Custard apple information kit

Reprint – information current in 1998

REPRINT INFORMATION – PLEASE READ!

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

This publication has been reprinted as a digital book without any changes to the content published in 1998. We advise readers to take particular note of the areas most likely to be out-of-date and so requiring further research: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- Financial information—costs and returns listed in this publication are out of date.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.deedi.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 1998. The information is not current and the accuracy of the information cannot be guaranteed by the State of Queensland.

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

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Queensland Government

Key ISSUES

This section contains more detailed information on some of the important decision-making areas and information needs. Use it in conjunction with Section 3. The information provided is not designed to be a complete coverage of the issue, but instead the key points that need to be known and understood.

Keys to making a profit

For most growers, the primary aim of their farming business is to make a profit. The secondary aim is to maximise that profit. This section provides an overview of the key elements in achieving maximum profits.

The simple profit equation

In simple terms, the profit from any enterprise can be expressed as:

Profit = returns - costs

Maximum profits come from maximising returns and minimising costs. Each has an impact on profit.

Maximising returns

Returns received from the custard apple enterprise are influenced by:

- price received for the product;
- volume of product sold.

Price received

The price received for custard apples is influenced by the:

- quality of the fruit on arrival in the market;
- market destination of the fruit;
- long-term reputation of the product.

Fruit quality

Quality of custard apples in the marketplace is essentially determined by five factors. They are:

Size. The best prices are paid for large fruit of count 13 or larger per single layer tray pack.

Cleanliness and appearance. The best prices are paid for fruit that is free from any marks or blemishes that affect appearance. Fruit must also appear to be characteristic of the variety when grown under normal conditions.

Flavour. Sweeter flavoured fruit has a tendency to achieve higher prices and repeat sales.

Shape. The best prices are paid for fruit that are well-shaped and typical of the variety (Figure 1).

Soundness and shelf life. The best prices are paid for fruit that is sound (free from cuts and punctures) and stored properly to maximise shelf life.

***Figure 1**. Good market shape for custard apples; African Pride (left) and Pinks Mammoth*

These quality characteristics are influenced by several pre and postharvest management practices, some more significantly than others. The impact of these management practices on quality is summarised in Table 1.

***Table 1**. Impact of pre and postharvest management practices on quality of custard apple fruit*

Management practice	Impact on quality: 5 = high, 1 = low, na = not applicable				
	Size	Cleanliness	Flavour	Shape	Soundness
Variety	5	3	5	5	na
Rootstock	3	1	na	1	na
Preharvest					
Nutrition	3	1	2	3	3
Irrigation	3	1	1	3	3
Pruning and training	5	5	na	1	1
Pest/disease management	2	5	na	1	5
Pollination	4	3	na	5	na
Postharvest					
Storage	na	3	2	na	4
Packaging	na	5	na	na	na
Postharvest handling	na	5	na	na	5
Transport	na	4	na	na	na

Market destination

Different markets have different price opportunities for the various product types. The key here is to make sure all market options are well researched to match the type of product you can produce (environment and management system) to the best market opportunity. This includes determining the potential competitors and when their product reaches the market.

Reputation

A product often receives a higher price because of its past reputation. A product that has been consistent in quality and supply, year after year, is usually bought first and often at the highest price. The development of a good reputation is now highly dependent on the implementation of quality management throughout your entire production and marketing system.

Volume sold

The other way of maximising returns is to maximise the volume of fruit produced. The main management factors affecting the volume of fruit harvested and marketed are shown in Table 2.

Table 2. *Impact of management on volume of fruit produced*

Management factor	Impact on volume of fruit produced: 5 = high; 1 = low
Variety x age	5
Rootstock	1
Pollination	4
Nutrition	2
Irrigation	2
Pruning and training	2
Pests and diseases	1

Variety by age of tree has the biggest impact. For example, whereas Pinks Mammoth trees 10 years and older on 12 m x 12 m spacings have been recorded producing up to 200 kg of fruit, they have also been known to produce little or no fruit. Typical average yields per tree are shown in Table 3.

Table 3. *Average yields of custard apples per tree (kg)*

Age (years)	3	4	5	6	7	8	9	10
African Pride	10	35	60	70	70	80	80	80
Pinks Mammoth	-	4	15	25	50	70	80	100

Where the most productive varieties are already in use, there is little that can be done with existing technology to significantly improve the volume of fruit produced. This effort also involves extra costs. Significant improvements in productivity depend mainly on the future development of better varieties.

Minimising costs

The first step in minimising costs is to examine where the major costs are. Typical costs are shown in Table 4.

Table 4. Costs of growing and marketing custard apples

Cost area	Cost per tray ($)
Growing	
fertiliser, chemicals, mulch, irrigation	1.20
labour for growing and pruning	1.30
hand pollination	1.10
Picking and packing	
picking labour	1.10
packing labour	1.40
packaging (carton and liner etc)	3.25
Marketing	
freight (domestic)	0.80
levies, inspection and insurance	0.59
commission	1.40
Total costs per tray	**12.14**

Seventy per cent of the costs are involved in picking, packing and marketing. As it is often difficult to reduce these costs significantly without affecting quality, cost minimisation often has little impact on overall profitability.

The key to profit

The key to maximising profitability appears to lie in maximising returns. The most effective way of maximising returns appears to be improving the price obtained.

Business management

Growing custard apples is a business, not a lifestyle. By becoming a custard apple grower you are entering a new business or at least adding a new enterprise to an existing business. In a business, financial and marketing plans are as important as production plans. No matter how good the product, the business will only be successful if it can profitably access markets.

Treating a custard apple enterprise as a business involves the development of business and marketing plans, recording farm information, financial management, marketing and control (implementation of quality management systems).

Business and marketing plans

All businesses need a plan to be successful. A plan helps to focus on what is the core business and what the business hopes to achieve. A business plan is generally drawn up for a 5 to 10 year period and is a living document; it must be reviewed and modified annually to ensure objectives are met.

A typical business plan includes the following sections:

1. Mission
2. Goals and objectives
3. Situation analysis—SWOT (Strengths, Weaknesses, Opportunities, Threats)
4. Action plan/implementation
5. Budget
6. Control plan

In addition to the business plan, marketing and financial plans may also need to be developed. A typical marketing plan includes the following sections:

1 Executive summary
2 Current marketing situation
   Domestic
   Export
   Competitive situation
3 Opportunity and issue analysis
   SWOT analysis (Strengths, Weaknesses, Opportunities, Threats) Issue generation and priorities
4 Objectives
   Financial
   Marketing
5 Marketing strategy
   Pricing
   Product description and lines
   Positioning and segments
   Distribution strategy
   Sales
   Advertising and promotion strategy
   Research and development
6 Action program and control
7 Budget

Recording farm information

Accurate and ordered recording of information on the farm is essential for good business management. Types of information that should be recorded include:

- preharvest factors (pest and disease monitoring records, spray program, labour inputs, pollination details, leaf and soil analysis, soil moisture monitoring, fertiliser and irrigation schedules);
- postharvest factors (labour, picking, packouts, handling and storage logs);
- quality management records and financial details.

This information can be recorded on a computer for quick access and comparison or it can be recorded in books or on forms and accurately filed. A lot of this information is used for the development of business and marketing plans and for checking to see if plan objectives have been met. This information is used to compare performance from year to year and in the establishment of best farm practice.

Besides their use in business and marketing plans, farm records have other significant benefits. They:

- meet the needs of an approved supplier program and Interstate Certification Assurance (ICA) protocols;
- record operations for Workplace Health and Safety audits;
- record operations for environmental audits that may be required

in the future under Farmcare, Landcare and Catchment Management schemes.

Farm block recording systems can be developed by using:

- available proprietary farm recording software such as SprayPal and Farm Care;
- recording systems in quality management manuals;
- your own recording system. (Consultants and DPI and NSW Agriculture extension officers may be able to provide assistance in setting this up.)

Examples of recording sheets are shown in Figure 2.

Fertiliser Program
Record details of fertiliser application. The amount can be recorded either on a per tree basis or per hectare basis.

Date	Block	Product	Amount	Method

Figure 2. *Examples of farm recording sheets*

Financial management

Accurate recording of financial inputs and outputs ensures that the true financial situation of the business is known at all times. This is important for decision-making. Accurate recording of inputs and outputs means including all costs, such as family labour, loan interest and depreciation.

Many computer-based financial recording packages are available; Quicken® is widely used by horticultural producers.

Economic analyses of custard apple enterprises

As a guide to setting up your financial recording program, two economic analyses are provided.

The first study, in the Mareeba-Dimbulah Irrigation Area on the Atherton Tableland, analyses a model or hypothetical farm of 5 ha of Pinks Mammoth. It provides the following details:

- variable costs at full production (includes growing, harvesting and marketing costs);
- fixed costs for a 5 ha orchard (includes an allowance for permanent

labour and the farmer's labour, administration costs, electricity, depreciation);

- the capital costs for a 5 ha orchard;
- an annual whole orchard profit and loss statement at orchard maturity; (This includes a gross margin—the difference between the gross income and the variable or operating costs.)
- a discounted cash flow analysis to determine the annual cost of production and profitability. The discounted cash flow analysis technique is used widely to analyse profitability for long-term tree crops where costs and benefits occur over a long period. The technique reduces the time stream of costs and benefits to an equivalent amount of today's dollars. That amount is known as the present value of the future stream of costs and benefits. The present values are calculated using compound interest and a specified discount rate (in this case 8%). The Net Present Value (NPV) is the difference between the present value of the benefits and the present value of the costs.

The second analysis is a study of a farm in the Sunshine Coast area growing African Pride and Pinks Mammoth. It provides the following details:

- variable costs;
- fixed costs;
- capital costs;
- an annual whole orchard profit and loss statement for each year of the expected 20 year lifespan of the orchard; (This includes a gross margin—the difference between the gross income and the variable or operating costs.)
- a discounted cumulative net cash flow, shown on the profit and loss statement, which has been calculated using a discount rate of 4%. (This shows the projected net cash flow in constant terms, taking into account the lost 'opportunity cost' of the money invested in the orchard.)

Economics of growing custard apples—Atherton Tableland

Information courtesy of Andrew Hinton, Economist, DPI, Mareeba. Figures used in the analysis were current as of November 1996.

Assumptions

Here are the main assumptions used in this analysis:

- The hypothetical orchard consists of a 5 ha, 720-tree custard apple farm (the 5 ha includes room for buildings).
- Trees are planted on an 8 m by 8 m spacing (144 trees/ha).
- The orchard is at steady state full production in the eighth year.
- Mature tree yields are considered to be 12 trays/tree. Fruit is marketed in Singapore (75%) and Brisbane (25%). Average prices

are $40/tray in Singapore and $20/tray in Brisbane, giving a weighted average price of $35 per tray, less commission, freight, levies and insurance.

- Capital equipment is bought at the start and is purchased new, except for a tractor and utility which are bought second-hand.
- Machinery operation includes fuel and oil costs only.
- No permanent labour is used. Casual labour is employed for pruning, thinning, harvesting and packing to supplement the owner's family labour.
- The orchard is well-managed.
- An orchard life of 20 years is used with a real discount rate of 8% to calculate the net present value (NPV).

Variable costs at full production

Item	No./yr	Unit	Units/ha	$/unit	$/ha
Machinery operation					
Applying defoliant	1	hour	1.5	12	18.00
Spreading fertiliser	4	hour	1	12	48.00
Pest/disease spraying	10	hour	1	12	120.00
Slashing	10	hour	2	8	160.00
Pruning and thinning					
Pruning	1	hour	54	11	594.00
Fertiliser					
Urea	1	kg	352.8	0.54	190.51
Muriate of potash	1	kg	237.6	0.45	106.92
Superphosphate	1	kg	24.48	0.38	9.30
Dolomite (spread)	0.5	kg	1 200	0.10	60.00
Defoliant (urea and Ethrel)	1	L	1 440	0.17	244.80
Weed control and mulching					
Glyphosate	3	L	0.576	9.75	16.85
Paraquat	2	L	0.72	9.57	13.78
Mulch (barley straw)	1	bale	144	8.00	1 152.00
Mulching labour	1	hour	36	11.00	396.00
Irrigation					
Water costs and pumping	–	ML	7	47.68	333.76
Pest/disease control					
Endosulfan	3	L	1.008	7.65	23.13
Kocide	3	L	1.44	6.33	27.35
Dimethoate	1	L	0.432	8.20	3.54
Lorsban – yeast solution	5	L	14.4	0.38	27.36
Lorsban – butt drench	1	L	2.59	17.82	46.19
Hand pollination					
Labour	1	hour	144	11.00	1 584.00
Harvesting and marketing					
Labour (picking, grading, cleaning and packing)	1	tray	1 728	3.21	5 546.88
Packaging	1	tray	1 728	3.25	5 616.00
Freight: Brisbane	1	tray	432	3.75	1 620.00
Freight: Singapore (includes road freight to Cairns)	1	tray	1 296	7.25	9 396.00
Levies	1	tray	1 728	0.59	1 019.52
Agent's commission (12%)	1	tray	1 728	1.38	2 384.64
TOTAL VARIABLE COSTS					**30 758.53**

Fixed costs for the 5 ha orchard

Item	Amount ($/year)
Allowance for family labour	25 000
Fuel and oil for utility and farm motorbike	1 000
Electricity for equipment, lighting and cold room	1 000
Repairs and maintenance	5 000
Administration	5 000
Depreciation	22 233
TOTAL FIXED COSTS	**59 233**

Capital costs for the 5 ha orchard

Item	Year/s of purchase	Cost ($)
Tractor (45 kW)*	0	30 000
Utility*	0,5	10 000
Slasher	0	3 500
Trailer	0	2 500
Fertiliser spreader	0	3 500
Air blast sprayer	0	10 000
Spray outfit for weeds (PTO)	0	1 000
Knapsack sprayers	0	2 000
Irrigation equipment and water allocation	0	14 300
Harvesting and pruning equipment	2/3/6	1 080
Cold room	2	25 000
Machinery shed and packing shed	0	25 000
Shed machinery	0	5 000
Grading equipment	2	5 000
Land ($8000/ha) – includes 2 ha for infrastructure and buffer zones	0	56 000
Land preparation and planting	0	3 996
Trees (grafted) including freight	0	7 200
TOTAL CAPITAL COSTS		**205 076**

* purchased second hand

Profit and loss statement for the 5 ha orchard (NPV)

Item	$/farm/yr	$/tray
GROSS INCOME	**181 259**	**35.00**
Variable costs		
Machinery operation	1 582	0.31
Pruning and training	2 530	0.49
Fertiliser, defoliation and mulch	8 032	1.55
Insect and disease control	523	0.10
Irrigation	1 458	0.28
Weed control	146	0.03
Hand pollination	6 481	1.25
Harvesting and marketing	76 638	14.80
TOTAL VARIABLE COSTS	**97 390**	**18.81**

continued …

Profit and loss statement for the 5 ha orchard (continued)

Item	$/farm/yr	$/tray
Fixed costs		
Allowance – family labour	26 273	5.07
Administration	5 000	0.97
Repairs and maintenance	5 000	0.97
Fuel and oil	1 000	0.19
Electricity	1 000	0.19
Capital costs	22 233	4.29
TOTAL FIXED COSTS	**60 506**	**11.68**
TOTAL COSTS	**157 896**	**30.49**
Return to management	**23 363**	***4.51**
GROSS MARGIN	**83 869**	
GROSS MARGIN/hectare	**16 774**	
GROSS MARGIN/tray		**16.19**

* Based on a discounted yield of 5179 trays for the orchard

Discounted cash flow analysis for the 5 ha orchard

Year	Yield (trays per year)	Receipts	Operating costs	Fixed costs	Capital costs	Annual cash flow	Discounted annual cash flow	Discounted accumulative cash flow
0				12 500	174 296	-186 796	-186 796	-186 796
1	0	0	3 640	37 000	0	-40 640	-37 630	-224 426
2	0	0	7 415	37 000	5 220	-49 635	-42 555	-266 980
3	720	25 200	28 789	37 000	25 520	-66 109	-52 480	-319 461
4	1 440	50 400	42 589	37 000	120	-29 301	-21 544	-341 004
5	2 880	100 800	65 386	37 000	8 000	-9 586	-6 525	-347 529
6	5 760	201 600	108 399	37 000	160	56 041	35 314	-312 215
7	6 480	226 800	120 881	37 000	0	68 919	40 213	-272 002
8	8 640	302 400	153 730	37 000	640	111 030	59 986	-212 015
9	8 640	302 400	153 730	37 000	0	111 670	55 863	-156 152
10	8 640	302 400	153 730	37 000	56 910	54 760	25 365	-130 788
11	8 640	302 400	153 730	37 000	0	111 670	47 894	-82 894
12	8 640	302 400	153 730	37 000	4 720	106 950	42 471	-40 423
13	8 640	302 400	153 730	37 000	520	111 150	40 870	447
14	8 640	302 400	153 730	37 000	160	111 510	37 965	38 412
15	8 640	302 400	153 730	37 000	8 000	103 670	32 681	71 093
16	8 640	302 400	153 730	37 000	120	111 550	32 560	103 654
17	8 640	302 400	153 730	37 000	0	111 670	30 181	133 835
18	8 640	302 400	153 730	37 000	680	110 990	27 775	161 610
19	8 640	302 400	153 730	37 000	0	111 670	25 875	187 485
20	8 640	302 400	153 730	37 000	-83 550	195 220	41 884	229 370
NPV	**50 847**	**1 779 632**	**956 200**	**375 772**	**218 291**	**229 369**		
Av/farm/ year	**5 179**	**181 259**	**97 390**	**38 273**	**22 233**	**23 363**		
Av/tray		**35.00**	**18.81**	**7.39**	**4.29**	**4.51**		

The analysis shows a peak overdraft of $347 529 in the fifth year and annual expenses exceeding annual income until the sixth year. The payback period, or the time required for accumulated income to exceed accumulated expenses, is 13 years. Put another way, it would take 13 years to recover the initial project outlay.

Economics of growing custard apples—Sunshine Coast

Information courtesy of Julie Miller, Economist, DPI Nambour. Figures used in the analysis were current as of July 1998.

Assumptions

- 10 ha of land purchased at a cost of $100 000;
- 4 ha planted to Hillary White and 4 ha to African Pride;
- mature tree yield of Hillary White is expected to be 12.85 trays/tree, with 58% being sold on the export market and 42% on the domestic market at an average price of $28.13/tray;
- mature tree yield of African Pride is expected to be 9.15 trays/tree, with 3% being sold on the export market and 97% on the domestic market at an average price of $16.06/tray;
- discount rate of 4% used (this is the 1998 bank rate less the inflation rate);
- machinery costs include fuel, oil and maintenance;
- all assets were sold at the end of the 20-year-period;
- payback period represents a discounted payback period;
- trees planted at a density of 144 trees/ha, with a life of 20 years;
- steady state production by the ninth year;
- casual labour required to help with thinning, picking, packing, and hand pollination;
- allowance for family labour of $25 000 annually;
- capital equipment is purchased throughout the period, and all is bought new, except for the utility which is bought second-hand;
- the orchard is well-managed.

Variable costs at full production (ninth year)

Item	$/unit	$/ha/yr
Machinery and operations		
Grass/weed spraying		46.35
Pest/disease spraying		78.82
Slashing/mowing		82.46
Trailer		26.00
Miscellaneous tractor operations		9.02
Fertiliser spreader		15.20
Dipping machine		3.13
Workshop equipment		5.38
Equipment shed		3.13
Packing shed		27.81
Cold room		40.35
Pneumatic secateurs		0.50
Pruning equipment		1.72
Utility		18.75
Pruning and thinning		
Pruning		0
Thinning		266.00

continued ...

Variable costs at full production (ninth year continued)

Item	$/unit	$/ha/yr
Fertiliser		
Urea	0.54	190.51
Muriate of potash	0.46	109.30
Superphosphate (every second year)	0.38	9.30
Defoliant (urea and Ethrel)	0.17	244.80
Weed control and mulching		
Roundup	23.5	11.75
Paraquat	12.78	25.56
Mulch (round bales)	8	1 152.00
Tests		
Soil tests	90	90.00
Leaf tests	78	78.00
Irrigation		
Water costs and pumping		200.00
Pest and disease control		
Endosulfan	18	54.36
Kocide	7.2	103.68
Dimethoate	11	4.73
Lorsban	5	38.90
Yeast	9.12	393.98
Hand pollination		
Labour (casual)		577.00
Harvesting and marketing		
Labour (picking, grading, cleaning and packing)	2.87	4 546.08
Dipping chemicals	0.0004	0.63
Packaging	3.25	5 148.00
Freight and commission	4.5	7 128.00
Levies	0.59	934.56
TOTAL VARIABLE COSTS		**21 665.77**

Fixed costs for the 8 ha orchard

Item	Amount ($/year)
Allowance for family labour	25 000
Repairs and maintenance	1 030
Administration	5 170
TOTAL FIXED COSTS	**31 200**

Capital costs for the 8 ha orchard

Item	Year/s of purchase	Cost ($/orchard)
Tractor (45 kw)	0	45 000
Utility	0,5,10,15	10 000
Slasher/mower	0	3 500
Trailer	0	2 500
Air blast sprayer	0	10 000
Spray outfit for weeds	0	1 000
Fertiliser spreader	0	3 500
Irrigation equipment	0	18 000
Picking bags	0	810
Pneumatic secateurs	1,6,11,16	400
Stackable tubs	3	6 000
Pruning equipment	0,5,10,15	1 100
Cold room	2	20 000

cont…

Capital costs for the 8 ha orchard (cont)

Item	Year/s of purchase	Cost ($/orchard)
Packing shed	2	25 000
Equipment shed	0	10 000
Shed machinery	0	4 000
Land ($100 000 for 10 ha without house)	0	100 000
Land preparation, planting	0	10 216
Trees (grafted) including freight	0	15 552
Roads	0	500
Boundary fencing	0	3 600
Benches	2	500
Hole digger	0	1 700
Dipping machine	2	5 000
TOTAL CAPITAL COSTS		**297 878**

A profit and loss analysis for the 8 ha orchard over 20 years is shown on the next page. The analysis shows that the peak overdraft of $511 768 is in the fifth year and annual expenses exceed annual income until the sixth year. The payback period, or the time required for accumulated income to exceed accumulated expenses, is 16 years. Put another way, it would take 16 years to recover the initial orchard outlay.

Marketing

Effective, targeted marketing will probably make the biggest difference to your success as a grower. Understanding what marketing is about provides you with a base on which to plan how the product will be produced.

Marketing is not:

- selling;
- waving your product goodbye at the farm gate in the belief that someone else will look after your best interests.

Marketing is:

- putting yourself in the consumer's shoes and profitably meeting their needs within the limitations of your resources.

Successful marketing implies knowing who and where your consumers are, and what they want. It also implies knowing at what level of return you are making a profit. Sadly, Australian horticulture provides many examples of growers who have no idea of how or if their product is meeting consumers' needs. The financial performance of many horticultural businesses also indicates that there is a lack of understanding about how cost of production is linked to marketing success. Many growers blame this on the 'marketing system', but this is admitting that growers are somehow outside the marketing system. Nothing could be further from the truth.

Here are some ideas as to how custard apple growers can get onto the 'inside' of marketing.

Profit and loss statement for the 8 ha orchard

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Item			$/orchard/yr																		
GROSS INCOME	**0**	**0**	**10,574**	**45,342**	**94,694**	**126,103**	**176,756**	**230,432**	**251,267**	**292,936**	**292,936**	**292,936**	**292,936**	**292,936**	**292,936**	**292,936**	**292,936**	**292,936**	**292,936**	**292,936**	**292,936**
Variable costs																					
Herbicides	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296
Fungicides	832	832	832	832	832	832	832	832	832	832	832	832	832	832	832	832	832	832	832	832	832
Insecticides	3,936	3,936	3,936	3,936	3,936	3,936	3,936	3,936	3,936	3,936	3,936	3,936	3,936	3,936	3,936	3,936	3,936	3,936	3,936	3,936	3,936
Soil treatments	2,264	3,952	8,040	10,184	11,400	12,568	13,728	15,024	14,976	14,992	14,992	14,992	14,992	14,992	14,992	14,992	14,992	14,992	14,992	14,992	14,992
Irrigation	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600
Harvesting and marketing costs	0	0	6,383	26,144	52,560	68,449	91,561	117 611	127 117	146 130	146 130	146 130	146 130	146 130	146 130	146,130	146,130	146,130	146,130	146,130	146,125
Pruning and training	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thinning	0	0	2,128	2,128	2,128	2,128	2,128	2,128	2,128	2,128	2,128	2,128	2,128	2,128	2,128	2,128	2,128	2,128	2,128	2,128	2,128
Hand pollination	4,616	4,616	4,616	4,616	4,616	4,616	4,616	4,616	4,616	4,616	4,616	4,616	4,616	4,616	4,616	4,616	4,616	4,616	4,616	4,616	4,616
Machinery, operations costs	3,956	2,299	2,869	2,869	2,869	2,869	2,869	2,869	2,869	2,869	2,869	2,869	2,869	2,869	2,869	2,869	2,869	2,869	2,869	2,869	2,869
TOTAL VARIABLE COSTS	**17,500**	**17,531**	**30,700**	**52,605**	**80237**	**97,294**	**121,566**	**148,912**	**158,370**	**177,399**	**177,399**	**177,399**	**177,399**	**177,399**	**177,399**	**177,399**	**177,399**	**177,399**	**177,399**	**177,399**	**177,394**
Fixed costs																					
Allowance – family labour	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000
Administration	5,480	5,170	5,170	5,170	5,170	5,430	5,170	5,170	5,170	5,170	5,430	5,170	5,170	5,170	5,170	5,170	5,170	5,170	5,170	5,170	5,170
Repairs and maintenance	800	1,030	1,030	1,030	1,030	1,030	1,030	1,030	1,030	1,030	1,030	1,030	1,030	1,030	1,030	1,030	1,030	1,030	1,030	1,030	1,030
TOTAL FIXED COSTS	31,280	31,200	31,200	31,200	31,200	31,460	31,200	31,200	31,200	31,200	31,460	31,200	31,200	31,200	31,200	31,200	31,200	31,200	31,200	31,200	31,200
TOTAL COSTS	**48,780**	**48,731**	**61,900**	**83,805**	**111,437**	**128,754**	**152,766**	**180,112**	**189,570**	**208,599**	**208,859**	**208,599**	**208,599**	**208,599**	**208,599**	**208,599**	**208,599**	**208,599**	**208,599**	**208,599**	**208,594**
GROSS MARGIN	**-17,500**	**-17,531**	**-20,127**	**-7,263**	**14,458**	**28,808**	**55,190**	**81,520**	**92,896**	**115,537**	**115,537**	**115,537**	**115,537**	**115,537**	**115,537**	**115,537**	**115,537**	**115,537**	**115,537**	**115,537**	**115,542**
Capital budget	-240,979	875	-50,500	-6,000	0	-8,470	-300	0	0	0	-12,470	-300	0	0	0	-8,470	-300	0	0	0	195,915
Net cash flow (NCF)	-289,758	-47,856	-101,827	-44,463	-16,742	-11,122	23,690	50,320	61,696	84,337	71,607	84,037	84,337	84,337	84,337	75,867	84,037	84,337	84,337	84,337	280,257
Accumulated NCF	-289,758	-337,614	-439,441	-483,904	-500,646	-511,768	-488,078	-437,758	-376,062	-291,725	-220,118	-136,081	-51,744	32,593	116,929	192,796	276,833	361,170	445,507	529,844	810,101
Discounted cumulative NCF	-289,758	-335,773	-429,918	-469,446	-483,757	-492,898	-474,176	-435,937	-390,856	-331,602	-283,227	-228,638	-175,961	-125,311	-76,609	-34,482	10,386	53,682	95,313	135,343	263,248
Discount rate	4%																				
Net present value	263,248																				
Payback period	16 years																				

Think as if you were a consumer

What does a consumer of custard apples look for? Is it price, quality, size, colour, firmness, or a combination of all five? If growers cannot reasonably guess at the answer, how can they set targets for production?

For example, one decision is whether to grow large fruit at a lower overall yield but a higher individual price or smaller fruit with higher overall yield and lower individual price. Another is how strict should be you be in grading out blemished fruit. Grading too strictly means fewer trays of very high quality fruit; grading too lightly means more trays of lower quality fruit.

Another decision is at what point are market returns the best? How can growers make these management decisions without information on what consumers want and how much they are prepared to pay?

There are two important sources of knowledge and information about what the market wants:

- Market research studies, which 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 & Development Corporation (HRDC) are sources of this information.
- Marketers who are in close contact with buyers and consumers. For the domestic market, specialist custard apple wholesalers in the major metropolitan markets are an invaluable source of detailed market knowledge. Market authorities in each of the major markets can provide some advice on custard apple wholesalers. For the export market, custard apple exporters are an equivalent source of expert market knowledge.

Know the marketing chain for your fruit

Knowing the marketing chain for your fruit means identifying all the steps and all the people that link your fruit at the farm gate to particular groups of consumers. One chain might include a transport company, an unloading company, a wholesale merchant, a supermarket buyer, a grocery section manager and consumers from a particular region of a city. Knowing how the chain works is important because you choose some of its players, and each of the players in the chain make decisions about your product that collectively influence its marketing performance.

Visit the markets in which your fruit is sold

There is no substitute for seeing how your fruit is performing in wholesale and retail markets. But just looking at the fruit is not enough. You should be monitoring the fruit's physical and financial performance and also assessing the performance of the people in your marketing chain. Remember that they are working for you, but they will happily ignore this if you are not interested in them.

Actively seek market information

Apart from visiting your markets, actively seek information about each consignment of fruit. Ask your agent for a report to indicate if the fruit is acceptable. No news is not necessarily good news. Often feedback does not reach growers unless they set up an easy system—fax or e-mail—to receive this information. Out-turn inspections by independent assessors is also a useful way to get information about your product.

Join a marketing collective (where available)

Small growers acting alone have little clout in the market and also miss out on sharing information with other growers. If you're considering marketing alone so that you can closely guard information that you don't want others to have, think again. Chances are that while you're busily guarding this information, the rest of the industry will pass you by because no one will want to share their information with you. Joining a marketing group of like-minded growers is a positive step towards overcoming the dual problem of lack of marketing clout and lack of information. The Jadefruit Custard Apple Marketing Group (JCAM), established by the Australian Custard Apple Growers' Association, is an excellent example of collective marketing where growers take responsibility for their marketing outcomes.

Control (quality management)

All business and marketing plans need a control process for monitoring, evaluation and modification of these plans. Quality management systems fulfil this control role. They are a method of developing a flow chart of the business with a series of checks for critical operations to ensure that they are carried out and done correctly.

Quality is built into every aspect of 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 things 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 totally aware of it.

In the past, the suitability of the product for its intended market was determined by what is called 'end point inspection'—inspection at the market level. This system has several important flaws. It is:
- expensive to reject product at this late point in its cycle;
- difficult to predict product performance during the rest of the marketing process when its past history is unknown;
- often driven more by tradition than by the real needs of consumers.

Modern quality management aims to build quality throughout the production and marketing process so that there is minimal need for rejections later. This system also provides your customers with documented evidence that the product they buy will meet their needs. Quality management, therefore, may be seen as a marketing tool to achieve better prices and repeat sales, as well as a tool to identify areas for improvement, 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 between growers.

There are five core principles of quality management:

- It is the customer who defines quality, not the grower.
- It 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.
- Decisions are based on facts, not feelings.
- It is the responsibility of everyone in the business, including the workers—it is not just the responsibility of management.

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

The 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. Recent outbreaks of food poisoning from other food products have made the community very concerned about food safety. 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 quality management practices being requested by customers can be separated into three broad levels:

- 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 your marketing arrangements and the potential risk of your product causing a food safety problem. Here is the current status.

If your product is supplied to a supermarket, either directly or indirectly, Figure 3 shows the minimum level of quality management needed by different businesses in your supply chain.

Some food service businesses, such as fast food outlets, are requesting an HACCP plan or specific quality management practices under an approved supplier program.

Depending on their customers, exporters will require some level of quality management.

There are no demands at this stage from non-supermarket retailers.

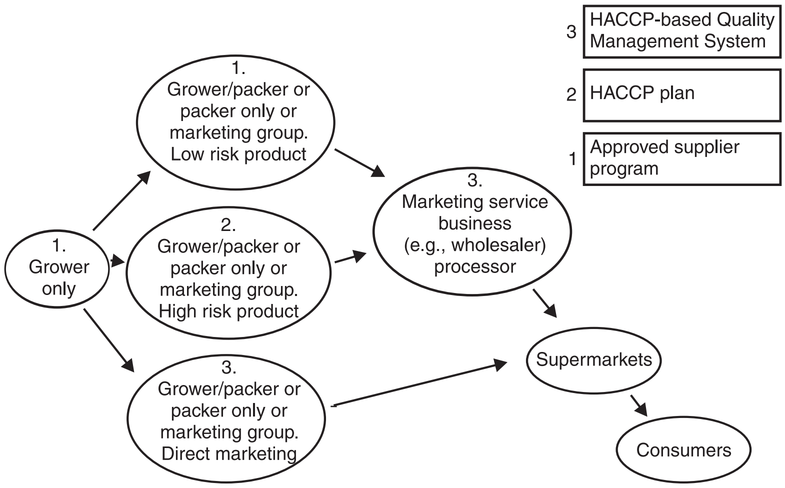


***Figure 3**. Minimum levels of quality management required for businesses to supply the supermarket sector*

Note that without at least approved supplier status, growers will be left to supply the non-supermarket sector of the market that is now minor and decreasing each year.

More on 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 own grower suppliers. This situation could include:

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

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

HACCP plan

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 is now also 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 residue, microbes causing illness, and physical contaminants such as glass and sticks that may lodge in products.

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 ™
- HACCP 9000
- supermarket quality management standards.

This level of quality management is 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, 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 one 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™ Quality Code

The SQF 2000™ Quality Code was developed by AGWEST Trade and Development specifically for small businesses in the food industry. It is recognised in Australia and in some Asian countries. The code has six elements and each element contains specific requirements, which must be addressed to achieve certification. The code includes HACCP, which provides assurance that the product is safe and meets customer and legislative requirements. To achieve certification, a registered skilled HACCP practitioner must develop, validate and verify the HACCP plan.

HACCP 9000

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

Supermarket quality management standards

An example of supermarket quality management 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.

Markets for custard apples

The custard apple industry is still considered a developing industry in Australia. The fruit is less well known than avocado, mango and banana and it is still thought of as an exotic fruit. This means that there is further potential for expansion on the domestic and export markets. However, market selection and management needs to be carefully planned to achieve any benefits.

Market mix

The development of a marketing plan, which shows the intended target markets and the approximate percentage of product destined for each of these markets, is essential. To do this, you need to know what consumers in each market want and then gear your production and marketing system to supply that product.

It is often best to select a mix of markets to offset the risk of something going wrong in any one. As it is often difficult or impossible to produce only top class fruit, markets for lower grade fruit with minor shape and blemish problems need to be part of the market mix (Figure 4).

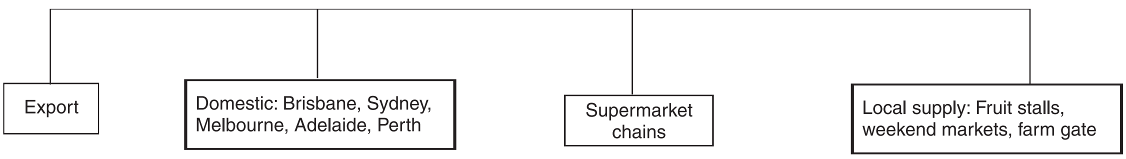


***Figure 4**. Intended market mix in a business plan*

Domestic markets

Current situation

Fruit of various quality grades, sizes and varieties are marketed on the major metropolitan wholesale markets of Brisbane, Sydney, Newcastle, Melbourne, Adelaide and Perth.

Except for the Perth market, higher prices are generally paid for larger fruit (count 6 to 12) that is free from blemish, sound and of a shape typical of the variety. Higher prices are also paid for early and late season fruit. During the early season market, fruit of Pinks Mammoth and Hillary White generally obtain a small premium over fruit of African Pride. This is because they have more consistent quality, larger size and a more established export reputation. Most wholesalers also prefer Pinks Mammoth and Hillary White. During the peak of fruit supply in June however, there is generally little no price differential between Pinks Mammoth/Hillary White and African Pride. The Perth market prefers smaller fruit (count 10 to 18).

Fruit at the lower end of the quality scale is often sold at lower prices at roadside stalls in tourist areas, at the farm gate, at weekend markets or through smaller local fruit shops. Savings in freight and other marketing charges mean that, even at lower prices, a positive return may be achieved from the sale of this fruit.

Prices

Average monthly prices for a range of domestic markets are shown in Figures 5 to 9. Throughputs for the major markets are shown in Figure 10. Quoted domestic market prices are gross prices, not net prices at the farm gate. Freight and other market costs (inspection fees, commission and levies) need to be taken into account. Some markets require disinfestation treatment for fruit fly.

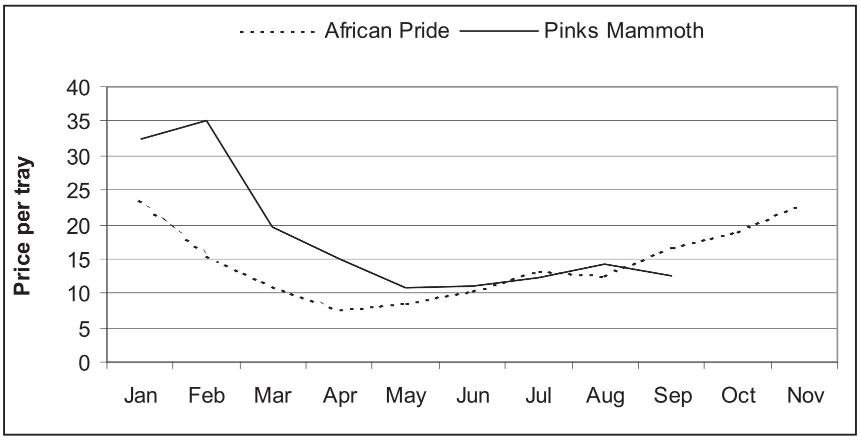


***Figure 5**. Average price for 7 kg trays at Brisbane Market 1995 to 1998*

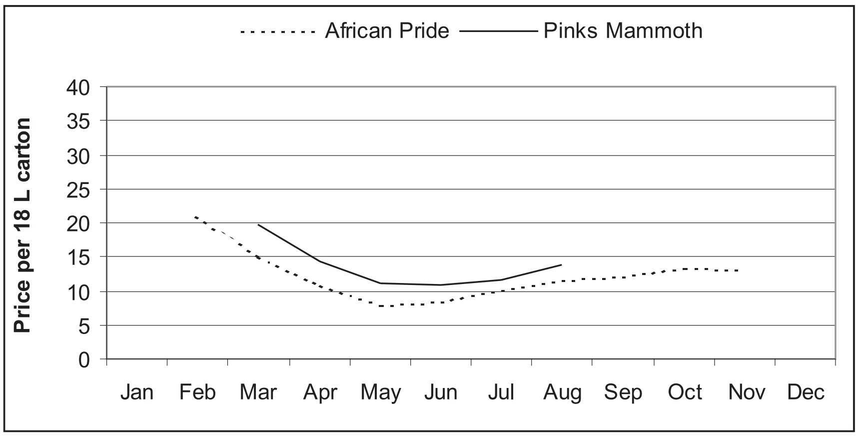


***Figure 6**. Average price for 18 L cartons at Brisbane Market 1995 to 1998*

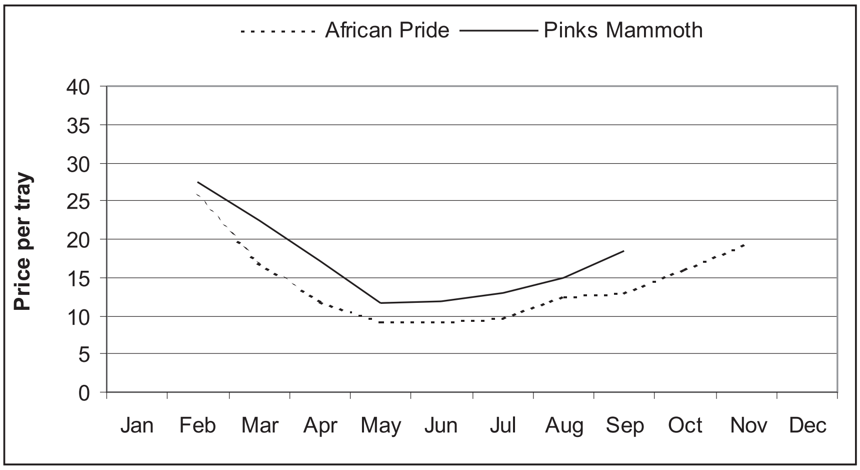


***Figure 7**. Average price for 7 kg trays at Sydney market 1995 to 1998*

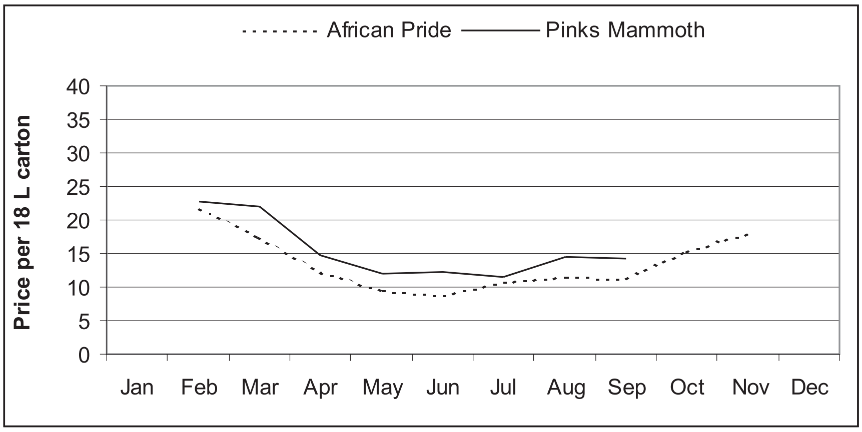


***Figure 8**. Average price for 18 L cartons at Sydney market 1995 to 1998*

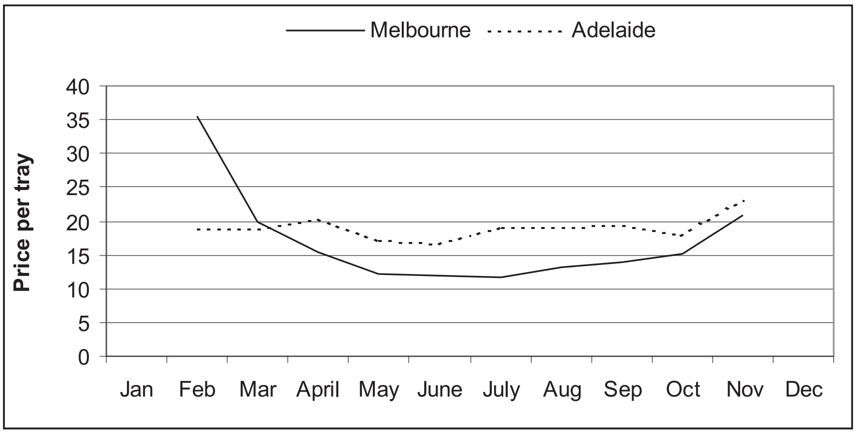


***Figure 9**. Average price for 7 kg trays at Melbourne and Adelaide markets 1994 to 1997*

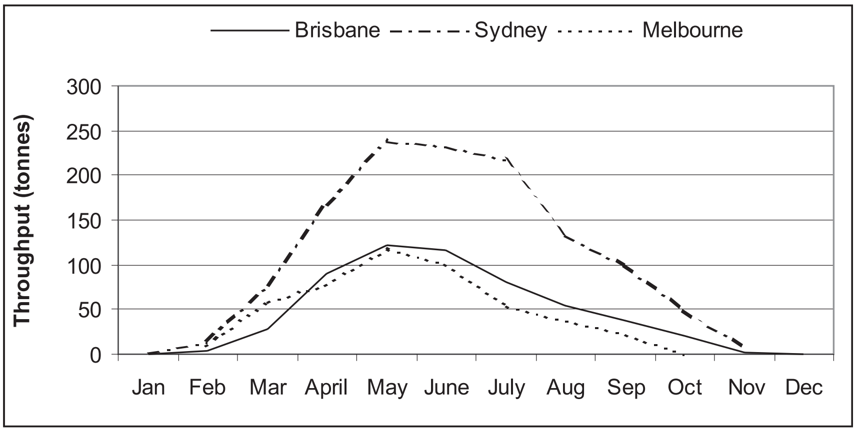


***Figure 10**. Average throughputs at major metropolitan markets 1994 to 1998*

Developing the domestic market

Many Australians express a liking for custard apples when they first try them. From a marketing point of view, the fruit offers several appealing characteristics. These include:

- sweetness;
- a range of sizes to suit different consumer needs;
- exotic appearance;
- convenience as a quick dessert or snack;
- nutritious qualities.

Recruiting new consumers to the product and ensuring they become repeat purchasers means that they must experience continued satisfaction with the product (consistent quality) and perceive it to be value for money.

For a new grower, this is a particular marketing challenge. It means finding out what attributes of the product are most important to consumers; learning how to manage the production system to consistently produce these attributes; and knowing what it costs to achieve such a result. As it is difficult for individual growers to do this alone, we recommend joining a grower group. Groups have the following advantages. They can:

- engage marketers, consultants or government agencies to do market research;
- collectively raise funds for product promotion;
- try production systems aimed at producing desired types of fruit;
- share information about costs of production.

Part of a group's strategy may be to develop a collective brand for the product. Brands allow consumers to identify a particular product and the benefits it brings to them. However, brands also remind them of products that don't meet their expectations.

Another opportunity for expanding the domestic market for custard apples is for groups to work cooperatively with supermarket chains. In the future, consumers will buy most fruit through supermarkets, which are targets for grower groups wanting to take an active role in market development. Collaboration with supermarket chains on a state or regional basis, backed up by the group's contributions of cash and product for promotion, is one way growers can improve their marketing power (and responsibility). In return, growers gain a much more informed view of consumer preferences; they expand consumption of their product; and they develop long-term relationships with their retailers. This strategy is not aimed at improving prices, it is aimed at improving returns through continued customer satisfaction.

The Australian Custard Apple Growers' Association has invested resources to further develop the domestic market by conducting merchandising programs in Sydney and assisting with details on fruit handling and storage. Expansion of the program into other areas of Australia would be beneficial.

Export markets

Current situation

Significant volumes of custard apples are exported to Singapore and Hong Kong. Some of this fruit is then re-exported into China (from Hong Kong) and Malaysia (from Singapore). Asian consumers love the sweet flavour and creamy flesh of custard apples and appear to prefer the slightly sweeter Pinks Mammoth and Hillary White. Other preferences are large fruit (count 6 to12) and freedom from blemish.

However, good quality fruit of African Pride also has export potential in Asia. It must be large and free from blemish. Some Asian consumers may clearly distinguish African Pride from Pinks Mammoth/Hillary White and align it more with their locally grown sugar apple. Although African Pride looks similar, it is larger and less seedy. Nonetheless, price may suffer as a result. African Pride may better suit western tastes and needs investigation in European and Canadian markets.

a key issue
Packaging
Section 4 page 129

For both varieties, careful packaging is critical to ensure fruit arrive in Asian markets free from bruising in transit (Figure 11).

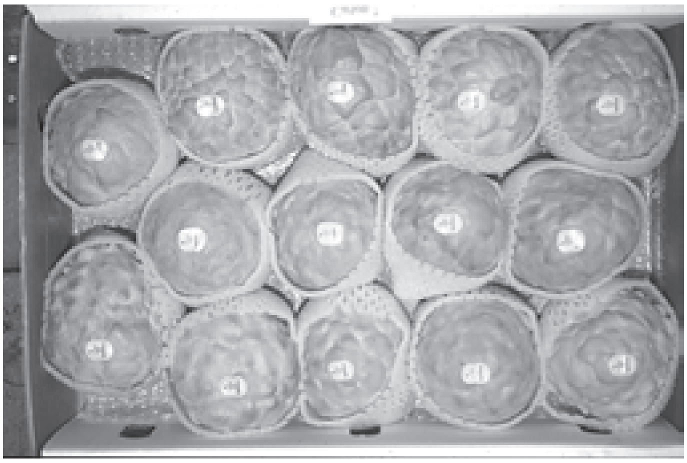


Figure 11. Well-packaged fruit for the export market

Prices

Prices received on the export market are generally much higher than those on the domestic market, however, the costs and risk are also higher.

Examples of prices for various volumes of custard apples exported by the Jadefruit Custard Apple Marketing Group (JCAM) to Singapore and Hong Kong since 1993 are shown in Table 5.

Table 5. Prices for custard apples exported to Singapore and Hong Kong by Jadefruit marketing group

	Pinks Mammoth		African Pride	
	Price/tray (net)	No. of trays	Price /tray (net)	No. of trays
1993 (to August)	$18.00 – $35.00 (av. $24.00)	4000	$10.00 – $28.00 (av. $15.00)	1329
1994 (to May)	$18.00 – $36.00	5620	$20.00 – $24.00	608
1995 (to September)	$25.90 – $29.10	8930	$15.10 – $21.35	9000
1996 (to October)	n/a	10 533	n/a	4537
1997 (to October)	n/a	19 797	n/a	1076

As custard apples have to be airfreighted to export market destinations, freight charges can be high (about $7 per tray to Singapore, $10 per tray to Hong Kong). This must be considered when negotiating gross price in the market.

There are relatively few entry restrictions into Singapore and Hong Kong. A phytosanitary certificate must accompany the shipment. Other markets are much stricter and some are not accessible to Australian custard apples. For example, custard apples are not permitted into Japan and the USA, as there is yet no suitable and acceptable disinfestation treatment for fruit fly.

Developing export markets

Export markets are likely to be the dominant future market for Australian custard apples and the future of the industry will rely heavily on developing export marketing strengths. The one clear signal for individual growers is that they must be prepared to adopt an export marketing mentality. This means accepting the following principles:

- Strict quality standards will apply.
- Growers will have to work collectively with other growers if they are to extract the potential rewards from exporting. Building good relationships is the key to developing markets. Growers need to go to the market and find out what it wants and how much consumers are prepared to pay. While individual growers can achieve this, they would probably be unable to supply enough product to build meaningful relationships with exporters, importers and retailers. Groups of growers can command more product, and therefore more attention from marketers. They can also build brands that identify their product to consumers.
- Growers will accept responsibility for the performance of their product on-farm and to the consumer. Good relationships with people along the marketing chain are built on reliability, meaning that each party in the relationship reliably satisfies the other; that is a 'win-win' situation is developed. The only way growers can extract their potential financial share from exporting is to actively become part of this network of relationships. This is a somewhat non-traditional view of export marketing in Australian horticulture.

  Groups of growers can join networks of existing relationships or they can initiate new networks. Existing networks may be accessed through exporters and importers known to be open to active grower involvement. Developing new networks demands more effort, but has the advantage of being 'untainted' by the effects of previous performance by all parties.
- At times, returns may be no better than domestic market returns.
- Growers may have to travel overseas, partially at their own cost. Growers cannot build reliable relationships in export markets without visiting them regularly. This may mean getting on a plane at short notice to investigate a serious problem with the product.
- The custard apple Jadefruit marketing group has conducted market research and out-turn inspections on its product in Singapore and Hong Kong for nearly every year since 1994. The Australian Persimmon Export Company is another outstanding example of export development. It has involved several of its growers in out-turn reports on its products in Singapore every year since 1994. This demonstrates that even a small new industry can adopt the principle of growers being physically present in export markets.
- Growers may have to try new and uncertain technologies, such as modified atmosphere packaging, and no one will guarantee they will work.

Growers who do not see these challenges as manageable should carefully consider whether the Australian custard apple industry of the future is the type of industry that suits their mental, financial and physical capabilities.

Disinfestation

Disinfestation is a process by which insect pests, including eggs and larvae, are killed without damaging the fruit. Traditionally this involved fumigation with methyl bromide or using chemical dips. These treatments, however, leave small residues of chemical, which are unacceptable to some people.

Non-residual treatments that are available include cold, heat, carbon dioxide, non-ionising irradiation, and pressure. Vapour heat has been promising in some other crops, but in small-scale trials on custard apples has damaged fruit. Several other methods and procedures remain to be assessed.

Testing of treatments involves determining that:

- there is no injury to the fruit;
- insects within the fruit are killed.

This makes the establishment of a suitable disinfestation treatment an expensive and protracted exercise. A relatively inexpensive and effective disinfestation treatment for custard apples is not anticipated in the immediate future.

Understanding the custard apple tree

The aim of custard apple growing is to produce a large crop of high quality marketable fruit. To achieve this, it is essential to have a good basic knowledge of what governs fruit production and quality. Here are the important things you need to know.

Parts of the custard apple tree

Vegetative growth

The custard apple is a large, semi-deciduous tree with large, single, entire leaves. Leaf buds lie in two rows arranged alternately on opposite sites of each shoot. In contrast, most other fruit trees have buds arranged in a spiral.

The custard apple tree is also unusual in that the leaf and flower buds are concealed underneath the leaf petioles (leaf stems). For buds to shoot and grow, leaves must first be shed naturally or mechanically removed.

In African Pride, up to two leaf buds and three flower buds lie underneath each petiole. In most other varieties, each petiole conceals two leaf buds and one or two flower buds (Figure 12).

Figure 12. *Two flower buds at a bud site*

Most cultivars of atemoya, particularly Pinks Mammoth, display apical dominance. This means the end two or three buds, especially on upright laterals or branches, will produce the strongest shoots (Figure 13). These end shoots produce hormones that suppress other shoots below them on that lateral. On laterals that are more or less horizontal, growth of shoots at bud sites along their length will be more even (Figure 14).

Figure 13. *The end two buds produce the strongest shoots*

***Figure 14**. Lateral growth is more even along horizontal limbs*

Very vigorous terminal shoots seldom produce flowers. If other shoots emerge midway along the lateral, they will usually be weaker and more likely to produce flowers and set fruit.

Flowers

The custard apple is hermaphroditic; that is the male and female parts are contained within the one flower. However, the female stage occurs before the male stage.

Each flower contains six petals but three are so small that the flower appears to have only three large, thick, creamy-green petals (Figure 15).

Figure 15. *Flower showing the three petals*

In the centre of the flower there is a low cone-like structure surrounded by a white collar. The cone-like structure consists of the female parts of the flower (stigmas, carpels and ovules) while the collar contains the male parts (many rows of spirally arranged stamens or pollen sacs). Inside the pollen sacs are the pollen grains. The parts of the flower are shown in Figures 16 and 17.

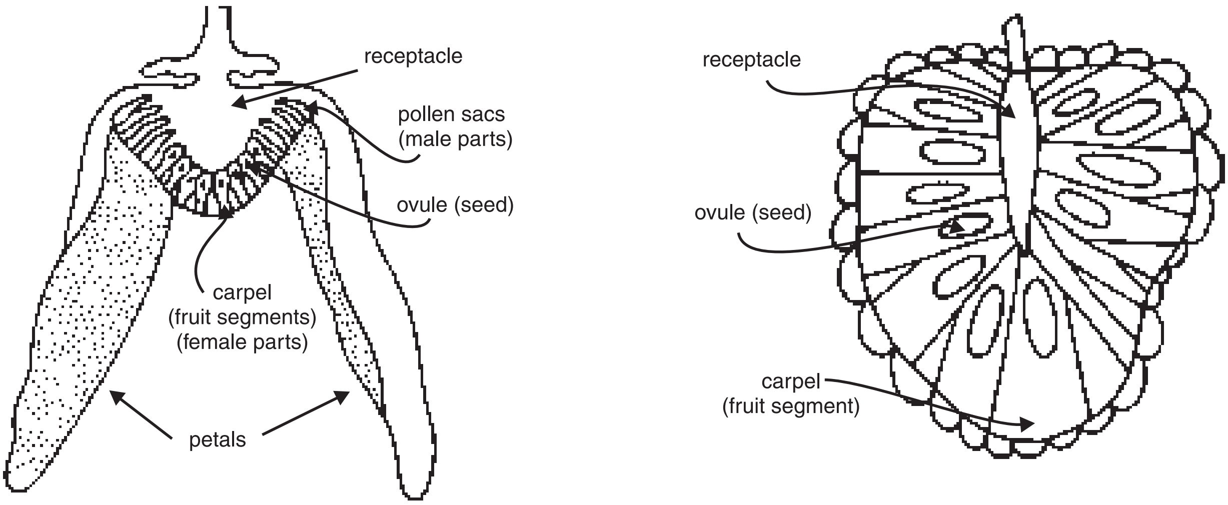


Figure 16. *Cross-section of a flower and fruit*

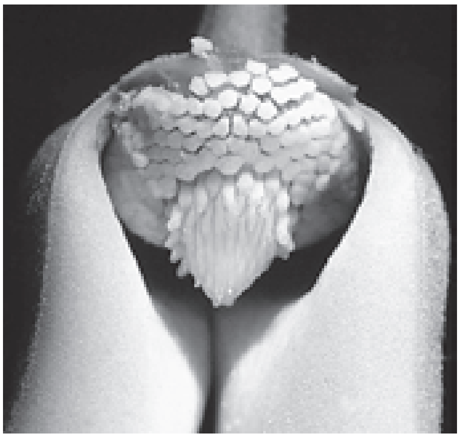


Figure 17. *A flower with one of the petals removed to show the female and male flower parts*

Flowers have three distinct stages: the slit bud stage; the female stage and the male stage (Figure 18).

Figure 18. *Slit (left), female (centre) and male (right) stages*

Typically, most flowers open to the slit bud stage (where the petals have just parted) around noon. By morning on the following day, the petals have opened to 1 to 2 cm apart at their tips (female stage). At this stage the female parts are receptive and appear moist while the pollen sacs are still white and tightly packed. In the afternoon, the petals open to almost 90° and the pollen sacs split and discharge their pollen (male stage). This is the typical two-day, 24 hour cycle of a custard apple flower. At temperatures above 32°C, however, the cycle may be reduced to less than 24 hours.

Poor natural pollination occurs mainly because the male and female parts of the flower do not mature at the same time. By the time the pollen is discharged, the female parts have dried and are no longer receptive to it. The process is not helped by the low pollen viability in some varieties. Once the pollen has been discharged, the petals wither and fall.

Most flowers are produced on new growth off one-year-old wood (Figure 19). Some flowers are also produced on mature wood older than one year.

Figure 19. Flowers produced on the basal nodes of new shoot growth

Fruit

Fruit are formed by the growth and fusion of many carpels, which are the fruit segments surrounding the seeds. The carpels form the pulp of the fruit and each carpel contains one or more ovules, which develop into seeds (Figure 16).

Only fertilised ovules develop into seeds. The seeds secrete hormones called auxins as they develop and these in turn stimulate the development of the fleshy carpel around the seed. When the pollination rate is low, some ovules are not fertilised and no seed develops. As a result, the carpel fails to flesh out and malformed fruit are produced.

Annual cycle of the custard apple tree

The custard apple tree follows a cyclic seasonal pattern of vegetative growth, root growth, flowering and fruit production. This cycle is repeated each year, though not necessarily at the same time or with the same intensity. This cycle is referred to as the phenological or growth cycle. The following notes provide some detail on the cycle for the south-east Queensland location of Nambour. See Figures 20 to 24 for variations on this cycle for other districts.

Vegetative growth

At Nambour, budbreak in custard apples starts in about late August to late September, when soil temperature is around 17°C and air temperature an average of about 23°C maximum and 12°C minimum. On some sites, budbreak can be as late as early October, or even later where pruning is delayed.

Vegetative growth occurs as three to five flushes in young trees and one to two flushes in bearing trees. In bearing trees, the first flush is the most vigorous, starting about 30 to 50 days after budbreak and peaking in November/December. The second weaker flush peaks in January/February. Growth stops at about the end of April, when soil temperature drops below about 18°C and air temperature drops below an average of 25°C maximum and 12°C minimum.

Leaf drop starts about July/August and can extend for up to three months. It starts on the outside of the tree canopy and moves inwards. The degree of leaf drop depends on tree vigour and environmental conditions. Dry, cold conditions will increase leaf drop.

Provided soil temperatures are high enough, vegetative budbreak occurs simultaneously with leaf fall as this exposes the buds under the leaf petioles. The timing of leaf fall is important, whether it is natural or artificially induced by chemical defoliants. Leaf fall influences the time of budbreak and subsequently the time of flowering and fruit maturity.

Root growth

Surface roots exhibit between three and four growth flushes. Root flushes are cyclical but generally out of phase with vegetative flushes. The first root flush starts just before budbreak and appears to be influenced by soil temperature and timing of leaf fall. The major root flush is about 30 days after the first major vegetative flush. Root flushes continue through to mid-winter when there is a strong root flush after the completion of harvesting. After this, the temperature becomes too low for growth.

For vigorous trees, vegetative and root flushes are clearly separated, but for artificially defoliated trees there is considerable overlap.

Flowering

At Nambour, flowering and fruit set extends over at least four months and has two peaks. The first flowering is from October to late December. Some of these flowers are produced directly off the previous season's wood but most are produced on the new growth off one-year-old wood. The first of these flowers opens about 40 days after budbreak. This flowering produces a small peak of fruit set in November. Strong competition between these early flowers and the vigorous shoot growth appears to be the limiting factor to fruit set at this time.

The second flush of flowers is from January to March, peaking in February and finishing by early March. This flowering produces most of the crop. Most of these flowers are produced on shoots of weak to moderate vigour. In most years, peak fruit set is in mid-January (110 days after budbreak). Very vigorous growth has been shown to produce up to 40% fewer flowers than growth of weak to moderate vigour.

Fruit growth

Fruit growth develops through three stages. At Nambour for African Pride, Stage 1 lasts for about 60 days after fruit set and is a period of rapid growth. Stage 2 lasts about 70 days and is a period of slower growth. Stage 3 is another period of rapid fruit growth and lasts only about 50 days. At Nambour, this makes the total fruit development period (FDP) for African Pride about 180 days (26 weeks).

Some varieties such as Hillary White have a shorter FDP of about 21 weeks, and so mature about 30 to 40 days before African Pride.

Fruit set during November matures quicker than fruit set later because of the warmer conditions during the main growth stage. At Nambour, FDP's of 19 weeks have been recorded for early set Hillary White.

For warmer growing regions of Australia such as Yeppoon and Mareeba, the FDP for African Pride is about 20 to 22 weeks. In cooler growing regions such as northern New South Wales, it is about 32 to 36 weeks.

Growth cycles for major growing areas

Typical phenological or growth cycles for different climatic regions are shown in Figures 20 to 24. Note the variation between the cycles because of climatic differences.

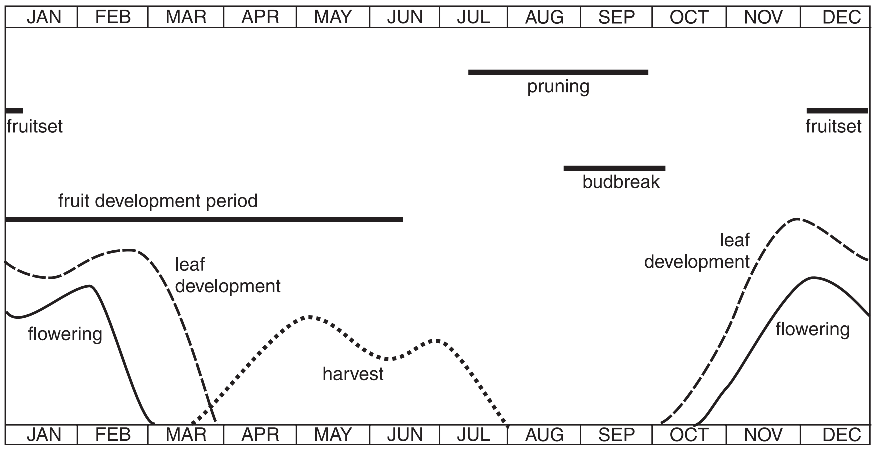


***Figure 20.** Custard apple growth cycle for Atherton Tableland (except Mareeba), Queensland*

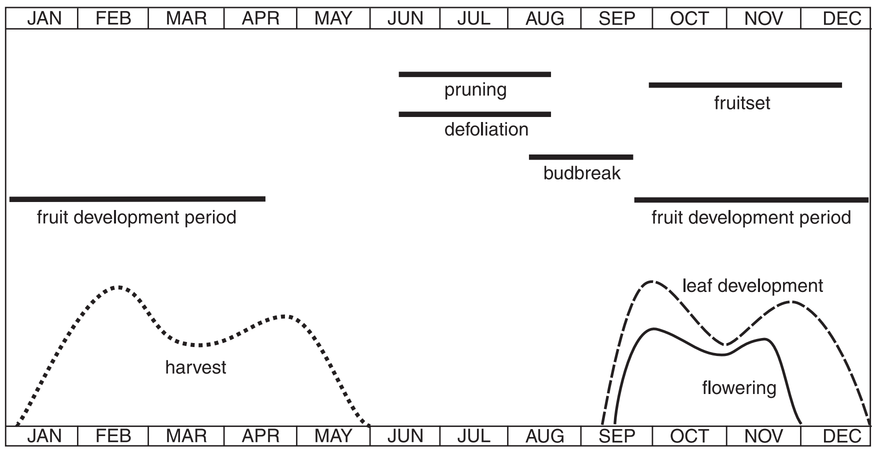


***Figure 21.** Custard apple growth cycle for Yeppoon and Mareeba, Queensland*

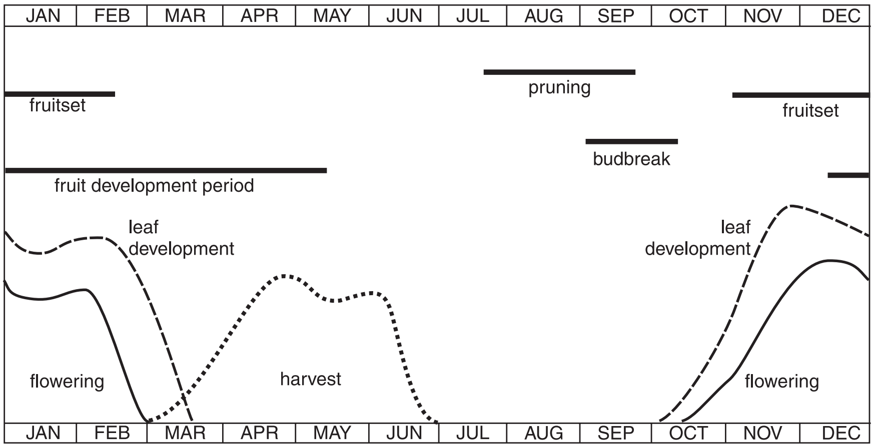


Figure 22. *Custard apple growth cycle for Bundaberg, Queensland*

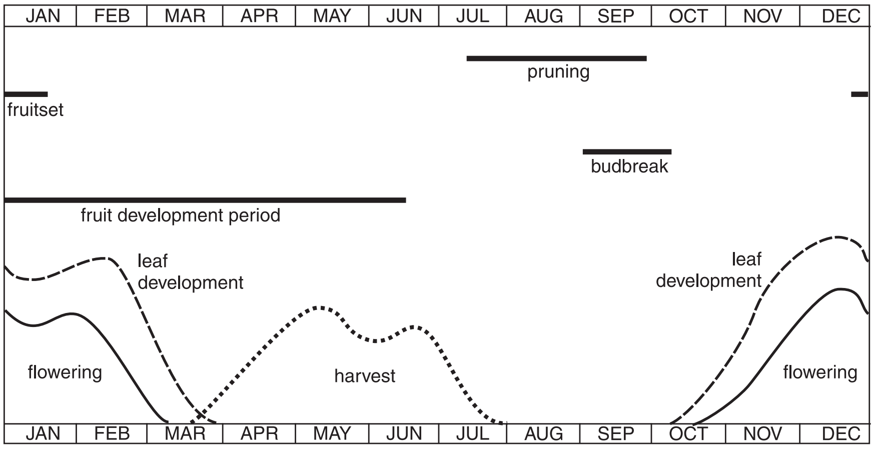


Figure 23. *Custard apple growth cycle for Nambour, Queensland*

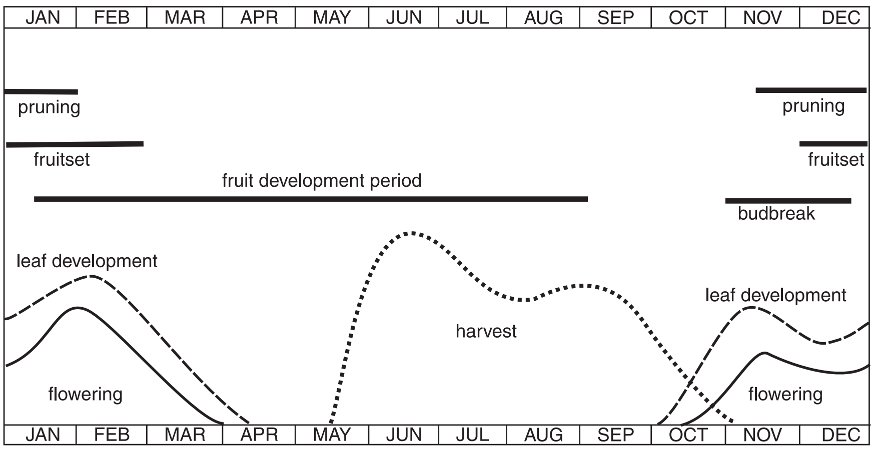


Figure 24. *Custard apple growth cycle for northern New South Wales*

Environmental effects on growth and flowering

Temperature

Both soil and air temperatures have a significant effect on the growth of custard apple trees.

Soil temperature

Soil temperature influences root and leaf growth through its effect on the rootstock. Cherimoya cultivars are used widely as a rootstock because they are more adapted to low and high soil temperatures than most other Annona species. Good root and leaf growth can be obtained with cherimoya rootstocks at soil temperatures between 15 and 28°C. By comparison the optimum soil temperature range for African Pride cuttings is between 17 and 22°C.

Air temperature

Air temperature has a strong influence on several growth phases.

Leaf and shoot growth. Even though custard apples are semi-deciduous, they are relatively sensitive to low temperatures. For example, leaf and shoot growth with atemoya varieties such as African Pride stops when air temperatures drop to about 12 to 13°C.

Mild frosts (to about -3°C) will cause twig and leaf death in bearing trees. More severe frosts (below about -5°C) may kill or severely damage bearing trees. Young trees are even more sensitive; a temperature of -1°C may severely damage them.

Growth slows considerably once temperatures reach 35°C. Optimum temperatures for growth are considered to range from 20 to 32°C.

Flowering. Temperatures of 25 to 28°C during flowering (October to February) favour good fruit set. At temperatures above 28°C, custard apples produce fewer flowers but more growth, and drying of flower parts increases. For this reason, coastal tropical regions, where temperatures regularly reach 28 to 31°C during December and January, are not ideal for atemoya varieties.

Fruit growth and development. Fruit development (the period between fruit set and fruit maturation) takes considerably longer at lower temperatures. Figure 25 shows the relationship between fruit development period (FDP) and mean monthly minimum temperature.

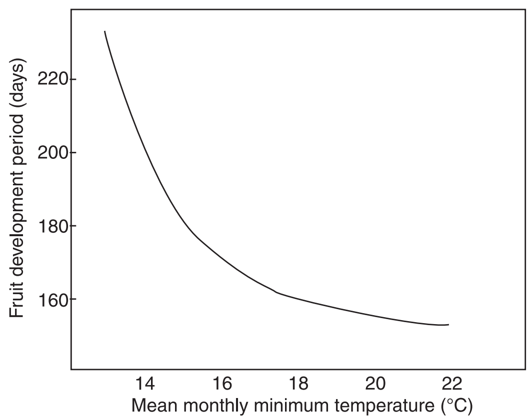


Figure 25. *Relationship between fruit development period (FDP) and temperature for African Pride*

Low temperatures below 13°C during the later stages of fruit development cause russetting of the fruit skin and, in severe cases, fruit splitting.

Humidity

Humidity has the biggest influence on fruit set, the best conditions being 70 to 80% relative humidity. Under these conditions, and with day temperatures of 25 to 28°C, the female stage of the flower is more likely to remain receptive until pollen is shed. Humidities of less than 60% will desiccate flowers. At very high humidities (90% or more), pollen deteriorates rapidly, reducing natural pollination.

Soil moisture

Uniform soil moisture throughout fruit set and development ensures high yields and helps prevent fruit splitting. In coastal Queensland, rainfall during the flowering and fruit filling period is not evenly distributed and irrigation is essential.

Custard apples are sensitive to high salt levels in irrigation water. Water with an electrical conductivity of more than 580 microSiemens/ centimetre (μS/cm) may reduce growth and cause leaf and fruit damage.

Soil drainage

Trees must remain healthy for good growth and flowering. Common causes of poor tree health are root and trunk diseases such as root rot and bacterial wilt. The main feeder roots of custard apple are relatively shallow and very susceptible to root rot from waterlogging. A depth of at least 1 m of well-drained soil is recommended to avoid damage from root rot.

Similarly, bacterial wilt is worst in poorly drained soils.

Wind

Custard apple trees have relatively soft wood and often weak branch crotches, making them extremely susceptible to wind damage, particularly when carrying a full crop (Figure 26). Wind reduces humidity during fruit set and causes damage to the fruit skin through twig rubbing and desiccation. A protected site using either natural or planted windbreaks is essential.

Figure 26. Wind damage in an unprotected site

Implications for management

Orchard establishment and management of young trees

There are several important environmental issues for orchard establishment and management of young trees.

- Select warm, well-protected, frost-free sites to maximise the amount of time trees are exposed to favourable temperatures for growth and flowering. A district that receives predominantly summer rainfall should have appropriate humidities during flowering and fruit set.
- Use only deep, well-drained soils to avoid later problems with root rot and bacterial wilt. Where drainage in the top metre of soil is marginal, plant on mounds.
- Choose a well-protected slope or provide sufficient wind protection to avoid wind damage and dehydration.
- Start with healthy trees propagated onto suitable rootstocks.
- Ensure trees get the best start by carefully preparing the planting site, using good planting techniques, and providing optimum conditions for early tree growth.

Bearing trees

Management of bearing custard apple trees is a complex process. While leaf, root and flower/fruit growth processes can be easily identified as being dependent on each other, they also compete for limited tree carbohydrates, nutrients and water. If this competition is not properly managed and the vegetative/reproductive balance gets out of step, fruit yield is ultimately reduced.

To manage trees better, it is important to understand the growth cycle and the way it is influenced by changes in weather, crop load and nutrition. Once this knowledge is consolidated, management practices can be modified and programmed to develop strategies for possible significant gains in productivity.

Here are some of the key management areas.

- **Nutrition.** Fertiliser application needs to be carefully managed to ensure that it is applied at appropriate times in the cycle. For nitrogen fertiliser, these include before budbreak (to ensure rapid and uniform budbreak); during the summer leaf flush (to feed the developing leaves, young fruit and main root flush); and during the main fruit development period in autumn (to help in fruit development and maturation). The quantities of fertiliser also need to be carefully managed to ensure amounts are adequate but not excessive. Too much fertiliser promotes excessive vigour, which may detrimentally affect flowering, fruit development and leaf fall. Leaf and soil analyses are essential tools in determining appropriate fertiliser rates.
- **Irrigation.** Watering needs to be managed carefully in those parts of the cycle where trees place the greatest demands on the root system for water. The critical time is in summer when the main leaf flush and the first stages of fruit development coincide. Moisture monitoring systems are recommended to guide the frequency and amounts of water applied.
- **Pruning and defoliation.** Pruning plays a key role in managing vegetative vigour and determining the size, number and distribution of fruit on the tree. The timing and severity of pruning needs to be geared to the growth cycle of the tree. For example, winter pruning just before budbreak ensures a more uniform and earlier budbreak. However, if late-maturing fruit is required, winter pruning is delayed to allow later budbreak.

  Defoliation may also be used to control excessive vigour and to induce an early budbreak for earlier fruit production.
- **Hand pollination.** This is used in some varieties such as Pinks Mammoth and Hillary White to improve fruit set, size and shape. It can also be used to manipulate the timing of fruit production to coincide with particular market windows. In these cases, management of other operations needs to be re-scheduled to take account of the different growth cycle.
- **Other.** Other important management operations include fruit thinning (particularly in African Pride) and pest and disease management.

Special manipulation of the growth cycle

Once growers are familiar with the custard apple growth cycle and what affects it, they may then attempt to manipulate the natural growth cycle to produce 'out of season' fruit. This may allow access to more profitable markets. The two main options are early and late cropping.

Manipulation for early cropping

Growers in warm subtropical regions (for example, Yeppoon) can manipulate the growth cycle for early cropping. The technique involves:

- artificial defoliation using 25% urea;
- early pruning at or after leaf fall;
- mulching to raise soil temperature;
- hand pollination of early flowers to increase early fruit set (may also be necessary due to poor pollen viability).

The technique has some limitations. It is unsuitable for:

- areas with late frosts because of the risk of damage to new shoots;
- cooler areas because the response to artificially defoliating trees is limited when soil and air temperatures are below about 12 to 15°C.

Current research is examining the use of rest-breaking chemicals to induce an early and more uniform budbreak. Results are incomplete and no suitable chemical is registered for use on custard apples.

Manipulation for late cropping

Growers in cooler subtropical regions (for example, northern New South Wales) can manipulate the growth cycle for late cropping. The technique involves:

- application of nitrogen and water in late winter and spring to delay leaf drop;
- pruning in late spring;
- shading and wind protection;
- pruning and leaf stripping in late spring and summer to promote a second wave of flowering;
- leaving a small amount of fruit from the previous season.

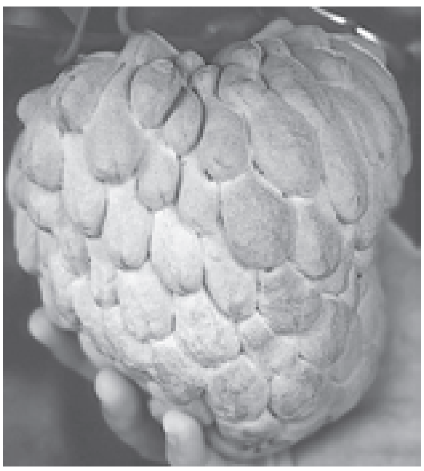
Selecting varieties

Success in commercial custard apple production depends largely on the correct selection of varieties. This is not always easy, as there are several varieties to choose from and many differing opinions on which varieties are best. This section will help you understand the different varieties and their advantages and disadvantages.

The custard apple family

The Annonaceae family, of which custard apple is a member, includes 120 genera containing over 2000 species. One of these genera, Annona, includes the atemoya, cherimoya, sweetsop or sugar apple, ilama; soursop, bullock's heart and pond apple. Species of another genus, Rollinia, are of minor importance.

In Australia, the atemoya is commonly known under the general name 'custard apple'. The common atemoya varieties grown in Australia are thought to be crosses or hybrids between two species, the cherimoya (*Annona cherimola*) and the sweetsop (*Annona squamosa*). As such, atemoya is not a true species. Varieties grown commercially are sometimes referred to as cultivars, to distinguish them from non-commercial varieties. Recent evaluation by the Australian industry of both overseas and domestic markets has shown high consumer acceptability of atemoya, and several varieties are gaining greater prominence in world markets.



Current varieties and their main characteristics

Atemoya hybrids (hybrids between *Annona cherimola* and *Annona squamosa*)

Pinks Mammoth

History. The first commercial variety grown in Queensland. Introduced from Guyana in the late 1800s by Mr Pink, Manager of the Queensland Acclimatisation Society. Quickly became a highly desired fruit in the Brisbane markets. Now overshadowed by other varieties because of production problems.

Major benefits. Excellent and consistent flavour and eating quality, regarded by many as the Australian industry standard.

Major problems. Shy and irregular bearing behaviour. Unless hand pollinated, has poor natural fruit shape, which makes fruit difficult to pack. Low yields. Soft and fragile when fully ripe, with a short shelf life.

Hillary White

History. Originated as a budsport (mutated shoot) on a Pinks Mammoth tree at Hillary White's orchard in the Redland Bay district of Queensland in the mid-1980s. Has largely superseded Pinks Mammoth as the most important variety grown in Queensland.

Major benefits. More precocious and consistent bearer than Pinks Mammoth. Fruit more attractive, smoother in appearance and of reasonable shape, making them easier to pack than Pinks Mammoth. Good flavour.

Major problems. Soft and fragile when fully ripe, with a relatively short shelf life. Requires hand pollination in most seasons to achieve good yields and fruit shape.

African Pride

History. Selected in South Africa in the early 1950s and introduced into Australia in about 1959. Still the leading variety grown in Australia today, but being replaced by Hillary White and other newer selections.

Major benefits. Precocious and regular bearer, which does not require hand pollination. Yields in excess of 25 t/ha possible. Remains firm fleshed when fully ripe, with good shelf life.

Major problems. Can be very seedy with a marginal flesh to seed ratio. Sometimes poor flavour. Prone to skin darkening and other fruit quality problems. Fruit often small unless thinned.

Palethorpe

History. Seedling of African Pride, selected in the early 1980s at Glasshouse Mountains, Queensland. Initially appeared promising but was not accepted by industry because of its long juvenile period and its high susceptibility to fruit fly. However, needs re-evaluation and may prove suitable if topworked to mature trees, thus reducing the juvenile period. Worthy of limited trial.

Major benefits. Excellent external fruit quality.

Major problems. Marginal flesh to seed ratio. Very susceptible to fruit fly. Long juvenile period before production starts.

Gefner

History. The leading cultivar grown in semi-tropical regions of the world. Selected in Israel in the 1960s. In semi-tropical regions, has produced fruit of reasonable quality.

Major benefits. Precocious and heavy bearing.

Major problems. In the subtropics, fruit are too small, exhibit poor flesh to seed ratio and are susceptible to splitting in low temperatures.

Maroochy Gold

History. Selection made at DPI's Maroochy Horticultural Research Station at Nambour in 1995. Cross between the red-skinned sugar apple (*Annona squamosa*) and Hillary White. Worthy of limited trial.

Main benefits. Limited testing to date indicates that this variety can set good crops naturally without hand pollination. Fruit are highly symmetrical in shape with very smooth skin. Flesh to seed ratio is moderate, but better than African Pride. Very good flavour and texture.

Major problems. None to date.

Maroochy Red

History. Cross between the red-skinned sugar apple (*Annona squamosa*) and Hillary White. Has a dark red skin and a slight pinkish tinge in the flesh. Worthy of limited trial.

Major benefits. Limited testing to date indicates that this variety can set good crops naturally without the need for hand pollination. Fruit are moderately symmetrical in shape, slighted pointed with very smooth skin. Flesh to seed ratio is moderate, but better than African Pride. Excellent flavour and texture.

Major problems. None to date.

Martin

History. Promising variety which was produced from a cross between Bullock's Heart (a local atemoya cultivar, not to be confused with the species *A. reticulata* which is also sometimes called Bullock's Heart) and Hillary White. Was the only selection made from 600 atemoya crosses grown at Bob Martin's orchard at Glasshouse Mountains, Queensland. Worthy of limited trial.

Major benefits. Vigorous tree which flowers profusely. Exhibits a higher level of natural set than Hillary White.

Major problems. In subtropical Queensland, if not hand pollinated, trees produce 40% large, highly symmetrically shaped fruit and about 60% small, poorly shaped fruit. For this reason, it is recommended that growers undertake some hand pollination to ensure adequate set of the larger size fruit. Smaller, deformed fruit should be removed at the completion of fruit set, normally January in south-east Queensland. Under wet summer conditions, fruit are susceptible to Diplodia fruit rot.

Cherimoya—*Annona cherimola*

Originates from the cool dry highlands of Ecuador and Peru. Grown commercially in New Zealand, Spain, Chile and California. Not grown in Australia to any commercial extent because of disease problems.

Fino de Jete

History and description. A Spanish cherimoya variety with finger-print, U-shaped depressions on the skin. Grows best in temperatures ranging from 7 to 18°C mean minimum and 15 to 28°C mean maximum. The tree grows up to 10 m high with typically round leaves, which have a velvety lower surface. The fruit is heart-shaped and flavour is more acid than the atemoya. Breaks dormancy earlier in the spring because of its lower temperature requirement for growth than atemoya. Fruit may mature as early as February in south-east Queensland.

Fruit quality characteristics

A summary of the fruit quality characteristics of the important commercial custard apple varieties is shown in Table 6.

***Table 6**. Fruit quality characteristics for mature fruit of the most important atemoya varieties in subtropical Australia*

Variety	Average weight (g)	Average seed no. per 100 g of flesh	Fruit symmetry*	Skin type*	Flavour*	Texture*
Pinks Mammoth	520	4 – 6	5	T	9	7
Hillary White	440	5 – 7	3	T	9	8
African Pride	380	6 – 10	2	I	7	7
Martin	480	7	2	T	8	8
Maroochy Gold	420	9	1	S	8	8
Palethorpe	420	11	2	T	8	7
Gefner	350	15	1	T	6	5

***Code**:

- Fruit symmetry: 1 = highly symmetrical, 5 = poorly symmetrical
- Skin type: T = tuberculate (lumpy/lobed), I = impressa (indented), S = smooth
- Flavour and texture are rated on a hedonic scale, where 1 = dislike extremely and 9 = highly acceptable

Variety selection

The selection of varieties is based on:

- climatic conditions
- target market.

Each variety has a set of climatic conditions for which it is best suited, and fruit with characteristics sought after by particular markets.

Climate

Figure 27 is a decision flow chart showing the suitability of varieties for various climatic conditions.

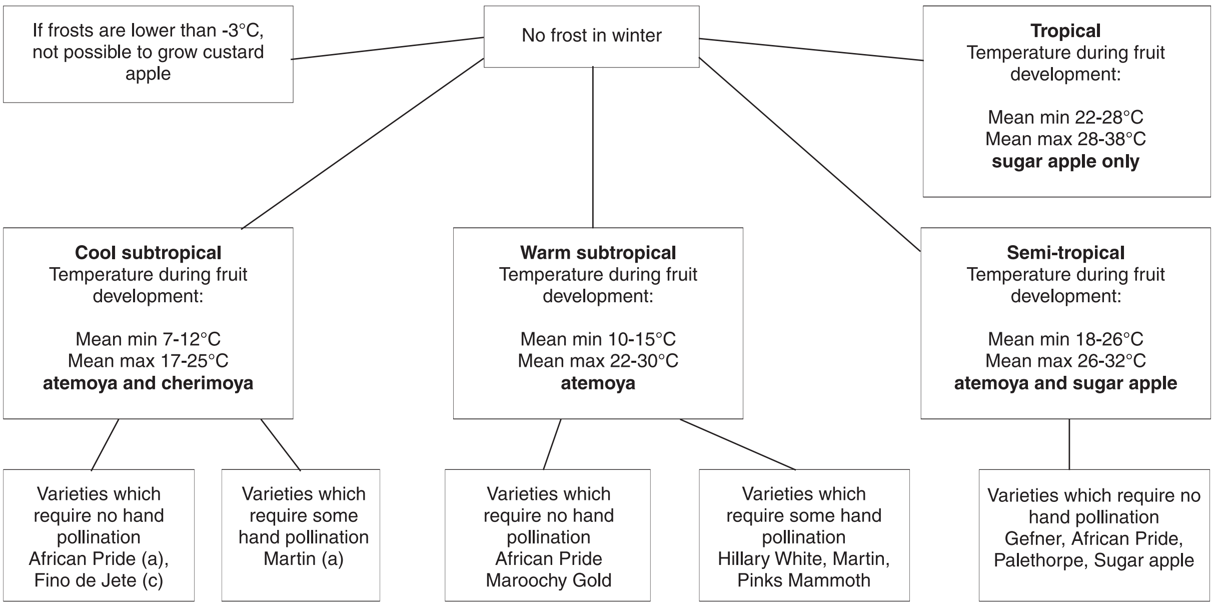


Figure 27. *Decision flow chart for selecting varieties for different climatic conditions*

Target market

African Pride and Pinks Mammoth/Hillary White varieties have vocal supporters but different preferences have developed in different markets in response to local factors.

The Asian export market appears to prefer Pinks Mammoth/Hillary White because of its slightly sweeter flavour. However, good quality fruit of African Pride also has export potential in Asia, particularly when fruit of Pinks Mammoth/Hillary White is in short supply. Some Asian consumers may clearly distinguish African Pride from Pinks Mammoth/Hillary White and align it more with their locally grown sugar apple. Although African Pride looks similar, it is larger, less seedy and has a better flavour. Nonetheless, price may suffer as a result.

African Pride may better suit western tastes and needs investigation in European and Canadian markets.

New variety breeding program

The custard apple industry in Australia is based on three main atemoya varieties only—African Pride, Pinks Mammoth and Hillary White. In Florida and Hawaii, the variety Gefner is the only one grown commercially.

All currently grown commercial varieties have limitations, however, breeding and selection programs in Australia and Florida are starting to yield promising results. In Australia, two new varieties—Maroochy Gold and Maroochy Red—have been named in recent years and more will follow. Some of these will replace existing varieties.

In the breeding programs, characteristics being sought in new varieties are summarised in Table 7.

Table 7. *Characteristics sought in selection of superior atemoya varieties*

Characteristic	Desired type
Tree morphology	
· Degree of apical dominance	low
· Number of fruit bearing laterals	high
Yield capacity	
· Percentage of flowers set	3 – 5%
· Precocity of bearing	2 – 3 years after planting
· Maximum yield at full maturity	more than 60 kg
Fruit quality	
Number of seeds per 100 g of flesh	less than 10
Fruit size range	300 – 600 g
Skin thickness	moderate to resist bruising
Skin colour	attractive green, yellow, red
Fruit shape	round, highly symmetrical
Skin type	smooth or mildly tuberculate or impressa (indented)
Skin russetting	none
Flavour	sweet, highly acceptable
Flesh texture	smooth, creamy
Flesh colour	creamy white to pinkish tinge
Postharvest	
Storage life	more than 10 days
Storage characteristics	little or no skin discolouration

Rootstocks

Most custard apple trees are propagated by grafting selected varieties onto seedling rootstocks. Tree size, vigour, yield and longevity, and fruit quality all depend on the rootstock. Selecting the right rootstock is critical. It is not easy, as there are several different rootstocks and many differing opinions on which one is the best. This section will help you make an informed decision about selecting rootstocks.

A summary of the options

There are two main options for propagating custard apples—grafting scions onto rootstocks and using cuttings. Cuttings are still experimental and are not yet widely used in commercial orchards. For rootstocks, there are several options (Figure 28) depending on the planting system.

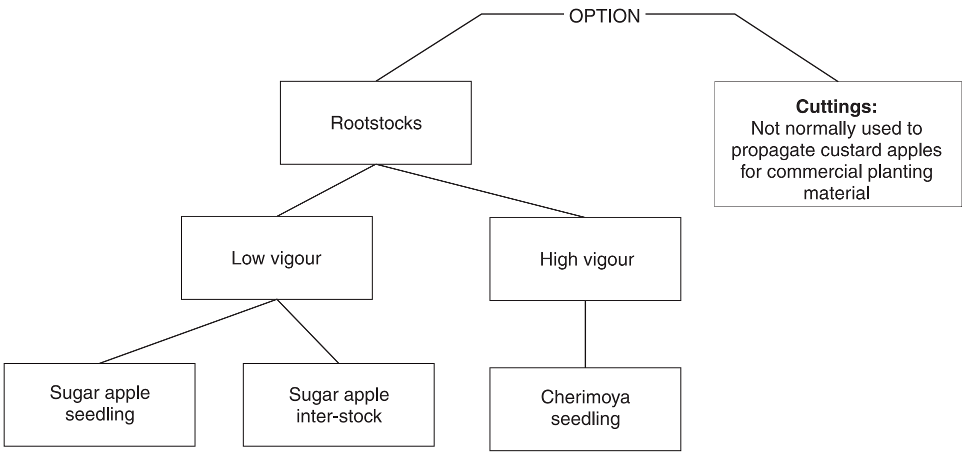


***Figure 28.** Options for propagating custard apples*

Rootstocks or cuttings

Although cuttings are not yet widely used in commercial orchards, they offer some advantages (Table 8).

Table 8. Advantages and disadvantages of cuttings and rootstocks

Rootstocks	Cuttings
Advantages	
· Trees are more stable in the ground	· Quicker to establish trees ready for planting
· Special disease resistant rootstocks can be used	· Cheaper to produce
· Well-proven; almost all custard apple trees are currently grafted onto seedling rootstocks	· Reach bearing age much more quickly
· Possible future opportunity to use clonally-produced rootstocks to produce trees with more uniform size, shape, yield and fruit quality	· Eliminates variability in trees due to seedling rootstocks
Disadvantages	
· Trees are more expensive to produce	· Trees are highly vigorous and difficult to manage—20 to 30% more vigorous than grafted trees on cherimoya rootstock
· Seedling rootstocks can be highly variable in growth and disease performance	· Trees are not as stable in the ground and are more susceptible to being blown down
	· Difficult to propagate. Success rate: less than 20% for most varieties and less than 5% for Pinks Mammoth
	· Still experimental

Important factors in selecting rootstocks

Graft compatibility between scion and rootstock

The known graft compatibilities between a range of *Annona* species and potential rootstock species are shown in Table 9.

Table 9. *Graft compatibilities of* Annona *and* Rollinia *species and hybrids*

Scion	Atemoya (*Annona atemoya*)	Cherimoya (*Annona cherimola*)	Sugar apple (*Annona squamosa*)	Bullock's heart (*Annona reticulata*)	Soursop (*Annona muricata*)	Pond apple (*Annona glabra*)	*Annona montana*	Rollinia (*Rollinia deliciosa*)
Atemoya	C	C	C	N	N	N	N	-
Cherimoya	C	C	C	C	-	-	N	-
Sugar apple	C	C	C	C	N	-	-	C
Bullock's heart	-	-	C	C	-	-	-	-
Soursop	-	C	-	C	C	C	-	-
Pond apple	-	C	-	C	C	C	-	-
Ilama *(Annona diversifolia)*	-	-	C	C	-	C	-	C
Rollinia	-	-	-	C	C	C	-	-

Code: C = compatible; - = unknown; N = not compatible

Table 9 shows that atemoya and cherimoya grafts are compatible with a wide range of *Annona* species. However, under subtropical conditions, the atemoya is incompatible on pond apple (*A. glabra*), bullock's heart (*A. reticulata*) and soursop (*A. muricata*), though the problem on pond apple may take ten years or more to show. The problem of incompatibility of atemoya on pond apple may be overcome by using cherimoya as an interstock (budwood of a different variety which is compatible and placed between the rootstock and the scion), as this is graft compatible on both species. However, this combination may only be suitable for tropical regions as the pond apple is slow growing in subtropical areas.

Disease resistance

In Queensland, bacterial wilt (*Pseudomonas solanacearum)* has been identified as a major cause of tree death. Symptoms of this disease are severe collar and root rot leading to rapid deterioration in tree health.

The sugar apple is highly susceptible to bacterial wilt and under subtropical conditions 70 to 80% of trees can die. Cherimoya appears to be much less susceptible, with usually less than 10% of trees affected. Some cultivars of cherimoya, such as White, appear to be more disease resistant than others.

Tree vigour and size

Atemoya and cherimoya grafted onto cherimoya produce vigorous trees. In contrast, tropical species such as the sugar apple and pond apple have a dwarfing effect on atemoya varieties when grown in subtropical environments. Under tropical conditions, the dwarfing effect is much less marked. This dwarfing effect of the sugar apple rootstock makes it easier to manage the canopy and increase yields per unit of canopy area. However, the sugar apple **cannot** be recommended as a rootstock because it is highly susceptible to bacterial wilt.

The use of sugar apple as an interstock has been evaluated as a possible alternative means of dwarfing scion varieties. Results show a 66% reduction in tree size compared to trees on cherimoya rootstock. Although fruit size was not altered, the fruit bearing load per hectare was increased by 40%. The incidence of woodiness, an internal fruit disorder, was also reduced by 70%. The fruit also appeared smoother and more symmetrical. Some varieties of cherimoya, such as Whaley, also exhibit dwarfing characteristics but have not yet been thoroughly tested.

However, a major problem is that, because of the variability in vigour and disease resistance of seedling cherimoya rootstocks, some trees on sugar apple interstock may be too weak for long-term productivity. This problem can probably only be resolved through clonal propagation of selected cherimoya rootstocks, and this has not yet been properly developed. Until these rootstocks have been extensively evaluated in commercial field trials, the use of sugar apple interstocks is still regarded as experimental.

Rootstock options

Wide planted orchards using high vigour cherimoya seedling rootstocks (Recommended)

Wide planted orchards using high vigour cherimoya seedling rootstocks are the main commercial system. Several different varieties of cherimoya, ranging from Whaley (moderate vigour) to White (high vigour), are used as seedling rootstocks. Cherimoya varieties also contain varying degrees of resistance to bacterial wilt, with White having the greatest resistance.

Here are the advantages and disadvantages of cherimoya rootstocks.

Advantages

- Trees are healthier and have a longer life due to better resistance to bacterial wilt.
- Fruit is better protected from sunburn.
- Rootstock is suitable for a wide range of climates.

Disadvantages

- Trees are difficult to manage because of size and vigour, making it more difficult to harvest, spray and prune.
- Good fruit set is harder to achieve because of the difficulty in controlling vegetative growth, particularly with Pinks Mammoth.
- There is an increased incidence of internal fruit disorders such as woodiness and brown pulp.

Close planted orchards using low vigour sugar apple seedling or sugar apple interstocks

There is considerable interest in rootstocks of lower vigour because of the excessive vigour of cherimoya rootstocks and cuttings. Here are the advantages and disadvantages of low vigour rootstocks.

Advantages

- Trees are much less vigorous and smaller, making harvesting, pruning, spraying, fruit thinning and other tree management operations much easier.
- The vegetative growth of varieties such as Pinks Mammoth is much less terminally dominant. Fruit may be produced more evenly over the tree's framework.
- Trees can be maintained at less than 2.5 m high and be trained on trellis systems such as Y-trellis and palmette trellis. This increases light penetration into the canopy, thereby improving fruit set and size.
- Trees can be planted at high densities of 600 to 800 trees/ha.
- Trees start bearing earlier (precocious).
- There is reduced incidence of internal fruit disorders such as woodiness and brown pulp.

Disadvantages

- Trees have a shorter life because of root diseases such as bacterial wilt (sugar apple rootstock only).
- There may be a greater risk of long-term tree decline from graft incompatibility effects.

The two possible options for low vigour rootstocks are sugar apple as the rootstock, and sugar apple as an interstock on cherimoya as the rootstock.

Sugar apple rootstocks (Not recommended)

The sugar apple is a tropical species that produces a dwarf compact tree when used as a rootstock under cooler subtropical conditions. Under these conditions, however, root growth is poor, particularly when trees reach full cropping stage. Also, about four years after planting, the rootstock becomes more susceptible to bacterial wilt, presumably because there is insufficient root growth to keep ahead of the loss of roots to the disease. Under tropical conditions, this is less of a problem and sugar apple is used successfully as a rootstock in Hawaii.

Sugar apple interstock/cherimoya rootstock (Still experimental—trial only)

Research at DPI's Maroochy Research Station, Nambour has shown that sugar apple used as an interstock can effectively dwarf trees similarly to sugar apple rootstock alone. This system takes advantage of the climatic adaptation and disease resistance of the cherimoya rootstock and the lower vigour and dwarfing properties of the sugar apple.

The main disadvantages are the extra cost of propagation, and the possibility that, because of the variability in cherimoya seedling rootstocks, some trees may be too dwarfed for good commercial production. There is also a greater chance of long-term graft incompatibility from two graft unions instead of one.

However, the system offers high yield potential—up to 30 to 50% increase over cherimoya or sugar apple rootstocks alone. This system would require more judicious pruning and fruit thinning, and better overall management, if fruit quality were to be maintained.

This system may have further merit once clonal propagation techniques are better developed, as this would eliminate the variability in seedling cherimoya rootstocks.

The technique, however, is still experimental and is recommended for small-scale trial only. Other interstock selections such as Gefner and African Pride also merit investigation where more vigour is required.

Propagation

When establishing an orchard, there is a choice of buying or propagating your own plants. Propagating custard apples, however, is a specialised job requiring skill and specialised equipment and we recommend that growers leave it to specialist nurseries. We get numerous enquiries, however, from people wanting to understand the process and have provided some basic notes on propagation.

Overview

Custard apple plants are generally propagated by grafting a selected scion variety onto a seedling rootstock. They can also be propagated by cuttings, but this method is not yet recommended for commercial orchards.

Use only scion wood and seed for rootstocks selected from trees of proven performance.

A grafted plant can be produced in about 18 months if a covered propagation shed is used. When plants are grown in the open, the process generally takes two years or more.

Raising seedlings for rootstocks

Seed extraction and germination

A cherimoya seed consists of a thick outer covering (testa) over a white endosperm, which, in turn, contains a small embryo. The endosperm is the white tissue (mainly starch) which forms the bulk of the seed. It acts as a food source for the embryo during its development.

The embryo is the collection of cells, which begin to form a new plant. The embryo is very small, develops slowly and is often immature when the fruit is harvested. It continues to develop after the seed is removed from the fruit, but will not germinate until it is mature. It is best to plant cherimoya seed soon after removal from the fruit. If seed is to be stored, dust it with a fungicidal powder, seal it in an airtight container and keep it cool.

Seed can be removed from the hard, mature fruit or fermented from fully ripe fruit. Removal from hard, mature fruit is more difficult but should give the best results. If seed is extracted by fermenting the pulp, surface sterilise the seed with a chlorine wash after extraction. To prepare the solution, dilute 10 mL of household bleach in 50 mL of water. Add a few drops of detergent and soak the seed for 20 minutes. After removal, wash the chlorine off with sterile water (boiled then cooled).

Seed is usually extracted and planted during autumn (March to May). A glasshouse or polytunnel is needed to grow the seedlings through winter. Under warm conditions, seed takes about one month to germinate. A germination rate of up to 60% can be expected. At lower temperatures, seed can take three to four months and the germination rate declines.

Pre-germinating seed

Before planting the seed, it is best to pre-germinate it. This enables non-viable seed to be discarded before planting and ensures a more even take of seedlings.

Where seed has been stored, inhibitors in the seed may reduce germination. To help improve germination, first soak the seed in water for 24 to 48 hours and discard seeds that float.

The aim of pre-germination is to activate the growth of the seed embryo just enough to rupture the seed coat for the young root (radicle) to appear. There are a couple of options for doing this:

- Place seed in a single layer between several layers of moist hessian. This allows the seeds to be easily inspected at regular intervals, and pre-germinated seeds easily removed without damaging the tender radicle.
- Place seed in a moist medium in a container. Suitable media include sawdust, peat moss, perlite or vermiculite. With this technique, it is easier to maintain appropriate levels of moisture, temperature, aeration and light. However, removal of the pre-germinated seed without damage is more difficult.

Regularly inspect the seed, remove pre-germinated seed and plant into containers.

Raising seedlings

Plant the pre-germinated seeds at a depth of 10 to 20 mm, one seed per container. Use a mixture containing equal parts by volume of peat and sand for raising the germinated seed. Deep, cell-type containers such as 'easyouts' are suitable (Figure 29). These allow the development of a single, strong taproot, which is air-pruned when it reaches the bottom of the container. This avoids twisted, tangled roots.

Figure 29. Cherimoya seedlings in 'easyout' containers ready for growing on

Raise the seedlings in a warm environment. Where heated beds are used, maintain the temperature at 28 to 32° C.

Transfer the seedlings to larger containers or nursery beds once they are 100 to 120 mm high. If seed is planted in April, the seedlings should be large enough to transplant by November/December.

Growing-on

Seedlings can be grown to grafting size and then to field-planting size in either polythene containers or nursery beds. There are advantages in both systems.

Container-grown plants

The main advantages of growing plants in polythene containers (polybags) are the ease of handling, the lack of disruption to the root system at planting, and the relative freedom from root diseases.

Ideally, the polybags used should be at least 300 to 500 mm deep (6 to 8 L). This encourages a straight, well-developed taproot. Plants will be kept in these bags for up to 15 months. Fertilise the plants regularly, especially if slow-release mixtures have not been used in the potting mix. Most nurseries use a slow-release fertiliser with occasional applications of urea. Alternatively, make a fertiliser solution by adding 45 g of urea and 30 g of sulphate of potash to 9 L of water. Apply 200 mL of this solution to each plant every two to three weeks. Commercial preparations of foliar fertiliser are equally suitable. Water plants two to three times a week.

Avoid excess growth as plants can become too large for easy grafting. Remove all side shoots to encourage a strong, upright stem for grafting.

Potting mixes

Many potting mixes are suitable; the choice will depend on availability and cost of ingredients. Two examples of suitable potting mixes are:

- one part sand : one part sawdust (by volume)
- one part sand : one part peat : one part soil (by volume).

Potting mixes, especially if containing soil, should be steam-pasteurised or sterilised with methyl bromide before use. Pasteurisation is achieved by heating the mix to 65°C for 40 minutes.

After treatment, add fertiliser to the mix. Some nurseries add the fertiliser before steam pasteurisation. Many fertiliser combinations are suitable but two commonly used combinations are shown in Table 10.

Table 10. *Common fertiliser combinations for potting mixes*

Combination 1 (per cubic metre of mix)	Combination 2 (per cubic metre of mix)
· 450 g sulphate of ammonia	· 1 kg 3 to 4-month slow-release mixed fertiliser
· 150 g superphosphate	· 2 kg 12 to 14-month slow-release mixed fertiliser
· 200 g potassium sulphate	· 4 kg dolomite
· 3 kg dolomite	· 1 kg DAP
· 1 kg trace element mixture	· 1 kg trace element mixture
Note: With this combination, seedlings need additional fertiliser after they have started to grow.	**Note**: With this combination, the slow-release fertilisers should last for several months.

Many brands of trace element mixture are commercially available. One kilogram of the trace element mixture referred to is approximately equivalent to:

- 50 g iron sulphate
- 12 g copper sulphate
- 6 g zinc sulphate.

Nursery beds

The use of nursery beds avoids the cost of polythene bags and potting mix. Bare rooted plants are usually cheaper to freight than containerised plants.

Nursery beds should contain at least 1 m of well-drained loam and be located in a warm, frost-free site with plenty of sunlight. The bed layout should provide easy access for thinning of trees, pruning, grafting and tree removal.

Transplant seedlings from 'easyouts' to the nursery bed in late spring.

Grafting and budding

Custard apple rootstocks can be grafted or budded. Grafting is preferable and relatively easy. Seedlings are usually grafted in mid to late August when sap flow has started. By this time, the seedlings are usually about 15 months old and up to 1 m high, with a stem diameter of about 10 mm.

The grafted plants should be large enough to plant out by January/ February.

Select grafting wood from the previous season's hardened (browned-off) growth. Each piece should contain three to six well-developed buds. The wood should be the same thickness as the seedling rootstocks.

Graft the seedlings 100 to 150 mm above ground level, using either a whip or cleft graft. Alternatively, bud the seedlings using a T-bud or chip bud.

Whip graft

To whip graft, make a sloping cut about 30 mm long on the base of the scion and on the top of the stock (Figure 30). This cut will need to be longer if the diameter of the wood is more than 10 mm. If the stock and scion are not the same size, match the cambium layers on one side only. The cambium, which is the slightly darker layer just under the bark, lifts with the bark. Secure the scion piece to the stock with budding tape. Always apply tape from the bottom upwards to produce an overlapping pattern which sheds water away from the graft.

The whip graft is difficult for the beginner, but once mastered it is a relatively quick method of grafting. Nurseries commonly use it.

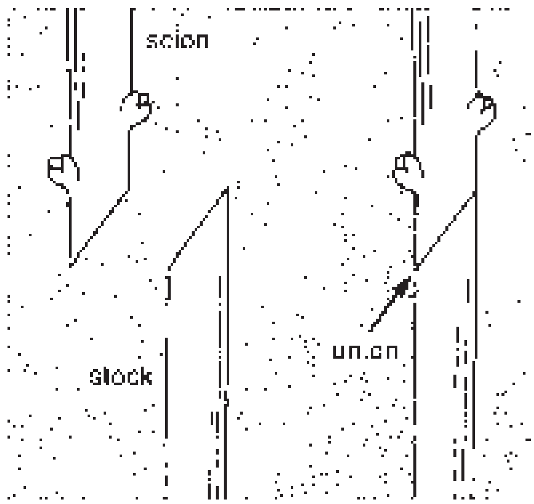


Figure 30. *Whip graft*

Cleft graft

The cleft graft is the easiest grafting technique for the beginner but is suitable only for young, flexible rootstocks.

Prepare the scion piece by cutting a 30 mm long, uneven wedge on the basal end (Figure 31).

Prepare the rootstock by cutting it off about 150 mm above soil level and making a 30 mm long cut down the centre of the stem. If the rootstock is larger in diameter than the budwood, place the cut off-centre. This is then called a 'modified cleft graft'.

Fit the scion so that the cambium is matched with the cambium of the stock on at least one side. Tape the union from the bottom upwards with budding tape.

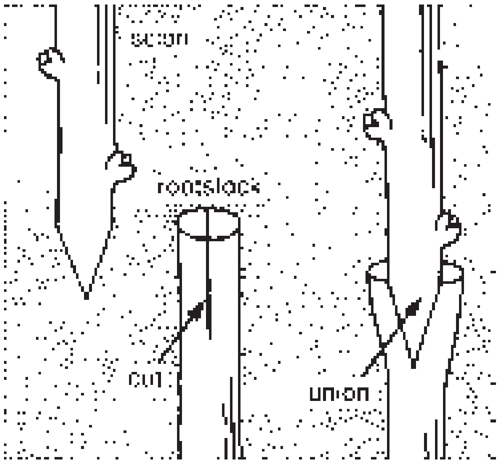


***Figure 31.** Cleft graft*

T-budding

For T-budding, cut a shield bud at least 40 mm long and 10 mm wide. Select a stock at least 15 mm in diameter. Make a 'T' incision, either upright or inverted (Figure 32). Push the shield bud in and tape it. Do not wrap the budding tape too tightly over the bud itself. The bud should start growing after 21 to 28 days. Cut the tape when the bud has taken. When growth is obvious, cut the stock 100 to 150 mm above the bud. Cut the remaining stub above the bud after the bud has grown 150 to 200 mm high.

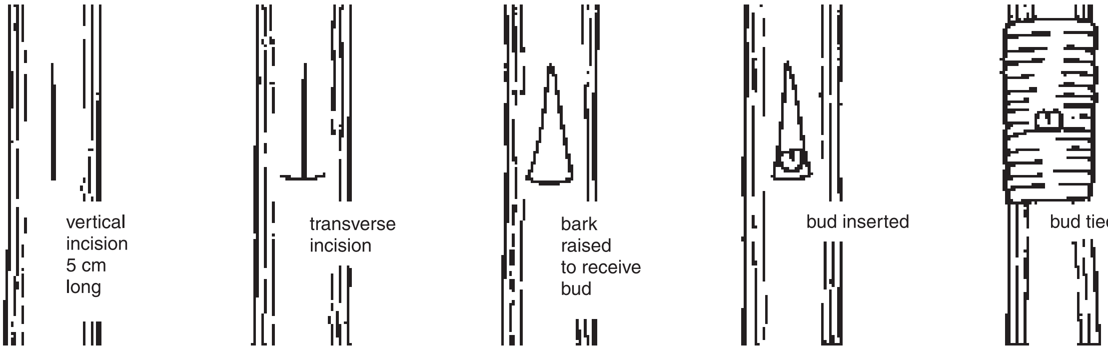


***Figure 32.** T-budding*

Chip bud/veneer graft

A chip bud is where a considerable piece of wood is removed with the bud. A matching piece is cut from the rootstock and the bud inserted. Chip budding is useful where the bark of the rootstock will not lift easily for T-budding.

A veneer graft is similar to a chip bud except that the scion piece used has more than one bud, usually three to four. To prepare budwood for a veneer graft, first trim it to three to four buds then remove a thin slice down one side (this should only just cut into the wood to expose the cambium on the margin of the cut). Cut the bottom of the budwood into a wedge shape. Remove a similarly shaped piece from the rootstock, insert the budwood into this cut and tape it in place.

Veneer grafts are useful where the scion wood and rootstock are of differing diameters (Figure 33).

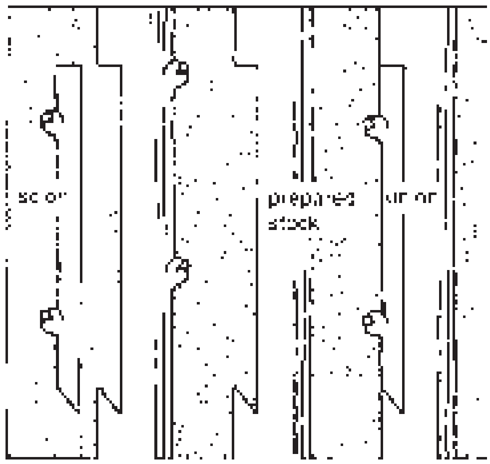


Figure 33. *Veneer graft*

Topworking

Topworking is a process where established trees in the field are grafted over to a new scion. This is an alternative to removing trees of non-performing varieties and replanting with new nursery stock.

The best times for topworking in south-east Queensland are from mid-August to early September and during April. Some sap flow is necessary to be able to lift the bark to insert grafts. Strong sap flow might retard the healing (callusing) process. Topworking in autumn allows the graft to heal (callus) before growth resumes in September. Topworking is much less successful from September to February when temperatures are high and the sap flow is strong. If trees must be topworked in summer, shade each plant.

Cut the tree to be reworked at a height of about 50 to 60 cm. It is best to cut back to the two main leaders rather than a single trunk. If any side limbs (called 'nurse limbs') exist below this, retain them until the grafts have established. Coat the upper surfaces of all limbs with a white water-based paint or talc/bentonite solution to avoid sunburn.

The bark graft is the first option (Figure 34). The number of scions used depends on the size of the limb to be grafted. Two to three scions per limb are usually sufficient to ensure a reasonable chance of a take.

Prepare the scion as per the whip graft. You can improve the percentage of success by slicing a small sliver of bark from the back or side of the scion where it is to be inserted into the stock. Make this cut just deep enough to expose the green cambium layer. Make a vertical cut through the bark of the stock. Lift a flap of bark on one side of this cut and insert the budstick. Wrap budding tape around the limb to hold the scions in place. Use a sealant such as grafting mastic to waterproof the graft union and the exposed cut.

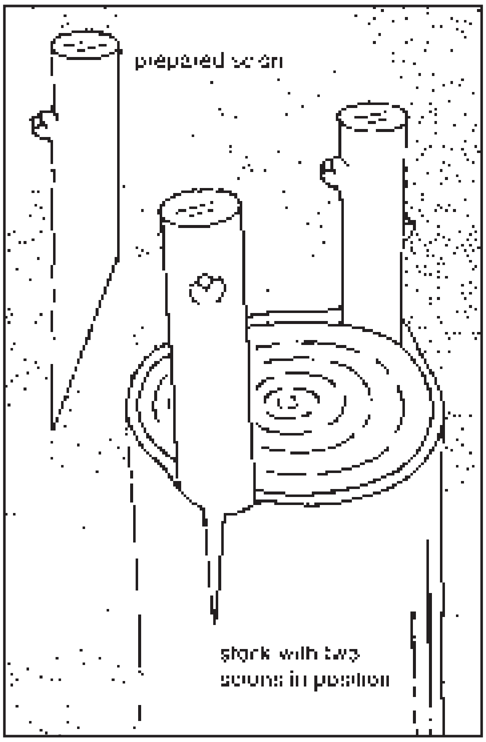


Figure 34. *Bark graft for topworking*

Place a white opaque plastic bag over the newly grafted limbs to keep them moist and cool. Additional shade will be necessary where the topworked tree is in direct sunlight (Figure 35). Remove the bag and tape when the scion has started to grow, usually two to three weeks after grafting.

Figure 35. *A topworked tree showing the plastic bag over the bark graft site*

The second option for topworking is to graft or bud new shoots that emerge from the limb. Any of the grafting or budding techniques mentioned previously are suitable here.

Nutrition

Plant nutrition is one of the keys to achieving good orchard performance. Both deficiencies and excesses of plant nutrients can adversely affect fruit yield and quality. Fertiliser use has to be carefully managed to ensure a balanced supply of all nutrients is maintained at the critical times during leaf growth and fruit development.

Why nutrition needs to be carefully managed

The unmanaged approach to fertilising custard apples involves applying fertiliser throughout the season without knowing whether the soil or the plant needs it or not. This can lead to excessively low or high levels of some nutrients in the soil and plants and can cause several problems. These include:

- reduced yields from nutrient imbalance;
- excessive shoot vigour, resulting in a reduction in flower numbers from shading, as well as increasing the amount of pruning;
- lower fruit quality from nutrient imbalance (woodiness and brown pulp disorders);
- contamination of groundwater from excess nutrients being leached out of the root zone.

In addition, blanket fertiliser applications fail to recognise that different varieties, different blocks of trees and different soil types have different fertiliser needs. Consequently, a blanket fertiliser rate tends to be too much for some and too little for others.

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

The managed approach

The modern approach to fertilising relies on regular monitoring of soil and plant nutrient levels so those nutrients are at all times kept at optimum levels for the plant. Three monitoring tools are used:

Pre-plant soil analysis. This ensures that the soil is suitable for the crop, and that nutrient levels are at their optimum levels before planting. It is particularly important to allow for the adjustment of insoluble nutrients such as phosphorus and calcium, which are difficult to adjust once the trees are in the ground.

Annual leaf analysis in bearing trees. This allows the fertiliser program to be fine-tuned each year to keep all nutrients within the optimum range. It allows variables such as the season, the crop load and the condition of the tree to be taken into account.

Regular and preferably annual soil analysis in bearing trees. This ensures that soil pH is kept within the desired range and monitors the important balance between pH, calcium, magnesium and potassium.

Understanding the important nutrients

Nitrogen

Nitrogen is the key nutrient affecting yield and fruit size. Too little nitrogen reduces photosynthesis and hence growth, causes early leaf fall and reduces fruit set and yield. On the other hand, too much promotes excessive vigour, reducing flowering and increasing the incidence of fruit quality disorders such as woodiness and brown pulp.

Fruit quality disorders occur when vegetative growth out-competes the fruit for nutrients, particularly calcium and boron. In soils high in organic matter, nitrogen is continually being released to the plant and nitrogen applications must be reduced until the desired leaf levels are achieved.

Nitrogen is easily leached from the soil and may have to be topped up with small applications after extended periods of rain.

New vegetative growth has a strong demand for nitrogen, which is a very mobile nutrient that is moved from the old leaves to young leaves during periods of rapid growth. It is most stable in the leaves after the last vegetative flush before cooler weather in March/April.

There is a strong interaction between nitrogen and pruning. There are two particular cases:

- For trees with few laterals, hard pruning causes excessive growth of a few dominant unproductive laterals. High levels of nitrogen only make this problem worse.
- For trees with many laterals, which are winter and summer pruned, additional nitrogen can be used to sustain the growth of the productive laterals.

In young trees, nitrogen is applied regularly so that the leaf canopy will grow as quickly as possible. In bearing trees, rates are based on leaf analysis, crop removal figures and a visual assessment of vigour. The total nitrogen requirement is best applied in three equal applications:

- just before budbreak to achieve uniform budbreak;
- in January to assist in fruit development;
- in May to help hold the leaves on and build up the energy reserves in the wood for winter.

Phosphorus

Like most tree crops, custard apple has a low requirement for phosphorus, particularly in the sandy loam soils where much of the crop is grown. As phosphorus is readily available in these soils, deficiencies are rare. The only situation where regular application may be necessary is in heavier clay soils where phosphorus becomes fixed and unavailable to the tree. Here, banding of phosphorus fertiliser in a strip along the row will generally meet the tree's needs for several years. Base the calculation of timing and rates on leaf and soil analysis and crop removal figures. Where phosphorus is required, late summer is the best time for application.

Phosphorus is not readily leached from the soil and levels quickly build up with regular applications of fertilisers containing phosphorus. Very high soil levels can block the uptake of other elements such as iron and zinc. Consequently, once soil and leaf levels are adequate, apply phosphorus only every second or third year as soil and leaf analyses dictate.

Phosphorus is also an important nutrient in growing a good green manure crop during land preparation and maintaining a healthy grass cover between the rows after tree establishment.

Potassium

Potassium is a major component of fruit and, if deficient, has a significant impact on fruit size and quality. Like nitrogen, it is readily leached from the soil. Potassium is highly mobile, but because it is not required to a great extent by leaves, new growth flushes do not draw large amounts away from the fruit.

Too much potassium may lead to imbalances with calcium and magnesium and it cannot be applied without regard to the levels of these nutrients in the soil. Soil analysis is an essential guide to maintaining these nutrients in the correct ratio. Annual applications of potassium fertiliser may be necessary, with most or all applied between budbreak and harvest to help build size in the developing fruits. Base rates on leaf and soil analysis and crop removal figures.

Calcium and magnesium

While the tree's need for calcium is high, calcium deficiency is rare except in trees with excessive shoot vigour where the incidence of internal fruit disorders such as woodiness and brown pulp are increased. These problems appear when the developing fruit fail to compete satisfactorily with the leaves for calcium. Early-season fruit appear to be the worst affected, presumably because the early set flowers have to compete with the first strong vegetative growth flush. Problems can also develop where soil pH is low and the availability of calcium to the plant is reduced. Where calcium levels become too high, the uptake of magnesium and potassium can be significantly reduced.

Magnesium is not required in large amounts but deficiencies can occur in leached, acid sandy soils. Again, high levels can interfere with the uptake of calcium and potassium.

Because of the links between pH, calcium, magnesium and potassium, base the calculation of timing and rates of these nutrients on leaf and soil analysis. Corrective application is generally only necessary once every few years.

Aim to keep the soil pH around 6.5 (1:5 water). The basic rules for adjusting pH are:

- Where pH needs raising, use dolomite where both calcium and magnesium levels are low and the ratio of calcium to magnesium is greater than 6:1. Otherwise use lime. Make sure the lime or dolomite used has a high neutralising value and a high degree of fineness.
- Where pH is at the correct level or higher, use gypsum to correct a calcium deficiency and magnesium oxide to correct a magnesium deficiency.

All liming materials are best applied in autumn.

Trace elements

Boron

Like calcium, boron is important for new growing tissue in root tips, shoots and fruit as well as cell wall development. It is also essential for good pollen germination and pollen tube growth. Boron deficiency results from insufficient boron in the soil or as a result of competition between fruit and vegetative growth. Insufficient boron causes fruit disorders such as woodiness and brown flesh.

Boron is readily leached from soil but is immobile in the plant. Consequently, there must be a ready supply from either the soil or foliar sprays.

Use leaf and soil analysis to monitor levels. Where boron is required, it is best applied to the ground under the tree. To apply it evenly and avoid possible toxicity, it is best mixed in water and sprayed on the ground. Apply boron from September to December. Where foliar sprays are used, apply these to the developing spring flush.

Zinc

Zinc deficiency is reasonably common particularly on soils with high pH or where heavy applications of lime have been made. High soil phosphorus levels also inhibit the uptake of zinc.

Use leaf and soil analysis to monitor levels. Where zinc is required, apply it to the ground under the tree in a band just inside the dripline. Foliar sprays provide only temporary relief. Where these are used, apply chelated zinc to the developing spring flush.

Copper

Copper deficiency is normally only a problem in leached sandy soils receiving high nitrogen rates or where phosphorus levels in the soil are very high. High levels of soil copper may induce an iron deficiency.

Routine sprays of copper-based fungicides generally prevent the development of copper deficiency.

Manganese

Manganese deficiency is rare, except in sandy, acid, coastal soils. A more common problem is manganese toxicity, which may occur in some red volcanic soils. With these soils, aim to keep soil pH at 7 (1:5 water), where manganese becomes unavailable to the tree.

Iron

Iron deficiency, which is common in custard apples, is thought to be caused by poor root health, but high soil pH and high soil levels of zinc, copper and phosphorus are also thought to be involved.

Where required, try foliar sprays of iron chelate and soluble ferrous sulphate.

A program for nutrition management

Before planting

Do a complete soil analysis before planting to enable all nutrients to be adjusted to their appropriate levels throughout the intended root zone. This is particularly important for the relatively insoluble nutrients such as phosphorus, calcium, zinc and copper, as these are best applied to the soil surface and then worked into the entire root zone. It is difficult to do this after the trees have been planted.

Get the results of the soil analysis interpreted by the laboratory, an agronomist or nutrition consultant. They will recommend appropriate fertilisers and rates to bring the levels of all nutrients within the desired ranges. The optimum soil nutrient levels to aim for are in Table 11.

Table 11. Optimum soil nutrient levels for custard apple

Element	Optimum soil levels
pH (1:5 water)	6.0 – 6.5 (5.0 – 5.5 for krasnozem soils)
pH (1:5 $CaCl_2$)	5.0 – 5.5
Organic carbon (Walkley-Black)	more than 2.0% C
Nitrate nitrogen (1:5 aqueous extract)	more than 20 mg/kg
Phosphorus (Colwell)	50 – 100 mg/kg P
Potassium (exchangeable)	more than 0.5 meq/100 g K
Calcium (exchangeable)	more than 5.0 meq/100 g Ca
Magnesium (exchangeable)	more than 1.6 meq/100 g Mg
Sodium (exchangeable)	less than 1 meq/100 g Na
Chloride (1:5 aqueous extract)	less than 250 mg/kg Cl
Conductivity (1:5 aqueous extract)	less than 2 dS/m
Copper (DTPA)	0.3 – 10 mg/kg Cu
Zinc (DTPA)	2 – 10 mg/kg Zn
Manganese (DTPA)	4 – 45 mg/kg Mn
Iron (DTPA)	more than 2 mg/kg Fe
Boron (hot calcium chloride)	0.5 – 1 mg/kg B
Calcium:magnesium ratio	3 – 5: 1
Total cation exchange capacity	more than 7 preferred
Cation balance (%)	calcium 65 – 80 magnesium 10 – 15 potassium 1 – 5 sodium less than 5

Young, non-bearing trees

If nutrient levels were adjusted properly before planting, there will be little need to apply any fertiliser other than nitrogen for the first one to two years.

Don't start fertilising until the young trees have begun to put on new growth. Then fertilise little and often, at least once every six to eight weeks from September to May. For each application, use about 15 kg/ha of a mixed fertiliser (13:6:12 N:P:K). From the second year, urea or nitram at a rate of about 15 kg/ha can be used. Avoid using urea, nitram or sulphate of ammonia during the first year.

Spread the fertiliser in a broad ring around the tree extending 50 cm beyond the canopy. Keep the fertiliser 10 cm away from the trunk to avoid collar burn. Alternatively, apply through the irrigation system (fertigation).

Bearing trees

From bearing onwards (normally considered from the second or third year), base all fertiliser application on leaf and soil analysis. In addition, consider crop removal figures for calculating nitrogen, phosphorus and potassium rates, and factor in tree vigour in the nitrogen calculation. Do leaf and soil analysis each year about two months before harvest (about mid-March in south-east Queensland).

Leaf analysis

Separate the orchard into trees of different varieties and different ages and where possible, sample each separately. Buy leaf sampling kits from your farm supply store and follow the instructions. Take leaf samples from trees representative of the variety and tree age, not from trees on the edge of the orchard or trees under stress. Sample four leaves from each of 20 trees, taking one leaf from each of the four sides of the tree. The correct leaves to sample are the youngest mature leaves on non-fruiting shoots (Figure 36). After sampling, keep leaves cool and send to the laboratory as soon as possible.

Figure 36. *Correct leaves to sample for leaf analysis*

Soil analysis

Buy a soil analysis kit from your farm supply store and follow its instructions. The traditional soil sample is taken from a depth of between 0 and 15 cm. However, where lime and superphosphate are regularly applied, they tend to accumulate in the top 15 cm of soil. If this zone alone is sampled, it will distort the picture for the rest of the root zone. We recommend you take two soil samples—one from the 0 to 15 cm zone, and the other from the 15 to 30 cm zone. If only one sample is taken, sample the entire 0 to 30 cm zone.

To obtain your sample(s), choose a reasonably uniform area of the orchard which is typical of most of the trees. If there is an obviously different area, sample it separately. Sample about 15 sites from each uniform area, taking samples from under the tree canopies but no closer than 30 cm from the trunks and within the wetted area of the sprinklers (Figure 37). Use a soil auger or spade to take samples, and store them in a clean bucket. Use two buckets if sampling at the two recommended depths. If lime, dolomite, gypsum or other fertilisers have been applied recently, scrape away a thin layer of soil before sampling.

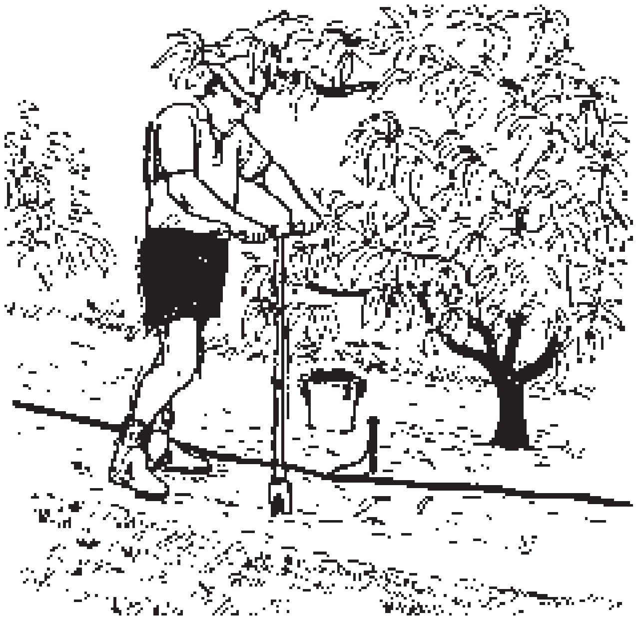
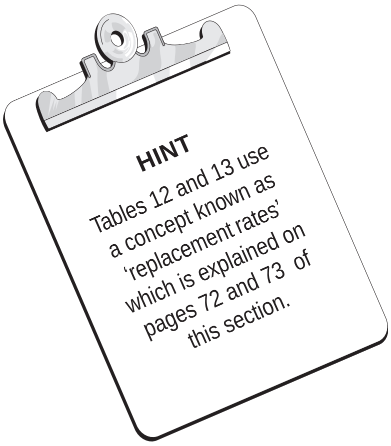


Figure 37. *How to sample for soil analysis*

When all 15 samples have been collected, mix the soil together and remove about a cupful for analysis. Do this by taking pinches of soil periodically during the mixing process. Place the cupful portion on clean newspaper or plastic sheeting in the shade for a few hours to air-dry. Place the air-dried soil in the plastic sample bag provided with your test kit and send to the laboratory as soon as possible. A full soil test including pH, electrical conductivity, phosphorus, potassium, calcium, magnesium, sodium, aluminium and trace elements is recommended.



Interpretation of leaf and soil analysis results

The laboratory will interpret the results and provide recommendations of appropriate fertilisers and rates to bring the levels of all nutrients within the desired ranges. If you want to do this yourself, or at least understand how it is done, Tables 12 and 13 provide broad guidelines to interpreting leaf and soil analysis results.

Table 12. *Interpreting soil analysis results*

Element	Desired levels	Interpretation
pH (1:5 water)	6.0 – 6.5	6.5 about ideal. If below 6.0, apply dolomite if calcium:magnesium ratio (in this table)is close to 3 – 5:1. Otherwise use lime.
pH (1:5 $CaCl_2$)	5.0 – 5.5	5.0 about ideal. If below 5.0, apply dolomite if calcium:magnesium ratio (in this table)is close to 3 – 5:1. Otherwise use lime.
Organic carbon – % C (Walkley-Black)	2.0 – 5.0	If less than 2, use green manure crops, mulches, and organic manures.
Nitrate nitrogen – mg/kg (1:5 aqueous extract)	more than 20	If less than 20, apply at replacement rates + 30 to 50% if losses are expected. If 20 to 40, apply at replacement rates. If more than 60, apply at less than replacement rates.
Phosphorus – mg/kg P (Colwell)	50 – 100	If less than 50, apply at rate of 30 kg/ha phosphorus; more if losses are expected. If 50 to 100, apply at replacement rates. If more than 100, no application is necessary.
Potassium – meq/100 g K (exchangeable)	more than 0.5	If less than 0.5, apply at replacement rates + 20 to 30% if losses are expected. If 0.5 to 1, apply at less than replacement rates. If more than 1, no application is necessary.
Calcium – meq/100 g Ca (exchangeable)	more than 5	If less than 5, apply lime, dolomite or gypsum depending on pH and calcium:magnesium ratio. If more than 5 and pH is more than 6.5 (1:5 water), no application is necessary.
Magnesium – meq/100 g Mg (exchangeable)	more than 1.6	If less than 1.6, with pH more than 6.5 and calcium:magnesium ratio of 4:1 or more, apply magnesium oxide at 100 to 200 kg/ha. If more than 1.6, with pH more than 6.5 and calcium:magnesium ratio of 4:1 or more, no application is necessary.
Sodium – meq/100 g Na (exchangeable)	less than 1	If more than 1, check quality of irrigation water and height of watertable.
Chloride – mg/kg Cl (1:5 aqueous extract)	less than 250	If more than 250, check quality of irrigation water and height of watertable, and use sulphate forms of potassium fertiliser.
Conductivity – dS/m (1:5 aqueous extract)	less than 2	If more than 2, check quality of irrigation water, fertiliser rates and height of watertable.
Copper – mg/kg Cu (DTPA)	0.3 – 10	Rarely out of adequate range.
Zinc – mg/kg Zn (DTPA)	2 – 10	If less than 2, check leaf analysis level to see if overall deficiency is confirmed. Follow recommendations there.
Manganese – mg/kg Mn (DTPA)	4 – 45	Rarely out of adequate range. If more than 45, aim for a pH (1:5 water) of 6.5 – 7.0.
Iron – mg/kg Fe (DTPA)	more than 2	Rarely out of adequate range.
Boron – mg/kg B (hot calcium chloride)	0.5 – 1	If less than 0.5, check leaf analysis level to see if overall deficiency is confirmed. Follow recommendations there.
Calcium:magnesium ratio	3 – 5: 1	See pH, calcium and magnesium above.
Total cation exchange capacity	more than 7	See pH, calcium, magnesium and potassium above.
Cation balance (%)	Calcium: 65 – 80 magnesium: 10 – 15 potassium: 1 – 5 sodium: less than 5	See pH, calcium, magnesium and potassium above.

Table 13. Interpreting leaf analysis results

Nutrient	Desired range	Interpretation
Nitrogen (% N)	2.4 – 3.0	If below desired levels, may indicate insufficient fertiliser, poor application or root damage. Use soil analysis results to determine rates of application. If within or above desired range, use soil analysis results to determine rates of application.
Sulphur (% S)	0.2 – 0.4	Rarely out of range.
Phosphorus (% P)	0.16 – 0.21	If within desired range, no action necessary. If below or above desired range, use soil analysis results to determine rates of application.
Potassium (% K)	1.0 – 1.5	If below desired levels, may indicate insufficient fertiliser or competition for uptake with high levels of calcium and/or magnesium. Use soil analysis results for potassium, calcium and magnesium to determine rates of application. Remember that potassium levels fall as the crop load increases on the tree, so timing of sampling is important when interpreting analysis results. If within or above desired range, use soil analysis results to determine rates of application.
Calcium (% Ca)	1.0 – 1.6	If below desired range, may indicate low soil pH, insufficient calcium fertiliser or an imbalance with potassium and/or magnesium. Use soil analysis results for potassium, calcium, magnesium and pH to determine type of fertiliser and rates of application. If within or above desired range, no action necessary. Maintain at the top end of this scale if the incidence of woodiness or brown pulp disorders in the fruit is high
Magnesium (% Mg)	0.35 – 0.5	If below desired range, may indicate low soil pH, insufficient magnesium fertiliser or an imbalance with potassium and/or calcium. Use soil analysis results for potassium, calcium, magnesium and pH to determine type of fertiliser and rates of application. If within or above desired range, no action necessary.
Zinc (ppm Zn)	20 – 28	If below desired range, may indicate high soil pH, excessive phosphorus or excessive nitrogen. If soil levels also low, apply zinc sulphate monohydrate to the soil under the trees at a rate of 2 to 3 g/sq. m. Alternatively, apply a foliar spray of zinc sulphate heptahydrate (1 kg) + hydrated lime (500 g) per 100 L water to the spring flush. If within or above desired range, no action necessary.
Copper (ppm Cu)	10 – 20	Rarely out of range if fungicide sprays are used.
Sodium (% Na)	less than 0.02	If more than desired level, check quality of irrigation water and soil analysis results.
Chloride (% Cl)	less than 0.03	If more than desired range, check quality of irrigation water and soil analysis results.
Iron (ppm Fe)	40 – 70	Rarely out of range except where heavy applications of lime or dolomite have been made.
Boron (ppm B)	30 – 80	If below desired range, apply 1 to 2 g of borax or 0.5 to 1 g of Solubor per square metre of soil surface beneath the trees. Boron can become toxic so check leaf levels 2 months later before any further applications are made. If within or above desired range, no action necessary.
Manganese (ppm Mn)	50 – 120	If below desired range, apply a foliar spray of manganese sulphate at 100 g/100 L to the spring flush.

Fertiliser rates using the nutrient replacement concept

Once you have worked out what nutrients require adjustment, the next step is to calculate the rates of fertiliser that need to be applied. For the main nutrients, we recommend you use the nutrient replacement concept. This bases nutrient and fertiliser application rates on how much nutrient is removed by the tree, adjusted by the expected losses of nutrient through leaching and soil fixation.

The starting point is determining nutrient removal by the tree. This has been calculated from research and is shown in Table 14.

Table 14. *Nutrient removal by trees with varying crop yields*

Crop yield (t/ha)	Total tree nutrient removal (kg/ha)				
	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
5	12.8	1.50	12.95	3.40	1.70
10	25.6	3.00	25.90	6.80	3.40
15	38.4	4.50	38.85	10.20	5.10
20	51.20	6.00	51.80	13.60	6.80
25	64.00	7.50	64.75	17.00	8.50
30	76.80	9.00	77.70	20.40	10.20

Depending on your soil type and situation, these figures can then be adjusted for leaching by rainfall or excessive irrigation, soil fixation and soil erosion effects. The following losses could be expected:

- 30 to 50% of nitrogen lost by leaching, the higher levels occurring in sandy soils;
- 20 to 30% of potassium and magnesium lost by leaching, the higher levels occurring in sandy soils;
- 50 to 80% of phosphorus lost by fixation, the higher levels occurring in red kraznosem soils;
- 5 to 20% of phosphorus and calcium lost by soil washing away in runoff, the higher levels occurring in sandy soils prone to erosion.

We recommend you adjust your rates to suit your orchard because soil type and weather conditions vary widely. The following rule of thumb can be applied in most situations:

- increase nitrogen rates by 30%;
- increase phosphorus rates by 100%;
- increase potassium rates by 30%;
- increase calcium rates by 10%;
- increase magnesium rates by 25%.

Based on this rule of thumb, the adjusted requirements for full nutrient replacement for the yield ranges given in Table 14 are shown in Table 15.

Table 15. *Nutrient requirements for full replacement (tree nutrient removal plus adjustment for leaching and other losses)*

Crop yield (t/ha)	Nutrient requirements for full replacement (kg/ha)				
	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
5	16.64	3.00	16.84	3.74	2.13
10	33.28	6.00	33.67	7.48	4.25
15	49.92	9.00	50.51	11.22	6.38
20	66.56	12.00	67.34	14.96	8.50
25	83.20	15.00	84.18	18.70	10.63
30	99.84	18.00	101.10	22.44	12.75

A fertiliser program

Once you have worked out nutrient replacement rates, go back to the leaf and soil analysis interpretation in Tables 12 and 13 and work out a fertiliser program. An example for an orchard yielding a crop of 25 t/ha and using full nutrient replacement rates is shown in Table 16.

In Table 16 the annual requirement for nitrogen is divided into three equal applications—before budbreak (August to October depending on the phenological cycle), January, and May. The January application may be halved, with one in December and the other in January. This provides a measure of insurance against the one application being lost by leaching from heavy summer rain. Other nutrients are applied with the nitrogen for convenience at one or two of the application times.

Table 16. *Fertiliser program for a custard apple orchard yielding 25 t/ha*

	Just before budbreak (August to October)	December	January	March	May	TOTAL
Nutrient requirements (kg/ha)						
Nitrogen	28		28		28	84
Phosphorus			15			15
Potassium	8	25	34	17		84
Fertiliser equivalent (g/tree)—density of around 150 trees/ha (spacing 8 m x 8 m)						
Either:						
Mixed fertiliser *(12:5:14)*	1600		1600		1600	4800
Or:						
Straight fertilisers:						
Urea	420	210	210		420	1260
Superphosphate			1160			1160
Muriate of potash	120	350	470	240		1180

Apply calcium, magnesium and trace elements according to leaf and soil analysis results.

Fertiliser choice

We recommend the use of manufactured fertilisers as they produce a more predictable and timely response. Custard apple trees respond well to organic fertilisers, which are useful in improving soil structure, organic matter levels and microbial activity. They are recommended as supplements to the manufactured fertilisers.

Within manufactured fertilisers, straight fertilisers are preferred as they allow a more individual response to the needs of each nutrient. They are also generally cheaper per unit of nutrient. Mixed fertilisers are more convenient to use but may cause a nutrient imbalance by oversupplying a particular nutrient.

Another important issue in the selection of fertilisers is how much they will contribute to soil acidity and soil salinity. If your soil is acid, choose the least acidifying fertiliser available (Table 17). Most mixed fertilisers are based on sulphate of ammonia and acidify the soil.

Table 17. Acidifying effect of common fertilisers

Fertiliser	Acidifying effect
MAP	highly acidifying
Sulphate of ammonia	
DAP	
Urea	↓
Nitram	
Superphosphate	
Muriate of potash	non-acidifying

If salinity is a problem, choose fertilisers with the lowest salt index (Table 18).

Table 18. Salt index of common fertilisers (For comparison, common salt has a salt index of 154)

Fertiliser	Salt index
Muriate of potash	114
Nitram	105
Urea	75
Potassium nitrate	74
Sulphate of ammonia	69
Sulphate of potash	46
DAP	34
MAP	30
Gypsum	8
Superphosphate	8
Lime	5
Dolomite	1

Fertiliser placement

Mature tree roots extend into the middle of the tree row so the whole orchard should receive some fertiliser. Set the fertiliser spreader to place most of the fertiliser under the tree canopy.

Fertigation

Fertigation (application of soluble fertiliser through the irrigation water) is recommended. It has many advantages over the manual application of solid fertilisers because:

- it uses less labour;
- there is more efficient nutrient uptake by the tree (fertilisers can be applied closer to the 'feeder' root zone);
- fertilisers can be applied more regularly and conveniently.

With efficient fertigation, annual nitrogen and potassium rates can generally be reduced by up to 25%.

With fertigation, fertiliser is dissolved in water in a drum or tank and sucked or injected through the watering system. The preferred equipment is a venturi injection pump or a pressure differential system. Fertilisers used must be highly soluble to avoid pump damage and pipe blockages. Mixtures of fertiliser must also be compatible to avoid the development of precipitates which can block sprinklers and also cause root damage. Other major requirements are good filtration and a uniform irrigation system that delivers similar amounts of water to all trees in the orchard.

The most suitable fertilisers for fertigation are shown in Table 19.

Table 19. *Soluble fertilisers for fertigation*

Fertiliser	Main nutrient supplied
Urea	Nitrogen
Calcium nitrate	Nitrogen, calcium
Potassium nitrate	Potassium, nitrogen
Potassium chloride	Potassium
MAP (technical grade)	Phosphorus, nitrogen

Several suitable commercial soluble fertilisers that supply a range of nutrients are also available; these include Flowfeed and Liquifert.

You can fertigate every time you water if you wish, but once every fortnight or a month is sufficient and most practical. Before you start fertigating, get a water testing laboratory to fully analyse your irrigation water. Make sure an iron test is included.

When fertigating, irrigate for a while at the start to wet the root zone, then inject the fertiliser. After injection is completed, continue irrigating for some time to wash fertiliser residues out of the irrigation system.

Irrigation and water monitoring

Although custard apple trees may not show it, water stress at critical times in the development of the crop can dramatically affect fruit yield, size and quality. Careful management of irrigation is a key factor in achieving good orchard performance.

Water management of custard apples

In subtropical Australia, custard apple trees flower and develop young fruit during the summer months of November to January. This period is often characterised by high temperatures, low humidity and low rainfall. In addition, many custard apple orchards are planted at low density, without adequate windbreaks and are irrigated infrequently. Together, these factors may lead to significant soil moisture stress during the critical fruit development period. This requires special attention to irrigation technique.

However, there is one qualification. During the early flowering period when trees are making their major growth flush, mild soil moisture stress (tensiometer readings of 20 to 40 kPa) appears beneficial in increasing flowering and consequently yields. However, the yield increase may be partially negated by a slight reduction in fruit size. The reduction in fruit size is greater on trees carrying heavier crop loads (more than 200 fruit). Severe water stress during flowering can also increase the incidence of woodiness and brown pulp disorders.

Growers who wish to experiment with mild water stress during early flowering should try the technique initially on a small number of trees (perhaps 5 to 10). Only use trees that have healthy root systems. Soil moisture levels will also need to be monitored using one of the monitoring systems outlined later in this section.

Trees should not be stressed during periods of high temperature (greater than 36°C) and low atmospheric humidity. Water stress does not adversely affect fruit set, probably because of its beneficial effects on reducing vegetative growth.

It is important to guard against the problem of under-watering but remember that it is easy to go to the other extreme and apply too much. This reduces yield through reducing soil aeration, increases the incidence of root and collar rot diseases and reduces fruit quality. Over-watering also leaches fertiliser out of the root zone. This wastes fertiliser and poses a serious environmental hazard of polluting ground water with excessive amounts of nutrients.

Irrigation essentials—a good irrigation system

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

Consult a qualified irrigation equipment supplier or designer in your area and get them to develop an irrigation design plan. There are two irrigation systems on which the plan can be based.

Under-tree minisprinklers with a microspray feature. This is the preferred system (Figure 38). The microspray feature is used for the first two years to limit water throw. Use sprinklers with an output of 80 to 250 L per hour. Remember, in the design of the irrigation system, to allow capacity for the extra sprinklers to water your windbreak trees.

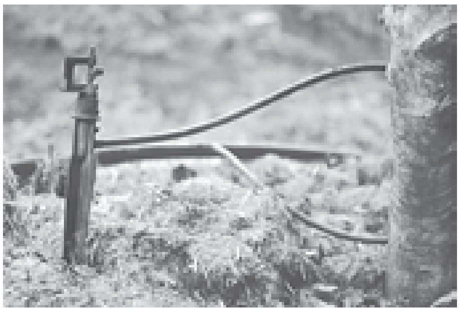


Figure 38. *Under-tree minisprinkler*

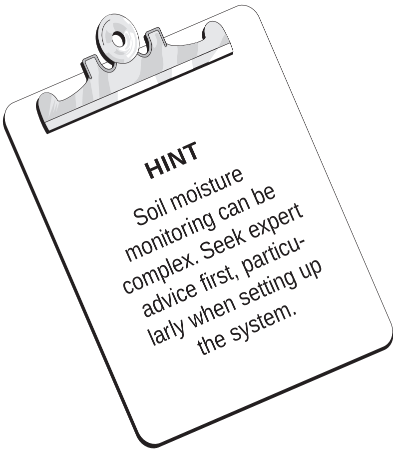
Trickle systems (either T-tape or Netafim buttons). For young trees, use one row of T-tape. When trees are about three to four years old, install a second row of tape on the other side of the tree row. With buttons, use two 8 L emitters per tree. Trickle systems need to be well-designed to operate effectively and must be properly maintained to prevent blockages. High level filtration with sand filters is essential. Although trickle watering requires more careful management than other irrigation systems, it has some advantages. It uses much less water and can be used to apply soluble fertilisers directly into the root zone.

Whatever system you use, it must be able to supply water to a depth of at least 75 cm, the normal depth that roots reach in the soil profile.

Irrigation essentials—a monitoring system

The second essential requirement of efficient irrigation is a monitoring or scheduling system that indicates when and how much water your crop needs. The importance of monitoring is confirmed by research, which shows that monitoring can generally reduce water use without affecting yield and fruit quality. Monitoring also makes sure you are applying enough water at the critical times and not overdoing it at other times.

A range of equipment and techniques is available for monitoring soil moisture and scheduling irrigation. The most common are the soil-based systems using tensiometers, soil moisture sensors, neutron soil moisture probes or soil capacitance systems such as the Enviroscan and Gopher. Another technique is a climate-based system that uses estimates of evapotranspiration. The soil-based systems are preferred and recommended. A brief comparison of the main systems is shown in Table 20.



Most of the roots of custard apple trees are in the top 75 cm of soil, so soil moisture monitoring devices used for irrigation scheduling need to concentrate on this part of the soil profile.

***Table 20.** Comparison of main soil moisture monitoring systems*

System	Advantages	Disadvantages
Tensiometers	· Relatively cheap · Easy to install yourself · Can be read by yourself · Allows continuous monitoring	· Labour intensive to collect and record data · Require regular maintenance · Can be inaccurate in extremely wet or dry soil · Less accurate in the top 10 cm of soil · Not accurate in very sandy soils
Soil moisture sensors e.g. gypsum blocks	· Relatively cheap · Easy to install yourself · Can be read by yourself · Continuous monitoring possible	· Labour intensive to collect and record data. Requires a digital meter to be brought to each sensor site to take readings · Can be inaccurate in extremely wet or dry soil · Less accurate in the top 10 cm of soil
Neutron probe	· Portable, can be moved around sites · Very reliable and accurate	· Not suitable for continuous monitoring · As equipment is expensive and radioactive, generally need to use a consultant who owns the equipment · Less accurate in the top 10 cm of soil · Less accurate in sandy soil unless sampled frequently
Capacitance probes e.g. Enviroscan, Gopher	· Continuous monitoring · Accurate at all depths and for all soils · Enables rapid reading and recording of results	· Expensive · Need skill in interpreting data
Evaporation pan	· Inexpensive. No in-field measurement is needed because the system uses weather data to predict irrigation need · Regular schedules can be developed in advance	· Less accurate as system ignores soil variability and the performance of the irrigation system · Cannot assess the effectiveness of rainfall received

Tensiometers

Tensiometers, provided they are well-sited and maintained, are a relatively cheap and effective way of monitoring soil moisture.

A tensiometer (Figure 39) consists of four basic parts—a hollow tube filled with water and algaecide, a ceramic tip, a water reservoir and a vacuum gauge which reads water tension on a scale of 0 to 100 centibars (cb) or kilopascals (kPa). In saturated soil, the vacuum gauge displays 0 kPa. As the soil dries over several days, water moves from inside the instrument, through the porous ceramic tip, into the soil. The gauge reading steadily increases to a maximum of about 90 kPa. When the soil is re-wet after rain or irrigation, water moves from the soil back into the tensiometer and gauge readings fall.

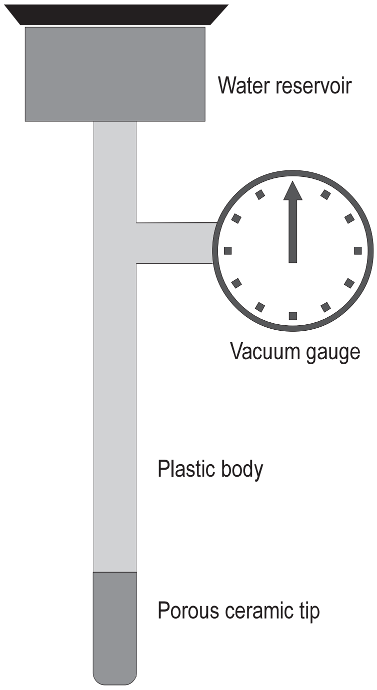


Figure 39. *Parts of a standard tensiometer*

Monitoring sites

Tensiometers are installed at monitoring sites throughout the orchard once trees are established. They are then left in place. Use at least one monitoring site for each variety or block. At each site, install two tensiometers—one shallow and the other deep. Position the shallow tensiometer (30 cm long) in the major root zone with its tip 15 to 20 cm deep and the deep tensiometer (60 cm long) with its tip 40 to 45 cm deep. Place tensiometers on the north-eastern side of trees, inside the dripline and where they will receive water from the microjets or trickle system (Figure 40). Where trickle systems are used, keep the tensiometers at least 15 cm from the trickle tube.

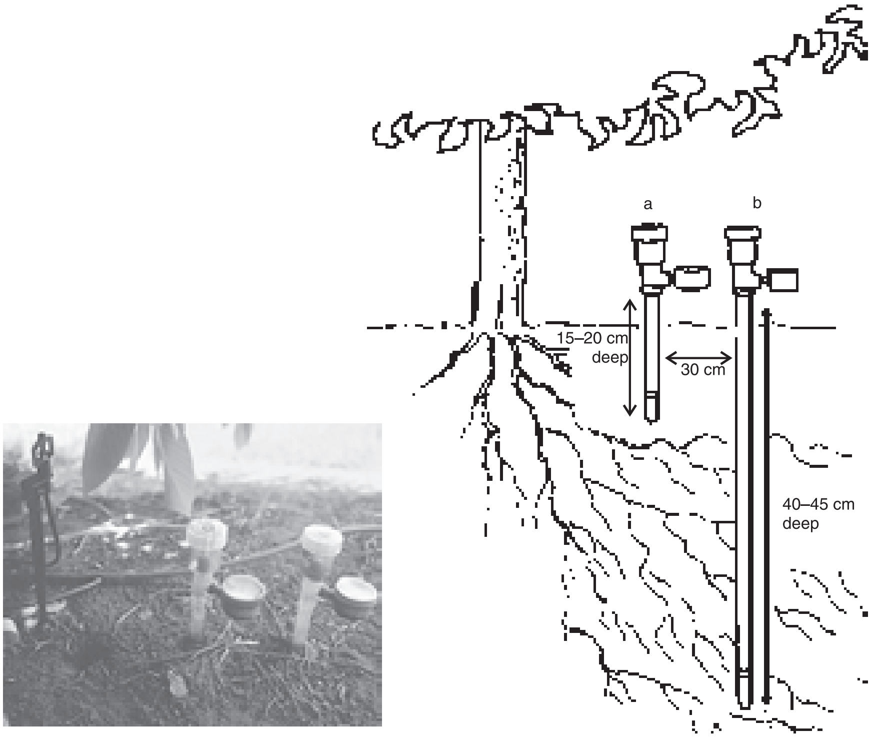


Figure 40. *Tensiometers in place, (a) in major root zone and (b) below most roots*

Installation

Assemble tensiometers and fill with good quality water to which algaecide has been added. A dye added to the water makes it easy to observe the level. Leave tensiometers to stand in a bucket of water (no need to pre-boil) at least overnight, but preferably for one to two days. Tensiometers are more reliable if a vacuum pump is used to remove any air from the tensiometer body and gauge. Make sure the pump fits snugly over the fill point on top of the tensiometer. Top up tensiometers with more water if necessary and use the vacuum pump to remove air bubbles. They are now ready to install following these two main principles:

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

Carry tensiometers to the installation site with the tips in water or wrapped in wet rags. Do not touch the porcelain tips as grease from the fingers can block the fine pores. Provided the ground is moist and well-cultivated, the shallow tensiometer can be pushed into the soil to the required depth of 15 to 20 cm. Don't push too hard. The tips are strong, but can crack under excessive pressure. Only experience teaches how hard is too hard. At $30 per tip, this is an expensive lesson. If you encounter a hard soil layer, take the tensiometer out and try somewhere else or use the deep tensiometer procedure.

To install the deep tensiometer, dig a hole to the required depth and keep the excavated soil nearby in a pile. We have found a 50 mm (two inch) auger the best tool. Place the tensiometer in the hole, over to one side. The next step is critical because good contact between the ceramic tip and the surrounding soil is most important.

Take the most crumbly, moist soil from the dirt pile and pack it around the tip at the base of the hole. A piece of 10 to 15 mm diameter dowel is useful for packing. Don't over-compact the soil into plasticine, but remove large air gaps. Continue replacing soil until the hole is filled (Figure 41). It doesn't matter which soil you use after you have packed the first 5 cm above the tip. Friable topsoil from a few metres away can be used to create a slight mound around the tensiometer. This minimises the risk of water draining down beside the tensiometer, leading to false readings.

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

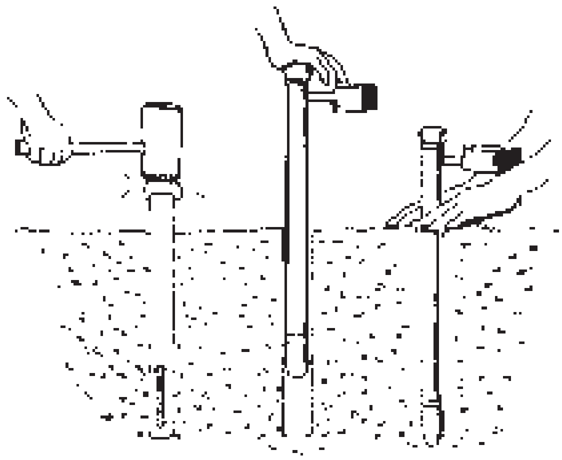


***Figure 41**. Installing deep tensiometers*

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

Clearly mark tensiometer locations to avoid damage from tractors and other equipment.

Reading

Read tensiometers early in the morning, before 8 a.m., and preferably at the same time each day. At this time there is little water movement in the soil or plant. Read at least twice a week but preferably every day or second day. Lightly tap the gauge before reading. It is best to read the tensiometers daily for the first few weeks to get a feel for the system.

The shallow tensiometer indicates when to water. The deep tensiometer indicates when the right amount of water has been applied.

Irrigating using tensiometers

Start watering when the shallow tensiometer reads 20 kPa (sandy soils) and 30 to 40 kPa (loam and clay loam soils). Stop watering when the reading on the deep tensiometer falls to 10 kPa. Slightly lower readings should be used for trickle systems. Reposition tensiometers every second year in winter to the new dripline position. Once a week, remove any accumulated air and check that gauges are working using the vacuum pump. Refill tensiometers with clean water.

Soil moisture sensors

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

Monitoring sites for the blocks are set up in a similar manner to those for tensiometers. Two blocks are placed at each site—one about 20 cm deep and the other about 40 to 50 cm deep. Positioning of the blocks and installation in holes is similar to that shown for tensiometers. Again there must be good contact between the blocks and the surrounding soil and the hole filled to the soil surface (Figure 42).

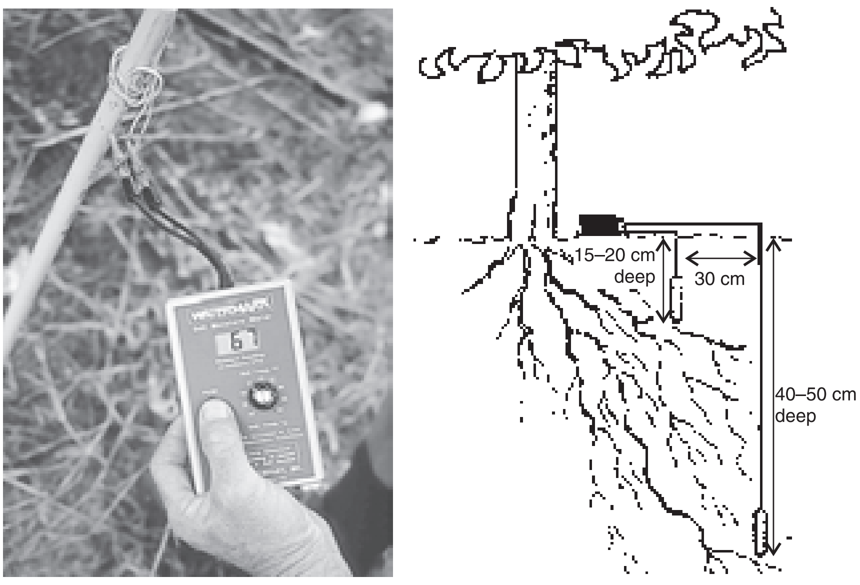


***Figure 42**. Gypsum blocks. Right: placement . Left: taking readings using an ohmmeter connected to the exposed wires*

Irrigating using gypsum blocks is similar to that recommended for tensiometers because the device is recording the same soil tension readings.

Note that gypsum blocks may need replacing in some soils every three years or so.

The neutron probe

The neutron probe is a sophisticated device consisting of a probe containing a neutron source and a detector. Several access holes are set up in the orchard and the probe is brought to these sites at regular intervals (Figure 43). When the probe is lowered into the access holes, neutrons from a radioactive source are emitted into the soil profile. When these fast neutrons collide with hydrogen atoms in water, they slow down dramatically and are deflected back to the detector, which responds to slow neutrons only. If the soil is dry, the neutrons don't slow down and are therefore not detected. Readings taken at various depths provide an overall view of soil moisture within the profile.

***Figure 43**. Neutron probe recording readings at a site*

The neutron probe is expensive and is generally used only by consultants to monitor and provide recommendations for watering. Although it is more accurate than tensiometers, its usefulness depends on how regularly readings are taken.

Capacitance probes

Capacitance probes such as the Enviroscan and Gopher are continuous moisture monitoring devices based on capacitance sensors. These continuously measure the dielectric constant of the soil and consequently its water content. The sensors are mounted on probes, which have slots every 10 cm to accommodate the snap-in sensors. These probes are then placed within vertical PVC access tubes installed semi-permanently in the orchard. The probes are generally left in place for the season and then moved to another tube or site as required. However, a probe can be moved from tube to tube to record readings at several different sites.

Sensors are positioned on the probes to provide readings at specific depths and measurements from the sensors are relayed at regular intervals via a cable to a data logger for recording. Data from the logger are downloaded to a computer every few days to show water use and to provide recommendations for watering. Figure 44 is a representation of the Enviroscan capacitance probe.

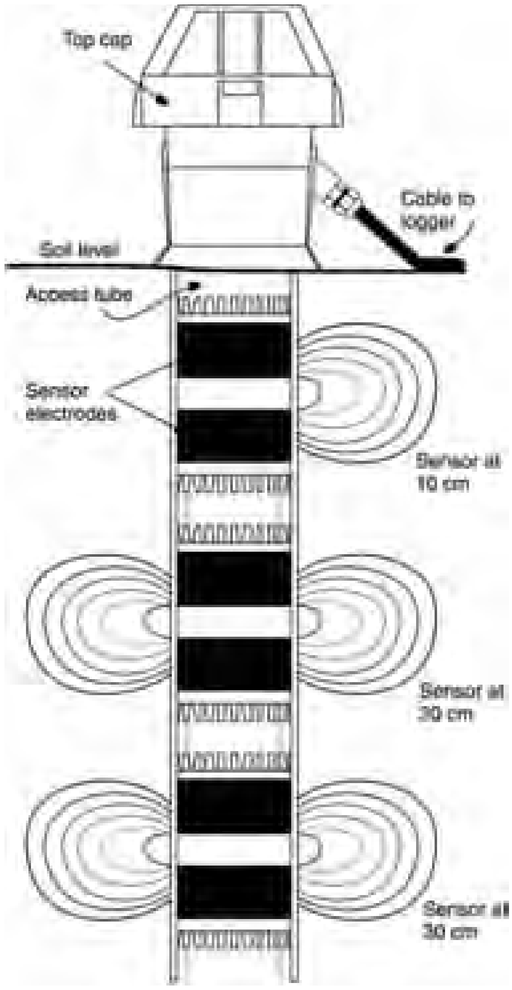


Figure 44. Diagrammatic representation of an Enviroscan probe

For custard apple, three probes are the minimum recommendation for a block but the number of sites depends on the variability in soil and varieties. The first probe should have sensors at 10, 30, 50 and 100 cm, the second probe with sensors at 10, 30, 50, 100 and 150 cm, and the third probe with sensors at 10, 20, 30, 50, 70, 100, 150 and 200 cm.

The equipment can be hired from some consultants.

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As interpretation of the data requires some skill, we recommend that consultants are used to set up the system and provide at least the initial advice.

Evaporation pan

The evaporation pan technique uses evaporation figures from a pan evaporimeter at a weather station to calculate water requirements at various times of the year. Evaporation figures for your district are available from the Bureau of Meteorology.

The evaporation figures are used in a formula to calculate potential water use. As the formula is complex, Table 21 provides an abbreviated working version to give you some idea of how it works.

Table 21. Using readings from an evaporation pan to calculate the number of hours of sprinkler watering per week

Step	Action	Formula
Step 1	Obtain a set of mean monthly evaporation figures (Epan) for August to March.	Monthly evaporation figures in mm (Epan)
Step 2	As the evaporation figures are generally based on a US Class A evaporation pan, multiply them by 0.85 to convert the figures to the equivalent of evaporation from a free water surface, to give the adjusted evaporation (ETo)	Epan x 0.85 = adjusted evaporation in mm (ETo)
Step 3	Multiply the figure from Step 2 by a crop factor representing the different growth stages of the tree. The suggested crop factors vary from 0.64 in August to 0.86 in October (for all values, see example in Table 18)	(ETo) x crop factor = water use in mm/month.
Step 4	Divide the figure from Step 3 by 4 to calculate the approximate water use per week. This equates roughly to the amount of water required from rain or irrigation. Ignore any rainfall of 5 mm or less	Water use per month ÷ 4 = water use per week in mm
Step 5	Calculate the output of your sprinklers in mm/hour by dividing their output in L/hour by the area of coverage in square metres	Sprinkler output L/hour ÷ coverage in square metres = sprinkler output in mm/hour
Step 6	Divide the figure from Step 4 by the figure from Step 5 to obtain the number of hours of sprinkler watering per week. Remember that the figure used from Step 4 needs to be adjusted for rainfall before calculation of sprinkler hours.	Water use per week ÷ sprinkler output in mm/hour = sprinkler hours per week

Table 21a shows an example using the formulae in Table 21 to determine the irrigation schedule for bearing custard apple trees growing at Nambour, Queensland.

Table 21a. Calculation of an irrigation schedule for bearing custard apple trees growing at Nambour, Queensland

Month	Step 1	Step 2	Step 3		Step 4	Step 5
	Mean monthly evaporation mm (E_{pan})	Adjusted monthly evaporation mm(ETo)	Crop factor	Water use mm/month	Water use mm/week	
August	102	87	0.64	56	14	
September	135	115	0.75	88	22	
October	164	140	0.86	120	30	**Output of sprinklers in mm/hour.**
November	186	158	0.83	131	33	
December	208	177	0.83	145	37	Sprinklers delivering 40 L/hour and covering 10 sq. m (1.75 m radius) = 4 mm/hour.
January	186	158	0.86	136	34	
February	151	128	0.86	110	28	
March	146	124	0.83	103	26	
April	123	105	0.83	87	22	Sprinklers delivering 40 L/hour and covering 40 sq. m (3.5 m radius) = 1 mm/hour.
May	87	74	0.8	59	15	
June	69	59	0.75	44	11	
July	78	66	0.75	50	12	

Step 6: Number of hours of sprinkler watering per week.

Month	Water use mm/week	Hours of watering/week	
		4 mm/hour output	1 mm/hour output
August	14	4	14
September	22	5	22
October	30	7	30
November	33	8	33
December	37	9	37
January	34	8	34
February	28	7	28
March	26	6	26
April	22	5	22
May	15	4	15
June	11	3	11
July	12	3	12

Tips for managing with limited water

- Eliminate weed competition near trees. Use herbicides rather than cultivation to avoid damaging surface feeder roots and increasing evaporation losses.
- Keep the interrow grass sward mown close to the ground.
- Mulch trees, particularly during the drier spring months. Mulch to a depth of 15 cm, covering the area under the trees to just beyond the canopy dripline.
- Don’t over-fertilise with nitrogen as the large leaf area produced increases evaporation losses from the tree.
- Irrigate at night and apply water to the active root area only.

Training and pruning

Although untrained custard apple trees will produce good yields, fruit quality will be lower and trees will be more difficult to harvest and probably suffer limb breakage. This makes training of trees a most important operation. Training is mainly through pruning but other techniques such as fruit and leaf removal are also involved.

When trees reach bearing age, pruning is mainly concerned with maintaining a cycle of fruiting wood production and renewal. The maintenance of a strong framework continues as a secondary objective.

Specific objectives of training and pruning

The main objectives of training and pruning are to:

- produce a strong, well-balanced tree resistant to wind damage;
- produce an open framework that allows easy penetration of sprays and access for harvesting;
- achieve an optimum balance between fruit size and the number of fruit set;
- minimise fruit marking from limb rub;
- control tree size;
- ensure a long, productive tree life;
- produce high quality fruit free of internal blemish.

Tree density

Growth of the tree and therefore pruning requirement is closely linked to planting density, which in turn depends on variety, rootstock and soil type. If trees are planted at high densities, shading encourages vigorous vertical growth and increases pruning costs. It also reduces fruit size and fruit quality.

Low densities improve fruit size and quality but result in very large trees that increase the costs of pruning and harvesting. Yields and cash flow in the early years of the orchard, however, are lower.

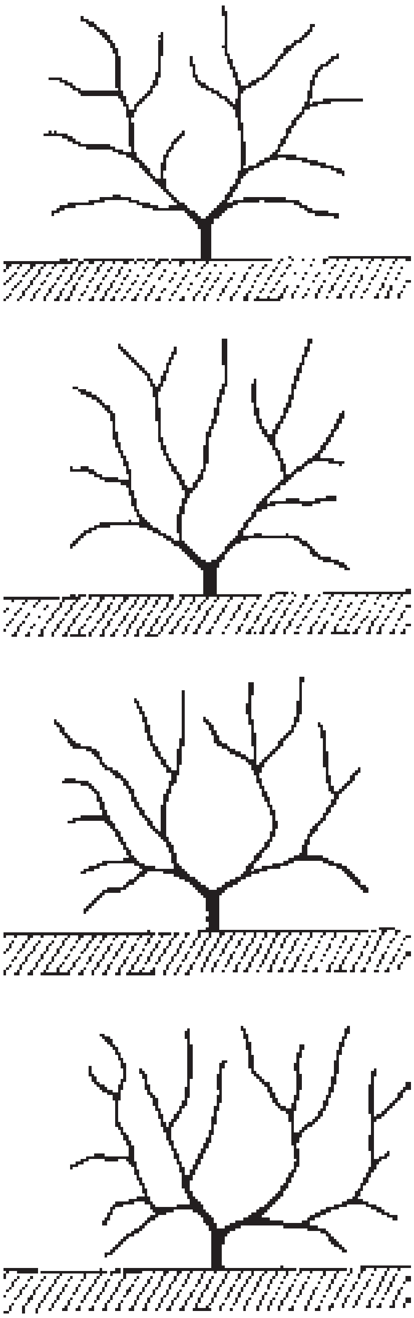

Figure 45. *Typical variation in the shape of custard apple trees trained to the open vase system. Note that this is a diagrammatic representation only. The main branches and leaders are shown but not the fruiting laterals*

Training systems

The traditional training system used for atemoyas in Queensland is the open vase. Training systems used elsewhere which may have application include the central leader and the Y-trellis.

Open vase

The open vase system is a variation of the open-vase system used in stonefruit except that the leaders are more upright. Trees are started in an open-vase shape but develop into an irregular central leader from about the second or third year because their non-symmetrical growth habit makes it difficult to maintain the desired vase shape. Consequently, mature trees trained to this system do not have a typical, definable shape. Figure 45 shows the typical variation in the shape of trees trained to the open vase system.

Once the tree is forced to spread in the first two to three years, it is prevented from becoming too tall too quickly. Growth is dissipated through several leaders resulting in a lower, more spreading tree. Eventually, a tree with three to five relatively upright leaders is formed.

It is difficult and undesirable to prune mature trees to a strict vase shape because they are likely to split at the main trunk under a heavy crop load.

Central leader

The central leader system is suited to less vigorous types such as the sugar apple and soursop. It is less suitable for atemoyas on cherimoya rootstock as the extra vigour results in a top-heavy tree, prone to being blown over by wind. Where the central leader system is used for this combination, the tree must be supported with stakes during the first four years until it becomes more stable. If this is done, the result is a mature tree that is structurally strong and less likely to split than trees pruned to the open-vase system.

Y-trellis (and varlatlons)

The Y-trellis system has been tried on a limited experimental scale with encouraging results. The trellis support means that limb breakage and tree toppling are essentially eliminated. Also, fruit should hang clear of the canopy, giving easy access for harvesting. Pruning is detailed but relatively easy. The problem is that trees may soon out-grow the trellis if close-planted or where vigour is not controlled.

Structural pruning for the open vase system

Newly planted trees

Sometimes the nursery will have pruned the trees several weeks before delivery, thus avoiding the need for pruning at or soon after planting.

In most instances, however, some pruning is required at planting or soon after.

If trees from the nursery have an unbranched trunk extending 70 cm or more above ground level, prune the tree back to a height of 60 cm and remove all other side-shoots (Figure 46).

If trees have already developed a fork at less than 70 cm high and that fork is wide and strong, prune both arms so that the largest is no longer than 40 cm. Remove all other side-shoots (Figure 47).

If the fork has a narrow angle and is likely to split, remove the arm at its base and prune the remaining trunk to a height of 60 cm (Figure 46). This should induce other side branches to shoot.

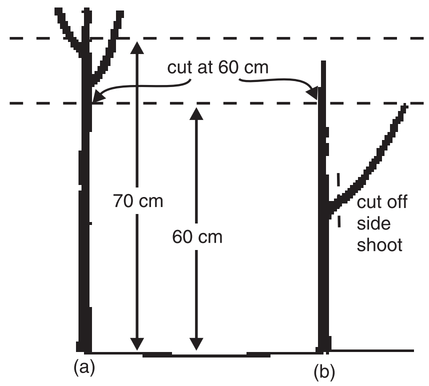

Figure 46. *Pruning trees at planting: (a) if they have no branches within 70 cm of ground level; (b) if they have a weak crotch*

Figure 47. *Pruning trees at planting if they have wide strong forks less than 70 cm from the ground*

Pruning non-bearing trees

The main aim of tree training in the first four years is to develop a framework of well-spaced, strong, wide-angled limbs (leaders). Fruit production is sacrificed to some extent to achieve this good basic tree shape.

To achieve this shape, prune trees about every three months, usually August (before budbreak), November and February. It is important to develop the tree quickly. This will help to reduce vigour and encourage lateral growth after the third year.

Prune the first limbs to 40 cm long. Prune the limbs arising from these to 50 cm long. Prune the following limbs to 60 cm and so on to a maximum of about 100 cm (Figure 48).

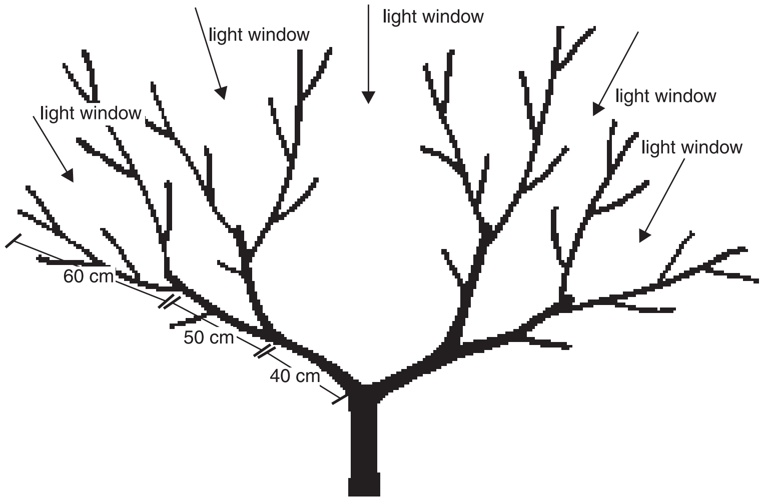

Figure 48. *Basic tree framework showing the progressive development of limbs (leaders)*

Remove strong non-symmetrical growth not required as leaders or laterals. This includes strong watershoots arising from the centre of the tree. Also remove any branches with weak crotches (Figure 49).

Figure 49. *A weak crotch*

Multiple shoots that develop behind previous pruning cuts need to be thinned in late spring before the shoots harden. Leave only two shoots pointed in appropriate directions, one each way.

Develop new shoots to fill in gaps in the canopy by forcing a bud in the desired position. Do this by:

- cutting off the leaf that covers the bud (where this is appropriate);
- cutting a 2 mm wide half-cincture above the bud (Figure 50).

The half-cincture is usually the only option if the bud is on a main limb. Make the half-cincture by cutting through the bark above the bud with a knife. It is not always successful, as these lower buds can sometimes be difficult to force without cutting the tree down.

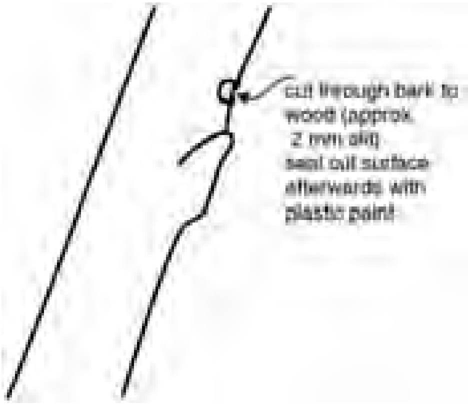

Figure 50. *A cincture above a dormant bud will generally force that bud to shoot*

In the first year, do not allow any shoots, other than those needed to form the leaders, to develop. Prune off unwanted shoots in the winter.

By the second or third year, the tree will normally be losing the distinct open-vase shape. Limbs usually twist in any direction, resulting in at least one leader crossing to the tree centre.

Pruning bearing trees

Once the tree's structure has been established, pruning then has two objectives:

- maintaining the structure and framework of the tree;
- managing fruiting wood to achieve good fruit yield and quality, and even distribution of fruit throughout the tree.

Principles

Most flowers are produced on the basal section of new season laterals 30 to 40 cm long. The other flowers are produced on one-year-old wood. Shorter or longer laterals produce fewer flowers. Strong shoots longer than 1 m on strong apically dominant varieties such as Pinks Mammoth/Hillary White produce virtually no flowers (Figure 51).

The term apical dominance refers to the growth habit of shoots. Strong apically dominant shoots have a low budbreak with only two to three buds at the terminal end of shoots breaking dormancy. As trees mature, apical dominance becomes less pronounced.

Older, more mature trees, especially of varieties such as African Pride, produce a larger number of weaker laterals and can be pruned more severely without stimulating highly vigorous growth. In contrast, young vigorous trees of Pinks Mammoth and Hillary White will produce strong compensatory regrowth on only a relatively small number of laterals. Fruit produced on very strong laterals longer than 60 cm is often irregular in shape, with bumpy skin and serious internal defects. Figure 51 compares three laterals - a good lateral with well-formed fruit, a strong lateral with poorly formed fruit, and a lateral too weak to be sufficiently productive.

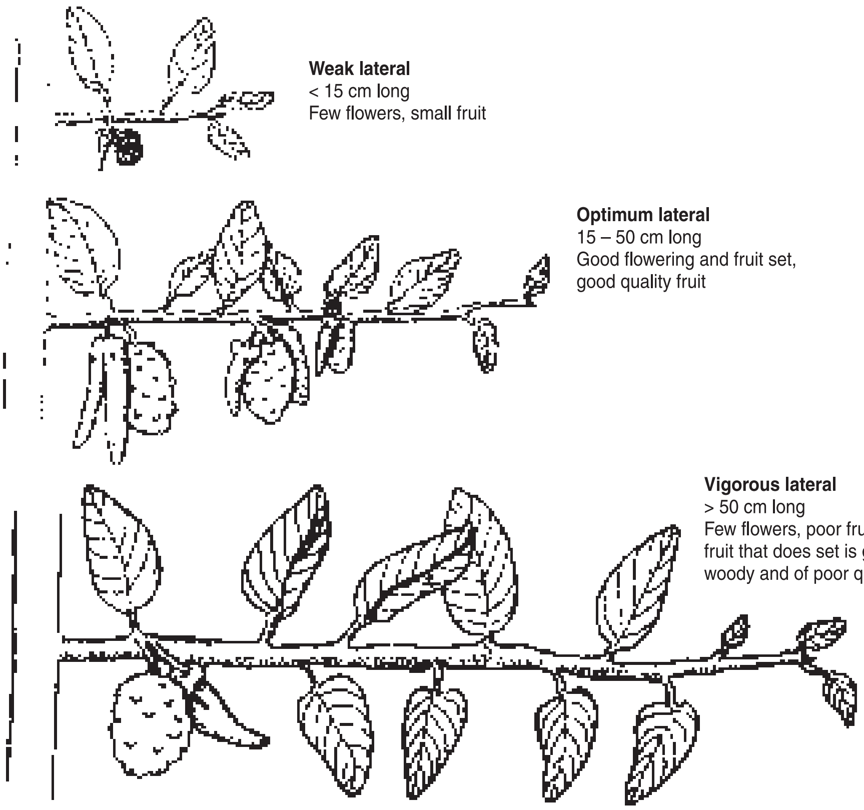

Figure 51. *Comparison of laterals showing productive capacity*

The aim of any productivity pruning is to increase the number of good fruiting laterals early in the life of the tree, and then to maintain sufficient numbers of these to produce high early yields. With strong apical dominant varieties such as Pinks Mammoth and Hillary White, rest release chemicals are being investigated as an alternative in promoting more fruiting laterals.

The second principle of productivity pruning is to achieve adequate light penetration into the centre of the canopy. This is vital for increasing flower numbers and improving fruit set, quality and size. It also prevents excessive weakening of fruiting laterals (less than 15 cm in shoot length) in the centre of the tree. This type of pruning also reduces the movement of fruiting wood to the outside of the tree as the tree ages (Figure 52); compare this with the desired result in Figure 53.

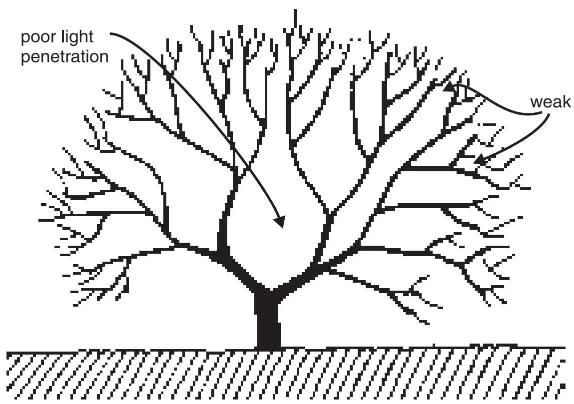

Figure 52. *Too much fruiting wood on the outside of the tree*

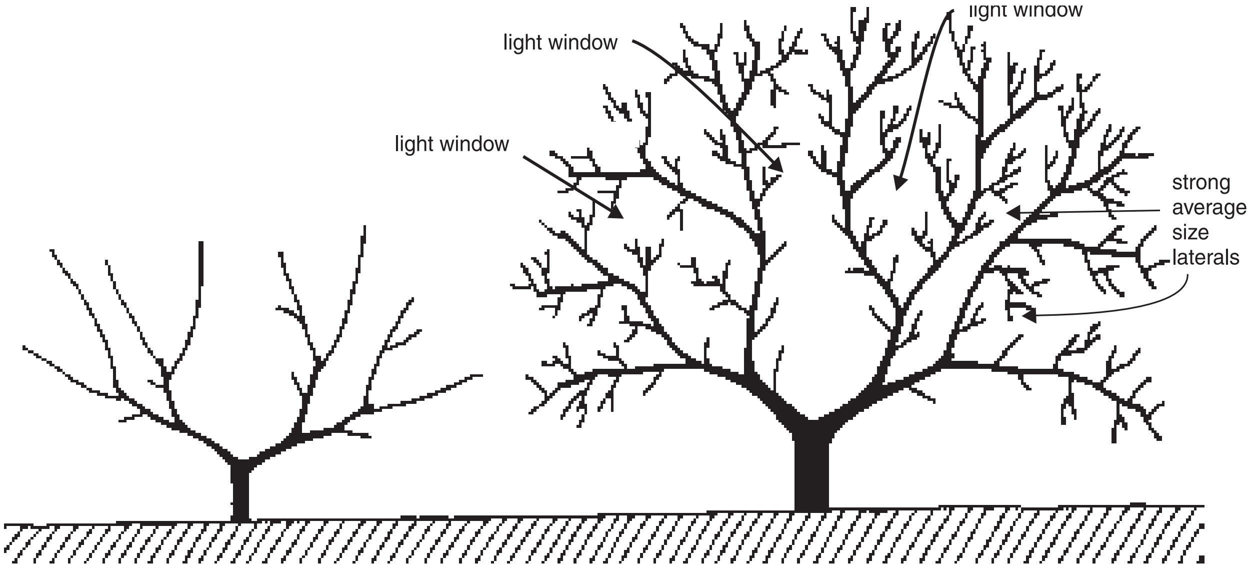

Figure 53. Right: a mature tree pruned to the open-vase system showing the fruiting wood evenly distributed throughout the tree. Left: the same tree at a year old showing the limbs (leaders) from which the mature tree has developed

Timing and severity of productivity pruning

Trees need pruning twice during the year:

- In winter just before budbreak (about August in south Queensland and July in north Queensland). This induces an earlier, more uniform budbreak. Where a late budbreak is required, trees are pruned later.
- In summer from about December to January. This pruning is to induce flowers on laterals that have not set fruit.

Note: Laterals, which are the shoots that grow off the leaders, produce the fruit. The leaders form the main framework of the tree and are not directly for fruit production.

Winter pruning

In general, prune all one-year-old laterals to four to six buds (10 to 15 cm long). In young, vigorous African Pride trees, prune laterals to about 10 buds (30 cm long).

When a lateral is pruned, it generally produces two strong end shoots from just below the pruning cut. Depending on vigour, weaker shoots are also produced further back on the lateral.

As this pattern continues over time, fruit is produced further away from the leader. As a result, fruit size will decrease, and fruit rub damage will increase. Allow laterals to extend for only two to three years before pruning them back close to the leader (Figure 54).

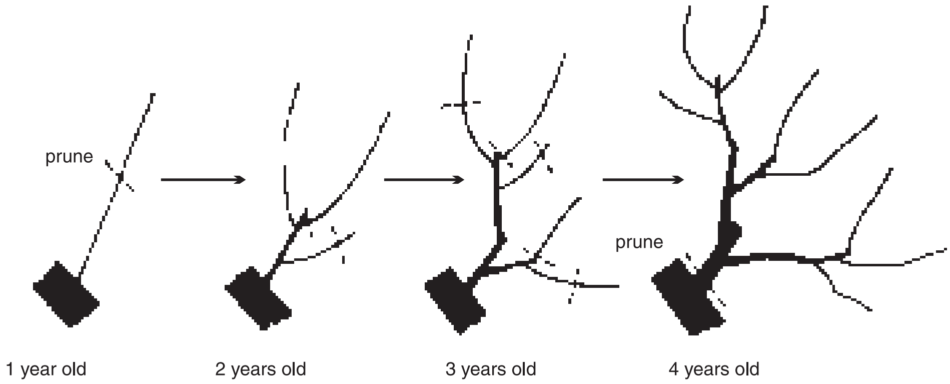

Figure 54. Development of a fruiting lateral over four years, showing pruning cuts each year. (Diagram assumes no summer pruning)

For how long laterals are retained depends on tree vigour and the amount of summer pruning. In practice, all laterals on a tree are at varying stages in the cycle and this means that only a percentage of laterals are replaced each year.

If the trees are very vigorous (average annual lateral growth of more than 1 m), leave more laterals unpruned at the winter pruning and do more summer pruning to increase cropping.

If trees are not pruned (or pruned too lightly), they quickly develop a dense weeping canopy with smaller fruit size and increased fruit blemish (Figure 55). Major chunk pruning is then required progressively every few years to enable access into the tree.

Spur pruning of young vigorous trees is detrimental to fruit quality and is not recommended.

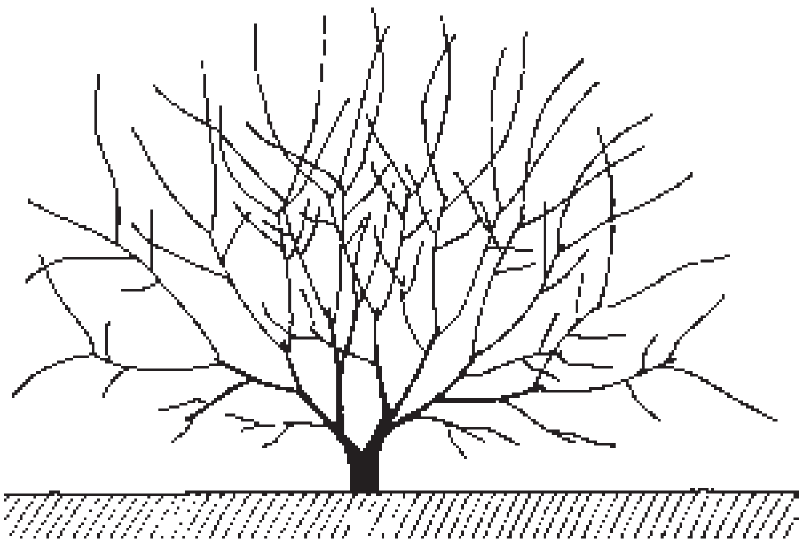

Figure 55. Growth habit of an unpruned or lightly pruned tree

Summer pruning

Young vigorous trees generally require more summer pruning than older, less vigorous trees. Do not summer prune if there is already a heavy crop on the tree.

In about early December, tip one-year-old laterals or new growth that has not set fruit and remove the end five or so leaves. The buds underneath should then produce new growth and flower about 30 days later (Figure 56). The process can be continued through to about late January. Tipping and leaf removal diverts the tree vigour into a greater number of weaker laterals.

Figure 56. *Left: typical summer lateral that has not set fruit. Right: lateral pruned with two leaves removed, showing the new shoots and flowers*

If new season growth is excessively vigorous, a second tipping and leaf removal and possibly a third may be needed later in summer to create more growing points.

Only up to about five leaves are generally removed. If more leaves are removed and all resultant new shoots produced fruit, the fruit may be too close together and require thinning. On very vigorous trees, up to ten leaves may be removed.

An experimental technique worth trying is to tip all laterals on the tree without leaf removal in early summer when new season laterals are 40 cm long. This has been shown to stop further growth and improve fruit set, shape and quality. However, this type of pruning may delay fruit maturity.

Window pruning for light penetration

If too much lateral growth is encouraged, some thinning out of three- to four-year-old limbs (leaders) will be needed to improve light penetration into the centre of the tree. This is best done after harvest or when trees are dormant. Also remove strong water shoots growing up through the centre of the tree and thin out dense clusters of laterals.

Skirting

Bearing trees need to be skirted regularly to prevent ants moving into the tree canopy and 'farming' mealybugs. Remove all limbs that touch the ground.

Crop loading

For less apically dominant varieties with high fruit set (for example, African Pride), trees may set excessively large numbers of smaller fruit. To improve fruit size, the number of fruit set must be reduced. This can be achieved by:

- reducing flower numbers by stronger pruning of laterals;
- removing laterals;
- thinning fruit after fruit set;
- reducing the frequency of hand pollination (only for varieties that are normally hand pollinated).

Pruning is the fastest method but it can produce shoots with excessive vigour. The best method appears to be fruit thinning—removing irregularly shaped fruit during the first stage (Stage 1) of fruit growth.

Table 22 shows the number of fruit normally expected on trees of African Pride and Pinks Mammoth.

Table 22. *Expected fruit numbers for trees of different ages*

Year	3	4	5	6	7	8	9	10
African Pride*	25	88	150	175	175	200	200	200
Pinks Mammoth**	0	8	30	50	100	140	160	200

* = 400 g/fruit; ** = 500 g/fruit

Topping

Keep mature trees no more than 5 m high by cutting back or thinning out the more upright leaders. This may be necessary twice a year—when trees are dormant and after the first major growth flush. In dense trees, this can be combined with window pruning.

Pest and disease management

Managing insect pests and diseases is a complex aspect of growing custard apples. There are several serious pests and diseases and some will inevitably develop during the life of the crop while others have the potential to destroy fruit yield and quality.

Pest and disease problems of custard apple

The status of pest and disease problems likely to affect the crop in Queensland and northern New South Wales is summarised in Table 23.

Table 23. *Status of pest and disease problems of custard apples*

Category	Major and common problems requiring special attention	Potentially major and common problems requiring regular attention	Minor or uncommon problems rarely requiring treatment
Insect and mite pests	Citrus mealybug Fruitspotting bug Queensland fruit fly	Yellow peach moth	Scales (nigra, latania, black, soft brown) Twospotted mite
Fungal diseases		Cylindrocladium spot Pseudocercospora spot Disease X	Black canker Diplodia rot Purple blotch Pink disease Armillaria root rot
Bacterial diseases		Bacterial wilt	

Problem pests

Three insect pests require special management. These are:

- citrus mealybug
- fruitspotting bugs
- Queensland fruit fly.

Citrus mealybug *(Planococcus citri)*

Importance and symptoms

Mealybugs infest the young fruit during December/January. If not controlled, a serious infestation may develop by late summer to autumn.

They produce a sweet, sticky substance called honeydew on which a fungus, sooty mould, grows. While brushing or using pressurised air will easily remove mealybugs after harvest, sooty mould cannot be easily removed. When a fruit becomes infested with about 10 or more adult female mealybugs, the combination of mealybugs and mould will usually result in downgrading after harvest. The mealybug infestation becomes economically serious when 25% or more of the fruit has one or more adult female mealybugs present.

Description

During summer, the life cycle of the mealybug takes about four weeks. Over about a fortnight, the mature female lays up to 500 eggs in a loose cottony mass. The eggs hatch in about a week and the light yellow crawlers (young mealybugs) move away and settle in protected areas such as creases in the fruit. They pass through three moults (or instars) before reaching the mature female stage or four moults before the adult male stage. The adult male is a fragile, short-lived insect with one pair of wings and aborted mouthparts.

Natural enemies

Natural control of citrus mealybug is very important, though not always completely effective. The main parasite is a small wasp (*Leptomastix dactylopii*). Other important natural enemies are the mealybug ladybird (*Cryptolaemus montrouzieri*) and the lacewing (*Oligochrysa lutes*). Natural enemies of minor significance are the small wasp (*Leptomastidea abnormis*), which parasitises second instar mealybugs, and syrphid fly larvae, which feed on young mealybugs.

Leptomastix wasp

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The Leptomastix wasp is 3 mm long and honey-coloured. The male is slightly smaller than the female. The female wasp parasitises mealybugs by inserting a single egg into the body of the mealybug. The developing wasp larva devours the contents of the mealybug, pupates and emerges. The life cycle from egg to emerged adult takes about three weeks.

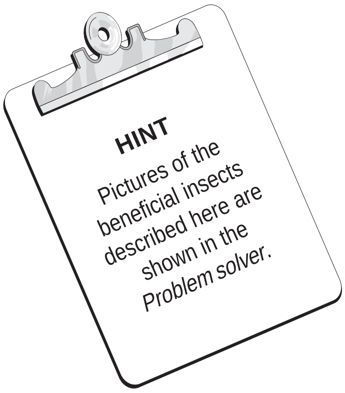
Wasps are available from suppliers of beneficial insects. Leptomastix wasps survive Queensland's winters but are slower to increase in spring than the citrus mealybug. For this reason, we recommend releasing 10 000 wasps per hectare during late December to late February. All wasps may be released at once or divided into two or three releases. Release the wasps throughout the orchard, not just in one section.

Once wasps are released, be careful with the use of insecticide sprays as most are toxic to the wasp adults. The young stages, being inside the mealybugs, are usually protected. Where sprays are being applied for fruitspotting bugs, it is best to delay releasing the wasps until one week after the last insecticide spray. Also, do not use insecticides on the day of the wasp release.

If spraying is necessary after the release, the most opportune times are one to two weeks after the release and again, if necessary, about four to five weeks after the release. This timing should avoid periods when the successive generations of adult wasps are emerging from the parasitised mealybugs.

Where sprays are required for fruit fly, use bait sprays and avoid cover sprays. With bait sprays, avoid releasing wasps on the same day as a bait spray is applied.

Cryptolaemus ladybird



The adult ladybird is about 4 mm long, black with orange on both ends. It is similar in size and shape to other species of ladybirds. The 10 mm long larvae are white and mealy with long waxy appendages. Younger larvae are often mistaken for the mealybug but closer examination will show that the ladybird larva has much longer waxy filaments than its host and grows much larger. Its life cycle takes about four weeks.

Both adults and larvae feed on mealybug eggs and crawlers. Although ladybirds are available from beneficial insect suppliers, a strategy for its release and management has not yet been developed.

Lacewings

The adult lacewing is a slender, delicate, green insect. Its body is about 10 mm long and its wings, held in a tent-like position when at rest, extend back for a further 10 mm. Its long antennae extend forward about 10 mm. The adult feeds on nectar and honeydew, but the larvae are voracious predators of young scales and mealybugs.

Lacewing eggs are laid singly or in clusters of about a dozen on the surface of leaves or fruit. Characteristically, each egg sits on a long stalk, so they are easily identified. The young larva is soft-bodied, spindle-shaped and has a pair of prominent sickle-shaped jaws. After it has devoured its prey, the remnants of the meal are attached to its back and soon the lacewing larva looks like a fluffy white mound 5 mm or more in diameter. The life cycle takes about three to four weeks.

This predator is not available from beneficial insect suppliers but is usually common in the orchard.

Ants and mealybugs

Ants such as the coastal brown ant (*Pheidole megacephala*) and the black house ant (*Iridomyrex glaber*) tend the mealybugs for their honeydew. They move the mealybugs around, even from tree to tree, and fend off the mealybugs' natural enemies. Fruit touching the ground is often covered with tunnels of dirt from ant activity. Control ants in December and, if necessary, again later in the season by spraying the lower trunk and the soil within a 0.5 m radius with a registered ant control spray. Trim lower branches up off the ground in winter and again in mid-summer to reduce ant access to the fruit.

Monitoring and spraying for mealybugs

Before you decide to spray, you need to know whether the mealybug infestation is severe enough and whether their natural enemies are active. This process is called monitoring. The mealybugs and their natural enemies can generally be easily seen with the naked eye; using a x10 hand lens will also help.

To monitor the population of citrus mealybug, select 20 trees at random per hectare and record the presence or absence of mealybugs on 10 randomly selected fruit per tree (without picking the fruit). Do this once every two weeks between January and April. While recording mealybug presence, also record the presence of natural enemies on the same fruit. Look for Leptomastix wasps, their cylindrical brown pupae amongst the mealybugs, and their remnants. Also look for Cryptolaemus ladybird larvae and lacewing larvae and eggs.

Spray or release Leptomastix wasps when:

- more than 25% of fruit (50 fruit out of the 200 inspected) have one or more large mealybugs present;
- less than 20% of mealybug-infested fruit (40 fruit out of the 200 inspected) show no sign of natural enemies.

Spotting bugs

Importance and symptoms

Spotting bugs affecting custard apples are the banana spotting bug (*Amblypelta lutescens 1utescens*) and the fruitspotting bug (*Amblypelta nitida*). Both are problems in south Queensland but the banana spotting bug is the only pest in north Queensland.

Symptoms are small, round black spots (2 to 10 mm in diameter) on the shoulders of young fruit. Damage penetrates about 1 cm into the fruit. Spotting bug damage can be confused with the diseases Diplodia rot, Cylindrocladium spot and black canker.

Description

Adult bugs are yellow-green and about 15 mm long. They can be difficult to find because, when disturbed, they either fly away or quickly hide. Females lay pale green, oval-shaped eggs about 2 mm long. There are five immature stages (nymphs) before the adult is formed. The nymphs are ant-like, pink to red-brown, with prominent antennae and button-like scent glands on the upper side of the abdomen. The scent glands are most prominent in the banana spotting bug.

Young assassin bugs are sometimes mistaken for spotting bug nymphs. Spotting bug nymphs are different in that they have a prominent flattened section on each antenna. Assassin bugs are useful natural enemies of caterpillars and grubs.

During summer, the spotting bug life cycle takes five to six weeks. There appear to be three overlapping generations—spring, summer and autumn. The adults from the autumn generation persist over winter.

Monitoring and control

Infestations are usually worst in trees adjacent to bushland where the bugs breed. Ornamentals such as *Bauhinia galpinii* are common hosts.

Monitor for the pest at fortnightly intervals from late December to late March. Select 20 trees at random per hectare and record the presence or absence of spotting bug damage on 10 randomly selected fruit per tree (without picking the fruit).

Spray if 2% or more fruit (four fruit out of the 200 inspected) have fresh bug damage. Remove affected fruit during monitoring so that only new damage will be seen at each sampling.

Severe outbreaks may require several sprays at 14-day intervals. It is often possible to spray only the infested parts of the orchard, particularly those adjacent to bushland areas.

No significant natural enemies of spotting bugs have yet been identified. Spraying is the only available treatment.

Queensland fruit fly (*Bactrocera tryoni*)

Importance and symptoms

Queensland fruit fly mainly infests fruit maturing from March to May. The fly's larvae feed inside the fruit, causing breakdown and rendering it inedible. Some interstate and export markets have strict quarantine restrictions on the presence of this pest in fruit. One infested fruit can result in the whole consignment being rejected. African Pride is affected more often than Pinks Mammoth or Hillary White.

Description

The adult fruit fly is wasp-like, with an 8 mm long body that is red-brown with yellow marks. The white eggs are 1 mm long and banana-shaped. They are laid in batches of about a dozen just beneath the skin, particularly around the stem of the fruit. The larvae grow into white maggots 7 mm long. These later leave the fruit and pupate in the soil. In summer, the life cycle takes about 17 days.

Monitoring and control

It is virtually impossible to detect fruit fly in unripe fruit. Fly activity is monitored by lure traps (Figure 57).

Figure 57. *Lure trap for fruit fly*

Lure traps, which attract male flies, consist of a synthetic attractant called 'Cue-lure' and an insecticide impregnated in a cotton wick. Replace the wick about every three months. One trap per hectare will give a good indication of fly activity. Monitor the trap weekly between March and May, count the flies and empty. During monitoring for other pests, also look for fruit flies on fruit.

Spray with a bait spray when trap catches of more than 50 flies per week are recorded or where fruit flies are observed on fruit. Be more vigilant with African Pride as it is more susceptible.

The bait spray consists of an insecticide mixed with a feeding attractant, yeast autolysate. The flies are attracted to bacteria growing on the yeast bait and absorb the insecticide. Spray about 50 to 100 mL of the mixture on about a square metre area of foliage per tree, low on the skirt. During periods of high fly activity, bait spraying may be required every week. In this case, check the traps twice a week and apply an extra bait spray if required. When bait spray is applied to only a small area of the tree there is little adverse effect on the natural enemies of other pests.

An alternative treatment is an overall cover spray, however, this is not recommended, as it is harmful to the natural enemies of other pests.

Orchard hygiene is also important in keeping fruit fly numbers down. Remove and bury old rotting fruit and avoid, where possible, leaving unsprayed alternative hosts such as guavas and citrus nearby.

A small braconid wasp (*Opius* sp.) parasitises Queensland fruit fly in the larval stage; however, it does not significantly control the pest.

Approaches to pest management

When developing pest and disease management strategies, it is important to understand the fundamental difference between the approaches to insect and mite pest management and to disease management.

Traditional approach to insect pest control

The traditional approach to insect pest control was to apply routine calendar sprays of chemicals. This approach had several problems.

- It was a waste of money if the pests were absent.
- Even when pests were present, it disregarded the fact that trees can tolerate small numbers of pests without significantly affecting yield and quality. In these cases, the cost of spraying is much greater than the benefit gained by controlling the pest.
- It increased the risk of chemical damage to the fruit.
- It was costly.
- It relied heavily on new chemicals being developed to replace those for which insects develop resistance. This contradicts the modern reality where fewer new chemicals are discovered and developed.
- It was severe on beneficial insects and mites and sometimes resulted in outbreaks of pests that were well-controlled naturally.
- It exposed the farm family and farm employees to a range of chemicals.
- It increased the amount of chemical residue in the fruit and the environment.

Modern approach to insect pest control—IPM

The modern approach to insect pest control involves less reliance on chemicals by using all or several complementary control measures in an integrated program known as Integrated Pest Management (IPM). There are several key elements of IPM:

- Using cultural control measures such as crop hygiene and crop rotation.
- Using biological control measures such as naturally occurring or introduced parasites, predators and pathogens (known as natural enemies or beneficial insects) of the insect pests.
- Using chemicals only where necessary. Preference is given to chemicals that are compatible with beneficial insects and 'softer' on the environment.
- Applying chemicals carefully with well-calibrated spray equipment to avoid crop damage, excess residues and off-site pollution.
- Checking the crop regularly to determine when pests are present and taking action only when pests are present and at damaging levels. This process of checking the crop for pests is called monitoring.

Pest monitoring

Monitoring works by first determining pest action levels—the pest populations at which damage is considered worthy of attention. The action level can be thought of as the point at which the damage is roughly equivalent to the cost of control. Pest populations are then regularly monitored and control measures applied only when pest populations approach or reach this action level. Monitoring then continues to allow pest populations to be managed at or below this action level. As well as the pests, the beneficial insects and mites, which naturally attack the pests, are also monitored. In some cases, they alone will be sufficient to check the pest populations.

more info
Pest consultants
Section 6 page 5

Monitoring requires skill in observing and identifying pests and beneficial insects. This requires considerable training and experience. For this reason, we recommend use of professional pest monitoring services.

IPM, however, has risks. It works best:

- in dry inland areas where pest pressure is lower;
- where pest consultants or skilled monitors are available for monitoring and provide on-the-spot technical advice;
- where growers are dedicated to IPM ideals and prepared to accept the odd failure inherent in a biological system, trading that off against the advantages offered.

Disease control

Diseases are difficult to monitor in the same way as insect pests. A disease is microscopic and, in most cases, by the time you see symptoms, it is well-established and difficult to control. We therefore rely on preventive sprays to control most disease problems. Monitoring is still useful for detecting obvious problem areas and for evaluating how well your disease prevention program is working.

The managed spraying alternative

If you are unable to employ the complete IPM system, you can still take advantage of the principal benefit offered—reduced chemical spraying—by using just some of the elements. This system uses the following strategy:

- Monitoring pest populations.
- Using chemicals only when action levels are reached.
- Giving preference to chemicals that are ‘softer’ on naturally occurring beneficial insects so that they can exercise maximum benefit.
- Applying chemicals carefully with well-calibrated spray equipment so that maximum impact is achieved with each spray.

This strategy is called managed spraying and is the minimalist position we recommend for pest control in custard apples.

Detail on monitoring pests

Whether you are using IPM or managed spraying, pest monitoring is the basic common requirement. We recommend you use professional pest monitoring services. These consultants visit the orchard about every seven to ten days during the main part of the season to monitor pest populations. After each visit, they provide a report on pest status and required sprays. The cost of using pest consultants depends on planting density and the pest and disease status of the orchard.

If you wish to do the monitoring yourself, we suggest you first get some training from a pest consultant. Here are the main requirements for monitoring.

Materials

- x10 hand lens, magnifying glass or small microscope
- notebook, prepared monitoring charts and pen
- plastic bags or small bottles and marking pen for samples
- sharp pocket knife
- roll of coloured plastic tape

Other

- commitment and the time to do regular monitoring at least every fourteen days
- good eyesight
- a good knowledge of the pests and beneficial insects and mites
- common sense

Monitoring is not intrinsically difficult, it is just a process of systematic observation and recording.

How many trees to monitor

Define your orchard as blocks. A block is trees of the same variety and about the same age. Each block should be monitored separately. If your orchard consists of trees of the same variety and age, treat it as one block.

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

How often to monitor

Although monitoring is useful throughout the whole season, the critical period is from December to June. During this period, monitor at fortnightly intervals except for fruit fly where traps need to be monitored weekly. During the remainder of the year, monitor trees every month or so for scales, ants and diseases.

Monitoring procedure

Prepare some monitoring charts to record the results (see example). Each time you monitor, select trees randomly but from different parts of the block. While moving between these selected trees, keep alert and visually scan intervening trees. Inspect 10 fruit selected at random from each of the 20 trees per hectare per block. The fruit do not have to be picked unless they are damaged by spotting bug or severely

PEST MONITORING CHART

Orchard:

Block: Date:

Tree no	Pest or disease							Beneficials			
	FSB	MB	QFF	S	YPM			L	C	W	
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											
TOTAL											
%											

KEY

Pest or disease

FSB — fruit spotting bug
MB — mealybugs
S — scales
YPM — yellow peach moth
A —ants
QFF — Queensland fruit fly

Beneficial insects

L — Leptomastix wasp
C — Cryptolaemus ladybird
W — lacewings

Insert other appropriate column headings. Record the number of fruit infested for each tree. For scale, record if tree is infested. For beneficials, record the number of fruit with beneficial insects.

damaged by other pests. Check any fruit symptoms with your hand lens. If you collect samples for later examination in the shed or office, place them in a plastic bag inside an esky. Mark the sample with the block number and date. Monitor one-year-old laterals for scale during October/November. While monitoring, carefully look over each sampled tree for signs of other insects, ant activity or any other leaf, twig or branch damage. Monitor fruit fly separately using lure traps.

Monitoring is best done on foot rather than driving as trees can be inspected more thoroughly.

After each monitoring, transfer the results from your monitoring charts to an orchard record, which will cover the full season. This will form a permanent record of the trend for each pest and beneficial insect over the season, and will be very valuable once data have been recorded over several years.

Pest and disease management program

It is relatively easy and straightforward to implement an IPM program in custard apples compared to many other orchard crops because:

- the major universal pest, citrus mealybug, can be generally well-controlled by naturally occurring or commercially available beneficial insects;
- there are few serious diseases; (Regular fungicide sprays, which may disrupt beneficial insects, are not generally required.)
- other pests such as spotting bug can be well-controlled by chemicals that are relatively non-disruptive to beneficial insects;
- fruit fly can be well-controlled by bait sprays. (Although bait sprays are disruptive to beneficial insects, they are applied to only a small area of the tree and are therefore relatively safe to beneficial insects.)

As a result, custard apples offer good potential to be grown with minimal chemical use.

Broad pest and disease management program

Flowers and young fruit in spring

The main pest threat in spring is spotting bug. Damaged flowers and fruit up to marble-size generally drop off. Fruit is most susceptible up to about tennis-ball-size. Very often, damage is in 'hot spots' and experience over several seasons may enable just these areas to be targeted. The chemical, endosulfan, which is used for controlling spotting bug, has minimal impact on beneficial insects at this time.

Expansion of fruit

As fruit begin to expand, mealybugs pose the biggest threat. Mealybugs are 'farmed' by ants and controlling ant activity in the tree is essential.

This is best achieved by skirting the trees during winter to a height of 50 cm and removing weeds and grass that may form 'ant bridges'. Spot spraying the trunk and the immediate surrounding soil surface with chlorpyrifos completes the ant management strategy.

Once ants are removed from the system, naturally occurring populations of mealybug enemies such as Leptomastix wasps, Cryptolaemus ladybirds and lacewings will often suppress mealybug populations satisfactorily without further intervention. However, where necessary, additional beneficial insects can be added through releases of commercially-produced species. Where spraying is necessary, petroleum oil sprays are preferred. Sprays of disruptive chemicals such as methidathion are a last resort.

Under this system, natural enemies of other pests such as nigra scale and yellow peach moth are allowed to do their job. These pests generally flare up only where overall cover sprays are used.

Fruit maturation—March to May

Queensland fruit fly presents its biggest danger during the fruit maturation period of March to May, especially for African Pride. Effective control can be achieved with minimal effect on beneficial insects by using bait sprays applied to small areas of the foliage of each tree. Cover sprays of dimethoate are effective but are highly disruptive to natural enemies of scales and mealybug.

Apart from Pseudocercospora spot in north Queensland, leaf and fruit diseases are not a major problem in well-managed orchards. The greatest risk is during or after prolonged wet weather. Copper oxychloride sprays are the most suitable response when diseases get out of hand. Mulching under trees to reduce soil splash and the annual removal of dead twigs and mummified fruit are important cultural control measures.

more info
Pest and disease management program Section 3 page 28

Detailed pest and disease management program

A detailed pest and disease management program with action levels from orchard monitoring is shown in Section 3 of this kit.

Spray application

Efficiency of pest and disease management can be enhanced significantly by good spray application. This means making sure that each spray reaches its target and provides good coverage of both leaf and fruit surfaces. The aim is to achieve about 70 to 100 droplets of spray per square centimetre, with droplets ideally about 50 to 100 micrometres in diameter (1000 micrometres = 1 millimetre). Droplets are best deposited when they are carried to the target in a turbulent air stream. For this reason, we recommend air blast machines.

Air blast machines

Air blast machines are designed to transport small droplets produced by hydraulic nozzles in an air stream to the target. The key factors in efficient operation of air blast machines are:

- nozzles producing small droplets;
- sufficient volume of air to replace the air within the canopy;
- direction of the air stream towards the target;
- turbulence produced by convergence of the air streams to aid in deposition of droplets;
- slow operating speed (2 to 3 km/hr) to ensure coverage is adequate.

Several different air blast machines are available. One suitable type is shown in Figure 58.

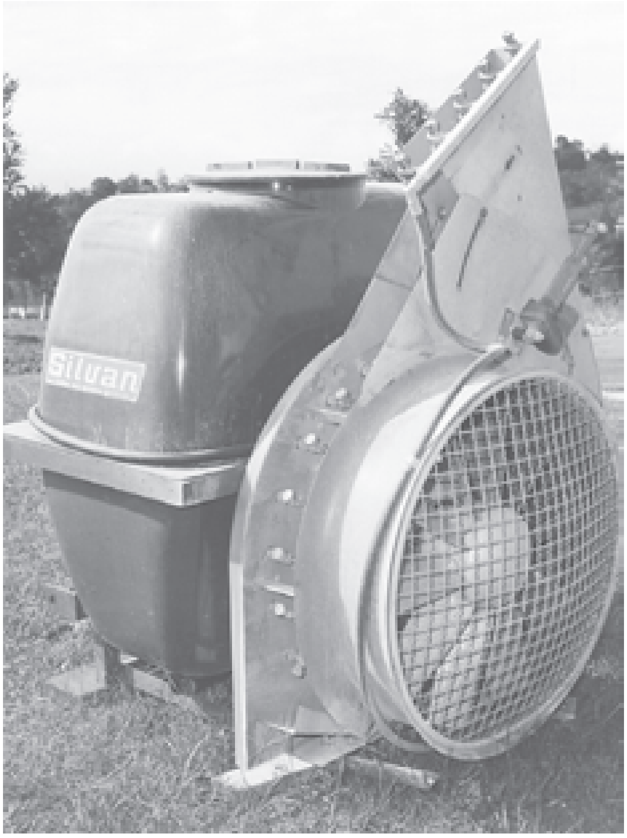


***Figure 58**. One suitable type of air blast machine for an orchard*

With air blast machines, we consider that effective coverage of a mature tree requires up to 8 L/tree. To achieve this coverage, the spray machine needs to be calibrated to ascertain its spray output per tree.

Calibration involves these steps:

1. Check that the pressure gauge is working properly.
2. Check spray nozzles and replace worn ones.
3. Calculate sprayer output in L/minute by this process:

• Fill the tank, set the pressure and operate the sprayer for a minute or so in a stationary position to get all lines full.

• Stop the sprayer and refill the tank to the top or a predetermined mark.

• Operate the sprayer in a stationary position for one minute.

• Measure the amount of water required to fill the tank to the top or the mark. This is the sprayer output in L/minute.

4. Mark out a distance of 100 m. Select a gear to produce an operating speed of about 2 to 3 km/hr. With the sprayer operating, time the travel over the 100 m. From this, calculate the actual speed in km/hr from the following formula:

$$\frac{\text{distance (m) x 3.6}}{\text{time taken (sec)}}$$

5. Application rate in L/ha is then calculated from the following formula:

$$\frac{\text{600 x sprayer output (L/min)}}{\text{row spacing* (m) x speed (km/hr)}}$$

* assumes both sides are being sprayed

6. Divide application rate by the number of trees per hectare to calculate application rate per tree. If less than 8 L/tree, travel at a slower speed. If more than 8 L/tree, speed may be increased.

Regularly check nozzles, pressure gauge and application rate.

Bait sprayer

Bait sprays for fruit fly control need to be applied with different equipment because:

- small volumes of spray are being applied (up to 35 L/ha);
- the spray is being directed to the lower part of the canopy only;
- the spray is best applied as a coarse spray rather than the fine spray required for other pests and diseases.

A suitable sprayer with coarse nozzles mounted either side can be built on a fat-track motorbike. The sprayer is best operated at a pressure of about 350 kPa delivering about 50 to 100 mL/tree.

Make sure the sprayer has adjustable nozzles so that the spray band can be positioned to suit the changing height of the leaf canopy.

Pollination

In the custard apple flower, pollen shedding and ovary receptivity are often poorly synchronised and this minimises the chances of adequate and complete pollination. As a result, natural fruit set and shape are poor in some varieties. Hand pollination is a technique developed to overcome these problems.

Understanding custard apple pollination

The custard apple flower

The custard apple flower is hermaphroditic (male and female parts in the same flower) and exhibits protogynous dichogamy, which means that the stigmas or female receptors are receptive before the pollen is shed by the male anthers. This separation of the female and the male stages limits the level of natural self-pollination in most varieties to between 0 and 8% (Table 24).

***Table 24**. Self-pollination percentages of major varieties*

Varieties with no self-pollination (0%)	Varieties with low self-pollination (1 to 3%)	Varieties with good self-pollination (more than 3%)
Pinks Mammoth	Hillary White	African Pride
	Martin	Gefner
	Most cherimoyas	Maroochy Gold
		Maroochy Red
		Fino de Jete

The degree of natural self-pollination depends on several factors, some of which can be manipulated to some extent by the grower (Table 25).

Table 25. Factors affecting natural self-pollination

Requirement for self-pollination	Factors affecting self-pollination	Impact
1. Stigmas receptive	Relative humidity	· 70 to 90% ideal (afternoon showers beneficial) · less than 60% or more than 90% detrimental (heavy or prolonged rain detrimental)
2. Viable pollen	Temperature	· higher than 35° C detrimental
	Relative humidity	· 40 to 65% ideal · more than 95% detrimental
	Boron nutrition	· optimum level beneficial
3. Pollen transfer	Pollinator insects (see below)	· thought to be responsible for 70% of natural self-pollination
4. Fertilisation	Flower self-incompatibility	· high in Pinks Mammoth and Hillary White · low in African Pride

Wind has very little impact on the level of natural self-pollination.

Insect pollination

Studies in Australia and Israel have shown that the main insect pollinators of custard apple flowers are nitidulid beetles (Family—Nitidulae) (Figure 59). These beetles can transfer pollen from the anthers to the stigmas in the same flower or to other flowers.

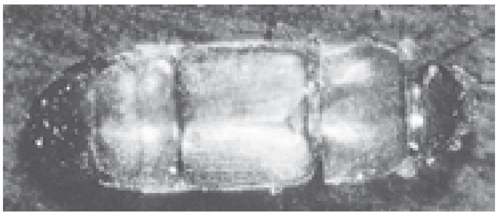


Figure 59. Closeup of nitidulid beetle

The population of nitidulid beetles in orchards at flowering time varies considerably and is influenced by many factors (Table 26).

Table 26. Factors affecting population build-up of nitidulid beetles

Factor	How it impacts
Availability of rotting fruit	Rotting fruit acts as a food source and attracts nitidulid beetles into the orchard. However, as it may be a more preferred source of food and shelter than custard apple flowers, it needs to be managed carefully. The most favourable conditions for build-up of nitidulid beetles in rotting fruit are high temperatures (25 to 30° C) and high humidities (75 to 95% RH).
Soil temperature	High soil temperatures (over 28° C) seem to stimulate massed flights of beetles and increase their likelihood of entering custard apple flowers.
Wind	Nitidulid beetles are weak fliers, even in light winds. This reduces their movement into custard apple flowers.
Rainfall	Rainfall and high humidities appear to be detrimental to beetle activity by reducing their flight and by reducing the attractiveness of the scent of custard apple flowers.

Maximising natural self-pollination

The best techniques for improving natural self-pollination are:

- maintaining high humidities in the orchard by late afternoon sprinkling;
- increasing nitidulid beetle populations in the orchard by placing rotting fruit attractants;
- using windbreaks to reduce wind movement and improve the movement of nitidulid beetles into the flowers;
- ensuring boron levels are maintained in the optimum range to maximise pollen viability.

An understanding of the process of natural self-pollination is important for improving productivity and for developing improved varieties. As varieties with high levels of natural self-pollination appear to have more self-compatible flowers, as well as heavily scented flowers more attractive to nitidulid beetles, these characteristics can be screened for in new variety breeding programs.

Hand pollination

Varieties with very low or no natural self-pollination (for example Pinks Mammoth and Hillary White) will have poor fruit set, yield and shape if allowed to self-pollinate naturally. Hand pollination is necessary to achieve commercially acceptable yields and fruit quality. On the other hand, varieties such as African Pride, which are self-compatible, produce heavy yields and good fruit shape without hand pollination.

However, besides improving fruit set, yield and shape, there are other reasons for hand pollination. These are to:

- manipulate flowering and fruit set and hence the harvest period to take advantage of high-priced, early or late season markets;
- manipulate the length of the harvest season;
- improve fruit size;
- overcome low pollen viability in early season flowers where an early crop is being sought (particularly in African Pride);
- overcome low natural self-pollination in drier areas where low humidities reduce stigma receptivity and pollen viability.

Sources of pollen for hand pollination

The best source of pollen is flowers of the African Pride variety. This variety produces large numbers of flowers and has a high degree of self-compatibility. By contrast, Pinks Mammoth produces few flowers and has a low level of self-compatibility. Growers of Pinks Mammoth and Hillary White should have some African Pride trees in their orchard to provide a source of pollen for hand pollination.

Collection and storage of pollen

Pick flowers from which pollen is to be collected during mid to late afternoon. Suitable flowers have petals nearly fully opened (Figure 60). The pollen sacs are creamy-grey and less tightly packed together; immature pollen sacs are white and tightly packed (Figure 61).

***Figure 60**. Flower suitable for collection*

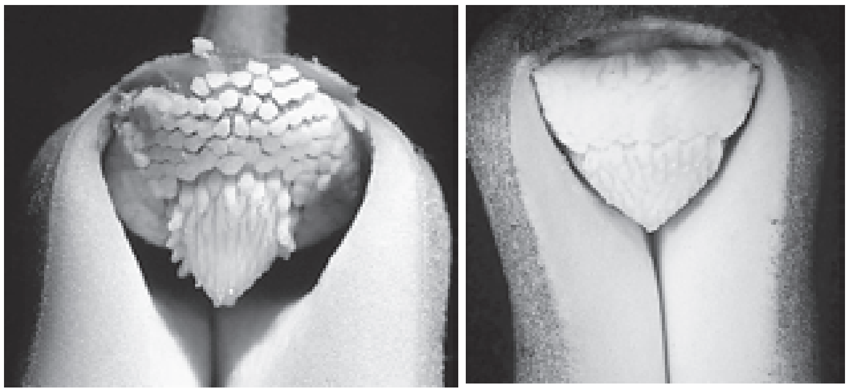


***Figure 61**. Left: flowers ready for collection, showing the pollen sacs separating (this flower is in the male stage). Right: immature pollen sacs are white and tightly packed (this flower is still in the female stage)*

On hot days with low humidity, the flowers will release their pollen sacs readily. Collect these by shaking the flowers over a piece of paper (Figure 62). Place the pollen sacs in a small open container and store at room temperature (less than 20°C) overnight for use the next morning. Discard the petals and flower stems.

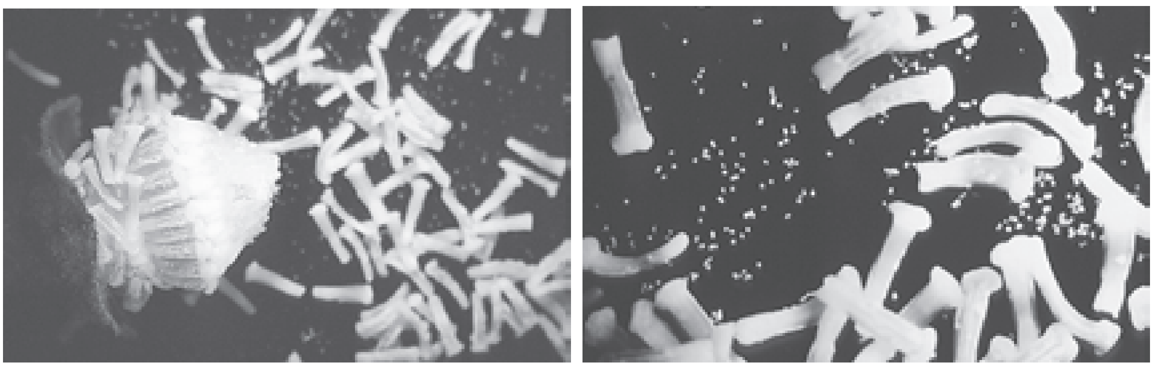


***Figure 62**. Left: pollen sacs separated from the flower. Right: close-up of pollen sacs, showing released pollen grains*

If the pollen sacs do not readily separate from the flowers, spread the flowers in a shallow layer in a tray and leave overnight. Pollen sacs can then be separated the next morning by again shaking the flowers over a piece of paper. Discard the petals and flower stems.

Do not store flowers in a closed container while waiting for pollen sacs to separate. A build-up of ethylene and moisture causes the pollen sacs to turn brown and pollen germination is significantly reduced.

Use the pollen within 24 hours of collection. About 20 to 30 collected flowers should provide enough pollen to pollinate about 50 to 60 flowers.

HINT

For more details about diluting collected pollen refer to *Pollen dilution* on page 117 of this section.

Methods of pollen application

There are three main methods for applying pollen to the flowers:

- camel hair brush
- pollination gun
- puffer.

All three can be used with the pollen undiluted or diluted with lycopodium dust or PVC dust. Dilution enables the pollen to go further as well as making it flow better through guns and puffers. However, the three methods are effective only when pollen is not strongly diluted.

Camel hair brush

This is a standard soft hair brush with the bristles trimmed (Figure 63).

***Figure 63**. Camel hair brush and pollen container for use in the field*

The camel hair brush method is the most effective because it applies the greatest amount of pollen to the stigmas of the flowers. As a result, the best fruit set and symmetry is produced. Fruit set and quality is only affected when pollen is diluted more than 30%.

Pollination gun

Pollination guns have the advantage that flowers can be pollinated much more quickly (from two to five times the pollination rate) than with the camel hair brush.

However, most guns do not apply the pollen as accurately and as uniformly as the brush. Guns also do not work well at upward angles as there is often not enough pressure to push the pollen upwards into the flower. Pressurised guns would overcome this problem but this is not a feature of most currently available guns.

In Queensland, however, the Japanese persimmon pollination gun (Figure 64) has been redesigned and early field-testing has shown it to be highly effective. At low dilution rates, the pollination gun produced fruit symmetry comparable with that of the brush application technique and fruit set only slightly lower. This slight reduction in fruit set would be more than compensated by the increased pollination rate of the gun.

***Figure 64**. Prototype of the Japanese persimmon pollination gun*

Puffer

Puffers consist of an air bladder, pollen container and fine discharge tube (Figure 65). They have similar advantages and disadvantages to the pollination gun but they need to be held upright to discharge properly.

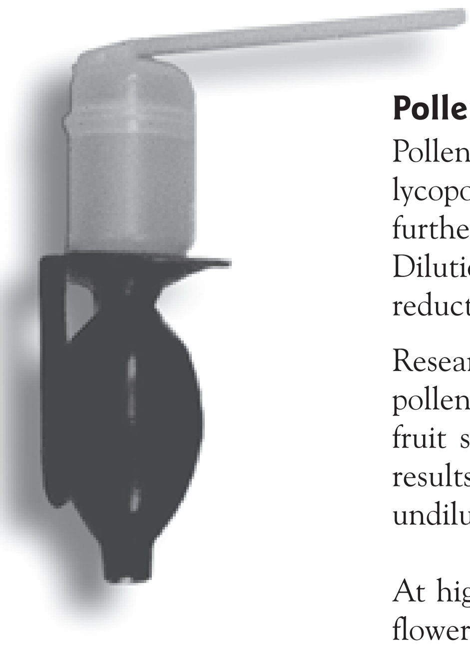


***Figure 65**. Puffer*

Pollen dilution

Pollen can be used undiluted or diluted with a carrier such as lycopodium dust or PVC dust. Dilution enables the pollen to go further as well as making it flow better through guns and puffers. Dilution, however, reduces the efficacy of pollination, the degree of reduction depending on the dilution rate and the carrier used.

Research has shown that at low levels of dilution (1 g of carrier per pollen sacs from 100 flowers), there is only a 10 to 15% reduction in fruit set compared to undiluted pollen. Both carriers give similar results. Fruit symmetry for the diluted pollen is similar to that for undiluted pollen.

At higher rates of dilution (2 g of carrier per pollen sacs from 100 flowers), there is a 30% reduction in fruit set using PVC dust and an 85% reduction in fruit set using lycopodium dust compared to undiluted pollen. It appears that the pollen grains adhere much more easily to PVC dust than they do to lycopodium dust. In addition, fruit symmetry for the lycopodium carrier was adversely affected, whereas it was relatively unaffected by the PVC carrier.

These results indicate that lycopodium carrier should never be used at the high rate. PVC dust is only suggested at the high rate in mid season, when pollen viability is high (Table 27). PVC dust is also cheaper than lycopodium.

Pollen carriers should be used in the knowledge that fruit set will always be slightly reduced. The benefit, however, is the increased number of flowers that can be pollinated per gram of pollen harvested.

***Table 27**. Guide to dilution rates for hand pollination*

Carrier type	Dilution rate (grams of carrier per pollen sacs collected from 100 flowers)		
	Early season	Mid season	Late season
Lycopodium	1.0	1.0	1.0
PVC	1.0	2.0	1.0

Pollinating flowers

Hand pollinate in the morning, preferably before about 7.00 a.m. but no later than about 11.00 a.m. Select flowers in the female stage (Figure 66).

***Figure 66**. Flower ready for pollination*

If using the camel hair brush, carry the pollen in a suitable container (Figure 63) which can be conveniently placed in a chest pocket or hung around the neck.

Gently separate the petals and transfer pollen from the container of pollen sacs to the female parts of the flower. Gently twist the brush to ensure even pollination of all stigmas (Figure 67). The number of stigmas pollinated will determine the potential size and shape of the fruit.

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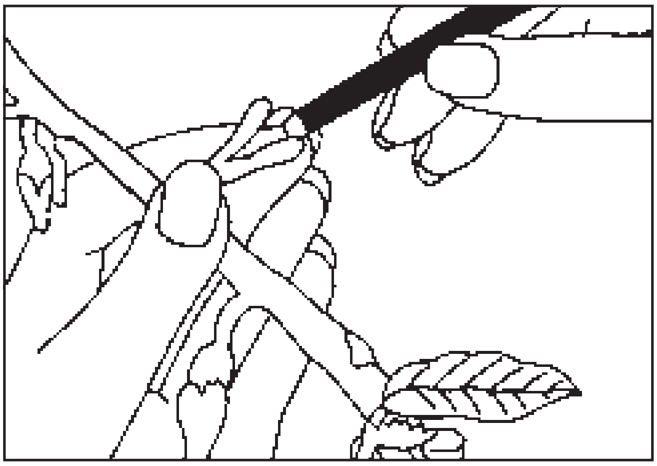


Figure 67. Hand pollinating flowers with the camel hair brush

Frequency of hand pollination

Trees can be hand pollinated every week during the flowering period. For each tree, to prevent overcropping and reduced fruit size, record the number of flowers pollinated and those that set fruit.

Manipulating the time of harvest

In south-east Queensland, the fruit development period for African Pride is about 26 weeks, and for Hillary White and Pinks Mammoth about 19 weeks. Depending on location, an earlier or later crop can be produced by intensifying the amount of hand pollination at the beginning of the season for African Pride and at the end of the season for Hillary White and Pinks Mammoth.

Economics of hand pollination

Using the brush technique, about 150 to 200 flowers can be hand pollinated per hour, with a success rate of between 50 and 100%. Using pollination guns and puffers, the rate can be increased to 400 flowers per hour.

With the brush technique, and assuming a minimum success rate of 75%, about 110 to 150 fruit could be set for every hour of hand pollination. This is equivalent to about 8 to 12 trays of fruit. Using an average price of $10 per tray, a gross return of $80 to $120 could be obtained for every hour of hand pollination. Gross returns could be increased significantly when hand pollination is used to target early season fruit for the high quality export market.

Factors affecting fruit set

The success of hand pollination depends largely on environmental conditions during fruit set. The physiological status of the tree plays a less important role.

Environment

Environmental conditions conducive to high fruit set are:

- high relative humidity
- moderate temperatures
- no heavy rainfall
- adequate moisture supply to the tree
- still conditions with little wind.

Of these, relative humidity, temperature and rainfall play the most important role.

Relative humidity. If relative humidity falls below about 70%, fruit set and shape is adversely affected. Good windbreaks help to maintain high relative humidity in the orchard. Light applications of irrigation using wide throw minisprinklers in the late afternoon also helps flowers to maintain their stigma receptivity until the next morning.

Temperature. Fruit set is reduced if flowers are pollinated during the hottest part of the day. The most favourable time to hand pollinate flowers is in the early morning before 11.00 a.m.

Rainfall. As fruit set is reduced by free water on the flowers, avoid hand pollination on days of light rain.

Trees

Fruit set is reduced during periods of strong vegetative flushing because of the competition between the growing shoots and the flowers.

Larger flowers (40 to 50 mm long) on the basal nodes of shoots set better fruit than smaller ones closer to the tips.

Trees in a good state of health set better crops. Pay close attention to nutrition and irrigation; boron nutrition is particularly important. Foliar applications of boron during the flowering period will generally enhance fruit set and quality.

Postharvest handling, storage and packaging

All of the good work put into growing the crop is wasted if the fruit are not handled and stored properly after harvest. This is especially important in custard apples as the fruit skin is very delicate and more easily damaged than most other subtropical fruits. Here are the main things you need to know.

Postharvest handling

A grower's aim is to produce custard apples of the highest quality with these characteristics.

External appearance:

- symmetrical
- blemish-free
- bright green

Internal appearance:

- bright, white flesh
- completely blemish-free, including around seeds and stem-core
- no more than about five (Pinks Mammoth and Hillary White) to eight (African Pride) seeds per 100 g of fruit weight

When soft ripe:

- bright skin
- green skin
- largely unblemished
- melting, soft flesh
- very sweet taste.

During postharvest handling and storage, the objective is to keep fruit in this condition for as long as possible. Blemish is the main concern as unblemished fruit commands much higher prices than even slightly blemished fruit.

Skin structure and fruit blackening

Even with perfectly handled fruit, skin blemishes increase gradually after harvest, and rapidly once the fruit softens. Microscope studies have shown that the custard apple skin is extremely thin and delicate, having no cushioning layer of protective cells common in many other fruits.

The skin cells protect the fruit, however, by responding to the slightest injury by exuding a deep yellow liquid resin, which eventually goes black and hardens. African Pride fruit blackens more readily than Pinks Mammoth but precise care is required in both cases to produce and market blemish-free fruit. The resin effectively prevents disease developing at skin injuries, and soft rots are unusual, even in over-ripe fruit.

Anything that damages or irritates the skin—cuts, bounce, rub, or excessive cold, dryness or humidity—will cause blackening. These injuries may first appear bronze, tan, faint purple, grey or brown before becoming black.

Plastic wraps can cause skin blackening in time by allowing excessive humidity or free moisture to build up, thereby encouraging fungal spores in the skin to germinate. These spores penetrate the skin cells, causing the liquid resin to be exuded, and the skin eventually goes black.

Maturity and fruit quality

African Pride

At their best, African Pride have an eating quality at least equal to that of Pinks Mammoth. However, African Pride fruit are much more variable in eating quality, and seedier. Research has shown that fruit of this variety can be picked at a relatively immature stage of development and yet still ripen to be edible. However, immature fruit are of less acceptable flavour than when fully developed, are extremely seedy, and can develop severe skin blackening.

Because of these difficulties, further work is needed to better define maturity in African Pride, and to determine suitable harvest parameters. In the meantime, we recommend the following process for determining maturity:

1. Make sure it is close to the normal time of harvesting for African Pride in your district.
2. Check fruit carefully for these external changes:
   - change in skin colour from dark green to a lighter green (dulling of colour);
   - grooves between the carpels widening and lightening in colour (creaming of the grooves may sometimes be present on the shoulders of the fruit);

- carpels become fuller and more rounded, particularly at the base of fruit. (The fruit may also appear rounder in shape and less pointed.)

3. Harvest a sample of fruit, hold at room temperature and check that it ripens to good eating quality within seven days.

Pinks Mammoth and Hillary White

Pinks Mammoth and Hillary White varieties have the highest reputation and value in Asian export markets because of their more consistent flavour and fewer seeds. Optimum commercial maturity is easily determined by creaming between the fruit carpels (knobby segments) when fruit are mature. Fruit is considered mature when more than 40% of the fruit surface shows creaming between the carpels.

In contrast to African Pride, if Pinks Mammoth/Hillary White fruit are harvested less than fully mature, they may fail to ripen properly. This results in poor eating quality and very increased skin blackening under refrigeration. There is a much narrower harvesting window for these varieties.

Harvesting and handling to maintain high quality

Custard apples must be mature when harvested to ensure that fruit will ripen to an acceptable eating quality. It is the grower's responsibility to market only fruit of acceptable maturity. When harvesting, keep fruit out of the sun to prevent undue heating. Clip the stems to a point below the shoulders of the fruit.

After harvest, fruit must be handled very carefully to avoid blemish. Remember that each rub, bounce or drop will eventually result in dark marks on the fruit.

When handling fruit, always place fruit down, never drop it or allow it to tumble. Place fruit carefully into picking bins and use soft-tyred transport to move bins to the packing shed. Handle crates and boxes of fruit with extreme care.

Line packing shed tables with a soft material such as a blanket and keep the surface very clean. Custard apple skin will mark or abrade very easily if dragged over dried leaves, bare wood, cardboard, dusty surfaces, other fruit or hard plastic. Damaged or marked fruit are substantially more sensitive to cold injury than unblemished fruit, developing much more skin injury during subsequent marketing.

Storage methods

For a marketable product, custard apples presently can only be stored for up to six days without significant discolouration and breakdown. Techniques for longer-term storage are under investigation but are not yet recommended. The various storage methods and their advantages and disadvantages are shown in Table 28.

Table 28. Storage options for custard apples

Length of storage	Method	Advantages	Disadvantages	Recommended
Short term (up to 6 days)	Refrigeration	· Extends shelf life · Allows fruit to reach market in good condition	· Expense of owning and operating cold room · Increased chance of chilling injury	Yes
	Ambient temperature storage	· No chance of chilling injury	· Can only access close markets—fruit must be sold within a few days · Fruit quality may deteriorate rapidly	No. A possible exception is where field temperatures at harvesting are less than 18° C. However, refrigeration is still the preferred option here
Long term (more than 6 days)	Controlled atmosphere (applied atmosphere of oxygen and carbon dioxide) in a sealed container)	· Shows remarkable promise in extending shelf life to 4 weeks	· Excessive losses from fungal infections which are unable to be controlled with existing fungicides · Fruit quality slightly reduced.	No
	Modified atmosphere (applied atmosphere of oxygen and carbon dioxide in semi-permeable sealed plastic bags)	· Shows promise in extending shelf life to 4 weeks	· 'Hard core' disorder unable to be managed with existing technology	No

Refrigeration

Understanding the need for refrigeration

Depending on the ambient temperature, custard apples can soften very quickly after harvest. Table 29 provides an estimate of the likely shelf life at different core temperatures for mature, unripe individual fruits. Slightly soft fruit will have a shelf life about half that shown, while more immature fruit will have a shelf life somewhat longer.

Table 29. Likely shelf life of fruit at different core temperatures

Fruit core temperature (°C)	Days between harvest (hard green) and eating soft
35	1½ – 3 days
30	2 – 5 days
25	2 – 6 days
20	3 – 7 days
15	4 – 9 days
13	6 – 15 days

In the field, skin temperature of the fruit can easily rise to 45°C in hot weather. However, the fruit is cooled by evaporation from the skin and the core temperature is usually lower than that of the skin. Fruit is also physiologically prevented from premature ripening while it is attached to the tree.

After picking, however, the core temperature of warm fruit can quickly rise to damaging levels, particularly if left in a pile or in close-stacked boxes. As well as this field heat, custard apples heat up naturally (like a pile of fresh grass clippings) by respiration. This is more pronounced in custard apples than in any other common fruit. If allowed to remain warm for any length of time, fruit very quickly lose shelf life and can easily become soft and unsaleable before they leave the farm.

Postharvest cooling is essential in warm climates. In these areas, the core temperature of custard apples needs to be lowered to 10°C as quickly as possible after harvest.

Understanding cold temperature injury

Custard apple, like several other subtropical fruits, is susceptible to cold injury following prolonged exposure to temperatures below 13°C. Symptoms of cold injury start with dull or slightly brown patches on the skin which, in some instances, become bronze or tan. With time or increasing injury, affected areas get bigger and become brown or black. In severe cases, the whole fruit becomes intensely black. The severity of injury depends mainly on the temperature and the duration of exposure, but also on the season and the growing area. Fruit of African Pride is noticeably more sensitive than that of Pinks Mammoth or Hillary White.

Refrigeration of custard apples is always a balance between fruit darkening from cold temperature injury when held below 13°C and the fruit going soft from premature ripening at temperatures above 10°C. As soft fruit is totally unmarketable, skin darkening can be tolerated more, but is still undesirable.

Recent research indicates a higher risk of damage where fruit are harvested during or soon after rain, and then refrigerated. Further study is required to establish safe harvest and postharvest practices.

General recommendations for refrigeration

Research has found that there is no single optimal storage temperature for all circumstances. In general, 10°C is recommended for storage, transport, and marketing. The use of higher or lower refrigeration temperatures depends largely on ambient temperature, but the weather, season, variety, postharvest handling practices, packaging materials and the market tolerance for dark-skinned fruit have an influence. Further work is needed to better define suitable temperatures and handling recommendations for different situations. In the meantime, the current best options are outlined in Figure 68.

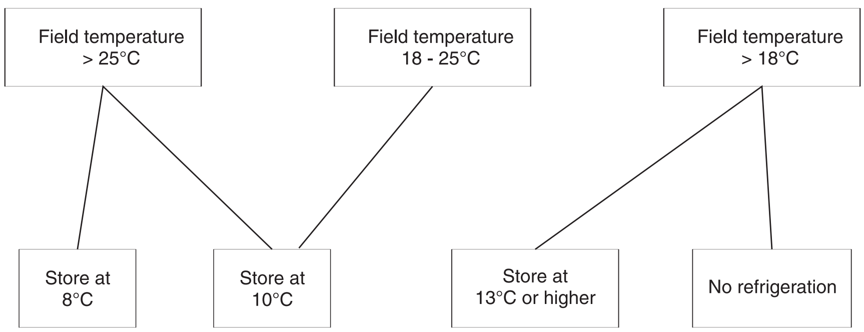


Figure 68. *Options for refrigeration of custard apples based on ambient temperature at harvest*

The advantages and disadvantages of each option are shown in Table 30.

***Table 30**. Options for refrigeration temperature for custard apples*

Option	Advantages	Disadvantages
Storage at 10°C	· Best balance between preventing premature ripening and minimising skin blackening	· Greater chance of high levels of skin blackening and chilling injury if fruit is stored for 6 days or more
Storage above 10°C (at 13°C or higher)	· Reduces chances of chilling injury with longer storage times	· Field heat not removed quickly unless forced-air or modified fan cooling is used · Greater chance of premature ripening
Storage below 10°C (8°C)	· Can remove field heat quickly if used for short-term storage · Can be used as a temperature buffer to ensure fruit does not heat up while being transferred to transport agents	· High risk of chilling injury which is additive over the entire storage period · Greater chance of high black skin levels if rain before or during harvest · No increase in shelf life
No refrigeration	· In cooler climates where field injury is possible, injury is not exacerbated	· In warmer areas, increases premature ripening and reduces storage life

Warnings

Be aware of the following situations where care with refrigeration is required:

- In warm to hot climates, fruit held at 10° C in stacked cartons can easily reach 12° C or more during delays in loading and transport. This can rapidly accelerate softening.
- Do not stack warm fruit unless they are forced-air-cooled. If warm fruit are placed in a stack, even in a cold room, they may not cool quickly enough, and can actually heat up. The addition of just a single improperly cooled carton to a stack can trigger the whole consignment to overheat. This is because warm fruit will self-heat faster than they can be cooled. To provide a safety buffer against such overheating, recent research examined the use of a storage temperature of 7° C, but this caused excessive blackening.
- Ensure that warm fruit in picking boxes and bins is not more than two layers deep, unless forced-air-cooled. Keep picking boxes and bins unstacked and open in the cold room, and ensure that the room's refrigeration capacity is not overloaded. Table or pedestal fans in the cold room directed towards the fruit will accelerate cooling of fruit in open boxes.
- For cool climate areas such as New South Wales, handling procedures with respect to temperature are under review. This is because cooling may be detrimental to fruit quality during the colder winter months. Further research is needed to clarify this.
- Custard apples should only be stored on the farm before transport and marketing for about three to four days. This assumes fruit is

stored at a temperature of 10°C. After longer periods of storage, some fruit will start to blacken and/or blacken severely within one to two days of removal to ambient temperatures.

If fruit were to be held for processing, where skin blackening was not a problem, longer storage periods may be possible, but the limits have not yet been defined.

Forced-air cooling

Forced-air cooling is used where large quantities of fruit need to be cooled quickly. Fruit cools much more rapidly if cold air can be forced to blow across the fruit. This can be done within an existing cold room by using a cover sheet and an axial fan (Figure 69).

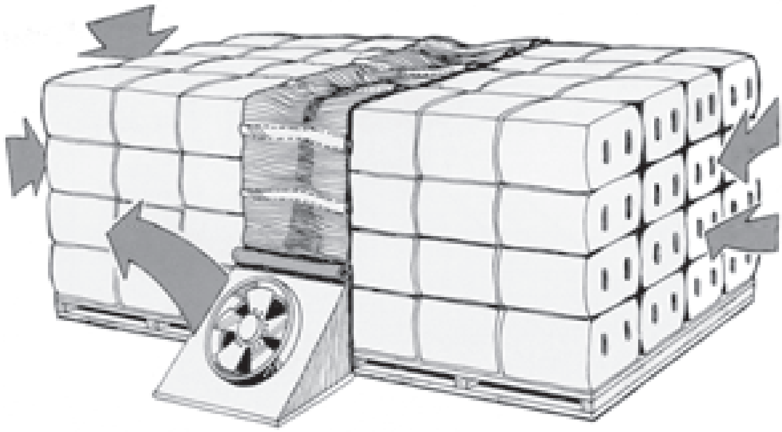


***Figure 69**. Forced-air cooling using a portable fan (illustration courtesy* AUF Fresh Produce Manual*)*

Cold air is dragged through the stacked fruit boxes by the fan and is recirculated in the cold room. Commercially built forced-air-cooling installations are available but are considered unnecessary unless substantial quantities of produce are being handled. A lower cost adaptation for smaller quantities of fruit could be fabricated using a modified table fan and a plastic sheet-shroud. This would probably be sufficiently effective for most growers handling up to 50 to 100 cartons per day.

Storage humidity

Storage humidity is traditionally kept high for refrigerated horticultural produce. Recent research, however, has shown little difference between storage at 60 and 95% relative humidity when fruit was stored at 20°C. The main issue is free moisture on the surface of the fruit (for example, from plastic sheets or bags) that may induce skin blackening in time.

A checklist for skin blackening

Skin blackening is one of the major postharvest problems in custard apples. It can develop at any stage from field to consumer. These are the possible causes of its development.

A checklist for skin blackening

On-farm—preharvest

- ❑ mechanical injury during growth
- ❑ mechanical injury during harvesting
- ❑ fruit too immature at harvest
- ❑ fruit chilled in field, production area too cold for too long
- ❑ rainy weather during harvest
- ❑ calcium levels too low
- ❑ wind too cold or too dry

On-farm—postharvest

- ❑ any prior damage above developing
- ❑ refrigerated too long
- ❑ refrigeration temperature too low
- ❑ mechanical damage during harvesting, handling, grading, packing
- ❑ free water on fruit, fruit sweating
- ❑ humidity too high (95%), fruit affected by condensate from plastic covers
- ❑ humidity too low for too long (less than 80% relative humidity)
- ❑ fruit too immature at harvest

Transport

- ❑ any prior damage above developing
- ❑ transport temperature too low for too long
- ❑ inadequate packaging, tray liners absent (mechanical damage during transport)
- ❑ sweating/condensate, plastic around fruit, humidity too high
- ❑ fruit too immature and humidity too low
- ❑ fruit in top of stack vibrating excessively during road transport

Wholesale

- ❑ any prior damage above developing
- ❑ holding temperature too low
- ❑ sweating/condensate, plastic around fruit, humidity too high
- ❑ humidity too low

Retail

- ❑ any prior damage above developing
- ❑ natural event, fruit over-ripe (fruit kept too long, unsold, shelf life too short)
- ❑ skin dehydrated (low ambient humidity of store)
- ❑ cold air from store air-conditioning vent
- ❑ held too long under refrigeration
- ❑ sweating/condensate from plastic wrapping
- ❑ refrigeration temperature less than 10° C

Packaging

Packaging involves three essential components:

- the fruit container (generally a fibreboard carton);
- packaging materials inside the carton;
- wrapping or strapping on the pallet.

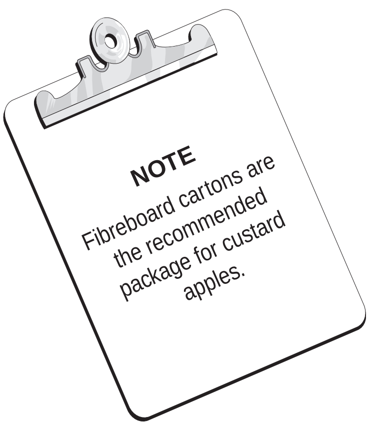
Each of these components is designed to prevent movement or vibration of individual fruit during transport and marketing. Packaging materials are tested in simulated road transport, using a variable frequency shaker-table. During these simulations, fruit are energised to vibrate, twist or bounce in the carton, rubbing and banging against each other and the carton surfaces. These trials show that when fruit vibrate or rub against other fruit or the bare carton surfaces, they mark very readily. Potential movement in the carton is exacerbated by the fact that fruit may shrink from moisture loss during transit and storage, losing up to 4% of its weight per day. Fruit have to be packaged to minimise movement and/or vibration and to absorb the energy imparted during any movement that does occur.

Cartons

There are two main choices for custard apple cartons:

- **Styrofoam or polystyrene cartons**. These cartons have some advantages. They have a bright, clean appearance and are simple and easy to use. The major disadvantage is that they are generally used unlidded and fruit is easily damaged or contaminated by foreign materials. They are also awkward to handle in the market and cannot be stacked on their side in airfreight containers. They are also regarded as being environmentally unsound.

  Styrofoam cartons are not recommended for custard apples.
- **Fibreboard cartons** (Figure 70). These cartons overcome all of the disadvantages of the styrofoam cartons and, if presented well, can have a similar bright attractive appearance. They require pre-assembly and this makes them a little more difficult and time-consuming to use.



There are two choices within fibreboard cartons:

- **T35 carton.** This is a two-piece, multipurpose carton with lid used widely in the fruit and vegetable industry. It has an 18 L capacity and generally holds about 10 kg of fruit. It is cheaper than the 18 L styrofoam carton and its larger capacity means that fewer cartons have to be stored. However, it has some major disadvantages. It has a relatively weak construction; it damages easily in transit and readily falls apart under high humidities. It is also more difficult to pack.
- **Standard tray carton.** This is a lidded tray supplied in different heights to allow for different sized fruit (110, 130, 160 mm) and in different fibreboard strengths (standard, export). It holds from about 6 to 11 kg of fruit, depending on the carton height and the

type of fruit packed. The export carton is internally waxed to provide increased strength for up to about 12 hours under highly humid conditions (for example, in Singapore). By contrast, standard cartons and T35's would rapidly fall apart under these conditions. The export carton is often used with a lid of standard carton strength to minimise overall carton cost.

An illustration of the carton types is shown in Figure 70. A summary of the choices for fibreboard cartons is shown in Figure 71.

***Figure 70**. Fibreboard cartons—back: T35; front: 130 mm and 110 mm trays*

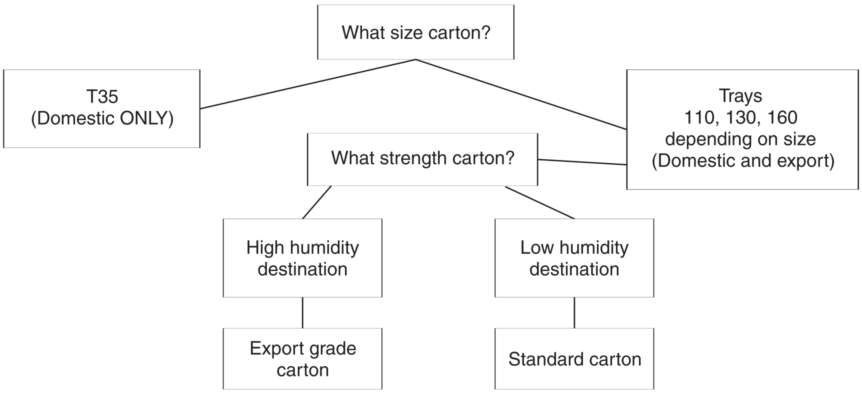


***Figure 71**. Summary of choices for fibreboard cartons*

Appropriate fibreboard carton size

Here are some hints to help choose the most appropriate fibreboard carton size:

- Choose a carton with a height to ensure a snug, tight pack. The tighter the pack, the less transport damage will occur.
- Keep fruit size in cartons even, with no more than 20% variation between the largest and smallest fruit.
- Pack fruit less than 300 g in size in T35 cartons.
- 110mm high cartons should hold a minimum of 6 kg of fruit; 130mm high cartons a minimum of 8 kg; and 160mm high cartons a minimum of 9 kg.

- Use the 130mm carton only when fruit pack above the inner of the 110mm carton. Similarly, use the 160mm carton only when fruit pack above the inner of the 130mm carton.
- Pack fruit with the stem-end down wherever possible. If fruit are too large for this, pack them on their sides.

Packaging materials inside the carton

Packaging materials should be used:

- on the top and bottom of the carton;
- between the individual fruit.

Packaging materials on the top and bottom of the carton

There are three main choices:

- no materials;
- 10 mm bubble wrap;
- others, including larger bubble wraps, foam and jiffy packs.

The advantages and disadvantages of each are shown in Table 31.

Table 31. *Options for top and bottom packaging materials*

Option	Main advantages	Main disadvantages
No materials	· No extra outlay on materials or extra packing effort	· Greatly increases the risk of damage from fruit rub and bounce · Fruit may become loose when they lose moisture and shrink during transit
10 mm bubble wrap **Recommended**	· Greatly reduces the risk of damage from fruit rub and bounce · Ensures a tighter pack and less movement, particularly when fruit lose moisture and shrink during transit · Better carton presentation than that provided by larger bubble wraps	· In hot and humid markets, some condensation may form on fruit · Extra outlay in packaging materials and time to pack
Other materials		
5 mm bubble wrap	· Slightly reduces risk of fruit damage compared to no material	· Provides minimal protection to fruit, especially African Pride · Bubbles readily burst · Extra outlay in packaging materials and time to pack
20 mm bubble wrap	· Greatly reduces the risk of damage from fruit rub and bounce (similar to 10 mm bubble wrap) · Ensures a tighter pack and less movement, particularly when fruit lose moisture and shrink during transit	· Presentation of carton not as attractive as 10 mm bubble wrap · In hot and humid markets, some condensation may form on fruit · Extra outlay in packaging materials and time to pack
Foam	· Reduces the risk of damage from fruit rub and bounce (similar to 10 mm bubble wrap) · Ensures a tighter pack and less movement, particularly when fruit lose moisture and shrink during transit	· Fruit may overheat and ripen prematurely · Extra outlay in packaging materials and time to pack
Jiffy packs	· Reduces fruit movement from bounce · Helps in tightening pack	· Allows fruit to rub so some risk of damage exists · Inferior to bubble wrap · Extra outlay in packaging materials and time to pack

Packaging materials between fruit

There are four main choices:

- no materials;
- poly socks (soft expandable polystyrene cylinder fitted over fruit with top open and bottom folded underneath—Figure 72);
- 10 mm bubble wrap;
- others, including tissue paper, 5 mm and 20 mm bubble wrap, foam and newspaper.

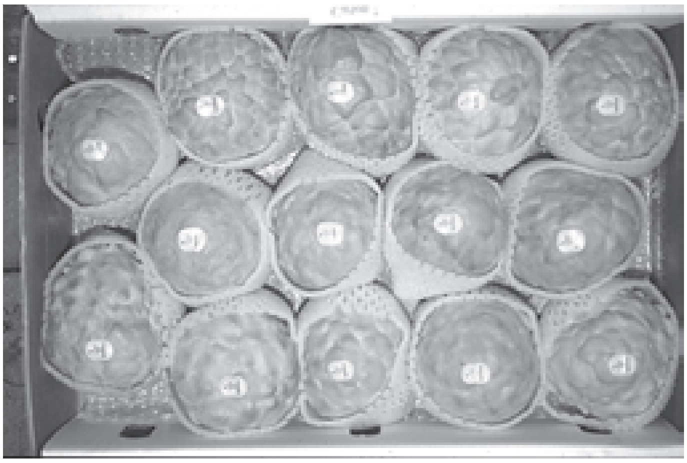


***Figure 72**. Effective use of poly socks*

The advantages and disadvantages of each are shown in Table 32.

***Table 32**. Options for packaging materials between fruit*

Option	Main advantages	Main disadvantages
No materials	· No extra outlay on materials or extra packing effort · May provide adequate protection if used with 'expert overfilling'	· Greatly increases the risk of damage from fruit rub and bounce, particularly for African Pride fruit and pointy fruit · Fruit may become loose when they lose moisture and shrink during transit
Poly socks **Highly recommended**	· Provides excellent presentation · Provides excellent protection against fruit to fruit rub. · When packed properly with socks folded under the fruit, provides excellent protection against fruit to carton rub · Most effective packaging material in reducing fruit movement in carton	· Extra outlay in packaging materials and time to pack
10 mm bubble wrap	· Greatly reduces the risk of damage from fruit rub and bounce · Ensures a tighter pack and less movement, particularly when fruit lose moisture and shrink during transit · Better carton presentation than that provided by larger bubble wraps	· In hot and humid markets, some condensation may form on fruit · Extra outlay in packaging materials and time to pack · Does not present as well as poly socks and tissue paper
Other materials		
5 mm bubble wrap	· Slightly reduces risk of fruit damage compared to no material	· Provides minimal protection to fruit, especially African Pride fruit and pointy fruit · Bubbles readily burst · Extra outlay in packaging materials and time to pack
20 mm bubble wrap	· Greatly reduces the risk of damage from fruit rub and bounce (similar to 10 mm bubble wrap) · Ensures a tighter pack and less movement, particularly when fruit lose moisture and shrink during transit	· Presentation of carton not as attractive as 10 mm bubble wrap · In hot and humid markets, some condensation may form on fruit · Extra outlay in packaging materials and time to pack

Option	Main advantages	Main disadvantages
Foam	· Reduces the risk of damage from fruit rub and bounce (similar to 10 mm bubble wrap) · Ensures a tighter pack and less movement, particularly when fruit lose moisture and shrink during transit	· Fruit may overheat and ripen prematurely · Extra outlay in packaging materials and time to pack
Tissue paper **Recommended for lower grade domestic market fruit**	· Tissue paper (particularly coloured) provides a very attractive pack · Relatively inexpensive	· Provides relatively little protection against fruit rub and bounce · Extra time to pack
Newspaper	· Relatively inexpensive	· Provides minimal protection to fruit, especially African Pride fruit and pointy fruit · Presents very poorly · Extra time to pack

More useful information on packaging materials

Here are some general comments about using packaging materials to minimise transit damage.

- **'Expert over-filling' (using no protective wraps) and strapping**. In this procedure, cartons (usually bulk T35's) are well over-filled, lidded and held extremely tightly on a pallet. Unripe custard apples don't bruise easily and can well tolerate compression loads that would damage other fruits. However, with such a procedure, custard apples still develop pressure point blackening, which, for top quality fruit, unnecessarily detracts from their appearance and value. Also, extra fruit are necessarily added to over-fill the carton, and a higher than average price is needed to compensate for it. Another disadvantage of this method is that it is labour-intensive to pack the cartons correctly. It is feasible for expert packers but is not recommended.
- **Tissue wraps**. These are cheap, generally present well, and require little labour to apply for a good-looking result. The tissues, however, give a false sense of security as they contribute little to pack tightness either in single or double layers, and therefore leave the fruit open to damage. This is particularly the case where the pack becomes loose from fruit shrinkage or fruit movement. Consequently, damage to fruit in tissue wraps is common in the market. Tissue wraps are recommended only for fruit at the cheaper end of the market.

- **Bubble wrap**. This is an excellent packaging material to prevent fruit rub on the top and bottom of the carton. It is also effective as an individual fruit wrap (even excellent as a double thickness) but becomes untidy quickly and presents poorly in the market. It is recommended as a carton liner but not as a fruit wrap. As a carton liner, it should ideally be placed on the side surfaces as well as the top and bottom. Always place the bubbles towards the fruit. The 10 mm size bubble is best, 5 mm is ineffective and 20 mm bubble wrap presents poorly.
- **Poly socks.** These are somewhat expensive compared to tissues, but are very effective, neat, and attractive. Combined with bubble wrap on the top and bottom, poly socks can totally eliminate

transit damage. They offer good insurance to top quality fruit and are highly recommended. The cost to benefit value for lower priced markets needs to be determined. Very pointy fruit may require an extra sock.

- **Other materials.** Plain newspaper is relatively ineffective and presents poorly. Shredded newspaper is possibly more effective but loose paper is abrasive and presents very poorly. Jiffy bags have looked promising but found to be inferior to bubble wrap. None of these materials is recommended.