◆ EPPO Standards ◆

GUIDELINES ON GOOD PLANT PROTECTION PRACTICE

STRAWBERRY

PP 2/9(1) English

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APPROVAL

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

REVIEW

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

AMENDMENT RECORD

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

DISTRIBUTION

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

SCOPE

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

REFERENCES

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

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

OUTLINE OF REQUIREMENTS

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

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

PP 2/9(1) English

Guidelines on good plant protection practice

STRAWBERRY

Specific scope

This standard describes good plant protection practice for strawberry.

Specific approval and amendment

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

This guideline on GPP forms part of an EPPO programme to prepare such guidelines for all major crops of the EPPO region. It should be read in conjunction with GPP Guideline no. 1 (Principles of Good Plant Protection Practice) (*Bulletin OEPP/EPPO Bulletin* **24**, 233-240, 1994).

In the EPPO region, crops of strawberry (*Fragaria ananassa*) are generally set up by transplanting runners in rows or beds outdoors in late summer (or earlier in southern Europe). The crop establishes over the first winter and bears fruit in spring or early in the following summer (as early as December or January in southern Europe). Crops are then left in place (perennial cropping) for usually 2-4 years (rarely more than 2 in southern Europe). Particular possibilities for applying plant protection treatments arise before or as new growth starts, and after harvest. Alternative growing systems are also used. These include "annual cropping", i.e. planting at any suitable time of year (using cold-stored runners if necessary) and harvesting as soon as possible, then removing the crop. In the warmer parts of the EPPO region, crops planted in summer can be protected under plastic tunnels through early winter to give a very early crop in midwinter. Strawberry crops can also be grown in various ways out of contact with the soil (though this is more usual for the production of planting material than for crops for fruit production). This guideline mainly aims to cover methods for controlling pests (including pathogens and weeds) of outdoor perennial crops for fruit production. It can if necessary be adapted for crops grown under protected conditions or as an annual crop.

In general, GPP for strawberry should be based on the following important elements. Strawberry should not normally be replanted after a preceding strawberry crop. The planting material should be healthy and, if possible, derive from a certification scheme (*Bulletin OEPP/EPPO Bulletin* **24**, 875-890, 1994). Good cultural hygiene is needed to avoid infestation of newly planted fields. The cultivar should be correctly chosen for the actual growing conditions. If possible, it should be resistant to the main strawberry pests. The fields where strawberries are planted should as far as possible be free from the soil-borne pests of strawberry, including perennial weeds. However, it is not considered GPP to use soil sterilants systematically to eliminate soil pests in strawberry fields; such treatments should be limited to what is strictly necessary. The cultivation methods used should be chosen to reduce the incidence and severity of the most important pests, e.g. limited use of fertilizers will keep foliage in a condition that restricts the development of *Botrytis cinerea*. Growing plants on ridges may be important to keep the soil relatively dry in order to control *Phytophthora fragariae*. Use of mulches can also protect strawberry plants from diseases and contribute to control of weeds. Some growers even grow strawberries out of contact with the soil, in containers, on special frames, etc. Use of threshold values or warning systems will ensure appropriate timing of the application of plant protection products and help to avoid unnecessary treatments.

The principal strawberry pests considered are the following:

- *Phytophthora fragariae* var. *fragariae* (red stele);
- *Phytophthora cactorum* (crown rot and leather rot);
- *Botrytis cinerea* (grey mould);
- *Verticillium* spp. (verticillium wilt);
- *Sphaerotheca alchemillae* (powdery mildew);
- leaf spots;
- *Colletotrichum acutatum* (strawberry anthracnose and black spot);
- soil fungi;
- *Xanthomonas fragariae* (angular leaf spot);
- viruses;
- aphids;
- *Anthonomus rubi* (strawberry blossom weevil);
- *Otiorrhynchus sulcatus* (European strawberry weevil, black vine weevil);
- thrips;
- *Philaenus spumarius* (common froghopper);
- *Aleurodes lonicerae* (honeysuckle whitefly);
- capsid bugs;

- *Harpalus rufipes* (strawberry seed beetle);
- caterpillars;
- soil insects;
- *Tetranychus urticae* (two-spotted spider mite);
- *Phytonemus pallidus* (strawberry mite);
- leaf nematodes;
- root nematodes;
- weeds.

Treatments with plant growth regulators are also considered.

Explanatory note on active substances

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

Phytophthora fragariae var. *fragariae* (red stele)

General

Red stele is caused by *Phytophthora fragariae* var. *fragariae*. It is the major disease of strawberries in many areas with cool, moist soil conditions. Severely diseased plants remain stunted and sometimes the young leaves become bluish-green and the older ones red, orange or yellow. Slightly diseased plants are hardly detectable above ground. Most often severely diseased plants occur in irregular patches rather than in rows. The fungus causes a root rot, with red discoloration of the stele above the rot.

The roots are infected by zoospores. Sporangia are formed at the root surface and oospores alongside the stele. The fungus survive as oospores in the soil. The pathogen is most frequently introduced into new areas with infected plants. Free water in the soil is necessary for the dispersal of zoospores. At least 15 pathotypes of *P. fragariae* var. *fragariae* have been identified world-wide. Some cultivars are infected by all pathotypes, while others are infected by only a few.

Basic strategy

The main basic strategy for control of *P. fragariae* var. *fragariae* is to use healthy plants that have been tested for the fungus, avoid infested planting sites, and use resistant cultivars. Another important control factor is to improve drainage and avoid soil compaction. Treatment with fungicides effective against oomycetes is part of the control strategy. It is GPP to dip the roots of transplants and to apply one foliar spray in autumn after planting. A single foliar spray is then recommended every year in autumn.

Main fungicides

Copper oxychloride, fosetyl-aluminium, metalaxyl.

Phytophthora cactorum (crown rot and leather rot)

General

Phytophthora cactorum probably has two pathotypes: one which infects flowers and berries causing so-called "leather rot", and one that may cause leather rot and also infect the crown of the strawberry plant ("crown rot"). Crown rot is generally a more serious problem than leather rot and may cause death of the plants. The first symptoms in the field are a bluish-green discoloration of the leaves and a red discoloration of the petioles. The youngest leaves start to wither. Intensive browning and eventual disintegration of the vascular tissue of the crowns is characteristic of the disease. Symptoms often appear first in the upper part of the crown and then spread basipetally.

P. cactorum apparently infects strawberry plants by means of zoospores. Symptoms become visible 1-4 weeks after planting. Warm, wet weather favours infection. Specialized strains of *P. cactorum* occur in the crown-rot disease, but no specialized strains have been found in the naturally occurring populations that cause fruit rot.

Basic strategy

The main strategy to avoid problems with crown rot is to use healthy plant material. Planting of resistant cultivars, adequate soil drainage, avoiding damage, and avoiding planting in low, wet sites are other important control measures. Mulching helps to keep fruit off the ground and minimizes rainsplash of soil with zoospores onto the fruits. The recommended fungicide treatments against crown rot are the same as for red stele (see *Phytophthora fragariae* var. *fragariae*). Spraying during flowering is effective against leather rot.

Main fungicides

Against crown rot: fosetyl-aluminium, metalaxyl, propamocarb hydrochloride. Against leather rot: chlorothalonil, dichlofluanid, thiram.

Botrytis cinerea (grey mould)

General

Grey mould, caused by *Botryotinia fuckeliana* (anamorph *Botrytis cinerea*), is an important fruit rot wherever strawberries are grown. The disease is common on green fruits as well as on ripening and harvested fruits. *B. cinerea* may also attack leaves and petioles, and flower buds, petals, and stems. The fungus occurs on numerous plants as a parasite and saprophyte. Races or pathotypes of *B. cinerea* specifically affecting strawberry have not been detected, so inoculum may come from many sources.

The fungus overwinters in the form of sclerotia and dormant mycelium in plant debris. Under favourable conditions *B. cinerea* produces one or more large crops of conidia, which serve as primary inoculum. When the plants flower, conidia infect the epidermis of petals, sepals, stamens or receptacles, remaining dormant or progressing only slowly through the flowering period. The fungus will then invade the developing fruits under moist conditions. Within a few days the fungus can begin secondary spore production, resulting in continuous inoculum production throughout the fruiting season. Humidity is the most important factor regulating grey mould development.

Basic strategy

It is GPP to grow strawberry cultivars that show a high degree of resistance to grey mould. Mulching and removal of debris may help control the disease. Limited use of nitrogen may cause a drier microclimate, which may help to restrict the disease development. Plants should not be planted too deep in the soil, to prevent stem infection.

The chemical strategy is to apply fungicides from the beginning of flowering and maintain protection during the entire flowering period. In practice, the number of applications will depend on local conditions. It is particularly important to respect pre-harvest intervals. There are reports on the development of resistance both to systemic and non-systemic fungicides. In particular, the possibilities for using the benzimidazole group of fungicides are now very limited. Alternation of fungicides is essential to prevent resistance problems.

Main fungicides

Captan, chlorothalonil, dichlofluanid, folpet, iprodione, procymidone, thiram, tolylfluanid, vinclozolin.

Verticillium spp. (verticillium wilt)

General

Both *Verticillium albo-atrum* and *V. dahliae* are pathogenic to strawberry. Verticillium wilt is important throughout the temperate zones. The pathogens have a wide host range and are capable of long persistence in the soil. Strawberry is affected mostly in the first year of growth. Outer leaves show browning symptoms, but inner leaves often tend to remain green until the plants die. Initial symptoms appear rapidly in late spring, especially if periods of environmental stress have occurred. In general, lush plant growth with high nitrogen is affected more severely than plants grown with moderate amounts of nitrogen.

Basic strategy

It is GPP to use healthy planting material and cultivars resistant to verticillium wilt. Crop rotation with non-susceptible crops is important. Fungicides may be applied if problems with verticillium wilt are expected. It is GPP to soak the transplants or to use a soil drench after transplanting.

Main fungicides

Benomyl, carbendazim, thiabendazole, thiophanate-methyl.

Sphaerotheca alchemillae (powdery mildew)

General

Powdery mildew caused by *Sphaerotheca alchemillae* attacks strawberry leaves, reducing photosynthesis. The mycelium may cover the entire lower leaf surface. The leaf edges roll upwards. In addition to the white fungal growth, purple to reddish blotches may also occur on upper and lower leaf surface. Other parts of the plant including the fruits may also be affected. Both yield and quality may be reduced by the pathogen. *S. alchemillae* mainly overwinters as mycelium on living infected leaves. Powdery mildew prefers dry and warm conditions.

Basic strategy

It is GPP to grow cultivars with a high degree of resistance to powdery mildew. Irrigation may reduce attacks in crops grown in dry, warm soil. Fungicide sprays may be necessary to control the disease. It is GPP to combine 2-3 treatments during flowering with grey mould control (see *Botrytis cinerea*). If heavy attack is expected, one fungicide spray before bloom and two sprays after harvest are recommended.

Main fungicides

Before harvest: benomyl, bupirimate, carbendazim, chinomethionat, dinocap, fenarimol, hexaconazole, imazalil, myclobutanil, nitrothal-isopropyl, penconazole, pyrazophos, sulphur, thiophanate-methyl, triadimefon, triforine. After harvest: pyrazophos, sulphur.

Leaf spots

General

Several fungi cause leaf spots in strawberry. The economic damage caused by the individual pathogens is difficult to assess because the diseases usually occur together.

Mycosphaerella fragariae (anamorph *Ramularia tulasnei*) is one of the most important species that causes leaf spots. The conidial stage is more common than the sexual stage. The lesions are small and circular with light centres and purplish margins. Conidia are produced in early summer on both upper and lower surfaces of leaves. They are disseminated primarily by splashing water.

Diplocarpon earliana (anamorph *Marssonina fragariae*) causes leaf scorch or red spot, the symptoms being irregular, purplish leaf spots with dark centres. Conidia may be produced year-round from acervuli on living leaves or on dead leaves in the spring, and they are dispersed by rainsplash. *D. earliana* is favoured by warm weather. In addition to the leaves, also petioles, fruit peduncles, pedicels, calyces, flowers and fruits can be attacked. At least two races of the fungus are known.

Two relatively minor leaf-spotting fungi may also be mentioned: *Gnomonia comari* (anamorph *Zythia fragariae*) causes leaf blotch and *Phomopsis obscurans* (syn. *Dendrophoma obscurans*) causes leaf blight. *Alternaria alternata* (widespread on many hosts) can also cause leaf spotting on strawberry.

Basic strategy

Use of disease-free planting material and resistant cultivars are essential elements in GPP against leaf-spotting pathogens. Fungicide applications may be necessary. Sprays against *Botrytis cinerea* normally have some action against the leaf-spotting pathogens. If additional treatments are needed, one spray before flowering and 1-2 sprays after harvest are recommended.

Main fungicides

Metiram, mancozeb, propineb, pyrazophos, tolylfluanid.

Colletotrichum acutatum (strawberry anthracnose and black spot)

General

Colletotrichum acutatum causes several types of infection on strawberry: spotting and girdling of stolons and petioles, black leaf spot and fruit rot. Attacks on ripening and ripe fruit and stolons are most common. The first symptoms on ripening fruits are small, round, firm and slightly sunken spots. The spots turn dark and enlarge rapidly until they cover the whole fruit. Finally the fruit dries and mummifies. On stolons and petioles, oblong, sunken and dark lesions are produced during summer. The lesions can girdle stolons and petioles, resulting in wilting and dying of daughter plants and leaves. The pathogen is mainly introduced into new areas in infected planting material. In the field, *C. acutatum* is dispersed by water-splashed conidia. It can overwinter in infected plants and rotted fruit. The disease is most serious in warm humid climates. Other *Colletotrichum* spp. are recorded to cause anthracnose in strawberry, particularly on the fruits (e.g. *C. fragariae* and *C. gloeosporioides*, the anamorph of *Glomerella cingulata).*

Basic strategy

The main strategy for controlling strawberry anthracnose is to use disease-free planting material. Test methods have been developed to screen for infected plants. Cultural methods, such as mulches or low nitrogen, that promote a drier microclimate are to be preferred. In areas where there is a need for irrigation, trickle irrigation should be preferred to sprinkling irrigation, in order to minimize watersplash dispersal of conidia. Fungicide treatments can be applied, if necessary, before flowering.

Main fungicides

Chlorothalonil, mancozeb, maneb, tolylfluanid.

Soil fungi

General

Various soil fungi can infect the roots and collar of strawberry plants, causing necrosis and rotting: *Thanatephorus cucumeris* (anamorph *Rhizoctonia solani*), *Rhizoctonia fragariae*, *Coniothyrium fuckelii*, *Cylindrocarpon radicicola*, *Fusarium* spp., *Pythium* spp. They are favoured by wet soil conditions, freezing and thawing, nematode damage. The *Rhizoctonia* spp. can also cause a rotting of the base of the petioles, which may show a red discoloration, and infect young stolons, which become deformed and develop slowly or not at all. Problems with *Rhizoctonia* spp. arise particularly in southern Europe.

Basic strategy

Control is mainly by avoidance of the conditions which favour rotting, and of preceding crops susceptible to *Rhizoctonia* spp. Some of the soil fungi concerned (especially *R. fragariae*) can be introduced on planting material, so healthy planting material should be used. Plants should not be planted too deeply. It is not considered GPP to use soil fumigation systematically to eliminate soil fungi in strawberry fields. Such treatments should be limited to what is strictly necessary. Nor is it generally advised to apply fungicides other than sprays against *Rhizoctonia*

infection of the petioles and stolons, in the case of serious attack.

Main fungicides

Against *Rhizoctonia* spp.: iprodione, pencycuron, tolclofos-methyl.

Xanthomonas fragariae **(angular leaf spot)**

General

Angular leaf spot caused by the bacterium *Xanthomonas fragariae* may cause heavy attack on the leaves and the whole plant may wilt. The pathogen is spread by infected planting material. The disease causes problems in only a few countries. No chemicals are recommended.

Basic strategy

The main strategy is to use healthy planting material derived from a certification scheme (*Bulletin OEPP/EPPO Bulletin* **24**, 875-890, 1994).

Viruses

General

The virus and virus-like diseases of strawberry can be grouped according to their manner of transmission. *Strawberry crinkle rhabdovirus*, *Strawberry mild yellow edge luteovirus* (and its associated potexvirus) and *Strawberry mottle 'virus'* are aphid-transmitted. Strawberry green-petal phytoplasma is transmitted by leafhoppers like *Macrosteles fascifrons*. *Arabis mosaic nepovirus* and *Strawberry latent ringspot nepovirus* are transmitted by the soil nematode *Xiphinema diversicaudatum*, while *Raspberry ringspot nepovirus* and *Tomato black ring nepovirus* are transmitted by *Longidorus elongatus.*

Basic strategy

The GPP to prevent spread of viruses in strawberry is to use healthy planting material derived from a certification scheme (*Bulletin OEPP/EPPO Bulletin* **24**, 875-890, 1994). Plants should preferably be planted into soil that is as far as possible free from virus-transmitting root nematodes. Under certain circumstances, it may be appropriate to treat against nematode vectors (see Root nematodes). Adequate control of aphids is important (see Aphids).

Aphids

General

Aphids may cause damage to the crop both directly and indirectly by transmission of viruses (see Viruses). The most important species are *Chaetosiphon fragaefolii* and *Myzus ascalonicus*. Wingless aphids breed on strawberry throughout the year, except during extremely cold winter weather. Aphids are normally of minor importance on strawberry.

Basic strategy

Damaging attacks occur only sporadically. Therefore it is GPP to treat only when the aphid population exceeds a threshold. Fruiting plants should be treated shortly before flowering.

Main insecticides

Acephate, azinphos-methyl, bromophos, chlorpyrifos, deltamethrin, demeton-S-methyl, diazinon, dimethoate, disulfoton, heptenophos, mevinphos, phosphamidon, pirimicarb, propoxur, pyrethrin, rotenone.

Anthonomus rubi **(strawberry blossom weevil)**

General

The egg-laying females cause destruction of the strawberry flower bud. Injured buds cease to develop and either fall to the ground or remain dangling from the partially severed stalks. Adults make characteristic small holes in the leaves and petals, but such damage is unimportant. The weevil is important in most strawberry-growing regions. *Anthonomus rubi* is also an important pest of raspberry.

Basic strategy

A. rubi is controlled by insecticide sprays, before flowering, when adults are first seen or when the first damaged flowering shoots are detected. One treatment is normally sufficient. It is important not to spray too early, to ensure that most of the beetles have left their overwintering place. Routine treatments are not justified. Strawberry crops may be infested from adjacent raspberry crops, on which the pest should also be controlled.

Main insecticides

Azinphos-methyl, cypermethrin, deltamethrin, fenvalerate, lambda-cyhalothrin.

Otiorrhynchus sulcatus **(European strawberry weevil, black vine weevil)**

General

Otiorrhynchus sulcatus and several other *Otiorrhynchus* spp. may damage strawberry roots. The eggs are laid on the soil surface and the larvae move down in the soil to find the roots on which they feed. The adults may also feed on strawberry leaves, but such damage is not serious. The weevil causes most

damage on sandy soils and on strawberry planted on black plastic mulch. Attacked plants grow poorly, wilt and often die. *Phyllobius pomaceus* is another weevil whose larvae and adults feed on strawberry plants like those of *O. sulcatus*, and can be treated similarly.

Basic strategy

Avoid establishing a new strawberry crop after or near (50-100 m) a previously infested field. Plastic mulching favours attacks by the larvae, and should be avoided if there is a risk of attack. *O. sulcatus* is favoured by sandy soils, and may build up under intensive strawberry cropping. Insecticide sprays reduce the population of the weevil and treatments are most effective before the weevils are fertile. One spray before flowering or just after harvest may be appropriate depending on the species involved. Treating only the rows adjacent to older fields can be sufficient. To optimize timing of insecticide applications, it is essential to monitor visually for the first signs of adult feeding. Crops should be treated when the majority of the adult weevils have emerged but before they have started to lay eggs. However, the emergence of adults can last over several weeks, which will make the suppression of egg-laying difficult. A drench treatment with entomopathogenic nematodes (especially *Heterorhabditis* spp.) is possible in regions where root weevils are a permanent problem, and if the life cycle of the beetle in this region is known. In cases where root weevil control is known to be necessary, soils can be treated before planting with granules or a drench (with incorporation). A drench to kill young larvae may be carried out after harvest. This type of treatment is only appropriate for heavy infestations.

Main insecticides

For soil treatment: carbofuran. For sprays: azinphos-methyl, chlorpyrifos, deltamethrin, endosulfan, fenvalerate, lambda-cyhalothrin, parathion.

Thrips

General

Thrips (*Frankliniella occidentalis, Thrips fuscipennis, T. tabaci*) cause damage on strawberry leaves, flowers and fruits. This is a serious problem, especially in southern Europe, where there may be 5-6 generations per year. Adults and nymphs cause discoloration of petals and silvering of young leaves or other tissue. Leaf feeding diminishes the vigour of the plants and fruit yield. Fruit quality is affected by direct feeding on the fruit (brown spotting). The introduction and spread of *F. occidentalis* in Europe in the last decade, and its spread on outdoor crops in southern Europe, has led to entirely new problems of thrips control.

Basic strategy

Treatments should be applied as soon as thrips (especially *F. occidentalis*) are seen in the crop (by visual observation or use of yellow or blue traps). Because thrips are difficult to control and because many active substances have only moderate efficacy against these pests, one may choose between two strategies (depending on the registered products which are available): either an effective product which may have negative aspects (such as high acute toxicity) can be applied only once at a suitable time, or 2-3 treatments of a less effective product may be applied at a fairly close interval (7 days) to ensure complete control of the infestation. Regular monitoring should then be maintained to check for reinfestation. It is not advisable to spray regularly at longer intervals.

Problems with resistance

Resistance to most insecticides has been encountered in thrips. In principle, insecticides should be alternated to avoid this. However, this may be a problem if the number of registered insecticides which have a sufficient efficacy on thrips is limited.

Main insecticides

Abamectin (in southern countries, where its high photolability leads to rapid degradation), acrinathrin, cypermethrin, deltamethrin, dichlorvos, endosulfan, fenitrothion, mercaptodimethur (effective but not widely registered for this use because of its high acute toxicity), phosalone.

Philaenus spumarius **(common froghopper)**

General

P. spumarius nymphs feed on the sap of strawberry and at the same time inject a secretion that reduces the growth of the berries and causes wrinkled, puckered dark green leaves. The presence of masses of spittle may be a nuisance during picking.

Basic strategy

Inspection of the crop before flowering is necessary. If the action threshold is reached, a treatment with insecticides is recommended.

Main insecticides

Azinphos-methyl, fenpropathrin, lambda-cyhalothrin.

Aleurodes lonicerae **(honeysuckle whitefly)**

General

Aleurodes lonicerae (syn. *A. fragariae*) normally causes no leaf damage, but after heavy attack and humid weather a layer of sooty mould may develop on

the leaves. Damage by this insect is most important in regions with a warm climate.

Basic strategy

In case of heavy attack, it is recommended to apply 1-2 insecticide sprays before flowering.

Main insecticides

Azinphos-methyl, cypermethrin, deltamethrin, demeton-S-methyl, fenpropathrin, oxydemeton-methyl, pirimiphos-methyl.

Capsid bugs

General

Plagiognathus arbustorum, *Lygus rugulipennis* and *L. pabulinus* are polyphagous plant bugs that attack and feed on flowers and young berries. They are an important cause of irregularly shaped or "cat-faced" strawberries, also called "button berries" or "apical seediness". They damage the fruit by puncturing the individual seeds, so that the berry stops developing in the immediate area of the destroyed seeds. Absence from plant injury is correlated with early maturing; later cultivars may suffer heavy damage.

Basic strategy

Good weed control in and near the crop reduces the number of bugs. Inspection of the crop before flowering is necessary to decide the need for insecticide treatments. Apply an insecticide before flowering, as soon as feeding punctures are seen.

Main insecticides

Bifenthrin, cyfluthrin, dimethoate, fenitrothion, mevinphos, propoxur.

Harpalus rufipes (strawberry seed beetle)

General

Adults of *Harpalus rufipes* (syn. *Ophonus pubescens*) live in the soil and emerge at night to feed on strawberry seeds. Fruits are deformed and may rot.

Basic strategy

Baits can be placed on the soil, before mulching.

Main insecticides

Mercaptodimethur.

Caterpillars

General

At least six species of leaf-feeding tortricids are common in strawberries: *Acleris comariana*, *Olethreutes lacunana*, *Cnephasia interjectana*, *Lozataenia fosterana*, *Pandemis dumetana* and *Sparganothis pilleriana*. Normally they cause insignificant damage and are kept in check by parasites. The larva may damage the flower buds and leaves in spring, from budbreak to flowering. The hymenopteran *Allantus cinctus* (rose sawfly) has larvae (pseudocaterpillars) which feed on strawberry leaves in a similar way.

Other lepidopteran larvae also attack strawberry. The larvae of *Hydroecia micacea* may tunnel into the crowns below soil level. Infested plants, or parts of plants, may wilt and die, especially under dry conditions. Early instar larvae of *Noctua pronuba* and *Agrotis* spp. (cutworms) feed on leaves and flowers, while older larvae feed on the outside of crowns and roots (see Soil insects). Other species (*Mamestra oleracea*, *Naenia typica* and *Orthosia* spp.) mainly feed on leaves, but also on flowerbuds and on flowers.

Basic strategy

Control is not usually necessary. The crop should be inspected at budbreak and just before flowering, and sprayed before flowering only in the case of a serious attack.

Main insecticides

Azinphos-methyl, bifenthrin, cypermethrin, deltamethrin, fenvalerate, lambda-cyhalothrin.

Soil insects

General

Various soil insects feed on the roots of strawberry and may cause wilting and drying up of the plants. These include: wireworms (*Agriotes* spp.), larvae of *Tipula* spp. (leatherjackets), white grubs (larvae of *Melolonthidae*), millipedes (e.g. *Scutigerella* spp.), cutworms (larvae of noctuids such as *Agrotis* spp. and *Noctua pronuba*).

Basic strategy

Knowledge of the level of the populations of leatherjackets, wireworms and white grubs in the soil is a basic need to make a decision on the treatment. If strawberry is planted in a soil with previous records of the occurrence of the pests causing damage, it may be advisable to treat the soil just before planting. Pyrethroids are widely used. It is important to treat when larvae are at early stages to achieve the necessary efficacy and appropriate warning systems can provide

guidance on the timing of such treatments. The application should be made using a high volume of water and the spray should be directed towards the plants near the soil. If cutworms damage the young plants, a single foliar spray, giving good coverage, may be recommended.

Main insecticides

Insecticides can be used as granules, sprays and sometimes as baits: carbofuran (soil treatment at limited frequency), chlorpyrifos (soil treatment or foliar spray), cyfluthrin (soil treatment), ethoprophos (soil treatment), gamma-HCH, lambda-cyhalothrin, parathion, phorate (soil treatment), temephos (soil treatment or bait).

***Tetranychus urticae* (two-spotted spider mite)**

General

Tetranychus urticae lives and feeds mainly on the underside of strawberry leaves. This causes pale spots also visible from the upper side of the leaves. The leaves may wither after heavy attack. The population is higher during warm dry weather. Severe attacks before harvest will reduce fruit size and quality.

Basic strategy

Plants should be checked for mite infestation between budbreak and flowering, or at the end of the harvesting period. Predatory mites are available on the market for control of *T. urticae*. If the action threshold is reached, treatment with an acaricide is recommended. Several treatments may be needed.

Main acaricides

Amitraz, abamectin, bromopropylate, chinomethionat, chlorpyrifos, clofentezine, cyhexatin, demeton-S-methyl, dicofol, dimethoate, fenbutatin oxide, fenpropathrin, hexythiazox, propargite, rotenone, tetradifon, triazophos.

***Phytonemus pallidus* (strawberry mite)**

General

Phytonemus pallidus mainly lives on young furled and unfurling leaves. The mites inject toxic saliva into the plant cells causing leaves to become roughened, wrinkled, discoloured and brittle. Severely infested plants become stunted and may even die. The mite causes leaf curl on some cultivars. Plant symptoms are most visible at the end of the harvesting period. The attack reduces both the size and number of fruits.

Basic strategy

The main control strategy is to use healthy plant material, and not to replant strawberry after strawberry. The pest is more serious in an intensive rotation. Strict cultural hygiene is needed to avoid infestation of newly planted fields. The plants should be examined for mite infestation at the end of the harvesting period, and in spring if infestation was noticed in the previous year. Sprays with plant protection products are recommended if any attack is observed. Two sprays, 10-14 days apart, are necessary. These treatments may be carried out after harvest or between budbreak and flowering.

Main acaricides

Amitraz, chinomethionat, dicofol, endosulfan, triazophos.

Leaf nematodes (mainly *Aphelenchoides fragariae*, *A. blasthophthorus* and *A. ritzemabosi*)

General

Aphelenchoides spp. live in the plant mainly within the crowns, the growing points and the runner buds. They often congregate in the fold and along the mid-vein of developing leaves. Leaves of infested plants are considerably puckered and distorted, the leaf-edge serration being malformed, reduced in number and sometimes absent. The petioles may be exceptionally long, thin and virtually hairless. Yield may be greatly reduced if the number of attacked plants is high.

Basic strategy

The main strategy is to use healthy plant material and remove infested plants. No treatment with nematicides in the field is recommended.

Root nematodes (mainly *Longidorus elongatus*, *Xiphinema diversicaudatum* and *Pratylenchus penetrans*)

General

Root nematodes may damage strawberry directly by feeding on the roots but also indirectly by transmitting viruses (see Viruses). Attacked root tips may swell into galls. The damage occurs in patches in the field. Root nematodes are free-living nematodes in soil, and there is a good correlation between the density of nematodes in the soil and strawberry yield.

Basic strategy

Crop rotation is GPP for root-nematode control. Soil fumigation may be carried out before transplanting, if there is a known risk. It is not GPP to treat soil systematically with nematicides. Such treatments should be limited to what is strictly necessary.

Main nematicides

1,3-dichloropropene, dazomet, metam-sodium.

Weeds

General

As in other row crops, strawberry normally has a limited ability to cover the ground to suppress weeds. This is most evident in the year of transplanting when annual weeds may be problematic. In established strawberry fields, the cover of strawberry plants is normally good enough to suppress the annual weeds to some extent in the row. Perennial weeds may be problematic even in the rows. Between the rows both annual and perennial weeds have no competitors.

Basic strategy

Herbicide treatments are normal practice in strawberry, but there are possibilities for mechanical weed control and mulches between and within rows. Use of mulches prevents the germination of weeds. The mulching material can be organic, for example wood chips or straw, or inorganic like polythene film. If polythene film is used, chemical control is normally needed in the plant holes in the first year only. If black polythene film is used in the late-summer cultivation of strawberries, weed control is not necessary. Mechanical weed control between the rows can be used especially in autumn after planting, but also subsequently in spring and in autumn.

Pre-planting treatments

It is GPP to use pre-planting treatments against perennial weeds. This may include herbicide treatments in the previous crop. Traditional fallow based on cultivation can be effective against shallow-rooted perennial weeds, such as *Elymus repens* (common couch), but to a lesser extent against deep-rooted broadleaved weeds such as *Cirsium arvense* (creeping thistle) and *Convolvulus arvensis* (field bindweed). These species are better controlled by translocated herbicides.

Treatments after planting

It is GPP to use residual pre-emergence herbicides, such as lenacil, simazine or metamitron as an overall application early in the spring on moist soil before the weeds have emerged. The latter herbicide may also be applied at the cotyledon stage of the weeds. Simazine is not recommended during the establishment of the plants. Another strategy is to use split application of residual herbicides in spring and late autumn.

Phenmedipham may be used as a post-planting treatment during the growing season before flowering. Non-selective contact herbicides (non-translocated) may be used between the rows by the directed application technique. It is important to apply these herbicides on young weeds. If needed, anti-monocot herbicides can be applied once or twice before flowering.

Control of unwanted strawberry runners

It is GPP to control runners with non-translocated herbicides by the directed application technique in autumn.

Main herbicides

Pre-emergence residual herbicides: acetochlor, benfluralin, chlorpropham, EPTC, fenuron, isoxaben, lenacil, metamitron, napropamide, pendimethalin, simazine, trifluralin.

Post-emergence selective herbicides: chlorthal-dimethyl, chloroxuron, clopyralid, metamitron, napropamide, phenmedipham, propachlor, propyzamide.

Post-emergence non-selective herbicides: diquat, glufosinate-ammonium, glyphosate, paraquat.

Selective anti-monocot herbicides: alloxydim-sodium, cycloxydim, fluazifop-P-butyl, quizalofop-ethyl, sethoxydim.

Plant growth regulators

General

Various substances are used to a limited extent to regulate the growth of strawberry crops. The aim may be a general stimulation of growth, with consequent increase in yield, or a more specific effect on development: advancing flowering, improving fruit set, stimulating fruit development. Products may also be used to reduce runner formation.

Main plant growth regulators

N-acetylthiazolidin-4-carboxylic acid + folic acid (general stimulation of growth), gibberellic acid (advancing flowering), (2-naphthyloxy), acetic acid (improving fruit set), chlormequat chloride (reducing runner formation).