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 2/29(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

Solanaceous crops under protected cultivation

Specific scope

This standard describes good plant protection practice for solanaceous vegetable crops under protected cultivation.

Specific approval and amendment

First approved in 2003-09.

This Standard on GPP for solanaceous vegetable crops 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(2) Principles of good plant protection practice. It covers methods for controlling pests (including pathogens and weeds) of vegetables of the family *Solanaceae* under protected cultivation, such as tomato *Lycopersicon esculentum*, capsicum or sweet pepper *Capsicum annuum* and aubergine *Solanum melongena*.

In the northern countries of the EPPO region, solanaceous crops are mainly produced under protection. Where climatic conditions allow it, these 'vegetable fruits' are grown in the open (see EPPO Standard PP 2/30 Outdoor solanaceous crops) but, in the regions which grow these crops out of season, fruits are produced under the protection of plastic tunnels or houses. 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 solanaceous crops 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. In Mediterranean countries, however, crop rotation is considered as a major component of solanaceous crop production under plastic, affecting both soil conditions and pest cycles. Cultivation of non-solanaceous crops for at least 2–4 years is recommended, depending on the resistance of the cultivar to particular pathogens. Cultivars resistant or less sensitive to diseases such as mildews and wilts should be used whenever possible.

Solanaceous crops are mostly 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. They should be raised in an isolated location, away from solanaceous crops. The seeds should meet normal certification standards. Normal precautions should be taken against damping-off diseases, including the use of seed treatments.

It is GPP to use seed treatments against pests of young plants, especially if such treatments result in fewer spray applications. Healthy planting material, use of seed treatments where possible and cultivation in disease-free soil or sterile growing medium are extremely important. The same applies to pathogen-free water, particularly when using recirculating water in combination with an artificial growing medium.

Solanaceous crops are mostly grown on an artificial growing medium such as rockwool. Rockwool and other matting should be reused only after steam sterilization, and tools and machinery should be cleaned after use. Damage to plants should be avoided. At the end of the growing season, the irrigation system should be disinfected (e.g. with hydrogen peroxide or peracetic acid) against pathogens. In empty glasshouses, windows should be cleaned of algae and green moss. In winter, screening may be used to limit heating costs. 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 plant protection products 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 plant protection products or alternating them can help to avoid the development of resistance.

It is GPP to use well-maintained equipment. Application 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 chemicals, 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 *Pyrenochaeta lycopersici*, *Didymella lycopersici, Verticillium dahliae*, *Phytophthora capsici*, *Fusarium oxysporum* f. sp. *radicis-lycopersici*.

Biological control as part of an integrated pest management (IPM) programme is becoming common practice in the production of protected solanaceous 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. The use of honeybees and bumble-bees for pollination of solanaceous crops is a common practice under protected cultivation, so care should be taken to protect them when applying a plant protection product. The beehives may need to be removed from the glasshouse, or covered up for a specified time, depending on the product. Biological control of soil-borne fungi is also under development (e.g. with *Trichoderma harzianum* or *Streptomyces griseoviridis*).

For plastic tunnels or houses, the choice of a suitable plastic film is important. Encouraging results have been obtained by the use of photoselective films which can reduce insect attack. A major limitation to successful production of solanaceous crops in the Mediterranean region, in particular of tomatoes, is infection by several viruses including *Tomato yellow leaf curl begomovirus* (TYLCV). The spread of *Bemisia tabaci*, a vector of TYLCV, is equally important. Transport of plants for planting between the nursery and the growing site should be done under adequate conditions, using cover sheets to avoid contamination of plants. Plastic houses should have screen nets, double doors and restricted staff access. Special attention should be given to the control of weeds, in and around the houses, as they can be reservoirs for many pests (including viruses) and also sources of weed seeds. Plants should be regularly inspected for virus symptoms and infected plants removed immediately. Monitoring of whitefly numbers, using yellow sticky traps, is good practice.

The main pests of solanaceous 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 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.

Foot and root rots

General

Several *Pythium* spp. can infect solanaceous plants 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,

Table 1 Principal pests of solanaceous vegetables under protected cultivation

Pests	Crops on which economic damage occurs
Foot and root rots	Tomato, capsicum, aubergine
Sclerotinia sclerotiorum	Tomato, capsicum, aubergine
Phytophthora nicotianae	Tomato
Phytophthora capsici	Capsicum
Pyrenochaeta lycopersici	Tomato, capsicum, aubergine
Didymella lycopersici	Tomato, capsicum, aubergine
Alternaria solani	Tomato
Septoria lycopersici	Tomato (aubergine)
Fusarium and verticillium wilts	Tomato, capsicum, aubergine
Fusarium oxysporum f. sp. *radicis-lycopersici*	Tomato
Botryotinia fuckeliana	Tomato, capsicum, aubergine
Phytophthora infestans	Tomato
Powdery mildews	Tomato, capsicum, aubergine
Fulvia fulva	Tomato
Bacteria	Tomato, capsicum
Viruses	Tomato, capsicum, aubergine
Aphids	Tomato, capsicum, aubergine
Noctuids and other caterpillars	Tomato, capsicum, aubergine
Leafminers	Tomato, aubergine
Thrips	Tomato, capsicum, aubergine
Whiteflies	Tomato, capsicum, aubergine
Mealybugs	Tomato
Capsid bugs	Tomato, capsicum, aubergine
Hauptidia maroccana	Tomato
Mites	Tomato, capsicum, aubergine
Meloidogyne spp.	Tomato, capsicum, aubergine
Weeds	Tomato, capsicum, aubergine

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, nematode damage. Fungus flies (*Mycetophilidae*) and shore flies (*Ephydridae*) should be kept at low levels as they are vectors of *Pythium*.

Thanatephorus cucumeris (anamorph *Rhizoctonia solani*) is a ubiquitous soil-borne fungus, which causes damping-off, root rot, basal stem root (foot rot), and fruit rot of solanaceous plants. It survives in soil, compost and infected debris as mycelium and undifferentiated sclerotia. The pathogen produces reddish-brown or dark brown lesions on germinating seedlings and they may be destroyed before or soon after emergence. The young stem is constricted and the plant dies. Root rot appears on the plants whose roots are damaged, especially if they are attacked by *Meloidogyne* spp. Above-ground stem canker develops occasionally at pruning wounds. In warm and wet areas, a brown rot with alternating light- and dark-coloured rings may develop on fruit of tomato.

Thielaviopsis basicola, black root rot, is a common soil inhabitant with a wide host range which destroys young feeder roots. It can be particularly damaging in tomatoes produced by the nutrient film technique.

Phytophthora cryptogea can cause a foot rot of tomato soon after planting out, and is usually associated with cold wet soil. It can also result in a root rot resulting in stunting, yield loss and even plant death. Good hygiene during plant propagation is essential; infection can arise from contaminated soil, drip lines or water.

Basic strategy

Cultural control measures including crop rotation, adequate drainage 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 fungi 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, quaternary ammonium compounds or other disinfectants (e.g. formaldehyde, sodium hypochlorite). In general, damage to the plants should be prevented. Temperature fluctuation should be avoided by using water with the temperature of the root medium. In systems where recirculating water is used, foot and root-rot diseases can spread rapidly, and the water should therefore be disinfected (e.g. by heating, slow sand filtration or UV). Seed treatment is also good practice. Presowing or preplanting incorporation of fungicides can provide early protection of seedlings.

Main fungicides

Seed treatment: metalaxyl-M, metiram, thiram.
Pot soil treatments: etridiazole, propamocarb.
Drenches: *Pythium*, *Phytophthora*: metalaxyl-M, propamocarb.
Drenches: *Rhizoctonia*: iprodione, mepronil, pencycuron, tolclofos-methyl.

Sclerotinia sclerotiorum

General

Sclerotinia sclerotiorum is an occasional problem on solanaceous crops, especially capsicum, whenever cool and moist weather conditions prevail during crop development. The inoculum comes from sclerotia in the soil. It is usually first noted on the stem base of plants, where it forms white cottony mycelium. In this mycelium and the diseased parts of the plant, large white, later blackish sclerotia develop. Plant parts above the affected areas wilt and rot. This disease is not a problem if plants are grown in artificial growing medium.

Basic strategy

Transplants should be disease-free or treated by dipping. Any condition that contributes to poor air circulation and the retention of moisture is likely to aggravate the disease. Affected plants and any plant debris containing sclerotia should be removed. If infestation is to be expected, the soil should be steam-sterilized. Fungicides can be applied as targeted sprays or drenches, as soon as symptoms are seen.

Main fungicides

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

Phytophthora nicotianae

General

Phytophthora nicotianae is the cause of buck-eye rot of tomato, which is uncommon but can be seen where overhead sprinklers are used for watering. The lower fruits show grey and red-brown patches with concentric rings. Infection is caused by water splash or contact with contaminated soil. It can also result in a root rot resulting in stunting, yield loss and even plant death.

Basic strategy

Hygiene is very important. At the end of the growing season, it is important to sterilize the growing medium by steam or solarization, and to clean tools and glasshouse walls. Infected plants should be removed and destroyed. Use of available partially resistant cultivars is recommended. If needed, fungicide treatments (sprays to protect fruits) are possible.

Main fungicides

Soil or artificial substrate application: etridiazole, propamocarb-hydrochloride.
Sprays: chlorothalonil, copper oxychloride.

Phytophthora capsici

General

Phytophthora capsici causes blight of capsicum. Attack occurs on the root or at the collar and spreads into the base of the stem. Plants wilt rapidly and finally die.

Basic strategy

Phytophthora capsici is a limiting factor in irrigated capsicum cultivation. Watering enhances the dispersal of zoospores.

Main fungicides

As for *P. nicotianae*.

Pyrenochaeta lycopersici

General

Pyrenochaeta lycopersici is responsible for brown root rot and corky root rot of solanaceous crops, especially soil-grown. As the latter name suggests, the outer layers of the roots become swollen and corky and gradually break off. Plant vigour is reduced and wilting may occur as the root system is progressively destroyed.

Basic strategy

Crops should be grown in unaffected soil. If the root system is badly affected, soil can be built up around the stem base to encourage new root production higher up the stem. This will only be useful if it is combined with fungicide treatment. A fungicide drench should be applied at first sign of the disease and, if necessary, repeated at monthly intervals.

Main fungicide

Drenches: carbendazim.

Didymella lycopersici

General

Didymella lycopersici causes didymella stem rot, a major disease especially of glasshouse tomatoes. All above-ground parts of the plant can be affected. First symptoms are dark brown stem lesions at soil level which may girdle the stem, so that the whole plant wilts. Numerous black pycnidia form on the stem lesions, and the plant may die. Lower leaves turn yellow and leaf lesions are brown with concentric rings. The centre of a lesion generally becomes lighter in colour, and a few pycnidia may develop. The infection spreads through wounds, particularly during routine trimming. Infection of fruits is rare in the glasshouse but common outdoors.

Basic strategy

Pathogen-free seeds should be used. Infected plant debris, a main source of inoculum, 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 from plant to plant in operations such as deleafing. General hygiene in an infected crop is vital. Crop rotation is recommended. Soil sterilization by steam or solarization is recommended. No resistant cultivars are available. When necessary, fungicides can be sprayed. At the end of cropping, all debris should be safely eliminated and the glasshouse and any reused substrates should be thoroughly sterilized (e.g. with formaldehyde).

Main fungicides

Sprays: carbendazim, copper oxychloride, iprodione, maneb.

Alternaria solani

General

Alternaria solani, causing early blight, may attack tomato at any growth stage. Stems, leaves and fruits can be affected.

Symptoms occur as irregular, concentric, necrotic spots. Brown spots appear on ripe and green fruits, and are subsequently covered by brown mycelium and conidial fructifications.

Basic strategy

Tomatoes may often be infected with *A. solani* and *Septoria lycopersici* (see below) simultaneously and the control measures are similar. It is important to start with healthy plants, and thus to use healthy or disinfected seeds, and to disinfect the seed-bed. Moist conditions should be avoided and relative humidity kept at low levels. Debris and infected fruits, leaves and stems should be removed. Fungicide sprays should be applied when first symptoms occur and with 8–10 day intervals depending on type of fungicide.

Main fungicides

Sprays: anilazine, azoxystrobin, chlorothalonil, copper, cymoxanil, difenoconazole, famoxadone, oxadixyl, procymidone.

Septoria lycopersici

General

Septoria lycopersici, causing leaf spot of tomato, can occur at any stage of plant development. Symptoms may appear on young glasshouse seedlings ready for transplanting and heavy attacks may kill them. Symptoms may also appear on the lower, older leaves and stems when fruits are setting. Initially, small (2–3 mm), water-soaked rounded spots, grey in the centre with black margins can be observed. Sometimes in the centre of the spot, black pycnidia with white conidial mass protruding may be visible. Heavily infected leaves turn yellow, dry up, and drop off. Fruits are rarely and only superficially affected. Optimal conditions for fungal development are a temperature of 25 °C and high relative humidity. Conidia are dispersed by wind, droplets and animal vectors. The fungus penetrates into the plant host through stomata. The pathogen survives on plant debris and on seed, and can also overwinter on solanaceous weeds.

Basic strategy

Eliminating initial sources of inoculum greatly reduces the disease potential. The production area should be free from susceptible weeds and of tomato debris from the previous season. Use of healthy or disinfected seed, seed treatment and disinfection of seed-bed are essential. Moist conditions should be avoided. Fungicide sprays should be applied when first symptoms occur.

Main fungicides

Sprays: anilazine, chlorothalonil, copper.
Seed treatments: thiram.

Fusarium and verticillium wilts

General

Various *formae speciales* of the soil-borne fungi *Fusarium oxysporum*, *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 problems in crops grown on artificial substrates.

The characteristic symptom for both wilts is brown or black discoloration seen in the vascular tissue in cross-sections of the lower stem. Accompanying effects may include drooping of the petioles (epinasty) in young plants, and wilting, yellowing and later shrivelling of the lower leaves. Invasion of these wilt pathogens occurs through wounds on roots, such as those produced by cultivation or as a result of nematode feeding. Aubergines are particularly susceptible to *Verticillium* spp. and seedlings are easily destroyed; clearly separated yellow spots are a characteristic symptom on leaves.

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 ditchwater or pond water should be avoided, because surface water may be contaminated with the pathogens. High nitrogen concentrations should be avoided. Crop rotation can reduce losses, but not eliminate the pathogens because of the wide host range of *Verticillium* spp.

In case of problems, an expert analysis should be done concerning the pathogens involved, because the susceptibility to fungicides of the pathogens varies considerably. The mode of application is usually 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.

Fusarium oxysporum f. sp. *radicis-lycopersici*

General

Fusarium crown and root rot of tomato, due to *Fusarium oxysporum* f. sp. *radicis-lycopersici*, is characterized by a sudden wilt just prior to first pick. Severely affected plants may die. It is distinguished from fusarium wilt by an extensive chocolate-brown root rot and a strong reddish-brown vascular staining up to 30 cm above the root collar. The disease has a lower optimum temperature than fusarium wilt, at 15–18 °C. The fungus persists in the soil, usually on plant debris, as chlamydospores. It spreads by conidia or infested soil dust, by water (irrigation, splash), and by wind.

Basic strategy

Use of resistant cultivars is the most effective control measure. Putting peat around the stem base encourages adventitious root growth, which will remain relatively disease-free. Reducing the fruit load early in the season can reduce the risk of a severe disease attack. It is recommended to disinfect the soil or the substrate before sowing or planting and to remove all dead plants. No fungicide treatment is effective during the crop cycle.

Botryotinia fuckeliana

General

Botryotinia fuckeliana (anamorph *Botrytis cinerea*) attacks many plants and plant parts, mainly through wounds. All solanaceous vegetable crops are affected. The fungus cause brown spots on every part of the plant. Infected plant parts die and are gradually covered by the grey mycelium (grey mould), or affected areas may become dried 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. A symptom known as ‘ghost spotting’ occurs as a reaction to a spore landing on the surface of an immature tomato fruit. Affected flowers do not set and consequently some fruit yield is lost.

Basic strategy

Hygiene is very important. 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. Debris and infected plants should be removed. However, if the humidity is kept low (generally below 85% relative humidity), leaves removed and dropped on the floor are not usually a source of infection. Fungicide sprays should be applied if necessary.

Problems with resistance

Strains of *B. fuckeliana* resistant to a number of commonly used fungicides can occur. These include benzimidazoles (e.g. carbendazim), dicarboximides (e.g. iprodione, procymidone). 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: carbendazim, fenhexamid, iprodione, procymidone, pyrimethanil, thiram, tolylfluanid.

Phytophthora infestans

General

Phytophthora infestans, the agent of potato late blight, also causes leaf, stem and fruit rot of tomato. Its sporangia are easily dispersed under wet conditions. Root and foot infection results in internal brown discoloration and wilting. Brown, water-soaked lesions appear on root and stem. Leaves are discoloured blue-green and shrink. Brown spots appear on ripe or green fruits and develop a concentric ring pattern of brown bands. Severely affected roots show necrosis and decay. The disease is most common in tomato when it is also present in local potato crops.

Basic strategy

Healthy planting material should be used, and its growth should be stimulated after transplanting. Damage to the plants should be avoided and pruning done only in the morning to allow wounds to dry. The growing medium should be steam-sterilized. Infected plants should be removed, and not replaced in the same holes. In general, wet conditions (plants, soil, plastic) should be avoided. If necessary, fungicide sprays should be applied.

Main fungicides

Sprays: chlorothalonil, copper hydroxide, copper sulphate, etridiazole, mancozeb, maneb, metalaxyl-M, propamocarb, propineb.

Powdery mildews

General

Powdery mildew is a relatively new disease of tomatoes. An *Oidium* sp. (*Erysiphe* anamorph) has recently become wide-spread. This was initially known everywhere as *Oidium lycopersici*, but it now seems that there are two species involved: *Oidium neolycopersici*, which forms conidia singly, and is widespread throughout the world except Australia, and *O. lycopersici*, which always forms conidia in chains, and is confined to Australia. *Oidium neolycopersici* can affect all aerial parts of the plant except the fruits. Severely infected leaves turn brown and shrivel, resulting in premature defoliation. Severe infections lead to a marked reduction in fruit size and quality. The spread of powdery mildew is favoured by dry conditions (typically during daytime), moderate temperature, and reduced light intensity. Infection is favoured by high relative humidity, but not by free water. The fungus survives on plant debris.

The pathogen on aubergine is *Oidium longipes*, which is not pathogenic for tomato. It causes chlorotic leaf spots on the upper side of the leaves which become necrotic after a while. The leaves are eventually overgrown by an expanding mycelial mat.

Capsicum, in particular, is attacked by the polyphagous *Leveillula taurica*, which mainly occurs in warmer countries. The host organ most affected is the leaf blade. Petioles, stalks and flowers are rarely affected and fruits are occasionally infected. Unlike other powdery mildews that produce only superficial mycelium, *L. taurica* develops within the host tissue. Diffuse yellow spots develop on the upper leaf surface, while the white powdery mass of the pathogen appears on the underside of leaves. Spots may become necrotic and plants defoliated, especially capsicums. This pathogen is favoured by high temperatures and dry weather and is most frequently found in Mediterranean countries.

Basic strategy

If an attack develops, the use of a fungicide spray becomes necessary. Recommended fungicides can cause phytotoxicity in winter (under low light conditions) or on young plants. Breeding programmes for disease resistance are under study, as well as the use of biological control for *O. neolycopersici*.

Resistance strategy

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

Main fungicides

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

Fulvia fulva

General

Fulvia fulva (synonym *Cladosporium fulvum*) mainly affects the leaves of tomato, causing large yellowish spots with undefined margins. On the lower side of infected leaves, a black-olive velvet mould develops (leaf mould). Infected leaves shrink and die. Similar symptoms may also appear on stems, petioles and flowers. Fruits, on which the disease cause blackish necrotic spots, are rarely affected. Plants heavily affected by the disease have a reduced yield and fruits ripen slowly. Infections take place with more than 80% relative humidity and temperature between 10 °C and 27 °C (optimum 22 °C). The pathogen survives as free conidia on infected plants and on the wood structures of the glasshouse. Infection also seems to be transmitted through the seed.

Basic strategy

Cultural techniques help to avoid infections, e.g. aerating the glasshouse, heating the glasshouse during early spring, avoiding water-logging during irrigation, use of resistant cultivars and healthy or treated seed, disinfection of the wood structures of the glasshouse. Fungicides may be applied when first symptoms are seen, and repeated two or three times with 7–8 days interval. Resistant cultivars have significantly reduced the incidence of this disease in many countries.

Main fungicides

Sprays: carbendazim, chlorothalonil, cyproconazole, dithianon, thiophanate-methyl, tolylfluanid.

Bacteria

General

Bacteria may cause various symptoms such as leafspots, galls and discoloration of the vascular bundles. The most important bacteria on solanaceous vegetable crops are seed-borne: *Pseudomonas syringae* pv. *tomato* (bacterial speck), *Clavibacter michiganensis* subsp. *michiganensis* (bacterial canker), *Xanthomonas vesicatoria* (bacterial scab and leaf spot of tomato), *Xanthomonas axonopodis* pv. *vesicatoria* (bacterial leaf spot of capsicum). The last three of these are quarantine pests for some countries in the EPPO region, so that young plants are required to be free from them. The same applies to *Ralstonia solanacearum* (bacterial wilt), which is an important pathogen of solanaceous vegetables in warmer countries, but does not occur (other than very sporadically) in the EPPO region.

Basic strategy

It is very important to start with uninfected planting material and to ensure good continuous growth. General hygiene is equally important: infected plants and debris should be removed, tools such as knives should be disinfected, etc. High temperatures and relative humidity should be avoided. The plants should be kept dry. The soil should be steam-sterilized (as deep as possible) after harvest if there were problems with the disease in a previous season. If a system of recirculating water is used, the water should be disinfected by, e.g. heating,

Table 2 Viruses attacking solanaceous crops and their modes of transmission

Virus	Transmission	Crop affected
Alfalfa mosaic alfamovirus	Aphids in a non-persistent manner	Tomato, capsicum
Capsicum mild mottle tobamovirus	Contact, seeds	Capsicum
Cucumber mosaic cucumovirus	Aphids in a non-persistent manner, contact, seed	Tomato, capsicum
Pepino mosaic potexvirus	Contact	Tomato
Potato Y potyvirus	Aphids in a non-persistent manner	Tomato, capsicum
Tomato chlorosis crinivirus	Whiteflies	Glasshouse tomato
Tomato mosaic tobamovirus	Contact, seeds	Tomato, capsicum
Tomato spotted wilt tospovirus	Thrips, especially *Frankliniella occidentalis*, in a persistent manner	Tomato, capsicum, aubergine
Tomato yellow leaf curl begomovirus	*Bemisia tabaci*, especially biotype B, in a persistent manner; indigenous European biotype (Q)	Tomato

slow sand filter, UV. Crop rotation with a non-host is recommended. If, in spite of these preventive measures, bacterial diseases are found on the crop, spraying with copper may limit spread.

Viruses

General

The following viruses are regularly found in solanaceous vegetables grown under protected cultivation: *Alfalfa mosaic alfamovirus*, *Cucumber mosaic cucumovirus*, *Capsicum mild mottle tobamovirus*, *Tomato mosaic tobamovirus*, *Potato Y potyvirus*. Symptoms may consist of mosaic, leaf yellowing, leaf deformation, growth reduction, chlorotic and necrotic spots, rings and patterns on leaves and fruits. Necrosis on tomato fruits can be confused with the symptoms of infection by *Phytophthora* spp. Symptoms and their severity vary with the virus isolate causing the infection, the plant species and 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).

Certain other tomato viruses have become important in European tomato crops only recently (*Tomato spotted wilt tospovirus*, *Tomato yellow leaf curl begomovirus*, *Tomato chlorosis crinivirus*, *Pepino mosaic potexvirus*). In some cases, their increased importance has been associated with the spread of newly introduced and indigenous strains of the vectors *Bemisia tabaci* and *Frankliniella occidentalis*. These viruses are regulated in many European countries, or are under consideration for regulation. It is normally required that young tomato plants should be free from them, and additionally in some cases that their place of production should be free.

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 (e.g. tomato cultivars on cv. Beaufort rootstocks) 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 to prevention of 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 sources of infection for further spread if vectors are present.

The use of certified propagation material (seeds and transplants) helps greatly 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.

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 in compartments). For viruses which are mainly transmitted by contact, hygienic measures are important. Disinfection of tools (e.g. 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, beginning operations always at the same starting point and by having staff always work in the same area of the crop (assign certain rows to each staff member).

Use of resistant cultivars is also important. Especially for tobamoviruses, many resistant tomato and capsicum cultivars are available. Cross-protection by inoculating young plants with an attenuated virus strain in principle reduces severity of symptoms when the plants are later infected by a virulent strain. This 'classic' method was used in the past especially for ToMV, but is now only applied occasionally because of its disadvantages, i.e. poor availability of attenuated strains, effects of such strains on other crops or cultivars, aggravated symptoms after natural infections by viruses other than the targeted virus.

Aphids

General

Aphids are sucking insects that can affect the health of solanaceous crops directly by feeding damage and also indirectly by transmitting viruses. The main species infesting solanaceous crops are *Aphis gossypii*, *Myzus persicae* and *Macrosiphum euphorbiae* and *Aulacorthum solani*. 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, and stunting and wilting of plants. Secondary damage is 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 a crop free from aphids at least delays the development of a population. Monitoring (yellow sticky traps and regular inspection of both plants and traps) is important to provide information concerning the presence of aphids. Some weed species can act as hosts for aphids and as reservoirs for viruses and should be controlled.

Various biological control agents are available for effective use against aphids: *Aphidoletes aphidimyza*, *Aphelinus abdominalis*, *Aphidius ervi*, *Aphidius colemani*, *Hippodamia convergens*, *Harmonia axyridis*, *Adalia bipunctata*, *Coccinella septempunctata*, *Chrysoperla carnea* and *Verticillium lecanii*. If aphid colonies do nevertheless begin to build up, it may be necessary to spray insecticides, but preferably only as a 'corrective' application. The active substances used should ideally be safe to natural enemies and to bees, 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 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: acetamiprid, cyfluthrin, beta-cyfluthrin, alpha-cypermethrin, cypermethrin, deltamethrin, diazinon, dimethoate, dichlorvos, fatty acids, imidacloprid, lambda-cyhalothrin, pymetrozine, pirimicarb, pirimiphos-methyl (smoke), zeta-cypermethrin.
Fog or mist: dichlorvos, pirimicarb.
Smoke: nicotine.

Noctuids and other caterpillars

General

Many polyphagous noctuid larvae feed on leaves of solanaceous vegetables, such as: *Agrotis* spp., *Autographa gamma*, *Chrysodeixis chalcites*, *Lacanobia oleracea* (which also feeds on fruits), *Spodoptera exigua* and *Spodoptera littoralis*. *Helicoverpa armigera* may be a problem in tunnels in southern Europe.

Spodoptera exigua is a subtropical and tropical noctuid, present in the south of the EPPO region, which can also invade glasshouses in the north. 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. In tomatoes, larvae also bore into the fruit. 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) which is safe to other natural enemies. 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, as it has a short biological cycle and develops very rapidly. Keeping the glasshouse closed at night prevents the moths from entering. Screens may also be used. Only young larvae are susceptible 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, azinphos-methyl, *Bacillus thuringiensis*, beta-cyfluthrin, bifenthrin, cyfluthrin, cypermethrin,

deltamethrin, diflubenzuron, fenpropathrin, lambda-cyhalothrin, spinosad, teflubenzuron.
Against adult moths: fumigation with dichlorvos or pyrethroids.
Against young larvae: *Spodoptera exigua* NPV (nuclear polyhedrosis virus), *Bacillus thuringiensis*, deltamethrin, diflubenzuron, lambda-cyhalothrin, methomyl, teflubenzuron.
Against eggs: *Trichogramma evanescens*.

Leafminers

General

Liriomyza bryoniae, *Liriomyza huidobrensis*, *Liriomyza trifolii* and *Phytomyza horticola* are the main leafminer pests of solanaceous vegetable crops. 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. *L. 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 the entering of flies through doors and windows. The use of yellow sticky traps and frequent inspection of the plants for mines and feeding punctures indicates the presence of the pest. Starting with clean seedlings and glasshouses free from the pest 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. *D. 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. *D. isaea* lays eggs next to the host and the larvae feed on the leafminer. This species can be found spontaneously after May. Where possible and when available, these parasites should be used.

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

Main insecticides

Sprays against larvae: abamectin, alpha-cypermethrin, cyromazine, dichlorvos, methomyl, oxamyl, thiacloprid, triazophos.
Sprays against adults: cypermethrin, deltamethrin, nicotine.
Smoke: dichlorvos, pirimiphos-methyl.

Thrips

General

Thrips were not a problem on solanaceous crops under protected cultivation until the introduction into Europe of *Frankliniella occidentalis*. Larvae and adults feed on the epidermal cells of leaves, buds and flowers. In general, symptoms of direct damage caused by thrips are light mottling and silvering of leaves and fruit and malformation and discoloration of buds and flowers. Heavy attacks may destroy seedlings. Indirect damage is caused by transmission of virus diseases, e.g. *F. occidentalis* is a notorious vector of *Tomato spotted wilt tospovirus* (TSWV) and *Impatiens necrotic spot tospovirus* (INSV). *Thrips tabaci* is found primarily on foliage, seldom invading flowers. Its sap feeding causes white flecking of leaves. *Echinothrips americanus* is easily recognized by the white band across the thorax at the base of the wings. It occurs mainly on foliage of capsicums but, as the population level increases, the blossom may be invaded.

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, in addition to plant monitoring. Yellow traps also indicate the presence of other pests (e.g. whiteflies, aphids, leafminers). Any plants infected with tospovirus should be rogued out to prevent them being a source of infection for other plants.

The predatory mites *Amblyseius cucumeris*, *Amblyseius degenerans* and the predatory bugs *Orius* spp. should be used on capsicums and aubergines when possible. The whitefly strain of the fungus *Verticillium lecanii* has a side-effect on thrips. 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. 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 often ineffective against *F. occidentalis* and are too persistent to be compatible with beneficial insects 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, formetanate, malathion, methamidophos, methomyl, oxamyl, pirimiphos-methyl, spinosad, 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 sap. The damage includes chlorotic spotting and chlorosis of leaves, the spotting of fruits, 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. Tomatoes are often severely infested. *B. tabaci* B biotype can cause uneven ripening of tomato fruits.

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* B biotype and indigenous European biotype (Q) transmit *Tomato yellow leaf curl begomovirus* (TYLCV), which is also regulated as a quarantine pest (see under Viruses) and *Tomato chlorosis crinivirus*, which appears on the EPPO Alert List as a potential new problem in Mediterranean countries.

Basic strategy

Crops should be regularly examined and yellow sticky traps used for monitoring. Insecticide control of whiteflies is often difficult due to resistance, and 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 insecticides 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 has been resistant to many insecticides for some years. Over-reliance on conventional insecticides has resulted in highly resistant *B. tabaci* biotypes, especially to imidacloprid, pymetrozine and thiacloprid. The only solution is to rely on biological control as the basic strategy.

Main insecticides

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

Mealybugs

General

Mealybugs, in particular glasshouse mealybug *Pseudococcus viburni*, are becoming a serious pest in some nurseries.

Basic strategy

Cultural control by preventing carry-over between crops on irrigation lines, glasshouse structures, packing trays, etc. can reduce sources of infestation. If necessary, buprofezin can be used, which is safe to natural enemies used against other pests.

Main insecticides

Sprays: buprofezin.

Capsid bugs

General

Under protected cultivation, the capsid bugs *Liocoris tripustulatus*, *Lygocoris pabulinus*, *Nezara viridula*, *Lygus rugulipennis* and other *Lygus* spp. may cause damage to solanaceous crops. In spring, the bugs migrate from neighbouring areas into glasshouses and attack capsicum crops and sometimes tomato and aubergine. Both nymphs and adults feed by sucking sap 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: diazinon, mevinphos, oxamyl, pirimiphos-methyl (smoke).

Hauptidia maroccana

General

The glasshouse leafhopper, *Hauptidia maroccana*, has become commoner as a pest with the reduced use of broad-spectrum insecticides within IPM. The adults and nymphs are found underneath the leaves and feeding damage appears on the upper leaf surface as a coarse pale mottling or white, indistinct spotting. If the infestation is severe, the leaves may appear chlorotic and resemble a mineral deficiency. Adults are 3 mm long and pale yellow with grey markings. They jump off leaves and fly short distances when disturbed. The creamy white immature nymphs are less active and easier to spot.

Basic strategy

Weeds, e.g. chickweed (*Stellaria* spp.), are alternative hosts, so weed control both in and around glasshouses is important in preventing infestations. The egg parasitoid *Anagrus atomus* can give effective control if releases start at the first sign of damage. If necessary, insecticides can be sprayed when leaf spotting is first seen. Buprofezin will give control of leafhopper nymphs and can be integrated safely with biological control agents within IPM.

Main insecticides

Sprays: bifenthrin, buprofezin.

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 solanaceous crops. They are extremely 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. *Tetranychus cinnabarinus* (carmine spider mite or 'hypertoxic' mite) can cause severe plant damage at low populations. *Polyphagotarsonemus latus* also causes crinkling, cracking, discoloration and malformation. Severe attack on aubergine may stop the growth. Tomato russet mite *Aculops lycopersici* is a particular pest of tomato. Heavy infestations may also cause injury to capsicum while aubergine supports heavy populations. Infestation usually starts at the base of the plant and spreads upwards. Mite feeding on tomato produces bronzed or russeted aspects to the stem and leaves. Hot, dry weather favours development of mites and, if populations are not checked, plants may be killed in only a few days.

Basic strategy

Spider mite infestations should be controlled thoroughly on the previous crop, to prevent carry-over between seasons. 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 temperature 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. The predatory bug *Macrolophus caliginosus* can also give good control of spider mites. Acaricides should be used only if and when biological control proves unable to suppress mite populations and should be selected for their safety to natural enemies and to bees. Good weed control in and outside the glasshouses reduces the number of mites.

Problems with resistance

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, chloropropylate, cyhexatin, dienochlor, flucycloxuron, fenazaquin, fenbutatin oxide, fenpropathrin, hexythiazox, oxamyl, tetradifon, tebufenpyrad.
Against *Aculopsis lycopersici* on tomato: dicofol, sulphur.

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 solanaceous crops grown in soil. This results in poor growth, stunting and occasionally wilting, and thus in poor yields.

Basic strategy

Healthy, nematode-free seedlings, clean soil and good general hygiene are sufficient to prevent nematode 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. Plants grown in rockwool should not be infested.

Weeds

General

In general, weeds are not a problem if a crop is grown on an artificial growing medium. In glasshouses, algae or moss can be a problem. Presence on glass can reduce light intensity. In plastic tunnels, a critical period for tomatoes is about 4–5 weeks after transplanting (or longer if the crop is directly seeded). It is during this period that weed competition must be suppressed to avoid a reduction in yield.

Basic strategy

Good general hygiene is important. If solanaceous crops 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

Against weeds: 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.