◆ EPPO Standards ◆

GUIDELINES ON GOOD PLANT PROTECTION PRACTICE

UMBELLIFEROUS CROPS

PP 2/22(1) English

European and Mediterranean Plant Protection Organization
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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 MEDITERRANNEENNE POUR LA PROTECTION DES PLANTES

PP 2/22(1) English

Guidelines on good plant protection practice

UMBELLIFEROUS CROPS

Specific scope

This standard describes good plant protection practice for umbelliferous crops.

Specific approval and amendment

First approved in September 2000.

This guideline on GPP for umbelliferous crops 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 EPPO Standard PP 2/1 Principles of Good plant protection Practice. The guideline covers methods for controlling pests (including pathogens and weeds) of crops of the family *Apiaceae* (i.e. umbelliferous crops).

The main umbelliferous crops are vegetables: carrot (*Daucus carota*), celery (*Apium graveolens*), celeriac (*A. graveolens* var. *rapaceum*), fennel (*Foeniculum vulgare* var. *dulce*) and parsnip (*Pastinaca sativa*). They are biennials grown for the swollen roots or leaf bases formed at the end of the first growing season. Umbellifers are also grown as herbs, such as parsley (*Petroselinum crispum*), coriander (*Coriandrum sativum*) and caraway (*Carum carvi*). Soil-borne pests and diseases are especially important. Crops should be grown in soils which are, as far possible, free from soil-borne pests. The basis of GPP in umbelliferous crops is adequate rotation and good waste-handling practices. Waste from processing or packing operations should not be returned to the soil or at least returned to the same field from which it was produced.

Treatments can be applied to the seeds as well as the soil and aerial parts of the crop and, where relevant, seed treatment is to be preferred. Growing crops should be monitored (soil sampled for nematodes before sowing) for the need for pest, disease and weed control treatments in conjunction with trapping, baiting and forecasting systems where available and proved effective. Treatments should then be applied following a risk assessment of the potential for economic damage. Some soil-borne diseases are only seen after harvest, and the risk assessment is based on previous history of the field.

The principal pests of umbelliferous crops considered are given in Table 1.

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.

CARROT

Carrots (*Daucus carota* subsp. *sativa*) are the main umbelliferous crop in most European countries. They are grown from seed outdoors through spring and summer. Carrots have to be grown on good fertile soils to ensure even growth of the roots.

Pythium violae and *Pythium sulcatum* (cavity spot)

General

First symptoms are slightly sunken elliptical lesions on the root surface beneath which can be found a cavity. Subsequently, the surface tissue breaks down exposing the cavity. The cavities finally become raised greyish areas. Cavity spot occurs especially on soils with poor drainage or structure. Secondary pathogens, including other *Pythium* spp., cause further rotting which can affect most of the root. All carrot crops are potentially susceptible. The least risk is with early harvested main crops, and the most risk with over-wintered field-stored crops. The number and size of lesions is very variable. Under high disease pressure, these *Pythium* spp. can cause damage to fine roots and subsequent branching of the main root. *Pythium violae* is thought to colonize roots at the seedling stage from soil-borne resting spores but symptoms only start to appear about 12 weeks after sowing. The rapid appearance of symptoms suggests that there may be discrete infection periods but interactions with weather factors are poorly understood.

Table 1 Principal pests of umbelliferous crops considered

Pests	Crops on which economic damage occurs
Pythium violae, P. sulcatum (cavity spot)	carrot, parsnip
Pythium spp., *Thanatephorus cucumeris* (damping off)	celery, celeriac
Helicobasidium purpureum (violet root rot)	carrot, parsnip, fennel
Phytophthora primulae (root and crown rot)	parsley
Phytophthora syringae (leaf blight)	fennel
Erysiphe heraclei (powdery mildew)	carrot, parsnip, fennel
Oidium sp (powdery mildew)	parsley, herbs
Plasmopara nivea (downy mildew)	parsnip, fennel
Peronospora sp. (downy mildew)	parsley
Alternaria dauci (alternaria blight)	carrot, parsley
Botryotinia fuckeliana (grey mould)	carrot, celery, celeriac, herbs
Cercosporidium punctum	fennel
Phomopsis foeniculi	fennel
Ramularia coriandri (leaf spot)	coriander
Septoria apiicola (leaf spot)	celery, celeriac
Septoria petroselini (leaf spot)	parsley
Alternaria radicina (black rot)	carrot, celery, celeriac, parsley
Thielaviopsis basicola	carrot
Itersonilia pastinacae (canker)	parsnip
Mycocentrospora acerina (liquorice rot)	carrot, parsnip, celery, celeriac, caraway
Phoma apiicola (root rot)	celery, celeriac
Rhizoctonia carotae (crater rot)	carrot, celery, celeriac
Thanatephorus cucumeris (crater rot)	celery, celeriac
Sclerotinia sclerotiorum (sclerotinia rot)	carrot, parsnip, celery, celeriac, herbs
Bacterial soft rots	carrot, parsnip, celery, celeriac

Pseudomonas sp. (bacterial blight)	coriander
Carrot motley dwarf virus complex	carrot, parsley, dill
Carrot mosaic potyvirus	carrot, dill
Parsnip mosaic potyvirus	parsnip
Parsnip yellow fleck sequivirus	parsnip
Celery mosaic potyvirus	celery, celeriac, parsley, coriander, dill
Psila rosae (carrot fly)	all umbelliferous crops
Noctuids (cutworms)	all umbelliferous crops
Cavariella pastinacae (willow-parsnip aphid)	parsnip, carrot, celery, celeriac
Cavariella aegopodii (willow-carrot aphid)	carrot, parsnip, celery, celeriac, herbs
Semiaphis dauci (carrot aphid)	carrot
Pemphigus pasekki (root aphid)	caraway
Myzus persicae	parsnip, celery, celeriac
Trioza apicalis (carrot psyllid)	carrot, parsnip
Euleia heraclei (celery leaf miner)	celery, celeriac, parsnip, parsley
Depressaria daucella (caraway moth)	caraway
Nematodes	all umbelliferous crops
Weeds	all umbelliferous crops

Basic strategy

No resistant cultivars are available, but new Nantes/Berlicum hybrids show some tolerance. Fresh land cannot be guaranteed disease-free, but good field records of previous problems with cavity spot and soil tests based on ELISA can identify risk. Rotation should be as wide as possible. Double cropping should be avoided. Metalaxyl is an effective fungicide, but presents a risk of resistance and enhanced soil microbial degradation. Lower rates per hectare can be used by band spraying, only on mineral soils, provided the band covers the full row width.

Main fungicides

Sprays : metalaxyl.

Seed treatment : metalaxyl, thiram.

***Helicobasidium purpureum* (violet root rot)**

General

The host range of *Helicobasidium purpureum* (syn. *H. brebissonii*) is very wide. Severe infection causes yellowing of foliage and wilting, usually in patches with late-season rotting and disappearance of foliage. Symptoms in the crop are: violet or purple dots (infection cushions) on roots with wefts of purple mycelium between infection cushions; a dense mycelial mat becoming cinnamon-brown with age; and purple mycelium visible at crown of carrot and on soil surface. Resting bodies (sclerotia) form around lateral roots. Soil sticks to infected roots. Root infection is not usually deep-seated but secondary organisms cause extensive damage. The main period of occurrence is September/November. The pathogen is widespread in all carrot and sugarbeet-growing areas. Sclerotia in soil germinate to give mycelium, which infects the root. Initial colonization is very slow and takes 3 months, but mycelium subsequently spreads over the root and from root to root. Mycelium also survives in infected carrot debris and can infect new host plants. Infected fragments can be spread by wind and machinery. Seasonal variation in severity is apparent. Typically, the disease occurs in patches and is aggravated by short rotations of root crops.

Basic strategy

No fungicides are available. Some cultivars appear to be less infected than others in the field but all can become infected to a high level. Crop rotation is the main means of control, and in this context cereal break crops are valuable. Rotation between susceptible crops (e.g. potatoes, sugarbeet) should be at least 5 years. Infested land should be avoided completely. Weeds should be well controlled and volunteer plants of susceptible crops removed. Infected carrots or soil from packing houses should not be dumped on land intended for root crop production. Early lifting avoids heavy infection.

Erysiphe heraclei (powdery mildew)

General

Symptoms are diffuse white mycelium on leaves and petioles, becoming denser with age and leading to loss of foliage. Powdery mildew occurs commonly but especially in years with hot dry summers. It probably survives from season to season via a "green bridge" of volunteer plants or overlapping crops. Conidia are wind-blown and cleistothecia are also produced. Attacks follow hot dry conditions and fungal development can be very rapid in late summer/early autumn.

Basic strategy

Control can be influenced by hygiene practices, weed control and correct irrigation to minimize crop stress. The crop should be monitored before applying fungicide to estimate whether the roots have reached their final size, since there is no yield response if crop is of adequate root size. Fungicide sprays should be applied during the early stages of disease.

Main fungicides

Sprays: difenoconazole, dinocap, fenpropimorph, hexaconazole, iprodione, myclobutanil, sulphur, tetraconazole, thiophanate-methyl, triadimenol, triforine.

Plasmopara nivea (downy mildew)

General

Yellowish spots develop on the upper surfaces of leaves and later turn black, while in damp conditions white patches of sporulating mildew appear on the underside of the leaves which eventually shrivel and drop.

Basic strategy

Diseased plant material should be destroyed after harvest. High plant density encourages high humidity and disease development, and the disease is more serious in irrigated crops. Umbelliferous host weeds should be controlled, and fungicides may be applied by spraying.

Main fungicides

Sprays: chlorothalonil, cymoxanil, mancozeb, maneb, metalaxyl.

Alternaria dauci (alternaria blight)

General

Alternaria dauci can cause seedling death, and dark brown lesions on leaves leading to chlorotic margin with shrivelling and death of leaves. There are records of root invasion in field and in store. This disease is seed-borne and can survive in carrot debris for short periods if dry. There is also limited survival in soil. A high temperature of 22-24°C plus 24-h leaf wetness will give severe infection. The optimum humidity for spore production is 96%. The life cycle can be completed in 8-10 days. The disease may also develop in store at temperatures >12°C. In warmer countries, this may be the most serious disease of carrots.

Another widespread carrot leaf pathogen *Cercospora carotae* causes symptoms similar to those of *A. dauci*. In contrast to *A. dauci*, it infects younger foliage rather than older leaves and appears earlier in the season. It is less damaging and not seed-borne.

Basic strategy

There is some evidence of varietal resistance to *A. dauci* but the current benefit from this is limited. Seeds should be tested, and fungicide-treated if the fungus is present. Hot-water treatment of the seeds at 54°C for 20 min is also effective. Debris from infected crops should be ploughed in as soon as possible after harvest to prevent spread to later crops. Crops should be monitored, and disease-development models used if possible, to determine whether application of fungicide sprays is necessary. Iprodione-resistant strains of *A. dauci* have been identified. Fungicides used against *A. dauci* will also control *C. carotae.*

Main fungicides

Sprays : chlorothalonil, difenoconazole, hexaconazole, iprodione, mancozeb, thiophanate-methyl.

Seed treatment : iprodione.

Alternaria radicina (black rot)

General

The host range of *Alternaria radicina* includes parsnips, celery and parsley, as well as carrots. Symptoms are seedling death, blackening of petiole base, leaf death, black rot of crown and rot of stored roots. High humidity is required for crown rot. The disease is seed-borne, but soil-borne transmission is most important. Infection can develop even at 0°C on stored roots.

Basic strategy

There is no evidence of varietal resistance. Seeds should be tested, and fungicide-treated if the fungus is present. Debris from infected crops should be ploughed in as soon as possible after harvest to prevent spread to later crops. Rotation should be a minimum of 3 years between crops. Fungicide sprays are recommended if there has been a previous history of the disease in the field.

Main fungicides

Sprays : chlorothalonil, difenoconazole, hexaconazole, iprodione, mancozeb.

Seed treatment : iprodione.

Sclerotinia sclerotiorum (sclerotinia rot)

General

Sclerotinia sclerotorium is polyphagous, attacking a very wide range of crops (carrots, potatoes, peas, rape) and weeds. Symptoms are browning of petioles followed by tissue collapse and death. White cotton-woolly mycelium containing black sclerotia is often seen on dead leaves in autumn. On the crowns, brown or black water-soaked lesions appear, with sclerotia attached to the surface. This is rare in field-stored crops but common in crops stored under refrigeration. The disease occurs in warm moist seasons, usually when foliage is dense and senescing. The fungus is widespread in European soils. Sclerotinia rot is mainly a problem in stored roots but may appear in the final packaged product if left at ambient temperatures. Soil-borne sclerotia germinate to give apothecia (producing ascospores) or can attack roots directly via mycelium. Air-borne ascospores discharged from apothecia are most likely to infect yellow or dead foliage. Once infection is established, the fungus spreads by direct contact of infected roots in field or cold storage.

Basic strategy

There is no evidence of varietal resistance. Crops should not be too densely planted. Application of nitrogenous fertilizer should be limited on more vigorous cultivars. Irrigation may help to reduce early foliage death. Site selection should be based on previous cropping with a wide rotation but this can be difficult to impose given the range of susceptible arable crops. Biological control is possible with the "biological fungicide" *Coniothyrium minitans*. It prevents pathogenic strains of *S. sclerotiorum* from penetrating and thereby infecting treated plants.

Main fungicides

Sprays : *Coniothyrium minitans*, dicloran, iprodione, vinclozolin.

Mycocentrospora acerina (liquorice rot)

General

In addition to carrot, this fungus attacks parsnip, celery and a very wide range of weeds. The symptoms are brownish water-soaked lesions turning black on shoulder or tips of roots. Foliar symptoms are uncommon but include irregular brown or black leaf spots (rather like alternaria blight) and blackening of petioles. It is mainly a storage disease but the fungus can colonize cavity-spot lesions in the field. Infection of foliage occurs in the field, but symptoms on roots are generally not seen until after storage. Soil-borne chlamydospores ensure survival in soil for several years. Foliar and soil-borne phases establish inoculum which threatens the stored crop. Wet weather favours build-up on foliage. Development on stored roots takes place over several months at low temperatures.

Basic strategy

Where prevalent, *Mycocentrospota acerina* limits the storage potential of carrots. There is no evidence of varietal resistance. Minimizing the amount of damage during harvest reduces the incidence of the disease. Raised temperatures and high humidity to allow wound healing before storage has given useful control, but this favours attack by *Sclerotinia sclerotiorum* (q.v.). Older roots are more susceptible. A minimum rotation of 4 years between root crops is essential. Good control of the disease can be achieved by a pre-harvest sprays (if the field has a history of the disease).

Main fungicides

Sprays : benomyl, chlorothalonil, iprodione.

Seed treatment : iprodione.

Rhizoctonia carotae **(crater rot)**

General

In addition to carrot, this fungus attacks celery, swedes, cabbage and beet. The symptoms are sparse white mycelium over the root surface, with small depressions which enlarge into shallow craters, eventually becoming more deep-seated. Small white then brown sclerotia are produced on the surface of rotted roots. Infection occurs in the field but symptoms are not seen until storage. The fungus persists in wood of storage bins from which new infections are initiated. It may also be present in the soil (as sclerotia) and initiate infection before harvest. Development is favoured by humid refrigeration conditions and continues at low temperatures.

Basic strategy

There is no evidence of varietal resistance. On farms with a previous history of the disease, control with fungicide is advisable. Fungicides should be sprayed in the field once or twice before lifting, with sufficient pressure to ensure the fungicide reaches the crown. Damage during harvesting should be avoided, and soil and leaf debris should not be left adhering to the roots. Good hygiene is required, with thorough cleaning of storage bins and stores.

Main fungicides

Sprays : chlorothalonil, fenpropimorph.

Botrytiotinia fuckeliana **(grey mould-storage rot)**

General

Botryotinia fuckeliana (anamorph *Botrytis cinerea*) is a ubiquitous fungus on plant material. The symptoms on carrot are brown soft rot of foliage, or rotting particularly at sites of damage or dehydration (e.g. tips of stored roots). White mycelium is produced in the dark but becomes grey with masses of grey conidia and black sclerotia (on or embedded in the rotted tissue) after exposure to light. Nests of rotted roots are apparent in store after spread by root-to-root contact. *B. fuckeliana* survives in the soil as sclerotia and on plant debris of many kinds (the apothecial stage is not generally of any importance). Infection occurs on dying leaf material under moist conditions and abundant spore production ensures there is plenty of inoculum to cause problems given the right conditions. Uninjured carrots are resistant to infection but spores can penetrate damaged roots. Grey mould can develop even at 0°C. Storage above 5°C can lead to growth of foliage, which then becomes infected.

Basic strategy

There is no evidence of varietal resistance. Damage during harvesting and handling should be minimized, with careful hygiene and storage. Crops may be sprayed before storage if symptoms are seen.

Main fungicides

Sprays : iprodione.

Thielaviopsis basicola **(black-root storage rot)**

General

Carrots face serious problems of quality deterioration and storage rot during cool storage. This may be caused by several different fungi (cf. above), which infect the foliage or crown in the field and spread further in store. *Thielaviopsis basicola* (syn. *Chalara elegans*) is a widespread soil-inhabiting fungus which can affect numerous host plants, but which becomes damaging to carrots only in store. It infects carrot roots superficially, penetrating via surface ruptures. The initial sign on carrot roots is a fine growth of mould that later becomes black, forming large (1-2 cm) irregular black lesions. These are frequently associated with senescent leaves or plant debris attached to the root. The roots are disfigured by infection, but there is no extensive rotting. Chlamydospores can persist for 3 years in the soil, but the fungus may live indefinitely in the soil as a saprophyte. Another similar fungus *Chalaropsis thielavioides*, widespread in soil as a saprophyte, behaves as a weaker pathogen than *T. basicola* on similar hosts. It is associated with a minor storage rot of carrot roots.

Basic strategy

Cold, wet, heavy soils are favourable for the disease and should be avoided if possible. The soil pH is also very important in controlling the disease; with a pH of 5.6 or lower, there is little or no disease at any

temperature. Rotation of crops, avoiding susceptible hosts, is recommended. There is no specific fungicide treatment.

Bacterial soft rots

General

The bacteria causing soft rot of carrot (*Erwinia carotovora*, *Pseudomonas* spp.) affect fleshy plant material generally. The symptoms, brown or orange slimy tissue, can also follow cavity spot (*Pythium* spp.) as a secondary rot. Soft rot can be found on plants in the field especially after wet weather. Development is rapid during packing or transport, or if the carrots are stored at high (ambient) temperature. The bacteria survive in the soil and plant debris. Insects may be involved in dispersal and carrots may be "inoculated" when they are washed before storage. There is no evidence of varietal resistance.

Basic strategy

Good post-harvest handling procedures, hydrocooling with chlorinated water and subsequent cool (close to 0°C) storage/transport minimizes bacterial development. Mechanical damage and long storage periods should be avoided. No chemical treatment is recommended.

Viruses

General

Carrot motley dwarf is caused by a complex of two viruses: *Carrot mottle umbravirus* (CMoV) is symptomless but, with *Carrot red leaf luteovirus* (CRLV), induces reddening or yellowing of the foliage. These viruses are transmitted in a persistent manner by *Cavariella aegopodii*. CRLV may be transmitted alone, but CMoV is only transmitted when both viruses are present in the same plant. Parsnips, celery and other umbellifers such as chervil, fennel and coriander are infected as well as carrots. Severe yield losses were reported in the 1970s and attempts at that time to prevent spread were unsuccessful. However, occurrence of the disease has been less common in recent years.

Carrot mosaic potyvirus (CtMV) is mechanically transmissible, and the vectors are the aphids *Acyrthosiphon pisum, Cavariella aegopodii* and *Myzus pericae.* A distinct mosaic appears on the outer leaves. Chlorotic spots are distributed over the leaf blade and yellow spots appear on petioles. Middle and lower leaves are curled and the whole plant is weakened.

Basic strategy

Good aphid control is important in years when aphids are numerous (see section on Aphids).

Psila rosae (carrot fly)

General

Psila rosae is one of the principal pests of carrots. The adult is a small, shiny black fly, 4–6 mm long. It has a wide host range, attacking also parsnips, parsley, celery, and about 60 different wild umbelliferous species. There are usually 2 main generations per year, adult flies being active in April, May, June and again from late July into September. Larvae of second and/or partial third generation can continue feeding through much of the winter in southern countries. Further north there are usually only 2 generations. Seedling plants can be stunted or killed by larvae feeding on roots (first generation). Larval feeding causes mines on more mature roots. All carrot crops are potentially susceptible, but crops drilled in November and January and harvested according to schedule are unlikely to suffer economic carrot fly damage. The least risk of damage is in early-lifted crops, and the greatest in over-wintered field-stored crops. Damage is often worse around edges of fields, in more sheltered fields but especially in locations with a history of umbellifer production.

Basic strategy

Umbelliferous crops should not be grown in a close rotation which would allow the local population of *P. rosae* to increase. Where possible, the distance between a new crop and an umbelliferous crop grown on another plot in the previous year should be at least 2 km to minimize the risk of adult attack. Sheltered fields are more at risk of damage and should be harvested by October. Exposed fields should be selected for crops to be overwintered in the field. The 20 m headland strip of fields which are to be overwintered should be harvested in October to minimize damage and pest carry-over if there is a high risk of pest damage. Seed treatment is generally to be preferred to soil-applied granules. Foliar spray may be used on mid-season and late-sown crops for the control of the first generation. Pest monitoring (trapping adult flies) should be used to determine the necessity for and optimum time of application of insecticide sprays. Where pyrethroid sprays are

applied, advance warning of onset of adult activity is important to time the spray accurately at the first adult activity. Predictive models utilizing soil and air temperatures to predict adult emergence are beneficial.

Main insecticides

Sprays : lambda-cyhalothrin, deltamethrin, disulfoton, pirimiphos.

Soil treatment : carbofuran, carbosulfan, chlorfenvinphos, chlorpyrifos, diazinon, ethion, fonofos.

Seed treatment : chlorfenvinphos, imidacloprid, isofenphos, tefluthrin.

Noctuids (cutworms)

General

Cutworms (soil-living larvae of *Noctuidae* such as *Agrotis segetum* and *Agrotis ipsilon*) cut clean fairly circular holes in carrot roots below the crown. Damage occurs in most years in the warm dry months of June, July and August (only in some years in north-west temperate countries). In very hot summers, a partial second generation of moths may appear in August/September. Adult moths emerge from late April and lay eggs on a wide range of weeds and crops. Egg-hatch varies according to temperature, and the caterpillars feed on the foliage for a short period then descend to the soil and feed in a typical cutworm manner. Most cutworms overwinter in the soil and pupate in the spring.

Basic strategy

Risk can be reduced by avoiding large areas of weedy headlands and provision of good weed control in carrot crops. Trapping adult moths can be used, in conjunction with a temperature-accumulation computer model, to determine the time of application of irrigation and/or sprays. Irrigation or rain of reasonable intensity will usually provide economic control (10 mm of rain on one occasion will kill cutworms on the foliage in the period of aerial feeding). Where there is regular irrigation, there are few problems with cutworm damage. Foliar sprays are preferable to soil treatments. The aim is to kill young cutworms on the foliage before they burrow into the soil. Some soil insecticides used to control *Psila rosae* will provide control of cutworms if applied at the correct time.

Main insecticides

Soil treatment : chlorpyrifos, deltamethrin, lambda-cyhalothrin.

Sprays: deltamethrin, lambda-cyhalothrin.

Aphids

General

Aphids (*Cavariella pastinacae*, *Cavariella aegopodii*, *Semiaphis dauci*) may cause direct injury, giving rise to plants with twisted and malformed foliage, which may be stunted or even killed. They also transmit carrot motley dwarf disease (q.v.), causing stunting, reddening of the outer leaves and a fine chlorotic mottle on the inner leaves. Aphids overwinter as eggs on a hardwood host, e.g. *C. aegopodii* ("willow-carrot aphid") on *Salix alba* or *Salix fragili*s. In May and June, winged females migrate to carrot crops, where a new colony of the species is established. A series of wingless and winged generations take place here until autumn. In warmer climates, adult females may overwinter on carrots which stay in the soil during the winter.

Basic strategy

Pest pressure can be decreased by not growing susceptible crops in succession and by separating over-wintering crops of carrot and parsley from new-season crops. Crop remains should be ploughed in as soon as possible after harvest. Crop monitoring and risk assessment of economic damage should precede any treatment. Some treatments applied for *Psila rosae* or cutworms will also give good aphid control.

Aphids may also require control if crops are affected by motley dwarf in summer. If overwintering crops are carrying aphids, it may be necessary to spray in spring before migration of the aphids.

Main insecticides

Sprays: cypermethrin, deltamethrin, demeton-S-methyl, dimethoate, heptenophos, lambda-cyhalothrin, malathion, pirimicarb, pymetrozine, tau-fluvalinate.

Trioza apicalis (carrot psyllid)

General

Trioza apicalis is 3 mm long, pale greenish-yellow in colour, with transparent wings. The nymphs are

flattened, pale yellow and wingless. They produce terminal waxy filaments. *T. apicalis* is an univoltine species which overwinters as adults. Both adults and nymphs feed by stylet insertion, causing leaf curl. The heavier infestations cause most foliage distortion and young plants die quickly. *T. apicalis* also transmits viruses.

Basic strategy

Early-sown carrots suffer less. Production under nets may provide good protection. Most psyllid populations are kept in check by high levels of natural parasitism and predation but, in case of severe attack, chemical sprays may be needed. In some places, resistance to various organophosphorus insecticides has been found.

Main insecticides

Sprays : cypermethrin, deltamethrin, demeton-S-methyl, dimethoate, heptenophos, lambda-cyhalothrin, malathion, tau-fluvalinate.

Nematodes

General

Heterodera carotae (carrot cyst nematode) is highly host-specific and occurs locally in temperate regions as an important pest of the carrot crop. Infestations in the field are usually seen as irregular areas of stunted plants. Wilting in dry soil or on sunny days may be observed. The extent of damage may be so severe as to include death of plants at the centre of the infested area. Lateral roots when attacked may die and be replaced by others. This regrowth may result in clusters of rootlets, giving a "bearded" appearance of carrot roots and yellowish-red leaf colour. *H. carotae* can damage the root apex, resulting in several growing points that give the root a digitate appearance. *H. carotae* may occur in association with *Meloidogyne incognita* on carrots.

Meloidogyne hapla (root-knot nematode) forms small discrete galls with related adventitious root proliferation, frequently situated at root tips because this species invades the apical meristem. Carrots deformed by root-knot nematode are unmarketable. *Pratylenchus penetrans* is a polyphagous endoparasitic nematode which attacks a number of umbelliferous crops. Symptoms include stunting, chlorosis and other deficiency symptoms, root pruning and sparseness and proliferation of the roots. *Ditylenchus dipsaci* is also capable of attacking carrot. Severe crown rot may develop in the autumn in nematode-infested mature carrots. Species of migratory root-feeding nematodes (*Longidorus* spp. and *Trichodorus* spp.) mostly cause damage on sandy and sandy peat soils which can contain large numbers. Many weeds can act as alternative hosts. Symptoms are stunting and splitting of the taproot (which may, however, also be caused by *Pythium* spp. , herbicide damage, compacted soil, etc.). All these nematodes can be spread by plants for transplanting, by transportation of plant root parts or soil, and by surface or irrigation water.

Basic strategy

Nematode damage is not generally of great importance but may be so locally, under certain cultural conditions. Cultural practices such as winter fallowing, late ploughing to expose nematodes to freezing, or herbicide treatment to suppress weed hosts may be partially effective. Rotation with non-host crops (e.g. with grasses to reduce *M. hapla* in carrot crops), trap-cropping, planting at times when the temperature is below the activity threshold (e.g. of *M. incognita*) are all methods which have some merit. A 5-year rotation (or 10 years where infestations are severe) is recommended in carrot-growing areas, if suitable non-host plants can be found for the nematode species concerned. Alternative cropping with nematode-suppressive plants is currently under study in many countries.

Chemical control is possible if warranted by damage potential and crop value. Soil sampling to determine the species and population density is recommended. Where available, thresholds should be used in order to decide whether granular nematicide treatment is needed. If numbers are very high, the field should be avoided. Fumigants are expensive, difficult to apply and generally not considered GPP, but can be effective. In the case of *H. carotae*, recolonization of soils occurs rapidly after fumigation when carrots are grown continuously.

Main nematicides

Soil treatment: carbofuran, carbosulfan, dazomet (pre-planting soil fumigant), oxamyl.

Weeds

General

Weeds can germinate throughout the life of umbelliferous crops, which are reasonably competitive except in the early stages. They can encourage or harbour pests, and good control is

desirable to avoid competitive effects and yield loss. Herbicides should only be applied when necessary, and it is advisable to carry out regular monitoring of crops and use weed threshold levels to determine whether herbicides should be applied.

Basic strategy

Selection of the correct rotation is essential for effective weed control. A rotation that enables use of a succession of different herbicides may provide the best option for weed control in carrots. If perennial weeds or annual umbelliferous weeds such as wild carrot are a particular problem, the carrot crop should follow a cereal crop, in which these weeds may be controlled. However, rotations of carrots following rape or potatoes should be avoided because of problems with volunteers. To prevent build-up of weeds and pests that are difficult to control, there should a break of a minimum of 5 years between successive carrot crops in a single field.

Preparation of the seedbed is important for successful weed control. Heavy soils should be deeply ploughed in the autumn and left over winter to produce a good tilth. On light soils, ploughing and pressing immediately before seedbed preparation in the spring will result in a firm surface. Seedbed preparation should be carried out with the minimum number of passes possible to reduce wheel damage and compaction. For optimum control of weeds by residual herbicides, the seedbed should have a fine firm tilth, and be free from clods. A good seedbed will also help to ensure an even and vigorous emergence and may reduce root malformation.

For early field carrots produced under floating plastic covers, preparation of a good seedbed is essential. A residual herbicide is applied immediately after drilling, and the crop covered as soon as possible after this. The optimum time for the covers to be removed is at the 7 true-leaf stage of the crop, and a post-emergence contact or residual herbicide should be applied as soon as possible after removal of the covers. If weed pressure is particularly high, the covers may be removed before the optimum crop growth stage to allow herbicide application. In some early crops grown under plastic covers, metribuzin has been used successfully to control *Reseda luteola* where it is a particular problem. However this herbicide has use restrictions, e.g. organic soils.

For late-drilled carrots, the "stale seedbed" technique may be used to control weeds in the absence of the crop. The seedbed should be prepared 2 weeks before drilling and left to allow the weeds to germinate. A contact herbicide or mechanical weed control may then be used immediately prior to drilling to control any weeds that have germinated. Use of a contact herbicide at this stage may help reduce moisture loss from the seedbed.

With light soils, wind erosion may be a problem. If the field is unlikely to have a high population of weeds, then pre-drilling or pre-emergence herbicides may be omitted from the weed control programme, and early flushes of weeds will protect the soil until the crop is large enough to prevent erosion. However, effective weed control then relies on post-emergence applications of contact or residual herbicide, so herbicide choice is critical. Alternatively the crop may be under-sown with barley, which will protect the soil, but the barley must be removed with an effective graminicide before it starts to compete with the crop.

Weeds in a carrot crop may be controlled by mechanical inter-row cultivation techniques. However if mechanical weed control is to be used in a reduced input system, then a pre-emergence or early post-emergence herbicide should be applied as soon as possible to control weeds within the crop row, as mechanical weeding will only control weeds between the rows. Once the crop canopy has expanded, small weeds within the crop row will be suppressed, and mechanical weeding will be sufficient to control the weeds between the rows. A variety of machinery may be used successfully to control weeds in carrots including brush weeders, tine weeders, steerage hoes, flame weeders and steam sterilization. Flame weeders and steam sterilization may be used pre-drilling on stale seedbeds, or pre-emergence of the crop.

The optimum time for use of brush weeders, tine weeders and steerage hoes is approximately 3-4 weeks after 50% crop emergence, when the weeds are still small. Two to three passes will provide optimum weed control while reducing wheel damage and compaction.

Specific weed problems

Perennial weeds are difficult to control selectively in carrot crops during the growing season. Effective control of perennial grasses is best achieved in the previous cereal crop, or by use of amitrole, dalapon, glyphosate or TCA applied pre-sowing of the carrots. Effective control of perennial broad-leaved weeds may be achieved by the application of a translocated herbicide to the preceding cereal crop. Particular problems can occur with *Elymus repens*, *Tussilago farfara* and *Sonchus asper*. These weeds must be controlled either in the previous crop or in the breaks between cropping, although a post-emergence treatment of dalapon may provide some useful suppression of *E. repens*.

Annual grasses and broad-leaved weeds may be controlled by the application of pre- and post-emergence herbicides to the carrot crop, but particular problems may be caused by annual weeds such as *Polygonum aviculare*, *Avena fatua* and *Matricaria* spp. Tri-allate has been used to provide good control of the grasses, and metoxuron will control *Matricaria* spp.

Main herbicides

Pre-emergence: aclonifen, chlorbromuron, chlorpropham, linuron, metoxuron, metribuzin, pendimethalin (or early post em.), pentanochlor, prometryn, tri-allate, trifluralin.

Post-emergence (monocots): asulam, cycloxydim, diclofop-methyl, fluazifop-P-butyl, linuron, metoxuron, metribuzin, pentanochlor, prometryn, propaquizafop, quizalofop-P-ethyl.

Post-emergence (dicots) : asulam, chlorbromuron, linuron, metoxuron, metribuzin, pentanochlor, prometryn.

CELERY AND CELERIAC

Celery (*Apium graveolens*) is essentially a summer vegetable grown outdoors either by direct drilling or from transplanted seedlings, but early production may be carried out under protection. Crops should be grown in soils which are, as far possible, free from soil-borne pests. The basis of GPP in celery crops is adequate rotation and good waste-handling practices. Waste from processing or packing operations should not be returned to the soil or at least returned to the same field from which it was produced.

Treatments can be applied to the seed as well as the soil and aerial parts of the crop, and in general seed treatment is to be preferred. Growing crops should be monitored for the need for pest, disease and weed control treatments in conjunction with trapping, baiting and forecasting systems where available and proved effective. Treatments should then be applied following a risk assessment of the potential for economic damage. Celery is also grown as a herb.

Celeriac (*A. graveolens* var. *rapaceum*) is grown for the root (but the foliage can also be used as a herb), usually from transplants planted from mid-May for harvesting from October. Most of the pests and diseases which attack celery will also attack celeriac.

Damping-off (*Pythium* spp. and *Thanatephorus cucumeris*)

General

Celery seedlings infected with *Pythium* spp. may show symptoms of damping-off at or soon after emergence. Roots are invaded by the pathogen and eventually the stems become constricted at soil level and plants topple over and die. Damping-off usually occurs in patches in the field associated with wet soil conditions. *Thanatephorus cucumeris* (anamorph *Rhizoctonia solani*) also causes damping-off but is less common than *Pythium* spp. Both pathogens can be a problem in propagation, especially in block-raised transplants.

Basic strategy

In direct-drilled field-grown crops, seedbed conditions should not be too moist during wet weather. Block-raised seedlings should be raised in sterilized compost, in containers or trays which are easily cleaned before subsequent use. Trays should be placed on a sterilized surface during propagation. Seeds treated with thiram against *Septoria apiicola* should be adequately protected. In the case of special risk of damping-off, specific fungicides may be applied by watering.

Main fungicides

Sprays: etridiazole, propamocarb hydrochloride (against *Pythium*), iprodione (against *T. cucumeris*).

Thanatephorus cucumeris (crater rot)

General

The development of brown crater-like spots on the leaf stalks has sometimes been associated with the soil-borne fungus *Thanatephorus cucumeris* (anamorph *Rhizoctonia solani*) and may be more of a problem on soft-grown or over-mature crops.

Basic strategy

There is no evidence of varietal resistance. Extending the rotation between carrot crops and celery should help to minimize infection. No chemical control is needed.

Septoria apiicola (leaf spot)

General

Septoria apiicola causes a common disease on celery. It is seed-borne, and usually appears on the old leaves and petioles as spots or lesions which may vary in colour from a lighter to a darker hue than normal leaf green tissue. The affected areas develop brown or necrotic spots particularly during cool, wet weather, leading to a blight of the foliage. Numerous black pycnidia can be seen on leaf lesions and these produce splash-borne spores which are capable of infecting healthy plants.

Basic strategy

Where celery is grown intensively, there may be a high risk of spread between crops and from volunteer plants and debris. Seed should be treated by a thiram seed soak for 24 h at 30°C. Crop debris should be incorporated into the soil as soon as possible after harvest and volunteer plants destroyed to prevent carry-over to new crops. A 5-year rotation between susceptible crops should be observed. Diseased seedlings should be rejected during transplanting. A fungicide spray may be used when symptoms first appear.

Main fungicides

Sprays : benomyl, carbendazim, chlorothalonil, copper oxychloride, mancozeb, maneb, metiram, propineb, thiophanate-methyl, thiram, zineb.

Mycocentrospora acerina (liquorice rot)

General

Liquorice rot is mainly a disease of overwintered, stored or long-season celery. Affected plants show a dark green or black rot of the roots, stems and bases of the petioles.

Basic strategy

Wide rotation is advised between susceptible crops. Fungicide sprays may be required if the field has a history of the disease.

Main fungicides

Sprays: iprodione.

Phoma apiicola (root rot)

General

Phoma root rot may occasionally cause losses of celery seedlings and may be a problem in direct-drilled crops. Symptoms on seedlings vary according to the severity of attack. The cotyledons of affected plants may wilt and the hypocotyl become reddish purple. As the plants mature, dark brown or black lesions develop on the roots and stems at soil level. On older plants, the roots may rot completely leaving only a black stub. Plants as severely infected as this wilt and become chlorotic. Roots of celeriac may be seriously affected (similar symptoms also being caused by *Alternaria radicina*; see Carrot).

Basic strategy

Phoma apiicola can be seed-borne and seed lots should be tested. At least 5 years should be allowed between susceptible crops to reduce the role of the soil-borne phase. Fungicide sprays may be used when symptoms are seen.

Main fungicides

Same as against *Septoria apiicola.*

Sclerotinia sclerotiorum (sclerotinia rot)

General

Sclerotinia sclerotiorum is polyphagous (see Carrot). Symptoms are browning of petioles followed by tissue collapse and death. White cotton-woolly mycelium containing black sclerotia is often seen on dead leaves in autumn. Soil-borne sclerotia germinate to give apothecia or can attack directly via mycelium. Wind-blown ascospores discharged from apothecia are most likely to infect yellow or dead foliage. Once infection is established, the disease can spread by direct contact of infected plants in the field.

Basic strategy

There is no evidence of varietal resistance. Irrigation may help to reduce early foliage death. Site selection should be based on previous cropping with a wide rotation but this can be difficult given the range of susceptible arable crops. Fungicides are not normally used against *S. sclerotiorum* alone but have some effect when used to control other diseases. Biological control is possible with the "biological fungicide" *Coniothyrium minitans* (see Carrot).

Main fungicides

Sprays : carbendazim, chlorothalonil, *Coniothyrium minitans*, iprodione.

Erwinia carotovora (soft-rotting bacteria)

General

Soft-rotting bacteria may cause losses in field-grown crops during cool wet weather following mechanical damage from slugs or *P. rosae*.

Basic strategy

Mechanical or other injury to plants should be minimized wherever possible, particularly during spraying operations. Good pest control will help avoid primary damage. No chemical treatment is recommended.

Viruses

General

Celery mosaic potyvirus (CeMV) is transmitted by aphids (*Myzus* spp., *Aphis* spp, *Cavariella* spp.) in a non-persistent manner. Infected plants show a green to light green mottling and malformation of the leaflets. On severely affected plants, leaflets become narrowed, cupped and twisted. Early attacks result in a pronounced overall stunting of plants. Some weed species are hosts to this disease.

Basic strategy

Control of umbelliferous weeds and volunteer celery can reduce the risk of severe outbreaks. Good aphid control in years when aphids are numerous is important (see Aphids).

Psila rosae (carrot fly)

General

Psila rosae attacks celery and a wide range of other umbellifers (see Carrot). There are usually two main generations per year, adult flies being active in April, May, June and again late July to September. All celery crops are potentially susceptible, but early celery crops grown under a fabric cover are rarely at risk. Damage is often worse around edges of fields, in more sheltered fields but especially in locations with a history of umbellifer production. Seedling plants can be stunted or killed by larvae feeding on roots or leaves (first generation). Larval feeding causes mining of petioles of more mature plants (first, second and sometimes third generation).

Basic strategy

Celery should not be grown in a close rotation with other umbelliferous crops, allowing the local population of *P. rosae* to increase. Where possible, the distance between early-sown crops and late crops should be 2 km to prevent pest carry-over. Sheltered fields are more at risk of damage. A forecasting system should be used (if locally validated) and pest monitoring (trapping adult flies) should be used to determine the necessity for and optimum time of application of insecticide sprays.

Main insecticides

Sprays : deltamethrin, disulfoton, lambda-cyhalothrin, pirimiphos.

Soil treatment : carbofuran, carbosulfan, chlorfen-vinphos, chlorpyrifos, diazinon, ethion, fonofos.

Noctuids (cutworms)

See Carrot.

Aphids

General

Aphids (*Cavariella aegopodii, C. pastinacae* and *Myzus persicae*) may cause direct injury, giving rise to plants with twisted and malformed foliage, which may be stunted or even killed. They also transmit *Celery mosaic potyvirus*. Aphids overwinter as eggs on a hardwood host (e.g. *C. aegopodii* on *Salix alba* or *S. fragilis*). In May and June, winged females migrate to celery crops, where new colonies of the species are established. A series of wingless and winged generations take place until autumn.

Basic strategy

The most likely source of infestation is the propagators, and growers should ensure they buy clean young plants. Pest pressure is decreased by not growing susceptible crops in succession and by separating overwintering crops of carrot and parsley from new-season crops of celery. Crop remains should be ploughed in as soon as possible after harvest. Crops should be monitored and the risk of economic damage assessed before deciding to apply insecticide sprays.

Main insecticides

Sprays : deltamethrin, demeton-S-methyl, dimethoate, lambda-cyhalothrin, pirimicarb, pymetrozine, tau-fluvalinate

Euleia heraclei (celery leaf miner)

General

The larvae of *Euleia heraclei* cause blister mines in the leaves of celery. Damage is rarely of economic importance but on occasion severe infestations can develop in May or June and the mines spoil the appearance of the product and may check crop growth.

Basic strategy

Celery should not be grown on land in the proximity of previously infested celery or parsnip crops. Soil or foliar treatments applied for *P. rosae* or *A. segetum* control will reduce numbers of *E. heracle*i, and it is not generally necessary to treat specifically against this pest. There are no resistant cultivars.

Main insecticides

Soil treatment: chlorfenvinphos, ethion.

Sprays: malathion.

Nematodes

General

Meloidogyne hapla attacks celery, but migratory root nematodes do not pose such a threat to celery as to root crops such as carrots. Endoparasitic nematodes occasionally affecting celery include *Pratylenchus bukovinensis*.

Basic strategy

See Carrots. Crop rotation is the most important strategy.

Weeds

See Carrots. In protected celery crops where partial soil sterilization is included in the rotation, other methods of weed control are not usually required. However if further weed control is required, the range of active substances available for use on protected crops may be more limited, e.g. prometryn.

Main herbicides

Chlorbromuron (in transplanted celery), chlorpropham, linuron,prometryn, pentanochlor.

FENNEL

Fennel (*Foeniculum vulgare*) is mainly cultivated in Europe as an annual vegetable for its edible bulbous leaf base (var. *dulce*, sometimes known as Florence fennel). A perennial form of fennel is also grown as a herb (for its leaves and seeds). Both are slightly sensitive to frost and best adapted to a Mediterranean climate. The swollen leaf bases of fennel can be harvested from mid-summer to autumn from earlier successional sowings. When the shoot base shows signs of swelling, it may be earthed up to encourage blanching. Cultivation under glass extends the cropping season. Fennel is best grown in a warm sunny position. Pests are seldom a problem, and plant protection products are rarely applied to this crop.

Phytophthora syringae (leaf blight)

General

This pathogen is soil-borne and causes leaf blight. Zoospores are disseminated by mass flow of soil water, irrigation or rain splash, and infection is mostly through wounds and natural openings such as lenticels.

Basic strategy

General cultural practices aimed at avoiding excess water and injury to plants should be employed. Fungicide sprays can be used if symptoms are seen.

Main fungicides

Sprays: metalaxyl.

Other diseases

Cercosporidium punctum causes spots on leaves and generally all above-ground parts of fennel and parsley. *Phomopsis foeniculi* has recently been described causing decline of fennel in France. Control of these two diseases is not generally needed. *Erysiphe heraclei* causes powdery mildew of fennel and is described under Carrot. It is most likely to develop in warm, dry weather particularly in crops under stress. Irrigation should be applied to field-

grown crops. *Plasmopara nivea* causes downy mildew of fennel and is described under Carrot.

Sclerotinia sclerotiorum causes the most important disease of fennel (see Celery). To counter it, the only course of action is a sound rotation. *Helicobasidium purpureum* causes violet root rot and is described under Carrot. There are no fungicides for control.

Psila rosae (carrot fly)

Fennel is a host for *Psila rosae*. See Carrot.

Weeds

The same principles apply as for other umbelliferous vegetable crops, but the choice of herbicide may be limited.

PARSNIP

Parsnips are cultivated like carrots. They are affected by a very similar range of pests. A few pathogens specific to parsnip are mentioned here.

Itersonilia pastinacae (parsnip canker)

General

Canker appears in 2 forms: as a dark brown canker which develops on the shoulders of roots and/or a predominantly black canker with a purple tinge more prevalent in wet seasons. The most common cause is *Itersonilia pastinacae* but similar lesions can be caused by *Phoma complanata* and *Mycocentrospora acerina. I. pastinacae* can also cause necrotic spotting of leaves and occurs in seed and debris which can lead to subsequent infection.

Basic strategy

Clean seed of canker-resistant/tolerant cultivars is available and should be used when possible. Late sowings in April for production of small roots harvested in late autumn minimize the incidence of canker. Soil coverage of crowns reduces the risk of infection by spores produced on leaves.

Viruses

Parsnip mosaic potyvirus (ParMV) is transmitted by the aphids *Cavariella aegopodii*, *C. theobaldi* and *Myzus persicae* in a non-persistent manner. It causes mild mosaic and symptoms disappear soon after infection. *Parsnip yellow fleck sequivirus* (PYFV) is transmitted by the aphids *C. aegopodii* and *C. pastinacae* in a semi-persistent manner. For vector transmission, this virus requires a helper virus (*Anthriscus yellows waikavirus*) which is acquired from *Anthriscus sylvestris* (cow parsley). Systemic veinal necrosis or chlorosis develops. Leaves produced later show a faint chlorotic mottle with yellow flecks. Good aphid control in years when aphids are numerous is important (see section on Aphids in Carrot).

Weeds

General comments and basic strategy are the same as for carrots. However, at early growth stages, parsnips are particularly poor competitors, so good seedbed preparation and the elimination of all perennial weeds before drilling is essential. Parsnips are also more susceptible to herbicides than carrots, making herbicide choice more limited.

UMBELLIFEROUS HERB CROPS

The main umbelliferous leaf herb crops in Europe are parsley (*Petroselinum crispum*) and coriander (*Coriandrum sativum*), both of which are grown on a field scale as well as by specialist units and under protection. The main umbelliferous crop grown in Europe for its seed is caraway (*Carum carvi*). Other umbelliferous herbs are grown in some parts of Europe, e.g. chervil *(Anthriscus cerefolium)*, dill *(Anethum graveolens).* Lovage *(Levisticum officinalis)*, cicely *(Myrrhis odorata)*, angelica *(Angelica archangelica)* and others are mainly grown in private gardens.

As with the major umbelliferous crops (carrots and celery), the basis of GPP is adequate rotations and the choice of a site free from potentially troublesome weeds. In general, herb crops succumb less to the major pest problems than the vegetable crops, probably because wider rotation is practised and these crops are not grown in close proximity to intensive vegetable crops. The umbelliferous herb crops are "minor crops" for which the choice of authorized plant protection products may be rather limited. For all the leaf herb crops, quality of the harvested leaves is of prime importance, since they are often used decoratively. Good control of leaf pests, with a minimum of visual symptoms, is thus essential.

The GPP requirements for parsley, coriander and caraway are considered separately.

PARSLEY

Parsley (*Petroselinum crispum*) is sown in the field from February to early June for cutting in June to December/early January. As an alternative to overwintering spring sowings, an August sowing may provide a light cut in November/December before overwintering. Covering with plastic advances cutting to late February/early March, and non-covered crops can be cut in April and May. Glasshouses or polythene tunnels are used for production in January and February.

Sclerotinia sclerotiorum (sclerotinia rot)

General

For a general description, see Celery. *Sclerotinia sclerotiorum* occurs on parsley in warm moist seasons, usually when foliage is dense and senescing. It is widespread in European soils.

Basic strategy

There is no evidence of varietal resistance. Crops should not be too dense and nitrogen application should be limited, except on the most vigorous cultivars. Irrigation may help to reduce early foliage death. Site selection should be based on previous cropping with a wide rotation but this can be difficult given the range of susceptible arable crops. Fungicide sprays may be required if there is a previous history of the disease. Biological control is possible with the "biological fungicide" *Coniothyrium minitans* (see Carrot).

Main fungicides

Sprays : *Coniothyrium minitans*, dicloran, iprodione, vinclozolin.

Alternaria dauci (alternaria blight)

General

This disease can cause seedling death, dark brown lesions on leaves leading to chlorotic margin with shrivelling and death of leaves. *A. dauci* is seed-borne and can survive in debris for short periods if dry, as well as in soil. A high temperature of 22-24°C plus 24 h leaf wetness will give severe infection. The optimum humidity for spore production is 96%. The life cycle can be completed in 8-10 days.

Basic strategy

Tested seed should be used, which should be fungicide-treated if infection is present. Hot-water treatment of the seeds at 54°C for 20 minutes is also effective. Debris from infected crops should be ploughed in as soon as possible after harvest to prevent spread to later crops. Fungicide sprays may be applied when symptoms are seen.

Main fungicides

Sprays: chlorothalonil, difenoconazole, hexaconazole iprodione, mancozeb, thiophanate-methyl.

Seed treatment : iprodione.

Septoria petroselini (leaf spot)

General

The fungus causes a brown to black spotting of the foliage, giving parsley an impression of being splashed with soil. The disease spreads rapidly in wet conditions. It can be seed-borne or survive in plant debris.

Basic strategy

No resistant cultivars are available. As the disease is seed-borne, only tested seed should be used. New sowings should not be adjacent to overwintered crops and crops should not be grown on the same land more than once in 5 years. Overhead irrigation can accentuate the problem by spreading spores. Although thiram treatment of seed gives good control of *S. petroselini*, there is the risk of a reduction in seedling vigour. Foliar sprays of fungicides may be applied if symptoms are seen.

Main fungicides

Seed treatment: thiram.

Sprays: azoxystrobin, difenoconazole, thiram.

Phytophthora primulae (root and crown rot)

General

This disease is usually associated with poor drainage, especially in overwintered crops. Affected plants are stunted and may be completely killed.

Basic strategy

There are no resistant cultivars. Poorly drained sites subject to water logging should be avoided. In such situations, the crop may be grown on small ridges or raised beds. High-volume fungicide sprays should be applied when symptoms are first seen.

Main fungicides

Sprays : metalaxyl, thiram.

Peronospora sp. (downy mildew)

General

Leaves become slightly discoloured on the upper surface, with a white downy growth on the lower surface.

Basic strategy

Downy mildew occurs during periods of high humidity and can be spread by water droplets from rainfall, or irrigation to new leaves. Fungicide sprays may be applied to protect the crop, as soon as the disease is first seen.

Main fungicides

Sprays : mancozeb, zineb.

Oidium sp. (powdery mildew)

General

The leaves become covered with a delicate, white powder of chains of spores which are dispersed by air currents during warm, dry conditions. Young shoots and leaves are most susceptible. In hot summers, parsley is badly affected.

Basic strategy

Wet weather or overhead irrigation retards disease spread. Foliar sprays of fungicides may be applied when symptoms are seen.

Main fungicides

Sprays : tebuconazole, triforine.

Viruses

General

The viruses causing motley dwarf of carrot (q.v.) also cause a severe disease of parsley. They are transmitted in a persistent manner by *Cavariella aegopodii*. Direct damage by this aphid is seldom as serious as that caused by the viruses it transmits, especially CRLV. Until late June or July, parsley infected with the virus may seem healthy, but the green foliage then shows a reddish discoloration which soon turns to a bleached yellow. These colour changes are accompanied by severe stunting of the plants and the crop is quickly rendered unmarketable.

Basic strategy

Good aphid control in years when aphids are numerous is important (see section on Aphids under Carrot).

Psila rosae (carrot fly)

General

See Carrots. All parsley crops are potentially susceptible but those most at risk are the overwintered crops. The worst attacks are usually the first generation during May and June with a second generation in August to September.

Basic strategy

See Carrots. Parsley should not be grown in a close rotation with other umbellifers which would allow the local population to increase. However, routine control measures are not advised unless there is a history of damage in the area.

Main insecticides

Sprays: deltamethrin, disulfoton, lambda-cyhalothrin, pirimiphos.

Soil treatment : carbofuran, carbosulfan, chlorfenvinphos, chlorpyrifos, diazinon, ethion, fonofos.

Aphids

See Carrots. Parsley is mainly attacked by *Cavariella aegopodii* (willow-carrot aphid).

Noctuids (cutworms)

General

See Carrots. Parsley is not particularly susceptible, but young plants may be damaged.

Basic strategy

See Carrots.

Main insecticides

Soil treatment : chlorpyrifos, cypermethrin, deltamethrin, lambda-cyhalothrin.

Nematodes

See Carrots. Parsley is not a host for *Heterodera carotae*.

Weeds

General

See Carrots.

Basic strategy

For the control of annual weeds, the practice of the "stale seedbed" technique offers many advantages. This is most easily adopted where herbs are grown on a bed system. After ploughing, land is marked out in beds, the width corresponding to the setting of the tractor wheels. Cultivation is carried out between these wheel lines and a seed or transplanting bed produced. This is allowed to stay untouched for several weeks. The weeds which grow are then killed off with a contact herbicide immediately before drilling or planting. With sown crops, another contact herbicide may be applied just before emergence. At this time, soil-acting residual herbicides may also be applied followed by a further application of a contact/residual herbicides at an appropriate crop growth stage.

Main herbicides

Asulam, clopyralid, chlorpropham, chlorthal-dimethyl, linuron, paraquat, pendimethalin, pentanochlor, prometryn, simazine, terbacil, trifluralin.

CORIANDER

Coriander (*Coriandrum sativum*) is produced throughout the summer months by successional sowings from June to August. Later sowings may be made either outdoors or under polythene tunnels for cutting the following spring. Young leaves, whole plants or the seed may be used.

Ramularia coriandri (ramularia leaf spot)

General

This disease can be a problem during humid weather, leading to necrotic edges to leaves and circular spots with a bleached centre on which the fungus sporulates.

Basic strategy

If the early symptoms of the disease are seen, fungicide sprays may be used to protect the foliage from further infection.

Main fungicides

Sprays: zineb.

Sclerotinia sclerotiorum (sclerotinia rot)

If coriander is grown in rotation after fleshy root crops, this may result in a build-up of sclerotinia rot. There are no fungicide treatments.

Pseudomonas sp. (bacterial blight)

In the early stages of infection, plants show brown necrotic lesions, with some water-soaking, on leaves, petioles and young shoots. Severely infected plants are usually stunted and yellowed. The pathogen can be seed-transmitted. There is no chemical control.

Psila rosae (carrot fly), noctuids (cutworms), *Cavariella aegopodii* (willow-carrot aphid) and nematodes

These are all potential problems on coriander, but in practice are rarely seen. See Carrots.

Weeds

See Parsley. The use of the "stale seedbed" technique, referred to under parsley, is particularly beneficial.

Main herbicides

Chlorpropham, chlorthal-dimethyl, clopyralid, linuron, paraquat, pendimethalin, pentanochlor, prometryn, simazine, terbacil, trifluralin.

CARAWAY

Caraway (*Carum carvi*) is a biennial plant grown from seeds. The seeds are used for the extraction of oil or directly for consumption as a spice in for example bread or cheese. Caraway oil is used as a preservative, for kümmel liqueur or in the (phyto) pharmaceutical industry, for example as a potato sprout inhibitor. The seeds are mostly sown in early spring with a cover crop, like peas or summer barley. The year after sowing, the caraway seeds are harvested, mostly in early July. If some of the stems remain in a vegetative state, their seeds are sometimes harvested in the third year (if a reasonable yield can be expected). There are also annual caraway cultivars which are sown in early spring and harvested the same year. The crop is grown on soils with moisture-retaining ability, e.g. clay. Treatments are applied as sprays to the crop, and seed treatment is not used.

Mycocentrospora acerina (browning disease)

General

Affected plants have dark brown spots on stems, leaves and bases of the petioles. When heavily infected, these parts wither and seed setting is inhibited. Young plants can be infected in autumn and die off. In winter, the roots of infected plants can rot. The occurrence of the disease is unpredictable, depending on the weather. If the weather at flowering is wet, spores can splash and infect the stem or umbel leading to less seed setting or drying out of the umbel (no seeds at all). The fungus also infects many plant species, including cover crops of caraway like peas.

Basic strategy

The severity of the disease is variable. There can be years without the disease and years with heavy infection. If iprodione is used for control of *S. sclerotiorum*, it will have a suppressive effect on *M. acerina*. Disease-free seeds should be used, and previously infested fields avoided. Reduction of sowing rate and nitrogen also has an effect.

Main fungicides

Sprays: iprodione.

Sclerotinia sclerotiorum (sclerotinia rot)

General

See Celery. The symptoms on caraway are white spots on the stem with cottony mycelium containing black sclerotia. Browning of the plants is followed by early ripening and death.

Basic strategy

Wide crop rotation is advised. Fungicide sprays may be applied as soon as symptoms are noticed or on fields where the disease is expected at early flowering. Biological control is possible with the "biological fungicide" *Coniothyrium minitan*s (see Celery).

Main fungicides

Sprays: carbendazim, *Coniothyrium minitans*, iprodione, vinclozolin.

Leaf aphids

General

On caraway, aphids cause direct injury, giving rise to plants with twisted and malformed foliage, which may be stunted or even killed.

Basic strategy

Insecticide sprays may be applied when damage is seen.

Main insecticides

Sprays: dimethoate, pirimicarb.

***Pemphigus pasekki* (root aphid)**

General

Aphids of the genus *Pemphigus* form petiole galls on poplars *Populus nigra* and migrate in summer to the soil where they infest roots of various secondary hosts e.g. caraway. They do not form galls on the roots, but disfigure them, causing stunting, general chlorosis and wilting. *P. pasekki i*s a very damaging pest on caraway. Attacked plants may die if infestation is high.

Basic strategy

Caraway should not be grown near poplars, especially *P. nigra*. Yellow water traps can be used to catch immigrating aphids and so to time spray treatments. An insecticide can be applied after harvest of the cover crop if infestation is expected.

Main insecticides

Sprays: vamidothion.

***Depressaria daucella* (caraway moth)**

General

Depressaria daucella overwinters as adults. At the end of March or April, these start flying and oviposit on the petioles of caraway. The period of oviposition depends on the weather, and determines when the larvae appear. They generally hatch in May, and feed on and mine the stem and petioles. Later they spin the umbels and destroy flowers and seeds. The larvae pupate in the stem. The adults emerge shortly before harvest.

Basic strategy

A single insecticide spray as soon as the larvae start to spin is generally sufficient.

Main insecticides

Sprays: deltamethrin, phosalone.

***Psila rosae* (carrot fly)**

General

See Carrots. Feeding by larvae of *Psila rosae* causes mining in summer or autumn mainly in the top of the plants. Heavily mined plants can rot in spring.

Basic strategy

Mostly control is not necessary because the plants re-establish.

Nematodes

See Carrots.

Weeds

General

Caraway is grown under a cover crop and the possibilities of weed control in the cover crop can be limited because of the young caraway plants. If the weeds cannot be controlled in the cover crop, they will be hardened off by the time it is harvested. The caraway plants are still small at that time and therefore sensitive to herbicides. If cereals are used as a cover crop, volunteer cereal plants after harvest can be a problem because the caraway plants are still small and not competitive. Perennial weeds can become a problem because of the long period of crops on the field.

Basic strategy

The basic strategy starts with the choice of field and the previous rotation. Perennial weeds should be controlled in advance of cropping caraway. Preparation of the seedbed is important for successful weed control with residual herbicides. This should be fine, firm, crumbly and level. Use of herbicides is the normal method of weed control in caraway. Small dicot weeds can best be controlled at the end of August until the end of October or in early spring. During the dormancy of the caraway in winter, monocots, dicots, annual and perennial weeds can be controlled.

Main herbicides

Chlorpropham, linuron, monolinuron.

During dormancy: glufosinate-ammonium, carbetamide, fluazifop-P-ethyl, sethoxydim.