Organisation Européenne et Méditerranéenne pour la Protection des Plantes
European and Mediterranean Plant Protection Organization

Normes OEPP
EPPO Standards

Good plant protection practice
Bonne pratique phytosanitaire

PP 2/32(1)

Organisation Européenne et Méditerranéenne pour la Protection des Plantes
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Approval

EPPO Standards are approved by EPPO Council. The date of approval appears in each individual standard. In the terms of Article II of the IPPC, EPPO Standards are Regional Standards for the members of EPPO.

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 Standards 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.

Outline of requirements

For each major crop of the EPPO region, EPPO Standards 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.

Existing EPPO standards in this series

Twenty-six EPPO standards on good plant protection practice have already been approved and published. Each standard is numbered in the style PP 2/4(1), meaning an EPPO Standard on Plant Protection Products (PP), in series no. 2 (guidelines on GPP), in this case standard no. 4, first version. The existing standards are:

PP 2/1(2) Principles of good plant protection practice. *Bulletin OEPP/EPPO Bulletin* **33**, 87–98
PP 2/2(2) Potato. *Bulletin OEPP/EPPO Bulletin* **31**, 183–200
PP 2/3(2) Lettuce under protected cultivation. *Bulletin OEPP/EPPO Bulletin* **31**, 201–210
PP 2/4(2) *Allium* crops. *Bulletin OEPP/EPPO Bulletin* **31**, 211–230
PP 2/5(1) Rodent control for crop protection and on farms. *Bulletin OEPP/EPPO Bulletin* **25**, 709–736
PP 2/6(1)* Hop. *Bulletin OEPP/EPPO Bulletin* **26**, 295–309
PP 2/7(1)* Vegetable brassicas. *Bulletin OEPP/EPPO Bulletin* **26**, 311–347
PP 2/8(1) Rape. *Bulletin OEPP/EPPO Bulletin* **26**, 349–367
PP 2/9(1) Strawberry. *Bulletin OEPP/EPPO Bulletin* **26**, 369–390
PP 2/10(1) Wheat. *Bulletin OEPP/EPPO Bulletin* **27**, 311–338
PP 2/11(1) Barley. *Bulletin OEPP/EPPO Bulletin* **27**, 339–362
PP 2/12(1) Beet. *Bulletin OEPP/EPPO Bulletin* **27**, 363–384
PP 2/13(1) Ornamental plants under protected cultivation. *Bulletin OEPP/EPPO Bulletin* **28**, 363–386
PP 2/14(1) Pea. *Bulletin OEPP/EPPO Bulletin* **28**, 387–410
PP 2/15(1) Tobacco. *Bulletin OEPP/EPPO Bulletin* **28**, 411–424
PP 2/16(1) Farm grassland. *Bulletin OEPP/EPPO Bulletin* **29**, 353–366
PP 2/17(1) Maize. *Bulletin OEPP/EPPO Bulletin* **29**, 367–378
PP 2/18(1) Pome fruits. *Bulletin OEPP/EPPO Bulletin* **29**, 379–406
PP 2/19(1) Rye. *Bulletin OEPP/EPPO Bulletin* **29**, 407–422
PP 2/20(1) Mushrooms. *Bulletin OEPP/EPPO Bulletin* **31**, 231–242
PP 2/21 (1) Sunflower. *Bulletin OEPP/EPPO Bulletin* **31**, 243–256
PP 2/22 (1) Umbelliferous crops. *Bulletin OEPP/EPPO Bulletin* **31**, 257–288
PP 2/23 (1) Grapevine. *Bulletin OEPP/EPPO Bulletin* **32,** 371–392
PP 2/24 (1) Oat. *Bulletin OEPP/EPPO Bulletin* **32**, 393–406
PP 2/25 (1) Leguminous forage crops. *Bulletin OEPP/EPPO Bulletin* **32**, 407–422
PP 2/26 (1) *Ribes* and *Rubus* crops. *Bulletin OEPP/EPPO Bulletin* **32**, 423–442

*Note that these two guidelines for hop and vegetable brassicas appeared in *Bulletin OEPP/EPPO Bulletin* as, respectively, numbers 5 and 6, whereas they are in fact numbers 6 and 7 respectively. This numbering error is now corrected.

These EPPO Standards have also been published together in a new publication, *Good Plant Protection Practice*, available from the EPPO Secretariat, 1 rue Le Nôtre, 75016 Paris (FR).

Good plant protection practice
Bonne pratique phytosanitaire

Outdoor cucurbits

Specific scope

This standard describes good plant protection practice for cucurbit vegetable crops grown in the open.

Specific approval and amendment

First approved in 2003-09.

This Standard on GPP for outdoor cucurbit vegetable 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. It covers methods for controlling pests (including pathogens and weeds) of crops of the family *Cucurbitaceae*, such as melon *Cucumis melo*, watermelon *Citrullus lanatus*, cucumber or gherkin *Cucumis sativus* and courgette or pumpkin *Cucurbita pepo* grown in the open field.

Cucurbit species include a variety of high-value crops grown worldwide, primarily for the fresh market but also for processing. Most cucurbit crops are grown in the field (processing cucumbers are grown almost exclusively outdoors), but some are produced under protected cultivation (see EPPO Standard PP 2/31 Cucurbits under protected cultivation). The fruits are relatively low in nutritional value, but provide a notable vitamin and mineral source. Some have a high sugar content, others an important starch content. The seeds of some are sources of oil and protein.

Cucurbits have relatively large seeds and can be direct-seeded, but containerized transplants are usually used. Cultural practices vary considerably with the production location and may be specific to particular cucurbits, but they all include site selection, field and bed preparation, irrigation and drainage, fertilization, seeding or the use of transplants. The length of the growing season should be considered, as some cucurbits require 120–140 days to reach maturity. In general, cucurbits grow vigorously in warm and hot weather with plenty of water. They are all sensitive to frost, but they differ in their ability to withstand cold. Cucurbits dislike being water-logged, so they should be grown in raised beds if the soil is prone to flooding. They prefer light, well-drained soils. However, raised beds dry out faster and require supplemental irrigation. Tunnels or row covers are often used in cooler climates to create a warmer environment, which gives young seedlings an early start. Row covers left in place until flowering delay the spread of aphid-transmitted viruses. Polyethylene mulch provides weed control, reduces water evaporation from the soil, minimizes nutrient leaching during heavy rainfall and protects the fruit from direct contact with the soil, subsequently reducing fruit rot.

Some cucurbits require insect pollination in order to set fruit. Honeybees are the most efficient pollinators and adequate measures should be taken to protect them when spraying plant protection products. Parthenocarpic cucumber cultivars do not require pollination.

The first appearance and spread of pests should be regularly monitored. Locally established thresholds should be used. Crop rotation, by selection of a field which has not been used recently for cucurbit production, usually eliminates the need for soil sterilization. Tolerant or resistant cultivars should be used when available.

Although biological control methods are widely used in protected cucurbits, biological control is still in the research stage on outdoor crops. Semiochemicals (pheromones, baits) for monitoring and control are being investigated. Trap cropping and cultural controls such as mulches, cultivation, and no-till production are employed by growers on a limited basis. Cultivation, for example, can only be used early in the season because most cucurbits are vine crops.

Weeds can be a major limitation to cucurbit production, especially when crops are not grown during their preferred season. In addition, weeds interfere with harvest by making fruits difficult to find. The vigorous growth of many cucurbits (melons, watermelon, squash) make integrated weed management feasible and reduces the need for herbicides (see section on Weeds).

The main pests of cucurbit vegetable crops covered by this guideline are given in Table 1.

Explanatory note on active substances

The EPPO Panel on Good Plant Protection Practice, in preparing this standard, considered information on specific

Table 1 Principal pests of outdoor cucurbit crops

Pests	Crops on which economic damage occurs
Damping-off	All cucurbits
Fusarium wilt	All cucurbits
Didymella bryoniae	Melon, cucumber
Powdery mildews	All cucurbits
Pseudoperonospora cubensis	All cucurbits
Botryotinia fuckeliana	Cucumber, courgettes, water melon
Cladosporium cucumerinum	Cucumber, melon, courgette
Glomerella lagenarium	All cucurbits
Bacteria	Cucumber, courgette, melon
Viruses	
Aphids	All cucurbits
Wireworms and white grubs	All cucurbits
Noctuids	All cucurbits
Thrips	Cucumber, courgette, watermelon
Whiteflies	Cucumber, melon, courgette
Mites	All cucurbits
Meloidogyne spp.	All cucurbits
Weeds	All cucurbits

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. It may be noted that many active substances currently used in registered products in EPPO countries will no longer be authorized in the EU after 2003-07.

Damping-off

General

Several *Pythium* spp. can infect cucurbits during their early stages of growth, causing seed rot, pre- and post-emergence damping-off, root or stem rot. Untreated seeds in infested soil may develop a soft rot. On germinated plants, before emergence, a dark brown or black water-soaked lesion develops. On the emerged plants, the stem becomes constricted or rotted and the plant collapses. Under unfavourable conditions, *Pythium* spp. survive in the soil as oospores in decayed substrates, potentially for many years. Under optimal conditions, this pathogen can grow indefinitely as vegetative mycelium on various organic substrates in the soil. *Pythium* spp. are favoured by wet soil conditions, freezing and thawing, and nematode damage.

Thanatephorus cucumeris (anamorph *Rhizoctonia solani*) is a ubiquitous soil-borne fungus, which causes damping-off, root rot and basal stem root (foot rot) of cucurbits. It survives in soil, compost and infected debris as mycelium and undifferentiated sclerotia. It can invade cucurbit fruits in contact with soil, leading to irregular scabby lesions on the underside of the fruits. Cucumber is the most susceptible of the cucurbits.

Thielaviopsis basicola, black root rot, is a common soil inhabitant with a wide host range which destroys young feeder roots. Young tissues and weak plants in nurseries are more easily and rapidly affected by the fungus, but mature plants in the open field may also develop the disease. Symptoms appear on roots as blackish areas with tissue necrosis, and shrinkage and rotting of the root. After the fungus invades the host at ground level, conidia form abundantly on affected parts of the plant. Infected plants appear stunted with early yellowing, and wilt.

Basic strategy

Planting on raised beds is recommended to allow for maximum water drainage after each irrigation. Hygiene is of great importance, particularly in nurseries, where the disease will normally be treated. Seed treatment is also good practice. Presowing or preplanting incorporation of fungicides can provide early protection of seedlings.

Main fungicides

Sprays or drenches: captan, iprodione, propamocarb, tolclofos-methyl.
Seed treatment: captan, carbendazim, thiram.

Fusarium wilt

General

Cucurbits are affected in the field by a number of vascular wilt diseases caused by different *formae speciales* of the soil-borne fungus *Fusarium oxysporum* (*melonis*, *cucumerinum*, *niveum*). Infection occurs primarily through the roots, but it may also be seed-borne. Plants may be affected at any stage of development. In young seedlings, a hypocotyl rot and damping-off may occur. In older plants, disease symptoms include dull green colour of the leaves followed by the yellowing and wilting of the older leaves and shoots. The most reliable symptom is necrosis and discoloration of the vascular tissue.

Basic strategy

The use of resistant cultivars or rootstocks is the most effective and practical means of controlling fusarium wilt. Long-term crop rotations or fallow periods will reduce the inoculum in the soil, but are generally ineffective because of the long survival of chlamydospores in the soil. Infected crop debris should be destroyed. There is no effective fungicide control. Recolonization of the soil occurs very quickly. Soil solarization has some potential in the field for controlling fusarium wilt. Liming the soil to pH 6.5–7.0 and reducing the level of nitrogen in the soil can reduce wilt. Seed treatment with carbendazim is possible to control seed-borne infection.

Main fungicides

Seed treatments: carbendazim.

Didymella bryoniae

General

Didymella bryoniae (synonym *Mycosphaerella citrullina*, *M. melonis*) affects the leaves, stems, and fruits of all cucurbits. The disease is known as black-stem rot (black rot on fruits), or gummy stem blight, due to the masses of black pycnidia and pseudothecia developing on lesions and the gummy exudates oozing from stem and fruit lesions. It is a pathogen of warm wet weather, which attacks through wounds, primarily older tissue. Cotyledons and young leaves of melon and watermelon are very susceptible. Circular, tan to dark brown necrotic areas appear first at the margins of the leaves, and enlarge rapidly until the entire leaf is blighted. Circular, tan to dark lesions may girdle the stem of a young plant and the plant dies. On fruits, lesions appear as small water-soaked areas, beneath which an extensive rot is found. Fruit infection frequently starts from infected flowers. In melons, symptoms progress from the centre of the plant outwards. Water-soaked spots on leaves, petioles and stems turn light brown to grey and elongate to streaks. Sources of infection are seeds, older plantings, plant residues and volunteer seedlings.

Basic strategy

Pathogen-free seeds should be used. When possible, it is best to use long rotations (at least 2-year rotation cycle) with crops other than cucurbits. Infected plant debris, a main source of inoculum, and volunteer seedlings should be removed and destroyed. Removed plants should be placed in bags *in situ*. It is very important not to handle the lesions, as spores are sticky and can readily be spread by workers or equipment. Application of extra potassium at fruit formation is recommended. Fungicides can be applied at the first signs of the pathogen, but control is often inadequate under the heavy disease pressure. A key spray application is to the stem base after planting. No currently available cucurbit cultivars have commercially acceptable levels of resistance. Isolates of *D. bryoniae* resistant to benzimidazole fungicides have been detected in some glasshouse cucumber crops.

Main fungicides

Sprays: bitertanol, carbendazim, chlorothalonil, iprodione, tolylfluanid, triforine.

Powdery mildews

General

Two fungi, *Podosphaera xanthii* (synonym *Sphaerotheca fuliginea*, *S. fusca*) and *Erysiphe cichoracearum*, can cause powdery mildew on cucurbits. The first symptoms are small pale diffuse spots on the upper surface of old leaves, followed by infection of stems and young leaves. These lesions expand and become white to pale-grey powdery masses composed of mycelium and countless numbers of spores. Severely infected leaves become brown, desiccate and die. As the disease develops, severe infection may cause premature leaf senescence and plant death. Fruit infection occurs rarely in watermelon and cucumber. Development of powdery mildew is favoured by moderate temperatures and relative humidity, dry soil conditions, reduced light intensity and abundant plant growth. Under field conditions, powdery mildew development is arrested at temperatures higher than 38 °C.

Basic strategy

Several cultivars of pumpkin, cucumber and melon (cantaloupe) have moderate to excellent resistance to powdery mildew. Plant debris should be removed and destroyed at the end of the season to reduce overwintering of the pathogen. Crops should be well spaced and excess nitrogen fertilization should be avoided. Some common weeds, e.g. *Sonchus* spp., may become infected and should be removed from neighbouring fields. Fungicides should be applied at intervals of 10–14 days from the first sign of disease.

Resistance

Strains of *P. xanthii* resistant to fungicides are readily selected out of the population. These have occurred in the case of MBC (carbendazim) and DMI fungicides (imazalil, fenarimol), bupirimate and, most recently, azoxystrobin. If a fungicide programme is required, different types of product should be alternated to minimize the loss of efficacy due to resistance. FRAC guidelines should be followed (http://www.frac.info/).

Main fungicides

Sprays: azoxystrobin, bitertanol, bupirimate, fenarimol, fenbuconazole, hexaconazole, imazalil, myclobutanil, penconazole, triforine.

Pseudoperonospora cubensis

General

Downy mildew is one of the most important foliar diseases of cucurbits in the open field. Under favourable climatic conditions (warm to hot wet weather), it grows rapidly and an entire field may appear to turn white within a few days. It first appears as small yellowish areas on the upper side of the leaves. On the lower leaf surface, blackish-purple spore masses appear over the yellow-brown lesions. Downy mildew develops on older leaves first but does not affect stems or fruit. Plants are very prone to infection at the time of flowering.

Basic strategy

Satisfactory control can be achieved by combining cultural practices, the use of resistant cultivars and fungicide application. Cultural practices include crop rotation, using plant spacing which reduces canopy density and avoiding overhead irrigation, which can prolong the duration of leaf wetness periods. The use of forecasting models is recommended if available. If fungicides are to be used, they should be applied with high-pressure sprayers to ensure complete coverage of the undersides of the leaves. Strains of the pathogen resistant to metalaxyl-M and azoxystrobin have been reported.

Resistance strategy

This pathogen may easily develop resistance, for example to metalaxyl-M or azoxystrobin. A suitable strategy should therefore be applied to avoid resistance. FRAC guidelines should be followed.

Main fungicides

Sprays: azoxystrobin, chlorothalonil, copper, cymoxanil, dimethomorph, folpet, fosetyl-Al, metalaxyl-M, propamocarb.

Botryotinia fuckeliana

General

Botryotinia fuckeliana (anamorph *Botrytis cinerea*) causes brown spots on every part of the cucurbit plant, but the most significant infection is on the fruit. Infected plant parts die and are gradually covered by the grey mycelium (grey mould), or affected areas may become dried out. Millions of spores are released into the air. The fungus survives as sclerotia or mycelium in dead or living plant tissue or as sclerotia in the soil. Grey mould is an important disease on cucumbers, courgettes and watermelons.

Basic strategy

Good hygiene is important in maintaining control. Infected plant debris should be destroyed continuously. Some of the fungicides used against *Pseudoperonospora cubensis* (e.g. azoxystrobin, chlorothalonil) will keep the inoculum of *B. fuckeliana* low.

Main fungicides

Sprays: cyproconazole, iprodione, procymidone, tolylfluanid, triadimenol.

Cladosporium cucumerinum

General

Scab or gummosis is caused by *Cladosporium cucumerinum*. This disease infects ridge cucumbers and courgettes grown in the open, especially in colder, wetter areas. The fungus is seed-borne and may also survive in soil on melon and pumpkin vines. It can attack any above-ground part of the plant. It causes scab-like depressions from which sap is exuded, which later turns into amber gum. Fruits are often distorted, especially if infected at an early stage. *Cladosporium cucumerinum* is rarely a problem in cucumber, because of the availability of many resistant cultivars. It remains a problem in other cucurbits.

Basic strategy

Poorly drained fields and excessive humidity should be avoided. Pathogen-free seed and resistant cultivars, when available, should be used. Rotation (2–3 years) of cucurbit crops with non-host crops is recommended. All diseased fruits should be removed from the field. Fungicide sprays are possible if the disease persists.

Main fungicides

Seed treatment: thiram.
Sprays: chlorothalonil, copper, mancozeb, myclobutanil, propineb, triforine.

Glomerella lagenarium

General

Glomerella lagenarium (anamorph *Colletotrichum orbiculare*) causes anthracnose disease of cucurbits. The pathogen is seed-borne. Another source of infection is diseased plant debris. Disease symptoms include pale yellow to yellow water-soaked leaf spots, later becoming brown or black (watermelon) with irregular margins. On petioles and stems, lesions are shallow, elongated, tan areas. On fruits, lesions are circular, sunken, water-soaked areas. Infected young fruit may die, whereas on older fruit, dark spots and severe cracks appear. The disease is favoured by wet weather conditions.

Basic strategy

Plant debris should be destroyed. Deep ploughing of crop debris immediately after harvest in combination with crop rotation of at least 2–3 years effectively reduces the inoculum level. Tolerant and resistant cultivars should be used whenever possible. Seed treatment with fungicides is effective against the fungus.

Main fungicides

Seed treatment: captan, thiram.

Bacterial diseases

General

Angular leaf spot, caused by *Pseudomonas syringae* pv. *lachrymans*, is the most widespread bacterial disease of cucurbits.

Table 2 Viruses attacking cucurbits and their modes of transmission

Virus	Transmission	Crop affected
Cucumber mosaic cucumovirus	Aphids in a non-persistent manner, contact, seeds	Melon, courgette, cucumber, watermelon
Cucumber green mottle mosaic tobamovirus	Contact, seeds	Especially glasshouse cucumber
Cucurbit yellow stunting disorder closterovirus	Whiteflies	Melon, cucumbers
Melon necrotic spot carmovirus	*Olpidium bornovanus* (zoospores), contact, seeds	Glasshouse melon and cucumber
Watermelon mosaic potyvirus	Aphids in a non-persistent manner, contact	Melon, courgette, cucumber
Zucchini yellow mosaic potyvirus	Aphids in a non-persistent manner, contact, seeds	Courgette, melon, watermelon

It is seed-borne and can overwinter in plant debris. The disease first appears on cotyledons as round to irregular, water-soaked spots. On leaves, it causes angular, brown, water-soaked spots. Lesions also develop on stems, petioles and fruits, on which the water-soaked spots are sometimes covered with white exudate. Fruit rot can penetrate deeply, causing an internal rot. It reduces fruit quality and yield. The bacterium spreads by splashing rain, by insects, by handling plants, and on farm machinery.

Basic strategy

It is very important to start with pathogen-free seed. Three-year crop rotation is recommended. General hygiene is equally important: infected plants and debris should be removed from the field, tools and machinery should be disinfected, etc. Nitrogen fertilization should be reduced. Cultivation of the soil when it is dry is most effective in reducing bacterial survival. Irrigation from surface drainage water near cucurbit fields should be avoided. A number of cucumber cultivars and other cucurbits are resistant to *P. s. lachrymans*. If detected early, copper sprays may give some control under field conditions. Copper is also used when cultural operations cause damage to the plants.

Viruses

General

The following viruses are regularly found in cucurbits grown in the field: *Cucumber mosaic cucumovirus*, *Cucumber green mottle mosaic tobamovirus*, *Melon necrotic spot carmovirus*, *Watermelon mosaic potyvirus*, *Zucchini yellow mosaic potyvirus*. Symptoms may consist of mosaic, leaf yellowing, leaf deformation, growth reduction, chlorotic and necrotic spots, rings and patterns on leaves and fruits. Symptoms and their severity vary with the virus isolate causing the infection, the plant species and the cultivar that is being infected, the plant stage and environmental conditions in which infection takes place. Symptoms are often not sufficiently characteristic for a reliable diagnosis to be made. Additional diagnostic methods may be needed (e.g. mechanical inoculation to test plants, ELISA test).

Cucurbit yellow stunting crinivirus has become important in European melon and cucumber crops only recently, and is still of very limited distribution. In some cases, its increased importance has been associated with the spread of the newly introduced vector *Bemisia tabaci*. This virus is under consideration for regulation.

To minimize the effects of viruses, it is important to know which virus causes the disease and how it is transmitted. Each virus has its own mode of transmission (Table 2). In addition, all are spread by grafting and by transport of infected plants.

Basic strategy

Virus diseases are difficult to control and can result in substantial crop losses. As there are no cures for virus-infected plants in the field, all measures should be directed at preventing infection. This includes removal or avoidance of sources of infection, prevention or limitation of virus spread by vectors, and improvement of crop resistance to viruses. It is important to eradicate all infected plants of both crops and weeds as these plants may act as a source of infection for further spread if vectors are present. Eradication of weed hosts is often an impossible task, because of the extensive host range of some viruses.

The use of certified propagation material (seeds and transplants) helps greatly to avoid early infections in the crop. Certification also relies on inspection and testing for viruses, and on spatial isolation and planting in periods with low vector populations.

Control of vectors is of great importance for viruses which are mainly transmitted by insects. This may include insecticides and biological control, although the latter is still in the research stage for outdoor cucurbits. Insecticide sprays are ineffective against viruses transmitted in a non-persistent manner, introduced into the crop by winged aphids coming from the surrounding crops. Treatments with mineral oils seem to show a certain efficacy against non-persistent viruses. The presence of vectors can be monitored by using yellow sticky traps, so as to apply insecticide correctly early in the season. Alternative preventive measures are, e.g. using insect gauze, mulching with reflecting plastic films that reject vectors (principally aphids), adapting time of transplantation in order to avoid exposing plants to inoculation during periods of greater presence of the vector. For viruses which are mainly transmitted by contact, hygienic measures are important. Disinfection of tools helps to reduce spread. During crop handling, virus spread can also be reduced by always working in the same direction in rows and beginning operations always at the same starting point. Use of resistant cultivars is also important. Especially for *Cucumber mosaic cucumovirus*, many resistant cucumber and melon cultivars are available. Watermelon is usually resistant.

Aphids

General

Aphids are sucking insects that can affect the health of cucurbits directly by feeding damage and also indirectly by transmitting viruses. The main species infesting outdoor cucurbits are *Aphis gossypii*, *Aphis fabae*, *Aphis craccivora* and *Myzus persicae*. Primary damage to plants results from the effects of colonies feeding on young tissues, which weakens and distorts new growth. Damage usually becomes obvious on cucurbits after the vines begin to run. Aphids cause chlorotic spotting, chlorosis and distortion of leaves, stunting and wilting of plants. In cases of heavy infestation, buds and fruits fall. Secondary damage arises from sooty mould growing on heavy honeydew secretions, which are deposited on leaves and fruit, resulting in reduced photosynthesis and fruit quality.

Basic strategy

If the weather is cool during spring, populations of natural enemies will be slow in building and heavy aphid infestations may result. Planting in a well-prepared, fertile seed bed helps to produce vigorous plants better able to withstand aphid attack. Monitoring (yellow sticky traps, water traps and regular inspection of both traps and plants) is important to provide information concerning the presence of aphids. It should begin just after the formation of the first true leaf. Some weed species can act as reservoirs for viruses and should be controlled. Spray treatment may be necessary when it becomes obvious that cultural and natural control measures are not keeping aphids under control. Before spraying, the crop should be checked for the presence of natural enemies, mainly coccinellids and syrphids. If they are found, selective insecticides should be preferred. Sufficient spray should be applied to wet all infested plant surfaces.

Problems with resistance

Several aphid species (especially *Aphis gossypii* and *Myzus persicae*) have populations with considerable resistance to certain groups of insecticides (e.g. pirimicarb, organophosphorus compounds), so product choice and rotation of products is very important. Products with a purely physical action, such as starch-based preparations or fatty acids, may be useful as spot applications and can control resistant aphids. The Insecticide Resistance Action Committee (http://plantprotection.org/IRAC/) provides a co-ordinated crop protection industry response to the development of resistance in insect and mite pests.

Main insecticides

Sprays: alpha-cypermethrin, beta-cyfluthrin, cyfluthrin, cypermethrin, deltamethrin, diazinon, dichlorvos, dimethoate, imidacloprid, lambda-cyhalothrin, nicotine, methomyl, permethrin, pirimicarb, pymetrozine, rotenone, zeta-cypermethrin.

Thrips

General

Both *Thrips tabaci* and *Frankliniella occidentalis* are polyphagous pests feeding on leaves, flowers or stems. Adult thrips are generally less than 2 mm long and are usually dark brown to tan. Thrips injury is caused by adults and nymphs. Feeding on leaves causes a characteristic silvery appearance, eventually browning and dying. Leaf tips wither, curl and die. The undersides of leaves are spotted with small black specks. Flowers become flecked, spotted and deformed, and many buds fail to open. *Frankliniella occidentalis* is primarily a flower feeder that feeds on both flower petals and pollen. Fruit scarring occurs on cucumber.

Basic strategy

Thrips populations should be monitored using coloured traps (blue, yellow or white) and by monitoring. Where available, thresholds should be used in order to decide whether an insecticide spray is needed (e.g. more than two thrips per leaf). The presence of natural enemies should be considered when deciding the need for treatment and the choice of insecticide. Thrips feed deep in the flowers and buds where they are sheltered from insecticides. The pest is resistant to many insecticides. After harvest, crop debris should be destroyed. Management of weeds within the crop is also recommended.

Main insecticides

Sprays: acetamiprid, acrinathrin, azadirachtin, deltamethrin, formetanate, imidacloprid, methomyl.

Whiteflies

General

Whiteflies such as *Trialeurodes vaporariorum* and, in recent years, *Bemisia tabaci* can cause serious damage to cucurbits in the field. Adults are small white insects about 1.5 mm long, easily disturbed into short flights. Whiteflies lay eggs on young foliage. On hatching, young larvae crawl to a feeding location on the lower leaf surface and become sessile. Adults and nymphs attack the underside of the leaves by sucking plant juices. The damage includes chlorotic spotting and chlorosis of leaves, spotting of fruit, and stunting and wilting of plants. Whiteflies excrete honeydew on which sooty mould fungi grow, turning the foliage and fruit black in colour and thus reducing the photosynthetic potential and fruit quality.

Bemisia tabaci is regulated as a quarantine pest in many countries, the risk being primarily to the glasshouse industry in northern countries and spread of different biotypes, as pests of field crops, in the south of the EPPO region. Young plants should be free from the pest and come from a place of

production which is free. *Bemisia tabaci* has the potential to transmit viruses that may be of importance to cucurbits, e.g. *Cucurbit yellow stunting crinivirus*, which appears on the EPPO Alert List as a potential new problem in Mediterranean countries.

Basic strategy

Crops should be examined regularly and yellow sticky traps used to trap adult whiteflies moving into a field. Monitoring should begin at the time of seedling emergence. Intermediate-aged and old leaves should be sampled for nymphs. Locally established thresholds should be used to determine the use of insecticide sprays. After harvest, crop debris should be removed.

Problems with resistance

Trialeurodes vaporariorum has been resistant to many insecticides for some years. Over-reliance on conventional insecticides has now also resulted in highly resistant *B. tabaci* biotypes, especially to imidacloprid.

Main insecticides

Against adults: acetamiprid, deltamethrin, fenpropathrin, imidacloprid, methomyl, pyrethroids.
Against larvae: buprofezin, teflubenzuron.

Wireworms and white grubs

General

The larvae of certain Elateridae (*Agriotes* spp., wireworms) and Melolonthidae (*Melolontha* spp., white grubs) damage the roots and stem bases of cucurbits in the field. These become yellow and younger plants die. Development of wireworms takes 3–5 years, and adults and larvae of different ages co-exist each year. Development of white grubs takes 2–3 years and is generally synchronized. The most serious damage normally only occurs in the third year after adult flight.

Basic strategy

Grassland or uncultivated land as a preceding crop should be avoided. The level of population of wireworms and white grubs in the soil is needed to make an informed decision on treatment and should be determined by soil sampling. If numbers are high (e.g. 10 larvae per m^2), the field should be avoided. Various insecticides can be used as soil sprays.

Main insecticides

Soil treatments: carbofuran, diazinon, fipronil, tefluthrin (spot treatment).

Noctuids

General

Many polyphagous noctuid larvae may typically attack cucurbit plants at or below soil level such as *Agrotis segetum*, *Agrotis ypsilon*, *Euxoa temera*. Melon is the most susceptible to their attack. They are favoured by hot, dry weather conditions.

Basic strategy

Females often lay their eggs on weeds, so risk can be reduced by avoiding large areas of weedy headlands and provision of good weed control in cucurbit crops. Trapping adult moths can be used, in conjunction with a temperature-sum method, to determine the time of application of irrigation and/or sprays. Irrigation or rain of reasonable intensity will usually provide economic control. Foliar sprays are preferable to soil treatments. The aim is to kill young cutworms on the foliage before they burrow into the soil.

Main insecticides

Sprays: alpha-cypermethrin, *Bacillus thuringiensis*, beta-cypermethrin, bifenthrin, cyfluthrin, deltamethrin, diflubenzuron, esfenvalerate, fenpropathrin, teflubenzuron.

Mites

General

Tetranychus urticae and *Tetranychus cinnabarinus* are polyphagous species, found mainly on the lower surface of leaves. Young and adult mites damage cucurbits by puncturing the epidermal cells with their stylets. Leaves are discoloured, shrivelled, desiccated and cannot protect fruit from sunburn later in the growing season. Colonies develop on all aerial parts of plants and usually contain all stages, from eggs to adults. If infestation becomes high, plants may be covered by seething masses of mites, and their webs become visible. Plants can be killed quite rapidly.

Basic strategy

Weed control around the field in autumn and spring can reduce the overwintering mite population. Destruction of weeds around the edges of fields during the growing season is not advisable because it forces mites to migrate into the field. Monitoring should begin early in the growing season (e.g. prior to flower production in pumpkin or male flower production in melon; prior to runner production for watermelon). Local thresholds should be followed, if available. If necessary, acaricide sprays can provide effective control. Care should be taken when selecting acaricides to preserve beneficial mites and other arthropod predators that aid in the control of mites. Acaricides that are harmful to them should be avoided. Biological control

using predatory mites (e.g. *Phytoseiulus persimilis*) used as soon as the first mobile forms are detected can provide good results if environmental conditions are suitable. The entomopathogen *Beauveria bassiana* is another alternative to acaricides. Poles used as support for growing cucurbits should be disinfected as mites may hide on them.

Some mite populations have developed resistance to acaricides and, in some cases, cross-resistance. Minimizing the use of acaricides should also delay such problems with resistance.

Main acaricides

Sprays: amitraz, clofentezine, cyhexatin, fenbutatin oxide, hexythiazox, pyridaben.

Meloidogyne spp.

General

Root-knot nematodes, *Meloidogyne* spp. are very destructive to all cultivated cucurbit species. They are polyphagous endoparasitic nematodes which cause knots, swellings and other malformations on the roots. Damage is usually associated with patches of stunted, chlorotic plants within a field. Symptoms include early yellowing of foliage, reduced size and number of leaves and excessive wilting. This results in lower yield and fruit quality. *Meloidogyne incognita* is the commonest species. It can be found in sandy soils causing high yield losses. *Meloidogyne javanica* prevails in warmer climates. *Meloidogyne arenaria* can be found mainly in loamy soils, often associated with *M. incognita*. *Meloidogyne hapla* is commonest in a continental climate or on winter crops in the Mediterranean region.

Basic strategy

Healthy, nematode-free seedlings, clean soil, good general hygiene, use of resistant cultivars (where available) are essential to prevent nematode infestation. Cultural practices such as deep ploughing, fallowing and destruction of susceptible weed hosts should be an integral part of crop management. Temperature, moisture, soil type, age of the plant at infection and inoculum density have profound influence on the damage caused by nematodes. Proper irrigation and nutrition reduce stress and may minimize nematode damage. Because of their wide host range, root-knot nematodes are difficult to control by crop rotation, except where non-hosts or resistant cultivars can be grown. If numbers are very high, the field should be avoided. Except for breeding or planting material, the use of nematicides is not considered GPP. Such treatments should be limited to what is strictly necessary. In some Mediterranean countries, good results are obtained by combining solarization with nematicides at reduced dose.

Main nematicides

Dazomet, oxamyl.

Weeds

General

Weed management options are influenced by the growth characteristics of each crop. In general, weeds can cause yield reductions, especially when crops are not grown during their preferred season. Weeds interfere with harvest by making fruits difficult to find.

Basic strategy

The vigorous growth of cucurbits makes integrated weed management feasible and reduces the need for herbicides. An integrated approach is needed because of the limited availability of registered, effective, selective herbicides. Monitoring the fields and keeping records of the weed species that occur in each field are advisable. Crop rotation allows different control measures to be used in the various cropping systems, thus avoiding the increase in specific weed populations. Cultivation kills most emerged weeds but can also bring more weed seeds to the soil surface, which may cause problems later in the season. Cultivation should be done as shallowly as possible and just before planting cucurbits. After planting or transplanting, cultivation is only possible before vines are produced. Hand weeding is used to supplement machine cultivation and thin the crop to the required density. Cucurbits can be mulch-planted to eliminate the need for herbicides.

Herbicides, in combination with good cultural practices, control many weeds of cucurbits. Herbicides are applied preplanting and incorporated, or after planting (pre-emergence) and incorporated with irrigation, or after planting (post-emergence) on emerged weeds. The choice of herbicide depends on the weed species expected to occur (weed history of the field) and sensitivity of the crop. Emerged cucurbit plants will be killed by contact with certain herbicides (e.g. glyphosate), so these can only be used before crop emergence. Special care should be taken about herbicides on the preceding crop in the field used for cucurbit production, because herbicide soil residues can limit the growth of sensitive cucurbits.

Main herbicides

Watermelon/melon
Pre-emergence: naptalam.
Pre-emergence (grasses): S-metolachlor.
Post-emergence (grasses): fluazifop-P-butyl, sethoxydim, haloxyfop-P-methyl, fenoxaprop-P-ethyl, propaquizafop.

Cucumber
Pre-planting: benfluralin, dazomet, naptalam.
Pre-sowing: glyphosate.

Courgettes
Pre-emergence (dicots): chlorthal-dimethyl, dazomet, diquat, glufosinate-ammonium.