◆ EPPO Standards ◆

GUIDELINES ON GOOD PLANT PROTECTION PRACTICE

BARLEY

PP 2/11(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 2/11(1) English

Guidelines on good plant protection practice

BARLEY

Specific scope

This standard describes good plant protection practice for barley.

Specific approval and amendment

First approved in September 1997.

This guideline on GPP for barley 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(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 barley (*Hordeum vulgare)*.

Barley is grown in the more temperate parts of the EPPO region. The grain is mainly used for animal consumption, but in some countries a substantial part is used for human consumption (malt, beer, various processed products). Barley straw can be used for animal consumption and barley may also be used green as forage (silage for example).

Barley crops are sown in spring or in autumn. Spring crops are exposed to pests for a shorter period. Seeds may be bought, certified or not, or may be produced directly by the farmer. Crop rotation with other cereals or field crops reduces the build-up of pest populations in the soil or in crop debris. In general, careful soil cultivation is recommended as an effective cultural control method. Minimal cultural practices such as direct drilling, though they may reduce labour costs, also favour the survival and build-up of pest populations in the soil. As barley is mainly grown for grain, the aim of protection against pests is to ensure a good quantity and quality of grain yield. The physical and chemical characteristics of grain are particularly important when processing is involved.

Use of resistant cultivars, optimum time of sowing, good crop rotation, use of healthy seeds, well prepared seedbed and cultural operations (destroying or burying stubble) are important elements in GPP on barley. Treatments with plant protection products may be necessary at any stage of development of the crop. The use of seed treatment is GPP when it is used against pests that cannot be controlled by foliar fungicides. It may also be GPP to use seed treatment against other pests, if the seed treatment results in fewer sprays and thus in a reduced amount of plant protection product early in the season. Barley is more tolerant of attack by soil pests than, for example, maize or sugarbeet, because seedling losses can be compensated by growth of adjoining plants. The products used for seed treatment should as far as possible cover the full range of fungal or insect pests concerned. It is important that seeds should be uniformly treated with product.

Simultaneous application of two or more active substances as sprays or seed treatments is GPP if the pests to be controlled are indeed present or to be expected. The farmer or adviser has to be familiar with the main pests, monitor fields regularly and make full use of existing early warning systems and economic thresholds. As soon as practical thresholds for weed infestation become available, these should be used. Dosages should relate to the pest spectrum observed, taking account of the individual effects and possible interactions. For fungal diseases in particular, it is GPP to select products and to time applications in an optimal way.

Except for spot application of perennial weeds and ULV-insecticide applications early in the season, boom sprayers, mounted on or towed by tractors, are the only equipment advised for sprays. It is GPP to reduce drift and unwanted dispersal of plant protection products as much as possible by using drift-preventing covers on the nozzles or equipment that produces a good and uniform droplet spectrum across all nozzles on the spray boom.

The risk of developing resistance to fungicides, insecticides and herbicides is a real threat. It is GPP to avoid spraying a fungicide or insecticide later in the season if an active substance with the same mode of action has already been applied as a seed treatment. An active substance with a different mode of action should preferably be used. The same holds for the control of the important powdery mildew and rust diseases: active substances should be alternated or coformulations containing products with different modes of action should be used as much as practicable.

The principal barley problems considered are the following:

- *Puccinia hordei* (brown rust), *P. striiformis* (yellow rust), *P. graminis* (black rust);

- *Erysiphe graminis* (powdery mildew);
- *Ustilago hordei, U. nuda* (smuts);
- *Pseudocercosporella herpotrichoides* (eyespot);
- *Gaeumannomyces graminis* (take-all);
- *Fusarium culmorum, Monographella nivalis* (foot rot, snow mould);
- *Typhula incarnata* (snow mould);
- *Pyrenophora teres* (net blotch);
- *Pyrenophora graminea* (leaf stripe);
- *Rhynchosporium secalis* (scald);
- aphids;
- thrips;
- *Tipula* spp. (leatherjackets);
- wireworms and white grubs;
- *Delia coarctata* (wheat bulb fly);
- *Agromyza* spp. (leaf miners);
- *Oscinella frit* (frit fly);
- *Zabrus tenebrioides* (corn ground beetle);
- *Haplodiplosis marginata* (saddle gall midge);
- *Oulema melanopus, O. gallaeciana* (cereal leaf beetles);
- nematodes;
- slugs;
- weeds;
- lodging.

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.

Puccinia hordei (brown rust), *P. striiformis* (yellow rust), *P. graminis* (black rust)

General

Rust fungi are highly specialized to their hosts, and barley is attacked by the formae speciales *hordei* of *P. hordei* and *P. striiformis*, and f.sp. *secalis* of *P. graminis*. In addition, pathotypes specialized to host resistance genotypes are common. Some of the cereal rusts have alternate hosts (*Ornithogalum* spp. for *P. hordei*; *Berberis vulgaris* for *P. graminis*), but *P. striiformis* is a short-cycle autoecious rust. Cereals are infected in the spring by air-borne aecidiospores coming from the alternate host or by air-borne urediniospores coming from other areas. Infections with *P. hordei* and *P. striiformis* can also occur in the autumn. This initial air-borne inoculum is practically ubiquitous and uncontrollable. Rust epidemics on cereals develop by repeated secondary urediniospore infection, and this is the stage which is subject to control. At the end of the season, teliospores are formed which give rise to the infection of the alternate host. The different rusts of barley differ in the pattern and colour of the uredosori formed on barley leaves. These are orange-brown for *P. hordei* and irregularly spread over the entire leaf surface. The uredosori of *P. striiformis* are yellow to orange, characteristically in rows on older leaves (in very susceptible barley cultivars the leaves turn yellow and die). Those of *P. graminis* form dark brown stripes on leaves and leaf sheaths. In general, brown rust is the disease of practical importance in Europe, but yellow rust is occasionally important enough to require treatment . The importance of black rust was much reduced by a campaign to eradicate its alternate host (*B. vulgaris*) early in the 20th century, and black rust is rarely found on barley.

Basic strategy

There is a range of cultural practices that may reduce rust infection of barley. First, resistant cultivars should be grown or, at least, very susceptible cultivars should be avoided. Volunteer barley should be destroyed and winter barley should not be sown too early. Excessive nitrogen application should be avoided, to prevent too heavy and too dense a stand. It may still be useful in some areas to destroy alternate hosts such as *Berberis vulgaris*. If the risk of infection by rusts becomes serious, application of a fungicide spray may be necessary. Normally, one or two applications are sufficient. In practice, thresholds may be used (e.g. for *P. hordei*, 25% of plants attacked after growth stage 31; first appearance of *P. striiformis*). Alternatively, the advice of warning services (based on various forecasting models) should be followed.

Main fungicides

Sprays: azoxystrobin, cyproconazole, epoxiconazole, fenbuconazole, fenpropidin, fenpropimorph, fluquinconazole, flusilazole, flutriafol, propiconazole, tebuconazole, triadimefon, triadimenol.

Erysiphe graminis (powdery mildew)

General

Erysiphe graminis forms patches of superficial white, then greyish mycelium (powdery mildew) on leaves, leaf sheaths and ears of barley. Leaves remain green and active for some time after infection, then the infected areas gradually die. The conidia, formed in great quantities as a white powder on the mycelium,

are wind-dispersed over considerable distances to infect healthy leaves. This air-borne inoculum is practically ubiquitous and uncontrollable. Infection by conidia requires high humidity (but not free water on the leaf surface), while sporulation and spore dispersal are favoured by rather dry conditions. Powdery mildew is thus favoured by an alternation of wet and dry conditions, as often occurs in north-west Europe. Infected areas on leaves become chlorotic and cease to photosynthesize. Early mildew attack reduces tillering and later infection reduces "green leaf area", and thus grain yield. Powdery mildew affects barley more seriously than the other major cereals. Cleistothecia may appear on old colonies (as black points) at growth stage 39-65, but these contribute relatively little to inoculum in the spring, which mainly comes from lesions on winter cereal crops.

Basic strategy

Barley is infected only by forma specialis *hordei* of *E. graminis*, so powdery mildew from wheat or rye cannot infect barley and vice versa. Winter barley should, however, not be grown next to spring barley. In general, barley is more heavily affected than wheat, and losses can be very severe if the disease is not controlled. A range of cultural practices exists that may somewhat reduce the infection by *E. graminis*. The growing of resistant cultivars is recommended, particularly with the durable Mlo resistance gene. The use of mixtures of resistant cultivars considerably reduces the risk of powdery mildew. If possible, winter barley should be sown late in regions favourable to powdery mildew. An open stand of barley reduces the incidence of powdery mildew as compared with a dense stand, heavily fertilized with nitrogen. If powdery mildew infection becomes serious, one or more fungicide sprays may be necessary; these should not be applied after growth stage 55. In most cases, it is not useful to treat winter barley in the autumn. However, occasionally, a treatment in autumn may be recommended especially on light soils, where mildew infection may exacerbate winter crop losses. Treatment in spring barley may commence as soon as mildew is seen, and in any case if the third-youngest leaf, after elongation has begun, is affected. In areas where powdery mildew infection can regularly be expected, fungicides may be applied as a seed treatment, but this may lead to problems of resistance.

Problems with resistance

E. graminis has been reported to show reduced sensitivity to fungicides of the sterol-biosynthesis inhibitor group, but this has not led to loss of control.

Main fungicides

Sprays: bromuconazole, cyproconazole, cyprodinil, epoxiconazole, fenpropidin, fenpropimorph, flusilazole, flutriafol, kresoxim-methyl, prochloraz, propiconazole, tebuconazole, triadimefon, triadimenol, tridemorph, triforine. Seed treatments: flutriafol, triadimenol.

***Ustilago hordei*, *U. nuda* (smuts)**

General

Ustilago hordei causes covered smut of barley. Seedlings are systemically infected by spores carried on the outside of the seeds or persisting in the soil. Shortly after flowering, infected tillers give rise to smutted ears. The diseased plants are stunted, and the grains are filled with a mass of black spores, enveloped by a transparent membrane until harvest.

Ustilago nuda causes loose smut of barley. Infection is seed-borne within the seed, the fungus penetrating the endosperm while the grain is being formed. Infected seeds give rise to systemically infected plants. Diseased ears are visible directly after heading. The black spores are released between glumes and broken-down grains, giving a loose black powder (loose smut). They are wind-borne to healthy ears, which they infect.

In both cases, losses arise from direct loss of infected ears. In *U. nuda*, ears may also be secondarily infected after harvest.

Basic strategy

Seeds of barley are externally contaminated by *U. hordei* during harvesting, when smutted grains are broken open and release their content of spores. Infection by these or soil-borne spores then occurs at the time of seed germination and can be prevented by a contact fungicide. In the case of *U. nuda*, the seeds are already internally infected at the time of harvest. Use of a systemic fungicide is needed to prevent further development of the fungus in the plant after seed germination. In any case, it is important to use disease-free certified seed, which is also fungicide-treated. Seed certification and seed treatment are very effective in controlling these diseases, which are now practically unknown in intensive cereal cultivation in Europe. If untreated farmer-saved seed is sown, however, these diseases reappear; this practice is therefore not GPP. It is also possible to have seed lots tested to decide whether they require treatment.

Main fungicides

Seed treatments: carboxin, fenpiclonil, tebuconazole, triadimenol, triticonazole.

***Pseudocercosporella herpotrichoides* (eyespot)**

General

Tapesia yallundae (anamorph *Pseudocercosporella herpotrichoides*) overwinters on stubble residues. Conidia formed in the spring (and, as recently discovered, also ascospores) constitute the primary inoculum. Plant are infected through the leaf sheath,

and the lesion gradually penetrates through to the stem, forming a lens-shaped spot with a darker border. If eyespot lesions reach the stem before growth stage 31/32, there is a risk of later foot rot and crop lodging. Secondary infection of other plants does not normally occur, so the aim of control is to prevent primary infection. In general, barley is much less affected by eyespot than wheat.

Basic strategy

Eyespot rarely requires treatment in barley. Barley is however a significant host for the survival of the pathogen. If treatment is required, it may be possible to combine it with treatment against other fungi.

Main fungicides

Sprays: cyprodinil, prochloraz.

***Gaeumannomyces graminis* (take-all)**

General

Gaeumannomyces graminis is a soil fungus which infects the roots of barley, on which it forms a characteristic black superficial mycelium. The infection may spread to the collar and lower leaf sheaths. The root system is partly or entirely destroyed, and infected plants produce bleached inflorescence (whiteheads) with no grain (take-all), especially under hot dry conditions. The fungus persists as saprophytic mycelium in crop debris, which infects new roots directly. There is no air-borne phase (see eyespot). Infection tends to occur as patches in the crop. Take-all is one of the most serious causes of yield loss in intensive wheat crops, but is less important on barley.

Basic strategy

As a root-infecting soil fungus, *G. graminis* is practically inaccessible to treatment with fungicides. Because the fungus does not persist very long in debris, control is achieved by crop rotation.

***Fusarium culmorum, Monographella nivalis* (foot rot, snow mould)**

General

Fusarium culmorum and *Monographella nivalis* are soil fungi which infect the foot of barley plants. Both can infect seedlings, and *M. nivalis*, in particular, can cause serious seedling losses. Both may also be seed-borne but the two fungi can also infect the roots of young plants directly from the soil. Under suitable conditions, root infection can spread to the stem base, which can be seriously damaged. In the case of *F. culmorum*, this spread is favoured by rather dry warm weather and the disease is mostly known from central and southern Europe. The base of the tillers turns brown or develops large brown spots; the tillers bend, and the crop lodges. In the case of *M. nivalis*, this spread occurs at low temperatures, characteristically under melting snow cover during the winter. The spots are lighter in colour. *F. culmorum* is an unspecialized parasite, able to infect the roots of many plants and to persist saprophytically. *M. nivalis* similarly attacks many other *Gramineae* and persists in the soil. Seedlings and young plants can be protected from primary root infection by treating the seeds with fungicide. Another member of the foot-rot complex, *Ceratobasidium cereale* (anamorph *Rhizoctonia cerealis*), has symptoms resembling eyespot but is less important. Other fungi with *Fusarium* anamorphs (e.g. *Gibberella avenacea*) also belong to this complex.

Basic strategy

Because of the build-up of inoculum on a preceding cereal crop, rotation will reduce foot-rot incidence to a certain extent. However, both pathogens remain as part of the natural soil microflora, and rotation is not as effective as against *Gaeumannomyces graminis.* Soil conditions should be optimal, and the seeds used should be certified and disease-free. Use of a fungicidal seed treatment against these fungi is effective routine GPP for barley. Seed treatment with contact fungicides can be used for low levels of infection (<10%) but systemic fungicides are recommended for higher levels.

Main fungicides

Seed treatments: benomyl, bitertanol, carbendazim, fludioxonil, fuberidazole, guazatine, prochloraz.

***Typhula incarnata* (snow mould)**

General

Barley is fairly commonly attacked by *Typhula incarnata* in areas prone to prolonged snow cover. Soon after snow cover has cleared, areas of dead plants with leaves joined together by a greyish mycelium begin to develop. The resting bodies of the fungus, sclerotia, develop within the fungal growth, and particularly on the stems. Sclerotia are about the size of clover seed, and develop from pale pink to dark reddish-brown.

Basic strategy

Differences in susceptibility between cultivars are known. If continuous cropping of barley is avoided, the risk of occurrence of the disease can be reduced. It is also reduced by providing sufficient manganese inputs. The risk is increased by dense crop stands. Sprays may be applied late in the autumn before snowfall when the risk is high, e.g. early snow in autumn or prolonged deep snow cover on unfrozen ground.

Main fungicides

Sprays: azoxystrobin, bitertanol, triadimenol.

Pyrenophora teres **(net blotch)**

General

Pyrenophora teres (anamorph *Drechslera teres*) is seed-borne or persists in crop residues (from which ascospores are released). Conidia formed on leaf lesions are air-borne and cause secondary infections. The leaf lesions appear as minute brown spots, that eventually become yellowish, with a net-like structure in younger plants. Mature plants develop stripe-shaped spots. The disease is particularly serious on winter barley.

Basic strategy

Disease-free seed of less susceptible cultivars should be used. Dense cropping favours the development of the disease, so the use of fertilizers should be optimized. Volunteer barley plants, grass weeds and remnants of nearby barley crops should be destroyed. Seed treatment with a fungicide is commonly used. If the disease nevertheless becomes serious, one or two fungicide sprays may be applied. The advice of warning services should be followed, if available.

Main fungicides

Sprays: azoxystrobin, bromuconazole, cyproconazole, epoxiconazole, fenpropimorph, fluquinconazole, flusilazole, prochloraz, propiconazole, tebuconazole. Seed treatment: fuberidazole, imazalil.

Pyrenophora graminea **(leaf stripe)**

General

Pyrenophora graminea (anamorph *Drechslera graminea*) is seed-borne. Infected plants develop yellow, later brown-coloured, longitudinal stripes on the leaves. Heading is poor, and the grain is poorly filled. This is the most important seed-borne disease of barley, affecting both winter and spring crops.

Basic strategy

Differences in susceptibility between cultivars are known. Fungicide seed treatment, such as used against other fungi, is the main method of control; it is important to use disease-free and fungicide-treated seed. In fact, seed treatment is very effective in controlling *P. graminea* (and *P. teres*), which is now uncommon in intensive cereal cultivation in Europe. If untreated farmer-saved seed is sown, however, these diseases reappear; this practice is therefore not GPP. It is also possible to have seed lots tested to decide whether they require treatment.

Main fungicides

Seed treatments: fenpiclonil, fludioxonil, imazalil, oxine-copper, triazoxide.

Rhynchosporium secalis **(scald)**

General

Rhynchosporium secalis is a common leaf pathogen which persists in crop debris. The leaf lesions appear as blue-green spots which turn grey with a clear dark-brown edge. The disease develops already in autumn and spreads by splashing during elongation. Lesions often occur at the base of the leaf sheath which stops further activity in the leaf.

Basic strategy

Differences in susceptibility between cultivars are well known. Volunteer barley plants, grass weeds and remnants of nearby barley crops should be destroyed. Late sowing reduces the incidence of the disease. The level of disease should be assessed in early spring and 1-2 treatments, as spray applications, may be needed in particular if the crop is grown under wet conditions. A warning system based on precipitation can be used to decide when to spray.

Main fungicides

Sprays: azoxystrobin, bromuconazole, cyproconazole, epoxiconazole, fluquinconazole, flusilazole, propiconazole, prochloraz, tebuconazole.

Aphids

General

Aphids, especially *Sitobion avenae*, *Metopolophium dirhodum* and *Rhopalosiphum padi* may become numerous on leaves of barley, and may inflict direct feeding damage or indirect damage because of the formation of sooty moulds or transmission of virus diseases, especially *Barley yellow dwarf luteovirus* (BYDV). Quality of grain is also affected by aphid infestation, but aphids rarely infest the ears of barley in northern Europe.

Basic strategy

BYDV is a frequent problem on early sown winter crops in some areas and occasionally infects spring barley crops after a mild winter. Damage can be prevented by late sowing (winter barley) or early sowing (spring barley). If a risk of aphid infestation exists in the autumn, winter barley crops should be sprayed with an insecticide. Thresholds may be used (e.g. 10% of seedlings with 1 or more aphids). The advice of warning services should be followed, if available. Seed treatment is also possible.

For the control of direct aphid damage on winter and spring barley, the barley crop should be regularly inspected in spring, and an insecticide spray application should be made if numbers reach a certain level. Various threshold levels are recommended, for example: 20-30% of tillers carry aphids before growth stage 37; 40% of tillers are infested after growth stage 37. A single spray is usually sufficient. Use of selective insecticides (e.g. pirimicarb) will favour natural enemies.

Main insecticides

Seed treatments: imidacloprid. Sprays: alpha-cypermethrin, beta-cyfluthrin, bifenthrin, chlorpyrifos, cyfluthrin, cypermethrin, deltamethrin, demeton-S-methyl, esfenvalerate, fenvalerate, heptenophos, lambda-cyhalothrin, pirimicarb, thiometon.

Thrips

General

Many species of thrips (*Limothrips cerealium*, *L. denticornis*, *Stenothrips graminum*, *Haplothrips aculeatus*, *Thrips angusticeps*, *Haplothrips tritici*, *Aptinothrips elegans*, *Anaphothrips obscurus*) feed on barley leaves, causing silvery spots; infested leaves may turn brown. Feeding on the ear during emergence causes whitish, empty grains. Thrips are only a problem in the northern part of the EPPO region.

Basic strategy

Thrips can be controlled by spray application of insecticides, but this is normally not necessary. A single treatment may be applied after emergence of the ears (growth stage 50), if numbers exceed two larvae per ear. Thorough inspection is necessary, for the insects are minute and difficult to see. Sprays should not be applied after the milky-ripe stage. Certain treatments applied against aphids will give incidental control of thrips.

Main insecticides

Sprays: alpha-cypermethrin, deltamethrin, esfenvalerate, fenvalerate, lambda-cyhalothrin.

Tipula spp. (leatherjackets)

General

Leatherjackets are the larvae of craneflies (*Tipula* spp.). They live in the soil and largest populations occur in grassland.

Basic strategy

Barley crops may be damaged when following grassland or uncultivated land. In general, this rotation should be avoided if possible. The presence of larvae can be checked before ploughing the grassland by either taking soil cores and extracting larvae in the laboratory or by pouring a salt solution onto the ground, which forces the larvae to the surface. Spring barley is likely to be at risk when 50 larvae per m^2 or more are present in early spring. Winter barley is less at risk from leatherjackets because the crop usually establishes before the main feeding period of the larvae. No specific threshold has been expressed. Attacks may be prevented by ploughing out grassland before mid-August. It is GPP to apply a soil insecticide treatment, by overall spray at high water volume, soon after ploughing grassland or uncultivated land if leatherjackets are known to be present or exceed the threshold. An overall spray at high water volume can also be applied to a growing crop if damage is seen.

Main insecticides

Overall sprays: *Bacillus thuringiensis* var. *israelensis*, chlorpyrifos, dimethoate, etrimfos, fenitrothion, lindane, triazophos.

Wireworms and white grubs

General

The larvae of certain *Elateridae* (*Agriotes* spp., wireworms) and *Melolonthidae* (*Melolontha* spp., white grubs) damage the stem bases and the roots of barley plants. These become yellow and the main shoot turns brown. Development of wireworms takes years, and adults and larvae of different ages coexist each year. Development of white grubs takes 3-4 years and is generally synchronized. Damage normally only occurs from the 3rd larval stage onwards, starting in the year after adult flight.

Basic strategy

Grassland or uncultivated land as a preceding crop should be avoided. However, if a barley crop is grown in such a high-risk rotation, an overall soil spray treatment as well as the seed treatment may be justified. The level of population of wireworms and white grubs in the soil is needed to make an informed decision on treatment and should be determined by soil sampling.

Main insecticides

Overall sprays: chlorpyrifos, diazinon, fonofos, lindane, tefluthrin, terbufos. Seed treatment: carbofuran, carbosulfan, fonofos, lindane.

Delia coarctata (wheat bulb fly)

General

Eggs of *Delia coarctata* are laid during the summer months in bare soil or in soil under a root crop. The eggs hatch in the following spring and the larvae bore into the barley plant. Both winter and early sown spring barley may be damaged. The central shoot of the attacked plant dies, turning yellow although the outer leaves remain green. The larvae move from tiller to tiller on the same plant and sometimes through the soil to another plant. Damage is common and often serious. This pest is less important on barley than on wheat, and the crop is less susceptible to damage. *Opomyza florum* is another cereal fly, which mines barley stems like *D. coarctata.*

Basic strategy

Damage can be reduced effectively by cultural methods. The crop rotation can be chosen so that barley does not follow a fallow or crop which provides suitable egg-laying conditions (bare soil during July and August). If the crop follows grass, ploughing out can be delayed to reduce egg-laying. Land lying bare after harvest should not be tilled in early August as this will encourage egg-laying. In high risk situations, early drilling with an increase in seed rate is recommended.

Control with insecticides is normal GPP against *D. coarctata* in areas where the pest is known to attack barley. The type of treatment is decided on the basis of crop-sowing date and the perceived level of risk based on sampling for eggs and previous cropping. Insecticides are preferably applied as seed treatments, but may also be applied as seedbed sprays at or soon after drilling, as sprays at the start of egg hatch or at peak egg hatch, and as sprays at the onset of plant damage. If a soil or seed treatment has been applied against wireworms, this may also have action against *D. coarctata*, according to the insecticide used.

Main insecticides

Seed treatments: chlorfenvinphos, fonofos. Sprays: chlorfenvinphos, chlorpyrifos, dimethoate, fonofos, omethoate, pirimiphos-methyl.

Agromyza spp. (leaf miners)

General

Agromyza spp. are small flies (3-5 mm long) which emerge in spring. The females feed by puncturing leaves along the veins. The eggs are deposited between the two epidermes of the leaves, and the larvae mine the mesophyll. The mines often become confluent, giving a typical appearance (mesophyll tissues in the upper third of leaf are completely destroyed). *Agromyza* spp. are locally important in northern Europe.

Basic strategy

Moderate levels of attack do not cause losses. Insecticide sprays may be applied from growth stage 31 in the case of heavy attacks, or if a threshold of more than 20% mining on lower leaves accompanied with puncturing of upper leaves is reached at growth stage 55. Aphid control has an incidental effect on *Agromyza* spp.

Main insecticides

Sprays: alpha-cypermethrin, bifenthrin, cypermethrin, deltamethrin, dimethoate, esfenvalerate, lambda-cyhalothrin, permethrin, tau-fluvalinate.

Oscinella frit (frit fly)

General

The larvae of *Oscinella frit* are 3-4 mm long, white, legless and lack a distinct head (though having black mouthparts). There are normally three generations a year, but only the autumn generation attacks barley when it is sown after infested grass. The larvae migrate from the ploughed-in grass to invade the barley plant, the centre leaf of which turns yellow and dies.

Basic strategy

If winter barley is sown after grass, the land should be ploughed early and at least 4 weeks before sowing. Similarly, grass-infested stubble should be ploughed soon after harvest. The risk of damage to barley is only slight in most years and does not justify routine insecticide spray treatments unless regular damage has occurred previously. Crops at risk should be examined from emergence and sprayed if a threshold of damaged shoots, e.g. 10%, is exceeded. Seed treatments are also effective.

Main insecticides

Seed treatments: chlorfenvinphos, fonofos. Sprays: alpha-cypermethrin, chlorpyrifos, cypermethrin, deltamethrin, esfenvalerate, lambda-cyhalothrin, pirimiphos-methyl, triazophos.

Zabrus tenebrioides (corn ground beetle)

General

The larvae of *Zabrus tenebrioides* live in the soil in a self-made tube. Leaves of young barley plants are pulled down into the tube. The larvae eat only the leaf blade. Damage can be detected from the remains of the leaves in the tubes. The pest tends to occur, and damage plants, in patches. The larvae are active in spring, and on mild winter days, and their development ends at the beginning of heading. *Z. tenebrioides* is mainly important in central and eastern Europe. It has

one generation every 2 years in the northern part of its range and one generation per year in the southern part. It can survive on volunteer cereals.

Basic strategy

Cultural control can be used to reduce the risk of attack: early harvesting of straw and destruction of volunteer cereals. In areas of heavy infestation, an overall insecticide treatment of soil is recommended before sowing. Seed treatments may be used but are less effective. If infestations are nevertheless observed, a corrective spray treatment may be applied. It is advisable to treat in the morning or in the evening, as the larvae do not feed during daytime. *Z. tenebrioides* can also occur sporadically in other areas of Europe. In this case, a spray treatment when damage is seen is sufficient.

Main insecticides

Overall pre-planting treatments: chlorpyrifos, diazinon, fonofos, lindane, tefluthrin, terbufos. Seed treatments: endosulfan, lindane. Sprays: chlorpyrifos, deltamethrin, parathion-methyl.

***Haplodiplosis marginata* (saddle gall midge)**

General

In May and June, female midges deposit their eggs on the surface of barley leaves. The whitish, later orange-red larvae attack the stems under the leaf sheaths. Larval feeding results in the formation of saddle-shaped galls. Spring-sown crops are more susceptible to damage than those sown in the autumn. Infestations are common but at low levels.

Basic strategy

The pest is associated with frequent cereal growing on heavy land. It can be avoided by practising a wide crop rotation and controlling grassy weeds wherever possible. In high-risk areas, insecticide sprays are necessary and should be directed against newly hatched larvae. If 10% or more of tillers have eggs present, an insecticide should be applied at egg hatch. Only one application is necessary.

Main insecticides

Sprays: beta-cyfluthrin, cypermethrin, deltamethrin, esfenvalerate, fenitrothion, lambda-cyhalothrin.

***Oulema melanopus*, *O. gallaeciana* (cereal leaf beetles)**

General

Oulema melanopus and *O. gallaeciana* (syn. *O. lichenis*) are shiny-blue beetles which feed on barley leaves, causing elongated holes. The yellow larvae are covered by a blackish, sticky substance and may be mistaken for small slugs. The larvae skeletonize the leaves, causing long white stripes.

Basic strategy

Damage is commonly seen, especially on spring-sown crops, but is often not very important. Chemical treatment is justified after reaching a threshold such as 15 adults per m^2 just before oviposition, or 0.5-1 larvae per stem. Treatments may be combined with those against aphids, in which case suitable active ingredients should be used.

Main insecticides

Sprays: alpha-cypermethrin, beta-cyfluthrin, cypermethrin, deltamethrin, dimethoate, esfenvalerate, lambda-cyhalothrin.

Nematodes

General

Two nematodes feed on the roots of barley: *Heterodera avenae* (cereal cyst nematode) which causes strong root branching and deformation, with cysts visible later in the season and *Meloidogyne naasi* (cereal root-knot nematode) which induces the formation of many extra roots and elongated root knots. Attacks are visible in the field as spots where crop growth is retarded. Spring-sown barley is especially susceptible to *M. naasi*.

Basic strategy

Commercial cultivars with resistance to *H. avenae* are available. Crop rotation is also useful, reducing the proportion of cereals and grass seed crops. Maize is not a host plant and can safely be grown. No treatment is recommended specifically against these nematodes. Soil disinfection in other crops such as potatoes has a good effect against these nematodes, but is not necessarily GPP (see EPPO Standard PP 2/2(1) Guideline on GPP for potato).

Slugs

General

Slugs (e.g. *Agriolimax arvensis*, *Deroceras reticulatum*) damage barley seedlings and hollow out barley seeds and the problem is increasing with direct drilling and when land is left uncultivated. Early slug damage can be very important. Later leaf feeding is not important. Slugs are largely a problem on medium to heavy textured soils in wet seasons.

Basic strategy

A firmly consolidated seedbed will restrict slug movement and encourage rapid seedling growth. The surface should be clod-free. To assess the risk of slug damage and the need for and time of molluscicide treatments, test baiting when the soil surface is moist is advised. The normal method of treatment is to scatter molluscicide formulated as a bait, and it is most effectively applied after seedbed preparation but a few days prior to drilling. Bait pellets can also be mixed with the seed. As slugs are often at the borders of the field, spot treatment is sometimes possible.

Main molluscicides

Mercaptodimethur, metaldehyde, thiodicarb.

Weeds

Basic strategy

Although chemical weed control is the most widely used method of weed control in barley, there are opportunities to use cultural methods before sowing the crop and during crop growth, e.g. competitive crops and mechanical weed control. It is GPP to destroy emerged grass and broad-leaved weeds by mechanical cultivation or use of herbicides in the stubble of the preceding crop. This is particularly useful where it is intended to prepare the seedbed without ploughing. Normally, it is GPP to cultivate, e.g. to plough and harrow, before sowing the barley crop, with a light harrowing and/or rolling after drilling to consolidate the seedbed, if necessary. Seedbed preparation methods depend on soil type, soil conditions and time of the year. The objective is to remove remnants of the previous crop, destroy weed populations and prepare a seedbed in optimal conditions to encourage rapid germination of a full, competitive stand of barley and to provide a level clod-free surface for maximum activity of a residual herbicide.

Herbicides can be applied pre-sowing, pre-emergence, post-emergence and pre-harvest. Weed control decisions should be based on economic damage thresholds if available (including the risk of seed return of aggressive weed species), or on past knowledge of the field, if a treatment before weed emergence is planned. Annual grass and dicotyledonous weeds may be controlled in the autumn provided that it is likely that weed thresholds may be exceeded. A suitable combination of residual and foliar-acting herbicides should be used. Late-sown crops or crops with low weed populations may not need herbicide treatment before the spring. Spring applications of suitable foliar-acting herbicides should be made only where annual grass or dicotyledonous weed thresholds are likely to be exceeded, or where weeds have escaped the autumn treatment, or where spring-germinating weeds predominate. With spring barley, seedbed cultivation should destroy a large proportion of the autumn or spring-germinated weeds. A post-emergence foliar herbicide may be necessary, with rates adjusted for weed size.

It is GPP to ensure that conditions favourable for active growth of crop and weeds exist in the spring before application of a foliar herbicide. Crop and weed growth stages should be followed carefully to avoid inefficient use of herbicides on large weeds and crop damage. The risk of a carry-over effect to a succeeding crop should also be considered.

In order to delay or minimize the development of herbicide resistance, guidelines are available and should be followed.

Perennial weeds such as *Phragmites australis*, *Juncus* spp., *Elymus repens*, *Cirsium* spp. and volunteer potatoes can be controlled shortly before harvest with non-selective foliar herbicides, e.g. glyphosate. The crop should be almost dead at this time and the grain nearly ripe, and the weeds should be alive and well exposed. Spot treatment with ropewick applicators is also possible at this time for some weeds.

Main herbicides

The numerous herbicides available for GPP in barley can be classified by their time of application (pre-sowing, pre-emergence or post-emergence) and their main target (annual grass weeds, dicotyledonous), as shown below.

Annual grasses only

Pre-sowing and pre-emergence: triallate. Post-emergence: diclofop-methyl, difenzoquat, flamprop-M-isopropyl, triallate.

Grasses/dicots

Pre-emergence: chlorotoluron, cyanazine, diflufenican, isoproturon, methabenzthiazuron, metsulfuron-methyl, pendimethalin, terbutryn, trifluralin. Post-emergence: chlorotoluron, diflufenican, imazamethabenz-methyl, isoproturon, metsulfuron-methyl. Pre-harvest: diquat, glyphosate.

Dicots only

Pre-emergence: isoxaben. Post-emergence: 2,4-D, amidosulfuron, bentazone, bifenox, bromoxynil, dicamba, dichlorprop-P, fluoroglycofen-ethyl,

fluroxypyr, ioxynil, MCPA, mecoprop-P, pyridate, triasulfuron, tribenuron-methyl.

Lodging

General

Under certain environmental and agronomic conditions (high nitrogen inputs, high density), barley can be prone to lodging. Whilst leaning crops may not cause adverse effects, severely lodged crops can suffer from uneven ripening and reduction of grain quality. Difficulties in pick-up of lodged barley by the combine harvester reduce harvestable yield. Increased weed contamination causes further harvesting difficulties and increases the cost of drying the grain. It is therefore important to minimize lodging, and in particular early lodging which causes the greatest problems. Lodging can be reduced by various means, including in particular the use of plant growth regulators.

There is also evidence to suggest that some plant growth regulators can improve root-system development, and influence tiller number and the number surviving to bear heads when applied early in the life of the crop. It is claimed that these can improve yield.

Basic strategy

The potential for lodging should be reduced by avoiding early sowing, careful nitrogen fertilization and avoidance of excessive seed rates. Certain barley cultivars (short or stiff-strawed cultivars) are resistant to lodging and can be grown without the use of plant growth regulators.

Plant growth regulators used for reduction of lodging are generally applied, as sprays, during the early stem-extension stage of growth (growth stage 20-32) either as single or split dose applications, in order to shorten and strengthen the lower internodes. Applications may also be made later during stem extension (growth stage 32-45) to shorten the upper internodes, thereby helping to reduce overall height. The use of plant growth regulators should be avoided if crops are under stress (e.g. drought) as the heading of plants may be inhibited.

Main plant growth regulators

Early stem extension (growth stage 20-32): imazaquin. Later stem extension (growth stage 32-45): ethephon, mepiquat chloride. Wider range of stem extension timings (growth stage 30-39/45): ethephon, trinexapac-ethyl.