COLE CROPS

INTRODUCTION

This group of crops belongs to the family Cruciferae, and is thus also referred to as cruciferous crops or crucifers. The commercially important crops all belong to the genus *Brassica*, hence the reference to brassica crops or simply brassicas.

The botanical names of these crops, arranged in order of commercial importance in South Africa, are:

Cabbage - *Brassica oleracea* L. var. *capitata*.
Cauliflower - *B. oleracea* L. var. *botrytis*
Sprouting broccoli (or calabrese) - *B. oleracea* L. var. *italica*.
Brussels sprouts - *B. oleracea* L. var. *gemmifera*.

Some other vegetables in the same family include chinese cabbage, choumoellier , horseradish, kohlrabi, kale, various mustards, radish, turnip, swede (or rutabago), as well as a number of lesser-known vegetables.

There are also several important, usually winter, cruciferous weeds such as pepperweed, shepherd's purse, wild mustard and wild radish.

A point to remember with all the above plants is that they are closely related, and have similar climatic requirements, and are usually attacked by a similar range of pests and diseases. However, cole crop requirements, though similar, are not identical and there may also be larger differences in requirements between different horticultural cultivars of, for example, cabbage, than there generally are between cabbage and cauliflower.

Over a period of time, plant breeders have developed many different varieties within any of the above groups of vegetables, so that cultivars may differ greatly in shape, colour, length of growing season, compactness of head, tolerance to heat or cold, tolerance to specific diseases, and so on.

ENVIRONMENTAL REQUIREMENTS

Climate

The cruciferous crops may all be classified as cool-season plants, and make best growth under cool, moist conditions.

Cabbage

Best yields and quality are normally obtained from crops maturing during the cooler months from autumn to spring. The optimum mean temperature is about 17°C, with an average maximum of 24°C, and an average minimum of 4 or 5°C. Cabbages are fairly resistant to frost and hardy varieties will often survive minimum temperature as low as minus 3°C without obvious damage. However plants, especially young plants and mature heads, are much more sensitive to cold when temperature differences between day and night are large, or where sudden cold snaps occur.

Notwithstanding the above, cabbages are fairly well-adapted to growing under warmer conditions; some varieties much more so than others. They can thus be grown virtually throughout the year in all but the hotter areas of the country. Yield and quality are, however,

poorer under hot and dry conditions, when a strong bitter taste may develop. Summer cabbage crops are generally not as successful as those harvested under cooler conditions. Various pests and diseases are also more prevalent and difficult to control during summer, and these further reduce yield and quality of such crops.

Cauliflower

Cauliflower has a very similar temperature and moisture requirement to that of cabbages for optimum growth and development, but is much less adapted to extremes of heat or cold. Growth is also poorer at mean minimums of less than 7°C. Mature curds, if not protected by leaves, can be easily damaged by only a few degrees of frost. Heavy frosts can cause serious damage to the crop, particularly with sudden cold snaps. Cauliflower will also seldom give an acceptable yield or quality if it matures during hotter weather. Production is thus generally limited to autumn, winter (except in very cold areas) and spring. Nevertheless, growers in areas with cool conditions during the summer months have the opportunity of realising premium prices for their crops when there is the demand for cauliflower on tables during special occasions such as holidays.

Broccoli

Once again cool, moist conditions are best. This crop also cannot withstand quite the same degree of extreme temperatures that cabbages can, but it will be much better than cauliflower with variations from the optimum conditions. Under high temperature conditions, the heads may turn an unattractive yellowish-beige colour, particularly after harvesting, but it can occur before harvest. Broccoli also has a tendency to abscission or partial abscission of buds leading to a condition known as "brown bud". It is generally accepted that it is more common with certain cultivars when they are growing under stress. Observation suggest that the problem is more common when cold snaps are followed by periods of warm weather. The problem is worse on the more mature heads. It can be alleviated by harvesting more sharply (taking less-mature heads than normal) and at shorter intervals, when such conditions prevail.

Brussels sprout

This crop can withstand colder conditions than cabbage, but is probably more sensitive to high temperatures than even cauliflower. Under high temperature conditions most varieties produce loose, open ("blown") sprouts, which have no value. Brussels sprouts should thus be grown for harvest during the coolest period of the year (winter) in most areas. Many of the European varieties produce mainly "blown" sprouts even under winter conditions in many of South Africa's subtropical areas. Cold weather produces firm, tight sprouts with a sweeter flavour.

Brassicas are all biennial crops, which normally require some colder temperatures to induce seeding. If young plants are subjected to prolonged exposure to temperatures less than about 7°C, they frequently bolt to seed in spring before making an economic crop. Plants sown just before, or during, winter are more inclined to bolt. This bolting tendency is aggravated by drought, poor nutrition and other stress factors. Certain cultivars are much less prone to bolting than others.

Soils

Brassicas are fairly heavy feeders. They grow well on soils with a high organic matter content. They can be grown successfully on a great variety of soils, varying from sands to fairly heavy clay, provided the soil is fertile and suitably drained, yet having no lack of moisture.

They do best on deep, heavy loams. The crop should never lack nutrients or water, so the less fertile and hotter, drier, light soils are less suitable - such soils can obviously be used successfully if well fertilized, especially with the addition of organic manures to which these crops respond particularly well, and if more careful attention is paid to good irrigation practices.

Compacted soils are also less suitable. Should crusting occur after rain or irrigation, loosening such soil by tillage is important in the early growth stages at least

Cultivars
There are a number of cultivars available in the seed trade, with new ones continually being developed. It is a good practice to keep in touch with seedsmen to get their latest recommendations on cultivars possibly more suited to the local conditions and the planned planting times.

Some of the most popular cultivars in KwaZulu-Natal are as follows:

Cabbage
The older open-pollinated cultivars still being grown include Cape Spitz, Drumhead and Glory of Enkhuizen. Gloria is also popular in some areas, even though it is susceptible to Black Rot, as are the three cultivars mentioned above. The most popular commercial cultivars are all hybrids and all show some tolerance to Black Rot. They include:

Conquistador, Green Coronet, Green Crown, Grand Slam and Star 3306 for production during the cool season. Cultivars with a greater measure of heat-tolerance include the well-known Hercules and Green Star, as well as Centauro, Beverly Hills, Star 3301 and Star 3304.

Cauliflower
Popular cultivars include Incline, Glacier, Arizona, Fremont, Siria, Star 4403, Star 4405 and Tenere.

Broccoli
Green Valiant is possibly the most popular, but fair-sized plantings of Liberty, Pirate, Star 2201 and Viking are also made.

Brussels Sprouts
The crop is seldom grown commercially in KZN. The cultivars Amarosa, Jade Cross and Prince Marrel are grown on a small scale. Long Island is grown in home gardens.

Table 14.
Sowing times.

	Cold areas Heavy frost	**Warm areas Light Frost**	**Hot areas Frost free**
Cabbage	September - February	All year	Feb - June/July
Cauliflower	December - Feb/March August - September	January - April July - September	Feb - March/April
Broccoli	September - January	January - September	Feb - June/July
Brussels sprouts	Nov/Dec - February	January - March	Feb - April

CULTURAL ASPECTS

Direct seeding

In many instances, particularly in the more advanced countries where labour is expensive and in short supply, direct seeding in the commercial field is the rule. However, this practice is seldom followed in South Africa, for several very good reasons:

the harsh climate,
lack of solid-set sprinklers,
the inability to control weeds adequately on the larger land.

This method is finding more favour in South Africa as better equipment becomes available and labour becomes more of a problem. However, it can be recommended only where individual sowings at any one time are relatively small, where irrigation equipment allows for frequent watering, where excellent pre-plant weed control has been achieved or the weed pressure is low and, for preference, when sowing during the cooler, yet moist, months of the year. Seed usage is several times higher with direct seeding than where transplants are used. Up to 2 kg of seed per hectare may be required. Thinning out to the desired stand is necessary. Seedlings should emerge within about 5 days at soil temperatures of 20°C to 30°C, but may take two or three weeks to appear at temperatures of 10°C. Usually there is no germination at temperatures below 5°C or above 35°C.

Seedbeds

A more normal method is to sow in well-prepared seedbeds and to transplant the seedlings when they are sufficiently developed. The soil and fertility requirements for seedbeds are the same as those for the land. Soils which cap should be avoided. Seedbeds should not be made on any site where crucifers have been grown within the past three years. Sites for seedbeds should not be exposed to very strong winds, but there should be good air movement to reduce disease incidence. Avoid sites too close to rivers or streams, or where dew is heavy, for the same reason. However, easy access to irrigation water is essential.

The site should be fully exposed to the sun, and not too close to competitive tree roots.

Seedbeds should have a firm, level surface; low spots become too wet at times and high spots are often too dry. Beds should be no more than 1 m in width and of any convenient length, with narrow access paths between them. They are often raised a few centimetres above the normal soil surface to reduce the chance of water-logging should heavy rains occur.

Use a minimum of 300 square metres of bed for every 500 g of seed sown. Denser plantings will tend to produce unsuitably long, thin, lanky seedlings, which do not perform well. Seed is sown thinly to a depth of not more than 15 mm, in rows drawn 150 to 200 mm apart. Although seed size (usually 200 to 300 seeds/g) and germination do vary, a rule of thumb is to plant about 60 to 70 g of seed for every 10 000 transplants required, where seedbed conditions are good. Many growers plant about 10% more seed than they require, to ensure that sufficient seedlings are available to fill the entire land.

Frequent light irrigations are necessary to prevent drying out of the top soil in which the seed is planted. Gradually increase the interval between irrigations to about 7 days when the plants are well-established.

Drenching the soil just after emergence with Previcur N or Proplant can reduce the incidence of "damping-off", caused by various soil fungi.

Spray the young seedlings (weekly) with a suitable fungicide as a routine spray or at the

first signs of Downy Mildew. The danger of outbreak of seedling diseases rises considerably under conditions of overcrowding, inadequate ventilation and poor drainage from the seedbed. Spray with sodium or ammonium molybdate when the seedlings are 3 to 4 weeks old where molybdenum deficiencies are known to occur, and follow this a week later with a solubor spray where the soil is deficient in boron.

Keep the seedlings moist and growing strongly for 3 to 6 weeks or until they are 7 to 10 cm tall. Then reduce watering over the last 7 to 10 days (but do not allow the plants to wilt severely) in order to harden them to withstand the shock of transplanting. Give the seedbeds a good soaking the day before transplanting in order to restore a good water regime in the seedlings, and to facilitate lifting of the plants with minimal root damage.

Short, sturdy, slightly hardened seedlings about 10 to 15 cm tall, and with 4 to 5 true leaves, transplant and perform better than soft lanky, etiolated plants. The latter develop as a result of sowing too densely (seedbed area is too small), over-use of nitrogen fertilizers and over-watering. Under warm conditions, Brassica seedlings may reach the required size within 4 to 5 weeks, but under cooler conditions may take 7 or 8 weeks, even with good seedbed practice. Young plants of the required size yield better than older ones. Only those plants which have reached the desired size are used for transplanting. Those developing more slowly may be transplanted slightly later when they are more developed, but are ultimately less likely to perform as well.

Seed Trays

As an alternative to open seedbeds, most commercial and many small-scale growers in KZN produce their plants in styrofoam or similar trays (the so-called speedling system), or purchase plants from specialised nurseries who use this system. Whilst this system has certain advantages, particularly for those growers who cannot produce seedlings well in open seedbeds, there are also some disadvantages. Even comparatively poor or off-type plants (so-called sibs) are often usable from such seedlings, but would probably not be used from seedbeds, and the high cost of transplants may cause some growers to revert to open seedbeds, particularly for open-pollinated varieties or those with less expensive hybrid cultivars. However, there is a saving in seed cost, and speedlings transplant more successfully, and with most growers perform better, with a more uniform, concentrated maturity, than do seedlings raised in seedbeds.

Transplanting

It is obvious from the afore-going that selected, well-hardened, young, stocky plants should be used. Weak plants or those showing any abnormality, such as double-stem, no growing point, or diseased roots or stems, should in no circumstances be used. Transplant as soon as the plants reach the desired size. Have sufficient seedlings to be in a position to ruthlessly discard poor plants. Try to use "first full" plants only, as far as possible.

Lift plants carefully with as little root damage as possible, moisten them if necessary and cover them with moist sacking until transplanted. Lift only sufficient plants at a time to keep the planters busy.

Plant into moist soil for preference, firm the soil around the roots and irrigate again as soon as possible after setting the seedlings. Ensure that the roots of the seedling point straight down and are not bent during the planting process. Ensure that the correct spacing and plant population is achieved. Planting out on raised beds or ridges is advisable in wet areas, to reduce the risk of water-logging and stem or root rots.

Spacing

Spacing and plant population affect head size, head shape and yield. Should the specific market

demand be for large heads, then wider spacings and lower population, will be adopted for any specific variety than where the market prefers smaller heads. With broccoli there is a strong tendency for the denser plantings to produce a much larger portion of the total yield from the main heads rather than from the less popular side sprouts. With the exception of brussel sprouts, where individual sprout size is hardly affected by spacing, the denser the planting (within limits), the larger the total yield, but the smaller the heads. Generally speaking it is found that most growers tend to under-plant, i.e. have lower than optimum population.

The size of the tractor and implements available will very often determine the row spacings used.

Bearing the above comments in mind, the following spacings are suggested:

Cabbages:
— Large-headed types: 500 mm to 600 mm x 400 mm to 500 mm (40 000 to 45 000 plants per hectare).
— Medium-headed types: 500 mm to 600 mm x 300 mm to 400 mm (55 000 to 65 000 plants per hectare).
— Baby cabbages: 300 mm to 350 mm square (80 000 to 100 000 plants per hectare)

Cauliflowers:
— Large-framed varieties: 750 mm to 900 mm x 500 mm to 600 mm (about 22 000 plants per hectare).
— Small-framed varieties: 600 mm to 750 mm x 400 mm to 450 mm (about 35 000 plants per hectare).

Broccoli:
— Large-framed varieties: 600 mm to 750 mm x 400 mm to 500 mm (about 33 000 plants per hectare).
— Small-framed varieties: 600 mm to 750 mm x 300 mm to 350 mm (about 45 000 plants per hectare).

Brussels sprouts:
— All varieties: 900 mm to 100 mm x 450 mm to 500 mm (about 22 000 plants per hectare).

Rotational cropping
A three- or even four-year rotation is advisable for cole crops, mainly to reduce the risk of disease build-up. Cruciferous weeds must be rigorously controlled during the period when cole crops are not grown, or otherwise much of the benefit of crop rotation can be lost.

"Topping" of Brussels sprouts
Artificial stopping of the plants is done on most factory crops, by removal of, or damage to, the growing point of the stem. Disbudding is usually carried out by hand in South Africa, but the use of rubber mallets to crush the growing point is sometimes used. If not stopped, the plant will usually develop a smallish head - nearly tennis ball size - at the growing point, when cold weather sets in. Should this occur the yield of sprouts is lowered. Stopping is usually done when the plant has developed to the 25th to 30th set of leaves, counted in the natural spiral in which they occur on the stem, or else at about the time of first pick.

Stripping of lower sprouts on Brussels sprouts
This is practised only where the sprouts at the base of the plant, often worthless where the lower leaves have dropped, are badly infested with insects (especially aphids), or where they are badly diseased with, for example, black rot. Stripping these lower sprouts tends to reduce

the insect or disease pressure on sprouts higher up the stem, and also allows spray chemicals more easily to penetrate to the remaining sprouts.

Tieing of cauliflower leaves

Where cauliflower curds are exposed to the sun, they tend to discolour and lose the desired whiteness. Some cultivars have good wrapper leaves around the curd and are naturally well-protected. Others are more open and the tieing up of long leaves round the curds to protect them is often resorted to. On hot days cauliflower plants often wilt quite severely, even when soil moisture is adequate. This will often expose the heads, even on cultivars with better natural protection, and tieing up of leaves can reduce the problem of discolouration.

Fertilizers

Cole crops have a high nutritional requirement. In many areas of KZN the main factors that limit yield are soil acidity, low soil phosphorus status, low soil nitrogen and potassium levels, and low or unavailable molybdenum. Suitable fertilizer programmes, based on reliable soil analyses, should be developed for each field. These crops also respond very well to organic manuring. Commercial production of brassica crops is conducted on lands which are intensively used in many areas. Because of this there is possibly a build-up of one of more of the major elements, and recommendations for fertilized rates based on a reliable soil analysis can result in significant cost reductions.

Soil acidity

Brassicas are sensitive to soil acidity. Soils of low pH often contain very high levels of available aluminium and manganese, which adversely affect growth and yield. Under such conditions aluminium can be deposited in the leaf veins, the lower epidermis of which often tends to crack open. High levels of available aluminium will tend to immobilize soil phosphorus, rendering it unavailable to the plant, giving rise to phosphorus deficiencies. Manganese toxicity may also be a problem on very acid soils, especially on the heavier soils favoured by cole crops. Molybdenum deficiencies may be induced on very acid soils, even where soil molybdenum levels are adequate. Cole crops have a particularly high molybdenum requirement.

pH (KCl) should be raised to over 5,5 and acid saturation of the soil reduced to below 2%, preferably 0%, before planting, by liming the soil. Liming will also increase the decomposition of plant residues in the soil, releasing more plant nutrients and making soil nutrients, such as molybdenum and phosphorus, more available.

Macro-nutrients

Nitrogen (N)

The nitrogen requirement of cole crops is relatively high. It is generally accepted that high-yielding crops, such as cabbages, as well as those with long growing seasons, such as Brussels sprouts or late-maturing large-framed cauliflower (like Snowcap), require 200 kg to 250 kg nitrogen per hectare. Broccoli and early-maturing cauliflower need 150 kg to 200 kg nitrogen for good yields. Half to two-thirds of the nitrogen is broadcast and ploughed in shortly before planting, together with the phosphorus and potassium requirements. The rest of the nitrogen is applied as side-dressings, early in growth; usually 2 to 3 weeks after transplanting and again about 3 weeks later, or all at about 6 weeks. On sandy soils subject to leaching more of the nitrogen is applied as side-dressings than is the case on heavier soils.

Deficiency symptoms are that leaves are smaller than normal, with an overall pale green or yellowish colour. The lower, more mature leaves are affected first, but all leaves may be deficient in severe cases. Stems tend to be thin and hard. Plants grow slowly.

Phosphorus (P)
Phosphorus promotes root development and thus ensures more vigorous growth, especially of young plants. Where the phosphorus status of the soil has been built up over several years, 40 kg of applied P per hectare should be adequate for most crops. On the more acid soils, or on soils deficient in phosphorus, best results are obtained by banding the fertilizer.

Plants deficient in this element also tend to grow slowly. Stems are thin and shortened. Leaves develop a purple coloration, first on the underside, and later throughout. Older leaves are affected first.

Potassium (K)
The potassium usage of cole crops is also high. Plant analyses indicate that they take up approximately as much potassium as nitrogen. Although total yields are seldom affected, except where severe deficiencies occur, quality is reduced. Heads tend to be softer and looser. Broccoli and cauliflower heads tend to have loose margins. Keeping quality is much reduced. Very high rates of potassium can increase the incidence of cracking in cabbages, and may also increase tip-burn, and calcium and manganese deficiencies.

Apart from the above symptoms, K deficiencies show up mainly on leaf margins, where the older leaves develop chlorosis and grey or tan areas near the margins, leading to "marginal scorch" or die-back.

The figures supplied in Table 15 give some indication of the N, P & K requirements of this group of crops.

Table 15.
The approximate absorption of nutrients by a good crop of broccoli and Brussels sprouts.

Vegetable	Yield	Plant part	Nutrient absorption (kg/ha)		
			N	P	K
Broccoli	11 t/ha	Heads	22	2	50
		Other	163	9	185
Brussels sprouts	18 t/ha	Sprouts	168	22	140
		Other	95	10	123

The absorption of cauliflowers is similar to that of broccoli. The figures for cabbages, on the other hand, would be more similar to Brussels sprouts; bear in mind that with cabbage almost the entire plant is marketed, with few nutrients being returned to the soil in plant residues.

As a general fertilizer dressing on fertile soils, an application of 500 kg 2:3:4 (30) at planting, followed by two dressings of 300 kg LAN, each at 3 and 6 weeks, is suggested. Corresponding figures on less fertile soils are 1000 kg 2:3:4 (30) and two dressings of 250 kg LAN each.

Secondary and micro-nutrients

Calcium (Ca)

Cole crops have a high calcium requirement. Deficiencies may occur on acid soils, on soils with very high potassium, or on very dry soils where calcium uptake is reduced.

Deficiencies cause a condition known as tip-burn, where the tips and margins of leaves become paler and paper thin, and eventually die back. Tip-burn is thus much more of a problem with cabbages and Brussels sprouts, because it can affect the edible part of the plant.

Most deficiencies occur where the absorption and translocation of calcium within the plant are reduced by environmental factors. Drought and high temperature conditions favour the occurrence of tip-burn and it is thus often more prevalent in summer crops than in those grown over winter. The use of calcium nitrate, or similar materials, as foliar sprays, can alleviate the condition.

Magnesium (Mg)

Magnesium deficiencies occur mainly on acid soils, on very light soils subject to leaching or on soils with a very high potassium level. It may be corrected by spraying with 5 kg/ha of magnesium sulphate.

Initially, older leaves show yellowing between the veins. Younger leaves may be affected later. Older leaves may drop with prolonged deficiency.

Molybdenum (Mo)

Cole crops are very susceptible to a molybdenum deficiency, with cauliflower accepted as being a very good indicator plant for such deficiencies. In seedbeds the first indication of a deficiency is a yellowing of the foliage, similar to that of a nitrogen deficiency. Young developing leaves become distorted, particularly in cauliflowers, showing the so-called "whiptail" symptoms; the mid-rib of the leaf develops normally, but the leaf blade does not fill out properly resulting in narrow, distorted leaves. The curds tend to be small, open and loose. Leaf symptoms on other cole crops are much less obvious than on cauliflowers.

Spray the plants with sodium- or ammonium-molybdate at the very first signs of deficiency, at the rate of 125 g in 500 l water per hectare. Should the deficiency be severe, a follow-up spray using 60 g of the chemical may be applied. Malformed leaves will not recover, but subsequent growth should be normal. Do not over-supply molybdenum as it can harm the plants. Molybdenum may also reach toxic levels in human tissues, but the levels of the element derived from consumption of these vegetables is less than from other sources. Routine spraying may be necessary in areas where molybdenum deficiency occurs.

Adequate liming of acid soils before planting will increase the availability of molybdenum.

Boron (B)

Soils in the high-rainfall areas of KZN are often low in available boron, and deficiencies may be expected on such soils. Should deficiencies be known to occur, cole crops, especially cauliflower, will respond well to foliar sprays of, for example, Solubor. Usually 3 kg will correct such deficiencies. Where any bean crop is included in the rotation, rather under- than over-apply boron, because high rates of boron can be very toxic to these crops (toxicity symptoms may be manifested in beans when soil boron levels are above 5 ppm).

A deficiency is characterised by an internal discolouration and cracking of the stem at the base of the head. A roughness, almost a cork-like appearance, on the lower surface of the mid-rib of the leaves, also occurs. Deficiency causes a browning of cauliflower curds. Internal

cracking of the stem of broccoli, without any discolouration, is common when the plants grow rapidly, especially at lower plant populations. This symptom should not be confused with a boron deficiency, which causes an internal discolouration.

Manganese (Mn)
Soil manganese is most available to plants on acid soils and may even reach toxic levels on very acid soils. Deficiencies of this element are encountered only on soils with a pH (KCl) of over 5.5. The deficiency may be corrected by a foliar spray of 5 kg/ha of manganese sulphate, or 2 to 3 kg/ha of manganese oxide, as soon as the deficiency is observed.

The deficiency initially causes yellowish mottled areas to develop between the veins of the younger leaves. This finally results in an overall pale appearance. Toxicity levels of manganese and aluminium can be reached in acid conditions at the root zone of cole crops.

Iron (Fe)
Deficiencies only occur on calcareous, alkaline soils with a pH (KCl) of over 7,0. Symptoms are very similar to those caused by manganese, and also occur first on the younger leaves. Yellowing is normally more intense than is the case with a manganese deficiency.
A foliar spray with 1% iron sulphate or chelate should overcome the problem.

Zinc (Zn)
Cole crops are less affected by zinc deficiencies than most other crops.

IRRIGATION

Brassicas can seldom be grown successfully without at least supplementary irrigation. They are cool-season, moisture-loving plants, which should never be exposed to drought-stress.

Until the plants are well-established after transplanting, they should be kept continually moist, with no more than 25% of the available water being used before re-watering. Up to about the halfway growth stage no more than 40% depletion of available water should be allowed. Thereafter the soil may be allowed to dry a little more, but irrigation should nevertheless take place as soon as 50% of available water is depleted.

Whilst roots may penetrate more deeply, the effective feeding depth for all cole crops is only about 600 mm. The crop factors used in irrigation scheduling are 0.4, 0.6, 0.7 and 0.70 for each fifth of the growing period.

Cauliflower, especially, should not be allowed to wilt once curds have formed as, apart from reducing yield, the curds may become exposed to the sun and discolour as a result.
Should there be any delay in marketing, mature heads of cabbages and mature Brussels sprouts may burst more easily after rain or an irrigation, particularly if this follows a dry spell.

WEED CONTROL

Weeds need to be adequately controlled because they are efficient competitors with the crop for nutrients, moisture and sunlight. Some weeds exude chemical substances which may inhibit the growth of the crop. Many cruficerous weeds occur, and these are often hosts of diseases and pests of cole crops. It is very important that weeds be controlled in the early stages of crop development, because early competition can adversely affect plant growth and result in the lowering of crop yields. Weed control can be achieved mechanically, by hand, chemically, or by a combination of these methods.

Mechanical or hand weeding
Mechanical weed control, by cultivation, should begin during land preparation, and should be repeated, when necessary, until plants are about half-grown, after which the risk of damaging the crop is too great. Mechanical cultivation is used between the rows, with some hand weeding being practised between plants in the row. The first cultivation/hoeing is usually done two or three weeks after transplanting. Caution should be exercised not to cultivate too deeply, nor too close to the plants, nor too often. Cole crops respond well to a cultivation to loosen the soil surface should this become crusted after heavy rain.

The major problem associated with mechanical or hand weeding is that many growers delay this operation for too long. Under wet conditions it is difficult to enter lands timeously, and diseases can be more easily spread down the rows.

Chemical control
There are several herbicides registered for use on cole crops. However, the same herbicide may not necessarily be used with safety on the different types of brassica crops. Cauliflowers, in particular, appear to be more sensitive than most other crops in this group.
The following chemicals are registered (1998) for use on cruciferous crops:

Alachlor (sold as Alachlor, Sanachlor, Lasso, Lasso MicroTech and Alanex)
This is registered for use on cabbage and certain cultivars of broccoli and Brussels sprouts (NOT cauliflower). It is applied as soon as possible after the first post-transplant irrigation, but pre-emergence of weeds. It controls mainly annual grasses and, under ideal conditions, yellow nutsedge.

Chlorthal-dimethyl (sold as Dacthal W-75)
Dacthal is applied within 1 day of transplanting to a weed-free, wet soil-surface on Brussels sprouts, cabbages and cauliflower (NOT broccoli). It controls mainly annual grasses.

Fluazifop-P-butyl (sold as Fusilade Super or Grasses)
This is essentially a post-emergent killer of various annual and perennial grasses and has no, or very little, effect on most broadleaf plants. It is registered for use on Brussels sprouts.

Metazachlor (sold as Butisan and as Preecede)
The herbicide is applied directly after transplanting, or within 5 days, but before weeds emerge. It controls annual grasses mainly, but also certain broadleaf weeds. It may control yellow nutsedge if conditions are right. The products are registered for use on broccoli and cabbage, but are known to harm cauliflowers.

Oxyfluorfen (sold as Goal and as Galigan 240)
Goal is registered for use on all four crops. It controls annual broadleaf weeds and certain grasses. It must be applied to a well-prepared soil surface. Transplant into treated soil and irrigate immediately. Under cooler weather conditions, where inversions occur, some crop damage may result to the young transplants.

Trifluralin (sold as Trifluralin , Digermin and Triflurex)
This chemical may be used on cabbage only. It controls mainly annual grasses and certain broadleaf weeds. It has a long residual action, which may harm susceptible successional crops. Trifluralin must be applied to a well-prepared soil, and must be mechanically incorporated within 10 minutes of application.

Some mechanical or hand weed control may still be advisable, even with the use of herbicides, because there are certain weeds which are not adequately controlled with chemicals.

Weed identification
The specific weeds causing the major problem should be identified, as this assists in the correct choice of the most appropriate herbicide. Identification, as well as age of weeds, might determine the correct dosage.

Succession crops
The herbicides selected should be considered when the rotational cropping programme is planned. For example, the earlier use of residual herbicides (such as atrazine) may detrimentally affect the cole crop grown in succession. So, also, the use of trifluralin on cabbages could affect the growth and performance of the following crop if it is sensitive to this chemical.

Environment
The clay content of the soil determines the dosage required for many herbicides. Moisture is necessary to transport and activate soil applications of herbicides. Other factors, such as inversion, may either detrimentally affect the crop, or may affect the degree of weed control obtained. When using herbicides the instructions on each container should be carefully read and followed. They are there for the applicator's and the consumer's protection.

PESTS

Cole crops are attacked by many insects, and also sometimes by mites and nematodes. The severity of attack varies from place to place, and from season to season. Not all the pests dealt with in this chapter will necessarily attack a particular planting. The most important pests of cole crops in KZN are larvae (caterpillars) of various lepidopterous insects, such as American bollworm, cutworms, diamond-back moth, loopers, greater cabbage moth and cabbage webworm, and various aphids, of which the grey cabbage aphid and green peach aphid are the most important. Bagrada bugs, thrips, red spider mite and nematodes can also cause problems at times.

See Table 16 for chemicals registered for their control.

American bollworm (*Helicoverpa armigera*)
The American bollworm is a major pest of many crops, including brassicas. The larvae damage mainly the leaves, and, although they may also feed on cauliflower and broccoli heads, normally cause more damage to cabbages and Brussels sprouts, where the edible product consists of leaves. Damage in the early growth stages of all these crops is often very severe, as their growing points can be destroyed.

The creamy-white eggs, about half a mm in diameter, are laid singly on the leaves. They hatch within 3 to 5 days under good conditions. When fully grown the larvae are up to 40 mm long and have a characteristic undulating white band on either side of the body. On the upper side are small black spots. The colour ranges from shades of green and reddish-yellow, to reddish-brown and black. The underside is greyish white. The larval stage lasts for 2 to 3 weeks. Pupation takes place in the soil. The adult moth has a wingspan of 40 mm and a body length of 18 mm. The forewings have two characteristic brown markings, while the hindwings have two distinct pale spots. In the warmer parts of KZN, there are generations throughout the year, although populations and damage are usually lower with the lower winter temperatures (less than 18°C).

Cutworm (*Agrotis* spp.)
Cutworm larvae may damage some of the lower leaves where these touch the ground. However, the major damage is caused when the stems of young seedlings are cut off close to ground level. Cutworms feed at night, and during the day can be found just below the surface

of the soil, next to the damaged plant. The caterpillars, which may reach a length of up to 40 mm, are usually a greasy grey to dark brown, almost black colour, with several black bumps or tubercles on each segment. The nocturnal moth has brown or greyish forewings and light brown hindwings.

Diamond-back moth (*Plutella xylostella*)
The larvae feed on the under-surface of the leaves without damaging the epidermis of the upper surface, thus leaving so-called "windows" in the leaf, which are diagnostic characteristics for these pests. The minute eggs are usually laid singly on the underside of leaves. The light green caterpillars are about 10 mm in length, with long slender bodies pointed at either end, with the pro-legs on the last segment spread apart, forming a distinctive "V" at the rear end. When disturbed, they wiggle frantically, or rapidly attach a silken thread to the leaf and drop off the leaf. They reach maturity in about 10 to 14 days, and then spin loose white cocoons, which they attach to leaves or stems, and pupate within them. Adult moths are small and slender, greyish or brownish is colour. Folded, the wings of the male moths display three distinctive diamond-shaped markings on their backs, hence the name "diamondback moth". When disturbed they flit from plant to plant.

Plusia looper (*Plusia* spp.)
The caterpillars are pale green, with a narrow white stripe along each side, and move around in the characteristic manner of loopers, by arching their backs as they propel themselves forward. After feeding for 2 to 4 weeks, the larvae pupate covered by pieces of leaves, which they have cut and stuck around the cocoon. The adult moths have bright golden forewings with brown borders, and brown hindwings. The wingspan is approximately 35 mm.

Greater cabbage moth (*Crocidolomia binotalis*)
The young caterpillars are green. Older stages are lined with white and black spots on the back. The young larvae frequently feed together. They spin a thin web over their feeding places on the leaves. Most damage is caused by early attacks when the growing point of the plant is destroyed.

Cabbage webworm (*Helula* spp.)
These are similar in appearance to the greater cabbage moth and cause similar damage. They are difficult to control because of their habit of spinning a web over their feeding places. It is thus difficult to apply chemical sprays to the feeding site.

Aphids (several kinds)
Various aphids may attack cole crops, the most common being the grey cabbage aphid, *Brevicoryne brassicae*, and the green peach aphid, *Myzus persicae*. Aphids cause damage by sucking the sap, and are also serious pests because they contaminate the edible product. The cabbage aphid tends to form colonies of a dense mass of these insects, and their feeding causes a chlorosis and malformation of the leaf. The green peach aphid tends to occur singly.

Bagrada bug (*Bagrada hilarus*)
These are small black shield bugs, with orange and yellow spots, and an orange cross on the back. Males and females often run about attached at the rear and facing away from one another. They are about 8 mm long. They cause damage by sucking sap from tender growth, resulting in a whitish, scarred appearance. Heavy infestation can seriously reduce growth and yields.

Thrips
The most important species on crucifers is generally *Thrips tabaci*. These small insects seldom cause serious damage but, when populations are high, are undesirable because of the contamination of the product by their very presence.

Red spider mite (*Tetranychus urticae*)
These minute reddish-brown "spiders", with four pairs of legs of equal length, and an oval body, are usually found on the underside of leaves, but also on tender young heads of broccoli and cauliflower. They weave a fine web on the lower surfaces of leaves. They are sucking insects and cause a bronzing and yellowing of leaves, and on broccoli heads a grey scarring on young stems.

Nematodes
Cole crops are affected by various nematodes, but damage is seldom serious unless populations are very high. Affected plants are unthrifty and may become stunted. They may show symptoms of moisture or nutrient stress.

Table 16.
Pesticides registered in 1999 for controlling various pests in crucifers.

Chemical	Formulation	Safe Period (days)	Sold as	1	2	3	4	5	6	7	8	9	10	11
acephate	SP 750 g/kg	3	Acephate, Orthene, Ace, Racet 750 SP											
alphacypermethrin	SC 100 g/l	4	Concord, Fastac											
alphacypermethrin	EC 100 g/l	4	Bestox, Fastac											
Bacillus thuringiensis var. *aizawai*	WG		Xen tari, Florbas											
Bacillus thuringienis var. *kurstaki*	WP	-	Thuricide, Dipel, Dipel 2X, Biobit											
betacyfluthrin	EC 50 g/l	4	Bulldock											
carbofuran	GR 100 g/kg	77	Carbofuran, Curaterr, Furadan, Agriterr, Alvuran											
chlorphenapyr	SC 240 g/l	7	Cordless											
chlorpyrifos	EC 480 g/l	7	Pyrinex, Chlorpyrifos, Dursban, Lorsban, Aviklorpirifos, Agropyriphos, Lirifos, Phantom, Pyrifos, Rochlop											
cyfluthrin	EC 50 g/l	4	Baythroid											
cypermethrin	EC 200 g/l or 20 g/l	4	Cypermethrin, Ripcord, Magnum, Doodskoot, Sipermethrin, Cymbush, Avi-sipermethrin, Ripcord 11, Garden Ripcord, Fruitfly, Supermethrin, Sherpa, Ploythrin, Rocyper											
cypermethrin-high cis	EC 200 g/l	4	Fenom											
delta endotoxin	SC 200 g/l	-	MVP 11 Bio Insecticide											
deltamethrin	EC 25 g/l	3	Decis											
demeton-S-methyl	EC 250 g/l	10	Demetox, Demeton											
diazinon	EC 275 g/l	14	Diazinon, Kayazinon											
dichlorvos	EC 1000 g/l	2	Dichlorvos, Dedevap, Devipan, Nogos, DDVP, Divos											
dicofol	WP 185 g/kg	7	Kelthane											
dimethoate	EC 400 g/l	14	Dimethoate, Fetron, Aphicide, Dimet, Dimeto, Aphids, Rogor, Perfekthion							**				
disulfoton	GR 50 g/kg	42	Disyston			*				*				

Chemical	Formulation		Safe Period (days)	Sold as	1	2	3	4	5	6	7	8	9	10	11
endosulfan	SC	475 g/l	-	Endoflo, Thioflo											
endosulfan	WP	475 g/kg	7	Endosulfan, Thionex											
endosulfan	DP	50 g/kg	7	Endosulfan											
gamma-BHC	EC	200 g/l	30	Lindane, Dyant,Ants, Ant and Garden Spray											
gamma-BHC	DP	6 g/kg	30	Lindaan, Bexadust											
lambda-cyhalothrin	EC	50 g/l	2	Karate											
mercaptothion	WP	250 g/kg	7	Mercaptothion,, merkaptotoks											
mercaptothion	EC	500 g/l	7	Mercaptothion, Malathion, Datathion, Malasol, Avigard,Garden Insects											
mercaptothion	DP	50 g/kg	7	Kopthion, Avi-mercaptothion , Stink powder											
methamidophos	SL	585 g/l	21	Methamidophos, Sniper, Thamida, Methamidofos, Patrole, Rometra, Tamafos, Tamaron, Methaphos, Midofos											
methomyl	SP	900 g/kg	4	Methomyl, Lannate, Methomex, Kuik, Methosan											
methomyl	SL	200 g/l	4	Methomyl, Lannate, Methomex											
mevinphos	EC	150 g/l	4	Mevinphos, Phosdrin											
oxydemeton-methyl	EC	250 g/l	10 : 14	Metasystox-R							** *				
oxydemeton-methyl	SL	100 g/l	10. 14	Metasystox - R Liquid											
parathion	EC	500 g/l	21	Parathion											
phenthoate	EC	500 g/l	3	Elsan											
phorate	GR	100 g/kg	56	Phorate , Thimet											
pirimicarb	WG	62,5 g/kg	7	Aphox											
pirimicarb	AE	1 g/kg	7	Pirimor Aphid Killer											
profenofos (premium grade)	EC	500 g/l	7 : 10	Selecron											
pymetrozine	WP	250 g/l	7	Chess											
thiometon	EC	250 g/l	28	Ekatin											
tralomethrin	EC	36 g/l	3	Tralate, Sibling											

Chemical	Formulation	Safe (days)	Sold as	1	2	3	4	5
trichlorfon	SP 950 g/kg	7	Trichlorfon, Dipterex, Dipterex Soluble Powder					

1 = American bollworm
2 = Cutworm
3 = Diamond-back moth
4 = Plusia looper
5 = Greater cabbage moth
6 = Cabbage webworm
7 = Aphid
8 = Bagrada bug
9 = Thrips
10 = Red spider mite
11 = Nematode

Note :

* For cabbages only
** For cabbages and cauliflowers only.
*** For cabbages, cauliflowers and brussels sprouts only.
Not suitable for quick-maturing cultivars.
Not for use after the edible parts start forming.
▉ Interval between last application and spraying is longer for brussels sprouts than for other crucifers.

DISEASES

Cole crops can be affected by many diseases. However, in each growing area and season, only a few are likely to occur on a single crop. Before planting, find out which diseases are likely to occur locally and, whenever possible, review records of disease incidence in the field to be planted. Choose cultural practices and crop cultivars that reduce the impact of key diseases. One should know where a pathogen originates, how it disperses and infects the crop plant, and what environmental conditions favour disease development.

Soilborne pathogens can sometimes be managed by such practices as deep ploughing, fumigation or changing soil pH. Crop rotation is useful for some soilborne pathogens that survive in infected plant residues and have a limited host range, for example black leg and black rot. Irrigation practices can limit the impact of many soilborne diseases. Many soilborne pathogens are spread only by movement of infested soil, plant debris, or transplants, although some have stages that can be dispersed in air (spread rapidly and move long distances) or water - the latter are generally not carried so far.

The use of disease-resistant cultivars, where available, offers the best means of control, but the timely application of fungicide sprays may be needed for some diseases.

Several pathogens are introduced on, or in, seeds; for example, black leg, black rot, Alternaria and ringspot. The use of disease-free seed, or adequate seed treatment, can avoid their introduction to new fields or new areas.

Table 18 lists where the pathogen survives when the crop is out of the field for some time, that is, the sources of primary inoculum for the diseases discussed in this guide.

Table 17.
Survival of pathogens causing diseases of cole crop.

Disease	Truly soilborne	Plant debris	Seedborne	Living plant (including hosts)
Damping-off	*			
Clubroot	*			
Fusarium wilt	*			
Verticillium wilt	*			
Phytophthora	*			
Sclerotinia	*			
Alternaria	*	*	*	
Ringspot	*		*	
Downy mildew	probably			*
Black leg		*	*	
Black rot		*	*	

Disease	Truly soilborne	Plant debris	Seedborne	Living plant (including hosts)
Albugo				
Mosaic or virus diseases				*

Damping-off
This common disease of seedlings is usually caused by *Rhizoctonia solani* or *Pythium* spp. *Phoma lingam* (see later) and *Phytophthora* spp., can also cause damping-off and root or stem rots. Pythium can also cause a seed rot. *Pythium* seed rot and damping-off occur primarily during cool, wet weather, while *Rhizoctonia* is favoured by warm soils.

Damping-off may occur after the seedlings germinate, even before they emerge from the soil. The most obvious is when it occurs after emergence. Lesions most often occur at or near the soil surface. The stem tissue collapses and becomes dark and shrivelled, and plants topple over and die. Often cole crops seedlings will survive for some time and will continue to grow slowly, but the affected area does not expand and gives rise to a spindly condition called wirestem. Such seedlings should not be used for transplanting.

Damping-off may occur anywhere in a field or seedbed, but it is usually in fields with a high green organic matter content with poor drainage or compacted soil. Over-watering or over-crowding of seedlings accentuates the problem. Plants beyond the third- or fourth-leaf stage are not susceptible.

Control

Use seed treated with a suitable fungicide.
Avoid planting when the soil is cold.
Prepare a good seedbed, which encourages quick germination and vigorous growth.
Ensure residues are thoroughly decomposed before planting.
Sow thinly on raised beds to improve aeration and soil drainage.
Practise good water management, preferably with sprinkler irrigation, to ensure that soils are not over wet.
Drench the seedbeds with an appropriate fungicide at first signs of damping-off, or even as a preventative measure.

Clubroot (*Plasmodiophora brassicae*)
This is a very destructive disease of many cruciferous plants. It persists in the soil for many years, and is favoured by acid soils with adequate moisture. It is dispersed from field to field by movement of infected plants, especially transplants, and movement of infested soil on machinery and surface water run-off. It can also be spread in manure from animals fed on infected plant material. Plants may be infected for some time before indicating stress. The first above-ground symptoms are usually a slight wilting of leaves during the day with recovery at night, followed by permanent wilting later. Infected plants are often smaller than others. Roots are enlarged into various shapes. Multiple infections of the same root cause the extreme swelling and grotesque distortion that characterise the disease. Such roots crack and are invaded by other organisms causing decay.

Control
Once in the soil there is no economical way to eliminate the disease. It persists for many years. Disease prevention is thus the only answer.

To prevent contamination of clean fields, wash machinery with high-pressure equipment to remove contaminated soil and other debris before moving from infected to non-infected fields. Prevent water movement from infected to clean fields. Ensure that infected plant material does not move over. Grow transplants in fumigated beds; young plants can be infected for some time before showing symptoms and cannot always be identified at transplanting. Speedlings (even from commercial speedling growers) irrigated with contaminated water can become infected, so ensure that the water source is not affected.

Clubroot spores do not germinate well in alkaline soil, so liming may help reduce disease incidence. However, liming may not be effective in well-buffered soil. Apply lime annually if the soil pH is below 7.

There is some evidence to suggest that a two- or more year rotation away from cruciferous crops, and into a cereal, can markedly reduce clubroot incidence.

Verticillium Wilt (*Verticillium dahliae*)
This soil fungus has a wide host range, including tomato, potato, pepper and cotton. Of the major cole crops, broccoli seems the most tolerant.

Typical symptoms on cole crops are stunting and irregular patches of yellow developing between major veins of older leaves. These symptoms are not obvious and may be overlooked. A diagonal cross-section through an infected stem will show discontinuous streaks of dark-brown discolouration in the woody, water-conducting vessels. Discoloured streaks also occur near the base of petioles. Streaking and leaf symptoms may be one-sided, as in Fusarium Wilt, in early infections. *Verticillium* does not kill cole plants, but it can limit yields. Cool soil and air temperatures favour infection and disease symptom development.

The fungus can persist in the soil for several years. Rotation is of little value because of the wide host range. There are no economically feasible controls available. Avoiding stress in the later part of the growing season may help limit damage.

Fusarium Wilt or Cabbage Yellows (*Fusarium oxysporum* f. *conglutinans*)
This fungus can destroy susceptible cultivars of cabbage; also kohlrabi and kale. Broccoli, Brussels sprouts and cauliflower are not known to be affected. The disease is most serious in summer; susceptible cabbage varieties suffer only mild symptoms in cool weather. It develops most rapidly at temperatures ranging from 24°C to 29°C; little development occurs below 15°C. The fungus can persist indefinitely in the soil, even with long periods of unfavourable temperature and drought. The fungus is spread with infected plants and in infected soil on farm machinery, drainage water, boots or tools. Once in a field it is dispersed through cultivation and other practices that move soil or plant debris about.

Control

Plant resistant cultivars.
Grow cabbages in winter, when disease development is slow; even then use resistant cultivars if possible.
Grow transplants in disease-free soil or fumigate the soil.
Rotate to nonhost crops, such as tomatoes or lettuce, to reduce buildup of the fungus in the soil.
Prevent infected soil or plant residues from contaminating clean fields.

Sclerotinia rot or White mould (*Sclerotinia sclerotiorum*)
White mould occurs on many crops, such as carrots, lettuce, beans, celery, potatoes, tomatoes and sunflower, as well as cole crops, where it can be a particular problem for seed production.

Cool, wet conditions favour disease development.

During wet weather any of the above-ground parts of infected plants may be covered with a white cottony growth. The plant tissue beneath the white mycelium usually turns soft and watery. Hard, black resting bodies - sclerotia - are produced in or on diseased tissue. These sclerotia enable the pathogen to survive in the soil for up to 2 or 3 years.

Control

Practise crop rotation with non susceptible crops - this is difficult on an intensive vegetable farm.

Deep ploughing, with complete inversion of the soil to a depth of at least 250 mm, prevents the germination of sclerotia and hastens their destruction by other micro-organisms, and thus reduces disease incidence.

Good water management, aimed at keeping soil surfaces as dry as possible, will reduce disease pressure.

Removal and destruction of infected crop residues will help.

Levelling the land and planting on ridges or raised beds will also reduce disease incidence, as these practices improve drainage and help to keep the soil surface dry.

Black leg (*Phoma lingam*)

This fungus causes many symptoms on cole crops such as seed rot, damping-off, root and stem rots, and leaf lesions. Usually stem rots start at or below ground level. Black leg damages roots and lower stem, so affected plants are often wilted and small. The most distinctive black leg symptoms occur on the basal part of the stem below the soil surface. The area has a semi-dry, tan-coloured rot and blackened areas, often with small black pycnidia (fruiting bodies) on the surface. When cut through, the blackening of the xylem is obvious.

This organism is also favoured by cool, moist conditions. It can be seedborne, or survive in plant debris in the soil.

Control

Rotate infected fields out of cruciferous crops for at least two years.

Use disease-free seed or treat the seed with hot water.

Fumigate seedbeds.

Plough infected debris under.

Downy Mildew (*Peronospora parasitica*)

This is a common disease of cole crops during cool, moist weather. Economic damage most often occurs in seedlings, where infections may kill large numbers of plants and retard growth of others. Severe leaf infections or stem or flower infections can stunt older plants, reducing yield and quality.

The most distinctive characteristic of downy mildew is the greyish white, fluffy growth that develops on the underside of infected leaves. Irregular yellow to brown spots develop on both leaf surfaces. These spots may turn purplish and later light brown or yellow. On seedlings leaf drop is common. Infection may spread to stems or flower parts. Dark brown or blackened areas will develop internally in curds or floral stems of cauliflower or broccoli, making them unmarketable. In the stems and heads of cabbage, the fungus may produce dark purplish spots; this internal darkening may not be visible until affected parts are sliced open. Secondary rots may develop. The fungus survives in over-lapping cruciferous crops. Sexual spores can survive in the soil for extended periods.

Control

In the case of broccoli, at least a few varieties that are tolerant to downy mildew are available.

Fungicidal treatment of seedlings is advisable where infections occur; repeat when

necessary.
Good water management can reduce the incidence of the disease.
Fumigation of seedbed soil.
Good seedbed preparation and practices, to allow aeration and drying.
Prevent over-lapping of plantings and plough in old crops as soon as harvesting has been completed.

Ringspot (*Mycosphaerella brassicicola*)
Brussels sprouts are the main cole crop commonly damaged by ringspot, although cabbages are affected in some areas. Cool, moist weather favours disease development and dissemination. The first symptoms are small, dark tan spots that enlarge rapidly and turn grey. Older spots are usually made up of a series of concentric rings. Numerous tiny dark bodies develop within the aging lesion. Lesions may cause severe defoliation, thus reducing yields. Affected sprouts showing spots are unmarketable.

The fungus can survive on infected plant refuse in the soil.

Control
Removal of, or ploughing in, plant debris.
Adopt a three-year rotation.
Chemical sprays.

Alternaria leafspot (*Alternaria* spp.)
Alternaria leafspot may be a problem during cool, rainy weather. Leaf spots begin as small, dark areas and enlarge rapidly to form large circular lesions that often develop a bulls-eye pattern, or "target spot". During wet periods the lesions appear dark brown. A brown, velvety, spore-bearing growth (only visible with a good lens) appears on the older lesions. There are, however, no tiny dark bodies as in ringspot. The disease is more of a problem on cabbages and Brussels sprouts as the leaf spots affect the marketable product. However, when cool, rainy weather occurs after curd formation in cauliflowers, severe damage can also be caused by the dark spots on the curds. Broccoli heads can also be made unmarketable by untimely cool, rainy conditions.

The spores are spread from plant to plant by the wind under favourable conditions. During unfavourable periods the fungus can survive in plant debris. Infected seed is a major source of inoculum for new outbreaks.

Control
Use disease-free seed or apply an appropriate seed treatment.
Remove or plough in plant refuse.
Certain chemicals used for downy mildew control, while not registered against Alternaria, will limit its spread.

White Blister or White Rust (*Albugo candida*)
White blister tends to be a more sporadic disease, but can infect many cruciferous plants. Raised white pustules form on the lower surfaces of leaves, with a yellowing on the opposite side of the leaf. Pustules sometimes have a greenish tint, but are generally pure white and look almost as though white enamel paint has been splashed onto affected parts. These pustules have also been observed on broccoli heads; affected buds are white and are stimulated to grow very large, with some malformation. Affected heads are not marketable. Under favourable cool, moist conditions the spread and development of the disease is rapid.

Control
This fungus is closely related to that causing downy mildew and can probably be controlled in a similar manner to downy mildew. Whilst no chemicals are registered for use against white

blister in South Africa, sprays against downy mildew will frequently keep it in check.

Black rot (*Xanthomonas campestris* pv. *campestris*)
This bacterial disease can be very destructive under rainy, humid conditions, particularly in warm weather. Summer crops are more severely affected. Increasing use of sprinkler irrigation in dry areas, and repeated cropping with crucifers, have caused it to become more prevalent. The most serious losses seem to occur in Brussels sprouts and cabbages, with cauliflower also fairly seriously affected. Broccoli yields seems to be less affected. Initially, yellow to light brown patches appear at the margins of leaves, and later a network of black veins develops within these areas. Affected areas turn brown and dry out, often leaving a characteristic triangular-shaped lesion on the leaf margin, with one point of the triangle directed towards the midrib. Sometimes the entire leaf's margin is affected. The pathogen spreads from the margin to areas within the leaf blade that soon become necrotic. Leaf drop of older, infected leaves is common. The bacteria continue to move into the main veins and vascular system of the plant, turning the tissue brown or black. Plants affected in the seedling stage may die or remain stunted.

The bacteria may be carried over in, or on, the seed of infected crucifers, on host plants, including cruciferous weeds, or in infected plant refuse in the soil. Splashing water from sprinkler irrigation or rain commonly disseminates the bacteria within a field. The bacteria enter the plant through natural openings at the margins of the leaves or through insect wounds.

Control

Use tolerant cultivars where these are available, e.g. cabbages.
Ensure the seed is disease-free or apply a hot-water treatment to seed.
Practise a minimum of a three-year crop rotation.
Control cruciferous weeds.
Deep plough to bury all infected plant material.
Increase the interval between irrigation. A drier regime is required.
Avoid sprinkler irrigation where possible.
Avoid growing crops over periods when conditions favour disease development.

Bacterial leafspot (*Pseudomonas syringae* pv. *maculicola*)
This bacterial disease is usually of a more sporadic nature. Cabbages and cauliflowers appear to be more susceptible than other cole crops. Most severe during cool, moist weather, it usually spreads during cool, rainy weather or under sprinkler irrigation. Its progress is checked when warm, sunny weather prevails.

The disease appears first as small, faint, water-soaked areas on the underside of leaves. These areas develop in a few days into brownish-to-purplish grey necrotic spots, somewhat irregular in outline. They may coalesce to form large irregularly-shaped spots. When the lesions are numerous, the leaf becomes puckered and the affected tissue may tear.

The bacterium is capable of living in soil and in infected plant material. It is believed to be seedborne.

Control

Control measures suggested for bacterial black rot will also be effective against bacterial leafspot.
There are also certain chemicals registered for the control of this disease.

Erwinia soft rot (*Erwinia carotovora*)
This bacterial soft rot is generally more of a problem on the harvested product than in the field, but it can affect growing crops.

It gives rise to a soft, watery rot of affected plant parts and to an unpleasant odour. It

is considered to be only weakly parasitic, needing a wound or injury to enter the plant. Sunburn, or insect or mechanical injuries, are points of entry.

No control measures are generally practised.

Table 18.
Chemicals registered in 1999 for the control of certain disease of cruciferous crops in South Africa.

Chemical	Formulation	Safe Period (days)	Sold as	1	2	3	4	5
benomyl	WP 500 g/kg	3	Bendazol, Benlate, Benomyl, Pilarben, Spotless					
copper ammonium carbonate	SL 661 g/l	3	Copper Count-N					
copper oxychloride	WP 850-860g/kg	3	Copper oxychoride					
copper oxychloride	WP 850 g/kg	3	Copper Oxychlor, Copper Oxychloride, Cupravit, Coprox, Cuprox Super, Dimildex, Koperchlor, Oxy-Atacamite,Rust,Supercup,Suprakop, Virikop.					
cupric hydroxide	WP 770 g/kg	3	Funguron-OH, Champion, Kocide, Hydrox, Supacop					
cupric hydroxide	WG 614 g/l	3	Kocide					
dichlorofen	EC 200 g/l	3	Xanbac D					
flusulfamide	SC 220 g/l	-	Scablok					
mancozeb	WP 800 g/kg	3	Mancozeb, Dithane M45, Miceb Super, Sancozeb, Tridex					
mancozeb	WG 750 g/kg	3	Dithane M45, Mancozeb, Penncozeb					
propamocarb hydrochloride	SL 722 g/l	***	Previcur N					
zineb	WP 700 g/kg	3	Zineb					

1 = Bacterial Spot
2 = Downy Mildew
3 = Ring Spot
4 = Soil Pathogens
5 = Clubroot

Note : *** Propamocarb hydroxide is restricted to use on seedbeds only.

Carefully read all instructions on the label of each container and follow them meticulously.

PHYSIOLOGICAL DISORDERS

Tipburn
Refer to calcium, under "fertilization".

Whiptail
Refer to molybdenum, under "fertilization".

Hollow stem
Hollow stem, a condition very common of broccoli, but much less so with cabbages and cauliflower, may occur during very rapid growth. On affected plants the interior pith tissue of the stem or head is collapsed or cracked and often hollow. High temperatures, in combination with high levels of nitrogen and large stem diameters, are associated with the disorder. Wide plant spacing also contributes greatly to the problem. It should not be confused with a boron deficiency - see "fertilization" - which can cause hollow stem; in the case of boron deficiency the cracked stem cavity is darkened.

Brown bud of broccoli
Flower buds of broccoli frequently turn brown or yellow. The cause is unknown, but observations indicate that it is more common when temperatures rise rapidly after a sudden cold spell. Some cultivars are less prone than others. Harvesting more severely reduces the severity of the problem.

Riceyness of cauliflower
Riceyness of cauliflower occurs when temperatures remain warm during curd development. The curd appears uneven and fuzzy, and floral parts start to grow through the head, prematurely. It is frequently associated with out-of-season production - high temperature - but can also be caused by late application of nitrogen.

Buttoning of cauliflower and broccoli
This is caused by planting too late into the cooler months. The small plants are induced by low temperature to form seed before they are large and strong enough to produce a good crop. It results in very small, usually loose, open, unmarketable heads.

Green leaves within the curds of cauliflower
Green leaves develop within the curds of cauliflower because the plants resume vegetative growth after curds start forming. The primary cause is that temperature fluctuations are too great. However, late nitrogen applications may also play a role.

HARVESTING AND MARKETING

Cabbages
Cabbages are harvested as soon as the heads are sufficiently hard and large enough, possibly even before full-sized. When the heads are quite solid, they will no longer increase in size and must then be harvested in spite of possibly being undersized, to avoid cracking and deterioration. The heads should be cut off in such a way that a few of the large, open wrapper leaves are retained for protection around the heads. When sent to municipal markets they are tightly packed into open mesh bags which hold about 25 kg to 30 kg of cabbages. Much of the cabbage crop in KZN is sold loose, often on the farm, to hawkers or directly to consumers.
Much of the cabbage crop in KZN is produced for harvesting over the April to September period,

when there is an increased demand, mainly from black consumers.

Commercial yields vary from about 40 to 80 tons per hectare; even higher yields are possible.

Cauliflower

The demand is for fresh-looking, white and firm curds. Heads are thus harvested before attaining full-size, ideally just before they show any sign of loosening, as this gives good-sized heads of good quality. Bear in mind that cut heads will still develop and loosen after picking. Great care should be exercised in handling the curds as they bruise easily, especially when turgid, and such bruises may show up as unsightly, discoloured patches a day or two later at the market. For this reason, retain sufficient leaves, with tips cut off some way above the heads, to entirely protect the curds on all sides. Harvesting should be done regularly, at least twice a week, even more often if plants are developing rapidly, to ensure that the crop does not become over-mature. Marketing may also be done in mesh bags as for cabbages, although crates are preferred. Much of the crop is, however, sold loose.

Yields of curds, excluding the protective leaves, generally average 10 to 15 tons for early maturing varieties and 15 to 20 tons for later varieties. Good crops may yield 50% higher.

Broccoli

Broccoli is a much more perishable product than the other cole crops, and is thus seldom seen in large quantities on municipal markets. Most of the crop is sold direct to retail outlets or the consumer, often as pre-packs. Heads also tend to develop rapidly and the crop should be harvested every two or three days.

Heads are picked, usually about a hand's breadth under the heads, as soon as they are well-sized and well-coloured, but before there are any signs of loosening. As with cauliflower, heads continue to expand and loosen after being cut, and quality deteriorates rapidly, especially when high temperatures occur.

The primary heads are the most sought-after and generally command the highest prices. They are gathered within about the first two weeks of the harvesting season and comprise 60 to 80% of the total crop of most cultivars. At the closer spacings, individual heads are somewhat reduced in size, but total yields are larger and the primary heads form a greater proportion of the crop. The secondary heads form on side shoots, which are stimulated to grow once the primary heads have been removed. They become progressively smaller over time. These side sprouts are harvested from the second or third weeks of harvest for a period of about four weeks, after which they become too small to have any value.

Commercial yields generally range from 6 to 9 tons per hectare. Yields of over 15 tons per hectare are possible from very good plantings.

Brussels sprouts

Brussels sprouts are grown for their small heads, 20 mm to 50 mm in diameter, that develop in the leaf axils up the entire length of the stem. They are harvested when sufficiently sized and firm. Harvesting commences when the lower sprouts on the stem are ready, and progresses as those higher up the stem achieve market maturity. This is a long-standing crop, which reaches maturity after about four months; picking may extend for a further three months or so, depending on temperatures. The sprouts ready for harvesting are generally a lighter green colour than less mature sprouts. As with cabbages, sprouts may crack if left too long before harvesting. If picked fairly severely (less mature) the interval between picks can be extended to two, or possibly even three, weeks during early cropping. However, where only mature sprouts are harvested, which also increases yield, weekly picking is normally practised.

In harvesting a plant, the leaves below the sprouts to be harvested are first broken off. The sprouts are then picked by pushing them sideways, usually with the heel of the hand. Any pieces of leaf-stalk or stem remaining attached to picked sprouts are removed before packing them in suitable containers for marketing.

Average yields vary between 8 and 12 tons per hectare.

Table 19.
Total tonnages sold on the Durban National Market per year from 1993 to 1997 and the mean annual prices (R per ton obtained).

Cauliflower

	1993	1994	1995	1996	1997
Tons sold p.a	2.52	2.249	2.318	1.541	1.344
Ave.R/ton	565	612	581	741	793

Broccoli

	1993	1994	1995	1996	1997
Tons sold p.a	162	162	142	135	138
Ave.R/ton	1967	2465	3142	3588	3516

Cabbage

	1993	1994	1995	1996	1997
Tons sold p.a	14.475	11.898	12.272	9.86	8.798
Ave.R/ton	203	251	231	309	335