6-2006

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June 2006

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Bulletin No. 4673 - ISSN 1833-7236 (Print) 1833-7244 (Online) - June 2006 - Replaces Bulletin 4197

Acknowledgements

The original bulletin (4197) was written by Allan McKay and Dennis Phillips in 1990. We thank officers of the Department of Agriculture for their helpful comments in the preparation of this bulletin.

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Growing Chinese Cabbage* in Western Australia

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*In the near future, it is likely that a new universal name in Australia will be chosen for 'Chinese cabbage' and this may be 'Wombok'.

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Introduction

Chinese cabbage is a member of the Brassiceae family, which may be called brassicas, crucifers or cole crops. This includes various crops such as broccoli, Brussels sprouts, cauliflower, cabbage, radish, turnips, swedes and weeds such as wild radish.

In general trade, the term Chinese cabbage can loosely be given to both the heading types (Brassica rapa L. subsp. pekinensis) and to non heading types such as pak-choi (Brassica rapa L .subsp. chinensis). This Bulletin deals with the heading type of Chinese cabbage. The Chinese name is Wong Bok, and this name is often used in Australia.

Chinese cabbage originated in China and is believed to be a cross between pak-choi and turnip (Brassica rapa L. var. rapa) plants. It is the main vegetable in China and a leading vegetable in Japan and Korea. It is not a true cabbage and belongs to the mustard group within the family Brassiceae. The heads have more than 50 leaves. They are more elongated and less tightly packed than cabbages. The broad outer leaves are pale green, with broad white midribs and veins. The inner leaves are more tightly compacted and are whitish green.

Production for the domestic and export markets in Western Australia is now about 2000 t per year, but has decreased in the last 10 years, due to a decline in exports. This has mainly been due to strong competition from China in recent years. The Bulletin's cover photo shows the Wong Bok type of Chinese cabbage harvested for export. Chinese cabbage has also become more difficult to grow in recent years because of diseases such as clubroot and pests such as diamondback moth. There has also been a reduction in registered pesticides and increased pesticide resistance.

Chinese cabbage is mainly used in 'stir fry' cooking, but it may also be boiled. It can also be eaten raw as a substitute for lettuce and it is finding increasing favour for use in salads and coleslaw. Heads contain about 93 per cent water. The dry matter contains good levels of carbohydrates, calcium, potassium, and vitamins A and C. It is the main constituent of kim-chi (Korean cabbage relish), which is a popular pickled food in Korea.

Production Districts

In Western Australia, Chinese cabbage was first grown as an export crop in the early 1980s and there was insignificant production for the domestic market. In 2005, less than half of the crop was exported, mainly from May to early August. An increasing amount is now being grown throughout the year in the Perth area for the domestic market.

Chinese cabbage is mainly grown on the Swan Coastal Plain, from West Gingin to Baldivis, and in the Manjimup district. The main area of production for export and domestic markets is now in the Perth area, but formerly a large area in Manjimup was grown for the export market.

Climate

Chinese cabbage prefers average temperatures of 18 to 22^{o}C during early growth, 14 to 16^{o}C during heading and 10 to 13^{o}C during final head development. At temperatures above 25 to 30^{o}C, heads are softer and may have some bitterness, with more risk of diseases such as bacterial soft rot. Chinese cabbage is less damaged by hail than lettuce. If frost occurs, the outer leaves can be removed and the plant may still be suitable for marketing.

Chinese cabbage is very sensitive to bolting which is caused by low temperatures during early growth. Bolting occurs when the flower stalk elongates within the head and is most advanced when the flower stalk breaks through the top of the head (see 'Growth Disorders').

Soils

Chinese cabbage is grown successfully on a range of soil types from sandy soils in the Perth area to the much heavier textured loams of the Manjimup district. Soils must be well drained. Chinese cabbage grows well where there are good supplies of organic matter in the soil. On the Swan Coastal Plain, compost at up to 50 cubic metres per hectare can be applied before planting and rotary hoed into the soil to add organic matter, retain moisture and improve soil fertility.

The crop grows best on neutral soils with a pH of 6.5 to 7.0 (measured in 1:5 water), but the soil pH may be in the range 5.2 to 8.0. Clubroot disease is more prevalent at low soil pH (acid soils). Therefore, on acidic soils, apply lime at least three months before planting to adjust the pH to above 6.5. The rate will depend on the soil pH, the ability of the soil to buffer pH change and the type of lime. Sandy soils require less lime than loams to achieve the same pH change. On soils with an alkaline pH (more than 7.0), Chinese cabbage is more prone to boron, manganese and other trace element deficiencies.

Rotation

Close rotations with other brassica crops are best avoided. Chinese cabbage can grow well if planted once every one to two years on the same soil, if there is no clubroot present, and there are no other brassica crops in the rotation. However, it is best grown once in three years on the same soil and rotated with crops that are not in the Brassica family. Areas infested with brassica weeds, particularly wild radish, should be avoided as the weeds are difficult to control and are alternative hosts for clubroot disease.

Figure 1. Head type: Wong Bok (left) and Michihili (right)

Varieties

There are two main forms of Chinese cabbage; Michihili and Wong Bok, which are distinguished by size and head shape (see Figure 1 and Table 1). Both types are grown for export. The Wong Bok type matures slightly earlier than the Michihili type. The Singapore market prefers Wong Bok and the Michihili type is popular in Taiwan.

Most commercially grown Chinese cabbage varieties are hybrids that are produced by Japanese and Taiwanese seed companies. Current varieties have been grown in Western Australia for many years. Major goals are to breed high yielding, uniform varieties that are not prone to bolting.

Table 1. Two main forms of Chinese cabbage

Head Type	Description	Head Length (cm)	Head width (cm)	Weight
Michihili	Long	30 to 40	9 to 12	0.9 to 1.2kg
Wong Bok	Short	20 to 30	12 to 20	1.0 to 1.5 kg

Wong Bok

Blues is an export variety, with firm heads. It has some bolting tolerance and can also be grown in spring.

WR Green 60 has a suitable head shape and is tolerant to 'gomasho' (see section on 'gomasho' for information on this growth disorder) and to soft rot. It is planted before April in the Perth area, as it is prone to bolting.

Yuki is an export and domestic variety that is reported to have some tolerance to clubroot and tip-burn. It is susceptible to soft rot.

Ming Emperor has good bolting tolerance and may be used to extend the season by planting late (after mid-April) in the Perth area. It is highly susceptible to 'gomasho'. It is also grown for the domestic market with plantings from summer to winter.

Kasumi II is too large for the export market. It is mainly used on the domestic market with plantings from spring to summer. It is susceptible to soft rot in summer and to 'gomasho'.

Manoko has good bolting tolerance and is good for late plantings.

Michihili

Green Rocket is the main variety. It is tolerant to 'gomasho' and produces uniform, high quality heads. However, it is susceptible to clubroot in the warmer months and to bolting when it is planted after early April in the Perth area. It is also prone to off-types. In Manjimup, Green Rocket is best planted in January and February.

Growth

As a wild plant, Chinese cabbage is a biennial and grows as a vegetative plant in warm temperatures. In winter and spring, it flowers when it receives a stimulus from low temperatures. It then produces seeds and dies. Under cultivation, Chinese cabbage is grown as an annual. It is harvested before the plant bolts and becomes fibrous.

Chinese cabbage is a fast growing vegetable, and will be bitter if it receives a check in growth. It is ready to harvest in about 65 to 70 days from sowing during summer in the Perth area and about 100 days when sown in late autumn. In the Manjimup district, plants mature about 90 days after sowing in summer.

Plants have four leaves 14 days after sowing in February. Plants then grow rapidly, with most growth occurring at 40 to 45 days after sowing. Plants begin to head about 40 to 50 days after sowing. Fully mature plants may have 50 to 60 leaves.

Plants establish faster when grown from transplants. Figure 2 shows a healthy crop of Chinese cabbage only four weeks after transplanting.

Land Preparation

If Chinese cabbage is to be planted after pasture on loamy and clay soils in the South West area, spray a knockdown herbicide such as glyphosate (active ingredient) to kill perennial grasses, docks and clovers. Use a chisel plough and disc or tyne cultivation to prepare the land at least six weeks before planting, so that plant residues are broken down before planting.

Following ploughing and application of trace elements, use a combined tyne/crumbler to give adequate soil preparation prior to planting. Tyne ripping to a depth of 450 mm may be required if a hardpan has developed following repeated cropping. On sandy soils, rotary hoe cultivation is used to prepare a good seed-bed.

Figure 2. Four weeks after transplanting

For export, most varieties of Chinese cabbage will produce firm heads when sown between January and early March in Manjimup or between February and mid April in the Perth area. By using the more bolt tolerant varieties, plantings may occur until early May in Perth, especially if transplants are used.

For the domestic market, planting in the Perth area may be from mid July to May. Avoid planting from June to mid July, as this results in more bolted plants. Weekly to fortnightly plantings are usually made to ensure continuity of supply throughout the season.

Chinese cabbage used to be always sown directly into the field, but transplanting seedlings is now popular.

If planting directly from seed, or when growing seedlings for transplants, seed should be bought in a sealed tin or packet and stored in a cool and dry place. Once a container is opened, use the seed within a couple of months. For best results, purchase fresh seed each year. Good seed should have a germination rate greater than 85%.

Sowing

Seed is not usually treated with hot water before planting. However, if there have been previous problems with diseases such as Alternaria leaf rot, black-leg, black rot and white leaf spot, it may be necessary to treat the seed with hot water to remove these diseases before planting. Check to see that the seed has not already been heat-treated. The seed is kept in hot water at 52^{o}C for 25 to 30 minutes and then cooled and dried. It should be planted as soon as possible after treatment.
Seed is small (320 to 350 seeds per gram) and round. In 2004, seed cost was about 0.3 cents per seed. Seed for precision sowing should be tested for germination. It is usually sown with a precision seeder with two to three seeds per site. These are spaced about 2 to 3 cm apart at each site. The recommended sowing depth is 10 to 15 mm.

Germination is rapid, with four to seven days from sowing to emergence.

Thinning by hand is necessary at two weeks after sowing to ensure an even plant spacing and this requires a lot of hand labour.

Transplanting

Chinese cabbage does not tolerate bare root transplanting, but can be grown in a suitable potting mixture in cell packs and transplanted into the field. Cell-pack seedlings are best purchased from a specialist nursery as good quality plants are normally produced and there is less chance of soil-borne diseases. Seedlings are usually grown in trays which hold 100 plants and the individual cell-pack may have a diameter of only 15 mm and a depth of 10 mm.

The advantages of transplanting in cell-packs are as follows:

- Can be used to extend the season in Perth to enable planting during May.
- Crops are more uniform.
- Registered herbicides can be applied to control pre-emergent weeds just after planting.
- Less weed competition and less need for weed control.
- Less irrigation, pests and disease management is required.
- More even spacing can be achieved.
- No thinning is required.
- Plants mature about 10 to 14 days earlier, compared with sowing at the same time.

The main disadvantage of cell-pack seedlings is the cost of the plants (4 cents each in 2004). There is also a risk of stunting the plants if they are kept too long in the cell-packs before planting.

If you produce your own transplants, they should not be over-watered, as they are prone to the disease 'damping-off'.

Plant with a mechanical planter. Irrigate immediately after planting.

Seedlings should be about 19 to 25 days old and up to 35 days old when transplanted from a nursery during summer and winter respectively.

Figure 3. Established crop only 14 days after transplanting

Spacing

Row spacing is usually 35 to 40 cm, with 35 cm between plants in the row for Wong Bok varieties and 30 cm between plants for Michihili varieties. At these spacings, about 500 g/ha of seed is needed. The export market now desires a smaller head and it may be necessary to plant as close as 35 by 30 cm, or 35 by 25 cm. It is important to ask the exporter or wholesale agent about the preferred size, so the spacing can be adjusted if necessary.

In the Perth area, four rows are planted per 1.5 m bed (distance between tractor wheels). Some growers plant the rows next to the tractor path at a closer spacing, as these plants would otherwise grow larger than the two inner rows.

Weed Control

Chinese cabbage is more sensitive to residual herbicides than other brassicas. Where Chinese cabbage is planted from seeds, use a paddock with a history of few weeds as there are no registered herbicides to control germinating weeds in direct seeded crops.

Herbicides may be used in transplanted crops. Use either propachlor (Ramrod Flowable®) at 12 L/ha or metolachlor (Bouncer® or Metolachlor®) at 3 to 4 L/ha to control germinating weeds. These are applied immediately after planting and then washed in for a few minutes by sprinkler irrigation. These herbicides belong to the same chemical group (amides).

If the site contains many weed seeds, much hand labour may be needed to control weeds for the first 5 weeks in seeded crops. After this time, the strong growth of the Chinese cabbage should result in less weed competition. Sites known to be infested with Brassica weeds such Wild Radish, Wild Turnip or London Rocket should be avoided because no selective herbicides are available to control these.

Sethoxydim (Sertin®) may be used to control emerged annual grass weeds in crops preferably when weeds are at the 2 to 6 leaf stage. Sertin® can be safely sprayed over Chinese cabbage plants, more than 42 days before harvesting.

Fertilising

Regular supplies of nutrients are essential to obtain high yields and quality. However, it is important to not over-fertilise, as this will increase costs and may result in induced deficiencies of some elements and could pollute waterways and groundwater.

Two months before planting submit representative soil samples to a laboratory to determine the pH (level of acidity or alkalinity), total salts (electrical conductivity) and available phosphorus and potassium. The results of these tests can give a guide to the rates of these fertilisers required by the crop.

Phosphorus must be applied before planting on loamy soils which fix phosphorus to the soil particles. The recommended method in districts such as Manjimup is strip application in bands approximately 20 cm apart incorporated to 15 cm depth immediately in front of the transplanter shoe. Potassium can also be applied this way on loamy soils. Mixed NPK fertilisers high in phosphorus are recommended to be applied before planting. Blends based on double or triple superphosphate or di ammonium phosphate (DAP), plus potassium are recommended. On these soils, pre planting fertiliser rates in excess of 1,200 kg/ha are often required.

The situation for sandy soils is different. Lower rates of phosphorus are generally required and it is much more available to the plants. Double or triple superphosphate can be applied before planting, while nitrogen and potassium fertilisers should be regularly top-dressed while the crop is growing.
Transplant seedlings will establish rapidly if they are dipped or drenched with a solution of potassium nitrate at 40 g/L, plus mono ammonium phosphate (MAP) at 5 g/L, immediately prior to transplanting. The cell potting mix should be thoroughly wetted by this solution for it to be effective and a rate of 500 ml of solution per tray applied within two hours of transplanting is recommended. Seedlings will wilt in the trays if transplanting is delayed beyond two hours.

Fertilisers applied after planting are usually banded on each side of the row from seven days after transplanting until practical row-closure (see Figure 4).

Figure 4. Banding fertiliser to seeded crop, just before thinning

Fertigation is used to apply fertilisers after row closure (about 35 days from sowing, or 25 days after transplanting). With this system, soluble fertilisers are applied through the irrigation water. After fertigation, apply water to wash the nutrients into the soil for three minutes with 'butterfly' sprinklers and six minutes for 'knocker' sprinklers'. Continue fertilising until one to two weeks before harvesting.

As a guide to the effectiveness of your fertilising program, submit a sample to a laboratory for leaf analysis. This is taken from 20 plants selected at random, using the youngest mature leaf from each plant. Symptoms of the most common nutrient deficiencies are described in Table 3, which includes optimum nutrient concentrations for youngest mature leaves. Leaf analysis shows the level of nutrients that have been taken up by the plant in recent weeks. Sap analysis is now being used more often to determine the level of nutrient uptake on the day of sampling. Results may be available quickly, but the absence of comparative data may make it more difficult to interpret the results.

Nitrogen

Nitrogen fertiliser needs to be applied regularly throughout the life of the crop because it leaches from the root zone in all soil types. Chinese cabbage is not sensitive to the form of nitrogen applied, and satisfactory results can be achieved with urea, ammonium or nitrate forms. Care should be taken not to apply high rates of nitrogen too close to harvest because this practice can aggravate bacterial soft rot development in the crop.

Phosphorus

Phosphorus (P) is usually applied before, or at planting to loamy soils as described earlier. Single superphoshate is not a preferred source of phosphorus, because it contains higher concentrations of cadmium, which is a heavy metal. Cadmium levels in vegetables are monitored regularly in quality assurance programs to ensure regulatory limits are not exceeded.

Potassium

Applications of potassium fertilisers are needed for maximum vegetable crop production on most Western Australian soils. In the Manjimup district, on loams, which are not prone to leaching, potassium fertiliser can be broadcast before planting. On sandy soils, potassium is easily leached, so that it is best applied at regular intervals while the crop is growing.

The two major sources of fertiliser potassium are potassium sulphate (41.5 per cent potassium) and muriate of potash or potassium chloride (49.8 per cent potassium). Muriate of potash is cheaper, but the sulphate is preferred if soil or irrigation water have salt levels that might adversely affect crop growth. Use 15 per cent more sulphate of potash, as it contains less potassium than muriate of potash.

Potassium and nitrogen may also be applied together as potassium nitrate (38 per cent potassium and 13 per cent nitrogen), which is a soluble fertiliser suitable for fertigation.

Magnesium

Magnesium is required at a good level, but not as much as the main nutrients; nitrogen, phosphorus and potassium. A deficiency may sometimes appear on acidic soils, especially in the Manjimup district. Apply in the general mix with trace elements before planting (see Table 2.)

Trace Elements

A range of trace elements is needed for healthy growth, but only small amounts are needed. They may be available from the soil in sufficient levels from previous fertiliser applications. They include boron, copper, iron, manganese, molybdenum and zinc.

On loams, trace elements are available in the soil for longer compared with soils on the Swan Coastal Plain. On sandy soils, trace elements generally need to be applied every two to three crops. However, the use of this trace elements mix before every crop of Chinese cabbage is beneficial.

Compound fertilisers such as NPK Blue® and Nitrophoska® contain trace elements and extra amounts may not be needed during cropping if these fertilisers are used. Apply the following rates of magnesium and trace elements to the soil in all areas.

Table 2 Magnesium and trace elements before planting

Nutrient	Fertiliser	Rate (kg/ha)
Magnesium	Magnesium sulphate	200
Manganese	Manganese sulphate	20 to 25
Boron	Borax	18
Copper	Copper Sulphate	18
Iron	Ferrous sulphate	18 (Perth) to 28 (Manjimup)
Zinc	Zinc sulphate	18
Molybdenum	Sodium molybdate	2

Nutrient Deficiencies

Table 3 Symptoms of nutrient deficiencies

Nutrient	Optimum leaf levels when heads are just visible	Deficiency symptoms	Comments
Nitrogen	3.0 to 6.0%	Pale inner leaves and yellow outer leaves. Reddish tints in old leaves.	
Phosphorus	0.5 to 0.9%	Plants are pale and stunted.	
Potassium	3.0 to 6.0%	Marginal and interveinal yellowing develops on older leaves, followed by scorching of affected areas. In severe cases, the whole leaf may be affected.	
Magnesium	0.20 to 0.50%	Distinct yellowing between the veins on oldest leaves.	
Calcium	1.0 to 3.0%	See 'tipburn'.	Leaf analysis is not reliable as a guide to calcium levels in plants.
Boron	20 to 40 ppm	Horizontal cracking on the outside of the mid-rib and a brown corkiness in the inside of the mid-rib can occur (see Figure 5). If severe, there may be leaf distortion and several growing points.	On alkaline soils (pH in water greater than 7.0), apply boron weekly as borax at the rate of 1 to 2 kg/ha by fertigation. Leaf analysis is not reliable as a guide to boron levels in plants.
Copper	4 to 7 ppm		
Iron	25 to 200 ppm		Leaf analysis is not reliable as a guide to iron levels in plants.
Manganese	30 to 60 ppm	Veins on the leaf remain green against a pale yellow background.	May occur on alkaline soils. Apply manganese sulphate monthly at 2 kg/ha by fertigation.
Molybdenum	0.5 to 1.0 ppm	Plants remain stunted and pale. Leaves become stiff, leathery and cup upwards.	On acid soils (pH in water less than 6), it may be necessary, two weeks after planting, or emergence, to spray sodium molybdate at 150 g per 100 L water.
Zinc	30 to 60 ppm	Similar symptoms to manganese, but new leaves become small and twisted as well as interveinal chlorosis.	Leaf analysis is not reliable as a guide to zinc levels in plants. May become deficient in alkaline soils.

Figure 5. Boron deficiency, showing brown corkiness on the mid-rib

Fertiliser program for sandy soils similar to the Perth area

Phosphorus may be applied, at the suggested rates shown in Table 4, which are based on research work with another brassica crop, cauliflowers.

Table 4. Suggested rates of double superphosphate to be broadcast and incorporated before planting on yellow Karrakatta sand

Soil test results for phosphorus (mg/kg)*	Kilograms per hectare of phosphorus	Kilograms per hectare of double superphosphate
0 to 5	175	1000
5 to 10	170	970
10 to 15	150	860
15 to 20	130	760
20 to 25	115	660
25 to 30	100	555
30 to 35	80	445
35 to 40	60	340
40 to 45	40	240
45 to 50	25	140
50 to 55	25	140
> 55	25	140

*Colwell soil test, note 1 mg/kg =1 part per million (ppm).

A maintenance application of 140 kg/ha of double superphosphate is recommended if soil phosphorus levels are adequate.

After planting, the most efficient method to meet the crops nitrogen and potassium demand is to spray Urea (low biuret form) together with potassium nitrate twice per week for the first two weeks after planting at the rates shown in Table 5. Banded applications of granular fertiliser should commence at around 14 days and continue at seven day intervals until row closure. After row closure, nitrogen and potassium fertiliser can be fertigated until 14 days before maturity. In winter, the main fertiliser program may have to be continued for up to five more weeks at half rates of urea per week.

Table 5. Post-planting main fertiliser program for Chinese cabbage growing from March transplants on sandy soil.

Time after planting	Sulphate of potash (kg/ha)	Urea (kg/ha) (Lb = low biuret-grade sprayed)	Potassium nitrate (kg/ha) (Gh = green-house-grade sprayed)	Mag-nesium sulphate (kg/ha)	Borax (kg/ha)
1 day		10 (LB)	20 (GH)		
4 days		10 (LB)	20 (GH)		
7 days		10 (LB)	20 (GH)		
10 days		10 (LB)	20 (GH)		
14 days			300 (Banded)		
3 weeks		140 (Banded)		50	3 (Sprayed)
4 weeks		140 (Banded)			
5 weeks	50 (Fertigated)	100 (Fertigated)		50	3 (Sprayed)
6 weeks	50 (Fertigated)	100 (Fertigated)			
7 weeks	50 (Fertigated)	100 (Fertigated)			3 (Sprayed)

The above fertiliser program, in addition to pre-planting fertiliser application, supplies nitrogen at 335 kg/ha, phosphorus at 88 kg/ha, potassium at 200 kg/ha, magnesium at 30 kg/ha, plus trace elements.

Fertiliser program for loamy soils similar to the Manjimup district.

Table 6 shows a suggested fertiliser program for the Manjimup district. Apply the higher rates of potassium on new land. Use the higher rate of magnesium on acidic soils.

Table 6. Fertilisers for loamy soils (such as Manjimup) for January sowing

Application time	Fertiliser	Rate
Before planting	Muriate of potash	300 to 600 kg/ha
	Magnesium sulphate	200 kg/ha
	Trace element mix (see text)	
At planting	DAP	750 kg/ha
	Triple Superphoshate (All Phos®)	1750 kg/ha
After planting Banded at 2, 3 and 4 weeks Fertigated (optional) at 8 weeks	Urea	100 kg/ha
	Urea	100 kg/ha
	Urea	100 kg/ha

Irrigation

Chinese cabbage does not have a deep root system and has a high demand for water for the whole growing period. It does not tolerate moisture stress in hot weather.

Perth area

In the warmer months, irrigating twice per day will give the best results. Apply 60 per cent of the water in the morning, preferably from 9.00 to 10.00 a.m. Apply the remaining 40 per cent of water in the afternoon, preferably from 1.00 to 2.00 p.m. Where temperatures exceed 35°C, apply three irrigations as this will result in less crop stress and more efficient use of water. Too much water in summer may result in more soft rot disease. In the cooler months, apply all of the water in mid morning.

On those days where foliar fertiliser applications are given, irrigate early in the morning so that the foliage is dry by the time of spraying. Delay or omit the afternoon watering to allow maximum nutrient uptake from the spray through leaves and roots.

On sandy soils, irrigate with 120 per cent of daily evaporation for the first two weeks after sowing to give good establishment and to stop wind erosion. Reduce the watering on young crops to 100 per cent of daily evaporation and then irrigate with 120 per cent of daily evaporation when the crop has reached full ground cover (see Table 7). This table is based on average evaporation at Medina Research Station, 30 km south of Perth. In areas not close to Medina, use evaporation data from the nearest weather station. These data represent average conditions and adjustments must be made for marked changes in temperatures, humidity, effective rainfall and wind speeds.

Table 7. Irrigation per day on butterfly and impact sprinklers for average conditions in Perth area based on 120 per cent evaporation replacement rate.

Month	Average evaporation millimetres/ day at Medina Research Station	Kilolitres of water needed per hectare per day at 120 per cent replacement rate	Minutes per day for a typical butterfly sprinkler	Minutes per day for a typical impact sprinkler
January	8.8	105	33	76
February	8.9	107	34	78
March	6.8	81	26	59
April	4.0	48	15	35
May	2.6	31	10	23
June	2.0	24	7	17
July	1.9	23	7	17
August	2.3	27	9	20
September	3.3	39	12	28
October	4.8	57	18	41
November	6.6	79	25	57
December	8.4	101	32	73

The irrigation data have been calculated for:

- butterfly sprinklers spaced at 6 x 6 m (277 sprinklers per hectare), with an output of 15 litres per minute, i.e. 4.15 kL/ha/minute, effectively applying about 25.0 mm per hour.
- impact ('knocker') sprinklers at a spacing of 12 x 12 m (69 sprinklers per hectare) with an output of 25 L per minute, i.e. 1.525 kL/ha/minute effectively applying about 10.4 mm per hour.

It is not necessary to irrigate if rainfall exceeds evaporation by 1.0 mm or more. Adjust the irrigation time if rainfall is lower than the actual evaporation.

Manjimup district

Semi-permanent sprinklers or lateral pivots are normally used for irrigation in the warmer months in the Manjimup district. Water in the morning if possible, so that the plants are dry by the evening and are less susceptible to diseases.

After planting, water every day for the first week if the weather is warm, followed by two to three irrigations per week when established. It is preferable to water according to 100 per cent daily evaporation water replacement, i.e. for an evaporation of 4.8 mm apply 4.8 mm (48 kL/ha) irrigation water. If the evaporation system is not used, as a general rule irrigate with 25 mm water (250 kL/ha) every two to three days. More water needs to be applied during hot periods.

Water Quality

Chinese cabbage has moderate tolerance to salinity. Water salinity should be less than an electrical conductivity of 160 millisiemens (mS/m) per metre (880 milligrams/litre total salts) for established plantings and less than 50 mS/m (275 mg/L total salts) for seedbeds and nurseries. Plants seriously injured by salt are stunted and have thick dark green leaves with marginal yellowing or burning.

Pests

Chinese cabbage is susceptible to a similar range of pests and diseases as other brassica crops. There are many pests and diseases of Chinese cabbage and regular crop surveillance, recognition and treatment is essential to maximise returns. Pests can vary in importance from season to season, depending on the weather and the management practices adopted by the grower.

Rotate pesticides regularly to prevent the development of resistance by pests to individual pesticides, or to pesticides in the same chemical group. Tables 8 and 9 show the chemical groups for various pesticides. It is important to rotate pesticides from different groups when controlling pests, especially the diamondback moth.

Chinese cabbage is mentioned specifically on some pesticide labels. However, many registered pesticides for use on this crop may also be listed for use on brassicas, crucifers or leafy Asian vegetables. Follow the guidelines for safe use of a pesticide on the pesticide label. When using pesticides, follow label directions carefully and wear protective clothing, including a respirator.

Only add wetting agents to pesticides if this is advised on the label. Overuse of wetting agents may strip the natural wax coating from leaves and promote disease. Spray late in the day. Observe the withholding period, which is the minimum number of days between spraying and harvesting.
The following pests may damage Chinese cabbage.

Insects

Various types of aphids may be found under the leaves, at the base of the leaves and on the young leaves. These are small sap sucking insects, and have winged or wingless forms. They may be a serious pest from March to May. They may require spraying, to prevent stunting, leaf distortion of young plants, cosmetic damage to the heads (especially for export), virus transmission and increased soft rot.

The most damaging caterpillar is the young stage of the diamondback moth or cabbage moth (Plutella xylostella), especially from September to April. The caterpillars are light green/brown and up to 12 mm long. They tunnel into the heart of the plant and can be difficult to control with insecticides. Adult moths are small and slender, grey to brown in colour; with white diamond-like markings on their backs. Pesticide resistance is a major problem affecting control of diamondback moth. Strategies to reduce the risk of insecticide resistance are based on using a biological insecticide containing Bacillus thuringiensis (Bt) during the early stages of the crop and alternating pesticides from different chemical groups at later stages. To obtain the best results, the larvae should be sprayed

when they are small. Regular crop scouting should be conducted to determine the need to apply insecticides to control diamondback moth. If pest pressure is low, the application of insecticides may not be necessary. Crop scouting can be done either by the grower or by using a commercially available crop scouting service. A resistance management strategy for diamondback moth control in vegetable brassica crops has been developed and is reviewed each spring.

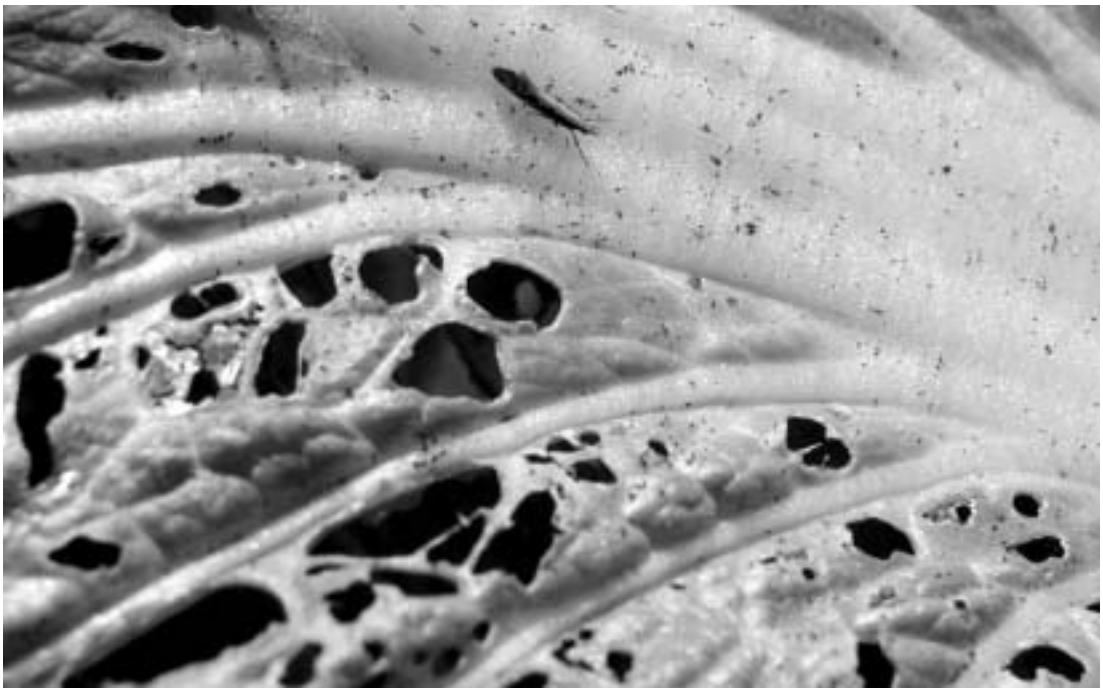

Figure 6. Damage caused by caterpillars (not visible) of diamond back moth. The slender moth can be seen in the middle and a single pupa (immobile resting stage) at the top.

The cluster caterpillar (Spodoptera litura) may bore holes, skeletonize the leaves and cause severe damage in the warmer months. The caterpillars are easily recognised by the triangular shaped markings along the back. Spraying is essential when the caterpillars are less than 10 mm long. Control of weeds, especially portulaca or pigweed is also most important. Caterpillars of other species such as cabbage white butterfly (Pieris rapae), and native budworm (Helicoverpa punctiger) may also damage Chinese cabbage.

Figure 7. Cluster caterpillars are browner and larger than diamond back moth caterpillars

Cutworm (Agrotis spp.) are fat brown, grey or pink caterpillars that live in the soil. They feed at night, often eating plants off at the base. Rutherglen bug is a plague insect which may damage crops in late spring/early summer. Springtails are small, jumping, insects that may damage the top of the heads in autumn. Adults and caterpillars of black beetle may also damage young crops.

Both the adults and larvae of the vegetable weevil (Listroderes obliquus) feed on Chinese cabbage. Adults are common in autumn and spring, while larvae can be troublesome in winter and spring if adults are left unchecked. This pest has been damaging mainly in the Manjimup district. Adults have a typical weevil snout, are dull brown-grey and about 8 mm long. Larvae are cream to pale green with a brown head and look like a fat maggot. Adults and larvae are often difficult to find, as they feed at night and shelter in the soil by day. They show their presence by their characteristic damage to plants of serrated edges of the leaves. The larvae are particularly damaging to the heads. If not controlled early, larvae will be protected from insecticide by wrapper leaves.

Other pests

Red-legged earth mites (Halotydeus destructor) are only 1 mm long, with black bodies and eight orange legs. They cause silvering of leaf surfaces, usually in autumn.

Slugs and snails may cause considerable damage to plants during wet weather.

The presence of swollen roots usually indicates clubroot disease and not nematodes. However, Chinese cabbage may sometimes be damaged by sugar beet nematode which appears as small, glistening, white globules on the roots. Root-knot nematode may occasionally damage roots. The use of metham sodium as a soil fumigant, two weeks before planting, should help to control nematodes. Table 8 shows some pesticides registered on Chinese cabbage. Before purchasing pesticides, check the labels to confirm if pesticides are still registered, or if an off-label permit is available.

Table 8 Pesticides registered on Chinese cabbage to control pests.

pest	Pesticide chemical name	Tradename®	Chemical group	Withholding period (days)
Aphids	dimethoate	Various	1B	7
	imidacloprid	Confidor	4A	7
	methamidophos	Nitofol, Monitor	1B	7
	pirimicarb	Pirimor	1A	2
Cabbage white and cluster caterpillars	thiodicarb	Larvin	1A	7
Cutworm	chlorpyrifos	Various	1B	Apply before planting
Diamondback moth caterpillars	Bacillus thuringiensis	Various (Organic)	11	0
	alpha-cypermethrin	Various	3A	1
	beta-cyfluthrin	Bulldock	3A	1
	chlorfenapyr	Secure	13A	7
	cypermethrin	Various	3A	1
	deltametrin	Various	3A	2
	methamidophos	Nitofol, Monitor	1B	7
	methidathion	Supracide	2B	7
	spinosad	Spinosad	5A	3
Redlegged earth mite	chlorpyrifos	Various	1B	5
Slugs and snails	methiocarb	Mesurol		7
Sugar beet nematode	fenamiphos	Nemacur	1B	Apply before planting

Diseases

Bacterial and fungal diseases can cause severe damage to Chinese cabbage. To minimise disease, rotate crops, control weeds, plough in old crops immediately after harvest and avoid planting in low-lying, sheltered sites in winter. Many of the diseases have similar symptoms, especially the leaf-spotting types and it may be necessary to have a laboratory examination to determine the cause of the disease. Residues of old crops should be destroyed immediately after harvesting, to limit the spread of diseases to adjacent younger plantings.

Leaf spot or blackspot (Alternaria species) is a fungus that may cause moderate damage to Chinese cabbage in cool, moist conditions. Small dark leaf spots develop, up to 10 mm diameter, often with concentric rings, resulting in a 'target spot' appearance. The disease is spread by wind-borne and water-borne spores.

Bacterial soft rot is caused by the bacterium Erwinia carotovora. This has occasionally resulted in total crop failure to mature plants, especially in hot weather and on heavy, poorly drained, soils. It is often a problem in transport and storage, as well as in the field. Soft mushy areas develop on heads, often first on old leaf bases near the ground. Later, much of the head may disintegrate into a light brown slime. Bacterial soft rot can be reduced by applying less nitrogen and by not over-irrigating. Soft rot bacteria enter the plants through wounds. Tipburn and burn from solid fertilisers, particularly from heavy nitrogen applications, allow the entry of the bacteria. Fertigation after head formation will reduce bacterial soft rot. Both low and heavy rates of fertilisers containing nitrates will also increase the potential for bacterial soft rot.

Figure 8. Soft rot showing typical slimy growth in summer

Black-leg (Leptosphaeria maculans/Phoma lingam) is a fungus which causes large white lesions, on the older leaves, within which are produced black fruiting bodies. The disease is carried on seed and is readily introduced by this means. Once present in the crop, the disease spreads by wind or water-splashed spores from crop residues in the surrounding fields. The disease is not usually a problem where seed is treated with hot water.

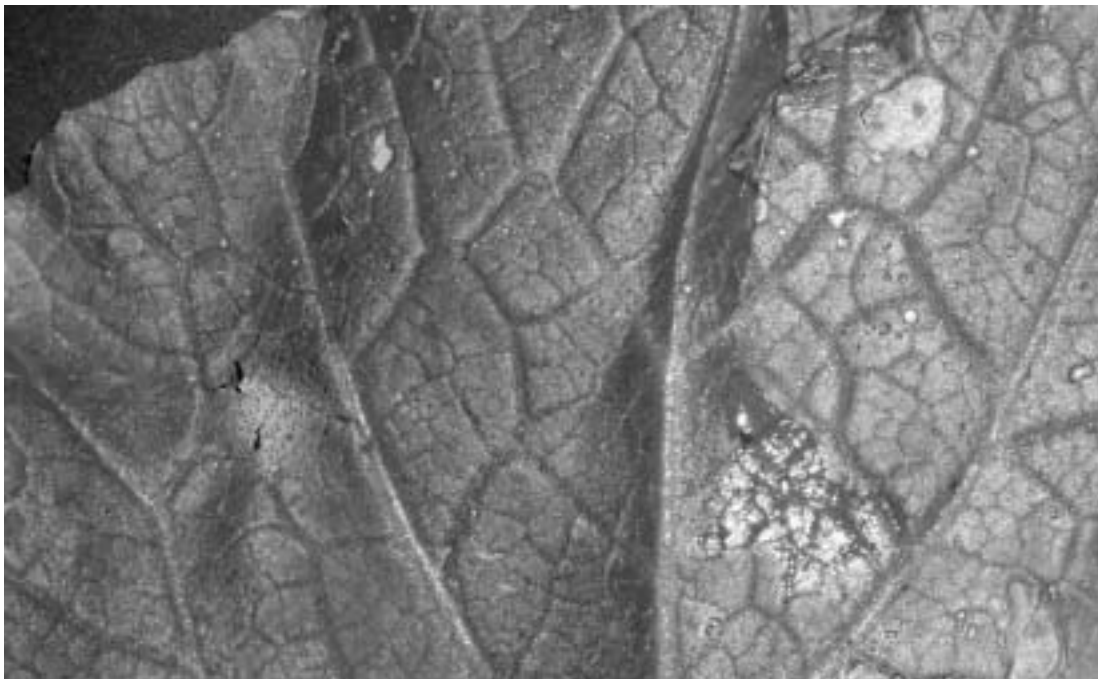

Figure 9. Lesions caused by black-leg, which also resembles some other diseases found in Chinese cabbage

Black rot (Xanthomonas campestris) is a bacterium which results in V shaped lesions on the edges of the leaves, especially in autumn and winter.

Clubroot is caused by the fungus Plasmodiophora brassicae, and has resulted in severe losses to Chinese cabbage and other brassica crops in all areas. Spores from the fungus can survive in the soil for up to 20 years. The first above-ground symptom of clubroot is wilting during the day. The roots of infected plants swell and become distorted. The effects of clubroot are more obvious during warm weather. As the disease advances, plants may wither and collapse. Clubroot is encouraged by acid soils and moist conditions. Liming, fumigation with metham sodium and wide rotations (no brassicas for four to five years) may help to reduce the severity of the disease.

Figure 10. Typical swollen roots caused by clubroot

Figure 11. Wilting in the field caused by clubroot

Sclerotinia (Sclerotinia sclerotiorum) is a fungus that damages Chinese cabbage and other vegetables during cool, wet conditions and often appears following tipburn. Up to one quarter of the crop may be damaged. Crops can be infected at any stage of growth and any part of a plant may become infected. Common symptoms are the development of a soft rot, with a water-soaked appearance. Fleecy, white fungal growth is produced on the rotted tissue and is usually followed by the formation of small, black, hard pebble-like fungal bodies. It is most common on the Swan Coastal Plain, where close rotations are practised with other susceptible crops. There are no pesticides registered for the control of Sclerotinia in Chinese cabbage.

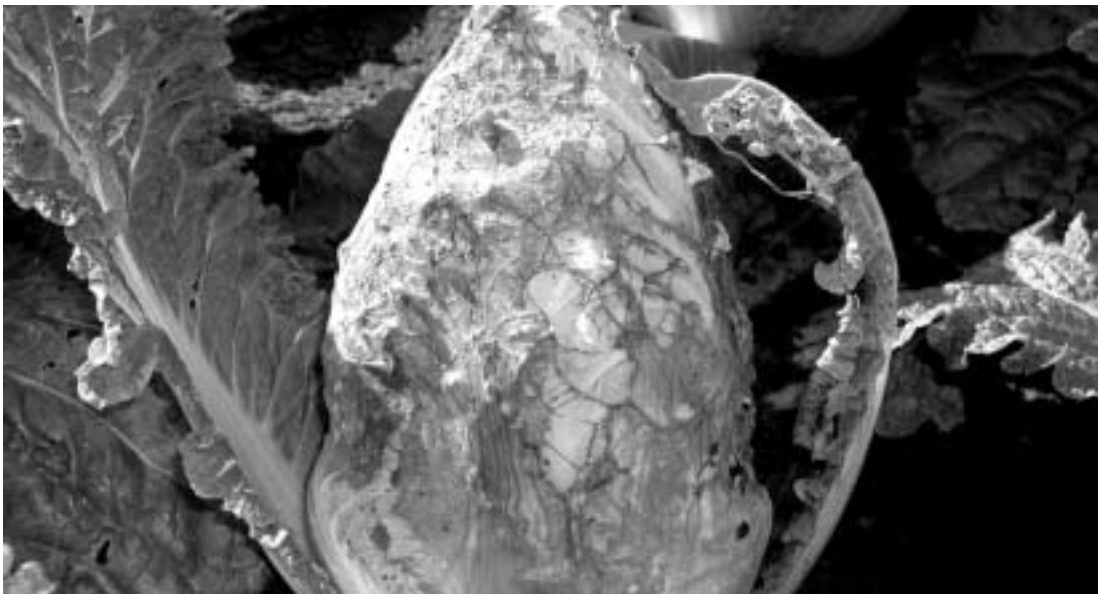

Figure 12. Sclerotinia disease showing typical white mould at the base of the head

Stemphyllium and ringspot (Mycosphaerella species) are fungal diseases which cause large circular spots on the old leaves in autumn and winter. They can be confused with other diseases of Chinese cabbage.

Chinese cabbage can occasionally be affected by cauliflower mosaic virus and turnip mosaic virus, which are spread by aphids. Leaves may be mottled and distorted.

White leaf spot (Pseudocercosporella capsellae) is caused by a fungus and is characterised by the development of white to brown spots about 10 mm across. The disease is first observed on

older leaves and, in severe cases, causes leaf losses. It is most common in wet autumn and early winter conditions.

A strain of White Blister Rust (Albugo candida) has recently been seen on Chinese cabbage. In the cooler months. it appears as small, white blisters on the underside of the leaves.The few pesticides for the control of diseases in Chinese cabbage are shown in Table 9.

Table 9. Pesticides registered on Chinese cabbage to control diseases

Disease	Pesticide active ingredient	Tradename®	Chemical group	Withholding periods (days)
Alternaria spot	copper hydroxide	Various	Phthalimide	1
	copper oxychloride	Various	Inorganic	1
	mancozeb	Mancozeb	Dithicarbamate	7
Black rot	copper hydroxide	Various	Inorganic	1

Black dot

Black dot is a condition in which thousands of small black dots are present per leaf, up to the ten oldest leaves, usually followed by leaf yellowing and burning on the leaf margins. This has resulted in 100 per cent damage to some plantings in the past 15 years.

A trial by the Department of Agriculture in 2003 showed that black dot was due to phytotoxicity from the fungicide with the active ingredient procymidone (Sumisclex® or Fortress®). This should not be used on Chinese cabbage and is not registered on brassicas.

Figure 13. Black dots on outer leaves and associated burning on leaf margins

Bolting

In the Perth area, extended periods of cold weather below 13^{o}C from April to September will cause Chinese cabbage to bolt, which will result in produce that is unmarketable. In the Manjimup district area, young plants may be affected by bolting from March to December. Bolting will occur when temperatures are low for one to three weeks during early growth. If temperatures are very low, a flowering stalk may emerge before a head has formed. If the flowering stalk is less than half way up the head, this is acceptable in the market place when supplies are low. Bolting may also occur if the soil is too dry after seeding. Varieties show different susceptibility to bolting (see 'Varieties').

Figure 14. Transplanted in late July and showing severe bolting in early October

'Gomasho'

'Gomasho', or speck or pepper spot, is a black to brown spotting or specking of the normally white leaf midribs of heads (see Figure 15). It may not be obvious in the field or at harvest, but develops in cool storage and has resulted in rejection of export consignments.

The disorder was named in Japan where 'Gomasho' means 'sesame symptom', referring to the small specks which are the shape and size of sesame seeds.

Despite much research in Western Australia and overseas, the cause of gomasho is not known. However, high nitrogen fertilisation, especially with nitrates near harvest, can make the disorder worse. The use of urea is preferable to nitrate fertilisers. Gomasho also appears to be worse in crops growing in cold, humid conditions in late May and June. Varieties vary in their susceptibility to gomasho (see 'Varieties'). The disorder is worst in alkaline soils.

If Gomasho is noticed at a low level during packing, it should be consigned to a close export destination such as Singapore and not placed into storage for a long time, or sent to Taiwan by sea-mail.

Figure 15. "Gomasho" on midrib of leaf

Oedema

Oedema occurs during periods of high humidity, when the plant pumps water faster than the water moves through the leaves. This ruptures the cell walls and causes raised corky blisters on the lower surfaces of the leaves.

Tipburn

Tipburn is characterised by scorching of the upper margins of young leaves, which also become cupped and distorted. It is mainly a problem because bacterial soft rot and Sclerotinia disease can develop on the dead tissue. The exact cause is unclear, but it would appear that calcium deficiency is a contributing factor. This does not move quickly in plant cells and tip-burn can still occur where there are good supplies of calcium in the soil. It also occurs more when temperatures exceed 26^{o}C, or conditions are humid or windy. However, it can also occur in cold and wet conditions.

Growers can help prevent the problem occurring by avoiding the following:

- Acidic soils. As soil pH falls below 6.0 (measured in water), calcium becomes less available to plants.
- Dry soil conditions.
- Excessive applications of ammonium based fertilisers, which compete with calcium for uptake and may burn the roots.
- Use of MAP or DAP fertilisers late in the life of the crop which do not contain any calcium and contain ammonium nitrogen.
- High levels of salt in the soil or irrigation water.

Calcium sprays, such as calcium nitrate (1 kg/100 L) applied to young crops, where all leaves are exposed to the spray, may reduce tipburn but the benefit is usually only small.

Yields

Yields of up to 100 tonnes per hectare are possible, with good commercial yields in the range of 50 to 70 tonnes (2000 to 2800 cartons) per hectare.

At least 80 per cent of plants should be marketable, with main losses caused by bolting, soft rot, diamondback moth, off-types and Sclerotinia disease.

Figure 16. Harvesting with assistance of a conveyor belt platform

Harvesting

Harvesting requires considerable hand labour, as Chinese cabbage is not fully mechanically harvested. A well grown Chinese cabbage crop can be 'face cut', i.e. the whole crop is picked at the same time. The best time for harvesting is early morning. Chinese cabbage is cut by hand, at ground level. Trim the outer leaves from the head and cut the butt flush with the outer leaf bases. The heads are placed directly onto a trailer by hand or onto a conveyor belt or gantry attached to a self-propelled harvesting-aid. They are carried on the gantry to bulk bins holding about 250 kg of Chinese cabbage.

There are normally three to four pickers and one packer. The harvesting-aid may hold up to eight bulk bins and is shaded. Each bin may be lined with plastic-bubble in tiers, to reduce bruising. Care should be taken not to block the ventilation slats on the sides of the bins, as this will reduce the time to cool down the produce in the cool storage room.

Do not leave Chinese cabbage exposed to the sun and handle carefully at all times to avoid bruising, especially when placing onto the conveyor belt and into bins.

Take the bins to the growers' packing shed or export packers within 30 minutes of harvesting and drive slowly on farm and rough roads to avoid bruising.

Domestic Markets

The domestic market prefers a slightly larger head than the export market. The best size is 8 heads in an 84 L crate, but 10 heads may also be packed. The heads must be full and firm. The heads are trimmed of old leaves, but less leaves are removed, compared with export of Chinese cabbage. In the supermarkets, large heads may be divided and displayed in polythene wrapping.

Chinese cabbage is mainly sold through the Market City Canning Vale markets, where the through-put is about 700 t per year.

There are no grading regulations for Chinese cabbage sold in Western Australia.

Export Markets

Demand for our Chinese cabbage in South-East Asia exists principally between April and October, when Taiwan is not exporting. Our peak supplies are from May to August, when the best quality is obtained.

The risk of bolting from late plantings prevents the reliable supply of export Chinese cabbage in September and October. There are also risks in using cool storage to extend the supply season, because 'gomasho' may become an increased problem with storage.

Prices for Chinese cabbage on export markets may be variable and growers have lost money in some years. There has been strong competition from China on export markets in South-East Asia in recent years.

A total of 410t of Chinese cabbage, worth $457,000 were exported from Western Australia in 2004/2005, representing 20 per cent of the total exports from Australia. This compares with 1991/92, when 5,894 t were exported from Western Australia. At that time, Western Australia consigned 80 per cent of the total exports from Australia and 82 per cent of Chinese cabbage was consigned to Hong Kong. The main markets for exported Chinese cabbage in 2002/2003 were Singapore (64 per cent), Taiwan (22 per cent) and only 4 per cent was consigned to Hong Kong.

Chinese cabbage is consigned by sea to export markets, especially in 40 foot containers. The best size for export is 0.9 to 1.2 kg, with no more than 1.5 kg per head.

A number of companies in Western Australia pack Chinese cabbage for export. Discard heads that do not conform to export requirements. Heads may be each wrapped in tissue paper or may be unwrapped. They are packed into two-piece cardboard cartons, with a net weight of 20 or 25 kg.

Transporting

Cooled and packed produce is trucked to the export wharf in either 'gate and tarp' Tautliner® trucks or Pantech® sea containers. A 6 m sea container holds a total of 400 cartons.

Most Chinese cabbage for overseas markets is sea-freighted in refrigerated containers, but air freighting may be conducted if produce is urgently required.

Sea consignments are kept at a storage temperature of 0 to 1^{O}C for the six-day voyage from Perth to Singapore.

Storage

When cut, heads of Chinese cabbage respire rapidly, thereby producing heat and losing moisture. In hot weather, place the bulk bins into a cool room as soon as possible after harvesting and quickly cool down to 0 to 1^{O}C with a forced air cooler or vacuum cooler.

Do not place the bulk bins from the paddock into a cool room where heads have already been cooled down to 0^{O}C to 1^{O}C, as these will absorb heat from the new consignment.

Do not store with produce (i.e. apples, tomatoes) that release ethylene gas into the air, as this can result in a decrease in quality.

If required and if mild symptoms of 'gomasho' have not been sighted at harvest, Chinese cabbage can be held in cool-store at 0 to 1^{O}C for several weeks, provided the relative humidity of the cool-store is maintained above 98 per cent. The Wong Bok types will stay in good condition in storage for a longer time than the Michihili types. Produce is usually stored for only a few days before being exported. If produce is stored for seven to nine weeks, a browning of the inside of the leaf midribs may occur, especially with the WR Green 60 variety.

Further Reading

Department of Agriculture, Western Australia, Farmnotes and Bulletins.

- Bulletin 4328. Soil testing for vegetable production on the Coastal Plain.
- Bulletin 4512 (2002). Fertigation of vegetables.
- Bulletin 4582 (2004). Pests of Vegetable Brassica Crops.
- Farmnote 66/95. 'Irrigating vegetables on sandy soils'.
- Farmnote 110. Clubroot disease of crucifers.
- Farmnote 112. Control of white blister rust in broccoli and cauliflower.
- Australian Pesticides and Veterinary Medicines Authority (APVMA) website:http://www.apvma.gov.au
- Horticultural Australia Ltd. 'Field Guide to Pests, Diseases and Disorders of Vegetable Brassicas'.
- 'InfoPest' MSDS, on CD or DVD, may be purchased from the DPI, GPO Box 46, Brisbane, Queensland 4001. This gives information on registered pesticides for horticultural crops and includes labels.
- RIRDC Research Report No. 97/1. Production and Post Harvest Handling of Chinese cabbage.
- Good Fruit and Vegetables September 2005 'Chemical to blame in 'black dot' probe.