◆ EPPO Standards ◆

GUIDELINES ON GOOD PLANT PROTECTION PRACTICE

ALLIUM CROPS

PP 2/4(2) 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 EUROPÉENNE ET MÉDITERRANÉENNE POUR LA PROTECTION DES PLANTES

PP 2/4(2) English

Guidelines on good plant protection practice

ALLIUM CROPS

Specific scope

This standard describes good plant protection practice for *Allium* crops.

Specific approval and amendment

First approved in September 1995.
Revision approved in September 2000.

This guideline on GPP for *Allium* crops 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.The guideline covers methods for controlling pests (including pathogens and weeds) of *Allium cepa* (onion), *A. cepa* var. *aggregatum* (= *A. cepa* var. *ascalonicum*) (shallot), *A. porrum* (leek), *A. schoenoprasum* (chives) and *A. sativum* (garlic). A broad range of pests has been found in the EPPO region on *Allium* crops. The guideline includes pests which occur in *Allium* spp. grown as vegetables under European conditions. Other *Allium* crops, e.g. crops for production of seed or planting material, are not covered but may be hosts of various pests common in vegetable *Allium.*

Allium vegetable crops may be grown from seed (onion, leek), transplanted from a seedbed (leek), grown from "modules" or "sets" i.e. small bulbs specially grown from seed (onion), or vegetatively propagated by division of bulbs (shallots, chives, garlic). Onions can be further subdivided according to the time and manner of harvesting: sown crops of appropriate cultivars may be harvested early as "salad onions" or as small bulbs for pickling; the main onion crop (whether grown from seed or sets) is harvested as fully grown bulbs. In terms of volume of commercial production, the main *Allium* vegetable crops grown in Europe are onions grown from seeds and leeks. The other crops are widely grown, but in smaller volumes.

Because the harvested product from an *Allium* vegetable crop is in general a bulb, which has grown in the soil, soil pests attacking the bulbs are particularly important. Crops should be planted in soil which is as far as possible free from *Allium* pests. The basis of GPP in *Allium* is, therefore, adequate crop rotation and good sanitation. Wastes from processing should not be returned to the soil. According to the manner of planting (see above), treatments can be applied to seeds, transplants, sets or bulbs, as well as to the soil or to the aerial parts of the plants. In general, treatment of the planting material is to be preferred. Growing crops should be examined for attacks by pests of the foliage and bulbs, and field treatments applied if infestation levels justify them. Control thresholds have been worked out for some *Allium* pests and it is GPP to use them if available. Cultivars with a degree of resistance are available for some pests. There is no adequate biological control of *Allium* pests at the present time.

The principal *Allium* pests considered are the following.

- damping-off diseases;
- *Stromatinia cepivorum* (white rot);
- *Botryotinia squamosa* (leaf blight, leaf rot);
- *Peronospora destructor* (downy mildew);
- *Phytophthora porri* (white tip);
- *Alternaria porri* (purple blotch);
- *Cladosporium* spp. (leaf blotch);
- *Puccinia allii* (rust);
- *Urocystis cepulae* (onion smut);
- *Botrytis aclada* (neck rot);
- *Colletotrichum dematium* f.sp. *circinans* (smudge);
- *Pyrenochaeta terrestris* (pink root);
- *Fusarium culmorum* (foot rot);
- *Fusarium oxysporum* f.sp. *cepae* (basal rot);
- *Aspergillus niger* (black mould);
- *Penicillium* spp. (blue mould);
- *Burkholderia gladioli* pv. *alliicola* (bacterial neck rot);
- virus diseases;
- *Thrips tabaci* (onion thrips);
- *Delia antiqua* (onion fly);
- *Ceutorhynchus suturalis* (onion weevil);
- *Delia platura, D. florilega* (bean seed flies);
- *Acrolepiopsis assectella* (leek moth);
- *Liriomyza* spp. (leafminers);
- aphids;
- caterpillars;
- *Ditylenchus dipsaci* (stem and bulb nematode);
- weeds.

Details are also given on plant growth regulators.

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.

Damping-off diseases

General

Various soil Oomycetes (*Pythium* spp., *Phytophthora* spp.) and bacteria cause pre- and post-emergence damping-off of *Allium*. The results are poor stands, often followed by yield losses.

Basic strategy

Damage by damping-off diseases can be minimized by preparing the *Allium* seedbed properly and sowing at the correct depth. The use of graded and fungicide-coated seeds should be considered.

Main fungicides

Seed treatments: hymexazol, mancozeb, thiram.

Dipping of bulbs: etridiazole, procymidone, thiram.

Soil treatments: propamocarb.

Stromatinia cepivorum **(white rot)**

General

White rot (caused by *Stromatinia cepivorum*, anamorph *Sclerotium cepivorum*) mainly damages onion, of different types (summer- and autumn-sown crops), and chives, at any stage of growth but can also be found in leek, shallots, garlic and various other *Liliaceae*. Garlic is as sensitive or perhaps more sensitive than onion. Attacked young plants may die before emergence or shortly afterwards. On infected older plants, the bottom of the bulb is covered with the white mycelium on which small black sclerotia can be found in large numbers. These plants start to wilt and never reach a normal bulb size. Most of them die during the growing season. The seedlings of spring-sown onions can be attacked during the spring and early summer and then again in the autumn as they reach maturity. The seedlings of autumn-sown onions can be attacked in the autumn and then again in the following spring, just before bulb development starts.

Basic strategy

Allium and related plants should not be grown in a close crop rotation. Even after 15 years or more without any *Allium* spp., viable sclerotia of the fungus may still be present to start a new epidemic. Sclerotia of the fungus may be disseminated by wind, and wind erosion should be avoided by appropriate wind breaks. Wastes from crop processing should never be returned to the field. Whenever possible, fields where alliums have previously been grown should be avoided. To make sure that the soil is not significantly infested with sclerotia of *S. cepivorum*, the soil should be tested by a reliable method. Healthy planting material should be used. Because the fungus is soil-borne, effective fungicide application is difficult. In German experiments, incorporation of fungicide into the soil layer where the onion plants have to be protected was greatly enhanced by watering crops after spraying with 5000-10000 L water per ha. Onion sets may be treated with fungicides by dipping before planting or as a soil drench 3-5 weeks after planting using 3000 to 5000 L water per ha. Use of dicarboximides has encountered problems through stimulation of soil microflora which rapidly degrades this group of fungicides.

Main fungicides

Soil drenches: iprodione, procymidone, vinclozolin.

Dipping: iprodione, tebuconazole (on onions and shallots), thiram, vinclozolin.

Seed treatments: iprodione, procymidone, vinclozolin.

Set treatments: iprodione, thiophanate-methyl.

Botryotinia squamosa **(leaf blight, leaf rot*)***

General

Botryotinia squamosa (anamorph *Botrytis squamosa*) causes leaf blight (or leaf rot) which occurs mainly during periods of wet weather or dew fall at temperatures between 12 and 25°C. Small (1-5 mm diameter) oval yellow to white spots can be observed. Heavily infected leaves die in 5-12 days. The fungus survives as sclerotia in the soil for 1 year or more. On the sclerotia, conidia form as the primary source of inoculum. In the spring, apothecia arise from the sclerotia and release ascospores. The related fungus *Botryotinia fuckeliana* (anamorph *Botrytis cinerea*) can be associated with collar rot of seedlings and leaf dieback, particularly in wet conditions or poor drainage situations.

Basic strategy

Crops should not be too densely sown. It is important to destroy plant debris from previous crops. If fungicide is used, spraying should start once plants reach a height of 25 cm, and continue at intervals of 7-10 days during periods of high risk. However, intervals can be greatly extended during periods of dry weather.

Differences in the susceptibility of onion cultivars have not been found. Seed treatment is also possible.

Main fungicides

Sprays: benomyl, carbendazim, chlorothalonil, dichlofluanid, iprodione, procymidone, thiabendazole, thiophanate-methyl, tolylfluanid, vinclozolin.

Seed treatments : benomyl, carbendazim, thiram.

***Peronospora destructor* (downy mildew)**

General

Peronospora destructor causes downy mildew of onions and shallots, but only rarely of leek and chives. Infected plants show curved leaves. On the long pale to yellow-coloured lesions, a greyish to purple mat of sporangiophores can be seen. During dry weather periods, the sporangia are not formed and only the pale greyish lesions can be observed. Leaves often die totally. Yield and quality of bulbs decline to a great extent. Cool wet weather (13-20°C; 80-95% RH) favours the development of the pathogen, which may survive as oospores in plant residues in the soil or as mycelium in sets. Under wet weather conditions, less than 1% of early infected plants are sufficient to infect the whole crop.

Basic strategy

Because the pathogen can survive in the soil as oospores for several years, good crop rotation is very important to minimize the risk of a soil-borne infection. At least 3 years without onions are necessary. Crops should not be sown too densely, nor overfertilized. Growing areas with long-lasting periods of wetness should be avoided. Spring-sown onions should be separated from autumn-sown crops. Onion sets can be treated with hot water or hot air, as in Norway and Finland (at 40°C; 48 h of hot air or 1 h of hot water). Because *P. destructor* needs very special conditions for its development, forecasting is possible. Epidemiologically important days are those with at least 11 h with more than 95% RH (at night) followed by another 6 h with RH values over 80%. RH can be measured with a normal meteorological station 2 m above ground, but 5% should be added to the RH values to adapt them to the conditions at the soil surface. Alternatively, occurrence of potato-blight periods may give some indication of risk. Chemical control can mostly not be avoided because of the above-mentioned basic infection level of 1% diseased plants. In growing areas where the disease occurs regularly, sprays should be applied preventively at 10- to 14-day intervals. After the outbreak of the disease, the fungicide may have to be applied weekly. In areas where there are outbreaks of downy mildew only from time to time, spraying should start as soon as the first symptoms are seen in the crop or there is any sign of the disease in the neighbourhood. In dry periods, sprays may be applied less frequently. Treatment of onion sets with fungicides is a possible method of controlling early infections.

Main fungicides

Sprays: benalaxyl, chlorothalonil, copper oxychloride, cymoxanil, dichlofluanid, dodine, mancozeb, maneb, metalaxyl, metiram, oxadixyl, propamocarb hydrochloride, tolylfluanid, zineb.

Dipping of sets: metalaxyl.

***Phytophthora porri* (white tip)**

General

White tip of leeks is caused by *Phytophthora porri*, which mainly attacks the crop from the end of July until September-December in humid conditions. Heavy rain, causing the soil to splash onto the foliage, can lead to serious infection. Onions are less often infected by the pathogen but seedling infection can occur. Leaves show white areas surrounded by a water-soaked zone. These areas become dry and papery. Lesions are most often restricted to leaf tips, but may also occur on the margins, centre or base of leaves.

Basic strategy

The pathogen survives as oospores in the soil and crop rotation is therefore the main method of control. Affected debris should not be returned to the land. Because the pathogen needs wet periods for establishment on the plant, crops should be grown in less humid areas and be irrigated only when really necessary. In many regions, the infection level rarely reaches the economic threshold, but yield losses up to 50% have been reported in some countries. Metalaxyl-resistant strains have been detected.

Main fungicides

Sprays: chlorothalonil, copper oxychloride, mancozeb, metalaxyl, propamocarb, thiram.

***Alternaria porri* (purple blotch)**

General

Purple blotch, caused by *Alternaria porri*, mainly affects leeks, but onions, chives, and shallots can also be infected. The first symptoms are small white lesions on the leaves. At RH over 70%, the typical purple blotches develop; they are elliptical, several centimetres long and surrounded by a yellowish border. Masses of spores can be found on these areas. Infected leaves are curled and may die. The disease is less prevalent and less troublesome in the cool temperate parts of Europe.

Basic strategy

Epidemics mainly arise from infected seeds or from residues in the soil. Accordingly, seed treatment and crop rotation are very important. The disease can be controlled by spraying fungicides but this becomes increasingly difficult as the crop approaches maturity.

Main fungicides

Sprays: chlorothalonil, iprodione, mancozeb.

***Cladosporium* spp. (leaf blotch)**

General

Different fungi cause leaf blotch in onions (*Mycosphaerella allii-cepae*, anamorph *Cladosporium allii-cepae*) and leeks (*Cladosporium allii*). The symptoms are ellipsoid lesions, up to 2.5×1.5 cm, with the long axis parallel to the leaf veins, initially yellow, later brown to blackish-brown due to the production of conidia.

Basic strategy

The fungi survive saprophytically on plant debris in the soil for a limited time, so infected debris may function as an inoculum source where *Allium* crops follow each other in close succession. Crop rotations of 2-3 years should be practised. Air-borne spread of spores occurs, so it is advisable to avoid planting new onion crops alongside existing ones. Prophylactic spraying of fungicides may help to control the disease and should start at first signs of infection.

Main fungicides

Sprays: chlorothalonil and propiconazole (leek only).

***Puccinia allii* (rust)**

General

Puccinia allii (syn. *P. porri*) is of economic importance on garlic, leeks and chives. It appears on leaves and stems as bright orange or somewhat brownish pustules along the veins. A severe infection may kill the leaves. The main period of development is during June and July (southern Europe) or August and September (northern Europe). Low temperatures in autumn/winter stop further development. The disease is more prevalent in dense and overfertilized crops.

Basic strategy

Before new crops are sown or planted, all overwintering leek crops should be harvested and debris removed. A long rotation time may prevent build-up of the fungus. Leek cultivars show differences in susceptibility, and local differences in cultivar susceptibility should be exploited. Volunteer plants should be destroyed. Application of fungicides should start at first signs of infection, and it is then very important that the fungicide reaches all parts of the leek plant. Forecasting systems to time treatments better are currently being evaluated.

Main fungicides

Sprays: bitertanol, chlorothalonil, cyproconazole, difenoconazole, fenpropimorph, hexaconazole, maneb, mancozeb, propiconazole, tebuconazole, triadimefon, triadimenol.

***Urocystis cepulae* (onion smut)**

General

Urocystis cepulae attacks all *Allium* species. Though generally uncommon, the disease can occasionally be serious on salad and bulb onions. Young plants are infected by teliospores which survive in the soil for up to 20 years. First symptoms are observed at the cotyledonary stage as dark, thickened areas which break open during further leaf development, showing characteristic dark spore masses. Plants may be killed in 3-4 weeks. Surviving plants show short, distorted leaves bearing lesions throughout their length. Bulb development is poor. The spores are spread by wind, rainfall, soil particles and plant residues, but there is no seed transmission. The optimum infection temperature is 13-22°C. Onion smut used to be a very minor disease but it has become more important since the area of autumn-sown onions has increased in recent years. Major problems now occur in spring- and autumn-sown onions.

Basic strategy

All sorts of dissemination of infected plants, plant residues or infested soil should be avoided to prevent spread of spores. Affected plants should be removed and burnt. Long rotations between *Allium* crops should be ensured. At present no fungicide is fully effective against this disease.

***Botrytis aclada* (neck rot)**

General

Neck rot of onions is caused by *Botrytis aclada* (syn. *B. allii*). *Botryotinia allii* (anamorph *Botrytis byssoidea*) also causes neck and bulb rot of alliums but is rarer than *Botrytis aclada* and *Botryotinia squamosa* (anamorph *Botrytis squamosa)*. In Europe, the disease is seed-borne. It is most severe under wet weather conditions or in areas with higher rainfall. Under these weather conditions, spores are produced in necrotic leaf tips that can cause a further spread of the disease in the crop. The main damage is to stored bulbs which develop the typical neck-rot symptoms, i.e. black sclerotia and grey mould on and in the base of the pseudostem (neck) tissues, 8-10 weeks after they have

been placed in store. The fungus invades seedlings from infected seeds and remains latent in the leaf tissues of the growing crop until the onions begin to ripen. It then invades the pseudostem and the upper bulb tissues. The fungus persists in soil for up to 2 years. Sclerotia serve as a second source of inoculum.

Basic strategy

Seed treatment with a systemic benzimidazole-based fungicide eradicates deep-seated infections in the seed tissues and controls the disease in crops grown from seed. Field sprays may slightly reduce spread of the disease. Where onions are planted as sets, treatment of sets is recommended. Under Nordic conditions, foliar sprays (2-3 times) starting end of June are common. Irrigation should be used very carefully to ensure fast ripening after the onions have reached optimal size. Excess nitrogen fertilization should be avoided because onions tend to get thicker necks that are easier invaded by the fungus. It is also important to destroy plant debris from previous crops. Onions should be lifted when approximately 30% green leaves remain and then field-dried for 7-10 days. If this is not possible, the bulbs should be dried at 25-35°C for 3-5 days before final storage. Maturing onion crops can also be harvested by cutting off their foliage, leaving a neck of about 80 mm, then taking directly into store where the bulbs are dried in bulk at 30°C in a rapid airflow.

Main fungicides

Seed treatments: benomyl, carbendazim, procymidone, thiabendazole, thiophanate-methyl, thiram, vinclozolin.

Dipping of sets: benomyl, carbendazim, iprodione, thiophanate-methyl.

Sprays: iprodione, carbendazim, chlorothalonil, dichlofluanid, mancozeb, procymidone, thiabendazole, thiophanate-methyl, tolylfluanid, vinclozolin.

***Colletotrichum dematium* f.sp. *circinans* (smudge)**

General

Smudge is mainly found in white onion cultivars. Dark green to black spots are observed on the outer layers of the bulb, usually in concentric rings. Spores appear on these spots under wet conditions. Chives prepared for forcing are also infected, and sometimes shallots and leeks. Infected tissues become yellow.

Basic strategy

Good crop rotation and post-harvest drying help to avoid the disease. Coloured cultivars of onions are generally more resistant. There is at present no effective fungicide available to control this disease.

***Pyrenochaeta terrestris* (pink rot)**

General

Pyrenochaeta terrestris causes pink coloration of the roots of all *Allium* species, especially in regions with warm climate or in seasons with higher temperatures. Seedlings are retarded in growth; older plants look stunted and show symptoms resembling drought stress. Bulb size is reduced. The fungus survives on onion root debris, saprophytically on roots of non-host plants (e.g. grasses) and as so-called resting bodies (microsclerotia), which have been found down to a soil depth of 45 cm.

Basic strategy

Onions and related plants should be grown in a broad crop rotation. Wastes from onion cleaning should never be returned to the field. There are differences in cultivar susceptibility, so one should grow the cultivars which are locally less susceptible. The soil can be disinfested by treatment with a broad-spectrum chemical, but this is not generally recommended as GPP. In hotter countries, soil solarization can be used to eliminate *P. terrestris* provided the soil is not infested to too great a depth. Sets can be treated by dipping in fungicide. Seed treatment is also possible.

Main fungicides

Dipping of sets: thiabendazole, thiram.

Soil treatments: dicloran.

Seed treatments: thiram.

***Fusarium culmorum* (foot rot)**

General

Leeks are attacked by *Fusarium culmorum* which invades young plants through wounds present at planting time. The plants look pale and weak in growth. Roots may rot and the stem base typically becomes red or pink, with rotting of leaf sheaths.

Basic strategy

Because damage caused by *F. culmorum* is enhanced by poor soil conditions, good preparation of the field before planting is important. As with other soil-borne diseases, good crop rotation is recommended, especially for seedbeds. The disease is usually patchy. It is more serious under warm moist conditions. Fungicides can be applied to the seeds, to seedlings in the seedbed or by dipping young plants at transplanting. Infection by *F. culmorum* is often associated with infestations of *Delia antiqua* and it is therefore important to control this pest.

Main fungicides

Seed treatments: benomyl, carbendazim, thiophanate-methyl.

Seedbed treatments: benomyl, carbendazim, thiophanate-methyl.

Dipping of young plants: benomyl, carbendazim, thiophanate-methyl.

Fusarium oxysporum f.sp. *cepae* (basal rot)

General

Fusarium basal rot has been found so far only in onions and garlic. Seedling emergence is poor. Plants look stunted and show basal rot. The infection starts at the bottom of the bulb and at the roots. Crops grown in warmer regions (>24°C) are more endangered. The fungus survives as chlamydospores. Transmission by seeds and sets may occur.

Basic strategy

Because the fungus survives for long periods as chlamydospores in the soil, good crop rotation is very important. In the warmer areas of Europe, soil solarization could help to control the disease. Fungicides are used as seed treatments or for dipping sets.

Main fungicides

Seed treatment: benomyl, mancozeb, thiabendazole, thiophanate-methyl, thiram.

Dipping of sets: benomyl, procymidone, thiophanate-methyl, thiram.

Aspergillus niger (black mould)

General

Aspergillus niger causes rotting in stored onions. It mainly occurs in warmer areas. Clusters of black spores form on and between the outer papery scales. *A. niger* survives in the soil and on plant debris. Infection takes place on the necks of onions during the ripening and senescence of the plants.

Basic strategy

Because *A. niger* is transmitted by seeds and sets, a pre-planting treatment may help to reduce infection levels. Irrigation should be stopped not less than 3 weeks before harvest. Damage should be avoided during lifting and loading into stores. As mentioned in the remarks on neck rot (*Botrytis aclada*), storage conditions should favour fast ripening at low RH (less than 80% RH). High temperatures (>30°C) for more than 10 days should be avoided. No fungicide is currently used against this disease.

Penicillium spp. (blue mould)

General

Various species of *Penicillium* cause blue mould of onions, garlic and shallots, especially under storage conditions. In garlic, *P. corymbiferum* causes damage of economic importance. As in the black mould complex, *Penicillium* spp. are favoured by relatively high storage temperature and RH. The fungi cause a blemish of the skin of stored bulbs; less often the tissue breaks down. In onions, the most dangerous temperature is around 9°C. However, humidity is a key factor in the development of *Penicillium* spp.

Basic strategy

Onions should not be wet when loaded into store and good humidity control should be ensured within stores. Prompt drying of the bulbs is of great value for the reduction of blue mould. Some garlic cultivars are less susceptible. Garlic bulbs can be treated with carbendazim or iprodione.

Main fungicides

Dipping: carbendazim, iprodione.

Burkholderia gladioli pv. *alliicola* (bacterial neck rot)

General

Bacterial neck rot, caused by *Burkholderia gladioli* pv. *alliicola*, occurs mainly on onions after physical damage, caused for example by a heavy infection of *Peronospora destructor*, storm, hail or wind. In wet years, the disease can be observed during the second part of the growing season. Other bacterial diseases affect *Allium* crops but are of relatively minor importance and require no special control measures: *Burkholderia cepacia* (onion), *Pseudomonas syringae* pv. *porri* (leek), *P. fluorescens* (garlic).

Basic strategy

All forms of physical damage should be avoided. In some countries, spraying is recommended after storm or hail as a protective measure. A 5-year crop rotation could help to eradicate the pathogen.

Main bactericides

Sprays: copper.

Viral diseases

General

The following viruses are important in *Allium* crops: *Onion yellow dwarf potyvirus* (OYDV), *Leek yellow stripe potyvirus* (LYSV), *Shallot latent carlavirus*

(SLV) and *Garlic latent carlavirus* (GLV). They are transmitted by various species of aphids, including *Myzus ascallonicus* and members of the *Aphis fabae* complex, in the non-persistent manner, which means that the aphids become viruliferous quickly but remain so only for a relatively short period.

Basic strategy

Nurseries for the production of onion sets should be inspected at regular intervals for possible virus-infected plants, which should be rogued immediately. Onion seeds should be produced in plots isolated from other crops of *Allium* spp. Some cultivars of certain vegetatively propagated *Allium* crops, such as garlic and shallot, are often totally infected by viruses and have accumulated several distinct viruses. In these crops, viruses may be controlled by the use of healthy planting material from which the viruses have been eradicated by meristem tip culture. Certification schemes are required to ensure that nuclear-stock plants are maintained under virus-free conditions and tested at regular intervals. Chemical control of aphid vectors is relatively ineffective at preventing viruses from entering the crop, because of the non-persistent manner of transmission, but could limit virus spread (see Aphids) within the crop.

***Thrips tabaci* (onion thrips)**

General

Thrips tabaci is one of the most important pests of all *Allium* crops. Infested plants become spotted and look silvery because of the feeding damage to the epidermal cell layer. The adverse influence on growth can be immense if infestation is severe and starts very early. Several generations per year can be observed with an infestation maximum from June to August. Dry, hot weather will speed thrips development. The mite *Aceria tulipae* causes similar damage on garlic.

Basic strategy

Due to the high risk of yield reduction or downgrading, control of *T. tabaci* is essential. Crop rotation and deep ploughing can help to reduce thrips populations. Intensive irrigation helps to reduce thrips attack. Fields should be sampled regularly during the growing season. The first appearance and flight of *T. tabaci* can be monitored with white-bowl water traps or blue or yellow sticky traps. Insecticide sprays should be applied as soon as the pest appears.

Main insecticides

Sprays: acephate, deltamethrin, ethiofencarb, fenitrothion, formetanate, malathion, methiocarb, methidathion, lambda-cyhalothrin, parathion-methyl, phosphamidon, quinalphos.

***Delia antiqua* (onion fly)**

General

The first sign of *Delia antiqua* damage is wilting. Leaves become yellowish and flaccid. The larvae mainly damage young plants, which can be completely destroyed. Onion sets are invaded from the base or side of the bulbs. Considerable damage can also occur when the larvae feed in mature bulbs, allowing bulb-rotting organisms to enter. In general, *D. antiqua* has 2-3 generations per year.

Basic strategy

Crop rotation and field sanitation reduce *D. antiqua* infestation. Infested waste onions and trimming from packing sheds should not be deposited on *Allium* fields or in their neighbourhood. Control of *D. antiqua* is essential. Treating seeds with insecticide is the most economical way of controlling larvae in areas where the pest occurs regularly. During the growing season, granules or liquid formulations of soil insecticides should be applied as bands along the rows. First appearance and flight of *D. antiqua* can be monitored with white- or blue-bowl water traps, or blue sticky traps. The sterile-male technique, which has been used in The Netherlands with success, may provide an alternative to insecticide treatment.

Main insecticides

Seed treatments: benfuracarb, diazinon, imidacloprid, isofenphos, tefluthrin.

Dipping of sets: diazinon.

Soil treatments: benfuracarb, carbofuran, chlorfenvinphos, chlorpyrifos, diazinon.

***Ceutorhynchus suturalis* (onion weevil)**

General

C. suturalis causes damage to overwintering seed onions and early planted set onions. The beetles appear in early April, feeding on the leaves. The larvae invade the leaf tissue. The pest has only one generation per year.

Basic strategy

The time of appearance of the adults and larval stage should be observed. Insecticide sprays should be applied protectively if the threshold of 2-4 weevils or larvae per leaf is exceeded. A 4-year crop rotation is recommended.

Main insecticides

Sprays: carbaryl, dimethoate, fenitrothion, deltamethrin, lambda-cyhalothrin, malathion, phosalone, quinalphos, tefluthrin.

Delia platura, *D. florilega* (bean seed flies)

General

The larvae of *Delia platura* and *D. florilega* damage germinating seeds and young seedlings especially in spring when the soil is cool and wet. These pests are usually a problem on soils with a high proportion of unrotted organic matter. Flies are attracted to soils recently cultivated. The damage occurs in the spring, often at the same time as that due to the first generation of *D. antiqua*, and the symptoms can readily be confused. Maggots should be carefully examined to distinguish the species involved. Later generations of bean seed flies usually occur alone and can cause serious damage to August-sown crops grown in rotations with other horticultural crops.

Basic strategy

All cultural methods which help rotting of the residues of the preceding crop minimize the chance of attracting bean seed flies. The seed treatments used to control *D. antiqua* will give some control of bean seed flies. Soil treatment with insecticides can be used to reduce larval numbers.

Main insecticides

Seed treatments: see *D. antiqua*.

Soil treatments: chlorpyrifos, diazinon, fonofos.

Acrolepiopsis assectella (leek moth)

General

The larvae of *Acrolepiopsis assectella* feed on leeks, onions and chives. Two to three generations may develop every year. The caterpillars live as miners at the beginning of their development, but later migrate to the core of the plant, feeding in a vertical cavity and destroying the young leaves. Attacked plants rot and die.

Basic strategy

A. assectella is one of the major pests of leek and chives. In some regions, it has to be controlled every season. For onions, however, attacks can generally be tolerated without causing any economic injury. Only in exceptional cases, when the level of attack is very high or when larvae feed on the bulbs, are control methods necessary. The flight period of the adults can be monitored by light and pheromone traps. Treatments should be applied on the basis of an infestation level estimated by field sampling. A preliminary threshold (5% of plants infested by larvae or showing fresh feeding mines) is available for leek. This is based on presence/absence sampling of 50 plants per field (up to 1 ha) and has been tested in several field experiments. Two applications are necessary. It is very important that the spray reaches the core of the plants. Young larvae can be controlled with biological products based on *Bacillus thuringiensis.*

Main insecticides

Sprays: *Bacillus thuringiensis*, cyfluthrin, deltamethrin, diazinon, lambda-cyhalothrin, parathion methyl, quinalphos, propoxur, tefluthrin.

Liriomyza spp. (leafminers)

General

Female leafminers make feeding punctures on the leaves of onion, while the young larvae form narrow mines inside the leaves. Young onion plants can be seriously damaged in dry weather. Onion leafminers, like *Liriomyza nietzkei*, usually have two generations (May-June and August until autumn). These pests are of no economic importance on leeks or chives.

Basic strategy

Insecticides should be applied when a damage threshold (e.g. 10% of leaves with feeding holes) has been reached.

Main insecticides

Sprays: abamectin, cyromazine, deltamethrin, diazinon, permethrin, propoxur.

Aphids

General

Several aphid species, especially *Myzus ascalonicus* and the *Aphis fabae* complex, are found on *Allium* crops. In general, aphid infestation results in no economic damage. Control will generally only be useful if there is a definite risk of virus spread (see Viral diseases).

Basic strategy

If chemical control is required, selective insecticides, preferably those which are least harmful to natural enemies of the aphids, should be used.

Main insecticides

Sprays: acephate, carbaryl, deltamethrin, diazinon, dichlorvos, dimethoate, ethiofencarb, fenitrothion, heptenophos, malathion, permethrin, pirimicarb (leeks only), pirimicarb, propoxur, pymetrozine.

Caterpillars

General

In leeks, caterpillars of various species of Lepidoptera, especially cutworms (larvae of *Noctuidae*), can attack the whole plant and cause considerable damage. Typical symptoms caused by young caterpillars are holes made by feeding. Older cutworms often feed at the stem of the plants, cutting the top from the tap roots close to the soil surface. The plants show wilting and poor growth. Damage caused by cutworms is noticed mainly during hot dry summers in light or medium soils.

Basic strategy

During field sampling for *Thrips tabaci* and *Acrolepiopsis assectella*, caterpillars are easily detected. Insecticides should be applied if a marked attack is observed. The flight activities of *Noctuidae* and other lepidopteran pests can be monitored by using pheromone traps. *Bacillus thuringiensis* can be used on first larval instars of cutworms.

Main insecticides

Sprays: chlorpyrifos, *Bacillus thuringiensis* var. *aizawai*, deltamethrin, diazinon, esfenvalerate, fenvalerate, lambda-cyhalothrin, permethrin, propoxur, trichlorfon.

Ditylenchus dipsaci (stem and bulb nematode)

General

The main nematode species damaging *Allium* crops is *Ditylenchus dipsaci*. This nematode invades germinating seeds, which may collapse. Later penetration causes deformed leaves and split stems. Multiplication of *D. dipsaci* within leaf tissue results in the typical bloat symptoms. The leaves become swollen and distorted.

Basic strategy

Because *D. dipsaci* attacks nearly 400 plant species, GPP involves good weed control and the removal of all infected *Allium* plants from the field. This should be combined with a long rotation of crops such as spinach, brassicaceous crops, lettuce or cereals (the choice of crop depends on the race of *D. dipsaci* present). Onion sets can be treated with warm water (3 h at 45°C) to kill the nematodes. For shallot sets, 43.5°C for 2 h and for garlic cloves 49°C for 20 min are needed. Onion seeds can be tested in the laboratory for stem nematode infestations. In some countries, granular nematicides are used in main crop onions and are applied in the seed furrow. Disinfection of infested fields is not recommended as GPP, for economic reasons and because the soil-disinfecting chemicals needed are often not registered.

Main nematicides

Sprays: oxamyl.

Seed treatments: dazomet, oxamyl.

Weeds

General

Allium crops generally do not completely cover the soil, so weeds can germinate throughout a long period. They are also poorly competitive through most of the growing season, and very sensitive to weed competition. Effective weed control is therefore of particular importance. Weeds cause more problems in *Allium* crops grown from seed than in transplanted crops or vegetatively propagated crops, because seedlings are more sensitive to herbicides and the development of the crop is slower.

Basic strategy

The basic strategy for weed control in *Allium* crops starts with the choice of the field and it is important to have a weed-free seedbed. The structure of the soil is important, and so is the preceding crop. Because perennial weeds are very difficult to control in *Allium* crops, they have to be controlled in the preceding crop. Cereals are the most suitable as preceding crops. After choice of the field, the preparation of the seedbed is very important in the strategy for weed control. The condition of the soil is important for optimal efficacy of soil-applied herbicides. The seedbed should be fine, crumbly and level. *Allium* crops which are sown early are particularly prone to weed competition as the crop will grow slowly, giving the weeds the advantage of a longer germination period.

The main methods of weed control in *Allium* are chemical, mechanical and thermal. The methods of mechanical control are harrowing and hoeing especially in leeks, while thermal control involves a "weed burner", used pre-emergence on small, just emerged, annual weeds. Chemical weed control is, however, the main method used in practice. The other methods may be used where possible, depending on weather and soil conditions. Herbicides are usually applied to the soil before weed emergence, because weed control is so important in *Allium* and post-emergence treatments are difficult to manage. The first herbicide treatment will usually be made after sowing or planting, but before weed emergence. It is very important that the crop should start under weed-free conditions. Certain contact herbicides can be used in *Allium* crops for post-emergence control of monocotyledonous and dicotyledonous weeds, but only on a hardened crop. Weed control systems based on reduced herbicide doses have been used in practice but require considerable management input.

Main herbicides

Herbicide use in *Allium* depends primarily on how the crop is planted and grown, and then on the range of weeds present in the crop. Accordingly, GPP is illustrated separately here for: main onion crops (grown from seeds to produce full-sized bulbs); shallots, onions grown from sets and garlic; salad and pickling onions (grown from seeds and harvested relatively early); leek; chives.

Main onion crops (grown from seeds to produce full-sized bulbs)

For the control of annual weeds, herbicides are mainly applied after sowing but before emergence of the crop, either directly after sowing (benfluralin, pendimethalin, propachlor) or at least 1 or 2 days before emergence (diquat, glufosinate-ammonium, glyphosate, glyphosate-trimesium). Annual weeds can also be controlled on weed-free soil by a post-emergence application of chlorpropham or propachlor, provided the crop has reached at least 6 cm. Other post-emergence herbicides which can be used on onions are chloridazon, clopyralid, cyanazine, fluroxypyr, ioxynil, linuron, propham, pyridate. For the control of monocotyledonous weeds herbicides can be applied post-emergence : cycloxydim, fluazifop-P-butyl, oxyfluorfen, propaquizafop, quizalofop-p-ethyl or sethoxydim

Shallots, garlic and onions (grown from sets)

For the control of annual weeds, herbicides are mainly applied within 2 weeks after planting, on weed-free soil. They include chlorpropham, pendimethalin and propachlor. Until shortly before emergence, the following herbicides may be used on small weeds: cyanazine, chloridazon, diquat. Post-emergence herbicides are essentially the same as for main onion crops (see above). For the control of mono-cotyledonous weeds, several herbicides can be applied post-emergence, e.g. cycloxydim (not in shallots), fluazifop-P-butyl or sethoxydim.

Salad and pickling onions

For the control of annual weeds, herbicides are mainly applied after sowing but at least 7 days before emergence, on weed-free soil : propachlor, pendimethalin. The following can even be applied up to 1 or 2 days before emergence: glufosinate-ammonium, glyphosate, glyphosate-trimesium. Small weeds can be controlled until shortly before emergence by the contact herbicide diquat. Annual weeds can also be controlled on weed-free soil, or when small, by a post-emergence application of propachlor, provided the crop has reached at least 6 cm. Similarly, bentazone, ioxynil and linuron can be used provided the crop has reached at least 10-15 cm. For the control of monocotyledonous weeds, the same herbicides can be applied as for shallots (see above).

Leeks

For the control of annual weeds in sown leeks, herbicides are mainly applied directly after sowing but before emergence : propachlor, chloridazon, pendimethalin. Chlorpropham can be applied pre-emergence or else post-emergence, on weed-free soil, until the crop reaches 4-8 cm. These herbicides and also metazachlor can be used on transplanted leeks, shortly after planting or after earthing up. Small weeds can be controlled directly with chloridazon, cyanazine, ioxynil, monolinuron, prometryn, pyridate. For the control of monocotyledonous weeds, several herbicides can be applied post-emergence, e.g. clopyralid, cycloxydim, fluazifop-P-butyl, haloxyfop, ioxynil, linuron, monolinuron.

Chives

For the control of annual weeds, propachlor or pendimethalin can be used by pre-emergence application, shortly after sowing, on weed-free soil. In a first-year crop of at least 6 cm, bentazone can be used post-emergence. Herbicides used for monocoty-ledonous weeds in onions may generally be used in chives.

Plant growth regulators

General

The only plant growth regulators used in *Allium* crops are sprout suppressants for prevention of green shoots from stored bulbs. Suppressants are widely used in crops of bulb onions and shallots prior to winter storage. Most onions which are intended for marketing from store from January onwards will be treated. In recent years there has, however, been a move to reduce their use because of residue problems. Cold-storage techniques, with or without modified atmosphere control, are to a limited extent replacing the use of suppressants.

Basic strategy

There are marked varietal differences in onions for suitability for storage. Only suitable cultivars should be used. The plants are treated in the field prior to harvest, while still with green foliage. The growth stage of application is critical as under or over-maturity of the onion will reduce the effectiveness of treatments. Salad onions, chives and leeks are not treated.

Main sprout suppressants

Main onion crops (grown from seed and sets), garlic and shallots: maleic hydrazide.