Sweet potato information kit

Reprint – information current in 2000

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 2000. We advise readers to take particular note of the areas most likely to be out-of-date and so requiring further research:

- Chemical recommendations—check with an agronomist or Infopest www.infopest.qld.gov.au
- Financial information—costs and returns listed in this publication are out of date. Please contact an adviser or industry body to assist with identifying more current figures.
- Varieties—new varieties are likely to be available and some older varieties may no longer be recommended. Check with an agronomist, call the Business Information Centre on 13 25 23, visit our website www.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 2000. The information is not current and the accuracy of the information cannot be guaranteed by the State of Queensland.

Queensland Government

Key ISSUES

This section contains more detailed information on some of the important decision-making areas and information needs for sweetpotatoes. The information supplements our growing and marketing summary in Section 3 and should be used in conjunction with it. The information provided on each issue is not designed to be a complete coverage of the issue, but instead the key points that need to be known and understood. Where additional information may be useful, we refer you to other parts of the kit. Symbols on the left of the page will help you make these links.

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:

Profit = returns – costs

Therefore to achieve maximum profits you need to **increase returns** and **reduce costs**. The potential impact on profit of each of these is discussed below.

Increase returns

More efficient production by, for example, increasing yields, greater mechanisation (reducing labour cost) and improving quality will all help increase returns.

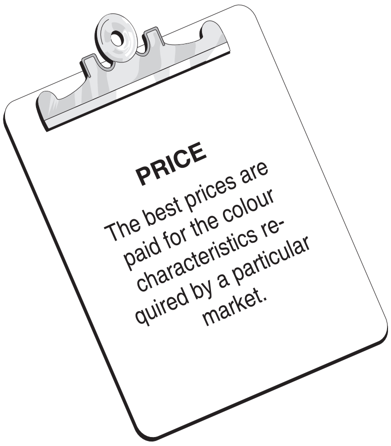
Your returns are influenced by:

- the price you receive;
- the number of cartons you sell.

Price received

The price received for sweetpotatoes is influenced by the:

- quality of the storage roots on arrival in the market;
- presentation (appearance/grade/carton);
- demand (volume/variety/alternatives);
- market destination of the storage roots;
- long-term reputation of your product.



Storage root quality

Six factors determine the quality of sweetpotatoes:

- **Colour.** This is a combination of internal and external colour. Consumer buying may be based on external or internal appearance, depending on the intended use. Within the dessert type the best prices are paid for storage roots with orange to red skin and bright orange flesh.
- **Size.** The best prices are paid for storage roots about 150 to 250 mm long and with a diameter of 45 to 90 mm.
- **Cleanliness and appearance.** The best prices are paid for storage roots that have clean, smooth skin and are free from any marks or blemishes that affect appearance. Marks, blemishes, insect damage and rots detract substantially from appearance. A customer's decision to buy is mainly influenced by the external appearance of most fruit and vegetables.
- **Flavour and texture.** Overseas research indicates that the preferred type of sweetpotato is one which, when cooked, has a 'dry' mouth-feel similar to the English potato, a white to light yellow flesh colour, and a moderately sweet taste. There is no Australian research information on consumer preference for flavour and texture.

  Many Asian and Polynesian cultures prefer the drier, firm textured, white-fleshed, staple type. These sweetpotatoes are sweeter than other traditional food, such as taro and yam, and also the English potato. In the USA, people of Anglo Saxon and African Negro descent like the moist, sweet, soft texture of the orange-fleshed, dessert type, while the Hispanic and Japanese populations in California prefer the staple type.

  Product description provides consumers with a choice and caters for their preference. However, if consumers take your product home and its performance does not match their expectations, they will not buy your product and you will lose repeat business. People are now consuming increasing amounts of gourmet foods, and eating and preparing food is a fashionable pastime, so flavour and texture will become increasingly important.
- **Shape.** The best prices are paid for storage roots that are well-shaped, elongate, oblong or oval and not excessively bent. Consumers consider ease of preparation, such as peeling, when buying; they don't want long, thin roots that leave little flesh when peeled. Likewise rough, lumpy and pitted storage roots are hard to prepare and are often avoided.
- **Soundness and shelf life.** The best prices are paid for storage roots that are sound (free from skin damage, cuts and punctures) and stored properly to maximise shelf life. Any skin damage allows moisture loss and entry of breakdown organisms. A common measure of soundness used by consumers is firmness; soft spongy product is often seen as not fresh.

These quality characteristics are influenced by several preharvest and postharvest management practices, some more important 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 sweetpotato quality

Management practice	Impact on quality (5 = high impact; 1 = low impact)					
	Colour	Size	Cleanliness	Flavour and texture	Shape	Soundness
Variety	5	4	5	5	4	3
Preharvest						
Nutrition	2	4	1	2	3	1
Irrigation	1	3	4	1	1	4
Pest/disease management	1	3	1	2	1	4
Harvest						
Age of crop	2	3	1	2	1	4
Harvesting	1	1	3	1	1	4
Postharvest						
Washing	1	1	4	1	1	4
Grading and packing	1	4	1	1	4	3
Storage	3	1	2	4	1	4
Packaging	1	1	1	1	1	3
Postharvest handling	2	1	2	2	1	5
Transport	1	1	1	1	1	2

Market destination

Different markets have different price opportunities for the various product types. The key is to research all market options thoroughly and match the type of product you can produce (dependent on environment and management system) to the best market opportunity. This includes determining your potential competitors and when their product reaches the market.

The role of the central markets for fruit and vegetable sales is diminishing as the major retailers now dominate the sales of sweetpotatoes. These major customers are looking for large volumes of consistent quality over an extended period. Growers need to align themselves with the major merchants who supply these chains or develop direct relationships with the retailers. Most growers on their own will not be able meet the supply expectations of these larger customers.

Reputation

Products often receive a higher price because of their 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. This is particularly important during periods of oversupply and low prices. Gaining a good reputation is now very dependent on implementing a quality management program throughout your production and marketing system. Packing produce in easily identifiable or well-branded containers may also help you build a recognised presence in the market.

Volume sold

The other way of increasing returns is to increase the volume of marketable storage roots sold. Increasing production usually requires some additional costs. Make sure that you don't spend more money to increase production than you can recoup from increased sales. The volume sold will depend on the quantity of storage roots produced and the demand for them on the market.

Customer demand can be affected by the volume of sweetpotatoes on the market, the price and the alternative products available. The main management factors affecting the volume of marketable storage roots produced and sold are shown in Table 2.

Table 2. *Impact of management on volume of storage roots produced and sold*

Management factor	Impact on marketable volume of storage roots (5 = high impact; 1 = low impact)	
	Marketable volume produced	Volume sold
Variety	3	4
Area planted	5	1
Time from planting to harvest	4	1
Nutrition	3	1
Irrigation	3	1
Pests and diseases	5	3
Postharvest handling	1	3
Quality	1	5
Reputation	1	3
Demand	1	5

Reduce costs

Reducing costs may not be a practical way of increasing profit. Unless you are careful where you reduce costs, you may reduce production or quality, or both, and therefore your income, by more than you save. The first step in reducing costs is to know what are your major costs.

Typical costs of producing a 20 tonnes per hectare sweetpotato crop in north Queensland and selling it on a $20 per carton Brisbane market are shown in Table 3.

Table 3. *North Queensland costs of growing and marketing sweetpotatoes*

	$/carton	$/ha
Total preharvest costs	$4.38	$4 377.59
Total harvesting and packing costs	$5.43	$5 429.07
Total marketing costs	$5.71	$5 716.67
Total variable costs	**$15.52**	**$15 523.33**

Cost reduction often has little impact on overall profitability. Seventy per cent of the costs are involved in harvesting, packing and marketing and it is difficult to reduce these costs significantly without affecting quality. Increasing mechanisation to minimise labour cost may reduce costs, but requires a large capital investment.

The key to profit

The key to increasing profit appears to be in maximising returns rather than minimising costs. The most effective way of maximising returns appears to be improving the price obtained. Your best chance of getting a higher price is to gain a reputation for producing a high-quality product.

It is critical for doing business in the sweetpotato industry that you establish links with customers to supply them on a regular and reliable basis. Negotiating supply arrangements well before planting is critical to success. You are at the mercy of the open market unless you have supply arrangements in place because the sweetpotato market is very fickle.

Economics of production

One way of assessing the economics of sweetpotato production is by calculating the gross margin for the crop. All data included in this gross margin are based on information provided to the authors. No responsibility can be taken for its accuracy. This data should be confirmed and changed where necessary by the user before any decisions based on the result are made.

The following gross margins are for sweetpotatoes grown on the Atherton Tableland and in southern Queensland at Gatton.

Assumptions

The calculations assume tip cuttings are planted and grown with good management and overhead irrigation. All machinery operations for southern Queensland include costs for fuel, oil, repairs and maintenance (F.O.R.M.); only fuel and oil are included in the north Queensland gross margin. No allowance is made for owner-operator labour.

Glossary of terms

The following terms are used in the economic data presented. You will need to make your own calculations to determine these figures for your operation.

Gross margin. A gross margin is the difference between the gross income and the variable or operating costs. The calculation does not consider fixed or overhead costs.

Variable or operating costs. These costs include the growing, harvesting and marketing costs.

Fixed or overhead costs. These costs include rates, capital, interest, electricity, insurance and living costs. Fixed or overhead costs are not included in a gross margin, but must be taken into account in calculating a whole farm budget.

Break-even price. The market price at which all growing, harvesting and marketing costs are recovered.

Break-even yield. The yield at which all growing, harvesting and marketing costs are recovered.

Cut loss price. The market price below which it is not worth harvesting. Above this price you will begin to recover your growing costs.

A sweetpotato gross margin for southern Queensland

Enterprise unit: 1 ha of sweetpotatoes

INCOME	Amount		$/carton	Total $/ha
Price (32 L carton)			$18.00	
Cartons/ha	1 250			
TOTAL INCOME				**$22 500.00**

VARIABLE PREHARVEST COSTS	/ha	$/unit	$/ha	Total $/ha
Land preparation (F.O.R.M.)				
Deep ploughing	1	$16.90/ha	$16.90	
Cultivation	1	$10.50/ha	$7.00	
Rotary hoeing	1	$19.40/ha	$19.40	
Bedding forming	1	$34.00/ha	$34.00	
Shallow cultivating	2	$6.70/ha	$13.40	
TOTAL LAND PREPARATION COSTS				**$94.20**
Planting				
Sweetpotato runners (each)	32 000	$0.01	$320.00	
Transplanter ($/ha)	1	$27.40/ha	$27.40	
Casual labour	32 hours	$12.00/hr	$384.00	
TOTAL PLANTING COSTS				**$731.40**
Fertiliser				
Dolomite	2.5 t	$140.00/t	$343.75	
CK 55	500 kg	$0.53/kg	$265.00	
Supplementary (potassium nitrate)	200 kg	$0.89/kg	$178.00	
Solubor (2 applications)	2.5 kg	$2.70/kg	$13.50	
Zinc (2 applications)	1 L	$14.00	$28.00	
Spreader	3	$6.00/ha	$18.00	
TOTAL FERTILISER COSTS				**$846.25**
Nematode control				
Nemacur	24 L/ha	$39.60/L	$950.40	
Application	1 hr/ha	$4.10/hr	$4.10	
TOTAL NEMATODE CONTROL COSTS				**$954.50**
Weed control				
Dual Gold	1.5 L	$34.50/L	$51.75	
Sertin Plus	1.6 L	$27.00	$43.20	
Sprayer ($/ha)	2	$4.10	$8.20	
TOTAL WEED CONTROL COSTS				**$103.15**

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VARIABLE PREHARVEST COSTS	/ha	$/unit	$/ha	Total $/ha
Insect control				
Rogor	2 x 0.75 L	$8.25/L	$12.38	
Chlorpyrifos	2 x 0.7 L	$24.00	$33.60	
Sprayer ($/ha)	4	$4.10	$16.40	
TOTAL INSECT CONTROL COSTS				**$62.38**
Irrigation				
Water charges	4.5 ML/ha	$9.15/ML	$41.18	
Power: single pumped (30 kW pump)	40 L/sec	$0.10/kWh	$93.75	
Pump repairs and maintenance	4.5 ML/ha	$16.00/ML	$72.00	
TOTAL IRRIGATION COSTS				**$206.93**
TOTAL PREHARVEST COSTS			**$2.40/carton**	**$2 998.81**

POSTHARVEST COSTS		$/ha	$/carton	Total $/ha
Harvesting and packing				
Sweetpotato carton (32 L)	1 250 cartons	$2 675.00	$2.14	
Slashing off tops	$20.00/ha	$20.00	$0.02	
Labour picking: 15 cartons/hr	83.3/hr @ $12.00/hr	$999.60	$0.80	
Labour washing: 15 cartons/hr	83.3/hr @ $12.00/hr	$999.60	$0.80	
Labour packing: 15 cartons/hr	83.3/hr @ $12.00/hr	$999.60	$0.80	
Labour casual (shift bins): 30 cartons/hr	41.7/hr @ $12.00/hr	$500.40	$0.40	
TOTAL HARVESTING AND PACKING COSTS	**1 250 cartons**	**$6 194.20**	**$4.96**	**$6 194.20**
MARKETING				
Freight (to Brisbane)	$0.60/carton	$750.00	$0.60	
Commission, levies	12.5%	$2 812.50	$2.25	
TOTAL MARKETING COSTS	**1 250 cartons**		$2.85	$3 562.50
TOTAL POSTHARVEST COSTS			**$7.81**	**$9 756.70**

SUMMARY TABLE

	$/carton	$/ha
TOTAL PREHARVEST COSTS	$2.40	$2 998.81
TOTAL HARVESTING AND PACKING COSTS	$4.96	$6 194.20
TOTAL MARKETING COSTS	$2.85	$3 562.50
TOTAL VARIABLE COSTS	**$10.21**	**$12 755.51**

Gross margin = Total income less total variable costs

	$/carton	$/ha
Total income (1 250 cartons/ha)	$18.00	$22 500.00
Less		
Total variable costs	$10.21	$12 755.51
GROSS MARGIN	**$7.79**	**$9 744.49**

BREAK-EVEN YIELD at $15.00 per carton	294 cartons/ha
BREAK-EVEN MARKET PRICE per carton (1250 cartons/ha)	$9.09 per carton
CUT LOSS PRICE per carton (1250 cartons/ha)	$6.35 per carton
GROSS MARGIN per MEGALITRE of IRRIGATION WATER	$2 165 per ML

Harvesting decision: At current price, is it worth harvesting?

On-farm price (market price less marketing costs)	$15.15
Harvesting and packing	$4.96
Therefore, it is worth harvesting	

Actual gross margin when price or yield changes

Yield/ha		Price per carton							
t/ha	cartons	$5	$10	$15	$20	$25	$30	$35	$40
15	750	– $3 896	– $611	$2 666	$5 951	$9 229	$12 514	$15 791	$19 076
20	1 000	– $4 189	$191	$4 561	$8 941	$13 311	$17 691	$22 061	$26 441
25	1 250	– $4 481	$994	$6 456	$11 931	$17 394	$22 869	$28 331	$33 806
30	1 500	– $4 774	$1 796	$8 351	$14 921	$21 476	$28 046	$34 601	$41 171
35	1 750	– $5 066	$2 599	$10 246	$17 911	$25 559	$33 224	$40 871	$48 536

Enterprise characteristics

Growing risk	Medium
Price fluctuations	Medium
Working capital requirement	Medium–high
Harvest timeliness	Low
Management skills	Medium
Quality premium	Yes
Spray requirements	Low–medium
Labour requirements—growing	Low
Labour requirements—harvesting	Medium

Last update: March 2000

A sweetpotato gross margin for the Atherton Tableland

Enterprise unit: 10 ha of sweetpotatoes

INCOME	Amount	$/carton	Total $/ha
Price (32 L carton)		$20.00	
Cartons/ha	1 000		
TOTAL INCOME			**$20 000.00**

VARIABLE PREHARVEST COSTS	/ha	$/unit	$/ha	Total $/ha
Nursery area costs (0.16 ha)				
Tip cuttings, labour to collect and lay (6 people)	6 x 18 hr	$13.50/hr	$242.90	
CK55	20 kg	$0.475/kg	$1.58	
Lorsban	0.1 L	$16.77/ha	$0.28	
Sertin Plus	1.6 L	$20.67/L	$5.51	
TOTAL SEEDBED COSTS				**$250.27**
Land preparation (fuel and oil)				
Land preparation	1 x 7 hr	$4.77/hr	$33.39	
TOTAL LAND PREPARATION COSTS				**$33.39**
Planting				
Labour to collect tip cuttings from nursery	6 x 18 hr	$13.50/hr	1 458.00	
Labour to plant cuttings (2 people)	2 x 16 hours	$13.50/hr	$432.00	
Transplanter	16hr/ha	$1.19/hr	$19.04	
TOTAL PLANTING COSTS				**$1 909.04**

VARIABLE PREHARVEST COSTS	/ha	$/unit	$/ha	Total $/ha
Fertiliser				
Tobacco 10	875 kg	$0.77/kg	$671.61	
Application	1 x 1.25hr/ha	$1.19/hr	$1.49	
Solubor	5 kg	$3.99/kg	$19.95	
Sprayer	1 x 0.75 hr	$4.77/ha	$3.58	
TOTAL FERTILISER COSTS				**$696.63**
Nematode control				
Nemacur	24 L/ha	$42.08/L	$1 009.92	
Application	1 x 1.6 hr/ha	$4.77/hr	$7.63	
TOTAL NEMATODE CONTROL COSTS				**$1 017.55**
Weed control				
Sertin Plus	1.6 L/ha	$20.67/L	$33.07	
Dual Gold	1.5 L/ha	$34.50/L	$51.75	
Sprayer ($/ha)	2 x 0.75 hr/ha	$4.77/hr	$9.54	
Interrow cultivation	2 x 1.25 hr/ha	$1.19/hr	$2.98	
Casual labour weeding	10 hr	$12.00/hr	$120.00	
TOTAL WEED CONTROL COSTS				**$217.34**
Insect control				
Lorsban	1 x 0.7 L/ha	$12.85/L	$9.00	
Endosulfan	1 x 2.1 L/ha	$11.46/L	$24.07	
Sprayer ($/ha)	2 x 0.75 hr/ha	$4.77/hr	$9.54	
TOTAL INSECT CONTROL COSTS				**$42.61**
Irrigation				
Irrigation (water and pumping)	4 ML/ha	$52.69/ML	$210.76	
TOTAL IRRIGATION COSTS				**$210.76**
TOTAL PREHARVEST COSTS		**$4.38/carton**		**$4 377.59**

POSTHARVEST COSTS	$/ha	$/carton	Total $/ha	
Harvesting and packing				
Sweetpotato carton (32 L)	1 000	$2 350.00	$2.35	
Slashing	1 hr/ha @ $4.77/hr	$4.77	$0.005	
Digging: 4.5 hours/tonne x 20 t/ha	90hr @ $4.77/hr	$429.30	$0.43	
Labour digging: (4.5hr/t x 20 t/ha)	90 hr @ $13.50/hr	$1 215.00	$1.22	
Labour washing, grading, packing: (4hr/t x 20 t/ha)	80 hr @ $13.50/hr	$1 080.00	$1.08	
Cooling	$0.35/carton	$350.00	$0.35	
TOTAL HARVESTING and PACKING COSTS	**1 000 cartons**	**$5 429.07**	**$5.43**	**$5 429.07**
Marketing				
Freight: farm to Mareeba	$15.00/pallet	$312.50	$0.31	
Freight: refrigerated to Brisbane	$125.00/pallet	$2 604.17	$2.60	
Commission	12.5%	$2 500.00	$3.13	
Levies	1.5% of gross	$300.00	$0.30	
TOTAL MARKETING COSTS		**$5 716.67**	**$5.71**	**$5 761.67**
TOTAL POSTHARVEST COSTS			**$11.14**	**$11 145.74**

SUMMARY TABLE

	$/carton	$/ha
TOTAL PREHARVEST COSTS	$4.38	$4 377.59
TOTAL HARVESTING AND PACKING COSTS	$5.43	$5 429.07
TOTAL MARKETING COSTS	$5.71	$5 716.67
TOTAL VARIABLE COSTS	**$15.52**	**$15 523.33**

Gross margin = Total income less total variable costs

	$/carton	$/ha
Total income (1 000 cartons/ha)	$20.00	$20 000.00
Less		
Total variable costs	$15.52	$15 523.33
GROSS MARGIN	**$4.48**	**$4 476.67**

BREAK-EVEN YIELD at $20.00 per carton 494 cartons/ha

BREAK-EVEN MARKET PRICE per carton (1 000 cartons/ha) $14.79 per carton

Actual gross margin when price or yield changes

Yield/ha		Price per carton							
t/ha	cartons	$5	$10	$15	$20	$25	$30	$35	$40
15	750	– $7 408	– $4 183	– $958	$2 267	$5 492	$8 717	$11 942	$15 167
20	1 000	– $8 419	– $4 119	$181	$4 481	$8 781	$13 081	$17 381	$21 681
25	1 250	– $9 429	– $4 054	$1 321	$6 696	$12 071	$17 446	$22 821	$28 196
30	1 500	– $10 439	– $3 989	$2 461	$8 911	$15 361	$21 811	$28 261	$34 711
35	1 750	– $11 449	– $3 924	$3 601	$11 126	$18 651	$26 176	$33 701	$41 226

Last update: May 2000

Business management

When you become a sweetpotato grower you are entering a new business, or at least adding a new enterprise to your business. Making this choice a business decision will help you keep the important issues in perspective. It means that thinking and planning about finance and marketing become as important as thinking and planning about production. No matter how good the product, the business will only be successful if you access profitable markets.

Operating a sweetpotato enterprise as a business involves developing business and marketing plans, recording farm information, financial management, marketing and control (implementation of quality management systems). If growing sweetpotatoes is an additional enterprise it should become part of your overall business plan and have its own marketing plan.

Business and market plans

To be successful all businesses need a plan. A plan helps you focus on your 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. Most financiers and investors want to see your business and marketing plans before they will lend you money.

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To help you develop business and marketing plans you should talk to your farm financial counsellor, a financial consultant, or undertake training provided under a government scheme such as those administered in Queensland by the Queensland Rural Adjustment Authority (QRAA).

The following outlines are a guide to the type of information you will need to develop plans that will help your business grow and prosper.

A typical business plan includes the following sections:

1. Mission
2. Situation analysis—SWOT (strengths, weaknesses, opportunities, threats)
3. Goals and objectives
4. Action plan/implementation
5. Budget
6. Control plan

As part of 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)
   - A determination of what opportunities will overcome which threats, and which strengths can be used to overcome which weaknesses
   - Issue generation and setting 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

Record keeping

Record farm information

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

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

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Quality management
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Your quality management system will determine the type and extent of records you need to keep.

This information is best recorded on a computer where it can be quickly accessed and compared, but it can be recorded in books or on forms. 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. The information is also used to compare performance from year to year and in developing best farm practice.

Record financial information

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.

There are several computer-based packages that will help you record financial information and keep an eye on your business.

a key issue
Gross margins
This section page 8

Gross margin analyses for sweetpotato production in north and south Queensland are provided as a guide for setting up your own financial recording program.

Marketing

The longer the marketing chain (the number of people between the grower and the consumer) the less control growers have over their produce and the lower their potential returns.

Growers have four ways of marketing their sweetpotatoes.

Traditional marketing. This is the longest marketing chain. Growers send produce to an agent or merchant at a central market. They have very little control over their product once it leaves the farm. This is a low risk, low capital option.

Form strategic alliances with major suppliers or marketers. Growers supply product to an established marketing network that has a recognised customer base. This type of alliance is more able to offer a constant, regular supply. It is also a low-risk, low-capital option.

Join marketing groups or cooperatives and joint packing facilities. Growers market their produce through a group, which may employ a marketing specialist. These groups are more able to offer a constant, regular supply and have enough volume to meet the needs of some larger customers. This option requires commitment and some increased investment, but offers the potential for higher returns.

Sell direct to the major customers (retailers). This is the shortest marketing chain and gives growers the most control over their produce. Growers need to produce high volumes of produce for large parts of the year. Direct selling involves a large financial input, and growers must either employ a marketing specialist or have those marketing skills. This option is limited to a small number of large growers, but has the best potential for higher returns.

Effective, targeted marketing will probably make the biggest difference to your success as a grower. An understanding of what marketing is about provides you with a base on which to plan how best to produce your product.

Marketing is not:

- selling;
- expecting that someone else will look after your product, with your best interests in mind, once it leaves your property.

Marketing is:

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

Successful marketing implies knowing who and where your customers 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 customers' needs.

Your **customer** is the person paying you for your sweetpotatoes, usually your agent, merchant or the retailer's buyer. The **consumer** is usually the person buying your sweetpotatoes in the retail store and taking them home. While it is fairly easy to find out your **customers'** needs, and if you are meeting them, it is much more difficult to find out the **consumer's** needs.

If you have made a good choice of **customer**, it will be someone who has a good knowledge of the needs of the **consumer**, however, unfortunately this is not always the case.

The financial performance of many horticultural businesses also indicates a lack of understanding about how cost of production is linked to marketing success. Many growers blame the 'marketing system' for poor financial results, which suggests that they think they are outside the marketing system. Nothing could be further from the truth.

The following suggestions may help you get onto the 'inside' of marketing.

Think as if you were a consumer

What does a sweetpotato consumer look for, what is most important? Is it price, quality, size, colour, shape, flavour, or a combination of these factors? If growers cannot reasonably guess at the answer to this question, how can they set targets for production?

For example, should you grow an orange-fleshed or white-fleshed variety? Orange-fleshed varieties make up the bulk of the market, but does your wholesaler have a niche market for the drier, white-fleshed varieties?

How should you grade out blemished sweetpotatoes? Grading too hard means fewer cartons of very high quality (and higher price); grading too lightly means more cartons of lower quality (and lower price).

At what point are market returns the best? How can a grower make these management decisions without knowing 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. These are generally conducted by industry and research organisations and are published in special reports. Grower organisations and Horticulture Australia are sources of this information.
- Marketers who are in close contact with buyers and consumers. For the domestic market, specialist sweetpotato 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 sweetpotato wholesalers. For the export market, sweetpotato exporters are a source of expert market knowledge.

Know the marketing chain for your product

Knowing the marketing chain for your product means identifying all the steps and all the people that link your product 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 where your product is sold

There is no substitute for seeing how your product is performing in wholesale and retail markets. But just looking at your product is not enough. You should be monitoring the product'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 ignore this if you do not show interest in them.

Actively seek market information

Apart from visiting the markets you should actively seek information about each consignment. No news is not necessarily good news. Ask your agent to report on the acceptability of your product. Set up a fax, phone or e-mail system to receive this information quickly. Outturn inspections by independent assessors are a useful way to get information about your product.

Join a marketing group (where available)

Small growers alone have little clout in the market, and also miss out on sharing information with other growers. If you're considering marketing on your own 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 your 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.

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 role. They are a method of developing a flow chart of the business and contain a series of checks for critical operations to ensure that they are done correctly.

Quality is built into every aspect of management

Quality is 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 needed to satisfy your customers.

Quality management is the way you run your business to satisfy customers. 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, minimising the need for rejections late in the marketing chain. This system also provides consumers with documented evidence that the product they are buying will meet their needs. Think of quality management as a marketing tool to achieve better prices and repeat sales, and a tool to identify areas for improvement, prevent mistakes and reduce wastage. It will also help you access markets with quarantine and other barriers to normal entry, and promote greater trust and cooperation between growers.

There are five core principles of quality management:

- The customer defines quality, not the grower.
- Quality management has to be planned, organised and managed; it does not happen by itself.
- Problems are identified at the earliest possible point, not at the end point.
- Decisions are based on facts, not feelings.
- Quality management is the responsibility of everyone in the business, including the workers—not just management or business owners.

It is not easy to put a quality management system together. You will need commitment, good planning, staff involvement, and simple and effective procedures including well-defined and objective quality standards.

a key issue

Quality management
This section page 20

Formal quality management systems are recommended because they remove the guesswork and are widely accepted throughout industry.

Quality management

Quality management is a vital step in sweetpotato production. How well you manage this will have a big effect on whether you make a profit or loss from your crop. The quality of your product depends largely on your management, as it will continue to decline the further it travels through the marketing system. Taking extreme care to avoid damage during harvesting, washing, packaging and palletising is an essential first step to putting a top quality product on the market.

Quality management for sweetpotatoes

Sweetpotato growers are implementing quality management systems driven by customer demand and food safety legislation.

Customer demand

Consumers are becoming more demanding. They want sweetpotatoes to be attractive, consistently acceptable in quality, nutritious and safe to eat, and they want convenience when buying. Their concerns about food safety have been heightened by recent outbreaks of food poisoning in other industries.

These consumer pressures have caused customers (retailers, processors, exporters and wholesalers) to be more demanding for quality and safety. For example, retail chains are increasingly requiring their suppliers to demonstrate that they have effective quality management systems in place. In other words, retailers want evidence that their suppliers can produce food that is safe to eat and will meet their quality requirements.

Most of the major retail chains in Australia are placing this requirement on selected direct grower suppliers and wholesalers. The wholesalers, to meet these requirements, in turn need to ensure that their grower suppliers have systems in place that will produce safe food of acceptable quality. After all, many of the food safety issues (particularly chemicals applied to produce) happen on-farm.

Processors and fast-food chains are also requiring their fruit and vegetable suppliers to have quality management systems in place to ensure supply of safe food.

Food safety legislation

For the first time Australia is to have national arrangements for safe and hygienic production, storage, transportation and retailing of food. New national legislation and food safety standards have been designed to ensure that safety measures are applied at all stages of the food supply chain.

Food businesses from primary producers through to retailers will have to meet the requirements of these new standards. The standards are risk-based, meaning that businesses with higher food safety risks will have to take more precautions when developing their quality management systems than some other food businesses.

Product specifications

The first step in developing a quality management system is a product specification that clearly defines quality and safety features. Many customers, for example Woolworths, have developed product specifications for their suppliers. Growers are also developing product specifications in consultation with customers.

Product specifications normally include:

1. General description—product type, customers, intended use.
2. Quality description—colour, maturity, size, shape.
3. Quality defects—both major (make the product unsound) and minor (detract from the appearance of the product).
4. Consignment requirements—packaging, palletising, labelling, temperature, transport.
5. Food safety—contaminants (physical, chemical and microbial).

A sample sweetpotato product specification is shown over the page.

A sample sweetpotato product specification

1. General description

Type/variety	Two root types: orange-fleshed and white-fleshed. Various varieties
Customers	Wholesalers and retailers in all Australian markets
Intended use	Fresh produce for human consumption

2. Quality description

Colour	Orange-fleshed: deep orange, moist flesh with smooth orange to red skin White-fleshed: white or purple flesh with uniform white, red or purple skin
Maturity	Firm skin, not shrivelled Dry matter: orange-fleshed >16%, white-fleshed >25%
Size	Small: 150 g – 250 g, medium: 250 g – 600 g, large 600 g – 1 kg Preference is for 17 cm x 7 cm sweetpotato
Shape	Elongate (carrot-like), oblong or oval. Not excessively bent

3. Quality defects

Major defects	Nil for unhealed wounds (cuts, splits and cracks), broken storage roots, weevil infestation, severe bruising and rots
Minor defects	
Cracks/healed wounds	No greater than 40 mm long, 3 mm wide and 3 mm deep
Insect (other than weevil)	No more than 2 healed holes
Skin blemish	No more than 6 sq. cm area in total
Sprouting	No more than 5 mm long
Defect tolerance	
Major defects	Must not exceed 5%
Minor defects	Must not exceed 10%
Major plus minor defects	Must not exceed 10%

Quality specifications can be reviewed, depending on seasonal conditions and specific customer requirements

4. Consignment requirements

Packaging/palletising	32 L fibreboard wilm or waxed inner carton. 18 kg minimum net weight Pallets: 8 cartons per layer x 6 or 7 layers high, preferably unitised for size
Labelling	Cartons clearly marked with grower name, address, net weight, type (variety), grade or class and traceability code (e.g. packed on date)
Pulp temperature	16° – 18°C at receival, unless otherwise negotiated
Transport	Refrigerated transport, unless otherwise negotiated

5. Food safety

Contaminants	Free of contaminants. Below Maximum Residue Limits (MRLs) for chemicals and below Maximum Permissible Concentration (MPC) for metals, as specified in the Australian Food Standards Code A12-A14

Product identification and traceability

The ability to identify and do a trace-back on products is an important part of product specification and quality assurance.

Product identification and traceability is the method used to trace product from its point of origin in the field, through the packing shed to the customer. It also enables trace-back from the customer to the product's point of origin. A traceability code could be a 'packed on' date, but many packers prefer a code that only they can interpret. Letters of the alphabet can be printed on the carton and circled for different days, blocks, etc. This gives the grower the ability to trace-back from individual cartons to the field. Computer-aided equipment that prints a code on each carton is also available.

What level of quality management do you need?

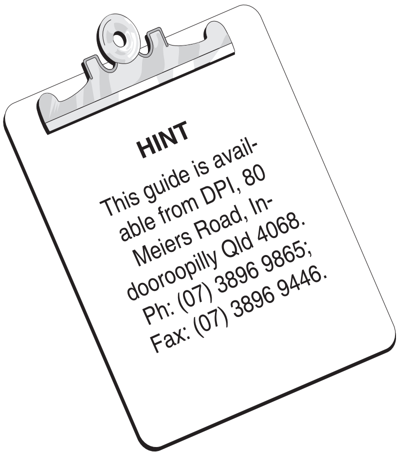
The three broad levels of quality management practices being requested by customers are:

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

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

Approved Supplier Program

An Approved Supplier Program is required when growers who supply packhouses, marketing groups, wholesalers, exporters or processors must meet specific requirements to be an approved supplier to these customers. However, growers may not need to have a certified quality system to meet these requirements.

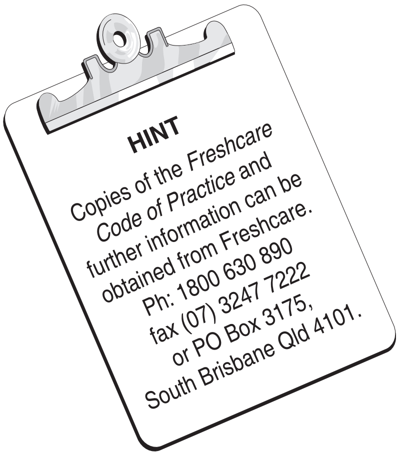


Approved supplier requirements may include:

- following agreed procedures for critical operations;
- keeping quality and safety records such as a spray diary;
- picking and packing to agreed quality standards;
- implementing a food safety plan.

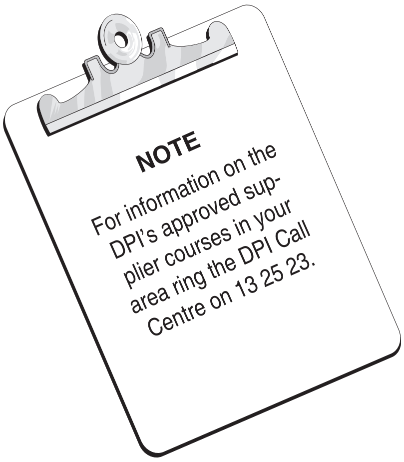
The customer (or on independent company on behalf of the customer) conducts audits to check that the grower meets the approved supplier requirements. A guide, *Developing an Approved Supplier Program for Fresh Produce—a Guide for Customers and Suppliers,* is available from DPI.

Freshcare



The fruit and vegetable industry has developed an on-farm, food safety program called Freshcare. Wholesalers, processors, packers and marketing groups may use Freshcare as a minimum requirement for their Approved Supplier Program. Certification to Freshcare is achieved through an independent audit on-farm for compliance with the Freshcare Code of Practice and is accepted by the three major retailers in Australia.

The DPI's Queensland Horticulture Institute runs training courses in approved supplier requirements for fresh produce. The course is



aimed at helping growers to develop skills and understand the requirements of Approved Supplier Programs with particular relevance to horticulture.

HACCP plans

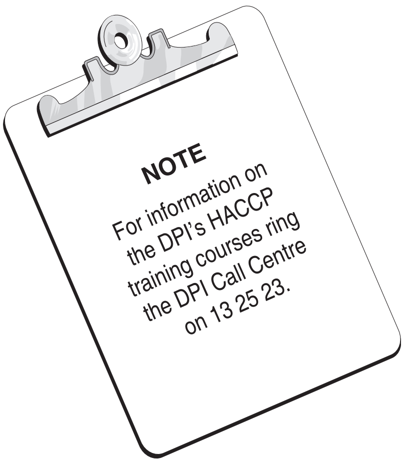
Hazard Analysis and Critical Control Point is an internationally recognised method to identify, evaluate and control hazards (things that can go wrong) to food products. HACCP was originally developed to provide assurance that food was safe to eat, but it is now being used to ensure that customer quality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

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

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

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

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



HACCP-based quality management standard or code

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

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

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

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

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

ISO 9002

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

SQF 2000^{CM} and SQF 1000^{CM} Quality Code

The SQF 2000^{CM} and SQF 1000^{CM} quality codes were developed by AGWEST Trade and Development, Western Australia, specifically for small businesses in the food industry. They are recognised in Australia and in some Asian countries. The codes have specific requirements that must be addressed to achieve certification. The SQF 2000^{CM} audit code includes HACCP and requires a HACCP plan to be developed, validated and verified by a HACCP practitioner. The SQF 1000^{CM} quality code is based on HACCP and requires a food safety plan to be prepared from a master industry HACCP plan that has been verified by a HACCP practitioner.

HACCP 9000

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

Supermarket quality management standards

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

Other certification schemes

AQIS Certification Assurance (CA)

Certification Assurance is a scheme established by the Australian Quarantine and Inspection Service (AQIS) as an alternative to end-point inspection. It is a voluntary arrangement between AQIS and an exporting business. The Certification Assurance system takes over the inspection function of AQIS, which now monitors the effectiveness of the Certification Assurance system by a regular program of audits.

Interstate Certification Assurance (ICA)

Interstate Certification Assurance has been developed by Australian state departments of agriculture as an alternative to inspection of product destined for states requiring treatment for fruit fly control. It consists of a series of operational procedures that growers must follow to meet interstate quarantine requirements. Queensland DPI audits each business at least once a year.

What is quality management going to cost?

There is no simple answer to this question.

Costs will depend on:

- size and complexity of the business;
- what level of quality management is wanted;
- how much knowledge the owner and staff have to develop and implement a system;
- whether outside help is needed.

Typical costs include:

- owner's time (this is the biggest cost);
- staff time involved in developing and implementing quality management;
- for large businesses, staff positions dedicated to quality management (monitoring, documentation);
- materials such as manuals, folders, posters, measuring equipment;
- training costs for owners and staff;
- consultant fees, if outside help is needed;
- auditing costs, if aiming for accreditation.

Quality management is an investment

There is a pay-off for quality management. As one grower has said: "An effective system does not cost, it pays." Like buying machinery, the time and money spent on quality management is an investment for future profitability.

Understanding the plant

An understanding of the plant will help you understand the conditions and treatments necessary to produce sweetpotatoes economically. Sweetpotato has been a staple food of many societies and is ranked seventh in food production in the world, and fourth in the tropics. Sweetpotato is a high energy food and an excellent source of provitamin A carotenoids, calcium and vitamin C. Some countries rely on sweetpotatoes for 60 to 90% of their energy requirements and a major part of their protein.

Introduction

The sweetpotato originated in tropical America and has spread around the world. It is a perennial vining plant that produces swollen subterranean storage roots, which are the most marketable part of the plant. The storage root is eaten as a vegetable and as a dessert. In some countries the above-ground vegetative plant parts are eaten as a vegetable. The whole plant is commonly used to feed stock in some countries and the storage roots also have some industrial uses such as ethanol and starch production.

Some attributes of sweetpotato that make it so important in tropical countries include its ability to withstand environmental extremes; its ability to cover the ground rapidly, reducing the need for cultivation and soil erosion; and its low input requirements for pesticides and fertiliser.

Botany of the plant

The sweetpotato (*Ipomoea batatas L.*) belongs to the family Convolvulaceae, which includes plants such as morning glory, bindweed and dodder, to which the sweetpotato is most closely related.

Flowers are more commonly produced under tropical environments rather than subtropical. The flowers are usually white to pale purple and, after cross-pollination, produce a capsule fruit containing viable seed. Although true seed is produced, commercial propagation is by transplanting vine cuttings. True seed production is used in breeding programs as a means of producing new varieties. All seed is the result of cross-pollination between two genetically different lines, and plants from this seed will differ from both parents.

Sweetpotato is a long-season crop of about 16 to 25 weeks. It takes longer for storage roots to develop in cool weather than in warmer conditions.

Stems

The stems are either prostrate or ascending and either straight or twining. The plant produces roots at the stem nodes, where leaves are attached. Leaf structure, shape and colour vary markedly, depending on variety in particular, but also on the environment. The leaves may be round, heart-shaped, triangular or lobed. Pigmentation ranges from green to purple and various shades in between. There is often distinctive colouring associated with the leaf base and veins, and on the petioles and stems. These traits are useful in identifying different varieties.

Storage roots (not tubers)

The edible storage roots are often referred to as tubers, however, this is incorrect as unlike the tubers of the English potato the sweetpotato does not develop from a modified stem. True tubers are swollen stems arising from stolons whereas the storage roots of sweetpotatoes are swollen roots originating from nodes on the original cutting. For this reason we recommend that cuttings are planted so that at least three nodes are in the ground. Strong attachment can result in difficulties at harvest when the storage roots do not release readily from the plant.

The skin and flesh colours of storage roots vary considerably. Skin colours include white, cream, orange, brownish-orange, red and purple. Flesh colours include white, cream, yellow, purple and orange. In some varieties, particularly white-fleshed ones, purpling develops in the central, fleshy part of the root.

The vegetative and storage root parts of the plant contain white sap (latex), which in some varieties can cause discolouration in storage roots.

Two broad root types are produced: orange-fleshed and white-fleshed varieties. Orange-fleshed varieties ideally have deep coloured, moist flesh with a smooth orange to red skin. They are elongated, have minimal ribbing and lower dry matter ranging from 16 to 25%. They are often referred to as dessert types.

White-fleshed varieties ideally have white or purple flesh, with white, red or purple skin. They are more prone to ribbing than the dessert types. The better red-skinned varieties have a double skin consisting of a clear waxy outer skin over an inner skin, which gives a more attractive appearance and makes them less susceptible to skin damage. White-fleshed varieties are often referred to as staple types and have relatively high dry matter ranging from 25 to 32%.

Sweetpotatoes vary in shape. The most common shapes, round, elliptical, oblong and long irregular or curved, are shown in Figure 1, with elliptic and oblong being the most desirable.

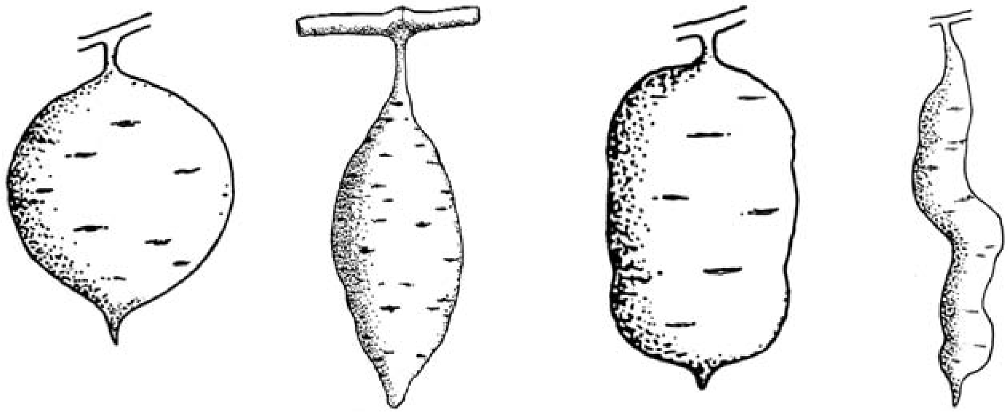


Figure 1. Common sweetpotato storage root shapes (from left): round, elliptic, oblong and long irregular or curved. Source: 'Descriptors for Sweetpotatoes' by Z. Huaman

Vegetative growth

Establishment

The preferred planting materials are vine tip cuttings and 200 to 250 mm long sprouts from storage roots. The initial growth stage in sweetpotato is vegetative. The crop is establishing sufficient leaf area and root mass to meet the demands of storage root development and bulking. This stage ideally lasts for about five to six weeks from transplanting, depending on growing conditions. Storage root initiation normally occurs between five and eight weeks after planting.

Sweetpotatoes must be planted under warm, frost-free conditions, as plants are sensitive to cool stress. Ideally temperature should be in the range of 24° to 30°C. Transplants are also sensitive to extremely hot conditions, as a vigorous root system is not developed and moisture supply to the transplant is restricted until roots establish.

After the cutting is planted new lateral shoots develop from the axillary buds where the leaf petioles join the stem. Once established the plants produce vigorous and prolific vines under ideal conditions of warm to hot day temperatures, warm nights and adequate moisture.

If night temperatures are too cool for growth (less than about 15°C), the plant remains dormant and vegetative growth stops until temperatures are warm enough. In tropical environments good vegetative growth and hence root production can be achieved year-round. However, in upland northern regions and southern parts of Queensland cool conditions during winter restrict vegetative growth and hence storage root development. Cold stresses will stimulate the development of malformed storage roots and temperatures of less than 15°C can cause chilling injury to storage roots.

Vine running

At about five weeks after planting and having established a good root system, the sweetpotato plant enters a prolific growing phase where the plant is ready to grow rapidly. The development of a good root system in the early stage is essential to allow sufficient water and nutrient uptake. Weeds must be controlled before prolific vine running (vining), as control is difficult once vigorous vining starts.

New runners are produced when active growth starts in the axillary buds (the small buds where the leaf petiole joins the stem). The continued growth from these buds results in the formation of further runners and these in turn can develop more runners themselves. As the runners grow, roots may develop at each stem node under prolonged wet conditions.

Rooting in lateral vines or runners is discouraged in most countries as some varieties develop storage roots on the laterals. These developing storage roots compete for nutrients against the storage roots formed on the main vine, resulting in lower marketable yield and difficulty in harvesting. Vine lifting is recommended at this stage in some countries.

Once vigorous vining has started weed control becomes a minor problem as sweetpotatoes grown under the right conditions will out compete weeds.

Excess vegetative growth

The aim in growing sweetpotatoes is to maximise storage root production by ensuring that vegetative growth is sufficient to support this. Any conditions that favour luxuriant growth will stimulate the sweetpotato to produce vegetative material and storage root initiation will be minimal. High nitrogen levels and excessive water application, particularly under warm to hot conditions, can reduce storage root production.

For sweetpotatoes, storage roots are a means of long-term survival under stressful conditions. They ensure the plants survive from season to season. The sweetpotato is a perennial plant and under luxuriant growth conditions produces prolific vegetative growth. This is because the plant does not detect the need, or receive the stimulus, to initiate the storage roots that may be required for its survival under stress.

Storage root initiation

Storage root initiation begins at about five to eight weeks after planting. At this point roots form directly from the nodes on the cutting then enlarge, with secondary growth or thickening to become storage roots. The continued growth of these roots for the duration of the crop produces the much enlarged storage roots, which are the marketable part of the plant.

Varieties

There are two basic types of sweetpotato. The more popular, orange-fleshed, dessert type is moist, soft and sweet and is preferred for sweet dishes. The white-fleshed, staple type is drier, firmer and starchy and is used in savoury dishes. Sweetpotato varieties differ in their growing conditions and are very specific to location, season and use.

Although some varieties are widely adapted, there is no one variety that will perform uniformly across all planting seasons, locations and production techniques. Neither is there one variety that is suited for both fresh market and processing, and all types of use. However, the availability of several varieties improves the chance that there is one that will suit your farm and the market you supply. We suggest that you try small areas of new varieties before making large plantings.

Select varieties

Variety selection is perhaps the most important decision you will make once you decide to grow sweetpotatoes. Will you plant varieties the market prefers but do not perform well on your farm, or will you plant varieties that perform well but are not wanted on the market?

There are numerous sweetpotato varieties with different plant and storage root characteristics that are preferred by consumers (Tables 4 and 5). In addition, some promising new varieties and advanced breeding lines have not yet been fully evaluated. We recommend you plant them for trial on the farm alongside your standard varieties. This will allow you to compare these newer varieties with your usual varieties and accept or reject a variety. The continual assessment of new varieties will help you determine those best suited to your farm, management and market.

Varieties that produce large storage roots require regular inspection in summer so they don't get too big before harvest, but may be ideal for winter production. Roots take longer to reach marketable size in cool weather.

Markets for sweetpotatoes

In the USA sweetpotatoes are divided into two broad categories—dessert and staple—based on their consumption and use. Dessert types are used for sweet and savoury dishes, and staple types for savoury dishes.

These categories are used less within Australia, where both types are sold on the fresh market, the main market for most Australian sweetpotatoes. Always determine the requirements of your market before selecting varieties.

Both types can be processed into different products. Soft, moist dessert varieties, such as L0-323, are processed into baby food. The variety Nemagold was developed specifically for the canning trade in the USA. Staple types are better suited to processing into chips, flour and ethanol, though this is not done in Australia at present.

There are some dual purpose varieties that can be used for both processing and the fresh market.

Fresh market

Sweetpotatoes are usually grown in Queensland and Australia for the fresh retail market. They are used as a complementary vegetable with various meats and other vegetables, and as a staple, dessert, or snack food. The type of dish required will largely determine the type of sweetpotato used.

Australian retailers classify fresh market sweetpotato on their skin colour, that is gold (orange-fleshed varieties), for example Beauregard, red (Northern Star), and white (WSPF).

Dessert type

Dessert type varieties are orange-fleshed, sweeter, softer and have lower dry matter content than the staple type. They are canned in syrup in the USA and also cured, then baked and served with sweet meats, for example pork and poultry, and ice-cream. The dessert type is also used in sweet dishes such as pies, muffins, cookies and bread.

Dessert type varieties include Beauregard, Beerwah Gold, Centennial, Hernandez and NC-3. Beauregard is the most commonly grown variety; however, several promising new varieties are being evaluated.

Staple type

Staple type varieties are those with white flesh, some with purple secondary colour. They are mealy and contain more complex carbohydrates. This type is often used as the main meal in many countries and is also used for industrial purposes, such as production of ethanol. Kestle, Northern Star and WSPF are staple varieties.

Other uses

Other uses for sweetpotato are not common in Queensland and Australia, but contribute significantly to the sweetpotato industry of other countries such as China. The sweetpotato is showing great industrial potential in the Philippines and Vietnam. Some varieties are suitable for the production of ethanol.

Varieties with high dry matter, high starch and low sugar are processed primarily into starch and flour and into secondary products such as noodles, cakes and pastries. Some countries are also considering these as feed for pigs and cattle.

If you intend exporting sweetpotato you have to consider the varieties you grow. Some Japanese importers have strict requirements, accepting only varieties with deep yellow flesh with no or very slight discolouration after peeling. The storage roots are boiled, frozen and transported to Japan where they are further processed into snack and other special foods.

Variety descriptions

HINT
The variety colour supplement is after page 38 in this section.

Dessert type

Beauregard. This variety was bred in Louisiana, USA and is the most popular variety in that state. In Queensland, it is the most popular among the 'gold' varieties and is preferred for its smooth pink with orange skin, elongate shape, good orange flesh quality and resistance to soil rot.

Its long (more than 200 cm) vines are green, have a tendency to twine and are relatively thin. The leaves have slight lobing, with a purple spot at the base of the main rib on the under side. Leaves are green when mature and purplish green when immature. It flowers freely.

Vine tip cuttings are thin, difficult to handle and lack vigour. We suggest you take cuttings from the lower portion of the vine. Studies show that these cuttings produce better yield than the lanky, thin tip cuttings.

Beerwah Gold. Selected at DPI's Beerwah Research Station from NC-3, this variety was one of the first 'gold' varieties introduced into Australia. It has brownish-orange (copper) skin with pink as a secondary skin colour, intermediate orange (gold) flesh and chunky roots. It produces a high yield in summer but takes longer to mature in autumn planting. It is prone to ribbing (horizontal constrictions of storage roots that develop in cool conditions). It is easy to grow and is a reliable producer under a wide range of growing conditions.

Its vines are green, short (100 to 120 cm) with short internodes (2 to 5 cm). The leaves have slight lobing and both mature and immature leaves are green. It rarely flowers.

Centennial. This variety was bred in the USA and was one of the first orange-fleshed varieties introduced into Australia. It formed the foundation of the orange-fleshed sweetpotato industry in Australia. It is still grown and has the best flesh quality.

It used to be the most popular variety and was extensively grown. Its production has declined over the years due to genetic deterioration and the build-up of soil rot organisms, to which it is very susceptible. It is early maturing, high yielding and produces large roots of excellent flesh quality. Vines are resistant to scab.

The vine is purple with green tips and sparse hairs. The leaves are very slightly lobed (round with teeth) and the under side has a purple spot at the base of main rib. The mature leaves are yellow-green and the immature leaves are slightly purple. It grows vigorously and produces good vine tip cuttings.

Hernandez. Bred from L0-323, this recent variety has a brownish-orange with red as secondary colour (red copper) skin and deep orange flesh. It is high yielding and has good resistance to soil rot, and relatively good resistance to root-knot nematode and Fusarium wilt. The skin is tough, making it easier to handle, but tends to be a little rough under wet conditions. The vine is spreading, and purple with green tips. The leaves are moderately lobed with a relatively purple petiole and pigmented veins. It produces more uniform roots than Beauregard, but has round elliptic-shaped roots that are less preferred in the market.

L0-323. This variety is from the breeding work in Louisiana. It is very quick maturing, has long, vigorous vines and is very heavy yielding. However, it produces very large roots if not harvested on time and is highly susceptible to foliage and stem scab. It is very prone to rot under prolonged wet conditions on heavy soil.

The storage root has orange skin and flesh, with very low dry matter. Although it was used as a parent in breeding programs it was not grown commercially in the USA

NC-3. It is very similar to Beerwah Gold with oblong-shaped, chunky storage roots. It does not produce excessively large roots, which may be due to the high number of storage roots per plant. It is relatively late maturing and requires 20 weeks to harvest for September to November planting and 25 weeks for later planting. The skin is brownish-orange with red secondary colour while the flesh has intermediate orange and yellow secondary colour. The storage roots store well.

It has a short, green vine with moderately long internodes (5 to 7 cm). The leaves are green when mature, yellow-green when immature and are slightly lobed. The main rib is partially purple.

Resisto. This variety has red skin and deep orange flesh. It is slow-maturing, nematode-resistant, with rough skin and small roots. It is free-flowering and moderately susceptible to scab. Suitable for home gardens.

Eureka. It has smooth, long, elliptic, well-shaped storage roots. The root skin colour is brownish-orange and the flesh orange. The vine is mostly purple without pubescence or hair. The leaves are very slightly lobed and veins on the under side are mostly purple. The mature leaves are green but slightly purple on the lower surface. Immature leaves are slightly purple.

L93-93Q24. This is a new variety and was rated highly by growers and retailers for its visual appeal. The storage roots are smooth and uniform in shape. The skin is pale red-purple and the flesh is deep yellow with a tinge of orange.

The vine is green with purple nodes and the tips are heavily haired. The mature leaf is green and triangular with very slight lobing. The under side has a purple spot at the base of the main rib. The immature leaf is yellow green. This variety flowers moderately. Flowers are pale purple with a purple throat.

Staple type

Northern Star. This variety was selected and named in Queensland and only recently released for commercial production. It is a replacement for Red Abundance and is the most common 'red variety' in the market. It has a 'double' skin, a clear waxy intermediate purple outer skin and a deep purple inner skin, making it tougher and less prone to skin damage. The skin is smooth with a small white spot around the eyes. It has pale cream flesh.

Demand is not as high as for the orange (gold) varieties. It is believed, however, that there is still room for an increase in production as retailers complain about irregularity of supply in the market. It is easy to grow and handle, quick maturing, heavy yielding and does not discolour in food preparation.

Northern Star has a purple vine with green, hairy tips, spreading and moderately long internodes (5 to 7 cm). The leaves are triangular and slightly lobed, with all veins under the leaf partially purple. The mature leaf is green while the immature leaf is yellow-green. The leaf petiole is long and moderately purple.

Red Abundance. Once the most popular staple type in Queensland, it has been replaced by Northern Star. The storage roots have intermediate red-purple skin and cream with yellow (secondary colour) flesh. Roots tend to be 'kinky' and break easily. They are sappy and go black when cut.

It has spreading, tough, green hairy vines with long internodes. The leaves are heart-shaped or cordate and green, both when mature and immature. It is moderately susceptible to foliage and stem scab.

WSPF. This variety has long, elliptic roots with smooth, cream skin and cream with purple flesh.

The vine is green with purple nodes and has sparse hairs on the tip. The leaves are deeply lobed and the underside has mostly or totally purple veins. The mature and immature leaves are green. It flowers sparsely and the flowers have pale purple limb (flattened upper part of the flower) and purple throat.

Q95-3. This is a promising variety with good eating quality. The roots are long, elliptic with smooth, thin, red-purple skin and cream with yellow flesh with no or very slight discolouration after cutting. The thin skin peels during harvesting and postharvest handling, making the storage root unattractive.

Kestle. A replacement for White Maltese, this variety is cream-skinned and has cream with pale yellow secondary colour flesh. It is commonly baked or used as a complementary vegetable. It has a tendency to produce large, lumpy, obovate roots with a long, tapered end. Harvesting earlier than usual can reduce the number of oversized lumpy roots.

It has green, spreading vines with purple nodes and hairs. The leaf is heart-shaped or cordate, with all veins at the back being partially purple. The mature leaf is green while the immature leaf is yellow-green.

White Maltese. This old, early maturing variety has cream skin and cream flesh. It produces a range of shapes from very chunky to long and slender roots and should be planted in lighter soil. It is also prone to cracking due to fluctuations in soil moisture.

The vine is spreading, thin, green with purple internodes, and with few hairs on the tips. The leaves are moderately lobed, with all veins underneath partially purple. Both the immature and mature leaves are green.

Variety characteristics

Sweetpotato variety characteristics, maturity, and vegetative and reproductive performance vary under different growing conditions. Tables 4 and 5 are a guide to the characteristics and performance of the main varieties as observed across different locations and growing conditions. The descriptions are based on Z. Huaman's book *Descriptors for Sweetpotatoes*.

more info
Where to get this book
Section 6 page 27

The sweetpotato variety colour supplement shows pictures of the storage roots and vines of some commonly grown and promising varieties.

Table 4. Morphological characteristics and maturity period of some sweetpotato varieties

Variety	Plant type	Foliage colour	Skin colour	Flesh colour	Comments
Beauregard	Spreading	Green, purplish-green immature leaves	Pale pink, orange secondary colour	Intermediate orange	Good flesh quality, well-shaped roots, consistent yield, thin tips, easy to manage, quick-growing, attractive
Beerwah Gold	Moderately compact	Pale green mature leaves, green with purple-edged immature leaves	Brownish-orange	Intermediate orange, yellow secondary colour	Chunky roots, consistent yield, easy to manage, medium maturity
Centennial	Spreading	Yellow green, slightly purple immature leaves	Pale brownish-orange	Intermediate orange, some cream spots	Large roots, high dry matter, quick-growing, rough skin. Tends to have longitudinal grooves
Hernandez	Spreading	Green leaves, vines purple with green tips	Brownish-orange, red secondary colour	Dark orange	Consistent yield, round, elliptic-shaped roots, medium maturity, shallow longitudinal grooves with medium to shallow eyes
Kestle	Spreading	Green, yellow-green immature leaves	Cream	Cream, pale yellow secondary colour	Inconsistent yield, obovate roots with a long, tapered end, medium maturity, pink eyes
L0-323	Spreading	Green	Orange	Orange	Very low dry matter, very quick maturing, very large roots, vigorous vine, heavy yielding
L93-93Q24	Spreading	Green, vines green with purple nodes	Pale red-purple	Deep yellow with orange tinge	Good yield, smooth skin, good long elliptic shape
NC-3	Moderately compact	Pale green, yellow-green tips	Brownish-orange, pink secondary colour	Intermediate orange, yellow secondary colour	Chunky roots, consistent yield, easy to manage, medium maturity, early sprouting
Northern Star	Spreading	Green, yellow-green immature leaves	Intermediate purple	Cream, pale yellow secondary colour	Easy to grow, quick-growing, high yielding, good flesh quality, attractive, no flesh discolouration after cutting. Smooth thick skin, but tendency to produce oversized roots
Q95-3	Spreading	Mature leaves green, immature yellow-green with purple edge	Intermediate red-purple	Cream, pale yellow secondary colour Cream,	Thin skin, which easily peels off during harvesting and postharvest handling
Red Abundance	Spreading	Green	Purple-red	intermediate yellow secondary colour	Variable production, skins readily
Resisto	Spreading	Green, vines have purple tips	Brownish-orange, red secondary colour	Dark orange	Small roots, rough skin; slow-growing. Suitable for home gardens
White Maltese	Spreading	Green	Pale cream	Cream, pale yellow secondary colour	Variable production, large roots
WSPF	Semi-erect, vines less than 1.5 m	Green	Intermediate cream	Cream, purple secondary colour	Smooth skin

Table 5. *Reaction to major pests and diseases and estimated yield of some sweetpotato varieties*

Variety	Reaction to major pests and diseases	Relative maturity	Marketable yield
Beauregard	Good tolerance to soil rot, susceptible to root-knot nematode and bacterial soft rot	Early – mid	High
Beerwah Gold	Moderately susceptible to scab, soil rot	Mid – late	Medium
Centennial	Susceptible to soil rot (pox) and sweetpotato weevil, resistant to scab	Early – mid	High
Hernandez	Resistant to root-knot nematode, soil-pox, and *Fusarium* wilt, less susceptible to sweetpotato weevil than Centennial	Mid	High
Kestle	Less susceptible to sweetpotato weevil than dessert type, susceptible to zinc deficiency	Mid – late	Medium
L0-323	Highly susceptible to scab	Early	High
L93-93Q24	Good tolerance to soft rot (*Erwinia* spp.) and soil rot, less susceptible to sweetpotato weevil than Centennial	Mid	High
NC-3	Moderately susceptible to scab and soil rot	Mid – late	Medium
Northern Star	Less susceptible to sweetpotato weevil than dessert type	Early	High
Q95-3	Moderate susceptibility to sweetpotato weevil	Early – mid	Medium – high
Red Abundance	Moderately susceptible to scab	Mid – late	Medium
Resisto	Nematode-resistant	Late	Low
White Maltese	Susceptible to scab	Early – mid	Medium – high
WSPF	Less susceptible to sweetpotato weevil than dessert type	Mid	Medium

Planting times

Sweetpotato is a high temperature, drought-tolerant crop and will not perform well under very low temperatures and wet conditions. The crop should be planted at a time that ensures the climatic and seasonal requirements will be suitable at critical stages of plant development such as storage root initiation and harvesting. Table 6 shows the main varieties, planting and harvesting times for the main production districts. Harvesting the storage roots usually starts 16 to 25 weeks after planting, depending on variety and temperature.

Table 6. *Main varieties, main planting and harvesting times for the major production areas.*

Varieties (all districts)	District	Plant	Harvest
Beauregard Hernandez Beerwah Gold Centennial	North Queensland Central Queensland (Bundaberg and Rockhampton)	March to June September to March	September to December October to July
Northern Star WSPF	Southern Queensland	Late September to January	February to June

Producing planting material

Planting material can introduce pests, diseases and viruses into your sweetpotato crop, so it is important to use clean planting material. This section describes how to produce cuttings and sprouts.

Where to get virus-free planting material

more info
Buying cuttings
Section 6 page 4

Small quantities of virus-free planting material can be bought from the Queensland Department of Primary Industries' research station at Redland Bay. These cuttings are used as mother plants to produce planting material for commercial plantings.

Depending on availability, 200 cuttings of up to four varieties, with a maximum of 100 per variety, can be bought from Redlands from the first week of October to the end of April. Larger supplies may be available after December. From 100 cuttings it will take about 24 weeks in warm weather to produce enough cuttings to plant 2 ha of crop.

Why use certified virus-free planting material?

There are several reasons for using certified virus-free material as an initial source of propagation material. Certified planting material would minimise the risk of:

- virus infection;
- genetic mutation;
- pests and disease.

Virus infection

Certified cuttings are produced from plants that have been tested and found free of virus. Sweetpotatoes are highly susceptible to virus and virus-like pathogens that reduce crop vigour and yield. Several weeds are hosts of virus diseases and the presence of these and other sweetpotato crops means virus infection is endemic in commercial crops.

Genetic mutation

Although propagated vegetatively, sweetpotatoes are prone to genetic changes at the growing points or eyes of the sweetpotato roots and shoot tips where new shoots develop. This genetic change or 'drift' is referred to as somatic mutation. It can alter important market traits including skin and flesh appearance, yield and root shape. Growers who have planted crops from the same material for several seasons may notice deterioration in some of these traits. For this reason we recommend that you regularly rejuvenate the crop by using sprouts from storage roots selected for trueness to type, or re-starting from clean mother plants selected for trueness to type.

Pests and diseases

Certified cuttings are free of insect pests, for example sweetpotato weevil and soil-borne and foliar diseases.

Using certified cuttings to produce planting material

Plant the cuttings, usually in early spring, in an area away from your commercial crop if possible, to minimise disease transfer from the old crops. The area should be large enough to produce sufficient planting material for your later plantings.

Prepare a seedbed and add a complete fertiliser (for example a 5:6:5 N:P:K mixture) to the bed at about 1000 kg/ha (100 g/sq. m).

Plant the certified cuttings as mother material the same as you would plant the commercial crop or closer. Ensure the cutting nursery is well fertilised and watered for rapid and prolific vegetative growth. Once established and new shoots are about 30 cm long, about six weeks, take cuttings from this mother material and plant them beside or in line with the mother cuttings. Add extra nitrogen as required to encourage vigorous vine growth.

Leave at least three new nodes, about 10 cm of vine, on the mother plant to allow the development of vigorous new shoots. One shoot develops from each remaining node. Allow the mother plants and the first cuttings to grow, and harvest them again once cuttings are 30 cm long. This will take about three weeks for the mother plants and six weeks for the cuttings. The mother cuttings will now have two established lateral vines, each developing two new shoots, and will produce four cuttings at the next harvest.

Table 7 (page 43) shows how, in warm weather, the original 100 certified cuttings could produce enough cuttings in 24 weeks to plant 2 ha. The shaded area indicates the original 100 cuttings and cuttings taken from them and planted in the nursery. The time taken to produce enough cuttings to start commercial plantings will depend on how well the plants grow, how big an area you want to plant and how many cuttings you plant into the nursery to produce more plants.

In north Queensland a nursery planted in October will produce enough vine tip cuttings for a commercial planting in March or April. In southern and central Queensland the nursery may have to be maintained over winter to supply enough vine tip cuttings for a spring planting of a commercial crop. Alternatively, in southern and central Queensland, roots from the nursery area could be used to produce sprouts in spring.

Cuttings for commercial plantings

Vine tip and back cuttings can be used for commercial plantings. They should be at least 25 cm long, so that at least three nodes can be planted in the ground. One hectare of established crop will produce enough material for about 6 ha of commercial planting.

Vine tip cuttings

Vine tip cuttings are preferred, as they are more vigorous and less likely to carry insects and diseases. Tip cuttings are normally taken from nursery areas or mature crops just before harvest. However, they can only be taken once from established commercial plantings because significant vine removal from a young crop will reduce storage root production.

Trim the cuttings to remove the lower, fully expanded leaves. If the cuttings are to be held for more than four days, trim the middle leaves, leaving only the immature leaves at the top. Trimming can be time consuming, but it reduces transpiration and assists establishment if cuttings are planted in hot conditions or immediately after collecting. Trimming also makes planting easier.

Tip cuttings will keep for up to two weeks in cool weather, provided they are kept moist with clean tank or chlorinated water, shaded and out of the wind. They are usually wrapped in hessian and stood on their cut end.

The length of cuttings may affect yield, depending on the variety and the number of buried nodes. Usually 25 cm long cuttings are planted. Cuttings can be planted immediately after removal but it is best to wait two to four days until some roots appear. Figure 2 shows a tip cutting ready for planting.

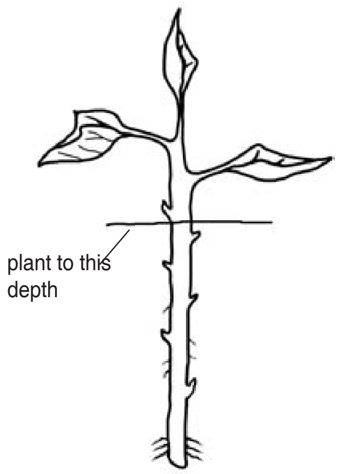


Figure 2. *A tip cutting ready for planting*

Table 7. *Multiplication of sweetpotato planting material from 100 virus-free cuttings planted in a nursery*

Number of plants in nursery	Week 6		Week 9		Week 12		Week 15		Week 18		Week 21		Week 24		Week 27	
	*Vtc/ plant	Total	Vtc/ plant	Total	Vtc/ plant	Total	Vtc/ plant	Total	Vtc/ plant	Total	Vtc/ plant	Total	Vtc/ plant	Total	Vtc/ plant	Total
# 100 (a)	2	200 (b)	4	400 (c)	8	800 (d)	10	1 000 (f)	10	1 000 (l)	10	1 000	10	1 000	10	1 000
200 (b)					2	400 (e)	4	800 (g)	8	1 600 (j)	10	2 000	10	2 000	10	2 000
400 (c)							2	800 (h)	4	1 600 (k)	8	3 200	10	4 000	10	4 000
800 (d)									2	1 600 (l)	4	3 200	8	6 400	10	8 000
400 (e)									2	800 (m)	4	1 600	8	3 200	10	4 000
1 000 (f)											2	2 000	4	4 000	8	8 000
800 (g)											2	1 600	4	3 200	8	6 400
800 (h)											2	1 600	4	3 200	8	6 400
1 000 (l)													2	800	4	1 600
1 600 (j)													2	3 200	4	6 400
1 600 (k)													2	3 200	4	6 400
1 600 (l)													2	3 200	4	6 400
800 (m)													2	1 600	4	3 200
Total												2235		2213		2888
Running total												**16 200**		**55 200**		**119 000**

*Vtc = The number of vine tip cuttings taken from the plants.

Numbers followed by the same letter are the same plants and these cuttings have been planted into the nursery to produce more cuttings.

Back cuttings

Back cuttings are cuttings that are taken from the older mature parts of vines. These cuttings do not perform as well as tip cuttings because:

- they are more mature and less active in growth;
- they vary in diameter, creating a more variable crop.

Sprouts

Sprouts make ideal planting material because they are physiologically young, vigorous, straight, have short internodes and are quick, easy and cheap to produce. They are usually free from the pests and diseases normally carried by cuttings from old crops.

Sprouts are the tip cuttings produced from storage roots (seed roots) selected from the previous certified cutting or commercial crop on the basis of yield and quality. They are planted into nursery beds. While harvesting, select your seed roots from plants that produce a good crop of high quality storage roots.

When selecting roots for growing in seedbeds inspect all roots for evidence of rots, scurf or other blemishes such as scabs or lesions. Try to select disease-free material.

Store these roots unwashed in ventilated containers in a cool (16 to 18°C) shed. Fresh air must be available and relative humidity should be at least 90% to avoid root dehydration. Seed roots may be stored for many months until required for sprout production. Stored roots reconditioned in a warm, humid atmosphere tend to sprout readily and more uniformly. Roots harvested in autumn tend to be reluctant to sprout while those dug in spring sprout freely. Storage and reconditioning seem to remove much of the apical dominance.

Establish long narrow seedbeds eight to 10 weeks before you require planting material. Select a well-drained, frost-free site, preferably with a northerly aspect to provide shelter from cold southerly winds. A light sandy soil is best. It should be prepared well in advance to avoid undecomposed organic matter being present at planting. If possible establish seedbeds in areas that have not been planted to sweetpotatoes, or fumigate, so as to minimise the risk of disease affecting your planted roots.

Add a complete fertiliser (for example a 5:6:5 N:P:K mixture) to the bed at about 1000 kg/ha (100 g/sq. m). A high rate of fertiliser promotes vegetative growth and ensures planting material is healthy. Seed roots are placed about 2 to cm apart in the bed and adjacent soil is thrown over the roots to a depth of 5 to 7 cm and raked level. Figure 3 shows seed roots laid out ready to be covered with soil.

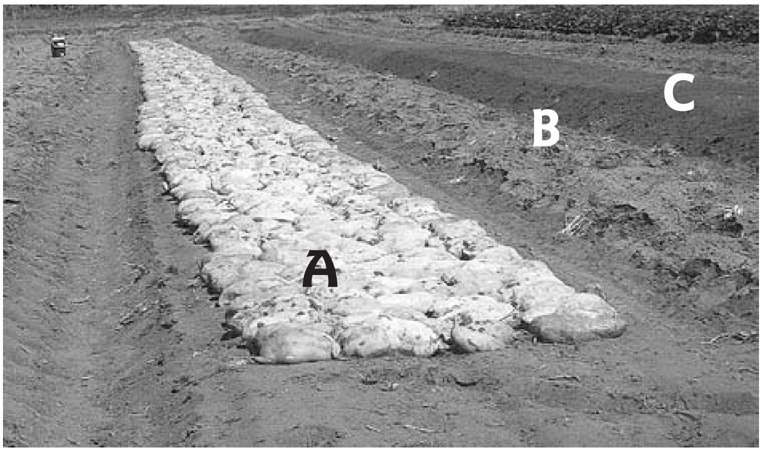


Figure 3. (A) Bed of seed roots laid out for sprout production, (B) covered bed and (C) bed of sprouts

The beds should be well watered and, in cool conditions, covered with clear plastic to help keep them warm. Once the sprouts have emerged insert wire hoops over the bed and raise the plastic over the wire hoops until it is about 45 cm high in the bed centre. During the day open the ends of the plastic sheets to prevent overheating and permit air circulation.

Cuttings can be taken when most of the sprouts are about 250 mm long. Cut sprouts about 25 mm above soil level with a knife or reciprocating mower and discard any cuttings shorter than 200 mm. Successive cuts can be made on the seedbed at three to five-week intervals. After the first cut, cuttings tend to be more prolific and even. Examine the new growth after each cutting to ensure virus and other diseases are not present.

Comparison of cuttings with sprouts

Sprouts have shorter internodes than cuttings, so it is easier to ensure that at least three nodes are in the soil. Sprouts are also less likely to carry insect pests or diseases.

Sprouts from seedbeds tend to be straighter and more uniform, making them easier to plant. Vine cuttings are much more variable in diameter and vigour and result in a more uneven crop. The quantity of marketable roots at harvest can be affected by the uneven maturity.

Cost of planting material

Taking cuttings off an established crop or nursery area is time consuming compared with growing and harvesting sprouts from a seedbed. It takes less than one-third of the time to produce the same amount of planting material from a bed of sprouts as from an established crop, depending on whether sprouts are cut by hand or a reciprocating mower.

Labour is the major cost in gathering planting material; other costs are similar. Producing sprouts costs about $50 per hectare, plus the value of the seed roots planted to produce the sprouts. It would cost about $1450 per hectare to gather enough cuttings from a commercial crop. Tables 8 and 9 show the advantages and disadvantages of using sprouts or cuttings as planting material.

Table 8. *Advantages and disadvantages of sprouts*

Advantages	Disadvantages
Cheaper to produce	Lost value of storage roots at market
Quicker to collect planting material	Takes longer to produce planting material than collecting from a commercial block
Less likely to carry pests and diseases	
Internodes are short, making it is easier to plant three nodes in the soil	

Table 9. *Advantages and disadvantages of cuttings*

Advantages	Disadvantages
Cuttings can be collected from a commercial block at any time	Costly to collect
	Internodes are long, making it harder to plant three nodes in the soil
	Should only take cuttings once from a block

Nutrition

The geological origin, depth, pH and recent cropping history influence the inherent fertility of the soil and your fertiliser program. Ideally, soils for sweetpotatoes are light-textured, deep, well-drained and acidic. These soils have relatively low fertility.

Adequate plant nutrients in the correct proportion are necessary to produce high yields of good quality storage roots. The management of nitrogen is critical in sweetpotato growing and high levels of potassium are removed by the plants. Sweetpotatoes have a relatively high requirement for boron.

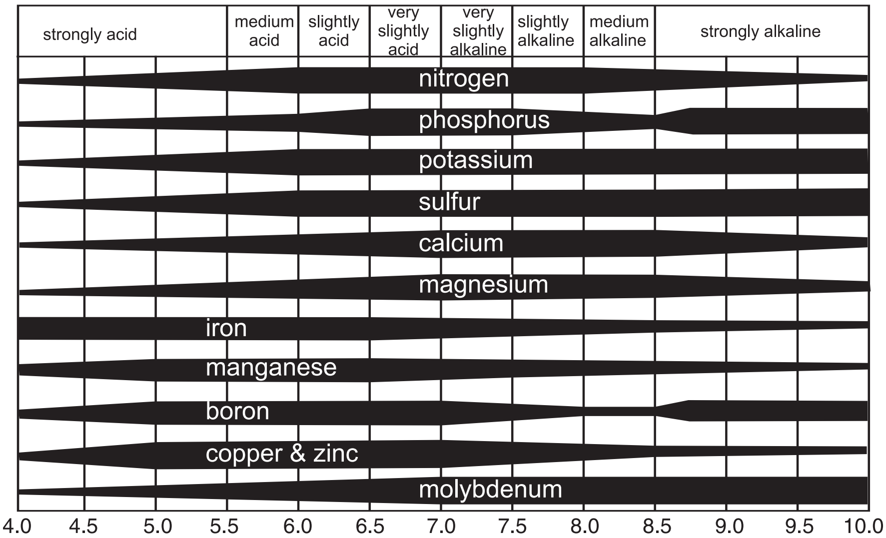
Plan your nutritional program

Getting the soil ready

The first step in providing adequate nutrition for your crop is to have a chemical soil analysis to determine what elements are available and, perhaps more importantly, what elements will be in short supply. This information is then used to plan a nutritional program to adjust the soil to the crop's requirements before planting. This will give the plants the best chance to produce a high yield of good quality storage roots.

A soil analysis measures the pH, conductivity, organic matter and the concentration of nutrients in the soil. Results will be interpreted by the laboratory and should be back in about two weeks, allowing time for the treatments to be incorporated into the soil. Your experience of the block of land, future cropping plans and the way you wish to manipulate the growth pattern of the crop will influence your nutritional program.

Soil pH. The pH level is a measure of the soil's acidity or alkalinity on a scale from 0 to 14, with 7 being neutral. A pH of 5 is 10 times more acid than a pH of 6. Soil pH between 5.5 and 6.0 is most desirable. In this range, most major and trace elements present in the soil are



available to the plants, without being at toxic levels. However, where soil rot (pox) is a problem, raising pH above 5.5 increases soil rot. Figure 4 shows how soil pH affects the availability of nutrients; the width of the band shows nutrient availability at different pH levels.

Figure 4. *Nutrient availability at different soil pH levels*

Many Queensland soils are acidic and require the addition of lime or dolomite to raise the pH. A complete soil analysis will show which form is most suitable and indicate a suitable rate by showing the available levels of calcum and magnesium. Different soil types require different quantities to change pH. Figure 5 is a guide to the application rates for lime to raise the pH in the top 18 cm of soil.

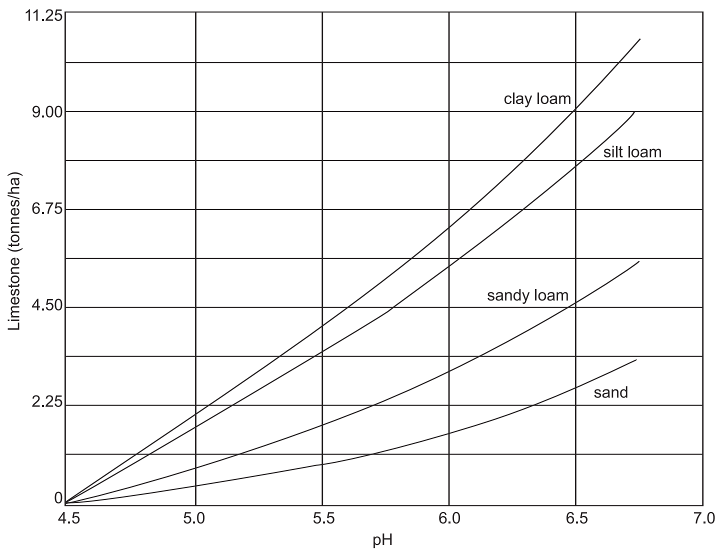


Figure 5. *Lime needed to raise soil pH. Source: Matheson* et al.*, 1975*

Gypsum. Application of gypsum will increase soil calcium levels but not change soil pH. It also improves soil structure. Naturally occurring gypsum is preferred to phosphogypsum in vegetable crops because of the cadmium in phosphogypsum. The nutrients in gypsum are readily available, however, it takes about one year for the physical effects of gypsum on soil structure to become fully apparent. Apply gypsum before the wet season so that it can leach accumulated salts beyond the root zone well before planting, thus improving the soil structure. Table 10 shows the appropriate management of calcium, magnesium and pH.

An application of 5 to 10 t/ha of gypsum can benefit heavy clay loams that have high sodium levels and a pH higher than 8.0. Table 10 is a guide to which product is most suitable for your situation.

Table 10. *Management of calcium, magnesium and pH in the soil*

Recommended action	Soil nutrient status							
	pH high				pH low			
	Calcium high		Calcium low		Calcium high		Calcium low	
	Mg high	Mg low	Mg high	Mg low	Mg high	Mg low	Mg high	Mg low
Gypsum 1.0 – 2.0 t/ha			✓	✓				
Dolomite 2.5 – 5.0 t/ha						✓		✓
Lime 2.5 – 5.0 t/ha					✓		✓	
Magnesium sulfate ($MgSO_4$) 100 – 250 kg/ha		✓		✓		✓		

Nutritional management

Sweetpotatoes require careful nutritional management to ensure high yields of top quality storage roots. Follow the recommendations of your soil analysis when applying fertiliser. Nutrients must be balanced to achieve early vine growth followed by storage root initiation and bulking of storage roots.

Table 11 shows the approximate amount of nutrients that 12 and 50 t/ha sweetpotato crops could be expected to remove from the soil. Remember that the elements in the stems and leaves will be returned to the soil when the crop is ploughed in.

Table 11. *Estimated removal of nutrients from the soil by sweetpotato crops of 12t/ha (average) and 50 t/ha (high), for situations where only storage roots are harvested, and where both roots and vines are removed*

Nutrient	Nutrient removal[a] (kg/ha) by a crop with yield of			
	12 t/ha		50/t/ha	
	Roots	Roots and vine[b]	Roots	Roots and vine[b]
Nitrogen (N)	26	52	110	215
Phosphorus (P)	6	9	25	38
Potassium (K)	60	90	250	376
Calcium (Ca)	3.6	16	15	65
Magnesium (Mg)	3	6.5	12.5	27
Sulfur (S)	1.8	4.3	7.5	18
Chlorine (Cl)	10	18	43	75
Iron (Fe)	0.060	0.160	0.250	0.670
Boron (B)	0.024	0.074	0.100	0.310
Manganese (Mn)	0.024	0.175	0.100	0.730
Zinc (Zn)	0.036	0.062	0.150	0.260
Copper (Cu)	0.018	0.037	0.075	0.155
Molybdenum (Mo)	0.004	0.006	0.015	0.023

[a] Concentrations of nutrients in sweetpotato roots and tops vary considerably. Quantities of nutrients removed have been based on representative concentrations from several sources (including Scott and Bouwkamp 1974; Bradbury and Holloway 1988; Woolfe 1992; Spence and Ahmad 1976; Diem 1962; Hill 1989; and the authors' own data), converted to fresh weight basis, assuming 70% moisture in the storage roots and 86% moisture in the vines.

[b] A vine:root ratio of 0.6 was assumed. Actual ratios may vary in the approximate range 0.13 to 1.4.

Source: O'Sullivan, Asher and Blamey, 1997.

Major elements

Nitrogen (N)

Plant size and leaf area are dependent on an adequate supply of nitrogen. Insufficient nitrogen will result in poorly grown, pale or yellow plants, low yields and smaller storage roots. Luxury levels of nitrogen encourage vegetative plant growth and vigour. Large amounts of decomposing matter can induce nitrogen deficiency, and then result in high nitrogen levels when decomposition is complete.

If excess nitrogen is available to the plants, storage root initiation is reduced, vine growth will be excessive, roots will become too large and quality will be poor. For these reasons, only half of the total amount of nitrogen required is applied before storage root initiation at about six to eight weeks. Nitrogen is easily leached from the soil by excess rain or irrigation.

Phosphorus (P)

Phosphorus is required during the early stages of the crop for plant development and root growth. Phosphorus-deficient plants have an open, sparse appearance with purple discolouration of the leaves. The potential yield of the crop is reduced if adequate phosphorus is not available to the young plant. Deficiency occurs in red or brown soils high in iron (Fe) and aluminium (Al). Phosphorus is not readily leached from the soil.

Potassium (K)

Adequate potassium is required to produce good yields of high quality storage roots. A good supply of potassium improves colour and firmness. Older leaves of potassium-deficient plants develop yellowish margins, which may turn brown. Ashen grey-green leaves at the base of the plant may be the first indication of deficiency, followed by leaf speckling and necrotic (dead) areas. Deficiencies can occur in sandy soils, acidic soils below pH 5.4, alkaline soils above pH 7.5 and where lime or dolomite have been applied. Potassium is leached from the soil by excess rain or irrigation, but not as easily as nitrogen.

Potassium is available as potassium nitrate, which supplies potassium and nitrogen; potassium sulfate, which supplies potassium and sulfur without adding extra nitrogen; and muriate of potash, which supplies potassium without nitrogen. Muriate of potash should not be used if soil or water chloride levels are high.

Calcium (Ca)

Calcium deficiency may occur in acidic soils and leached or poorly structured soils. With severe deficiency shoot growth is restricted and the growing points may die. Uneven soil moisture; cool, humid atmosphere causing low respiration rates; and poor quality water increase the severity of the problem. Apply lime, dolomite or gypsum as recommended by the soil analysis.

Magnesium (Mg)

Magnesium can be deficient, particularly in high rainfall areas and where soils are fairly acid. Yellow mottling between the veins of older leaves is a symptom of deficiency. High levels of calcium and potassium reduce the relative proportion of available magnesium, creating an imbalance. Apply dolomite or spray magnesium sulfate ($MgSO_4$) on the soil as recommended by the soil analysis. If not enough dolomite was applied before planting, or high rates of potassium nitrate were used, foliar sprays of magnesium sulfate (2 kg/100 L) can be applied to correct deficiencies. Apply magnesium sulfate as a broadcast application using a spreader, or through the irrigation system, at about 250 kg/ha.

Sulfur (S)

Sulfur is usually found in sufficient quantities to prevent deficiency in most commercial, low analysis N:P:K fertilisers, superphosphate, gypsum, sulfate of potash, magnesium sulfate and sulfate of ammonia.

Trace elements

Apply trace elements if deficiencies have developed in previous crops or where soil analysis results suggest a possible deficiency. Some are best applied to the soil before the final cultivation. Soil applications will often last for a few years, whereas foliar applications only benefit the plants to which they were applied.

Do not exceed the rates suggested below. The addition of urea at 500 g/100 L of water will increase the leaf's absorption of trace elements. Spray to wet the leaves to point of runoff. Solution concentrations greater than 1% are likely to cause leaf burn. Apply foliar nutrients separately from pesticide sprays.

Boron (B)

Boron deficiency is more likely in well-drained, sandy, neutral to alkaline soils, particularly in cool, humid weather, or if soils were heavily limed or are low in nitrogen. Storage roots may be short and dumpy, may split then heal, and be misshapen. Internodes are shorter and the stem and petioles may be twisted. Young leaves may thicken and the leaves and stem near the shoot tip may become brittle and break easily.

If boron is deficient, spray 8 to 15 kg/ha of Solubor on the soil during final land preparation. A foliar spray of Solubor (200 to 500 g/100 L) about three weeks after planting and again one to two weeks later will improve top growth. However, there are indications that Solubor is not translocated into the roots to prevent damage.

Copper (Cu)

Copper deficiency can occur on sandy soils and may be induced by liming. Vine growth is reduced and leaves wilt. Storage roots show darkening of the skin and a dark discolouration beneath the skin.

Iron (Fe)

Iron deficiency is associated with high pH calcareous soil, sandy soil and acid soil with high manganese levels. It appears as chlorosis of the youngest leaves.

Apply iron chelate or iron sulfate at 100 g/100 L once the plants have started to grow.

Manganese (Mn)

Manganese deficiency can occur in high pH soils and appears as interveinal chlorosis associated with small spots and wilting. However, manganese toxicity is more often a problem, particularly in soils with a pH below 6.0. Manganese toxicity appears as necrotic (dead) spots on the older leaves, but more commonly as chlorosis of the younger leaves through iron-induced deficiency.

Molybdenum (Mo)

Molybdenum deficiency is more common in leached soils below pH 6.0. It has not been reported in sweetpotatoes. If other crops such as cucurbits or lettuce grown on this block or similar soil on the farm showed a deficiency, a precautionary foliar spray of 100 g/100 L of sodium molybdate could be applied.

Zinc (Zn)

The availability of zinc decreases at pH levels above 7.0 and below 5.0. Vine tips and younger leaves turn yellow, particularly between the veins, and may be small, resulting in the term 'little leaf' for zinc deficiency. High phosphorus levels and wet or cold conditions can induce zinc deficiency.

Soil applications before planting are the most effective way to prevent this deficiency on acid soils. Applications may be broadcast over the entire area or banded in the rows at rates of up to 10 kg/ha of zinc. The higher rates may remain effective for several years.

To correct plant symptoms zinc may also be applied as a foliar spray. This is a convenient way to control zinc deficiency on alkaline soils, if required.

Soil applications are best made using zinc sulfate monohydrate (35% Zn). Zinc sulfate heptahydrate (22.7% Zn) can be dissolved in water and sprayed on the soil using a boom spray or injected through the trickle irrigation system. Table 12 shows application rates for boron, copper, iron, manganese, molybdenum and zinc.

Table 12. Application rates for boron, copper, iron, manganese, molybdenum and zinc

Element	Product	Rate	Comments
Boron	borax (11.3% B)	16 – 30 kg/ha	Use low rate on sandy soil and high rate on clay soil. Deficiency is more likely on sandy soils, particularly if heavily limed, alkaline or low in nitrogen.
	Solubor (20.5% B)	8 – 15 kg /ha 200 – 500 g/100 L	Spray on the soil and incorporate. Foliar spray, 2 to 4 applications 1 to 2 weeks apart once cuttings start to grow. Do not exceed a total of 5 kg/ha. Solubor is not compatible with zinc sulfate heptahydrate.
Copper	copper sulfate	500 g/100 L + 500g/100 L hydrated lime	Apply 1 spray when vines start to run.
Iron	iron sulfate iron chelate	100 g/100 L	Apply once plants start to grow and repeat if necessary.
Manganese	manganese sulfate	100 g/100 L	Apply 3 foliar applications 2 weeks apart after plants are established.
Molybdenum	sodium molybdate	100 g/100 L	Foliar spray about 2 weeks after planting, if indicated.
Zinc	zinc sulfate monohydrate	20 kg/ha	Broadcast onto the soil before planting and work it in.
	zinc sulfate heptahydrate	30 kg/ha 500 g/100 L	Spray on soil or apply through the trickle irrigation. Apply 2 to 3 foliar spray applications 1 to 2 weeks apart once cuttings start to grow. Do not mix with boron.

Fertilisers

Fertilisers are commonly sold as mixtures of nitrogen (N), phosphorus (P) and potassium (K). The percentage of each of these elements in the mix is expressed as a ratio of N:P:K. For example 100 kg of a fertiliser with an N:P:K ratio of 14:15:13 contains 14 kg nitrogen, 15 kg phosphorus and 13 kg potassium.

Fertilisers can be applied before planting, at planting, and at establishment (establishment fertiliser), and as supplementary fertiliser during crop growth as side dressings and in the irrigation water (fertigation). The fertiliser program should be based on soil and cropping history, and leaf and sap analysis. Table 13 shows a range over different soil fertility for the total requirements of the major elements nitrogen, phosphorus and potassium to grow a sweetpotato crop.

Table 13. The total requirements of the major elements in kg/ha

Application (infertile soil)	Minimum (fertile soil)			Average soil			Maximum		
	kg/ha			kg/ha			kg/ha		
	N	P	K	N	P	K	N	P	K
Establishment	0	30	40	40	40	80	60	40	100
Supplementary	0	0	40	60	0	40	60	0	80
Total	**0**	**30**	**80**	**100**	**40**	**120**	**120**	**40**	**180**

Establishment fertiliser

The establishment fertiliser should provide an even, vigorous, but not over-vegetative sweetpotato vine. The plants should develop a strong root system. Generally about 40% of the total nitrogen requirement, all the phosphorus and 50 to 60% of the potassium should be applied before or at planting. Not more than half of the total nitrogen requirement should be applied before storage root initiation.

When methyl bromide is used as a soil fumigant, pre-plant nitrogen may need to be reduced by 20% to prevent excessive vegetative growth.

Requirements for establishment fertiliser are best determined from the results of a complete soil analysis. If a soil analysis is not used, apply a pre-plant fertiliser which will supply about the following rates: 40 kg of nitrogen (N), 40 kg of phosphorus (P) and 80 kg of potassium (K) per hectare. For a fertile soil the minimum rates to apply are 0 kg of nitrogen, 30 kg of phosphorus and 40 kg of potassium per hectare Table 14 shows fertiliser rates and element supplied for two common N:P:K mixtures. Apply fertiliser in a band or incorporate within the plant rows.

Table 14. *Fertiliser rates and element supplied for two common N:P:K mixtures*

N:P:K mixture	Amount	Element applied (kg/ha)					
	kg /ha	N	P	K	S	Ca	Mg
14 : 15 : 13	250	35	38	33	3	0	0
6.4 : 6.1 : 22.8	625	40	38	143	13	28	33

On soils with a high availability of phosphorus use a 15:4:12 or similar mixture. Other elements that are required in relatively large amounts include calcium, magnesium and sulfur.

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Sulfur does not usually need to be applied separately as it is found in sufficient quantities in most commercial N:P:K fertilisers, superphosphate, gypsum, magnesium sulfate and sulfate of potash. Lime, dolomite and gypsum are sources of calcium. Dolomite and magnesium sulfate are sources of magnesium.

Apply the establishment fertiliser to the soil surface in a 60 cm wide band and incorporate with a rotary hoe during final soil preparation or bed-forming, or band in at the base of the plant after planting. In soils where phosphorus may be tied-up (mainly krasnozems and red earths), basal fertilisers are drilled into the bed in narrow bands 10 cm to the side and below the plant roots after the cuttings have become established, at about two weeks (Figure 6).

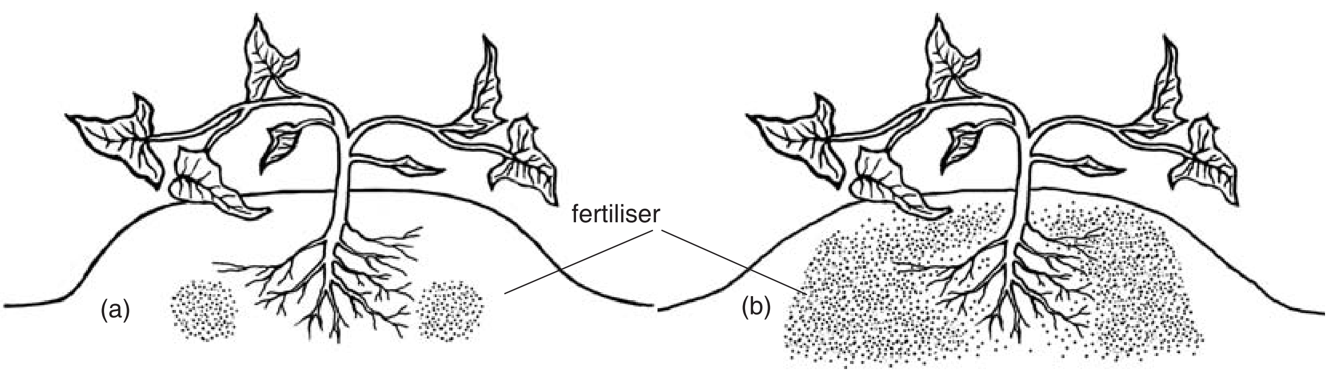

Figure 6. *Pre-plant fertiliser, (a) drilled and (b) banded*

Monitor plant nutrients and fertilise

The establishment fertiliser will allow the crop to grow up to storage root initiation. Applying fertiliser every few weeks without knowing whether the plants need it wastes money and is environmentally irresponsible. You can take the guesswork out of fertiliser applications by monitoring plant nutrient levels. If test results are unavailable, Table 16 (on page 55) is a guide to supplementary fertiliser applications.

Plant nutrient monitoring

Leaf testing is a benchmarking tool that has little direct relevance to the current crop. Its value is in judging the fertilising schedule used in this crop and how it may be improved for the next crop. Optimum values are given in Table 15. Use the results of soil and leaf tests to refine the fertiliser schedule for the next cro.

Do a leaf analysis when the plants are eight weeks old. Take the eighth leaf, including folded young leaf, back from the vine tip. Buy a tissue sampling kit from your farm supply outlet and follow the instructions. The laboratory will interpret your results. Figure 7 shows the correct leaf to take.

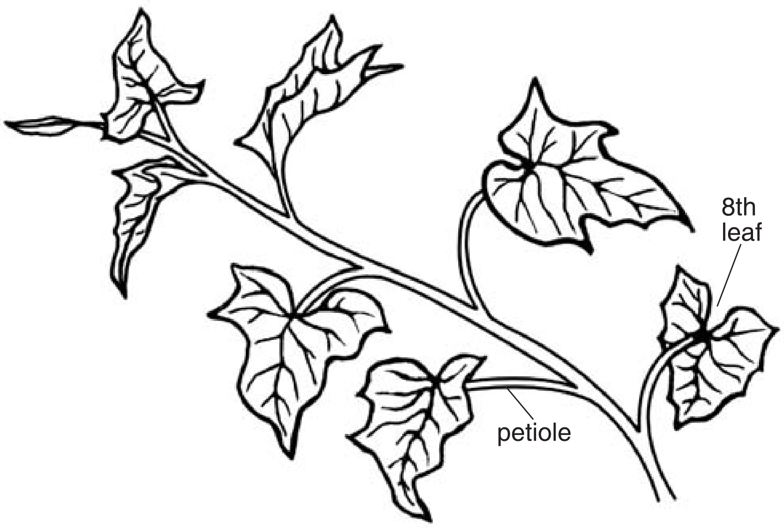

Figure 7. *The eighth leaf back from the vine tip*

The optimum levels for the seventh to ninth leaf back from the vine tip, taken 28 days after planting into a nutrient solution, are shown as a percentage or in mg/kg (ppm) in Table 15. This more rapid growth in a nutrient solution is considered to be equivalent to sampling a crop eight weeks after planting.

Table 15. Critical and adequate leaf nutrient concentrations

Nutrient	Deficiency	Adequate range	Toxicity
Nitrogen (N)	4.0%	4.2 – 5.0%	
Phosphorus (P)	0.22%	0.26 – 0.45%	
Potassium (K)	2.6%	2.8 – 6.0%	
Calcium (Ca)	0.76%	0.9 – 1.2%	
Magnesium (Mg)	0.12[a]%	0.15 – 0.35%	
Sulfur (S)	0.34%	0.35 – 0.45%	
Chlorine (Cl)	–	–	0.9 – 1.5%
Iron (Fe)	33 mg/kg	45 – 80 mg/kg	
Boron (B)	40 mg/kg	50 – 200 mg/kg	220 – 350 mg/kg
Manganese (Mn)	19 mg/kg	26 – 500 mg/kg	1600[a] mg/kg
Zinc (Zn)	11[a] mg/kg	30 – 60 mg/kg	70 – 85 mg/kg
Copper (Cu)	4 – 5 mg/kg	5 – 14 mg/kg	15.5[a] mg/kg
Molybdenum (Mo)	0.2 mg/kg	0.5 – 7 mg/kg	

[a] These critical nutrient concentrations have been found, on occasion, to be inconsistent with field observations, or to vary with environmental conditions.

Source: O'Sullivan, Asher and Blamey, 1997.

Sap testing is a means of rapidly assessing a plant's nutrient status during crop growth. This test has a 24-hour turn-around time. It can be used to highlight deficiencies of any essential element or to monitor the nitrate and potassium levels during the crop cycle. Sap testing allows growers to manage the crop more precisely or to correct any nutrient problems before yield or quality are affected.

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Sap testing involves collecting leaf stalks (petioles) of the youngest fully expanded leaves, usually the fourth or fifth back from the growing point, extracting sap with a garlic press, and analysing its nutrient content. Sap testing may start when vines are 50 cm long and continue fortnightly to the mid-bulking stage. Figure 8 shows which leaf to collect.

You can do the tests yourself, but we recommend you use a commercial sap-testing service for the tests and advice on the results.

Nitrogen and potassium are the most easily managed and influential nutrients in sweetpotatoes. Sap testing for nitrogen, phosphorus, potassium, calcium, magnesium and zinc should be done at least monthly. Other nutrients should be tested at least twice during the season.

Figure 8. *The youngest, fully expanded leaf from the growing point*

Apply supplementary fertiliser

Leaf and sap tests are useful guides when deciding on extra fertiliser requirements and are usually available from the same laboratories as soil analysis. Supplementary fertiliser may be drilled in beside the plant at the last working, spun on as broadcast dressings, applied with irrigation (fertigation), or applied as a combination of all these starting at about six to eight weeks after planting. The total amount required can be split into several applications through the bulking stage.

Table 16 gives some options for applying supplementary fertiliser. These fertilisers can be drilled in beside the plant at the last working or broadcast over the crop and irrigated in. Your choice of fertiliser and rate to apply should be based on a plant nutrient test, previous applications, cropping history and nutrient removal (Table 11).

Table 16. *Supplementary fertiliser rates and element supplied*

Fertiliser	Amount	Element applied (kg/ha)		
	kg /ha	N	P	K
Potassium nitrate OR	250	33	0	95
Urea plus	130	60	0	0
Sulfate of potash	100	0	0	41

Fertilising through irrigation water (fertigation)

Fertiliser can be applied through overhead sprinkler or trickle irrigation systems, but most growers use an overhead system. Fertigation, however, uses less labour than manual application of solid fertilisers. With these systems fertilisers can be applied more regularly and closer to the roots. Before fertigating get a water-testing laboratory to analyse your irrigation water.

The fertiliser schedule used should be based on the results of soil, leaf and sap tests. If these tests are unavailable, Table 16 is a guide to fertigating sweetpotatoes. Higher rates may be required on poor soil, while lower rates could be used on fertile soil.

With fertigation, fertiliser is dissolved in water in a drum or tank and sucked or injected through the watering system. Fertilisers used must be highly soluble to avoid damaging the pump and blocking pipes. Suitable soluble fertilisers are listed in Table 17. There is also a range of soluble commercial fertiliser blends.

Table 17. Fertilisers that can be dissolved in water for fertigation

Fertiliser	Elements applied	% of elements
Urea	Nitrogen	46% N
Calcium nitrate	Calcium, nitrogen	18.8% Ca, 15.5% N
Ammonium nitrate	Nitrogen	34% N
Magnesium sulfate	Magnesium, sulfur	9.6% Mg, 12.4% S
Potassium nitrate	Potassium, nitrogen	38.3% K, 13 % N
Potassium chloride	Potassium, chlorine	50% K, 50% Cl
Potassium sulfate	Potassium, sulfur	41% K, 18% S
MAP (mono ammonium phosphate, technical grade)	Nitrogen, phosphorus	12% N, 26.6% P
MKP (mono potassium phosphate)	Potassium, phosphorus	28.6% K, 22.8% P

Note: Overuse of potassium (K) and calcium (Ca) can induce magnesium (Mg) deficiency in soils low in magnesium or with low cation exchange, that is less than 2 milli-equivalents per 100 g (meq %) of soil on your soil test. In this situation apply 250 kg/ha of magnesium sulfate ($MgSO_4$) through overhead solid-set systems, or smaller more frequent applications through trickle irrigation.

Foliar fertilisers

Foliar fertilisers contain soluble nutrients that are sprayed on the crop and absorbed through the leaves. They may be nitrogen, potassium, or magnesium, specific trace elements or a 'shotgun' mixture of many major and trace elements dissolved in water.

As the plant's primary means of absorbing nutrients is through the root system, foliar fertilisers should not be used to replace soil applications, particularly for the major elements. However where specific trace element deficiencies have been identified, or disease, nematodes or waterlogging have made the roots ineffective, foliar fertilisers may help the plants survive until new roots develop and can again support them.

Do-it-yourself sap testing

Sap analysis procedures are somewhat complex, so we recommend you use sap-testing consultants or a sap-testing laboratory. Where these services are unavailable, the following guidelines may be useful. Make sure your meter has been calibrated and check it regularly.

Essential equipment

- Garlic press
- Small plastic capped tube
- 1 mL plastic pipettes
- 4 mL plastic pipettes
- Several 20 mL calibrated capped jars or tubes
- 500 mL wash bottle
- Plastic measuring cylinder
- Merckoquant test strips for nitrate, phosphorus, potassium and calcium

Optional equipment

- Nitrachek meter for more accurate reading of the nitrate test strips

Or, preferably

- Merck RQflex meter for accurate reading of the nitrate, phosphorus, potassium, calcium (and manganese if required) test strips

Procedure

1. Collect a random sample of 50 to 60 leaf petioles (leaf stalks) from different plants. Remember to sample by mid-morning and to keep each variety as a separate sample.
2. Cut the petioles into small segments about 2 mm long.
3. Using the garlic press, squeeze sap into the plastic-capped tube.
4. Mix the sap thoroughly.

Nitrate and calcium tests

5. Add 1 mL of the sap into the 20 mL calibrated jar and make up to the 20 mL mark with distilled water. Mix thoroughly.
6. Briefly immerse each strip.
7. Read the concentration.
8. Multiply by 20 to get the concentration in the undiluted sap.

Potassium and phosphorus

9. Pipette 1 mL of the sap from step 4 above into another jar.
10. Use a pipette to add 4 mL of distilled water.
11. Mix thoroughly.
12. Briefly immerse each strip.
13. Read the concentration.
14. Multiply by 5 to get the concentration in the undiluted sap.

Irrigation and water management

Irrigation management is one of the keys to producing a high yielding, good quality sweetpotato crop. An efficient irrigation system and schedule applying good quality water is essential to ensure that the correct quantity of water is applied when the plants need it.

Water requirements

Water quality

Sweetpotatoes are susceptible to saline irrigation water, but poorer quality water can be used on light-textured soils with good drainage. Have the water checked by a laboratory; it should be low in sodium (Na) and chlorides, and have a low conductivity. Acceptable conductivity, measured in deciSiemens per metre (dS/m), varies with soil type (Table 18). Conductivities above these figures may cause serious reductions in yield.

Table 18. *Conductivity above which yield may be reduced*

Soil type	Sand	Loam	Clay
Conductivity	3.0 dS/m	1.7 dS/m	1.0 dS/m

Source: DNR Water Facts, W55

Water quantity

Sweetpotatoes need up to five megalitres (ML) of water per hectare of crop. This is about 500 mm total of rain and irrigation. Most roots are in the top 60 cm of soil and readily available soil moisture should be kept in that root zone.

The amount of water required varies with the locality, the soil type and length of growing season. Sandy soils have a much lower waterholding capacity than clay-based soils and consequently need more frequent irrigation. The soil texture will also determine the amount of water applied at any one time.

Water management to produce quality sweetpotatoes

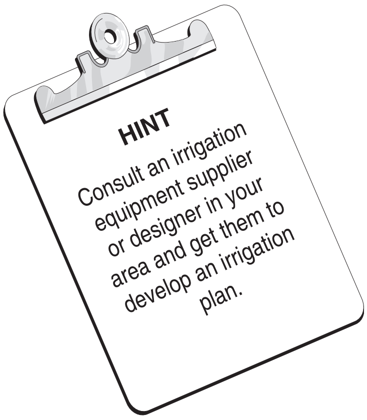
Good water management is essential to produce quality storage roots. The best way to manage water application accurately is to use an irrigation-scheduling device. Inaccurate irrigation is the major cause of poor nutrition. Monitoring both gives you the best chance to achieve maximum profits.

Most growers tend to over water in the early stages of the crop. Leaching of fertiliser, in particular nitrogen from the root zone, is common and fertiliser is often wasted. Table 19 shows the symptoms of poor water management at different growth stages.

Table 19. *Symptoms of poor water management at different plant growth stages*

Growth stage	Amount of water	
	Not enough water	Too much water
Planting to storage root initiation	Poor growth Poor uptake of nitrogen, calcium and boron Small plants	Leaching base fertiliser Root diseases, e.g. scurf Lush growth
Storage root initiation to harvest	Small plants Low calcium, nitrogen and boron uptake Small storage roots Growth cracks occur when water is applied Low yields	Excessive vine growth, poor uptake of calcium, phosphate and zinc Storage root breakdown Poor flesh structure due to low calcium balance Poor keeping quality Enlarged lenticels Low dry matter

Irrigation must No. 1—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.

Irrigation methods

Overhead irrigation is the most common irrigation method used in sweetpotatoes, but trickle irrigation is sometimes used.

Overhead irrigation

Overhead irrigation includes travelling irrigators or sprinkler systems. Overhead irrigation is suitable for any soil type and undulating country. Table 20 shows the advantages and disadvantages of overhead irrigation.

Table 20. Advantages and disadvantages of overhead irrigation

Advantages	Disadvantages
Can be used in most situations	Washes spray off plants
Will seal up cracks in the soil	Expensive to set up
Can be used to reduce losses from frost	Wets interrow and headland areas, promoting weed growth
	Affected by wind
	Difficult to apply regular, small amounts unless using a solid-set system
	High pumping costs because it requires high pressure, particularly for travelling irrigators
	Cannot use plastic mulch
	Higher water use than trickle
	Must use high quality water
	Difficult to apply fertilisers with irrigation unless using solid-set

Trickle irrigation

Trickle irrigation is the most easily controlled method. The equipment is expensive, but has a long life. If trickle tubing is to be re-used it should be treated with chlorine to reduce the risk of blockages. Soluble fertiliser mixtures and some pesticides can be applied easily through the irrigation system. Use a trickle tube with outlets no more than 20 cm apart. Table 21 shows the advantages and disadvantages of trickle irrigation.

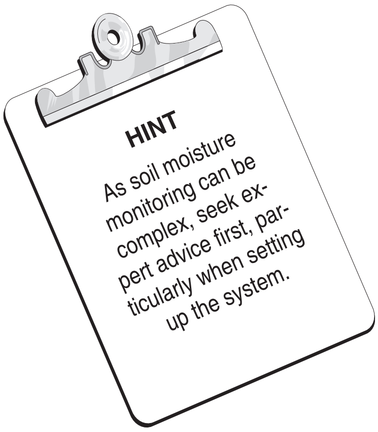
Table 21. Advantages and disadvantages of trickle irrigation

Advantages	Disadvantages
Does not wet plants and wash off sprays	Requires a greater intensity of management
Easy to regulate applications	High initial cost
Can apply small amounts often (daily if necessary) in the critical period	Requires regular maintenance during the growing period
Only wets the root area	Can block up if good filters are not used
Can grow crop on plastic mulch	Not suitable for steeply undulating country due to variable output
Can easily apply nutrients through the system	Susceptible to damage by crickets
Not affected by wind	Must take precautions to filter water or treat it for iron bacteria, or both
Uses less water than other systems	May not seal cracks in the soil, allowing weevils to enter
Can use poorer quality water than overhead systems	
Pumping costs are cheaper because the pressure required is lower	

Irrigation must No. 2—a monitoring system

The second essential requirement of efficient irrigation is a monitoring or scheduling system to tell you when and how much water your crops need. Research has shown that monitoring can reduce water use considerably without affecting yield and storage root quality. It also makes sure you are applying enough water at the critical 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 or soil capacitance systems such as the Enviroscan or Gopher. The other technique sometimes used is a climate-based system that uses estimates of evapotranspiration. The tensiometer or capacitance systems are preferred and recommended. A brief comparison of the main systems is shown in Table 22.

Table 22. Comparison of the main soil moisture monitoring systems

System	Advantages	Disadvantages
Tensiometers • Relatively cheap	• Easy to install • Can be read by growers • Continuous monitoring	• Labour intensive to collect and record data • Require regular maintenance • Can be inaccurate in extremely wet or dry soil
Capacitance probe e. g. Enviroscan, Gopher	• Continuous monitoring • Accurate at all depths and for all soils • Enable rapid reading and recording of results	• Expensive • Need skill in interpreting data

Getting the best from your irrigation

To get the best from your irrigation system use tensiometers or capacitance probes to help you make decisions about when to irrigate and how much water to apply. Remember that pesticide applications, irrigation systems, labour, the availability of water, and disease risk all influence your decision to irrigate.

A strategy for irrigating sweetpotatoes

Establishment. Ensure adequate moisture for a good strike and for the plant to begin to access the basal fertiliser application.

Up to storage root initiation. After successful establishment let the soil dry out slightly from the surface, without stressing plants, to encourage a bigger root system and root development down to 30 to 50 cm. This allows roots to access a larger volume of soil nutrients and moisture, and reduces germination of weed seeds.

Storage root initiation to harvest. Maintain soil moisture near the full point (field capacity) by not allowing the crop to take more than 50 to 70% of the available moisture. This facilitates root filling, which is a physiological response from the plant to maximise cell elongation when soil moisture is easily accessible. Uneven moisture availability at this stage will result in growth cracks.

Reduce soil moisture about one to two weeks before top removal to toughen the skin and assist harvesting.

Harvest. Ensure even soil moisture. A light irrigation to moisten top soil before harvest reduces skin damage by reducing clods and allowing soil to be elevated to cushion the roots. Table 23 shows the optimum range for readings on the shallow tensiometer (20 cm) for the different stages of plant growth. Irrigate if the tensiometer reading is above the higher figure. If the reading stays below 10 kPa, the soil is too wet.

Table 23. Optimum range for shallow tensiometer readings from planting through harvest

Soil type	Tensiometer reading		
	Up to storage root initiation	Storage root initiation to first harvest	During harvest
Sandy loams	10 – 25	10 – 30	20 – 30
Clay soils	15 – 30	10 – 40	20 – 40

Tensiometers

A tensiometer consists of four basic parts—a hollow tube filled with water and algaecide, a ceramic tip, a water reservoir and a vacuum gauge which reads water tension on a scale of 0 to 100 centibars (kilo-Pascals or kPa, Figure 9). In more complex systems, the conventional vacuum gauges are replaced with pressure transducers or portable electronic readers. In wet soil, the vacuum gauge displays 0 to 5 units 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.

The DPI has a useful booklet about using tensiometers—*Water it Right: a Guide to Using Tensiometers*.

more info

Where to get this book
Section 6 page 24

A monitoring site consists of one shallow tensiometer installed in the major root zone and one deep tensiometer below most of the roots (Figure 10). A crop planting should have at least two monitoring sites. Shallow tensiometers should be placed within 10 cm ofthe crop row and midway between plants, though this can vary slightly. Install the shallow tensiometer with the tip 20 cm below ground and the deep tensiometer 60 cm deep. Install tensiometers after the crop is established, disturbing the plants and surrounding soil as little as possible.

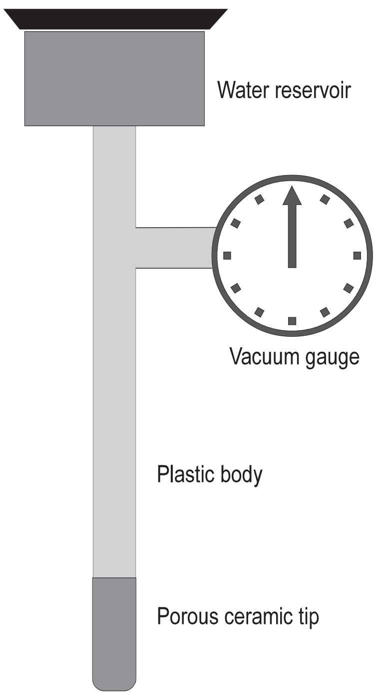


Figure 9. Parts of a standard tensiometer

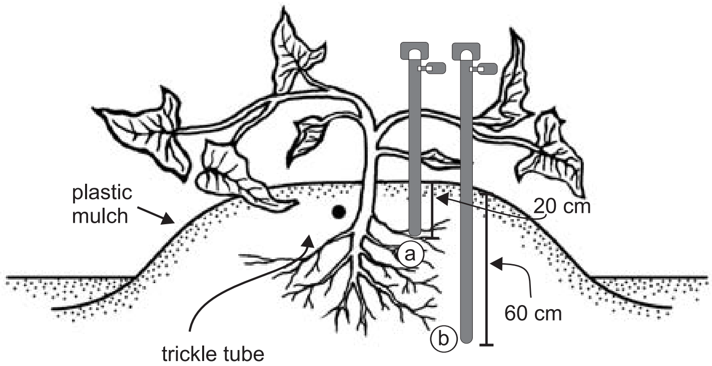


Figure 10. *Profile of a typical tensiometer-monitoring site in sweetpotatoes (a) in root zone and (b) below main roots*

The shallow tensiometer indicates when to water. The deep tensiometer indicates when the right amount of water has been applied. If deep tensiometer readings fall to less than 10 kPa within two days after irrigation, there is more water than the root zone can hold. Constant values after irrigation indicate the root zone is saturated. If readings continue to rise immediately after irrigation, not enough water has been added to the root zone.

Installation

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

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

To install the deep tensiometer, dig a hole 60 cm deep, keeping the excavated soil nearby in a pile. A 50 mm (2 inch) auger is the best tool. Put the tensiometer in the hole, over to one side. The next step is critical. 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 any large air gaps. Continue replacing soil until the hole is filled. It doesn't matter which soil you use once you have packed the first 5 cm above the tip. Friable topsoil from a few metres away can be used to create a slight mound around the tensiometer. This minimises water draining down beside the tensiometer, causing false readings.

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

The tensiometers are now ready to operate. Use the vacuum pump to again remove air bubbles. Tensiometers may take a few irrigation cycles to settle 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 and rainfall.

Clearly mark tensiometer locations, otherwise tractors, harvesters, rotary hoes and other machinery may damage them.

Reading

Read tensiometers at the same time early in the day, preferably before 8.00 a.m. At that time there is little movement of water in the soil or plants and they are almost in equilibrium. Errors caused by heating of the gauge or water column are also avoided. Read at least twice a week, but preferably every one to two days. Lightly tap the gauge before reading.

It is a good idea to plot the daily readings on a chart. This will show what has happened in the past, for example when crops were irrigated and whether it affected the deep tensiometer. By extending the line on the chart it can be used to predict hen the next irrigation will be needed. Figure 11 shows diagrammatically how the tensiometer reacts to different amounts of irrigation while Figure 12 is a sample chart with shallow and deep tensiometer readings plotted over several irrigations.

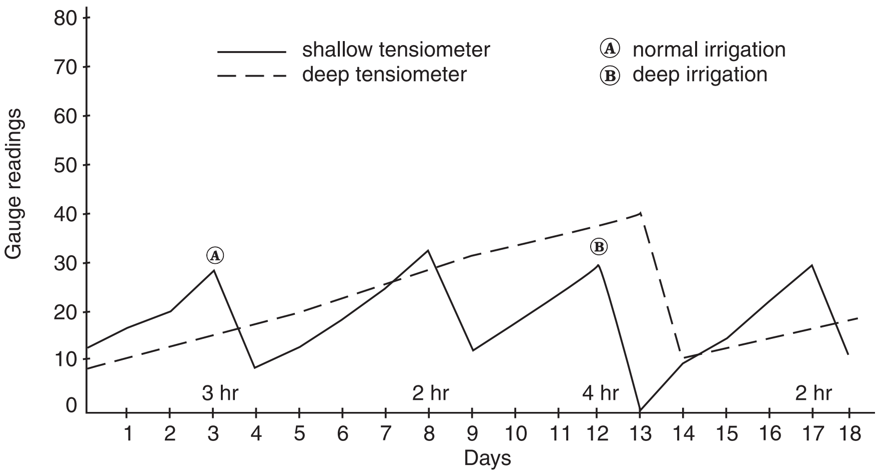


Figure 11. *Diagrammatic representation of tensiometer reaction to different amounts of irrigation*

A. Shortly after a good irrigation.
B. By extending the line from A through B, you can predict when an irrigation will be needed.
C. Just before irrigation.
D. After an irrigation which did not penetrate adequately.
E. Soil dried sooner because of inadequate irrigation.
F. Reflects an adequate irrigation following E.
G. It is helpful to show the date and hours of irrigation.

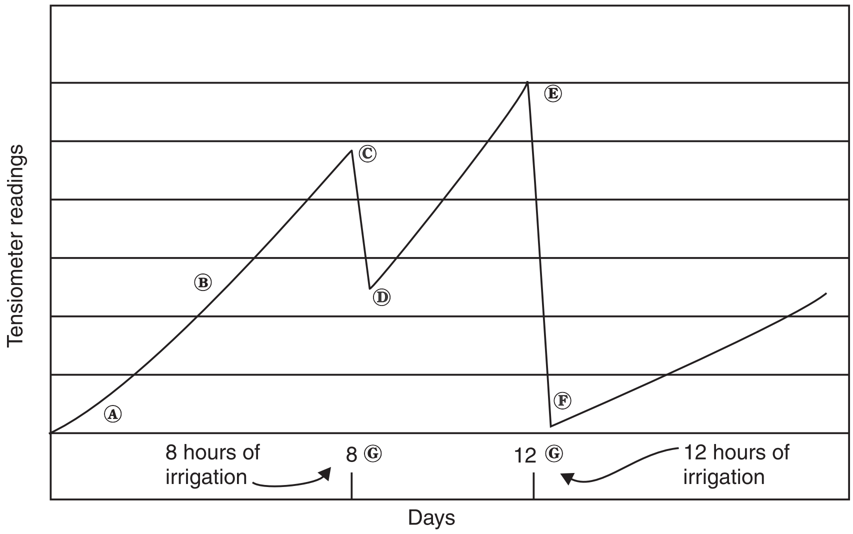


Figure 12. *A sample chart showing tensiometer readings plotted daily*

Maintaining tensiometers

Ensure that the water level is topped up regularly in the tensiometer. It is best to do this after irrigation, when the water level should not be more than 3 to 5 cm below the gauge. It will probably be more than this just before irrigation is due.

Use a vacuum pump to remove air bubbles if the water level was very low. After removal from the soil, protect the tensiometer tip from dry air until it has been emptied, cleaned and dried.

Troubleshooting tensiometer problems

No water in the tensiometer; gauge reads 0

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

Air entering over several days; gauge registering more than 5

There is either a hairline crack in the tip or a substantial air gap in the soil around the tip. Remove the tensiometer. If there are no obvious tip cracks, re-install the tensiometer. If the problem persists, replace the tip.

No change in readings over several days

The gauge may be faulty or blocked. Check that the gauge is working.

- Apply suction to the tensiometer with a vacuum pump. If the needle does not move, there is a problem with the gauge.

Tensiometer readings increase beyond 80 then fall to 0, accompanied by air in the tensiometer

The soil has become too dry for the tensiometer to operate. After irrigation, refill the tensiometer and treat as if it had just been installed. If this happens frequently, consider whether you are under irrigating. If you are happy with your irrigation, try installing the shallow tensiometer slightly deeper. This problem should never happen with the deep tensiometer.

Getting started with tensiometers

A good grower starter pack would include two 30 cm and two 60 cm tensiometers, a suitable vacuum pump and algaecide. The total cost should be about $800. The best tensiometers have replaceable tips, gauges and reservoirs. Some new tensiometers include an in-built pump, but are more expensive.

Tensiometers should be installed at two monitoring sites in a crop. Continue usual irrigation practices and get a feel for how tensiometers operate. Once you are confident using them, make slight changes to your irrigation and observe what happens. For example, if the reading of the deep tensiometer always fall after irrigation, reduce the amount of water you apply.

Tensiometers are easiest to use in overhead irrigated vegetables; flood, furrow and drip irrigation systems are more complex because positioning of the tensiometer is more critical.

Capacitance probes

Capacitance probes are continuous moisture monitoring devices based on capacitance sensors. These continuously measure the dielectric constant of the soil and consequently its water content. As the soil's water content increases, so does its dielectric constant. Dissolved salts do not significantly affect this reading, which means that fertiliser applications or irrigation water quality do not alter the soil moisture estimates.

There are two types of capacitance probes: permanent and portable probes.

In permanent systems, for example Enviroscan and Buddy, 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 in the soil after the crop is established. The probes and tubes are left in place until the end of the season.

Sensors are positioned on the probes to provide readings at specific depths. Measurements from the sensors are relayed at regular intervals through a cable to a data logger 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 13 is a diagrammatic representation of an Enviroscan probe.

With portable probes, for example the Gopher or Diviner, the probes have a single sensor head which is carried from site to site and lowered into vertical PVC access tubes installed in the soil after the crop is established. Readings are made at the required depths. The sensor is connected to a hand-held data logger for on-site display of the soil moisture profile, and later downloading into a computer. Portable probes are less expensive than permanent probes, but do not allow continuous monitoring.

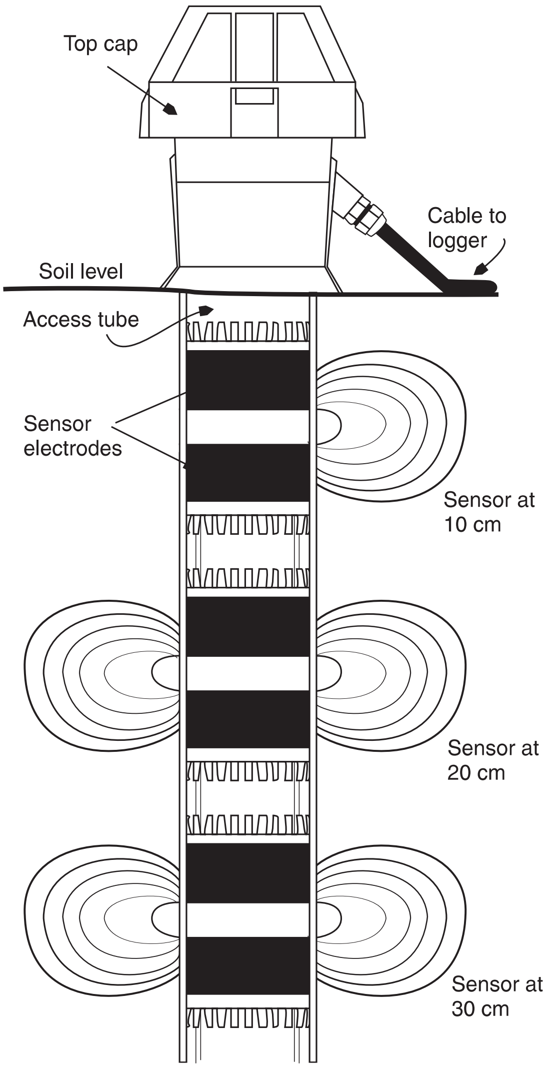


Figure 13. *Diagrammatic representation of an Enviroscan probe*

With both systems, after downloading, the computer analyses the data and provides an accurate and dynamic understanding of the crop's daily water requirements and the effectiveness of irrigation and rainfall. Results are presented in millimetres of precipitation required to bring the soil water content up to field capacity. Irrigation watering time is then easy to calculate. Data are displayed as readily available soil water, water deficit and total soil water over the nominated root zone depth.

This information removes the guesswork from irrigation decisions and provides a basis for further manipulation of the crop.

For sweetpotatoes, two probes are recommended for a block of plants but the number of sites depends on the variability in soil and varieties. The probes should have sensors at 10, 20, 30 and 50 cm.

The current cost of a logger, solar panel, 100 m of cable, two 50 cm probes, eight sensors and software is about $5000. Equipment can also be hired from some consultants.

Interpretation of the data requires skill. We recommend that consultants be used to set up the system and provide at least the initial advice.

Maintenance of a trickle irrigation system

Before developing your trickle irrigation system, have the water tested to make sure that it is suitable for your crop and whether it contains soluble iron. Iron levels above 1 mg/L can cause problems. Iron bacteria in the water can turn the soluble ferrous iron into insoluble ferric iron that precipitates as a red sludge, which will block the trickle outlets. Chlorinating the water will kill the bacteria and prevent precipitation.

Filters

A good filtration system is essential because the trickle outlets are very small. There are three main types of filters: sand filters, mesh and screen filters, and multi-media filters. The type of filter needed will depend on water quality. Talk to a reputable irrigation specialist before deciding on the type of filter you need.

Filters should be cleaned regularly, either manually or automatically. You should also flush out the pipes regularly; the dirtier the water the more often you need to do it. Fit flushing valves to the ends of trickle tubing so that the system is automatically flushed after each irrigation.

Chlorination

Chlorination is an effective way of cleaning and keeping trickle tape clean by oxidising and destroying organic matter and micro-organisms. The quantity of chlorine required to oxidise these organisms is referred to as the chlorine demand of the water. The chlorine left after oxidisation is the residual chlorine, which can be measured at the end of the irrigation system using a swimming pool test kit. You should aim to have 1 mg/L (ppm) chlorine at the end of your system, indicating you have used enough chlorine. The amount of chlorine required will depend on the quality of the water.

Chlorine is corrosive and toxic, so read the label carefully and handle it with care. It is available as liquid sodium hypochlorite, usually around 10 to 12.5% chlorine, or granular calcium hypochlorite, usually around 65 to 70% chlorine.

Chlorination can be continuous, using 1 mg/L residual chlorine; on a regular basis at about 10 mg/L; or as a slug dose using 500 to 1000 mg/L. Test the water at the end of the system to ensure there is about 1 mg/L residual chlorine.

When chlorine is used regularly it is injected over the last 20 to 30 minutes of irrigation.

The slug dose is only used if the trickle outlets are badly blocked or before used tape is to be reused. Chlorine at this concentration may damage plants. It is left in the system for 24 hours, then flushed out. First flush water out of the main lines, then the sub-mains and finally through the open ends of the trickle tubing. If the mains and sub-mains are not flushed first, all the sediment cleaned from them will go into the trickle lines.

Chlorine can be injected into the irrigation water on either the suction or the discharge side of the pump, but before the filter. The filter must be resistant to corrosion by chlorine. Make sure the pump runs for long enough after you stop injecting chlorine to ensure that no chlorine is left in the pump or any other metal part of the system.

Calculating how much chlorine to inject

To calculate how much chlorine to inject you need to know:

- the chlorine concentration of your chlorine product;
- the flow rate of your pump in litres per minute;
- how long it takes the water to reach the furthest point of your system.

Table 24 shows the amount of two chlorine products required to make two concentrations of chlorine.

Table 24. *Chlorine product required for two concentrations of chlorine*

Concentration required	12.5% chlorine product		65% chlorine product	
	rate per 100 L	rate per 500 L	rate per 100 L	rate per 500 L
10 mg/L	8 mL	40 mL	1.5 g	7.5 g
500 mg/L	400 mL	2 L	75 g	375 g

If the pumping rate is 500 L per minute, you will need to add each minute the amount required for 500 L, for as long as it takes the water to reach the furthest point of your system. You can use a swimming pool test kit to determine when the chlorine has reached this point or put dye in the water.

An integrated approach to pest and disease management in the field

Managing pests and diseases is an important aspect of sweetpotato growing. Various pests or diseases may cause problems at some stage in the life of the crop and can reduce yield and quality. This section describes an integrated approach to pest and disease management that takes account of prevailing conditions and suggests more sustainable methods of sweetpotato production.

The traditional approach

The regular application of chemicals on a calendar basis is the traditional approach to pest control. This approach has several problems.

- It is costly, with several sprays being applied each season even if there are no pests in the crop.
- Plants can tolerate significant numbers of certain pests without adverse effects on yield and quality.
- It does not account for climatic conditions and their effects on insects.
- The resultant overuse of pesticides increases the potential for early development of resistance to the available chemicals.
- Extra treatments may result in excessive residues on the crop.
- Overuse of chemicals may increase unnecessary exposure to spray operators and field staff.
- Beneficial species are destroyed or their efficacy is reduced, resulting in increased importance of usually minor pests.

NOTE

The term 'pests' includes insects, mites, fungi, bacteria, viruses, phytoplasmas and nematodes.

The integrated pest management (IPM) approach

The objective of integrated pest management (IPM) is to move pest control away from a system that relies on regular (calendar) sprays to one that combines cultural, biological and chemical measures, if and when needed. These methods need to be compatible with other crop production practices and sensitive to farmers' socioeconomic conditions.

IPM relies on competent crop monitoring, careful pesticide selection and treatment decisions based on sound biological and economic need. The use of competent pest scouts is recommended.

The main elements of an IPM approach to pest management are:

- using pesticides only if monitoring indicates there is a real need;
- using clean, pest-free planting material to establish new crops;
- promoting the build-up of beneficial insects by using pesticides sparingly;
- if required, selecting pesticides known to have minimal impact on beneficial species in the crop;
- destroying all crop residues and volunteer plants and allowing adequate fallow between crops to reduce carry over of pests;
- calibrating all equipment to ensure good coverage, especially if spraying the underside of leaves for mite and aphid control;
- early harvesting to reduce impact of sweetpotato weevil;
- planting more disease and insect-resistant varieties, if these are available.

Use clean planting material

Planting material such as stem cuttings or storage roots often harbours pests and diseases and this infested material will result in poor crop performance and low yield. Feathery mottle virus and little leaf are commonly carried over and spread from crop to crop through infected stem cuttings. If crowns and runners infested with sweetpotato weevil are used for planting material, the weevil will be spread to new crops. To prevent this:

more info
Buying cuttings
Section 6 page 4

- Obtain planting material from a reliable source free of weevil or other pests. Two DPI research stations provide virus-free cuttings of the most commonly grown varieties for a minimal fee.
- Use stem tip cuttings because they are often the healthiest part of the stem. They usually have the lowest disease infection and insect infestation and grow faster, producing better yields than cuttings from the lower portion of the plant.

Farm hygiene

Good farm hygiene is the simplest but often the most overlooked method of pest management. Maintain a high standard of hygiene and quarantine in the field, in the packing shed, and in the surrounding areas. Good farm hygiene results in fewer pests developing on and being spread around the farm. To achieve a good level of farm hygiene, follow these farm practices:

Establish and maintain a clean nursery. This is often overlooked but a properly maintained nursery is an important source of pest and disease-free plants.

Promptly destroy old crop residues and weeds. Destroy old crop residues, weeds and volunteer (self-set) plants that are a reservoir of pests and diseases. Plough in crops as soon as harvesting is completed.

Remove alternative hosts of pests and diseases. Relatives of the sweetpotato, such as members of the morning glory family, support the carry over of pests and diseases and enable them to become established in new crops.

Remove reject storage roots. Reject storage roots can become breeding sites for pests and diseases. Promptly remove them from in and around the field by feeding them to stock, or crushing and burying them well away from your production area.

Select the right site. Select a site that does not have a history of recurring problems with pests and diseases. Remember that:

- nematodes are more often a problem in sandy soils;
- soil rot is favoured by relatively dry soil and increases in pH;
- planting on exposed ridges can stress plants and make them more susceptible to mites;
- frost and chilling injury is more likely in lower areas where air flow is restricted.

Cultural control

Select the best production period. The time of year will influence what problems you have with the crop. Select a production period that will minimise pests and diseases. Remember that:

- foliage diseases are usually worse in warm, wet weather;
- sweetpotato weevil and nematodes are usually worse in warm weather;
- mites prefer warm, dry conditions.

more info
Variety descriptions
This section
pages 34 to 39

Select the right variety. The variety you choose will be determined by your market, soil temperature, time of production and known or expected problems. Refer to the variety descriptions in this section for disease tolerance or resistance.

Land preparation. Good and thorough land preparation gives the sweetpotato plant a good start, helps to control weeds, assists hill formation, reduces the chance of waterlogging and may reduce the severity of damage caused by soil-borne pests and diseases.

Irrigation. Timely irrigation, especially during warm weather, prevents the soil from cracking, thus reducing the chance of pests, (for example sweetpotato weevil) entering the developing storage roots. It also minimises the severity of soil-borne diseases like soil rot (pox).

Trickle, overhead or furrow irrigation have different impacts on pests and diseases. Remember that:

- overhead irrigation can wash sprays off plants;
- crops grown on the flat are more prone to waterlogging than hilled crops;
- furrow irrigation may lead to excessively wet soil, causing root rots and enlarged lenticels, and also increased soil compaction.

Hilling-up. Hilling-up between two and four weeks after planting helps to control weeds. It also minimises weevil entry into roots by reducing soil cracks.

Cover cropping. Cover crops and the broken-down organic matter they supply improve soil structure and the water and nutrient-holding capacity. A dense and well-grown cover crop will suppress weed growth and reduce weed problems in future crops.

Crop rotation. Continuous cropping with sweetpotato must be avoided, as this practice will result in disease and pest build-up and reduced yields. Do not plant sweetpotatoes for three years after a previous sweetpotato crop.

Early harvesting. Harvesting one or two weeks earlier will reduce weevil damage.

Biological control

more info
Beneficial suppliers
Section 6 page 6

Biological control agents (beneficials) can be used to manage some insect pests of sweetpotatoes; however, growers cannot rely entirely on natural or introduced beneficials for control.

Beneficial insects and mites

Beneficial insects that help control pests may be either parasites or predators. Parasites include small wasps that lay eggs in aphids and then develop within the aphid, causing it to become a mummy.

Predators include predatory mites that eat twospotted mites and lacewings that eat a range of insect pests.

Handle parasites and predators carefully and follow the supplier's instructions.

Sex pheromone traps

Sweetpotato weevil is the most important pest of sweetpotato. One useful monitoring tool is the sex pheromone trap. A pheromone is a substance secreted by a female insect and which attracts male insects of the same species. The commercial female weevil sex pheromone traps male weevils, helping to determine the levels of weevil population.

The value of reducing the male population by trapping has still to be proven, as is the economic threshold (pest numbers which cause economic loss) based on trapping.

Pest monitoring

Monitoring is an essential part of IPM as it forms the basis for decision-making related to pest management. Without monitoring you have no evidence of what pest management strategies are needed or how well your current strategies are working. Pest monitoring requires a keen eye for detail, time and a good knowledge of the crop, the pests and beneficial species. For these reasons we recommend you use a well-trained and competent pest consultant or scout.

HINT
To get this DPI Note go to our web site: www.dpi.qld.gov.au/dpinotes/Welcome.html

If you do not hire a professional pest scout we suggest that you get some training from a pest consultant or scout. There are a few procedures to follow in doing your own monitoring. Ideally, inspections should begin in the planting material nursery and continue until the end of harvesting. The intensity of monitoring will vary with the crop stage, pest pressures and the weather conditions.

Before planting, monitor for soil insects using the 'germinating seed bait' technique described in the DPI Note *Control of Soil Insects in Central Queensland.*

What you will need to monitor a crop

1. A monitoring log book. A sample page that you can photocopy is on page 80 of this section.
2. A 10 power hand lens. Most optometrists stock these.
3. Plastic freezer bags for identification samples of unfamiliar problems, for example insects, diseases, weeds and plant symptoms.

more info
Common problems Section 5

It is not necessary to identify all the problems you find, but the more you can identify the better.

How to monitor a crop

1. Set aside enough time to check a block carefully.
2. Know what you are looking for in general terms before going out to the block.
3. Look in the most likely places on the plant for each particular pest or disease. See 'Pest and disease monitoring' for details.
4. Check each area or block weekly and record the numbers of pests

or unhealthy plants fortnightly to determine trends.

5. Check a good cross section of the block—pests can often be in patches or at one end or side of a block.
6. Write down what you find in a monitoring log or a diary.
7. Simple tables and graphs of data help define patterns. Maps help identify local problems and pest movement.

Don't worry about not seeing a particular problem—you will. Unhealthy plants quickly catch your eye as you walk through a block. Initially, you will probably find a lot of suspect plants but not be able to identify the problem.

If a plant doesn't look healthy and you don't know why, put it in a plastic bag and have it identified. Department of Primary Industries' extension staff or local pest scouts provide this service. A small 10 power hand lens assists with viewing small insects. Soon you will be skilled at identifying the range of pests and diseases on your farm.

Pest and disease monitoring

This procedure is one of several that can be used for pest and disease monitoring, as indicated in Step 3 of 'How to monitor a crop'.

1. Check overall appearance of the plants, paying attention to variations in colour and vigour. Yellowing patches should be inspected closely for mite infestation, waterlogging or heavy disease infection.
2. Look for wilted or yellowing plants, leaf chlorosis, curling, or lesions on stems and examine these for symptoms of pests, diseases or physical damage.
3. Thoroughly examine at least 10 and preferably 20 average plants per block up to about 2 ha and increase this number for larger blocks. Select the plants at random as you walk through the block.
4. Check around layflat hoses, hydrants, filters or other objects where spray coverage may be poor to see if any pests are present. Check around the block for possible sources of reinfestation. Carefully note and record the following information:
   - The number of sweetpotato weevils. Check around the crown and runners near the crown for adult weevils and check exposed roots for damage.
   - The number of Convolvulus hawk moth larvae, cluster caterpillars, sweetpotato leafminers, leafeating beetles, grasshoppers, mites, aphids, silverleaf whitefly or other sucking pests.
   - The number of beneficials, predators, parasites and dead insects.
   - The presence of any diseases, for example sweetpotato feathery mottle virus, foliar scab, Alternaria leaf spot and little leaf disease.
   - The number of leaves showing mite damage.

- Note any other symptoms on the plant.
- Weed types and stages of growth, and if they are harbouring insect pests or diseases.
- The number of sweetpotato weevils in pheromone traps.

Record all observations in the monitoring log (see sample page 80).

Making pest management decisions

The first decision you must make is whether management actions, including pesticide applications, are needed to avoid economic losses from pest damage. The management of pests in your crop depends on making the right decisions. You should aim to:

- introduce parasites and predators (beneficials), if suitable ones are available;
- spray only when the pest level becomes economically damaging, that is the cost of control is less than the losses incurred if not treated;
- spray at the most susceptible stage in the pest's life cycle;
- spray the affected blocks, not the whole crop;
- use sprays that will be least damaging to beneficials.

Monitoring and action thresholds help you make these decisions. An action threshold is the critical level at which a decision is made. Below this threshold maintain as many cultural practices as possible to reduce the pest's impact on your crop. Above this threshold start specific control measures targeted at the pest. The thresholds are based on the average number of pests found per plant.

$$\text{Threshold} = \frac{\text{total number of pests recorded}}{\text{number of plants inspected}}$$

Thresholds for insect pests are generally based on monitoring pest numbers and stages found in the crop. They should reflect the pest level that will cause economic damage. If pest pressure is high, you will be over the threshold; if it is low, you won't reach the threshold.

The threshold you set will also depend on the activity of beneficial insects and the risks involved in not controlling the pest. For example, beneficials may build up rapidly with aphid populations and be more effective than chemicals.

Thresholds for other pests are normally based on the block history, stage of development of the crop, weather conditions and other observations. Record all these in your monitoring log, as they can be used to judge when outbreaks may occur.

Using threshold levels

No scientific research has established definite action threshold levels for sweetpotatoes. By monitoring the numbers of pests in your crop now, and the levels of pests or disease that cause economic damage or loss, you will be able to determine your action thresholds and apply these in future crops.

An increase in pest activity may indicate the need for:

- checking application equipment;
- a different pest control strategy;
- a different pesticide selection;
- an additional pest control strategy;
- a shorter spray interval.

A decrease in pest activity may indicate the need for:

- a longer spray interval;
- a softer pesticide selection;
- reduced targeting of that pest.

You can decide which specific pests need to be controlled by comparing the numbers recorded in your monitoring log.

Once you have decided what pests need to be targeted, you can decide what control actions to use. The *Problem Solver Handy Guide* lists the registered pesticides for use in sweetpotatoes.

Sweetpotato pest and disease monitoring log

Block:____________________________________ Date: ______________________________

Weather since last monitored:____

Use the following code to determine to check: # – number; P – presence; S – symptoms; D – plant dead

	Insects, mites and beneficials										Diseases						Comments
Code	**#**	**#**	**#**	**#**	**P**	**P**	**#**	**#**	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**e.g. 3 parasitised aphids per leaf**
1	**Sweetpotato weevil**	**Sweetpotato leafminer**	**Aphids**	**Cluster caterpillars**	**Mites**	**Silverleaf whitefly**	**Hawk moth larvae**	**Grasshoppers**	**Beneficials**	**Foliar scab**	**Alternaria leaf spot**	**Scurf**	**Soil rot**	**Base rot**	**Feathery mottle virus**	**Little leaf**	
2																	
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Pest management in the field

Insect and mite infestations are a major cause of losses in yield and quality in sweetpotatoes. Successful management of the main pests is essential for economic production. Once the plants are well established they can withstand significant foliage loss without any loss of yield. The main pests are sweetpotato weevil, sweetpotato leafminer, aphids, mites, silverleaf whitefly, soil insects, Convolvulus hawk moth and cluster caterpillar.

Sweetpotato weevil

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Pictures of pests
Section 5

Sweetpotato weevil (*Cylas formicarius elegantulus*) is the most important pest of sweetpotatoes in Queensland and in all sweetpotato-growing countries of the world. The adults are 6 mm long and resemble large ants. They are mainly metallic dark blue with orange thorax and legs. The eggs are laid at the base of the stem and on the exposed part of storage roots. The larvae, which do most of the damage, are 10 mm long, white with brown heads.

Adult weevils feed on the tender buds, leaves, vines and storage roots. Serious damage may cause shrivelling. Damage appears as small feeding and egg-laying punctures on the surface and the larval tunnel within the stems, crowns and storage roots is filled with frass. Weevils in the crown reduce the plant's nutrient flow, restricting growth. The larvae do not burrow down into the storage roots from the crown.

The damage may lead to secondary bacterial and fungal infection. As a result the storage roots produce chemical compounds (terpene phytoalexins) that render them bitter and inedible, even when the damage is minor. If left uncontrolled infestation can cause total yield loss.

Recent research indicates that orange-fleshed, dessert varieties are more susceptible to sweetpotato weevil damage than white-fleshed staple varieties. There may be some differences between varieties but this research is not conclusive.

Monitoring for sweetpotato weevil

The following methods indicate the presence of adult weevils, but economic thresholds for treatment have not yet been determined.

- Pheromone traps attract and trap the male weevils. Set three to four traps baited with a commercial lure per block to determine the population level of sweetpotato weevil in the field. Traps should be placed near known 'hot spots' or on the side of the crop closest to old sweetpotato crops. The effectiveness of trapping in reducing storage root damage has not been fully assessed.
- Regular counts of the trapped male weevils, number of larvae on sampled stems and storage roots at harvest, measurement of tunnel length and percent root infestation from sampled parts can be used to monitor the population and damage levels.

Control of sweetpotato weevil

The best way to control sweetpotato weevil is to use an integrated pest management (IPM) approach. This includes the following actions.

Use clean, weevil-free planting material. The sweetpotato weevil is transferred by weevil-infested vine cuttings. Cuttings to establish new plantings should come from weevil-free nurseries.

Eliminate host plants such as other *Ipomoea* species. The removal of other host plants, for example morning glory, that grow on the border of sweetpotato fields, will reduce the presence of weevil in the fields. It also reduces the source of infestation in the next sweetpotato crop.

Cover soil cracks. Adult weevils enter the storage roots through soil cracks, not through tunnels in the stem. Prevent the soil from cracking by hilling-up within 30 to 45 days after planting (depending on the variety and the rate of plant growth) or mulching. This reduces the severity of damage. Overhead irrigation will also close cracks in the soil.

Field hygiene and crop rotation. Sweetpotato weevil will build up in the remains of plant debris and storage roots left in the field after each crop. Cultivate to destroy all volunteer plants to prevent damage to the next sweetpotato crop. Plant other crops, preferably leguminous ones, after sweetpotato.

Biological control

The use of biological control against pests and diseases enhances sustainability and is environmentally safe. Research overseas has shown some potential for biological control in sweetpotato, but none of these agents has been tested in Queensland.

Chemical control
Insecticides should only be applied when necessary. Pheromone traps in conjunction with crop monitoring can be used as a guide for treatment. Any significant increase in trap catch or numbers during monitoring can indicate the need for treatment.

Sweetpotato leafminer

The damage caused by larvae of the sweetpotato leafminer *(Bedellia somnulentella)* can be serious enough to reduce yield. The young larva enters the leaf and forms serpentine mines, which coalesce into blotches. Severely damaged leaves become brown and shrivelled. The lower surface of the heavily infested leaves turns black and becomes covered with silken webs.

Control
The easiest and most practical way to control leafminer is to use insect-free planting material. It is naturally controlled by the wasp *Apanteles* sp. Some chemicals are also effective.

Spray with an appropriate chemical from the *Problem Solver Handy Guide* if monitoring indicates increasing damage.

Aphids

Large numbers of aphids can damage plants by sucking sap, causing wilting and leaf puckering. Colonies of these small, winged and wingless insects are found primarily on the undersurface of the young leaves where they suck plant sap and produce sticky honeydew. Sooty mould grows on the honeydew, giving plants a blackened appearance. Aphids can also cause serious losses by spreading sweetpotato feathery mottle virus.

Green peach aphid
Green peach aphid (*Myzus persicae*) is small to medium-sized, about 1.25 to 2.5 mm long. It is usually green, with a darker thorax. It causes distortion of young leaves and shoots, with excessive damage causing leaves to curl. In most cases these symptoms are followed by the virus disease symptoms.

Melon or cotton aphid
Melon aphid *(Aphis gossypii)* is yellowish to green or black and about 1.5 mm long. The female produces 15 to 20 nymphs a day and several generations occur in a year. It transmits many virus diseases.

Monitoring
Monitor crops to ensure that aphids do not build up to levels that will cause economic damage. Look for aphids under the leaves and

also look for golden, mummified adults, which indicate presence of parasites, as well as a range of predatory insects.

Control

Effective management includes good farm hygiene, planting varieties resistant to virus, and minimal use of pesticides to foster beneficial insects.

Hygiene

Destroy old crops as soon as harvesting is completed and destroy weeds that are alternative hosts to aphids. Check cuttings to make sure you are not planting infested plants.

Beneficials

Natural enemies of green peach aphid include predatory ladybirds and parasitic wasps, while lady beetles and lacewings prey on melon aphids.

Several species of parasitic wasps lay their eggs in aphids. A wasp larva develops within each aphid, which dries and becomes swollen, tan-brown and mummified. An adult wasp emerges from the aphid mummy.

Beneficials can be effective in controlling aphids, but often aphid numbers build up to high levels before the beneficials gain control.

Insecticides

If necessary, spray to control aphids with an appropriate chemical from the *Problem Solver Handy Guide*. Aim for thorough coverage of the undersides of leaves. Green peach aphid has built up resistance to several insecticides.

Mites

Twospotted mite *Tetranychus urticae* and bean spider mite *Tetranychus ludeni* infest a wide range of plants. They congregate along the veins on the underside of the leaves, where a web-like mat is produced when populations become very high. Leaves on which large numbers of spider mites are feeding turn reddish on the upper surface and eventually dry out and die. Spider mites are worst in warm, dry conditions. They can be spread by wind, and are carried on clothing, machinery, birds and insects. They can also make some workers itchy.

Monitoring

Monitor for mites by looking for the yellow stippling on the upper surface of leaves and checking the undersurface for mites with your hand lens.

Control

Mites can be very difficult to control in warm, dry conditions. It is important to monitor the crop and take action as early as possible to prevent a major flare-up. Good farm hygiene, predators and miticides can be used. Spray when monitoring indicates mite numbers are increasing sufficiently to cause economic damage.

High volumes (1000 to 2000 L/ha) and pressure will improve coverage of the critical underside of leaves. Angling the spray jets forward about 20 degrees, just above the canopy, will help push the spray forward under the leaves. Passing over the crop in both directions may also assist in improving coverage of the underside of the leaf, but doubles spraying time.

Hygiene

Clean up old crops immediately after harvest and remove weeds and volunteer hosts from around the crop. Check cuttings to make sure you are not bringing infested plants onto your property.

Predators

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Predatory mite suppliers
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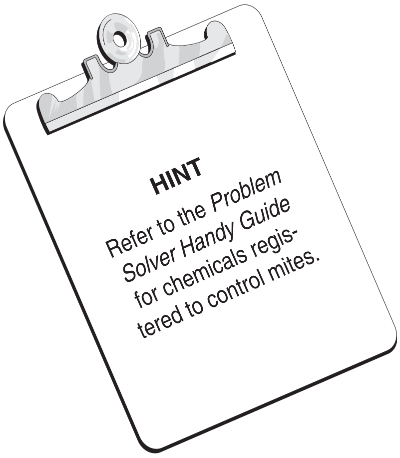
Predatory mites can be bought to control spider mites. They are not cheap and many of the chemical insecticides used to control other pests will also kill them. The companies supplying predatory mites will provide a list of chemicals that are least harmful to them. Releasing predators into the headlands around new plantings may help reduce mite numbers before they move into the crop. Some natural mite predators, and adults and larvae of the ladybird *Stethorus* spp., lacewing larvae and predatory thrips may also be present.

Miticides



Several chemical miticides are registered to control spider mites; however, mites can develop resistance to these chemicals fairly quickly, particularly if the same miticide is used regularly. Some chemicals, particularly pyrethroids, kill predators and can lead to a rapid buildup of mites. Good coverage of the underside of leaves is essential for the chemicals to be effective.

Silverleaf whitefly

Silverleaf whitefly is a recent introduction to Australia. The white-winged adults and scale-like nymphs suck sap from the plants, reducing plant vigour. They excrete honeydew on which black sooty mould grows. Silverleaf whitefly also transmit geminiviruses, but little is known about the threat they pose to sweetpotatoes.

Monitoring

Monitor the undersides of leaves to determine the population build-up.

Control

Accurate treatment thresholds have not yet been determined and potential pesticide treatments are yet to be developed. Minimise the use of broad-spectrum insecticides, as they reduce the impact of beneficials.

An IPM approach, including farm hygiene, preservation of beneficial insects and the use of insecticides when necessary, is the best way to manage silverleaf whitefly.

Hygiene

Ensure that seedlings brought onto the farm are free of silverleaf whitefly. If possible, plant new crops well away and upwind from older, infested crops. Destroy old crops immediately after harvesting is completed.

Beneficials

Several species of tiny wasps parasitise silverleaf whitefly nymphs. Predators, including lacewing larvae and ladybirds (coccinellids), eat nymphs and adults, and adults are caught in spider webs.

Insecticides

If necessary, spray with an appropriate chemical from the *Problem Solver Handy Guide*. As silverleaf whitefly is a new pest to Australia, chemical registrations are still being obtained, so check if other insecticides are registered or have a permit for use. Silverleaf whitefly is resistant to many insecticides. Some soft insecticide options (oils) may help reduce their numbers with minimal damage to beneficials. It is important to get good coverage of the underside of leaves when spraying and time sprays to target the more susceptible, younger nymphs.

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Soil insects

Crickets

Field and mole crickets feed on the storage roots. Pre-plant control may be achieved with a registered insecticide applied as for cutworms. Baits are the best control method in established crops. Mix a registered insecticide with 10 kg/ha of bran, and add enough water to produce a moist, crumby mixture. Let stand for two to three hours before using.

Cutworm, wireworm and white grub

Cutworms (*Agrotis* spp.) can chew off the vine cutting soon after planting. Wireworms are larvae of click beetles (Elateridae). White grub is common in areas with decaying logs, manure, grass clippings and other organic matter. They are also more common in lighter soils. Grub damage can affect more than 20% of marketable yield and can be as important or more important than sweetpotato weevil in some areas with sandy or sandy loam soil.

All three insects feed on the storage roots, reducing their marketable value and assisting entry of soil rot organisms.

Control

The soil should be treated with a registered insecticide applied to the soil surface and incorporated before hilling-up.

Convolvulus hawk moth

The convolvulus hawk moth larva (*Agrius convolvuli*) is a large and voracious feeder on sweetpotato foliage. Its prominent posterior horn makes it distinctive and its colour varies from green to brown with distinct patterns. The larva is about 90 mm long and over-winters as a pupa in the soil.

A few larvae can defoliate the plant. They feed on the leaf blade, causing large irregular holes, and may eat the entire blade, leaving only the petiole. The larvae are not known to cause widespread major damage. Spray with an appropriate insecticide from the *Problem Solver Handy Guide* when necessary.

On small areas, for example nursery areas, handpicking the larvae as you see them may help reduce the population and prevent a possible serious outbreak.

Cluster caterpillar

The cluster caterpillar (*Spodoptera litura*) can cause major damage to the crop. The adult moth lays as many as 350 eggs on the underside of the leaf. The newly hatched larvae are green and congregate (cluster), turning dark brown and becoming solitary as they mature. The young larvae scrape and scarify the leaf surface. As they develop they feed on the whole leaf blade, leaving only the veins. Larvae damage both young and mature leaves and can tunnel into exposed storage roots.

Spray with an appropriate chemical from the *Problem Solver Handy Guide*. The bacterium *Bacillus thuringiensis* provides biological control and some predatory wasps, spiders and bugs have been effective.

Disease management in the field

A range of field diseases affects sweetpotatoes, but good management practices can minimise their effects. A key point to remember is that other crops (for example, tomato) and weeds (such as morning glory) can be host to some sweetpotato diseases. Weed control and careful selection of rotational crops is of prime importance.

Soil-borne diseases

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Outbreaks of soil-borne diseases can be expected in the same area year after year. The causal bacteria or fungi or both survive in soil for long periods and can be carried to new areas in contaminated soil, on implements and with water wash. The first symptom is usually wilting from damaged, inefficient root systems or a girdled stem. There are five diseases that can cause serious losses in sweetpotato.

Scurf

Scurf is caused by the fungus *Monilochaetes infuscans*. Damage is mainly confined to the storage root skin, making these roots unsaleable. Dark lesions develop on both the roots and storage roots, but are more commonly seen on the storage roots near their point of attachment to the plant. The symptoms can often be easily rubbed or scraped off and infection does not progress into the flesh. The colour of the damage can vary, depending on the variety infected. Red-skinned lines develop black symptoms, while lighter-skinned varieties usually have brown damaged areas. Scurf is more common in waterlogged crops.

Crop rotation is the main control method. The scurf fungi can persist for two years in sands and three to four years in silt loams or clay loams. Use a one-year in three rotation on sandy loams and a four to five-year rotation on heavier soil types.

Any roots showing symptoms of scurf should not be used as seed pieces in nursery beds. Vine tip cuttings from an infected crop should be washed to avoid transferring infected soil with the planting material.

Soil rot (pox)

Soil rot (pox), caused by the actinomycete (bacteria-like organism) *Streptomyces ipomoea*, stunts plants by severely damaging the fibrous root system. Infected storage roots develop black scabby lesions, often with cracks. The lesions expand fairly slowly, killing the infected part of the root. Infection can also show as above-ground symptoms of leaf yellowing, poor vigour, early flowering and occasional vine wilting.

Storage roots can become infected at any stage of development, and the extent of decay depends on when infection starts. In most instances, lesions are roughly circular and progress only a few millimetres into the flesh. The decay is dark and corky in appearance.

Low pH soils (below pH 5.2) provide some protection against soil rot, which increases with pH. It is also favoured by relatively dry soil. Crop rotation will help lower the inoculum level, but soils known to be infected should be fumigated with metham sodium.

Fusarium root rot

Fusarium root rot is caused by the fungus *Fusarium oxysporum* sp. *batatas* and possibly other species of Fusarium including *F. solani*. Root rot can cause serious storage root losses because the pathogen can move rapidly into the flesh, often causing the whole root to decay. Symptoms are an expanding, brown, superficial discolouration of the skin and a wrinkled appearance. The symptoms are initially round and sometimes develop rings of darker discolouration as the lesion expands. White fungal mycelium can sometimes be seen on the surface while, internally, the flesh becomes black as the infection advances. When cut, infected roots have cavities characteristic of *Fusarium* spp. infection.

The risk of losses to *Fusarium* spp. can be reduced by controlling nematode or soil insect damage to storage roots. It is more severe when soil moisture is low. Most recent varieties have good resistance to *Fusarium* spp.

Bacterial soft rot

Bacterial soft rot is caused by the bacteria *Erwinia* spp. Infection produces a soft, smelly, breakdown of storage roots. Infection develops in wet conditions and where the skin has been damaged. Warm weather favours field infections.

Bacterial soft rot can be a serious postharvest problem.

Sclerotium base rot

Sclerotium base rot caused by the fungus *Sclerotium rolfsii* generally affects young plants and causes a brown discolouration at ground level.

Infection is more common in warm, wet weather. The white fungus spreads over the base of the near-dead plant and is followed by the appearance of small, round, brown fruiting bodies called sclerotia, which can survive in the soil for years. Infections are usually determined by seasonal conditions described above. Though the fungus has a wide host range and sclerotes well adapted to survival, base rot is usually sporadic within and between crops.

If Sclerotium base rot was a problem in previous crops, it is likely to affect the sweetpotatoes. Do not over fertilise, particularly with nitrogen.

Management of soil-borne diseases

Avoid planting sweetpotatoes in soils high in undecomposed organic matter, which sustain a high population of these fungi. Soils for sweetpotato production must be well drained, as the incidence of soil rot losses is highest in poorly drained areas. Maintain soil structure by incorporating green manure crops, but ensure they are decomposed before planting.

In addition, avoid planting in heavily compacted soils with poor structure, slow drainage and low aeration, as these are prone to soil-borne diseases. Soil preparation for plastic-mulched beds often provides these conditions. On heavy soils prone to waterlogging, make hills higher to increase soil depth and drainage.

Use an irrigation-scheduling device, such as tensiometers or a capacitance probe, to ensure that plants are neither over-watered, causing waterlogging and low oxygen levels, nor stressed through under-watering. Young plants that are not over-watered will develop bigger root systems as they search for water, however plants should not be stressed.

Most soil-borne disease pathogens can be introduced on planting material. It is essential to plant only healthy, disease-free propagating material and prevent the introduction of pathogens in the first place. Use a crop rotation of at least three years between sweetpotato crops to reduce disease risk. Plant disease-resistant varieties, if they are available.

If soil-borne diseases occur regularly, avoid the area. Or use a fumigant, for example metham sodium, especially in seedbeds for sprout production, as part of an integrated management program. This will not eliminate all pathogens, but will reduce infections substantially if applied correctly.

Farm hygiene is important in managing soil-borne diseases. Every effort should be made to limit movement of vehicles, especially those from off-farm, onto production areas. Most soil-borne pathogens are easily transported in soil attached to vehicle underbodies and farm implements.

Nematodes

Root-knot (*Meloidogyne* spp.) and root lesion (*Pratylenchus* spp.) nematodes can be a serious problem in soils that have previously grown susceptible crops. However, the use of virgin lands does not guarantee the soil will be free of root-knot nematodes because of host weeds, grasses and some native trees, for example wattle, which can sustain root-knot nematode populations. These nematodes are also more common in light, sandy soils rather than heavy or compacted soils where movement of larvae is restricted. Crop injury is most severe in late summer, when nematodes are most active. Yield and quality are reduced.

Infested plants grow poorly, often with leaf yellowing even when nutrition is adequate. They may be stunted and wilt, despite adequate irrigation. The root-knot larvae enter the feeder roots close to the growing point and form galls or knots, disrupting vascular tissues and inhibiting nutrient and water uptake. Cutting the roots longitudinally through the galled area exposes the mature female nematodes as small, pearly white globes about the size of a pinhead.

Infested storage roots show small surface blistering and may have longitudinal cracking. Flesh under the skin may have brown spots where the female nematode has developed and deposited eggs. Immature female nematodes and larvae can be seen through a microscope.

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The female root-knot nematode may produce up to 300 eggs, which hatch within the roots and the 21 to 28-day life cycle continues, even during root storage. Tissue damage at this stage makes the storage roots more susceptible to other postharvest diseases.

Determine the presence of nematodes in the area by checking the history of the field or by examining the roots of susceptible plants for galling. If presence of nematodes is confirmed, determine whether nematicide treatment is warranted.

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Rotations with non-host crops such as Jumbo forage sorghum, or a fallow period of one year, will reduce nematode populations. Recent research has shown organic mulches (sawdust, manure, sugar cane residues) suppress nematode activity. Some varieties, such as Hernandez, are resistant to nematodes.

Monitoring for nematodes

Monitor the roots of host broadleaf weeds before the final cultivation. Monitor roots for nematodes at the end of a crop to give you an indication of the need for nematode control measures in your **next** crop. Serious damage is unlikely unless nematode levels are high.

Thorough sampling of a block at the end of the crop will provide more information than simply having soil analysed for nematodes before planting the next crop. Do not expose the samples to extremes of temperature.

This is one technique for sampling nematodes:

- Dig up plants from several areas of the block, taking care to retrieve the fine feeder roots.
- Carefully examine all roots for the presence of galls.
- The number and size of galls is an indication of the degree of root-knot nematode infestation.

Some laboratories will test soil and root samples for nematodes.

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Testing laboratories
Section 6 page 6

Foliar diseases

The severity of leaf diseases will vary markedly with weather conditions.

Foliar scab

Scab caused by the fungus *Sphaceloma batatas* has gained importance in Queensland since it was diagnosed in 1982. The disease produces small, brown, corky lesions on stems, petioles and veins on the back of the leaves. The lesions may coalesce and form scabby patches on both petioles and stems. Under severe infection, the leaves and stems become reduced and distorted, and the growing points die. Humid, wet conditions favour disease-spread.

This fungal disease is prevalent in wetter growing areas of the Atherton Tableland and also on the north Queensland coast. It has not yet been found in drier areas of the Tableland, for example Mareeba, or in south-east Queensland.

Alternaria leaf spot

Alternaria leaf spot is caused by several species of the *Alternaria* fungus. Brown, target-spot lesions develop, mainly on the older leaves. As they age, these spots dry and crack. It is unusual for this common disease to cause significant production loss. Occasionally, symptoms can develop on the vine stems and petioles and sometimes these lesions can girdle the stems. The disease is favoured by warm, humid conditions. Symptoms are more severe in low vigour crops suffering stress due to cool, wet weather or nutritional disorders.

Cercospora leaf spot

Cercospora leaf spot is caused by species of the fungi *Cercospora* and *Pseudocercospora*. This leaf spot is considered a minor disease. Symptoms are small, pale-coloured lesions with dark margins (usually circular in shape). Warm, wet weather favours infection.

Management of foliar diseases

Use clean planting material to establish the new planting. Destroy old crops and crop residues because they can provide inoculum for most foliar diseases. Good farm hygiene and weed control in a wide margin around the crop is sound practice. Make sure that dumps for reject storage roots and other crop residues will not regenerate and provide a source of infection for nearby crops. Where possible, bury reject roots.

Foliar diseases are generally not a problem when crops are grown under optimum temperature, nutrition and moisture conditions. The chance and severity of foliar scab infection can be reduced by avoiding diseased planting material and using resistant varieties.

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Centennial is highly resistant to foliar diseases, Beerwah Gold is moderately resistant, and L0-323, NC-3 and Red Abundance are susceptible.

Alternaria and Cercospora leaf spots are generally not an economic problem and plants can tolerate a degree of infection without loss of yield. There may be varieties with some tolerance to both these diseases.

If necessary use appropriate chemicals from the *Problem Solver Handy Guide.*

Diseases caused by virus and phytoplasma

Virus-like symptoms are caused by sweetpotato feathery mottle virus and a phytoplasma-like organism, sweetpotato little leaf disease. When both these diseases infect a plant, yield losses have exceeded 80%.

The virus present in infected Queensland plants often does not show symptoms. Development of symptoms is influenced by the rate of growth, plant age and weather conditions.

These diseases are spread with plant sap. They are carried from generation to generation by obtaining planting material from infected plants.

Sweetpotato feathery mottle virus

Sweetpotato feathery mottle virus is the most common virus disease of sweetpotatoes. It produces a range of symptoms including loss of vigour, leaf distortion, yellow mottling and spots (sometimes ringed with purple and chlorotic feathering along the veins, which are sometimes highlighted by purple pigment. Virus-infected plants often produce fewer or smaller (sometimes marble-sized) storage roots. Some strains of this virus cause brown, internal discolouration and corkiness.

The virus is spread by aphids feeding on the foliage. It also occurs in weeds.

Sweetpotato little leaf disease

Sweetpotato little leaf disease, caused by a phytoplasma-like organism, is common in sweetpotatoes. Symptoms may develop slowly over four to eight weeks after infection. Yields are considerably reduced when infection starts early in the life of the plant.

Infected plants show severe stunting and have an erect, bushy appearance. Shoots are often small and thin while leaves are smaller and yellow, particularly around the margins. Leaf stunting, shortening of internodes and shoot proliferation (also referred to as witches broom) are easily recognised field symptoms of this disease.

The disease is transmitted by leafhoppers during feeding. It is also moved with infected planting material that may harbour leafhopper eggs. Broadleaf weeds, such as morning glory and bellvine, as well tomatoes can carry sweetpotato little leaf disease.

Management of virus and phytoplasma diseases

Good farm hygiene, including destroying old crops immediately after harvest and control of weeds and vectors in a wide margin around the crop, is sound practice. Spray to control aphids with appropriate chemicals from the *Problem Solver Handy Guide*.

The use of virus-free mother plants or planting materials is also recommended. DPI maintains stocks of virus-free material of all commercial varieties in an insect-proof screen house. This material is field-planted each year to produce seed roots to establish nursery beds from which growers can obtain tip cuttings. We recommend that growers buy and bulk-up disease-free planting material at least once every two years.

On the farm, new material should be produced well away from previous plantings and sprayed regularly to control virus-transmitting insects.

Do not use affected plants as sources of planting material and avoid selecting planting material from an affected crop, as recently infected plants may not be showing symptoms. Symptoms will develop if infected material is planted.

Storage root problems

Erwinia soft rot

Erwinia spp. bacteria can cause soft rot infections of storage roots in the field or in storage. They enter the roots through wounds. The bacteria do not normally survive in soil for extended periods, but can exist on plant tissue or on weeds in a crop and invade storage roots before harvest.

Symptoms include softening of flesh tissue, which rapidly spreads and turns the root into a brown mush with a distinctive smell. Another form exhibits little signs of infection externally, but internal breakdown is just as rapid. In some instances, browning is confined to the vascular cells.

Warm weather favours field infections. Washing systems can infect large numbers of storage roots if the wash water becomes contaminated with bacteria. Surface damage allows entry to the pathogen so harvest and handle storage roots carefully.

Other rots

Various fungal pathogens and secondary rot organisms are associated with storage rots. Some of these may be capable of infection, but most were probably opportunistic organisms invading through growth cracks and insect damage before harvest.

Rhizopus spp. infections normally develop through wounds after harvest, as Rhizopus is an air-borne pathogen common in and around packing sheds. It produces a soft rot similar in appearance to infection by *Erwinia* spp., but with rapidly growing, grey fungal material on the root surface.

At low storage temperatures most disease progress is curtailed, but *Mucor* spp. can still produce a slow decay. It is a fairly common postharvest pathogen in several crops and produces a characteristic smell.

Management of storage root problems

Avoid fields with poor drainage. Bacterial soft rots can rapidly decompose storage roots in the field or postharvest. Keep root damage as low as possible as bacterial soft rots enter through wounds and are particularly troublesome during warm, moist weather. Harvesting in wet weather also increases the risk.

Use clean wash water. Apply a postharvest spray or dip of a registered surface sterilant to remove bacteria from the root surface. This should be done immediately after harvest followed by rapid drying and cool storage.

Disease control checklist

This checklist of disease management strategies is aimed at reducing yield losses and maximising profit in sweetpotato production (see page 96).

Disease control checklist

Pre-planting

- ❑ Field is well drained.
- ❑ Avoid fields with a history of disease.
- ❑ All old crops on farm turned in.
- ❑ Nematode assay required.
- ❑ All crop residues rotted down in proposed field.
- ❑ Pre-planting fumigation, if previous history indicates fumigation may be necessary.
- ❑ Virus weed hosts destroyed.
- ❑ Spray gear checked (new nozzles) and calibrated.
- ❑ The variety selected has resistance to diseases present, for example Centennial is resistant to scab, Hernandez to soil rot and root-knot nematode.

Establishment

- ❑ Cuttings are disease-free.
- ❑ Monitor for planting losses.

Early growth

- ❑ Be prepared to start a spray program.
- ❑ Monitor for foliar diseases and insect vectors of virus.
- ❑ Monitor fertiliser and irrigation for steady crop growth.

Storage root development

- ❑ Monitor for insect vectors of virus diseases.
- ❑ Increase surveillance of foliar diseases and reduce spray interval in wet conditions.
- ❑ Check for signs of scab, pox, scurf, base rot and soft rot.
- ❑ Maintain steady crop growth without heavy top development.

Harvesting

- ❑ Maintain foliar disease control program, paying attention to the chemical withholding period.
- ❑ Monitor roots for postharvest problems, for example symptoms of scurf, pox and soft rot; dip if necessary.
- ❑ Note position of any wilt-affected areas and determine cause.

Crop end

- ❑ Look at roots for signs of nematodes.
- ❑ Plough in and cultivate as necessary to prevent the growth of volunteer plants from roots left in the field.

Postharvest management

Careful handling and postharvest treatment of sweetpotatoes is critical to marketing top quality storage roots. You can then be confident they will not break down in the market chain.

Curing

In Australia, sweetpotatoes are marketed as a fresh vegetable. In the USA, sweetpotatoes are cured as a standard practice immediately after harvest. Storage roots are then cooled, stored and marketed as required through to the next harvest. Cured sweetpotato is not available in Australia, but it commands premium prices in the USA. Tobacco curing barns are suitable for curing sweetpotatoes.

Curing allows damaged skin on sweetpotatoes to heal rapidly, thereby preventing infection and fungal decay. It reduces shrinkage and weight loss, and improves the cooking quality by converting starch to sugars. A cured sweetpotato is sweeter than one freshly harvested and is preferred for sweet dishes.

To heal wounds you must maintain the correct temperature, high relative humidity and an adequate supply of oxygen (aeration). A temperature of 30°C and a relative humidity of 90 to 95% is optimum. Storage roots are not washed before curing.

Curing prevents the development of ugly, dark, surface scars caused by the drying and death of cells exposed by skin damage to the roots during harvest. The relative humidity in the curing and storage facility can be increased by several methods, including humidifiers. Moisture from the soil on freshly harvested roots and moisture given off by the roots will help maintain the desired relative humidity in properly constructed and insulated curing and storage rooms.

Curing rooms must be ventilated to permit carbon dioxide (produced by respiration of sweetpotatoes) to escape and be replaced with oxygen from the air. Start curing sweetpotatoes immediately after harvest.

Roots harvested when soil and air temperatures are high can be cured properly in four days, whereas those harvested when air temperatures are lower require up to seven days.

Properly cured sweetpotatoes will occasionally have sprouts 3 to 6 mm long. Roots that are over cured usually have sprouts longer than 12 mm. Skinned areas and shallow wounds heal without the affected areas becoming dark, sunken and 'scabby', if the sweetpotatoes are placed under ideal, controlled curing conditions immediately after digging. If the roots are chilled by, for example, leaving them in the field or under open sheds overnight, the healing process is slower, and decay and shrinkage increases in storage.

Cooling

Sprouts and pest and disease problems develop more slowly at low temperatures. Take storage roots to the shed or place them in the shade as soon as possible after harvesting and keep them moist. After washing and packing, cool fresh product for transport to market. Cured roots for storage are cooled dirty immediately after curing. Table 25 lists suitable conditions and maximum storage life for cured and uncured storage roots.

Table 25. *Conditions and maximum storage life for sweetpotatoes*

	Temperature	Relative humidity	Maximum storage life
Cured roots (dirty)	13 – 16°C	85 – 90%	52 weeks
Fresh roots (washed)	16 – 18°C	85 – 90%	4 weeks

The forced-air cooling system is the fastest and most efficient. It ensures uniform cooling throughout as air is passed through the bulk bin or carton, giving rapid and equal cooling. The time taken to cool storage roots depends on the capacity of the equipment installed, the amount of product and the ventilation provided in each bin or carton. With forced-air cooling, a pallet of product would take up to six hours to cool; with room cooling it could take more than 24 hours.

Seek specialist advice before buying a cold room, as there are several important design features you need to consider.

Washing and postharvest chemical treatments

When storage roots reach the packing shed they should be kept moist and are usually tipped into a water bath attached by a creep feed to the washing machine. To remove soil, high pressure water is sprayed over the roots as they pass along a series of roller brushes.

Storage root treatment

Dirty water is drained away near the end of the brushes and a spray jet system applies a chlorine wash to the storage roots. This solution is recirculated and replaced every day or during the day if it becomes dirty.

The pH of the water must be adjusted to about 6.5 to 7.5 with a food safe acidifier, for example acetic acid. At a pH above 7.5 the chlorine wash becomes less effective while below pH 6.5 the chlorine breaks down rapidly. Chlorine should be applied within three hours of harvest for best effect. After this the rot organisms may have penetrated too far into the storage roots to be controlled.

Regularly check the level of chlorine in the water with, for example, a swimming pool test kit, and add more chlorine as it dissipates. Redox meters can also be used to check chlorine levels. If the water becomes dirty, replace it to reduce root infection and staining. Dirty water also causes rapid breakdown of chlorine.

Calcium hypochlorite is registered for the control of bacterial and fungal organisms. These organisms can cause root breakdown throughout the handling and marketing system. This breakdown may be fungal (Rhizopus rot) or bacterial soft rot. The *Problem Solver Handy Guide* lists the appropriate postharvest treatments.

more info: Postharvest treatments *Problem Solver Handy Guide*

Use screens to separate the wash section of the equipment from the treatment area, so that water does not dilute the mix. Insertion rubber split into 25 mm strips is effective. A slower brush speed and sponge rollers to absorb the water will also reduce dilution.

Use sponge rollers and an air fan to dry storage roots before packing to prevent build-up of rot organisms on the moist roots.

Shed hygiene

Clean shed equipment, floors, surrounds, cold rooms and harvesting equipment and bins regularly to reduce the chance of storage root infection from these sources. Chlorine solutions are effective but corrode metal equipment and some rubber compounds. Quaternary ammonia compounds are also effective and non-corrosive.

How to calibrate a boom spray

To ensure good plant coverage by chemicals it is important that the spray equipment being used is calibrated to apply the correct amount of chemical accurately where it is needed. Most sprays fail because the chemical was not applied correctly.

Introduction

Before calibrating a boom spray it is important that you fully consider your target. If, for example, your target is sweetpotato weevil around the crown of the plant you will need high volumes of spray to penetrate the foliage. It should be directed over the hill at the crown. For a mature crop sprayed with a boom spray up to 2000 L/ha is applied, depending on the density of the foliage. One method of calibrating a boom spray is given here.

These calibration methods are a guide to ensuring that the equipment is performing correctly. The equipment should initially be set up by someone experienced in setting spray equipment for sweetpotato crops. They will help you select the type of equipment needed (pump, diameter of hoses, type of nozzles) and general setting up of the equipment to protect your crop adequately. The nozzles are usually set up so that the spray pattern overlaps the next nozzle by at least one-third.

Before calibration, measure the output of each nozzle for a set time, for example 30 seconds, and discard any nozzle that varies more than 10% from the others. You will need a good quality, oil-filled, pressure gauge to get accurate pressure readings. When calibrating set the gauge at the pressure you will be using for spraying. More information is available in the DPI book *Pesticide Application Manual*.

Boom spray without droppers

To calibrate a boom spray without droppers use the following method.

To find the volume of spray applied per hectare you need to know the total output of your nozzles and the time it takes to cover 1 ha, that is:

Volume per hectare = output X time to cover 1 ha

Step 1

Output = either the total output of all nozzles

OR

Average output multiplied by the number of nozzles

For example: If your spray rig has 20 nozzles (four spraying over each of five rows), with an average output of 3 L per minute, then:

Output per minute = 20 X 3 = 60 L/minute

Step 2

Calculate the effective spray width (swath) of the boom.

Swath width (m) = number of rows X row spacing (m)

For 10 row lands you spray five rows at a time, so if rows are 1.2 m apart, then:

Swath width (m) = 5 X 1.2 = 6 m

Step 3

To determine the time to cover 1 ha you need to know the swath width (from Step 2 above) and the time to cover 100 m. Mark out 100 m and note how long it takes the tractor to travel 100 m in the gear and engine revolutions you will be using when spraying.

Step 4

$$\text{Time to spray 1 ha} = \frac{\text{10 000 (sq. m /ha) X time to cover 100 m}}{\text{swath width X 100}}$$

Divide this figure by 60 to get the time per hectare in minutes.

For example: If swath width = 6 m (from Step 2) and time per 100 m (Step 3) = 90 seconds then:

$$\text{Time to spray 1 ha} = \frac{\text{10 000 X 90}}{\text{6 X 100}} = \text{1500 seconds}$$

Divide this by 60 = 25 minutes per hectare

To work this out using a calculator: 10 000 X 90 = 900 000; divide by 6 = 150 000; divide by 100 = 1500 seconds; divide by 60 = 25 minutes per hectare.

Step 5

Volume of spray per hectare = output per minute (Step 1) X time in minutes to cover 1 ha (Step 4).

From the examples above:

Volume of spray per hectare = 60 X 25

Volume/ha = 1500 L/ha

Amount of chemical per tankful

To determine the amount of product to put into the tank, use these calculations.

Rate of product per hectare:

$$\frac{\text{Tank capacity (L) X recommended rate of product (L/ha or kg/ha)}}{\text{application rate (L/ha)}}$$

Example:

$$\frac{3000\text{ (L) X 2.2 (L or kg/ha)}}{1500\text{ (L/ha)}} = 4.4\text{ (L or kg)}$$

OR

Rate of product per 100 L:

$$\frac{\text{Tank capacity (L) X recommended rate of product (L or kg /100 L)}}{100}$$

Example:

$$\frac{3000\text{ (L) X 0.2 (L or kg/ 100 L)}}{100} = 6\text{ (L or kg)}$$

Alternatives to methyl bromide

The continued use of methyl bromide, the main soil fumigant used in sweetpotatoes, is under threat. Many questions are being asked about its future and the alternatives available. Here are the main points you need to know.

The immediate problem with methyl bromide

Gases such as chloroflurocarbons (CFCs) and other halons, and the bromine from methyl bromide, are attacking and breaking down the ozone layer in the atmosphere. This destruction of the ozone layer will, amongst other things, increase the risk of skin cancer, particularly in countries like Australia. As a result, Australia is part of an international effort to reduce bromine emissions.

This is being implemented through Australia's involvement as one of 149 nations that are signatories to an international agreement called the *Montreal Protocol on Substances that Deplete the Ozone Layer*. Through this Protocol, it was agreed in 1995 to phase out the use of methyl bromide in Australia by 2005. The Commonwealth Government is progressively restricting import of methyl bromide over the period to 2005. This policy is being administered by the Federal Government agency, Environment Australia.

Pros and cons of methyl bromide

These are the main advantages of methyl bromide.

- It has provided a reliable and consistently effective soil treatment in a wide range of soil types and environments.
- Its broad spectrum of activity means it can be used as an effective insurance against a range of diseases, pests and weeds.
- Specialised equipment makes it relatively easy to apply.
- It dissipates from soil relatively quickly. In warm, moist soil crops can be planted as soon as three to four days after treatment.
- It produces what is known as 'a non-specific fumigation response'—a

plant growth response which is often beneficial but is not well understood.

Besides its ozone depletion problem, methyl bromide has some other important problems.

- It may leak into groundwater. Methyl bromide has been banned in The Netherlands because of this problem.
- Its wide spectrum of activity means methyl bromide may also kill beneficial soil organisms and mycorrhiza. Although the short-term effects may be minimal, the long-term effects on soil fertility and structure are still largely unknown.
- As methyl bromide is a highly toxic and dangerous gas, it needs to be applied by experienced operators under carefully managed conditions.

Possible alternatives

The range of possible alternatives for methyl bromide is shown in Tables 26 and 27. Some are practical alternatives; some are still highly theoretical and are only included to give a complete picture. Research is progressing to assess alternatives.

Table 26. *Chemical alternatives to methyl bromide*

Chemical	Effective against			Current status
	Diseases	Nematodes	Weeds	
Metham sodium	✔	✔	✔	Cheaper and easier to apply than methyl bromide. Effective, but not as effective as methyl bromide. Requires more accurate placement or irrigation water to spread it through the soil. Limited by 2 to 3-week plant-back period. Most effective when applied under plastic sheeting.
Basamid	✔	✔	✔	Effective, but very costly. Limited by 2 to 3-week plant-back period. Most effective when applied under plastic sheeting.
Chloropicrin	✔	✔		Excellent disease control but poor weed control. Limited by 6-week plant-back period. Has very objectionable odour. Sold only as a mix with methyl bromide.
Fungicides	✔			Effective against some specific diseases, but limited by cost, potential disease resistance and rapid degradation in soil.
Nematicides		✔		Effective against nematodes and some soil insects. Problems include high mammalian toxicity, potential to contaminate groundwater and rapid degradation in soil.
Herbicides			✔	Problems include cost of application and potential for crop damage.

Table 27. Non-chemical alternatives to methyl bromide

Chemical	Effective against			Current status
	Diseases	Nematodes	Weeds	
Steam/hot water	✔	✔	✔	Effective but cost seriously limits usefulness.
Soil solarisation	✔	✔	✔	Effective in some situations, but limited by cost, climate and season.
Resistant varieties	✔	✔		Tolerance levels vary and tend to be specific in existing varieties. Best medium to long-term solution.
Cultivation			✔	Limited application for weeds only.
Crop rotation	✔	✔	✔	Effective against some problems. Limited by amount of land available.
Organic treatments	✔	✔		Beneficial in improving soil fertility. Limited by cost, reliability and lack of information.
Biofumigation	✔	✔		Beneficial in improving soil fertility. Recent trials indicate some potential.
Biological control	✔	✔	✔	Specific to certain problems. Limited practical applications to date.
Artificial soil	✔	✔	✔	Limited to hydroponic systems.
Irradiation	✔	✔		Limited by practicality and cost.
Quarantine and use	✔	✔		Useful only against problems of clean planting materialtransported on planting material.

Tables 26 and 27 indicate that practical alternatives to methyl bromide are limited at this stage. No other registered or existing chemical has the same attributes as methyl bromide, so there is no easy shift to another chemical. Research indicates that a mixture of chloropicrin and another fumigant may be a practical solution. Some growers consider metham sodium as the only current alternative, but it is doubtful if this represents a long-term solution. The past 20 years has seen the demise of five or more fumigants—current ones may also go the same way.

Future strategies for the grower

Here are some strategies that may be worth considering.

Mixtures and application rates. In the short-term while methyl bromide is being phased out, you may find that the 70:30 and 50:50 mixtures of methyl bromide and chloropicrin are as effective as methyl bromide alone. Also, you might like to experiment with reduced application rates, particularly if you are fumigating sandy soils or if your target is nematodes rather than fungal diseases. The use of less permeable plastic will allow you to get the same result with less methyl bromide.

Why are you using methyl bromide? This is a necessary question as methyl bromide has been used widely as a general insurance against many problems, in some cases even when the problem didn't exist. Identify your main target problems before you first started to use methyl bromide. You can then decide on the alternatives.

Soil fertility. Think of your soil not as an inert medium to support the plants, but rather as a living fertile system in which soil bacteria, mycorrhiza, earthworms and other soil micro-organisms interact with nutrients and organic matter. This is important, as no single approach will probably provide an effective alternative to methyl bromide. The answer will lie in choosing a combination of complementary approaches.

Management of problems. Alternatives to methyl bromide will require more sophisticated management of pest, disease and weed problems. You will need to understand the problems better, diagnose them more accurately, properly select appropriate control measures and integrate these into an effective and compatible program.

Try the alternatives. Study the alternatives to methyl bromide, talk to experts and get their advice on your problems. While methyl bromide is still available, experiment on your farm by comparing the alternatives with methyl bromide. Remember to leave some untreated soil for comparison.

Other production systems

An alternative production system that potential sweetpotato growers may consider is organic production. There is an increasing demand for organically grown produce in Australia and overseas. The following notes provide a basic outline of key issues for potential producers. A list of information sources and contacts is in Section 6.

Growing sweetpotatoes organically

Do some extensive market research to determine the size of the organic market and the prices you can realistically receive for your produce, particularly if it is not of the highest quality. The often-reduced quality and yields from organic production systems may not be offset by the higher prices that may be received.

Organic production of sweetpotatoes is difficult because of the number of pests and diseases that affect sweetpotatoes and their susceptibility to these problems. Virgin ground, isolation from major production areas and quarantine restrictions for entering the planted area would be desirable.

Producing crops organically is usually understood to mean production without using synthetic chemicals. The philosophy of organic agriculture, however, is much more than that. Organic production systems are designed to produce high quality food while enhancing soil health, recycling organic wastes, increasing crop diversity and not relying heavily on external inputs. Organic production, therefore, seeks to protect the environment by working with rather than dominating the natural system.

Organic production is not a low input production system, as the reduced use of chemicals and other external inputs need to be offset by a higher level of management skills. Increased costs will be incurred for labour, alternative methods and materials to control pests, diseases and weeds, and to provide adequate nutrients.

HINT
For grower associations and organic web sites, refer to Section 6 pages 3 and 32.

To maximise market advantage, organic producers should seek organic accreditation with one of Australia's organic organisations:

- Biological Farmers of Australia
- National Association for Sustainable Agriculture
- Bio-Dynamic Agricultural Association of Australia
- Organic Federation of Australia
- Organic Retailers and Growers Association of Australia.

more info
Where to get this book
Section 6 page 27

The booklet *Organic Agriculture—Getting Started* by David G. Madge is an excellent information source for prospective organic producers and well worth reading.

Some points to consider in organic production

Production timing is critical to but does not ensure success. Sweetpotatoes grown vigorously under optimum warm weather are more tolerant of pests and diseases. Cool weather with heavy dews and fogs will increase the risk of some diseases. Pests are generally less active in cool conditions.

Crop rotation with other unrelated crops is important to managing disease and weed problems. Income derived from organic production needs to be spread over several different crops. This will reduce the adverse economic effects of a crop loss from pests, weeds or diseases that can be beyond the control of the organic farmer.

Monitor crops regularly for diseases and insect pests to help prevent problems. This is particularly important for managing mites, silverleaf whitefly, sweetpotato leafminer and sweetpotato weevil, all of which can cause major problems, particularly in warm weather.

more info
Pest management in the field
This section page 81

There are few effective organic control measures for pests and diseases of sweetpotatoes. Crop rotation and good farm and crop hygiene practices can help to reduce risks of pest and disease outbreaks.

Organic growers need to be aware of the natural predators of aphids and other insects.

Organic fertilisers (minerals, manures and compost) are in effect slow release fertilisers, with nutrients being released over some months. Their speed of availability is largely influenced by temperature and moisture availability. Sweetpotatoes are a fairly quick-growing crop and shortfalls or excessive levels of nutrients, particularly nitrogen, will affect crop quality. It is more difficult to fine-tune nutrient supplies to the crop with organic fertilisers than conventional ones.