◆ EPPO Standards ◆

GUIDELINES ON GOOD PLANT PROTECTION PRACTICE

VEGETABLE BRASSICAS

PP 2/7(1) English

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APPROVAL

EPPO Standards are approved by EPPO Council. The date of approval appears in each individual standard.

REVIEW

EPPO Standards are subject to periodic review and amendment. The next review date for this set of EPPO Standards is decided by the EPPO Working Party on Plant Protection Products.

AMENDMENT RECORD

Amendments will be issued as necessary, numbered and dated. The dates of amendment appear in each individual standard (as appropriate).

DISTRIBUTION

EPPO Standards are distributed by the EPPO Secretariat to all EPPO Member Governments. Copies are available to any interested person under particular conditions upon request to the EPPO Secretariat.

SCOPE

EPPO guidelines on good plant protection practice (GPP) are intended to be used by National Plant Protection Organizations, in their capacity as authorities responsible for regulation of, and advisory services related to, the use of plant protection products.

REFERENCES

All EPPO guidelines on good plant protection practice refer to the following general guideline:

OEPP/EPPO (1994) EPPO Standard PP 2/1(1) Guideline on good plant protection practice: principles of good plant protection practice. *Bulletin OEPP/EPPO Bulletin* **24**, 233-240.

OUTLINE OF REQUIREMENTS

For each major crop of the EPPO region, EPPO guidelines on good plant protection practice (GPP) cover methods for controlling pests (including pathogens and weeds). The main pests of the crop in all parts of the EPPO region are considered. For each, details are given on biology and development, appropriate control strategies are described, and, if relevant, examples of active substances which can be used for chemical control are mentioned.

EUROPEAN AND MEDITERRANEAN PLANT PROTECTION ORGANIZATION
ORGANISATION EUROPEENNE ET MEDITERRANEENNE POUR LA PROTECTION DES PLANTES

PP 2/7(1) English

Guidelines on good plant protection practice

VEGETABLE BRASSICAS

Specific scope

This standard describes good plant protection practice for vegetable brassicas (leaf brassicas, flower head brassicas and root brassicas).

Specific approval and amendment

First approved in September 1996.
Edited as an EPPO Standard in 1998.

This guideline on GPP for vegetable brassicas forms part of an EPPO programme to prepare such guidelines for all major crops of the EPPO region. It should be read in conjunction with GPP Guideline no. 1 (Principles of Good Plant Protection Practice) (*Bulletin OEPP/EPPO Bulletin* **24**, 233-240, 1994).The guideline covers methods for controlling pests (including pathogens and weeds) of *Brassica* spp. grown outdoors as vegetable crops.

The *Brassica* spp. concerned can conveniently be grouped as:

1 leaf brassicas - *B. oleracea* var. *capitata* (cabbage), *B. oleracea* var. *gemmifera* (Brussels sprouts), *B. oleracea* var. *acephala* (kale), *B. chinensis* (Chinese cabbage);

2 flowerhead brassicas - *B. oleracea* var. *botrytis* (calabrese, cauliflower, broccoli), *B. oleracea* var. *gongylodes* (kohlrabi);

3 root brassicas - *B. rapa* (turnip), *B. napus* var. *napobrassica* (swede).

Of these, cabbage, cauliflower and turnip are the most widely cultivated in Europe. The same or related species or cultivars are also grown as fodder crops, or for seed production (mustard, rape). Rape in particularly is very widely grown and has many pests in common with vegetable brassicas. It can be an important source of inoculum for nearby crops. A separate guideline for GPP in rape is in preparation. Crops grown for the production of seed for planting are not covered by this guideline.

Most brassica pests can be found to a greater or lesser extent on all three types of brassica. Where GPP is different for the different types, the information in the guideline will be presented separately. In general, the nature of the marketed product (leaves, heads, roots) will influence the GPP approach for the particular pest. The quality of the marketed product is particularly important for flower heads.

Vegetable brassicas are mostly grown from seed (sown in seedbeds or in peat blocks or pots) and transplanted into the field, but are sometimes direct-drilled. A rotation of several years is normal and this helps to avoid disease build-up in debris and soil between successive brassica crops. In general, it is preferable to separate brassica crops in space and time to avoid unnecessary spread of pests. Only healthy seed (or seedlings) should be used to avoid introducing pests into the crops. In some cases, tested seed can be obtained. Cultivation methods can aid reduction in levels and sources of inoculum, for example by destruction of cruciferous weeds which may harbour pests, removal or destruction of crop debris, correction of poor nutrition and drainage, increasing air movement within crop canopies. Resistant cultivars are available in some cases to alleviate the more severe effects of locally important pests. This should be fully exploited, for example, for cultivars of Brussels sprouts and cabbage against *Erysiphe cruciferarum*, *Mycosphaerella brassicicola* and *Albugo candida*.

Though plant protection products are widely used in GPP for vegetable brassicas, there is considerable scope for reducing their usage by maximizing use of the cultural and other non-chemical means of disease control mentioned above. Growers need to be better educated in these methods and convinced of their importance. Chemical treatments should in any case be used selectively and not on a routine basis. If seed treatments are available for control of seed-borne pathogens and soil pests, they should be prefered. Treatments at the seed-bed stage can prevent early build-up of pests. Treatments can then be applied to the soil or as foliar sprays. There is scope to reduce field spraying and target it more effectively by, for example, regular scouting of crops, use of pest forecasting methods, use of spraying methods which reduce dose rate, water volume and spray drift without compromising the efficacy of pest control. Finally, it may be noted that there may also be pest problems in storage of harvested brassicas.

The principal brassica pests considered are the following:

- *Leptosphaeria maculans* (canker and leaf spot, dry rot);
- *Mycosphaerella brassicicola* (ringspot);
- *Peronospora parasitica* (downy mildew);
- *Albugo candida* (white blister);
- *Erysiphe cruciferarum* (powdery mildew);
- *Alternaria brassicae* and *A. brassicicola* (dark leaf spot);
- *Pyrenopeziza brassicae* (light leaf spot);
- *Botrytis cinerea* (grey mould);
- *Rhizoctonia solani* (wirestem);
- *Pythium* spp. (damping-off);
- *Plasmodiophora brassicae* (clubroot);
- *Phytophthora* spp. (root rot, storage rot);
- *Verticillium dahliae* (wilt);
- *Xanthomonas campestris* pv. *campestris* (black rot);
- *Erwinia* and *Pseudomonas* spp. (soft rots, spear rot);
- *Pseudomonas syringae* pv. *maculicola* (bacterial spot);
- *Cauliflower mosaic caulimovirus;*
- *Turnip mosaic potyvirus;*
- minor diseases;
- *Brevicoryne brassicae* and *Myzus persicae* (aphids);
- *Phytomyza rufipes* and *Scaptomyza apicalis* (leaf miners);
- *Delia radicum* (cabbage root fly);
- *Delia floralis* (turnip root fly);
- *Psylliodes chrysocephala* (cabbage stem flea beetle);
- *Ceutorhynchus pallidactylus* (cabbage stem weevil);
- *Ceutorhynchus pleurostigma* (turnip gall weevil);
- *Meligethes* spp. (pollen beetle);
- *Aleurodes proletella* (cabbage whitefly);
- caterpillars;
- cutworms;
- *Phyllotreta* spp. (flea beetles);
- *Heterodera cruciferae* (brassica cyst nematode);
- slugs;
- weeds.

Explanatory note on active substances

The EPPO Panel on Good Plant Protection Practice, in preparing this guideline, considered information on specific active substances used in plant protection products and how these relate to the basic GPP strategy. These details on active substances are included if backed by information on registered products in several EPPO countries. They thus represent current GPP at least in those countries. It is possible that, for any of numerous reasons, these active substances are not registered for that use, or are restricted, in other EPPO countries. This does not invalidate the basic strategy. EPPO recommends that, to follow the principles of GPP, only products registered in a country for a given purpose should be used.

Leptosphaeria maculans (canker and leaf spot, dry rot)

General

Leptosphaeria maculans (anamorph *Phoma lingam*) is primarily a seed-borne pathogen with a number of different strains existing which vary in their virulence. Infected seed can give rise to spots on the cotyledons and the fungus may then spread to attack all parts of the plant. Leaf spots have ashen-grey centres and contain small black pycnidia producing spores which cause further disease spread. Within the plant, leaf infection can cause direct mycelial infection of petioles and stems. Stem infection occurs as light brown or purplish cankers from which the disease takes its name; these all contain pycnidia. Other plant parts can also be attacked - stem base, roots, flower stalks, pods and finally seeds. Severely affected plants are stunted and may wilt and die. The fungus can survive on and spread from infected crop debris. Dissemination is favoured by wet, windy weather.

The same pathogen also causes a dry rot of root brassicas. It is generally more important on roots of swede than turnip, particularly in early sown crops. Infection usually becomes noticeable in fields in the autumn and may spread during storage causing severe losses. Light transversely elongated spots occur on the roots and later enlarge, become brown and split open. Pycnidia are produced at the edges of the sunken lesions. Eventually the root may break down with a brown dry rot; secondary invasion by soft-rotting bacteria may lead to a wet decay (see *Erwinia* and *Pseudomonas* spp.). The main source of inoculum is crop residues in the soil although seed infection also occurs. In wet conditions, pycnidia produce masses of spores which are dispersed by rain-splash and wind. The fungus can remain viable in soil for several years and can survive passage through farm animals. Cruciferous weeds are attacked and can be a source of inoculum.

Basic strategy

For leaf spot and canker of leaf and flowerhead brassicas, the aim is to prevent introduction of the fungus on infected seed and to reduce its chances of survival in the field. Seed infection can be well controlled by fungicidal seed treatment (see below) or hot water treatment. Tested seed can be used. In the field, fungicide sprays have not always been found to give satisfactory control of leaf and stem infection. Therefore, cultural control methods should be optimized to reduce survival of the pathogen between successive brassica crops. Seedbeds should not have grown brassicas for several years or be situated near

other brassica crops or debris. Brassicas should not be cropped on the same field more than once in 4 years (but preferably longer). Diseased crop remains should be removed and burnt to prevent survival of fungus. If fungicides are used, they should be applied from the start of the attack. Little varietal resistance is available in brassica cultivars.

For root brassicas, long rotations should be practised and affected debris should be disposed of correctly. Cruciferous weeds should be controlled. Diseased roots should not be incorporated in compost or manure and affected debris and manure from animals fed on diseased roots should not be spread on fields. Seed treatments are used to give control of the seed-borne phase. Field spraying is not effective.

Main fungicides

Seed treatments: benomyl, thiabendazole, thiophanate-methyl, thiram. Sprays: iprodione.

Mycosphaerella brassicicola **(ringspot)**

General

Ringspot is an important disease of leaf and flowerhead brassicas in the wetter, western areas of northern and north-western Europe. The main sources of infection are infected crop debris, mature crops, overwintering rape. Pseudothecia on debris produce ascospores which are air- and splash-dispersed. These require leaf wetness and temperatures of 16-20°C for optimum infection and leaf lesion development. Leaf spots are typically circular, grey to black, contain numerous small black "pycnidia" (spermagonia) and may be up to 1.5 cm diameter. Spermagonia produce spermatia ("conidia") which are also spread by wind and rain. The older leaves are usually attacked first and turn yellow and wither prematurely. The fungus is able to penetrate seed coats but seed-borne infection is not thought to be a significant factor in epidemiology of the disease. Survival is on remains of infected leaves or in the soil.

Basic strategy

Cultural control methods aimed at minimizing successful survival, spread and infection by the fungus should be practised. These involve crop rotation, isolation of seedbeds, siting of crops (at least 500 m from rape crops), disposal of diseased leaves and avoidance of damp crowded crops and excess fertilizer. Cultivars with good resistance to ringspot are becoming more available, particularly for Brussels sprouts (e.g. Cor, Gabion, Lunet, Topaz). Reliance is generally placed on fungicide treatment in the field, beginning at first signs of infection. Better timing of sprays, and thus a reduction in fungicide usage, could be achieved by adoption of forecasting schemes currently under evaluation.

Main fungicides

Benomyl, chlorothalonil, difenoconazole, thiophanate-methyl.

Peronospora parasitica **(downy mildew)**

General

Downy mildew is common on all types of vegetable brassicas but is probably most damaging on flowerhead types and kohlrabi grown under cover, and least damaging on root brassicas. It can be severe on seedbeds under protection, particularly when exposed to conditions of high humidity, leaf wetness and cool temperatures. Infection may appear first on the cotyledons as yellow speckled patches on the upper leaf surface with corresponding white fungal growth on the under surface. The fungal growth comprises sporangiophores bearing sporangia which spread the disease. Severely infected seedlings are stunted or killed. Similar leaf symptoms occur in the field although the lesions appear as less well-defined yellowish brown areas between the main veins with white to grey fungal growth underneath. Severely affected leaves may senesce prematurely and drop off allowing secondary soft-rot invasion. Infected Brussels sprout buttons show discrete black spots, which affect the quality of the product. The curds or heads of flowerhead brassicas are severely affected, rendering them unmarketable. The fungus forms oospores in affected tissue which can survive in soil or debris for many months or years and be a major source of inoculum.

Basic strategy

Control of infection in the seedbed is essential, both to avoid early loss and to prevent introduction into the field. This will involve reduction of humidity and leaf wetness under protection and use of prophylactic fungicides to prevent infection establishing.

In the field, cultural methods include crop rotation to avoid build-up of the soil-borne phase and reduction of the favourable conditions afforded by, for example, humid sheltered sites and closely spaced plants. There is some evidence of resistance in commercially available cultivars of cabbage, broccoli and kohlrabi. Control by fungicides in the field, as opposed to the seedbed, tends to be difficult. Products used for control of *Albugo candida* have activity against *P. parasitica*.

Main fungicides

Chlorothalonil, cymoxanil, metalaxyl, propamocarb hydrochloride (especially in the seedbed), copper hydroxide, maneb, mancozeb.

Albugo candida (white blister)

General

This is locally an important pathogen of both leaf and flowerhead brassicas and can also affect cruciferous weeds, for example *Capsella bursa-pastoris*, although it is uncertain whether cross infection occurs. Primary infection is via stomata by zoospores from germinating oospores on plant debris or in soil. Wind-borne sporangia germinate by formation of zoospores. The symptoms are raised white patches, initially smooth and glossy, appearing mainly on the underside of the leaves, stems or inflorescence. They later become more powdery and blister-like, and may cause plant distortion. Both seedlings and young plants can be affected. Infection of Brussels sprouts button and cabbage heart leaves greatly reduces marketability. Similarly, *A. candida* can severely affect the curds or heads of flowerhead brassicas, thereby rendering them unmarketable. Root brassicas are not significantly affected.

Leaf wetness is required for infection to occur. The disease has a long incubation period at low temperature but develops more rapidly above 16°C. Disease levels usually increase in the autumn, decrease slightly and then build up again in winter. Infection is often associated with attacks by *Peronospora parasitica*. Oospores produced in infected tissue remain dormant in soil for several months.

Basic strategy

Avoidance of attack is facilitated by crop rotation, dry open sites for seedbeds and careful siting of crops. Destruction of potential sources of inoculum is important, i.e. removal and destruction of infected plants, crop debris and weeds. Some cultivars of Brussels sprouts (e.g. Predora, Lunet, Lauris, Peer Gynt) have good resistance to *A. candida*.

Heavy reliance is placed on fungicidal sprays in the field, from the first signs of disease. Most growers rely upon systemic fungicides. Forecasting methods are being evaluated and should offer scope for optimal timing of sprays in the future with associated reduction in numbers of applications.

Main fungicides

Metalaxyl.

Erysiphe cruciferarum (powdery mildew)

General

Powdery mildew can affect most brassicas but Brussels sprouts, cabbage and swedes can be severely infected, with resultant loss of yield and marketability. The fungus can only survive on green tissue; therefore affected brassica crops provide the main source of infection. The first signs of infection are patches of thin white mycelium radiating out sparsely on either leaf surface. This can develop into a much denser mat of white powdery growth covering parts of, or the whole, leaf surface. Spidery patches of growth are also common on stems of susceptible Brussels sprout cultivars. Buttons of the latter may show fine black speckling with or without sparse mycelium.

The disease is spread by windborne conidia from infected tissue; cleistothecia may also be present. It is typically severe in warm dry summers with temperatures of 15-20°C and periods of high humidity. Spring-sown crops often show the first symptoms in July with rapid development occurring during August and September.

Basic strategy

Powdery mildew, of all the brassica diseases, offers the best chance for control by host resistance. Many Brussels sprout hybrid cultivars possess good resistance, as do some autumn and winter cabbage cultivars and some swedes (e.g. Marian). Cultivar resistance should therefore be fully exploited, particularly in localities prone to seasonal attack and for root brassicas on light dry soils. Otherwise, factors favouring disease occurrence and development should be avoided. These include excess nitrogen fertilizer, water stress, presence of cruciferous weeds and dense crops. The standard practice for powdery mildew control is high-volume fungicide application from first observation of symptoms, but over-reliance to this approach can be avoided by paying attention to the other possibilities mentioned above. In the case of root brassicas, late attacks after bulking is complete do not significantly affect yields and should not require treatment.

Main fungicides

Pyrazophos, sulphur, triadimefon, triadimenol, triforine.

Alternaria brassicae and *A. brassicicola* (dark leaf spot)

General

Alternaria brassicae and *A. brassicicola* are both seed-borne and are common on cabbage (including during storage), kohlrabi, Chinese cabbage, cauliflower and Brussels sprouts. Other major sources of inoculum are diseased debris, infected brassica crops (including rape) and cruciferous weeds. Spores can spread from seed crops and rape during harvesting.

All aerial parts of the plant may be attacked. Symptoms range from small discrete black spots to large zonate lesions up to 12 mm diameter with brown centres. Lesions may bear a sooty mass of spores and be surrounded by a chlorotic halo. The centres become thin and papery with age, eventually dropping out to give a "shot-hole" effect. The conidia spread by wind

and rain and infection is favoured by warm (optimum 20-24°C) moist conditions. The two species differ in their temperature requirements, *A. brassicicola* being more readily checked by low temperatures.

On root brassicas, *A. brassicae* can cause severe leaf spotting and even defoliation in turnips, but swedes are less susceptible. Leaves are covered with typical papery, pale brown spots 3-5 mm diameter surrounded by a yellow halo. Infection can be severe in areas of humid climate and in warm, wet seasons.

Losses in yield and marketability occur when Brussels sprouts buttons are infected. Dutch white cabbage is affected during storage. Cauliflower curds and Chinese cabbage can also suffer extensive rotting due to *Alternaria* attack later in the year.

Basic strategy

There is little or no cultivar resistance available in leaf or flowerhead brassicas, but some cultivars of turnip possess moderate to good resistance to *A. brassicae.* Control measures involve control of the seed-borne phase, high-volume sprays in the field from first symptoms and cultural methods to limit survival and spread. Seed treatment is strongly recommended and seedlings raised under protection require disease control by environmental manipulation. Regular scouting of crops and correct diagnosis should allow timely treatment with an effective fungicide. The threat from infected debris and weeds can be reduced by attention to crop residue disposal, isolation of crops and weed control. Pre-storage dips may be employed to protect Dutch white cabbage from infection during storage.

Main fungicides

Sprays: anilazin, chlorothalonil, difenoconazole, iprodione, mancozeb, maneb, vinclozolin. Seed treatment, storage dip/drench: iprodione. Iprodione is specially recommended for root brassicas.

***Pyrenopeziza brassicae* (light leaf spot)**

General

Pyrenopeziza brassicae (anamorph *Cylindrosporium concentricum*) is common at low levels, but can be severe occasionally, on Brussels sprouts, cauliflower and swede; it is less serious on cabbage. The main sources of inoculum are infected crops and debris. The conidia are spread by wind and rain splash. Young lesions are initially superficial, developing on upper leaf surfaces, and silvery in appearance due to cuticle lifting. Lesions become paler and more bleached with age and may coalesce forming large patches, particularly on lower leaves. The fungus usually produces typical concentric rings of white spore droplets in cool wet conditions. It is typically seen in north-western Europe.

All aerial parts of the plant may be affected. The disease can be damaging on Brussels sprout buttons. The sexual stage of the fungus has occasionally been found in rape crops; apothecia producing ascospores were observed on rotting petioles. This could allow long-distance spread of the pathogen although its significance is not yet known.

Basic strategy

Infected crop debris should be ploughed in to restrict survival of the fungus but it is prudent also to practise a crop rotation for 4 years or more between brassica crops. Light leaf spot is a common disease of rape, so proximity to rape crops should be avoided. There is good resistance to light leaf spot in some commercial cultivars of Brussels sprouts, e.g. Cavalier, Richard, Lunet and this cultivar resistance should be more fully utilized. Normal practice is to spray with high volumes of fungicides. However, control is often unsatisfactory due to the difficulty in correct diagnosis and hence optimum spray timing.

Main fungicides

Benomyl, carbendazim, chlorothalonil, prochloraz.

***Botrytis cinerea* (grey mould)**

General

Botryotinia fuckeliana (anamorph *Botrytis cinerea*) can attack all aerial parts of brassica plants and can be damaging on Brussels sprouts buttons and cabbage hearts. The fungus usually enters via damaged tissues, for example following frost, tipburn, mechanical damage, pest attack. It can also affect undamaged tissues if these are in contact with infected material. The usual symptoms are presence of typical grey fungal growth and softening of tissues; bacterial soft rots may invade affected areas. *B. cinerea* can also affect stored Dutch white cabbage usually following dehydration of wrapper leaves or mechanical damage.

The disease is favoured by cool (10-15°C) wet weather and by high nitrogen application although insufficient nitrogen can have the same effect. The main sources of infection are dead or dying plants and crop debris. Sclerotia may be formed in infected tissues, thus providing a means of longer-term survival.

Basic strategy

Specific control measures against *Botrytis* are not usually employed. Avoidance of damage and wet conditions at the seedling stage should be practised, particularly under protection. In the field, avoid damage and use of high levels of nitrogen, and dense crops. It is important to destroy plant debris from the previous crops. High-volume sprays of fungicides may give incidental control of *B. cinerea* in the field.

Pre-storage fungicide dips may be used for protection of Dutch white cabbage.

Main fungicides

Benomyl, carbendazim, chlorothalonil, iprodione (spray or storage drench), thiabendazole (storage spray), vinclozolin.

***Rhizoctonia solani* (wirestem)**

General

Thanatephorus cucumeris (anamorph *Rhizoctonia solani*) is a ubiquitous soil-borne fungus, which causes damping-off of brassica seedlings and wirestem of older plants. The stems of seedlings affected by damping-off are softened and collapse at ground level. If attack occurs later or conditions are less favourable for the fungus, stem bases show a hard brown shrunken symptom (wirestem) which may cause collapse and death of the plant. The pathogen can also attack roots, severe infection causing death. *R solani*, and the related minor pathogen *R. carotae*, can also cause a storage disease (crater rot) of root brassicas, especially swedes.

R. solani survives in soil, compost and infected debris as mycelium and undifferentiated sclerotia. Infection is usually more severe in seedlings raised in beds, frames or under glass than in direct-drilled crops. Factors which stress or check plant growth will favour attack, e.g. under or over-watering and slow winter growth.

Basic strategy

Cultural control measures are usually relied upon to reduce the chances of attack. These include a wide crop rotation and hygienic disposal of crop debris. When previous infection has occurred or where there is a perceived risk of *R. solani* attack, protectant fungicides may be incorporated into compost or soil. Soil sterilization will also control the fungus, but is not GPP.

Main fungicides

Seed treatments: chlorothalonil, thiram, tolclofos-methyl. Sprays on seedbeds, or spraying/drenching of transplants before transplanting: iprodione, pencycuron.

***Pythium* spp. (damping-off)**

General

In common with many crops, brassicas can be infected by species of *Pythium* which cause pre- or post-emergence damping-off (see also *Rhizoctonia solani*). Infection usually occurs at or just after emergence and the seedling stem becomes constricted or rotted and the plant collapses. *Pythium* spp. can also cause root rot. Infection is favoured by cold wet conditions in propagation and in the field. *Pythium* spp. are common soil-inhabiting fungi able to survive for long period.

Basic strategy

Crop rotation, adequate drainage and avoidance of sowing or planting in cold wet soils should aid prevention of severe attacks by *Pythium* fungi. Good hygiene should be practised in propagation areas. Plants raised in peat blocks should not be overwatered or allowed to dry out. Seed treatments containing thiram, and/or pre-sowing or pre-planting incorporation of fungicides, can provide early protection of seedlings.

Main fungicides

Incorporation: etridiazole, propamocarb hydrochloride. Seed treatment: metalaxyl, thiram.

***Plasmodiophora brassicae* (clubroot)**

General

Clubroot is a common problem on most brassica species, and also affects cruciferous ornamentals and weeds. Of the leaf and flowerhead brassicas, cabbage, Chinese cabbage, Brussels sprouts and cauliflower can be severely affected. The first symptoms of infection in the field are wilting and bluish leaf discoloration, particularly noticeable during periods of water stress; severely affected plants may die. Roots are galled due to invasion by motile zoospores via root hairs. Infected roots eventually rot, releasing masses of resting spores into the soil which may remain viable for at least 20 years in the absence of cruciferous hosts. When a suitable host is grown, resting spores are stimulated to form infective zoospores. Infection usually does not occur below 18°C but can occur down to 10°C. Soil temperatures of 20-24°C favour disease development. Disease incidence is higher in poor acid soils and can be particularly severe in years of high rainfall and warm soil temperatures. Disease severity increases progressively as soil moisture content rises from 50% of maximum water-holding capacity up to saturation.

Clubroot can also be extremely damaging on root brassicas and its effects even more obvious than on leaf and flowerhead types. Infected roots exhibit tumour-like swellings and the main root may be distorted. Premature decay and extensive soft rotting often follow.

The most common means of spread is for seedlings to become contaminated from infected soil or water in the seedbed. Early infection can lead to galling within blocks prior to planting. Infested soil adhering to machinery, equipment and footwear also spreads the pathogen, as can drainage water. Spread in manure from animals fed with infected material also occurs.

Basic strategy

Liming to increase the soil pH to at least 7.0 is the mainstay of clubroot control. Long rotations of at least 8 years between brassica crops are important but the resting spores can remain viable much longer than this. Care must be taken in the seedbed and during transplanting to avoid contamination by infested soil and water. Fields destined for brassica cropping can be tested for presence of clubroot. Drainage problems should be corrected and cruciferous weeds controlled. Infected brassica material should not be fed to stock. Resistance is claimed for a number of cultivars of, for example, Chinese cabbage and root brassicas.

Turnips are generally more resistant to clubroot than swedes and some cultivars have good resistance. Swede cultivars such as Marian have moderate resistance and may be less severely attacked but will still show symptoms on affected sites.

Effective fungicides for clubroot control have always been lacking, although mercurous chloride (now prohibited) was at one time relied upon for early protection. Some soil sterilants can be used to reduce the pathogen population either in the seedbed or in the field but the main emphasis on disease control has to be cultural. Soil sterilization can only be considered GPP in the seedbed. The best available fungicidal control is a thiophanate-methyl dip for transplants.

Main fungicides

Thiophanate-methyl.

***Phytophthora* spp. (root rot, storage rot)**

General

Phytophthora megasperma occasionally causes a root rot of brassica crops, particularly Brussels sprouts and cauliflower. It has also been recorded on rape. Infected plants are wilted, stunted and exhibit rotting of stem and root cortex. The disease is favoured by wet, compacted soil conditions and waterlogging, such as are found on headlands and low-lying areas of fields. *P. porri* sometimes causes a rot of stored Dutch white cabbage and Chinese cabbage. The symptoms are presence of a firm pale brown rot extending from the butt end into the head. Soil is the main source of the pathogen and should not be allowed to contaminate trimmed heads.

Basic strategy

Fields with a history of *Phytophthora* infection should be avoided. Soil compaction and drainage problems should be corrected. For stored cabbage, only healthy heads should be stored and should remain uncontaminated and dry. Dip treatments are sometimes employed but heads should be well drained after treatment to minimize bacterial invasion.

Main fungicides

Metalaxyl (pre-storage dip).

***Verticillium dahliae* (wilt)**

General

Verticillium wilt is an occasional disease of Brussels sprouts, cauliflower and Chinese cabbage. The fungus is soil-borne and may be a distinct pathological strain. The symptoms are first seen on the lower leaves which turn yellow, then brown and finally fall. The fungus penetrates the vascular system of the plant causing a dark brown or black discoloration. Infection may occur in patches in the field and is favoured by wet conditions.

Basic strategy

The disease is rarely of economic importance and does not warrant specific control measures. Adequate rotation should be practised to avoid build-up of this and other soil-borne diseases. If present, affected plants should be removed and burnt.

Main fungicides

None.

***Xanthomonas campestris* pv. *campestris* (black rot)**

General

Black rot is a seed-borne bacterial disease sometimes found on Brussels sprouts, cabbage, cauliflower, kale, swede and turnip. It also affects other crucifers such as radish and the weed *Capsella bursa-pastoris*. Seed-borne infection may kill young plants in the seedbed. The main symptoms are V-shaped yellow areas at the leaf margins, with associated vein blackening which may extend down into the petiole and stem. Black vascular staining occurs within affected petiole, stem and root tissue. In crops, patches of infected plants are usually evident. Severely affected plants may lose lower leaves and exhibit one-sided stunting. The bacterium can also survive on debris in the soil. Spread within a crop is mainly by rain splash. The bacterium invades the plant through pores at the leaf margin (hydathodes) or occasionally via stomata or root wounds. Severe attacks are favoured by hot wet weather in summer and autumn.

Basic strategy

Control of *X.c. campestris* relies on use of pathogen-free seed and correct disposal of debris in the field. Avoid transfer of soil and debris from infested fields. A

3-year rotation with non-cruciferous crops is recommended. Tested seed can be used, or hot-water treatment (20-25 min at 50°C) can help to reduce seed contamination. There is no chemical control available.

Erwinia and *Pseudomonas* spp. (soft rots, spear rot)

General

Bacterial soft rotting is very common in most brassica crops, whether of the leaf, flowerhead or root type. It can be particularly damaging in stored cabbage, Chinese cabbage, cauliflower, kale, turnip and swede. All plant parts can be affected by soft rots, including internal tissues of stem and root. Bacterial invasion usually follows frost, pest or mechanical damage, and develops mainly under warm weather conditions. Plants may be predisposed by nutritional deficiency or imbalance. The soft-rotting bacteria (most commonly *Erwinia carotovora*, *Pseudomonas cichorii* and *P. marginalis*) are common soil inhabitants. The effects of their invasion are accentuated by wet conditions and therefore some seasons have a high level of damage.

Calabrese is affected in the field by a specific soft-rotting disease, spear rot, which is not fully understood though *P. marginalis* and *Erwinia carotovora* pvs *carotovora* and *atroseptica* have been consistently isolated from infected spears. The symptoms first appear as a small watersoaked area on the spear, developing into a black slimy rot. Infection is most common in crops harvested in late summer, autumn and early winter when cooler, damper air conditions limit transpiration. With roots still active in warm soil, water pressure in the flower buds causes cell rupture, thus favouring infection. High rates of nitrogen application tend to exacerbate spear rot.

Basic strategy

There is no chemical control available for soft rots. Prevent insect damage. Affected plants should be burned or buried and should not be stored. Cropping other susceptible hosts should be avoided for at least 2 years on infested sites. Avoid harvesting under wet weather conditions. Fully ripened cabbage is more susceptible in store. Any predisposing factors should be identified and corrected to minimize future losses.

For spear rot of calabrese, treatment with a protectant copper-based fungicide can be used in the field from button formation onwards. Avoidance of high nitrogen levels is desirable. Some resistance has been found in calabrese cultivars (Samurai, Clipper, Green Valiant) and the more resistant cultivars should be grown, provided that they meet the necessary quality standards. There is a tendency for flatter-headed cultivars to be worse affected.

Main bactericides

Copper oxychloride (for spear rot of calabrese).

Pseudomonas syringae pv. *maculicola* (bacterial spot or rot)

General

This bacterial disease is locally important on cauliflower particularly in coastal areas and is most severe during cool damp weather. Symptoms can appear in the seedbed as small, angular to round, water-soaked lesions, later becoming darker and surrounded by a chlorotic halo. Lesions may coalesce to form larger elongated spots. Severe seedling infection may result in plant death. Similar symptoms occur in the field. In addition, many spots 5-7 mm in diameter surrounded by a water-soaked area may form on the leaf undersurface. These spots later become darker with a yellow halo. Affected leaves are puckered and distorted and may have large brown lesions and fall off if severely affected. Such plants may be stunted and lack curds. Affected curds initially have brown spots affecting one floret. As the curd develops, infected florets become dark brown, rotted and sunken, and secondary soft-rotting organisms may invade the tissue.

The pathogen is primarily seed-borne, being carried on or with seed heads. Infection is via stomata or wounds caused by insect, frost or mechanical damage. Water is necessary for infection and spread of the bacterium. It can overwinter in affected plant tissues and debris.

Basic strategy

No bactericidal control is available for this disease. Control is reliant upon use of disease-free seed and planting material. Hot water treatment of seed can be used as for *Xanthomonas campestris* pv. *campestris*. Good hygiene is essential in propagation areas to avoid carry-over and spread of the pathogen. In the field, damage should be avoided and polythene-covered crops isolated from uncovered ones. Other diseases and pests should be controlled. Cauliflower cultivars vary in susceptibility to the disease and resistance should be exploited.

Cauliflower mosaic caulimovirus

General

Cauliflower mosaic caulimovirus (CaMV) is becoming increasingly common following a number of years of increased activity of its main aphid vectors, *Brevicoryne brassicae* and *Myzus persicae*. Disease incidence is usually low but it can occasionally be

serious in some crops of Brussels sprouts, cabbage and cauliflower in intensive growing areas. CaMV can severely affect the curds or heads of flowerhead brassicas, rendering them unmarketable. Cruciferous weeds and ornamentals may also be affected. The symptoms vary according to crop but leaf mosaic and mottling, vein clearing and banding, and plant distortion and stunting are typical. *Broccoli necrotic yellows rhabdovirus* may also occur in CaMV-infected plants and can exacerbate the symptoms in Brussels sprouts.

The virus is transmitted in the semi-persistent or non-persistent manner, being acquired in 1-2 min and transmitted in under 1 min without a latent period. Once infective, an aphid is capable of transmitting the virus for several hours. The virus persists in cruciferous crops, ornamentals and weeds. There is no evidence of seed transmission.

Basic strategy

Control of the aphid vectors with insecticide (see section on Aphids) is used to restrict spread of virus and reduce direct damage. It is more difficult to prevent introduction of virus into crops initially by use of aphicides but cultural control methods can help to avoid aphid attack and virus carry-over. Such methods include control of cruciferous weeds, isolation of seedbeds from crops, separation of successive sowings or plantings and avoidance of sheltered sites. Destruction of crop remains, particularly after overwintering crops, is essential to eliminate an important source of infection.

Turnip mosaic potyvirus

General

Turnip mosaic potyvirus (TuMV), previously known as *Cabbage black ringspot virus*, is transmitted by the same aphids as CaMV and may infect the same plants as the latter. Brussels sprouts sometimes show leaf symptoms and stunting due to TuMV infection but the various types of cabbage can be rendered unmarketable from severe attacks. The disease is also important on root brassicas. Leaf symptoms on cabbage are chlorotic spots with darker borders or concentric dark and light green venation on the young leaves with darker necrotic rings and spots on older leaves. Necrotic spotting extending into the heart can cause losses in marketability, particularly in stored Dutch white cabbage. Chinese cabbage can also be severely affected with necrotic lesions, crinkling and stunting of heart leaves, up to 100% damage.

Virus transmission is in the non-persistent manner, being acquired and transmitted in under 2 min and retained in the vector for under 4 h. The main sources of infection are crop remains and mature brassica crops. Cruciferous ornamentals and weeds also harbour the virus. It is not known to be seed-borne. Over 50 aphid species are capable of transmitting TuMV.

Basic strategy

There is some resistance available in commercial cabbage cultivars. Apart from that, the aim is to control the aphid vectors (see section on Aphids) and restrict the chances of introduction, spread and carry-over as detailed for CaMV.

Minor diseases

Two other foliage diseases occur sporadically on brassicas but are rarely of economic significance: *Pseudocercosporella capsellae* (white leaf spot may be a problem in northern countries, penconazole is recommended when symptoms are observed); *Pleospora herbarum* (leaf spot). Brassicas can be affected by the bacterial pathogens *Agrobacterium tumefaciens* (crown gall) and *Rhodococcus fascians* (leafy gall), and are also infected by several viruses of minor importance (*Turnip yellow mosaic tymovirus*, *Radish mosaic comovirus*, *Turnip rosette sobemovirus*, *Turnip crinkle carmovirus*). Soil-borne fungi like *Sclerotinia sclerotiorum* (stem rot) and *Helicobasidium brebissonii* (violet root rot) can be controlled in general like *Rhizoctonia solani. Streptomyces scabies* (scab) can attack root brassicas.

Brevicoryne brassicae (cabbage aphid) and *Myzus persicae* (peach potato aphid)

General

Aphids, especially *Brevicoryne brassicae*, are important and widespread pests of brassicas, especially Brussels sprouts, cabbage, cauliflower and swedes. Heavy infestations cause leaf distortion and the growth of young plants may be checked. Quite small infestations can reduce the quality of Brussels sprout buttons and cabbage. Heavy infestations of root brassicas, particularly when plants are under stress, can cause yield losses. Both aphid species transmit *Cauliflower mosaic caulimovirus* and *Turnip mosaic potyvirus* (see sections on CaMV and TuMV), which are widespread and damaging in some seasons. Aphid colonies often persist on crops and crop debris throughout the winter, if mild. Serious aphid infestations develop during prolonged warm summer weather. Control measures are required in most years.

Basic strategy

Most aphid infestations develop from overwintering colonies or eggs on brassica crops and debris. These should be destroyed by early May. Crops should be monitored regularly to ensure aphids do not become established, becoming very difficult to control. Systemic insecticides, granules or sprays are particularly effective. For early brassica sowings, foliar sprays are recommended and repeated as necessary. For later sowings/plantings, granular aphicides applied to soil or foliage will give prolonged aphid control. Wherever possible, dual-component granular

insecticides for control of aphids and *Delia radicum* should be applied. When considering the choice of a foliar spray, a specific aphicide like pirimicarb is preferred, since it will preserve most insect natural enemies as well as giving more effective control of organophosphorous-resistant *M. persicae*.

If very late applications are necessary near to harvest, a spray of short persistence or a chemical with a fumigant action should be used. Where it is necessary to eradicate infestations in August/September, pendant lances are essential to improve spray coverage of lower leaves and buttons of Brussels sprouts. In several countries, control thresholds for *B. brassicae* have been evaluated and introduced into practice. Supervise pest control should be done if possible.

Main insecticides

Sprays: demeton-S-methyl, heptenophos, methamidophos, pirimicarb (all types of vegetable brassicas); dimethoate, oxydemeton-methyl, quinalphos, thiometon (leaf and flowerhead brassicas).Granules: carbofuran (all types of vegetable brassicas); disulfoton, phorate (leaf and flowerhead brassicas); chlorpyrifos, diazinon (leaf brassicas).

Phytomyza rufipes **and** ***Scaptomyza apicalis*** **(cabbage leaf miners)**

General

These two species of leaf miner are widespread and occasionally cause serious damage, especially to leaf brassicas. Adult *Phytomyza rufipes* puncture the leaf surface causing numerous yellow pin-pricks to develop which can affect the quality of the produce. The larvae mine within the midribs and leaf petioles causing leaf drop. Larvae of *Scaptomyza apicalis* make large blotch mines in the leaf lamina, which affects the marketability of the produce. In flowerhead brassicas, larval attacks in the young shoots of calabrese grown for processing are particularly important.

Basic strategy

As large populations can develop in rape, susceptible brassicas should be grown as far as possible from rape crops. Some systematic granular insecticides applied to control cabbage aphids or *Delia radicum* will give some control of leaf miners. Foliar sprays are recommended when serious attacks develop. Usually only one application is necessary.

Main insecticides

Cypermethrin, deltamethrin, dimethoate, methamidophos, permethrin, trichlorfon.

Delia radicum **(cabbage root fly)**

General

Delia radicum (syn. *D. brassicae*) is a widespread and destructive pest causing damage to brassicas in all areas in most years. The larvae feed on the roots or in the lower stems, often killing young plants and affecting crop yield and quality. Maggots mining or severing the roots may lead to wilting or discoloration of the foliage. Occasionally, larvae tunnel into buttons of early-maturing cultivars of Brussels sprouts, leading to crop rejection by processors. In root brassicas, damage by maggots to the crown may lead to development of multiple crowns and secondary rotting caused by bacteria and fungi. Maggots of later generations may scar the roots, affecting marketability but not yield. There are 2-7 generations each year, across Europe, the heaviest attacks usually resulting from eggs laid by the first generation of flies in April and May, or second generation in July.

Basic strategy

Crops planted or sown when adult flies are scarce, i.e. between generations, are less liable to severe damage. However, this is rarely practical on a commercial scale. Low-level crop covers used to encourage earlier crop maturity, or net-type covers, can also reduce incidence of *D. radicum* damage.

Chemical control measures must be preventive because little can be done to stop an attack in progress. Insecticides should be placed accurately around the base of the plant or with the seed at sowing. The effects of insecticides on populations of the natural enemies of *D. radicum* can be reduced by applying chemicals to the soil close to the seed/plant rather than broadcasting or spraying over the soil surface. In northern Europe, all sowings and plantings made from mid-April should receive a routine insecticide treatment. For earlier sowings and plantings, treatment should be delayed until late April. Information on the anticipated start and peak of each generation is available in some areas to growers to enable more effective timing of certain insecticide applications.

Methods of chemical control vary depending on growing practice:

- *seedbeds* only require insecticide treatment if plants are to remain in the bed after late April. Plants will need further protection after transplanting. In the seedbed, incorporate insecticide granules before sowing, apply granules at sowing or use an overall insecticide spray after sowing;
- *plants raised in peat blocks or loose-filled cells* should have appropriate granular insecticide mixed into the peat compost before block making or an insecticide should be applied as a drench to blocks or cells immediately before planting. Such treatments restrict insecticide to an area immediately around the roots;
- *in the field*, a band of insecticide granules is applied at sowing, sub-surface at transplanting or over the

plants after emergence or transplanting. Dual-component granules for the combined control of *D. radicum* and aphids should be used whenever possible to reduce overall insecticide application in areas where both pests are a problem;

- *Brussels sprout buttons and Chinese cabbage leaves* may have to be protected in areas where larval infestations cause a problem. Spray with an insecticide when later generations of *D. radicum* are forecast to be active; a repeat application may be necessary.
- *for root brassicas*, rapid plant growth and early harvesting of roots will help to minimize damage. In areas where later generation attacks are important, foliar sprays may be applied in mid-late July or granules in mid-season.

Main insecticides

Sprays: azinphos-methyl, diazinon, dimethoate, trichlorfon (all types of vegetable brassicas); chlorfenvinphos (leaf and root brassicas); chlorpyrifos (leaf and flowerhead brassicas); triazophos (leaf brassicas). Granules: aldicarb, carbofuran, carbosulfan, chlorfenvinphos, chlorpyrifos (all types of vegetable brassicas); fonofos (leaf and root brassicas); dimethoate (leaf brassicas).

Delia floralis **(turnip root fly)**

General

Delia floralis, which occurs mostly in northern Europe, is almost indistinguishable from *D. radicum*. It mainly affects root brassicas. The larvae often tunnel more deeply into the stems and there is only one generation each year which is active from mid-summer until early autumn. Damage is usually seen from late September.

Basic strategy

In areas where *D. floralis* is a problem, late-sown root brassicas should be treated with a granular insecticide at sowing or shortly after emergence. For earlier sown crops, a second application of granules made over the rows should be applied in late July or early August.

Main insecticides

Carbofuran, chlorfenvinphos, dimethoate.

Psylliodes chrysocephala **(cabbage stem flea beetle)**

General

Attacks by *Psylliodes chrysocephala* are localized and occasionally damaging. The larvae tunnel into the leaf petioles and stems of overwintering leaf brassica seedlings in late summer/early autumn. Plants may be killed but usually only plant vigour is affected. Attacks tend to be more common in areas growing a large density of rape, on which this pest is very common.

Basic strategy

Susceptible brassicas should be grown as far as possible from rape crops. Insecticides applied for *Delia radicum*, if they have some systemic activity, will give some control of *P. chrysocephala* infestations. Otherwise, spray at the first sign of damage or when a threshold of capture in water traps is reached. Usually only one application is necessary.

Main insecticides

Granules: carbofuran, lindane. Sprays: carbaryl, cyfluthrin, cypermethrin, deltamethrin, fenvalerate, malathion, methamidophos.

Ceutorhynchus pallidactylus **(cabbage stem weevil)**

General

Ceuthorhynchus pallidactylus (syn. *C. quadridens*) is a widely distributed but sporadic pest affecting brassicas raised in outdoor seedbeds. The larvae feed in the stems and petioles of plants which frequently wilt after transplanting.

Basic strategy

Build-up of this pest can be reduced by setting up seedbeds on different sites in successive years. Also, because large populations build up in rape, it is advisable to site seedbeds as far away from rape crops as possible. Where *C. pallidactylus* is a persistent and damaging pest, it is recommended to use a systemic granular insecticide in the seedbed to control it at the same time as *Delia radicum*.

Main insecticides

Granules: carbofuran, carbosulfan. Sprays: cyfluthrin, cypermethrin, deltamethrin, endosulfan, malathion, methamidophos, phosalone.

Ceutorhynchus pleurostigma **(turnip gall weevil)**

General

A common, but often localized pest. It attacks most brassica crops, especially late-sown or late-planted cabbage and cauliflower and occasionally root brassicas. The grubs feed on the roots within hollow galls. Seedlings or recent transplants may suffer a check in growth but yields are rarely affected.

Basic strategy

Wide crop rotations help to reduce infestations. Residues from previous crops on which the pest will survive should be removed rather than ploughed in. Insecticide seed treatment will give some control of *C. pleurostigma*, as will some of the insecticides applied to control *Delia radicum*.

Main insecticides

Seed treatment: lindane.

Meligethes **spp. (pollen beetle)**

General

In some seasons, large numbers of pollen beetles migrating from oilseed rape in July, invade brassica crops and feed on developing florets of cauliflower and calabrese. Damaged tissue turns brown, often making the produce unsaleable.

Basic strategy

Wherever possible avoid growing susceptible crops likely to be heading in July close to crops of oilseed rape. Sprays of pyrethroid insecticides will give some control but they must be applied at first sign of pollen-beetle invasion and repeat sprays may be necessary. Forecasts may be made of time of likely migration of pollen beetles from rape.

Main insecticides

Alpha-cypermethrin, cyfluthrin, cypermethrin, deltamethrin, endosulfan, esfenvalerate, fenvalerate, lambda-cyhalothrin, permethrin.

Aleurodes proletella **(cabbage whitefly)**

General

Aleurodes proletella is a locally important pest of Brussels sprouts and cabbage. It occurs only occasionally on flowerhead brassicas. Feeding of the nymphs on the leaves causes discoloration and lack of vigour. The honeydew produced attracts fungal growth causing loss of quality.

Basic strategy

The destruction of overwintering brassica crops on which whitefly can survive will help to minimize the movement of the pest to the new season's crops. Control of an established infestation is difficult, so frequent crop monitoring is required to ensure damaging infestations do not develop. Several insecticide spray applications may be necessary, applied at high water volumes during prolonged hot and dry weather which encourages rapid build-up of the pest.

Main insecticides

Cypermethrin, deltamethrin, methamidophos, permethrin, pirimiphos-methyl.

Caterpillars

General

The lepidopteran larvae which are most commonly found on, and damaging to, brassicas are those of *Mamestra brassicae* (cabbage moth), *Pieris brassicae* (large white butterfly), *P. rapae* (small white butterfly), *Evergestis forficalis* (garden pebble moth), *Plutella xylostella* (diamond-back moth), *Autographa gamma* (silver Y moth) and *Spodoptera littoralis* (Mediterranean brocade moth). The damage caused varies with the species but they all feed on the foliage, flowers or heart, while fouling the plants with excrements. Root brassicas may be attacked by the same species, but usually suffer little damage. However, even small numbers of caterpillars can affect the quality of Brussels sprout buttons and cauliflower heads, especially when grown for processing. Control measures are usually necessary in most years for caterpillars of *M. brassicae* and *P. rapae*, for *P. xylostella* in warm, dry summers and for *E. forficalis* in localized areas only. *S. littoralis* occurs in southern Europe only.

Basic strategy

Control of caterpillars must be linked to a thorough programme of crop monitoring. Crops should be checked regularly for eggs of young caterpillars and sprayed when these are easily found. Pheromone traps are available for some species, e.g. *P. xylostella*, and these should be used to indicate when crop inspections should begin. The synthetic pyrethroids give very effective control of most species providing they are applied before the caterpillars have burrowed into the heart of the plant. For the control of *P. xylostella* and *P. rapae* caterpillars, it may be necessary to apply an organophosphorous insecticide with translaminar activity. Formulations of *Bacillus thuringiensis* var. *thuringiensis* can be used (except for noctuids and *E. forficalis*).

All insecticides should be applied in high water volumes using pendant lances to improve spray coverage on lower leaves and buttons of Brussels sprouts. Usually, only one spray is necessary but if adults infest crops over a long period, a second spray is required. Some control of aphids may be achieved with insecticides applied to control caterpillars. On root brassicas, control measures are rarely justified except when severe attacks by caterpillars of *P. xylostella* occur on young plants.

Main insecticides

Alpha-cypermethrin, *Bacillus thuringiensis* var. *thuringiensis*, cypermethrin, deltamethrin, endosulfan, esfenvalerate, fenitrothion, lambda-cyhalothrin, permethrin, quinalphos, thiometon (all types of vegetable brassicas); chlorpyrifos, cyfluthrin, triazophos, trichlorfon (leaf and flowerhead brassicas); fenvalerate (leaf brassicas). Against the noctuids *A. gamma*, *M. brassicae* and *S. littoralis*, use especially the insecticides also recommended against cutworms (see below).

Cutworms

General

Cutworms are the caterpillars of certain *Noctuidae* which feed on plants at or just below ground level, severing them from their roots. The most damaging cutworm is the caterpillar of *Agrotis segetum* (turnip moth)**,** but others including *Noctua pronuba* (large yellow underwing moth) and *Euxoa nigricans* (garden dart moth) also attack brassicas on occasions. Most damage occurs just after transplanting or in the seedling stage when the crop is direct-drilled. Crops sown or planted into weedy ground are vulnerable to attack especially in warm, dry summers. Cutworms are important pests of root brassicas, biting holes in the swollen tap root which may kill small plants or make large ones unsaleable.

Eggs are laid on weeds and on brassica plants. After hatching, the caterpillars feed for 10-14 days above ground on foliage and then move down into the soil to feed as a cutworm. Once in the soil, cutworms are difficult to control with insecticides and little can be done to halt attacks in progress.

Basic strategy

To minimize the risk of damage, sow or plant into weed-free soil. Also, because the young caterpillars feeding above ground die in wet soil, the frequent irrigation of susceptible crops should prevent serious damage occurring. Crops at risk are best treated with an insecticide while the caterpillars are very small and feeding above ground. Adult moth activity can be monitored using pheromone traps. On this basis, together with weather and soil-type data which provides information on caterpillar survival and development, spray warnings can be issued. Usually only one insecticide treatment, applied in a high water volume, is necessary. Insecticides applied to the soil to control *Delia radicum* may give some control of cutworms.

Main insecticides

Chlorpyrifos, cyfluthrin, deltamethrin, permethrin (all types of vegetable brassicas); cypermethrin, lindane, triazophos, trichlorfon (leaf and flower head brassicas).

***Phyllotreta* spp. (flea beetles)**

General

Phyllotreta spp. (e.g. *P. cruciferae*, *P. nigripes*) are widespread and often serious pests of all seedling brassicas. Transplanted crops are rarely affected. Damage is especially severe on root brassicas in dry seasons, when plant emergence may be slow. It is usually the first generation of beetles infesting crops in May and June which causes most damage.

Basic strategy

Crops sown before early April or from late June usually suffer less damage, so reducing the need for insecticide applications: a well-prepared, moist seedbed with adequate fertilizer will ensure rapid germination and help seedlings grow quickly through the susceptible stage. Soil treatment with granular formulations of the systemic insecticides applied to control *Delia radicum* at sowing will give effective control of flea beetles. Many seed stocks are routinely treated with an insecticide which is effective against light to moderate flea beetle attacks. Where seed treatment has not been used or a heavy attack develops, post-emergence sprays are recommended. One or two applications may be necessary.

Main insecticides

Granules: aldicarb, carbofuran, carbosulfan. Seed treatments: furathiocarb, lindane, isofenphos. Sprays: alpha-cypermethrin, cyfluthrin, deltamethrin, fenitrothion, fenvalerate, lindane, lambda-cyhalothrin, permethrin, trichlorfon.

***Heterodera cruciferae* (brassica cyst nematode)**

General

Heterodera cruciferae is a widespread pest which can be found in most soils in which brassicas are frequently grown. Infestations retard crop growth, putting plants under stress although crop yields are rarely affected. The nematode survives in the soil in the absence of a host crop and 2-3 generations may be completed in one year on a long-growing crop.

Basic strategy

Crop damage can be avoided by not over-cropping with brassicas. Chemical control is not usually necessary, except sometimes in seedbeds where large nematode infestations can build up.

Main nematicides

Aldicarb, dazomet, ethoprophos, oxamyl.

Slugs

General

Slugs (e.g. *Agriolimax arvensis*, *Deroceras reticulatum*) damage brassica seedlings, sometimes feed on established plants and can be particularly troublesome on Brussels sprouts, feeding on the buttons. On root brassicas, slugs graze on leaves and eat holes in the tap root, sometimes causing severe damage to seedlings. Slugs are largely a problem on medium to heavy textured soils in wet seasons causing most damage in the late spring and autumn.

Basic strategy

A firmly consolidated seedbed will restrict slug movement and encourage rapid growth of brassica seedlings. To assess the risk of slug damage and the need for and time of molluscicide treatments, test baiting when the soil surface is moist is advised. The normal method of treatment is scatter molluscicide formulated as a bait. On Brussels sprouts, the most effective time to apply bait pellets is when the crop just meets between the rows and when the soil is damp. Care should be taken to ensure that bait pellets do not come to rest in plant material to be harvested. Such contamination could lead to crop rejection and encourage the development of infection by *Botrytis cinerea*.

Main molluscicides

Metaldehyde, mercaptodimethur.

Weeds

General

Weed control in brassica crops is absolutely essential, particularly in the early stages of crop growth, if competition for water and nutrients and damaging cosmetic effects greatly reduce the yield and quality, and therefore the value of the crop. Mechanical weed control is possible, especially in the more widely spaced, leafy crops, but growing practices and availability of labour generally mitigate against such practice. Consequently, chemical weed control has now become normal practice in these crops. GPP for weed control in brassicas is presented here in relation to the three main types of herbicide application: pre-planting herbicides, pre-emergence residual herbicides, foliar-acting herbicides.

Pre-drilling and pre-planting herbicides

Basic strategy

The requirement for a clean, weed-free start means that in many cases the weed control programme should begin prior to the drilling or planting of the crop. Treatment to either the previous crop in the field, or the bare land, or the fallow between crops is often worthwhile, particularly for control of some of the troublesome perennial weeds, e.g. *Elymus repens* (couch grass).

The chemical most often used for this purpose is glyphosate. Paraquat and glufosinate-ammonium can also be used in this period between crops, though neither of these will give good long-term control of perennial weeds. They can be very useful, however for cleaning up annual weeds and are often so used.

Main pre-drilling and pre-planting herbicides

Glufosinate-ammonium (against annual weeds, with some action on aerial parts of perennial weeds), glyphosate (against annual and perennial broad-leaved and grass weeds), paraquat (sometimes combined with diquat) (against annual weeds), trichloroacetic acid (against grass weeds, particularly *Avena fatua* and *E. repens*).

Residual herbicides

Basic strategy

To ensure the necessary clean start in crops, selective residual herbicides are invariably used pre-emergence. These can be used pre-drilling or planting (trifluralin, or pendimethalin on transplanted crops only) or post-drilling or transplanting. Depending upon the herbicide chosen, the control can last for a varying time between 6 and 20 weeks. In some cases, the treatment will be repeated post-emergence when it begins to run out, thought this may not be necessary in crops which quickly cover the ground and therefore shade out weeds.

Main residual herbicides

The most widely used herbicides are chlorthal-dimethyl (against annual broad-leaved and grass weeds, narrow spectrum), propachlor (against annual broad-leaved and grass weeds, especially in seedbeds, short persistence), trifluralin (against broad-leaved and grass weeds, needs incorporation). Among others less commonly used are carbetamide (post-emergence or post-transplant use on spring cabbage only, winter application), metazachlor (pre-emergence use only on root brassicas, post-emergence only on drilled leafy or flowerhead brassicas, post-planting on transplanted crops), pendimethalin (pre-planting on transplanted leafy and flowerhead brassicas), propyzamide (against annual grasses and *Stellaria media*, post-emergence or post-transplant winter use in spring cabbage only), tebutam (tank mix incorporation with trifluralin, or tank mix pre-emergence or post-transplanting with propachlor).

Foliar-acting herbicides

Basic strategy

Soil-acting residual herbicides, though often effective, seldom give sufficient control of weeds throughout the

life of the crop. Foliar-acting, selective contact herbicides are often used to back up the residuals and to remove small weed seedlings. As the crop matures, however, the shading effect may itself stop weed growth sufficiently to avoid competition. The herbicide chosen will depend upon the particular crop and the weed spectrum present. Clopyralid is especially used for control of composite weeds, e.g. *Senecio vulgaris* (groundsel), *Matricaria* spp. (mayweeds) and *Cirsium arvense* (thistle). Sodium monochloroacetate can be used on all types of vegetable brassicas except cauliflower and root brassicas, though some important and troublesome weeds (*Chenopodium album*, *Matricaria* spp., *Polygonum convolvulus*) are resistant. Desmetryn can be used in cabbage and Brussels sprouts, singly or in tank mix. Grass weeds can be checked by the use in the growing season of appropriate graminicides.

Main foliar-acting herbicides

Against broad-leaved weeds: clopyralid (all types of vegetable brassicas, mainly against composite weeds), desmetryn (Brussels sprouts, cabbage), sodium monochloroacetate (Brussels sprouts, cabbage, calabrese, broccoli).

Against grass weeds, alloxydim-sodium (swede, turnip), cycloxydim (swede, cabbage, cauliflower, Brussels sprouts), diclofop-methyl (cabbage, Brussels sprouts, broccoli; against annual grasses, but not volunteer cereals, and *Avena fatua*), fluazifop-P-butyl (white cabbage, swedes), quizalofop.