Brassica information kit

Reprint – information current in 2004

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 2004. We advise readers to take particular note of the areas most likely to be out-of-date and so requiring further research: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- Financial information—costs and returns listed in this publication are out of date.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 2004. The information is not current and the accuracy of the information cannot be guaranteed by the State of Queensland.

Queensland Government

Chapter 4

Key ISSUES

This chapter contains more detailed information on some of the important decision making areas and information needs for brassica growers. The information supplements our growing, harvesting and marketing guide in Chapter 3 and should be used in conjunction with it. Where additional information may be useful, we refer you to other parts of the handbook. 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
- Increase returns
- Reduce costs
- The key to profit

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 units of product you sell.

Price received

The price received for broccoli, cauliflower and cabbage is influenced by the:

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

Product quality

Quality is about providing a product that meets customer needs and expectations. Six factors determine the quality of cabbage, cauliflower and broccoli:

- **Freshness.** Apart from price, freshness is probably the most important quality characteristic for cabbage, cauliflower and broccoli. The product must appear fresh and crisp, as though freshly harvested, without a hint of yellowing or wilting.
- **Colour.** This can vary somewhat depending on the market supplied and intended use of the product. In general, product should be of an even colour with best prices paid for dark green broccoli with a bluish hue, pure white cauliflower curds and fresh green cabbage heads (or deep reddish purple in the case of red cabbage). Check to ensure that you meet the colour characteristics required by a particular market.
- **Size and shape.** As with colour, the preferred size and shape of heads can vary with specific markets, so check requirements, particularly if exporting. Heads should be compact and heavy for their size. Cauliflower curds and broccoli heads should be dome shaped with an even surface texture. Broccoli heads should have small, evenly sized buds (beads). The amount of 'trimming' required can also vary with specific markets. Check with your wholesaler on, for example, the amount of outside leaf cover to leave on cabbage or cauliflower heads or the preferred stem length for broccoli heads.
- **Cleanliness and appearance.** The best prices are paid for heads that have a clean, fresh appearance. Marks, blemishes and insect damage detract substantially from appearance. A customer's decision to buy is mainly influenced by the external appearance of most fruit and vegetables. The product must look inviting for consumers to place it in their shopping trolley.
- **Flavour and texture.** Product must be crisp with no off flavours. While people tend to 'buy with their eyes', if consumers take your product home and its eating performance does not match their expectations, they will not return to buy your product. Your customers will lose repeat business. People are now consuming increasing amounts of gourmet foods, and preparing and eating food is a fashionable pastime, so flavour and texture will become increasingly important.
- **Soundness and shelf life.** The best prices are paid for product that is sound (free from damage, cuts, bruises and rots) and stored properly to maximise shelf life. Any damage allows moisture loss and entry of breakdown organisms. A common measure of soundness used by consumers is firmness and colour; a soft, wilted, yellowing product is seen as not fresh.

The above quality characteristics are influenced by a number of preharvest and postharvest management practices, some more important than others.

Product quality is, in the first instance, determined by how well the crop is grown. This includes decisions about varietal selection, land preparation and planting and the effectiveness of nutrient, irrigation, pest and disease management practices. Harvest timeliness, harvesting techniques and postharvest handling practices associated with cooling, grading, packing, storage and transport of the product cannot improve on the inherent quality of the product but only maintain it.

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 opportunities. This includes determining your potential competitors and when their product reaches the market.

The role of the central markets is diminishing as the major retailers now dominate the sales of fruit and vegetables. 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.

a key issue
Business management
This chapter page 96

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 assurance 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.

a key issue
Quality assurance and food safety
This chapter page 104

Volume sold

The other way of increasing returns is to increase the volume of marketable heads, cartons or ice packs 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 product grown and the demand for it on the market. Customer demand can be affected by the volume of cabbage, cauliflower or broccoli on the market; the price, the weather and the alternative or substitute products available.

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 your major costs are.

a key issue
Economics of Production
This chapter page 81

Typical costs of producing brassica crops in south-east Queensland are shown in Tables 17, 18 and 19. These are based on the gross margin examples on pages 87 to 95 in this chapter.

Table 17. Example costs of producing and marketing a winter crop of cabbage yielding 16 000 heads per hectare and sold in fibreboard bulk bins at $1 per head on the Brisbane market.

	$ per head	$ per hectare
Total growing costs	0.22	3 520
Total harvesting and packing costs	0.37	5 920
Total marketing costs	0.25	4 000
Total variable costs	**0.84**	**13 440**

Table 18. Example costs of producing and marketing a winter crop of cauliflower yielding 1700 cartons per hectare and sold at $12 per carton on the Brisbane market.

	$ per carton	$ per hectare
Total growing costs	2.77	4 709
Total harvesting and packing costs	5.61	9 537
Total marketing costs	2.35	3 995
Total variable costs	**10.73**	**18 241**

Table 19. Example costs of producing and marketing a winter crop of broccoli yielding 900 ice packs per hectare and sold at $16 per ice pack on the Brisbane market.

	$ per icepack	$ per hectare
Total growing costs	4.75	4 275
Total harvesting and packing costs	6.66	5 994
Total marketing costs	2.50	2 250
Total variable costs	**13.91**	**12 519**

Cost reduction often has only a limited impact on overall profitability. As the examples above show, the majority of costs are associated with harvesting, packing and marketing. It is difficult to reduce these costs significantly without affecting quality. Streamlining operations and increasing mechanisation to minimise labour cost, especially for harvesting and packing, may reduce costs but requires a large capital investment. Increasing yields may reduce growing and some harvesting costs but will have little impact on the cost of marketing and packing the product.

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 consistently.

It is critical for doing business in the brassica vegetable 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 vegetable market is very fickle.

Economics of production

One way of assessing the economics of brassica production is by calculating the gross margin for the crop. A gross margin is gross income minus variable costs. Gross margins are useful tools for farm budgeting or for estimating likely returns or losses on a crop. Gross margins are not a measure of farm profit as fixed and capital costs are not included in the calculations.

- Introduction
- Farm profitability
- Assumptions made in gross margin examples
- Example gross margins for winter cabbage, cauliflower and broccoli

Introduction

To be a successful brassica grower, you must not only grow a high quality product consistently but also market your product at a price that will make a profit. The topic *Keys to making a profit* in this chapter gives an overview of the key elements in achieving maximum profits.

An important factor in maximising profits is a sound understanding of the potential costs and returns of growing and marketing the crop. Gross margins are commonly used to estimate likely returns or losses of growing small crops, however fixed and capital costs also need to be considered when looking at overall farm profitability. Farm profitability is influenced by equity, debt levels and cash flow required, as these impact on business flexibility and the financial risks associated with growing brassica crops.

a key issue

Keys to making a profit
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Glossary of terms

The following terms are used in the cost 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. Gross margins are not a measure of farm profit, as they do not include capital costs or fixed costs. They do provide a useful tool in terms of farm budgeting and estimating the likely returns or losses of a particular crop.

Variable or operating costs. These costs include the growing, harvesting and marketing costs for the crop. They typically include all costs which vary with the area of crop grown.

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.

Sensitivity analysis. Calculating gross margins using various yields and prices to estimate likely returns or losses on a crop.

Fixed or overhead costs. Costs that typically do not vary with the number of hectares of crop grown. Fixed costs are not included in gross margins, but must be taken into account in calculating a whole farm budget.

Capital costs. The cost of land, buildings, plant, machinery and equipment. Interest on investment or money borrowed to purchase these items can be used to estimate the cost of capital investments.

Equity. The difference between farm assets and farm liabilities – the part of the business that you own.

Equity percentage. The ratio between equity and total assets.

Farm profitability

A lot of attention is given to input costs which are easily identified, can be allocated to a particular crop and need to be included in a gross margin, for example, fertiliser, chemicals, casual labour. Fixed and capital costs are not always considered by farm business managers when assessing profitability, as these costs are much harder to calculate. However, to ignore these costs can lead to financial disaster or a least an erosion of capital.

Gross margins

Gross margins are a useful for estimating likely returns or losses, particularly in relation to other small crops that you may be considering. They are also useful for farm budgeting purposes. A gross margin is gross income minus variable costs. It does not include fixed and capital costs. Gross margins are a good starting point for making economic decisions but they have some major limitations.

- Example gross margins must be modified to suit your particular situation. Realistic estimates of marketable yields, prices and costs must be made. This can be difficult for first time vegetable growers.

- Prices can vary a great deal from year to year and yields are sensitive to adverse weather conditions. Calculating gross margins using various yields, prices and costs can be a useful exercise in illustrating the riskiness of growing brassica crops. This method of assessing likely returns or losses using variations in price and yield is called a sensitivity analysis.
- While the cost of casual labour for transplanting, harvesting, packing etc. is usually included in the gross margin, owners often do not include the cost of their own labour in the overall cost of production. Are you prepared to work for nothing?

Sensitivity analyses examples are given at the end of each of the gross margins for cabbage, cauliflower and broccoli on pages 87 to 95.

Fixed or overhead costs

Fixed costs typically do not change with the number of hectares of crop grown. They usually include rates, vehicle registration, interest, leasing costs, electricity, insurance, administration costs, permanent labour and living expenses (the salary of the farm owners). These costs can be difficult to allocate to a specific crop unless good records are kept. They are commonly around 10% of the variable costs of the gross margin.

Capital costs and equity

If you need to borrow a large amount of capital to set up and start brassica production, you will be paying interest on loans, overdrafts or other types of credit. An alternative may be to lease land, plant and equipment or use contract services for transplanting, harvesting, cooling and packing. Calculating capital costs is a complex process and the following example provides a very simplistic method for starting to think about capital costs.

Brassica crops are often produced on prime land with extensive irrigation equipment. This type of land will typically cost $10 000 or more per hectare. Assuming a rate of 10% interest only, if a brassica crop ties up the land for half the year, the cost of land will be $500 per hectare of brassica crop grown.

Good machinery and equipment are not cheap. Assuming that the minimum required for producing 20 ha of brassica crop is two tractors, overhead irrigation pipes, transplanter, cultivation tools, fertiliser spreader, boom sprayer and fork-lift, $150 000 will be spent very quickly. Again, using a 10% interest rate, capital costs of plant and equipment will be $15 000 per year. If half of this cost is allocated to producing 20 ha of brassicas, then machinery and equipment will cost $375 per hectare of crop grown.

According to the above simplistic calculations, the capital cost to provide the basics of land, machinery and equipment would cost $875 per hectare of brassica crop grown. Capital costs vary from farm to farm depending on the cost of capital, the cost structure of the business, the type of plant, machinery and equipment used, land values and cropping mix. You will need to calculate these costs for your own business.

An example of total costings

Experienced vegetable growers aim to allocate most fixed and capital costs to specific crops in order to obtain an estimate of total production costs per unit of product. For example, by using contract labour and leasing land, plant and equipment, these growers are able to more accurately calculate total costings on a per head, bin, carton or ice pack basis.

Using the gross income from the cabbage gross margin on page XX and the simplistic fixed and capital cost calculations outlined earlier, a market price of $1 per head and a marketable yield of 16 000 heads per hectare would give a net profit of approximately $0.02 per head (Table 20). Remember also that it will take several months from transplanting to first harvest. Additional capital will be required to finance this gap in cash flow.

Table 20. Total costings example for a winter cabbage crop yielding 16 000 heads per hectare and sold at $1 per head market price.

	Totals ($)	
Costs and returns	**per head**	**per hectare**
Gross margin	0.16	2526
less:		
Fixed costs - 10% of variable costs	0.08	1347
Capital costs - 10% interest on land, plant, equipment	0.06	875
Net profit	**$0.02**	**$304**

Equity

Equity is the difference between what you own to the money borrowed. A profitable business will build equity over time while a business making a loss will erode its equity. Equity gives an idea of the level of risk and the likelihood of being able to meet financial commitments. It is often expressed as a percentage.

Table 21 shows common ratios used to describe equity. For example, if your farm is worth $1.2 million, your debt on the farm is $120 000 and you need to borrow $120 000 to get into brassica production, your equity position will be 80%. You are therefore in a relatively strong position.

Table 21. Common ratios used to describe equity

	Equity
Strong	80 – 100%
Damaged	60 – 80%
At risk	40 – 60%
Critical	Less than 40%

Some other financial performance indicators that you need to consider when assessing the financial health of your business are:

1 Debt to equity ratio
2 Return on assets
3 Net cash flow required.

If you are in a weak financial position, you are in a poor position to take risks. Brassica production is a capital intensive, high-risk business.

Assumptions made in example gross margins

The following gross margins are for transplanted cabbage, cauliflower and broccoli crops grown in the Lockyer Valley during the main production period in winter with product sold through the Brisbane market.

To illustrate variations in harvesting and marketing, three gross margin scenarios are presented:

- Cabbage harvested into bins and sold on a per head basis
- Cauliflower packed into cartons in field using a harvest aid and contract labour
- Broccoli cut into bins using a harvest aid then cooled before packing into ice packs

These are common methods of harvesting and marketing each of these crops but there are other possibilities, for example, cauliflower may be sold on a per head basis, broccoli may be sold by the kilogram and sugarloaf cabbage may be packed into cartons. Transplanting, harvesting, cooling and packing operations can be contracted out for all three crops.

The gross margin calculations make the following assumptions:

- Quality container grown transplants are bought from a seedling nursery and the crop is grown with good management and overhead irrigation.
- There is access to a reliable pool of casual labour. Labour rates are based on the current rural award for casual workers of $13.26 plus 10% on costs for superannuation and workcover. To keep good people you may need to pay above the award rate. No allowance has been made for the cost of organising and managing staff or workplace health and safety requirements.
- All machinery operations include costs of fuel, oil, repairs and maintenance (F.O.R.M.). An allowance for labour costs to operate machinery is included separately using the current rural award for

casual labour. Land preparation costs vary depending on factors such as soil condition, size of the enterprise and type of equipment used.

- No allowance has been made for quality assurance costs associated with growing, harvesting and marketing the crop.

Disclaimer

The gross margins that follow do not represent district gross margins but are provided as examples only. All data included in these gross margins are based on information provided to the authors and no responsibility can be taken for their accuracy.

Gross margins must be modified for your particular situation and data should be confirmed and changed where necessary by the user before any decisions based on the results are made. So as to enable you to more easily identify differences between your particular situation and the assumptions we have made in our example gross margins, we have included detailed information on our workings and the data we have used in our calculations.

Winter cabbage–gross margin example for the Lockyer Valley

Note: all costs are rounded to the nearest cent

GROSS INCOME	Yield heads /ha	Market price per head	Total $/ha
	16000	$1.00	$16000.00

VARIABLE GROWING COSTS	Amount /ha	$/unit	$/ha	Total $/ha
Land preparation (F.O.R.M.)				
Deep ripping	1 x 3 hrs	13.00 /hr	39.00	
Offset discs	2 x 1.5 hrs	13.50 /hr	40.50	
Power harrows (or rotary hoe)	1 x 2.8 hrs	14.50 /hr	40.60	
Light cultivation	1 x 0.7 hrs	12.00 /hr	8.40	
Bedforming	1 x 1.5 hrs	8.00 /hr	12.00	
Casual labour	11 hrs	14.60 /hr	160.60	
TOTAL LAND PREPARATION COSTS				**$301.10**
Planting				
Cabbage seedlings (average yield is 80% of plant density)	20 000	0.06 each	1200.00	
Tractor and transplanter (F.O.R.M)	4 hrs	8.00 /hr	32.00	
Casual labour (a team of 4 plant 5000 plants/hr)	16 hrs	14.60 /hr	233.60	
TOTAL PLANTING COSTS				**$1465.60**
Fertiliser				
CK77(S)	1 x 400 kg	0.63 /kg	252.00	
Nitram	2 x 125 kg	0.65 /kg	162.50	
Solubor	2 x 0.75 kg	2.40 /kg	3.60	
Sodium molybdate	2 x 0.18 kg	33.00 /kg	11.88	
Soil analysis (4 ha per test)	0.25	90.00 /test	22.50	
Apply pre-plant fertiliser (F.O.R.M.)	1 x 1 hr	8.00 /hr	8.00	
Sidedress (F.O.R.M.)	2 x 0.5 hrs	8.00 /hr	8.00	
Spray micronutrients (F.O.R.M.)	2 x 0.5 hrs	12.00 /hr	12.00	
Casual labour	3 hrs	14.60 /hr	43.80	
TOTAL FERTILISER COSTS				**$524.28**
Weed control				
Goal	1 x 1.5 L	40.67 /L	$61.01	
Sprayer (F.O.R.M.)	1 x 0.5 hrs	12.00 /hr	$6.00	
Casual labour (chipping & spraying)	5 hrs	14.60 /hr	$73.00	
TOTAL WEED CONTROL COSTS				**$140.01**
Insect control				
Dipel WG	6 x 0.75 L	64.12 /L	288.54	
Regent	1 x 0.25 L	418.39 /L	104.60	
Success	1 x 0.4 L	170.92 /L	68.37	
Crop monitoring (4 ha per hour)	20 x 0.25 hrs	55.00 /hr	275.00	
Sprayer (F.O.R.M.)	8 x 0.5 hrs	12.00 /hr	48.00	
Casual labour	4 hrs	14.60 /hr	58.40	
TOTAL INSECT CONTROL COSTS				**$842.91**

Winter cabbage *(continued)*

VARIABLE GROWING COSTS	Amount /ha	$/unit	$/ha	Total $/ha
Disease control				
Copper oxychloride	2 x 2 kg	4.73/kg	18.92	
Sprayer (F.O.R.M.)	2 x 0.5 hrs	12.00 /hr	12.00	
Casual labour	1 hrs	14.60 /hr	14.60	
TOTAL DISEASE CONTROL COSTS				**$45.52**
Irrigation				
Water Charges	4 ML	29.00 /ML	116.00	
Power: single pumped (40 L/sec using 30 kW pump at $0.10 /kW hr)	4 ML	20.83/ML	83.33	
Pump repairs and maintenance	4 ML	16.00/ML	64.00	
TOTAL IRRIGATION COSTS				**$263.33**
TOTAL GROWING COSTS			**$0.22/head**	**$3582.75**

VARIABLE HARVESTING and MARKETING COSTS		$/unit	$/bin	Total $/ha
Harvesting and packing				
Octa bin (125 heads/bin)	128 bins/ha	20.00/bin	20.00	2560.00
Casual labour (team of 4 cut 3 bins/hr)	1.3 bins/hr	14.60/hr	18.98	2429.44
Cooling		5.00/bin	5.00	640.00
Tractors, trailer, forklift (F.O.R.M.)	3 bins/hr	8.00 /hr	2.67	341.76
TOTAL HARVESTING and PACKING COSTS		**$0.37/head**	**$46.65/bin**	**$5971.20**
Marketing				
Freight to Brisbane (125 heads/bin)		0.12/head	15.00	1920.00
Commission/levies (12.5 % of market price)		0.13/head	15.63	2000.00
TOTAL MARKETING COSTS		**0.25/head**	**30.63/bin**	**3920.00**
TOTAL HARVESTING and MARKETING COSTS		**$0.62/head**	**$77.28/bin**	**$9891.20**

Summary table

	$/head	$/ha
Total growing costs	0.22	3858
Total harvesting and packing costs	0.37	5971
Total marketing costs	0.25	3920
TOTAL VARIABLE COSTS	**$0.84**	**$13474**

Gross margin = Total income less total variable costs

	$/head	$/ha
Total income (16 000 heads/ha)	1.00	16000
Less total variable costs (rounded)	0.84	13474
GROSS MARGIN	**$0.16**	**$2526**

Winter cabbage *(continued)*

BREAK EVEN YIELD at a market price of $1.00/ head	9383 heads /ha
BREAK EVEN MARKET PRICE (16000 heads/ha)	$0.82 /head
BREAK EVEN ON FARM PRICE (16000 heads /ha)	$0.60 /head
GROSS MARGIN per MEGALITRE of irrigation water	$633 per ML

Actual gross margin when price or yield changes (sensitivity analysis)

		Price per head				
Yield	**Heads/ha**	**Low $0.60**	**$0.80**	**Medium $1.00**	**$1.20**	**High $1.40**
Low	14000	($3180)	($730)	$1720	$4170	$6620
	15000	($3127)	($502)	$2123	$4748	$7373
Medium	16000	($3074)	($274)	$2526	$5326	$8126
	17000	($3021)	($46)	$2929	$5904	$8879
High	18000	($2968)	$182	$3332	$6482	$9632

Enterprise characteristics

1. growing risk	medium
2. price fluctuations	high
3. working capital requirement	medium
4. harvest timeliness	medium/high
5. management skills	medium
6. spray requirements	medium/high
7. labour requirements – growing	low
8. labour requirements – harvesting	medium

Last update: January 2004

Winter cauliflower— gross margin example for the Lockyer Valley

Note: all costs are rounded to the nearest cent

GROSS INCOME	Yield cartons /ha	Market price per carton	Total $/ha
	1700	$12.00	$20 400

VARIABLE GROWING COSTS	Amount /ha	$/unit	$/ha	Total $/ha
Land preparation (F.O.R.M.)				
Deep ripping	1 x 3 hrs	13.00 /hr	39.00	
Offset discs	2 x 1.5 hrs	13.50 /hr	40.50	
Power harrows (or rotary hoe)	1 x 2.8 hrs	14.50 /hr	40.60	
Light cultivation	1 x 0.7 hrs	12.00 /hr	8.40	
Bedforming	1 x 1.5 hrs	8.00 /hr	12.00	
Casual labour	11 hrs	14.60 /hr	160.60	
TOTAL LAND PREPARATION COSTS				**$301.10**
Planting				
Cauliflower seedlings (average yield is around 70% of plant density)	24 000	0.10 each	2400.00	
Tractor and transplanter (F.O.R.M)	5 hrs	8.00 /hr	40.00	
Casual labour (a team of 4 plant 5000 plants/hr)	20 hrs	14.60 /hr	292.00	
TOTAL PLANTING COSTS				**$2732.00**
Fertiliser				
CK77(S)	1 x 400 kg	0.63 /kg	252.00	
Nitram	2 x 100 kg	0.65 /kg	130.00	
Solubor	2 x 0.75 kg	2.40 /kg	3.60	
Sodium molybdate	2 x 0.18 kg	33.00 /kg	11.88	
Soil analysis (4 ha per test)	0.25	90.00 /test	22.50	
Apply pre-plant fertiliser (F.O.R.M.)	1 x 1 hr	8.00 /hr	8.00	
Sidedress (F.O.R.M.)	2 x 0.5 hrs	8.00 /hr	8.00	
Spray micronutrients (F.O.R.M.)	2 x 0.5 hrs	12.00 /hr	12.00	
Casual labour	3 hrs	14.60 /hr	43.80	
TOTAL FERTILISER COSTS				**$491.78**
Weed control				
Goal	1 x 1.5 L	40.67 /L	61.01	
Sprayer (F.O.R.M.)	1 x 0.5 hrs	12.00 /hr	6.00	
Casual labour (chipping & spraying)	5 hrs	14.60 /hr	73.00	
TOTAL WEED CONTROL COSTS				**$140.01**
Insect control				
Xentari	4 x 0.75 kg	74.87 /kg	224.61	
Avatar	1 x 0.25 kg	328.45 /kg	82.11	
Success	1 x 0.4 L	170.92 /L	68.37	
Crop monitoring (4 ha per hour)	18 x 0.25 hrs	55.00 /hr	247.50	
Sprayer (F.O.R.M.)	6 x 0.5 hrs	12.00 /hr	36.00	
Casual labour	3 hrs	14.60 /hr	43.80	
TOTAL INSECT CONTROL COSTS				**$702.39**

Winter cauliflower *(continued)*

VARIABLE GROWING COSTS	Amount /ha	$/unit	$/ha	Total $/ha
Disease control				
Dithane M-45	1 x 2.2 kg	9.15 /kg	20.13	
Copper oxychloride	2 x 2 kg	4.73/kg	18.92	
Sprayer (F.O.R.M.)	3 x 0.5 hrs	12.00 /hr	18.00	
Casual labour	1.5 hrs	14.60 /hr	21.90	
TOTAL DISEASE CONTROL COSTS				**$78.95**
Irrigation				
Water Charges	4 ML	29.00 /ML	116.00	
Power: single pumped (40 L/sec using 30 kW pump at $0.10 /kW hr)	4 ML	20.83/ML	83.33	
Pump repairs and maintenance	4 ML	16.00/ML	64.00	
TOTAL IRRIGATION COSTS				**$263.33**
TOTAL GROWING COSTS			**$2.77/carton**	**$4709.56**

VARIABLE HARVESTING and MARKETING COSTS		$/unit	$/carton	Total $/ha
Harvesting and packing				
Cauliflower carton (10 heads/ 78L carton)	1700 cartons/ha	2.89/carton	2.89	4913.00
Contract picking & packing (team of 8 cut & pack 60 ctns/hr –assume 3 passes needed)	Contract price:	2.20/carton	2.20	3740.00
Cooling		0.25/carton	0.25	425.00
Tractors, harvest aid, trailer, forklift (F.O.R.M.)	60 cartons/hr	16.00 /hr	0.27	453.33
TOTAL HARVESTING and PACKING COSTS			**$5.61/carton**	**$9531.33**
Marketing				
Freight to Brisbane (1700 cartons)			0.85	1445.00
Commission/levies (12.5% of market price)			1.50	2550.00
TOTAL MARKETING COSTS			**$2.35/carton**	**$3995.00**
TOTAL HARVESTING and MARKETING COSTS			**$7.96/carton**	**$13526.33**

Summary table

	$/carton	$/ha
Total growing costs	2.77	4710
Total harvesting and packing costs	5.61	9531
Total marketing costs	2.35	3995
TOTAL VARIABLE COSTS	**$10.73**	**$18236**

Gross margin = Total income less total variable costs

	$/carton	$/ha
Total income (1700 cartons /ha)	12.00	20400
Less total variable costs	10.73	18 236
GROSS MARGIN	**$1.27**	**$2164**

Winter cauliflower *(continued)*

BREAK EVEN YIELD at a market price of $12.00/ carton	1165 cartons /ha
BREAK EVEN MARKET PRICE (1700 cartons /ha)	$10.55 /carton
BREAK EVEN ON FARM PRICE (1700 cartons /ha)	$8.38 /carton
GROSS MARGIN per MEGALITRE of irrigation water	$541 per ML

Actual gross margin when price or yield changes (sensitivity analysis)

		Price per carton				
Yield	**Cartons/ha**	**Low $8.00**	**$10.00**	**Medium $12.00**	**$14.00**	**High $16.00**
Low	1300	($4003)	($1728)	$547	$2822	$5097
	1500	($3894)	($1269)	$1356	$3981	$6606
Medium	1700	($3786)	($811)	$2164	$5139	$8114
	1900	($3677)	($352)	$2973	$6298	$9623
High	2100	($3568)	$107	$3782	$7457	$11132

Enterprise characteristics

1. growing risk	medium/high
2. price fluctuations	high
3. working capital requirement	medium/high
4. harvest timeliness	high
5. management skills	high
6. spray requirements	medium
7. labour requirements – growing	low
8. labour requirements – harvesting	medium/high

Last update: January 2004

Winter broccoli—gross margin example for the Lockyer Valley

Note: all costs are rounded to the nearest cent

GROSS INCOME	Yield ice packs /ha	Market price per ice pack		Total $/ha
	900	$16.00		$14 400
VARIABLE GROWING COSTS	**Amount /ha**	**$/unit**	**$/ha**	**Total $/ha**
Land preparation (F.O.R.M.)				
Deep ripping	1 x 3 hrs	13.00 /hr	39.00	
Offset discs	2 x 1.5 hrs	13.50 /hr	40.50	
Power harrows (or rotary hoe)	1 x 2.8 hrs	14.50 /hr	40.60	
Light cultivation	1 x 0.7 hrs	12.00 /hr	8.40	
Bedforming	1 x 1.5 hrs	8.00 /hr	12.00	
Casual labour	11 hrs	14.60 /hr	160.60	
TOTAL LAND PREPARATION COSTS				**$301.10**
Planting				
Broccoli seedlings	40 000	0.06 each	2400.00	
Tractor and transplanter (F.O.R.M)	6.5 hrs	8.00 /hr	52.00	
Casual labour (a team of 4 plant 6000 plants/hr)	26 hrs	14.60 /hr	379.60	
TOTAL PLANTING COSTS				**$2831.60**
Fertiliser				
CK77(S)	1 x 250 kg	0.63 /kg	157.50	
Urea	1 x 100 kg	0.52 /kg	52.00	
Solubor	2 x 0.75 kg	2.40 /kg	3.60	
Sodium molybdate	2 x 0.18 kg	33.00 /kg	11.88	
Soil analysis (4 ha per test)	0.25	90.00 /test	22.50	
Apply pre-plant fertiliser (F.O.R.M.)	1 x 1 hr	8.00 /hr	8.00	
Sidedress (F.O.R.M.)	1 x 0.5 hrs	8.00 /hr	4.00	
Spray micronutrients (F.O.R.M.)	2 x 0.5 hrs	12.00 /hr	12.00	
Casual labour	2.5 hrs	14.60 /hr	36.50	
TOTAL FERTILISER COSTS				**$307.98**
Weed control				
Dual Gold	1 x 1.5 L	44.26 /L	66.39	
Sprayer (F.O.R.M.)	1 x 0.5 hrs	12.00 /hr	6.00	
Casual labour (chipping & spraying)	3 hrs	14.60 /hr	43.80	
TOTAL WEED CONTROL COSTS				**$116.19**
Insect control				
Xentari	3 x 0.75 kg	74.87 /kg	168.46	
Success	1 x 0.4 L	170.92 /L	68.37	
Crop monitoring (4 ha per hour)	12 x 0.25 hrs	55.00 /hr	165.00	
Sprayer (F.O.R.M.)	4 x 0.5 hrs	12.00 /hr	24.00	
Casual labour	2 hrs	14.60 /hr	29.20	
TOTAL INSECT CONTROL COSTS				**$455.03**
Disease control				
Dithane M-45	1 x 2.2 kg	9.15 /kg	20.13	
Sprayer (F.O.R.M.)	1 x 0.5 hrs	12.00 /hr	6.00	
Casual labour	0.5 hrs	14.60 /hr	7.30	
TOTAL DISEASE CONTROL COSTS				**$33.43**

Winter broccoli (continued)

VARIABLE GROWING COSTS	Amount /ha	$/unit	$/ha	Total $/ha
Irrigation				
Water Charges	3.5 ML	29.00 /ML	101.50	
Power: single pumped (40 L/sec using 30 kW pump at $0.10 /kW hr)	3.5 ML	20.83/ML	72.91	
Pump repairs and maintenance	3.5 ML	16.00/ML	56.00	
TOTAL IRRIGATION COSTS				**$230.41**
TOTAL GROWING COSTS			**$4.75/ice pack**	**$4275.74**

VARIABLE HARVESTING and MARKETING COSTS		$/unit	$/ice pack	Total $/ha
Harvesting and packing				
Broccoli ice pack (8kg)	900 ice packs/ha	3.00/ice pack	3.00	2700.00
Picking & packing (team of 8 pick into bins, cool, then pack and ice–assume 2 passes)	6 ice packs/hr (per person)	14.60/hr	2.43	2187.00
Cooling		0.30/ice pack	0.30	270.00
Ice		0.60/ice pack	0.60	540.00
Tractors, harvest aid, trailer, forklift (F.O.R.M.)	48 ice packs/hr	16.00 /hr	0.33	297.00
TOTAL HARVESTING and PACKING COSTS			**$6.66/ice pack**	**$5994.00**
Marketing				
Freight to Brisbane (900 ice packs)			0.50	450.00
Commission/levies (12.5% of market price)			2.00	1800.00
TOTAL MARKETING COSTS			**$2.50/ice pack**	**$2250.00**
TOTAL HARVESTING and MARKETING COSTS			**$9.16/ice pack**	**$8244.00**

Summary table

	$/ice pack	$/ha
Total growing costs	4.75	4276
Total harvesting and packing costs	6.66	5994
Total marketing costs	2.50	2250
TOTAL VARIABLE COSTS	**$13.91**	**$12520**

Gross margin = Total income less total variable costs

	$/ice pack	$/ha
Total income (900 ice packs /ha)	16.00	14400
Less total variable costs	13.91	12520
GROSS MARGIN	**$2.09**	**$1880**

BREAK EVEN YIELD at a market price of $16.00 /ice pack	625 ice packs /ha
BREAK EVEN MARKET PRICE (900 ice packs /ha)	$13.61 /ice pack
BREAK EVEN ON FARM PRICE (900 ice packs /ha)	$11.41 /ice pack
GROSS MARGIN per MEGALITRE of irrigation water	$537 per ML

Winter broccoli (continued)

Actual gross margin when price or yield changes (sensitivity analysis)

		Price per ice pack				
Yield	**Ice packs /ha**	**Low $12.00**	**$14.00**	**Medium $16.00**	**$18.00**	**High $20.00**
Low	700	($1938)	($713)	$512	$1737	$2962
	800	($1604)	($204)	$1196	$2596	$3996
Medium	900	($1270)	$305	$1880	$3455	$5030
	1000	($936)	$814	$2564	$4314	$6064
High	1100	($602)	$1323	$3248	$5173	$7098

Enterprise characteristics

1. growing risk	medium
2. price fluctuations	high
3. working capital requirement	medium/high
4. harvest timeliness	high
5. management skills	medium/high
6. spray requirements	medium
7. labour requirements — growing	low
8. labour requirements — harvesting	medium/high

Last update: January 2004

Business management

When you become a brassica grower you are entering a new business, or at least adding a new enterprise to your existing 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 becomes 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.

- Business and marketing plans
- Record keeping
- Marketing
- Market access
- Control (quality assurance systems)

Business and marketing 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.

Operating a brassica enterprise as a business also involves recording farm information, financial management and control (implementation of quality assurance systems). If growing cabbage, cauliflower or broccoli is an additional enterprise, it should become part of your overall business plan but have its own marketing plan.

more info
Queensland Government services
Chapter 5 page 286

To help you develop business and marketing plans you should talk to a financial consultant or undertake training provided under a government scheme such as those administered in Queensland by the Queensland Rural Adjustment Authority (QRAA). DPI&F financial counsellors can provide a framework to help you evaluate the risks associated with different cropping programs.

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 inputs, yields, packouts, handling and storage logs);
- Quality assurance records and financial details.

a key issue
Quality assurance and food safety
This chapter page 104

Your quality assurance 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.

Field and packing shed data is usually first recorded in field booklets or on forms. Hand-held computers could also be used. Data can then be transposed to a desktop computer where it can be easily accessed and compared. A lot of this information is used to develop business and marketing plans and for checking to see if business 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.

a key issue
Economics of production
This chapter page 81

There are several computer-based packages that will help you record financial information and keep an eye on your business. The example gross margin analyses of cabbage, cauliflower and broccoli production in this chapter are provided to illustrate the type of financial information you will need to collect for your own financial recording system.

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 six ways of marketing their brassica crop.

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 product. Growers need to produce high volumes of produce for an extended part of the year to ensure continuity of supply to their customers. Direct selling involves a large financial input and requires good marketing skills. Growers must either employ a marketing specialist or have those skills themselves. This option is limited to a small number of large growers, but has the best potential for higher returns.

Sell direct to consumers or smaller retailers. This involves supplying product direct to specialist fruit and vegetable shops, resorts, restaurants, farmers markets or selling produce from the farm. The market chain for these niche markets is also short but you will have to organise sales and distribution, which can be time consuming. This type of marketing is limited by small market size, requires commitment but is a relatively low-risk, low-capital option.

Export. This involves using an exporter to sell into overseas countries. This is a relatively long market chain, requires a substantial financial investment and extensive market research. It involves higher risk than most domestic marketing options, but the rewards can be high if a sound marketing strategy is used. This option requires a long-term commitment to exporting and is generally limited to large growers that can consistently supply the required volumes and quality.

Effective, targeted marketing will probably make the biggest difference to your success as a grower. Understanding what marketing is about provides you with a base on which to plan how to best 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 cabbage, cauliflower or broccoli, usually your agent, merchant or the retailer's buyer. The **consumer** is usually the person buying your product in the retail store and taking it home. While it is fairly easy to find out your **customers'** needs and whether you are meeting them, it is much more difficult to find out the needs of the **consumer**. 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 poor financial performance of many horticultural businesses also indicates a lack of understanding about how cost of production is linked to marketing success. Some 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 cabbage, cauliflower or broccoli consumer look for? What is most important? Is it price, quality, size, colour, shape, flavour, convenience or a combination of these factors? If growers cannot reasonably guess at the answer to this question, how can they set targets for production?

a key issue
Product quality
This chapter page 77

For example, should you grow a 2 kg or 4 kg head cabbage? Larger cabbage make up the bulk of the fresh market, as retailers often cut cabbage into half or quarter for their customers, but your wholesaler may have profitable markets for smaller heads or sugarloaf cabbage. How important is bead size and stem length in broccoli? Too long or short a stem and too large a bead detract from overall appearance, but the degree to which this impacts on market price may vary depending on the target market.

How should you grade out blemished product? Grading too hard means fewer heads, cartons or ice packs of very high quality (and often higher price); grading too lightly means more product 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 and consumers want:

- 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 vegetable 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 brassica wholesalers. For the export market, brassica exporters are a source of expert market knowledge.

Know the marketing chain for your product

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Marketing information
Chapter 5 page 282

Understanding 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 makes 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 wholesaler 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 another 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.

Market access

More information on *Quality management* is found in Chapter 3, pages 70 & 71. More information on *Other certification schemes* is found in this chapter page 109

Quarantine and food safety issues can preclude access to markets if not addressed. Some export countries and interstate markets have strict quarantine regulations.

Most Australian and many overseas customers require their fruit and vegetable suppliers to have an on-farm food safety system in place.

Control (quality assurance systems)

All business and marketing plans need a control process for monitoring, evaluation and modification of these plans. Quality assurance (QA) systems fulfil this role. They are a method of documenting and controlling critical operations to ensure that they are done correctly.

Quality is built into every aspect of management

In a QA system, 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, ensuring product is safe to eat and delivering on time. In short, quality includes all those things needed to satisfy your customers. Quality assurance is the way you run your business to satisfy customers. Growers are constantly engaged in quality assurance, 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 assurance 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 assurance as a marketing tool to achieve better prices and repeat sales, and as a tool to identify areas for improvement, prevent mistakes and reduce wastage. It will also help you access markets with quarantine, food safety and other barriers to market entry, and promote greater trust and cooperation between growers and their wholesalers.

There are five core principles of quality assurance:

- The customer defines quality, not the grower.
- Quality assurance 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 assurance is the responsibility of everyone in the business, including the workers—not just management or business owners.

a key issue
Quality assurance and food safety
This chapter page 104

It is not easy to put a quality assurance system together. You will need commitment, good planning, staff involvement, and simple and effective procedures including well-defined and objective quality standards. Formal quality assurance systems are recommended because they remove the guesswork and are widely accepted throughout industry.

Quality assurance and food safety

Quality assurance (QA), sometimes called quality management (QM), refers to how you run your business to satisfy customers and ensure that your product is safe to eat. It includes all the steps you take to grow a quality product and maintain this quality after harvest, but also underpins the broader aspects of running your business.

- Quality assurance systems
- What level of quality assurance do you need?
- Approved supplier programs
- HACCP plans
- HACCP based quality assurance schemes
- Other certification schemes
- What is quality assurance going to cost?

Quality assurance systems

Effective quality assurance (QA) systems are characterised by planned, controlled activities that are constantly monitored and improved. They are backed up with good staff training, record keeping and development of other documents that provide written proof that your management is achieving the desired results for customers or other interested parties. QA systems are now being used to provide assurance to customers that products are of the desired quality and are safe to eat.

Why do growers have to implement a QA system?

New national Food Safety Standards became enforceable from February 2001. Growers and packers are exempt from meeting the Food Safety Standards except where they conduct some form of processing or sell direct to the public. However, they are indirectly implicated because a food business such as a retailer, wholesaler or processor is required to take all practical measures to ensure that they only accept food that is not contaminated.

Contamination is defined as 'a biological substance, chemical agent, foreign matter or other substance that may compromise food safety or suitability.' Unlike quality, the safety of food cannot be determined by looking at the produce.

The new Food Safety Standards are driving retailers, wholesalers and processors to demand growers to implement some form of food safety system. Retailers such as Woolworths/Safeway, Coles and Metcash/IGA are well down the track with over 90% of packers and wholesalers who supply direct to their distribution centres certified to an acceptable system. Woolworths, Coles and Metcash are also well down the track of having all the distribution centres that supply stores certified to a quality assurance system, as well as food safety training and implementation at store level.

Direct suppliers, for example packers and wholesalers, to the retailers are required to establish an approved supplier program for their suppliers. If there is a business between you and the retailer, then you are known as an **indirect supplier**. Most growers are indirect suppliers and are required to implement some form of quality assurance to be an approved supplier.

Some customers require suppliers to implement systems that cover quality requirements as well as food safety. These quality assurance systems also provide business improvement benefits such as reducing waste, downtime, repacking and lost sales. One significant problem avoided is often more than enough to justify the cost of implementing and maintaining the system.

a key issue
Environmental management page 111 and *Farm Safety* page115

The push for on-farm quality assurance and food safety systems is also occurring in overseas markets. In some markets such as the UK, the requirements are more demanding than in Australia with a move towards including requirements for environmental management and worker welfare.

Providing quality

Consumers are becoming more demanding. They want fruit and vegetables to look attractive, be 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.

Quality is also about service to your customers. For example, you can have excellent quality product, but if you promise 10 pallets to a customer and only send five, then you have not satisfied your customer, and 'quality' has not been achieved.

Product specifications

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

Product specifications normally include:

more info
Grading and packing
Chapter 3 pages 65 to 69

- General description—product type, customers, intended use.
- Quality description—colour, maturity, size, shape.
- Quality defects—both major (defects that make the product unsound such as bacterial rots, unhealed wounds such as cuts, splits and cracks, severe bruising and wilting) and minor (defects that detract from the appearance of the product such as mechanical damage, insects, hollow stem and discolouration)

more info
Increase returns
This chapter page 76

- Consignment requirements—packaging, palletising, labelling, temperature, transport.
- Food safety—free of contaminants (physical, chemical and microbial).

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.

There are three components to effective product identification and traceability.

- Each batch of produce must be clearly marked with a traceability code. 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.
- The batch code, field origin and destination must be recorded.
- Records must be kept for farm and packing operations

What level of quality assurance do you need?

The type of quality assurance or food safety system that a grower needs to implement depends on what their customers require. This may be a packer, marketing group, wholesaler, retailer, processor, exporter and so on.

The three broad levels of quality assurance systems being requested by customers are:

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

There are many options for a grower to choose from. You need to base your decision on what your customer wants and what is achievable and affordable to implement and maintain.

Approved supplier programs

An Approved Supplier Program is developed by a business such as a wholesaler, processor, packer or exporter to address specific requirements for their suppliers for food safety, quality and so on.

In its simplest form it involves the grower carrying out good agriculture practices that will provide assurance that the product is safe to eat. The grower has to keep sufficient records to demonstrate that the practices are a part of everyday operations. Completing a spray record is an example of a record that is typically required. The customer or an independent party will periodically check that the grower is carrying out the agreed practices.

'Guidelines for on-farm food safety for fresh produce' have been developed to help assess the risk of food safety hazards and provide information on the good agriculture practices needed to prevent, reduce or eliminate the hazards. The guidelines include a checklist of good agriculture practices. The practices have been identified from industry food safety programs based on the Hazard Analysis and Critical Control Point (HACCP) method. Some customers are using the checklist to develop their approved supplier program for growers.

A copy of the guidelines can be obtained from the Department of Agriculture, Fisheries and Forestry (DAFF)— contact details on page 202.

Other customers are requiring their approved suppliers to implement an independently certified program such as Freshcare, SQF 1000^CM^, SQF 2000^CM^ or HACCP. Some food service customers such as Spotless Catering, McDonalds and airline caterers have developed their own specific Approved Supplier Programs. Some retailers in Europe are requiring grower suppliers to implement the EurepGAP protocol.

Freshcare

Freshcare is a national, on-farm food safety program for the fresh produce industry. The program is owned and managed by Freshcare Ltd, a non-profit company representing peak industry organisations. Freshcare is based on HACCP principles and provides independent verification that a recognised food safety program is followed by the certified business.

more info
Freshcare Code of Practice contact details Chapter 5 page 282

The foundation of Freshcare is a Code of Practice. The Code of Practice describes the practices required on farm to provide assurance that fresh produce is safe to eat and has been prepared to customer specifications. Certification to Freshcare is achieved through an independent external audit for compliance with the Code of Practice. Freshcare is acceptable for indirect suppliers to Woolworths and direct and indirect suppliers to Coles.

HACCP plans

HACCP (Hazard Analysis and Critical Control points) is an internationally recognised method to identify, evaluate and control hazards to food products. HACCP was originally developed to provide assurance that food was safe to eat, but it is now being used to assure that customer quality requirements are also met. Guidelines for the implementation of HACCP have been developed by the international organisation, Codex Alimentarius Commission.

more info
HACCP training courses
Chapter 5 page 282

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. There are a number of independent auditing companies that will certify HACCP plans according to the Codex Alimentarius Commission guidelines. HACCP training courses are run by a number of organisations.

HACCP based quality assurance schemes

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

The SQF 2000^{CM} and SQF 1000^{CM} codes are managed by the Food Marketing Institute (FMI) in the USA. The SQF 1000^{CM} code applies only to primary production while the SQF 2000^{CM} code applies to any type of business. Both codes cover food safety and quality hazards and each code has three certification levels. At the highest level (level 3), a HACCP plan must be developed, validated and verified by a SQF Expert.

more info
The Australian SQF information desk contact Chapter 5 page 282

SQF 2000^{CM} has recently gained recognition from the Global Food Safety Initiative. There are businesses certified to SQF 2000^{CM} in the USA, Japan, Thailand, Australia and a number of other countries. SQF 1000^{CM} and SQF 2000^{CM} at the highest certification level are acceptable for direct and indirect suppliers to Coles and indirect suppliers to Woolworths.

Woolworths Quality Assurance Standard (WQA)

Woolworths Quality Assurance Standard (WQA) is mandatory for all Woolworths direct suppliers of fresh food. It is available by invitation only and focuses on the product quality and safety of individual products. WQA includes a HACCP Plan, significant support programs and the need for an Approved Supplier Program.

more info
Woolworths Quality Assurance Standard contact Chapter 5 page 282

As from 31st December 2004, Woolworths direct suppliers sourcing from growers must have evidence that the grower has a certified food safety system such as Freshcare, SQF 2000^{CM}, SQF 1000^{CM}, HACCP, WQA.

ISO 9002 and ISO 9002 plus HACCP

ISO 9002 is an international standard for quality management systems. It was developed originally for manufacturing companies and is now used by many industries. It contains requirements covering all aspects of producing products and servicing customers but does not require HACCP. For customers requiring HACCP, an independently audited HACCP plan has to be added to ISO 9002.

more info
ISO 9002 contact Chapter 5 page 282

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 CA system takes over the inspection function of AQIS, which monitors the effectiveness of the CA system by a regular program of audits.

more info
AQIS offices contact Chapter 5 page 284

Interstate Certification Assurance (ICA)

Interstate Certification Assurance was developed by the Queensland DPI&F and has been used nationally by other state departments of agriculture since 1998. It is a voluntary alternative to inspection of product destined for states requiring treatment for fruit fly control. ICA consists of a series of operational procedures that growers must follow to meet interstate quarantine requirements. Queensland DPI&F audits each business at least once a year.

more info
Interstate Certification Assurance contact Chapter 5 page 285

What is quality assurance 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 certification.

Environmental management

Farmers are under increasing pressure to demonstrate their environmental credentials to the wider community. Farmers also need to ensure that they comply with a range of state and federal environmental legislation. One way of dealing with these issues is to make a start towards implementing an environmental management system on your farm or to at least check that your business is operating within your industry's Code of Practice and following environmental best practice guidelines.

- Environmental Management Systems (EMS)
- Protocols, Codes of Practice and Best Practice Guidelines

Environmental Management Systems (EMS)

a key issue
Quality assurance and food safety page 104
Farm safety page 115

An Environmental Management System (EMS) is a systematic approach to managing the impacts a business has on the environment. An EMS does not dictate levels of environmental performance, however a minimum requirement is that it enables a business to comply with legislative requirements concerning the environment. It should also build on existing activities such as industry best management practices, industry codes of practice, quality assurance and food safety schemes and workplace, health and safety considerations.

An EMS is not a product you buy off the shelf but a process that helps you to improve your business's environmental performance. This process has a number of steps:

- An environmental risk analysis to identify, assess and prioritise potential environmental impacts
- Setting environmental objectives and targets
- Developing an environmental management program to meet these objectives and targets
- Monitoring, measuring and recording environmental performance to check that objectives and targets are being met
- Reviewing the system at regular intervals and improving the system as needed

The EMS process is based on the 'plan, do, check, review' management cycle to continuously improve the environmental performance of a business (Figure 25).

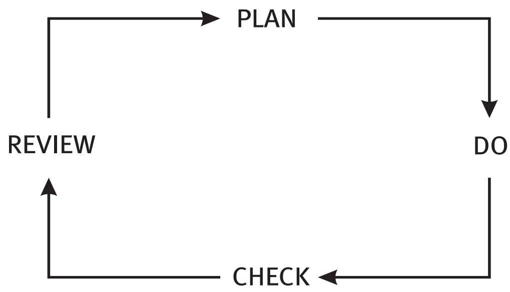

__Figure 25.__ The plan, do, check, review cycle for continuous improvement

ISO 14001 is the most widely recognised auditable international EMS standard. It is a 'process standard', that is, it does not prescribe a particular level of environmental performance that a business must achieve other than the need to comply with all relevant legislation and industry codes of practice. As a process standard, ISO 14001 however does have quite stringent requirements as to the steps (processes) a business must take to implement ISO 14001 on their farm.

In addition to the steps listed for implementing a general EMS, ISO 14001 has a number of additional components and features. Amongst these, it requires a business to have:

- An implemented, documented environmental management policy which is communicated to staff and available to the public
- An implemented, documented environmental management system that includes staff training, communication, resourcing and responsibility aspects
- Procedures in place:
    - to meet legal and industry requirements
    - for responding to accidents and emergency situations
    - to take action to mitigate identified environmental impacts

more info

ISO 14001 – contact Standards Australia Chapter 5 page 282

The system must also be auditable by an accredited third party.

Protocols, codes of practice and best practice guidelines

Protocols, codes of practice and best practice guidelines differ from a process standard such as ISO 14001 in that they do prescribe a certain level of environmental performance that the business should strive to achieve.

EurepGAP for fruits and vegetables was started in 1997 as an initiative by European retailers, the Euro-Retailer Produce Working Group

(EUREP). It is a protocol of good agricultural practice (the 'GAP' in EurepGAP). Since then, it has been further developed by a European group of representatives from all stages in the fruit and vegetable sector with the support of producer organisations outside the European Union (EU). The EurepGAP protocol lists requirements addressing quality, food safety, environmental management and workplace health and safety.

Global support and interest in EurepGAP has increased dramatically over the last three to four years. Currently there are a significant number of Australian horticultural export businesses working towards EurepGAP in order to meet compliance deadlines for 2004 stipulated by UK/ European retailers and importers. In April 2004, Woolworths accepted EurepGAP as an acceptable Quality Assurance Certification (alongside HACCP, Freshcare, SQF) as outlined in their standard WQA.

more info
A guide to EurepGAP for Australian growers
Chapter 5 page 291

Farmcare Code of Practice. Developed by Queensland Fruit and Vegetable Growers Ltd. (QFVG) to meet industry's legislative requirements and provide guidelines for growers, Farmcare is designed to assist Queensland's fruit and vegetable growers to meet their general environmental duty of care under the Environmental Protection Act 1994. The Farmcare Code of Practice for fruit and vegetables was developed under the umbrella of the Queensland Farmers Federation (QFF) Environmental Code of Practice.

Farmcare outlines a range of potential environmental harms and management options for minimising impacts from those harms. The code is split into seven sections:

- Land and soil management
- Water management
- Biodiversity management
- Air management
- Noise management
- Waste management
- Integrated crop management

more info
QFVG's Farmcare Code of Practice
Chapter 5 page 282

Farmcare has no certification capability and cannot be externally audited.

Enviroveg is a relatively new program initiated by the Australian Vegetable and Potato Growers Federation (AUSVEG). Enviroveg is committed to encouraging vegetable growers throughout Australia to adopt and implement good environmental management practices.

The Enviroveg manual is divided into eight sections that address the different aspects of managing a businesses's environmental impacts.

more info
AUSVEG's Enviroveg
Chapter 5 page 282

Each section lists specific environmental best practices, provides a scoring system and back up information. The program also includes training and review components and a self-assessment checklist. This checklist is designed to help growers compare their current farming practices with those listed as environmental best practice under the Enviroveg guidelines. At present, Enviroveg has no certification or third party auditing capability but this may change in the future.

A number of other EMSs, protocols and best practice guidelines will be, or already are, operating within Australia. There are moves at the national level to coordinate and clarify the role that these various environmental management programs will have in horticulture. These efforts are also targeted at better linking environmental management with existing QA, food safety and workplace health and safety programs.

We do not know if or when or what type of EMS will be required in the horticulture industry within the next few years. It will partly depend on the markets and customers you are aiming to supply. As a minimum, you should become familiar with QFVG's Farmcare Code of Practice.

Farm safety

Recent statistics suggest that agriculture is the second most dangerous industry in Australia, with on average, one death occurring on a farm every three days. As an employer and farm business manager, you are responsible for ensuring that you, your staff and your family are working in a safe environment. This responsibility not only rests on your concern for people and their well-being but also makes sound business sense.

- The farm as a workplace
- Your workplace health and safety obligations
- The Managing Farm Safety program

The farm as a workplace

This article is largely based on material from the Australian Centre for Agricultural Health and Safety at the University of Sydney and Farmsafe Queensland. Contacts are provided in Chapter 5 pages 279 and 293

Australian agriculture is traditionally viewed as an industry where people work and live in the country, enjoying wide-open spaces, fresh air, good health and a lifestyle relatively free from outside interference. The reality of life on the farm is somewhat different. Australian agriculture has one of the highest rates of workplace accidents and farmers, unpaid family members and farm workers are in one of the highest risk groups for occupational injury and disease.

According to the Australian Centre for Agricultural Health and Safety, tractor accidents remain the main cause of serious and fatal injuries, but vehicles, motorbikes, particularly 4 wheeled ATVs, mobile plant and post-hole diggers also cause their share of serious and fatal accidents. In addition to the high number of fatalities occurring on farms, estimates indicate that between 200 and 600 injuries per 1000 farms require attention at rural hospitals each year.

Farmsafe Queensland reports that manual handling injuries are common particularly those causing musculoskeletal injury. In 2000-2001, the fruit and vegetable industry accounted for 25% of the total compensation paid in the rural industry (Source: Qstats, Queensland Government 2001). These statistics however only represent the tip of the iceberg, with many injuries, including cuts, fractures and back injuries, not reported to hospitals, workers compensation sources or insurance providers and so not appearing in official statistics.

Not only do farm accidents cause pain and suffering, they usually represent a major financial burden to the farming business in terms of delays in getting work done, payment for medical treatments and rehabilitation, wages for replacement workers, high workers compensation, personal accident and disability premiums.

Your workplace health and safety obligations

Until recently, agriculture has lagged behind other major industries when it comes to improving its occupational health and safety performance. According to the Australian Centre for Agricultural Health and Safety, there are a number of reasons for this:

- Farmers often carry out a range of different task under different conditions in the course of a typical working day, and between seasons
- Farm work is often undertaken in physical isolation
- Farm workplaces and work processes are often difficult to control, for example the weather
- Farm work is often carried out under pressure, when seasonal or weather conditions demand that jobs are completed on time to avoid gaps in planting or downgrading in product and price
- Farm businesses rely on a seasonal workforce particularly at harvest and hours worked during peak season are often long and physically demanding
- Farm safety risks and solutions are not well-defined and legislation may be difficult to interpret and apply in practical terms on farm
- Lack of relevant information, tools, education and training in managing farm occupational health and safety risks
- Attitudes, values and perceptions of risk
- Lack of financial incentives and the high cost of addressing farm occupational health and safety risks by small business owners
- The family home is often located on the farm which places children and visitors at risk

a key issue
Safe storage, use and disposal of pesticides
This chapter page 256

Over the past two to three years, the situation has changed rapidly and there is now some urgency amongst horticultural industries to address workplace health and safety issues. Prosecutions under the Workplace Health and Safety Act, Electrical Safety Act and the Dangerous Goods Safety Management Act are adding a significant cost to farm production. There have also been an unprecedented number of successful civil action claims brought against corporate farms and individual producers in recent years. Added to this, the size of horticultural businesses is increasing with some larger enterprises employing not 10 or 20 staff, but hundreds of staff during peak season.

more info
Rural Code of Practice and Rural Safety links
Chapter 5 page 294

The biggest potential cost to farm businesses is the cost of doing nothing. Contemporary occupational health and safety legislation requires that employers/ managers implement a risk management approach to health and safety requirements on farm. The underlying principles of risk management relate to:

- Identifying hazards
- Assessing risks
- Controlling risks

This approach has some similarities with the Hazard and Critical Control Points (HACCP) approach for identifying food safety and quality risks within Quality Assurance (QA) systems. Many horticultural businesses have already implemented some form of QA so the risk management approach to occupational health and safety is not a new concept for most vegetable growers.

The Managing Farm Safety program

Your obligations as an employer and farm manager are based on three principles:

- A concern for people and their well-being – people have a right to go home in no worse condition than when they came to work.
- It makes good business sense – people are your most valuable resource. Injury and illness costs time and money. Both impact on your profitability.
- To meet statute and common law obligations.

To discharge your common law obligations you must provide:

- A safe place of work
- Safe systems of work
- Safe plant and machinery
- Competent and trained staff

Under common law, an employer is judged by 'the four tests':

- Foreseeability – is there a risk? Can it be foreseen?
- Prevention – is there a reasonably practicable method of preventing the risk?
- Causation – was the injury caused by an agent of injury to which the employer had prior knowledge?
- Reasonableness – failure to eliminate risks shows a lack of reasonable care.

The best way to meet your workplace health and safety obligations is to take part in the **Managing Farm Safety** program developed by Farmsafe Australia. The Managing Farm Safety program is aimed at developing skills in risk management of farm safety – an approach that is consistent with the way other farm business risks are managed. Farmsafe Queensland offers a complete package of information, training and systems that allows a primary producer to manage farm safety in their workplace. The training course and resource package are based on real data about the major risks on Australian farms, including specific agricultural industries, and takes into account the requirements of current occupational health and safety legislation.

more info
Farmsafe Queensland
Chapter 5 page 279

Understanding brassica plants

An understanding of the plant will help you to understand the conditions and management necessary to produce brassica crops successfully. Brassicas are essentially cool season crops although varieties that tolerate warmer conditions have been developed.

Cabbage has been cultivated since ancient times and was prized for its nutritional and health benefits by the Romans. Cauliflower and broccoli are more recent additions to the human diet. Today, brassica vegetable crops are grown in most parts of the world, making an important contribution to human nutrition and health.

- Introduction
- Botany of brassica plants
- Crop growth cycle
- How temperature affects growth

Introduction

Brassica or cole crops belong to the very complex *Brassicaceae* family of plants. This family consists of some 3000 species of annual, biennial and perennial herbs. Another term for this group of plants is crucifers due to the shape of its flower, or mustards, as pungency is a family characteristic.

Brassicas are thought to have originated on the coasts and islands of the Mediterranean. Plant selection over the centuries has resulted in a vast array of different plant types. The family includes important vegetable and oil seed crops, animal feed and green manure crops, and a range of ornamental species. Weeds such as Shepherd's purse, wild turnip, turnip weed, wild radish, Indian hedge mustard, bitter cress and peppercress are also members of the *Brassicaceae* family of plants.

Cole crops were cultivated in Europe since ancient times, initially probably more for their medicinal properties than food value. Cabbage was an important vegetable crop in Europe during the middle ages, its usage soon spreading worldwide. Cauliflower has been grown in Australia since first settlement but broccoli has only become a popular vegetable in the last 25 or so years. Today, all three crops are grown for the fresh, processing and export markets.

Brassicas were traditionally grown in temperate climates, however modern varieties have been developed to suit a range of climatic conditions including those of sub-tropical and tropical regions. Commercial brassica production in Queensland is almost exclusively based on F1 hybrid varieties.

Botany of brassica plants

Cabbage (*Brassica oleracea* var. *capitata*), cauliflower (*Brassica oleracea* var. *botrytis*) and broccoli (*Brassica oleracea* var. *italica*) are various forms of the species *Brassica oleracea*. This species also includes Brussels sprouts, kale and kohlrabi.

a key issue

Other brassica vegetable crops
This chapter page 263

Turnips, swedes, most mustards, heading and non-heading Chinese cabbage, and many other Asian leafy vegetables are also of the genus *Brassica*, however these vegetables are not of the same species as cabbage, cauliflower and broccoli. Radish, watercress, rocket, horseradish and daikon belong to different branches of the *Brassicaceae* family altogether.

Cabbage, cauliflower and broccoli seedlings can be difficult to tell apart at first, but each type soon develops its characteristic features as the crop becomes established. As plants develop, their taproot readily branches resulting in a fairly shallow root system with many fibrous roots concentrated within top 300 to 350 mm of the soil. Plants will develop a strong taproot system if not damaged during transplanting.

Leaves are usually thick, waxy and leathery. Cabbage head shape and leaf colour varies depending on variety. Cauliflower leaves are usually narrower than cabbage leaves and broccoli leaves are usually smaller, rounder, with a more distinct petiole than either cabbage or cauliflower. Plant height ranges from 400 to 600 mm for cabbage, 500 to 800 mm for cauliflower and 500 to 700 mm for broccoli, depending on variety and growing conditions.

Flowers are mostly yellow or pale yellow, sometime white, and have four petals that form a square or cross. Insect pollinators are attracted to the abundant flowers and nectar. The different forms of *B. oleracea* are readily cross-pollinated but are usually self-incompatible (will not readily self-pollinate). Small round, dark brown seeds are formed in a pod about 3 to 5 mm wide and 50 to 100 mm long. The seed matures 50 to 90 days after fertilisation.

Brassica crops are grown as annuals, however cabbage, most cauliflower and some broccoli types are biennial plants. These plants require low temperature exposure (vernalisation) to induce them to flower. Plants with a biennial growth pattern will tend to bolt (initiate premature flowering) if a period of cold weather is followed by warmer conditions. Tropical cabbage and cauliflower types and warm season broccoli varieties are less likely to bolt under hot growing conditions and these types of cauliflower and broccoli require little vernalisation for head formation to occur.

a key issue
Varieties
This chapter page 127

The F1 hybrid varieties that are grown commercially in Queensland have been bred to suit specific growing conditions. A variety's response to temperature is therefore an important consideration when selecting varieties to suit specific production areas and growing seasons.

Crop growth cycle

Cabbage, cauliflower and broccoli crops are harvested at different stages of their growth cycle. Cabbage crops are cut while still in the vegetative stage, as heads are mature before flower initiation occurs. Cauliflower crops must complete the vegetative stage and begin the flower initiation process to form curds. Broccoli must pass through the vegetative stage, initiate flowering and form immature flower buds.

The cabbage head consists mostly of leaf tissue. It is a single large terminal bud of tightly overlapping leaves that are attached to and enclose most of the unbranched short stem. If not harvested, heads will grow beyond the mature, firm stage and split.

The cauliflower head or 'curd' consists of stem tissue. It is made up of tightly clustered shoot tips that are formed on thick, fleshy, repeatedly branched ends of the short, thick stem. Once curds have passed their peak for marketing purposes, they loose compactness, whiteness and shape, and eventually start to flower.

The broccoli head consists of tightly clustered immature flower buds that are formed on the branched florets on the upper portions of the stem. Once past their peak for marketing purposes, broccoli heads loose their compact dome shape and start flowering. Secondary heads form on side shoots that develop in the lower leaf axils.

The cropping cycle of brassica plants can be divided into three stages; an establishment phase, a pre-heading phase (vegetative stage) and a heading phase. In cabbages, the heading phase occurs during the vegetative stage of the plant's growth. In cauliflower and broccoli, the heading phase is the start of the reproductive stage of the plant. These cropping cycles are illustrated in Figures 26 to 28.

The aim of the **establishment phase** is to produce an even stand of healthy plants. Established cabbage seedlings resemble a loose rosette shape with leaves formed close to the ground and little increase in plant height. Established cauliflower plants also form leaves close to the ground but these tend to be more upright than in cabbage and there is some increase in plant height. Established broccoli plants form leaves as the plant grows in height, with older leaves angled at 45 degrees to the soil. Younger leaves stand upright and buds start to form in the leaf axils of older leaves.

The aim of the **pre-heading phase** is to develop a plant frame that will later support the development of a quality head or curd. During this phase, leaves continue to form and increase in size. In cabbage and cauliflower these leaves form close to the soil with cabbage showing limited increase in plant height. In cauliflower plants, leaves are more upright with plant height increasing as leaves expand. Broccoli leaves form along the plant stem as the plant increases in height and buds in the leaf axils grow to form side shoots.

At the **heading phase**, the aim is to produce heads or curds of even size and maturity. Head formation in cabbage starts with the youngest leaves first standing upright, then subsequent leaves fold together to form a loose head. The young head continues to grow in size and fills rapidly to form a mature head of tightly compacted leaves.

In cauliflower, curd initiation starts when new leaves first grow upright, then fold together in a spiral to protect the developing curd. There is some increase in plant height with upright leaves surrounding the curd as it grows and becomes more visible. The plant is 'buttoning' when the curd is about 10 mm in diameter. Curds are mature when their optimum size has been reached and they are still compact.

Head formation in broccoli begins with the development of a tiny 'button' of tightly packed immature flower buds at the growing point of the plant, surrounded by upright leaves. As the head grows, the stem elongates to produce a head of tightly packed flower buds on top of a many-branched stem. As with cauliflower, the plant is at 'buttoning' when heads are about 10 mm in diameter. Mature heads are ready for harvesting when their optimum size has been reached and they are still dome shaped and compact.

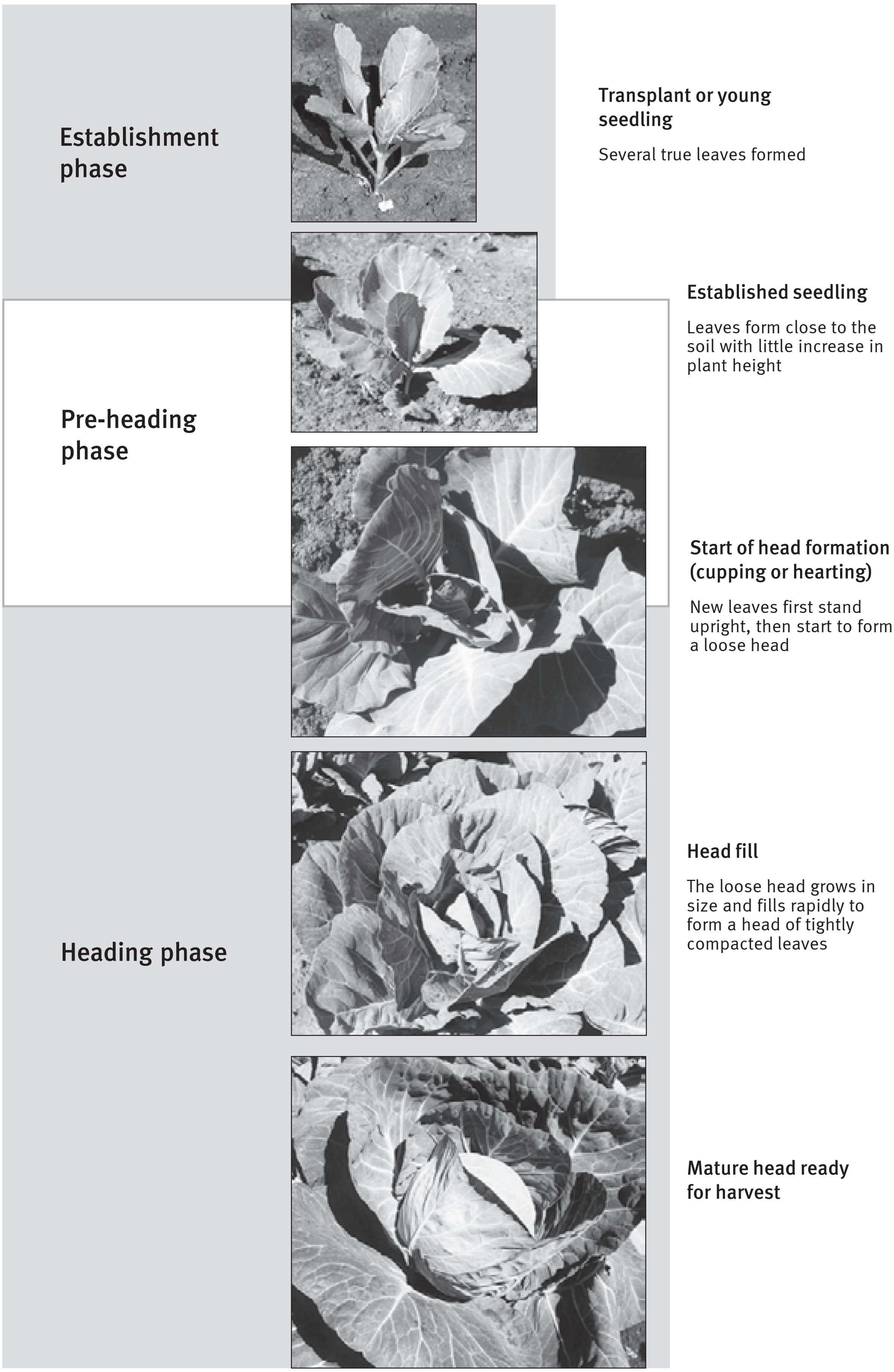

Figure 26. *Growth cycle of cabbage crop (adapted from Theunissen and Sins 1984)*

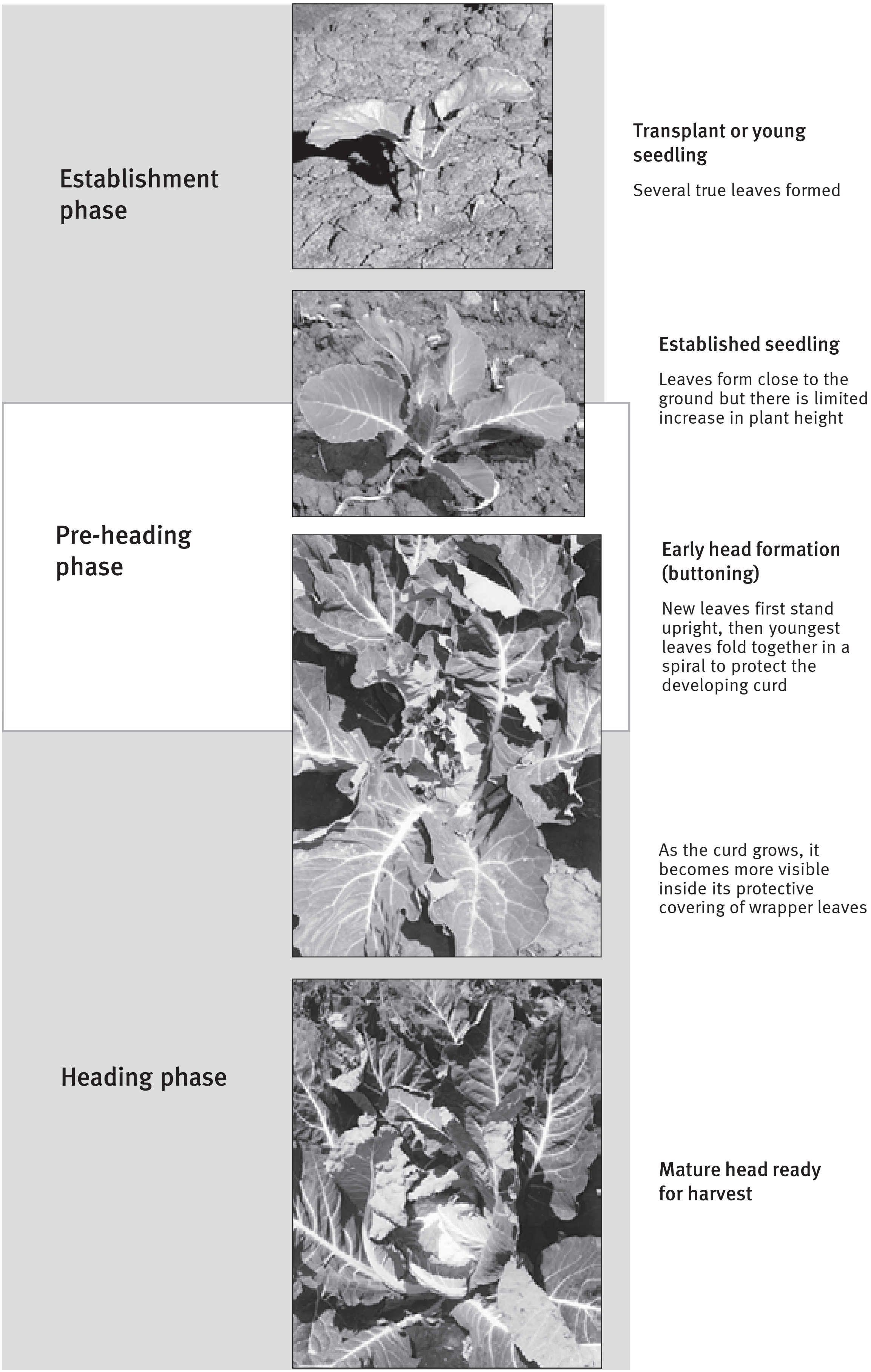

Figure 27. *Growth cycle of cauliflower crop (adapted from Theunissen and Sins 1984)*

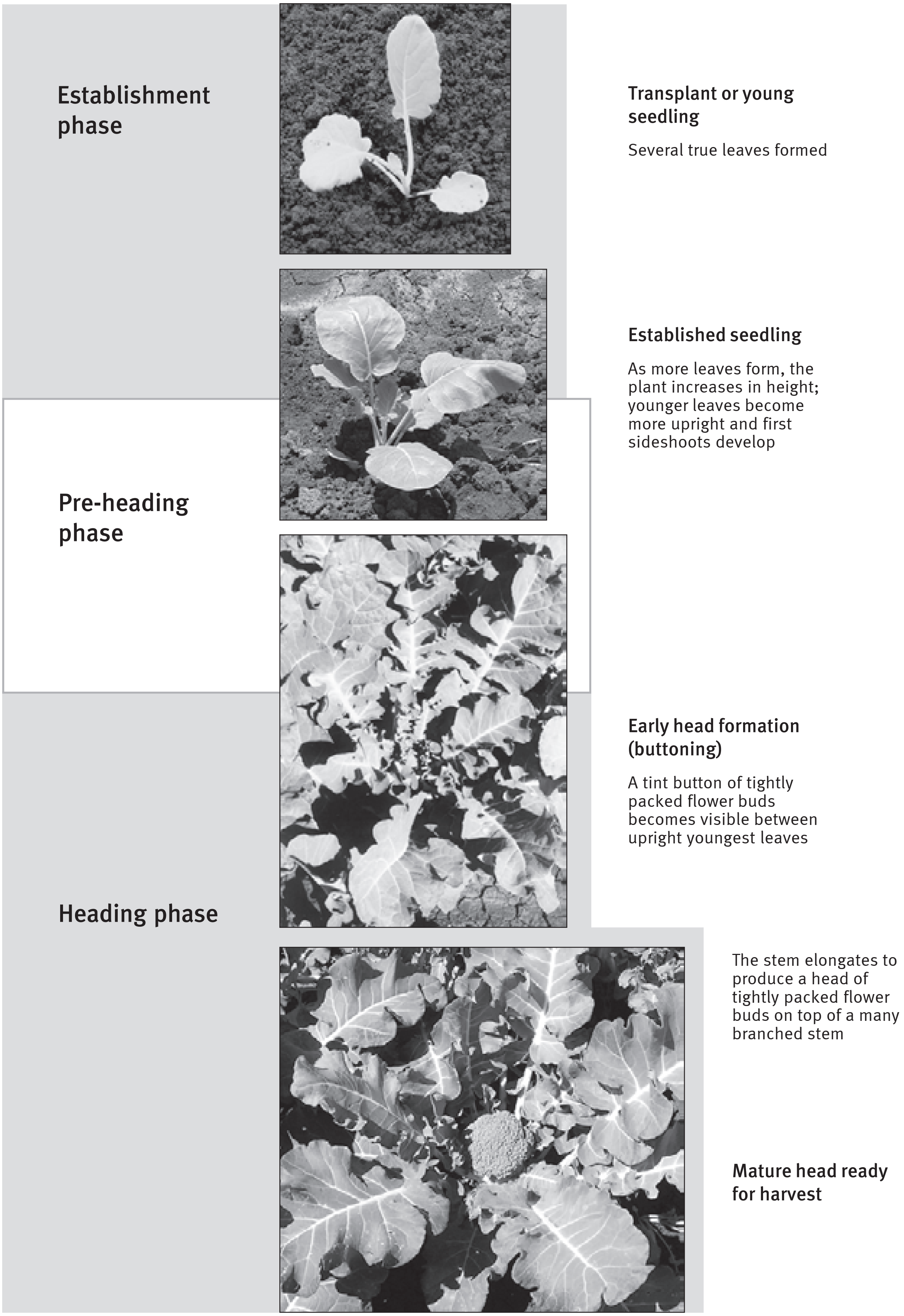

Figure 28. *Growth cycle of broccoli crop (adapted from Theunissen and Sins 1984)*

How temperature affects growth

Traditionally cabbage, cauliflower and broccoli were considered cool season crops, but varietal developments have expanded the season for all three crops, particularly for cabbage. Best quality heads or curds however are still produced when plants mature under cooler conditions. Variety choice, pest and disease incidence and the vagaries of the season will impact on the risk of growing brassica crops ‘out of season’.

Seeds will germinate over a wide soil temperature range, from 7° to 35°C for cabbage, 7° to 29°C for cauliflower and 5° to 35°C for broccoli. However the optimum temperature range is 20° to 28°C. Germination is very slow below 5° C and falls off rapidly above 38°C.

Cabbage has a wide climatic tolerance with some varieties adapted to tropical heat and others able to withstand frosts to -4°C. Most cabbage varieties grow best at temperatures between 15° to 20°C. Depending on variety, exposure to prolonged periods below 10°C will cut short normal vegetative growth and trigger flowering (vernalisation). Day temperatures above 27° C will check growth and may lead to bolting, splitting of heads and tipburn problems.

Broccoli grows best under cool conditions. The optimum temperature range for growth is 15° to 21°C with day temperatures of 35°C the upper limit. Some varieties will tolerate hot conditions but both quality and yields are reduced when night temperatures rise above 15°C resulting in poor head shape, leafy heads, uneven bud size, hollow stem and soft rots. Broccoli can tolerate light frosts but temperatures of -5°C and below can damage heads and will kill young seedlings.

Cauliflower is less tolerant of temperature extremes than either cabbage or broccoli. It is best suited to cooler growing conditions preferring mild to warm days (18° to 30°C) and cool nights (10° to 15°C). Cauliflower can tolerate light frosts to –5°C but cold temperatures and lack of sunlight, for example, overcast days, in the seedling stage can lead to blindness (non-heading). Vegetative growth is promoted by temperatures above 27°C. Warm conditions can delay curd initiation and contribute to curd disorders such as riceyness (elongated flower buds), misshapen and small curds, hollow stem, curd discolouration and small jacket (wrapper) leaves. Prolonged cool temperatures (below 14°C) can retard growth but promote curd initiation.

Varieties

The quality of the final product depends largely on the variety you plant. Although some varieties are widely adapted, there is no one cabbage, cauliflower or broccoli variety that will perform uniformly across all planting seasons, locations and production techniques.

'Standard' varieties for main season production are likely to perform well if grown in the right time slot for your district. Seed companies regularly release new varieties, but a variety that performed well in one district or on another farm in your area will not necessarily perform well on your farm. We suggest that you try small areas of new varieties on your farm before making large plantings.

- Plant types
- Crop scheduling
- Selecting varieties and planting times
- Variety descriptions

Plant types

Cabbage

There are numerous different cabbage types suitable for different markets and customers. Green cabbage, sometimes also referred to as white cabbage, is the most commonly grown in Queensland. Smaller areas are planted to savoy and red cabbage varieties.

Leaf colour can vary from light green to dark green to dark blue-green to reddish purple (as in red cabbage). Leaf texture can be smooth or wrinkled (as in savoy cabbage). Within the green cabbage group, head shape varies from round (ballhead) to oval and flattened (drumhead) to conical (sugarloaf). Queensland cabbage is grown primarily for the domestic fresh market but the demand for semi-processed cabbage for coleslaw, salad mixes, fresh cuts and other pre-prepared food products is steadily increasing.

With the exception of tropical varieties, cabbages are cool season biennial plants that are grown as annual plants. The commercial cabbage industry is based on F1 hybrid varieties, with a wide range of varieties available to suit different districts and climatic conditions.

Cauliflower

A large number of cauliflower varieties are available in Australia with variety preference being largely dependent on market and environmental requirements. As cauliflowers are particularly sensitive to temperature fluctuations, varieties are grown in well-defined time slots in the different production regions.

Cauliflower varieties can be grouped into three maturity types – short (or early) maturing, medium (intermediate) maturing, and long (late) maturing. Over the last 15 years, F1 hybrids have largely replaced open pollinated, late maturing varieties and the Queensland cauliflower industry is based almost exclusively on short maturing F1 hybrids. The majority of Queensland cauliflower is produced for the domestic fresh market, with smaller quantities exported. Small quantities are also used in the pre-prepared food industry. Pure white curds are preferred although there are small niche markets for purple, green and cream coloured curds.

Broccoli

Broccoli varieties grown in Queensland are of the calabrese type, a green sprouting, single headed, annual type of broccoli which does not need much vernalisation (low temperature exposure) to produce heads. Only minor quantities of other types such as purple or white sprouting broccoli are grown for niche markets. The bulk of the Queensland crop is destined for the domestic fresh market, but a significant proportion of product is exported to markets in South East Asia and Japan. Some broccoli is also used in the pre-prepared food industry.

Since the early 1970s, commercial broccoli production has been based on F1 hybrid varieties. While broccoli is less sensitive to temperature variations than cauliflower, cooler growing conditions produce higher yields of quality heads.

Varieties are sometimes described as early, mid or late season. This refers to a variety's ability to form quality heads under different environmental conditions. While a range of varieties will perform well during the main season in different production districts, there are no varieties available that are really suited to either high temperature or low temperature extremes.

Crop scheduling

Making reasonable estimates of days to harvest is important for crop scheduling; the working out of a planting schedule which will provide a consistent supply of product for your customers. Seasonal weather variations will impact on the accuracy with which this can be done, but estimates based on prevailing temperatures for your district and varietal characteristics should ensure a fairly consistent supply of product throughout the cropping season.

Different parts of the plant are harvested in cabbage, cauliflower and broccoli and this impacts on harvesting, cooling and storage practices. It also influences crop scheduling decisions as cabbages can be left in the field for a week or so once heads reach maturity, while cauliflower and broccoli must be harvested as soon as they reach harvest maturity. For this reason, cauliflower and broccoli are often planted on a weekly schedule to ensure continuous harvesting over several months. Discuss crop scheduling requirements with your seedling supplier or local seed company representative to help with selection of suitable varieties.

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Cabbage

Crop scheduling is not as critical in cabbage as it is for broccoli and cauliflower crops as cabbage varieties have been bred to remain in good condition in the field and resist bolting. This 'holding ability' is an important characteristic when selecting varieties.

Table 22 provides a guide to the number of weeks from transplanting to harvest. Sugarloaf cabbage is faster maturing than round or drumhead cabbage by one to two weeks, depending on variety and growing season. Cabbage is ready for harvest when heads are firm to touch.

Table 22. Time to maturity for cabbage in the major production districts.

Season	Weeks from transplanting to harvest	
	Lockyer/coastal	**Highland areas**
Autumn/spring	10 - 12	12 - 14
Winter	13 - 16	*
Summer	*	9 - 11

*not commercially viable at these times of the year

Cauliflower

Cauliflower varieties vary widely in their response to temperature and matching a variety's specific temperature requirements to its intended production time slot is one of the challenges of crop scheduling. Choosing the correct variety can be particularly difficult for autumn and spring production when variations in temperature are more likely to occur.

The short maturing varieties grown in Queensland require little vernalisation for curd formation. Their ability to tolerate warm temperatures at different stages of the crop growth cycle varies and needs to be taken into consideration when deciding on varieties for the planting program.

Tropical varieties are adapted to warmer conditions and will produce curds at relatively high temperatures but these varieties may also go to flower after as little as one or two weeks of low-temperature exposure. Varieties developed for cooler conditions will tend to produce ricey and open curds if exposed to warm temperatures during curd development.

The number of leaves formed by the plant when exposed to cooler temperatures also plays a role in curd initiation. In general, curd initiation only occurs after plants have passed a critical stage in their vegetative growth. This is sometimes called the post-juvenile or transitional stage and in short maturing varieties this typically occurs after the plant has formed 15 to 20 leaves. Since tropical varieties require little vernalisation, under cool growing conditions they will tend to form small plants before initiating curds and starting to flower.

Table 23 provides a guide to the number of weeks from transplanting to harvest. Curds are ready for harvest when fully expanded but still compact and white. We strongly recommend you check maturity times and environmental requirements for specific varieties with your seedling or seed supplier.

Table 23. Time to maturity for cauliflower in the major production districts.

Season	Weeks from transplanting to harvest	
	Lockyer/coastal	Highland areas
Autumn/spring	10 - 12	12 - 14
Winter	12 - 14	*
Summer	*	9 - 11

*not commercially viable at these times of the year

Broccoli

Broccoli plantings are usually made on a weekly schedule to ensure continuous harvesting over several months. Heads must be cut as soon as mature, while still compact and before floral buds have opened. A day can make a lot of difference to head quality and in warmer weather, heads might be harvested in two or three cuts within a week. Table 24 provides a guide to the number of weeks from transplanting to harvest.

The DPI&F Prime Note *Broccoli development, yield and quality–importance of temperature,* can be found at www.dpi.qld.gov.au

Harvest dates can be estimated using temperature calculations. Maximum and minimum daily temperatures are used to calculate average daily temperatures or daily 'degree days'. An adjustment for a base temperature of 0°C and an optimum temperature of 20°C needs to be made in these calculations. Thermal time requirements, the accumulated number of 'degree days', are specific for a variety and these can be used to predict harvest dates.

Table 24. Time to maturity for broccoli in the major production districts.

Season	Weeks from transplanting to harvest	
	Lockyer/coastal	Highland areas
Autumn/spring	8 - 10	10 - 12
Winter	10 - 13	*
Summer	*	8 - 9

***not commercially viable at these times of the year**

Selecting varieties and planting times

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Variety selection should be based on the preference of the target market and the environmental constraints of the site where the crop is to be grown. Main planting and harvesting times for the major production areas of Queensland are shown in Table 25.

Table 25. Main planting and harvesting times for brassica crops in the major production districts of Queensland.

District	Crop	Transplant	Harvest
Lockyer & Fassifern Valleys, Eastern Darling Downs	broccoli cabbage cauliflower	February to August February to mid August February to late July	April to October Mid May to October Mid May to September
Highland regions (Granite Belt and Toowoomba)	broccoli cabbage cauliflower	Mid August to February Mid August to February September to February	Late October to May November to May November to May
Southern coastal areas	broccoli cabbage cauliflower	Mid March to July February to July Mid March to mid June	June to September Mid April to September Mid June to mid September

There are several standard varieties of cabbage, cauliflower and broccoli for main season production in the major production areas. These varieties have been tested over several seasons and in a number of locations and are likely to perform well if grown in the right time slot for your district. These varieties are listed in Table 26.

Seed companies regularly release new varieties and standard varieties change, sometimes from one season to the next. A variety that performed well in one district or on another farm in your area will not necessarily perform well on your farm. We recommend that you make small plantings of promising new varieties on the farm for trial alongside the current 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. Seed companies, seedling producers, other brassica growers, and local agricultural suppliers and consultants are valuable sources of information on choosing varieties. Attend any field days where different varieties are on display.

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Table 26. Popular brassica varieties grown in the major production districts of Queensland

District	Cabbage	Cauliflower	Broccoli
Lockyer and coastal districts	Warrior, some Kameron and Neptune (winter). Sugarloaf – Endeavour, also Cape Horn, Sunrise.	Charlotte, Thalassa, Fremont and Cauldron for early season. Escale for mid season, some Discovery.	Atomic or Viper for early season. Babylon for mid season, also Mongoose and Ironman. Bravo for late season.
Darling Downs and Stanthorpe	Kameron and Warrior. Endeavour for sugarloaf.	Discovery for spring, some Escale. Cauldron, Fremont and Charlotte for warm season.	Babylon, some Mongoose and Ironman for spring. Atomic or Viper for summer, also Shilo.

Quality characteristics to look for

Hybrid cultivars have introduced a degree of crop uniformity essential for remaining in today's competitive industry. Aim for a once over harvest in cabbage and two or three passes to harvest a planting of broccoli or cauliflower.

When assessing varieties you need to consider the following characteristics:

- Market acceptance – will the variety produce heads of the required quality?
- Yield – the number of marketable heads, cartons or ice packs per hectare
- Degree of disease resistance or tolerance, for example, to black rot, downy mildew, bacterial soft rots
- Response to water and heat stress, tolerance to warm or cold temperatures or fluctuations in temperature, frost hardiness
- Time to maturity, crop uniformity, percentage of plants not true to type
- In broccoli and cauliflower – tendency to premature buttoning and blindness (plants do not form heads)

In cabbage, look for solid, dense heads with short core length and good wrapper leaves. Other features to consider are head size and colour and holding ability. Check varieties for tolerance to internal tipburn if producing during warmer weather.

In cauliflower, curd size and shape, density, compactness and weight, whiteness, surface evenness and texture are important quality parameters. Check varieties for susceptibility to hollow stem if producing under warmer conditions. The degree of self-covering should also be considered. As the plant matures, the curd becomes more exposed to light. This causes yellowing or pink/purple discolouration of the curd. Traditionally, growers tied the outside leaves with rubber bands to protect the curd from light, but the more common practice these days is to break one or more leaves over the developing curd, as this is less labour intensive. Varieties with upright leaves that protect the curd from light will make this job easier. Too much self-covering however, increases the humidity around the curd, which increases the risk of head rots.

In broccoli, look for compact, heavy, dome shaped heads with small, evenly sized buds (beads) and even colouring. Check also for the tendency to form sideshoots and susceptibility to hollow stem. Check with your market on preferred head size, stem length and colour (blue-green to dark green).

Variety descriptions

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The following variety descriptions have been supplied by the seed companies listed in Table 27. This list of seed companies is not complete and the varieties described represent a list of brassica varieties generally available in Australia. Some may not be suitable for planting in Queensland. Anyone using this information should check its validity for Queensland conditions with their seedling or seed supplier and the relevant seed companies.

Table 27. Seed company identification

Code	Company	Code	Company
B	Bejo	LV	Lefroy Valley
C	Charlcon Seeds	SPS	South Pacific Seeds
F	Fairbanks Seeds	Syn	Syngenta Seeds (S&G)
H	Henderson	T	Terranova Seeds

Green cabbage

Cheers (C). An excellent main season hybrid. Compared with Grand Slam, it is 5 days earlier and grows as large and as vigorous, with more uniform heads and larger wrapper leaves. Dark blue-green in colour. Tolerant to black rot and resistant to fusarium yellows.

Corinth (H). A Green Coronet style, that is up to 7 days quicker to mature. Produces a large head 4–6 kg in weight with a flattened top. Corinth has shown good adaptability to a wide range of field and temperature conditions. Excellent field holding ability. Good tolerance to black rot. Suitable for both fresh market and processing

Eureka (T). Globe shaped, green head type weighing 3.5–4 kg with excellent sweet flavour. Transplant to maturity takes 12–13 weeks.

Excellent field holding ability. Fusarium yellows and tipburn resistant, with partial resistance to black rot.

Grand Slam (F). Semi round, large mid season for fresh market and processing.

Green Coronet (C, SPS, T). Adaptable variety, Current industry standard. Flattened globe, medium green head type, weighing 4–4.5 kg. Excellent holding ability. About 15–17 weeks from transplant to maturity.

Jupiter (T). Flattened globe, green head type, weighing 4–4.5 kg. Deeper head than Green Coronet. About 13–14 weeks from transplant to maturity. Excellent field holding ability. Suitable for both warm and cool season production.

Kameron (SPS). Offers a highly uniform product with large size for cool season production. Produces a large, flattened globe shaped head with a maturity similar to that of Green Coronet. Low level of off-types. Excellent holding ability. Good tolerance to black rot. A proven performer throughout Australia.

Kaporal (LV). Attractive, blue green coloured cabbage with flat round head and size potential of 4-5kg. A very dense head, short internal core. Adaptable in warm and cool season production.

Matador (Syn). A type suitable for the large fresh market and processing. Mid maturity is 85–90 days from transplant. A vigorous plant with a large frame and strong root system. Leaves are thinly veined, blue/green in colour with a waxy texture. Heads are globe to flat globe in shape with a white internal colour. The heads show little sign of basal budding and will obtain a size in excess of 4.5 kg. The internal structure is very dense with a small core. Tolerant to black rot and fusarium yellows. For fresh market and warm season growing.

Matsumo (B). 3–4 kg flat round variety with attractive appearance. Good protection around a blue/green finish. Matures 10–12 weeks from transplanting. Very good tasting variety, strong against fusarium and black rot.

Megaton (B). Large cabbage (can achieve 10 kg). Ideal for processing (coleslaw) or for fresh market. Matures 14–16 weeks from transplanting. Strong resistance to fusarium.

Neptune (T). Flattened globe, blue green head type, weighing 4.5–5 kg. About 14–15 weeks from transplant to maturity. Large winter type for fresh market or processing. Good field holding ability.

Paris (LV). Flattened globe, bright green head cabbage, weighing 3–4kg. Excellent adaptability, maturing in approximately 80–91 days from transplant. Internal structure is dense with a good texture and flavour. Heads have a very small core. Fusarium yellows resistance and good tolerance to black rot.

Royal Slam (C). A large heavy type similar in size, appearance and maturity to Grand Slam but yields are better on sandy soils. Heads average 20 cm across and about 2 kg at maturity with excellent wrap. Colour is bright bluish green. Averages 90 days to harvest from transplant. Plants have a strong resistance to black rot and fusarium yellows.

Stauncha (LV). Spring harvest variety. Has good field holding ability and is bolt tolerant in the difficult spring harvest period.

Sheraton (SPS). An earlier maturing Green Coronet type, offers extremely high uniformity producing flat globe shaped heads with virtually no off-types. Large upright frame with blue green colour and field tolerance to black spot and target spot.

Surprise (B). Uniform small or 'mini' variety with bright green finish and super sweet taste. Matures 8–10 weeks from transplanting. Strong resistance to bolting.

Warrior (Syn). Matures between 84–98 days from transplant. Strong and vigorous in establishment and growth. Frames are medium large and wrap the head tightly facilitating good protection for transport. Head is round to slightly flat globe in shape with a small core and fine internal wrapping leaves. External colour is blue green with a very white internal colour. Tolerant to internal browning (tip burn). Heads are normally 3.5–4.5 kg in weight. Has excellent holding ability and can be left in the field at certain times of the year to reach up to 8 kg. Tolerant to black rot and fusarium yellows. Suitable for the fresh market and processing, a preferred choice for coleslaw suppliers due to clean white internal quality and sweet taste.

Sugarloaf cabbage

Cape Horn Improved (T). Improved sugarloaf type, sweet tasting and early maturing. Conical, light medium green head type, weighing 1–1.5 kg. About 10 weeks from transplant to maturity. Fair field holding ability.

Capricorn (B). Slightly taller sugarloaf type with sweet taste and fine internal quality. Ideal for late summer and autumn harvest maturing 10–12 weeks from transplanting.

Caramba (B). Cape Horn type, maturing 10–12 weeks from transplanting.

Endeavour (H). Popular sugarloaf type, with attractive blue-green foliage. Approximately 1.2–1.5 kg. Slightly slower to mature than Sunrise and Cape Horn. More tolerance to bacterial leaf scald and slower to burst than most other varieties.

Sunrise (H). Early maturing Cape Horn style sugarloaf type with a light to medium green colour. Produces heads up to 1.5 kg with a sweet taste and conical shape.

Torpedo (Syn). A vigorous plant with blue/green leaves. Pointed head weighing 1.2–2 kgs, with smooth dark green wrapper leaves and short core. Matures 58–70 days from transplant. Highly tolerant to fusarium yellows. Suitable for all production areas and timeslots except during the bolting period (spring). Suitable for fresh market and processing.

Savoy cabbage

Alcosa (B). Rapid maturing fine blistered type with attractive bright green head. Will make a high quality 'mini' or small/medium fresh market savoy. Strong against Fusarium and bolting.

Gloster (Syn). A medium sized Savoy cabbage, a vigorous plant type with a medium frame and good wrapping. Outer leaves are heavily savoyed with a grey green colour. Produces a flat globe shaped head with a white interior, short core and fine texture. Average weight is around 2.5 g with little or no basal budding. Matures early, between 80–100 days from transplant. Tolerant to black rot.

Melissa (B). Typical fine blistered European savoy with protective frame, dense internal structure and attractive colour. Strong against Fusarium, can be harvested 10–12 weeks from transplanting.

Savanna (T). Semi-savoy type leaf. Flattened globe, medium green head type, weighing 4.5–5 kg. About 13–15 weeks from transplant to maturity. Good field holding ability. Suited to cool mild climate.

Savoy Dianna (H). Savoy Dianna has a round head, dark blue/green external colour and attractive blanched inner leaves. Good presentation and is more savoyed than standard varieties. Heads are 2–2.5 kg and has yielded well in trials. Field holding capacity has also been very good. Performs best when harvested in the cooler months, but should be trialed all year round.

Savoy King (C, F, SPS). Savoy type leaf, very popular on all markets. An outstanding, second early hybrid. Large, semi-flat, short cored and good textured heads. Excellent for fresh market for good quality heads. Matures 13–15 weeks from transplant. Flattened globe, medium green head type, weighing 4.5–5 kg. High yield potential but with poor holding ability. Withstands heat and cold better than other savoys and in mild climates, it may be sown in spring, summer and autumn. Not recommended for close planting.

Savoy Prince (F, T). Matures 13–14 weeks from transplant. Flattened globe, medium green head type, weighing 4.5–5 kg. Poor field holding ability. Very popular for spring production. Tough plant, superior in shipping and keeping.

Red cabbage

Cairo (B). Productive flat/round hybrid with excellent colour and uniform maturity, approximately 13–15 weeks from transplanting. High quality product, strong against fusarium.

Cardinal Red (T). Globe shaped, red head type, weighing 1.5–2 kg. About 12–13 weeks from transplant to maturity. Good field holding ability. Makes better size growing into warm season.

Kremlin (Syn). A high yielder with large, flat globe shaped head with deep red/purple internal colour and thin inner leaves and an average weight of 2.6-3kg, excellent uniformity. Mature at 80 days from transplant. Used for both fresh market and processing. Tolerant to black rot. Adaptable top a wide range of growing conditions with field holding ability

Primero (B). Excellent early maturing variety, 10–12 weeks from transplant. Dense structure, well coloured, ideal for 'baby', 'mini' or medium size production.

Red Ace (C). High yielding, early mid-season, producing 2–3 kg solid, slightly flat round heads. Very good colour, medium red exterior with greenish tinge and medium red interior with tough wrapper leaves for added shipping protection. Very good field holding ability for marketing flexibility. Low level black rot tolerance; tipburn tolerant.

Red Rookie (F, T). Round, solid. globe shaped, red head type, weighing 1.5–2 kg. About 12–13 weeks from transplant to maturity. Good field holding ability. Best suited to cool season production.

Red Sky (LV). Semi round, medium sized weighing 2.5–3.5 kg. Good field holding ability. Harvest in cool season production slots.

Red Storm (LV). Cool and mild season harvest variety, with an average size of 3–4 kg. Produces a flat round head with an intense red colour.

Superba (F). Good keeping market. Firm, dark red globe shaped head.

Cauliflower

Admiral (T). Very tight, deep domed head, regular shape, good presentation. Medium large, good quality curd. Very good inner leaf protection. Good uniformity and short cutting period, but good holding ability Strong, vigorous, upright frame with excellent leaf wrap. Matures about 13–14 weeks from transplant. Excellent quality, recommended for harvest in late autumn and spring in cool-cold temperate regions.

Advantage (T). White, medium large, good quality curd with very good inner leaf protection. Admiral type with improved seed. Excellent quality recommended for harvest in late autumn and spring in cool-cold temperate regions. Very tight full dome with good holding ability. Strong, vigorous, upright frame with excellent leaf wrap. Matures about 13–14 weeks from transplant.

Ambassador (T). Snow white, deep solid heavy curd. Excellent curd protection. A robust plant suited to June/July harvest in temperate areas. Protective upright frame. Matures about 16–18 weeks from transplant.

Arctic (T). Large, well domed curd that is well covered. A tall framed upright variety, which performs consistently in autumn and spring slots and also for winter harvest in mild areas. Matures about 13–14 weeks from transplant.

Beluga (LV). Winter harvest variety for Stanthorpe and Darling Downs, to be harvested after Escale. Matures in about 15 weeks. Very vigorous plant, with good curd cover.

Brittany (F). New introduction suited to harvest from late autumn to early winter on the Darling Downs and autumn in Stanthorpe. Matures about 90 days from transplant. Erect, vigorous plant with good curd cover.

Bulla (H). Produces well covered, dense, white and smooth curds weighing between 1–1.5 kg. Suited to late autumn and spring harvest in cool climates and winter harvest in warmer regions. Matures about 13 weeks from transplant.

Cauldron (T). Medium sized, dome shaped curd with a good wrap. Compact and erect with adequate cover for warm season harvest. Matures about 10–13 weeks from transplant.

Celsius (LV). Curds are very firm and smooth with good depth. Has excellent self covering ability, ensuring bright white curd. Summer harvest variety for Stanthorpe and Darling Downs. Matures 11–13 weeks from transplant. Suitable for export.

Celeste (SPS). An exceptional uniform cut. Medium framed, fast maturing variety in the Plana class. Grows well as a mini cauliflower under high density. Best suited to mild harvest conditions during spring and autumn.

Charlotte (SPS). A version of Fremont with similar maturity timings and plant habit for Queensland, WA and NSW. Provides adequate cover for the very solid and heavy curd, with improved white colour. In trials Charlotte has not shown the sometimes characteristic tipburn problem associated with Freemont. Has an extremely uniform cut.

Chaser (Syn). Plant is tall and upright, cool weather tolerant with strong vigour even at seedling stage. Strong wrapping leaves and inner covering. Boron application is recommended during vegetative growth phase in warm conditions. Curds are excellent quality, snow white with deep shape, very well structured, heavy and dense. Suited for fresh market and export. Suits mild to cool harvest. Field tolerance to black rot.

Clyde (T). Early maturing variety suitable for warmer production. Strong frame that provides an excellent cover for white, quality heads under warm conditions. Suitable for 'mini' cauliflower production. Matures 10–12 weeks from transplant.

Colorado (LV). Very vigorous plant, producing a smooth, white curd. Winter harvest to follow Escale on the Darling Downs and in the Stanthorpe area. Matures about 13 weeks from transplant.

Discovery (SPS). Exceptional covering ability; extremely heavy and solidly formed, very white curd. Large upright frame and tight wrapper leaves that are self covering under most conditions. A very versatile variety suited to late spring, summer and autumn in southern areas and can also be grown mid winter in some areas of Queensland. Stores well and is suitable for export.

Donner (SPS). Very strong plant produces an extremely uniform very white curd of exceptional weight. Suitable for both domestic and export markets.

Escale (LV). A good density curd with excellent cover. Standard variety in southeast Queensland. Wide adaptability for fresh and export markets. Mature at about 13 weeks.

Flamenco (B). Vigorous, quick maturing hybrid with protective frame for ideal 'mini' variety in 10 weeks from transplanting.

Fremont (SPS). Large upright frame and excellent curd quality. A versatile variety that has become established as the early season cauliflower for warm conditions in NSW, WA and Queensland.

Greena (H). A green curd cauliflower. Plant size is medium with reasonable curd cover. Matures 10–14 days earlier than other similar lines. Trials indicate Greena is suited for harvesting from mid autumn to early spring.

Huntsman (T). Vigorous variety with a strong frame and medium to large solid white curds. Good to very good curd cover. Excellent field uniformity, high yield potential. Matures 12–13 weeks from transplant. Suitable for planting over an extended season.

Kilda (H). Reselected from the parents of Lucie to improve curd cover, depth and frame size. Has excellent early heat tolerance. Can be cut from late autumn through to spring in warm areas such as the Lockyer Valley. Matures about 10–11 weeks from transplant.

Monarch (Syn). Plant has strong foliage and superior self protection. Curds are deep white, smooth, very heavy and outstanding quality. Excellent uniformity. Suitable for the fresh market and export. Matures 80–115 days from transplant.

Morpheus (Syn). Very vigorous, strong framed plant with excellent self protection. Versatile variety suited to spring and late autumn harvest in temperate areas. Curds are deep white, smooth, very heavy and excellent quality. Good uniformity. Matures 80–85 days after transplant. Suited to the fresh market and export.

Nautilus (LV). Early maturing, vigorous plant with good self covering ability. Matures about 11 weeks from transplant. Has good heat tolerance and is suitable for early and late summer harvest.

Normandy (F). New introduction to be trialed for the winter harvest segment in Stanthorpe. Extremely vigorous and erect plant with excellent curd wrap. Matures 16–17 weeks from transplant.

Nova (T). Early maturing, heat tolerant CMS variety. Australian bred for production in warmer climates. Curd is well wrapped and deeply tucked. Very adaptable variety.

Omeo (H). The plant is large framed and covers the curd well. Medium to large curd, well tucked, heavy and very white. Bred to handle cold conditions and harvests best from winter into mid spring in the Granite Belt region. Matures 15–16 weeks from transplant.

Ossa (H). New variety with a small/medium frame and compact heavy heads about 1.7—2.3 kg. Excellent curd wrap, upright leaf growth and bright white curds. Suitable for mid-March to May transplant in the Lockyer Valley. Matures 12–13 weeks from transplant.

Ravella (C). An excellent variety for harvest during the cooler periods. Heat tolerant during early development and tolerates late frosts moderately well. Exceptional uniformity at harvest with extremely white, good size and weight heads. Excellent fresh market pack.

Rushmore (C). High quality, pure white heads; globe shape is very uniform with good frame. Abundance of bottom and top protection from dark green leaves.

Savannah (SPS). Excellent self covering frame suited to cool conditions either side of the main winter months. Produces uniform, dense white curds with good weight. Matures 16–17 weeks from transplant.

Selection 174 (T). Creamy white, deep, heavy curd that is well protected by inner leaves Matures 13–15 weeks from transplant. A reliable, standard, open pollinated variety.

Sergeant (Syn). A CMS variety, extremely quick maturing, versatile with excellent density. Medium size frame with good self protection. Curds are deep white, very domed with excellent density and an extremely high level of uniformity. Suited for fresh market and export. Black rot tolerant. Matures in 70–77 days.

Skywalker (B). Vigorous tall frame around a well domed, deep tucked, solid white curd. For autumn, mild winter and spring harvest. Matures 12–15 weeks from transplant.

Starlight (T). Australian bred CMS Atlantis type for production in colder climates. Adaptable variety suited to fresh market and processing. Excellent wrap and very good weight. Maturity is approximately 1 week earlier than Atlantis.

Summer Love (Syn). Strong framed plant with outstanding self covering. Curds are deep white, smooth, very dense and very heavy. Good uniformity. Suited to fresh market and export. Strong heat tolerance with no pinking. Matures 80–85 days from transplant.

Thalassa (LV). Curd has good depth and density, with good self covering ability. Tolerant to mild/cool autumn conditions. Matures 12 weeks from transplant.

Trojan (Syn). Medium to tall plant; erect habit provides very good protection. White, dense, heavy curd with strong self covering. Suited to fresh market and processing. Good tolerance to black rot. Good holding ability. Suited to warm growing conditions producing a consistently high quality curd. Matures 84–100 days from transplant.

Virgin (Syn). Tall, erect plant with strong vigour that can be grown into and out of cool conditions with little effect on frame size. Excellent quality, dense white curd with good self covering. Suited to processing and fresh markets. Matures 74–85 days from transplant.

Violet Queen (F). Purple domed cauliflower. Cooks deep green, with excellent taste.

White Frosty (C). Very dense, white heads with tight protection from inner wraps. Heads mature uniformly. Harvest late for summer. Performs well throughout the season in cooler districts.

White Jewel (C). Produces solid high quality heads for harvest throughout the season. Early maturing, upright, vigorous variety.

White Mount (C). Very white, deep smooth curds averaging 18 cm across with excellent weight, density. Self covering plant habit. Has performed well under varying conditions and shown excellent results for summer and autumn harvest.

White Planet (C). Produces heavy, deep, dense snow white curds of 1.5–2.2 kg with good self covering ability. Large frame with erect broad leaves. Suitable for fresh market growers. Produces high percentage first quality curds.

White Star (F). Firm white dome protected by a vigorous upright leaf.

Broccoli

Atomic (SPS). Blue green dome shaped heads with fine bead and good weight. Early maturing variety which handles warmer weather, with the potential to extend past the traditional Shilo timeslot into slightly cooler weather. Not suited for early spring harvest.

Babylon (SPS). Attractive, well domed head with medium small bead and exceptional weight and colour. A very versatile shoulder season variety alongside Marathon /Greenbelt. Maturing approximately 5 days later than Greenbelt but earlier than Marathon. This variety offers growers an excellent choice under variable spring/autumn conditions in southern states and winter in Queensland.

Ballistic (F). Warm weather harvest variety with a medium dome head and medium fine beads. Not suited to early spring harvest where premature bolting can occur.

Bandit (Syn). Vigorous plant with very few side shoots and long dark leaves. Easy to harvest, high-set heads are smooth and heavy with very tight, uniform fine beads, deep dome shape and very good colour; excellent uniformity and outstanding quality. Suitable for fresh market and processing and best harvested from late autumn to mid-spring in temperate areas. A Marathon/Legacy type that matures 83–93 days from transplant.

Belstar (B). Short open plant with fine beaded dome, strong stem and uniform maturity, 10–12 weeks from transplant. Ideally sited to autumn, mild winter and early spring harvest. Strong resistance to mildew.

Bravo (SPS). Fine beaded, well domed heads, best suited for harvest mid to late winter and spring. Vigorous open plant with a thick stem and good weight. Can be planted at higher density to give greater yield per acre.

Endurance (T). Exceptionally dense, high quality heads with fine beads. Very well domed and dark green in colour. Recommended for cooler season production. Matures 11–12 weeks from transplant.

Evergreen (SPS). Produces firm medium dome shaped heads with fine bead and dark green colour. Has the ability to handle temperature variation better while maintaining exceptional uniformity of colour. Performed well in late autumn, winter and spring.

Greenbelt (C, F, SPS, T). Dark green, compact domed head with medium/fine beads. Industry standard for autumn and spring production. Adaptable and reliable with excellent uniformity. Matures in about 10-11 weeks from transplant. Highly tolerant to bacterial leaf spot. Second early hybrid for fresh market/processing suited to close planting.

Grevillea (H). High yielding variety with a large domed, very dense head and fine beads. The head is well tucked and a very thick stalk gives exceptional weight to the cut head. Cuts with outstanding results from mid autumn to late spring. Up to one week later than Marathon in maturity. Trials have shown good autumn heat tolerance

Ironman (SPS). A very versatile fine beaded broccoli with heavy head weights due to dense florets rather than a thick stem. Good cold weather and water stain tolerance.

Marathon (C, F, SPS, T). Dense well domed deep green head with very fine beads. Vigorous plants, produces quality heads for cool season production. Medium-late hybrid for fresh market/processing. Tolerant to bacterial leaf spot, black rot, tolerant to hollow stem. Matures in about 11-12 weeks from transplant. Reliable industry standard.

Mascot (SPS). Improved version of Maverick.

Maverick (SPS). An extremely versatile variety which can maintain fine bead and excellent quality and weight under a range of conditions. Well domed heads with excellent uniformity, fine bead and attractive blue green colour. Similar maturity to Green Belt with thicker butt, better head weight and holding ability under adverse conditions.

Monaro (Syn). Green mild season harvest. Matures 80-90 days from transplant. An upright plant with few side shoots. The head is very domed with medium to small beads. Heads are very dense with a heavy butt, typically weighing between 400-600 grams. Highly tolerant to hollow stem development. Produces a uniform yield and has early maturity.

Mongoose (LV). New introduction for cool Greenbelt and warm Marathon harvest periods. Very versatile for production in difficult shoulder production periods. Suitable for fresh market and export production.

Paragon (C). Fine, extra dark-green beads form large, domed and firm heads. Has a good holding ability until heads become extra large and excellent keeping quality after cutting. Long stems hold heads at high position making harvest easier, a little taller than Greenbelt. Has tolerance to brown bead and downy mildew.

Ruben (Syn). A type in the Marathon/Legacy timeslot. Beads are very fine, uniform and tight. A strong vigorous plant, takes about 85 –95 days from transplant to harvest. Excellent uniformity. Outstanding head quality, very few side shoots. Suited to fresh and processing markets, best harvested from late autumn to mid spring in temperate areas.

Shilo (SPS). Adapted to early autumn cropping in south-east Queensland; medium to large bead, some heat tolerance; 8 weeks from transplanting to maturity.

Superior (C). A Greenbelt type mid-early hybrid, maturing one week earlier, plant grows taller than Greenbelt. Produces a smooth, large, high domed head. Beads are mid-sized and deep green. An easy harvester, heads have a higher position than Greenbelt and less lateral shoots below. Attractive appearance for the fresh market. More tolerant to heat compared to Greenbelt. Resistant to downy mildew.

Viper (LV). Exciting new introduction for harvest in the warm Greenbelt slot, where Greenbelt can suffer a quality decline. Viper should not be harvested early in cool season production areas and performs best grown in the heat or from heat to cool.

Direct seed or transplant

Brassica crops can either be direct-seeded into the field or grown in containers and transplanted. If you decide to use transplants, you can either buy them from a seedling nursery or grow them yourself.

To reduce risks and simplify production, we strongly recommend that first-time brassica growers buy transplants from a reputable vegetable seedling nursery.

- Transplanting versus direct-seeding brassica crops
- Why grow your own seedlings?
- Growing container-grown seedlings
- Transplanting
- Things to remember

Transplanting versus direct-seeding brassica crops

Using transplants reduces production risks while direct-seeding brassica crops reduces planting costs.

Advantages of container-grown seedlings

- Seedlings are raised in a sheltered environment when outside conditions are often unfavourable and planted out when conditions are more favourable, giving them a head start over seed planted in the field.
- Early production may lead to better market access.
- Less water is required during establishment.
- Weed management is less of a problem as a greater range of herbicides can be used in transplanted brassicas. Transplants also have a better chance of outgrowing emerging weeds.
- Seed costs are lower.
- More time is available for land preparation.
- Lower losses in the field from cutworm or wireworm attack.
- Shorter time in the field. This can be an important consideration where there is limited land available for vegetable production.
- Better crop uniformity, particularly if seedlings are graded for size before or at planting out.
- No thinning is required.

- Transplanting machinery is usually uncomplicated and simple to operate.
- Adverse conditions such as rain or hot weather have less effect on plant establishment.

Disadvantages of container-grown transplants

- It costs more to establish a crop using seedlings than direct seeding.
- Sunburn will cause losses if seedlings get too tall or are not hardened off properly.
- Transplant shock may influence head quality and crop stand, particularly if transplanting under less than ideal conditions. Transplant shock is not a major consideration when high quality, cell-grown transplants are planted out carefully.
- Labour intensive.

Advantages of direct seeding

- Planting costs are reduced by as much as $1000 per hectare.
- Labour requirements are lower. The major input is weed control and thinning of seedlings, depending on seeding equipment used.

Disadvantages of direct seeding

- Direct seeding significantly increases the risks associated with pests and diseases, adverse weather, soil crusting and weed management. These risks affect not only final plant density, but more importantly, crop uniformity. Keep in mind that your aim is a once over harvest of cabbage and two or three passes to harvest broccoli and cauliflower. Uneven crop establishment will generally result in a less uniform crop stand and more variable crop maturity. This will significantly increase harvesting costs.
- Field-growing time is increased by about two weeks. This can be important where there is limited land available for vegetable production.
- More water is required during crop establishment.
- Fewer options are available for managing weeds.

Why grow your seedlings?

Most growers consider that they are more likely to obtain top quality seedlings by leaving this job to an expert. Farmers who are already well organised and keep good records are usually the most successful at growing their own seedlings. Those farmers who are still becoming established or are having major problems in other areas of their production system, particularly with pests and diseases and managing labour, will have the most problems in raising their own seedlings.

The cost of buying seedlings is often the motivating factor for growing seedlings or deciding to direct seed into the field. Some farmers can grow seedlings for less than a professional nursery, others cannot. Only by keeping good records of costs can you demonstrate the real cost of producing your seedlings.

Apart from the cost of growing seedlings, you should also consider the availability of suitable labour, expertise in seedling production or ability to access such expertise and the quality and quantity of water available. The most successful seedling production unit is usually managed by a full-time employee or family member who is appointed and trained to do this job.

Advantages of growing your seedlings

- It is possible to have better control over the timing and quality of seedlings.
- The cost MAY be lower than from a seedling nursery, but this largely depends on how you do your sums.
- A farmer who can produce top quality vegetables should have minimal problems producing vegetable seedlings.

Disadvantages of growing your seedlings

- Labour, capital and expertise are required and these will either cost money or your time.
- As with any new enterprise, there can be some failures and this could cause major disruption to planting and harvesting schedules. Buying in transplants reduces risk.
- There is always the temptation to attempt to cut costs by using cheaper but often unsuitable materials. This has caused many disasters.
- By having a much smaller throughput than a seedling nursery, it is more difficult to produce a set number of seedlings per batch. Under or over production can be costly, either by making each plant more expensive or disrupting planting and harvesting schedules. Economies of scale should also be considered.
- Adequate quantities of good quality irrigation water are essential for producing quality brassica seedlings. A farmer who is having major problems in producing vegetables should cancel or postpone any planned entry into seedling production.

- A farmer, or potential farmer, who is in general financial difficulties should not contemplate raising seedlings as a means of reducing costs. Financial problems can easily be compounded, especially if there are seedling production problems.

Growing container-grown seedlings

Seedlings are best grown by nurseries that have the right equipment and the expertise to grow plants well. Poorly grown plants have a lower yield potential than well-grown, sturdy plants. Some growers, however, prefer to produce their own seedlings.

The seedling mix

To grow healthy seedlings, it is essential to use an open, well-drained, sterile potting mix with sufficient nutrients to give the seedlings a good start. Many different mixes have been used successfully; one of these is shown in Table 28.

Table 28. A suggested mix for container-grown seedlings.

Ingredient	Amount / 200 L
Peat	100 L
Vermiculite	100 L
Dolomite	800 g
Fine milled superphosphate	400 g
Potassium nitrate (fine)	400 g

Mix ingredients thoroughly, add about 5 L of water and mix again. This dampens the peat so that water penetrates more easily into the filled trays. Mix ingredients for up to three minutes. Over-mixing will damage the vermiculite and reduce the aeration and water-holding ability of the mix. The pH of media ingredients can vary and dolomite rates may need to be adjusted to obtain a mix pH of 6 to 6.5. Water with high bicarbonate levels (above 600 mg/L bicarbonate) can cause the pH to rise during seedling growth in which case the initial mix should be around pH 5.5.

The granular formulation of the fungicide metalaxyl can be added to the seedling mix as it is being prepared to reduce the risk of damping off (*Pythium* spp.). Check the product label for rate and instructions.

A wide range of trays is used but the inverted pyramid Speedling type trays seem to give the best results. The larger the cell the more space is available for plants, resulting in shorter, sturdier plants. If cells are too small, seedlings can be soft, lanky and more susceptible to disease. A 198 Speedling tray is a common cell size used, although commercial seedling nurseries may use their own specialist trays.

Planting

Use only seeds of high vigour and reliable germination. Check if the seed has been treated with a fungicide to control fungal seed infections (*Pythium*, *Rhizoctonia*, downy mildew, black leg and *Alternaria*).

more info
Hot water treating seeds
This chapter page 234

Fungicides are not effective against bacterial diseases such as black rot and bacterial scald. Hot water treat seed to control black rot, bacterial scald and some fungal seed infections. Hot water treatment can reduce seed vigour.

Fill trays evenly with mix. Plant one seed per growing cell and cover with 6 mm of mix or vermiculite. Some nurseries plant extra seeds into some cells then manually prick out spare seedlings to fill empty cells where seed has not germinated. This practice maximises the use of nursery space and trays but requires thinning of seedlings. Vacuum seeders are used in most nurseries to drop one seed per cell into the trays.

To assist uniform and rapid germination, the seeded trays are often placed in a warm room on pallets. Take care to ensure that the seedling only starts to emerge from the tip of the seed before taking the trays out and placing them on racks, either outdoors or in the greenhouse. The racks should be at least 500 mm above ground level for drainage, air pruning of the roots and to prevent soil-borne diseases being spread by water splash from the ground. Waist high racks are easier for staff to work with.

Watering

Water trays once or twice daily and up to three times daily in hot weather. Water that has an electrical conductivity (EC) of less than 1.5 deciSiemens per metre (dS/m) is essential for good vigorous seedling growth. Above this level, reduced growth and leaf burn may occur.

Water with high bicarbonate levels and conductivity levels above 1.0 dS/m will require modifications to the seedling mix and close monitoring of pH levels. Water slowly to ensure complete wetting of the mix. Over watering is a mistake easily made and causes nutrient leaching and disease build-up. Sufficient water has been applied when water is first noted dripping from the bottom of the cells.

Uniform watering is important to ensure optimum growth of all seedlings. Wind plays havoc with water distribution from the small sprinklers used in nurseries. Trees or shade cloth windbreaks will help to prevent poor water distribution and promote vigorous seedling growth.

Fertilising

Apply nutrients with a high nitrogen content (for example Aquasol® or Thrive®) as a foliar spray when plants are about one week old. Spray once or twice weekly until plants are hardened off. Alternatively, a solution of 330 g calcium nitrate and 170 g potassium nitrate dissolved in 10 L of water can be made up. Shortly before use, dilute 20 mL of this solution in 10 L of water. Apply 5 L of this diluted mixture per square metre of seedling trays.

The calcium and potassium mixture will not supply trace elements. Brassica crops are susceptible to molybdenum and boron deficiencies. Apply sodium molybdate (10g/10L) with wetting agent three to four days after seedling emergence and again shortly before transplanting. Apply Solubor (25g/10L with wetting agent 10 to 14 days after seedling emergence and again just before transplanting. If seedlings are to be planted into a soil known to be low in any other particular element (for example, zinc or manganese) apply special foliar sprays before transplanting. Note that Solubor is not compatible with zinc sulphate heptahydrate.

a key issue
Nutrition
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Protecting seedlings

Hygiene is the most important consideration in protecting your seedlings. Clean mixing areas, sterilised trays, sterile seedling mixes, raised benches, safeguards against disease spread, limited entry to the nursery area and quarantine of diseased seedlings are all important nursery practices. Control weeds in and around the nursery to reduce disease and insect risks to seedlings.

Monitor seedlings for pests and diseases. Spray with protective fungicides to control bacterial and fungal leaf diseases such as downy mildew and black rot. Good coverage of plants is essential for effective control. If necessary, spray to control insect pests such as caterpillars, aphids, thrips and silverleaf whitefly.

more info
Chemical Handy Guide
Chapter 6 page297

To promote sturdy growth, grow seedlings in full sun. In extremes of weather, take the seedlings back into the greenhouse or under shade cloth. Use thirty percent shade cloth to protect plants from adverse weather conditions.

Transplanting

Seedlings are ready for transplanting into the field once they will pull cleanly out of the tray; that is when the roots have fully penetrated the mix (Figure 29). For cup transplanters, seedlings should be no more than 10 cm tall for best results. Waterwheel planters are not affected by seedling height; however, if seedlings are small and soft; or large, leggy and root-bound they may suffer increased transplant shock and not establish well in the field.

To harden seedlings off before planting out expose them to full sunlight several days before planting. Soft seedlings are one of the main causes of transplant losses. Grade out weak or spindly plants, using only vigorous, healthy plants.

Figure 29. Cabbage (upper) and broccoli (lower) seedlings ready for planting out

To minimise transplant shock:

- Plant in the early morning or late evening and avoid transplanting on hot or windy days.
- Check that staff and equipment are planting seedlings properly, making sure good contact between the soil and root ball is achieved.
- Water well immediately before and after planting out.

Things to remember

When growing your own seedlings, remember:

- Sterilise trays before re-use.
- Do not over-compact mix in trays.
- Keep potting mix moist; use low output sprinklers which give an even cover of all trays. Cells on the outside of trays tend to dry out faster. Water until trays start to drip.
- Regularly check the conductivity of the water; seedlings require better water quality than plants out in the field and poor quality water can stunt and burn seedlings.
- Drain water out of pipes before watering; this water may be hot and scald plants.
- Keep trays level; this prevents low spots being over watered and high spots being left dry.
- Put trays on wire-based, raised benches to allow air pruning of roots; air pruning prevents root growth out of the bottom of trays because roots dry out as they come out of the mix.
- Pay attention to hygiene to prevent diseases coming into and spreading within the nursery.
- Maintain a regular spray program for leaf diseases as conditions in the nursery are ideal for disease development; ensure that your sprayer gives good plant coverage.
- Adequate ventilation of the greenhouse or shade house is essential.
- Protect plants from wind and heavy rain.

Nutrition

The geological origin, depth, pH and recent cropping history influence the inherent fertility of the soil and your fertiliser program. Soils used for growing brassicas vary in their inherent fertility, as the crop will grow in a wide range of soil types providing they are well-drained and have about 300 mm of friable topsoil.

Adequate plant nutrients in the correct proportion are necessary to produce high yields of good quality cabbage, cauliflower and broccoli. The aim is to achieve even crop growth without water and nutritional stresses. Brassica crops have a high demand for the major nutrients particularly nitrogen, and are susceptible to molybdenum and boron deficiency.

- Plan your nutritional program
- Nutrient management
- Fertilisers
- Monitoring plant nutrients

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 done to determine what nutrients are available, and perhaps more importantly, what nutrients will be in short supply. This information is then used to plan a nutritional program and to adjust the soil to the crop's requirements before planting. A chemical soil analysis takes the guesswork out of fertiliser scheduling and will give the plants the best chance to produce a high yield of quality heads or curds.

more info
Laboratories for chemical soil analysis Chapter 5 page 281

A soil analysis measures the pH, conductivity, organic matter and the concentration of nutrients in the soil. Take the sample eight or more weeks before your expected planting date. 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 also 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. Brassica crops prefer a slightly acid soil, around pH

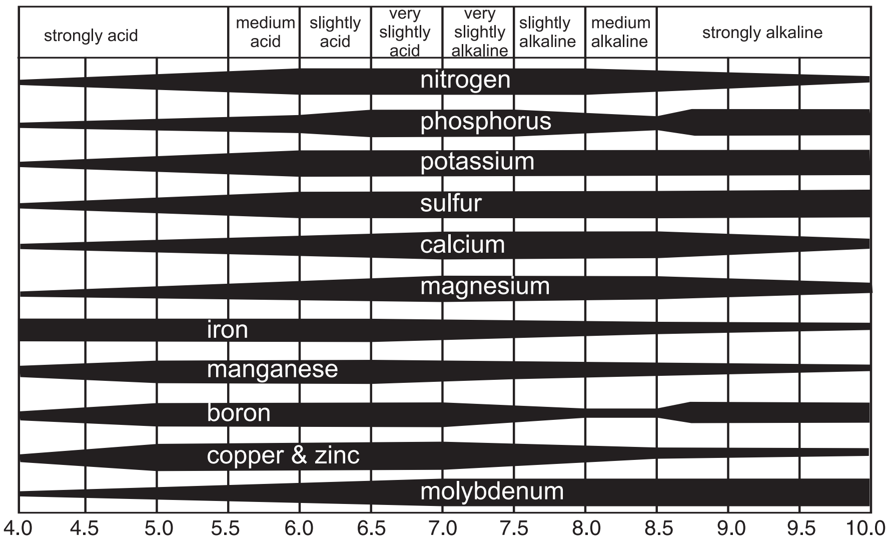

Figure 30. *Nutrient availability at different soil pH levels*

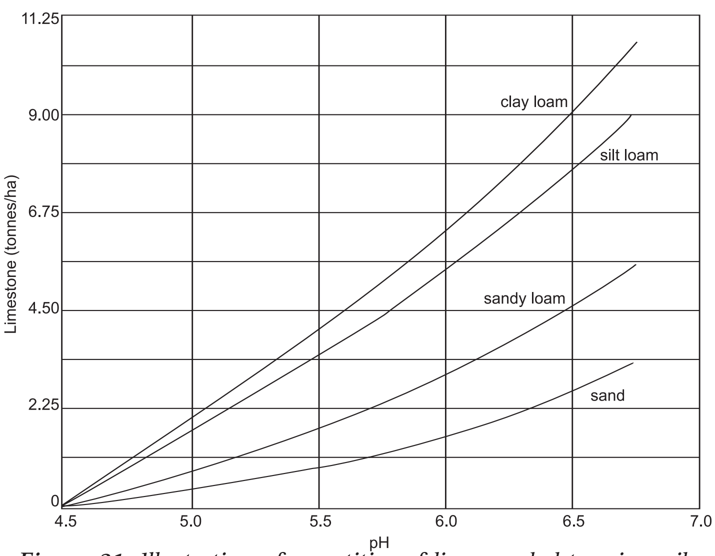

Figure 31. *Illustration of quantities of lime needed to raise soil pH (Source: Matheson et al. 1975)*

6.0 to 6.5. In this range, most major and trace elements present in the soil are available to plants at adequate levels (Figure 30). In more acidic soils, molybdenum deficiency may occur. Brassica crops can also be grown successfully on slightly alkaline soils, up to pH 7.5, but trace elements such as boron may not be as readily available to plants. Raising soil pH to between 7.0 and 7.5 is an important tool for managing the soil-borne disease club root.

Many Queensland soils are acidic and require the addition of lime or dolomite to raise pH. A complete soil analysis will show which form is most suitable and indicate a suitable rate by showing the available levels of calcium and magnesium. Different soil types require different quantities to change pH. Figure 31 is a guide to the application rates for lime to raise the pH in the top 18 cm of soil.

Gypsum. Application of gypsum increases soil calcium levels but does not change soil pH. Use naturally occurring gypsum, as phosphogypsum is derived from the manufacture of phosphatic fertilisers and usually contains the heavy metal, cadmium.

Some heavy clays used in brassica production have high sodium levels and a pH higher than 8.0. These types of soils do not maintain their structure when wet and tend to form a hard surface crust as they dry out. An application of 5 to 10 t/ha of gypsum can improve the structure of these soils. However, these high rates of gypsum will temporarily raise the total salt level in the soil. Electrical conductivity (EC) is a measure of the salt level or salinity in the soil. For cabbage, a soil EC above 1.8 deciSiemens per metre (dS/m) may adversely affect seed germination and plant growth. For cauliflower the threshold EC is 2.5 dS/m, for broccoli it is 2.8 dS/m.

Apply gypsum before the wet season so that rains can assist in leaching the sodium beyond the root zone well before planting, thus improving the soil structure. The nutrients in gypsum are readily available but it takes about one year for the effects of gypsum on soil structure to become fully apparent. Table 29 is a guide to the appropriate management of calcium, magnesium and pH. Note that the gypsum rates to supply calcium are much lower than the rates used to improve the soil structure of high sodium clay soils.

Table 29. 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		✓		✓		✓		

Organic additives and cover cropping

Animal manures are useful for increasing the level of organic matter in the soil in the short term as they improve soil structure and supply all or some of the nutrients required by the crop. Cover crops (green manure crops) are valuable for crop rotation programs, protect the soil from erosion, help suppress weeds and add organic matter to the soil. Cover crops will also utilise any nutrients left over from the previous cash crop, in effect, recyling nutrients and reducing the risk of highly soluble elements such as nitrogen leaching into the ground water.

more info
Prepare the land
Chapter 3 pages 41 to 46

Incorporate organic additives and cover crops into the soil several months before planting, allowing at least six to eight weeks in warm weather and several months under cool conditions for materials to decompose properly. A cover crop can tie up soil nitrogen as it breaks down and may require an application of nitrogen. A cover crop with a good green colour indicates plenty of nitrogen in the plant biomass and extra nitrogen should not be required for breakdown. However, a yellow or brown crop (such as stubble) with little nitrogen in the plant biomass will require additional nitrogen for breakdown.

Repeated applications of manure add substantial amounts of phosphorus to the soil. Fowl and feedlot manure also contain chloride, which may become a problem unless leached from the soil by rain. Undecomposed manures or plant materials can lead to disease problems such as *Rhizoctonia*. There are also quality assurance and food safety issues to consider when using manures.

It is more difficult to manipulate supply of nutrients to plants using organic additives as rates of nutrient release will vary with soil and weather conditions. Although the nutrient content of manures may be low, manures are often added in large quantities meaning that large quantities of nutrients are actually added to the soil. An ideal time for applying animal manures is during the cover-cropping phase. Adjust fertiliser rates downwards following the application of large quantities of manures.

Nutrient management

Brassica crops require careful nutritional management to ensure high yields of top quality produce. Nutrients must be balanced to achieve early vigorous growth so that plants build an adequate frame that will later support the development of quality heads. Follow the recommendations of your soil analysis when applying fertilizer but also take into account the cropping history of the paddock. This includes factoring in the nutrient content contained in previous crop residues and green manure crops and nutrients applied through animal manures or other organic additives.

Nutrient budgeting

A nutrient budget is somewhat like an accounting system for nutrients. This involves calculating the amount of nutrients applied to a paddock and estimating the amount of nutrients removed through harvesting product, losses through leaching and volatilization into the atmosphere. The nutrients lost to the system are then replaced through appropriate fertilizer applications. Nitrogen, phosphorus and other major nutrients are the main elements considered in nutrient budgeting.

While the different brassica crop types all take up large quantities of nitrogen, cauliflower crops are perhaps the most demanding. However, cabbage crops remove the most nitrogen from the paddock at harvest since most of the plant is harvested with the head. In contrast, a large proportion of nutrients are returned to the soil with plant residues in cauliflower and particularly broccoli crops. This material will quickly break down in Queensland's mild climate to provide an important source of nutrients for the following crop. The return of large amounts of nitrogen and other major elements to the soil needs to be taken into account when planning the fertilizer requirements of the next crop.

Table 30 shows the approximate amounts of major nutrients that are exported off the farm by average crops of broccoli, cauliflower and cabbage. Remember that the unharvested portion of the crop (stems, leaves and roots) also take up nutrients from the soil in the short term, but these will be returned to the soil when the crop is ploughed in.

Table 30. The estimated amount of nutrients removed from the soil by the harvested portion of average cabbage, cauliflower and broccoli crops.

	Nutrient removal					
Nutrient	**Cabbage**		**Cauliflower**		**Broccoli**	
	kg/t of fresh weight harvested[a]	kg/ha with a crop yield of 40 t/ha	kg/t of fresh weight harvested[a]	kg/ha with a crop yield of 25 t/ha	kg/t of fresh weight harvested[a]	kg/ha with a crop yield of 8 t/ha
Nitrogen (N)	*3.5*	140.0	*3.1*	77.5	*5.0*	40.0
Phosphorus (P)	*0.5*	20.0	*0.6*	15.0	*0.8*	6.4
Potassium (K)	*3.2*	128.0	*3.6*	90.0	*4.0*	32.0
Sulphur (S)	*0.4*	16.0	*0.6*	15.0	*0.8*	6.4
Calcium (Ca)	*0.54*	21.6	*1.3*	32.5	*0.37*	4.0
Magnesium (Mg)	*0.19*	7.6	*0.23*	5.8	*0.18*	1.4

[a] Concentrations of nutrients in cabbage, cauliflower and broccoli crops vary considerably. Quantities of nutrients removed by heads or curds have been based on representative concentrations given in D. Reuter, unpublished data, National Land and Water Audit Project 5.4, 2001. These were based on fresh weight concentrations per kilogram, assuming 92% moisture in cabbage, 91% moisture in cauliflower, and 90% moisture in broccoli.

Irrigation

Plants absorb nutrients primarily from the soil solution. Irrigation practices should aim to provide even soil moisture across the paddock and over time, without leaching nutrients below the root zone. This is particularly important for making the best use of the more mobile elements such as nitrogen, sulphur, potassium and boron.

a key issue
Irrigation management
This chapter page 168

While nutrient deficiencies are the more common problem, some elements, particularly nitrogen, chloride, sodium, manganese and boron can cause toxicity problems if taken up in excess quantities by plants.

The following descriptions of nutrients illustrate the complexity of designing an effective nutrient management program, particularly on problem soils, and reinforce the importance of a comprehensive soil test for calculating fertilizer requirements.

Major elements

Nitrogen (N)

Plant size, leaf area and eventual head or curd size are dependent on an adequate supply of nitrogen. Insufficient nitrogen will result in poorly grown, pale or yellow plants and low yields of small heads. Large amounts of decomposing organic matter can induce nitrogen deficiency and then result in high soil nitrogen levels when decomposition is complete.

Too much nitrogen in the last phase of growth can cause quality problems such as head or curd splitting and cracking. Excess nitrogen can contribute to hollow stem problems and reduces the shelf life of the finished product. Nitrogen is also easily leached from the soil. For these reasons, nitrogen fertiliser is usually split into several applications, with the first applied just prior to planting. The remainder is applied as side dressings up until early heading in cabbage or early buttoning in cauliflower and broccoli. Nitrogen requirements are particularly difficult to estimate without a soil analysis and an estimate of total crop uptake.

Phosphorus (P)

Phosphorus is required during the early stages of crop growth for plant development and root growth. The potential yield of the crop is reduced if adequate levels of phosphorus are not available to the seedling and young plant. Phosphorus deficient plants have stunted growth with purple discolouration of the older leaves, however these symptoms can be confused with cold weather effects. Low soil phosphorous levels are more common in red or brown soils, high in iron (Fe) and aluminium (Al) that tie up large amounts of phosphorus, making the nutrient unavailable to plants. Phosphorus is not readily leached from the soil however significant amounts of phosphorus may be lost from paddocks through soil erosion.

Potassium (K)

Adequate potassium is required to produce firm, high quality heads. Leaves of potassium deficient plants develop yellowish to greyish margins, which may turn brown and necrotic (dead). Yellowing and necrosis of the area between the veins is also a common symptom (leaf scorch). Symptoms are usually first seen in older leaves. Deficiencies can occur in sandy soils, acidic soils below pH 5.4, alkaline soils above pH 7.5. and in soils where large amounts of lime or dolomite have recently been applied. Potassium is leached from the soil by excess rain or irrigation, but not as easily as nitrogen.

Calcium (Ca)

Low soil calcium levels tend to occur in leached, acidic or poorly structured soils but calcium deficiency problems are not restricted to these soil types. Calcium is needed for strong cell walls and membranes. Calcium is not very mobile within the plant and as a result, the young tissues and growing point of the plant are the first affected. Calcium deficiency is associated with tip burn, the browning and death of margins in young leaves, brown bud in broccoli, and internal browning in cabbage.

Plant deficiency can occur even in soils with adequate levels of calcium present. Warm to hot weather, rapid plant growth, uneven soil moisture and poor quality water increase the severity of the problem. Apply lime, dolomite or gypsum as recommended by a soil analysis. Preventative foliar sprays of calcium may help overcome deficiency problems when plants are growing rapidly. Apply 800g calcium nitrate in 100 L of water at weekly intervals. Sprays are ineffective for internal browning as the nutrient solution must reach the affected plant part.

Magnesium (Mg)

Soil magnesium levels can be low in acid, leached soils particularly in high rainfall areas. High levels of calcium and potassium reduce the relative proportion of magnesium available to plants, creating an imbalance. Yellow mottling between the veins of older leaves, often starting from the tip and margin of the leaf, is a sign of deficiency. 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 or lime were used, foliar sprays of magnesium sulfate (2kg/100L) can be applied at high volume to correct deficiencies.

Sulphur (S)

Sulphur is usually found in sufficient quantities in most commercial low analysis N:P:K fertilisers, superphosphate, gypsum and sulphate of ammonia. Plant deficiency problems are not common.

Trace elements

Brassicas are particularly sensitive to deficiencies in the trace elements boron and molybdenum. Apply trace elements if deficiencies have developed in previous crops or where soil analysis results suggest a possible deficiency. Some trace elements 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 the point of run off. Solution concentrations greater than 0.25% are likely to cause leaf burn. Apply foliar nutrients separately from pesticide sprays.

Boron (B)

Boron deficiency contributes to a disorder known as hollow stem and is common in brassica crops in most districts. Plants require a continuous low supply of this trace element and unlike most trace elements, boron is easily leached from the soil.

Boron is associated with some of the functions of calcium within the plant. In boron deficient crops, tissues become brittle and crack easily. Midribs, stems and petioles may develop transverse cracks and corkiness.

The growing point may die leading to multiple side shoots. Cauliflower curds can become bronzed or brown. Discolouration and cracking of internal stem tissue, the typical symptoms of hollow stem, are not apparent until harvest begins.

The factors that contribute to boron deficiency problems are complex and interact with each other. Light, sandy soils low in organic matter tend to be low in boron and boron applied to these types of soils is also easily leached. Organic matter is one of the chief sources of boron in acidic soils and the presence of high levels of soil organic matter reduces the risk of boron leaching from the soil. In heavier soils, boron is held by clay particles in the soil but becomes less available to plants with increasing soil pH even if boron levels are relatively high.

The ratio of boron to calcium in the soil, but also soil potassium levels and sodium in irrigation water, will affect the availability of boron to plants. For example, boron uptake may be reduced in soils that have been recently limed as the calcium to boron ratio in the soil is increased. In high boron soils, high nitrogen levels may be useful for controlling excessive boron uptake, but in low boron soils, a nitrogen application may help to reduce boron deficiency problems.

Weather conditions also impact on boron uptake by plants. Fast plant growth rates during warm weather, especially if combined with excessive nitrogen applications, contribute to hollow stem problems. In cold weather, plants may have an increased demand for boron but reduced growth rates may lead to plants not taking up enough boron through their roots. Low soil moisture can also impact on boron uptake and in dry soils or during drought conditions plants may be unable to access boron even when the level of boron in the soil is adequate.

In soils with low boron levels, the preferred option is to apply 5–7 kg/ha Solubor to the soil before planting. Alternatively, use foliar sprays as a preventative treatment, especially if the causes of boron deficiency are complex. Apply 250 g/100 L Solubor as a high volume spray within 2 weeks of transplanting and repeat at fortnightly intervals. Two to three applications may be needed. Note that Solubor is not compatible with zinc sulphate heptahydrate and excessive applications of boron can lead to toxicity problems.

Molybdenum (Mo)

Brassicas are sensitive to molybdenum deficiency, which causes a disorder known as whiptail. The problem occurs widely but is more common in leached soils with pH below 6.0. Cauliflower is particularly susceptible and susceptibility can vary with variety. Whiptail symptoms include yellow and mottled outer leaves, death of leaf margins in young leaves and an inward curling of leaves causing a narrowing and twisting of the leaf blade. In youngest leaves, only a midrib with irregular patches of leaf blade may eventually develop.

Molybdenum is present in such minute quantities in the soil that this element is not measured in a soil analysis. The decision whether to apply molybdenum or not is based on the pH of the soil, crop susceptibility and past or district experience. In acid soils, raise the soil pH to 6.5 to increase availability of molybdenum. Foliar sprays of molybdenum are not effective once the disorder has developed. Apply sodium molybdate before planting if deficiencies have occurred in previous crops or district experience shows this to be necessary. Alternatively, apply foliar sprays of 60 g sodium molybdate, applied in 30 to 100 L of water per hectare, early in the crop's growth. Use two sprays over seedling trays and another two or three sprays after transplanting but before heading starts.

Zinc (Zn)

The availability of zinc decreases at pH levels above 7.0 and below 5.0. Zinc deficient plants may be stunted and appear pale from a distance. On closer inspection, leaves are yellow between the veins, and may be small and distorted. High phosphorus levels and wet or cold conditions can induce a zinc deficiency.

A soil application of zinc sulphate monohydrate (20-30 kg/ha) incorporated before planting is the most effective way to prevent zinc deficiency problems on acid soils. The higher rates may remain effective for several years. To correct plant symptoms, zinc can also be applied as a foliar spray. This is a convenient way to control zinc deficiency on alkaline soils. Use 100 g zinc sulphate heptahydrate in 100 L of water during early crop growth and spray to the point of runoff. Do not mix with boron.

Manganese (Mn)

Manganese deficiency can occur in high pH soils, causing a white to yellow grey mottling between the veins and around the margins of older leaves. However, manganese toxicity is the more common problem, particularly in acid soils with pH below 6.0.

Periodic water logging and overuse of acidifying fertilisers can contribute to toxicity problems. Symptoms include a yellowing of the leaf margins in older leaves, often followed by leaf cupping and inward rolling of leaf margins. Mottling and necrosis of leaf areas between the veins may also occur. Brassica crops are sensitive to both manganese deficiency and manganese toxicity. High soil manganese levels can be particularly damaging to newly planted seedlings.

To correct a deficiency, consider applying several foliar sprays of manganese sulfate at 100 g/100 L once plants are established. To correct a manganese toxicity, raise the soil pH above 6.0 and improve soil drainage if there are water logging problems.

Iron (Fe)

Iron deficiency is associated with high pH calcareous soil, sandy soil or acid soil with high manganese levels. Excessive liming, low soil temperatures or low soil oxygen supply can add to the problem. The disorder appears as a chlorosis of the youngest leaves. Soil applications of iron may not be effective and good soil management is a better long-term option. Improve drainage, avoid over watering and adjust soil pH. A test strip of a foliar spray of iron chelate or iron sulphate at 100 g/100 L could be considered once transplants are established.

Copper (Cu)

Copper deficiency can occur on sandy soils and may be induced by liming. Crops affected may be patchy, with wilted plants, stunted growth and poor yields. The youngest leaves are most affected. Soil applications of copper sulphate (bluestone) will correct a deficiency for a number of years. Alternatively, foliar sprays of copper within four weeks of transplanting can be used. Applications of registered copper fungicides for disease control may also prevent copper deficiency in the soil. Excess use of copper sprays can be phytotoxic.

Sodium (Na) and chloride (Cl) toxicity

Brassicas are moderately sensitive to high concentrations of salt (sodium chloride) in the soil or irrigation water. Toxicity symptoms include light grey to brown necrotic patches between the leaf veins and browning and death of leaf margins and tips. Similar symptoms can be caused by potassium deficiency, fertiliser burn or water stress. Irrigation practices and drainage can help minimise salt build up in the root zone. Avoid use of fertilisers containing chloride such as potassium chloride.

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Gypsum
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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 13:15:13 contains 13 kg nitrogen, 15 kg phosphorus and 13 kg potassium.

Fertilisers can be applied before planting, at planting or at establishment (establishment or pre-plant fertiliser) and as supplementary fertiliser during crop growth as side dressings or through the irrigation water (fertigation). The fertiliser program should be based on soil analysis results and cropping history and can be fine-tuned using leaf and sap analysis. Foliar sprays are often used to manage specific trace element deficiencies.

Table 31 provides guidelines on the total crop requirements of the major elements nitrogen, phosphorus and potassium in soils of different fertility on a per hectare basis. In row crops such as brassicas, establishment and supplementary fertilizers often banded onto the top of the bed or drilled in alongside the rows, rather than broadcast across the entire paddock.

Table 31. Total requirements of the major nutrients in soils of different fertility

Application	Fertile soil kg/ha			Average soil kg/ha			Infertile soil kg/ha		
	N	**P**	**K**	**N**	**P**	**K**	**N**	**P**	**K**
Establishment	0–15	0–15	0–15	30	30	30	40	60	70
Side dressing	25–60	–	0–15	110	–	50	140–160	–	75
Total	**25–75**	**0–15**	**0–30**	**140**	**30**	**80**	**180–200**	**60**	**145**

Establishment fertiliser

The establishment fertiliser should provide adequate nutrients for even, vigorous growth to allow plants to develop a strong root system and good plant frame. Generally all the phosphorus, about 30 to 50% of the total nitrogen requirement and 40 to 50% of the potassium should be applied before or at planting. In fertile soils or if the previous crop was heavily fertilised, additional fertiliser may not required for establishing the crop. In the absence of a soil analysis, refer to the best bet options in Table 32.

Table 32. Fertiliser rates and elements supplied for two common N:P:K mixtures

N:P:K mixture	Amount Kg/ha	Element applied (kg/ha)		
		N	**P**	**K**
13.5 : 15 : 12.5	300	40.5	45	37.5
15.1 : 4.4 : 11.5	300	45.3	13.2	34.5

On soils with high phosphorus availability, use a 15:4:11 N:P:K or similar mixture. Other elements that are required in relatively large amounts include calcium, magnesium and sulphur. Sulphur does not usually need to be applied separately as it is found in sufficient quantities in most commercial N:P:K fertilisers, superphosphate, gypsum and sulphate of potash. Lime, dolomite and gypsum are sources of calcium. Dolomite and magnesium sulfate are sources of magnesium. These elements are applied when getting the soil ready for planting.

Apply the establishment fertiliser either at planting by narrow banding 5 cm to the side and below transplants or before planting, by banding along the intended row position and incorporating (Figure 32). In soils where phosphorus may be tied-up (mainly krasnozems and red earths), narrow banding at planting is the more effective option.

Applying supplementary fertiliser (side dressings)

The establishment fertiliser should provide enough nutrients to establish the crop and start building a good plant frame. Side dressings are aimed at providing adequate nutrients to maintain even and vigorous growth, so that plants develop a frame and leaf area that can later support formation of high quality heads. The amount of supplementary fertiliser required by the crop will vary with soil type, the amount of fertiliser applied at planting and degree of nutrient leaching that may occur through rain or irrigation.

Supplementary fertiliser may be drilled in beside plants at the last working, spun on as broadcast dressings, applied with irrigation (fertigation), or applied as a combination of all these starting two to four weeks after transplanting. The total amount applied can be split into several applications, but all fertiliser should be applied before early heading or buttoning. Lighter, less fertile soils will require more frequent applications of nitrogen and potassium. For soils low in nitrogen, the first side dressing should be applied within two weeks of transplanting.

Supplementary fertiliser rates and timing and frequency of applications should be based on soil type, soil analysis results, previous fertilizer applications and cropping history of the paddock. Leaf and sap tests are useful guides for monitoring the effectiveness of the fertiliser program and are usually available from the same laboratories as soil analysis.

Table 33 gives some best bet options for supplementary fertiliser rates in soils of different fertility. Fertile soils tend to be soils with higher clay and organic matter content. These soils are less prone to nutrient leaching. Lighter, sandier soils tend to be less fertile, with less organic matter content and are more prone to nutrient leaching.

Table 33. Supplementary nutrient requirements in soils of different fertility in kg/ha (based on the total requirements of the major nutrients given in Table 31)

Nutrient	Minimum (Fertile soil)	Average	Maximum (Infertile soil)
Nitrogen (N)	**25 kg** in one application	**110 kg** in 2 or 3 applications	**140-160 kg** split into 3 or more applications
Potassium (K)	**0-15 kg** in one two applications	**50 kg** in one or application	**75 kg** in one or two applications

Fertilising through the irrigation water (fertigation)

Until recently, few brassica crops in Queensland were grown using trickle irrigation, however this has changed over the past year or two. Some growers have switched to trickle irrigation systems and are applying supplementary fertilizer through fertigation.

With these systems, fertilizers can be applied in smaller amounts more regularly and closer to the plant roots, allowing for more efficient use of both water and fertiliser. To do this effectively, the irrigation system must be capable of delivering an even amount of water (and therefore fertiliser) to the crop without leaching nutrients beyond the root zone. Before fertigating, get a water-testing laboratory to analyse your irrigation water.

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 34. There is also a range of soluble commercial fertiliser blends.

Table 34. Fertilisers that can be dissolved in water for fertigation.

Fertiliser	Main nutrients supplied	% of nutrient
Urea	Nitrogen	46% N
Calcium nitrate	Calcium, nitrogen	18.8% Ca, 15.5% N
Ammonium nitrate	Nitrogen	34% N
Potassium nitrate	Potassium, nitrogen	38.3% K, 13 % N
Potassium chloride	Potassium	50% K, 50% Cl
Potassium sulfate	Potassium, sulpfur	41% K, 18% S
Magnesium sulfate	Magnesium, sulphur	9.6% Mg, 12.4% 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: Do not mix calcium-based products with phosporus-based products or any product containing sulfates. 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 small amounts of magnesium sulfate ($MgSO_4$) more frequently through the irrigation system.

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 the plant. Table 35 provides a summary of application rates for managing trace element deficiencies.

Table 35. Application rates for managing trace element deficiencies in cabbage, cauliflower and broccoli crops

Element	Product	Rate	Comments
Boron	borax	10 – 14 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	5 – 7 kg/ha	Spray on the soil and incorporate before planting if soil level is low.
		250 g/100 L	Preventative foliar spray. Brassicas are susceptible to boron deficiency. Apply first spray within 2 weeks of transplanting. Repeat at fortnightly intervals for 2 to 3 sprays. Add a wetting agent and urea at 500g/100L. Note:Solubor is not compatible with zinc sulphate heptahydrate.
Molybdenum	sodium molybdate	300 g/ha	Spray on the soil and incorporate before planting if soils are deficient. Raise soil pH to 6.5.
		6 – 10 g/10 L	Preventative foliar spray. Brassicas are susceptible to molybdenum deficiency. Apply 2 sprays on seedbeds or seedling trays.
		60 g/100L in 30-100 L/ha	Foliar spray if molybdenum deficiency has occurred in the past or is suspected. Apply 2 to 3 sprays after transplanting early during crop growth, before heading commences. Add a wetting agent and urea at 500g/100L.
Manganese	manganese sulphate	100 g/100 L	Foliar spray if manganese deficiency is suspected or has occurred in the past. More likely in alkaline soils. Apply 3 sprays at fortnightly intervals once plants are established.
Zinc	zinc sulphate monohydrate	20-30 kg/ha	Broadcast onto soil and incorporate before planting if soil zinc level is low. More common in wet or cold conditions or if phosphorus levels are high.
	zinc sulphate heptahydrate	200-250 g/100 L	Foliar spray if zinc deficiency is suspected or soil zinc levels are low. Apply 3 to 4 sprays at fortnightly intervals with a wetting agent during early crop growth but before heading. Note: Do not mix with boron.
Iron	iron chelate or iron sulphate	100 g/100 L	Foliar spray if problems have occurred in the past. Consider doing a test strip once plants are established. Improved soil management may be more effective.
Copper	copper sulphate	5 – 20 kg/ha	Broadcast onto soil and incorporate before planting if soil copper level is low.
		500 g/100 L	Foliar spray if problems have occurred in the past. Apply within first month of transplanting.

Monitoring plant nutrients

Applying fertiliser every few weeks without knowing whether the plants need it wastes money and is environmentally irresponsible. A comprehensive soil test should provide the basis for working out establishment fertiliser requirements and to decide on the frequency and rates of supplementary fertilizer applications. Plant nutrient monitoring through leaf or sap tests can help to fine-tune the fertiliser program.

Leaf testing

Leaf testing is a bench-marking tool that has little direct relevance to the current crop. Its value lies in judging the fertilising schedule used in the current crop and how it may be improved for the next crop. Leaf tests measure the percentage of nutrient that has accumulated in the leaf and only provides information on how well the crop has been grown up to that point.

Do a leaf analysis when broccoli and cauliflower are at early heading (buttoning) and cabbage is at head maturity. Buy a tissue sampling kit from your farm supply outlet and follow its instructions. The youngest mature leaf or wrapper leaf is usually taken for the sample. The laboratory will interpret your results. Optimum values for leaf test results are given in Table 36.

Table 36. Optimum leaf nutrient levels (based on dry weight) for cabbage, cauliflower and cabbage

Nutrient	Normal level		
	Cabbage Wrapper leaf at head maturity	**Cauliflower** Youngest mature leaf at buttoning	**Broccoli** Wrapper leaf at early heading (buttoning)
Nitrogen (N) %	3.0 – 5.0	3.0 – 5.0	3.2 – 5.5
Phosphorus (P) %	0.3 – 0.5	0.3 – 0.7	0.3 – 0.7
Potassium (K) %	3.0 – 4.5	3.0 – 4.0	2.0 – 4.0
Calcium (Ca) %	1.5 – 3.0	1.0 – 2.0	1.2 – 2.5
Magnesium (Mg) %	0.2 – 0.7	0.2 – 0.7	0.2 – 0.7
Sulphur (S) %	0.3 – 0.8	0.3 – 0.8	0.3 – 0.8
Sodium (Na) %	0 – 1.0	0 – 1.0	0 – 1.0
Chloride (Cl) %	0 – 1.8	0 – 1.8	0 – 1.8
Copper (Cu) ppm	5 – 20	5 – 20	5 –20
Zinc (Zn) ppm	20 – 200	20 – 200	20 – 200
Manganese (Mn) ppm	25 – 200	25 – 200	25 – 200
Iron (Fe) ppm	50 – 200	50 – 200	50 – 200
Boron (B) ppm	25 – 60	25 – 60	25 – 60
Molybdenum (Mo) ppm	0.5 – 3.0	0.5 – 3.0	0.5 – 3.0

Source: Weir and Cresswell, NSW Agriculture, 1993. Note the optimum concentrations given for some elements vary from those given in Reuter and Robinson, CSIRO, 1997.

Sap testing

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 is affected.

Sap testing involves collecting leaf stalks (petioles) and the mid-rib of the youngest fully expanded leaves, extracting sap with a garlic press, and analysing its nutrient content. Sap testing may start once plants are fully established and continue through to just before harvest.

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. Sap nutrient levels can be affected by over or under watering and stressful growing conditions.

Irrigation management

Irrigation management is one of the keys to producing a high yielding, good quality brassica crop. Well-grown brassica vegetables get 85% of their water from the upper 35 cm of the soil profile, so wasting water and leaching nutrients can easily occur. An efficient irrigation system and accurate water scheduling are essential.

- Introduction
- Irrigation must No. 1—a good irrigation system
- Irrigation must No. 2—a monitoring system
- Water requirements of brassica crops
- Tensiometers
- Troubleshooting tensiometer problems
- Getting started with tensiometers
- Capacitance probes
- Maintenance of a drip irrigation system

Introduction

There are two basics needed for effectively managing irrigation:

- A water supply of adequate quality and quantity and an irrigation system that can apply this water uniformly when needed
- A system to monitor soil water status in order to apply water at the right frequency and rate

Depending on the season, soil type, brassica crop type and irrigation system used, the crop will require between 2.5 to 4 ML of water per hectare of crop grown (equivalent to 250 to 400 mm of water over 1 ha of land). This means that if surface water is your main source of irrigation water, you will need a storage capacity of 6 to 8 ML for each hectare of crop grown to ensure adequate water supplies are available to meet peak irrigation demands even in unseasonably dry conditions. Brassica plants are moderately sensitive to poor quality water. Electrical conductivity (EC) is a measure of salinity. Table 37 shows the water conductivity threshold for different soil types at which yield reductions may occur in cabbage, cauliflower and broccoli crops.

Table 37. Water conductivity threshold for different soil types

	Sandy soil	Loam soil	Clay soil
Cabbage	3.5 dS/m	2.0 dS/m	1.2 dS/m
Cauliflower	3.2 dS/m	1.8 dS/m	1.1 dS/m
Broccoli	4.9 dS/m	2.8 dS/m	1.6 dS/m

Source: NRM Facts, water series W55

To convert from μS/cm to dS/m use the formula in Chapter 1 page 12.

Until recently water conductivity was reported in microSiemens per centimetre (μS/cm), however it is now reported as deciSiemens per metre (dS/m).

A well-grown, unstressed brassica vegetable crop gets about 60% of its water needs from the top 20 cm of the soil profile. Almost 85% of the crop's water needs come from the upper 35 cm of the soil profile.

The first basic requirement is an irrigation system suited to growing brassica vegetable crops. This means the system, whether travelling irrigator, overhead sprinklers, drip (trickle), or less commonly, furrow irrigation, uniformly delivers the required amounts of water on demand, when the crop requires it, at a rate the soil is capable of absorbing without runoff. These basics should be met before investing additional time and effort in fine-tuning irrigation scheduling.

The second basic for managing irrigation effectively is a system of scheduling irrigation—knowing when and how much water the crop needs. The right decisions can increase yield and quality and reduce wastage of irrigation water, and of fertiliser. Our guidelines assume the producer is using tensiometers to monitor soil water status, but the principles can be equally applied to other soil water monitoring equipment such as capacitance probes, for example Enviroscan® or Diviner 2000® systems, by making the appropriate adjustments to the critical values for starting irrigation.

Irrigation management in a nutshell

- Each enterprise has its own unique set of circumstances—soils, climate and irrigation system. With an understanding of basic principles, producers can adjust their irrigation strategies to suit.
- Ensure your irrigation system delivers water uniformly, on demand, at a rate that your soil is capable of absorbing without runoff.
- If monitoring soil water status, probes such as tensiometers should be measuring at least at 15 cm and 60 cm soil depth.
- For best yields and quality: irrigate broccoli when shallow tensiometers reach 35 kPa; cabbages 40-60 kPa; with cauliflower intermediate between these two ranges. Commence irrigation at lower tensiometer values in warm, dry weather, or on sandier soil types.
- For the first 3 weeks after transplanting (5 weeks after emergence in direct-sown brassicas), do not rely on tensiometer readings to indicate when to irrigate. Crop root systems are insufficiently developed to give definitive readings during those establishment periods.
- As a first approximation, brassica vegetables require 15-20 mm per week for the first 7 weeks after transplanting, increasing to 25 mm per week until harvest.
- Budgeted total irrigation requirements are 2.5–3 ML/ha for broccoli, 3–3.5 ML/ha for cauliflower, and 3.5–4 ML/ha for cabbages.
- Drip irrigators should be applying 3–8 mm every day or alternate day.

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. Consult an irrigation equipment supplier or designer in your area and get them to develop an irrigation plan.

Brassica crops require an overhead sprinkler system to get the plants established and this system can then be used to water the plants until harvest. Alternatively, once established, the crop can be watered using drip or furrow irrigation. Overhead irrigation is the most common irrigation method used in brassicas, however in the last year or two a number of growers have switched to drip (trickle) irrigation systems.

Crops can be established using drip irrigation, however some adjustments need to be made to do this successfully. Growers that use drip irrigation to establish their crops plant the two brassica rows closer together on the bed to bring young plants within the wetting zone of the single row of tape running down the centre of the bed.

Overhead irrigation

Overhead irrigation includes travelling irrigators or sprinkler systems. Overhead irrigation is suitable for any soil type and undulating country. Table 38 shows the advantages and disadvantages of overhead irrigation.

For overhead sprinkler systems, use single knocker, impact sprinklers on short risers to allow spray machinery to pass overhead. The recommended sprinkler jet size is 2.0 to 2.4 mm. When using overhead systems, water in the morning so the foliage is dry by evening. This will reduce the risk of disease but will also improve irrigation uniformity, as wind speeds are usually lower in the morning.

Table 38. Advantages and disadvantages of overhead irrigation

Advantages	Disadvantages
Easier than furrow irrigation to regulate water application	High pumping costs because it requires high pressure, particularly for travelling irrigators
Can be used in most situations	Expensive to set up
Can be used to reduce losses from frost	Wets interrow and headland areas, promoting weed growth
	Spreads bacterial diseases
	Affected by wind
	Difficult to apply regular, small amounts
	Washes spray off plants
	Moderate water use
	Must use high quality water
	Difficult to apply fertilisers with irrigation

Drip irrigation

Drip or trickle irrigation is the most easily controlled irrigation method. The equipment is expensive, but has a long life. The selection of which type of drip system to use is complex and we recommend you consult with suppliers or irrigation designers to aid in decision-making. Table 39 shows the advantages and disadvantages of drip irrigation.

Flow rates and emitter spacings will depend on soil type and anticipated weather during the growing period. Emitters should be spaced no more than 40 cm apart along the drip tube in clay loam or clay soils. On sandier textured soils, spacings should be reduced to 20 to 30 cm.

Soluble fertiliser mixtures and some pesticides can be applied easily through the irrigation system. If drip tubing is to be re-used it should be treated with chlorine and/or acids to reduce the risk of blockages. Many producers have found that reusable tubing is more economical in the medium term, even though there is a greater initial capital outlay for drip tube and retrieval/storage equipment.

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

Table 39. Advantages and disadvantages of drip irrigation

Advantages	Disadvantages
Does not wet plants and wash off sprays	Requires a greater intensity of management
Easy to regulate applications to plant needs	Requires regular maintenance
Can apply small amounts often, (daily if necessary) in the critical period	Not suitable for steeply undulating country due to variable output
Only wets the root area	High initial cost
Can apply nutrients through the system	Can block up if good filters are not used
Not affected by wind	Susceptible to damage by crickets
Can use poorer quality water than overhead systems	Must take precautions to filter water and /or treat it for iron bacteria
Uses less water than other systems	
Cheaper pumping costs because it requires low pressure	

Furrow irrigation

Furrow irrigation requires an even, gentle slope and a soil type that allows water to spread laterally without penetrating too deep into the soil. Table 40 shows the advantages and disadvantages of furrow irrigation.

Table 40. Advantages and disadvantages of furrow irrigation

Advantages	Disadvantages
Cheap to set up and operate	Very high water use
Does not wash spray off plants	Often have wet row ends and waterlogging
Not affected by wind	Cannot apply fertilisers with irrigation
Can use poorer quality water than for overhead irrigation	Cannot apply regular, small amounts of water
	Poorer weed control
	Must have level ground
	Can result in erosion if slope is too steep

Irrigation must No. 2– a monitoring system

The second essential requirement for efficient irrigation is a system to tell you when and how much water your crop needs. This is known as a monitoring or scheduling system. The importance of monitoring is confirmed by research, which shows that water use can be considerably reduced with monitoring without affecting yield and product 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. 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 41.

Table 41. Advantages and disadvantages of irrigation scheduling systems

System	Advantages	Disadvantages
Tensiometers	Relatively cheap	Labour intensive to collect and record data
	Easy to install and move	Require regular maintenance
	Many sites per planting	Can be inaccurate in extremely wet or dry soil
	Can be read by growers	
Capacitance probes	Accurate at all depths and for all soils	Relatively expensive
	Continuous monitoring	Need skill in installing and interpreting data
	Enables rapid reading and recording of results	

Water requirements of brassica crops

Brassica plants are shallow rooted and susceptible to water stress although research suggests that cabbage are able to better tolerate water stress than broccoli. The following guidelines assume you are using tensiometers to schedule irrigations.

For the first three weeks after transplanting, whilst crops are developing their root system, do not wait for tensiometers to reach critical values, but water once or twice per week, obviously depending on the weather. For direct sown crops, do not rely on the shallow tensiometer readings until about 5 weeks after seedling emergence.

Once crops are well established, use tensiometer readings to time irrigations:

- With broccoli start irrigating once shallow tensiometer values reach 35-45 kPa from early vegetative growth through to harvest.
- In cabbage, start irrigating when the shallow tensiometer reaches 50-60 kPa during early vegetative growth. Once head development starts, irrigate when the shallow tensiometer values reach 40-50 kPa to maintain head weight and quality.
- For cauliflower, we have no experimental tensiometer values but suggest they would be intermediate between broccoli and cabbage.

Note that the lower shallow tensiometer values in the ranges given above should be used to trigger irrigation in:

- Warm, dry weather or
- On sandier soil types.

In both situations, there are smaller margins for error than in more temperate conditions, or soils with superior water holding capacity. Crops will stress sooner.

On black earth soils such as those of the Lockyer Valley, producers should use the following irrigation budgets as guidelines for their water requirements.

Cabbage

For the first 8 weeks after transplanting, each irrigation should be 15-20 mm every 7-10 days. During head development and up to harvest, this should be increased to 15-25 mm every 5-8 days.

Our research indicates that the target evapotranspiration for transplanted cabbage is 300-320 mm. The irrigation requirement is therefore between 3.5 to 4 ML/ha, allowing for inefficiencies and drainage losses.

Broccoli

Irrigate every 6-8 days. For the first 7 weeks after transplanting, each irrigation should be 15-20 mm. From seven weeks until harvest, increase each irrigation to 20-25 mm as the broccoli root system fully develops. Research suggests the target evapotranspiration for transplanted broccoli is:

- 230-280 mm for autumn and spring crops
- 180-220 mm for winter crops

Allowing for inefficiencies and drainage losses, the budgeted irrigation requirement for broccoli is between 2.5 to 3 ML/ha.

Cauliflower

Water requirements and a water budget somewhere between broccoli and cabbage would be a reasonable first approximation for cauliflower crops.

If using drip irrigation

Producers using a drip system rather than overhead sprinklers would require less total irrigation. However the application regime would be very different, supplying smaller amounts of 3-8 mm of water every day or alternate day.

Delayed irrigations

The timing of irrigation also relates to other agronomic requirements such as nutrition or pest management, particularly where overhead systems are in use. Irrigation can be fitted in around these events, adjusting the quantities applied correctly. Use a ballpark figure of 3 mm extra water for each day the shallow tensiometers are greater than the trigger value.

Under watering

The most common problems from under watering are poor plant establishment, small plants, reduced head size, loss in head weight and quality and early heading or bolting. Under watering, especially if combined with warm weather, can lead to tipburn— internal browning of leaf margins in cabbage and brown bead in broccoli.

Over watering

Apart from wasting water, over irrigating leaches nutrients such as nitrogen below the crop root zone, causing nutrient deficiencies, lower yields and poorer crop quality. Leached nutrients can adversely affect off-site water quality, a problem that growers have a responsibility to avoid. Over watering can increase the risk of diseases such black rot and club root.

Tensiometers

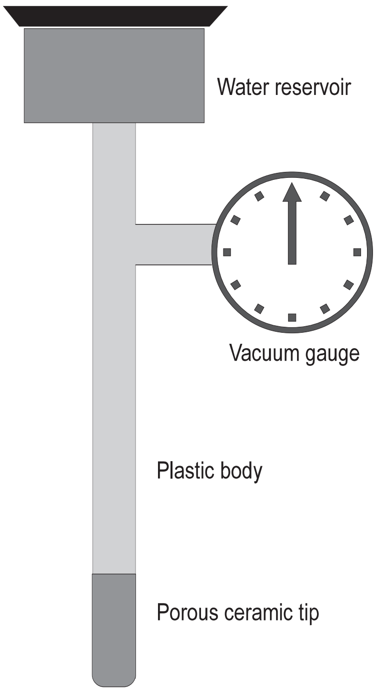


Figure 32. Parts of a standard tensiometer

Tensiometers are a relatively cheap and effective way of assessing the water status of soil. They are particularly suited to shallow rooted, well-watered crops such as vegetables. Tensiometers measure the availability of soil water to plants.

Common designs consist of four basic parts (Figure 32)—a hollow tube filled with water and algaecide, a ceramic tip, a water reservoir and a

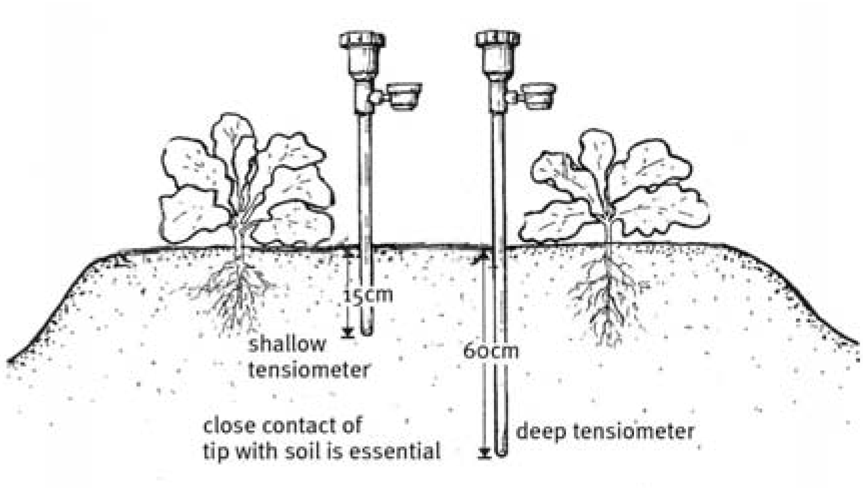


Figure 33. *Profile of a typical tensiometer monitoring site in brassicas.*

vacuum gauge, which reads water tension on a scale of 0 to 100 centibars (kiloPascals or kPa). More complex systems replace the conventional vacuum gauges with pressure transductors or portable electronic data loggers. 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 if there is no further irrigation or rain. When the soil is re-wet after rain or irrigation, water moves from the soil back into the tensiometer, and gauge readings fall.

A monitoring site consists of one shallow tensiometer installed in the main root zone, and one deep tensiometer below most of the roots (Figure 33). A crop planting should have at least two monitoring sites, for example, a two-hectare block of brassicas on similar soil type. Shallow tensiometers should be placed within 15 cm of the crop row and midway between plants, though this can vary slightly. Install the shallow tensiometer with the tip 15 to 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.

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 fully saturated. If readings continue to rise immediately after irrigation, not enough water has been added to the root zone.

Installation

Tensiometers have not been commonly used in vegetables because of perceived problems with installation, maintenance, use and interpretation. These can be overcome by combining new tensiometer designs with simpler ways of using them.

In much of the information about tensiometers, exacting procedures are frequently stressed as essential. These include:

- only using pre-boiled water to fill tensiometers;
- drilling precise installation holes;
- servicing tensiometers with a vacuum pump every few weeks.

Many of these procedures over-complicate tensiometer use. There is no substitute for hands-on experience and familiarity. We have installed more than 1000 tensiometers in the last 10 years using the methods outlined here and less than 5% have failed, usually from cracked tips.

Preparing for use

Assemble tensiometers and fill with good quality water to which an 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. The pump must fit snugly over the fill point on top of the tensiometer to effectively suck air. Top up the tensiometers with more water if necessary and use the vacuum pump to remove any air bubbles. The tensiometers are now ready for installation.

Installing

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 into the soil to 15 cm. Don't push too hard. The tips are strong, but can crack under excessive pressure. Only experience teaches how hard is too hard. At $30 per tip, this is an expensive lesson. If you encounter a hard soil layer, either 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. We have found a 50 mm (two inch) auger 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. Do not 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 the risk of water draining down beside the tensiometer, leading to false readings.

Alternatively, a pipe or a precisely manufactured auger the same diameter as the tensiometer can be used to make a suitable hole provided the tensiometer then fits snugly into the soil.

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 do not 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 morning, preferably before 8 a.m. because 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 when the next irrigation will be needed. Figure 34 shows diagrammatically how the tensiometer reacts to different amounts of irrigation whilst Figure 35 is a sample chart with shallow and deep tensiometer readings plotted over several irrigations.

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.

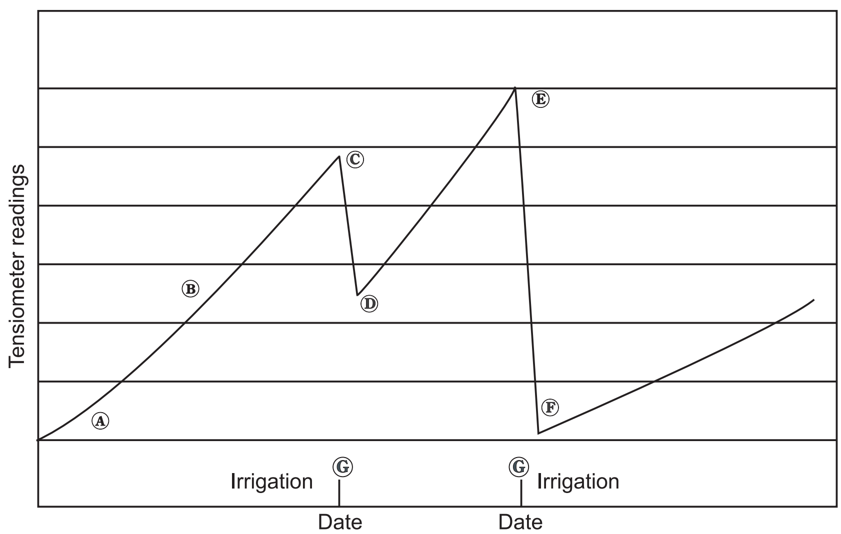


Figure 34. Diagrammatic representation of tensiometer reaction to different amounts of irrigation

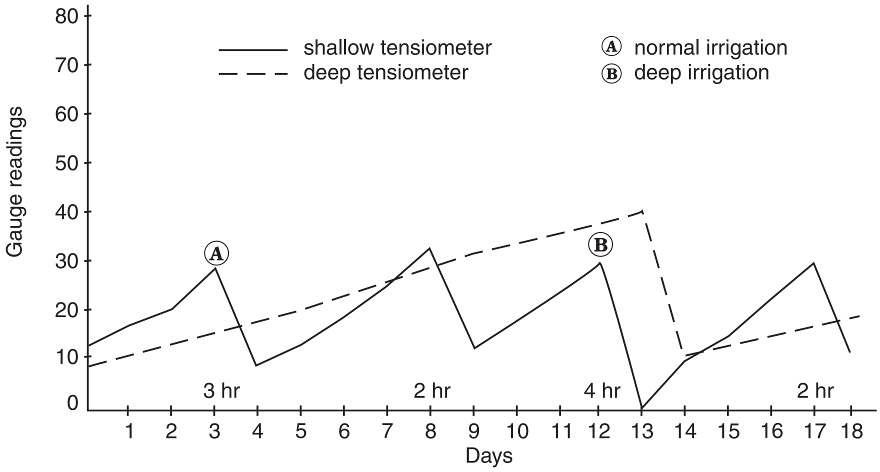


Figure 35. A sample chart showing tensiometer readings plotted daily

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, then 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 the gauge is working by applying suction to the tensiometer with a vacuum pump.

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, algaecide and a one-metre long 50 mm diameter auger. Total cost should be less than $800. The best tensiometers have replaceable tips, gauges and water reservoirs. Alternatively, investigate the benefits of tensiometers that use a transportable electronic gauge, with optional data logger and software. Where more than 5 to 6 tensiometers are purchased, these electronic systems are almost certainly more economic.

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

Tensiometers are the 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 measure the dielectric of the soil to determine its moisture content. As the soil's water content increases, so does the soil's dielectric constant. This reading is not significantly affected by dissolved salts, which means that fertiliser applications or irrigation water quality do not alter the soil moisture estimates. Figure 36 shows the main components of a capacitance probe.

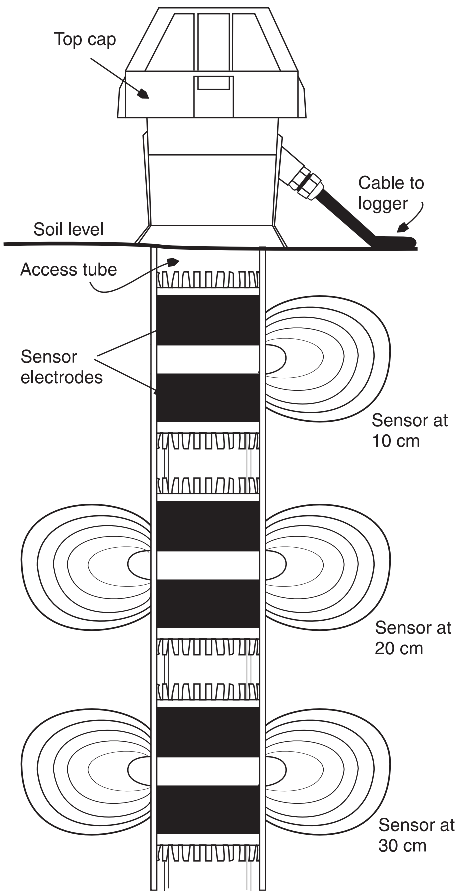


Figure 36. Diagrammatic representation of a permanent capacitance probe

There are two types of capacitance probes:

Permanent probes. These probes have slots every 10 cm to accommodate snap-in sensors. These 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 via a cable to a data logger and recorded. Data from the logger is downloaded to a computer every day or every few days to show water use and to provide recommendations for watering. An example of permanent probes is the Enviroscan® system.

Portable probes. These 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. The sensor head is lowered into the tube and readings are made at the required depths. The sensor head is connected to a hand-held data logger for on-site display of the soil moisture profile and later downloading into a computer.

These are less expensive than the permanent probe set-ups, but do not allow the same level of continuous monitoring. An example of portable probes is the Diviner 2000® system.

For brassica crops, two probes is the minimum recommendation for a block of plants but the number of sites depends on the variability in soil and varieties. Probes should measure soil moisture at 10, 20, 30 and 50 cm depth.

Although the capacitance probes may appear relatively expensive, they directly relate to soil water content and therefore may be easier for some growers to interpret than tensiometers. Capacitance probes are less affected by soil type than neutron probes, and their function at shallow depths is superior. The permanent probes also allow continuous and regular monitoring of soil moisture. Most growers purchase the equipment but it can also be hired from some consultants. The current cost of a logger, solar panel, 100 m of cable, two one-metre probes, 8 sensors and software is about $5000. The interpretation of the data requires skill and we recommend that consultants be used to set up the system and provide at least the initial advice.

Maintenance of drip irrigation systems

Filters

The outlets of drip irrigation tape are very small so a good filtration system is essential. There are three main types of filters—sand filters, mesh and screen filters, and multi-media filters. The type of filter you need will depend on water quality. You should talk to a reputable irrigation specialist before deciding on the type of filter you need.

The 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 this. Fit flushing valves to the ends of the 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 microorganisms. 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 so that you know that 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 done continuously, using 1 mg/L residual chlorine; on a regular basis at about 10 mg/L; or as a slug dose using 500 to 1000mg/L. Test the water at the end of the system to ensure there is about 1 mg/L residual chlorine. When using chlorine 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, and then flushed out of the system. 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 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 42 shows the amount of two chlorine products required to make two different concentrations of chlorine.

Table 42. 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 your 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 to indicate when it has moved through the system.

Integrated pest and disease management

Managing pests and diseases effectively is an important aspect of growing brassicas. Various pests and diseases may cause problems at different stages in the life of the crop and can reduce yield and quality. Diamondback moth has developed resistance to a number of insecticides and can be particularly difficult to manage in warmer weather. Diseases can be difficult to control under wet conditions. This section describes an integrated approach to pest and disease management based on preventative strategies, crop monitoring, prevailing weather conditions and a range of management options.

- Introduction
- The integrated pest management approach (IPM)
- Preplanting decisions and preventative tactics
- Crop monitoring (pest scouting)
- Making pest management decisions
- Cultural control
- Biological control
- Chemical control

Introduction

The traditional approach to pest and disease management is to apply routine sprays of chemicals based on what you think is happening in the crop or to spray pesticides by the calendar. This approach has several problems:

Cost. It is costly and time consuming, with many sprays being applied each season, even when there are no insects in the crop and disease damage is unlikely.

Plant tolerance. It disregards the fact that plants can tolerate small numbers of pests without significantly affecting yield and quality at certain times during the cropping cycle. When pest levels are low, the cost of spraying is much greater than the benefit gained by controlling the pest.

Resistance problems. It relies heavily on new chemicals being developed to replace those against which insects and diseases have developed resistance, for example Diamondback moth (DBM).

Exposure. It heightens the risk of exposure to pesticides for the farm family and employees during daily farm activities. It also increases the risks of chemical residues in the product and the environment.

Risk. Routine spray applications increase the risk of poor control as specific insects or diseases and specific stages of their life cycle are not targeted.

Natural enemies Routine spraying of broad-spectrum pesticides may induce pest problems by killing natural enemies of pests. Outbreaks of DBM are a good example of this type of population imbalance.

Impact on the environment In the near future, farmers may need to demonstrate how they are reducing their impact on the environment.

Sole reliance on chemicals to provide quick fix solutions to pest and disease problems is a high-risk strategy in the long-term. A more sensible approach to effective crop protection is to manage pests and diseases with a range of management tools. This is called integrated pest management (IPM).

The integrated pest management approach (IPM)

The objective of IPM is to move pest control away from a system that relies on regular (calendar) sprays to one that combines cultural, biological and chemical control measures. IPM aims to maximise the use of biological control. Other control measures must play a supportive rather than a disruptive role, with chemicals only used if and when needed.

How to get started on an IPM program

IPM is about integrating a wide range of tactics to prevent pests and diseases from causing economic damage to the crop. Figure 38 shows the different components that make up an IPM system in brassica crops. They include:

- **Preventative tactics** that minimise the risk of pest and disease problems occurring in the first place. This requires forward planning and careful design of the production system.
- **Regular crop monitoring** or pest scouting to provide reliable information for making pest management decisions.
- A **thorough knowledge of pests and diseases**, their impact on the crop and the effectiveness of different control options under different situations. Good record keeping can help to develop this knowledge.
- **Strategic use of pesticides** to prevent economic crop losses.

Pre-planting decisions and preventative tactics

- Farm hygiene
- Selecting the right site
- Designing the production system
- Selecting your production period
- Selecting the right variety
- Grow healthy plants

↓

Regular crop monitoring

- Problem identification and risk assessment
- Sound understanding of pests, diseases and the crop

↓

Making pest management decisions

- Action thresholds and critical crop growth stages

↓

Do nothing, wait and see OR

Select the best control option for the situation

- Cultural controls – improve farm hygiene, destroy weeds, change irrigation, fertiliser or harvesting practices
- Biological controls – protect natural enemies, release predators and parasites, apply biological insectides
- Chemical control – select most suitable and use strategically, aim for good plant coverage, manage resistance

↓

Check effectiveness of decisions

- Continue to build skills and knowledge, for example, by keeping good records and reviewing the season

Figure 37. *Components of integrated pest management (IPM) in brassica crops*

There is no recipe for IPM but a critical first step is switching from scheduled sprays to strategic sprays based on crop monitoring results. IPM can appear to be a higher risk and more complex way of managing pests and diseases.

- It may take more time and can initially complicate decision making;
- Crop monitoring results can be difficult to interpret;
- It requires a higher skill level and it takes time to develop these skills;
- There are, at present, no market rewards for IPM grown product and there is a limited market tolerance to blemishes. This can cause problems, particularly in export crops where tolerance to insect contaminants is low or nil.

However, the advantages of using IPM can be substantial:

- Softer chemicals are preferred and broad-spectrum chemicals are used less frequently. This reduces the risks associated with pest resistance to chemicals and maximises the impact of natural enemies on pests.
- Crops are inspected frequently and regularly leading to a better overall knowledge of what is happening in the crop—potential problems are recognised sooner and more specific management options can be implemented.
- More strategic use of chemicals reduces health risks to producers, their families and staff. IPM is also less likely to cause problems with neighbours or the community.
- More environmentally benign products are preferred in IPM programs and this reduces negative impacts on the environment.
- IPM leads to a more robust system, as it does not rely on a single control method – more management options become available.
- It promotes the build-up of natural enemies and can lead to improved farm hygiene as more preventative management options are implemented.
- Learning through experience builds confidence in making sound pest management decisions, as decisions are based on an improved understanding of pest, disease and crop dynamics.

Pre-planting decisions and preventative tactics

Planning ahead and careful design of the production system will minimise risk of disease and pest problems. This is particularly important for managing diseases but will also have an impact on insect problems through the season.

Farm hygiene

Good farm hygiene is one of the simplest but most often overlooked methods of managing diseases and pests. It reduces the risk of bringing diseases and pests onto, and being spread around, the farm. Good farm hygiene includes the following management practices:

A production break. To avoid carrying over a pest or disease problem from one season to the next. A summer production break is an important tool for reducing DBM problems in areas with warm to hot summers such as the Lockyer Valley.

Crop rotation. Avoid double cropping brassicas.

Cover cropping (green manuring). These crops improve the soil's structure and its water and nutrient holding capacity, as well as providing a break from intensive production.

Land preparation. Good land preparation assists with plant establishment and reduces the risk of waterlogging and plant losses from damping-off and other soil borne diseases.

Destruction of old crop residues and weeds. Old crop residues and weeds can be reservoirs of pests and diseases. Destroy weeds and plough in crops as soon as harvesting is completed.

Healthy seedlings. Do not plant seedlings that are weak, diseased or infested with insects. Check them before planting out.

Good hygiene. Apply a high standard of hygiene and quarantine in the field and the packing shed. Restrict access to the farm or parts of the farm, by suppliers, contractors and visitors. Avoid moving soil around the farm with dirty equipment, machinery, vehicles and on worker's boots. Work from young to old plantings rather than the other way around when cultivating the ground, irrigating, fertilising, spraying, crop monitoring and harvesting.

Selecting the right site

Select a site that does not have a history of problems or the problems that have occurred are more common in a different season. Keep records to help build a picture of disease and pest risks on different parts of the farm. Remember that:

- Sclerotinia rot is more likely in poorly drained paddocks, particularly if the paddock is shaded for a part of the day.
- Club root risk increases in neutral to acid, and poorly-drained soils.
- Frost damage is more likely in lower lying areas and where airflow is restricted.

- On some farms, a paddock may have a history of DBM problems, for example, where soils are not well drained and plants regularly become waterlogged. Avoid these paddocks for early season plantings.
- Separate new blocks of plantings from earlier plantings if land availability permits – ideally by more than 400 metres.
- In weedy paddocks, risks of losses through soil borne disease and soil insects increase. Weeds also reduce airflow through the crop and make crop monitoring more difficult. Weedy crops are more difficult to spray effectively.
- Planting new crops upwind of older crops reduces the risks of prevailing winds carrying insects into younger crops. Bacterial diseases such as black rot can also be spread through wind-blown water droplets.

Designing the production system

Farm management practices not only have an influence on pest and disease problems but also impact on control options available for dealing with them.

- Plants stressed through poor irrigation or nutrition are more prone to disease and pest problems than healthy, well-grown plants.
- Overhead irrigation washes sprays off plants.
- Furrow irrigation can delay follow-up sprays needed to manage a pest outbreak.
- Bedding up improves drainage and air circulation around plants – both help reduce disease problems.
- Good spray coverage is more difficult to achieve in high-density plantings. Air circulation in the crop is also reduced, increasing disease risk.

Selecting the production period

The season has an influence on the problems you are likely to have with your crop. Select a production period that will minimise pests and diseases. Remember that:

- Crops grown out of season are more likely to suffer stress through adverse environmental conditions. Stressed crops are more susceptible to pests and diseases.
- Year round production increases the risks of DBM, heliothis, some thrips and silverleaf whitefly insecticide resistance problems. Grow the crop in the time slot that best suits brassica production in your area.
- Caterpillar problems are usually worse in warm weather.

- Thrips prefer warm, dry conditions, aphids prefer the milder conditions of autumn and spring.
- Foliar diseases and bacterial head rots are usually worse in warm, wet weather. Club root is more prevalent in warm, moist soil conditions.
- Sclerotinia rot is more common in winter.

Selecting the right variety

Seasonal weather conditions, market requirements and any known or expected disease problems should determine choice of variety. Varietal resistance or tolerance to diseases should be an important part of your disease management strategy. Discuss disease resistance or susceptibility of varieties with your seedling or seed supplier. Consider also the following:

- Broccoli grown out of season tends to develop flat uneven heads. Under warm, rainy conditions, water pools on the surface of heads making them more susceptible to head rots.
- Cauliflower grown out of season tends to develop ricey, open, uneven, discoloured heads making them more susceptible to disease and insect problems.

a key issue
Varieties
This chapter page 127

- Good spray coverage is more difficult to achieve on some varieties, for example, cabbage with strongly crinkled leaves, cauliflower with a high degree of self-covering.
- Some varieties may be more attractive to pests such as thrips and DBM.

Grow healthy plants

Crops that are well grown are less likely to suffer from pests and diseases. Avoid stressing plants through poor transplanting techniques, inadequate nutrition or irrigation. Select the appropriate variety for the season and avoid growing crops out of season. Maintain good soil health and keep weeds in check.

Crop monitoring (pest scouting)

The first step in moving away from a routine spray schedule is to spray only when pests are, or are likely to cause, economic crop damage. Crop monitoring is essential for any IPM program as it provides information on what is happening in the crop. This information is crucial for making sound insect and disease management decisions and provides timely information on how well your current pest management strategies are working and how they could be improved.

Another advantage of crop monitoring is an overall better crop awareness. Since crops are inspected systematically on a regular basis, crop condition and potential problems are detected earlier.

We recommend you use a competent crop consultant to do the monitoring if one is available in your district. If you do not hire a consultant, we suggest that you or a staff member get some monitoring tips from a consultant, as well as attend any training courses that might be available in your area. Ideally the same person should check the crop each time.

Becoming proficient at crop monitoring is about building up skills and experience. This requires a significant commitment in time, however there are a few procedures to follow when doing your own monitoring. Inspections should begin in the nursery or with transplants and continue until the end of harvesting. The intensity of monitoring will vary with the crop growth stage, the number of pests present and prevailing weather conditions, as well as the experience and confidence level of the person doing the monitoring.

What is involved in crop monitoring?

Books to help with insect pest and disease identification are listed in Chapter 5 page 289

Commitment to a regular monitoring program is essential. This involves setting aside time for checking crops at regular intervals and following the same procedure each time.

The time it takes to monitor varies with your skill level, the size of the plants and the number of plants you aim to check. There is generally a compromise between accuracy of information gathered and cost (time). The fewer plants checked, the less accurate the information on which to base your pest management decision will be. Pheromone traps and sticky traps can augment monitoring data but not replace it.

The tools you will need

more info
Sample monitoring log
This chapter page 201

- A notebook or monitoring log book.
- A x10 power hand lens. Most optometrists stock these.
- Containers and plastic freezer bags for collecting unidentified pests and diseases.

It is not necessary to identify all the problems you find, but the more you can identify the better the results will be. Become familiar with diseases, insects and natural enemies in the companion book, the *Brassica Problem Solver and beneficial identifier* and invest in one of the field guides listed in the references section in Chapter 5.

How to monitor a crop

The purpose of monitoring is to get as good a picture of pest activity and disease incidence in your crop for the time you have available to check crops. By monitoring a crop we mean counting numbers of pests and incidence of disease and recording this information in a monitoring log.

- Check each area or block regularly, twice a week in warmer weather and once a week in winter. Try to cover a good cross section of the block as pests and diseases can occur in patches or at one end or side of a block. There may also be hot spots for different problems on the farm.
- Thoroughly examine at least 10 plants, preferably 20 plants, per hectare and increase this number for larger blocks. If you are planting on a weekly basis, you may need to group adjacent plantings of a similar age into blocks for monitoring purposes.
- Select plants at random as you walk through the block. In addition, check next to hydrants, spray lines and other objects were spray coverage might be poor. Keep an eye out for damaged or unhealthy plants and inspect these for signs of disease or insects.
- Write down what you find in a notebook or monitoring log book. Records help monitor trends.
- Insects are more active in the morning and late afternoon, so that is the best time to monitor.

What to look for

Know what you are looking for in general terms before going out to the field. Check the overall appearance of the plant then, starting from the youngest part of the plant, thoroughly inspect the head or growing point, upper and underside of leaves and stems. Look for and record:

- The number of DBM eggs, larvae and pupae. To the untrained eye, DBM eggs and small larvae can be very difficult to find. Look for pinholing and windowing damage on leaves as this indicates DBM activity.
- In warm weather, watch for other caterpillar pests — heliothis and cabbage white butterfly eggs and small larva, and signs of cluster caterpillar activity, particularly their egg masses.
- Note the level of aphids, thrips and silverleaf whitefly in the crop, for example high, medium or low; or presence/absence.
- Record incidence of black rot and other bacterial diseases as well as signs of sclerotinia rot, downy mildew and other fungal diseases.
- Record any natural enemies seen in the crop.
- Note any other symptoms on the plant.

- Record weed types and stages of growth, and if they are harbouring insects or diseases.
- Destructively sample some plants to check for larvae and other insects in developing heads.
- If you are using traps, record the number of moths in pheromone traps and pests and natural enemies on sticky traps.
- Make a note of moths, butterflies, silverleaf whitefly and other insects that may fly out of the crop as you are walking through it.

In seedlings, also look for:

- The number of plants affected by centre grub. Webbing and wind-blown soil around the growing point of the plant are a good indication of centre grub activity. Gently open up the growing point to check for centre grub in suspect plants.
- Signs of cutworm activity. Cut off seedling stems or seedlings that have fallen over are a good indication. Search the top few centimetres of the soil around the plant for the curled up cutworm.

Record all observations in your monitoring log. Don't worry about not seeing a particular problem — you will. Small insects, larvae and eggs can be difficult to find at first, but with practice this becomes easier. Unhealthy plants are easily noticed as you walk through a block.

Initially you will probably find many 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, store in the refrigerator and have it checked a qualified professional as soon as you can. Make sure you label the plant with your name and contact details.

Insect traps to assist with crop monitoring

Pheromone traps and coloured sticky traps work by first attracting the insect and then catching it. While these traps may seem like an easier and cheaper option for monitoring pests, traps cannot replace regular, systematic crop monitoring.

Figure 38. *A pheromone trap in the field*

Pheromone traps work by hanging a lure containing a chemical (pheromone) that attracts male insects over a sticky card in the base of a trap (Figure 38). As the male insects enter the trap, they get caught on the sticky card. The lure is specific to each insect species and there are commercially available lures for heliothis and DBM. Traps should be put just above crop height as this is where they catch the most moths.

Coloured sticky traps attract insects through reflectance and commercial traps are available in white, blue and yellow. The colour chosen depends on what insects you are trying to catch. The yellow sticky trap

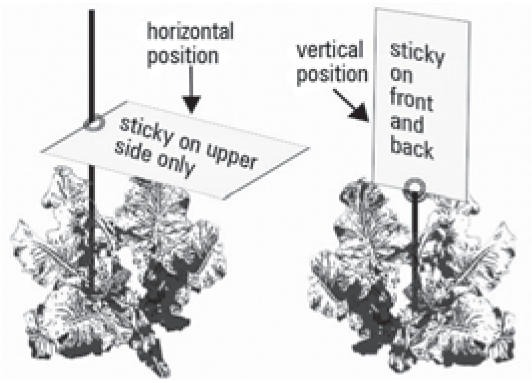


*Figure 39. **Yellow sticky traps positioned in the crop***

is best for DBM but will also catch other insects including natural enemies.

Sticky traps can be hung vertically or horizontally in the crop (Figure 39). Using one trap hung horizontally per $100m^2$ of crop, research has found that there is a relationship between the number of DBM adults caught on the trap per day and the number of moths and larvae in the crop. To use less traps means that there is unlikely to be a relationship.

For both pheromone and sticky traps, the number of insects on the traps is recorded regularly, usually weekly, or twice weekly when there are high numbers of insects. At each count, moths on the sticky card in the pheromone traps need to be removed or the sticky card replaced. Similarly, after counting insects on the coloured sticky traps, insects need to be removed or the sticky cards replaced.

For practical purposes, information from pheromone and sticky traps is not accurate enough to make spray decisions, but traps can be useful for 'predicting' when larvae will be in the crop. Another shortfall of using traps, especially pheromone traps, is that they do not monitor all pests that can cause economic losses in brassica crops. Cost should also be considered as traps are not necessarily cost effective at the density at which they need to placed within the crop to give any sort of meaningful result. The consultant or grower still needs to check crops regularly for pests.

Research suggests that at a density of one sticky trap per $100m^2$ of crop, within 3 days of finding DBM adults on sticky traps, there will be a slightly lower corresponding number of small larvae in the crop. Sticky traps are also useful as general indicators of insect activity including natural enemies such as parasitic wasps, lacewings and other predators.

Pheromone traps can be used as general indicators of moth activity. As a generalisation, within one week of seeing DBM adults in the traps, it is worthwhile to be extra vigilant for DBM eggs and small larvae while monitoring the crop.

Making a pest management decision

Once you have finished checking the crop, you need to decide whether or not you need to take any action to avoid economic crop losses through insects or disease. In many instances, this will be a decision about whether or not to apply a chemical. With IPM, the goal is to select the most appropriate management option for a specific problem.

For managing insect pests, this normally means to delay or avoid spraying, particularly of broad-spectrum chemicals, for as long as possible.

For managing a disease, you may need to consider putting in place a protectant fungicide program if weather conditions favour disease development. You should aim to:

- spray only when insect pests reach economically damaging levels;
- spray at the stage in the pest or disease life cycle when it is most susceptible to chemical control;
- spray the affected blocks, not the whole crop;
- use sprays that will be least disruptive to natural enemies;
- introduce parasites and predators if suitable ones are available.

You may also decide to review other pest management strategies that you already have in place for their effectiveness, for example, farm hygiene and quarantine practices, varietal resistance, site selection, the production system and crop rotation programs.

Action thresholds – guidelines for making management decisions

Crop monitoring data only has value if it is interpreted against some type of action threshold. An action threshold is the critical level at which a decision needs to be made about controlling the pest to avoid economic crop losses. Below this threshold, maintain as many cultural practices as possible to reduce the pest's impact on your crop. Above this threshold start implementing specific control measures targeted at the pest in question.

The thresholds you set will depend on the risks involved in not controlling the pest. This will be influenced by:

- the crop and its stage of development—brassicas can tolerate some insect damage at certain stages of the crop growth cycle;
- the block history and previous crop monitoring results—these will give you information on trends;
- weather conditions especially temperature/likelihood of windy days or rainfall and potential problems with paddock access;
- other management operations that need to be carried out, for example, irrigations, harvesting;
- the activity of natural enemies;
- the range and effectiveness of management options available.

Action thresholds for insects are often based on the average number of pests per plant:

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

They may also be based on the number of pests in a set number of plants, for example 2 heliothis eggs/ 10 plants checked. Thresholds can also be based on presence/absence sampling where the number of plants affected by a disease or infested by an insect is recorded to give a percentage of plants affected. An even simpler method is to record pest pressure (number of pests present) as high, medium or low.

In practice, there may be more than one pest or disease present in your crop. You will need to combine these different methods of recording and interpreting monitoring data depending on:

- Information available—precise action thresholds based on the average number of pests per plant have not been developed. Broad spray guidelines for the key insect pests of brassicas are presented in the Table 43.
- The national diamondback moth project team has developed a DBM sampling plan based on presence/absence sampling.
- With experience, your skill level and your confidence in interpreting monitoring data will increase and you will be able to refine action thresholds for your particular situation.

Diamondback moth sampling plan. Details on where to get this plan can be found in Chapter 5 page 293

Remember that the aim of an action threshold is to 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.

Using action thresholds

Table 43 presents broad action thresholds for several key insect pests of brassica crops grown in South-East Queensland. These were developed through several years of field work in the Lockyer Valley and are based on checking 10 plants per planting (less than ½ ha). They are conservative threshold levels but provide a good starting point for interpreting monitoring results. Experienced consultants and farmers who have used IPM for several years use higher threshold levels. Action thresholds for thrips and silverleaf whitefly are still under development.

If you are just starting to use IPM, use the levels in Table 43 as a guide to when specific action should be taken as follows:

- Use the lower number when pest pressure is likely to be high or when the crop is at a sensitive crop growth stage for that pest
- Use the higher number when pest pressure is likely to be low or when the crop can tolerate a low level of damage
- Use the medium number at other times.

Table 43. Guidelines for making spray decisions

Pest	Broccoli	Cauliflower	Cabbage
diamondback moth & heliothis	4 to 6 small caterpillars in 10 plants	2 to 4 small caterpillars in 10 plants	1 to 3 small caterpillars in 10 plants
centre grub	1 caterpillar per 20 seedlings — potential of 5% plant loss		
cluster caterpillar (*Spodoptera*) & cabbage cluster caterpillar	1 to 2 egg masses in 10 plants — wait for eggs to hatch before taking action		
cabbage white butterfly	10 small caterpillars in 10 plants — wait to see how many survive by the next crop check before taking action		
silverleaf whitefly	Tentative: one or two flies per leaf in 40% of plants checked, less in seedlings		
thrips	If thrips are active at head closure (cupping) in cabbage, consider spraying		
aphids	3 to 4 aphids found on most seedlings checked		

Sensitive crop growth stages

Brassica crops can tolerate substantial crop damage at different stages of their development without a corresponding loss in head weight. In crops close to harvest however, contamination by live insects is a quality problem and will impact on final yield. Field experience has shown that the following growth stages are critical for managing pests effectively:

- Seedlings – up to three weeks after transplanting and up to four weeks after planting direct seeded crops.
- Cabbage – head closure (cupping or hearting) to early head fill, that is, six to nine weeks after transplanting depending on variety and season.
- Cauliflower – two or three weeks around early head formation (buttoning), that is, six to 10 weeks after transplanting depending on variety and season.
- Broccoli – the two weeks around buttoning (early head fill), that is, six to 10 weeks after transplanting depending on variety and season.

a key issue

Understanding brassica plants
This chapter page 119

Using the monitoring log

You can decide which specific insect or disease needs to be controlled by comparing the numbers recorded in your monitoring log against action thresholds.

more info

The Chemical Handy Guide
Chapter 6 page 297

Once you have decided what insects or diseases need to be targeted, you can decide what control actions to use. Realistically, chemicals are often the only option available. The *Chemical Handy Guide* lists the chemicals and pest control agents currently registered for cabbage, cauliflower and broccoli crop in Queensland and their registered uses.

Reviewing trends to improve decision making

Use previous monitoring results to refine action thresholds and improve decision making in future crops.

The example of a completed monitoring log on page 201 illustrates the type of information you can record to help you make pest and disease management decisions.

An increase in pest or disease activity may indicate the need for:

- checking application equipment;
- a different control strategy;
- a product from a different chemical group;
- an additional control strategy;
- a shorter spray interval;
- more frequent crop monitoring.

A decrease in pest activity may indicate the need for:

- reduced targeting of that pest or disease;
- a longer spray interval;
- a softer pesticide selection;
- less frequent crop monitoring.

Cultural controls

Most cultural control options are part of the planning phase of IPM. Trends in crop monitoring data help to pinpoint problems and improve preventative pest and disease management tactics in future crops. Some practices that you could use in the current crop include:

- Rogue out diseased plants, for example by destroying club root affected plants and quarantining the affected area.
- Scuffle or chip out weeds to remove weed hosts of insect pests and diseases, to improve spray coverage and to improve air circulation.
- Destroy crops immediately after harvest to prevent pests breeding up in harvested crops.
- Clean up sheds and greenhouses, change harvesting procedures and generally improve hygiene around paddocks to reduce bacterial head rot problems.
- Limit access to paddocks or the farm to prevent further spread of a disease.
- Change irrigation or fertiliser practices.

Biological controls

Nature provides many mechanisms for keeping pests and diseases in check. Insect pests can be attacked by predators or parasites, or they can be killed by disease – fungal, bacterial and viral. Biological agents and mechanisms that help to control plant diseases are less well known and understood. Healthy soils can be more resistant to some soil borne diseases and research indicates that there is competition between disease organisms and other micro-organisms.

Working with nature is fundamental to IPM. With careful planning, an effective monitoring program, a good understanding of the cropping system and a willingness to tolerate some pest damage at times, it is possible to base DBM control on natural enemies. This in turn will help with the management of other insect pests.

Protecting natural enemies

A wide range of natural enemies help to control insect pests in brassica crops. The more important of these include the *Diadegma, Cotesia* and *Trichogramma* wasp parasites. Spiders, assassin bugs, lady beetles, lacewings and a variety of other predators also make a significant contribution to keeping pest insects in check. These 'good guys' build up over the season (and over the years) if they are allowed to get established and flourish on your farm.

If possible avoid using pesticides that may kill natural enemies. Natural enemies also need a food source and breeding sites to survive. For predators, insects provide the food source. For parasites, flowering plants around the farm may provide food and shelter, but the insect pest itself provides the breeding site. In both cases, a low level of insect pest activity is needed for predators and parasites to survive in the crop. Make note of natural enemies when monitoring crops to help with decision-making.

a key issue
Natural enemies
This chapter page 218

Releasing predators and parasites

Natural enemies that are commercially available include:

- *Trichogramma* wasps, which lay their eggs into heliothis eggs. In the field, *Trichogramma* have also been found in DBM and cabbage cluster caterpillar eggs.
- Parasitic wasps that lay eggs into aphids and then develop within the aphid, causing it to become a mummy.
- Lacewings that eat a range of small insect pests.

more info
Details on where to buy natural enemies
Chapter 5 page 280

Handle parasites and predators very carefully and follow the supplier's instructions for release and establishment procedures.

Biological insecticides

Bacillus thuringiensis (Bt) is a bacteriological insecticide used to control various caterpillar pests in brassica crops. It is usually considered a biological control option but is applied in the same way as an insecticide. Bt is particularly useful in IPM programs as it does not kill natural enemies. Several newer insecticides also have a low impact on natural enemy populations but these are not usually considered biological insecticides.

Over-reliance on Bt or any other narrow spectrum insecticide is not IPM. There is also a risk of pests such as DBM and heliothis becoming resistant to Bt if the product is overused. This would take a very effective, convenient and IPM compatible control option out of the DBM management arsenal.

Chemical control

Unless your pest management decision was to do nothing but wait and see, chemicals are often the only realistic control option available. Crop monitoring enables you to select the most suitable chemical for a specific problem or combination of problems.

Factors that you need to consider when selecting a chemical control option are:

- The likely impact on natural enemies;
- The timing of the application – your aim should be to target the most vulnerable part of the pest's lifecycle.
- Ability of your sprayer to achieve good plant coverage.
- Resistance management – follow any regional resistance management guidelines that may be in place in your district.
- Current and predicted weather conditions – temperature, rain, wind.
- Other operations that need to be carried out in the crop, especially irrigation.
- Is the product registered for that specific pest and crop situation?
- The withholding period for the product, especially if nearing harvest.

more info
Impact of insecticides on natural enemies
This chapter page 222

more info
Chemical Handy Guide
Chapter 6 page 297

Read the product label. It is a legal document and provides useful information on how to best use the product.

Pest and disease monitoring log (for copying)

Date:	Crop & growth stage:
Block:	Weather:

	DBM			Heliothis									Comments
Plant number	Eggs	Larvae	Pupae	Eggs	Larvae	Centre grub	Other caterpillars	Silverleaf whitefly	Thrips	Other pests	Black rot & scald	Other diseases	
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													
16													
17													
18													
19													
20													
Total													
Average per 10 plants													
Trap numbers													
Decision													

Example of a completed pest and disease monitoring log

Date: *Monday 19th April 2004*	**Crop & growth stage:** *Cabbage. Heads starting to close, 5 weeks post-transplant*
Block: *Creek flat*	**Weather:** *Showery on Fri & Sat. Cooler. More rain likely*

	DBM			Heliothis									Comments
Plant number	Eggs	Larvae	Pupae	Eggs	Larvae	Centre grub	Other caterpillars	Silverleaf whitefly	Thrips	Other pests	Black rot & scald	Other diseases	*Odd Diagdegma wasp in crop*
1										L			*Aphids*
2	6												
3									L		✔		*DBM pinholes*
4				1W									
5							E						*Cabb. cluster*
6													
7													
8							E			L			*Cabb. cluster. Aphids*
9	8												*DBM pinholes*
10		2s											
11			1P										*Parasitised pupa*
12											✔		
13			1P										
14		1s											
15				1B									
16										1			*Green vegie bug*
17		1m											
18													
19							2E						*Cabbage white*
20													
Total	14	4	2	2	-	-	4		-	Low	-	-	*Cabb. cluster eggs close to hatching. Low level of aphids; a few thrips*
Average per 10 plants	7	2	1	1	-	-	2		-	Low	-	-	
Trap numbers	*Pheromone - 9 DBM moths. Sticky traps - cabb. cluster moth & 4 lacewings*												
Decision	*Apply Bt spray in 2 days time. Keep an eye on heliothis and black rot. Switch to Avatar if rain is likely later in the week. May need protective spray of copper.*												

Note: You may want to develop abbreviations to record different pest information.
In above example, E=egg or egg mass, s=small, m=medium, W=white, B=brown, L = low, P = pupa

Insect management in the field

Insects can cause major yield and quality losses in brassica crop and successful management of these pests is essential for economic production. Brassicas can tolerate some damage once seedlings are established and before heading commences without significant loss in yield. The key pest is Diamondback moth. Other caterpillar pests including heliothis, cabbage cluster caterpillar and cluster caterpillar can cause problems at different times of the growing season. Centre grub and cutworm can severely damage seedlings and thrips, aphids and silverleaf whitefly can reduce crop vigour and cause major quality problems.

- Introduction
- Diamondback moth
- Management of diamondback moth
- Heliothis
- Cabbage cluster caterpillar and cluster caterpillar
- Centre grub
- Cutworm
- Cabbage white butterfly
- Thrips
- Silverleaf whitefly
- Aphids
- Managing insecticide resistance

Introduction

Diamondback moth (DBM) is likely to be the most important and most persistent caterpillar pest on farms that use scheduled sprays of broad-spectrum insecticides. Other pests (and natural enemies) are usually killed incidentally by these broad-spectrum insecticide applications. In the long term, this approach will tend to increase DBM problems and contribute to DBM developing insecticide resistance. Sprays will become less and less effective.

On farms that have implemented an integrated pest management (IPM) program, pest problems are usually more varied. Different pests cause problems at different times of the season and during different parts of the cropping cycle. DBM is less likely to be a persistent problem with natural enemies contributing to control of the pest. In IPM, broad-spectrum insecticide use is minimised, narrow-spectrum insecticides are

a key issue
Integrated pest and disease management
This chapter page 183

Colour photos of the major insect pests and their natural enemies can be found in the companion book, the *Brassica problem solver and beneficial identifier*.

used strategically and insect resistance problems to chemicals are less likely to develop.

Detailed descriptions of each of the main brassica insect pests follow. These descriptions include an overview of each pest's life cycle, tips on crop monitoring and an outline of the specific options available to control the pest. We strongly recommend that you employ a consultant to monitor crops for you and help you to implement an IPM program for managing pests.

To help with selection of insecticides within an IPM framework, tips on using insecticides effectively and principles for managing insecticide resistance are provided after the insect pest descriptions. We also refer you to the section on Natural enemies for information on how to make the most of this 'free' biological pest management option.

Diamondback moth

Diamondback moth (*Plutella xylostella*) is also known as cabbage moth as it specifically attacks crops and weeds that belong to the Brassicaceae family of plants. Diamondback moth (DBM) is potentially the most damaging pest of brassicas. Your approach to managing DBM will influence your management of other insect pests.

DBM adults are weak fliers but can move over long distances with the wind, both between and within districts and regions. Recent research however suggests that moths are not very mobile once they have settled in a crop, moving short distances within the crop but tending not to leave it. Therefore, while the activity of your neighbours and other Brassica growers in your district will have some impact on DBM populations on your farm, the choices you make about how to best manage DBM on your own property will have the bigger impact.

Your decisions will directly affect the degree to which DBM becomes a problem on your farm and how difficult it will be to manage DBM successfully. District or regional management practices while important will tend to have a secondary impact.

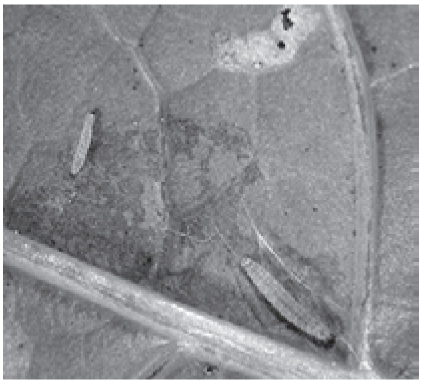
DBM can quickly reach damaging levels. This is partly due to its relatively short lifecycle (about 20 days in hot dry weather), the ability of the female moth to lay numerous eggs and the feeding habit of caterpillars, which makes them difficult to target effectively with sprays. DBM has also developed resistance to a number of insecticides and this further complicates DBM management.

We recommend that you use an integrated approach based on crop monitoring, maximising control through natural enemies and strategic use of narrow-spectrum insecticides to target specific insect problems.

Our experiences with DBM over the past 10 years illustrate that the overuse of broad-spectrum insecticides tends to induce DBM problems by killing off predators and parasitoids that usually help keep the pest in check.

Monitoring for DBM

An understanding of the pest's life cycle and the ability to find small larvae and preferably, eggs, are important for making effective control decisions. Large larvae are easier to find in the field but are very difficult to control. Insecticide applications should target caterpillars less than 5 mm in length. Look for pin holing (leaf mining) and windowing in leaves as well as small grubs and eggs.



Small and medium-sized diamondback moth caterpillars with pin holing (leaf mining) damage (top)

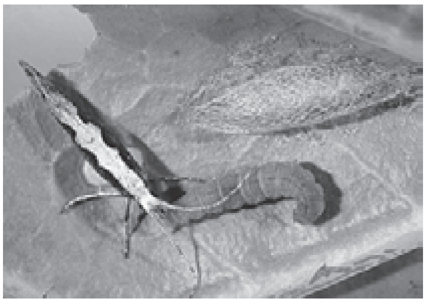
Because DBM is not very mobile once it has settled in a crop, the distribution patterns of the pest within a crop can be very patchy. This 'patchiness' at low levels of infestation can make it difficult to detect a potential DBM problem early enough. DBM numbers can appear to build up out of nowhere, particularly in warmer weather.

Crops should be checked frequently, with enough plants inspected each time, to make sound treatment decisions. Check crops more frequently in warm weather, at least twice per week, as DBM (and other insects) develop faster at higher temperatures. Pheromone traps and coloured sticky traps can be placed into the crop to augment monitoring data and act as an early alert for DBM activity.

more info
Pheromone traps and coloured sticky traps
This chapter page 192

DBM lifecycle and description

Moths are greyish-brown, to 10 mm long and when at rest in the crop, the folded wings of the female moth form a short row of roughly diamond-shaped, cream marks on its back. In male moths, this pattern is less distinct – some male moths are buff brown in colour.



Diamondback moth (cabbage moth) with pupa (top right) and mature caterpillar

Females lay flat oval-shaped, pale yellow eggs, about 0.5 mm in length, singly or in small groups. Eggs tend to be laid alongside veins on the upper side of leaves but can be found anywhere on the plant. Under high pest pressure, most eggs are found in groups on both sides of the leaf and on stems. Eggs hatch after 3 days in hot weather but can take up to 8 days to hatch in cooler weather.

After hatching, the small larva burrows into the leaf tissue causing leaf-mining damage. After several days, the larva emerges on the leaf underside to continue feeding, making typical 'windows' or holes. When disturbed, larvae will wriggle backwards and drop from the plant on a thin strand of silk.

When fully grown, larvae are around 10 mm in length, plump and bright green. They pupate inside a loose silken cocoon. These are often stuck to the underside of the leaf, but they can also be found elsewhere on the plant including broccoli and cauliflower florets. After 5 to 10 days an adult moth emerges from the pupa. Moths are most active in the early evening, but they can also be seen flying out of the crop during the day when disturbed.

Management of diamondback moth

Year round brassica production and poor farm hygiene combined with frequent applications of broad-spectrum insecticides are almost certain to lead to persistent DBM problems on your farm in the longer term. Successful management of DBM relies on a combination of preventative strategies that make the most of biological control and well-targeted insecticide applications. This dynamic approach requires a sound understanding of the pest and its natural enemies, and the ability to interpret monitoring results correctly.

Preventative control options

A production break is essential for breaking the life cycle of DBM from one season to the next as this practice will help to reduce overall pest pressure coming into the new season. During the warmer months, the DBM life cycle can take as little as 17 days from egg to adult and the pest can quickly build up in numbers and become unmanageable. A summer production break is the corner stone of any successful IPM program in areas with warm to hot summers such as the Lockyer Valley and Eastern Darling Downs.

Problems with centre grub, heliothis, thrips and other insect pests can impact on DBM management strategies. Avoid using broad-spectrum insecticides to control other insect pests by delaying planting until these pests are likely to be less active, accepting higher levels of damage in early plantings and using a ‘soft’ insecticide option if necessary.

Before planting out, check seedlings for pests and diseases. Keep the farm clean of brassica weeds and destroy and incorporate crop residues as soon as possible after harvest to deprive the pest of its food source. Old crop residues that were frequently sprayed with insecticides are likely to harbour insecticide resistant DBM but few natural enemies.

Biological control

A range of natural enemies attack DBM in crops where broad-spectrum insecticide use has been avoided or minimised. The most significant of these is the parasitic wasp *Diadegma semiclausum*, a small black wasp about 7 mm long which lays its eggs into young DBM larvae. Several other wasp parasitoids and a range of predators also attack DBM. Spiders are probably one of the more important of these.

Wasp parasitoids and predators can give good control of DBM in mild to cool weather when crops are grown under an IPM program. Some experienced growers have been able to reduce spray applications significantly and it is not uncommon for winter crops to be grown with either no spray applications or with only one or two well targeted sprays of a biological or narrow-spectrum insecticide.

Guidelines for action threshold are found in *Integrated pest and disease management* in this chapter page 196

To assess natural enemy activity, look for *Diadegma* wasps, spiders and other predators while crop monitoring. Check DBM pupae for brown wasp cocoons by pulling aside the gauze-like silky covering of the DBM pupa. The wasp cocoon is white in colour when freshly formed but turns brown as it matures. Exit holes in parasitised DBM pupa are also signs that Diadegma is active and helping with DBM control. You may also want to sample DBM caterpillars by pulling them apart to check for the wasp larva.

If the crop is not at a critical crop growth stage (seedling, buttoning or head closure) delay making a spray decision if DBM counts are low and natural enemy activity is high. The weather can also help, with a large proportion of small larvae often killed by rainfall.

There are a several very effective insecticide options available for managing DBM. These take some of the risk out of the 'do nothing, wait and see' course of action. Don't forget to take the presence or absence of other insect pests into consideration when making this management decision.

Biological insecticides

Bacillus thuringiensis (Bt), a bacterium, provides the active ingredient of several biological insecticides. It is effective against DBM, heliothis and most other caterpillar pests. Good plant coverage is essential as larvae must feed on and obtain a good dose of the product.

Time the spray applications to target small larvae. It may take several days before larvae are dead but they will stop feeding well before then. Bt affects only caterpillars and fits well into an IPM program. It does not harm the adult stages of natural enemies and is relatively soft on their immature stages. Insect resistance to Bt has been reported overseas so the product should be used with care within an integrated pest management program.

When DBM populations are high, naturally occurring fungal and viral insect diseases can sometimes help to bring DBM numbers back to manageable levels. DBM density in the crop needs to be high for the infection to spread from individual to individual and weather conditions need to be suitable.

more info
The Chemical Handy Guide
Chapter 6 page 297

Chemical control

Insecticides should only be applied when necessary. A number of chemical options are available for controlling DBM and whenever possible, choose the insecticide that is the least disruptive to natural enemies. Spray only those blocks of crop where DBM or other pests are likely to cause economic damage.

a key issue
Effective spray application
This chapter page 244

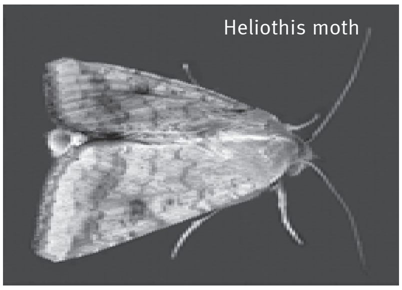
To obtain a good spray result, time insecticide applications to target small larvae and ensure that your spray equipment is capable of achieving good plant coverage including the underside of leaves where DBM larvae feed.

For information on the impact of insecticides on natural enemies
This chapter Table 45 page 222

DBM has developed resistance to insecticides in the synthetic pyrethroid, organophosphate, carbamate and organochlorine groups of chemicals. Most of these chemicals are broad spectrum and toxic to natural enemies. They are best avoided unless a specific pest problem other than DBM is being targeted for which there is no 'soft' option available. DBM resistance to at least one of the newer narrow-spectrum insecticides has been reported overseas so do not overuse these chemicals.

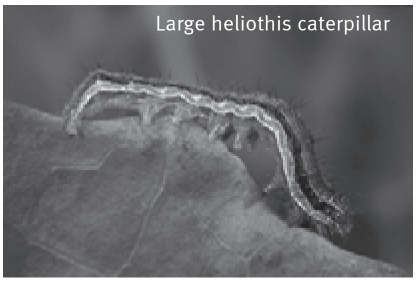
Heliothis

Heliothis grubs are the larvae of *Helicoverpa armigera* and *H. punctigera*. These caterpillars attack a range of crops. *H. armigera* (corn earworm, tomato grub) is an introduced species while *H. punctigera* (budworm) is a native species. *H. armigera* is the more difficult to control because of insecticide resistance problems. Heliothis is most active during the warmer months of the year when it is occasionally found in high numbers in brassicas. It can cause extensive damage, particularly in cabbage crops.



Heliothis moth

Heliothis moths can travel over long distances both within and between districts and regions. The moth is active at night and lays eggs singly on leaves, sometimes stems or heads. Eggs are round, ribbed and 1mm in diameter. Newly laid eggs are white; as eggs mature they develop a brown ring and as they near hatching they appear dark brown. Small caterpillars are brownish with tufts of hair. As they mature, the hairs become less prominent and caterpillars become more colourful. Mature caterpillars pupate in the soil.



Large heliothis caterpillar

Control of heliothis

Heliothis are usually controlled successfully by a combination of biological means and well-targeted spray applications. Crop monitoring is critical for detecting infestations early and timing sprays to control hatching larvae.

Look for eggs and small grubs when crop monitoring. Eggs are laid overnight and there are usually definite peaks in activity. Larvae chew holes in leaves and bore into the heart of cabbage. Larger larvae (over 20mm long) are very difficult to control with insecticides. Consider crop growth stage and activity of natural enemies before making a spray decision.

Biological control

Many parasites and predators attack heliothis eggs and larvae and these can often provide sufficient control when pest pressure is low. The egg parasite *Trichogramma* (a tiny wasp) occurs naturally and can destroy many eggs. Parasitised eggs turn black and are easily spotted when crop monitoring. *Trichogramma* are also available commercially and can be released into crops as a natural 'insecticide' to increase the percentage of eggs parasitised. For brassica crops, this technology is still experimental, so growers should be cautious. *Trichogramma* wasps are susceptible to most chemical insecticides. Follow the supplier's instructions and treat the wasps carefully, as they are delicate insects.

more info
Details on where to buy natural enemies
Chapter 5 page 280

Larger wasp parasitoids including *Microplitis* and *Cotesia*, the Tachinid fly as well as a range of predators such as spiders, birds, predatory bugs and beetles can make a significant contribution to biological control of heliothis.

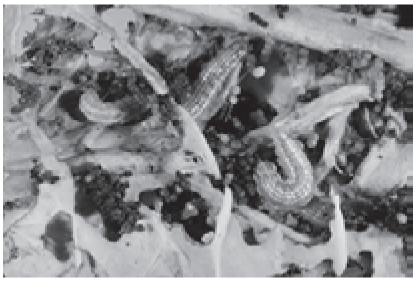
Chemical control

A range of insecticides is registered for heliothis control and these are listed in the Chemical Handy Guide. *H. armigera* has developed resistance to most insecticides in the older chemical groups. Avoid using insecticides specifically for heliothis control unless risk of crop damage is high. Minimise disruption to natural enemy activity by choosing a 'soft option' insecticide and spraying only blocks that are at risk. Time sprays to target small larvae and ensure that your spray equipment achieves good plant coverage.

Cabbage cluster caterpillar and cluster caterpillar

Both these pests have the potential to cause serious crop losses during the warmer months of the year. Cabbage cluster caterpillar, *Crocidolomia pavonana*, is most common in late summer and early autumn. Its host range is restricted to brassica crops. Cluster caterpillar, *Spodoptera litura*, can occur from spring through to autumn and has a wider host range including lettuce, tomatoes and strawberries.

Moths of both species lay eggs in clusters but they are relatively easy to tell apart. This is important for making management decisions.

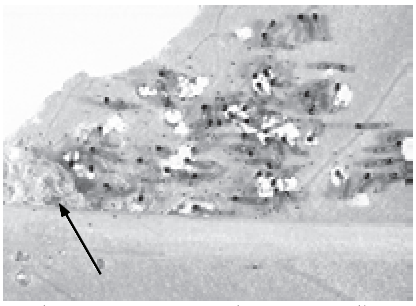

Large cabbage cluster caterpillars feeding under webbing

Cabbage cluster caterpillar moths lay light yellow eggs in clusters resembling overlapping scales. These egg clusters turn orange-brown as they mature. Larvae feed in groups and produce webbing, which often stretches across the heart of the plant. They grow to about 25 mm in length and cause extensive damage often skeletonising plants through their feeding.

Cluster caterpillar moths lay round, cream coloured eggs in clusters that are covered with moth scales, giving the egg cluster a hairy appearance. Young caterpillars feed in groups but older caterpillars are solitary. Mature caterpillars are up to 50 mm in length. Caterpillars can skeletonise leaves and tunnel into cabbage heads.

Both cabbage cluster caterpillar and cluster caterpillar pupate in the soil.

Control of cabbage cluster caterpillars and cluster caterpillars

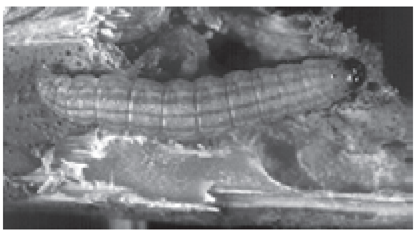

Newly hatched cabbage cluster caterpillars which have emerged from the egg mass (arrowed)

Natural enemies will contribute to control in crops grown with IPM. Sprays applied for other caterpillar pests – DBM, heliothis, cutworm and centre grub – will often provide incidental control of both pest species. However, during the warmer months, a spray to specifically control cabbage cluster caterpillar or cluster caterpillar may occasionally be needed.

Look for egg clusters and newly hatched groups of larvae on leaves as part of your overall crop monitoring program. If potentially damaging numbers are found, wait for eggs to hatch (2 to 3 days in warm weather) before spraying with a 'soft option' insecticide. To avoid extensive crop damage, aim for good plant coverage and target small caterpillars. Insecticides available for controlling the two pest species differ. Check the Chemical Handy Guide for registered insecticides for each of the species.

Centre grub

Centre grub, *Hellula hydralis*, can cause serious damage to seedlings by destroying the growing point of the plant. This causes the plant to either die, produce no head or multiple, unmarketable heads. Once plants are well established, centre grub tends to burrow into the midrib of leaves causing less damage and usually not warranting control.


Centre grub

The pest is most active during summer and autumn. Tiny, creamy-pink eggs are laid on younger leaves but these are very difficult to find when crop monitoring. The small caterpillar burrows into the growing point of the plant and can be mistaken for small DBM larvae. Centre grub has a darker head and brown longtitutional stripes along its body, while DBM has no stripes and will quickly wriggle backwards when disturbed.

When centre grub is likely to be active, look for signs of webbing and wind-blown soil around the growing point of the plant when crop monitoring seedlings. Gently open up the growing point of suspect plants with, for example a pencil, to check for presence of the grub.

Control of centre grub

One aim of centre grub management is to reduce the need for broad-spectrum insecticides to control high numbers of centre grub early in the season as these sprays kill natural enemies before they have a chance to become established on your farm. This is particularly important for effective DBM management later in the season as it will encourage *Diadegma* and other natural enemies of DBM to become established quickly on your farm early in the season. To achieve this, two preventative management strategies to consider are:

- to delay planting to avoid peak centre grub activity
- to tolerate higher levels of damage in summer and autumn planted crops.

For low infestations of small centre grub, a well-targeted spray of *Bacillus thuringiensis* should give adequate control. Good coverage of the growing point of the plant is essential, as the grub needs to ingest a large enough dose of the insecticide before it reaches the unsprayed plant tissue inside the heart of the plant. Alternatively, select a registered narrow-spectrum insecticide from the Chemical Handy Guide.

When centre grub activity is high, preventative sprays of seedling crops may be needed. Work out the percentage of plants affected by centre grub to calculate potential crop loss to help you make a spray decision. For example, if you find centre grub in three plants out of 20 plants checked, you are likely to loose 15% of seedlings through centre grub damage. Spray only seedling crops, not those crops that are already well-established and past the critical stage for centre grub damage.

Cutworm

Cutworms, *Agrotis* spp., are a sporadic pest during the warmer months. They can sometimes cause significant losses in seedling crops. At night, caterpillars chew seedling stems at or near ground level causing plants to fall over or wither and die. Seedlings may also be dragged into the soil overnight.

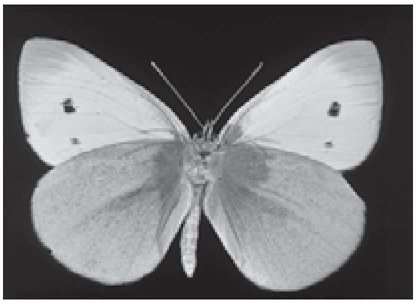

Curled up cutworms

Avoid planting into weedy paddocks or low-lying ground when cutworms are likely to be active. Good soil preparation can reduce incidence of cutworm by destroying alternative food sources and larvae in the soil. Check seedling crops for signs of cutworm damage. If you notice gaps in seedling crops or plant damage, check for curled up caterpillars in the top few centimetres of soil around affected plants.

Caterpillars are dark in colour and up to 35 mm long. If cutworms are causing economic damage use an appropriate insecticide from the Chemical Handy Guide. In some seasons you may need to apply preventative sprays to seedling crops if cutworm activity is consistently high and causing major losses.

Cabbage white butterfly

Cabbage white butterfly, *Pieris rapae*, has the potential to cause extensive damage but is usually controlled by insecticides applied to control other pests.



Cabbage white butterfly

Cabbage white butterfly is most active during the warmer months. The female butterfly lays single, bullet-shaped yellow eggs, 1.5 mm high, on leaves. Very young caterpillars are light green in colour, look similar to DBM caterpillars, but do not mine the leaf or cause windowing damage. As caterpillars grow, they become velvety and dark green in colour with a thin yellow stripe on either side and on top. Mature caterpillars are up to 30 mm long and pupate on the leaves.

In crops grown under an IPM program, cabbage white butterfly is rarely the main reason for applying an insecticide but may contribute towards making a spray decision for other pests. In crops that were not sprayed for other pests, cabbage white butterfly can reach damaging levels although a range of natural enemies attack the pest.

When crop monitoring, look for eggs and caterpillars as well as signs of natural enemy activity such as bundles of white *Cotesia glomerata* cocoons next to dead mature caterpillars and emergence holes of *Pteromalus puparum* in pupae. Cabbage white butterfly is easily controlled with insecticides including the biological insecticide *Bacillus thuringiensis*. Unless caterpillar numbers are very high a spray is unlikely to be needed specifically for cabbage white butterfly.

Thrips

Thrips are tiny insects that rasp the leaf surface to suck up exuded sap, giving affected areas a silvered appearance. They are difficult to see with the naked eye unless you know what you are looking for. Thrips can build up to damaging levels in warm, dry conditions and occasionally cause major quality problems in spring crops.

Several species of thrips can attack brassica crops but onion thrips (*Thrips tabaci*) is the most commonly found thrips species in brassicas. Melon thrips (*Thrips palmi*) and Western flower thrips (*Frankliniella occidentalis*) are less common. Both melon and Western flower thrips have developed resistance to most insecticides registered for the control

Contact your district APHS officer for up-to-date information on interstate quarantine requirements Chapter 5 page 285

of thrips and they can be very difficult to control once they have reached damaging levels in the crop. Melon thrips also has interstate quarantine issues associated with it in some districts.

Control of thrips

Effective crop monitoring is essential particularly for cabbages, as any potential problem needs to be identified early and managed promptly. Check seedlings for thrips before planting out and keep on the lookout for signs of thrips damage when crop monitoring. Yellow sticky traps can be used to monitor for thrips but only an expert can identify them to species.

Keep the farm clean by keeping weeds under control, practicing crop rotation, and destroying crop residues immediately after harvest. Thrips are carried on the wind so plant new crops upwind of older crops. The pest also attacks most crops, so talk with your neighbours about what crops will be planted where on their farm and share information on any problems with thrips control as the season progresses.

Thrips are attacked by a variety of predators and these help to suppress thrips populations. Avoid using insecticides unless thrips numbers are building up rapidly and are likely to cause problems. If you need to spray, apply a chemical that is the least disruptive to natural enemies and recheck crops for thrips several days later. The early heading (cupping) stage in cabbage is the most critical for controlling thrips. Under high thrips pressure, one or two follow up sprays may be needed.

If insecticides do not give good control you may need to have the thrips identified to species. If you are dealing with melon thrips or Western flower thrips they may be resistant to the insecticides you have applied.

Silverleaf whitefly

Silverleaf whitefly, *Bemisia tabaci* Biotype B, is a wide-spread pest of many vegetable crops in Queensland and can be very difficult to control in warm, dry conditions. The pest has only recently become a problem in Queensland brassica crops.

Silverleaf whitefly adults are small flying insects between 0.8 and 1.2 mm in size, that feed and lay their eggs on the underside of leaves. They are more active during the morning hours. Eggs and young nymphs (the juvenile stage) are minute, light yellow or creamy in colour, 0.3 to 0.6 mm in size and difficult to see without x10 magnification. Older nymphs are yellow then develop into a non-feeding pupa – the red-eye pupal stage. They are easier to spot in the field once they have reached this stage. The life cycle of the pest from egg to adult can be as short as 18 days in hot weather and take as long as 50 days in cool conditions.

Silverleaf whitefly adults and nymphs secrete honeydew on which black sooty mould grows. This causes significant quality problems in brassicas, especially cabbage and broccoli, when pest infestations are high. The pest feeds on the sap of plants, reducing plant vigour and while feeding, also injects toxins into the plant. In broccoli this causes a condition known as white stem.

Whiteflies on underside of cabbage leaf (above); close-up below

Control of silverleaf whitefly

Chemical options for silverleaf whitefly are currently limited as few insecticides are registered or under permit for control of the pest in brassicas. Silverleaf whitefly populations in Queensland have developed resistance to insecticides in the organophosphate, carbamate and synthetic pyrethroid groups of chemicals. Avoid using organophosphate insecticides as these can cause flare-ups of silverleaf whitefly problems.

Management strategies should aim to maximise cultural and biological controls. This starts by maintaining good hygiene on the farm, keeping broadleaf weed hosts under control, planting new crops upwind of old crops and checking seedlings for pests and diseases before planting out.

Natural enemies will provide some control over the pest so avoid the use of broad-spectrum insecticides and implement an IPM program to control pest and diseases in your crop. Avoid planting highly susceptible crops on your farm, for example soybeans, pumpkins, watermelon, other cucurbits and tomato. These crops provide ideal breeding hosts for silverleaf whitefly and as they mature and age, silverleaf whitefly will tend to migrate from them into the brassica crop.

While crop monitoring for other pests, look for silverleaf whitefly adults, pupae and large nymphs, particularly on the underside of older leaves. If whitefly numbers appear to be increasing (above one or two flies per leaf), spray with an appropriate insecticide from the Chemical Handy Guide, preferably one that is 'soft' on natural enemies. Make sure that you achieve good plant coverage, especially of the underside of leaves, when spraying.

It is important to act quickly if whitefly numbers start to build up, especially during the warmer months, as the pest can be very difficult to control once it has become established in the crop. Apply a clean up spray before destroying old crops to prevent whitefly adults migrating into young crops.

Aphids

Aphids are small soft-bodied insects that are usually of minor importance in brassicas. They prefer mild weather and can sometimes cause problems in spring and autumn planted crops. A range of natural enemies usually keep aphids numbers below damaging levels.

Winged females first colonise plants. Nymphs are wingless; adults can be winged or wingless. The females give birth to live young and populations can quickly build up under the right conditions. Aphids are usually found in colonies on the underside of older leaves. They cause damage by sucking sap from plants and heavy infestations can cause yellowing, wilting and leaf curling. In seedlings, aphids can reduce evenness of crop stands by suppressing plant growth. The presence of dense colonies of the pest can make product unattractive and unsaleable. Aphids also spread the turnip mosaic virus.

Several species of aphid can infest brassica crops. Green peach aphids, *Myzus persicae*, are pale yellow-green. Cabbage aphids, *Brevicoryne brassicae*, have a grey mealy appearance and can cause marketing problems, especially in cabbage. The turnip aphid, *Lipaphis erysimi*, is dark green and usually not a problem.

Control of aphids

Natural predators such as lady beetles and their larvae, lacewings and hoverfly larvae, damsel bugs, pirate bugs and brown smudge bugs usually attack aphids. Wasp parasitoid also help to suppress aphid numbers turning the aphid into a pearl-like shiny 'mummy'.

To minimize aphid problems, check transplants for pests before planting out, control weeds that are alternative hosts to aphids and destroy old crops as soon as harvesting is completed. When crop monitoring, look for aphids on the underside of leaves and around the growing point of seedlings and make a note of any predators and parasitised aphid mummies.

In good growing conditions and with the help of natural enemies, aphids generally do not warrant spraying. If aphids are likely to suppress crop growth or cause marketing problems, select an appropriate insecticide from the Chemical Handy Guide, choosing a product that is least disruptive to natural enemies. Green peach aphid has built up resistance to several insecticides so check the product label for specific use directions.

Managing insecticide resistance

The best way to manage insecticide resistance is to avoid use of chemicals whenever possible. Therefore any insecticide resistance management strategy starts with the implementation of an IPM program and regular crop monitoring. Insecticides should play a supportive not dominant role in this integrated approach to managing pests.

Selecting an insecticide

Once crop monitoring results indicate that a spray is needed to avoid economic crop damage, there are a number of factors to consider in choosing the chemical option that will give the best outcome:

What to spray

- What products are registered for the pest and crop in question;
- Specific pests that the insecticide will control;
- Likely impact on natural enemies;
- Resistance status if this is known;
- Persistence of the insecticide in the field;
- Withholding period of the product.

When to spray

For more information on the impact of insecticides on pests and natural enemies see Table 45 on page 222

- Target the most susceptible stage of the pest, for example, small larvae;
- Morning or late afternoon, to avoid hot or windy conditions;
- Check the product label for specific instructions on getting the best result from the chemical product.

How does insecticide resistance develop?

a key issue
Effective spray application
This chapter page 244

Insecticide resistance is the ability of some individuals in a pest population to survive a rate of chemical that other individuals in the population cannot survive. This characteristic is inherited and the resistant survivors pass the gene for resistance on to the next generation. Resistance develops when a population of insects is repeatedly exposed to an insecticide from a specific group of chemicals. Susceptible individuals die while those individuals that survive, continue to reproduce. Over time, this leads to a population of insects that are resistant to the insecticide.

When insects develop resistance, the grower needs to apply more frequent applications of the insecticide to kill the pests at the registered rate as the insecticide starts to become less effective. This further speeds up resistance development. Eventually the old insecticide essentially becomes ineffective and a new insecticide is needed to replace it. Insecticides are expensive to develop and register, so new replacement insecticides do not come along quickly.

Which insecticides are at risk?

Insecticide resistance problems have been recorded in DBM, heliothis, silverleaf whitefly, melon thrips, Western flower thrips and green peach aphid.

Insecticides are categorised into chemical groups (or classes) according to their particular chemical properties and mode of action in killing insects. Once a pest develops resistance to an insecticide from a particular insecticide group, it also tends to be resistant to other insecticides in that group. The end result is that products from that chemical group no longer give good control of the pest.

- DBM are resistant to the synthetic pyrethroids (SPs) and organophosphates (OPs) groups of chemicals in all major brassica growing areas in Australia.
- DBM resistance to carbamates and organochlorines has been recorded in Queensland.
- DBM resistance to *Bacillus thuringiensis* (Bts) and spinosad has been recorded overseas illustrating that biological insecticides and the more recently developed chemistries are not immune to resistance problems if overused.
- While Bt is still giving good control, there are early signs that DBM may be developing resistance to this insecticide in some districts of Queensland.

The registration of five new insecticides in the late 1990s has given the brassica industry a unique opportunity. Each of these insecticides represents a different chemical group and, if used wisely, should provide brassica growers with effective chemical control options for many years to come.

A national insecticide resistance management (IRM) strategy for DBM has been developed by the Australian Insecticide Resistance Action Committee (AIRAC). This strategy is based on rotating insecticides from different chemical groups according to a window strategy.

Minimising insecticide resistance risks

There are some overall principles for managing insecticide resistance in DBM, heliothis, thrips and aphids:

- Any resistance management strategy should be implemented within the framework of an IPM program and spray decisions must be based on crop monitoring results.
- Avoid continuous use of an insecticide from any specific chemical group—rotate insecticides from different chemical groups. In the case of DBM, implement the window strategy developed by AIRAC.
- Time spray applications to target the most susceptible stage of the pest, for example, small DBM caterpillars, young nymphs
- Aim to achieve good plant coverage – regular maintenance and calibration of spray application equipment is essential

For a copy of the national DBM insecticide resistance management strategy contact AIRAC. See Chapter 5 page 293 for details.

- Do not follow a spray failure with an insecticide from the same chemical group
- Follow instructions on the insecticide label and take heed of any restrictions on the number of sprays allowed per crop
- Do not exceed the dosage specified on the label – not only is this practice illegal, it is counterproductive and could lead to insecticide residue problems in the harvested product.
- Do not mix two or more insecticides together unless you are targeting two different pest problems and you are confident that there are no chemical incompatibility problems—check the label for specific use details. For the same reason, avoid mixing insecticides with fungicides and foliar nutrients whenever possible.

Natural enemies (beneficials)

Not all the 'insects' we see are causing devastation in your crop. Many are in fact beneficial – natural enemies of the real pests doing the damage. It is important to be able to recognise 'friend from foe', and take the necessary action. This section will help you make that distinction.

- Introduction
- Parasitoids
- Predators
- Insect pathogens
- Enhancing the effectiveness of natural enemies
- Key parasitoids and predators in brassica crops

Introduction

Natural enemies such as insects, spiders, birds and frogs can help to control insect pests in your crop. Tolerating some level of crop damage, avoiding the use of broad-spectrum pesticides, strategic use of narrow-spectrum chemicals and biological insecticides such as *Bacillus thuringiensis* (Bt) will increase natural enemy activity within the crop.

Natural enemies alone can at times achieve a standard of pest management acceptable to market requirements in brassicas. However, it is rare for natural enemies to provide adequate control of insect pests for the whole season. Natural enemies are a crucial component of any integrated pest management (IPM) program with other management strategies such as chemicals providing a supportive rather than disruptive role. The aim is to work with nature rather than against it.

Colour photos of the major insect pests as well as parasitoids and predators of these pests can be found in the companion book, *Brassica problem solver and beneficial identifier.*

Natural enemies fall into two groups – parasitoids and predators. A third group of organisms that help to control pests are pathogens – bacteria, viruses and fungi that infect and kill insects.

Our studies show that in brassica crops grown with an IPM program, between 40 to 70% of pests may be 'controlled' by natural enemies with no loss in crop yield or quality. Predators make up 30 to 50% of this free 'pest' control, with research suggesting that spiders are the most abundant predators in brassicas, followed by beetles, lacewings and ants.

Parasitoids

Parasitoids are organisms that parasitise and kill their hosts. The adults are free-living and are usually wasps or flies. Parasitoids usually feed on nectar and pollen. The adult lays its eggs within or on the host pest at a critical life stage. This immature stage then develops on or within the insect host, completing their entire development within that host by consuming it and eventually killing the host.

Parasitoids tend to be very specific to their host. There are various wasp parasitoids that attack either moth eggs, caterpillars, pupae, aphids or silverleaf whitefly nymphs.

Egg parasitoids such as *Trichogramma* attack and develop in a range of moth eggs, typically turning the egg a silvery black. Larval parasitoids include wasps such as *Diadegma*, *Cotesia*, *Microplitis*, *Apanteles* and *Pteromalus* species and the tachinid fly. Parasitised caterpillars show few external signs of parasitism. *Diadromus collaris*, a pupal wasp parasitoid, lays its eggs into the pre-pupae and newly formed pupae of DBM.

Aphids are often parasitised by tiny wasps whose feeding larvae turn aphids into noticeable bloated, pearl-like buff or brown shells commonly called 'mummies'. The aphid parasitoid emerges through a circular hole in the abdomen of the aphid shell. *Eretmocerus* and *Encarsia* are the two main wasp parasitoids that attack silverleaf whitefly nymphs.

To determine the level of parasitoid activity in your crop:

- Estimate the number of pests affected by parasitoids when crop monitoring by working out, for example, rough percentages of aphid mummies, parasitised diamondback moth (DBM) pupa and black moth eggs (parasitised by *Trichogramma* wasp).
- You may also want to sample caterpillars for parasitoids by pulling them apart to check for wasp larva.
- You could also collect and rear the pest to observe if parasitoids will emerge from their host. Emergence could take from one day to several weeks. This practice will also be invaluable for building on your knowledge of pests and their natural enemies.

Only a limited number of parasitoids are mass reared commercially. The most common is the egg parasitoid *Trichogramma pretiosum*, which has a wide host range.

Predators

Predators feed directly on their prey and include insects such as lacewings, ladybirds, assassin bugs, predatory shield bugs, hover flies and ants; as well as spiders, birds and frogs. Most predators are generalists and attack a wide range of insects including aphids, thrips, moth and butterfly eggs and caterpillars. Not all predators are generalists. Some prefer to hunt specific insects. Predators usually attack insects that are smaller than themselves and supplement their diet with nectar, pollen and fungi.

In most cases it is the larvae of predators that are the main feeders and they tend to prey on eggs, small caterpillars and the slower moving sap-suckers including aphids, thrips and whitefly nymphs. Some predatory bugs however will prey on large caterpillars. Spiders are common generalist predators. Wolf spiders are common soil predators, whereas the crab spiders, jumping spiders, orb weavers and many others are active predators in plant canopies.

Insect pathogens

Insects can be infected with a number of fungal, bacterial and viral diseases, however in nature, these diseases tend to have the most impact on pest numbers when pest populations are high and the weather is humid or rainy.

Enhancing the effectiveness of natural enemies

The following actions will help increase the effectiveness of natural enemies:

1. Monitor crops to help reduce unnecessary insecticide usage;
2. Use chemicals (insecticides and fungicides) only when necessary;
3. Use a narrow-spectrum chemical to control the pest whenever possible and limit its direct impact on natural enemies. Table 45 provides an overview of insecticides registered for use in cabbage, cauliflower and broccoli crops and their likely effect on natural enemies.
4. Spray only those blocks of crop where pests and diseases are likely to cause economic losses—the untreated blocks will provide a reservoir of natural enemies;
5. Provide an alternative food source for adult parasitoids and predators—for example, weeds or other flowering plants are a good source of nectar and pollen. Make sure you assess these plants for their

potential to become a serious weed problem or act as an alternate host for pests and diseases.

6. Tolerate some level of insect pest activity in your crop—without pests to parasitise or feed upon, natural enemies will not survive in your crop.
7. Trial mass (inundative) releases of commercially reared natural enemies so they become effective more quickly. Inundative releases have variable results and only a limited number of species are available. For brassica crops, these include the egg parasitoid *Trichogramma pretiosum* and general predators such as lace wings.

more info
Details on where to buy natural enemies
Chapter 5 page 280

Key parasitoids and predators in brassica crops

a key issue
Insect management
This chapter page 202

Some of the more important parasitoids and predators of brassicas are listed in Table 44. This table also summarised the relationships between these natural enemies and the major insect pests found in brassica crops.

Table 44. Relationships between natural enemies and pests found in brassica crops

Pest	Parasitoids									Predators					
	Diadegma	Cotesia	Pteromalus	Apanteles	Microplitis	Trichogramma	Diaeretiella	Eretmocerus & Encarsica	Tachinid fly	Spiders	Lacewings	Ladybirds	Assassin bug Predatory shield bug	Other predatory bugs	Hover flies
DBM eggs						✓				✓	✓	✓		✓	✓
DBM larvae	❋			✓					✓	✓	✓	✓	✓	✓	
Heliothis eggs						❋				✓	✓	✓		✓	✓
Heliothis larvae		✓			✓				✓	✓	✓	✓	❋	✓	
Other caterpillar pests		❋ larvae	❋ CWB	✓ larvae	✓ larvae				✓ larvae	✓	✓	✓	❋	✓	✓
Aphids							❋			✓	❋	❋		❋	❋
Thrips										✓		✓		✓	
Silverleaf whitefly nymphs								❋		✓	✓	✓		✓	

❋ Indicates potentially high impact of natural enemy on host or prey population
✓ Indicates some impact of natural enemy on host or prey population
DBM = diamondback moth
CWB = cabbage white butterfly larvae

Table 45: Impact of insecticides on pests and natural enemies (developed in conjunction with members of the National diamondback moth project team)

Legend

✔ = registered for pest
R = resistance in Qld populations

Impact rating—estimated percentage reduction in natural enemies

VL=very low less than 10% | L = low 11-20% | M = moderate 21-40% | H = high 41-60% | VH = very high over 61%

Insecticides	Pests									Overall IPM rating[3]	Natural enemies[4]					
Active ingredient	Diamondback moth	Centre grub	Cabbage cluster caterpillar	Cluster caterpillar	Heliothis	Cabbage white butterfly	Aphids	Thrips	Silverleaf whitefly	Impact on natural enemies 1 = hardest 5 = softest	Egg parasitoid *Trichogramma*	Larval & pupal parasitoids[4]	Predatory beetles	Predatory bugs	Lacewing	Spiders
Bacillus thuringiensis (Bt)	✔	✔	✔			✔				5	VL	VL	VL	VL	L	VL
chlorfenapyr	✔					✔				3	VH	M	M	M	L	L
emamectin benzoate	✔					✔				3	M	M	L	H	L	M
endosulfan					✔R	✔	✔	✔		3	VH	M	M	M	L	M
fipronil	✔		✔			✔				3	VH	H	L	M	VL	M
imidicloprid							✔		✔R	2½	VH	M	H	H	L	L
indoxacarb	✔				✔	✔				3½	L	M	H	L	VL	VL
methomyl		✔	✔	✔	✔R	✔				2	H	H	VH	H	H	M
organophosphates[1]	✔R	✔	✔	✔	✔R	✔	✔	✔	✔R	2½	H	H	H	H	L	H
pirimicarb							✔			4½	M	VL	VL	L	VL	VL
pymetrozine							✔		✔ broccoli	4	L	L	L	L	L	L
spinosad	✔	✔	✔		✔	✔				3½	VH	M	VL	M	VL	VL
synthetic pyrethroids[2]	✔R	✔	✔	✔	✔R	✔	✔		✔R	1	H	VH	VH	VH	H	VH

1 Organophosphates: for example, methamidophos, methidathion, chlorpyrifos—Group 1B insecticides, specific registrations & complete listings in Chapter 6

2 Synthetic pyrethroids: for example, cypermethrin, deltamethrin, esfenvalerate—Group 3A insecticides, specific registrations & complete listings in Chapter 6

3 IPM rating derived from an average toxicology effect on all natural enemies by the product after spraying

4 The authors gratefully acknowledge the following people for permission to use data from their research: Jianhua Mo, Greg Baker, Nancy Endersby, Peter Ridland, Guo Shi-jian, Lui Shu-sheng, Lewis Wilson, Jonathan Holloway, Robert Mensah and David Murray; as well as information from The Good Bug Book 2nd Edition (1995) and the Cotton IPM guidelines 2001 field guide.

Disclaimer: Information provided is based on the current best information available. Users should check the label for further details on registration status, instructions for safe use and handling and impact on natural enemies. When using a product under temporary permit, the user must hold a copy of the permit and follow its instructions. Further information on a product can be obtained from the manufacturer.

Disease management

A range of diseases affect brassica crops but good management practices can minimise their impact on both yields and quality. Preventative strategies based on a sound crop rotation program, effective farm hygiene practices and use of resistant varieties are essential for successful disease control. Particular diseases will vary in their importance from season to season. Bacterial diseases such as black rot and head rot can be very difficult to control under adverse weather conditions.

Soil-borne diseases

Soil-borne diseases often occur in the same field year after year, with the organisms that cause these diseases surviving in soil for long periods. Old crop residues, volunteer crops and alternative weed or crop hosts will encourage diseases to remain active in the soil, so an effective crop rotation program and good soil preparation are important management tools.

The full colour companion book, *Brassica problem solver and beneficial identifier* has photos of the most common diseases. Details on where to get this book as well as other relevant publications can be found in Chapter 5 page 290

Soil-borne diseases can be carried to new areas in contaminated soil on vehicles, tractors, machinery, implements and boots or through contaminated water. Once the disease has become established in a field it may be very difficult to eliminate. For example, the fungal disease club root is almost impossible to eradicate from a paddock once the soil is infected, as its spores can survive in the soil for at least 20 years. Prevention through good farm hygiene will reduce the risk of bringing diseases onto the farm and spreading them from paddock to paddock.

Damping off and wirestem

The organisms most often responsible for damping off in seedlings are *Pythium* species and *Rhizoctonia solani*. Both fungi are extremely common in soils of sub-tropical and temperate regions. Seedlings of most crops are liable to attack, with soil and weather conditions playing a major role in disease development. Damping off caused by *Pythium* occurs primarily in cool, wet conditions while *Rhizoctonia* is more common in warmer soils. Direct seeded crops in paddocks with high levels of undecomposed plant residues, poor drainage and compacted soil are most at risk.

Pythium invades stem tissue and roots causing a wet rot. Plants often collapse, wither and die. The fungus can also cause a seed rot that kills seeds before they germinate. Damping off through *Pythium* is primarily a problem in seedling nurseries and in direct seeded crops. The disease is less destructive in transplanted crops as plants are not susceptible to *Pythium* after the three or four true leaf stage.

Rhizoctonia solani tends to be associated with a disease known as wirestem, a dry rot of the seedling stem. The fungus invades the soft outer tissue of the stem at or near ground level causing stem girdling. Affected seedlings often continue to grow slowly, becoming stunted and spindly, but they may not die. The fungal pathogen that causes black leg, *Leptospaeria maculans*, can cause similar symptoms.

To control damping off and wirestem problems, use transplants rather than direct seeding crops. Ensure seedlings get away quickly by choosing the right variety for the season, planting out healthy seedlings and paying attention to fertiliser and irrigation management during crop establishment. If direct seeding, avoid planting seed when the soil is cold or chances of rain are high. For both transplanted and direct seeded crops, ensure plant residues are thoroughly decomposed before planting and seed beds are well prepared. Plant on beds to improve drainage.

Sclerotinia rot

The fungus *Scerotinia sclerotiorum* attacks a wide range of crops, weeds and ornamental species. Cool, wet weather favours development of the disease. Typical symptoms are a water-soaked rotting of leaves, stems and heads accompanied by a white, fluffy fungal growth (mycelium). Large, compact resting bodies called sclerotia are produced in or on diseased tissue. These sclerotia are white at first but later turn black and hard. They can be up to 10 mm long. The fungus can rapidly rot stems, leaves and heads, causing wilting and then collapse of the plant.

Sclerotia can survive in the soil for many years. During moist weather, sclerotia near the soil surface germinate to produce small structures called apothecia. These structures contain spores that are released into the air and carried by the wind. Spores germinate when they land on old, decaying plant tissue on which the fungus rapidly multiplies to infect adjacent healthy tissue. Spore gemination requires free water from dew, rain, fog or overhead irrigation.

To reduce *Scerotinia* problems, rotate brassicas with resistant crops such as grasses and grains. Avoid planting paddocks with a history of

Good penetration of foliage and correct timing of spray applications are essential for effective sclerotinia control. For information on spray application, see page 244 in this chapter.

Scerotinia problems especially when cool, wet weather is likely to prevail. Avoid planting in wet, shady areas and irrigating close to harvest. If the disease is likely to be a problem, spray young crops with an appropriate fungicide from the *Chemical Handy Guide* in Chapter 6. Deep plough diseased crops immediately after harvest.

Club root

Club root is a persistent and serious disease of brassica crops nationally. It is caused by the fungus *Plasmodiophora brassicae*, which can remain viable in the soil for many years even in the absence of susceptible host plants. The fungus has a wide host range, including a few non-brassica species, however typical root symptoms are only seen in members of the brassica family of plants, both crops and weeds.

At time of publication, distribution of club root within Queensland appeared limited to the Granite Belt district and one isolated identification in the Lockyer Valley. So far, other Queensland production areas appear to be unaffected.

Plasmodiophora brassicae enters the plant through the fine hairs on young roots and through wounds on secondary roots. Roots can be infected at any stage of growth. As roots grow, they develop characteristic club, spindle-shaped or knot like swellings and the entire root system may be affected. Millions of resting spores develop in mature galls of clubbed roots and in warm, moist soil some of these spores germinate to release swimming spores. These swimming spores move through moist soil to infect other roots.

Spores can be spread mechanically through movement of contaminated soil on vehicles, machinery, implements, pallets, bins, workers boots and transplants. Water runoff from infected fields, contaminated irrigation water, movement of dung or compost that contains infected root material, and grazing lifestock can also spread the disease. The fungus has no airborne spores but can be carried on windblown dust.

The fungus depends on high soil moisture to infect roots, develops best under soil temperatures between 20 to 25°C and prefers acidic soils (pH less than 7.0).

Controlling club root

Effective farm hygiene practices are your best line of defense in preventing club root infecting your property. Look out for possible sources of contamination such as infected transplants, dirty machinery and equipment, vehicles, dirty bins and boots. Restrict entry to the farm or parts of the farm by putting up signage to control traffic of contractors, visitors and staff onto and around the farm.

Comprehensive information on managing club root is available through the National Club Root Project. Contact the Department of Primary Industries Victoria or Horticulture Australia Limited.

more info — Chemical control options *Chemical Handy Guide*

Very early stages of the disease are impossible to recognize. The first above ground symptoms are a wilting of infected plants particularly during hot, dry weather. Severely infected plants are stunted with pale-green to yellowish leaves. When crop monitoring, check any wilting plants for signs of typical spindle, knobby or club-shaped roots. If you find suspect plants, take care not to remove plants or soil from the potentially infected site. Quarantine the area and contact the nearest DPI&F office for help with identification and management.

Don't panic! Growers in other areas of Australia continue to grow brassicas on land that is infected with club root. Aim to reduce spread of the disease onto clean paddocks by maintaining a good farm hygiene program and manipulate the soil environment so that it is hostile to the fungus:

- Implement at least a three year crop rotation between brassica crops.
- Control brassica weeds around the farm.
- Increase soil pH to around 7.2.
- Improve soil drainage and take care not to over water crops.
- Avoid warm season production.
- Consider fumigating infected areas or applying a fungicide.

Black leg

The fungus *Leptospaeria maculans* can infect plants at any stage of growth, causing light-brown sunken spots near the base of stems which eventually turn black and split, girdling the stem. Tiny black fruiting bodies called pycindia may appear on affected stem and leaf areas. Internally the stem shows a brown, dry rot. Affected plants wilt and often show a reddish colour on leaf margins.

The fungus can be introduced in infected seed and survives on old crop residues. Spores from pycindia are spread by rain or irrigation splash. Crop rotation and good soil preparation contribute to effective management of the disease. Black leg is more common in areas with a cool climate and with the use of hot-water treatment of seed, it is now considered a minor disease in Queensland.

Yellows

The fungus *Fusarium oxysporum* f.sp. *conglutinans* causes plants to loose vigour and leaves to turn yellow. In young plants, one side of the plant tends to be retarded in growth, with leaves bending sideways and becoming pale-yellow in colour. If the stem is cut across at ground level, a brown discolouration of the water-conducting tissue can usually be seen.

The fungus can survive in the soil for long periods. It is spread through soil movement and infects plants through the roots, growing into the water conducting tissue. Warm weather favours the disease and potassium deficiency may intensify symptoms. Use resistant varieties and ensure adequate potassium is available to the crop.

Nematodes

Root lesion nematodes are not a major problem in Queensland. They can be of concern in the Granite belt from time to time. Nematodes damage roots, resulting in a reduction of the root system and secondary infections by fungi and bacteria. Affected plants appear stunted, sometimes chlorotic, and usually several plants show symptoms in the one area of the crop.

Sclerotium base rot

This fungal disease is usually not a problem in Queensland brassica crops. *Sclerotium rolfsii*, the cause of the disease, is a common soil-borne fungus that affects many vegetables, ornamentals and field cops. It is most active during warm, wet weather, causing rots of the stem, roots and leaves in contact with the soil. Affected plant tissue becomes covered in a coarse, white cottony fungal growth in which white, spherical resting bodies called sclerotia develop. These become light brown as they mature, resembling cabbage seed. The fungus can survive for years as sclerotia in the soil or in host plant debris. Sclerotia are spread through movement of infected soil, infested plant material and contaminated equipment.

Foliar diseases

The incidence and severity of foliar diseases will vary markedly with weather conditions. In wet weather, bacterial leaf and head diseases usually cause the most problems but several fungal leaf diseases can also cause significant crop losses at times.

Black rot and bacterial leaf scald

The bacterium *Xanthomonas campestris* pv. *campestris* causes two distinct types of symptoms. Infection by the bacteria through water pores (hydathodes) at the leaf margins causes yellow, V-shaped areas with dark veins to develop around the leaf margin. These dry out and turn brown causing typical black rot symptoms. Vein blackening may extend down the leaf into the petiole and stem causing browning of the vascular tissue.

Some strains of bacteria infect plants through the leaf stomata (breathing pores) or tiny wounds causing tan, circular spots with yellow halos between leaf veins. These merge and dry out causing typical leaf scald symptoms. Affected areas often crack and disintegrate giving leaves a tattered appearance.

Both black rot and leaf scald are common diseases of brassicas and can cause serious losses in wet weather. The bacteria can be introduced on seed and survive on undecomposed crop residues and susceptible weeds such as wild radish and shepherd's purse. Once established in the crop, the disease is spread through water splash in windy, wet conditions or by irrigation. It can also be spread by insects, or mechanically through equipment or people.

more info
Hot water seed treatment
This chapter page 234

Use black rot tolerant or resistant varieties. Ensure seed has been hot water treated to control seed borne infection. To reduce spread of the disease in the field, work from new to old crops, control weeds and insects and plough in brassica crops immediately after harvesting is completed. Practice crop rotation.

Use an appropriate chemical from the *Chemical Handy Guide* when weather favours disease development or at the first sign of the disease. These chemicals act as protectants, so good plant coverage is essential for effective control. Under extended wet weather, the disease can be very difficult to contain.

Peppery leaf spot

The bacterium *Pseudomonas syringae* pv. *maculicola* causes small, purple to brown spots with fine yellow halos, giving leaves a general flecked appearance. Under wet conditions, the spots may merge to cover large areas of the leaf. Infected veins can cause leaf puckering.

Prolonged wet, cool conditions and plant injury or stress provide favourable conditions for the disease to develop. Cauliflower is the most susceptible and occasionally severe losses occur following frost or cold, wet weather. The bacteria are seed borne and can survive in crop residues. The disease is spread by water splash and mechanically through machinery, people or by insects. Control options are the same as for black rot and leaf scald.

Zonate leaf spot

This disease is caused by the bacterium *Pseudomonas chichorii*. It is considered a minor disease of cabbage. Circular to irregular, water-soaked spots develop on infected leaves. These spots are at first light-brown but darken as they mature, with irregular spotting and necrotic areas evident well into the head if cover leaves are pulled back.

The disease has a wide host range including lettuce and clover, survives on undecomposed crop residues and also in the soil. Overhead irrigation and wet, windy conditions can rapidly spread the disease. Avoid planting highly susceptible cabbage varieties. Consult your seedling supplier or seed companies for advice on varietal susceptibility.

Downy mildew

This disease is often a serious problem in seedling nurseries as crowding of plants provides the ideal conditions for downy mildew. It is less of a problem after transplanting, although the fungus *Peronospora parasitica* can infect seedlings, leaves, curds and heads.

In seedlings, yellow to pale green spots develop on the upper side of leaves with a white fluffy mildew showing on the leaf underside. Cotyledons (first pair of seedling leaves) may be completely covered in this white mildew. In older leaves, small necrotic areas develop, giving the leaf a flecked or speckled appearance. In cool, moist weather these spots grow into large patches with white mildew on the leaf underside. With a return to drier conditions, these patches dry out and die. Affected cauliflower heads may show a dark-brown discolouration.

The white mildew produces many spores, which are spread by wind and water. These spores are produced overnight and need water to germinate. Management practices that reduce the length of time leaves are wet will help to limit disease spread. Avoid irrigating plants in the morning and improve air circulation around plants in the nursery and field.

The fungus survives on volunteer brassicas, weeds and crop residues. Keep seedling production areas free of susceptible hosts, practice crop rotation, control weeds around the farm and destroy brassica crops after harvest. Plant disease-free seedlings and maintain a well-balanced nutritional program. Potassium deficiency may make plants more susceptible to the disease.

Apply protectant fungicides at the first sign of the disease and continue a regular spray program while conditions are wet and cool. Good coverage of the underside of leaves is essential for effective control.

Ring spot

The fungus *Mycosphaerella brassicicola* infects plants under extended cold, wet conditions although symptoms may not be seen until a fortnight later. The disease first causes small, dark, circular spots on leaves but these can grow up to 20 mm in diameter, turning greyish-brown towards the centre. Small black pin-sized fruiting bodies (pycnidia) are produced on the surface of the spots, usually forming concentric circles. The disease has caused serious losses in cabbage crops grown in highland areas during the winter.

The fungus survives on crop residues in the soil from one season to the next. It is also seed borne. In the field, the disease is spread through spores that are ejected from the black pycnidia and carried on the wind. To control the disease, plough in crops immediately after harvest and do not double crop brassicas. Use an appropriate fungicide at the earliest sign of the disease and continue treatment while weather conditions are cold and wet.

Alternaria spot (target spot)

The fungus *Alternaria brassicicola* causes large brownish to black spots on leaves, stalks and heads. Dark sunken areas may develop on cauliflower curds. As the disease progresses, masses of black spores are formed in these lesions and spots may become dry and papery and fall out.

Alternaria spot is a minor disease. It is most likely to occur in the field in cauliflower, sometimes in the nursery in other brassicas. Warm, moist weather favours disease development. The fungus is seed borne, survives in old crop residues and is spread by wind and water splash. Control options include crop rotation, destroying old crop residues and hot water treatment of seeds.

Grey mould

The disease is caused by a species of *Botrytis* fungus and is rarely seen in the field in brassicas. It can cause head rots in cool, showery weather, and very occasionally, may cause rots in heads during storage, transit and at the marketplace. *Botrytis* has a wide host range, is spread through spores carried on the wind and can survive from season to season as sclerotia in the soil or on crop residues.

White blister

White blister is caused by the fungus *Albugo candida*, of which there are eight or more races (strains) worldwide. Different races infect a limited range of different brassica species and an epidemic of the disease damaged cauliflower and broccoli in Victoria in 2002. Symptoms include yellow-brown spots on the upper surface of leaves and small, raised white blisters underneath. Blisters may also be found on roots, stems and heads. The swellings contain masses of white dusty spores. Severely affected leaves and heads may show abnormal growth and reduce marketability of heads.

more info
Information on interstate movement provisions
Chapter 6 page 285

Although *Albugo candida* occurs in Queensland on Chinese cabbage and some brassica weeds, it has never been a problem on cabbage, cauliflower and broccoli crops in this State. The fungus causing the disease in Victoria may be of a different race to that found in Queensland. To prevent the possible spread of the new strains of white blister into Queensland, legislation now controls the movement of brassicas and prohibits the introduction of brassica plants into Queensland.

Bacterial head rots

Bacterial head rots can cause major crop losses in brassicas. The disease affects crops both in the field and after harvest and warm, wet weather provides ideal conditions for head rot problems to develop. Broccoli is particularly prone to the disease both in the field and during storage and transit.

It is unclear which specific species are involved in bacterial soft rots in brassica crops, but they include *Erwinia* spp. and *Pseudomonas* spp. Symptoms of head rot are quite characteristic with a slimy soft rot developing on broccoli heads, cauliflower curds or less commonly, cabbage heads. The rot is usually accompanied by a sour unpleasant smell.

The bacteria occur within decaying plant material in soil and are spread in the field by water splash, on cutting knives and through people. Bacteria invade heads through injury sites, so avoid damaging heads in the field and during harvesting and packing operations. The disease can also be spread through contact between produce during transit and storage. Under warm to hot temperatures, the disease can rapidly become severe in wet weather. High application rates of nitrogen and excessive insect damage may contribute to head rot problems.

Control

Bacterial head rot problems can almost be eliminated by good field and shed hygiene, cooling the produce before transport and proper low temperature storage. Avoid harvesting wet crops and sterilise cutting knives if the disease is present in the field. Remove field heat from heads as quickly as possible after harvest and store at 0°C with 95% relative humidity. Dip harvested heads in a chlorine solution if problems with bacterial rots are likely.

more info
Postharvest dips
Chapter 6
Chemical Handy Guide

Select the right variety for the season. Flat, concave or uneven heads or curds tend to pool water causing injury to tissues, and so providing entry sites and ideal conditions for bacteria to multiply. Avoid excessive nitrogen applications, control insect pests and practice crop rotation.

Diseases caused by viruses

Virus diseases are generally not a problem in cabbage, cauliflower and broccoli grown in Queensland. The turnip mosaic virus is considered a minor disease and cauliflower mosaic virus has not been recorded in Queensland, although it has been found in all other states of Australia.

The turnip mosaic virus causes only a mild leaf mottling in warmer weather. During and after cold weather, symptoms become more severe with cabbage and cauliflower showing characteristic dark, necrotic rings that enclose areas of normal green tissue. The main sources of turnip mosaic virus are other diseased brassica crops and brassica weeds. The virus is spread by aphids, so destroying crop residues and brassica weeds and controlling aphids helps to restrict spread of the disease. Use tolerant varieties and avoid growing cabbages in very cold weather if the disease has been a problem in your district.

Disease management checklist

a key issue
Integrated pest and disease management
This chapter page 183

Use the checklist to review and improve your disease management practices. Refer also to the section on integrated pest and disease management.

Before planting

- Crop rotation program in place—avoid fields with a history of disease.
- Practices in place to limit the spread of soil through people, vehicles, machinery and implements.
- Weed hosts controlled around the farm.
- Field drainage improved if necessary—hill up or plant on raised beds.
- All old crops on the farm slashed or pulverised and incorporated—soil kept moist to assist breakdown of crop residue.
- All crop residues rotted down at time of planting.
- Spray gear checked (new nozzles) and calibrated.
- Cropping schedule developed to avoid high risk weather conditions.
- Right varieties selected for the season.
- Varieties selected have tolerance or resistance to diseases likely to cause problems.
- Soil treated with fungicide/fumigant if previous history indicates that this is necessary.
- The seed has been hot water treated.
- Soil analysis taken and fertilizer program developed.

Establishment

- Seedlings disease-free, hardened off and spindly plants discarded.
- Planted into well prepared soil.
- Planting density allows for good air circulation as crop develops.
- Crop monitored for plant losses.
- Fertiliser and irrigation monitored for steady crop growth.
- Prepared to start a spray program.

Growing the crop

- Crop regularly monitored for insect pests and first signs of disease—have symptoms correctly identified.
- Increase surveillance of foliar diseases and reduce spray interval in wet conditions.
- Maintain steady crop growth.
- Control host weeds in and around the crop.
- No nitrogen applied after buttoning or early head fill to reduce head rot risk.

Around harvest

- Maintain disease control program, paying attention to the chemical withholding period.
- Monitor for bacterial head rots in the field and apply sprays in wet conditions.
- Sterilise cutting knives if bacterial head rot occurs in the field—use 70% alcohol.
- Avoid harvesting in wet conditions.
- Remove field heat from produce as quickly as possible after harvest.
- Monitor heads for postharvest problems.
- Note position of any areas with diseased plants and determine cause.

Crop end

- Slash or pulverize harvested crops and incorporate.
- Deep plough diseased crop residues immediately after harvest.
- Control weeds and volunteer plants through cultivation—establish cover crops.
- Apply glyphosate to stop growth if crop is club root affected.

Hot water seed treatment

Seed should be treated in hot water to control black rot, black leg, bacterial leaf scald and Alternaria seedling blight. If buying transplants, ask the supplier if seed has been hot water treated. Commercial seed is often pre-treated, so if you are raising your own seedlings, check that the seed has not already been treated.

Hot water treating seed is a precise process and temperature and immersion time are critical. To avoid 'cooking' the seed and reducing germination rates use the following temperature and immersion times:

Cabbage	50°C for 30 minutes
Cauliflower	50°C for 25 minutes
Broccoli	50°C for 20 minutes

Do-your-own hot water treatment

Commercial laboratories will treat seed for you and we encourage you to use these services in preference to treating your own seed. If you decide to hot-water treat seed yourself, the equipment needed to treat small quantities of seed (up to 25 g) includes an accurate thermometer (0° to 60°C, calibrated in half degrees), electric frypan, large saucepan, fine mesh kitchen sieve, spoon, clock and absorbent paper tray. For less than 25 g of seed, a thermos flask is adequate to treat seed. Precision hot water treatment equipment is commercially available.

To treat seed at 50°C, practise this method without seed until you are able to maintain a constant water temperature during seed treatment.

1. Warm the electric frypan and add 3 to 4 cm of water slightly above 50°C from a hot water system or electric jug. Fill the saucepan two-thirds full of water at the same temperature. Stand the saucepan in the frypan on two pieces of wire about 2 mm in diameter to reduce the 'bottom heat' effect of the frypan during treatment. Gently stir the water in the saucepan with the spoon until the temperature drops to 50°C. When reading the thermometer, have the tip immersed to half the depth of the water.
2. Heat the water to 50.5°C to allow for the temperature to drop when the seed is added. Pour the seed into the water and stir it with the spoon until it is wet. If some seed floats, stir more vigorously. For hard to wet seed, add two drops of wetting agent (household detergent).
3. Keep the seed in motion by gently stirring. Read the temperature and heat when necessary by turning the thermostat switch until the red light comes on, heating for five to 10 seconds, and then turning the thermostat switch until the red light goes off.
4. Repeat the procedure every one to two minutes or when the temperature drops below 50°C. If the temperature rises quickly and approaches 51°C, lift the saucepan and rest it on the frypan edge, or add cold water until the temperature drops to 50°C. Maintain the water temperature at 50°C in this way until the recommended seed treatment time has elapsed.
5. When the hot water treatment is complete, pour the contents of the saucepan through the sieve and spread the seed on absorbent paper, away from direct sunlight, and leave until it is dry.
6. Treat the seed with thiram before planting to prevent fungal seed rots, if it has not already been pre-treated with this fungicide commercially. Hot water treated seed should be planted into pasteurized, soil less potting mix.

Points to remember

- Accurate control of temperature and time of immersion are critical. Excessive time and temperature may result in poor germination and unthrifty seedlings.
- Store seed in muslin or paper bags, not in sealed tins or jars, and do not store for long periods. The shorter the storage period the better. It is best to hot water treat only the quantity of seed you intend to plant almost immediately.
- Some seed containers may indicate that the seed has been 'thiram treated'. This treatment is effective for controlling fungal seed infections (*Pythium*, *Rhizoctonia*, downy mildew, black leg and *Alternaria*) but is not effective against bacterial diseases such as black rot and bacterial scald. Hot water treatment is still necessary for this seed.
- Check seed vigour by carrying out a germination test before hot water treating. Poor quality seed may have its germination greatly reduced by hot water treatment.

a key issue

Effective spray application
This chapter page 244

Using fungicides effectively

The *Chemical Handy Guide* provides a comprehensive list of pesticides registered for use in brassica crops. Always check the product label for specific registration details and use instructions.

Attention to farm hygiene, a sound crop rotation program and good agronomic practices are essential for a successful disease management program. While chemical options are available for managing most diseases in brassica crops, diseases can still be difficult to control under unfavourable weather conditions. In particular, chemical options registered for the control of bacterial leaf and head diseases will only give limited control under extended wet weather.

Some disease problems may regularly occur in particular seasons or fields on your farm. It may be best to avoid planting particular paddocks at certain times of the year; or avoid planting brassicas altogether during particular months of the year in your district.

Fungicides can be either protectant or systemic in their mode of action. Protectant fungicides protect the plant surface by killing bacteria and fungal spores or by preventing germination of spores. The toxic effect on the disease organism is not selective and resistance problems are unlikely to develop. Effective control relies on thorough coverage of the plant and early application of the chemical, before the disease becomes established in the crop.

Systemic fungicides are absorbed into the plant and exert a selective toxic effect against certain life processes of the fungus. This type of activity has been called 'systemic', 'eradicant' or 'kickback' since it stops the progress of established disease infections. Disease organisms can develop resistance to these types of chemicals as their mode of action is selective and resistant individuals may survive exposure to the chemical. While fungicide resistance is a major consideration for disease control in some crops, for example downy mildew in onion and cucurbit crops, at present it is not a major issue for brassicas. This may change in the future. Take the following points into consideration when using chemical control options:

- Impact of prevailing weather conditions on disease development.
- Crop monitoring information—watch for early signs of disease development.
- Correct identification of a disease problem.
- Mode of action of the chemical—protectant or systemic.
- Timing and application of the chemical—good plant coverage is critical.

Managing weeds

Effective weed management is essential for producing high yielding, quality brassica crops. While brassicas are relatively competitive against weeds, economic and environmental considerations mean that producers should aim for a more integrated multi-faceted approach to weed management. This entails combining preventative practices that reduce the overall numbers of weed seeds in the soil with strategic use of herbicides.

- Introduction
- Management immediately before planting and early in-crop
- In-crop cultural practices
- Late in-crop and postharvest weed management

Introduction

Depending on the establishment method, brassica vegetables, particularly the taller, quicker-maturing crops such as broccoli and cauliflower, can be relatively competitive against weeds. Nevertheless, effective weed management is an essential requirement for reliably achieving high-quality brassica produce.

As with insects and diseases, brassica producers must take a longer-term view of weed management, and not simply rely on reactionary herbicide solutions. Economic and environmental considerations mean we must adopt an integrated, multi-tactic approach to managing weeds in brassicas.

Herbicide options vary between brassica vegetable crops, so refer to herbicide labels, databases such as DPI&F's Infopest, or seek expert advice, before assuming a product is legal to use. Minor use permits for herbicides in brassica vegetables are regularly reviewed and updated, therefore consult databases or advisory services for the latest products.

more info
DPI&F Infopest database
Chapter 5 page 290

Site selection and preparation

Weed management starts well before paddocks are prepared for the current crop. Although a range of pre-emergence herbicides is registered for the major brassica vegetables, it is still difficult to grow brassicas in land with large weed seedbanks. Pre-planting management is a key to success. Ideally, brassica vegetables should be grown in land with at least a two-year history of effective weed control. This can be achieved with selective crop rotation and cover cropping. Where large populations of troublesome weeds such as nut grass *(Cyperus rotundus)* exist, it may be impossible to economically grow brassicas without a preparatory weed management strategy.

Pre-planting management

Weed management in the actual brassica crop starts with planting into a weed-free seedbed. Three possible options for achieving this are:

- **Option 1.** Form beds well before planting, then pre-irrigate to germinate an initial flush of weeds. These weeds are killed by spraying with a knockdown herbicide (using glyphosate, paraquat, or diquat, depending on weed species present).

  Alternatively, weeds can be killed with a very shallow cultivation. Moderate to deep cultivations will cause more weeds to germinate in the crop and should be avoided. If farming organically, flaming, steam or hot water treatment are alternatives to knockdown herbicides.

- **Option 2.** Form beds just before planting, with final cultivation to prepare the seedbed and kill any emerged weeds. This is not the preferred option in paddocks with substantial weed burdens.

- **Option 3.** Form beds before planting, then fumigate, for example, with metham (refer to fumigant labels for specific rates). This option has the additional benefits of controlling some diseases, nematodes and insect pests, depending on the rates used. The use of methyl bromide is being phased out in Australia, and the long-term future for most broad-spectrum fumigants is unclear.

Management immediately before planting and early in-crop

Broadleaf weeds

Broadleaf species are the most significant weeds in brassica production. Of concern are plants from the Brassicaceae family, such as wild radish (*Raphanus raphanistrum*), wild turnip (*Brassica tournefortii*), turnip weed (*Rapistrum rugosum*), shepherd's purse (*Capsella bursa-pastoris*), London rocket (*Sisymbrium irio*), and lesser swinecress (*Coronopus didymus*), all of which are related to the cultivated crops.

Other significant weeds in brassica crops are fat hen (*Chenopodium album*), small-flowered mallow (*Malva parviflora*), nettles (*Urtica* spp.), deadnettle (*Lamium amplexicaule*), pigweed (*Portulaca oleracea*), fumitories (*Fumaria* spp.), amaranthus (*Amaranthus* spp.*)*, blackberry nightshade (*Solanum nigrum*), thornapples (*Datura* spp.), apple of Peru (*Nicandra physalodes*), knotweed (wireweed) (*Polygonum aviculare*), potato weed (*Galinsoga parviflora*), common sowthistle (*Sonchus oleraceus*), and cobbler's peg (*Bidens pilosa*).

Herbicide strategies

Six different active ingredients are registered for pre-emergence weed management in vegetable brassicas. Several brand names are registered for most of these active compounds, so for simplicity the active compound name is used throughout the text.

Refer to the Chemical Handy Guide Chapter 6 page 306 for trade names of herbicides

These herbicides must be sprayed just before or just after planting, before weeds have emerged (see details for individual products). Oxyfluorfen, and to a lesser extent pendimethalin, may kill recently emerged seedlings of some weed species, but this should not be relied upon as a regular strategy. **None of the herbicides will kill established weeds.** There are currently no selective herbicides for controlling emerged broadleaf weeds in brassica vegetable crops.

In the following discussions, no specific details are given on application rates, as product formulations comprise the same actives at different concentrations, leading to different registered product application rates and crop uses. Choosing which herbicide to use will depend on:

1. planting method,
2. weed species likely to be a problem;
3. relative costs of application,
4. following crops in the rotation;
5. types of herbicides used in previous crops.

To avoid the build-up of resistant weed spectrums, it is important not to continuously use herbicides with the same modes of action. Note that not all herbicides are registered for all brassica vegetables, and it is very important to refer to product labels to determine legal uses.

Transplanted brassicas

Oxyfluorfen is a Group G herbicide, which kills emerging and very small seedlings. This herbicide should be applied 4 to 7 days before transplanting, with higher water volumes where young seedlings are present. Note that oxyfluorfen is unlikely to kill young, emerged grass seedlings. For pre-emergence activity, oxyfluorfen needs to be activated by irrigation or rainfall, but does not require immediate incorporation by water. Once the herbicide has been applied, minimise soil disturbance by planting and other operations, to maintain the chemical barrier to weed emergence.

Of the available registered herbicides, oxyfluorfen kills the widest spectrum of important broadleaf weeds, and is certainly cost effective. It can occasionally cause burning of seedling crop leaves, particularly in hot, humid conditions, or where lower leaves are continually in contact with the soil. Any damage is usually transitory, and does not affect crop performance. The concentrated herbicide is a Dangerous Poison, and requires strict adherence to safety precautions in handling, application, and disposal. The herbicide is also very toxic to aquatic organisms, and should not be used where there is a risk of contaminating waterways. Always refer to the instructions on the herbicide label. No significant residues in the harvested product will be present where this herbicide is properly used.

Metolachlor is a Group K herbicide, with multiple sites of action, and hence low risk of stimulating herbicide resistance. It is mainly absorbed by weed shoots as they emerge through the soil surface, and hence must be present at the time of weed germination. Spray metolachlor immediately after planting, into a weed free situation, followed by sufficient irrigation to wet to a depth of 3 to 4 cm, within 24 hours. Minimise soil disturbance after application.

Metolachlor will effectively control many grass and broadleaf weeds, such as potato weed, pigweed, some amaranthus, and deadnettle. It is not very effective against fat hen, small-flowered mallow, or brassica weeds such as turnip weed or wild radish. Where these latter weeds are known to be a problem, an alternative product should be used. Metolachlor can cause stunting and chlorosis of crop seedlings, particularly in sandy or red alluvial soils. Producers will need to tailor the rates of application to suit their particular environment and soil type. Refer to the herbicide labels for more information. Metolachlor can be a cost-effective rotational herbicide with oxyfluorfen in a long-term strategy.

Propachlor is also a Group K herbicide, with a similar mode of action to metolachlor. Application practices are the same as with metolachlor, and this product controls a similar broadleaf and grass weed spectrum. Compared to metolachlor, it is probably less effective against Solanaceae (eg. thornapples, nightshades), and more effective against fat hen and mallows. Propachlor carries less risk of crop damage than metolachlor, however it is significantly more expensive, with high application rates registered for use. Propachlor can also be sprayed in a tank mix with pendimethalin **before** transplanting, or separately after transplanting (**with pendimethalin sprayed before transplanting**). This twin application gives improved control of brassica weeds, fat hen, sowthistle, and knotweed, compared to propachlor alone. Refer to either label for details.

Pendimethalin is a Group D herbicide that inhibits tubulin development in emerging shoots and particularly roots. Pendimethalin controls many broadleaf and grass weeds, and is particularly active against fat hen, and when combined with propachlor, against brassica weeds. This herbicide is not effective against most Asteraceae weeds (e.g. potato weed) or

Solanaceae weeds. Pendimethalin must be applied **before** transplanting, and incorporated by 12 to 25 mm of irrigation within 24 hours.

As with the other pre-emergence herbicides, minimise soil disturbance after application. Brassica vegetables are only marginally tolerant of pendimethalin, and can be significantly damaged in adverse conditions such as waterlogging, very cold weather, or overspray. New users should be cautious, confirming the best rates for their particular circumstances, before spraying large areas. Pendimethalin residues may break down sufficiently slowly in some soils that enough herbicide remains to affect following crops. Producers need to consider rotational implications when deciding on whether to use this product.

Direct-sown brassicas

Producers may elect to grow brassica vegetables by direct sowing rather than using transplants. Weed management in direct-sown crops is more difficult than in transplanted crops, for several reasons. Firstly, the period between planting and crop canopy closure is up to five weeks longer than with transplants, and thus weeds have a much greater opportunity to emerge and compete with the crop. Secondly, the herbicide options for use in direct sowing, and the spectrum of weeds they control is restricted when compared with transplanted crops. Thirdly, weeds that emerge at the same time as a direct sown crop are more difficult to remove by cultivation, as there is no differential in root system anchorage between the crop and weeds.

It is thus much more imperative that **pre-cropping** weed management is successfully undertaken in direct-sown brassica vegetables, compared to those established by transplanting.

Chlorthal-dimethyl is a Group D herbicide that also inhibits tubulin formation, and controls a range of broadleaf and grass weeds. Weed shoots mainly absorb chlorthal-dimethyl as they emerge through the soil surface, and hence the chemical must be present as weeds germinate. Spray chlorthal-dimethyl immediately after planting, into a weed free situation, followed by sufficient irrigation to wet to a depth of 3 to 4 cm, within 24 hours. Minimise soil disturbance after application. This herbicide is applied at high rates (up to 15 kg/ha), and is relatively expensive. An option is spraying in narrow strips over the row, and using other practices, such as inter-row cultivation, to manage weeds in the unsprayed areas. Experience has shown that chlorthal-dimethyl suppresses, rather than controls, many weeds that commonly occur in brassica vegetables.

Trifluralin is closely related to pendimethalin, and is also a Group D herbicide that inhibits tubulin development in emerging shoots and particularly roots. Trifluralin is mainly active against grasses, although it does manage broadleaf weeds such as pigweed, some amaranthus and knotweed. Trifluralin is registered for application before planting, and must be immediately (within 2-6 hours) incorporated by 25 to 50 mm of irrigation or cultivation. As with the other pre-emergence herbicides, minimise soil disturbance after application. Trifluralin residues can break down sufficiently slowly in some soils that enough herbicide remains to affect following crops. Producers need to consider rotational implications when deciding on whether to use this product.

Both chlorthal-dimethyl and trifluralin can also be used in transplanted vegetables. However, the other pre-emergence herbicides mentioned in the transplanting section are probably more effective in most transplanting situations.

In-crop cultural practices

Broadleaf weeds appearing in brassica vegetable crops can only be killed by cultivation or hand weeding. If pre-emergence herbicides have been applied, cultural operations should still minimise disturbance of the chemical barrier and stimulation of further weed emergence.

There is an optimum time window when cultural operations are most effective. If done too early, the full benefits of the pre-emergence herbicides are lost as there is still time for further weed germinations before the brassica crop canopy closes. If done too late, weeds may be too large to kill with shallow cultivation, and there may be insufficient space to cultivate between rows without damaging the crop. The optimum timing for these operations varies with environmental conditions, weed species present, brassica cultivar, and soil type. For example, if a late summer planting of broccoli in the Granite Belt needed cultivation, this would best be done about four weeks after transplanting.

Tall, leafy brassicas such as broccoli and cauliflower are relatively competitive against weeds (particularly low growing weeds such as deadnettle), and can shade out late-emerging plants. Thus the focus is on early weed control, and killing tall-growing species such as fat hen, sowthistle, and to a lesser extent small-flowered mallow, that can break through the crop canopy. Cabbages can be more problematic, as they are the slowest maturing major brassica vegetable, and not as effective at shading the soil as broccoli or cauliflower. Cabbage may require a second hand weeding toward the end of the cropping period, to kill late-emerging weeds and prevent seed-set.

Grass weeds

Grass weeds are seldom a problem in brassica production. Most grasses will be controlled by the same pre and post-planting cultural practices used to manage broadleaf weeds. All the pre-emergence herbicides previously mentioned control many grass species prior to emergence.

The herbicides fluazifop-P-butyl, sethoxydim, quizalofop–P-ethyl, quizalofop–P–tefuryl and clethodim are registered for post-emergence grass control in some brassica vegetables. If a post-emergence herbicide spray to manage grass weeds is necessary, the choice of chemical depends mainly on (i) grass species to be killed, (ii) registration status for the particular brassica vegetable crop (iii) relative costs of application and (iv) applicable withholding period (see Table 46). Each product controls a slightly different weed spectrum (check labels for individual species).

Producers should note that some grasses are not controlled by these post-emergence herbicides, and that other species are becoming resistant. All five products are Group A herbicides, to which several grasses, for example ryegrass, have or are developing resistance.

Refer to the *Chemical Handy Guide* in Chapter 6 page 306 for trade names of grass herbicides.

Table 46. Registration status and withholding period for post-emergence grass herbicides in brassica vegetables.

Herbicide	Broccoli	Cauliflower	Cabbage
Fluazifop-P-butyl	42 days	42 days	42 days
Sethoxydim	42 days	42 days	42 days
Quizalofop-P-ethyl	Not registered	14 days	63 days
Quizalofop-P-tefuryl	Not registered	14 days	63 days
Clethodim	Not registered	Not registered	7 days

Late in-crop and postharvest weed management

Whilst late-emerging weeds will not affect brassica yields, they should still be managed. Species such as potato weed, fat hen, and small-flowered mallow can grow dramatically in the last few weeks before harvest, and interfere with cutting and packing processes. In an integrated weed management program, it is important to minimise populations of weeds setting seed. It may be economically sensible to devote labour resources to selective hand-weeding in the weeks leading up to harvesting, particularly if weed seed-set can be prevented. It is important to destroy weeds in the paddock once brassicas have been harvested, rather than let them set seeds.

Effective spray application

To ensure good pest control the pesticide must be applied correctly. To achieve this, spray equipment must be set up correctly and calibrated regularly. It will then apply the correct amount of chemical, where it is needed, in the correct droplet size for good plant coverage. Most sprays fail because the pesticide was applied incorrectly.

- Introduction
- Selecting the type of sprayer
- Selecting hydraulic nozzles
- Checking spray coverage in the field
- Other influences on pesticide effectiveness
- Spray drift
- Sprayer calibration
- Cleaning spray equipment

Introduction

In cabbage, cauliflower and broccoli crops the target for insect and disease control is usually the entire plant. For weed control, the target is either bare soil or weed foliage.

Where the plant is the target, good plant coverage is essential. Spray droplets should be distributed uniformly over the entire plant, both on the tops and the underside of leaves. This can only be achieved with well maintained, correctly set up and regularly calibrated application equipment.

Essentials of good spray application

Efficient spray application means uniform droplet distribution on target surfaces with minimum losses due to drift, evaporation or run-off. The essentials are:

- hitting the target;
- good timing;
- suitable droplet size;
- suitable water volume;
- sufficient coverage;
- appropriate environmental conditions;
- using label rates;

- clean water;
- accurate pest and disease identification;
- appropriate spray equipment;
- correctly calibrated equipment.

The target

Spray deposit uniformity and distribution will influence the ability of pesticides to effectively control insect pests and diseases. Two factors which influence spray uniformity and distribution are the crop canopy and the application equipment used.

Crop canopy

The crop canopy has a large influence on spray penetration and distribution on the plant. Distribution is difficult to manipulate when spraying over the top of plants with a boom because the deposit is highest in the top part of the canopy, on the upper side of leaves and reduces rapidly as you move down the plant.

Unfortunately, insect pests tend to be more active on the underside of leaves and lower down in the crop canopy. The more humid conditions under leaves, lower down in the canopy, and in more mature crops also favour disease infection and development in those parts of the canopy.

Selecting the type of sprayer

The *Pesticide Application Manual* published by DPI&F provides in depth information on all aspects of spray application. For details on where to get this book, see Chapter 5 page 290

To be effective it is essential that the equipment used is able to efficiently apply chemical to the target. The ability to do this depends on many factors including the equipment type, droplet production, droplet size, amount of water applied, water quality and spray drift.

Spray application can become highly technical. There are also big differences in spray equipment costs. If you are new to small crops production, obtain professional advice to help with equipment selection.

For brassica production, conventional boom sprayers or air-assisted boom sprayers should give you a good result providing they are set up correctly. Sprayers should initially be set up and calibrated by someone that is experienced in setting up spray equipment for brassicas. It is a good idea to use two sprayers – one for applying herbicides, the other for applying insecticides, fungicides and foliar nutrients.

Hydraulic boom sprayers

The following types of ground rigs are used to apply pesticides to brassicas using hydraulic nozzles.

Conventional boom

Conventional hydraulic nozzles are spaced 500 mm apart on a boom sprayer. The best results are achieved when spraying in a light breeze at about 7 kilometres per hour (kph). The wind is beneficial because it creates turbulence to assist carrying the droplets into the crop canopy. At lower wind speeds the droplets will fall under gravity and there will be little or no redistribution of droplets deeper into the crop canopy or on leaf undersides. At higher wind speeds there is likely to be some drift.

Conventional boom with air assist

Usually this sprayer is a conventional hydraulic nozzle boom sprayer with the addition of a high volume output fan mounted centrally above the boom with an air duct extending the full length of the boom. The slotted outlet of the air duct produces a curtain of air adjacent to the spray nozzles. This air curtain directs the spray down into the crop canopy causing agitation of the plants and improves spray coverage on both sides of the leaves.

Some recent versions of air assisted booms allow the option of angling the direction of the air stream either forward or backward to improve coverage.

Conventional boom with droppers

The performance of a conventional hydraulic nozzle boom sprayer can be improved by the addition of droppers. These are short lengths of semi-rigid plastic tubes attached to the boom with nozzles at the lower end. They are positioned between plants to direct spray from a lower angle, increasing spray penetration and coverage. Droppers are used in crops such as tomato and sweet corn. They are less commonly used in brassicas.

CDA sprayers

Controlled Droplet Application (CDA) is a method of spray application where 80% of all droplets produced are within a very narrow size range, usually about 100 to 150 microns (µm).

Most CDA sprayers incorporate air assist as part of their design. The air stream directs spray down into the plant canopy causing turbulence that assists in achieving better overall coverage. These sprayers are another example of air assisted sprayer.

Some CDA sprayers have shrouds to help reduce drift and improve target coverage. They operate without any air assist and droplet size is in the 100 to 150 µm range. As long as the skirt around the shroud forms a seal with the ground, droplets within the shroud are not subject to external wind forces and fall onto the target by gravity. Typical application rates are around 45 L/ha for a single head with a swath width from 0.6 to 1.2 m.

Aircraft

Aircraft are sometimes used to apply pesticides in brassicas under wet conditions when access to paddocks with ground rigs is restricted. The types of nozzles used by aircraft are either hydraulic or controlled droplet application (CDA) nozzles.

Selecting hydraulic nozzles

Correct nozzle selection is very important in achieving the desired droplet range. The size and number of droplets produced has a critical influence on the coverage achieved. Table 47 shows a range of nozzle types, their spray angle, droplet size and pressure required.

Table 47. Nozzle types and some performance features

Nozzle type	Spray angle	Droplet size	Pressure
Conventional flat fan	80° – 110°	fine to medium	1 – 4 bars
Pre-orifice flat fan	80° – 110°	medium to coarse	2 – 4 bars
Flood jet	150°	medium to coarse	1 – 6 bars
Air inclusion	110°	coarse	5 – 6 bars
Hollow cone	80°	fine	5 – 10 bars

Note: This is only a guide and not a complete list. Nozzles give a range of droplet sizes that varies with spray pressure. A complete list and accurate technical data can be obtained from manufacture's nozzle charts.

How droplets are produced

Sprayers used in agriculture produce droplets by one of three methods:

- A hydraulic nozzle produces droplets when liquid is forced through a small orifice under pressure. These nozzles can be used on conventional booms and aircraft.
- A controlled droplet applicator for example rotating cage, inverted cone or a flat serrated disc produces droplets by means of centrifugal force when liquid is introduced at the centre of the rotating element. These nozzles can be used on both ground rigs and aircraft.
- Droplets can be produced by air shear when liquid is metered into a very high velocity air stream. These nozzles are only used on aircraft.

Droplet size

Droplets are usually measured in microns (µm); one micron equals 0.001 mm. All hydraulic nozzles produce a range of droplet sizes. This is called the 'droplet spectrum'. Droplets produced by a single nozzle can vary from 50 to 600 µm at any fixed pressure.

The most common way to classify spray droplets is by the Volume Median Diameter (VMD) which is defined as that droplet diameter which divides any given sample of spray droplets into two equal parts by volume.

Nozzles are classified by the British Crop Protection Council (BCPC) according to the type of droplet spectrum they produce (Table 48). These classifications are included in most nozzle catalogues and are a useful guide for assessing the drift potential and suitability of a nozzle for a given spray job.

Under this classification the International Standard Orifice (ISO) is used by all companies so that nozzle colour matches flow rate and droplet size for all nozzles at a given pressure.

Table 48. Droplet size categories

BCPC category	Approximate VMD range	
VF	very fine	less than 150 microns
F	fine	150 – 250 microns
M	medium	250 – 350 microns
C	coarse	350 – 450 microns
VC	very coarse	450 – 550 microns
EC	extremely coarse	more than 550 microns

The most common droplet sizes used in agriculture are very fine (<150 µm), fine (150–250 µm), medium (250–350 µm) and coarse (350–450 µm).

Droplet spectrums with fine and medium droplets are most commonly recommended when targeting plants. This is a trade off between biological efficacy and reducing spray drift. When targeting the soil with pre-emergent herbicides larger, coarser droplets are more suitable because they are less likely to drift.

Not only do droplets need to be uniformly distributed over the target area, but their density on the target must also be sufficient to achieve good results. For insecticides, systemic fungicides and herbicides, the suggested droplet density is 20 to 30 droplets/cm^2. A higher density of 50 to 70 droplets/cm^2 is recommended for protectant fungicides.

What's wrong with large droplets?

- Fewer droplets are produced. One 400 µm diameter droplet has the same volume as 64 droplets with a 100 µm diameter.
- Fewer droplets mean there is less likelihood of the pesticide reaching the target organism.
- Large droplets are more difficult to retain on the leaf surface. They tend to bounce or roll off, cascading down the foliage and onto the ground.
- Large droplets are heavier and reach the target due to gravity. They are not usually deflected by air movement, so their redistribution within the crop foliage is limited.

Quantity of water applied (water rate)

The amount of water applied and the droplet size helps determine droplet density. Low water rates cause insufficient droplet density and poor coverage. High water rates result in plants dripping with excess pesticide and environmental pollution.

Good spray application aims to use a water rate that gives a uniform droplet distribution at the desired density. As plants grow, more foliage needs to be covered so a larger volume of water needs to be applied per hectare to ensure good canopy coverage. For ground rigs, the spray volumes commonly used in brassicas are about 200 L/ha for young plants increasing to 600 L/ha to 800 L/ha as the crop reaches maturity.

Checking spray coverage in the field

There are two main ways of checking spray coverage in the field—fluorescent dye with ultra violet lights or water sensitive cards.

Contact your local farm chemical supplier for advice on where to get these tools.

Fluorescent dye

A fluorescent dye mixed in water is sprayed at the normal pesticide application rate, then using a special ultra violet light, dye deposits on the crop are looked at in the field after dark. The light illuminates the spray droplets and shows how the spray has been distributed on the plant. The dye also shows if you are getting adequate coverage on the upper and lower leaf surfaces.

Water sensitive cards

These cards are coated with a material that changes colour from yellow to bluish purple when moisture is present. They are attached to the top and underneath of leaves with staples. After the area has been sprayed inspect the cards for coverage. Droplet density can be estimated by comparing the result against standard cards with a known density. Another method is to place a card with a 1 cm^2 cut-out window on the water sensitive card, then use a hand lens to count the droplet stains.

Other influences on pesticide effectiveness

There are other factors that influence the effectiveness of pesticides. They include water quality and pesticide compatibility.

Water quality

The quality of water available on farms is highly variable and water from some sources can cause important application and effectiveness problems. Ideally, water should be clear, colourless, odourless and neutral (pH 7.0), that is, not acid, alkaline or brackish. Use the spray as soon as possible after mixing. If left standing for lengthy periods, undesirable interactions can occur between the water and some pesticides. To avoid unnecessary delays make all equipment checks and calibrations before mixing the pesticide. Where possible, select water for the following characteristics.

Low total solids. Some disadvantages of using dirty water, such as blocked nozzles, are obvious. However, solids may also bind to pesticide chemical molecules and remove them from the spray mixture as sediment. Suspended clay minerals are a common problem in spray water and reduce the efficacy of some chemicals.

Neutral pH. Acid or alkaline water may hydrolyse pesticides (cause them to decompose). Additives are available to neutralise water if you cannot avoid using high alkaline or acid water.

High salt levels. Excessive salt content in water can cause phytotoxicity (damage to plant tissue, for example burning). This is most common with bore water. It can also affect the pesticides being used.

Water 'hardness'. Hard water containing calcium or magnesium salts may cause problems with mixing because it reduces the stability of suspensions and emulsions. Difficulty producing a lather with soap indicates hard water. Many pesticide formulations make allowance for water hardness by having buffer agents in their formulation.

How to check water suitability

Use the following procedure to get a quick guide to the suitability of water for spray application:

1. Make up, in a stoppered clear glass container, 500 mL (or other appropriate known volume), of spray diluted according to the manufacturer's instructions. Make sure you observe the manufacturer's safety instructions for handling the product when doing this test.
2. Invert the container 100 times (shake vigorously).
3. Allow it to stand for 30 minutes. If, after this time, 'creaming', sedimentation or separation into layers occurs, the water may not be suitable for spraying the pesticide or combination of pesticides you tested.

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Sedimentation in this quick test could be caused by pesticide breakdown, but this is unlikely unless the chemical is old. Different brands of the same pesticide may react differently because of different additives in each formulation.

If you suspect the water is unsuitable, have a sample chemically analysed for salt and hardness levels, then get an informed opinion on its suitability for spraying.

Pesticide compatibility

Mixing incompatible pesticides can cause changes in the physical character or chemical structure of one or both pesticides, or produce phytotoxic compounds. Such changes can result in application problems, phytotoxity to plants or reduced efficacy.

Avoid mixtures of pesticides if at all possible.

- If considering mixtures of pesticides follow the manufacturer's instructions and label advice carefully. Only use mixtures if they are recommended by the manufacturer or if previous experience has proved them satisfactory in a range of situations.
- Where information is unavailable and the use of mixtures is unavoidable, the test procedures outlined above in water quality will provide a **rough guide** for assessment. If the untried mixture is going to precipitate, it is far better to discover the problem when testing, before the chemicals are already in the spray tank.

  Note: The absence of any obvious physical change is not a foolproof indication of absolute compatibility.
- To check if phytotoxity to plants is likely, spray a test strip of crop and observe the mixture's effect over time. Again, it is far better to discover that the mixture will burn plants in a small test strip, before you have sprayed the whole crop.

When mixing different formulation types, add them to the tank in the following order:

1. wettable powders and dry flowable dusts, then;
2. suspension concentrations and water soluble formulations, then;
3. surfactants, and lastly;
4. spraying oils and/or emulsifiable concentrates.

Spray drift

Spray drift is the movement of spray particles away from the target area. There are two types of drift, airborne and vapour drift. Vapour drift depends on the environmental conditions, such as temperature and humidity, prevailing at the time of application and for a few days afterwards.

Airborne drift is affected mainly by droplet size and wind speed. The big trade off is in droplet size, because the smaller the droplet the better the coverage but the more susceptible it is to airborne drift. Very fine droplets are desirable to achieve the maximum spray coverage efficiency, however they are also the most susceptible to spray drift and evaporation.

The principles of good spray application require not only good target coverage, but also the reduction of spray drift and the negative impacts it might have on the environment, public health and property.

How to reduce spray drift

- Reducing the application pressure increases the VMD, so fewer small droplets are formed. If the pressure is reduced too much, the normal spray angle of the nozzle will be reduced and striping may occur across the spray swath.
- Reducing boom height above the crop will reduce drift but take care not to go lower than the manufacturer's recommendations or striping may occur across the spray swath.
- Most manufacturers have 'low drift' nozzles for use with hydraulic spray booms. A pre-orifice disc in the nozzle tip assembly reduces pressure at the exit orifice and creates larger droplets to reduce drift. These nozzles produce the same flow rate as the standard nozzle but are designed to reduce the percentage of droplets below 100 mm.
- Air inclusion nozzles or air induction nozzles that reduce drift are also available from most manufacturers. They draw air in through aspiration holes in the nozzles and mix it with the spray liquid. The liquid mixture leaving the spray tip contains large air-filled droplets with a VMD of 400 to 600 mm. This eliminates almost all the very fine and fine droplets.

Manufacturers claim that these nozzles are able to provide good spray coverage with large droplet sizes because the air-filled droplets shatter on impact to provide coverage that is comparable to conventional nozzles.

- Air assisted booms have been shown to reduce drift, when compared with a conventional boom, because the forced air stream carries more of the spray down into the crop canopy.
- Shrouded sprayers have been shown to reduce drift by 50%.
- The use of some spray additives can reduce the number of very fine droplets formed, so reducing drift.

Sprayer calibration

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 who is experienced in setting up spray equipment for brassica crops. They will help you select the type of equipment you need (pump, diameter of hoses, type of nozzles) and the general setting up of the equipment so it adequately protects your crop. 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 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.

Conventional boom spray

To calibrate a boom spray, 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 one hectare, 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 15 nozzles, with an average output of 2.5 L per minute, then:

Output per minute = 15 X 2.5 = 37.5 L/minute

Step 2

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

Swath width (m) = number of nozzles X nozzle spacing (m)

For 15 nozzles at 0.5m apart (nozzle spacing):

Swath width (m) = 15 X 0.5 = 7.5 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 at the engine revolutions at which you will be 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 = 7.5 m (from Step 2); and time per 100 m (Step 3) = 60 seconds then:

$$\text{Time to spray 1 ha} = \frac{\text{10 000 X 60}}{\text{7.5 X 100}} = \text{800 seconds}$$

Divide this by 60 = 13.33 minutes per hectare

To work this out using a calculator: 10 000 x 60 = 600 000; divide by 7.5 = 80 000; divide by 100 = 800 seconds; divide by 60 = 13.33 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 = 37.5 X 13.33

Volume /ha = 500 L/ha

Amount of chemical needed per tankful

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

Rate quoted as product per hectare:

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

Example:

$$\frac{\text{3000 (L) X 2.2 (L or kg/ha)}}{\text{500 (L/ha)}} = \text{22 (L or kg)}$$

OR

Rate quoted as product per 100 L:

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

Example:

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

Things to remember

To increase the water rate per hectare, you can reduce tractor ground speed, increase pressure or select larger nozzles. To reduce water rate you can increase tractor ground speed, reduce pressure or select smaller nozzles.

- **Do not** alter the operating pressure outside the range recommended in the manufactures' nozzle charts.
- When checking the flow rate of CDA sprayers it is sometimes easier to disconnect the supply line from the head assembly and collect the spray liquid before the droplets are produced.
- Most manufacturers of hydraulic nozzle boom sprayers offer the option of an electronic controller that monitors ground speed and nozzle flow, and can automatically adjust the pressure so that the predetermined application rate is held constant. The performance of

these instruments is usually very reliable but it is advisable to check them occasionally by performing the calibration procedure outlined above.

Cleaning spray equipment

a key issue
Safe storage, use and disposal of pesticides
This chapter page 256

At the end of each day, sprayers should be flushed out with water to prevent a build up of chemicals. When chemicals are changed or spraying is completed at the end of the season, a more thorough cleaning is required and decontamination may be necessary. Refer to the label for specific cleaning instructions. For most chemicals the following general procedure may be used:

1. Hose down the inside of the tank and fill to approximately 1/3 full with water.
2. Operate for 10 minutes with water flushing through nozzles.
3. Drain remaining water.
4. Repeat steps 1, 2 and 3.
5. Remove nozzle tips and screens and clean in detergent solution.
6. Fill tank to approximately 1/3 full with water and add a cleaning agent if required, leave overnight, then drain.

Make sure you clean spray equipment in an area where runoff will not cause problems.

Safe storage, use and disposal of pesticides

Pesticides are generally an unavoidable part of farming. Many pesticides pose some threat to people and the environment if they are misused or handled carelessly. This section provides some general guidelines for the safe storage, use and disposal of pesticides. For more detailed information refer to the appropriate local authorities in your region.

Safe storage of pesticides

Chemicals stored on farms must be held in a building or enclosure specifically designed and used for storing chemicals. The main things to consider when planning a chemical storage shed are where to build it and the design of the building.

Choosing a site

The storage shed should be positioned so that it:

- minimises any risk of chemicals affecting people, products or the environment;
- is easily accessible;
- is secure;
- has an adequate water supply.

Storage shed design

The shed must be designed and built in such a way that it meets the following minimum standards. It must:

- be lockable;
- be made of fire resistant material;
- have a sloping concrete floor;
- have a bund wall deep enough to hold at least 25% of the total liquid in the store;
- have a collection pit connected to the store;
- be well ventilated and well lit;
- have non-absorbent shelving;
- be large enough to allow adequate separation of herbicides from other pesticides;
- have a dry-powder fire extinguisher outside but nearby;
- have appropriate warning signs.

Safe use of pesticides

READ THE LABEL before opening and using any pesticide, follow the manufacturer's instructions and make sure you know what to do if anything goes wrong.

The Material Safety Data Sheet (MSDS) details the properties of the chemical, the effects on health, precautions to take and what to do in an emergency. You should obtain an MSDS when you purchase the product and keep it close to the chemical in case of an emergency.

Handling pesticides

Always handle pesticides with great care because most have the potential to damage the health of you, your family and/or the environment. This is particularly true when handling the concentrated formulation, but the diluted product should still be handled carefully.

If a pesticide is swallowed, immediately contact the **Poisons Information Centre** on **13 11 26**

Always handle pesticides in a well ventilated area and triple-rinse emptied containers. **Do not take risks**, use common sense when handling pesticides.

Protective clothing

Always wear protective clothing when handling and using pesticides. The type of protection required will depend on the pesticide being used - follow the manufacturer's instructions. The following is a guide to the Do's and Don'ts of pesticide handling.

Do's:

- do cover as much of your body as possible;
- do use washable fabric overalls, disposable overalls, or waterproof clothing;
- do wear goggles and a close fitting respirator with the correct filter for the chemical you are using;
- do wear a hat;
- do wear unlined rubber gloves;
- do wear trouser legs outside your boots;
- do soak protective clothing in bleach overnight and wash after each use.

Don'ts:

- don't wear leather or cloth material that will absorb pesticide;
- don't wash protective clothing with family laundry.

Applying pesticides

Remember the following points when applying pesticides:

- read the label;
- make sure that the pesticide you are using is registered in your state, on your crop for the pest you are trying to control;

DPI&F note, *Using agricultural pesticides 3. Safe storage and handling* can be found on the DPI&F website, www.dpi.qld.gov.au

- check the withholding period;
- before spraying, use clean water to check for leaks or blockages and calibrate your application equipment if this has not been done recently;
- do not spray in windy conditions if the wind is likely to blow the spray onto non-target areas.

After spraying

After spraying do the following:

- thoroughly clean the spray equipment in an area where runoff will not cause problems;
- remove protective clothing then have a shower as soon as possible;
- make sure you wash before eating, drinking or smoking.

Safe disposal of pesticides and their containers

A major problem facing users of pesticides is the disposal of empty containers and unwanted chemicals. ChemClear is an industry-funded program for on-going collection and disposal of unwanted registered chemicals.

For more information about **ChemClear** call 1800 008 182 or visit the ChemClear website on the internet at www.chemclear.com.au

A method for safe disposal of used pesticide containers is provided by drumMUSTER. It is the national program for the collection and recycling of empty, cleaned, non-returnable chemical containers used in crop production and on-farm animal health. It was developed by several organisations including the National Farmers' Federation (NFF), the National Association for Crop Protection and Animal Health (Avcare), the Veterinary Manufacturers and Distributors Association (VMDA), and the Australian Local Government Association (ALGA).

How does drumMUSTER work

Since February 1999, farm chemical users have paid a 4 cents per litre or kilogram levy on crop production and on-farm animal health products sold in non-returnable chemical containers over one litre or kilogram. This levy funds the drumMUSTER program and is available to reimburse participating councils for all agreed costs incurred in running a drumMUSTER collection.

For more information about drumMUSTER collections, contact your local council or visit the drumMUSTER website, www.drummuster.com.au and go to the collection calendar.

The drumMUSTER program has two objectives:

- To reduce the amount of packaging at the source by encouraging manufacturers to adopt alternatives such as bulk or re-fillable containers, new packaging technology and formulations including water soluble sachets, gel packs and granules.

- To ensure that non-returnable crop production and animal health product containers have a defined route for disposal that is socially, economically and environmentally acceptable.

The drumMUSTER program was set up to provide councils across Australia with financial and planning support so that implementation is cost-neutral. Further, it provides a service to ratepayers so that:

- fewer bulky containers end up as landfill in rubbish dumps;
- farmers are able to dispose of chemical containers;
- the community has a cleaner environment.

A few chemicals may not be eligible for disposal through drumMUSTER. Eligibility is indicated by a drumMUSTER eligible container logo or the drumMUSTER eligible container re-use logo.

Preparing containers for collection

The drumMUSTER program is only for **clean, empty** containers. The container must be cleaned to meet the Agsafe Cleanliness Standards. Containers will not be accepted by drumMUSTER if any residue is visible on the inside or outside of the container, including threads and caps. The container should still have the labels on so inspectors can identify the material being handled.

Once you have emptied a chemical container, immediately clean the container and store it in a safe location until you can deliver it to a drumMUSTER collection.

- Containers must be flushed, pressure-rinsed or triple rinsed and allowed to dry before being taken to the collection centre.
- Do not puncture plastic 20 L containers included in reconditioning/re-use programs, or displaying the RE-USE logo.
- Puncture steel containers by passing a steel rod or crowbar through the neck/pouring opening and out through the base of the container.
- Do not place caps on the container, however they may be brought separately to a collection.

The brochure '*The Agsafe Standard For Effective Rinsing Of Farm Chemical Containers*' will provide more details and is available from local resellers.

Organic production

An alternative production system that some growers may consider is organic production. There is an increasing demand for organic product both on the domestic market and overseas and prices can look attractive. However both production costs and losses through weeds, diseases and insects can be higher in organically grown crops.

- Growing crops organically
- Some points to consider

Growing crops organically

If you are considering organic production, it is probably either because you see organics as a better way of farming or as a means to increase profitability by targeting a specific market niche with your product. Or your reasons may be a combination of the two.

Whatever your reasons, do extensive market research to determine the size of the organic market and the prices you can realistically expect to receive for your produce, particularly if it is not of the highest quality. The reduced quality and the lower yields that can occur in organic production systems may not be offset by the higher prices that may be received.

Producing crops organically is usually understood to mean producing without using synthetic inputs. 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 external inputs needs 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 to the crop.

Brassicas do have some advantages when it comes to organic production in comparison to some other vegetable crops. In Queensland, diamond back moth (DBM) and other important caterpillar pests of brassicas can be successfully controlled biologically during the cooler months of the year. In addition, bacterial diseases are the most likely to cause significant losses in brassica crops. These diseases are difficult to control with chemical sprays alone so non-chemical control methods are essential for effective disease control in any case.

Nevertheless, successful organic production of cabbage, cauliflower and broccoli can be difficult. Diseases and weeds can create problems, reducing crop yields and quality. Sufficient land must be available for effective crop rotation programs that reduce weed seed banks and minimise soil-borne disease risks. In the absence of chemical control options, effective farm hygiene practices, including quarantine restrictions for entering planted areas, become even more critical.

Caterpillar pests can cause extensive damage and natural enemies and biological insecticide sprays may not adequately control these pests at certain times of the year. For insect pests such as thrips and silverleaf whitefly, biological control will often not prevent significant yield and quality losses. Isolation from major production areas, controlling weed seed hosts and growing crops within the right production time slot for the district will help these reduce risks.

Access to good technical advice for managing insects, diseases and weeds in organic cropping systems can also be hard to come by. Nutrient management is also more complex as availability of nutrients to the crop from organic fertilisers is largely dependent on temperature and soil moisture.

more info
Organic organisations and publications
Chapter 5 page 277

To maximise market advantage, organic producers should seek organic accreditation with one of Australia's organic organisations so that they are able to sell their produce under a recognised organic label. All farm inputs need to be certified by these organisations.

Some points to consider

Production timing is critical but does not ensure success. Cabbage, cauliflower and broccoli grow best in temperate conditions. Cool weather, particularly cool nights, will produce high quality heads. Pests are also less active at lower temperatures and so, are less likely to cause problems at that time of the year. Avoid warm weather production, particularly when frequent rainfalls are likely, as this can make the crop prone to diseases such as bacterial head rots, black rot and bacterial leaf scald, damping-off, *Rhizoctonia* and *Sclerotinia*.

Crop rotation with other unrelated crops is important in managing disease and weed problems. Most organic growers have found that weeds are one of the more difficult problems to manage. Income derived from organic production needs to be spread over a number of different crops. This will reduce the adverse economic effects of a crop loss from insect pests, weeds or diseases that can be beyond the control of the organic farmer.

There are few effective organic control measures for diseases of brassicas. There are varieties that are tolerant of or have resistance to diseases such as black rot, downy mildew, yellows (*Fusarium*), zonate leaf spot and turnip mosaic virus. Hot water treatment of seed can help reduce the risk of some diseases. Crop rotation, thorough soil preparation and sound farm and crop hygiene practices can help to reduce risks of disease outbreaks.

Many organic farming practices are also used in conventional production. Refer to the sections on *Nutrition* page 152, *Integrated pest and disease management page* 183 and *Integrated weed management* page 237 in this chapter.

Integrated pest management relies on many of the practices associated with organic farming. These practices and management options are described in more detail elsewhere in this chapter. Monitor crops regularly for diseases, insect pests and natural enemies. This is particularly important for managing DBM, other caterpillar pests, thrips, silverleaf whitefly and aphids.

Organic fertilisers (minerals, manures and compost) are in effect slow release fertilisers, with nutrients being released over some months. The speed at which these nutrients become available is largely influenced by temperature and moisture availability. Brassicas are fairly quick-growing crops and short falls 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.

Other brassica vegetable crops

The Brassicaceae family of plants encompasses many different vegetable crops other than cabbage, cauliflower and broccoli. They include Brussels sprouts, Chinese cabbage, various root crops and many Asian leafy vegetables. In some respects, management for these crops is similar to growing cabbage, cauliflower and broccoli but there are also some important differences.

The following notes highlight those areas where practices are markedly different from those described for cabbage, cauliflower and broccoli in this handbook. An extensive list of references for these other brassica vegetable crops is included in Chapter 5.

- Botany and climatic requirements
- Business and marketing considerations
- Establishing the crop
- Irrigation and nutrition
- Insect pest, disease and weed management
- Harvesting and post-harvest handling

Botany and climatic requirements

The diversity of the vegetables belonging to the *Brassicaceae* family of plants is illustrated by the list in Table 49 on page 265. Within this family, the majority of cultivated brassica vegetables fall within the *Brassica* genus namely; *B. oleracea*, *B. rapa*, *B. juncea* and *B. napus*. The root crops, radish and horseradish, as well as rocket, white mustard, watercress, land and garden cress belong to a different genus of the brassica family.

The topic on *Understanding brassica plants,* page 262 in this chapter may be helpful for gaining a general overview of the botany, growth cycle and climatic requirements of brassica vegetable crops.

In general, all brassicas grow best in cooler conditions, although there are exceptions depending on the specific species or variety grown. Some have better heat or frost tolerance, others need moister growing conditions, require more even climatic conditions or need a period of cool weather to initiate flowering (vernalisation).

While climate requirements of a plant species or variety need to be considered in commercial production, the plant part that is to be harvested for consumption (Table 49) is also an important consideration in how the crop is best managed to produce a quality product.

European leafy vegetables

Brussels sprouts are relatively hardy but require good management to produce quality sprouts. The crop grows best under cool conditions with average daily temperatures of 18°C or less. Brussels sprouts are frost tolerant and best sprouts are produced during sunny days with light morning frosts. Hot weather will cause sprouts to be soft, loose and open. Most areas in Queensland, with the exception of the Granite Belt district, are therefore unsuitable for Brussels sprouts production.

Kale and collards are very hardy and are able to withstand heavy frosts. Kale does not do well in hot weather, while collards can tolerate high temperatures.

Watercress is tolerant of a wide range of climatic conditions but grows best in cooler weather. Exposed parts of the plant are susceptible to frost, but submerged plant parts can survive frosts as long as the water doesn't freeze.

Asian leafy vegetables

Chinese cabbage prefers cooler conditions, ideally between 13° to 20°C. Bolting can be a problem in late winter, spring and summer. Bolting can be caused by low temperatures (below 12°C) at the seedling stage, days with greater than 12 hours sunlight and water or nutrient stress. Wind protection to prevent leaf damage is essential as damaged leaves contribute to bacterial soft rot problems.

Choy sum and pak choy grow best at temperatures between 15°to 20°C. Choy sum is not frost tolerant, but pak choy tolerates light frosts. Pak choy requires moist, uniform growing conditions as hot temperatures with long days will induce bolting. The stems of young plants bruise easily and wind protection should be provided.

Mizuna is very hardy and both heat and cold tolerant. Mibuna is less adapted to temperature extremes and can bolt in spring if conditions are too cold.

Mustard greens prefer warm, humid conditions and tolerate high rainfall, however this crop is generally not frost tolerant (some varieties are).

Japanese mustard spinach or komatsuna is usually grown as a cool season crop. It can tolerate some extremes of cold and hot temperatures but not for extended periods.

Chinese broccoli has some frost tolerance but can also be grown in the tropics, however it grows best in milder conditions. Optimum growing temperatures are from 18° to 28°C. Low temperatures promote early flowering.

Root and stem vegetables

Radish, including daikon, grows best in cooler conditions and will tolerate light frosts although leaves may be damaged. In hot weather, the plants produce small tops and roots quickly become pithy and very pungent. Horseradish is a very hardy perennial but requires a cool climate to do well.

Kohlrabi, turnips and swedes are hardy vegetables that prefer cooler weather, however slow growth can produce woody, cracked product. Turnips and swedes grow best between 4° and 15°C but extended cold weather can also cause them to bolt. Kohlrabi may fail to form and may bolt if exposed to temperatures below 10°C for any length of time.

Table 49. Scientific and common names of some cultivated brassica vegetable types

Botanical name	Common name	Plant part harvested
Brassica oleracea var. *capitata*	Cabbage	Leaves (head)
Brassica oleracea var. *botrytis*	Cauliflower	Immature inflorescence
Brassica oleracea var. *italica*	Broccoli	Immature floral parts, tender stems and leaves
Brassica oleracea var. *gemmifera*	Brussels sprouts	Axillary buds (leaves)
Brassica oleracea var. *acephala*	Kale and collards	Leaves
Brassica oleracea var. *gongylodes*	Kohlrabi	Swollen stem
Brassica rapa	Turnip, white turnip	Fleshy ‘root’ (hypocotyl)
Brassica pekinensis	Chinese cabbage, wong bok	Leaves (head)
Brassica rapa var. *chinensis*	Pak choy, bok choy, pak tsoi, chinese white cabbage	Leaves
Brassica rapa var. *parachinesis*	Choy sum, flowering pak choy, Chinese flowering cabbage	Flower shoots and younger leaves
Brassica rapa var. *nipposinica* or var. *japonica*	Mizuna and mibuna greens	Leaves
Brassica rapa var. *komatsuna*	Japanese mustard spinach, komatsuna	Leaves
Brassica rapa var. *rosularis*	Tatsoi	Leaves
Brassica alboglabra	Chinese broccoli, white-flowering broccoli	Flowers, stems and young leaves
Brassica juncea	Mustard greens, Indian mustard, leaf mustard	Leaves, seed
Brassica napus var. *napobrassica*	Swedes, Swedish turnip, rutabaga	Fleshy ‘root’ (hypocotyl and stem)
Brassica nigra	Black mustard	Leaves, sprouts, seed
Armoracia rusticana	Horseradish	Root
Barbarea verna	Land cress	Leaves
Diplotaxis tenufolia	Wild rocket	Leaves
Eruca sativa	Salad rocket	Leaves
Lepidium sativum	Garden cress	Leaves
Raphanus sativus	Radish	Root
Raphanus sativus var. longipinnatus	Daikon, oriental winter radish, long white radish, Japanese radish	Root
Rorippa nasturtium-aquaticum (*Nasturtium officinale*)	Watercress	Leaves, tender shoots
Sinapsis alba	White mustard	Leaves, sprouts, seed

Business and marketing considerations

While climatic requirements of a plant species or variety are an important consideration for successful production, business and marketing aspects are equally if not more important.

One of the limitations of growing less well-known vegetables is that detailed information on how to best grow, harvest and market these crops is usually not readily available. It is also difficult to find the right expertise or obtain sound professional advice on these crops, particularly when problems occur.

See *Economics* and *Business management* in this chapter pages 81 to 103.
Refer also to Chapter 5 for contacts and references.

In general, this lack of information makes it more difficult to develop realistic business and marketing plans for minor vegetable crops. Estimates of likely returns, losses and risks are usually based on 'guesstimates' and incomplete information. Nevertheless, it is still essential to make the choice to grow a minor vegetable brassica crop a business decision.

Many of the principles described in the sections on economics and business management in this chapter also apply to minor vegetable crops. The list of reference material and contacts in Chapter 5 provide a starting point for gathering information on which to make sound decisions.

Marketing considerations

Do extensive market research to determine marketing options, the size of the markets you intend to supply and the specific requirements of these markets. With the exception of Brussels sprouts and Chinese cabbage, you will be targeting niche markets and these are usually small and easily oversupplied. Oversupply will impact on prices and therefore profitability of the crop. Make sure you make realistic calculations of what it will cost to produce and market the crop and what prices you could reasonably expect to receive for your product.

In recent years, markets for loose and packaged leaf vegetables have increased steadily. These various fresh-cut salad leaf mixes were once dominated by lettuce but some mixes now contain a large proportion of other types of leaves including leafy brassicas. They are often, but not always, grown hydroponically.

Establishing the crop

In general terms, the information in Chapter 3 on land preparation, planting and establishing crops applies, however there are some differences. For example, root crops require deeper, lighter soils than other brassicas while watercress is grown in water not soil. Some crops

For more information see *Getting the crop started* and *Getting the crop established* in Chapter 3 pages 34 to 54

are best direct seeded, while others are best transplanted. Plant spacings also vary, as does tolerance to soil acidity or alkalinity between the different crop types.

Brussels sprouts grow on a range of soil types but do best on fertile medium to heavy soils that are high in organic matter with a pH of 6.0 to 6.8. Brussels sprouts are usually established using transplants. Plant seedlings in double rows on 1.5 m wide raised beds, with 60 to 80 cm between plants along the row.

Turnips and swedes prefer soils which are moderately deep and fertile with a pH of 6.0 to 6.5. Seeds are sown 1 cm deep in rows 30 cm apart onto raised beds. Seedlings are thinned within a few weeks of germination to a spacing within the row of 8 cm for turnips and 12 cm for Swedes. **Kohlrabi** can be grown on a wide range of soils. The crop is usually established using seedlings planted on raised beds at fairly high densities – 25 x 25 cm to 30 x 45 cm.

Horseradish will grow in most soils but will not do well in sands and shallow heavy clays. The best crops are produced on light-textured, well-drained fertile loams. Land should be deeply tilled before planting. Most commercial crops are grown from setts or root cuttings, usually planted into furrows.

Watercress is an aquatic herb that is grown in pools of gently flowing water in full sun. An adequate supply of good quality water is essential for commercial production. Plants can be propagated from seed or cuttings. Watercress beds can last for 10 years without replanting.

Chinese cabbage will grow on a wide range of soils, but a sandy loam is preferable as the plant is susceptible to a range of soil-borne diseases. Good drainage to a depth of at least 30 cm is essential to limit losses to root rots. Deep rip soil to improve drainage if necessary. Soil pH should be between 6.0 and 7.0. Ensure soil is well prepared before planting with all previous crop residues broken down completely.

Chinese cabbage can be direct seeded but transplanting is the preferred method of establishing the crop as this minimises bolting problems. Plastic mulch with trickle irrigation can be laid as the beds are formed. While expensive, this will improve weed, water and nutrient management.

Plant transplants on beds in single rows 75 cm apart, or double rows 35 cm apart and 80 cm between beds; with 25 to 35 cm between plants in the row. Adjust plant spacing to the size of the variety.

Pak choy prefers rich, loamy soils with high fertility, organic matter and water retention. The ideal soil pH is 6.5 to 7.0 as plants are sensitive to acidic soils below pH 6.0. Plant on raised beds in rows 15 to 30 cm apart with 25 to 45 cm between plants depending on the size of the variety.

Choy sum will perform on a wide range of soil types as long as they are fertile, high in organic matter and have good drainage. Soil pH should be between 6.0 and 7.0. Plant from seed or seedlings at a spacing of 10 cm between plants on raised beds

Mustard greens prefer well-drained sandy loams with high organic matter but will grow on a wide range of soils. Ideal soil pH is 5.5 to 6.8. The crop is quite tolerant of acidic soil. Plant from seed or seedlings in rows 30 to 45 cm apart with 10 to 45 cm between plants.

Mizuna and mibuna grow on a wide range of soil types but perform best on rich, loamy soils with high water retention. Plant from seed or seedlings on raised beds. They can be grown as seedling, semi-mature or mature plants. Plant 10 cm apart if harvesting as seedlings, 20 cm apart if cutting for leaves and 40 cm apart if harvesting mature plants.

Komatsuna is usually sown in situ on raised beds, 2 to 5 cm apart and thinned out to 20 to 45 apart one or two weeks after emergence. Thinned seedlings can be replanted or sold in bunches.

Chinese broccoli grows on most soil types as long as the soil is well-drained, fertile and high in organic matter. Ideal soil pH is 6.0 to 7.0. The crop is best direct seeded although it can be transplanted. Sow two to four rows on raised beds with 8 to 12 cm between plants and thin out after 3 weeks. These seedlings can be bunched and sold as the first harvest. A high density planting slows down the maturation process and produces a better quality product.

Varieties

Contact seed and seedling suppliers for varietal recommendations for your district and discuss quality requirements with your potential market. Seed for some of the less-well known types of brassicas may be difficult to obtain. If you can find one, talk with a grower who is already producing the brassica crop you are interested in. Horticultural magazines often also feature articles on these lesser known brassica types and the varieties that are available. The interrnet is also a good source of contacts and information

If direct seeding, keep in mind that the cheapest seed is not always the best choice as poor germination rates and seed vigour will lead to poor yields. Quality of seed or transplants is particularly important for crops that are planted at high density, as establishment costs can represent a much higher proportion of overall production costs than for crops that are planted at lower density.

Irrigation and nutrition

Brassica vegetables need to be grown quickly without a check in growth through a lack of water or nutrients. The general principles outlined in the topics on nutrition and irrigation management in this chapter apply, however specific fertiliser and irrigation requirements will vary depending on the brassica type grown.

For general principles of nutrition and irrigation management, see this chapter pages 152 to 182

As for cabbage, cauliflower and broccoli crops, your fertiliser program should be based on the results of a comprehensive soil analysis. Some brief comments on the different minor brassica crops follow, however we urge you to seek out specific information for the type you plan to grow, where this information is available.

Chinese cabbage has similar nutrient requirements to cabbage but careful management of nitrogen is more critical to produce a quality crop. Excess nitrogen appears to be involved in Gomasho, a physiological disorder which causes black to brown spotting of the midribs. The exact cause of this problem is unknown. Excess nitrogen can also leave plants more susceptible to soft rots and tip burn. Do not apply nitrogen in the last three weeks before harvest.

Chinese cabbage has a shallow root system and should not be water stressed. Use tensiometers to monitor soil moisture levels. Establish crops using overhead irrigation. Consider growing the crop with trickle irrigation and plastic mulch as this will improve weed control and make it easier to manage nutrients and irrigation effectively.

Brussels sprouts have similar nutrient and irrigation requirements to cabbage. Heavy applications of nitrogen can result in loose sprouts.

Kohlrabi requires uniform growing conditions. A check in growth can cause them to become fibrous while sudden rapid growth can cause them to crack. **Turnips and swedes** have similar nutritional requirements to cabbage.

Horseradish needs a continuous supply of nutrients and moisture to produce quality roots. The crop can also benefit from an application of manure well before planting.

Most **Asian leafy vegetables** require frequent light watering, either daily or twice daily, as they have shallow root systems. In contrast, the root system of komatsuna grows more deeply, so the crop should be watered less frequently but more heavily. Shallow-rooted crops need regular, light applications of nutrients and can benefit from an application of manure applied several weeks before planting. Over fertilising should be avoided as excess nitrogen can increase the incidence of bacterial soft rots.

Insect pest, disease and weed management

Information for managing insect pests and diseases provided elsewhere in this chapter also applies to minor brassica vegetable crops in general terms. This includes the sections on:

- Integrated pest and disease management;
- Insect management in the field;
- Disease management in the field;
- Natural enemies;
- Effective spray application;
- Safe storage, use and disposal of pesticides.

An exception is the topic dealing with weed management, as it contains quite detailed information on chemical options available for managing weeds in cabbage, cauliflower and broccoli crops. These herbicides are generally not registered for use in minor brassica vegetable crops. However, the integrated approach to managing weeds described does apply and cultural control options such as crop rotations, timely cultivations and planting into weed-free seed beds become even more important where herbicide options are limited.

Chemical control options

One of the limitations of growing minor brassica vegetable crops is that there are few chemical control options available for managing weeds, diseases and insect pests. For some of these crops chemical control options are non-existent.

IMPORTANT
The chemicals mentioned in this handbook refer to cabbage, cauliflower and broccoli crops ONLY.
It is illegal to apply a chemical to a crop for which it is not registered.

It is critical that you READ THE LABEL before using any chemical product to ensure that it is registered for the crop and the intended use. If in doubt, contact the distributor or manufacturer of the product to double-check that the product can be legally applied to the crop in question.

For minor vegetable crops the only chemical options available are often obtained through temporary permits. You must hold a copy of the permit to legally use the chemical in question.

Two sources of information for chemical registrations and minor use permits are the DPI&F Infopest database and APVMA website. See Chapter 5 pages 278 and 290 for contact details.

Chemical registrations and minor use permits are regularly reviewed and updated, therefore consult databases or advisory services for the latest products.

Some further comments

Avoiding hot weather production, effective crop rotations, thorough soil preparation and good farm hygiene are all practices that will help with weed, disease and insect pest management.

Management decisions should be based on regular crop monitoring results and management strategies selected should aim to protect natural enemies.

In general, the insects and diseases that can cause problems in cabbage, cauliflower and broccoli also affect minor brassica vegetables. Susceptibility and impact of any damage however may vary depending on plant type or variety grown. There are several diseases and disorders which tend not to affect cabbage, cauliflower or broccoli crops but can cause major losses in some types of minor brassica vegetables. For example:

- In Brussels sprouts, aphids, particularly the cabbage aphid, can cause serious marketing problems. Once aphid colonies are established in sprouts, it is difficult to obtain effective spray coverage of sprouts to clean up infestations. Careful crop monitoring and management of aphids early in the crop are essential.
- Aphids can also become troublesome in leafy brassica vegetables such as komatsuna, choy sum, pak choy and mustard greens.
- Brassica crops grown for their roots and stems may be more susceptible to some soil-borne diseases, for example, black root of radish caused by the fungus *Aphanomyces raphani*.
- Chinese cabbage and radish are susceptible to white blister, a fungal disease caused by *Albugo candida*. Other minor brassica vegetables may also be susceptible.
- Densely planted crops that are watered frequently are more likely to be affected by slugs and snails. Bacterial rots and leaf diseases and fungal diseases such as downy mildew can also be more difficult to control in these crops.
- The young, tender leaves of leafy brassica vegetables are very attractive to birds such as pigeons and sparrows.

Harvesting and post-harvest handling

Your seed or seedling supplier should have information available to help you calculate days from planting to harvest for the specific brassica types that you are interested in. Ask also about realistic yield estimates for your district. Discuss specific market requirements and specifications with your wholesaler.

Brussels sprouts are harvested about 3 months after transplanting when sprouts are 3 to 5 cm in diameter and 20 to 40 g in weight. To harvest, the sprout and its associated leaf is broken off at the stem. As the lower leaves are removed, the plant will continue to grow upwards producing more sprouts. Harvesting can be done once-over (machine harvest) or progressively as the sprouts mature. The growing point of the plant may be pinched out to hasten sprout maturity but this practice can decrease yields by up to one third. A single plant can yield up to 3 kg of marketable sprouts.

Sprouts should be cooled as soon as possible after picking using either forced air or hydro-cooling. Before packing they should be cleaned, trimmed and sorted, removing any damaged or loose sprouts. Brussels sprouts can be stored for up to a month at 0°C and 90-95% humidity.

Chinese cabbage matures in 6 to 11 weeks depending on the variety and season. Harvest in the morning once plants are dry and remove field heat as soon as possible after harvest. Chinese cabbage requires high humidity cooling as it has no protective outer layer and is very prone to wilting. Aim for a once over harvest as for green cabbage. Grade the plants for size, trim off outer leaves and pattern pack into cartons depending on market requirements. Short varieties are usually packed vertically with butts up whereas long varieties are packed horizontally. Yields will depend on weather conditions, variety and plant spacing. Chinese cabbage can be stored at 0°to 1°C and a relative humidity of 95% for up to a month, but the longer the storage period the shorter the shelf life once marketed.

Turnips can be bunched or topped. Those for bunching are harvested at about 5 cm in diameter, then washed and tied in bunches of 4 to 6 plants. Turnips for topping are harvested at 7 to 8 cm in diameter. **Swedes** are harvested at about 10 to 12 cm in diameter. Topped roots are sold by volume or weight and packed in transparent plastic bags. **Kohlrabi** are harvested at 5 to 8 cm in diameter, before they become tough and fibrous. The roots are cut off then they are usually bunched, sometimes topped.

Watercress is usually harvested on a monthly basis, with several beds harvested in rotation to ensure a continuous supply. Remove the top 15 cm of the plants, gather into bunches and trim from the cut end to a length of about 10 cm. Wash thoroughly, cool then pack into plastic bags or waxed cartons. Store at 0°C and high humidity. Watercress leaves wilt and become yellow and slimy if handled poorly.

Horseradish is not harvested until after the autumn growth has taken place. Digging is usually done with a heavy plough. The roots are trimmed of tops, side shoots, and all lateral and bottom roots, before being washed and tied in bundles and packed. Roots can be stored in pits or storage cellars for extended periods at 0°C and 95% humidity.

Leafy Asian vegetables (choy sum, mustard greens, mizuna and mibuna, pak choy, komatsuna) are cut whole and a number of plants are bunched together and tied. Mizuna and mibuna can also be harvested by cutting individual leaves from plants regularly so that a fresh crop is continually produced. For Chinese broccoli, flowering stems with compact florets and small leaves are cut to 15 to 20 cm lengths and tied into bunches of 5 to 7 plants. Remove field heat from leafy Asian vegetables as soon as possible after harvest using high humidity forced-air cooling then storing at 2° to 5°C with 90 to 95% relative humidity. Some growers use hydro-cooling methods for removing field heat from pak choy.

'Baby' leaves of brassicas such as mizuna, tatsoi and pak choy are harvested and then added to fresh-cut salad mixes, which often includes lettuce. Rocket or wild rocket are also popular in these mixes. Leaves are harvested, washed in sanitised water, spun-dried, refrigerated before sending to a secondary processor for inclusion in fresh-cut salad mixes. These mixes are usually packed into a plastic film or bag that lines the box to be used for transport. This plastic packaging is permeable to carbon dioxide (CO_2) and oxygen (O_2) in a manner that allows the atmosphere inside the package to be maintained at a certain CO_2/O_2 ratio. This lowers the respiration rate of the product and slows deterioration. Modified atmosphere packaging (MAP) can increase the storage life of some leafy brassicas by more than 100% when used in combination with low storage temperatures.

Chapter 1

Before you START

If you have never grown cabbage, cauliflower or broccoli before, then you will find this section very useful. It is a brief checklist of the essential things you need to know before you start. It will help you make the right decisions. The information here is brief and to the point. We provide more detail on important areas in other sections of the book. Symbols on the left of the page will help you make these links.

Contents

A brief overview of the Queensland brassica industry

Official statistics suggest that the Queensland brassica industry is relatively static, although supply tends to fluctuate from year to year. In 2001–02, around 40 000 tonnes of cabbage, cauliflower and broccoli were produced from about 2 800 hectares. Table 1 shows the industry had a farm gate value of about $21 million and a gross value of around $32 million.

Table 1. The Queensland brassica industry

Crop	Area (ha)	Production (tonnes)	Farm gate value ($ millions)	Gross value ($ millions)
Cabbages	366	13,148	2.7	4.7
Cauliflower	693	15,058	4.1	8.2
Broccoli	1758	11,569	14.3	18.8
Totals	**2817**	**39,775**	**21.1**	**31.7**

Source: *Australian Bureau of Statistics* 2001–02 estimates

Most Queensland brassicas are grown in the south-eastern corner of the State in the Lockyer Valley, Eastern Darling Downs and the Granite Belt. Small growing areas exist in coastal areas and other horticultural production districts of the state.

The industry primarily supplies the domestic fresh market, either through the central market system or direct to supermarket chains which account for the majority of sales. There are small markets for semi-prepared or semi-processed product (coleslaw, salad and vegetable mixes).

Brassicas from Queensland are sold throughout Australia. Fresh cabbage, cauliflower or broccoli can be sourced from Queensland at any time of the year but the main supply period is from May to September when the Lockyer Valley and Eastern Darling Downs are in full production. During the warmer months, production is centred in the cooler highland areas of the Granite Belt and around Toowoomba.

Returns can vary greatly. Prices are often low during peak production in winter. Summer prices are often high. In regions with warm or hot summers such as the Lockyer Valley, lows yields, reduced head quality and pest and disease problems are often not offset by these higher summer prices.

Some larger brassica growers have actively pursued export markets for a number of years with some success. The major overseas markets for Queensland brassicas are south-east Asia and Japan, with $5.7 million of broccoli, $1.8 million of cauliflower and smaller quantities of cabbage exported during 2002–03 (Source: *Australian Bureau of Statistics*).

Know what you are getting into

The average price for broccoli, cauliflower and cabbage varies between seasons, making profitability and cash flow inconsistent and hard to estimate. The market is often oversupplied, particularly during winter and early spring, when returns may be below costs of production.

Consistent yields and quality can be difficult to achieve due to insect pests (for example, diamondback moth), disease problems (for example, head rots) and climatic factors. These include frosts, heat wave conditions or wet weather during harvest. Varieties also perform differently in various growing areas and under different growing conditions.

Growing brassicas is labour intensive, particularly at planting and harvest times, and there can be problems getting a good, reliable labour force.

Successful production requires cool to mild growing conditions, a well-drained soil and reliable irrigation. Capital costs can be high depending on arrangements for harvesting and packing of product. Access to rapid pre-cooling and cold storage facilities is essential for broccoli and highly desirable for cauliflower. Cabbage can be cooled and stored in a conventional cold room.

IMPORTANT
Do a marketing and business plan. This will give you a more accurate picture of what you are getting into.

Table 2 lists the some of the strengths, weaknesses, opportunities and threats (SWOT) affecting the brassica industry.

Table 2. Factors affecting the brassica industry of Queensland

Strengths	Weaknesses	Opportunities	Threats
Staple, well known products	Not suited to warm weather production	Value adding and semi-processing	Overproduction
High nutritional value	Cabbage and cauliflower not fashionable	Health aspects of the product	Lack of irrigation water (drought)
Versatile product	Generic promotions	Targeted promotion	Substantial price fluctuations
Value for money	Competition from southern states in domestic markets	New varieties	Club root
Convenient	Strong competition in export markets	Niche markets, organics, eco-labelling	Insecticide resistance problems
Reliable crop to grow in season with good management	Highly perishable product (broccoli, cauliflower)	New export markets	Labour, packaging and freight costs

What can you expect to make?

Yields vary considerably, depending on climatic conditions, pests and diseases, variety, season and planting density. Prices vary greatly, depending on supply and quality.

Cabbages are usually supplied in bulk bins and sold on a per head basis. Sugarloaf cabbages are often sold in waxed fibreboard cartons. Cauliflowers are sold either on a per head basis or, more commonly, in 78L cartons that hold 10 or 12 heads. Broccoli is usually sold in icepacks holding 8 kg of heads or in waxed fibreboard cartons holding 10 kg of product.

Production and marketing costs for cabbages, cauliflower and broccoli vary, depending on yields achieved, the size and efficiency of the operation and the cost structure of the business. Each farm is different. The estimates given in the following sections are intended only to illustrate the level of costs involved for growing, harvesting and marketing the different brassica crops.

IMPORTANT
Estimate costs for your situation. See *Economics of production* in Chapter 4, Key issues.

Of the three crops, cauliflower is by far the riskiest crop to grow as production costs are high and yields can vary substantially. Cauliflowers also require a fair amount of agronomic and management expertise to grow successfully. Cabbage and broccoli are easier to grow. However, since broccoli is the more perishable of the three products, timeliness of harvest and access to adequate cooling facilities complicate crop management.

Cabbage yields and prices

Marketable yields commonly range from 14 000 to 18 000 heads per hectare.

more info
Market prices
Chapter 6 page 282

Price can range from $0.20 to $4.00 or more per cabbage head, but is usually in the $0.60 to $2.00 range. Figures 1 to 3 show average prices for ballhead cabbages on the Brisbane and Sydney markets and throughput of all cabbages at the Brisbane market for 2001 to 2003. The bigger the variation above or below the average price, the greater the opportunity or risk involved.

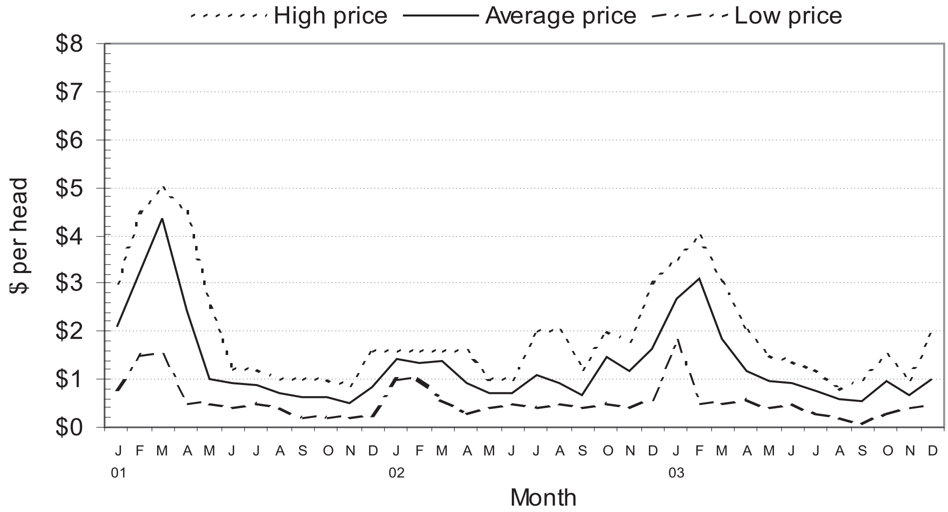

*Figure 1. Average monthly price for ballhead cabbage on the **Brisbane** market 2001 to 2003*

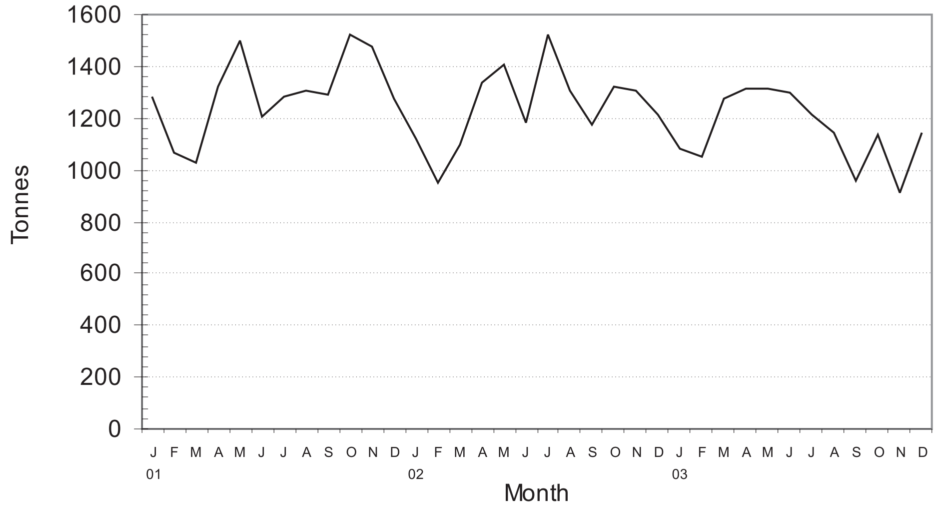

*Figure 2. Throughput of cabbage on the **Brisbane** market 2001 to 2003*

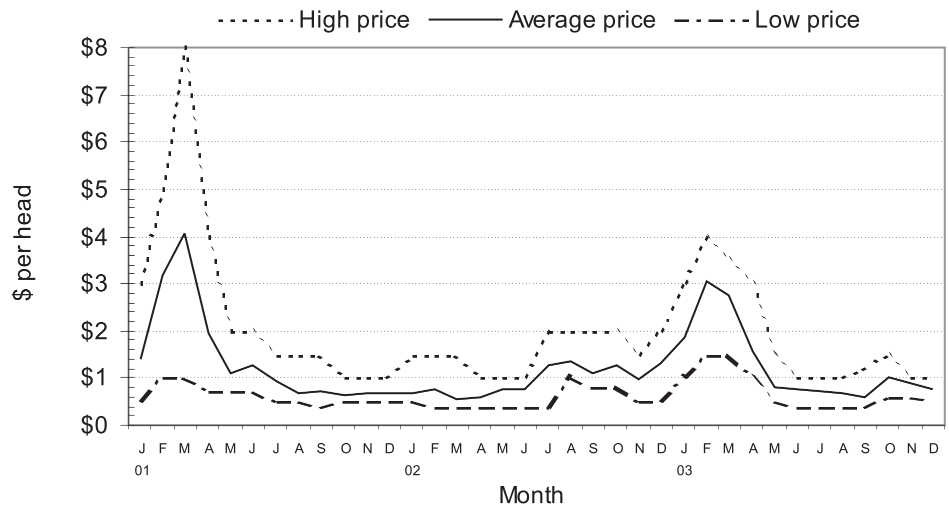

*Figure 3. Average monthly price for ballhead cabbage on the **Sydney** market 2001 to 2003*

Production costs for cabbage

Production and marketing costs in southern Queensland are at least $0.70 per head. Variable growing, harvesting and marketing costs range from $10 000 to $16 000 or more per hectare.

Table 3 shows the estimated average costs of a southern Queensland crop yielding 16 000 heads per hectare sold in fibreboard bulk bins at $1.00 per head on the Brisbane market.

Table 3. Example costs of producing and marketing a cabbage crop grown in southern Queensland

Costs	$ per head	$ per hectare
Growing	0.22	3 520
Harvesting (pick, pack & bin)	0.37	5 920
Marketing (freight and commission)	0.25	4 000
Total variable costs	**0.84**	**13 440**

Gross margin

At an average yield of 16 000 heads per hectare and an average price of $1.00 per head, the gross return would be $16 000/ha. The gross margin (income after deducting growing, harvesting and marketing costs) for the yield, price and cost averages used here would be $2560/ha. To determine your net income, deduct fixed and capital costs such as rates, vehicle registration, insurance, electricity, administration, interest and living expenses.

a key issue
Cabbage gross margin
Chapter 4 page 87

Cauliflower yields and prices

Marketable yields commonly range from 1 500 to 2 000 cartons per hectare. Yields can be substantially lower during unfavourable growing conditions.

Price can range from $2.00 to $50.00 per carton, but is usually in the $8.00 to $18.00 range. Figures 4 to 6 show average prices and throughput at the Brisbane market and prices at the Sydney market for 2001 to 2003. The bigger the variation above or below the average price, the greater the opportunity or risk involved.

more info
Market prices
Chapter 6 page 282

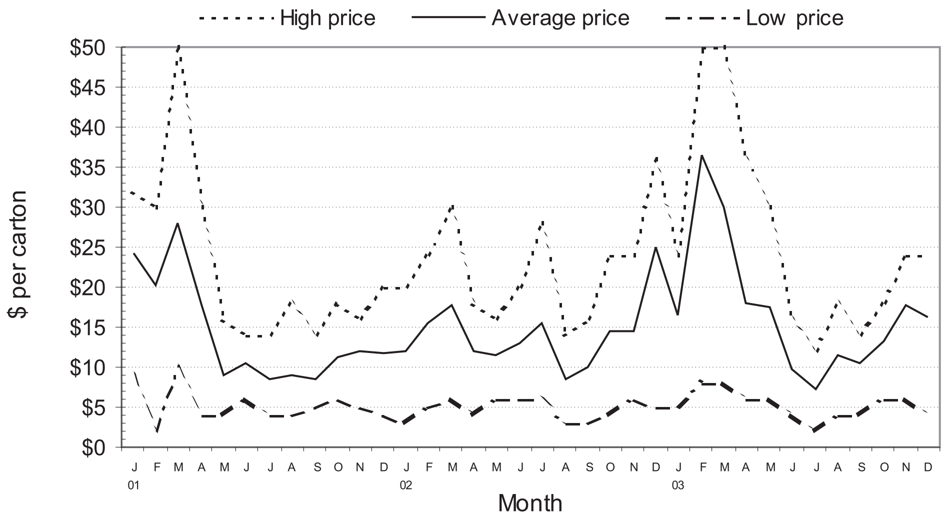

*Figure 4. Average monthly price for cauliflower on the **Brisbane** market 2001 to 2003*

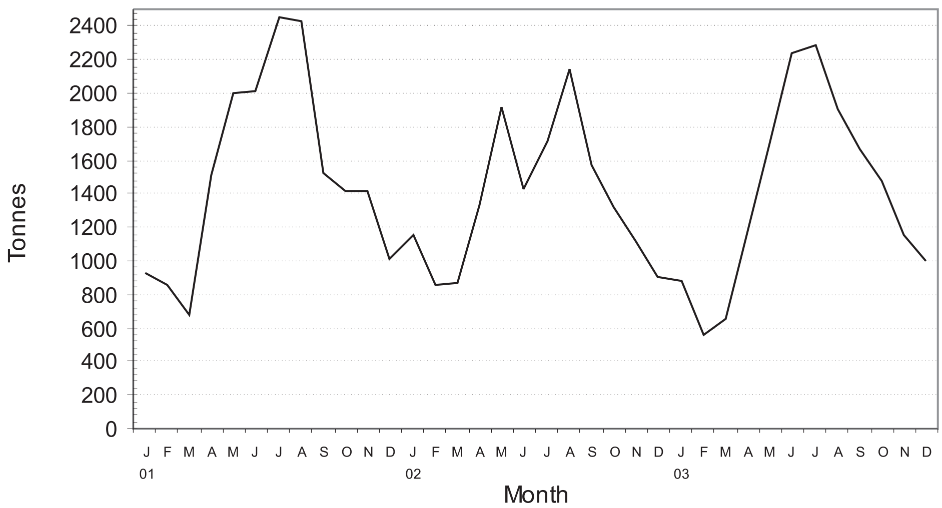

*Figure 5. Throughput of cauliflower on the **Brisbane** market 2001 to 2003*

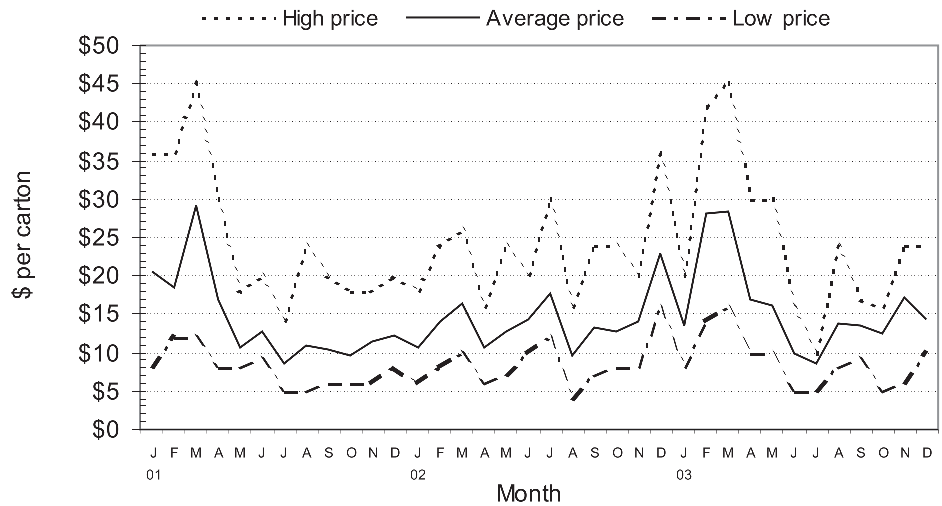

*Figure 6. Average monthly price for cauliflower on the **Sydney** market 2001 to 2003*

Production costs

Production and marketing costs in southern Queensland are at least $9.50 per carton. Variable growing, harvesting and marketing costs are at least $14 000/ha, but can be $20 000 or more per hectare. The evenness of crop maturity will have a significant impact on harvesting costs.

Table 4 shows the estimated average costs of a southern Queensland crop yielding 1 700 cartons per hectare sold at $12 per carton on the Brisbane market.

Table 4. Example costs of producing and marketing a cauliflower crop grown in southern Queensland

Costs	$ per carton	$ per hectare
Growing	2.77	4 709
Harvesting (pick, pack & carton)	5.61	9 537
Marketing (freight and commission)	2.35	3 995
Total	**10.73**	**18 241**

Gross margin

a key issue
Cauliflower gross margin
Chapter 4 page 90

At an average yield of 1 700 cartons per hectare and an average price of $12 per carton, the gross return would be $20 400/ha. The gross margin (income after deducting growing, harvesting and marketing costs) for the yield, price and cost averages used here would be $2159/ha. To determine your net income, deduct fixed and capital costs such as rates, vehicle registration, insurance, electricity, administration, interest and living expenses.

Broccoli yields and prices

Marketable yields commonly range from 700 to 1000 icepacks per hectare.

more info
Market prices
Chapter 6 page 282

Price can range from $3.00 to $40.00 per icepack, but is usually in the $12.00 to $22.00 range. Figures 7 to 9 show average prices and throughput at the Brisbane market and prices at the Sydney market for 2001 to 2003. The bigger the variation above or below the average price, the greater the opportunity or risk involved.

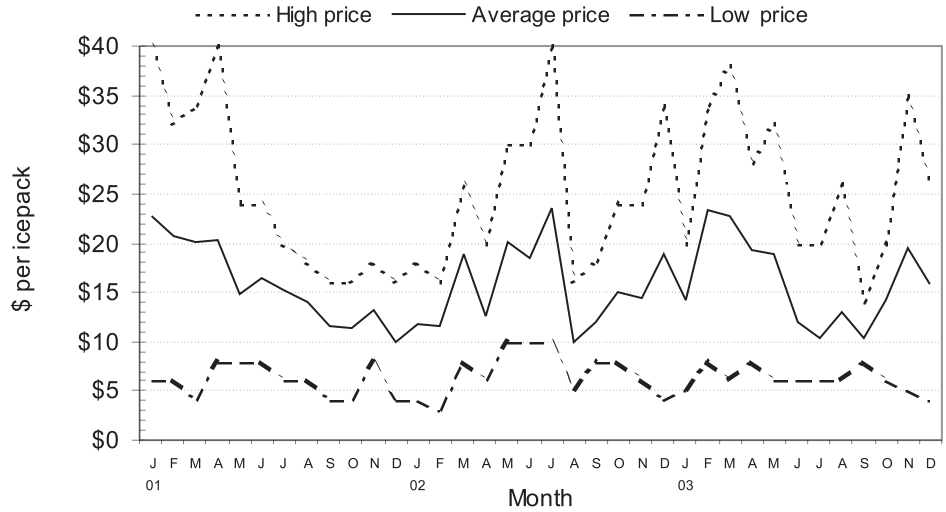

*Figure 7. Average monthly price for broccoli on the **Brisbane** market 2001 to 2003*

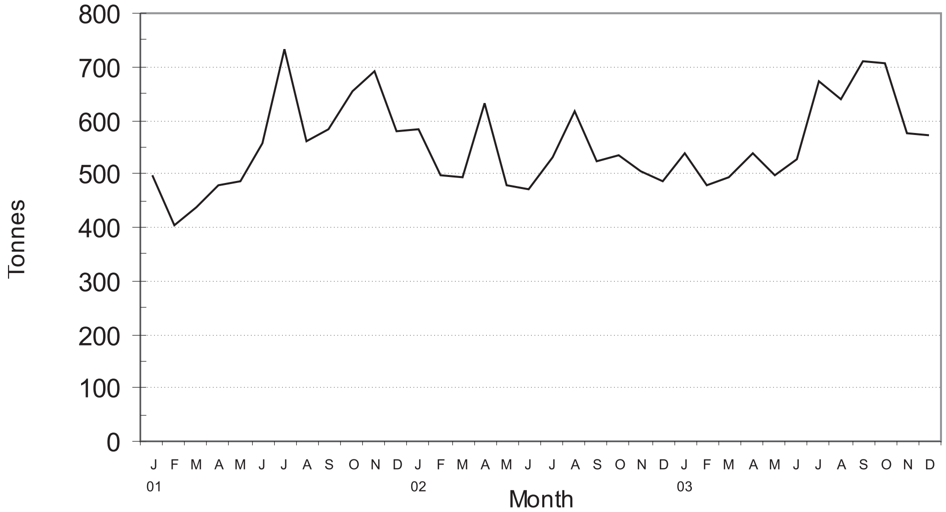

*Figure 8. Throughput of broccoli on the **Brisbane** market 2001 to 2003*

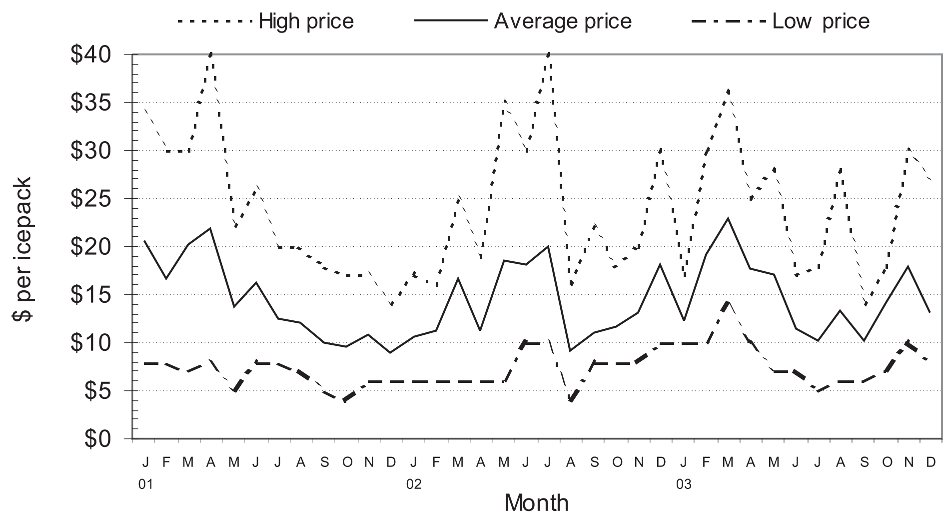

*Figure 9. Average monthly price for broccoli on the **Sydney** market 2001 to 2003*

Production costs

Production and marketing costs in southern Queensland are at least $13.00 per icepack. Variable growing, harvesting and marketing costs range from $11 000 to $15 000 or more per hectare.

Table 5 shows the estimated average costs of a southern Queensland crop yielding 900 icepacks per hectare sold at $16.00 per icepack on the Brisbane market.

Table 5. Example costs of producing and marketing a broccoli crop grown in southern Queensland

Costs	$ per icepack	$ per hectare
Growing	4.75	4 275
Harvesting (pick, pack & icepack)	6.66	5 994
Marketing (freight and commission)	2.50	2 250
Total	**13.91**	**12 519**

Gross margin

a key issue
Broccoli gross margin
Chapter 4 page 93

At an average yield of 900 icepacks per hectare and an average price of $16 per icepack, the gross return would be $14 400/ha. The gross margin (income after deducting growing, harvesting and marketing costs) for the yield, price and cost averages used here would be $1881/ha. To determine your net income, deduct fixed and capital costs such as rates, vehicle registration, insurance, electricity, administration, interest and living expenses.

Capital required

Assuming that you own or have access to suitable land, it would cost around $250 000 to $300 000 to buy the minimum amount of new machinery, plant and equipment needed to set up a 20 to 30 hectare brassica enterprise. This will depend on which crop you grow and what harvesting and packing arrangements you use. Cabbage would generally be less capital intensive than broccoli or cauliflower.

To reduce capital outlays, you could lease or borrow equipment and contract harvesting and packing operations. Second-hand equipment prices are normally about half that of new equipment, depending on condition and age.

You will also need to finance production and marketing of the crop. Brassicas are usually planted on a weekly schedule over a number of months. You may be looking at investing $100 000 to $200 000 in variable growing, harvesting and marketing costs before receiving a gross return from the first harvest.

The farm you need

Soil

more info
Getting the crop started
Chapter 3 page 34

Brassicas will grow on most soil types but the crop needs at least 300mm of friable, well-drained topsoil. Poorly drained soils or heavy clay soils become waterlogged after rain or irrigation, making crop management more difficult. Brassicas prefer a slightly acid soil (pH 6.0 to 6.5) but will tolerate a slightly alkaline soil, up to pH 7.5.

Climate

Brassicas grow best under cooler temperatures. Mild, sunny days with temperatures between 15° and 25°C and cool nights with temperatures between 10° and 15°C are considered ideal. Heavy winter frost (below –4°C) can damage heads and will kill young seedlings. Some varieties will tolerate hot conditions but high temperatures will reduce both head quality and yields. Cauliflower is particularly sensitive to temperature extremes.

During extended rainy weather, plants are more likely to become infected with diseases such as black rot and bacterial head rots. These are difficult to manage once the disease is established in the field. Rainfall will also restrict machinery operations, particularly on heavy soils.

Brassica crops are attacked by a range of butterfly and moth larvae (caterpillars). These can be difficult to control, particularly in the warmer months.

Slope

Ideally slopes should be no more than 3%. A slight slope will provide better drainage while still allowing for efficient irrigation and use of machinery. Steep slopes will be more difficult and expensive to work. Uniform slopes are desirable but not essential. Soil erosion can be a problem on steep slopes while depressions can result in waterlogging.

more info
Prepare the land
Chapter 3 page 41

Slopes above 5% require recognised soil conservation practices. Slopes above 8% make machinery operations hazardous and it can be difficult to maintain uniform irrigation.

Water

An adequate water supply is essential to ensure economic yields of high quality product. Each crop will require 2.5 to 4 megalitres (ML) of water per hectare, depending on season, soil type and crop type. This is equivalent to 250 to 400 mm of total rain and/or irrigation over one hectare of land.

When surface water, for example dams, is your main source of irrigation water, a storage capacity of 6 to 8 ML will be required for each hectare of crop grown. This will ensure that you have adequate water supplies to meet peak irrigation demands even in unseasonably dry conditions.

Brassicas are usually watered with overhead irrigation systems although some growers are switching to drip (trickle) irrigation.

a key issue

Irrigation management
Chapter 4 page 168

The crop is moderately sensitive to poor quality water. Electrical conductivity is a measure of water salinity. Table 6 shows the water conductivity threshold for different soil types at which yield reductions may occur.

Table 6. Water conductivity threshold for different soil types

	Sandy	Loam	Clay
Cabbage	3.5 dS/m	2.0 dS/m	1.2 dS/m
Cauliflower	3.2 dS/m	1.8 dS/m	1.1 dS/m
Broccoli	4.9 dS/m	2.8 dS/m	1.6 dS/m

Source: *NRM Facts, water series W55*

Until recently water conductivity was reported in microSiemens per centimetre (µS/cm), however it is now reported as deciSiemens per metre (dS/m).

To convert from µS/cm to dS/m use the following formula.

microSiemens per centimetre (µS/cm) divided by 1000 = deciSiemens per metre (dS/m)

Example: 1200 µS/cm divided by 1000 = 1.2 dS/m

To convert from deciSiemens per metre to microSiemens per centimetre multiply by 1000.

Example: 1.2 dS/m x 1000 = 1200 µS/cm

The machinery and equipment you need

The machinery and equipment required will depend on the size of the enterprise and crop grown. Table 7 lists the machinery and equipment considered essential for brassica production on a small scale (20 to 30 hectare). Machinery, plant and equipment listed as desirable would make management easier by increasing flexibility and would be considered essential in a larger enterprise.

The prices listed in the table are estimates only. Rather than buying new machinery you could lease, borrow or buy second-hand equipment to reduce capital outlays. Harvesting, cooling and packing can be contracted out in most major vegetable production districts.

Table 7. Estimated cost of new machinery and equipment

Equipment	New price $
Essential	
Tractor (26 kW) for planting, cultivation, spraying, harvest	30 000
Tractor (45 to 60 kW) for discs, ripper, rotary hoe	60 000
Truck or tractor and trailer	10 000–40 000
Cultivation equipment	20 000–25 000
Bed-former	2 000
Transplanter	4 000
Fertiliser spreader	10 000
Spray equipment for crop	10 000
Irrigation equipment	80 000
Tractor mounted forklift	10 000
Pallet jack	700
Desirable	
Power harrows (1.5m width with bed-former)	17 000
Spray equipment for herbicides	4 000
Harvest aid	26 000
Shed forklift	30 000
Slasher/pulveriser	3 000–6 000
Sorting/packing tables and equipment	10 000
20 pallet coldroom	35 000
Forced air cooling facilities (8 pallet room)	50 000

The labour you need

One person could grow 10 to 15 hectares of crop over a six-month period with additional labour to help with transplanting, harvesting and packing. Cabbage production is less labour-intensive than cauliflower and broccoli growing.

Three people plus a driver are required for planting. This team could plant out around 5000 to 7000 transplants per hour.

A team of four can cut around three half-tonne bins of cabbage per hour. Six to eight people are needed to operate a harvest aid efficiently. Using a harvest aid, a team of eight could pick and pack between 40 to 50 icepacks of broccoli per hour or 60 to 80 cartons of cauliflower per hour. Cutting and packing rates would slow considerably when more than two or three passes are needed to harvest the crop.

Transplanting, harvesting, cooling and packing operations can be contracted out for all three crops; this reduces problems associated with managing a large number of staff.

Other considerations

Growing brassica crops involves hard, physical work. This includes land preparation, planting, spraying for weed, pest and disease control, fertilising, irrigating, harvesting and packing. There is a high labour requirement for transplanting, picking and packing, particularly for product sold in cartons or icepacks.

Management skills or access to consultants with these skills are required for managing finances, administration, staff and the crop. Good communication skills, or staff with these skills, are essential for successfully managing labour and organising markets. Skills in machinery operation and maintenance, the ability to read and understand chemical labels, and skill in observing and fixing problems in their early stages, are essential. Careful attention to detail is necessary to be a successful brassica grower.

Quality of the end product is most important in successful cabbage, cauliflower or broccoli growing. This starts with good land preparation, careful selection of varieties to suit the district and season and continues through the growing of the crop, harvesting, cooling, packing and marketing.

a key issue

Organic production
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Brassica crops may be grown organically. However, it can be difficult to achieve adequate weed, pest and disease control.