◆ EPPO Standards ◆

GUIDELINES ON GOOD PLANT PROTECTION PRACTICE

POTATO

PP 2/2(2) English

oepp
eppo

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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 EUROPÉENNE ET MÉDITERRANÉENNE POUR LA PROTECTION DES PLANTES

PP 2/2(2) English

Guidelines on good plant protection practice

POTATO

Specific scope

This standard describes good plant protection practice for potato crops (primarily ware potatoes).

Specific approval and amendment

First approved in September 1994.
Revision approved in September 2000.

This guideline on GPP for potato 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. It covers methods for controlling pests (including pathogens and weeds) of potato (*Solanum tuberosum*).

The guideline is primarily designed for ware potatoes (i.e. potatoes grown for consumption or processing). The problems of GPP in seed-potato production are not included, being considered of specialized interest only. Potato GPP depends first of all on planting healthy seed tubers on uninfested land. Official regulatory measures should be taken to ensure that seed potatoes are free from specified diseases (mainly viral and bacterial) and from potato cyst nematodes, and meet tolerance standards for other pests. The fields in which potatoes are planted should as far as possible be free from soil-borne pests, and precautions should be taken to remove sources of inoculum of the most important foliar pathogen, *Phytophthora infestans* (late blight). Treatment of the soil against soil-borne pests (especially potato cyst nematodes) potentially represents a major use of plant protection products on the crop, and it is particularly advisable to seek to limit such treatments by finding alternative approaches, and to regulate such treatments officially. Pre-planting herbicide treatment is usual. Certain products may be applied as granules or similar formulations before or at planting, but most products are applied as sprays to the crop in leaf. A particular feature of the potato crop is that the haulms are killed by spraying or other means some time before the tubers are harvested for a number of reasons, in particular to minimize spread of virus diseases by aphids in seed potatoes, and in areas of high infection pressure to reduce tuber infection by blight. Finally, tubers may be treated before storage, with products against storage pests or with plant growth regulators to suppress sprouting in store.

The principal potato pests considered are the following.

- *Phytophthora infestans* (late blight);
- *Alternaria solani* (early blight);
- *Thanatephorus cucumeris* (black scurf and stem canker);
- *Verticillium dahliae* (verticillium wilt);
- storage diseases;
- *Leptinotarsa decemlineata* (Colorado beetle);
- aphids;
- *Phthorimaea operculella* (potato tuber moth);
- soil insects (wireworms, white grubs);
- noctuids (cutworms);
- *Lygocoris pabulinus;*
- *Empoasca vitis, E. solani*, *Eupteryx atropunctata* (leafhoppers);
- *Globodera* spp. (potato cyst nematodes);
- slugs;
- weeds.

In addition, haulm killers (desiccants) and sprout suppressants represent other major uses of plant protection products on potato. Seed-tuber treatments are being increasingly used to control certain storage diseases (*Fusarium* spp., *T. cucumeris*, *Helminthosporium solani*) in the daughter tubers.

Explanatory note on active substances

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

Phytophthora infestans **(late blight)**

General

Late blight of potato is an extremely damaging disease, which can spread very quickly under favourable conditions. During active growth of the crop, it destroys the foliage and reduces tuber yields in consequence. At a later stage, if blight is present on the leaves, there is a risk that sporangia will be washed off by rain into the soil and will therefore infect the tubers. This risk is even greater at the time of harvest, and this is one of the main reasons why haulm killers are applied to potato crops. Tubers infected by *P. infestans* in the field are liable to serious rotting and damage in store. Commercial potato growers, and especially seed-potato growers, cannot afford to allow significant late-blight epidemics to develop. In addition, even small areas of heavy infection can act as foci for spread to surrounding potato crops.

In addition, there has been a general resurgence of late blight in Europe in recent years, linked possibly to fungicide resistance and to the introduction of the A2 mating type of *P. infestans*, which was detected in several countries in Europe in the 1980s. When the two mating types are present, oospores can be formed and constitute an additional source of inoculum. They can survive in the soil for several years and give earlier infection of the crop. The sexual process of oospore formation also allows increased genetic recombination.

Basic strategy

The basic strategy in the control of *P. infestans* in potato crops is to prevent the establishment of any infection within the crop. For this purpose, fungicides with three types of activity can be used: (1) those with protectant (contact) activity on the surface of leaves; (2) those with penetrant (locally systemic) activity; and (3) systemic fungicides. By application of products containing two or even three active substances with such activities, it is theoretically possible to provide protection from infection for up to 10 days and to treat successfully infections established within the previous 4 days (in practice, such a long interval as 14 days is only recommended when the risk of blight is low). It is therefore necessary to apply fungicides as soon as the threat of infection appears and to continue application at regular intervals (normally 7-12 days depending on weather or infection situation, varietal resistance and fungicide used) throughout the growing season until haulm killing, haulm removal or harvest, taking into account the required pre-harvest intervals.

The elements of this strategy can be analysed in terms of the following: destruction of initial inoculum by hygienic precautions; optimum combination of types of fungicides used; optimum timing of the first application; deciding the frequency and timing of later applications; protection of the tubers at the end of the season; other measures.

For the timing of applications, decision-support systems (DSS) are used, giving recommendations based on the epidemiology of the fungus, climatic conditions, infection pressure and the costs and efficacy of crop protection measures. Almost every European country has its own DSS.

Destruction of initial inoculum

Sources of inoculum can be removed by appropriate hygienic precautions. If waste potatoes are left in the field or at the farm as waste heaps, these are liable to be a major source of inoculum in the following season. Thus, waste potatoes should be removed or destroyed. If this is not possible, waste heaps should be prevented from sprouting by treatment with a herbicide such as chlorthiamid or dichlobenil, or by covering with black polythene. Volunteer potatoes growing as weeds in other crops should also be destroyed by suitable herbicide treatments. Since blight can also be introduced into a crop on infected seed tubers, it is essential to use high-quality blight-free tubers. In intensive potato cultivation, the ideal aim is to keep blight at such a low level over a large area, and to apply hygienic methods so rigorously that there is an absolute minimum of initial inoculum.

Optimum timing of the first application

The decision when to begin fungicide application can be based on the phenological stage of the crop, or on a warning system. The usual stage at which first application is recommended is when the foliage of adjacent plants is about to meet between the rows (i.e. just before the rows close). In certain situations of high blight risk, the first application may be made earlier, when the foliage meets within the row or, under exceptional circumstances, when foliage appears or when plants reach 20-30 cm. Such early treatment is not generally good practice and is only justified by special circumstances, e.g. main crops emerging adjacent to infected early crops. In general, it is preferable to time the first application in relation to regional warnings made by advisory services. These are generally based on monitoring of temperature, humidity and rainfall. Growers are advised *not* to spray until a threshold specific to the forecast system is reached. Sprays have then to be applied before sporulation on the lesions resulting from this infection period.

The first spray resulting from a forecast system is generally timed later than that based on a phenological criterion, so this system gives rise to fewer applications overall. It is accordingly good practice to follow a warning system. However, warning systems generally operate at regional level and do not always correspond sufficiently closely with local conditions. Even where warning services exist, they are not necessarily followed as widely as they should. Farmers are always well advised to inspect their own crops for blight foci, and act accordingly.

Deciding the frequency and timing of later applications

The general strategy is to maintain protection against blight continuously from the time of the first infection period. The timing of applications is determined primarily by the type of product used and the neighbourhood of sources of inoculum. The basic treatment strategy is always protective rather than curative.

Protectants alone are often only effective for 7-8 days (depending on rainfall, irrigation and obviously on the product used). Penetrants can be applied up to 2 days after infection, so a penetrant/protectant two-way mixture can be used if a normal protectant spray has had to be postponed (for example, by bad weather).

Systemic fungicides, in the presence of sensitive strains of *P. infestans*, are particularly suitable when the plant is actively growing, since the new foliage which is being produced cannot be protected otherwise. Because of the risk of appearance of resistance (see below) and because systemics are more costly, it is good practice to restrict the number of systemic applications and to limit them to the time of their greatest effectiveness. Systemic compounds are generally used in a formulation with a protectant. A simple two-way formulation (e.g. metalaxyl + mancozeb) gives protection for about 10 days. Three-way formulations with a local systemic (e.g. oxadixyl + cymoxanil + mancozeb) may extend this.

In practice, the timing of applications will depend on local conditions, cultivar, time in the season, weather, fungicide used, etc. Farmers recognize that there are "blight years" in which more treatments are needed than in "normal years". Warnings of infection periods can be followed not only for the first treatment but also for later ones, i.e. treatment can be postponed in the absence of new infection periods.

Examples follow of some of the general rules which are used in certain European countries. These reflect local constraints and are not necessarily applicable throughout the EPPO region:

- until flowering, application every 5-10 days with a protectant fungicide;
- during maximum vegetative growth, maximum of two applications with systemic fungicides at 14-day intervals;
- after flowering, in weather conditions suitable for the fungus, a combination of protectant and penetrant active ingredients every 5-10 days;
- after flowering, in weather conditions not suitable for the fungus, contact fungicides every 10 days;
- treat frequently with protectant fungicides at low dose rates (within the approved range) rather than less often at high rates.

In practice, in north-western Europe where weather conditions are particularly favourable to blight, more applications may be needed than in the continental parts of Europe.

Protection of the tubers at the end of the season

Towards the end of the season, the strategy is based on the use of a different set of fungicides, in combination with haulm killers if necessary. Organo-tin compounds or fluazinam are used to protect against tuber infection. The organo-tin compounds are in any case not recommended for earlier use because of the risk of phytotoxicity unless there is an early infection which must be controlled. Although copper-based fungicides can be used throughout the season, it is also recommended to use them late rather than early: they tend to depress yield if used early, and are conveniently and effectively used in combination with haulm killers.

Haulm killing is a blight control method, amongst its other aims (see section on haulm killing). It is always used on seed-potato crops to minimize virus infection. It is recommended to apply a haulm killer if blight incidence exceeds a certain threshold, typically 20% of plants carrying at least one infected leaf. This threshold should only be recommended in combination with weather and soil conditions that favour blight.

Other strategies

There are differences in susceptibility between cultivars and if possible less susceptible cultivars should be used. This remains true even if the *P. infestans* population includes virulent races capable of overcoming the resistance. Various cultural practices can affect the risk of blight infection. In particular, ridging the crop reduces the risk of tuber infection.

Problems with fungicide resistance

Due to the development of resistance to systemic phenylamide fungicides, various strategies for their use are recommended. There is fairly general consensus that systemic fungicides should be used for a maximum of two or three applications per season and, if possible, that different systemic products (with different resistance mechanisms) should be alternated with each other or alternated or combined with protectants within a season. There is no consensus on timing. Despite many reports of resistance, phenylamides (metalaxyl, oxadixyl, ofurace, benalaxyl) are still valuable systemic compounds against late blight. Although resistance to other fungicides has not been confirmed in *P. infestans*, the risk of resistance should be taken into account in potato spray programmes.

Main fungicides

Systemic compounds: benalaxyl, metalaxyl, metalaxyl-M, ofurace, oxadixyl, propamocarb.

Local-systemic compounds: cymoxanil, dimethomorph.

Protectant compounds: chlorothalonil, copper hydroxide, copper oxychloride, fentin acetate, fentin hydroxide, fluazinam, mancozeb, maneb, propineb, zineb.

Alternaria solani (early blight)

General

Alternaria solani can infect potato foliage and cause early senescence and yield reduction. The disease is most severe under warm conditions (temperature optimum 26°C). The main source of infection is tubers, plant debris or soil in which it ca survive for 2-3 years. The disease is widespread, but often the level of disease is reckoned to be of minor importance.

Basic strategy

Disease severity can be reduced by keeping 3-year intervals between potatoes. In many countries, attack remains at a low level which does not require any chemical control. In countries with risk of severe attack, fungicide sprays should be applied from appearance of the first symptoms on the leaves. Normally a single treatment should be sufficient. Most fungicides applied against late blight will also control *A. solani*.

Main fungicides

Sprays: chlorothalonil, fluazinam, mancozeb, propineb.

Thanatephorus cucumeris (black scurf and stem canker)

General

Thanatephorus cucumeris (anamorph *Rhizoctonia solani*) forms small black scurf-like sclerotia on the surface of potato tubers. From these sclerotia, the fungus can infect and destroy the young shoots of tubers in store, or else infect young shoots before they emerge, or cause stem lesions at ground level on older shoots. As a result, potato plants establish badly. Heavily infected plants yield few, malformed tubers, moderate infections can produce fewer, larger tubers and the presence of sclerotia on tubers can reduce their quality. The fungus can persist on debris in the soil. The disease is observed in areas with disturbed soil pH values (more acidic soils).

Basic strategy

Initial inoculum of the fungus should be reduced as much as possible, by using healthy seed potatoes and avoiding planting in soil known to be infested by the fungus. Tubers may be treated with a fungicide before or during planting. This used to be done by dipping, but this favours bacterial rots. The recommended practice is now by spray (preferably low volume) or dust during planting. Some planting machinery incorporates suitable application equipment. Treatment of the soil before planting is not recommended as good practice, as it is not very effective and uses unnecessary quantities of product. Treatment along the row after planting is similarly to be avoided.

Main fungicides

Seed treatments: carbendazim, fenpiclonil, flutolanil, imazalil, iprodione, mancozeb, mepronil, pencycuron, thiabendazole, tolclofos-methyl.

Verticillium dahliae (verticillium wilt)

General

Verticillium dahliae can infect potatoes and cause a wilting and premature senescence. The main source of infection is microsclerotia in the soil, although recent studies have shown that the pathogen can also be carried in the vascular tissue of seed tubers. Infected plants lose haulm prematurely and this results in yield reductions. As the infected tissues decay, microsclerotia are released into the soil. The symptoms of verticillium wilt may easily be confused with those caused by other pathogens or abiotic factors. Verticillium wilt on potato is sometimes also caused by *V. alboatrum.*

Basic strategy

In some countries, a soil test is available for checking soil infestation levels of *V. dahliae* and advice can be given on the suitability of the land for potato production. Cultivars vary in susceptibility to the disease, and most are affected to some degree. Land that has grown *Verticillium*-susceptible crops, such as linseed, in the previous few seasons should be avoided. There are no fungicides available for the control of this disease.

Storage diseases

General

Potato tubers are rotted in store by a number of fungi, including *Fusarium coeruleum*, *Gibberella cyanogena* (anamorph *F. sulphureum*), *Phoma exigua* var. *foveata*, and *Phytophthora infestans* (q.v.). They are also affected by bacterial rots (mainly *Erwinia carotovora* subsp. *atroseptica* and subsp. *carotovora*). Such rotting can cause serious losses. The surface of the tubers may be defaced or distorted by fungi (*Rhizoctonia solani*, q.v.; *Polyscytalum pustulans*; *Spongospora subterranea*; *Helminthosporium solani*, *Colletotrichum coccodes*), or bacteria (*Streptomyces scabies*). While the presence of such superficial infections has relatively little importance as such, they facilitate rotting and reduce the market value of tubers (grading is related to percentage of surface area affected).

Basic strategy

The general strategy is preventive. Storage conditions should be optimized, for example by controlled-temperature storage using curing when going into store, followed by cold storage. There are differences in how individual diseases respond to such treatment. Stores should be clean and if necessary disinfected.

Visibly damaged or diseased tubers are removed. To help ensure that the potatoes entering store are in optimum condition, they should be harvested as far as possible only when the following conditions are satisfied: the skin is set, mechanical damage is limited, soil conditions are dry and haulm has senesced or has been desiccated. Less susceptible cultivars may be used. For *Fusarium* spp. and *P. e. foveata*, treatment of the seed potatoes at planting will reduce the general level of infection in the crop and subsequent rotting in store. The same applies to *T. cucumeris* (q.v.), although in that case the treatments are also aimed at reducing stem canker in the field. For blight (*P. infestans*, q.v.), control during the growing season and suitably timed use of haulm killers will reduce tuber infection. Some storage diseases, such as *Spongospora subterranea*, are essentially field problems (e.g. over-irrigation) and if addressed during the growing season would be substantially reduced in stores.

In general, the treatment of potato tubers with fungicides before storage is being increasingly replaced by disease-avoidance strategies using suitable storage conditions. The use of bactericides before storage is not recommended, but in any case there have never been any products with adequate action against *E. carotovora*.

Problems with fungicide resistance

Resistance exists in *Helminthosporium solani, Polyscytalum pustulans* and *Fusarium sulphureum* to the fungicide thiabendazole. Research has shown that thiabendazole resistance can develop within one season of use. To prevent the spread of resistance, it is advisable to minimize repeated use of the same fungicide from year to year and to use products containing a mixture of active substances wherever possible.

Main fungicides

Sprays: benomyl, fenpiclonil, imazalil, iprodione, pencycuron, prochloraz, thiabendazole, thiophanate-methyl, tolclofos-methyl.

***Leptinotarsa decemlineata* (Colorado beetle)**

General

The larvae and adults of *Leptinotarsa decemlineata* seriously damage potato foliage by feeding. They are a major pest of potatoes in much of Europe, though rare in or still absent from some countries (which in consequence have practically no need to apply insecticide sprays to ware potato crops). In warmer or more continental countries, where there may be two or even three generations per year, control is needed every year. Elsewhere, treatment is needed only occasionally.

Basic strategy

Leptinotarsa decemlineata is controlled by insecticide sprays, preferably applied as soon as young larvae are seen (the older larvae and adults are less sensitive). A single treatment is normally sufficient against an outbreak, but more treatments may be needed against successive generations. Thresholds such as 15 larvae per plant, or 20% damage to the foliage, have been suggested. In areas where beetle attacks can regularly be expected, mainly at a very early growth stage of the plants and when products are used for other purposes (e.g. control of soil insects), treatment of the seed tubers with a systemic product is possible.

Leptinotarsa decemlineata populations readily become resistant to insecticides, but this problem has proved relatively easy to solve in Europe by alternation of products between years (the situation in North America is apparently much worse). Many attempts have been made to find adequate biological control agents, but none are yet effective or reliable enough to be recommended as good practice.

Main insecticides

Sprays: abamectin, acetamiprid, alpha-cypermethrin, azinphos-methyl, *Bacillus thuringiensis* var. *tenebrionis,* bensultap, beta-cyfluthrin, bifenthrin, carbaryl, carbosulfan, chlorfenvinphos, chlorpyrifos, cypermethrin, deltamethrin, esfenvalerate, fenvalerate, fipronil, hexaflumuron, lambda-cyhalothrin, lufenuron, methidathion, permethrin, phosalone, phosmet, phosphamidon, pyridaphenthion, quinalphos, tau-fluvalinate, teflubenzuron, thiocyclam, trichlorfon.

Pre-planting treatment of tubers: imidacloprid.

Aphids

General

Myzus persicae, *Macrosiphum euphorbiae*, *Aphis gossypii, Aphis nasturtii* and other aphids attack potato crops. Their greatest importance is on seed crops, where timely control is essential to prevent introduction of viruses. However, this guideline for GPP concerns only ware potatoes, which are not significantly damaged by viruses introduced into the crop during the current season. Aphid attack on ware crops can cause malformation (e.g. "false top roll"), yellowing and necrosis of the leaves. This can result in yield loss depending on the severity and timing of attack. Attacks are often patchy within the crop, and are serious enough to require control only in some years.

Basic strategy

Because damaging attacks occur only sporadically, it is good practice to treat only when there is a risk of a high aphid population developing at a susceptible growth stage (e.g. around BBCH 40-50), such that crop losses could be envisaged if the population was left uncontrolled. A single treatment is usually sufficient. Although some insecticides can be applied as granules at planting (and are in seed crops), this is not recommended for ware potatoes, as it does not take account of infestation levels. It may be possible to combine treatment against aphids with *L. decemlineata* sprays. *Myzus persicae* strains resistant to most organophosphorus and pyrethroid compounds are common in France, UK and probably elsewhere in Europe. Recently, *M. persicae* populations resistant to dimethyl carbamates have also been found. In such cases alternative insecticides should be used.

Main insecticides

Sprays: acetamiprid, bifenthrin, cypermethrin, deltamethrin, demeton-S-methyl, dimethoate, disulfoton, esfenvalerate, ethiofencarb, fenvalerate, heptenophos, imidacloprid, malathion, methamidophos, lambda-cyhalothrin, oxamyl, oxydemeton-methyl, phosalone, phosphamidon, pirimicarb, pymetrozine, tau-fluvalinate, thiometon, triazamate.

Phthorimaea operculella **(potato tuber moth)**

General

Phtorimaea operculella can be a very serious potato pest, especially in the Mediterranean region. Damage is most frequent on stored tubers after the spring growing season and on young plants in the autumn growing season. The larvae bore holes and galleries in the tubers. This attack results in lowered market value and quality of the infested tubers. Larval penetration holes are unsightly and induce soft rot. Potato crops are practically always damaged to a certain extent by *P. operculella*, and damage can sometimes reach alarming levels in farmers' stores. Under optimal conditions and in the absence of control, the pest multiplies extremely rapidly and infestation levels can easily reach 100% within 2-3 months.

Basic strategy

Infestation may start early in the field, up to 15 days before tuber maturity, either directly (eggs laid on the tuber surface) or indirectly (larvae from eggs laid on the soil around the plant). Around harvest time, a substantial number of tubers may already be infested. This harvest-time infestation is responsible for the further development of infestation in stores. Some agronomic practices have been found to be of great help in reducing the infestation at harvest time:

- depth of planting (15 cm);
- ridging (once or twice during the growing season, to reduce the number of uncovered tubers which are directly accessible to the pest);
- irrigation (sustained up to 1 week before harvest, this prevents soil cracking and thus infestation by larvae);
- early harvest (the later the harvest, the higher the level of infestation at harvest);
- early storage (tubers should not be left in the field; they should be moved to the store as soon as possible to reduce the risks of infestation).

These cultural practices can be used successfully to reduce infestation in the field. Field treatments with insecticides specifically against *P. operculella* are not normally necessary. However, if larval populations rise above a certain threshold (for example 2-3% infestation), commonly used insecticides, such as those used against *L. decemlineata*, can be applied.

Good control in the store depends on prophylactic measures (sorting tubers before storage), chemical treatment (dipping or spraying before going into store), and the design of the store and manner of storage. It may also be useful to treat the store room.

Main insecticides

Sprays:

- in the field: azinphos-methyl, carbaryl, malathion;
- for tubers going into store: carbaryl, cypermethrin, deltamethrin, malathion;
- for store rooms: chlorpyrifos-methyl, malathion , pirimiphos-methyl.

Soil insects (wireworms, white grubs)

General

Soil insects such as wireworms (e.g. *Agriotes* spp.) and white grubs (*Melolontha* spp.) may attack the crop at a very early stage, or else very late, damaging the tubers.

Basic strategy

Grassland or uncultivated land as a preceding crop should be avoided. Knowledge of the level of the populations of wireworms and white grubs in the soil is a basic need to make a decision on treatment. If potato is planted in a soil with previous records of damage due to these pests, it may be advisable to treat the soil just before planting. Various insecticides can be used as granules or sprays.

Main insecticides

Sprays: chlorpyrifos, diazinon, carbofuran, tefluthrin.

Granules: carbofuran, carbosulfan, chlorpyrifos, terbufos.

Noctuids (cutworms)

General

Larvae of noctuid moths, especially *Agrotis ipsilon* and *A. segetum* (cutworms, i.e. soil-inhabiting larvae) may attack potato. Late-instar larvae are thick, grey-brown with darker marks, and are usually curled up in the soil when found. Depending on the species, they can be 30-35 mm long when fully grown. Final instar larvae overwinter in the soil and pupate in the spring, sometimes after a short resumption of feeding. Adults arising from these pupae are on the wing from May to July depending on location and species (there may be a partial second generation in some years in August/September), and larvae arising from eggs laid by these adults cause damage in crops. Feeding occurs mostly at night. Early instar larvae feed on the crop foliage, but most damage occurs when later instar larvae move down into the soil. Plants may be cut at or just below ground level shortly after emergence, and significant holing of tubers later in the season can occur if conditions are suitable for cutworm survival.

Basic strategy

Cutworms are best controlled when larvae are feeding on the foliage during the early part of the larval development period. Once larvae have moved down in the soil, control by applying insecticides to the growing crop is not effective. An appropriate cutworm forecasting/warning system can be used to provide information on the optimum (early) timing of insecticide sprays. Small larvae can also be controlled by the application of irrigation, where available. Again, timeliness of application is important and is best achieved using warning systems.

Main insecticides

Sprays: chlorpyrifos, cypermethrin, deltamethrin, diazinon, lambda-cyhalothrin, temephos.

Lygocoris pabulinus

General

This widespread and common mirid pest is in particular found to attack young leaves of potatoes. Toxic saliva injected when feeding causes necrotic spots on leaves, leading to leaf deformation and early senescence. Attack often starts around hedges and other woody hosts where the overwintering eggs are laid. There are two generations per year.

Basic strategy

Chemical control measures are seldom warranted, but sometimes damage may be serious and so insecticides may have to be used. Treatments can be limited to the area close to hedges.

Main insecticides

Sprays: alpha-cypermethrin, cypermethrin, dimethoate.

***Empoasca vitis*, *E. solani*, *Eupteryx atropunctata* (leafhoppers)**

General

These sucking insects can become a problem in potatoes, in particular in Scandinavian countries. Adult leafhoppers overwinter. In northern countries generally there are two generations per season, but in warm climate breeding is continuous. Feeding causes foliage curling, stunting and dwarfing, accompanied by yellowing or browning of leaves. Severe attack give rise to early senescence and yield loss.

Basic strategy

In potatoes there may be a need for foliage sprays, in which case care should be taken to reach the under-surface of the leaves where the leafhoppers live. The need for chemical control is greater in late-harvested potatoes. No specific thresholds exist, but yellow sticky traps can be used to monitor the appearance and number of insects in the crop. Temperature sums can also be used to find the flight time of the pest and the development time of the second generation.

Main insecticides

Sprays: alpha-cypermethrin, cypermethrin, dimethoate.

***Globodera* spp. (potato cyst nematodes)**

General

There are two species of potato cyst nematodes, *Globodera rostochiensis* and *G. pallida*, which feed on the roots of potato plants, stunting their growth and reducing yields. They are specific to potato and tomato and, although their populations in soil decline to low levels over a period of years in the absence of the host, populations may retain viability for many years after the last cultivation of potatoes. Their natural spread is slow and limited in extent.

Potato cyst nematodes are quarantine pests in many countries and phytosanitary regulations accordingly require soil testing to be performed, particularly for seed potatoes. In areas where potato cyst nematodes occur, some phytosanitary authorities have built up detailed field-by-field records of their incidence and apply strict regulations defining the fields on which potatoes may be grown. There is, however, debate at present whether the application of such systems to ware potatoes is still good practice.

Basic strategy

The main strategy for potato cyst nematode control in ware potatoes is laid down by regulations in most countries (the same applies to seed potatoes, for which the standard of control is much higher). Control aims to prevent spread to new fields and to reduce populations in infested fields: seed potatoes must not carry *Globodera* spp., there should be a minimum rotation of 3 years, early harvesting is recommended before cysts are mature, fields where potatoes are to be grown can undergo a soil test to determine whether nematode populations fall below an acceptable threshold and which pathotype is concerned. If the pathotype is known, an appropriate resistant cultivar of potato can be chosen. To follow such a strategy is good practice, whether or not it is officially imposed.

This strategy may be supplemented in some cases by an option to treat the soil, by fumigation at the end of the season, or by incorporating granular nematicides before planting. In most areas, incidence of *Globodera* spp. is moderate and the above strategy (which effectively removes at a given moment a certain proportion of potential potato-growing land) does not impose a serious constraint. In such areas, nematicide treatment is certainly not good practice, and is indeed often prohibited. In areas of intensive high-value potato production, such a limitation is not currently considered economically acceptable, and nematicide treatment is used. It is not good practice to treat soil systematically with nematicides. Such treatments should be limited to what is strictly necessary, and may be subjected to official limitations. It should be noted in addition that *G. pallida* is less easily controlled and is becoming the prevalent species in many areas due to the use of cultivars resistant to *G. rostochiensis*.

Another element in the general control strategy is to control volunteer potatoes in other crops (since these allow *Globodera* populations to persist). Limits like 4 volunteer plants per m^2 are in use.

Main nematicides

Fumigation: metam-sodium, 1,3-cis-dichloropropene, dazomet.

Granules: carbofuran, ethoprophos, fenamiphos, fosthiazate, oxamyl.

Slugs

General

A number of slug species can attack potatoes, of which the most important belong to the genera *Deroceras* (e.g. *D. reticulatum*), *Tandonia* (e.g. *T. budapestensis*) and *Arion*. These can all burrow into potato tubers, resulting in large cavities in the tuber flesh. Some potato cultivars are more susceptible to damage than others. Slug damage to potato foliage can also occur, but this is insignificant. Slugs tend to be most numerous in moisture-retentive soils, and/or in soils containing high levels of decaying organic matter. Soil moisture and prevailing weather conditions largely govern activity on and under the soil surface; damp soil conditions and warm, moist nights favour high slug activity. Under prolonged dry conditions, slug populations can appear to be very low, but the return of wetter conditions often leads to a rapid resurgence in slug activity.

Basic strategy

Successfully suppressing the risk of slug damage to potato requires an integrated approach, as no single method is likely to be fully effective. The components of the strategy should be site selection, cultivar choice, activity monitoring, molluscicide use and harvest date. Where possible, fields should be selected which do not have known high slug populations. If slug damage is anticipated, cultivars that are known to be most susceptible to slug damage should not be grown. Once the crop is planted and tuber initiation has occurred, slug activity should be monitored using suitable traps. Molluscicide pellets can be applied when slug activity is high or anticipated to increase (e.g. when rain is forecasted). Pellet applications made in July are usually most effective; a second application 4 weeks later can sometimes improve damage suppression. Harvesting tubers as early as possible will also help to limit damage.

Main molluscicides

Pellets: methiocarb, metaldehyde, thiodicarb.

Weeds

General

Control of weeds in potato is considered necessary to safeguard quality and yield. There are possibilities for mechanical weed control in potato, although chemical weed control remains the normal practice. Herbicides are applied principally against annual dicotyledonous weeds, which would compete with the crop. They may also be needed against specific annual problem weeds (e.g. *Avena fatua, Galium aparine, Datura stramonium*) or perennial weeds (*Elymus repens, Panicum repens*).

Basic strategy

The recommended good practice is to ridge shortly before emergence, let the ridges settle, then treat once with a herbicide spray shortly before or just after the start of crop emergence (when many of the weeds have already emerged). Most herbicides used in potato are recommended for this pre-emergence treatment. Only a limited number of post-emergence herbicides (see below) exist to control specific weeds.

The anti-monocot herbicides can be applied at any time in potato crops, but in practice are generally applied post-emergence, when it is apparent that there is a specific infestation problem. If the land is known to be heavily infested with *E. repens*, a pre-planting application (with incorporation) of EPTC may be useful.

An alternative strategy is ridging shortly before emergence of the crop, followed by harrowing, and earthing up after emergence. This is usually combined with a "low-dose system" herbicide.

Main herbicides

Pre-planting: EPTC , against *E. repens.*

Pre-emergence: aclonifen, alachlor, cyanazine flurochloridone, glufosinate-ammonium, glyphosate, linuron, metobromuron, metolachlor, propachlor, monolinuron, pendimethalin, prometryn, prosulfocarb, terbuthylazine, terbutryn, trietazine.

Early post-emergence: metribuzin (cultivar-dependent) until plants are 5-10 cm tall (also pre-emergence).

Post-emergence (against monocot weeds): alloxydim-sodium, cycloxydim, diclofop-methyl, fluazifop-butyl, haloxyfop, propaquizafop, quizalofop-ethyl or sethoxydim.

Post-emergence (against dicot weeds): bentazone (cultivar-dependent), mainly against *Galium aparine* and *Polygonum convolvulus,* dinoterb, metribuzin (not for all potato cultivars).

Post-emergence (against mono and dicots): rimsulfuron, mainly against *G. aparine, Chenopodium album, P. convolvulus* and suppression of *E. repens.*

Haulm killing or desiccation

General

The aim of haulm killing in potato is to kill all leaves and stem at a suitable time, in order to:

- prevent infection of tubers by *P. infestans* from leaves and stems during lifting (most important point);
- stop tuber development;
- prevent virus transport from haulm to tubers (important for seed potatoes);
- promote skin formation;
- reduce the spread of storage diseases pre-harvest, including *P. infestans, T. cucumeris, Erwinia* spp.;
- eliminate leaf and stem material, thereby exposing the soil to drying to facilitate mechanical lifting.

Haulm killing is always recommended for crops destined for storage.

Available methods

At present, haulm killing is mainly carried out by chemical treatment, but mechanical methods are available (mainly flailing, but also cutting, crushing or pulling). It should be noted that there is a risk of spread of certain bacterial and fungal diseases by using methods such as flailing especially if the haulm is wet when this is carried out. Burning is also a method under development. It is good practice to use non-chemical methods as far as possible, but they rarely provide complete haulm kill alone and are usually carried out in sequence with chemical treatment. If the methods are combined, the mechanical treatment is applied first and the chemical treatment a few days later. The chemical treatment may then be made at reduced dose.

Chemicals for haulm killing

Diquat dibromide, glufosinate-ammonium, metoxuron are chemicals used for haulm-killing.

Diquat dibromide should not be applied in very dry soil conditions and glufosinate-ammonium in very wet soil conditions. Metoxuron is much slower acting, and is less suitable as a desiccant than other chemicals.

Sprout suppression

General

Ware potatoes for consumption or processing are often stored for long periods and tend to sprout. This reduces the weight and commercial value. Sprouting can be reduced by ensuring adequate storage conditions and by treating the tubers with a chemical sprout suppressant before or during storage.

Basic strategy

Potato stores should be kept at low temperature (2-5°C) by natural ventilation or mechanized cooling ensuring that relative humidity is not so low as to cause weight loss or bad wound healing. Damaged or diseased potatoes should be removed as the store is filled and the tubers should be dry and free from soil. For relatively short periods of storage, such conditions should be sufficient to suppress sprouting. If potatoes are to be stored for several months, it is good practice to treat with a chemical sprout suppressant. Potatoes stored for processing for fried products (chips, crisps) must be stored at a higher temperature (7-12°C); in this case, treatment with a chemical sprout suppressant will be needed in all cases.

The applications are made one or several times during the storage period, the first usually after a certain time in store (e.g. in November/December in northern Europe) and the last so as to respect the prescribed interval between treatment and consumption. Sprout suppression and disease control can be achieved at the same time. The products are applied as sprays (including ULV application), dusts, by misting through the ventilation system of the store, or as a smoke. Applications should ensure an even distribution to minimize the risk of increased residues in some tubers.

Main products

The main chemical sprout suppressants used are chlorpropham, d-carvon, tecnazene. Maleic hydrazide applied to the growing crop in the field will also help sprout suppression in the store.