Factsheet 15/08

Aquatic ornamentals

Project HNS 145

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Pest, disease and weed management in ornamental aquatic plants

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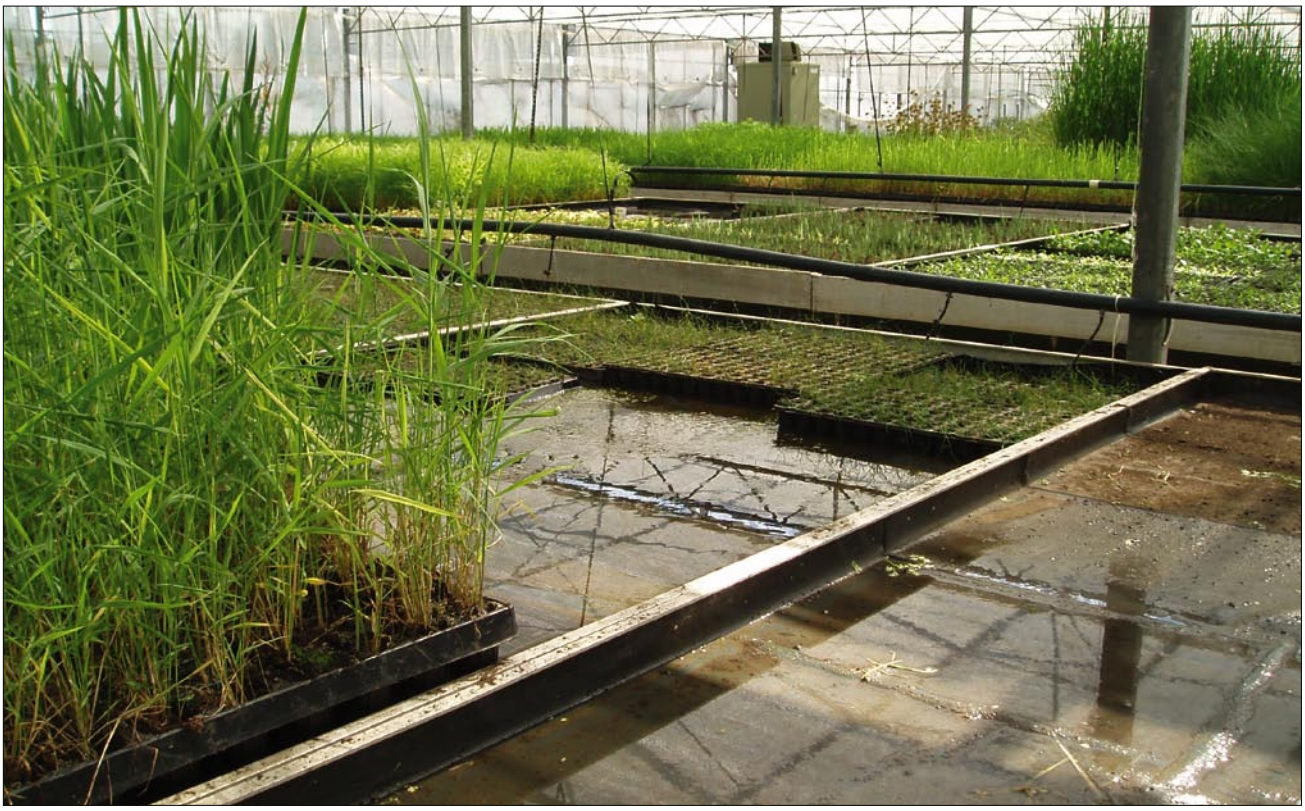
This factsheet provides growers with information about the key pests, diseases, aquatic weeds and algae in the production of aquatic and pondside ornamental plants. It aids growers in the recognition of each organism and the damage they cause. It also provides guidance in control through cultural, biological and chemical means.

Background

A wide range of plant species are produced by specialist aquatic plant nurseries, with each species suited to a habitat at a particular water depth. They may be grown fully or partially submerged in ponds or tanks, or stood in shallow water on benches (Figure 1). Some pondside plants are grown without standing water. The plants grown are principally perennials, and many are produced under protection.

Many pest, disease and weed problems affecting ornamental aquatic plants are common to other areas of horticulture. However, some root and rhizome diseases and weeds lend themselves to aquatic plant production as they are readily spread in the water around the plants. Few plant protection products are specifically approved for use in the production of ornamental aquatic plants.

There is currently little published information to help growers to identify the sources of damage caused to aquatic and semi-aquatic plants or the conditions that favour their development. This factsheet summarises the key pests, diseases and weeds encountered by aquatic plant growers and provides potential integrated control options.



1 Pondside plants in multicell trays on flooded benches. The water is not drained from the benches until they are cleaned between production batches

Pests: Identification and symptoms

Two key pests, water lily beetle and water lily aphid, are specific to aquatic plants, while other significant pests (eg two-spotted spider mite and vine weevil) are common to both aquatic and non-aquatic ornamental plants.

Water lily beetle *(Galerucella nymphaeae)*

Adult beetles are 6–8 mm long and yellowish-brown to dark-brown. As well as water lilies they feed on various plant species including arrow-heads (*Sagittaria* spp.), *Polygonum* spp. and willows (*Salix* spp.). They hibernate amongst vegetation close to ponds and become active and start feeding on water lily leaves in May or June. The adults feed on the leaves, creating grooves in the leaf surface, which subsequently develop into long irregular-shaped holes (Figure 2).

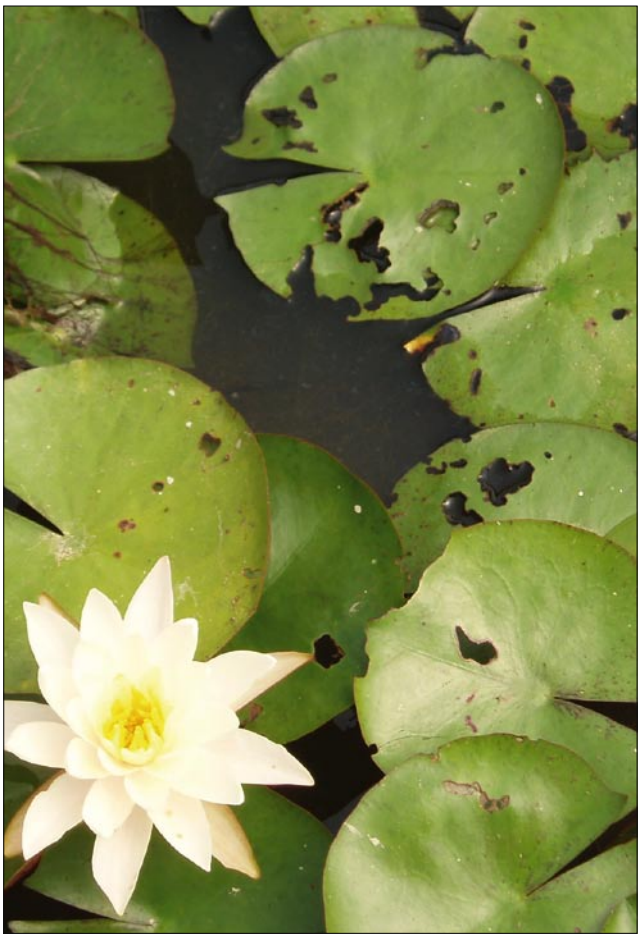
Egg laying begins in the same months and the time from egg to adult shortens with increasing temperature, ranging from 19–29 days. The larvae have shiny, dark brown or black bodies with a yellow underside, and three pairs of legs towards the front. They hatch from eggs and feed on the upper surface of both *Nymphaea* water lilies and the yellow pond-lily (*Nuphar luteum*) causing grazing damage (Figure 3) and holes in the leaf surface. Pupae are 5–7 mm long, shiny and black, and attached to the leaf surface at one end.

Second generation adults emerge from pupae in July and August and lay more eggs. A third generation may also occur in warmer areas.

Water lily aphid *(Rhopalosiphum nymphaeae)*

Wingless aphids are up to 3 mm long, dark olive to brown in colour, with a dusting of whitish wax. The body is oval and plump, with two pale, long, dark-tipped tubes (siphunculi) at the rear. The pest is common on water lilies (*Nymphaea* and *Nuphar*), but also on many other aquatic plant species. These include water plantain (*Alisma* spp.), flowering rush (*Butomus* spp.), bulrush (*Typha* spp.), arrowhead (*Sagittaria* spp.), soft rush (*Juncus* spp.), pondweeds (*Potamogeton* spp.), duckweeds (*Lemna* spp.), and the non-native species, water hyacinth (*Eichhornia crassipes*) and water lettuce (*Pistia stratiotes*).

In autumn, when many native aquatic plants die back to survive the winter under water, dark brown shiny black winged aphids can develop, and fly to *Prunus* spp. to lay over-wintering eggs. When the eggs hatch in spring, these aphids fly back to their summer hosts to feed and reproduce. Aphid numbers can build up rapidly on the leaves (Figure 4) and flowers of aquatic plants, particularly in warm conditions, often causing stem and leaf distortion. The aphids have specialised body hairs which trap air, thus enabling them to feed on submerged plant parts, and walk on the water between plants.



2 Holes made in water lily leaves by water lily beetle larvae and adults, reduce plant quality

3 Water lily beetle larvae and two pupae, with leaf grazing damage

Other aphids

Various other aphid species can occur on aquatic and pondside plants, as they attack plants from a range of plant families. These include the peach-potato aphid (*Myzus persicae*), the melon and cotton aphid (*Aphis gossypii*), the potato aphid (*Macrosiphum euphorbiae*) and the glasshouse and potato aphid, (*Aulacorthum solani*).

The peach-potato aphid is green or pink, and the siphunculi (rear tubes) are green with dusky tips. The melon and cotton aphid is small with a yellow, green or black body and short black siphunculi (Figure 5). The potato aphid is a long, green or pink aphid, often with a darker stripe down its back. Its siphunculi are long and green, without darker tips. The glasshouse and potato aphid is shiny green, with a dark green patch at the base of the green, black tipped, siphunculi.

Aphid feeding can result in leaf yellowing and distortion. Plant quality is adversely affected by the presence of the aphids, their cast skins and the sticky honeydew they excrete, which can lead to the growth of sooty moulds. Aphids usually breed throughout the year, giving birth to live young. Winged forms develop during the spring and summer and spread infestations to other host plants.

Two-spotted spider mite (*Tetranychus urticae*)

Two-spotted spider mite has a very wide host range and has been reported on water lilies and many marginal and pondside plants including rush (*Acorus* spp.), *Iris* spp., *Lobelia* and purple loosestrife (*Lythrum* spp.). The pest is mainly a problem on protected plants, but in hot summers it can also cause damage outdoors.

Adult mites are about 0.5 mm long (Figure 6) and usually green in colour, with two dark patches on their backs. Adults become active in the spring, in response to increasing temperature

4 Water lily aphids feeding on water lily leaves and flower stalks. They also feed on a wide variety of other aquatic plant species

5 The melon and cotton aphid is one of the aphid species found on both aquatic and other ornamental plants

6 Two-spotted spider mite has both green, and red (overwintering), forms

and daylength. Eggs are laid on undersides of leaves and hatch into juvenile mites, which feed and develop into adults. All stages of mites feed on the undersides of leaves, moving to growing points and flowers in severe infestations. In warm conditions, many generations can occur. In September and October (or earlier in the year if the plant host is senescing), adult females turn a brick-red colour (Figure 6), before hibernating in sheltered parts of the structure of glasshouses or polythene tunnels, or in plant debris.

A fine yellow speckling on the upper surface of leaves is usually the first sign of spider mite damage, although on thick-leaved plants, yellow leaf patches can occur. Badly infested leaves turn yellow, and then brown as the leaf or whole plant senesces. In severe infestations, the mites spin webs over the plant surfaces. The reduction in photosynthetic leaf area leads to poor plant vigour and even death.

Glasshouse whitefly *(Trialeurodes vaporariorum)*

The most common whitefly species occurring on ornamental plants is the glasshouse whitefly, *Trialeurodes vaporariorum*. Glasshouse whitefly has a wide host range, including water lilies and various pondside plants, and is mainly a problem on plants grown under protection. In heavy infestations, leaf yellowing can occur and sooty moulds can develop on the sticky honeydew excreted by the whiteflies.

Adult whiteflies are about 1 mm long, with white wings held together horizontally when at rest. They are usually found on the undersides of leaves and in growing points (Figure 7). Adults lay small, oval eggs on the leaf undersides, which produce mobile 'crawler' larvae. The larvae soon produce the later sedentary life stages, known as 'scales', which are oval, flat and greenish (Figure 7). The final, largest scale stage is the pupa, which is oval and white.

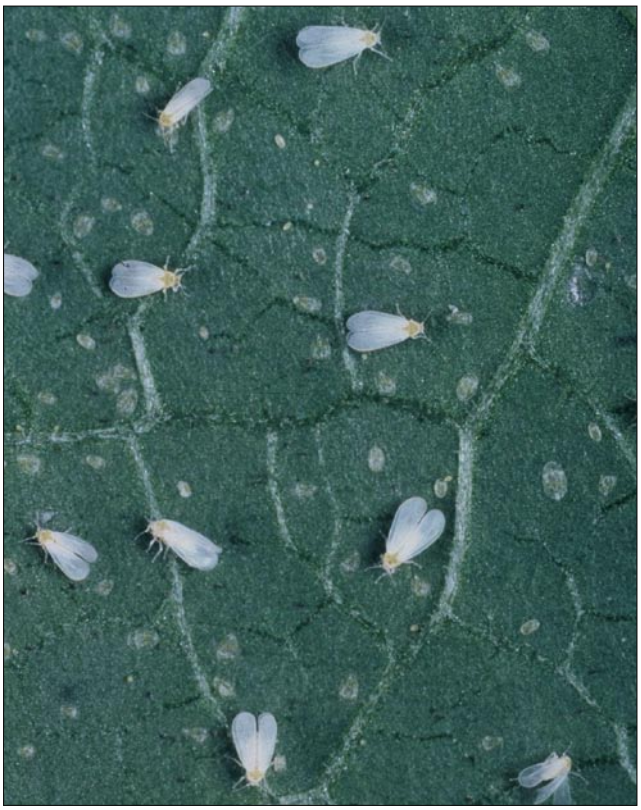
The adults of the quarantine species, tobacco whitefly (*Bemisia tabaci*), are smaller than glasshouse whitefly and hold their wings slightly apart and more upright, so that the yellow body is visible. The older scales tend to be yellow rather than white, and can be slightly pointed at one end. They might occur on imported plants and any suspect whiteflies should be notified to your local Plant Health and Seeds Inspector (PHSI).

Further information can be found at: **www.defra.gov.uk/planth**

Vine weevil *(Otiorhynchus sulcatus)*

Both the adults and larvae damage ornamental plants.

Adults usually emerge from pupae in May and June to feed at night, causing notching to leaf margins. Under protection, the adults (which are all female) may be found all year. They are 7–10 mm long, with a black body with yellow speckling. The main egg-laying season is usually between July and September. Larvae hatch from eggs, usually during August and September. They are white, plump, 8–10 mm long with a brown head and they tend to curl into a 'C' shape around plant roots (Figure 8). They feed on the roots of a wide range of plant species and can cause plant yellowing, wilting or even death. The larvae can continue to feed throughout the winter and spring under protection, pupating between mid-April and June. Attacks have occurred on pondside plants (ie without submerged roots), such as *Primula* spp., Arum lily (*Zantedeschia aethiopica*), *Astilbe* hybrids and bamboos.



7 Adult whiteflies and scales on the underside of a leaf

8 Vine weevil larvae tend to curl into a 'C'shape

Diseases: Identification and Symptoms

Plant diseases are mainly caused by fungi, bacteria or viruses. They may either infect a wide range of aquatic or terrestrial hosts, or be limited to a single plant family. Some are secondary diseases, requiring existing damage to enter plants. Although there is little published information available on diseases of aquatic and semi-aquatic plants, as most species are sold in their native form, the author has extrapolated information that is available on wild plants to supplement information recorded on commercial nurseries.

The most common diseases of aquatic ornamental plants are described below. A fuller list of aquatic plant diseases is provided in the Appendix to HDC report HNS 145.

Root and rhizome diseases

Diseases can affect the roots and rhizomes of most plants. They can rapidly kill seedlings and cause older plants either to lose vigour or die. The symptoms depend on the pathogen and the host susceptibility. In aquatic and semi-aquatic plants, as early wilting may not occur because of good water availability, root decay may be well advanced by the time foliar collapse is noticed. Root pathogens can disperse to a fresh host before infected plants are removed, and dispersal, in particular by fungi with swimming spores, is facilitated by free water in the compost.

Water lily crown rot (*Phytophthora* spp.)

Phytophthora infects water lily crowns, and progresses up leaf and flower stems causing them to become soft and blackened. As the disease progresses, fewer leaves are produced and those that are produced turn yellow shortly after unfolding at the surface. The rhizome becomes mushy and highly pungent. The disease is most often seen in two to three year old plants, with symptoms most apparent in summer. Some varieties, such as 'Attraction' and 'Chromatella', are more commonly reported to succumb to crown rot, and varieties said to be resistant have been bred by Perry in the USA.

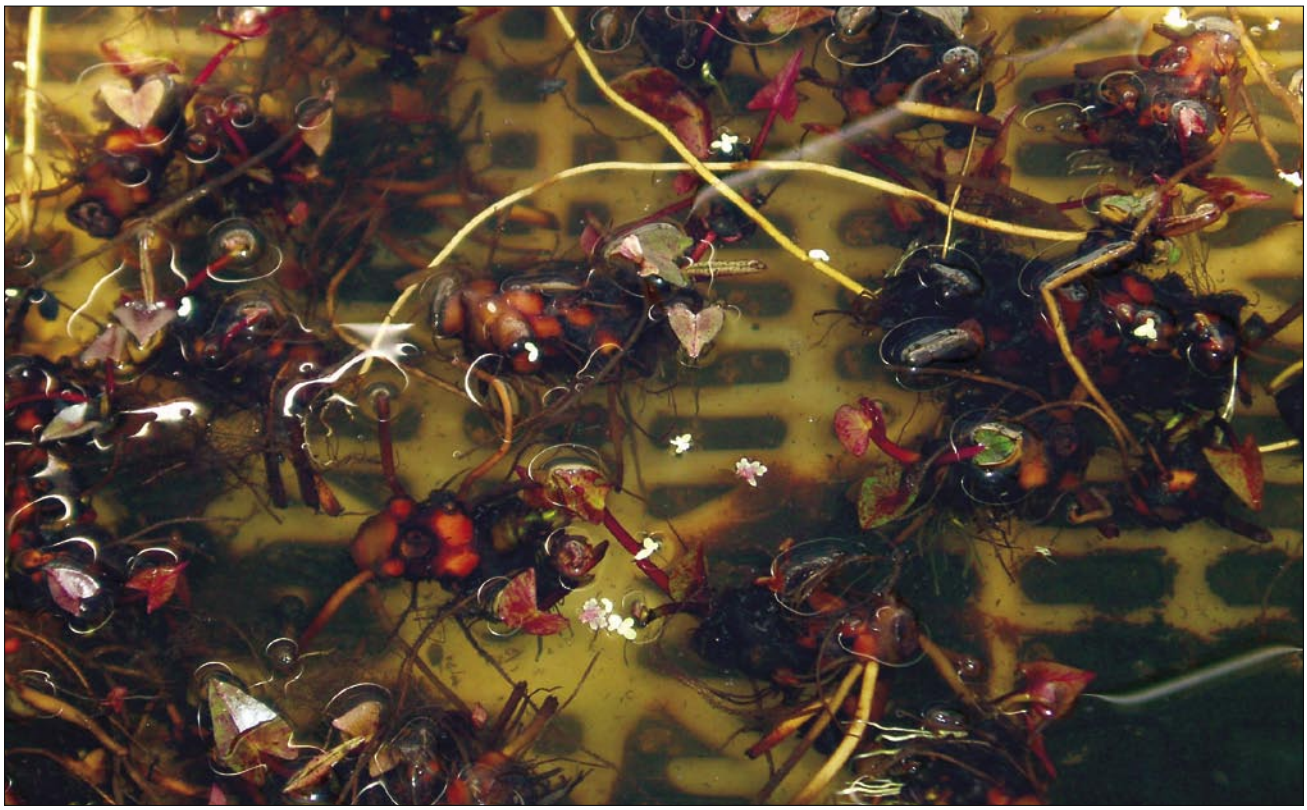
Phytophthora releases motile spores (zoospores) and these may infect healthy plants in the same body of water. They can enter through either wounded or intact tissue. Symptoms may appear in around ten weeks. Plants can also become infected if grown from either rhizome pieces or eyes (Figure 9) taken from crown rot infected plants, although it is possible to select healthy material from beyond the rotted area. Material taken for propagation may have been contaminated externally by zoospores and so these need to be killed before planting into clean compost. There is a Specific Off-label Approval (1501/05) for the product SL567A (containing metalaxyl-M), for use as a rhizome dip, and also as a foliar spray to control water lily crown rot (see 'Chemical control' section).

Phytophthora rot of Calla lily

The fungus *Phytophthora erythroseptica* can cause a rhizome rot of Calla lily (*Zantedeschia aethiopica*). The dark brown, water-soaked lesions develop on the surface, becoming dry and sunken. Internal tissue becomes grey and rubbery.

Other fungal root rots

Fungal pathogens such as species of *Pythium*, *Phytophthora* and *Rhizoctonia* spread in water and from



9 Water lilies being propagated from eyes. Phytophthora crown rot is able to spread in propagation material

contaminated compost between a wide range of hosts, causing death through root and stem base rots. Damage by fungi and various insect, snail and nematode pests can also aid the entry of bacteria and hasten death. The primary cause of plant damage may not be obvious.

Bacterial rots

The tubers of Calla lily and the rhizomes of yellow flag (*Iris pseudacorus*) are prone to bacterial soft rot caused by *Pectobacterium carotovora*. The initial symptoms of iris bacterial soft rot are water-soaked streaks on the leaf blades progressing upwards from the base of the leaf fans. The rotted leaves can be pulled away easily from the fans, although if left they become dry and brownish-grey. The rhizomes become rotted, and the interior becomes reduced to a viscous cream-coloured mass that may be rather pungent. Divided tubers and rhizomes are at particular risk, but the bacteria can also enter following damage by pathogens or pests (Figure 10). The bacteria can enter unwounded tissue and spread through irrigation water, water splash, plant to plant contact, and contamination by hands or tools. In Calla lily, infection can remain latent, the tubers appearing firm and healthy, and these can become a major source of infection.

Foliar diseases

Powdery mildews

Most plant species, under certain conditions, can become infected by powdery mildew on foliage, flowers or fruit. Threads of the fungus (mycelium) spread across the aerial plant surface and insert feeding organs (haustoria) into the tissue. In the early stages, the fungus can be difficult to see, but there may be yellowing or tissue distortion. White patches then appear, enlarge and become powdery as spores are produced under conditions of high humidity. The mycelium can spread in dry conditions and spores are carried in air currents. The spores do not require a water film to germinate, only high relative humidity, and so pondside plants grown in humid conditions on flooded benches or wet capillary matting are prone to infection. Plants are rarely killed by the fungus, but their vigour and quality is reduced.

When environmental conditions or nutrition become unfavourable, many powdery mildew fungi survive by producing tiny black spheres (spore cases) amid the old mycelium. These survive to release spores in the spring. The powdery mildew mycelium cannot survive on dead tissue, but protected crops can provide a ‘green-bridge’ overwinter.

Powdery mildew fungi are highly specialised pathogens and each has a very narrow host range. However, powdery mildew can often be found throughout a production area of mixed plant species. This can be explained by the fact that the same environmental conditions are favourable to the powdery mildews of many species. Common powdery mildews affecting aquatic ornamentals include *Erysiphe aquilegiae* var. *aquilegiae* on marsh marigold (*Caltha palustris*) (Figure 11), *Erysiphe boicellata* on water mint (*Mentha aquatica*), *Golovinomyces cichoracearum* var. *cichoracearum* on hemp agrimony (*Eupatorium cannabinum*) and *Erysiphe polygoni* on amphibious bistort (*Polygonum amphibium*).

Rusts

Rusts occur on many different species of aquatic plants, with most having a limited host range. Rust spores erupt through the surface of the host, and are usually brightly coloured. Different coloured pustules often appear on the same host, with orange or brown summer spores and black overwintering spores.

Most rust species prefer warm conditions. Summer spores are wind or splash dispersed. They require the presence of a film of water before they will germinate. The fungus grows

10 Yellow flag transplants rotting at the base through water-borne disease, probably both bacterial and fungal

11 Powdery mildew is commonly found coating marsh marigold leaves and can lead to leaf death

inside the plant and produces haustoria to absorb nutrients. The mycelium cannot survive on dead tissue, and so relies on over-wintering spores for survival on senescent tissue.

Reeds, rushes, bulrushes, water lilies and willow are all affected by a range of rust species, most of which require alternate hosts to produce another spore stage to complete their life cycle.

Reeds (*Phragmites*) host two rusts. These are *Puccinia phragmitis*, which alternates on either ornamental rhubarb (*Rheum*) or docks (*Rumex* spp.) (Figure 12) and *Puccinia magnusiana*, which requires spearwort (*Ranunculus* spp.) to complete its life cycle.

Soft rush (*Juncus effusus*) is a host to *Uromyces junci* which requires common fleabane (*Pulicaria dysenterica*) to complete its life cycle.

Two aquatic plants, the bulrush (*Schoenoplectus* spp.) and the floating heart water lily (*Nymphoides peltata*), can act as hosts to *Puccina scirpi*, which can complete its life cycle on both.

Different species of willow (*Salix* spp.) are infected by different species of *Melampsora* rust (Figure 13), but their alternate host is not always present in Britain.

Leaf spots

Spotting or blotching on leaves can occur for many reasons, and although fungi commonly cause such damage, yellowing and necrosis can also be caused by bacteria, viruses, insects, nutrient deficiencies and phytotoxicity. Senescing or damaged leaves may also become colonised by weaker fungi.

Fungal leaf spots are often specific to a particular host family, so this reduces the likelihood of cross-infection between commercial crops. Table 1 lists some of the fungal pathogens that give rise to leaf spots on a range of host species.

12 Reed rust – the lifecycle is completed on specific broad-leaved hosts

13 Willow rust – various species are present on different willows

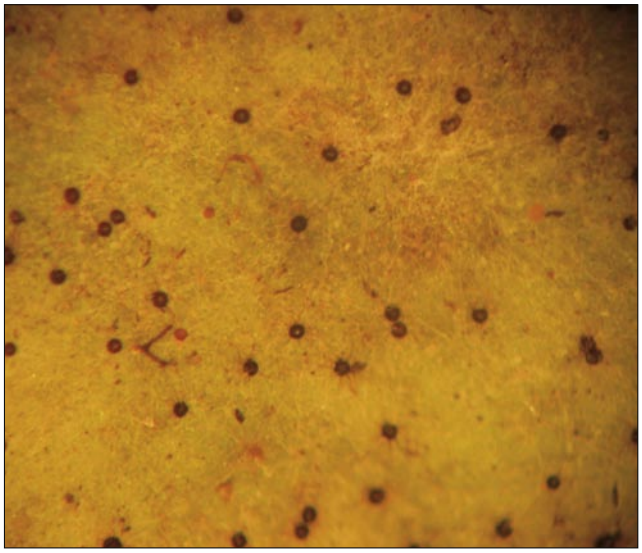
Table 1 Examples of some fungal pathogens causing leaf spots on UK aquatic and semi-aquatic plants

Host common name	Host specific name	Fungus
Yellow flag	*Iris pseudacorus*	*Ectostroma iridis, Mycosphaerella iridis, Phoma pseudacori*
Cowslip	*Primula vulgaris*	*Ascochyta primulae, Cercospora primulae, Ramularia primulae*
Marsh marigold	*Caltha palustris*	*Pseudopeziza calthae, Ramularia calthae*
Soft rush	*Juncus effusus*	*Mollisia juncina, Pyricularia borealis*
Reedmace	*Typha latifolia*	*Colletotrichum typhae, Phaeosphaeria typhae*
Water lily	*Nymphaea* spp.	*Ovularia nymphaearum*

Fungal leaf spots may be circular or irregular in shape, sometimes developing concentric rings as they enlarge (Figure 14). In some species (eg *Ascocyhyta* spp.) tiny spherical bodies containing spores are embedded within the spot. In other species spore-bearing structures may emerge from particular points such as leaf stomata (eg *Ramularia* spp.), while in other species, spores are produced across the whole lesion surface (eg *Cercospora* spp.). Spore production is often greater under high humidity, then the spores are splashed (Figure 15), or blown in dry conditions, to other tissue.

Only *Ovularia nymphaearum* is reported to cause a leaf spot on *Nymphaea* species of water lilies in the UK. It produces circular pale brown spots with dark edges on the upper surface of the leaves. Small pustules of pale yellowish spores develop in the lesions.

14 Fungal leaf spot on brandy bottle lily, which will enlarge to kill the leaf



15 Fruiting bodies within the brandy bottle lily leaf spot. Spores will splash from these to other lilies in the same tank

Weeds and algae

Floating weeds and algae can be invasive and persistent problems. Troublesome weed species in the UK include water fern (*Azolla filiculoides*) and duckweeds (*Lemna minor, L.trisulca, L.gibba* and *L.polyrhiza*). They can rapidly colonise tanks and must be physically removed from other aquatic plants before these are sold (Figure 16).

Tiny pieces of water fern can regenerate and microspores are produced, that sink in water, before rising again on germination to produce a 'sporeling'. Water fern has become naturalised in parts of Britain, and is one of a number of alien species that have become invasive in the wild, and consequently not sold by most nurseries.

Duckweeds multiply rapidly by budding of leaf-like segments. They can also produce seeds from inconspicuous flowers. Duckweeds can survive on wet concrete and mud and are easily carried on footwear.

Algae also contaminate tanks. Single-celled species cloud the water and cause scums. They may be carried on plants to customers' ponds. However, the principal problem is caused by blanketweed (filamentous algae). It can block filtration systems and become entwined around plants and require removal before sale. It can grow from broken strands, multiply rapidly by division, and also mate to produce resting zygotes. Algae are able to encyst to survive desiccation.

16 Duckweed, water fern and blanketweed in a water lily tank. They will need to be cleaned off plants before they are sold

Control of pests and diseases

Cultural and Physical control measures

Cultivar resistance
Cultivar disease resistance may exist in aquatic plants, but breeding for resistance has only been recorded for water lily crown rot.

Hygiene
It is most important to start with clean propagating material, and then to be vigilant for any signs of plant damage. Demonstration of good hygiene measures is a requirement for the issuing of plant passports. Nurseries must always follow good hygiene practices and should:

- ensure mother plants are included in pest and disease monitoring and control programmes.
- only collect seeds from healthy plants as fungi, bacteria and viruses can be seed-borne.
- utilise micropropagation of semi-aquatic plants where possible to remove bacteria, fungi and viruses from stock.
- inform the Plant Health and Seeds Inspectorate if importing water lily rhizomes or plants from outside the EC.
- ideally, place newly bought-in plants away from the main growing areas and inspect them regularly to confirm freedom from pests, diseases and weeds before moving them into production areas (see HDC Factsheet 06/08 *'A guide to best practice in handling bought-in plants*').
- sterilise propagation tools continually during use and regularly wipe down propagating benches.
- consider the use of preventative fungicide compost drenches if appropriate.
- start the day with 'clean' tasks, before moving onto work with older plants or those with known pest or disease problems.
- place boot-dips at entrances to glasshouses or tunnels, wash hands and change protective clothing when moving between areas.
- clean and disinfect trolleys, benches, containers and matting as a routine.
- use sticky traps to monitor flying insects, together with plant inspection (using a hand lens) to detect other pests and diseases on foliage, flowers and roots.
- promptly remove infected or infested plant parts or whole plants.
- insert discarded plants in bags or bins on removal, so that the pests or diseases do not have time to disperse to new hosts.
- cover infected and infested plant waste to prevent pests and diseases (both wind-blown or insect-carried) from returning to the growing areas.

Water quality
Pests, pathogens and algae can spread in irrigation water, with overhead irrigation exacerbating disease splash and pest spread between plants. Inadequately treated re-circulated water can pose a particular threat, but water collected from glasshouse roofs is also likely to contain propagules (spores, seeds and tissue fragments) of a multitude of organisms, including bacteria, fungi and algae. Species of *Pythium* and *Phytophthora* have been isolated from nursery reservoirs and roof water.

There are several ways to remove pathogens from water. The volume of water to be treated and the throughput required will help to determine the method selected. Physical removal by normal methods of filtration is rarely sufficient for control because of the microscopic size of the organisms. However there are other effective measures.

- Slow sand filtration has been found to be particularly effective because a biofilm develops which traps pathogens.
- Ultraviolet radiation treatment of pre-filtered water as it passes through a chamber can be used on large volumes, and smaller units are available for misters.
- Ozonation, or chlorination of water can work effectively.
- Heat treatment is possible, but can be relatively expensive.
- Investigations are underway to determine the effectiveness of copper electrodes.

Biological control measures

Pests
Many biological control agents (predators, parasitoids, insect-pathogenic nematodes, insect-pathogenic fungi and bacteria) are now available for use against a wide range of pests. These are mainly used in protected crops, but some can be used outdoors between late spring and autumn, if temperatures are suitable. There are many benefits in using biological control methods, including:

- No problems with pest resistance to pesticides
- No harvest intervals or handling periods following pesticide use
- No pesticide phytotoxicity
- Safe to nursery staff
- Environmentally-friendly
- Meets customer demands for reduced pesticide inputs

Biological control agents should be used in a carefully planned Integrated Pest Management (IPM) programme. This may include appropriate cultural control methods and also the use of compatible pesticides, selected as having minimal adverse effects on biological control agents.

Full details of how to use biological control agents within an IPM programme are available from the suppliers and from other IPM

consultants. Some examples of biological control agents available for controlling aquatic plant pests are listed in Table 2.

Diseases

Natural products are available for use in compost during conventional plant production, some working by competition between microbes and others by enhancing plant resistance to attack. In the UK products marketed for terrestrial plants include;

- those containing microorganisms eg GlioMix (containing *Gliocladium*), Stimagro (containing *Streptomyces* spp.) and Trianum-P (containing *Trichoderma harzianum* T-22).
- mycorrhizal rooting stimulants (eg endoRoots). Their activity in saturated or submerged compost is not known.
- compost teas containing a range of microorganisms, which can be applied with irrigation.
- products containing natural plant extracts (eg Biosept All Clear and Orosorb).
- commodity chemicals (eg potassium bicarbonate).

Chemical control measures

Although growers generally implement cultural, physical and biological control methods, there are times when the use of chemical pesticides are necessary to eradicate certain pest, disease and weed problems.The current legislation (2008) permits chemical pesticide use on aquatic plants:

- where products carry Full Label Approval for ornamental plants.
- where products carry Specific Off-Label Approval (SOLA) for ornamental plants.
- under the Long-Term Arrangements for the Extension of Use (LTAEU), which permits any pesticide with a full or off-label approval on an edible crop to be extrapolated for use on a non-edible ornamental crop.

At the time of printing, the Long-Term Arrangements for the Extension of Use (LTAEU) are being phased out. A large number of pesticide products that are currently used by ornamental plant growers will be granted Specific Off-Label Approvals (SOLAs) over a period of time. The Long-Term Arrangements will remain in force until large numbers of products have received SOLAs.

However, growers should continually acquaint themselves of changes in pesticide legislation. The most accurate information can be acquired from pesticide suppliers and the Pesticide Safety Directorate (PSD) Tel. (01904) 640500 or on their website: **www.pesticides.gov.uk**

The legal status

Growers are often unsure of what they are legally permitted to do. The following list provides aquatic plant growers with some practical implications of the current approvals for aquatic plants:

- Pesticide products approved for use on ornamental plants may also be used on aquatic and semi-aquatic ornamental plants, provided that the relevant conditions on the product label are satisfied.

Table 2 Examples of some biological control agents available for controlling aquatic plant pests in the UK

Common name	Pest species	Biocontrol agent	Agent type
Water lily beetle	*Galerucella nymphaeae*	None yet available	None yet available
Water lily aphid	*Rhopalosiphum nymphaeae*	*Aphidoletes aphidimyza* *Chrysoperla carnea*	Predatory midge larvae* Predatory lacewing larvae*
Melon & cotton aphid	*Aphis gossypii*	*Aphidius colemani*	Parasitic wasp
Peach-potato aphid	*Myzus persicae*	*Aphidius colemani*	Parasitic wasp
Potato aphid	*Macrosiphum euphorbiae*	*Aphidius ervi*	Parasitic wasp
Glasshouse & potato aphid	*Aulacorthum solani*	*Aphidius ervi*	Parasitic wasp
Two-spotted spider mite	*Tetranychus urticae*	*Phytoseiulus persimilis,* *Amblyseius californicus,* *Amblyseius andersoni* *Feltiella acarisuga*	Predatory mites Predatory midge larvae
Glasshouse whitefly	*Trialeurodes vaporariorum*	*Encarsia formosa*	Parasitic wasp
Vine weevil	*Otiorhynchus sulcatus*	*Steinernema kraussei*	Insect-pathogenic nematode**
Aphids and whitefly	Various species	*Verticillium lecanii*	Insect-pathogenic fungus
Caterpillars	Various species	*Bacillus thuringiensis*	Bacterium

Table 2 notes:

* Aphid predators are less specific to particular aphid species than parasitic wasps, but there is no specific information available on the feeding activity of these on water lily aphid.

** Nematodes are unable to survive in unaerated water and so may not be effective in plants grown on flooded benches.

- Some product labels prohibit use on aquatic, semi-aquatic or pondside plants, such as certain pesticides approved for the control of vine weevil.

- All plants need to be in the same cropping situation (ie outdoor or protected) as stipulated on the full label approval or SOLA.

- Treatment can be applied to ornamental plants that will subsequently be planted in or adjacent to ponds. This includes reeds that may be used in water filtration schemes.

- LTAEUs exclude use in or near water, but this exclusion applies only to water courses etc. Use under the LTAEU is permitted where there is contained water integral to aquatic ornamental plant production.

- Products approved for use on watercress can be used on ornamental plants under the LTAEU as long as conditions of use on the watercress approval are complied with, including the situation of use (outdoor/protected).

- Growers should be sure to read the advisory information and conditions of use on all approvals. For instance, some stipulations can be set. An example is SOLA 1501/05 which permits the use of metalaxyl-M (SL 567A) as a rhizome dip and foliar spray to control crown rot in water lilies. In this case, all treated plants must be washed before sale and a holding period of 10 weeks must be observed for dipped plants.

- Use of pesticides under SOLA or LTAEU is at growers' own risk. If a pesticide has not been used on a certain plant species before, it is recommended that only a small number of plants are treated initially, and records kept of efficacy and any phytotoxicity (see HDC Factsheet 01/08 '*A guide to simple and effective nursery trials*').

Pests and diseases

Where possible, cultural control measures should be used to help prevent the pest or disease problem arising. Use of biological control agents within IPM will reduce the need for pesticides. If a pesticide is needed within IPM, one should be selected with minimal adverse effects on biological control agents. Fungicides are generally considered less harmful to beneficial species than certain insecticides and acaricides. However, some do have adverse effects.

Biological control suppliers should be consulted for full details of safety of insecticides and fungicides to individual biological control agents.

Tables 3 (below) and 4 (overleaf) list examples of fungicides and insecticides that can be used to control a range of pests and diseases in aquatic and semi-aquatic plants. Their IPM compatibilities are summarised.

Table 3 Examples of fungicides and bactericides approved for use on aquatic and semi-aquatic plants

Primary or key target	Active ingredients	Typical products	Use within IPM	Crop situation and other useful information
Botrytis	boscalid & pyraclostrobin	Signum	Limited information	Outdoor and protected
	chlorothalonil	Bravo 500	Safe to most biocontrols	Outdoor and protected
	iprodione	Rovral WG	Safe to most biocontrols	Outdoor and protected
	mepanipyrim	Frupica SC	Limited information	Outdoor and protected
	prochloraz	Scotts Octave	Safe to most biocontrols	Outdoor and protected
Leaf spots	prochloraz	Scotts Octave	Safe to most biocontrols	Outdoor and protected
Powdery mildew	azoxystrobin	Amistar	Safe to most biocontrols	Outdoor and protected
	chlorothalonil	Bravo 500	Safe to most biocontrols	Outdoor and protected
	myclobutanil	Systhane 20 EW	Safe to most biocontrols	Outdoor and protected
	propiconazole	Bumper 250 EC	Safe to most biocontrols	Outdoor and protected
Rust	azoxystrobin	Amistar	Safe to most biocontrols	Outdoor and protected
	myclobutanil	Systhane 20 EW	Safe to most biocontrols	Outdoor and protected
	propiconazole	Bumper 250 EC	Safe to most biocontrols	Outdoor and protected
Phytophthora, Pythium	propamocarb-hydrochloride	Filex	Safe to most biocontrols	Outdoor and protected. Drench or compost incorporated
	etridiazole	Standon Etridiazole 35	Safe to most biocontrols	Outdoor and protected. Compost incorporated
Rhizoctonia	azoxystrobin	Amistar	Safe to most biocontrols	Outdoor and protected
Bacteria	copper oxychloride	Cuprokylt	Harmful to some biocontrols for up to 1 week	Outdoor and protected. Foliar protectant non-systemic spray

Table 3 notes:

- For full list of targets, active ingredients and products see product labels.
- For full details of compatibility of fungicides with individual biological control agents, and their persistence, contact biological control suppliers or consultants.
- Agrochemical approvals regularly change. Growers should always check the current approval status of products listed before use.

Table 4 Examples of insecticides and acaricides approved for use on aquatic and semi-aquatic ornamental plants

Primary or key target	Active ingredients	Typical products	Use within IPM	Crop situation and other useful information
Aphids (eg *Aphis gossypii* and *Myzus persicae*)	acetamiprid	Gazelle	Harmful to some biocontrols for up to 2 weeks	Outdoor and protected
	cypermethrin	Toppel 100 EC	Harmful to biocontrols for up to 12 weeks	Outdoor and protected. *A.gossypii* and *M.persicae* resistance likely.
	deltamethrin	Decis	Harmful to biocontrols for up to 12 weeks	Outdoor and protected. *A.gossypii* and *M.persicae* resistance likely.
	fatty acids	Savona	Harmful to some biocontrols for up to 3 days	Outdoor and protected
	natural plant extracts	Eradicoat/Majestik	Safe to biocontrols once spray deposit dry	Outdoor and protected
	nicotine	Stalwart	Harmful to some biocontrols for up to 2 days	Outdoor and protected
	pirimicarb	Aphox	Harmful to some biocontrols for up to 1 week	Outdoor and protected. *A.gossypii* – resistant. *M.persicae* – resistance likely.
	pymetrozine	Chess WG	Safe to most biocontrols	Protected
	pyrethrins	Spruzit	Harmful to biocontrols for up to 1 week	Outdoor and protected. *A.gossypii* and *M.persicae* resistance likely.
	thiacloprid	Calypso	Harmful to some biocontrols for up to 2 weeks	Outdoor and protected
Beetles*	cypermethrin	Toppel 100 EC	Harmful to biocontrols for up to 12 weeks	Outdoor and protected
	deltamethrin	Decis	Harmful to biocontrols for up to 12 weeks	Outdoor and protected
	pyrethrins	Spruzit	Harmful to biocontrols for up to 1 week	Outdoor and protected
	thiacloprid	Calypso	Harmful to some biocontrols for up to 2 weeks	Outdoor and protected
	thiacloprid	Exemptor	Harmful to some biocontrols for up to 6 weeks	Outdoor and protected. Applied as a compost incorporation, for containerised ornamentals only.
Caterpillars	*Bacillus thuringiensis*	Dipel DF	Safe to biocontrols	Outdoor and protected
	cypermethrin	Toppel 100 EC	Harmful to biocontrols for up to 12 weeks	Outdoor and protected
	deltamethrin	Decis	Harmful to biocontrols for up to 12 weeks	Outdoor and protected
	iflubenzuron	Dimilin Flo	Safe to most biocontrols	Outdoor and protected
	indoxacarb	Steward	Safe to most biocontrols	Outdoor and protected
	methoxyfenozide	Runner	Safe to most biocontrols	Outdoor (Off-label)
	pyrethrins	Spruzit	Harmful to biocontrols for up to 1 week	Outdoor and protected
	spinosad	Tracer	Harmful to some biocontrols for up to 2 weeks	Outdoor and protected (SOLA)
	teflubenzuron	Nemolt	Safe to most biocontrols	Outdoor and protected
Spider mites	abamectin	Dynamec	Harmful to some biocontrols for up to 3 weeks	Outdoor and protected
	bifenazate	Floramite	Safe to most biocontrols	Protected (Off-label)
	bifenthrin	Gyro	Harmful to biocontrols for up to 12 weeks	Outdoor and protected
	clofentezine	Apollo 50 SC	Safe to biocontrols	Outdoor and protected
	fenbutatin oxide	Torq	Safe to most biocontrols	Protected
	natural plant extracts	Eradicoat/Majestik	Safe to biocontrols once spray deposit dry	Outdoor and protected
	spiromesifen	Oberon	Harmful to some biocontrols for up to 3 weeks	Protected (SOLA)
	tebufenpyrad	Masai	Harmful to some biocontrols for up to 2 weeks	Outdoor and protected
Vine weevil**	imidacloprid	Intercept 70 WG	Harmful to some biocontrols for up to 6 weeks	Outdoor and protected. Applied as a drench to containerised ornamentals only.
	imidacloprid	Imidasect 5GR	Harmful to some biocontrols for up to 6 weeks	Outdoor and protected. Applied as a compost incorporation, for containerised ornamentals only.
	thiacloprid	Exemptor	Harmful to some biocontrols for up to 6 weeks	Outdoor and protected. Applied as a compost incorporation, for containerised ornamentals only.
Whiteflies	acetamiprid	Gazelle	Harmful to some biocontrols for up to 2 weeks	Outdoor and protected
	buprofezin	Applaud	Safe to most biocontrols	Protected. Whitefly resistance likely.
	cypermethrin	Toppel 10	Harmful to biocontrols for up to 12 weeks	Outdoor and protected. Whitefly resistance likely.
	deltamethrin	Decis	Harmful to biocontrols for up to 12 weeks	Outdoor and protected. Whitefly resistance likely.
	fatty acids	Savona	Harmful to some biocontrols for up to 3 days	Outdoor and protected
	natural plant extracts	Eradicoat/Majestik	Safe to biocontrols once spray residues dry	Outdoor and protected
	spiromesifen	Oberon	Harmful to some biocontrols for up to 3 weeks	Protected (SOLA)
	teflubenzuron	Nemolt	Safe to most biocontrols	Outdoor and protected. Whitefly resistance likely.
	thiacloprid	Calypso	Harmful to some biocontrols for up to 3 weeks	Outdoor and protected
	thiacloprid	Exemptor	Harmful to some biocontrols for up to 6 weeks	Outdoor and protected. Applied as a compost incorporation, for containerised ornamentals only.

Table 4 notes:

* There are no pesticides with a specific recommendation for the control of water-lily beetle.

** Compost incorporated chlorpyrifos (SuSCon Green) & fipronil (Vi-Nil) must not be applied to growing media for aquatic or semi-aquatic plants.

- For full list of targets, active ingredients and products see product labels.
- For full details of compatibility of pesticides with individual biological control agents, and their persistence, contact biological control suppliers or consultants.
- Agrochemical approvals regularly change. Growers should always check the current approval status of products listed before use.

Control of weeds and algae

Weeds

Biological control

There is a form of biological control available for the control of *Azolla* water fern species in the UK. It is marketed under the trade name Azollacontrol and utilises the North American weevil, *Stenopelmus rufinasus*. This weevil can only feed and reproduce on *Azolla* species and it will control the weed throughout the growing season. However, there are currently no other forms of biological weed control available for use in aquatic plant production.

Chemical control

Growers should be acquainted with the different types of approval available for use of herbicides in aquatic plant production and the legal implications (see pest and disease control section – chemical control).

Previous approvals for the use of the herbicides Clarosan (terbutryn) and Reglone (diquat) for aquatic weed control have been withdrawn. Where total weed control is required, the broad spectrum translocated, non-persistent herbicide glyphosate can be sprayed onto emergent and floating weeds in tanks. Products include Glyfos and Roundup Pro Biactive. Alternatively, granules of Casoron G (dichlobenil) or Depitox (2,4-D) can be applied to **enclosed** water, but the water cannot be used for irrigation for 14 and 21 days, respectively.

Algae

A number of control measures are available to aquatic plant growers, based on cultural (based on nutrition), physical and biological control techniques. It is also possible to use chemical and biocidal products that are available through the amateur market.

Cultural control

Excessive levels of nutrients in water encourage the development of algae. The principal way of reducing levels of algae is to reduce the levels of nutrients in the water. This can be achieved in several ways:

- Nutrients may be lost from compost in potted plants. The use of slow release fertiliser granules can limit this.
- Biological filters are available to remove nitrates from water.
- A product sold under the trade name Phoslock is available that absorbs phosphorous from the water and locks it in the sediments at the bottom of ponds.
- Aeration can provide some control of algae by mixing the water column so that conditions of high fertility are removed from the surface where algae collect to photosynthesise (Figure 17).

Physical control

- Growth of single celled and filamentous algae in waters deeper than 60 cm can be inhibited by the addition of a water-soluble dye (DyoFix). One application can last for up to three months. It is only suitable for deep tanks or ponds, growing plants with some leaves held above water.
- Ultrasonic waves have been shown to rupture the cells of blanketweed. Ultrasound units are available for various water volumes. They are also claimed to control *Fusarium* and *Pythium*.
- Ultraviolet clarifiers can be used on water entering a pond to kill algae, fungi and bacteria.

17 Various forms of aeration can be employed to provide some control of algae

Biological control

- Barley straw can reduce algal growth when loosely packed and placed to float in ponds several months before conditions for blooms are optimum. Other straws such as lavender can be used, but may be less effective. Straw pellets are also available and may release natural chemicals immetdiately, reacting photochemically to activate humic acids that produce hydrogen peroxide to keep the water clear.

- Microbial control of single celled and filamentous algae is possible using a bacterial product (Aquaclean) containing plant extracts that help to activate the different microbes.

- The fry of grass carp eat filamentous algae, but they are not an ideal way to control blanketweed, for once the fish get older they eat plants.

Chemical control

Where growers have employed cultural, physical and biological methods of control and still have excessive levels of algae, there may be justification to employ chemical control measures.

For growers considering using chemical biocides, a number of aquatic algaecide products are approved for use in the UK by the Health and Safety Executive (HSE). However these products are primarily intended for the amateur market. As such, the HSE does not require these products to be tested for their safety to plants.

Commercial growers must undertake risk assessments (for example under COSHH) before using any chemical products. Even though products may be intended for use by amateurs, commercial growers may still be permitted to use them provided that they can demonstrate that the use is acceptable and that any risks can be adequately controlled.

A number of active ingredients work as effective aquatic algaecides. Products are available from aquatics sundries suppliers including:

- benzalkonium chloride and copper sulphate (Waterlife Algizin P)
- dimethylamine-epichlorohydrin copolymer (Interpet Feature Algae Control)
- monolinuron (TetraPond Algofin)

As products containing copper sulphate may be toxic to plants and monolinuron acts as a herbicide, growers should give careful thought to their selection of products.

It is worth noting that algaecides are also available for ground treatment, but some are hazardous to aquatic wildlife, and so run-off or drift should be avoided if used on pathways between tanks. Some disinfectants are effective against both pathogens and algae eg peroxyacetic acid (Jet 5) or tar acids (Jeyes Fluid) and so may be useful when cleaning tanks and trays between batches.

Caution may be required when using algaecides in the presence of Reeds (*Phragmites* spp.) to prevent disruption of the algal-bacterial associations on their underwater surfaces, which assist in the water purification ability of this plant.

Further information

Useful publications

- Buxton, J., Bennison, J., Brough, W. and Hewson, A. (2006). Integrated Pest Control for Protected Ornamental Crops – Best Practice Guide for UK Growers. Defra/ADAS. Available from:
  ADAS Boxworth
  Tel. 01954 268214/205

- Alford, D. V. (1991). A Colour Atlas of Pests of Ornamental Trees, Shrubs and Flowers. Wolfe Publishing Ltd.

- Alford, D. V. (Ed.) (2000). Pest and Disease Management Handbook. Blackwell Science/British Crop Protection Council.

- Malais, M.H. and Ravensberg, W.J. (1992). Knowing and Recognising: The Biology of Glasshouse Pests & Their Natural Enemies. Koppert BV. And Reed Business Information.

- Centre for Aquatic Plant Management, Centre for Ecology and Hydrology, Wallingford. Information sheets on algae & weed control. **www.capm.org.uk**

- Helyer, N., Brown, K. and Cattlin, N. (2003). A Colour Handbook of Biological Control in Plant Protection. The Royal Horticultural Society, Manson Publishing.

- HDC Project report HNS 82 (1997) – Control of aquatic weeds in nurseries and water storage systems: a literature review.

- HDC Project report HNS 145 (2007) – Guidelines for integrated pest and disease management for ornamental aquatic plants.

- HDC Factsheet 02/03 – Vine weevil control in hardy nursery stock.

- HDC Factsheet 16/04 – Control of Phytophthora, Pythium and Rhizoctonia in container-grown hardy ornamentals.

- HDC Factsheet 08/05 – The biology and control of two-spotted spider mite in nursery stock.

- HDC Factsheet 14/05 – Control of whiteflies on protected ornamental crops.

- HDC Factsheet 15/06 – Water quality for the irrigation of ornamental crops.

- HDC Factsheet 10/07 – Guidelines on nursery hygiene for outdoor and protected ornamentals.

- HDC Factsheet 01/08 – A guide to simple and effective nursery trials.

- HDC Factsheet 06/08 – A guide to best practice in handling bought-in plants.

- HDC Grower guide – Slow Sand Filtration – A flexible, economic biofiltration method for cleaning irrigation water.

Suppliers of products and sundries

Suppliers of biological control agents:
This list is not exhaustive and no criticism is implied of suppliers not included here.

Agralan Ltd (Biobest products)
The Old Brickyard, Ashton Keynes
Swindon, Wiltshire SN6 6QR
Tel. (01285) 860015
www.agralan.co.uk

Azolla control CABI Bioscience
Bakeham Lane, Egham
Surrey TW20 9TY
Tel. (01491) 829080
www.azollacontrol.com

Becker Underwood UK
(nematode products)
Unit 1 Harwood Industrial Estate
Harwood Road, Littlehampton
West Sussex BN17 7AU
Tel. (01903) 732323
www.beckerunderwood.com

BCP Certis
Occupation Road, Wye, Ashford
Kent TN25 5EN
Tel. (01233) 813240
www.bcpcertis.com

Biowise
Hoyle Depot, Graffham, Petworth
West Sussex GU28 0LR
Tel. (01798) 867574
www.biowise-biocontrol.co.uk

Fargro Ltd
(agents for Syngenta Bioline)
Toddington Lane, Littlehampton
West Sussex BN17 7PP
Tel. (01903) 721591
www.fargo.co.uk

Koppert UK Ltd
Unit 8, 53 Hollands Road, Haverhill
Suffolk CB9 8PJ
Tel. (01440) 704488
www.koppert.co.uk

Syngenta Bioline
Telstar Nursery, Holland Road
Little Clacton, Essex CO16 9QG
Tel. (01255) 863200
www.syngenta-bioline.co.uk

Biological agents and sticky traps can also be obtained through most horticultural supplier

Suppliers of algae control products:
A.G.A. Group
Merton Hall Ponds, Merton
Norfolk IP25 6QH
Tel. (01953) 886824
www.agagroup.co.uk
(Ultrasound control of algae)

Bionetix UK
North Dean Business Park
Stainland Road, Greetland
Halifax HX4 8LR
Tel. (01422) 363462
www.bionetix.co.uk
(Aquaclean bacterial control of algae)

Phoslock UK Office
Building A, Trinity Court Wokingham
Road, Bracknell, Berkshire RG42 1PL
Tel. (0870) 734 6334
www.phoslock.co.uk
(Phoslock to inhibit algae in ponds)

Town End (Leeds) plc
Industrial Dyes and Dyestuffs UK
Silver Court, Intercity Way
Stanningley, Leeds, W. Yorkshire
Tel. (0113) 2564251
www.dyes.co.uk
(Dyofix to inhibit algae in ponds)

Waterlife Research Ind. Ltd
Bath Road, Longford
Middx UB7 0ED
Tel. (01753) 685696
www.waterlife.co.uk
(Algizin algaecide)

Suppliers of aquatics sundries including filters and chemicals:
Bennetts Water Gardens
B3175 Chickerell Link Road
Weymouth, Dorset DT3 4AF
Tel. (01305) 785150
https://shop.waterlily.co.uk

Bradshaws Direct
Internet direct sales
www.bradshawsponds.co.uk

Life Force
Internet direct sales
www.lifeforceonline.co.uk

Maidenhead Aquatics
Various local stores and Internet direct sales
Email. info@maidenaquatics.co.uk
www.maidenheadaquatics.co.uk

Seapets
Internet direct sales
www.seapets.co.uk

World of Water Direct
Various local stores and Internet direct sales
Tel. (0870) 803 4343 for stores
Tel. (01580) 243 333 for mail order
www.worldofwater.com

Wroot Water Limited
Wroot, Doncaster DN9 2BU
Tel. (01302) 771881
www.wrootwater.com
(Filters and ultra violet water disinfection units)

Acknowledgements

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Further information: A full copy of the final report for HDC Project HNS 145 is available from the HDC office (01732 848383) or website www.hdc.org.uk

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