Factsheet 10/07

Ornamental crops

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Guidelines on nursery hygiene for outdoor and protected ornamental crops

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Preventing potentially harmful micro-organisms, pests and weeds from entering a nursery and minimising their spread will reduce crop wastage and help keep associated labour and pesticide costs down. This factsheet contains information on the key areas of good practice for maintaining a high standard of nursery hygiene.

Action points

Glasshouse structure, machinery and equipment

- Clean and disinfect regularly.
- Avoid taking machinery and equipment from 'dirty' areas to 'clean'areas.

Containers

- Store under cover, or shrink-wrap; if stored outside, regularly check on the condition of the wrapping.
- Where containers are re-used, clean and disinfect them first.
- Store old containers separately from new ones.

Growing media

- Store loose media in a covered bunker on a concrete slab above soil level. If storing media outside, keep it in sealed bales or bags and regularly check on the condition of the wrapping.
- Keep the media mixing area clean.

Plants

- Inspect incoming young plants carefully for pests, diseases and weeds.
- Monitor growing crops and stock plants regularly (eg weekly) for pests and diseases.
- Remove affected plants promptly.
- As well as checking plants, use sticky traps to monitor for pests.

1 Good nursery hygiene preserves plant health by minimising entry of pathogens, pests and weed seeds on a nursery

Benching, standing and growing areas

- Clean and disinfect regularly between successive crops.
- Renew old capillary matting or woven plastic ground covers, especially those known or suspected to be contaminated with a serious pathogen or pest.
- Ensure ground covers are flush to paths and the base of stanchions to prevent weed growth.
- Level beds to eliminate puddles.
- Control algal growth by avoiding over-watering, ensuring good drainage and, if necessary, use of an algaecide.
- Ensure uniform irrigation.

Water

- Maintain good weed control around reservoirs to prevent seed blowing into the water.
- Cover water-storage tanks.
- Clean irrigation pipework (eg every autumn) to prevent algal build-up in pipes and around nozzles.
- Clean roofs and gutters regularly if roof water is collected.
- On propagation nurseries, and where crops susceptible to the common waterborne root-infecting pathogens are grown, decontaminate recycled water or use collected rainwater.
- Test recycled water regularly for fungal pathogens, especially in storage tanks and at the point of use.

Non-cropped areas

- Maintain control of weeds on paths, bed edges, around glasshouses, tunnels, buildings and reservoirs, and at the perimeters of the site.
- Aim for a 1 metre wide weed-free strip around the edges of glasshouses and tunnels.

Waste and crop debris

- Place in covered containers and empty these frequently.

Introduction

The purpose of nursery hygiene is to preserve plant health. It is primarily achieved through sanitation practices aimed at reducing the populations of disease-causing organisms such as fungi, bacteria and viruses, pests such as insects, mites and nematodes, and weed seeds. With non-indigenous quarantine organisms such as the tobacco whitefly, *Bemisia tabaci*, or the fungus *Phytophthora ramorum*, the aim will be to eradicate them. Generally however, the aim is to deplete the organisms to such an extent that the risk of them causing a problem during crop production is minimal. Avoiding an outbreak of a damaging root disease such as brown core in primula or *Phytophthora* root rot in conifers can save thou-sands of pounds in staff labour, pesticides and their applica-tion and crop losses.

Examples of problems exacerbated by poor nursery hygiene include:

- **Poinsettia root rot** (*Pythium* spp.) where a mass of roots from previous crops has accumulated in the capillary matting and has not been adequately treated.
- **Geranium bacterial wilt** (*Xanthomonas campestris* pv. *pelargonii*) with the bacterium persisting from one season to the next in dried leaf debris.
- **Pansy black root rot** (*Thielaviopsis basiciola*) where dust containing spores of the fungal pathogen has contaminated the roots of young plants.
- **Grey mould** (*Botrytis cinerea*) where dead plants and crop debris are allowed to accumulate.
- **Root rot** (*Phytophthora* spp.) in conifers where the sand bed has become contaminated with the fungus from a previous crop.
- **Pests** such as thrips building up on old flowering bedding plants and spreading to adjacent or following crops.
- **Vine weevil** re-infestation occurring after infested crops have been

2 Pansy black root rot (*Thielaviopsis basiciola*) is a good example of a disease that can thrive where nursery hygiene is poor

disposed onto compost heaps adjacent to production areas.

- **Sciarid** and **shore fly** populations developing on algal growth where there is standing water.

- **Weeds** such as bittercress, groundsel and willowherb developing in the growing medium of container-grown plants close to weed-infested bed edges.

The appropriate level of sanitation for a nursery will depend on whether plants are being propagated or produced for final sale; the types of crops being grown and their pest and disease susceptibility; recent experience of pest, disease and weed problems, and other factors such as certification and retailer requirements, and any regulations stipulated by the Defra Plant Health and Seeds Inspectorate (PHSI). Maintaining a high level of nursery sanitation practices is especially important after an outbreak of a quarantine or other serious root or stem disease or pest problem. Most of the practices required are simple common sense.

For common, native pathogens and pests that frequently re-enter a nursery, a balance needs to be struck on the effort expended in reducing resident populations with the risk of re-entry. However, if high populations of pathogen, pests or weed seed are allowed to build up, a resultant crop disease or infestation is almost inevitable.

It is generally more cost-effective in the long run to prevent pathogens and pests from being introduced into the production cycle than to attempt to control them through the use of pesticides. Even where the pathogen or pest cannot be excluded, effective nursery hygiene practices enhance other strategies designed to minimise pest and disease risk.

A clean start will help to reduce potential plant losses from both diseases and pests, maintain plant quality, prevent excessive labour and pesticide costs and minimise the risk of pesticide resistance occurring.

The recommendations in this factsheet are compliant with the hygiene requirements when operating to the British Ornamental Plant Producers (BOPP) Certification scheme.

Identifying the cause of a problem

Identification and knowledge of the biology of particular pathogens, pests and weeds that are causing crop damage on a nursery will allow hygiene practices to be tailored to these specific organisms. This is particularly important for persistent problems. In a study investigating sources of *Pythium* on ornamental nurseries (HDC project PC 97a), intensive testing concluded that contaminated structures and/or water initiated infection on most nurseries. Cleaning and disinfecting contaminated surfaces and treatment of infested water are therefore key points for the prevention of *Pythium*. To aid identification of a problem:

- Compile a list of common pests and diseases for the crops you grow and provide appropriate training, if required, so that staff can recognise them.

- Ensure that all staff know that they should report a suspected pest or disease outbreak, and the reporting procedure.

- If you are uncertain of the identity of a pest or weed, or the cause of a disease, seek advice from a specialist crop consultant, or send a sample to a plant clinic for identification. There are plant clinics offering pest and disease identification services at CSL and STC:

The Plant Clinic
Central Science Laboratory
Sand Hutton
York YO41 1LZ
Tel. (01904) 462000

The Plant Clinic
Stockbridge Technology Centre
Cawood
Selby
North Yorkshire YO8 3TZ
Tel. (01757) 268275

Where an uncommon and potentially serious pathogen or pest is found on incoming plants, a decision will need to be made either to reject the consignment, or to destroy the plants, or to treat the problem and quarantine and monitor the plants to ensure that the treatment has been effective.

If the disease or pest is known or suspected to be a non-indigenous quarantine organism, you must immediately inform your local Plant Health and Seeds Inspector. Contact details are available on the Defra website at:
www.defra.gov.uk/planth/senior.htm
or the:
PHSI HQ
York
Tel. (01904) 455174

3 Thrips damage on chrysanthemum; identifying the cause of a problem enables the most appropriate hygiene measures to be selected

4 An adult western flower thrips

Sources, spread and survival of pathogens, pests and weeds

A check-list of the common ways in which pests, pathogens and weeds arrive and spread on a nursery, arranged by inspection area, is given in Table 1. Outline control measures are also listed. For some organisms there are several ways of spread, some of which are difficult to control, such as flying insects and spores spread in air currents. This does not mean that attempts to control entry and spread on a nursery should be abandoned. Where practical measures can be taken, these will help to prevent or delay the introduction of organisms into the crop and hence reduce the risk of a pest or disease outbreak, or a weed infestation.

Information on the survival of selected pests, pathogens and weeds is summarised in Table 2. Many have the ability to survive for months or even years in the absence of a crop.

Table 1 A check-list of the common pathogens, pests and weeds in ornamental crop production, arranged by inspection areas, with outline control measures

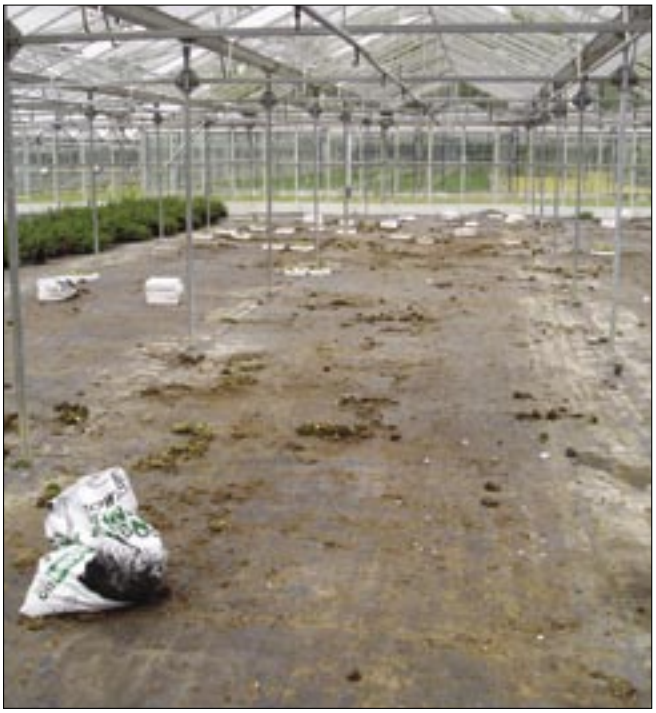
Inspection area	Type of problem spread this way	Control measures
The nursery		
Glasshouse structure	Virus, some fungal pathogens, over-wintering pests (eg spider mites)	Clean and disinfect. Control spider mites on the crop before they over-winter.
Benches and matting	Some fungal pathogens (especially root-infecting fungi such as *Pythium* and *Fusarium*). Some pests with ground-dwelling life stages eg thrips, sciarids, shore flies, leaf miners.	Clean and disinfect. Renew old matting. Remove dead/dying plants and debris. If appropriate, apply biological control agents eg ground-dwelling predatory mites, beetles or nematodes.
Floors	Some fungal pathogens in debris and dust; various pests (as for benches and matting), also slugs, snails, woodlice and vine weevil; insects and nematodes on plant debris or feeding on algal growths; moss and liverworts.	Clean the floor; control algal growth, mosses, liverworts. Renew covering. Level hollows to eliminate puddles. Apply biological control agents if appropriate, as for benches and matting.
Machinery and equipment	Fungal spores, bacteria, viruses, weed seed, pests eg thrips and leaf miner pupae.	Regularly clean seeders, transplanters, potting machines (especially fingers on machines), secateurs, knives etc. Keep work areas clean.
On wheels of fork lift trucks, soles of shoes etc	Water moulds, root-infecting pathogens, virus, ground-dwelling pests eg thrips and leaf miner pupae.	Allocate specific vehicles to high-risk areas. Clean vehicles regulary. Place disinfectant-soaked matting across entrances to high-health status areas.
New containers	Fungal pathogens, weed seed.	Regulary brush or vacuum pathways and areas around potting machines. Store under cover or shrink-wrapped if outside. Store old pots separately from new ones.
Re-used containers	Some fungal pathogens (eg *Thielaviopsis*, cause of pansy black root rot); weeds (eg bittercress around edge of old pots); slugs and snails under trays, pests on plant debris eg thrips, leaf miners, nematodes, spider mites.	Clean and disinfect before re-use (eg high-pressure wash the trays using water containing a disinfectant). Note: disinfectants alone may not kill weed seeds; cleaning is essential.
Growing media, soil and dust	Occasional fungal pathogens, weed seed (especially in dust), some pests.	Protect growing media from dust and run-off water. Cover bunkers and part-used or damaged bags. Agree growing media specification and keep samples.

Table continued...

Inspection area	Type of problem spread this way	Control measures
Cropping aspects		
Seed	Some fungal and bacterial pathogens, less commonly viral pathogens; contaminating weed seeds.	Use certified, high quality seed. Request seed treatment where there is a known risk of a seed-borne pathogen. Seed testing.
Incoming cuttings and young plants	Some fungal, bacterial and viral problems; some pests eg thrips, leaf miners, whiteflies, nematodes and vine weevil (in plugs or liners).	Inspect and quarantine incoming stock; use sticky traps. Use virus-tested stock. Use stock indexed for vascular pathogens. Avoid placing plants on the ground or a dirty work surface. Apply biological control agents or pesticides if required.
Water	Some fungal pathogens (especially water moulds), bacteria and weed seed.	Cover storage tanks. Routinely test recycled and stored water, and storage tanks, for plant pathogens. Treat recycled water. Check water treatment equipment is working correctly. Clean and disinfect irrigation lines. Avoid irrigating with contaminated water, especially young plants. Do not drop hoses on dirty ground. Avoid water splash. Keep reservoir banks free of weeds and plant debris.
Crop covers (eg fleece)	Some fungal pathogens and pests.	Wash or treat crop covers between crops, or use new ones.
Growing and standing areas	Weeds, pathogens, pests. On sloping sites, run-off water can spread root pathogens to plants lower down the slope (especially *Phytophthora*).	Sweep floors and benches regularly, disinfect as necessary. Ensure standing areas are adequately drained. Ensure ground cover material is in good repair and covers all the growing area up to path edges. Replace capillary matting as necessary. Skim sand beds. Check uniformity and distribution of irrigation. Remove diseased and infested plants promptly. Put IPM strategies in place on new crops promptly. Seek to devise production routes to minimise old crops contaminating new crops. Do not set down new crops in spaces between old crops.
Insect movement	Flying pests eg aphids, adult thrips, leaf miners, leafhoppers, whiteflies, sciarid and shore flies. Crawling pests eg slugs, snails, adult vine weevil. Some fungi and viruses carried within insects (eg *Pythium* and *Fusarium* with sciarid flies, Tomato spotted wilt virus with western flower thrips).	Use sticky traps to monitor insect levels. If appropriate, use roller traps for mass trapping of pests. Monitor indicator plants. Control pests that cause crop damage or transmit disease.
Air currents	Small pests eg thrips, some fungal pathogens, wind-blown weed seed.	Use sticky traps to monitor for thrips and other pests. Consider screening vents with insect-proof mesh, or use sticky traps under vents or next to doors. Use wind breaks to reduce weed seed blown in from surrounding fields.
Contact between plants	*Botrytis*, crawling pests eg spider mites, aphids, thrips larvae.	Remove affected plants. Give adequate plant spacing (unless using biological control agents eg *Amblyseius* spp. and *Phytoseiulus persimilis*, which need plants to be touching).

Table continued…

Inspection area	Type of problem spread this way	Control measures
Cropping aspects		
Waste plants and crop debris	Some fungal pathogens and pests (eg western flower thrips on unwanted flowering plants).	Place unwanted plants and debris in covered skips or other covered containers. Cover any heaps of plant waste near the nursery. If composting in open heaps, locate them away from production areas.
Non-cropping aspects		
Non-cropped areas	Pests on weeds (eg whitefly and leaf miners on chickweed and sowthistle under benches or around edges of glasshouse). Occasional fungal pathogens on weeds (eg rusts, botrytis). Weed seeds.	Control weeds in and around cropping areas and outside glasshouses, especially next to stored growing media, water tanks and reservoirs. Use vegetation-free strips, or closely mown grass around houses and production areas. Do not allow rubbish to accumulate near growing media mixing areas.
Staff and visitors	Some fungal and viral pathogens and pests (eg powdery mildew, spider mites and thrips on clothing).	Ensure staff are trained in and follow nursery hygiene procedures; display the nursery hygiene rules and practices as a reminder. Ensure visitors and contractors working on site report to reception and follow the nursery hygiene policy. Avoid staff movement from infected/infested areas to 'clean' areas. Use protective clothing, gloves and hand-sanitisers in high health status areas. Use disinfectant foot dips. Wash hands regularly. Do not allow staff to raise their own plants on site, unless a risk assessment indicates minimal risk.
Despatch areas	Pathogens, pests and weed seed on wheels of trolleys, fork lift trucks and lorries.	Clean floor regularly. Clean and disinfect trolleys before re-use. Devise routes to avoid cross-contamination between despatch and production areas.



5 Dirty floor or bench coverings can be a source of root-infecting fungi, especially *Fusarium, Pythium, Phytophthora, Rhizoctonia* and *Thielaviopsis,* and some pests

6 Once-used pots and trays need to be cleaned before re-use and treated to kill pathogens, pests and weed seeds and covered after treatment

Table 2 Persistence of some key pathogens, pests and weeds on structures or in soil

Pathogens	**Persistence**	**Comment**
Black root rot dispersal spores	4–5 years in root tissue	May occur in nursery sweepings. Capable of prolonged saprophytic survival in soil.
Botrytis cinerea dispersal spores	Weeks to around 1 year	Many environmental factors affect survival (eg sunlight, frequent wetting and drying). Ability to infect plants may decline more rapidly than ability to germinate.
Downy mildew dispersal spores	Days	Information relates to *Peronospora parasitica* on leaves under typical field conditions.
Fusarium oxysporum resting spores	Years	Cyclamen fusarium wilt tends to re-occur on a nursery after a severe outbreak, possibly due to persistence between crops on matting or benches.
Powdery mildew dispersal spores	Days	Washing a glasshouse with water can trigger spore germination and reduce survival.
Rhizoctonia solani resting structures	Years	Capable of prolonged saprophytic survival in soil.
Sclerotinia sclerotiorum resting structures	6–8 years	Contans WG is available for biological control of soil-borne resting structures; also consider soil disinfestation, or growing out of the soil if a serious problem.
Pythium resting spores	Years	Will survive drying.
Phytophthora dispersal spores	Weeks	Varies with species.
Phytophthora resting spores	Months to years	Varies with species, but generally several years.
Soft rot bacteria (eg *Pectobacterium carotovorum*)	Days	Commonly occurs in soil and water so re-infestation may readily occur.
Tomato mosaic virus (ToMV)	Years	Can survive for years in plant debris.
Pests		
Aphids	Weeks to months	Most species do not produce eggs. Aphids will only survive on host plant material eg crop plants, weeds or leaf debris.
Leaf miner pupae	Weeks to months	*Liriomyza* spp. (including quarantine spp.) can survive for several months in soil or compost, depending on species and temperature. Native *Chromatomyia* spp. pupate in the leaf and can survive in leaf debris.
Caterpillars and moth pupae	Months	Some species pupate in soil or growing media and can over-winter. Other species eg carnation tortrix can over-winter as larvae in rolled up leaves of host plant.
Two-spotted spider mite	Months	Can over-winter in glasshouse structure and equipment.
Vine weevil	Months	Larvae and pupae (both in soil or compost) and adults (in sheltered refuges) can be found all year round in glasshouses, but usually over-winter as larvae and pupate and emerge as adults in spring.

Table continued…

Pests	Persistence	Comment
Western flower thrips (WFT)	Months	Depending on temperature and moisture, may over-winter as adults, larvae or pupae, on plants, plant debris, weeds or in soil.
Glasshouse whitefly	Weeks to months	Will only survive on host plants, weeds or leaf debris. Can over-winter in glasshouses and on weeds outdoors in mild winters.
Weeds		
Annual meadow grass	> 5 years	
Chickweed	Many years	Most germinate within a year, but a small percentage can remain dormant for 60+ years.
Common sorrel	> 5 years	
Groundsel	> 5 years	Most germinate within a year, but a few can remain viable for longer.
Hairy bittercress	> 5 years	
Liverwort spores	Around 1 year	Spores kept at room temperature were 100% viable after a year, 50% after 14 months and failed to germinate after 17 months totally.
Pearlwort	> 5 years	

Clean-up procedures

These will vary according to crop. For outdoor crops, a thorough nursery clean-up and treatment of standing areas once a year, as they become empty in the summer, is generally satisfactory. For glasshouse crops, treatment is usually in late summer, just before the start of autumn production, or in late winter following crops such as poinsettia or cyclamen, just before the start of spring bedding production.

- It is common sense first to remove all dead plants, weeds and crop debris throughout the area to be cleaned. Thoroughly sweep or vacuum dust, debris and peat from benches, pathways and standing areas.

- Remove debris from the glasshouse or cropping area in a sealed container. Transport the debris in covered skips or trailers for disposal at a compost heap or to a local authority disposal site. Research on bedding plant nurseries indicated that sweepings commonly contain spores of the black root rot fungus (*Thielaviopsis basicola*) and they may contain various other pathogens and pests.

- If you wish to compost plant material, apply to the Environment Agency for an exemption from the Agricultural Waste Regulations. Site any compost heap as far away from the glasshouse or cropping area as possible.

- Next, the structure and surfaces in an area should be washed clean, using a power hose for example, before a disinfectant is applied. A suitable detergent can be useful where water alone is insufficient to remove accumulated dirt. Thorough cleaning prior to disinfection both reduces the risk of re-infestation and ensures the effectiveness of disinfectants against plant pathogens is maintained.

- Disinfectant should be applied primarily to the floor and also to the structure if a need has been identified. For further information on the choice and use of chemical disinfectants, see HDC Factsheet 15/05.

- Irrigation pipes and nozzles should be cleaned, for example by flushing them with acid to remove limescale, or a disinfectant.

Remember, the following areas need cleaning:

- Glasshouse structure

- Floors, benches and other propagation or production areas (eg potting areas)

- Matting and other floor or bench covers (brush clean, power hose or replace)

- Pots and trays if re-used

- Irrigation systems

- Potting machines and associated equipment and areas

- Storage areas (eg cold stores)

Minimising re-entry of pathogens, pests and weeds

Inspection of incoming plants

All batches of incoming plants should be carefully inspected for diseases, pests and damage symptoms, checking both the leaves and roots. Pay particular attention to imported plants and cuttings, and to favourite host plants of certain pests and diseases.

If a disease or pest is found, inform the supplier immediately. Depending on the nature of the problem and the severity of the disease or pest, either dispose of the plants, or treat them with a suitable pesticide or biological control agent.

Where possible, maintain a growing environment unfavourable to any disease found. Where a pest or pathogen is found and the plants are accepted and control measures taken, keep them in a quarantine area if possible and monitor them regularly to ensure that the problem is well controlled. **If a disease or pest is known, or suspected, to be a non-indigenous quarantine organism (eg *Bemisia tabaci* or the South American leaf miner, *Liriomyza huidobrensis*), PHSI should be informed immediately.**

Routine monitoring

After potting, the growing crop should be monitored frequently for pests and disease. Examine plants taken from several positions in the crop, including from any still or sheltered areas, next to heating pipes and stanchions, low spots prone to flooding, close to doorways and under vents in glasshouses. Look for:

- Stunted or discoloured growth
- Atypical growth (eg leaf, petal or flower distortion) that may be due to either direct pest damage or to virus infection
- Leaf spots, yellowing or necrosis
- Root rots and plant wilting
- Stem base constriction or browning
- Presence of pests (eg aphids, caterpillars, leaf miners, thrips, two-spotted spider mite, whiteflies)
- Pest damage symptoms (eg aphid or whitefly sticky honeydew or sooty moulds, thrips flecking or silvering to leaves).

Plants affected by a disease or pest should be removed from the growing area as soon as possible, or the problem identified and treated. For certain pests (eg leaf miners), removal of individual leaves showing the first symptoms can delay infestation before biological or chemical control measures can be put in place. Early detection can reduce plant-to-plant spread and minimise losses.

In addition to inspecting plants, position fresh sticky traps in the glasshouse or tunnel to help monitor levels of pest activity. Yellow traps will catch most flying insects and are best for monitoring whiteflies and sciarid flies, whereas blue ones are generally more attractive to western flower thrips (WFT). Check the traps weekly and keep records of selected pests found and their levels.

Quarantine provisions

When there are relatively few deliveries of plant material on to a nursery, and the facilities are available, maintain the incoming plants in a separate glasshouse or isolated area for 2–4 weeks and examine them frequently (eg twice-weekly) for diseases and pests. This is particularly important for imported plants or cuttings that may harbour quarantine pests or diseases. Some pathogens (eg rusts) have a latent period ranging from a few days to a few weeks between infection and symptom development, and plants only recently infected may not show any symptoms at delivery. Similarly, some pests (eg thrips) may be present as eggs in leaf tissue or pupae in growing media, and thus are not visible on the plants at first.

Minimising pest entry to glasshouses

For very high value propagation material, consider insect-proofing the glasshouse with appropriate mesh over the vents and installing double doors. Remember that mesh over vents will reduce light transmission and also air movement unless fans are installed, so it could lead to reduced growth. Monitor for insect activity using sticky traps, 'indicator' plants (those known to be highly attractive or susceptible to certain pests) and regular crop examination. Long 'curtain' traps eg 'Mastertrap' can be useful for mass trapping pests in empty structures or between adjacent crops following a heavy infestation eg of thrips, whitefly or leaf miners. They may be recommended by PHSI if a quarantine species is or has been present. However, they can also catch flying biological control agents so they should be positioned and timed with care.

7 Carefully inspect all incoming plants; if a quarantine organism such as tobacco whitefly *(Bemisia tabaci)* is found, PHSI should be informed immediately

8 Netted vents can be used to exclude flying pests from high-health status areas, though fans will be required to ensure adequate air exchange

Growing media

If any green waste material is used, check that it has been adequately treated to minimise the risk of contamination with pathogens, pests or weed seeds (eg to PAS 100 Standards). Loose growing media should be stored in a covered bunker, on a concrete slab above soil level to prevent contamination by run-off water, or in sealed bales or bags. Do not include soil in the growing medium unless it has been heat-treated to kill micro-organisms. If growing media is to be mixed, this should be done on a clean concrete slab, never on the ground. Forklift trucks and equipment should be assigned to the area to prevent the introduction of pathogens, pests or weed seeds on tyres of equipment used elsewhere. Avoid unnecessary movement of people in the area to prevent the introduction of pathogens, pests or weed seed on shoes. Do not return sweepings of waste peat into the storage bunker or bag.

Storage and treatment of water

The most common supplies of water on a nursery are mains water and bore hole water, and the risk of a plant pathogen being introduced with these is extremely low. However, once stored, the water may become contaminated by spores of damaging plant pathogens, especially *Pythium, Phytophthora* and *Fusarium,* which are carried in air currents, in wind-blown dust and with crop debris. Open tanks should be securely covered, preferably with a cover that sheds debris and water (as opposed to a floating cover).

The risk of plant pathogens occurring in water is probably increased where rainwater is collected from roofs and is significantly increased where surplus used irrigation water (drainage water from beds) is collected for recycling. Where roof water is collected for use, regularly clean roofs and gutters. Water drawn from rivers or lakes may also contain plant pathogens and requires decontamination.

According to the crop being grown, some nurseries collect and use roof water and/or surplus used irrigation water without any treatment to control plant pathogens. These nurseries may recognise the risk of root disease and have assessed it to be low for the crops they grow; and/or rely on routine fungicide programmes to suppress pathogen activity.

A small but increasing number of growers treat recycled irrigation water to control plant pathogens before it is used for irrigating crops, especially if used in propagation or on crops very susceptible to root pathogens such as *Phytophthora*. The main methods currently used for treating recycled water on ornamental nurseries are chlorination and slow sand filtration (SSF). For further information on SSF, see the HDC grower guide: 'Slow sand filtration – A flexible, economic biofiltration method for cleaning irrigation water'. Both of the above treatments require a pre-filter for effective operation (see HDC Factsheet 15/06 on water quality).

Numerous other methods of water treatment have been shown to reduce pathogen levels including UV light, heat, ozonation, micro-filtration, settlement tanks and various chemicals (eg copper-based electrode, hydrogen peroxide). No one method is suitable for all nurseries and the advantages and disadvantages of each need to be considered in relation to the particular nursery. For further information, see HDC Report CP 4.

9 Cover water storage tanks to keep out dust and debris; contamination of irrigation water by *Phytophthora* or *Pythium* may lead to widespread root disease outbreaks on a nursery

Maintaining nursery hygiene

Benches and growing areas

Outdoor crops are usually placed on a woven plastic ground cover over consolidated soil or gravel, or on to graded gravel beds or capillary sand beds. Glasshouse container-grown crops may be placed on capillary matting over a plastic lining or directly onto the floor covering. These bench or floor coverings can harbour pests and diseases. Many pests have ground-dwelling life stages eg thrips and leaf miner pupae, sciarid and shore fly eggs, larvae and pupae. Other pests eg thrips and spider mites can drop or be knocked off plants to the ground and can survive by feeding on fallen leaves.

Spores of root or stem base infecting fungal pathogens are likely to be leached from the growing medium of infected plants with irrigation and contaminate the matting. Roots can grow from containers into the capillary or woven plastic matting and thereby increase the risk of pathogen persistence between crops (eg *Phytophthora* and *Pythium* spp.) and the difficulty of disinfecting the matting. Root infection from contaminated matting or the soil or sand beneath is most likely after flooding.

Benches, floors and beds should be level so as to avoid wet spots. With outdoor crops, ensure there is good

drainage from beds. Roadways should preferably be lower than beds, or well constructed with drains so that surface water contaminated by soil does not drain from the roadway on to beds.

Between batches of plants, brush or vacuum any debris from the standing area surface and, if necessary (eg after a particular root disease problem or before a high value crop, or at an annual clean-up), apply a suitable disinfectant (see Factsheet 15/05). Ensure that sufficient water is used to thoroughly soak the matting, and any roots in it.

Manage irrigation and misting systems carefully (eg use a low pressure), to avoid over-watering and splashing of pooled water on to pots (see Factsheet 01/06). Ensure that there is good drainage away from outdoor beds so that upward movement of soil water into the bed does not occur.

Cleaning and disinfecting machinery and equipment

Ensure that potting and transplanting machines, knives, secateurs and equipment are regularly cleaned (eg daily), especially the fingers on potting machines. Do not borrow dirty machinery or equipment from other nurseries. Clean and disinfect pots, trays and other containers before re-use, eg high-pressure wash using water containing a disinfectant. HDC-funded project HNS 147 is currently identifying candidate methods for disinfesting plant containers of pests, pathogens and weed seeds.

Testing water for plant pathogens

It is recommended that stored water used for irrigation, especially recycled water, is regularly tested to determine what pathogens, if any, are present, and to what extent. Samples should be taken at various times in the production cycle, as pathogens can be seasonal in activity (eg *Phytophthora* spp.). Water samples should be taken at the storage point or water source, and at the point where it is delivered to the plants. Testing at the point of use is most important. If a water treatment system is in use, testing of samples before and after treatment will help determine how well the system is working.

A range of tests is now available including:

- Bait tests, using plant tissues susceptible to the pathogen(s) of concern
- Lateral Flow Devices (LFD) to test for *Pythium* and *Phytophthora* (in the sediment after filtration)
- Culturing for bacteria and fungi on selective nutrient media to determine their presence and abundance

The LFD test for *Pythium* can be done on-site by nursery staff, the other tests require samples to be sent to a specialist laboratory. Before sending samples, check with the testing laboratory on the sample required (eg volume of water, depth from which it should be collected, storage temperature) and inform them of the pathogen(s) you are concerned about. Currently, the following laboratories offer a water-testing service:

Stockbridge Technology Centre
Cawood
Selby
North Yorkshire YO8 3TZ
martinmcpherson@stc-nyorks.co.uk

Dr Tim Pettitt
C/o Eden Project
Bodelva
Cornwall PL24 2SG
tpettitt@edenproject.com

Lateral flow test kits can be purchased from:

Pocket Diagnostic
Central Science Laboratory
Sand Hutton
York YO41 1LZ
www.forsitediagnostics.com

Disposal of dead, diseased or infested plants

Dead, badly-diseased, infested or unwanted plants should all be removed from the crops as soon as possible. During crop production, place diseased or infested plants into a sealed bin-liner or container before carrying them through the house for safe disposal. Unwanted flowering

10 Dead, diseased or infested plants should be removed from a crop promptly

11 Control weed growth to reduce the risk of weed seed contaminating the crops inside; weeds can also act as reservoirs for certain pests and virus diseases

plants, in particular, can harbour thrips, aphids and other pests and should be disposed of promptly. Waste plants should be placed in a covered skip that is emptied regularly, or composted in an area at least 10 m from production areas, preferably downwind and where there is little movement of people or vehicles.

Compost heaps are only permitted if an exemption is obtained from the EA under the 2006 Agricultural Waste Regulations. Diseased plants should not be composted but disposed of with general waste or removed from the nursery in covered skips or trailers to a local authority disposal site. Check that any seepage from compost heaps (which may contain pathogenic fungi) does not contaminate watercourses or the nursery growing area.

Weed control in non-cropped areas

Maintain control of weeds in areas such as paths, bed edges, between and around glasshouses, tunnels and buildings, around reservoirs and at perimeters of the site. Aim for a 1 metre wide weed-free strip around the edges of glasshouses and tunnels.

Cultural control to reduce disease risk

Maintaining a growing environment favourable to good crop growth will reduce the risk of some diseases becoming established. This applies to both the aerial and root environment. For example, avoiding prolonged periods of high humidity will reduce the risk of grey mould (see HDC Factsheets 23/02, 24/02 and 25/02); avoiding prolonged leaf wetness will generally reduce the risk of downy mildews, rust diseases, white blister and some leaf spots (see HDC Factsheets 19/02, 04/04, 05/04 and 12/04). Ensuring good drainage and avoiding overwatering and growth checks will reduce the risk of *Pythium* and *Phytophthora* root rots (see HDC Factsheet 17/04). Avoid pH extremes to reduce the risk of black root rot and *Pythium* root rot.

IPM to reduce pest risk

Integrated Pest Management (IPM) is the combination of cultural and biological control measures, together with minimal use of compatible pesticides, to maintain pest levels below economically damaging levels. There are many benefits of using IPM, eg allowing growers to produce high quality plants whilst meeting customer demands for minimal use of pesticides.

Cultural control methods include nursery hygiene practices such as weed control, plant and sticky trap monitoring, physical screening and avoiding environmental conditions conducive to pest development, which have all been discussed earlier in this factsheet. Knowledge of pest biology helps to plan suitable cultural control measures.

Biological control agents commonly used on protected ornamentals include parasitic wasps, predatory mites and insects, and insect-pathogenic nematodes, fungi and bacteria which act as 'biopesticides'. IPM programmes, including timing and rates of natural enemy release should be designed carefully. Once biological control agents have been released, it is important to monitor their progress closely and to manage the IPM programme carefully, eg choice of compatible pesticides and fungicides if needed, to avoid adverse effects on the biological control systems.

Staff should be trained in pest and natural enemy recognition, and in methods for using biological control agents and compatible pesticides within IPM programmes. Information and advice is also available from biological control suppliers and distributors and from consultants. Examples of how IPM strategies can be tailored for management of specific pests on ornamentals are given in HDC Factsheets 08/02 (sciarid flies) 08/05 (two-spotted spider mite), 14/05 (whiteflies) and 15/07 (leaf miners). The ADAS/Defra Best Practice Guide for Integrated Pest Management in protected ornamental crops is available from:
ADAS Tel. (01954) 268214

12 Sticky traps are useful to help monitor for pests; blue traps are generally best for monitoring WFT

Acknowledgements

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