◆ EPPO Standards ◆

GUIDELINES ON GOOD PLANT PROTECTION PRACTICE

WHEAT

PP 2/10(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 2/10(1) English

Guidelines on good plant protection practice

WHEAT

Specific scope

This standard describes good plant protection practice for wheat.

Specific approval and amendment

First approved in September 1997.

This guideline on GPP for wheat 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 wheat (*Triticum* spp.), including soft wheat (*Triticum aestivum*) and hard wheat (*Triticum durum*).

Wheat is grown in most parts of the EPPO region. The grain is used for human and animal consumption. Wheat straw can be used for animal consumption. Wheat is grown in rotation with other cereals or field crops.

Wheat crops are sown in spring or in autumn. Spring crops are exposed to pests for a shorter period. 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 wheat 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, cultural operations (destroying or burying stubble) are important elements in GPP on wheat. Cultivars with good resistance to lodging should be used in areas where lodging is a major problem. 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. Wheat 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 should be familiar with the main pests, monitor fields regularly and make full use of existing early warning systems and economic threshold values. 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. For the control of the important powdery mildew and rust diseases, active substances should be alternated or coformulations containing products with different mode of action should be used as much as practicable.

The principal wheat problems considered are the following:

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

- *Erysiphe graminis* (powdery mildew);
- *Leptosphaeria nodorum* (glume blotch);
- *Mycosphaerella graminicola* (leaf spot);
- *Tilletia tritici*, *Ustilago tritici* (bunt and smut);
- *Tilletia controversa* (dwarf bunt);
- *Pseudocercosporella herpotrichoides* (eyespot);
- *Gaeumannomyces graminis* (take-all);
- *Fusarium culmorum*, *Monographella nivalis* (foot rot, snow mould);
- *Gibberella zeae*, *Fusarium culmorum* (ear rot);
- *Pyrenophora tritici-repentis* (leaf blotch);
- 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);
- *Eurygaster* and *Aelia* spp. (shield bugs);
- *Cnephasia pumicana;*
- *Psammotettix striatus;*
- *Contarinia tritici*, *Sitodiplosis mosellana* (wheat blossom midges);
- *Mayetiola destructor* (Hessian fly);
- *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 striiformis (yellow rust), *P. recondita* (brown rust), *P. graminis* (black rust)

General

Rust fungi are highly specialized to their hosts, and wheat is attacked by the formae speciales *tritici* of the three main rust fungi, *Puccinia striiformis*, *P. recondita* and *P. graminis.* In addition, pathotypes specialized to host resistance genotypes are common. Some of the cereal rusts have alternate hosts (*Thalictrum* spp. for *P. recondita*; *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. striiformis* and *P. recondita* can also occur in the autumn from late tillers or volunteers. 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 wheat differ in the pattern and colour of the uredosori formed on wheat leaves. These are yellow to orange in *P. striiformis*, characteristically in rows on older leaves (in very susceptible wheat cultivars the leaves turn yellow and die). The darker uredosori of *P. recondita* are irregularly spread over the entire leaf surface. The uredosori of *P. graminis* form dark brown stripes on leaves and leaf sheaths. In general, yellow rust and brown rust are the diseases of practical importance in Europe. The importance of black rust was much reduced by a campaign to eradicate its alternate host (*Berberis vulgaris*) early in the 20th century, and black rust is only now occasionally serious in areas with warm summers in central and eastern Europe and on hard wheat in southern Europe.

Basic strategy

There is a range of cultural practices that may reduce rust infection of wheat. First, resistant cultivars should be grown or, at least, very susceptible cultivars should be avoided. Volunteer wheat should be destroyed and winter wheat 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 in spring, application of a fungicide spray may be necessary. Normally, one or two applications are sufficient, but more may be needed on very susceptible cultivars. In practice, thresholds may be used (e.g. first appearance of *P. striiformis*, appearance of

P. recondita on leaf 3). Alternatively, the advice of warning services (based on various forecasting models) should be followed. If rusts are present with other diseases at growth stage 39-65, it is common practice to apply fungicides against the whole disease complex.

Main fungicides

Sprays: azoxystrobin, cyproconazole, epoxiconazole, fenbuconazole, fenpropidin, fenpropimorph, flusilazole, fluquinconazole, 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 wheat. 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. Moderate levels of mildew can be tolerated. 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

Wheat is infected only by forma specialis *tritici* of *E. graminis*, so powdery mildew from barley or rye cannot infect wheat and vice versa. Winter wheat should, however, not be grown next to spring wheat. In general, wheat is not as heavily affected as barley (see EPPO Standard PP 2/11(1) Guideline on GPP for barley), but losses can be severe if the disease is not controlled. A range of cultural practices exist that may somewhat reduce infection by *E. graminis*. The growing of resistant cultivars is recommended. An open stand of wheat reduces the incidence of powdery mildew as compared to a dense stand, heavily fertilized with nitrogen. If powdery mildew infection becomes too serious, one or more chemical applications may be necessary; this should not be after full ear emergence (growth stage 59). Treatment may commence at first appearance of symptoms after growth stage 31. If powdery mildew is present with other diseases, it is common practice to apply fungicides against the whole disease complex.

Problems with resistance

E. graminis has been reported to show reduced sensitivity to fungicides of the sterol-biosynthesis inhibitor group, which has been characterized by gradual loss of performance, particularly in the triazole group of fungicides. Though fungicides of the benzimidazole group are effective against *E. graminis*, it is not GPP to use them on wheat because of resistance problems with *Pseudocercosporella herpotrichoides* (see below).

Main fungicides

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

***Leptosphaeria nodorum* (glume blotch)**

General

The disease caused by *Leptosphaeria nodorum* (synonym *Phaeosphaeria nodorum*; anamorph *Septoria nodorum*) can be seed-borne, but soil-borne debris is the main source of infection. Seed-borne infection can cause seedling losses. Wind-borne ascospores may bring the disease into a first-year wheat crop. Small brown blotches, sometimes increasing considerably, appear on leaves and leaf sheaths. Plant-to-plant spread is by rain splash of pycnidiospores. A few weeks before ripening, the glumes are also infected, their tips turning brownish with minute reddish/light brown points (pycnidia). Grain in infected ears does not fill properly. The disease is associated with heavy rain during summer. Glume blotch is the major disease of wheat in north-western Europe, but is less important further south.

Basic strategy

Commercial cultivars are available with a moderate degree of resistance. The use of disease-free seed is recommended, but seed treatments will give acceptable control of seed-borne infection if seed with a low incidence of the pathogen is used. If infection is heavy, fungicide sprays may be needed. One spray should be applied after flag-leaf emergence and a further application may be needed at ear emergence if conditions are very conducive. The aim of control is to prevent infection of the ear and flag leaf. The advice of warning services should be followed, if available. If glume blotch is present with other diseases, it is common practice to apply fungicides against the whole disease complex.

Main fungicides

Seed treatments: carboxin, triadimenol. Sprays: azoxystrobin, bromuconazole, chlorothalonil, cyproconazole, epoxiconazole, fluquinconazole, kresoxim-methyl, mancozeb, prochloraz, propiconazole, tebuconazole, triadimenol.

***Mycosphaerella graminicola* (leaf spot)**

General

Mycosphaerella graminicola (anamorph *Septoria tritici*) causes speckled leaf blotch or leaf spot of wheat. The disease is not seed-borne, the primary inoculum usually being wind-blown ascospores from pseudothecia formed on last year's stubble. Spring-sown crops tend to escape this inoculum. However, if crops are sown into infected stubble or trash, the primary inoculum may also be pycnidiospores from this source. Yellow, later brown-yellow, spots appear on the leaves, with dark-brown specks (pycnidia) and apical yellowing of the leaf (tip-burn). Plant-to-plant spread is by rain-splashed pycnidiospores. Infected leaves die entirely or partly. The glumes are rarely infected (see *Leptosphaeria nodorum*). The disease is favoured by rainfall, especially in thin crops, and occurs on wheat crops throughout Europe, though especially in the west.

Basic strategy

Commercial cultivars with moderate levels of resistance are available. Early drilled crops are more severely affected. It is important to prevent infection of the upper leaves. One or two fungicide sprays may be needed, applied when infection is seen after growth stage 39, and earlier in the case of rainfall favouring infection of the upper leaves. The advice of warning services should be followed, if available. If leaf spot is present with other diseases, it is common practice to apply fungicides against the whole disease complex.

Main fungicides

Sprays: as for *Leptosphaeria nodorum.*

***Tilletia tritici*, *Ustilago tritici* (bunt and smut)**

General

Tilletia tritici (syn. *T. caries*) causes covered smut or bunt of wheat. Seedlings are systemically infected by spores carried on the outside of the seeds. The disease can also be soil-borne. Shortly after flowering, infected tillers give rise to ears which become blue-green and during ripening the glumes open slightly. Diseased plants can be stunted, and the grains are filled with a mass of black spores, retained within the seed coat (covered smut).

Ustilago tritici (syn. *U. nuda*) causes loose smut of wheat. 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 at harvest.

Basic strategy

Seeds of wheat are externally contaminated by *T. tritici* during harvesting, when bunted grains are broken open and release their content of spores. Infection then occurs at the time of seed germination and can be prevented by a contact fungicide. In the case of *U. tritici*, 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 and fungicide-treated seed. Treatment is very effective in controlling these diseases, and certification is of use against *U. tritici*. Therefore, these diseases are now practically unknown in intensive cereal cultivation in Europe. However, bunt is commonly found on seed samples and, if untreated farmer-saved seed is sown, 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 against *Tilletia tritici*: bitertanol, carbendazim, fenpiclonil, fludioxonil, guazatine, mancozeb, maneb, tebuconazole, triadimenol, triticonazole. Seed treatments against *Ustilago tritici:* carbendazim, carboxin, tebuconazole, thiabendazole, triticonazole.

***Tilletia controversa* (dwarf bunt)**

General

Tilletia controversa causes dwarf bunt, a disease which can only develop in regions where snow cover persists for several weeks. Therefore, this disease is mainly observed in regions above 600 m. Although *T. controversa* can be seed-borne, the main source of inoculum is soil infested with teliospores. The spores can persist for at least 10 years. For germination of the spores, light is essential and the temperature optimum lays between 1 and 8°C. Only spores on the soil surface germinate and infect the seedlings shortly after emergence. A persistent snow cover favours this rather long process of infection. Heavy infection at the stage of tillering results in severe damage. The symptoms are similar to those caused by *T. tritici*, but the plants are usually drastically shortened. The disease causes losses

of grain that can be as high as 50%. The bunt balls are crushed during threshing, the teliospores are transported with the wind and contaminate the soil of neighbouring fields.

Basic strategy

It is recommended to avoid growing winter wheat in areas where *T. controversa* occurs. Spring wheat should be cultivated instead, as it can escape from the disease. Certified and fungicide-treated seed should be used to prevent infection. Every effort should be made to avoid contaminating healthy soils.

Main fungicides

Seed treatments against soil infection: bitertanol, difenoconazole.

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. Plants are infected through the leaf sheath, and the lesion gradually penetrates through to the stem, forming a lens-shaped spot with a darker border. Another fungus, *Ceratobasidium cereale* (anamorph *Rhizoctonia cerealis*), forms lesions with a darker, more sharply defined border (sharp eyespot). If eyespot lesions reach the stem before growth stage 31/32, there is a high 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. Fast- and slow-growing strains of *P. herpotrichoides* occur in different areas; this situation is monitored by warning services, which should be consulted if necessary.

Basic strategy

A number of factors predispose wheat crops to eyespot: high soil pH, cereal as preceding crop, early sowing date, cultivar, dense sowing, dense tillering. Good cultural conditions reduce the incidence. Winter wheat should be sown late and rather shallow (the disease is of no importance on spring wheat). The proportion of cereals in the crop rotation should not be too high; in a 50% rotation of cereals with non-cereals, a 2-year change may be advisable rather than a crop change every year. Cultivars with a certain degree of resistance are available. Since fast- and slow-growing strains of the fungus may show different susceptibility to fungicides, the advice of warning services should be sought as to the strains locally present. If at the start of stem elongation (growth stage 31) more than a threshold percentage of tillers shows eyespots, a fungicide spray should be applied. This threshold varies according to the strain and the climatic conditions from 15 to 35%. The advice of warning services should be followed, if available. Use of plant growth regulators to shorten the length of the stem and reduce lodging may reduce the effects of eyespot infection.

Problems with resistance

P. herpotrichoides was slow to develop resistance to the benzimidazole group of fungicides, but this resistance is now common. Resistance to triazoles (which, in any cases, are less effective against the slow-growing strains) and prochloraz has also been found in certain areas.

Main fungicides

Sprays: cyprodinil, flusilazole, prochloraz.

Gaeumannomyces graminis **(take-all)**

General

Gaeumannomyces graminis is a soil fungus which infects the roots of wheat, 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 cereal crops, and is the principal reason why it is not GPP to grow wheat continuously.

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 readily 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 wheat 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 may 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 wheat. 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, fuberidazole, fludioxonil, guazatine, mancozeb, prochloraz, thiophanate-methyl.

***Gibberella zeae*, *Fusarium culmorum* (ear rot)**

General

Infection of ears by *Gibberella zeae* (anamorph *Fusarium graminearum*) or *Fusarium culmorum* is favoured by wet weather conditions (relative humidity over 75%) after ear emergence. Infection by *F. culmorum* is by rain-splashed conidia coming from infected debris in the soil, and the ear-rot phase can be considered as an extension of the foot-rot phase of this fungus (q.v.). Lightly infected ears give rise to infected seeds. *G. zeae* forms perithecia on infected debris and on wheat ears after infection, and the inoculum consists mainly of air-borne ascospores. Infection of the leaves can lead to large, oily blotches. The fungus is not important as a foot-rot pathogen of wheat (though it is important on maize). Ear rot reduces yield, decreases the thousand-grain weight and leads to bad quality indices. Under improper storage conditions, the fungi in infected wheat may produce toxins which are health-hazardous for human or animal consumption.

Basic strategy

Tolerant cultivars should be used. In areas at risk, heavy nitrogen fertilization and late sowing should be avoided. The foot-rot phase of *F. culmorum* should be controlled by treating the seeds with a fungicide (see Foot rot). If climatic conditions favourable to ear rot appear, preventive fungicide sprays should be applied especially in central Europe where this disease is most important. In other areas, fungicide sprays applied against other diseases generally control ear rot.

Main fungicides

Sprays: azoxystrobin, carbendazim, epoxiconazole, tebuconazole.

***Pyrenophora tritici-repentis* (leaf blotch)**

General

Pyrenophora tritici-repentis is a fungus which gained importance in the 1980s. It infects a wide range of cultivated and wild monocotyledonous plants. The pathogen overwinters on stubble residues and initial infection in spring is caused by ascospores from this source. Symptoms are observed in late March-early April in the form of light-brown ascospore lesions with yellow margins on the lower leaves of winter-wheat plants. Following secondary conidial infection, small dark-brown spots, then oval or fusiform light-brown spots develop. Finally, leaves dry from the tip. *P. tritici-repentis* and *Leptosphaeria nodorum* may appear together. Conidial infection requires warmth (20-22°C) and precipitation.

Basic strategy

Stubble residues should preferably be ploughed in. Less susceptible cultivars should be used in areas at risk. Infection may occur from the two-node stage to flowering. A single fungicide spray may be applied at the time of appearance of symptoms.

Main fungicides

Sprays: carbendazim, epoxiconazole, flusilazole, prochloraz, propiconazole, tridemorph.

Aphids

General

Aphids, especially *Sitobion avenae*, *Metopolophium dirhodum* and *Rhopalosiphum padi*, may become numerous on tillers and ears of wheat, 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*).

Quality of grain is also affected by aphid infestations. *Diuraphis noxia* is important in the eastern part of the EPPO region.

Basic strategy

The wheat 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: 30% of tillers carry aphids before flowering; 70% of tillers are infested during and shortly after flowering up to caryopsis watery ripe. A single spray is usually sufficient. Use of certain selective insecticides (e.g. pirimicarb) will favour natural enemies.

Virus diseases are not normally a problem in wheat and chemical control of aphids for that purpose is generally not necessary. In areas with mild winter climate, there may however be a problem with *Barley yellow dwarf luteovirus*; damage can be prevented by late sowing (winter wheat) or early sowing (spring wheat), or by spraying an insecticide in the autumn. Seed treatment of winter wheat is also possible.

Main insecticides

Seed treatments: imidacloprid. Sprays: alpha-cypermethrin, beta-cyfluthrin, bifenthrin, chlorpyrifos, cyfluthrin, cypermethrin, deltamethrin, demeton-S-methyl, esfenvalerate, fenvalerate, formothion, 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 wheat 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

Wheat 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 wheat is likely to be at risk when 50 larvae per m^2 or more are present in early spring. Winter wheat 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 damaging populations of leatherjackets are present. 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 wheat plants. These become yellow and the main shoot turns brown. Development of wireworms takes several 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 wheat 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 wheat plant. Both winter and early-sown spring wheat 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 can be serious. *Opomyza florum* is another cereal fly which mines wheat stems like *D. coarctata.*

Basic strategy

Damage can be reduced effectively by cultural methods. The crop rotation can be chosen so that wheat 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*. The type of treatment is decided on the basis of previous cropping, crop-sowing date and the perceived level of risk based on sampling for eggs. Insecticides are preferably applied as seed treatments, but may also be applied as seedbed sprays at or soon after sowing, 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 wheat when it is sown after infested grass. The larvae migrate from the ploughed-in grass to invade the wheat plant, the centre leaf of which turns yellow and dies.

Basic strategy

If winter wheat 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 wheat is only slight in most years and does not justify routine insecticide spray treatment unless regular damage has occurred previously. Crops at risk should be examined from emergence and sprayed if more than 10% of shoots are damaged. Seed treatments are also effective.

Main insecticides

Seed treatments: chlorfenvinphos, fonofos. Sprays: alpha-cypermethrin, chlorpyrifos, cypermethrin, deltamethrin, esfenvalerate, lambda-cyhalothrin, permethrin, 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 wheat 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.

Eurygaster and *Aelia* spp. (shield bugs)

General

Pentatomid bugs (e.g. *Aelia acuminata*, *A. rostrata*, *Eurygaster austriaca*, *E. integriceps*, *E. maura*, *E. testudinaria*) are mainly important in south-east Europe and Mediterranean countries. Adults overwinter in uplands and migrate to cereal crops in spring. Nymphs develop on the wheat crop and cause damage by feeding on the young grain (injection of saliva which affects bread-making quality).

Basic strategy

Most commonly, sprays are applied at full heading to protect the young grain, on the basis of a threshold density of nymphs. An alternative strategy is to spray at the end of winter, when the adults migrate, on the basis of forecasts of adult development.

Main insecticides

Sprays: alpha-cypermethrin, deltamethrin, dimethoate, fenitrothion, lambda-cyhalothrin, quinalphos.

Cnephasia pumicana

General

Adults are small moths with 1.5-cm wingspan. They lay eggs in summer under the bark of trees. In spring, the larvae are carried to wheat crops by wind. They can be found mainly on field edges. They perforate the leaf surface and mine the leaves, causing leaves to curl upwards. At heading, they move to the ears on which they can cause serious damage.

Basic strategy

Insecticide sprays should be applied if a threshold of one larva per 20 tillers is observed.

Main insecticides

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

Psammotettix striatus

General

This leafhopper transmits a phytoplasma causing a yellow dwarfing disease of wheat. The symptoms can be confused with *Barley yellow dwarf luteovirus*.

Basic strategy

Generally controlled by treatments against aphids. Sprays against *Psammotettix striatus* may be needed if aphids are not treated.

Main insecticides

Sprays: as for aphids.

Contarinia tritici, *Sitodiplosis mosellana* (wheat blossom midges)

General

The larvae of *Contarinia tritici* feed on the floral parts of wheat, preventing pollination and development of the grain. The larvae of *Sitodiplosis mosellana* feed on the developing grain, resulting in reduced grain size and milling/baking qualities. In most seasons and regions, damage is slight. However, *S. mosellana* in particular can cause serious losses in northern Europe.

Basic strategy

Regular rotation will reduce numbers of midges. Intensive wheat growing and successive cropping will increase the risk of damage. When control measures are required, sprays should be applied between ear emergence and start of flowering.

Main insecticides

Sprays: chlorpyrifos, dimethoate, fenitrothion, lambda-cyhalothrin, thiometon.

Mayetiola destructor (Hessian fly)

General

The larvae damage the stems of wheat causing them to lodge. Damage occurs sporadically, mainly in northern Europe.

Basic strategy

An insecticide spray should be applied at the time of egg-laying, according to warning systems if available. A suggested threshold is 15 eggs per stem.

Main insecticides

Sprays: alpha-cypermethrin, deltamethrin.

Haplodiplosis marginata (saddle gall midge)

General

In May and June, female midges deposit their eggs on the surface of wheat 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 grass 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 wheat 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 substances 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 wheat: *Meloidogyne naasi* (cereal root-knot nematode) which induces the formation of many extra roots and elongated root knots, and *Heterodera avenae* (cereal cyst nematode) which causes strong root branching and deformation, with cysts visible later in the season. Attacks are visible in the field as spots where crop growth is retarded. Spring-sown wheat is especially susceptible to *M. naasi*.

Basic strategy

Crop rotation is 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 wheat seedlings and hollow out wheat seeds, and the problem is increasing with direct drilling and when land is left uncultivated (e.g. "set

aside" according to the Common Agricultural Policy of the European Union). 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 wheat, 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 wheat 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 wheat 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 wheat, 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 wheat can be classified by their time of application (pre-sowing, pre-emergence, post-emergence or pre-harvest) and their main target (annual grass weeds, dicotyledons), as shown below.

Annual grasses only

Pre-sowing and pre-emergence: triallate. Post-emergence: clodinafop-propargyl + cloquintocet-mexyl, diclofop-methyl, difenzoquat, fenoxaprop-P-ethyl + fenchlorazole-ethyl, flamprop-M-isopropyl.

Grasses/dicots

Pre-emergence: chlorotoluron, diflufenican, isoproturon, methabenzthiazuron, pendimethalin, prosulfocarb, terbutryn, trifluralin. Post-emergence: chlorotoluron, diflufenican, imazamethabenz-methyl, isoproturon, methabenzthiazuron, metoxuron, metsulfuron-methyl, prosulfocarb. 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, thifensulfuron-methyl, triasulfuron, tribenuron-methyl.

Lodging

General

Under certain environmental and agronomic conditions (high nitrogen inputs, high density), wheat 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 wheat 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 wheat 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): chlormequat chloride, imazaquin. Later stem extension (growth stage 32-45): ethephon, mepiquat chloride. Wider range of stem extension timings (growth stage 30-39/45): chlormequat chloride, ethephon, trinexapac-ethyl.