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Horticultural Development Council

Guidelines for integrated pest and disease management for ornamental aquatic plants

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AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

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Headline

Reduction in pests, diseases and weeds is possible with early recognition, greater awareness of favourable development conditions, and the selection of the most appropriate control measures for ornamental aquatic plant production.

Background and expected deliverables

Aquatic plants suffer from a range of pest, disease and weed problems including water lily beetle, water lily crown rot and blanketweed. The industry currently has no standard effective control methods and there is little published information about their biology and control in the UK.

A recent HDC-funded scoping study highlighted the need for knowledge transfer for the aquatic plant industry, including the development of point-of-sale information for customers. Apart from an HDC funded project on water lily crown rot in 1989 (HNS 26), no research or knowledge transfer work has been undertaken for aquatic plant growers.

No insecticides or acaricides and only a few herbicides are approved specifically for use on plants growing in or adjacent to enclosed waters because of potential adverse effects of pesticide contamination on aquatic wildlife.

With regard to fungicides, SL-567A (metalaxyl-M) has a specific off-label approval (SOLA, no. 2005/1501) for control of crown rot on protected and outdoor water lily. This can be used as a dip treatment on rhizomes and tubers prior to potting on and as a surface treatment over leaves.

Pesticide approvals for use on watercress can not be extrapolated to aquatic ornamental plants under the Long Term Arrangements for Extension of Use (LTAEU). As a result, the management of pests, diseases and weeds on aquatic ornamentals relies heavily on finding suitable cultural and biological control methods.

There have been major worldwide developments in the use of integrated crop management (ICM) and integrated pest management (IPM) techniques in other protected and some outdoor crops, including the use of biological control agents, water purification and plant extracts. Some techniques could be transferred directly to aquatic and semi-aquatic ornamental plant production and others might be adapted following research.

The increased use of ICM would be of immediate benefit in the production of quality plants where conventional pesticides cannot be used.

The expected deliverables of the project were:

1. A review of existing knowledge on the chemical, cultural and biological control of pests, diseases and weeds of aquatic ornamental plants to identify best practice techniques.
2. Up-to-date information on the current status of key pests, diseases and weeds causing problems in UK aquatic ornamental plant production including:
    a. control measures in use;
    b. identification of specific gaps where more effective control measures are needed;
    c. identification of research needs.
3. To communicate to UK growers best-practice techniques for the control of pests, diseases and weeds on aquatic ornamental plants.

Summary of the project and main conclusions

Literature review of pest, disease and weed incidence and management

IPM programmes including the use of biological control agents are widely and successfully used for pest control in non-aquatic ornamentals, on many UK nurseries. There is considerable scope for growers of aquatic plants to use these techniques.

Research is needed on non-chemical methods for some pests specific to aquatic plants, or on the validation of the efficacy of some available control methods on aquatic plants.

There is **limited published information** on the bacteria, fungi and viruses most likely to be found causing plant diseases on aquatic nurseries.

A large number of **fungi** are capable of infecting aquatic and semi-aquatic plants in their natural growing conditions in the UK, but there is scant information on their prevalence and importance on nurseries. Symptoms include leaf spots, powdery mildews, rusts, smuts and stem die-back.

Products containing **plant extracts** (e.g. Biosept All Clear), **microorganisms**, or chemicals such as **phosphates** that may help to induce disease resistance are available for use, but no information was available on their activity on the range of species grown by aquatic nurseries.

Hygiene measures (in particular during propagation), and other management techniques required as a component of Plant Passporting procedures are key cultural control methods for pests, diseases and weeds.

Slow sand filters are able to remove weed propagules, bacteria and fungi from non-mains water supplies, and may be useful for treating irrigation water on nurseries producing aquatic ornamental plants.

Pest and disease problems on UK nurseries visited

The main pest problems reported or identified were vine weevil, two-spotted spider mite, water lily beetle and water lily aphid. Glasshouse whitefly and various aphid species can infest some protected marginal and aquatic species. Whorled pond snails can damage water lily leaves.

The main disease problems were seedling damping-off and rotting of plantlets attributed to *Pythium.* Powdery mildew was the most obvious foliar disease. Some unidentified leaf spots occur on water lilies towards the end of the growing season. Water lily crown rot is less prevalent than it was in the late 1980s when the source of infection was attributed to certain imports.

Pest and disease control measures used by growers visited

Physical intervention is commonly used, including hosing larger plants with water, washing plants or roots, and hand-picking snails and removing damaged leaves.

Hygiene measures are commonly employed including the segregation of separate batches of plant stocks and cleaning tanks and benches between batches.

Natural products are sometimes used. There is some use of garlic as a spray treatment to improve vigour, and of barley straw in water to reduce algal growth. The effect of such products on pests and diseases is not known.

Biological pest control is sometimes used, e.g. entomopathogenic nematodes against vine weevil and parasitic wasps (*Encarsia formosa*) against glasshouse whitefly.

Chemical control of pests and disease is used where other measures fail.

Financial benefits

In 2006, aquatic plant production made up 1% of the ornamental plant sector in the UK. However, aquatic plant growers also produce a wide range of terrestrial hardy and herbaceous perennials that increases the value of produce grown by this sector.

The market for aquatic plants is likely to grow with an increase in international and domestic trade in aquarium plants, aquatic plants for outdoor water bodies such as fishponds, and a developing market for swimming ponds. These customers all require high standards of plant health, and have a low tolerance of weed or algal contamination.

This report provides information on the recognition of pests, diseases, weeds and algae, and the conditions that favour their development, to assist early remedial action.

- If widely adopted, customers will know that a quality product can be expected, and purchase with increased confidence from UK growers.

Action points for growers

- Ensure that staff are able to recognise common pests and diseases, and know how they are spread.
- Monitor and promptly remove, cut back, or spot treat, infested or infected plants.
- Introduce biological control organisms where and when appropriate, to areas with recurring problems.
- Ensure that plants have good nutrition, light, water, ventilation and adequate heat to reduce stress, so that they are better able to resist pests and diseases.
- Disinfect nursery equipment, benches and tanks to stop pathogen, pest and weed transfer.

- Remove pathogens, algae and weed propagules from stored irrigation water and re-circulated water by installing and maintaining an efficient water filtration and treatment system.

- Consider using ultrasound, dyes, flocculators or microbial products against algae in tanks.

- If a pesticide is necessary, check this project factsheet, product labels and information on compatibility with biological control agents, to select the most appropriate product to target the particular insect, mite, fungal or bacterial problem present.

- Assess the risk to non-target aquatic organisms before using pesticides.

- Record successes, or any problems, with any type of control measure used, so as to develop the most appropriate and efficient integrated pest and disease management strategy for each plant species.

Science Section

Introduction

Aquatic plants have a range of pest and disease problems (e.g. water lily beetle, water lily crown rot) with no industry standard methods for effective control, and little published information on them in the UK. A recent HDC-funded scoping study highlighted the need for knowledge transfer for the aquatic plant industry, including the development of point-of sale information for customers.

Apart from a 1989 project on water lily crown rot (HNS 26), there has been no research or knowledge transfer work specifically for growers of aquatic ornamental plants. At the start of this project, it was thought that few chemical control measures were available to aquatic plant growers as no insecticides or acaricides had approval for use on plants growing in or adjacent to enclosed waters, and fungicide use was limited to one product. This was because of potential adverse effects of pesticide contamination on aquatic wildlife. However, as a result of this project and the consequent clearer understanding of the production techniques of aquatic plant producers, further guidance has now been issued from the Pesticides Safety Directorate (PSD). Water tanks and flooded benches used on nurseries for plant production have been deemed to be outside the original meaning of "in and around water". It is thus possible to use pesticides approved for use on ornamentals, and also to utilise the Long Term Arrangements for Extension of Use (LTAEU) from edible crops, provided the relevant conditions of the label are satisfied. Some product labels prohibit the use of the product on aquatic or marginal plants, e.g. certain pesticides approved for vine weevil control (see page 14). LTAEUs would include, for example, products approved for use on watercress. Before this clarification, it was considered that the management of pests and diseases of aquatic ornamentals needed to rely mainly on developing suitable cultural and biological control methods. It is now apparent that guidance is also needed on the integration of pesticides with other management techniques, in order to develop integrated crop management programmes. This should include information on the compatibility of pesticides with biological control agents. However, cultural or biological control should be the first course of action.

There have been major worldwide developments in the use of Integrated Crop Management (ICM) and Integrated Pest Management (IPM) techniques in other protected and outdoor crops, including the use of biological control agents, plant extracts and water purification. Some techniques could be transferred directly to aquatic and semi-aquatic plant production, and others might be adapted following research. The increased use of ICM would be of immediate benefit in the production of quality plants.

The overall aim of this project is to collate and communicate to UK growers existing relevant and practical information on integrated pest, disease and weed management for aquatic ornamental plants (including plants for both water and marginal habitats).

Objectives

1. To review existing knowledge on the cultural, chemical and biological control of pests, diseases of aquatic ornamental plants to identify best practice techniques.
2. To determine the current status of key pests and diseases causing problems in UK aquatic ornamental plant production and the control measures used now. To identify specific gaps where more effective control measures are needed and to identify gaps requiring further research.
3. To produce a report and a Factsheet on pest and disease management in aquatic ornamentals using information collected in Objectives 1 and 2.

Review of existing knowledge of chemical, cultural and biological control of pests and diseases of aquatic plants.

An on-line literature search and other internet searches were done to obtain information to supplement ADAS knowledge and experience of potential diseases, pests and weeds which could cause problems in the culture of aquatic and semi-aquatic ornamental plants. Much of the recent literature concerned problems with invasive aquatic plants and work on their biological control; this work is outside the scope of this project and is not reviewed here. Information on the diseases and pests of ornamental plants (both aquatic and terrestrial) sold by aquatic plant growers was collated from plant production and plant pathology textbooks, but they provided no indication of the incidence or severity of problems on UK nurseries. It is possible that some of the plant species-specific pests and diseases described for the USA and other countries are present in the UK, either as natives or through introduction with a non-native host, but no non-native pests or diseases were found during this project. Information on the identification of non-native pests and diseases that might occur on UK crops is available at www.defra.gov.uk/planth/ident.htm.

Pests

Integrated Pest Management (IPM)

IPM is the use of a combination of cultural, biological and chemical control methods to maintain pests below economically damaging levels. IPM programmes are widely and successfully used on non-aquatic ornamentals (including bedding and pot plants, hardy nursery stock and cut flowers) grown in glasshouses or polythene tunnels on many UK nurseries. Many pests of non-aquatic ornamentals are common to aquatic ornamentals and it is likely that similar IPM programmes could be used successfully on nurseries growing aquatic plants. However, some pests are specific to aquatic plants and others may not be controlled well by methods used on non-aquatic plants, if different growing conditions (e.g. standing the plants in water) are used.

IPM programmes on aquatic plants should focus primarily on cultural and biological control methods. Although most pesticides approved for use on ‘conventional’ ornamentals can be used on aquatic plants (with the exception of those where label restrictions prohibit such use), many pesticides are harmful to aquatic organisms (Anon, 2007). It is assumed that fish are not present in aquatic plant production areas. However, as good practice, caution should be exercised when considering whether the application of a pesticide is necessary, especially if there are any vertebrates e.g. frogs, or invertebrates (e.g. dragonflies) and other pond wildlife present in the sprayed area. Some of the products that are compatible with biological control agents used in IPM programmes in other edible and non-edible crops are listed on pages 33 – 35.

Three significant pests (water lily aphid, water lily beetle and leaf mining midges) are specific to aquatic plants, and other significant pests (e.g. vine weevil and two-spotted spider mite) are common to both aquatic and conventional ornamental plants:

Water lily aphid (*Rhopalosiphum nymphaeae*)

Water lily aphid (*Rhopalosiphum nymphaeae)* is a common pest of water lilies (*Nymphaea* and *Nuphar*) and many other aquatic plant species. In temperate climates, the water lily aphid lays eggs in autumn on *Prunus* species. The eggs survive the winter on these winter (primary) hosts. In spring and early summer the eggs hatch and aphids migrate to summer (secondary) hosts. Summer hosts include a wide variety of aquatic plant species, e.g. *Alisma* (water plantain), *Butomus* (flowering rush), *Nuphar* (pond-lily), *Nymphaea* (water lily), *Typha* (bulrush), *Sagittaria* (arrowhead), *Juncus* (soft rush), *Potamogeton* (pondweeds), Lemna (duckweeds), *Eichhornia crassipes* (water hyacinth), *Pistia stratiotes* (water lettuce) and *Hydrilla verticillata* (Hydrilla) (Blackman and Eastop, 2000; Center *et al.*, 2002).

Wingless aphids are about 1.6-2.6 mm long, dark olive to brown in colour, with a light dusting of whitish wax on the body which gives a dullish appearance. The body is oval and plump, with two long pale siphunculi (‘exhaust pipes’ at posterior end) with dark tips. Winged aphids are similar in size to the wingless forms but are dark brown to shiny black in colour with a whitish wax on the bottom surface of their body. The water lily aphid is able to walk on the water surface. It has specialised hairs on its body which trap and hold air, thus allowing the aphid to feed on submerged parts of the plants (Center *et al*, 2002).

Aphid numbers can build up rapidly in optimal conditions. Water lily aphids feed on the petioles, leaves and flowers. Dense colonies of aphids can form on the upper surface of lily leaves, congregating along the leaf veins and on flower buds (Alford, 1991). As the aphids grow in size they leave white cast skins on the leaves. Heavy infestations reduce plant vigour and cause stem and leaf distortion and flower discolouration, thus spoiling the appearance and reducing the quality of the plants. Aphid nymphs can take 7-10 days to develop into adults, depending on plant host and temperature. Optimal temperatures are 21 to 27°C (Center *et al.*, 2002), but development has been recorded between 15 and 30°C (Nasser and Mohamed, 1992). It was predicted that under stable conditions, a population could double in only 2.2 days (Hance *et al.,* 1994a).

<u>Control</u>

Cultural control: In small ponds, low numbers of aphids may be wiped off leaves and flowers by hand. Alternatively, or in larger ponds, hosing infested leaves with a strong jet of water can dislodge the aphids. Certain varieties of some aquatic plant species are reported to be resistant to the water lily aphid. Hance *et al*. (1994b) tested six species of water fern and three of them (*Azolla pinnata, A. nilotica* and *A. rubra*) were shown to be totally resistant to the aphid. Research on why these *Azolla* species are resistant to the water lily aphid might help to identify insect-resistant varieties of economically important aquatic plants. Growing resistant varieties could be an effective and inexpensive cultural control method for this pest in the future.

Biological control: Biocontrol agents for aphids are commercially available. Parasitoids (parasitic wasps) are specific to certain aphid species and water lily aphid may not be susceptible to commercially available parasitoid species. Predators (e.g. ladybirds, lacewings and the predatory midge, *Aphidoletes aphidimyza*) will feed on most species of aphid and would be worth releasing under protection, on a small experimental scale at the first sign of aphids. However, as *Aphidoletes* larvae fall to the ground to pupate, pupae are unlikely to survive if plants are stood in water. Ladybirds and lacewing larvae can also occur naturally and should be conserved and encouraged by using IPM strategies for other pests.

Chemical control: See below under chemical control of 'other aphid species'.

Other aphid species

Various aphid species other than the water lily aphid can occur on many aquatic and pondside plants. Some of these aphid species are polyphagous (i.e. they can attack plants from a range of plant families) and are also common pests of ornamental plants grown for the conventional (non-aquatic) market. 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 usually green but can sometimes be pink or red. The two siphunculi ('exhaust pipes') at the rear of the body are green with dusky tips. The melon and cotton aphid is a small aphid, often found in groups on stems or young growth. The body can be yellow, pale green, olive green or black, and the siphunculi are short and black. The potato aphid is a long, green or pink aphid, often with a darker stripe down its back. The siphunculi are long and green, without darker tips. The glasshouse and potato aphid is a shiny green aphid, with a darker green patch at the base of both siphunculi. The siphunculi are green, with distinct black tips. Further guidelines on identification are given in HDC identification cards 'Diseases and pests of bedding plants'.

The aphids can cause leaf yellowing and distortion. Plant quality is also 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. They 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.

<u>Control</u>

Cultural control: Nursery hygiene measures, including careful disposal of plant debris and weeds, can reduce sources of infestation. Washing or hosing the aphids off the plants can sometimes be practical, as for water lily aphid, above.

Biological control: Naturally-occurring predators and parasites can sometimes contribute to control of aphids. Commercially available biological control agents can be used for all four aphids listed above. They are likely to be most effective under protection, but could be used outdoors in the summer. The parasitic wasp, *Aphidius colemani* is effective against both the peach-potato aphid and the melon and cotton aphid, and a related species, *Aphidius ervi* is effective against the potato aphid and the glasshouse and potato aphid. The female wasps lay their eggs inside the aphid's body and the parasite develops inside, turning the aphid into a brown, papery 'mummy'. The adult wasp emerges from a hole cut into the top of the mummy, then flies off to find more aphids to parasitise. Commercially available aphid predators include the lacewing, *Chrysoperla carnea*, the ladybird *Adalia bipunctata* and the midge, *Aphidoletes aphidimyza*.

Chemical control: Aphicides compatible within IPM include:

- pymetrozine (Chess WG), which acts as an anti-feedant.
- Plant extracts (Eradicoat, Majestik) and fatty acids (Savona), which need good coverage to be effective.
- Pirimicarb (e.g. Aphox), but *Aphis gossypii* and some strains of *Myzus persicae* are resistant.
- Nicotine (e.g. Stalwart).

Other aphicides e.g. thiacloprid (Calypso), acetamiprid (Gazelle) and pyrethrins (Pyrethrum 5 EC) are less compatible with IPM. Pyrethroid insecticides e.g.

bifenthrin (e.g. Starion, Talstar), cypermethrin (e.g. Toppel 10) and deltamethrin (e.g. Decis) are incompatible with IPM as their harmful effects can persist for up to three months after application, and *Aphis gossypii* and *Myzus persicae* may be resistant.

See pages 33 - 35 and check with biological control suppliers for further information on the effects and persistence of pesticides on individual biological control agents.

Water lily beetle (Galerucella nymphaeae)

The water lily beetle is a common pest of water lilies (Nymphaeae spp.) throughout Europe. The preferred host of the larvae is the yellow pond-lily (*Nuphar luteum*) (Center *et al.*, 2002), but white water lily (*Nuphar alba*) is also very susceptible (Alford, 1991). Adult beetles feed on a variety of species including arrowheads (*Sagittaria* spp.), smartweed (*Polygonum* spp.), willows (*Salix* sp.), water chestnut (*Trapa natans*) and water shield (*Brasenia schreberi*) (Center *et al.*, 2002).

Adult beetles are 6-8 mm long and yellowish-brown to dark-brown. Adult females lay eggs in groups of 12-18 eggs on the upper surface of the water lily leaves (Kouki, 1993). The eggs are about 0.75 mm across, oblong with rounded ends and pale yellow to yellowish-orange in colour, with a finely patterned surface. Both adults and larvae (shiny dark brown or black in colour, with a yellow underside) feed on the upper side of the leaves of water lilies, above the water surface (Wallace and O' Hop, 1985; Juliano, 1988). At first they chew grooves or small depressions into the leaf surface and later make long irregular-shaped holes or slots, where they bite completely through the leaf (Alford, 1991). This grazing also exposes the interior of the leaves to microbial attack (Wallace and O' Hop, 1985). Heavy infestations can lead to leaves being completely shredded, and flowers may also be damaged (Alford, 1991). The larvae pupate on the leaf surface. Pupae are about 5-7 mm long, shiny and black and are attached to the leaf surface at one end. If disturbed, pupae rear up off the leaf surface, probably as a defence response against predators.

Adult beetles hibernate amongst vegetation close to ponds. They become active and start feeding on water lily leaves in May or June. Adult females lay about 10 eggs per day, usually on younger rather than older water lily leaves (Kouki, 1993). Eggs take about 4-7 days to hatch into larvae, depending on environmental conditions. The larvae feed in groups at first but then feed singly, on leaves and sometimes on flowers (Alford, 1991). There are three larval stages, which take about 7-19 days to complete development (Center *et al*, 2002). Pupation lasts for about five days and adults emerge from the pupae in July and August. Time from egg to adult depends on temperature, ranging from 19 days in warm weather to 29 days at cooler temperatures (Juliano, 1988). There are usually two generations per year but a third may occur in heated pools and in mild southerly locations (Alford, 1991).

Control

Cultural control: Strict nursery hygiene is essential and plant debris in and around the ponds should be removed regularly, and disposed of away from the nursery to reduce hibernation sites for adult beetles. On small ponds, larvae, pupae and adults, or severely infested leaves could be removed by hand. On large ponds, hosing infested leaves with a strong jet of water may dislodge the beetles. Alternatively, infested leaves may be submerged with weights for a few days. All life stages will drown in the water.

Biological control: No biocontrol agents are commercially available for control of this pest. Naturally occurring beneficial insects may predate various life stages of the water lily beetle. Ding and Blossey (2005) reported that predation by the water strider (*Gerris insperatus*) and a ladybird species (*Coleomegilla maculata*) significantly reduced larval and pupal survival. These species are not native to the UK, but native pond skaters (*Gerris* spp.) and ladybirds may contribute to natural control of the pest.

Chemical control: There are no pesticides with a specific recommendation for the control of water-lily beetle. Pesticides with efficacy against beetles include:

- thiacloprid (Calypso).
- Pyrethrins (Pyrethrum 5 EC).
- Pyrethroid pesticides e.g. cypermethrin (e.g. Toppel 10) and deltamethrin (e.g. Decis)

All the above pesticides are harmful to biological control agents, with the pyrethroid pesticides having the most persistent side effects (up to 3 months after application).

See pages 33 -35 and check with biological control suppliers for further information on the effects and persistence of pesticides on individual biological control agents.

Leaf-mining midges (Chironomus spp.) and 'false' leaf-mining midges (e.g. Cricotopus spp.)

Leaf-mining midge adults are small, delicate humped-back flies, 1-2 mm long and resemble gnats or mosquitoes. The males have antennae with long hairs. Swarms of male midges are often seen hovering around water. Adult midges lay eggs in the water or on the leaf surfaces. The larvae of leaf-mining midges feed in between the upper and lower surfaces of the leaves, whereas those of false leaf-mining midges make tracks on the leaf surface. Pupation occurs within the leaf and pupae can swim to the surface of the water to allow adult emergence.

Severely damaged leaves can be skeletonised. The pests are considered to be more of a problem in new ponds, where naturally occurring beneficial insects that might control them are less established. Plant hosts include water lilies, broad-leaved pondweed (*Potamogeton* spp.) and other plants with floating leaves.

Control

Cultural control: Badly damaged leaves should be removed from the pond and the debris destroyed. Thick leaved plant varieties seem more resistant to attack (Nguyen, 2001).

Biological control: Damage is rarely seen in established ponds, where the pest may have been controlled by naturally occurring beneficial insects. In Australia, *Bacillus thuringiensis* is used to control the larvae (Nguyen, 2001). There is a SOLA (3149/ 2006) for Vectobac 12 AS (*Bacillus thurgiensis israelensis*) to control the larvae of chironomid midges for use on protected and outdoor watercress. This product may be applied to protected and outdoor aquatic ornamentals under the LTEAU provided that label and SOLA conditions are adhered to. Commercially available biological control agents for other leaf miners may be effective against leaf mining midge larvae, but this would need testing.

Chemical control: There are no pesticides with a specific recommendation for leaf mining midges of aquatic plants. Pesticides with efficacy against other leaf mining fly larvae include:

- abamectin (Dynamec)
- thiacloprid (Calypso)

Both the above pesticides have harmful effects on biological control agents. Check with biological control suppliers for further information on the effects and persistence of pesticides on individual biological control agents.

Vine weevil (Otiorhynchus sulcatus)

Vine weevil has a very wide host range, including many ornamental plant species grown both under protection and outdoors. During this project, vine weevil was confirmed on water lily and many pondside/bog plants e.g. *Astilbe*, *Filipendula*, *Ligularia*, *Phyllostachys*, *Primula* and *Zantedeschia*.

The adult is a large (about 9 mm long), rough-bodied black weevil with yellow speckling on its back. The white, plump larvae can be found around the roots and are 8-10 mm long with a tan-coloured head capsule. Pupae are white and have the developing legs wrapped round the body. Adults chew characteristic notches around the edges of leaves. Larvae feed on the roots and can 'girdle' stem bases. Root damage leads to reduced plant vigour, leaf yellowing and wilting.

Adult weevils usually emerge from pupae in May and June, although under protection they may be found throughout the year. Adults are nocturnal, hiding under pots, plant debris and other refuges during the day, thus they are often undetected by growers. The adults are all female and the main egg-laying season is between June and September. Larvae hatch from around August and can feed throughout the winter and spring under protection. Pupation in the growing media usually occurs between mid-April and June.

<u>Control</u>

Cultural control: Nursery hygiene and removal of badly infested plants and plant debris will reduce the vine weevil population on the nursery.

Biological control: Various insect-pathogenic nematode products are commercially available for the control of vine weevil larvae. *Steinernema kraussei* (Nemasys L) is the most widely used, as it can be used at lower temperatures (minimum 5°C) than other products. The nematodes are applied as a drench to the compost or growing medium and are most effective against young larvae in August-September. Although the nematodes need moist compost or soil to survive and move to find their host, they will drown in unaerated deep water. They are likely to be most effective on aquatic plants with only part of the root system submerged in water.

Chemical control: Two compost-incorporated pesticides used in 'conventional' containerised ornamental production must NOT be used in compost for aquatic plants, due to label restrictions:

- chlorpyrifos (SuSCon Green). Label restriction: 'To avoid any possible contamination of ponds and waterways, SuSCon Green should NOT be applied to growing media for aquatic or semi-aquatic plants.'
- Fipronil (Vi-Nil). Label restriction: 'Vi-Nil should not be used in compost for aquatic plants or marginals.'

Imidacloprid (Intercept 70 WG) is approved for use as a drench on containerised ornamentals and the label does not restrict use on aquatic plants. The approval for use of Intercept 5GR, for compost-incorporation, expired on 31 May 2007.

Two-spotted spider mite (<u>Tetranychus urticae</u>)

Two-spotted spider mite has a very wide host range, including many ornamental plant species. During this project, the pest was confirmed on water lily and many marginal and pondside plants, e.g. *Acorus*, *Iris*, *Lobelia* and *Lythrum*. The pest is more of a problem on protected plants, but in hot summers it can also cause damage outdoors.

All stages of mites are usually found on leaf undersides, although in severe infestations, they can also occur on growing points and flowers. Adult mites are about 0.5 mm long and usually green in colour, with two dark patches on their backs. Adults become active in the spring, in response to increasing temperature and daylength. Eggs are laid on leaf undersides and these hatch into juvenile mites, which feed and develop into adults. In warm conditions, the pest breeds rapidly and 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, before hibernating in sheltered parts of the structure of glasshouses or polythene tunnels, or in plant debris.

The first sign of spider mite damage is usually a fine yellow speckling on the upper surface of leaves, 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.

<u>Control</u>

Cultural control: Nursery hygiene is important, particularly towards the end of the season, to reduce overwintering sites for the pest. Spider mites can survive control measures directed onto the plants by moving to overwinter within the building framework. Spider mites thrive in hot, dry conditions, so misting the plants with water can help to reduce population growth.

Biological control: Predatory mites and midges are available for the control of spider mites, e.g. the predatory mite *Phytoseiulus persimilis*. This is effective if released at the first sign of spider mites, and if temperatures reach 20°C for at least a few hours each day. Two more recently available predatory mites, *Amblyseius californicus* and *Amblyseius andersoni*, are more tolerant of cooler temperatures and can be released before spider mites are seen, as they can survive on other prey and food sources e.g. pollen. *A. californicus* only has a licence for release under full protection (i.e. not outdoors or in open-sided tunnels). As predatory mites are unable to fly, plants must be touching to allow the predators to crawl from plant to plant. The adults of the predatory midge, *Feltiella acarisuga* can fly to find spider mite colonies in which to lay its eggs, so that the larvae can feed on the spider mites as soon as they hatch. It is likely that these predators will be as effective on aquatic plants as on 'conventional' ornamentals.

Chemical control: Acaricides compatible within IPM include:

- fenbutatin oxide (Torq). Approval for use expires on 31 December 2007.
- Plant extracts (Eradicoat and Majestik) are safe to biological controls once spray deposits are dry. Good coverage is essential.

Other pesticides effective against spider mites have harmful effects on some biological control agents, e.g. abamectin (Dynamec), tebufenpyrad (Masai) and spiromesifan (Oberon). See pages 33 – 35 and check with biological control suppliers for further information on the effects and persistence of pesticides on individual biological control agents.

Whiteflies

The most common species occurring on ornamental plants is the native glasshouse whitefly, *Trialeurodes vaporariorum*. Tobacco whitefly, *Bemisia tabaci*, is not native to the UK and is quarantine pest, notifiable to Defra Plant Health and Seeds Inspectorate (PHSI) whenever found or suspected. There is a risk of importing this pest on imported water lilies. See below for action required if the presence of this pest is suspected. Whiteflies have a wide host range, and are usually more of a problem on plants grown under protection. In the survey of UK aquatic nurseries in this project, whiteflies were confirmed on water lily and various marginal plant species.

Adult whiteflies are small (about 1 mm long), moth-like insects with white wings. They are usually found on the undersides of leaves and in growing points. The glasshouse whitefly holds its wings together horizontally when at rest, whereas the tobacco whitefly tends to hold its wings slightly apart and at an angle, so that the yellow body can be seen between the wings. Adult whiteflies lay small, oval eggs on the leaf undersides. The young 'crawler' larvae are mobile, but soon settle down on the leaf surface. The following three larval 'scale' stages and the pupal stage are sedentary. The scales are oval, flat and greenish at first. The final, largest scale stage (pupa) is oval and white in glasshouse whitefly and yellowish and pointed at one end in tobacco whitefly. The adult whitefly emerges through a slit in the top of the pupal case. Adults can fly from plant to plant and can enter glasshouses from outside through the vents or doors.

If the presence of tobacco whitefly is suspected, the local Defra PHSI must be informed immediately. PHSI will take a sample for laboratory identification to check whether it is a quarantine species. This is particularly important if plants have been imported. Contact details for PHSI are available on the Defra website at: http://www.defra.gov.uk/planth/senior.htm or the PHSI HQ, York, tel: 01904 455174.

The presence of whiteflies on ornamental plants can make them unsaleable. In heavy infestations, leaf yellowing can occur and sooty moulds can develop on the sticky honeydew excreted by the whiteflies.

<u>Control</u>

Cultural control: Nursery hygiene measures, including careful disposal of plant debris and weeds, can reduce sources of infestation. Yellow sticky traps can be used inside doors or between batches of plants, to reduce whitefly spread from infested areas. Long yellow roller traps can be used for mass trapping of adults, but are rarely effective on their own as a means of control. Large areas of yellow sticky trap can also catch flying beneficial insects e.g. parasitic wasps used in biological control, so should be used and positioned with care.

Biological control: The most widely used biological control agent for control of whiteflies in glasshouses or polythene tunnels is the parasitic wasp, *Encarsia formosa*. Temperatures of 18°C or above are necessary for at least a few hours a day for effective control. *E. formosa* is supplied as parasitised whitefly scales. The adult parasitic wasps emerge from the scales and lay their eggs in whitefly scales on the crop. When parasitised, the scales turn black. *E. formosa* should be as effective on whiteflies infesting aquatic plants as on 'conventional' ornamentals. A new biological control agent, *Amblyseius swirskii* has recently become available, which eats both whitefly eggs and young scales and also thrips larvae. *A. swirskii* is a predatory mite, similar to *Amblyseius cucumeris* which is widely used for thrips control. *A. swirskii* is not native to the UK and may only be released in fully protected structures (i.e. not outdoors or in open-sided tunnels). Most of the research and experience to date with this predator is on protected edible crops e.g. cucumber and pepper, and its use on ornamentals is still experimental.

Chemical control: Pesticides compatible within IPM include:

- Plant extracts (Eradicoat and Majestik) which are safe to biological controls once spray deposits are dry. Good coverage is essential.
- Teflubenzuron (Nemolt). However, many UK whitefly populations are resistant.
- Buprofezin (Applaud). However, many UK whitefly populations are resistant.

Other pesticides effective against whiteflies have harmful effects on some biological control agents, e.g. thiacloprid (Calypso) and spiromesifan (Oberon). Most UK whitefly populations are resistant to the pyrethroid pesticides e.g. bifenthrin (Starion / Talstar), cypermethrin (e.g. Toppel 10) and deltamethrin (e.g. Decis). The pyrethroid pesticides are also incompatible with IPM, as they are harmful to biological control agents for up to three months after application.

See pages 33 – 35 and check with biological control suppliers for further information on the effects and persistence of pesticides on individual biological control agents.

Diseases

Although there is a very wide range of diseases recorded on many of the principal aquatic plants (see www.ecoflora.co.uk), the lack of literature on the commercial importance of these suggests that generally the majority do not cause problems in modern production nurseries. However, it is also possible that symptoms are not currently being recognised as disease-related. A list of host-specific diseases recorded on aquatic plants in the UK, USA and Europe is given in Appendix 1. Information on diseases of some UK land plants commonly sold by aquatic plant nurseries is also included. This table does not include a full listing of diseases with a wider host range (Ellis and Ellis, 1985; Pirone, 1978). Epidemiological information on specific diseases shared by non-aquatic hosts is available from the European Handbook of Plant Diseases (Smith *et al.,* 1988).

Bacterial diseases

Little is known about the bacterial pathogens of important aquatic crop plants (Andrews, 1976). Soft rots caused by species of *Pectobacterium carotovora* (syn. *Erwinia carotovora*), appear to be the only bacterial diseases recorded on aquatic plants in the UK. It occurs on *Iris germanica* (Lacy *et al.*, 1982), and is relatively common on calla lily, *Zantedeschia aethiopica* (Nyalala, 2006; O'Neill, pers. comm.). Other, apparently saprophytic bacteria have also been recorded from various countries (Chand *et al.*, 1992).

Fungal diseases

Fungi are the most common pathogens of foliage plants in general and cause their most serious diseases (Chase, 1987). Leaf spots are the most prevalent of plant diseases, belonging to many genera, with numerous species within each (Westcott, 1971). Because the range of aquatic subjects is large, the range of diseases which growers of aquatic plants may encounter is also potentially very wide (see Appendix 1). Both foliar and root diseases have been recorded on UK aquatics nurseries. Powdery mildews and rusts may be favoured in marginal plants, as spores disperse from dry foliage and germinate in high humidity.

Virus diseases

There are relatively few virus diseases recorded on aquatic plants. In the USA, water forget-me-not, *Myosotis*, can suffer from Impatiens Necrotic Spot Virus (INSV). The leaves may wilt, yellow and become mottled or have sunken spots. The plants may be distorted or stunted, with areas of necrosis, and stems may die. The virus is spread by thrips feeding on plants, and it can only survive on live hosts (Sedbrook, 2004). Dasheen mosaic virus (DMV) has a worldwide distribution (www.dpvweb.net) and causes leaf distortion, foliage ring-spot and breaking of flowers on calla lily. The disease is carried in the tubers, and then spread by aphids and thrips. The disease can be eliminated by using tissue-cultured plants and certified, virus free planting material (Nyalala, 2006). In the USA/The Netherlands, hosta virus X potexvirus (HVX) can cause a severe mosaic on infected plants, although some cultivars are tolerant. The virus is spread by contact

(Currier and Lockhart, 1996; Lockhart, 2002). Tomato ringspot virus (TomRSV) is carried by a nematode and causes hosta leaf mottling and chlorosis (Lockart and Currier, 1996). Virus symptoms can be confused with nutrient deficiencies.

Viruses (and other diseases) do not often colonise the meristematic tissue of plants and so it is possible to take material from the apical meristem for micropropagation. In Denmark, 75 out of 160 aquatic plant species grown by one company are micropropagated (Christensen, 1996) and techniques have been developed for the more difficult types, including submerged species (Őzturk *et al.*, 2004).

Natural decay

Outdoor aquatic plant sales in the UK tend to have a relatively short season, within the warmer, lighter days of the year. An end of season increase in unhealthy leaves can become accepted as part of the life cycle of the plants. It is however far from clear whether the decline of the plants actually follows on from the invasion and multiplication of a pest or disease rather than a senescing plant becoming susceptible to colonisation by organisms.

Recent research on diseases of specific aquatic plants

Published research on diseases of aquatic plants is sparse and has principally focused on identifying bacteria and fungi with potential as bio-control agents. Descriptions of these diseases and relevant results are summarised.

Calla lilies

Calla lily tubers are prone to bacterial soft rot caused by *Pectobacterium carotovora*. Divided tubers are at particular risk, but the bacteria can also enter following damage by other pathogens, such as species of *Pythium, Rhizoctonia, Fusarium* and *Phytophthora* or nematodes. The bacteria spread through water splash, insects, and plant to plant contact and contamination by hands or tools. Infection can remain latent, the tubers appearing firm and healthy, and these can become a major source of infection (Nyalala, 2006). This disease was confirmed on Calla lily in the UK in 1988 (O'Neill, pers. comm.).

A strain of *Phytophthora erythroseptica* can cause leaf blight. The leaves become chlorotic, wilt, and the margins curl upwards and the petioles rot. The rhizomes are unaffected. However, another strain of the same fungus causes dark brown, water-soaked lesions on the surface of rhizomes. The lesions become dry and sunken. Internal tissue becomes grey and rubbery (although odourless) and there is a demarcation line between diseased and healthy tissue (Corr, 1993).

Duckweeds

Duckweeds are sold by some UK aquatic plant nurseries, and so the health of duckweed can be of importance. In the USA, *Pythium myriotylum* was found killing duckweed in Louisiana lagoons. In inoculation experiments, *Lemna gibba, L. minor* and *Spirodela polyrrhiza* were most susceptible, while *L. valdiviana* was more resistant. *L. aequinoctialis* and *S. punctata* appeared to be resistant (Rejmankova *et al.*, 1986). This species of *Pythium* is one of the most common in soils, often causing damping-off of seedlings and root-rot. Motile spores (zoospores) are produced which can infect many plant species. *Pythium* can survive saprophytically and it has thick-walled resting spores that allow it to survive over winter. The fungus is disseminated in surface drainage water, in soil and on equipment and shoes (Cross, 2005). *Pythium myriotylum* was also found recently causing small, wilted, white plants in commercial ponds in Israel, with rapid progress to 70% mortality within a month. Inoculation tests found that infection did not develop at 17 or 22°C, but did at 28 to 32°C with plants at high density (Flaishman and Hadar, 1997).

Hostas

In the USA, a root and crown rot caused by *Fusarium* spp. has caused uneven shoot emergence and serious decline of plants. Typically, the leaves turn yellow and then pale brown before withering. The roots near the crown show vascular staining and further away have cortical decay. The crown develops pockets of necrosis. The disease requires wounded tissue to enter the plants, and is carried on cutting knives when the crown is divided, or when plants are cut back (Wang and Jeffers, 2000).

Irises

Bacterial soft rot, caused by *Pectobacterium carotovora* (syn. *Erwinia carotovora*) can be a problem in iris rhizomes (Westcott, 1971). The bearded iris, *Iris germanica*, is most commonly affected. 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 at or below the soil line, and the interior becomes reduced to a viscous cream-coloured mass that may be foul-smelling. In the USA, *Erwinia carotovora* subsp. *carotovora* is carried into and down the leaves to the rhizome by the larvae of the iris borer (*Macronoctus onusta*). This insect is not found on *Iris pseudacorus* in the UK, but it is possible that the native iris leaf miner, *Cerodontha iridis* (www. ecoflora.co.uk) could spread bacterial infection. *Erwinia chrysanthemi* can also cause soft rots of iris. Both species of bacteria can be carried in surface water used for irrigation, and although they can penetrate unwounded plants, damage by snails, nematodes or insects will favour infection (Lacy *et al.*, 1982). The disease can be halted by removing infected leaves before infection spreads to the rhizomes (Westcott, 1971).

Reeds

Reeds (*Phragmites* spp.) are used in the management of water quality and their role is influenced by the communities of microorganisms developing on the underwater surfaces of the plants. The mature biofilm comprises algal-bacterial associations and their extracellular products. The most frequent bacteria in Hungary were species of the genera *Pseudomonas, Acinetobacter, Shewanella, Agrobacterium, Aeromonas* and *Bacillus* (Ács *et al.*, 2003). This information may have a bearing on the use of algae control products and disinfectants in reed propagation areas on nurseries as the plants will need to re-establish their micro-organism associations to be able to carry out the required metabolic activity when planted in water treatment beds. In Hungary, the potential plant pathogens *Agrobacterium* sp., *Aureobacterium* sp. and *Curtobacterium* sp. were found on reeds, and also the growth promoting bacteria *Pseudomonas fluorescens* (Ács *et al.*, 2003).

Water lilies

The most potentially troublesome water lily disease is crown rot, caused by a *Phytophthora* fungus that can kill off entire clumps. Infected leaf and flower stems become soft and blackened near the crown, and then progressively so upwards. Frequently, a flower bud will rot from the stem before it has reached the water's surface. As the disease progresses, fewer leaves are produced and those that are, turn yellow shortly after unfolding at the surface. The tuber becomes mushy and strongly malodorous. The disease will spread to other lilies in the same pond (Nash, 1996). It is possible to cut off the rotting rhizome and replant a healthy piece of rhizome in clean compost. There is also a specific off-label approval (SOLA 2005/1501) for the use of the fungicide metalaxyl-M as a propagation material dip and as a foliar spray. The disease does not now seem to be causing a significant problem on UK nurseries.

An HDC project (HNS 26) investigated crown rot in the UK. In 1988, twelve water lily growers said they had crown rot affected plants, the disease being more common in particular varieties, such as Attraction, Chromatella and Odorata Sulphurea. Sixteen varieties, including Rembrandt, Ellisiana and Brackley Rosea, were reported as being little affected. Significantly, three growers who did not report crown rot had not imported Japanese plants. Rot symptoms usually appeared in April and were most severe from June to September. Stressed plants were more susceptible. Symptoms were more frequently seen on two to three year old plants, although one-month-old plants grown from tubers and three-month-old plants from eyes could be affected. From 10% to 50% of plants in a pond could be lost. Experiments showed that rhizome rot will develop within 10 weeks if plants are grown in water contaminated with stained water lily crown tissue. There was also localised infection of stab inoculated leaf or crown tissue. An unidentified species of *Phytophthora* was isolated from yellow leaves with black margins. However, it was possible that there was more than one cause of tuber discolouration at the crown. This was supported by the fact that some growers had found that fungicides controlling *Pythium* and *Phytophthora* were only partially effective and that some control was achieved using fungicides acting on non-Phycomycetes.

A crown rot of water lily caused by *Phytophthora* species has also been identified in the Netherlands (O'Neill, pers.com.) and research on the problem was undertaken at Boskoop Research Station.

Several species of *Pythium* have been isolated in the Netherlands from decaying leaves of water lily, *Nymphoides peltata.* These were *P. marsipium, P. pleroticum, P. diclinum* and *P. apleroticum*. A number had sporangia, and some produced sexual reproductive structures. It was not clear whether or not the fungi started the leaf decay (Jacobs, 1982). *P. marsipum* has also been found on decaying leaves of *Nymphaea tuberosae* and *P. apleroticum* has been recovered from the alga, *Spirogyra* (Waterhouse, 1968).

A destructive leaf spot disease, *Colletotrichum nymphaeae,* was found on *Nymphaea alba* in lakes in the Netherlands, and had possibly become more damaging combined with insect activity (van der AA, 1978). A morphological and molecular comparison of isolates of *Colletotrichum nymphaeae* collected from *Nymphaea odorata* and *Nuphar luteum* in Europe, with isolates collected from *Nymphaea odorata* and *Nuphar luteum* subsp. *polysepalum* in North America suggested that the North American fungus was a new species *C. nupharicola* (Johnson *et al.,* 1997). A number of leaf spots, including *Alternaria* sp*.,* species of *Cercospora* and *Phyllosticta, Helicoceras nymphaearum, Helicosporium nymphaearum* and *Ovularia nymphaearum* are recorded as being present on water lily in the USA (Pirone, 1978), but only *O. nymphaearum* is reported to require control 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 (Scopes and Ledieu, 1983).

Disease control methods

Cultural control and hygiene

An overview of disease management on ornamental plants can be obtained from the University of Florida website www.edis.ifas.ufl.edu/PP123 (Bledsoe *et al*., 2004). There are also a number of HDC factsheets of relevance to aquatic plant nurseries e.g. Factsheet 23/02 (Control of grey mould (Botrytis) in container-grown ornamentals; unheated greenhouse crops), and Factsheet 16/04 (Control of *Phytophthora, Pythium* and *Rhizoctonia* in container grown hardy ornamentals).

Hygiene in the propagation area

Hygiene must start with the stock plants. They should be included in routine health inspections and treated or discarded as necessary (Higgs, 1982). If cuttings can be traced back to a particular stock plant, then if any problems arise the original plant can be discarded before it is used again. A clear procedure should be established for the collection and disposal of plant waste. The material must not be left in open piles adjacent to the growing areas or else pests and diseases can be carried or blown onto the plants.

Cutting tools (knives, secateurs and scissors) must be sterilised continuously during use, with a spare tool left to soak in sterilant solution and then swapped with the used tool after a small number of cuttings. The solution should be changed regularly, particularly for those products that may be inactivated by organic material. Viruses and bacteria are easily carried on tools, and fungal hyphae or resting spores may also be transferred. Hands and clothes should also be kept clean and disposable gloves and aprons may be worn. It is also essential to keep the propagating bench clean, sterilising the surface regularly. Cleaning is more effective on smooth surfaces and so if cutting is done on either a small board that can be discarded when it becomes scarred, or on a glazed tile, the work-bench can be protected from cuts that will harbour pathogens.

Cuttings may be dipped in a fungicide plus rooting compound. Alternatively, a fungicide drench can be applied to control damping off and possibly other soil-borne fungal diseases. Trays of seed may also benefit from a fungicide drench, particularly if the seed is self-saved.

Compost should be fresh and free from diseases. Compost bag stacks should be raised off the ground and covered to prevent contamination. Opened bags should be closed between use to prevent spores and flies entering. Flies and fungus gnats that lay their eggs in compost are able to carry disease between plants and from debris, and the larvae can feed on plant rootlets and provide openings for soil-borne diseases. Sticky traps (e.g. yellow for aphids, blue for thrips) should be used to monitor, ideally daily, for the appearance of flying insects; the traps are rarely effective as control measures in themselves.

Diseases can be carried on footwear, and so the entrance to propagating areas, and entrances from outdoors, benefit from having shoe dips. The dips can be a tray with capillary matting soaked in disinfectant. Sticky white plastic sheets (where sheets are ripped off to reveal a fresh surface) are available as door mats where it is dry and not too dusty, perhaps at the entrance to high hygiene areas such as quarantine compartments or micro-propagation areas. The HDC Project PC 97a dealt thoroughly with the sources of *Pythium* inoculum on nurseries and the efficacy of surface sterilants. Danish trolleys, benches, footwear and puddles were some of the places where *Pythium* was usually detected. Jet 5 and sodium hypochlorite were found to be effective disinfectants. The HDC Factsheet 10/07 gives advice on nursery hygiene.

<u>Maintaining hygiene in established plants</u>

Newly propagated material should be placed on freshly disinfected benches. Flooded benches allow diseases to spread easily, especially those caused by species of *Pythium* and *Phytophthora* with swimming spores. Standing-out areas can be treated with disinfectant following a serious or persistent problem. As a minimum measure, all weeds and debris must be removed from the area. Ground cover matting will virtually eliminate the growth of weeds, algae, mosses and liverworts and prevent their spread to the surface of pots. Trickle irrigation is preferable to overhead watering as the latter can splash diseases between plants and provide a good microclimate on the foliage for diseases.

Where diseases or pests are on plants such as grasses, which grow up again from the base, or on end-of season plants, the foliage may be cut off to remove the problem rather than using a pesticide. Care should be taken when doing this that the disturbance of the foliage does not spread the disease or pest. Wearing a warehouse coat or apron that can be removed before working in another area, and hand washing, will reduce the movement of spores and insects. The debris should be placed in a plastic bag that is then immediately sealed and removed for waste disposal. Cutting tools should be cleaned, ideally in disinfectant, before using in another area of the nursery. The infected or infested plants must be inspected regularly after cutting or spraying, as it is unlikely that control will be complete.

<u>Removal of pathogens from water</u>

Clean water is essential for good plant management. Water collected from glasshouse roofs is likely to contain propagules (spores, eggs, seeds and tissue fragments) of a multitude of organisms, including bacteria, fungi and algae (Higgs, 1982). Disease spread in water is of particular concern where nutrient solution is recirculated to crops.

In the surveys of aquatic nurseries, *Pythium* spp. were found to be a problem causing iris rot and seedling damping off. HDC Project PC 97a found that water from ponds, rivers, reservoirs and greenhouse roofs were often contaminated by *Pythium*, and advised water treatment before its use on the nursery. Based on trials, slow sand filtration was considered particularly effective. Copper can kill *Pythium* zoospores, but it can only be used as a trace element as part of a feed solution, not as a fungicide. Research is being conducted (HDC Project HNS 142) on the use of copper electrodes for the treatment of irrigation water to control *Pythium* and *Phytophthora.* Surfactants such as Agral or Enhance at 40 ppm was also found to kill zoospores and these can be used to treat irrigation water as long as it is left to stand before use, and not used directly on plants to kill *Pythium.*

Five main water treatment methods have been demonstrated to be effective at eliminating plant pathogens from contaminated water:

1. *Ultraviolet radiation (UV):* Ultraviolet radiation treats the solution as it passes through a treatment chamber. The UV lamp needs to give an exposure of 100 mJ/cm^2 to control bacteria and 300 mJ/cm^2 to control viruses. Pre-filtration is essential.

2. *Ozonation*: Ozonation affects cell membranes, the ozone is delivered into a dosed mixing chamber at a rate of 10 g of O_3 / hr /m^3 of water or nutrient solution. The solution pH has to be lowered to 4.0 for optimal results and the ozone has to be in contact with the solution for one hour before it can be used.

3. *Heat treatment:* The nutrient solution is heated in a heat exchanger to 95°C for 30 seconds. Solution pH has to be reduced to 4.5 before exposure in order to reduce calcium precipitation on the plates. This has been the most common sterilisation technique used in Netherlands glasshouses, but has high energy costs.

4. *Chemical treatment*: Chlorine is dosed into the water and it must then be stored for a time to allow dissipation of chlorine. It creates an environment hostile to algal growth.

5. *Slow sand filtration*: Slow filtration is carried out at 100 litres/m^2/hour. Fine granulated sand (0.15 – 0.35 mm) or granulated rockwool appears to be adequate for fungi. The efficiency of the system for bacteria is in the 95 – 99% range for a once through percolation.

A Grower Guide on slow sand filtration has been published (2005) by HDC which compares treatments and information on all methods is available at www.priva.ca.

Manipulation of the growing environment

Diseases can spread within the plant and then rapidly develop when environmental conditions become suitable. Plants crowded together can facilitate the spread of diseases in particular, as these benefit from the higher humidity microclimate amongst the foliage. Plants growing on flooded benches in aquatic nurseries may be more at risk from diseases such as *Botrytis* that sporulate in high humidity.

Statutory control

Detailed information on importing plants, and plant passport regulations within the European Community (EC), together with the requirements for phytosanitary certificates, is provided by the UK Department for Environment Food and Rural Affairs (Defra). The booklets "The Plant Health Guide for Importers" (Anon, 2006) and "Plant Health Guide to Plant Passporting and Market Requirements" (Anon, 2005) are available, and guidance is also given at http://www.defra.gov.uk/planth/pass.htm. A nominated responsible person on nurseries can issue plant passports, but each site must satisfy Defra requirements that include the monitoring and treatment of disease, and ensuring that batches of propagation material remain separately identifiable. The local PHSI require notification of the importation of water lily rhizomes and plants from outside the EC so that the material can be inspected.

Biological control

There is an increasing interest in the use of natural products, including microorganisms (bacteria and fungi) for biological control of diseases. In the USA there are at least fifty commercial products formulated for the biocontrol of plant pathogens and/or growth promotion involving the induction of plant host defences (www.oardc.ohio-state.edu). The pathogens controlled by each product are specified and include many of the key causes of crop loss across a wide range of hosts. Fungi that are named as controlled include species of *Botrytis, Sclerotinia, Phytophthora, Fusarium, Pythium, Alternaria, Verticillium,* and bacteria include *Erwinia, Agrobacterium* and *Streptomyces.* As well as microbial suppression, other chemicals induce host resistance. These include chemicals such as salicylic acid, ß-aminobutyric acid, phosphonates and calcium. Extracts of plants such as giant knotweed and of composts have also been shown to be effective in some situations. These products are unlikely to be available in the UK in the immediate future.

In the UK, Contans WG (containing *Coniothyrium minitans*) has recently been approved (Anon, 2007). This targets *Sclerotinia sclerotiorum* and *S. minor*, neither of which are currently reported from UK aquatic plant production. There are other products available in the UK containing micro-organisms e.g. GlioMix (containing *Gliocladium)* and Stimagro (containing *Streptomyces* spp.) (www.fargro.co.uk), Trianum-P (containing *Trichoderma harzianum* T-22) (www.koppert.com). Products containing mycorrhizal rooting stimulants are also available (e.g. endoRoots, www.novozymes.com). As these products do not refer to the control of specific pathogens (but to improving plant health) they do not currently require PSD registration and do not need to prove specified control.

Various novel products have been investigated in ornamental disease control trials (e.g. HDC Projects HNS 125 and HNS 135) which either improve plant health or otherwise impede the colonisation of the plant, such as compost tea, extract of giant knotweed, and phosphite. Research is needed to see whether any products would be of benefit on aquatic plants, either added to the potting medium or sprayed on un-submerged foliage. The products could allow marketing of pond plants directly after treatment, rather than allowing an interval to elapse after pesticide application. The lack of a detrimental effect of the products on the aquatic ecosystem would need to be confirmed. Some natural plant extracts have recommendations for use in organically grown watercress production; Biosept Crop Gold and Orosorb improve crop health and Majestik controls foliar feeding insects. Potassium hydrogen carbonate, (a commodity product approved as a fungicide) can also be used.

Disinfectants

Disinfectants can regularly be used to treat floors and equipment, and also as boot dips. They can control algae, mosses, nematodes, fungi and viruses. Disinfectants belong to several different chemical groups, and some are more effective than others at controlling particular micro-organisms. The HDC Factsheet 15/05, details the types, the activity spectrum of particular products and the research conducted using particular plant pathogens. Fungi such as *Phytophthora* and *Pythium* will be important targets, and Jet 5 (peroxyacetic acid) or bleach (sodium hypochlorite) can be used in propagating areas (HDC Factsheet 16/04).

Aquatic weeds

The two principal weeds causing contamination of UK growing areas are the water fern (*Azolla filiculoides*) and the duckweeds (*Lemna minor, L. trisulca, L. gibba* and *L. polyrhiza*). Nurseries have reported the ease with which these plants are brought in or moved around on frogs and birds visiting the growing areas. Water fern can multiply vegetatively to such an extent that large heaps are netted out of ponds, and the risk of a customer linking the purchase of a new ornamental plant to an explosion of water fern in their pond is high. Water fern is able to survive British winters and has become naturalised in many places, particularly in Southern Britain (Clegg, 1986). Both weeds may, however, also be requested by customers, but some nurseries will not sell water fern and are vigilant for any material that may arrive on purchased stock. There is concern about "invasive aliens" and the Royal Horticultural Society (www.rhs.org.uk) and Plantlife International (www.plantlife.org.uk) are campaigning to restrict the sale of some non-native aquatic plants in the UK.

Cultural and chemical control measures for aquatic weeds in either water storage reservoirs or plant growth tanks have been reviewed (HNS 82, 1997). Duckweeds, water fern, Canadian pondweed (*Elodea canadensis*), Nutall's pondweed (*E. nutallii*), spiked water-milfoil (*Myriophyllum spicatum*), broad-leaved pondweed (*Potamogeton natans*) and reeds, rushes and sedges were found causing problems in a survey of nurseries. In water storage reservoirs (or where total plant control is acceptable), as much physical removal as possible of the aquatic weeds can be followed by the use of glyphosate. Dichlobenil can also be used in shallow or small water bodies. However, manufacturers' guidance needs to be followed on the interval required for the dissipation of herbicide residues, before using the water for irrigation or restocking tanks (HNS 82, 1997).

Control of water fern

Herbicides (e.g. glyphosate) are available for the control of water fern, but these also kill other plants. Left uncontrolled, the dense rafts can reduce light levels penetrating beneath the surface water to oxygenating waterweeds. CABI Bioscience (www.cabi-bioscience.org) is selling "Azollacontrol" which makes use of the North American weevil, *Stenopelmus rufinasus*. This weevil can only feed and reproduce on *Azolla* spp. and has proved itself to be a successful biological control agent in trials in South Africa and the UK. It can be used as soon as *Azolla* spp. appear and will control the weed throughout the growing season.

It is not easy totally to remove water fern from plant material as even if the plants are hosed off tiny pieces can regenerate. *Azolla* sp. has microspores that sink to the bottom of the water, only to rise again when they germinate and the first leaf appears on the sporeling (Sporne, 1975).

Control of duckweed

Duckweed will survive in wet areas of mud or on wet concrete around nursery benches or ponds, and is easily carried on workers' boots. The weed multiplies rapidly by budding of leaf-like segments and also can produce seeds from inconspicuous flowers (Von Denffer *et al.,* 1980). Although duckweed is commonly skimmed off the water in nursery propagation tanks, and washed off pots of plants before sale, complete physical removal is impossible, as tiny parts will always remain to produce new duckweed plants.

Control of other aquatic weeds

There will not normally be a major problem on nurseries as tanks on most nurseries are usually drained and cleaned out at least once a year. Aquatic weeds, such as Parrot feather (*Myriophyllum aquaticum*) and Canadian pondweed (*Elodea canadensis*), are more likely to remain if unsold stock, or mother plants, remain in tanks when new stock is added. However, weeds can be removed when pots removed for sale are picked over to remove old leaves and other debris, and the surface gravel and labels are renewed.

Algae

Types of algae and their growth

Algae are a major problem in aquatic plant production. Unicellular algae can cloud the water and cause scums, and can attach to plant surfaces. Customers purchasing plants for aquariums are unlikely to accept plants with algal growth that will multiply and cause a green tank. Filamentous algae forming blanketweed are a major problem for aquatic plant growers as the weed needs to be manually removed from plant crowns (often remaining lodged if the plant is just swilled in rinse water) or they will reproduce and look unsightly in customers' ponds. Filamentous algae can block water circulation systems and are unwelcome in ponds used for swimming.

Algae are not easily destroyed and can encyst to survive desiccation. They have also been found to be viable after passing through the gut of mayflies; the alga *Scenedesmus* was viable after passage through the gut of Crustacea (Round, 1977).

Algae belong to several classes and are uni- or multicellular, variously pigmented, autotrophic water plants (Von Denffer *et al.*, 1980). Typical methods of rapid multiplication can be seen from the following examples.

- Species of *Euglena*, the most important genus in the class Euglenophyceae, are flagellate and occur in nutrient rich ponds where they turn the water green. It reproduces by division. Cysts are produced in unfavourable conditions by laying down a thick mucilaginous sheath and these can survive prolonged desiccation.
- The class Chlorophyceae, green algae, has several orders and includes species varying from unicells, to filaments and even leaf-like thalli. The structures of *Volvox* spp. are comprised of a large number of cells within a hollow sphere with two flagella. As well as dividing to produce daughter colonies, ova are produced which after fertilisation become a thick walled resting zygote. *Scenedesmus* sp. is another common freshwater green alga and forms aggregates of four to eight cells. *Spirogyra* spp. grow by division and elongation of all the cells, and vegetative reproduction is effected by filaments separating at the cross walls into short lengths. Sexual reproduction occurs by the joining of parallel filaments, and a resting zygote is produced. This will give rise to a new filament in suitable conditions.

Blue-green algae, belonging to the primitive class Cyanophyceae, with no true nucleus, and are not true algae. Their reproduction is exclusively vegetative by rapid cell division. Cysts (akinetes) are also formed and permit survival through unfavourable periods.

Control of algae

Control of nutrients

Water rich in nutrients such as nitrogen and phosphorus encourages algae, with a high organic content supplying the growth factors needed by flagellates such as species of *Euglena, Phacus, Lepocinclis* and *Trachelomonas* (Round, 1977). In natural waterbodies, phosphates from sewage (digested food and detergents) and agricultural run-off cause high algal numbers. In nurseries, the potting compost, or added slow release fertiliser, is an important source of nutrients. Gravel on the surface of the pots probably reduces the rate of loss to the water, but unless the roots can be sealed in (thence depriving them of oxygen) there will always be nutrient escape. Decaying plant tissue will also release nutrients.

In the USA, the addition of alum (aluminium sulphate) to a body of water is used to cause phosphorus to precipitate on the bottom sediments where it becomes unavailable for algal growth with an effect that has lasted for up to 15 years. Where fish are present it is recommended that sodium aluminate is also added as a buffer to the alum treatments to prevent severe shifts in pH. Oxygenation using mechanical aerators can also prevent the release of reduced forms of phosphorus from the bottom sediments (Petty, 2005).

A product marketed as Phoslock (containing a clay, bentonite, and a rare earth element, lanthanum) has been developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Australia to limit the growth of algae. It absorbs phosphorous from the water, and then settles to the bed of the water body to also prevent the escape of phosphorous from the sediment (www.phoslock.com.au). It may be effective for blanketweed control. Another product, Nishikoi Phos-Kit, also reduces nutrients to control blanketweed.

There is a wide range of biological filters available that remove nitrates and so eliminate algae. UV clarifiers can also be used to kill algae, fungi and bacteria. Some filters combine both features (www.lilyblooms). A carbon based product, Beaver Pond Conditioner, is sold for use either in the bottom of ponds or in a biofilter to give algae control and absorb toxins from pond water.

Mixing of the water column

Some success has been achieved with aeration and mixing of the water column, particularly to control blooms of blue-green algae when scum-like aggregations of some genera of Cyanophyta form under conditions favouring high fertility at the water surface (Moss, 1980).

Light reduction

Another technique, which inhibits the growth of mat forming algae in waters deeper then about 60 cm, is the addition of a water-soluble dye (usually blue). This practice is mostly used for submersed flowering plant control, and algae at the edges of the water body usually survive (Petty, 2005). Tanks used for aquatic plants on nurseries do not usually have shelving sides and so algae control would be more effective. DyoFix Pond Black has been used successfully in ponds at the Royal Botanic Gardens at Kew. DyoFix Pond Blue (rather then Pond Black) should be used in ponds with fish. One application of the powder can last up to three months and is harmless to filters and plants (www.dyofix.co.uk). The dye blocks the sun's rays, controlling single-celled algae and blanketweed, but it would probably not be suitable for use with plants that remain totally submerged in summer. As the product does not contain pesticides, plants can be marketed from treated water without a holding period.

Use of fish

Although the fry of grass carp may eat filamentous algae, together with rotifers and crustaceans, they are not a satisfactory way to control blanketweed because once the fish get older they eat plants. Plankton grazing often also causes development of the larger, gelatinous and unpalatable blue-green algae. Blue-green algae are not digested by the grass carp, and only one fish species, a tilapia, is so far known to have the required acidic conditions in its gut to digest these algae (Moss, 1980).

Manual removal of blanketweed

Physical removal will never eliminate filamentous algae from ponds because of the regrowth of fragments. Dredged material should be removed from the pondside as it can survive desiccation. Pressure washing of emptied benches and tanks between seasons will reduce the algal load at the start of the season.

Ultrasound

A Belgian ultrasound unit to control blanketweed has been investigated by the Centre for Aquatic Plant Management. Development work is being privately financed in the UK (D. Everett, pers. com.). LG Sound has tested a new generation of ultrasonic algal control devices for a wide range of situations including lakes, water treatment plants, fish farms and swimming pools. The submerged transducer transmits ultrasonic waves specifically to target the algal cell structure, causing the vacuole to implode. Single celled algae are killed, but the vibrations are harmless to humans, animals, fish and aquatic plants. The device requires a power supply and there is a solar powered option. Some fungi such as species of *Fusarium* and *Pythium* are also controlled. There is a UK distributor (www.lgsonic.com, www.agagroup.org.uk).

Use of barley straw

Evidence has been accumulating since the late 1970's that barley straw can be used to control nuisance blooms of algae in freshwater systems. In successfully treated waterbodies surveyed in Britain, algal species composition has remained the same and there has been no effect on invertebrates, fish or waterfowl. There has, however, been less success with the use of barley straw in North America. This could be related to factors including the timing, dosage and positioning of the straw, but might be because the variety or its growing conditions differ from those in the UK (Geiger *et al.,* 2005; www.azgardens.com). A comprehensive literature review has been completed by Geiger *et al.* at http://www.barleyworld.org/barleystraw/, and a summary of the information is given at www.aquabotanic.com. A common explanation is that as the straw decomposes under aerobic conditions, phenolic compounds such as lignin, and especially oxidised phenolics, are slowly leached into the surrounding water. An alternative hypothesis is that the straw provides a carbon source for carbon-limited microbial growth and their growth causes phosphorus limitation. Not all species of algae are suppressed, but these include species of *Chlorella, Microcystis* and *Scenesdesmus.* A set of procedures has been developed based on numerous successful field trials:

- Add barley straw several months before bloom conditions are expected to occur. In the UK its effect will then continue for up to six months.
- Use an adequate amount of straw, distributed fairly uniformly over the area. Work by Newman (1999) suggests 50 g/m^2 initially, decreasing to 25 g/m^2 and a maintenance dose of 10 g/m^2. Add more straw in muddy water, but not more than 500 g/m^2 as oxygen depletion may occur.
- Ensure the straw is well aerated. Only use bales in streams with strong currents, otherwise pack loosely in a net tube.
- Keep the straw near the water surface, usually by attaching floats.
- Apply straw again in autumn.

This treatment would be suitable for water lily tanks on nurseries as well as for customer's lily ponds. It is also recommended as being an environmentally friendly and cost effective method of algal control in water storage reservoirs (HNS 82, 1997).

Lavender straw packs (Beaver Water Plants) are also sold to clear algae from ponds. Wheat, linseed, oilseed rape and maize can also be used instead of barley, but their quantity and frequency of application may need to be greater than that for barley straw. Hay and green plant materials should not be used because they can release nutrients which may increase algal growth (Newman, 1999).

In the USA, Microbe-lift Barley Straw Pellets are claimed to be better than barley straw because they release the natural chemicals immediately. They are also enriched with peat and humic acid. The pellets are said to react photochemically with sunlight, activating humic acids to produce hydrogen peroxide that helps to keep the water clear. The humic acid chelates metals such as copper or arsenic. The organic peat softens pond water, reducing nitrate and phosphate concentrations (www.lilyblooms.com). In the UK, Interpet Barley Straw Extract is sold to clear ponds of both blanketweed and green water algae.

Microbial control

In the UK, Bionetix markets Aquaclean, a bacterial product (www.bionetix.co.uk). The Aqualibrium company has a product containing plant extracts and plant and fruit oil which works by activating different types of microbes that produce oxygen for the fish, and clears both green algae and blanketweed. It was originally developed for the shrimp farming industry in India, and is now distributed in the UK by Blueflint Marketing (www.aqualibrium.eu). Another product available in the UK is Nishikoi Blanc-Kit Excel. This product utilises natural minerals and botanical compounds to combat blanketweed.

Products sold in the USA that use microbes in ponds include Aqua-Zyme Pond Clarifier (marketed by Tetra Pond) that clears pond water when used in spring and summer. It contains a high concentration of natural, beneficial bacteria and enzymes that consume the organic matter and nutrients in the pond water. It is safe for fish and plants (www.merrifieldgardencenter.com). This may be similar to Water Garden Microbe Start (marketed by Kent Marine), which is also recommended to "jump-start" biological filters.

Microbial Pond or Lake Clarifier Tabs, or Bioclean Lake / Pond Clarifier Tablets are slow dissolving blocks of beneficial microbes (bacteria and moulds) and enzymes that eliminate pond scum and algae and reduce sludge. Nitrates and phosphates are removed from the water, and cellulose, pectin and lignin in the pond bottom degraded. The tablets incorporate an oxygenator ingredient to improve water quality (www.lilyblooms.com/biocleanpondclarifier3oztablet-p-252244608.html) and are safe for all wildlife, the only by-product of the bacterial metabolism being carbon dioxide (www.azgardens.com). Blanket Weed Buster (marketed in the UK by Interpet) contains bacteria which compete for nutrients with the algae and consume pond sludge.

Another natural product marketed is BioWorld Algae Competitor Microbes (together with BioWorld Liquid Optimizer) containing "hearty strains" of selected, naturally occurring algae competitor and organic degrading microbes, plus a formulation of liquid nutrients, vitamins and minerals which maximises the ability of microbes to reproduce and thrive. It gets rid of filamentous algae and waste sludge (www.adbio.com).

A number of parasites, bacteria, viruses and chytrids have been isolated or identified for some common phytoplankton, but either cannot be cultured, or not on a sufficient scale to seed a large area of water at reasonable cost (Moss, 1980).

Biocides for algal control in the UK

In the UK, the Health and Safety Executive (HSE) has taken over responsibility from PSD for the approval of products for use as biocides under the Control of Pesticides Regulations (COPR). Some products fall outside the scope of the COPR, including those which:

- Act on the growth of the plant, for instance those that deprive algae of nutrients by chelating them or by using some form of physical means
- Physically remove the algae to the bottom of the pond (flocculators)

- Consist of unprocessed straw

Approved biocides, including aquatic algaecides, listed by their active ingredients, are given by the HSE at www.hse.gov.uk/pesticides/bluebook/approvals. The following aquatic algaecides are listed:

- benzalkonium chloride and copper sulphate (Waterlife Algizin P)
- copper sulphate pentahydrate (e.g. King British Green Algae Control)
- dimethylamine-epichlorohydrin copolymer (e.g. Interpet Feature Algae Control)
- monolinuron (TetraPond Algofin)

These products are produced for the amateur market and, all except those intended for water features, are for use in ponds that may contain plants and fish, to give control of both blanketweed and other algae.

It is recommended that as much of the blanketweed as possible is removed from ponds prior to the use of algaecides, to reduce the amount of decomposing matter that will be produced that will result in a lower oxygen content of the water. Once the blanketweed is controlled, conditions should be made less favourable to the re-establishment of algae, possibly by the use of a nutrient-reducing product e.g. Phos-Kit (www.tadpoleaquatics.co.uk/treatment.htm).

Some disinfectants such as Jet 5 (peroxyacetic acid plus hydrogen peroxide) and Jeyes Fluid (high boiling point tar acids) also kill algae (HDC Factsheet 15/05), and can be used on pathways and equipment, but are not intended for use in ponds. Label information on waste disposal gives information on product safety in the aquatic environment, and will be relevant where ponds could receive run-off from paths.

Other chemical control measures in the UK and USA

In the UK, terbutryn (Clarosan) is no longer approved to control algae in lakes and watercourses (www.pesticideguide.co.uk/news.asp). In the USA, endothal (dimethylalklamine salts) can be used (Brunson and Jacobs, 2004; Petty, 2005). Copper sulphate kills blue-green algae, but these are often soon replaced by copper-tolerant Chlorophyta (Moss, 1980).

One USA company recommends the use of Pond Care Algae Fix (by Aquarium Pharmaceuticals) to kill green and string algae and blanketweed in the weeks before the enzymes in the barley straw work properly. It is safe for fish and plants, but the water must be kept oxygenated as the algae die and consumes dissolved oxygen. Another product, Green Clean Aquatic Algaecide is a non-copper based algaecide that eliminates a broad spectrum of algae (especially string algae) on contact. Its active ingredient sodium carbonate peroxyhydrate creates a powerful oxidation reaction that destroys algal cell membranes within 60 seconds. It biodegrades completely (www.lilyblooms.com).

Some products are marketed without specific mention of their active ingredients. Algaefix (by Aquarium Pharmaceuticals) controls many types of green and hair algae and blanketweeds in ponds that contain live plants (www.merrifieldgardencenter.com). Water Garden Pro-Clear Green Water Controlled (marketed by Kent Marine) produces and maintains crystal clear pond water, and Water Garden Poly-Ox Organic Material Oxidizer / Sludge Remover (marketed by Kent Marine, www.kentmarine.com) oxidizes suspended and dissolved organic matter. Both are safe to fish and plants (www.azgardens.com).

Approvals for pesticide use in aquatic production

The current legislation permits pesticide use on ornamental aquatic plants either where products carry full label Approval for ornamental plants, or Specific Off-Label Approval (SOLA) for this use, or under the Long-term Arrangements for the Extension of Use (LTAEU).

It has been confirmed with PSD that pesticide products approved for use on ornamental plants may be used in plant production on nurseries growing aquatic ornamental plants, provided that the relevant conditions on the product label are satisfied. Some product labels prohibit use on aquatic, semi-aquatic or marginal plants, e.g. certain pesticides approved for the control of vine weevil (see page 14).

Approved pesticide use includes application to aquatic ornamental plants (such as water lilies) growing in glasshouses, tunnels or outdoors in static or moveable tanks without fish in them. Aquatic ornamental plants grown with their roots in shallow static water on benches can also be treated. Plants grown in containers on capillary matting or standing areas receiving irrigation are in identical production systems to ‘conventional’ ornamentals and thus can also be treated with products approved for use on ornamentals. All plants need to be in the same situation (i.e. outdoor or protected) as stipulated on the label or SOLA.

Treatment can be applied to ornamental plants that will subsequently be planted in or adjacent to ponds, including reeds that may be used in water filtration schemes. A Local Environment Risk Assessment for Pesticides (LERAP) would only be required in relation to any application on the nursery to prevent contamination of surface water other than that containing the plant pots or trays as part of the propagation and growing area.

SOLAs for ornamental plants apply to aquatic ornamentals, but SOLAs for fungicide use on ornamentals grown in re-circulating hydroponic systems only apply to aquatic ornamental plants if grown in the same situation.

LTAEUs exclude use in or near water, but PSD have confirmed that this exclusion applies to watercourses etc, not to the contained water integral to aquatic ornamental plant production. Products approved for use on watercress can be used under the LTAEU as long as conditions of use on the watercress approval are complied with, including the situation of use (outdoor/protected).

Products that work by mechanical means, such as Agri 50, Eradicoat and Majestik, are currently exempt from pesticide regulations.

On aquatic nurseries carrying a wide range of pond plants, a significant proportion of the growing area is no different to that found on other horticultural nurseries. Where plants are grown in water the trays or tanks are usually self-contained, and so there is little probability of pesticide run-off into drainage water. Flooded benches may be cleaned out between batches, but tanks may be left for longer periods before they are drained out.

There is a SOLA (2005/1501) for the use of the fungicide metalaxyl-M as the product SL 567A on outdoor and protected water lilies for the control of crown rot.

- It may be used as a dip treatment of rhizomes or tubers at transplanting at a maximum concentration of 1.0 mL in 10 L of water
- Dipped plants must not be sold or supplied until 10 weeks after treatment
- It may be used as a pond surface spray for leaf treatment at 5 mL product per m^2
- Treated plants must be grown in or already be growing in leakproof tanks
- Both dipped plants and water lilies which have received a surface spray treatment must be rinsed in fresh water before sale or supply
- Water which has been oversprayed or received freshly treated plants must be disposed of in accordance with the SOLA. The product is harmful to fish.
- Resistance to phenylamines is appearing and so curative use of the product should be avoided.

Choice of pesticide products

When choosing the most appropriate pesticide, in addition to selecting one that is approved for use, other factors need to be considered:

Efficacy and Crop Safety: Use of pesticides with SOLAs is at grower’s own risk. When pesticide products are used under LTAEUs from edible crops, where no approval for use on ornamentals exists, their use is at growers’ own risk, both of poor efficacy and of

phytotoxicity (Anon, 2007). There is no guarantee that a product will work against the particular pest or disease present on an aquatic plant, even if a similar problem (e.g. aphids, mites, powdery mildew, or rust) is mentioned on the label for another crop.
A few plants should be tested before extending treatment to the whole batch of plants. Where blocks of different plant species are grown together, and where it is not possible to contain any pesticide spray to the affected species, or when a species is sprayed for the first time, it is essential that records are kept of any crop damage problems. This will help to prevent a recurrence of the damage on another occasion.

Pesticide Resistance: Some pests and diseases are resistant to certain active ingredients. Any known resistance should be taken into account when selecting a pesticide, and any resistance management guidelines on the label or SOLA should be strictly adhered to, in order to avoid the further development of resistance. Further information is available on the Insecticide Resistance Action Group (IRAG) website: http://www.pesticides.gov.uk/rags.asp?id=702 and the Fungicide Resistance Action Group (FRAG) website: http://www.pesticides.gov.uk/rags.asp?id=644

Compatibility with biological control agents used in IPM: On nurseries using IPM programmes, pesticides can sometimes be needed prior to the introduction of biological control agents, or for spot treatments to allow these agents to regain control. Biological control suppliers should be consulted for full details of safety of pesticides to individual biological control agents. General guidelines on the compatibility of pesticides within IPM are given below in Tables 1 to 5 (Buxton *et al.*, 2006). The tables do not include all pesticides, or all of the pests and disease listed on each label, and they incorporate information for non-ornamental plant hosts. The majority of products listed are either harmful or very toxic to aquatic organisms (Anon, 2007).

Table 1: Relatively safe insecticides / acaricides to biological control agents within IPM.

Active ingredient	**Product example**	**Key target pests** (see labels for details and full list)	**Comments**
Bacillus thuringiensis	Dipel DF	Caterpillars	
buprofezin	Applaud	Whiteflies	Whitefly resistance likely
clofentezine	Apollo 50 SC	Spider mites	
diflubenzuron	Dimilin Flo	Caterpillars	
fatty acids	Savona	Aphids, mealy bugs, spider mites scale insects, whitefly	
fenbutatin oxide	Torq	Spider mites	Use permitted until 31 Dec 2007
natural plant extracts	Eradicoat / Majestik	Aphids, mealy bugs, spider mites, thrips, whitefly	
pymetrozine	Chess WG	Aphids,	
spinosad	Conserve	Thrips	
teflubenzuron	Nemolt	Caterpillars, whitefly	Whitefly resistance likely
Verticillium lecanii	Mycotal / Vertalec	Whitefly / Aphids	

Table 2: Moderately harmful insecticides / acaricides to biological control agents – use with care within IPM

Active ingredient	**Product example**	**Key target pests** (see labels for details and full list)	**Comments**
abamectin	Dynamec	Leaf miner, two-spotted spider mite, western flower thrips	
acetamiprid	Gazelle	Aphids, whitefly	
imidacloprid	Intercept 70 WG	Aphids, whitefly, sciarid flies, vine weevil	First case of whitefly resistance in UK recorded 2007
nicotine	Stalwart	Aphids	
pirimicarb	Aphox	Aphids	*Aphis gossypii* and some strains of *Myzus persicae* are resistant
pyrethrins	Pyrethrum 5 EC	Aphids, caterpillars	
spiromefisan	Oberon	Whitefly, spider mite	SOLA for ornamentals
tebufenpyrad	Masai	Spider mites	
thiacloprid	Calypso	Aphids, whiteflies, western flower thrips	SOLA for ornamentals

Table 3: Harmful insecticides / acaricides to biological control agents – NOT COMPATIBLE WITH IPM.

Active ingredient	**Product example**
bifenthrin	Talstar, Starion
cypermethrin	Toppel 10
deltamethrin	Decis
malathion	Fyfanon 440

Table 4: Relatively safe fungicides to biological control agents within IPM

Active ingredient	Product example	Some key diseases possibly controlled (see labels for details and full list)
azoxystrobin	Amistar	Powdery mildews, rusts
etridiazole	Standon Etridiazole 35	Phytophthora, Pythium
iprodione	Rovral WP	Alternaria, Botrytis, Sclerotinia
myclobutanil	Systhane 20EW	Powdery mildews, rusts
oxycarboxin	Plantvax 75	Rusts
propamocarb hydrochloride	Filex	Phytophthora, Pythium
tolclofos-methyl	Basilex	Pythium, Rhizoctonia

Table 5: Moderately harmful fungicides to biological control agents within IPM

Active ingredient	Product example	Some key diseases possibly controlled (see labels for details and full list)
bupirimate	Nimrod	Powdery mildews
carbendazim	Delsene 50 Flo	Botrytis, powdery mildews
chlorothalonil	Bravo	Ascochyta, Botrytis, downy mildews, powdery mildews, Phytophthora blight
copper ammonium carbonate	Croptex Fungex	Leaf spots, Pythium
copper oxychloride	Cuprokylt	Bacteria, downy mildews, Pythium, rusts
fosetyl-aluminium	Aliette 80 WG	Phytophthora, Pythium
mancozeb + metalaxyl M	Fubol Gold WG	Downy mildews, Phytophthora blights, White blister
mepanipyram	Frupica	Botrytis
prochloraz	Scotts Octave	A range of foliar fungus diseases
propiconazole	Bumper 250 EC	Powdery mildews, rusts, leaf spots
sulphur	Thiovit Jet	Powdery mildews

- **Full details for the use of biological control agents and compatibility of pesticides are available from biological control suppliers or consultants.**
- **Regular changes occur in the approval status of pesticides arising from changes in pesticide legislation or from other reasons. For the most up to date information, please**

check with a professional supplier or with the Information Office at the Pesticides Safety Directorate (PSD) Tel: 01904 640500; or on their website (www.pesticides.gov.uk).

- **Always follow label recommendations or statutory conditions for use on Specific Off Label (SOLA) notices of approval.**

- **Always follow instructions for Pesticide Resistance Management guidelines given on the label or SOLA.**

- **Growers must hold a paper or electronic copy of the current SOLA before using any product under the SOLA arrangements. Any use of a pesticide with a SOLA is at grower's own risk. Relevant SOLAs are sent to HDC members by HDC, or are available from PSD (see above) or from consultants.**

- **Use pesticides safely**.

Current status and control of key pests, diseases and weeds in aquatic plant production in the UK

Current pest, disease and weed problems

In order to obtain a clearer idea of the current pest, disease and weed problems on aquatic plants in the UK, visits were made to three ornamental plant nurseries between September 2005 and July 2006, and telephone calls made to a further three ornamental aquatic plant growers in February 2007. These growers were some of the main producers within the relatively small number of UK ornamental aquatic plant producers. The pest and disease problems identified are given in Tables 6 – 8. The exact identity of the pest or disease was not always known.

Pests

The existence and importance of each problem differed between the sites. The main pest problems were vine weevil (*Otiorhynchus sulcatus*) and water lily beetle (*Galerucella nymphaeae*) which were causing serious localised problems, particularly in outdoor production. Vine weevil larvae were active even in plants with continually saturated roots. Two-spotted spider mites (*Tetranychus urticae*) were also seen to build up on certain plants in glasshouses, making them unsaleable. Water lily aphids (*Rhopalosiphum nymphaea*) were seen in high numbers on water lily leaves held above water on one nursery, but were not seen at another. The pest seemed to be more numerous on particular plants.

The whorled pond snail (*Lymnaea stagnalis*) was present on all nurseries, causing holes in the water lily leaves. The ramshorn snail, *Planorbis planorbis* was less common and not a pest as it feeds mainly on algae attached to plant surfaces. However, both snails produced jelly-like egg masses that were attached to the underside of pond plant leaves, and these were often not acceptable to customers and so had to be rubbed off the leaves before the plants were sold.

Some water lilies are imported to the UK from the USA. The Defra PHSI examines these to ensure they are not carrying the tobacco whitefly, *Bemisia tabaci*. No other pest or diseases are reported from this imported material (W. Alford, PHSI, pers. com.).

Diseases

Powdery mildew was the main foliar disease on some pondside or marginal plants grown both indoors and outdoors, and may have been of more than one species. Seedling death and Iris plantlet or rhizome rot, usually attributed to *Pythium*, occurred at times in propagation areas. Some unidentified leaf spots were seen on water lilies (covering in one tank up to 25% of the leaf area), but these were mainly noticeable towards the end of the season and were not of great concern to the growers.

Water lily crown rot, probably caused by *Phytophthora* sp. (described more fully in the literature review), was not currently causing plant losses, as growers were vigilant and had management strategies in place to ensure it did not cause a problem. One nursery had such severe losses from crown rot 18 years ago that they were nearly put out of business. Since then, each new batch of plants is kept in its own tank, and water flow has been stopped between tanks. The disease was said to progress too quickly for chemical control to be effective. Another nursery had not had any crown rot for at least the last ten years. This was attributed to the fact that they grew-on water lilies from their own mother plants, and any young plants bought-in were from Holland and had caused no problems. In the crown rot outbreak of the late 1980s, Japanese imports were considered to be a likely source of the disease (HDC report, HNS 26). China currently supplies water lilies to the UK. They are cheap, but one grower considered them to be of poor quality. At a third nursery, water lily rhizomes were imported from Eastern Europe, in particular Hungary. Each rhizome provided many eyes that were being collected and grown on to produce mature plants without any problems.

Rotting *Iris pseudacorus* seedlings were sampled at one nursery where there was a recurring problem of plants dying from the base up after transplanting. Outer leaves became soft and brown, with the rot progressing to the inner leaves. White mycelium was visible around the base of the plants just above the compost and *Pythium* sp. was isolated from the soft base of the leaves. Healthy roots could still be present even when the shoots had collapsed. Plants were grown from seed and germinated in a tightly packed seed tray and did not show any damping-off. At two weeks old they were pricked out into multicell trays, and it is at this stage that they started to die. It was not known where the disease was coming from. Both these trays and the seed trays were in a small propagating house on wet (not flooded) matting and watered with tap water. No pesticides were used in this propagation house.

Weeds and Algae

All nurseries had the filamentous alga, blanketweed, in some ponds and spent time manually removing this from the tanks. Duckweed was a serious problem where floor-laid capillary matting was kept wet with re-circulated water. Duckweed was also present in some tanks, speculated to have been carried there by frogs. Any water fern arriving in tanks was removed. Liverworts thrived on the surface of pots growing in moist conditions. All weeds had to be picked, or washed off, prior to plant sale, but small pieces probably survived to propagate.

Table 6: Pests and diseases found on UK nurseries in 2005 and 2006 - deep marginal pond plants.

Plant species	Common name	Pest	Disease
Nuphar luteum	Brandy bottle lily	None found	Pycnidial leaf spot
Nymphaea	Water lily	Water lily aphid (*Rhopalosiphum nymphaeae*) Whitefly (not identified but likely to be glasshouse whitefly, *Trialeurodes vaporariorum)* Spider mite (probably two-spotted spider mite, *Tetranychus urticae*) Water lily beetle (*Galerucella nymphaeae*) Vine weevil (*Otiorhynchus sulcatus*) China mark moth (*Nymphula nymphaeata*) Pond snail (*Lymnaea stagnalis*)	Crown rot, (*Phytophthora)* Leaf spots Virus (chlorotic rings on leaf)
Various		Snail eggs European marsh frog (*Rana ridibunda)* (frogs transfer weeds between ponds)	

Table 7: Pests and diseases found on UK nurseries in 2005 and 2006 - marginal pond plants.

Plant species	Common name	Pest	Disease
Acorus gramineus cv. Variegatus	Japanese rush, Dwarf rush	Spider mite	Brown specks, coalescing at leaf bases (Virus?)
Caltha palustris	Marsh marigold	None found	Powdery mildew (especially in tunnels)
Iris pseudacorus	Yellow flag	Iris sawfly (*Rhadinocerea micans*) Two-spotted spider mite (*Tetranychus urticae*)	Basal leaf rot (young plants) - *Pythium* isolated Leaf spot
Iris spp.	Iris	Iris sawfly (*Rhadinocerea micans*)	Rhizome rot (at propagation) Leaf yellowing / soggy roots Leaf spot.
Lobelia cardinalis	Lobelia	Two-spotted spider mite (*Tetranychus urticae*)	None found
Myosotis scorpioides	Water forget-me-not	None found	Powdery mildew
Oenanthe fistulosa		'Woolly aphid' - not identified to species	None found
Phragmites communis	Norfolk reed	'Green aphid' – not identified to species	None found

Table 7: (continued). Pests and diseases found on UK nurseries in 2005 and 2006 - marginal pond plants

Plant species	**Common name**	**Pest**	**Disease**
Ranunculus lingua cv. Grandiflorus	Spearwort	'Black aphid'– not identified to species Whitefly– not identified to species Leaf miner – not identified to species 'Woolly aphid'– not identified to species	Powdery mildew
Sagittaria spp.	Arrowhead	Ducks (feed on bulbs)	None found
Schizostylis coccinea	Kaffir lily	Two-spotted spider mite (*Tetranychus urticae*)	Rotting base, white fungus (possibly *Pythium*)
Thalia dealbata	Mexican Blue Feather	Two-spotted spider mite (*Tetranychus urticae* "Aphid'– not identified to species	None found
Present in marginal plant production areas	Various species (with leaves out of water)	Aphids (not a problem on all sites) Whitefly Leatherjackets (*Tipula* spp.) Shore fly (*Scatella tenuicosta*) Vine weevil (*Otiorhynchus sulcatus*) on semi- immersed roots Spider mite Carnation tortrix (*Cacoecimorpha pronubana*)	Seedling damping off *Pythium* spp. Powdery mildew Viruses causing mottling

Table 8: Pests and diseases found on UK nurseries in 2005 and 2006 - pondside and bog plants

Plant species	**Common name**	**Pest**	**Disease**
Astilbe hybrids	Goat's beard	Vine weevil (*Otiorhynchus sulcatus*)	None found
Aruncus dioichus	Goat's beard	Aruncus sawfly (*Nematus spiraeae*)	None found
Filipendula	Meadowsweet	Vine weevil (*Otiorhynchus sulcatus*)	Powdery mildew
Hosta spp.	Plantain lily	Slugs and Snails (terrestrial)	Leaf spot
Ligularia		Vine weevil (*Otiorhynchus sulcatus*)	Powdery mildew
Lythrum	Purple loosestrife	Two-spotted spider mite (*Tetranychus urticae*)	Powdery mildew
Lysichiton	Skunk cabbage	Two-spotted spider mite (*Tetranychus urticae*)	Root rot possibly *Phytophthora* spp.
Phyllostachys	Bamboo	Aphids Vine weevil, *Otiorhynchus sulcatus* Bamboo mite, two-spotted spider mite, *Tetranychus urticae*	None found
Phalaris arundinacea cv. Variegata	Gardener's garters (grass)	'Green aphid' – not identified to species	Powdery mildew
Primula spp.	Primula, Cowslip, Candelabra	Vine weevil (*Otiorhynchus sulcatus*)	Crown rot (*Phytophthora*)
Zantedeschia aethiopica	Arum lily	Vine weevil (*Otiorhynchus sulcatus*)	Powdery mildew (in tunnel overwinter). Root rot (*Phytophthora*)

Measures employed on UK nurseries to reduce pests, diseases and weeds

On the UK nurseries visited, various techniques were used to manage pests and diseases. They are recorded here as part of the survey report, but their inclusion, particularly the use of pesticides, does not constitute a recommendation.

Physical intervention

- Hosing-off plants *in situ* on benches (e.g. for aphids). This was only suitable for older or shorter plants that would recover from being bent over by the water jet.
- Pushing the leaves under water to remove pests (e.g. water lily aphids). It was not known, however, whether dislodged insects drowned or survived to re-colonise the leaves.
- Washing aquarium plants under the tap prior to dispatch to remove whitefly, duckweed, and blanketweed.
- Hand removal of water snails from propagation areas (and keeping them to sell to customers).
- Removing damaged leaves (e.g. those damaged by snails, caterpillars, water lily beetles or leaf spots).
- Cutting down grasses and rushes (then possibly using a pesticide) to remove pests (e.g. aphids).
- Netting outdoor ponds to stop duck feeding.
- Keeping recently purchased stocks in separate batches to allow pest and disease monitoring.
- Only accepting sale-or-return plants back onto the nursery if the retailer is known to practice good plant husbandry.
- Cleaning out tanks and benches between production batches.
- Ultrasound to control algae was under investigation for swimming ponds.

When vigorous varieties of water lilies overhang free-standing tanks these leaves are more susceptible to aphids. Although the water level in tanks can be raised to submerge the leaves and keep the plants free from pests, it is not possible to cover leaves growing outside the tanks. Water lilies were grown in media produced on site, principally using unsterilised loam (never peat, as it would float), usually with the addition of slow-release fertiliser. It was not easy to achieve a balance between providing sufficient nutrients to ensure strong plant growth, while reducing the probability of algal blooms from nutrients released into the water.

Most nurseries provided guidance to their customers on maintaining plant health, particularly on ensuring plants received the correct growing conditions. Brochures, information sheets, web pages and retail-area display boards were all available.

Biological control or use of natural products

- Garlic spray, reputed to improve plant vigour. Applied on one nursery by motorised knapsack.
- Barley straw to reduce algal growth in swimming ponds.
- Insect pathogenic nematodes (*Steinernema* sp.) watered onto multicell trays for the control of vine weevil larvae. This was found to be effective on marginal plant plugs even in 20 mm of water.
- Insect pathogenic nematodes (*Steinernema* sp.) applied via the irrigation water to control vine weevil larvae on outdoor pots of bamboo.
- Parasitic wasp (*Encarsia formosa*) against glasshouse whitefly (*Trialeurodes vaporariorum*).
- Naturally-occurring parasitic wasps were reported to control aphids
- Wagtails allowed entry to glasshouses to feed on insect pests.
- Naturally-occurring predatory dragonfly larvae in outdoor ponds.

One nursery where biological control methods had been used for whitefly had discontinued this in favour of insecticide application, because the plants required spraying for other problems. Although yellow sticky traps (to monitor for aphids and whitefly) were present on some nurseries, they were not replaced very often.

Where water plants, such as Norfolk reed, *Phragmites communis,* were sold in large batches for use in waterways and sewage treatment schemes, the appearance of the plant was less important and so pest control was not particularly important.

Chemical control

All nurseries used pesticides, using both products approved for use on protected and outdoor ornamental use and those permitted for use under the current Long-Term Arrangements for Extension of Use (LTAEU). There was awareness by growers of the possibility that chemical residues might remain on the plant (or in the compost), which might cause a problem in a customer's pond, and nurseries ensured that sprayed material was not sold until at least two weeks after pesticide application. Although one nursery washed all plants and their roots (sprayed and unsprayed) prior to dispatch to reduce the risk of pesticide residues coming from the plants, there is no evidence that this is effective.

Pesticides were generally applied to plants in the situations in which they were being grown (i.e. either on capillary matting or standing areas, with roots standing in water, or less frequently with the whole plant immersed except for the floating leaves). Trays were often arranged tightly on benches so that there was little water surface to receive direct chemical application. The water-filled benches and tanks receiving pesticides were self-contained, only being emptied on-site once the plants had been sold. None of the ponds growing plants for sale contained fish.

The pesticide products used by growers are given in Table 9. Note that applications were principally made to plants growing on benches or standing areas, with foliage out of water.

Table 9: Examples of pesticide usage for pest, disease and weed management in aquatic plant production on UK nurseries and their targets

Product *	Active ingredient	Target *
Dynamec	abamectin	Two-spotted spider mite
Applaud	buprofezin	Glasshouse whitefly
Talstar 80 Flo	bifenthrin	Glasshouse whitefly
(Various)	nicotine	Water lily aphid
Intercept WP	imidacloprid	Vine weevil
Vi-Nil**	fipronil	Vine weevil
Toppel 10	cypermethrin	Water lily beetle
(Unspecified)		*Pythium* (damping off)
(Unspecified)		Powdery mildew
Roundup	glyphosate	*Azolla*, *Crassula*

*N.B. The products listed are not necessarily the most effective or least environmentally harmful.

** Product label states Vi-Nil should NOT be used in compost for aquatic plants or marginals.

Biological control options and pesticides compatible with IPM are given in the literature review and on pages 33 - 35.

Although metalaxyl-M can be used on water lilies under SOLA 2005/1501, no growers were using the product as they did not currently have crown rot problems.

Pests, diseases, weeds and algae in UK watercress production

A visit was made to a company producing watercress for consumption, to see if any information on crop health and control measures could be transferred to the ornamental aquatic plant industry. The watercress was planted into large tanks of flowing water (with outflow into a river) and was semi-emergent. Flea beetles (*Psylliodes* and *Phyllotreta* spp.) ate holes in, and cabbage white butterflies (*Artogeia* and *Pieris* spp.) laid eggs on, the leaves out of the water, while Chironomid larvae grazed on the submerged leaves. Blanketweed was present around the base of the plants. However, none of these were a problem, because the lower part of the plant was not harvested, and the harvest was usually too frequent to allow eggs to hatch. The cut stems were washed thoroughly in the processing plant. Precautions were taken during propagation against *Pythium* damping-off using a mixture of Proplant (propamocarb hydrochloride, SOLA 2004/0625), SL 567A (metalaxyl-M, SOLAs 2004/0719 and 2005/1516) and Aliette 80WG (foseyl-aluminium, SOLA 2003/0867) applied straight after sowing the peat plugs. A multi-strand electric fence was used to keep frogs from entering the tanks, and fleece had been used to protect against birds. Further information on watercress production and use of approved pesticides on watercress is given at www.assuredproduce.co.uk.

Research and development priorities for pest, disease and weed management on aquatic plants

- There is a lot of information available on the use of IPM on protected ornamentals, which could be transferred to aquatic growers. Relevant information on IPM from other sectors will be summarised in the project factsheet, and if there is sufficient support from the aquatics industry, a workshop for growers could be provided.
- Further research is needed on testing or validating integrated strategies for controlling selected pests and diseases on aquatic plants, e.g. water-lily aphid, water-lily beetle, vine weevil, powdery mildew and *Pythium* and *Phytophthora* root rots. Strategies for testing could include biological control organisms, natural products and the use of resistant plant varieties.
- The effectiveness of either ultrasound devices, or copper electrodes, against water-borne diseases in water plant tanks needs testing. Their use could remove the need for fungicide applications to plants.
- A large range of fungi can be found on the plant species grown on nurseries, but the individual case study visits done in this project were confined to a single visit, and did not include detailed examination of all growing areas. Further surveys on nurseries would be needed to assess if there are diseases (such as leaf spots), possibly unrecognised by growers, that are causing reductions in aquatic plant quality
- There are a number of algal control products on the market e.g. ultrasound, dyes, microbes and a clay flocculator. Their effectiveness in nursery aquatic plant tanks needs testing.

Discussion

Visits to aquatic plant nurseries showed that a wide range of plants were being grown, with different production areas to accommodate the various water depth requirements. Some of the species that were supplied to be grown submerged, such as those planted in aquariums, were kept on nurseries either on benches or in tanks where only the roots were in water. Pondside, or bog plants, and some marginal species were grown so that only their roots remained wet. Water lilies were the principal plants grown totally submerged in tanks. Flooded benches and plant tanks held static, contained, water. A large number of species were set out in pots or multicell trays, as is common commercial practice in non-aquatic ornamental plant production, i.e. on capillary or woven matting. Plants were principally perennials, and mostly produced in glasshouses and tunnels.

In the plant tanks, water lily beetle, *Galerucella nymphaea* and water lily aphid, *Rhopalosiphum nymphaeae*, were reducing water lily quality. Most growers were using cultural control methods for both pests, e.g. removing leaves damaged by water lily beetle and hosing off or submerging aphid-infested leaves. There is potential for research on other non-chemical methods of control, e.g. using varieties resistant to water lily aphid, and validating the efficacy of commercially available predators and parasitoids against the pest.

Water lily crown rot, attributed mainly to *Phytophthora* sp., was not the problem it had been in the 1980s. The original problem may have been caused by imported Japanese plant material, and with material currently imported from other countries it should be standard practice that each batch of propagated material is kept in its own tank, at least for the first three months when symptoms should become apparent. *Colletotrichum nymphaeae* causes leaf spot water lilies in the Netherlands, whereas in the UK *Ovularia nymphaearum* is recognised as a leaf spot. Unidentified leaf spots were seen on water lilies on nurseries, but because they were most obvious at the end of the season they were not considered a problem. Without the spotting, however, it is possible that the lilies could have been marketable for longer.

Plants grown with their foliage out of water in glasshouses and tunnels were susceptible to pests and diseases common to non-aquatic protected ornamental plants. Two-spotted spider mite, *Tetranychus urticae*, various aphids and powdery mildew were noted in the survey. Vine weevil, *Otiorhynchus sulcatus,* was causing damage, inside and outdoors, even where plant roots were submerged. One grower reported that insect-pathogenic nematodes were effective against the pest on plants stood in water. However, these nematodes are unable to survive for long in static water and research is needed on the effectiveness of applications to plants stood in water.

Blanketweed was a major problem in tanks, multiplying quickly and entwining around the plants. A range of novel control methods has been reported but further work is required to develop fully effective strategies. One nursery was investigating the use of ultrasound for blanketweed control, but it is not clear whether this is effective on filamentous as well as single-celled algae. Sales literature indicates that fungal spores, as well as algae, are ruptured by the ultrasound devices available, and this warrants investigation. Various chemicals are available for the control of mainly single-celled algae. Dyes have been very effective in display ponds (with vertical sides) to block out the light from all types of algae, while still allowing plants with leaves above the surface to grow. Dyes might be a relatively cheap measure worth investigating. A product containing plant extracts that activates microbes and leads to the control of algae and blanketweed might be effective, and is also safe for fish. *Pythium myriotylum* kills duckweed, but its potential as a biological control agent is likely to be limited by its lack of host-specificity.

Most nurseries washed plants, or cut off damaged leaves, to remove pests, weeds and leaf spots. Where damage, for example by mites or powdery mildew, was severe, the whole plants were either cut down, or pesticides approved for use on ornamentals applied. Information on pesticide crop safety is built up on each nursery. There was hardly any use of products for stimulating the plant's own natural defences. The mixture of species in any one area, and the need to spray some and not others at any one time, was said to limit the use of biological control. This was a commonly held belief by growers of non-aquatic ornamentals, when comprehensive IPM programmes were developed during the 1980s. However, IPM is now successfully used on many UK nurseries growing mixed ornamentals. A need for training growers of aquatic plants in IPM was identified. It may be necessary to validate IPM methods currently used on non-aquatic ornamentals, on aquatic plants

Pesticide choice was not limited by lack of approved products for use on inland water and watercourses as, although plants were stood in water, the tanks or trays were self-contained. Thus, pesticides approved for use on protected and outdoor ornamentals may be used on aquatic plants in production areas, provided that the relevant conditions on the label are satisfied. Label restrictions prohibit the use of SuSCon Green and Vi-Nil in compost for aquatic plants or marginals. The visits to aquatic plant nurseries highlighted the need to communicate information regarding pesticide use on aquatic plants to growers, including the choice of approved pesticides, efficacy and resistance issues, and compatibility with biological control agents used within IPM. Key information will be communicated to growers via the project factsheet.

Water was often taken from the mains or a bore-hole, but more attention could probably be paid to ensuring the disease-free status of water which was either being collected from glasshouse roofs or taken from ponds or rivers, or re-circulated. Plants stood in water provide ideal conditions for the spread of spores in irrigation water. The spread of *Pythium* and bacterial soft rot, such as occurs in Irises, might be reduced by the use of slow sand filters, and these should also trap duckweed seeds, water fern fragments and liverwort gemmae.

There is potential for research into the nutritional and growing media structure requirements of water lilies and other aquatic plants grown in saturated compost. Peat is not usually used because it floats out of submerged pots and so loam is often used, but coir has proved suitable on one nursery. The release of slow-release nutrient granules may not be as effective when the granules are continually saturated, leading to poor plant growth or algal bloom. Plants can run out of nutrients. There are a number of pesticides for compost incorporation, or for application as drenches, and also microbial and nematode biological control agents that are applied as drenches. There is no information on their effectiveness when plants are permanently stood in water.

A significant number of plant species grown on the nurseries were British natives. A large number of diseases have been recorded “in the wild” on many of them. No particular diseases were reported on these plants by nursery staff, but it is possible that the fungi may be causing damage which has not be recognised as a disease. There are also some diseases reported in the USA on ornamental plants, but it is not known whether they are present in this country.

There has been hardly any published work worldwide on the pests and diseases of aquatic or semi-aquatic plants. Most work concentrates on finding organisms that could be used for biological control of invasive alien plants, but these species are mainly now not offered for sale by UK nurseries. There is concern from environmental bodies about the blockage of UK waterways by alien aquatic plants. Many of the other plants sold are of great benefit to British wildlife, because with the filling in of rural ponds and the herbicide treatment of waterways these species and their fauna are rare in the wild. Promotion of native aquatic planting in gardens and landscape schemes should be encouraged.

Conclusions

For many of the plants grown on aquatic nurseries, the control measures for non host-specific pest and diseases are the same as in other ornamental plant sectors. Pesticides are applied away from natural waterbodies, and there is no regular run-off from nursery benches and tanks into drains or rivers. Thus, pesticides approved for use on 'conventional' ornamentals may also be used in the production of aquatic plants, providing any label conditions or restrictions are followed. There is potential for greater uptake of IPM programmes, including the use of biological control agents against pests. The use of biological control of diseases would require further development, including determining any benefits from the use of either microbial health-promoting supplements or plant extracts.

Many host-specific fungal diseases have been recorded in the natural environment on the native plants grown on UK nurseries, but there is both a lack of knowledge of their prevalence and importance in the nurseries, and ignorance of the identity of some of the diseases causing problems on the nurseries.

Technology transfer

A Factsheet will be produced in this project, giving information on the cultural, biological and chemical control measures of the pests, diseases and weeds of aquatic, marginal and bog plants.

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Appendix 1. Tables of plant hosts and associated pathogens

Appendix 1a: Pondside or bog plants

Host-specific, and some plurivorous, diseases recorded in the UK, USA and Europe. (* = British native plants)

Host Common Name	Host Species	Disease	Disease Species	Seen	Symptoms
Bugle	*Ajuga reptans* *	Powdery mildew	Not specified	UK	White powdery covering
		Leaf spot	*Ramularia ajugae*	UK	Oval pale spot with dark border
Artemisia	*Artemisia lactiflora*	Powdery mildew	*Erysiphe artemisae*	UK	White powdery covering
		Grey mould	*Botrytis cinerea*	UK	Grey or grey-brown effuse colonies
Hemp Agrimony	*Eupatorium cannabinum**	Powdery mildew	*Golovinomyces cichoracearum* var. *cichoracearum*	UK	White powdery covering
Meadowsweet	*Filipendula ulmaria**	Rust	*Triphragmium ulmariae*	UK	Orange or yellow pustules
		Stem dieback	*Diaporthe lirella*	UK	Blackened stem
		Powdery mildew	*Erysiphe ulmariae*	UK	White powdery covering
		Powdery mildew	*Sphaerotheca alchemillae*	UK	White powdery covering
Water Avens	*Geum rivale**	Downy mildew	*Peronospora gei*	UK	Yellow patches, downy under
Plantain Lily	*Hosta* sp.	Root & crown rot	*Fusarium* spp.	USA	Yellow leaves, crown vascular staining
		Hosta virus X	Hosta virus X	USA	Leaf mosaic
		Tomato Ringspot Virus	Tomato Ringspot Virus	USA	Mottling and chlorosis
Marsh Cinquefoil	*Potentilla palustris**	Leaf spot	*Cercospora comari*	UK	Reddish-brown spots
		Leaf spot	*Venturia palustris*	UK	Irregular brownish spots

Appendix 1a contd: Pondside or bog plants

Host-specific, and some plurivorous, diseases recorded in the UK, USA and Europe. (* = British native plants)

Host Common Name	Host Species	Disease	Disease Species	Seen	Symptoms
Cowslip	*Primula vulgaris**	Rust	*Puccinia primulae*	UK	Brown pustules
		Leaf spot	*Ascochyta primulae*	UK	Whitish, yellow bordered spots
		Leaf spot	*Cercospora primulae*	UK	Chocolate brown spots, grey centres
		Downy mildew	*Peronospora oerteliana*	UK	Sporulation under yellow angular lesions
		Leaf spot	*Ramularia primulae*	UK	Pale brown spots, bright yellow border
Ornamental Rhubarb	*Rheum*	Rust	*Puccinia phragmitis*	UK	Reddish-purple spots (aecia stage)
		Leaf spot	*Ramularia rhei*	UK	Round, pale brown spots, crimson border
Yellow Meadow Rue	*Thalictrum flavum**	Rust	*Puccinia recondita* f.sp. *persistens*	UK	Dark brown telia
		Leaf spot	*Haplobasidion thalictri*	UK	Buff spots with purple borders, olivaceous brown colonies

Appendix 1b: Ferns and Horsetails. Host-specific diseases recorded in the UK, USA and Europe.

Host common name	Host Species	Disease	Disease species	Seen	Symptoms - including spore type
Broad Buckler Fern	*Dryopteris dilatata**	Rust	*Milesina kriegeriana*	UK	Sunken pustles, white spores
		Petiole speck	*Leptopeltis filicina*	UK	Subcuticular spores in petioles & veins
		Pinnule curl	*Taphrina athyrii*	UK	Angular brown spots, tissue curl
Horsetail	*Equisetum fluviatile**	Stem spot	*Titaeospora equiseti*	UK	Acervuli in rows, brown staining
Adder's Tongue	*Opioglossum vulgatum**	Leaf spot	*Curvularia crepinii*	UK	Effuse grey colonies, later black

Appendix 1c: Marginals

Host-specific, and some plurivorous, diseases recorded in the UK, USA and Europe. (* = British native plants)

Host name	Host species	Disease	Disease species	Seen	Symptoms
Sweet Flag	*Acorus calamus**	Ascochyta leaf spot	*Ascochyta acori*	UK	Lower leaf browning
		Ramularia leaf spot	*Ramularia aromatica*	UK	Oval brown leaf spots
Water Plantain	*Alisma plantago-aquatica**	Smut	*Doassansia alismatis*	UK	Yellow-brown spots
		Leaf spot	*Rhynchosporium alismatis*	UK	Leaf browning
Marsh Marigold	*Caltha palustris**	Powdery mildew	*Erysiphe aquilegiae* var. *aquilegiae*	UK	Powdery covering
		Rust	*Puccinia calthae*	UK	Brown pustules
		Rust	*Puccinia calthicola*	UK	Dark brown pustules
		Leaf spot	*Pseudopeziza calthae*	UK	Brown spots old leaves
		Leaf spot	*Ramularia calthae*	UK	Pale leaf spots
Scouring Rush	*Equisetum hyemale**	Leaf spot	*Ascochyta equiseti*	UK	Bleached area dead stems
		Leaf spot	*Titaeospora equiseti*	UK	Reddish-brown dying stems
Marsh St John's Wort	*Hypericum elodes**	Leaf spot	*Mycosphaerella elodis*	UK	Brown leaf spots
		Leaf spot	*Septoria hyperici*	UK	Brown, yellow-bordered spots
Water Irises	*Iris* spp.	Bacterial soft rot	*Pectobacterium* (syn. *Erwinia) carotovora*	UK	Leaf streaks, rhizome rot

Appendix 1c contd: Marginals

Host-specific, and some plurivorous, diseases recorded in the UK, USA and Europe. (* = British native plants)

Host name	Host species	Disease	Disease species	Seen	Symptoms
Yellow Iris, Yellow Flag	*Iris pseudacorus**	Leaf spot	*Ectostroma iridis*	UK	Brown elongate lesion with halo
		Leaf spot	*Mycosphaerella iridis*	UK	Brown spots
		Leaf spot	*M. macrospora*	UK	Oval brown grey centre spots
		Leaf spot	*Phoma pseudacori*	UK	Elongate grey spots at leaf tips
Water Mint	*Mentha aquatica**	Powdery mildew	*Erisyphe biocellata*	UK	Powdery covering
		Rust	*Puccinia menthae*	UK	Brown pustules
		Leaf spot	*Ramularia menthicola*	UK	Round pale spots, dark border
Musk	*Mimulus* spp.*	Grey mould	*Botrytis cinerea*	UK	Grey or grey-brown effuse colonies
Water Forget-me-not	*Myosotis scorpiodes**	Smut	*Entyloma fergussoni*	UK	Pale circular leaf spots
		Impatiens Necrotic Spot	Impatiens Necrotic Spot Virus	USA	Wilt, leaf spots
Spearwort	*Ranunculus* spp.	Powdery mildew	*Erysiphe aquilegiae* var. *ranunculi*	UK	White powdery covering
Greater Spearwort	*Ranunculus lingua**	Rust	*Puccinia magnusiana*	UK	Yellowish pustules under leaf (alternate host Phragmites australis)
Lesser Spearwort	*Ranunculus flammula**	Rust	*Puccinia magnusiana*	UK	
Arrowhead	*Sagittaria sagittifolia**	Leaf spot	*Cercospora alismatis*	USA	Brown spots
		Smut	*Doassansia sagittariae*	UK	Pale brown raised spots
Greater Reedmace	*Typha latifolia**	Leaf spot	*Colletotrichum typhae*	UK	Orange brown, darker margin
		Leaf spot	*Phaeosphaeria typhae*	UK	Leaf spots
Brooklime	*Veronica beccabunga**	Downy mildew	*Peronospora grisea*	UK	Patches of violaceous sporulation
Calla "Lily"	*Zantedeschia aethiopica*	Bacterial soft rot	*Pectobacterium carotovora*	UK	Rotted tubers
		Leaf blight	*Phytophthora erythroseptica*	UK	Wilted chlorotic leaves
		Mosaic virus	Dasheen mosaic virus	USA	Leaf spot and distortion

Appendix 1d: Grasses, rushes and sedges

Host-specific, and some plurivorous, diseases recorded in the UK, USA and Europe. (* = British native plants)

Host name	Host species	Disease	Disease species	Seen	Symptoms
Meadow Foxtail	*Alopecurus pratensis**	Leaf spot	*Mastigosporium album*	UK	Black spots
Bamboo	*Arundinaria* spp.	Rusts	*Puccinia kusanoi*	UK	Brown tiny pustules
			Puccinia longcornis	UK	Brown tiny pustules
Sedges	*Carex* spp.*	Rusts	*Puccinia* spp.	UK	Pustules
		Glume smuts	*Anthracoidea* spp.	UK	Dark spore masses
Lesser Pond Sedge	*Carex acutiformis**	Glume spot	*Mollisia dactyligluma*	UK	Pale brown apothecia
			Niptera pilosa	UK	Grey-brown apothecia on leaf bases
		Leaf spot	*Septoria caricicola*	UK	Round, white, brown bordered spots
Greater Pond Sedge	*Carex riparia**	Spiklet smut	*Farysia thuemenii*	UK	Olive-brown spore mass
		Stem spot	*Myriosclerotinia sulcata*	UK	Small wine-glass shaped fruiting bodies from dark, spindle-shaped sclerotial lumps
		Leaf spot	*Septoria caricicola*	UK	Round, white, brown bordered spots
Cotton Grass	*Eriophorum angustifolium**	Leaf base spot	*Niptera pilosa*	UK	Grey-brown apothecia mainly on leaf bases
Reed Sweet Grass	*Glyceria maxima**	Leaf smut	*Ustilago longissima*	UK	Parallel elongate brown pustules
Creeping Soft Grass	*Holcus mollis* *	Crown rust	*Puccinia coronata*	UK	Brown pustules
		Rust	*Puccinia holcina*	UK	Brown pustules
		Leaf smut	*Entyloma crastophilum*	UK	Black rust-like pustules
		Glume smut	*Tilletia holci*	UK	Blackish spore mass
		Leaf spot	*Ramularia holci-lanati*	UK	D. brown spots, yellow margins
		Leaf spot	*Colletotrichum holci*	UK	Oblong brown spots

Appendix 1d contd: Grasses, rushes and sedges

Host-specific, and some plurivorous, diseases recorded in the UK, USA and Europe. (* = British native plants)

Host name	Host species	Disease	Disease species	Seen	Symptoms (Alternate host for rust species)
Soft Rush	*Juncus effusus* *	Rust	*Uromyces junci*	UK	Brown pustules (Fleabane)
		Leaf spot	*Mollisia juncina*	UK	Yellow then brown small bodies in spots
		Leaf spot	*Diplorhinotrichum juncicola*	UK	Eye-shaped pale lesion, purple border
Woodrush	*Luzula* spp.*	Rust	*Puccinia obscura*	UK	Gold pustules on purple spots. (Daisy)
Purple Moor Grass	*Molinia caerulea**	Rust	*Puccinia brunellarum-moliniae*	UK	Golden pustules (Self-heal)
		Rust	*Puccinia nemoralis*	UK	Brown pustules (Cow-wheat)
Gardener's Garters, Reed Canary-grass	*Phalaris arundinacea**	Rust	*Puccinia sessilis*	UK	Small golden brown pustules (Marsh-orchids, Cuckoo Pint, *Allium*)
Reed	*Phragmites* *	Rust	*Puccinia magnusiana*	UK	Small pustules (*Ranunculus)*
		Rust	*Puccinia phragmitis*	UK	Pustules (*Rheum*)
		Stem smut	*Ustilago grandis*	UK	Blackish-brown spore mass
		Ergot	*Claviceps microcephala*	UK	Small ergots form in seed heads
		Stem spot	*Leptosphaeria arundinacea*	UK	Lesion. Dark resting bodies on dead sheaths
Bullrush	*Schoenoplectus lacustris* syn. *Scirpus lacustris**	Rust (rare)	*Puccinia scirpi*	UK	Reddish brown pustules (Floating Heart Lily).
			Myriosclerotinia scirpicola (*also Myrioconium* state)	UK	Black pustules. Dark resting bodies on lower stems
Reedmace	*Typha* spp.*	Leaf spot	*Colletotrichum typhae*	UK	Orange-brown lesions, dark margins

Appendix 1e: Water, floating and submerged plants.
Host-specific, and some plurivorous, diseases recorded in the UK, USA and Europe. (* = British native plants)

Host name	Host species	Disease	Disease species	Seen	Symptoms
Water Hyacinth	*Eichornia crassipes*		*Rhizoctonia solani*	USA	Plant death
Duckweed	*Lemna* spp.*		*Pythium myriotylum*	USA Israel	Wilted plants
Water Milfoil	*Myriophyllum spicatum*		*Mycoleptodiscus terrestris*	USA	Plant death
Fringed Water Lily, Floating Heart	*Nymphoides peltata**	Rust	*Puccinia scirpi*	UK USA	Pustules. (Alternate host: Bulrush *Schoenoplectus)*
		Leaf rot	*Pythium* spp.	NL	May be secondary infection
		Leaf smut	*Burrillia decipiens*	USA	
Water Lily	*Nymphaea* spp.	Fungal leaf spots	*Alternaria* sp.,	USA	Blackish brown spore masses
			Cercospora exotica	USA	Brown spots with raised borders
			C. nymphaeacea	USA	Brown spots with raised borders
			Helicoceras nymphaearum	USA	
			Helicosporium nymphaearum		Pink tinged colonies – conidia. (Alternate state *Tubeufia* sp.)
			Mycosphaerella pontederiae	USA	Brown spots with small fruiting bodies, pseudothecia
			Phyllosticta fatiscens	USA	Spots with pycnidia
			P. nymphaeacea	USA	
			P. nymphaeicola	USA	

Appendix 1e contd: Water, floating and submerged plants.
Host-specific, and some plurivorous, diseases recorded in the UK, USA and Europe.

Host name	Host species	Disease	Disease species	Seen	Symptoms
Water Lily	*Nymphaea* spp	Leaf spot	*Ovularia nymphaearum*	UK USA	Circular brown spot
		White smut	*Entyloma nymphaeae*	USA	Smut sori
		Rhizome rot	*Pythium* sp.	USA	Soft rotting
		Nymphaea rot	*Phytophthora* sp.	UK	Blackening & rotting of stem
	*Nymphaea alba**	Leaf spot	*Colletotrichum nymphaeae*	NL	Black acervuli within spot
	Nymphaea odorata	Leaf spot	*C. nymphaeae*	EU	Black acervuli within spot
Amphibious Bistort, Willow Grass	*Polygonum amphibium* (syn. *Persicaria amphibia)**	Rust	*Puccinia polygoni-amphibii*	UK	Brown pustules
		Powdery mildew	*Erysiphe polygoni*	UK	White powdery covering

Appendix 1f: Waterside trees and shrubs

Host-specific, and some plurivorous, diseases recorded in the UK, USA & Europe. (* = British native plants)

Host name	Host species	Disease	Disease species	Seen	Symptoms
Alder	*Alnus* spp.*	Leaf spot	*Taphrina sadebackii*	UK	Yellow 10mm spots on leaf underside
		Leaf curl & blister	*Taphrina tosquinetii*	UK	Leaves larger, thickened & incurved
		Powdery mildew	*Microsphaera penicillata*	UK	White powdery covering
			Passalora bacilligera	UK	Yellow-green angular areas on leaf
			Sporidesmium wroblewski	UK	Brown colonies on leaf & catkins
Bog Myrtle	*Myrica gale**	Leaf spot	*Ramularia destructiva*	UK	Red-brown spots, twigs & under leaf
Willow	*Salix* spp. *	Rust	*Melampsora* spp. (different on the various willow spp.)	UK	Yellow pustules. (Alternate hosts not always represented in Britain)
	Salix spp. (some)	Rust	*Melampsora epitea*	UK	Orange-yellow pustules. Yellow-brown to black-brown pustules
	Salix spp.	Leaf & twig spot	*Capnodium salicinum*	UK	Mat of brown hyphae & fruiting bodies
		Powdery mildew	*Uncinula adunca* var. *adunca*	UK	White powdery
			Apostemidium spp.	UK	Bark - Blackish specks
			Oramasia hirsuta	UK	Bark - Brown spore mass
			Trimmatostroma salicis	UK	Bark - Black powdery spore mass
	S. caprea, S. viminalis	Die-back	*Pyrenopeziza salicis*	UK	Bark ruptured - brown hyphae

Appendix 1f contd: Waterside trees and shrubs.
Host-specific, and some plurivorous, diseases recorded in the UK, USA & Europe. (* = British native plants)

Host name	Host species	Disease	Disease species	Seen	Symptoms
Willow	*Salix vitellina*	Leaf and stem die-back	*Physalospora miyabeana* (also as *Colletotrichum*)	UK	Leaf and stem necrosis. Brown fruiting bodies. Concentric spore masses
	Salix repens	Stem infection	*Rosellinia desmazieresii*	UK	Bark has small fruiting bodies
	Salix triandra	Leaf spot	*Marssonina* sp.	UK	Dark spots
	Salix alba	Leaf and stem spot	*Venturia saliciperda* (also as *Pollaccia*)	UK	Large black spots on leaves and twigs
			Camarosporium salicinum	UK	Pycnidia fruiting bodies on twigs
Weeping Willow	*Salix alba* var. *vitellina x babylonica*	Die-back	Anthracnose		
		Leaf & twig spot	*Marssonina* (also as *Drepanopeziza* spp.)	UK	Greyish-brown spots
Bog Wortleberry	*Vaccinium myrtillus**	Rust	*Pucciniastrum vaccinii*	UK	Yellow pustules
		Leaf & stem gall	*Exobasidium vaccinii*	UK	Powdery colonies. Swelling, distortion
		Twig die-back	*Monilinia baccarum*	UK	Apothecia on twigs
		Leaf and stem spot	*Leptosphaerulina myrtillina*	UK	Brown, purple bordered spots
		Powdery mildew	*Podosphaera myrtillina*	UK	Thin white covering