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 2/31(1)

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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

Cucurbits under protected cultivation

Specific scope
This standard describes good plant protection practice for cucurbit vegetable crops under protected cultivation.

Specific approval and amendment
First approved in 2003-09.

This Standard on GPP for cucurbits under protected cultivation 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 vegetable crops of the family *Cucurbitaceae* under protected conditions, such as melon *Cucumis melo*, cucumber or gherkin *Cucumis sativus* and courgette *Cucurbita pepo*.

Most cucurbit crops are grown in the open (see EPPO Standard PP 2/32 Outdoor cucurbits), but some are produced under protected cultivation, which includes glasshouses, plastic tunnels or houses. Tunnels or row covers are often used in cooler climates to create a warmer environment, which gives young seedlings an early start. Under these conditions, the basic strategies to control pests remain broadly the same. General hygiene standards need to be maintained at a very high level. GPP in cucurbits also implies good management of the protected environment, for the incidence of pests can be much affected by general cultural conditions. This is of particular importance since most of these protected crops are capital- and labour-intensive. With the given intensive cultivation methods, crop rotation is rarely possible and such crops are liable to rapidly spreading pest attacks. However, in Mediterranean countries, crop rotation is considered as a major component of cucurbit production under plastic, affecting both soil conditions and pest cycles. Cultivation of non-cucurbit crops for at least 2–4 years is recommended, depending on the resistance of the cultivar to particular pathogens. Capsicums, tomatoes and aubergines should be avoided in rotation with cucurbits to minimize disease problems. Cultivars resistant or less sensitive to diseases such as mildews and wilts should be used whenever possible. Due to breeding of new cultivars, northern European cucurbits are resistant to *Corynespora cassiicola*, *Cladosporium cucumerinum* and *Glomerella lagenarium*. These pathogens no longer cause significant problems under protected cultivation. The use of resistant rootstocks can provide good protection if available (e.g. *Cucurbita ficifolia* which is resistant to *Fusarium oxysporum* f. sp. *cucumerinum*).

Cucurbits have relatively large seeds and, in northern European glasshouses, they are generally direct-seeded into rockwool blocks or grown from seedlings raised in small peat pots (or similar containers) or peat blocks, transplanted as a whole into the final growing medium. The grower frequently buys in the seedlings from another source, but may also produce them himself. Thus, the guidelines for the different pests given below refer separately to the recommended practice for seedlings. Seedlings should be produced in a high-quality compost or in rockwool. They should be raised in an isolated location, away from cucurbit crops. The seeds should meet normal certification standards. Normal precautions should be taken against damping-off diseases, including the use of seed treatments. Cucurbits may also be grown in hydroponic systems. In southern European countries, cucurbits are mostly direct-seeded into the soil. Seeds are planted in rows or in mounds of soil and, after germination, the seedlings are thinned to the desired population.

It is GPP to use seed treatments against pests of young plants, especially if such treatments result in fewer spray applications. Cultivation in disease-free soil or sterile growing medium is extremely important. The same applies to pathogen-free water, particularly when using recirculating water in combination with an artificial growing medium. The plants should be well spaced to permit effective air movement and ventilation, as well as to reduce interplant competition for light, water and nutrients. Damage to plants should be avoided. Tools and machinery should be cleaned after use. At the end of the growing season, the irrigation system should be disinfected against pathogens. In empty glasshouses, windows should be cleaned to remove algae and green moss. In winter, screening may be used to limit cost of heating. In early spring, the screens should be removed to avoid excessive humidity and loss of light, and thus prevent disease infections. Netting of windows and ventilation openings is useful in preventing the entry of insects such as aphids, moths, adult leafminers and whiteflies, but screen apertures need to be very small for thrips and other minute insects.

Pests should be monitored at regular intervals. A spray programme of different active substances is GPP if certain pests, which can only be chemically controlled, are indeed present or to be expected. Locally established threshold values should be used. Dosages should satisfy the requirements on the label, taking account of the individual effects and possible interactions. Combining or alternating products with different modes of action can help to avoid the development of resistance.

It is GPP to use well-maintained equipment. Application of plant protection products is mainly done by spraying, e.g. with power sprayers, or as a space treatment, e.g. with low-volume mist (LVM) applicators or exhaust fogging machines. LVM applicators have the advantage of being set automatically, so there is reduced exposure of personnel. Application through trickle irrigation is also GPP. Applying plant protection products by means of overhead sprinklers or by dusting may cause unreliable effectiveness because of uneven deposition. In glasshouses, it is particularly important to respect safety regulations for workers applying plant protection products, re-entering after spraying, and handling sprayed plants. Any re-entry interval (REI) and harvest interval (HI) specified on the label should be respected. When applying plant protection products, especially for space treatments, windows and doors should be thoroughly closed to avoid emission into the environment. Waste water should be safely eliminated.

Soil sterilization is a common practice for pest control (including weed control) in protected crops. It is GPP to use steam sterilization or solarization for this purpose, but it is not considered GPP to use soil sterilants systematically. Such treatments should be limited to what is strictly necessary. In southern countries, soil solarization is an effective control technique for soil-borne plant pathogens, nematodes and some weed species. It is a hydrothermal process of heating moist soil by covering it with transparent plastic film for at least 40 days during the hottest season. Soil should be previously cultivated and irrigated abundantly in order to favour better heat transmission through the soil and to increase susceptibility of the pathogens to heating. Thin plastic film (0.025–0.05 mm) increases the efficacy and reduces the costs at the same time. The solarization technique gives best performance in warm climates, or in temperate ones if applied in closed plastic tunnels or glasshouses. Solarization integrated with other techniques (fumigation with reduced dosages, biological control agents, organic amendments, etc.) may increase effectiveness and reduce the soil coverage period. Solarization has been found to be effective for controlling infections caused by soil-borne pathogens such as *Didymella bryoniae*, *Verticillium dahliae*, *V. albo-atrum*, *Fusarium oxysporum* f. sp. *cucumerinum*, *Fusarium oxysporum* f. sp. *melonis*.

Biological control as part of an integrated pest management (IPM) programme is becoming common practice in the production of protected cucurbit crops. If biological agents are used and the use of plant protection products is necessary, the side-effects of plant protection products on the biological agents should be taken into account for the choice and the time of application of the plant protection product (see, for example, the tables published by Plantenziektenkundige Dienst, 1998). If plant protection products with harmful effects on natural enemies have nevertheless to be used, spraying only part of a crop can be an option to avoid total failure of the biological control system. If honeybees or bumble-bees are used for pollination, care should be taken to protect them when applying a plant protection product. Parthenocarpic cucumber cultivars do not require pollination.

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 active ingredients 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.

Table 1 Principal pests of cucurbits under protected cultivation considered

Pests	Crops on which economic damage occurs
Damping-off and root rot	Cucumber, melon, courgette
Sclerotinia sclerotiorum	Cucumber, melon, courgette
Phomopsis sclerotioides	Cucumber, melon, courgette
Fusarium and verticillium wilts	Cucumber, melon, courgette
Didymella bryoniae	Cucumber, melon, courgette
Pseudoperonospora cubensis	Cucumber, melon, courgette
Botryotinia fuckeliana	Cucumber, melon, courgette
Bacteria	Cucumbers for pickling (gherkin)
Viruses	Cucumber, melon, courgette
Aphids	Cucumber, melon, courgette
Noctuids	Cucumber, melon, courgette
Leafminers	Cucumber, courgette
Thrips	Cucumber, melon, courgette
Whiteflies	Cucumber, melon, courgette
Capsid bugs	Cucumber
Mites	Cucumber, melon, courgette
Meloidogyne spp.	Cucumber, melon, courgette
Weeds	Cucumber, melon, courgette

Damping-off and root rot

General

Several *Pythium* spp. (*P. aphanidermatum*, *P. ultimum*) 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 or substrate may develop a soft rot. On germinated plants, before emergence, a dark brown or black water-soaked lesion develops. On the emerged plants, stem becomes constricted or rotted and the plant collapses. An attack of *Pythium* spp. is stimulated by fluctuations in climate conditions. 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. *Phytophthora cryptogea* can also cause a root rot.

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. In cucurbitaceous crops grown in glasshouses, *T. cucumeris* is of little importance. 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.

Basic strategy

Cultural control measures including crop rotation, adequate drainage, planting on raised beds and avoidance of sowing or planting in cold wet soils are usually relied upon to reduce the chances of attack. Hygiene is of great importance. Since these organisms are soil-borne, it is important to use pathogen-free soil, substrate, pots, etc. This can be done by using new or steam-sterilized material. Cleaning and sterilization of pots, glass, etc. is also possible with copper sulphate and quaternary ammonium compounds and other disinfectants (e.g. formaldehyde, sodium hypochlorite). In general, damage to the plants should be prevented. Temperature fluctuation should be avoided by using water at the temperature of the root medium. In systems where recirculating water is used, the diseases can spread rapidly, and the water should therefore be disinfected (e.g. by heating, sand filter or UV). Seed treatment is also good practice. Presowing or preplanting incorporation of fungicides can provide early protection of seedlings. Fungus flies (*Mycetophilidae*) and shore flies (*Ephydridae*) should be kept at low levels as they are vectors of *Pythium*.

Main fungicides

Seed treatment: thiram, carbendazim.
Pot soil treatments: captan, etridiazole, propamocarb, tolclofos-methyl.
Drenches: *Pythium*: etridiazole, metalaxyl-M, propamocarb, fosetyl-aluminium.
Drenches: *Rhizoctonia*: iprodione, mepronil, pencycuron, tolclofos-methyl.

Sclerotinia sclerotiorum

General

Sclerotinia sclerotiorum occurs in glasshouses but rarely causes an epidemic level of disease. The fungus is soil-borne and sclerotia survive in the soil for a long time. It is usually first noted on the stem base of the plants or, where the soil is covered with polythene, in dense canopy growth under the vents, where it forms thick, white cottony mycelium. In this mycelium and the diseased parts of the plant, large white, later blackish sclerotia develop. Lesions may girdle the stem and plants wilt and rot. Lesions on leaves also occur but only spread if conditions are very favourable.

Basic strategy

Transplants should be disease-free or treated by dipping. Plants should be well spaced. Any condition that contributes to poor air circulation and the retention of moisture is likely to aggravate the disease. Infected plants and any plant debris containing sclerotia should be carefully removed and destroyed. There are no resistant cultivars. If infestation is to be expected, the soil should be steam-sterilized. Fungicide sprays give some control.

Main fungicides

Sprays: carbendazim, diethofencarb, iprodione, procymidone, thiophanate-methyl.

Phomopsis sclerotioides

General

Phomopsis sclerotioides is soil-borne and can infect all cucurbits infecting the roots and causing the condition known as black root rot. It can also appear on artificial substrates but it is mainly a problem in soil-grown crops. When roots are infested, the take-up of water is blocked. Symptoms are black angular spots on roots and wilting of the plants. The roots become yellow-brownish to black and finally rot. The fungus can spread by air, water or soil/substrate. Under unfavourable circumstances, the fungus can survive for years as sclerotia in the soil.

Basic strategy

If a resistant rootstock of *Cucurbita ficifolia* is used, the disease presents no problem. Otherwise, steam sterilization of soil or artificial substrate is recommended. Pathogen-free irrigation water should be used and recycling water disinfected. Infested plant material should be removed. To avoid black root rot, soil temperatures should be favourable for the growth of the host.

Fusarium and verticillium wilts

General

Various *formae speciales* of the soil-borne fungi *Fusarium oxysporum* (f. sp. *cucumerinum*, f. sp. *melonis*) and *Verticillium albo-atrum* and *V. dahliae* cause wilting and sometimes death of plants. These fungi parasitize the vascular system.

Verticillium wilt is a cool-weather disease. The two *Verticillium* spp. survive in soil, as dark resting mycelium or microsclerotia, respectively, in debris from infected plants. Infected plants show mild to moderate wilting during the warmest part of the day but recover at night. As the disease advances, some marginal and interveinal chlorosis develops on lower leaflets. Fusarium wilt is a warm-weather disease, most prevalent on acid, sandy soils. *Fusarium oxysporum* can persist in the soil for several years. Both *Fusarium* and *Verticillium* can also cause serious problems on artificial substrate (especially *Fusarium*).

The characteristic symptom of both wilts is brown or black discoloration seen in the vascular tissue in cross-sections of the lower stem. Wilt symptoms are usually one-sided, i.e. individual runners collapse prior to the death of the plant. Invasion of these wilt pathogens occurs through wounds on roots, such as those produced by cultivation or as result of nematode feeding.

Basic strategy

Only healthy planting material should be used. Resistant cultivars or resistant rootstocks may prevent early infection, but cannot prevent infection completely. Movement of infected plants and infested soil (with machinery, tools, transplants), and of *Fusarium*-infected seeds, should be prevented. Hygiene solves most problems, and all possible precautions and actions associated with proper sanitation and management should be taken. The soil should be steam-sterilized before planting or transplanting and also after harvest if there were problems with the disease in the previous season. Diseased plants and plant debris should be removed and destroyed. After harvest, the pallets, water hoses, glass walls, etc. should be cleaned thoroughly. The water table should be checked and kept sufficiently low. Irrigation with ditch water or pond water should be avoided, because surface water may be contaminated with the pathogens. High sodium and nitrogen concentrations should be avoided. If possible, resistant cultivars should be used or a resistant rootstock such as *Cucurbita ficifolia*. Crop rotation can reduce losses, but not eliminate the pathogens because of the wide host range of these fungi. *Verticillium* spp. have a wide host range, so effective weed control is important.

Any problems should be investigated thoroughly and expert advice should be sought concerning the pathogens, because the susceptibility to fungicides of the pathogens varies considerably. Apart from the active substance, the mode of application varies, from spraying to drenching. Seed treatment is also possible. In southern countries, soil solarization is an effective control technique.

Main fungicides

Seed treatment: carbendazim.
Drenches: carbendazim, thiophanate-methyl.

Didymella bryoniae

General

Didymella bryoniae (synonym *Mycosphaerella citrullina*, *M. melonis*) is one of the most common above-ground diseases of cucurbits grown under protected cultivation. The disease is known as black-stem rot, 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 in older tissue. In cucumber, necrotic areas first appear at the margins of the leaves, and enlarge rapidly until the entire leaf is blighted. Circular, tan to dark lesions may girdle the stem 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. Infected plant debris, a major 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. Excessive humidity should be avoided by heating and opening vents. Guttation of the plants should be avoided by slowly heating the glasshouse in the morning. Application of extra potassium at fruit formation is recommended. When possible, it is best to use long rotations (at least 2-year rotation cycle) with crops other than cucurbits. 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 culture.

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 a white to pale-grey powdery mass 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. Powdery mildew is seldom seen on the fruits, but decreased photosynthesis may cause significant reductions in the quality and yield of fruits. Development of powdery mildew is favoured by moderate temperatures and relative humidity, dry soil conditions, reduced light intensity and abundant plant growth. On cucurbits in the glasshouse, conidium release is triggered by irrigation or air movement, which then disperse conidia from plant to plant. Conidia can survive the winter period on cucurbits in glasshouses and are dispersed by wind from glasshouse to field crops during the spring and summer.

Basic strategy

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. Alternating programmes or mixtures are preferred. Several cultivars of pumpkin, cucumber and melon (cantaloupe) have moderate to excellent resistance to powdery mildew. Some common weeds, e.g. *Sonchus* spp., may become infected and should be removed from the glasshouse and its neighbourhood.

Resistance

Strains of *Podosphaera 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, sulphur, triforine.

Pseudoperonospora cubensis

General

Downy mildew is one of the most important foliar diseases of cucurbits. In heated glasshouses, downy mildew is not a big problem but, in unheated houses or under lower temperatures, it can be a severe problem. High humidity stimulates growth of the pathogen. 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.

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. If fungicides are used, they should be applied with high-pressure sprayers to ensure complete coverage of the undersides of leaves. Strains of the pathogen resistant to metalaxyl-M and azoxystrobin have been reported. FRAC guidelines should be followed.

Main fungicides

Sprays: azoxystrobin, chlorothalonil, copper oxychloride, fosetyl-Al, metalaxyl-M, myclobutanil, propamocarb.

Botryotinia fuckeliana

General

Botryotinia fuckeliana (anamorph *Botrytis cinerea*) attacks many plants and plant parts, mainly through wounds. All cucurbits are affected. The fungus causes grey rot on every part of the plant. Infected plant parts die and are gradually covered by the grey mycelium (grey mould), or affected areas may dry out. Lesions release millions of spores into the air. The fungus survives as sclerotia or mycelium in dead or living plant tissue or as sclerotia in the soil.

Basic strategy

Hygiene is very important. Debris and infected plants should be removed. Soil and growing medium should be well drained and a dense stand avoided. The relative humidity should be generally low, without too much water sprinkled over the plants. Wet plants and condensation should be avoided or dried as soon as practicable. As far as possible, wounding should be avoided and pruning wounds kept small and regular. Foliar sprays can be applied to minimize air-borne infection by *B. fuckeliana*.

Problems with resistance

Strains of *B. fuckeliana* resistant to a number of commonly used fungicides can occur. These include benzimidazoles (e.g. carbendazim) and dicarboximides (e.g. iprodione, procymidone). If a programme of fungicide sprays is required, different types of product should be alternated to minimize the loss of efficacy due to resistance. FRAC guidelines should be followed.

Main fungicides

Sprays: carbendazim, chlorothalonil, diethofencarb, iprodione, procymidone, pyrimethanil.

Bacteria

General

Bacterial diseases are of little importance in cucurbits in glasshouses. *Pseudomonas syringae* pv. *lachrymans* is seed-borne and is rarely found in cucumber, melon and courgette in glasshouses. It sometimes causes a problem of angular leaf spot in cucumbers for pickling. *Erwinia carotovora* subsp. *carotovora* can cause a slimy soft-rot of the stem base in soil-grown crops. Infection usually follows pest attacks, but can occur through natural growth cracks. 'Root mat', caused by rhizogenic strains of *Agrobacterium tumefaciens* biovar 1, can affect both soil-grown and hydroponic cucumber crops. Infection results in abnormal plant growth, typically upward growth of roots from the surface of the propagation block, and swelling of the stem base.

Basic strategy

It is very important to use pathogen-free seeds and to ensure good continuous growth. Crop rotation with a non-host is recommended. With all bacterial diseases, good hygiene is essential and plant debris should be removed, tools should be disinfected, etc. Glasshouses should be disinfected with formaldehyde. Steam sterilization of soil or substrate is recommended. The stem base should be kept dry as far as practicable to avoid *E. c. carotovora* (basal stem rot). In glasshouse-grown cucurbits, reduction of the relative humidity to 80–90% can reduce the spread of *P. s. lachrymans*. A number of cucumber cultivars and other cucurbits are resistant to this pathogen.

Viruses

General

The following viruses are regularly found in cucurbits grown under protected cultivation: *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, leaf curling, 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 newly introduced and indigenous strains of the 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 viruses 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, 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.

The use of certified propagation material (seeds and transplants) greatly helps to avoid early infections in the crop. Seeds can be made free from tobamoviruses by treatment with hot air or certain chemicals. Certification also relies on inspection and testing for viruses, and on spatial isolation and planting in periods with low vector populations. 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.

Control of vectors is of great importance for viruses which are mainly transmitted by insects. This may include insecticide and biological control, as well as physical precautions (e.g. using insect gauze and dividing glasshouses into compartments). For viruses which are mainly transmitted by contact, hygienic measures are important. Disinfection of tools (e.g.

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
Cucumber green mottle mosaic tobamovirus	Contact, seeds	Especially glasshouse cucumber
Cucurbit yellow stunting crinivirus	Whiteflies	
Melon necrotic spot carmovirus	*Olpidium bornovanus* (zoospores), contact, seeds	In glasshouse
Watermelon mosaic potyvirus	Aphids in a non-persistent manner, contact	Courgette
Zucchini yellow mosaic potyvirus	Aphids in a non-persistent manner, contact, seeds	

with skimmed milk) and recycling water 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, having staff always work in specific rows, using disposable gloves which are regularly changed, and having staff and visitors wear protective oversuits if they are moving between infected and uninfected areas. Glasshouses should be cleaned and disinfected thoroughly at the end of cropping. For soil-grown crops, steaming reduces the risk of carry-over in the soil. Rockwool blocks that are to be reused should be steamed thoroughly. 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 cucurbits are *Aphis gossypii* and *Myzus persicae*. Primary damage to plants results from the effects of colonies feeding on young tissues, which weakens and distorts new growth. Aphids cause chlorotic spotting, chlorosis and distortion of leaves, stunting and wilting of plants. 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

Starting with a crop free from aphids at least delays the development of a population. Monitoring (yellow sticky traps and regular inspection of both traps and plants) is important to provide information concerning the presence of aphids. Some weed species can act as reservoirs for viruses and should be controlled. Various biological control agents are available for effective use against aphids: *Aphidoletes aphidimyza*, *Aphelinus abdominalis*, *Aphidius colemani*, *Hippodamia convergens*, *Harmonia axyridis*, *Chrysopa carnea*, *Adalia bipuncta*, *Coccinella septempunctata* and *Verticillium lecanii*. If aphid colonies do nevertheless begin to build up, it may be necessary to apply insecticide sprays but preferably only as a 'corrective' application. The active substances used should be safe to natural enemies or have a short persistence so that not all life stages of natural enemies are affected and so that natural enemies can be reintroduced shortly after application. 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 or organophosphorus products), 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, methomyl, pirimicarb, pymetrozine, rotenone, zeta-cypermethrin.
Fog or mist: pirimicarb, pymetrozine.

Noctuids

General

Many polyphagous noctuid larvae feed on leaves of cucurbits, such as *Spodoptera exigua*, *Spodoptera littoralis*, *Chrysodeixis chalcites* and *Lacanobia oleracea*. *Spodoptera exigua* is a subtropical and tropical noctuid, present in the south of the EPPO region, which can also invade glasshouses in the north. Its light- to dark-green caterpillars up to 3 cm in length feed on young leaves, shoots and flowers. Young larvae feed on the under surface of leaves and skeletonize them. Larger larvae make irregular holes in leaves. Buds and growing points may be eaten and fruits pierced. The moths are grey-brownish and hide during the day.

Spodoptera littoralis is an A2 quarantine pest. It is a totally polyphagous noctuid pest that can be found outdoors in the south and in glasshouses in the north. Females lay eggs in egg masses on the lower leaf surface. Damage arises from feeding by larvae, leading to complete defoliation. The number of generations depends on climatic conditions. Weeds act as a reservoir for females and should be controlled.

Basic strategy

Adults normally enter the glasshouse or plastic tunnel with the planting material, or else through openings during the spring and summer growing season. In general, IPM techniques, favouring natural enemies, should be used. Insecticide sprays may be applied if necessary, including *Bacillus thuringiensis* (against the first- or second-stage larvae). Not all strains are effective (*S. littoralis* is resistant to many strains). Natural enemies which are suitable for biological control include the egg parasite *Trichogramma evanescens* and the predatory bug *Podisus maculiventris*.

Control of *S. exigua* requires frequent inspection of the crop, since the pest has a short biological cycle and develops very rapidly. Keeping glasshouses closed at night prevents the moths from entering. Screens may also be used. Only young larvae are sensitive to the available insecticides. A product based on

Spodoptera exigua nuclear polyhedrosis virus is also available, which kills larvae in 3–6 days.

Main insecticides

Sprays: alpha-cypermethrin, *Bacillus thuringiensis*, bifenthrin, cyfluthrin, deltamethrin, diflubenzuron, esfenvalerate, fenpropathrin, teflubenzuron.
Against young larvae: *Spodoptera exigua* NPV (nuclear polyhedrosis virus), deltamethrin, diflubenzuron, lambda-cyhalothrin, methomyl, teflubenzuron, *Podisus maculiventris*.
Against eggs: *Trichogramma evanescens*.

Leafminers

General

Liriomyza bryoniae, *Liriomyza huidobrensis*, *Liriomyza trifolii* and *Phytomyza horticola* are the main leafminer pests of cucurbits. Adult flies (female) cause small white feeding spots on leaves, normally of little significance. The larvae mine in the leaves. The larvae of *L. huidobrensis* are whitish to yellow; the pupae are brown or black. The larvae of *L. trifolii* and others are yellow; the pupae are greyish-black. Pupation occurs outside the leaves, in the soil beneath the plants or on the foliage. Leafminers are mostly polyphagous. *Liriomyza huidobrensis* and *L. trifolii* are regulated as quarantine pests in many countries of the EPPO region, so that young plants should be free from them.

Basic strategy

Infestation in the glasshouse is caused by infested planting material and by entry of the adults through doors and windows. Use of yellow sticky traps and frequent inspection of the plants for mines and feeding punctures indicate the presence of the pest. Starting with clean seedlings is of great importance. Insect nets are used in some countries.

The parasitic hymenoptera *Dacnusa sibirica*, *Diglyphus isaea* and *Opius pallipes* are used as biological control agents in glasshouses and can provide effective control of leafminers. These parasites are native in Europe and can be naturally present in glasshouses. *Dacnusa sibirica* and *O. pallipes* lay their eggs within leafminer larvae. Larvae of these natural enemies may remain within the pupal stage of the leafminer in empty glasshouses and become active in early spring. *Diglyphus isaea* lays eggs next to the host and the larvae feed on the leafminer. This species can occur naturally after May. Where possible and when available, these parasites should be used.

Some insecticides, particularly abamectin and the growth regulator cyromazine, are effective as sprays against larvae of some populations of *L. huidobrensis* and *L. trifolii*, but other leafminer populations are resistant to a range of insecticide groups including abamectin, and this makes insecticide control difficult. Insecticides are not effective against pupae. Resistance to pyrethroids is also known.

Main insecticides

Sprays (larvae): abamectin, cyromazine, dichlorvos, methomyl, triazophos, oxamyl, thiacloprid.
Sprays (adults): cypermethrin, deltamethrin.
Smoke: dichlorvos, pirimiphos-methyl.

Thrips

General

Thrips were not a problem on cucurbits under protected cultivation until the introduction into Europe of *Frankliniella occidentalis*. Larvae and adults feed on the epidermal cells of leaves, buds and flowers. Heavy attacks may destroy seedlings. In general, symptoms of direct damage caused by thrips are light mottling and silvering of leaves and malformation and discoloration of buds and flowers. In addition, a significant problem caused by thrips is the distortion of fruits. Another species, *Thrips tabaci*, is found primarily on foliage, seldom invading flowers, and the damage symptoms are flecking and silvering to the leaves. Indirect damage is caused by transmitting virus diseases.

Basic strategy

Starting with thrips-free planting material is important. Yellow or blue (especially for *F. occidentalis*) sticky traps should be used to monitor the presence of thrips. Yellow traps also indicate the presence of other pests (e.g. whiteflies, aphids, leafminers). The predatory mites, *Amblyseius cucumeris* and *Amblyseius degenerans*, and the predatory bugs, *Orius* spp., should be used when possible, introducing them at the start of the crop cycle and regularly maintaining numbers. The whitefly strain of the fungus *Verticillium lecanii* has a side-effect on thrips. The ground-dwelling predatory mites, *Stratiolaelaps* (*Hypoaspis*) *miles* and *Gaeolaelaps* (*Hypoaspis*) *aculeifer*, can contribute to control by preying on ground-dwelling thrips life stages. If population densities of thrips increase, an insecticide treatment may be necessary, which in the case of *F. occidentalis* is not easy due to its resistance to many plant protection products and to the harmfulness of many insecticides to natural enemies. Because of the hidden way of life of many thrips, including *F. occidentalis*, fumigation may be preferred to spraying, particularly if the thrips have infested the flower buds. Pyrethroid insecticides are too persistent to be compatible with natural enemies and can destroy all possibilities of biological control for up to 12 weeks (e.g. *A. cucumeris*). Insecticides used against other insects have some limited action.

Main insecticides

Sprays: abamectin, acrinathrin, cypermethrin, deltamethrin, fenpropathrin, malathion, methamidophos, methomyl, oxamyl, pirimiphos-methyl, thiocyclam, thiacloprid.
Fog or mist: dichlorvos.

Whiteflies

General

The whitefly *Trialeurodes vaporariorum* is a widespread and abundant polyphagous pest of glasshouse vegetables. In recent years, another species, *Bemisia tabaci*, has also become important on glasshouse crops. Adults are small white insects about 1.5 mm long, easily disturbed into short flights. On hatching, young larvae crawl to a feeding location on the lower leaf surface and become sessile. In heated glasshouses, breeding continues throughout the year. Adults and nymphs attack the underside of the leaves by sucking plant juices. The damage includes chlorotic spotting and chlorosis of leaves, the spotting of fruit, and the 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 new problem in Mediterranean countries).

Basic strategy

Crops should be examined regularly and yellow sticky traps used for monitoring. Insecticide control of whiteflies is possible, but involves heavy inputs of insecticide sprays or fumigations which are quite incompatible with the general policy of biological control of other glasshouse pests. So GPP relies on biological control, supported by the development of appropriate management practices. Use of insecticide sprays should then be kept to a minimum, used in emergency situations, preferring those that are harmless to natural enemies.

The hymenopteran parasite *Encarsia formosa* gives good results against *T. vaporariorum*, but *B. tabaci* is a poor host of this species. The entomopathogenic fungi *Verticillium lecanii* (whitefly strain) and *Paecilomyces fumosoroseus*, the predatory bug *Macrolophus caliginosus*, the parasitic hymenoptera *Eretmocerus eremicus* (used principally for *T. vaporariorum*, especially at high temperatures, and *E. mundus* (most effective against *B. tabaci*) and the predatory beetle *Delphastus pusillus* can be used for the control of both whitefly species.

Problems with resistance

Trialeurodes vaporariorum populations have 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. The only solution is to rely on biological control as the basic strategy.

Main insecticides

Sprays: abamectin, bifenthrin, buprofezin, cypermethrin, deltamethrin, diazinon, dichlorvos, fenpropathrin, imidacloprid, malathion, methomyl, oxamyl, pirimiphos-methyl, pymetrozine, thiacloprid.
Fog or mist: buprofezin, diazinon, pyrethrin or teflubenzuron.

Capsid bugs

General

Under protected cultivation, capsid bugs may cause damage to cucurbits, in particular *Lygus rugulipennis* to cucumbers. In spring, the bugs migrate from neighbouring areas into glasshouses. Both nymphs and adults feed by sucking juices from the plant. Toxic saliva injected when feeding causes necrotic spots on foliage, leading to leaf tattering. Heavy feeding causes deformed fruits, and kills buds and shoots.

Basic strategy

Good weed control in and outside the glasshouses reduces the number of bugs. Crops should be inspected to decide if insecticide sprays are necessary. Control is mostly by contact insecticides, as adults are quite mobile.

Main insecticides

Sprays: pymetrozine.

Mites

General

Two distinctive forms of glasshouse spider mite with closely related biology, *Tetranychus urticae* and *Tetranychus cinnabarinus*, together with the tarsonemid mite *Polyphagotarsonemus latus*, cause damage to cucurbits under protected cultivation. They are all polyphagous. Young and adult mites suck mainly on the lower side of leaves by puncturing the epidermal cells with their stylets. Leaves are discoloured and often drop prematurely. Colonies develop on all aerial parts of plants and usually contain all stages, from eggs to adults. If infestation becomes high, especially under favourable glasshouse conditions, plants may be covered by seething masses of mites and their webs are visible. Plants can be killed quite rapidly. *Polyphagotarsonemus latus* causes crinkling, cracking, discoloration and malformation. Hot, dry weather favours development of mites and, if populations are not checked, plants may be killed within a few days.

Basic strategy

Spider mite infestations should be controlled thoroughly towards the end of the season, to avoid carry-over to the next crop. Glasshouses and equipment, e.g. irrigation lines and drippers, should be thoroughly cleaned between crops. The glasshouse structure can be treated with quinomethionate. Mites thrive at high temperatures and low relative humidity. Increasing the relative humidity or moistening the foliage may slow build-up of mite populations (but favours fungal diseases). Mite control should rely primarily on natural enemies. The predatory mite *Phytoseiulus persimilis* is an effective biological control agent, and the predatory mite *Neoseiulus californicus* and predatory midge *Feltiella acarisuga* can also be used for biological control. Acaricide sprays should be used only if and when biological control proves unable to suppress mite populations. Good weed control in and outside the glasshouse reduces the number of mites.

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

Main acaricides

Sprays: abamectin, acrinathrin, amitraz, bifenthrin, benzoximate, bromopropylate, clofentezine, cyhexatin, dicofol, dienochlor, flucycloxuron, fenazaquin, fenbutatin oxide, fenpropathrin, hexythiazox, oxamyl, tetradifon, tebufenpyrad.

Meloidogyne spp.

General

Meloidogyne arenaria, *Meloidogyne hapla*, *Meloidogyne incognita*, *Meloidogyne javanica* and *Meloidogyne thamesi* are endoparasitic root-knot nematodes which cause knots, swellings and other malformations on the roots of cucurbits grown in soil. This results in poor growth, stunting and occasionally wilting, and thus poor yields.

Basic strategy

Healthy, nematode-free seedlings, clean soil and good general hygiene are sufficient to prevent nematode infestation. Growing the plants in soil-free substrates, e.g. rockwool, prevents infestation. In northern countries, leaving glasshouses open and unheated for a period in winter is sufficient to eliminate *Meloidogyne* spp. Cultural practices such as crop rotation and cultivation should be an integral part of crop management. Hot-water treatment of plant material, steam sterilization and solarization of the soil are effective curative treatments and nematicide treatments are not normally necessary. Weeds should be thoroughly controlled. Root-knot-resistant cultivars exist and should be used, as appropriate.

Weeds

General

In general, weeds are not a problem if a cucurbit crop is grown on an artificial growing medium. In glasshouses, algae or moss can be a problem. Presence on glass can reduce light intensity.

Basic strategy

Good general hygiene is important. If cucurbits are grown in soil, the soil can be sterilized (e.g. by steaming or solarization methods). Mostly this will be sufficient to start weed-free production. Mechanical and hand weeding can solve some of the problems. Weeds growing between rows are the easiest to control. They are usually handled by either shallow tillage or mulching. A herbicide treatment may be necessary and is normally applied between rows. In rotation systems, herbicides are not favoured because of possible phytotoxicity to the following crop. If herbicides are spilt on heating pipes, it is recommended to clean these before the heating is put on.

After application for control of algae and moss, doors and windows should remain closed for a few days to avoid damage of crops in neighbouring compartments. Dead algae and moss should be removed a few days after treatment by scrubbing and spraying with water.

Main herbicides

Between rows: glyphosate.
In empty glasshouses to clean windows of algae and moss: alkyldimethylbenzylammonium chloride.

Reference

Plantenziektenkundige Dienst (1998) Effects of active substances of plant protection products on biological control agents used in glasshouses. *Bulletin OEPP/EPPO Bulletin* **28**, 423–429.