◆ EPPO Standards ◆

GUIDELINES ON GOOD PLANT PROTECTION PRACTICE

HOP

PP 2/6(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 2/6(1) English

Guidelines on good plant protection practice

HOP

Specific scope

This standard describes good plant protection practice for hop.

Specific approval and amendment

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

This guideline on GPP for hop 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). The guideline covers methods for controlling pests (including pathogens and weeds) of production crops of *Humulus lupulus* (hop).

GPP in the control of hop pests is composed of several elements whose use makes it possible to achieve effective pest control and at the same time to optimize the use of plant protection products.

(1) Choose planting material which is disease-free on planting (if possible derived from a certification scheme). Use a cultivar which is suitable for the soil type and climatic conditions and is, if available, resistant to the main pests of hop.

(2) Use cultivation methods to reduce pest incidence, for example: careful use of fertilizers to limit bushy growth suitable for fungal multiplication, removal of weeds which can act as reservoirs of infection, defoliation of the basal part of the plant reducing risk of infection by mildews or spider mites, cleaning of tools to avoid spread of viruses and *Verticillium*, etc.

(3) Use threshold values, based on pest incidence or climatic conditions, to decide whether it is necessary to employ control measures and, if so, to select the most appropriate timing for application of plant protection products.

(4) Use careful application technology, involving correct adjustment of the equipment, and adjust dose rates and volumes to the state of the crop and the pest levels.

(5) Choose the plant protection product so that it is the most suitable for the pest to be controlled, at the particular time of application. It should, as far as possible, be specific to the pest and it should not be of a type likely to lead to the development of resistance in the pest.

The principal hop pests considered are the following:

- *Pseudoperonospora humuli* (downy mildew);
- *Sphaerotheca humuli* (powdery mildew);
- *Botrytis cinerea* (grey mould);
- *Verticillium albo-atrum* and *V. dahliae* (verticillium wilt);
- *Fusarium sambucinum*;
- *Arabis mosaic nepovirus* and its vector *Xiphinema diversicaudatum*;
- *Prunus necrotic ringspot ilarvirus*;
- *Phorodon humuli* (damson-hop aphid);
- *Otiorrhynchus ligustici* (lucerne weevil);
- *Tetranychus urticae* (two-spotted spider mite);
- weeds.

Treatments against unwanted hop shoots and 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.

Pseudoperonospora humuli (downy mildew)

General

There are two forms of infection by *Pseudoperonospora humuli*. *Primary infection* develops in the hop shoots already infected in the previous year. The fungus overwinters as mycelium in the rootstock and accompanies the growing shoots in the spring. Less frequently, primary infection can result from oospores in pieces of bine or leaves in the soil

germinating and releasing zoospores; these latter infect the young shoots developing from the rootstock. The young plants thus infected are stunted and yellow, and the leaves show sporulation of the fungus along the veins. Sporangia produced on infected leaves are carried by the wind to healthy plants, on which they release zoospores which can infect when water is present (as rain or dew) at lenticels or stomatal openings. This is the *secondary infection* which affects the bines, leaves, flowers and cones. The bines usually show damage only at the upper end where the internodes are reduced and the leaves become discoloured, turning brown. Flowers and cones also become dry and brown, and may fall from the plant, and severe infections can lead to complete loss of yield.

Basic strategy

Although some hop cultivars (e.g. Halltertauer Mittelfrüh, Brewers Gold, Atlas, Blisk, Savinjski Gold) are particularly susceptible to downy mildew, others (including Hüller Bitterer, Halltertauer Gold, Wye Challenger, Aurora, Bobak, Buket, Cekin, Cicero, Celeia) are tolerant to the fungus. This should be taken into account in GPP.

The general aim is firstly to reduce as much as possible the level of primary infection in order to limit the inoculum for secondary infection, and thereafter to prevent secondary infection by preventive treatments. If infection has been heavy the previous year, it is GPP to treat the emerging shoots with a fungicide. Where the local practice is to cut the young shoots below ground level in early spring (March-April), it helps to reduce infection to make a deeper cut, removing the major source of inoculum at the base of the shoots. When the previous year's infection was not high, it is sufficient to examine the emerging shoots and apply a fungicide spray only if the percentage of occurrence of the characteristic symptoms exceeds a threshold level (for example 3%). It is also advisable to remove, as far as possible, any shoots showing symptoms.

Secondary infection is best prevented by applying preventive spray treatments, with contact or systemic fungicides, at the time when sporangia are being carried in the air. Plant protection services provide warnings of periods of high infection risk, when the number of sporangia in the air passes a threshold value and the weather conditions are suitable for infection. In the case of tolerant cultivars, usually only two or three applications are necessary, provided they are determined by a warning system. Without a warning system, preventive treatments must be applied at regular intervals (e.g. 10-14 days) throughout the growing season, or at shorter intervals (e.g. 4-7 days) if infection is high in the area and the weather conditions are moist with frequent rain and with temperatures between 15 and 20°C.

Main fungicides

Benalaxyl, Bordeaux mixture, chlorothalonil, copper hydroxide, copper oxychloride, cymoxanil, dichlofluanid, dithianon, fentin acetate, fosetyl-aluminium, mancozeb, metalaxyl, metiram, propineb, zineb.

***Sphaerotheca humuli* (powdery mildew)**

General

Sphaerotheca humuli overwinters as cleistothecia in infected plant tissue in the soil. In the spring the cleistothecia release ascospores which are carried by the wind to the leaves of young hop plants where they develop into superficial white mycelium (powdery mildew). In mild winters, mycelium may also survive in buds, and give rise to primary conidial inoculum. Further infection is performed by conidia developed on the mycelium and again carried in the air to other plants. Warm dry conditions favour spread and development of the fungus. All parts of the hop plant can be infected by powdery mildew. A white powdery covering is the typical symptom and this may turn red-brown later in the year. Flowers are particularly susceptible and can be completely destroyed, becoming small, hard, white bodies from which cones cannot develop. Cones can be infected and become red-brown at harvest time.

Basic strategy

Although certain cultivars (Brewers Gold, Northern Brewer, Hersbrucker Spät) are recognized to be particularly susceptible, others (Wye Target) show tolerance. This should be taken into account in GPP. Inoculum can be reduced by pruning away young shoots showing infection in the spring.

The aim is to eliminate the disease before flowering, after which the damage can be severe and control becomes difficult. Fungicides are applied when the first white spots are found on the plants. It is important to examine the whole plant for symptoms. Further applications may be necessary after 10-14 days, if symptoms are again found. It is recommended to use high-volume sprays. Products containing sulphur are normally used against low infections and with frequent applications; they can, however, be phytotoxic and should not be used after flowering.

Main fungicides

Bupirimate, dinocap, penconazole, pyrazophos, sulphur, triadimefon, triforine.

Botrytis cinerea (grey mould)

General

Botryotinia fuckeliana (anamorph *Botrytis cinerea*), which causes grey mould on many different hosts, can cause serious damage on hop in favourable conditions. Grey mould develops particularly well in sheltered and damp places. Some factors may favour development of the fungus, e.g. excess nitrogen fertilization. The plants are infected by air-borne conidia. The infection spreads downwards from the tip of the cones. The whole cone can rot and fall. The fungus is visible as grey conidiophores on the cones.

Basic strategy

Fungicide sprays may be applied as soon as infection is seen.

Main fungicides

Dichlofluanid, vinclozolin.

Verticillium albo-atrum and *V. dahliae* (verticillium wilt)

General

Verticillium albo-atrum and *V. dahliae* survive as a resting mycelium or microsclerotia, respectively, in the soil and on diseased plant remnants, on the soil surface or incorporated into it. Mycelium or conidia are able to infect plants through healthy or wounded roots. Following root invasion, the mycelium passes into the vascular tracts throughout the plant and subsequently induces a wilting condition. Latent infection of dicotyledonous weeds can occur, making detection and eradication of the disease extremely difficult. Saprophytic survival of the fungus in the soil is a declining phase, especially in the absence of dicotyledonous plants; the fungus may disappear under grass sward after 3-5 years. *V. dahliae* is favoured by higher temperatures than *V. albo-atrum*.

The first symptoms on leaves usually appear in late July or early August as a yellowing of the lower leaves, which gradually spreads to other leaves higher up the bine; only occasionally is the whole plant affected. The lower leaves dry out, wither and may fall, while wedge-shaped necrotic areas may develop on the upper leaves. Bines often become swollen ("fat bine") and externally may appear brown and corky. Notching or cutting the bine about 0.3-1 m from the base will reveal a characteristic light-brown discoloration of the internal woody tissues. Aggressive strains can give much more severe disease on susceptible cultivars ("progressive wilt"). Leaf symptoms appear earlier (end of May onwards), yellowing progresses more rapidly, and the whole plant is affected and may die before the end of the season.

Basic strategy

Healthy planting material should be used, and good crop sanitation applied if any verticillium wilt is seen. Many resistant cultivars are available. There is no chemical control.

Fusarium sambucinum

General

Gibberella pulicaris (anamorph *Fusarium sambucinum*) and other *Fusarium* spp. may be locally important under favourable conditions, mainly soil compaction and waterlogging, causing a basal canker of hops. The lesions develop just below the soil surface, near the point where the shoots emerge from the perennial rootstock. Infected hop shoots may wither and die if the cankers girdle the shoots. The disease is sporadic in occurrence.

Basic strategy

Avoid conditions suitable for development of the fungus. Fungicide drenches may be applied in spring.

Main fungicides

Benomyl, fentin acetate, maneb.

Arabis mosaic nepovirus and its vector nematode *Xiphinema diversicaudatum*

General

The nematodes feeding on the roots of infected plants store particles of the virus (ArMV) in their oesophagus and can then transmit the particles to healthy plants. The plants thus infected begin to show disease symptoms in the growing season after transmission. The symptoms produced vary depending on the cultivar of hop and the strain of the virus. In general, plants grow slowly or not at all and fall from the supporting wire-work. "Nettlehead" disease is the most dramatic symptom: the plants are small and yellowish, with a nettle-like appearance. Even in the absence of such obvious symptoms, yield can be reduced by as much as 25%.

The hop strain of ArMV originally enters a hop garden with the planting material. In some areas, ArMV has never been introduced, so the problem of controlling the disease does not arise, irrespective of the presence of the nematode vector. Where ArMV is present, its importance is mainly determined by the abundance of the vector, which is influenced by cultural practices. Symptoms caused by ArMV are thus local in occurrence, and more frequent in some countries than in others. In gardens where they do occur, they are very damaging, since affected areas have to be rooted out and replanted.

Basic strategy

Once plants have become virus-infected, they cannot be cured and should be removed from the hop garden. Viruliferous nematodes will remain in the soil. If the garden is to be replanted, the only control strategy is to use virus-free planting material (preferably from a certification scheme) and prevent its re-infection, by directing a control programme against the nematodes. If the soil can be kept free from hop (and preferably also dicotyledonous weeds) for two growing seasons, the nematodes lose the ability to transmit ArMV. It is thus GPP to plant grass for 2 years before replanting. If this is not possible, another approach is to treat the soil with nematicides which, if properly applied to soil with 40-60% of field moisture capacity, can reduce nematode numbers by more than 95%. This treatment will reduce the risk of re-infection and can be used to limit the period of absence of hop to one growing season. Such treatments are GPP only if limited in extent to what is strictly necessary on economic grounds.

The nematicide should be applied as a directed treatment, specifically to the area concerned. This may be the site of a removed hop plant, in which case a spot treatment using a hand-held soil injector is recommended. It may also be a row or area within a hop garden, in which case a strip or area treatment using a tractor-drawn soil fumigation machine is recommended. After treatment, the soil should be covered with a polythene sheet.

Main nematicides

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

Prunus necrotic ringspot ilarvirus

General

Strains of *Prunus necrotic ringspot ilarvirus* (PNRSV), including *Apple mosaic ilarvirus*, infect most of the hop-growing areas of the EPPO region to a greater or lesser extent. Some traditionally grown cultivars are 100% infected. There are no known vectors and it is thought that transmission may occur by contact between adjacent plants or as a result of cultural operations, such as cutting, thinning, training, etc., since infection most often occurs in plants beside already infected ones. The most common means of re-infection of newly planted gardens is by means of infected planting material or by the regeneration of infected plants from the previous crop.

Infected plants are normally without obvious symptoms although mosaic or ring and line pattern symptoms have occasionally been observed, especially at high temperatures. However, the yield from infected plants is reduced both in weight of cones and in alpha-acid content; the latter can be reduced by 14-33%.

Basic strategy

It is not possible to disinfect PNRSV-infected plants in the field. However, virus-free plants can be obtained by heat therapy or by meristem tip culture, and these can be used to establish nuclear stock for certification schemes. Although healthy plants may, in time, become re-infected, the rate of re-infection is slow, especially if the crop is distant from PRNSV-infected plants.

The basic strategy is, therefore, to use only virus-free sets from certification schemes as planting material, and to take care to ensure that there are no remains of the previous crop of infected material in the hop garden; preferably, re-planting should not be performed until 2 years after the previous hop crop. The equipment used for cultural operations should, as far as possible, be cleaned between use on different plants.

***Phorodon humuli* (damson-hop aphid)**

General

Winged adults of *Phorodon humuli* migrate from species of *Prunus*, which are their winter hosts, to hop from May to August, with the peak of migration in mid-June. On hop, the aphids colonize, in preference, the young growth of leaves, shoots, flowers and cones and multiply rapidly, each female giving birth to up to five nymphs per day for a period of 3-4 weeks. Multiplication rate depends on climate and is highest in warm moist conditions. Up to nine generations can occur on hop before the aphids return to their winter host in August-November. Aphid feeding causes leaf and shoot distortion and can lead to leaf drop. In addition to direct physical damage, the contamination of leaves and cones by honeydew from the aphids, and consequent development of sooty-mould fungi, results in further reduction in plant vigour and yield. Yield of cones can be reduced by as much as 25%. The quality of the cones is also adversely affected by sooty mould and by the presence of aphids within. They are often unmarketable as a result.

Basic strategy

All hop cultivars are infested by *P. humuli* to some extent, but some react less severely than others. Control on some cultivars can be more difficult, especially early maturing cultivars and those with open cone structure.

The intention of control is to reduce infestation as much as possible before flowering, when even a small amount of feeding damage can lead to yield reduction, and ideally to produce plants free from aphids during cone formation and maturation. This strategy is pursued by assessing the number of aphids present on the hop plants after the migration from *Prunus* begins and then spraying when the numbers reach a threshold level. For example, each week after the beginning of migration, 50 leaves are collected (mainly from the upper leaves of the plants in the hop garden and when

more than 300-400 aphids are found on any one leaf, or an average infestation level of 50-100 aphids per leaf, the first spray is applied. In other parts of the region, the first spray is applied when a threshold value of 20 aphids on average per leaf is reached or when more than 100 aphids are found on a single leaf. Subsequent sprays may be necessary if these threshold values are reached again. After flowering begins, much reduced threshold values will lead to a spray application. In general, if the first and second sprays are carefully performed, there is no need for further sprays.

Problems with resistance

Resistance to most insecticides has been encountered in *P. humuli.* In principle, insecticides should be alternated to avoid this. However, this may be a problem if the number of registered insecticides is limited.

Main insecticides

Carbosulfan, cyfluthrin, cypermethrin, deltamethrin, demeton-S-methyl, dimethoate, endosulfan, fenpropathrin, heptenophos, imidacloprid, lambda-cyhalothrin, mephosfolan, methomyl, omethoate, triazamate.

***Otiorrhynchus ligustici* (lucerne weevil)**

General

The life cycle of *Otiorrhynchus ligustici* lasts for 2 years, or sometimes 3 years if the climate is unfavourable. After a maturation feeding in spring, female beetles lay 100-800 eggs just beneath the surface of the soil. The resulting larvae live at a depth of 20-30 cm on the hop root system. They overwinter once or twice. The larvae pupate during the summer and by August the adult beetles have developed, but pass the winter underground within the pupal skin. In the following spring, as the soil warms (threshold of 5°C at 10 cm depth), the adults come out onto the soil surface and feed on the young shoots of the hop plant. Feeding takes place mostly at night. The tips of the shoots are the preferred feeding sites and damage can sometimes occur up to 2 m on the hop plant. Under cooler conditions the beetles feed below ground on the shoots developing from the rootstock. *O. ligustici* is more commonly found in hop gardens on light sandy soil.

Damage results from: (1) adult feeding on the shoots which, under heavy infestations, can lead to general delay of shoot growth and resulting lack of suitable bines for training; (2) larval feeding on the root system resulting in general weakening of the plant or even to death of the root system.

Basic strategy

The only practical method of control is to apply insecticide sprays against the adults in spring (March/April) when they are feeding above ground. The selection of the most appropriate time is crucial: the beetles are only susceptible to control when the temperature is above 15°C and they are active. The threshold for attempting control is when 20% of fresh shoots show feeding damage. When infestation is low, sprays are applied by band application.

Main insecticide

Methamidophos, methidathion.

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

General

Spider mites cause most damage on hops planted on light soils and when the weather is dry and warm. Infestation usually begins in the middle of May when the overwintering female mites emerge from diapause and start feeding on the lower leaves of the hop plants. The female lays about 25 eggs, from which the juveniles hatch within 6-10 days and thus begins a population development which can have 5-9 generations during the growing season. The mites form a web on the leaf under which they are protected from wind and predators. They are 0.5 mm in length and are greenish-yellow in colour with two darker spots on the back. Later in the season the colour changes to green-brown and finally to red which is the colour of the overwintering female. The feeding of the mites initially causes characteristic light speckling followed by extensive leaf drop. Infestation of the cones causes them to turn copper-red and fail to close successfully; yield quality and quantity are thus considerably reduced.

Basic strategy

The control strategy against spider mites is to apply acaricide sprays when mite populations reach a certain threshold. Treatment with acaricides will only begin after all mites have emerged from diapause in late May or early June. A suitable threshold is when the number of mites reaches 5 per leaf on 20% of the leaves examined or if any webs are seen. Further applications will be necessary if 10% of the leaves carry living mites. It is recommended to apply high-volume sprays, in order to reach all parts of the hop plants, especially the undersides of leaves and the lower parts of the plant.

Problems with resistance

T. urticae attacks many other crops on which frequent applications of acaricides are made. This has contributed to a high level of resistance to several groups of acaricides available for use in hop. Most populations are resistant to all organophosphorus compounds and, increasingly, to organochlorines. It may be advisable to use different active substances, if several applications are needed in one growing season.

Main acaricides

Amitraz, dicofol, fenpropathrin, omethoate, propargite, tetradifon.

Weeds

General

Grasses and dicotyledonous weeds growing in hop gardens compete with the crop for moisture and nutrients. In addition, it is considered that they improve conditions for certain diseases. For example, by increasing humidity near ground level, they favour the spread of downy mildew, or they maintain infection of the soil by *Verticillium albo-atrum*. However, the presence of weeds can sometimes be considered an advantage in preventing soil erosion and binding surplus soil nitrates.

Basic strategy

In different parts of the EPPO region, weeds are controlled in hop either by several herbicide treatments throughout the growing season or by mechanical cultivation. Herbicide treatment presents few problems in hop gardens, where, because of the nature of the crop, there is little danger of phytotoxicity and, therefore, chemicals can be used that attack all the weeds present. Pre-emergence residual treatments are applied to established crops in late winter or early spring. Contact herbicides can be used later in the season when the hop plants have grown sufficiently so that contact with the leaves can easily be avoided.

In areas where soil cultivation is used, the spring weeds are generally eliminated by the early-season soil-cultivation operations necessary for controlling hop growth (see below). Weeds germinating during the summer months should be killed at the seedling stage. If left to develop deep root systems (because of soil being too wet, for example), it is then impossible to kill them by cultivation without disturbing the root systems of the hops. In this case, treatment either by hand or with herbicides must be used.

Main herbicides

A very wide range of herbicides can safely be used in hop. A few examples are given, including some which may be suitable for specific difficult weeds.

Pre- or early post-emergence treatments: asulam (especially *Rumex* spp.), fluazifop-P-butyl (grass weeds especially *Elymus repens*), isoxaben, lenacil, metobromuron, oxadiazon (especially *Convolvulus arvensis*), pendimethalin, prometryn, propyzamide (mainly grass weeds), simazine.

Contact treatments: paraquat dichloride.

Treatment against unwanted hop shoots and leaves

General

Only a limited number of the shoots growing from the rootstock are allowed to grow up the supporting strings for hop production. The remainder must be removed during the course of the growing season in order to direct more vigour towards the selected shoots. In addition, the lower leaves of the selected shoots are removed, for several reasons: the more open base of the crop allows more air movement and, therefore, reduces risk of fungal diseases; treatment with soil-applied plant protection products is made easier; harvesting with mechanical pullers is also improved.

Basic strategy

Removal of unwanted hop shoots and of the lower leaves was traditionally performed by hand, mainly during the training operation. It is now most commonly done by directed spray treatment with herbicides.

Main herbicides

Cyanamide, diquat dibromide, sodium monochloroacetate, tar oils.

Plant growth regulators

General

Increased yield (cone set) and a reduction in leaves and seeds in hop cones may be achieved by the application of plant growth regulators.

Basic strategy

Treatment is generally applied before the beginning of flowering in order to improve fruit set. Depending on the product, this may be a single spray application in April/May or two applications, the first 2 weeks before, the second immediately before, beginning of flowering. A treatment later in August may increase alpha-acid content, cone size and weight.

Main plant growth regulators

Gibberellic acid.