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GUIDELINES ON GOOD PLANT PROTECTION PRACTICE

MUSHROOMS

PP 2/20(1) English

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APPROVAL

EPPO Standards are approved by EPPO Council. The date of approval appears in each individual standard.

REVIEW

EPPO Standards are subject to periodic review and amendment. The next review date for this set of EPPO Standards is decided by the EPPO Working Party on Plant Protection Products.

AMENDMENT RECORD

Amendments will be issued as necessary, numbered and dated. The dates of amendment appear in each individual standard (as appropriate).

DISTRIBUTION

EPPO Standards are distributed by the EPPO Secretariat to all EPPO Member Governments. Copies are available to any interested person under particular conditions upon request to the EPPO Secretariat.

SCOPE

EPPO guidelines on good plant protection practice (GPP) are intended to be used by National Plant Protection Organizations, in their capacity as authorities responsible for regulation of, and advisory services related to, the use of plant protection products.

REFERENCES

All EPPO guidelines on good plant protection practice refer to the following general guideline:

OEPP/EPPO (1994) EPPO Standard PP 2/1(1) Guideline on good plant protection practice: principles of good plant protection practice. *Bulletin OEPP/EPPO Bulletin* **24**, 233-240.

OUTLINE OF REQUIREMENTS

For each major crop of the EPPO region, EPPO guidelines on good plant protection practice (GPP) cover methods for controlling pests (including pathogens and weeds). The main pests of the crop in all parts of the EPPO region are considered. For each, details are given on biology and development, appropriate control strategies are described, and, if relevant, examples of active substances which can be used for chemical control are mentioned.

EUROPEAN AND MEDITERRANEAN PLANT PROTECTION ORGANIZATION
ORGANISATION EUROPÉENNE ET MÉDITERRANÉENNE POUR LA PROTECTION DES PLANTES

PP 2/20(1) English

Guidelines on good plant protection practice

MUSHROOMS

Specific scope

This standard describes good plant protection practice for mushroom-growing.

Specific approval and amendment

First approved in September 2000.

This guideline on GPP for mushroom 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) of cultivated mushrooms.

Cultivated mushrooms are an important food resource and the most valuable protected crop grown in many European countries. The most widely grown edible mushroom in Europe is *Agaricus bisporus*. Several other species are also now cultivated, e.g. *Pleurotus ostreatus* (oyster mushroom) and *Lentinula edodes* (shii-take). The latter is widely grown in the Far East and its production may develop in Europe. However, this guideline concentrates exclusively on *A. bisporus*, because the substrates and cultivation technology of the other species are quite different and their volume of production in Europe is currently small.

A. bisporus is cultivated on a specially prepared medium. Its preparation typically involves a three-stage process such as the following. The growing medium is initially prepared from a mixture mainly of cereal straw and horse, pig and/or poultry manure, aerated and watered for 8 days (pre-treatment). After the incorporation of additional components to increase nitrogen provision and improve structure, the stack undergoes further aeration and watering for a period of 7 days to promote composting (Phase I). The next stage in the process (Phase II) takes place in controlled conditions, allowing temperatures to rise to 60°C for 8-12 h before cooling to 48°C for conditioning. Phase II takes about 6 days, producing a friable material. This "peak-heat", or pasteurization, process serves to release and convert ammonia to amino acids, as well as reducing populations or activity of harmful organisms.

On completion of Phase II, the growing medium is "spawned" i.e. mixed with "spawn" (a culture of mycelium-inoculated grain), and placed in trays, boxes, bags or beds. These containers are kept in the housing unit which may consist of purpose-built sheds, converted buildings or in some cases caves or tunnels. Optimum conditions for mycelial growth ("spawn run") are maintained for approximately 2 weeks, holding a temperature of 25°C and CO_2 concentration of 5000-7000 ppm. The growing medium is then covered with a layer of a nutrient-poor "casing" material (usually moss-peat and chalk) as a stress stimulant to induce fruiting. The first mushrooms are harvested 18-21 days later with further fruiting periods ("flushes") at 7- to 14-day intervals.

Use of plant protection products in mushroom culture is limited. Problems of phytotoxicity and pest resistance are of particular significance. In the past, mushroom growers depended more on chemical pesticides to manage pests, but now they employ specific insect growth regulators and rely on physical, cultural, and biological controls.

Disease control depends largely on good hygiene practice and all requirements should be meticulously and consistently satisfied. Preventive measures, when applied efficiently, can keep pest populations to a minimum. Satisfactory mushroom production depends on many factors, e.g. farm layout and cleanliness (ventilation, air filters, run-off water, which often disseminates spores of pathogens); reliable personnel (human agency is an important factor in pest dissemination, either directly or indirectly); equipment and its disinfection; procedures in crop preparation, cropping and post-cropping; the right choice, and use according to the label, of disinfectant. It is essential to have quality systems for compost production, and to use only high-quality compost, which has been correctly pasteurized (at proper temperature) before use, then pasteurized again after production. One of the most common sources of pathogens is contamination of the casing, which should therefore be stored in a covered area well away from sources of contamination. If it becomes contaminated, it can be pasteurized (60-70°C for 30 min), treated with 1% formalin (27 L m^{-3} casing) or destroyed.

Mushroom crops should be regularly inspected for pests (including pathogens). For example, black-light traps can be used to attract insects. Outbreaks of pests should be treated immediately. Diseased material should be removed with care or isolated *in situ*. At the end of cropping, all surfaces should be sterilized, which is often done with steam, the whole crop and

structure being heated to approximately 70°C for several hours. This process is known as "cook-out". If outbreaks of pathogens have occurred, cooking out may be needed at even higher temperatures or for longer periods.

Mushroom crops can be directly attacked by fungi, bacteria, viruses, insects, mites and nematodes. Weed moulds, i.e. other fungi which act as competitors or antagonists of the mushrooms, are frequently responsible for crop loss, so this guideline covers them as well.

There are also non-pathogenic disorders that can affect crops and may lead to a very poor yield. The fruiting bodies are deformed or show various anomalies in development (drippy gill, hard gill, cock's comb, stroma). These disorders may be confused with pest symptoms. They arise essentially from faulty growing conditions: excessive fluctuations in temperature or humidity, poor ventilation, toxicity of chemicals used for hygienic purposes or for treatment of wood. This guideline does not consider them further.

The principal mushroom pests considered are the following:

- *Mycogone perniciosa* (wet bubble);
- *Verticillium fungicola* (dry bubble);
- *Hypomyces rosellus* (cobweb);
- *Trichoderma* spp. (green mould);
- *Diehliomyces microsporus* (false truffle);
- weed moulds;
- *Pseudomonas tolaasii* (bacterial blotch or brown blotch);
- *Pseudomonas* sp. (mummy disease);
- viruses;
- phorid flies;
- sciarid flies;
- cecidomyiid midges;
- mites;
- nematodes.

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.

Mycogone perniciosa (wet bubble)

General

Mushrooms affected by *Mycogone perniciosa* are misshapen, with very swollen stems and caps. Their surface shows a brown-beige discoloration, and may ooze reddish-brown droplets of liquid. A specific fusty smell can be recognized in the mushroom house. Spread of the disease takes place by spores and mycelium, which infect the developing fruiting bodies as they grow through the casing. Infection most commonly starts from infected casing, and is then spread by phorid and sciarid flies, dust in air ducts, workers, picking trays and equipment. Water run-off is also one of the main means of spread. Wet bubble is a serious disease of mushrooms.

Basic strategy

Greatest attention should be paid to hygiene. Phorid and sciarid flies should be controlled. The casing may, before use, be treated with formalin, then covered with plastic material for 3 days. Early recognition of the presence of the disease is important for effective control. If the infection is serious, fungicides may be mixed with the casing or sprayed on the surface of the casing. In general, there have been no problems with resistance, but carbendazim may be rapidly broken down by the natural microflora of the mushroom bed. After production, the mushroom house should be properly cooked out.

Main fungicides

Sprays: carbendazim, chlorothalonil, prochloraz manganese.

Verticillium fungicola (dry bubble)

General

Dry bubble (*Verticillium fungicola* var. *fungicola*) occurs only on *Agaricus bisporus* and can cause considerable damage and yield loss. The fungus does not grow in the compost, but comes into the mushroom house with the casing, flies, dust etc., and infects the developing fruiting bodies as they emerge. The mushrooms are discoloured, cracked or shrivelled, and at a later stage may have a very crooked and swollen stem. They are unsaleable. The dry leathery state of the mushrooms, without any ooze of droplets and without an unpleasant smell, distinguishes dry bubble from wet bubble in most cases (see above).

Basic strategy

Good hygiene during picking, control of mites and flies, and efficient removal of finished crops are essential preventive control measures. If the disease nevertheless develops, fungicides may be sprayed on the developing crop. Some isolates show decreased

sensitivity to prochloraz manganese and almost all are resistant to carbendazim.

Main fungicides

Sprays : chlorothalonil, prochloraz manganese.

***Hypomyces rosellus* (cobweb)**

General

The presence of *Hypomyces rosellus* (anamorph *Dactylium dendroides*) can be recognized by the appearance of a white cobweb of mould covering not only the mushroom but also the surrounding casing. This cottony, wool-like mycelium sometimes turns pink or red and affected mushrooms turn brown, and eventually die. The fungus is a soil inhabitant, and probably enters the mushroom house with soil dust. Once present, it produces abundant spores which are spread rapidly by air movement, watersplash and excess water run-off. It typically appears only on the later flushes.

Basic strategy

Strict hygiene will prevent epidemic attacks. The fungus should be excluded from the mushroom house by ensuring that no soil contaminates the compost or casing. Spread of the spores should be prevented as far as possible. Care should be taken to remove infected stumps of picked mushrooms. They should not be touched. To minimize the spread of spores, wet tissue is applied to the infected area and covered with salt to isolate/disinfect the area. The compost layer before delivery of the casing and the casing soil itself after casing may be treated with 2% formalin solution. Formalin may also be applied to affected areas of crop. In case of serious infection, a fungicide spray may be used.

Problems with resistance

Some isolates of *H. rosellus* are resistant to thiabendazole, and others to benzimidazole fungicides generally. Many show decreased sensitivity to prochloraz manganese.

Main fungicides

Sprays: benomyl, carbendazim, prochloraz manganese, thiophanate-methyl.

***Trichoderma* spp. (green mould)**

General

Trichoderma spp. such as *T. viride* and *T. koningi* have long been known as "green moulds", generally considered to be weed moulds (see below). *Trichoderma viride* grows as green mycelium on the compost or casing, or on dead mushrooms, or on the boxes. *Trichoderma koningi* grows as a cottony mycelium over the developing mushrooms and can cause a wet rot. Both these fungi can cause a relatively unimportant spotting of the mushroom caps. However, a more serious disease, which appeared in the 1980s, is caused by a strain of *T. harzianum*. This grows in the compost, where it parasitizes the mushroom mycelium and can cause serious losses. Red pepper mites (*Pygmephorus sellnicki*, see below) are particularly associated with its presence.

Basic strategy

Proper pasteurization of the compost and good general hygiene are the main measures for control of *Trichoderma* spp. No fungicides are recommended specifically against these moulds.

***Diehliomyces microsporus* (false truffle)**

General

This ascomycete, which normally occurs in soil, is pathogenic to the mycelium of *A. bisporus* in the compost. It occurs mainly during the summer months because it has a higher optimum temperature (30°C) for spore germination. It may completely replace the mushroom mycelium in the compost, in which case there is no crop. Its yellowish-white mycelium is initially difficult to distinguish from mushroom mycelium but if it is present a chlorine-type smell can often be found in the mushroom house. The compost becomes darker and wetter than normal. Crinkled, walnut-like bodies (the false truffle ascocarps of *D. microspora*) appear in the compost and later also on the surface of the casing. If the infection occurs later, mushrooms growing at the edge of affected patch turn yellow and die. Further mushroom yield is greatly reduced.

Basic strategy

The main aim is, by good hygiene, to exclude the pathogen from the mushroom house or, if it occurs, to eliminate it. Contamination of compost and casing by soil should be avoided. The compost should initially be carefully pasteurized. Air filters should be used. At the end of the crop, the mushroom house should be very well cooked out. If the disease nevertheless occurs, the temperature in the "spawn run" should be reduced to 20°C to suppress it. Infected small patches on the casing can be treated with 2% formalin solution and covered with plastic sheeting after treatment. There is no specific fungicide treatment. A longer cook-out at a higher temperature may finally be needed.

Weed moulds

General

Weed moulds grow in the compost and may affect the growth of mushroom mycelium by direct antagonism or by competing for nutrients. In either case, the amount of compost available to the mushroom is decreased and the yield is proportionally reduced. In some cases, the presence of weed moulds indicates that the medium is unsuitable for mushroom growth and may point to errors in compost preparation.

Chaetomium spp. occur in the case of poor quality of compost. Factors such as pasteurization at too high a temperature, great temperature fluctuations or serious lack of oxygen (below 16%) lead to a high ammonia (NH_3) content, which favours the appearance of the ammonia-tolerant *Chaetomium olivaceum* (and also *C. globosum*). About 10 days after spawning, greyish-white mycelium appears in the compost, followed by an olive-green fuzz of woolly perithecia on the straw. The fungus gives a characteristic musty smell. Mushroom yield can be adversely affected.

Scopulariopsis fimicola (white plaster mould) occurs in wet, greasy compost which has not had enough oxygen during fermentation and is therefore under-composted, whereas *Papulaspora byssina* (brown plaster mould) is an indicator of excessively wet compost. The compost remains sticky and dark in colour. These weed moulds are most often observed in lower beds. *S. fimicola* produces dense white patches of mycelial growth, so that the surface of the casing or compost appears to be densely covered with flour. Colonies of *P. byssina* are initially white but at maturity they turn into a granular cinnamon-coloured mass. Both pathogens produce large number of spores and disseminate easily. No mushroom mycelium grows on places where plaster mould occurs.

Sporendonema purpurascens (lipstick mould) is a common weed mould, growing in the compost and casing and producing white mycelial growth, which turns bright pink and later powdery carmine red. It is spread via spores during watering or picking. It causes minor reductions of yield.

Basic strategy

Control with fungicides is not possible. The only practical measure is prevention: the peak heating of the compost should be at the right temperature, aeration should be adequate and the compost should not be too wet. Spread of the plaster moulds can be reduced by good general hygiene. If *Chaetomium* spp. or *Verticillium* spp. occur, it is very important that cooking out should be carried out properly after harvest (compost temperature 12 h at 70°C).

Pseudomonas tolaasii (bacterial blotch or brown blotch)

General

Bacterial blotch is one of the most common and damaging diseases of the mushroom crop. The young fruiting bodies, and later the caps, are colonized by *Pseudomonas tolaasii* as they develop. *P. tolaasii* is favoured by temperature over 20°C and particularly by wet conditions, e.g. when, after watering, the mushrooms are not dry within 2-3 h. The first symptoms are light brown patches on the caps. A toxin produced by the pathogen causes lysis of the mushroom cells, releasing enzymes which cause a number of cells to die, limiting infection to a surface lesion. The pathogen is generally present wherever mushrooms grow, but only causes damaging symptoms when conditions are favourable. In places where mushrooms stay wet for long periods, the initial pale blotches may turn dark brown and spread over the whole surface of the mushroom cap. The stems can also be affected. Blotch symptoms can also develop after harvesting, especially if the mushrooms are stored at a fluctuating temperature which allows water condensation on their surface.

Basic strategy

Temperature and RH should be controlled to ensure that water droplets or moisture films on mushrooms dry up within 2-3 h. Good ventilation should be ensured after watering. Chlorine at 150 ppm, applied every time the casing is watered, helps to keep the incidence down.

Pseudomonas sp. (mummy disease)

General

Mummy disease is relatively uncommon, but can be very damaging. It is thought to be due to an internal infection of the mycelium by a bacterium (*Pseudomonas* sp.). Infected fruiting bodies turn greyish in colour and open prematurely. With further growth, the stalk becomes malformed, pale brown in colour with asymmetric tilting of the cap. The base of the stalk may be swollen and may develop rhizomorphs. The mushrooms become tough, and spongy or leathery. During picking, they feel gritty and a large clump of casing remains clinging to the base. If the stem is cut through, a cracking noise is heard and the cut face is reddish-brown. Infected mushrooms do not decay, but dry and wither. The disease is spread by living infected mushroom mycelium, and not by spores. It can spread through an affected bed at a rate of 10-30 cm per day, but not from one bed to another.

Basic strategy

Since the bacterial growth is intracellular, control is difficult. There is no direct chemical treatment. Spread can be limited by preventing mycelial contact between trays or by isolating affected beds or patches (by digging a 20-cm wide channel about 2 m long on either side of suspect patch). Overwatering should be avoided. Where the disease occurs, all compost and casing material should immediately be removed, and the floor and side planks treated with formalin. The bacterium may persist in mushroom mycelium in wood, so careful cooking out at the end of growing cycle is essential (70°C for 12 h). Mummy disease may be associated with a particular source of spawn. If it persists, it is advisable to change to a different spawn.

Viruses

General

In cultivation of *A. bisporus*, one virus disease is known. This disease, known simply as virus disease, die-back or La France disease (because it was first found on the farm of the La France brothers in USA in 1948), is extremely infectious and may cause great damage. The degree to which die-back becomes apparent in a crop depends on the time of the infection, the quantity of diseased spores and the virus concentration. There are a multitude of symptoms, the only common factor being yield loss. Some of the symptoms are: the cap and stem of infected mushroom are almost in one piece ("drumstick"); the stems are long and in many cases somewhat bent; the caps are small and flat; the fruiting bodies are greyish-white to brown, loose in the casing and develop slowly and open quickly.

Basic strategy

The disease is transmitted by infected spores and mycelium. The spores are transmitted by the air flow (ventilation air or wind), and dirty containers in the case of inadequate cooking out. At the end of the production cycle, the hall should be cooked out at 70°C for 12 h; after sowing the spawn, paper sheets should be put on the compost and moistened twice a week with 0.5% formalin solution (the paper should be removed a day before casing); air vents and air supply ducts should be fitted with 2-µm filters during the entire growing period. Filters should be disinfected. If die-back is found at the farm, diseased fruiting bodies should be removed and a 2% formalin solution sprayed. If the disease occurs on a serious scale, the crop should be cooked out immediately. In this case, a virus-resistant variety of mushroom should be used for some time. Mushroom viruses can be detected by IEM (immunosorbent electron microscopy) and double-stranded RNA analysis (dsRNA).

Phorid flies

General

Phorid flies, also called humpback flies or scuttle flies, are small (< 2 mm), brownish-black flies that move quickly. They are easily recognized by their humpbacked appearance, short wings, and very short, inconspicuous antennae. Three species are known as mushroom pests: *Megaselia halterata, Megaselia nigra* and *Megaselia bovista*. Damage is caused by the larvae, which feed on fungal mycelium and pupate in the compost. The larvae and pupae are not so easy to observe as the adults. Early infestation, during spawning, is the most dangerous and heavy populations of larvae can totally destroy mycelium so that few mushrooms develop. The larvae of *M. halterata* (the commonest species) feed only on the mycelium in the compost and casing but do not enter the mushroom, whereas those of *M. nigra* develop from eggs that are laid on the developing mushroom and bore into the stalks and caps of the mushrooms. The time from egg-laying to adult emergence is 15 days at 24°C (50 or 24 days at 15 and 20°C, respectively). Adults can cause indirect damage as vectors of mites, nematodes, fungal diseases and bacteria.

Basic strategy

Preventive measures are most important. Adults are attracted by the smell of growing mycelium so strict measures should be taken for at least 4 weeks after spawning. Used compost should be taken right away from the mushroom house, and all waste should be destroyed. During end-of-crop pasteurization, the temperature should be held at 58°C for 12-18 h or at 70°C for 8-12 h, which will kill phorid larvae. The ventilation system should be properly protected by fly-proof screens at inlets and outlets; screens or dust filters are not generally sufficient. Infestation is easily detectable because light attracts the adult flies. Blacklight traps (fluorescent light) can be used for monitoring. If necessary, insecticide sprays may be applied several times, especially after spawning, during casing, 10 days after casing, a week later and between flushes up to 2 days before harvesting.

Main insecticides

Sprays: chlorfenvinphos, deltamethrin, diazinon, dichlorvos, nicotine, permethrin, resmethrin, sulfotep, and also insect growth regulators: cyromazine, diflubenzuron, methoprene.

Sciarid flies

General

Sciarid flies are mosquito-like (2 mm long), with long, upright antennae, black head and thorax and dark brown abdomen. They occur in nature on decaying materials (leaves, fungi, wood, manure etc.). The

females lay eggs in the compost or casing. Larvae grow up to 5 mm in length and are shiny white with a dark head. They feed on compost as well as mycelium and will also burrow into mushrooms at all stages of production. Adults sciarids may also act as vectors for fungal diseases (see *Mycogone perniciosa*, *Verticillium fungicola*), bacterial diseases, mites and nematodes.

The commonest species in Europe are *Lycoriella solani*, *Lycoriella auripila*, *L. castanescens* and *L. ingenua. Bradysia* spp. also occasionally occur.

Basic strategy

Control methods for sciarids are the same as for phorid flies, but biological control with the parasitic nematode *Steinernema feltiae* is also possible.

Main insecticides

As for phorid flies.

Cecidomyiid midges

General

Cecidomyiid midges (e.g. *Heteropeza pygmaea*, *Mycophila speyeri*, *Mycophila barnesi*) are minute dark brown insects (< 1 mm), which very occasionally cause problems in mushroom growing. The larvae (up to 2 mm in length and white, yellow or orange in colour) live in the compost, eating the mycelium and also ascending the exterior of the mushroom stalks and caps. Larvae are usually produced paedogenetically (i.e. without mating). When the compost is wet, the larvae remain in it; when it is dry, they climb to the surface and aggregate at the edges of beds or boxes. They often fall to the floor where they can easily be transferred on different utensils and on the clothes and shoes of the workers. Initial infestation is from contaminated peat.

Basic strategy

Phenolic or cresylic disinfectants can be effective against larvae concealed in structures. Strict hygiene, especially in peat storage, is required.

Main insecticides

As for phorid flies. Some larvicides (not IGRs) control *Mycophila* spp.

Mites

General

The tarsonemid mite *Tarsonemus myceliophagus* can be a serious pest of mushroom culture when present in very large numbers. The adults are very small (< 0.2 mm), having a relatively hard and shiny integument. The life cycle requires only 11 days at 24°C and 12 days at 16°C. Significant damage occurs when the initial infestation takes place soon after spawning. This mite feeds on all parts of the mushroom. Tyroglyphid mites such as *Tyrophagus lintneri* and *Caloglyphus mycophagus* may be harmful to mushrooms already damaged by other pests. Their body is 1-1.5 mm long with long hairs and they move slowly.

Many other mites may occur in mushroom beds and their presence in high numbers indicates poor husbandry. *Pygmephorus* spp. (red pepper mites) are very small (0.25 mm) and feed on moulds. If they are numerous, they can be the cause for crop rejection, due to their bright colour. *Linnopodes antennaepes* has very long legs, moves fast and feeds on mites and nematodes. *Histiostoma feroniarum*, which is saprophagous, sometimes occurs in large numbers on the caps of mushrooms. Predatory mites (e.g. species of the genera *Arctoseius*, *Dendrolaelaps* and *Macrocheles*) might also be found, and indicate that their prey (mites, nematodes, insects) are present.

Basic strategy

Good hygiene should be maintained in the mushroom houses, with use of appropriate air filters. Flies should be controlled, because they can be vectors of mites. Control of weed moulds is also important, because they are a preferred food for mites. Pasteurization at 58-60°C for 6-8 h should destroy mites in the compost. Casing should be disinfected at 65-70°C for 3 h. If mites nevertheless occur, dichlorvos fogs may be applied between flushes. From spawning until 10 days after casing, the acaricide dicofol may be used.

Main acaricides

Sprays: dicofol.

Fogs: dichlorvos.

Nematodes

General

Nematodes are present in almost all mushroom houses because both compost and casing material provide favourable environments where they can feed on decaying organic matter or on mycelium. Mycophagous species (*Ditylenchus myceliophagus*, *Aphelenchoides composticola*, *A. avenae*, etc.) feed exclusively on fungi and are the most important nematode parasites of *A. bisporus*. However, saprophagous rhabditids (*Caenorhabditis elegans* and others) can also develop abundantly at infestation sites.

Virtually all growers of *A. bisporus* experience nematode infestations because the mushrooms are grown in substrates that invariably contain an indigenous nematode fauna prior to inoculation with mycelium. These nematodes are generally not a problem in mushroom houses where good hygiene is

maintained and the production cycle is not more than 8 weeks. Under optimal conditions, however, these nematodes can multiply very quickly, producing extremely high populations in a short time and causing cropping problems.

The first sign of infestation by mycophagous species is crop reduction, usually in patches. The surface compost sinks and the underlying substrate becomes soggy and foul-smelling.

Most *Pleurotus* spp. (oyster mushrooms) are resistant to attack by mycophagous nematodes and some are even able to parasitize saprophagous nematodes and use them as a food source.

Basic strategy

The best way of controlling nematodes is to ensure strong mushroom mycelial growth in the compost by efficient pasteurization and conditioning of the compost (55-60°C for up to 8 h). *Ditylenchus myceliophagus* may, however, survive in an anhydrobiotic state within the wood of trays in the absence of mushroom crops, and be resistant to heat treatment. In such circumstances, it may be necessary to wet trays before pasteurization. The casing may also be disinfected (65°C for 3 h), but this treatment may be harmful to the sporophore-inducing microflora. At the end of the production cycle, the halls should be well cooked out. Heavily infested crops should be removed and destroyed.

Great attention should be paid to general hygiene in and around the mushroom house and to the control of potential vectors (particularly flies). Formalin can be used to clean up peat and also as a general disinfectant of woodwork and equipment. Draining water may also spread nematodes. Ventilation ducts should be screened and seals maintained around doors. Newly-spawned crops may be protected with aerosols, smokes or fogs of pyrethrins or other volatile insecticides.

Nematode-trapping fungi such as *Arthrobotrys robusta* and *Arthrobotrys oligospora* have been developed as biological control agents for mycophagous nematodes. When added to the compost at spawning, even in the absence of nematodes, they may stimulate mycelial growth and improve cropping.