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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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GROWER SUMMARY

Headline

- Survey results indicate HNS growers should not have difficulty demonstrating compliance with Sustainable Use Directive (SUD) requirements
- There is potential to increase the level of ICM and further reduce use of pesticides without loss of plant quality

Background

Integrated Crop Management (ICM) combines the use of non-chemical and reduced or alternative chemical pesticide practices for the effective management of pests, diseases and weeds. Specifically, it comprises:

- The use of cultural control measures, notably good crop husbandry
- Regular monitoring and reporting of problems and awareness of pest / disease thresholds
- Prompt follow-up actions following monitoring
- A preference for and adoption of non-chemical control measures where possible
- Specific and targeted use of pesticides (where possible)
- Avoiding routine chemical programmes that may lead to pest or disease resistance
- Promoting and adopting the use of lower risk plant protection products (where risk relates to their likely safety for humans and the environment), where possible.
- Regularly reviewing and appraising the success – or otherwise - of ICM programmes and implementing corrective actions promptly as necessary

The nursery stock industry in the UK has adopted ICM to varying degrees and this project has sought to clarify the situation in terms of broader industry uptake. The EC Directive on the Sustainable Use of Pesticides (SUD) requires adoption of general principles by all professional users by 1 January 2014, determination of the current level of adoption of available ICM measures and any research and development and knowledge transfer activities still required. There is a need to combine current best industry practice with research information, so that HNS growers are better able to adopt and develop ICM as their first option for long term sustainable crop protection.

The main purpose of the work was to help the industry understand and manage crop protection and plan for the future. The overall aims were as follows:

- To assess and critically review the current use of ICM by the UK Hardy Nursery Stock (HNS) sector.
- To identify the potential for wider uptake to enable producers to develop and adopt practical, economically-viable ICM practices to replace, reduce or remove the use of pesticides, particularly those pesticides which are at a higher risk of being lost to the industry.

The specific objectives were:

1. To establish the current extent of use of ICM and determine the strengths and weaknesses of available strategies and identify gaps in current ICM programmes for HNS.

2. To identify, list and assess the feasibility and practicality of current ICM practices.

3. To briefly describe the potential impact on HNS growers from ongoing changes to plant protection product legislation and the implementation of the EC Sustainable Use Directive (SUD).

4. To provide guidance on the ICM practices required to improve – or at least maintain at present levels - production efficiency in an environmentally sustainable way.

5. To create a publication for the HNS sector on practical, cost-effective ICM practices currently available and guidance on how to adopt them.

Summary

Current use of ICM on UK nurseries

All 30 respondents to a postal questionnaire and telephone survey of UK HNS growers in spring 2011 were using Integrated Crop Management (ICM). The extent of use reported by growers ranged from 7-68% of potential measures identified as applicable to the main crop on their nursery (assuming the usual range of problems for that crop occur). A third of growers were using at least 50% of potential measures relevant to their main crops. The importance of well-informed staff, good growing conditions, hygiene measures and regular monitoring were recognised as key to the successful implementation of ICM.

Notable biological control successes reported were strategies available for vine weevil, slugs and caterpillars, with biocontrol methods for sciarid flies reported as moderate to good. Biological control of aphids, thrips and two-spotted spider mite (TSSM) was reported as less reliable, giving mostly moderate control only. Integration of pesticides was thus usually needed for these pests and this allowed good control within the ICM programmes. Biological control of whitefly control was reported as unreliable, with several growers obtaining only moderate or poor control. Training and on-site guidance in best practice for use of biological control agents were noted as being required.

Good *Botrytis* control by Serenade ASO (*Bacillus subtilis* QST 713) and powdery mildew by potassium bicarbonate was reported. No biological control products were available in 2011 for many diseases (e.g. downy mildew, leaf spots). Nurseries were selecting a range of chemical fungicides for particular diseases and obtaining good control. Herbicides were universally effective, with Ronstar G (oxadiazon) and Flexidor 125 (isoxaben) use dominating. Although a few growers had instead managed to achieve control using bark toppings on pots, there is a lack of alternatives for weed control on container plants.

Feasibility and practicality of current ICM practices

A total of 47 measures were identified as current ICM practices on HNS. Measures were considered for their feasibility for use on individual crop types, their practicality, efficiency (effort : reward ratio) and success.

The number of measures feasible for each crop type, grouped according to problem type and strategy, are shown in Table 1. The main ICM strategies for pests were monitoring (five measures) and use of biological control agents (nine measures); the main strategies available for diseases were crop husbandry (11 measures), (micro) biological products (three measures) and hygiene (six measures). Options identified for ICM of weeds were very limited (two measures only). The 47 individual measures and their likely current feasibility are shown in the matrix in the Science section of the report (Table 6.1).

The overall practicality of the 47 measures for protected containers is shown in Table 2 using a 1-5 index where 1 = inefficient in action; high effort, low reward and 5 = very efficient in action; low effort, high reward. Measures considered most practical (index 4 or 5) for pest control were the use of biocontrols and monitoring; measures considered most practical for disease control were growing media selection, environment control and removal of infected material. In outdoor crops, some environmental control measures are not possible, but there

is increasing importance of electronically monitored irrigation and the use of weather records and forecasting for pest and disease prediction.

Table 1: Number of current ICM practices available and relevant for growers to use on different HNS crop types (F = field, C=container grown), grouped according to pest type and strategy – March 2012.

	Number of ICM practices available:							
	Pests			**Diseases**				**Weeds**
Crop type	**Monitoring**	**Biocontrol**	**Other**	**Husbandry**	**Biological products**	**Hygiene**	**Other**	**Any**
Alpines	5	7	3	10	2	6	4	2
Aquatics	2	0	1	5	2	6	4	2
Climbers	5	9	3	9	2	6	4	2
Conifers	5	3	3	10	2	6	4	2
Edible (herbs)	5	9	3	11	3	6	4	2
Heathers	3	3	3	10	3	6	4	2
Hedging (CG)	5	1	2	8	2	6	5	2
Hedging (FG)	3	0	2	8	2	6	3	2
Herbaceous	5	9	3	9	2	6	4	2
Roses (CG)	4	6	3	9	3	6	5	2
Roses (FG)	2	0	2	8	3	6	3	2
Shrubs	5	9	3	11	3	6	4	2
Trees (CG)	3	1	2	10	3	6	5	2
Trees (FG)	3	0	2	8	3	6	3	2
Ceanothus	4	5	2	10	3	6	4	2
Choisya	4	5	2	10	3	6	4	2
Clematis	4	8	3	9	2	6	4	2
Cordyline / Phormium	2	4	2	10	3	6	4	2
Hebe	4	2	3	10	3	6	4	2
Photinia	4	6	3	9	2	6	4	2
Lavender	4	4	3	10	3	6	4	2
Total number identified	5	9	4	11	3	6	5	2

There is increased grower uptake of biological control methods for pests on outdoor containerised HNS in Denmark and in soft fruit crops in the UK. There is scope for much wider uptake on outdoor HNS in the UK.

Table 2: Overall practicality rating of current ICM practices from the survey for pest, disease and weed control on HNS in protected containers (1 = inefficient in action; high effort, low reward; 5 = very efficient in action; low effort, high reward)

Pest control	**Rating**	**Disease control**	**Rating**	**Disease control contd.**	**Rating**
Monitoring by:		Husbandry:		Hygiene:	
Sticky traps	4	Growing media selection	5	Sweeping	4
Pheromone traps	3	Clean seed, cuttings etc	4	Covered disposal	4
Plant inspection	5	Cleaned water	4	Pressure-washing	4
Indicator plants	2	Sub or drip -irrigation	3	Removal of infected material	5
Quarantine areas	3	Electronic water monitoring	4	Disinfection of beds etc.	3
Biocontrols for:		Spot watering	4	Sterilise pots/trays	3
Aphids	5	Irrigation scheduling	4		
Caterpillars	5	Crop grouping by water need	4	**Weed control**	
Leaf miners	5	Spacing	4	Nursery weed clearing/hygiene	4
Sciarid fly	5	Diagnostic kits	3	Biofumigants	1
Slugs/snails	5	Environment control	5		
TSSM	5	Products:			
Vine weevil	5	Bio-stimulants	3		
Western flower thrips	5	Bio-pesticides	4		
Other:		Microbial products	2		
Crop rotation	2	Other:			
Selective pesticides	4	Weather records/forecasts	4		
Pot toppers/mulches	4	Disease forecasting	2		
Banker plants	2	Water sampling	3		
		Water baiting	3		

Note – The ratings shown are an overall assessment and can be expected to vary with crop type, nursery growing practices and pest or disease pressure.

Impact of changing pesticide legislation and the SUD on HNS growers

The availability of pesticides for use on HNS crops is reducing due to:

- Failure of products to make Annex 1 listing on re-registrations under 91/414/EEC;
- The introduction of a new EU regulation for pesticide approvals: the Plant Protection Products Regulation 1107/2009, with new hazard criteria;
- Implementation of the Water Framework Directive (WFD);
- Implementation of the Sustainable Use Directive (SUD);

- Gradual loss of the Long Term Arrangements for Extensions of USE (LTAEU) as individual products are assessed for Specific Off Label Approvals (SOLAs) and more recently Extension of Authorisation for Minor Use (EAMUs);
- Application of re-entry intervals following pesticide use in glasshouse crops;
- Commercial decisions by agrochemical / marketing companies.

At the same time, new pesticides and biopesticides are being introduced to the UK market, some with label or EAMU approvals for use on HNS crops. As the changing pesticide legislation and implementation of the SUD and WFD are taking place over a number of years, and because the future introduction and withdrawal of products for commercial reasons is unknown, any impact assessment is only valid at the time it is done.

An assessment in December 2011 identified which of the products named in the questionnaire as being currently used on nurseries had a final use date before 31 December 2015. These comprised 10 insecticides/acaricides, 11 fungicides and six herbicides. Key losses (identified by having a high score for current grower usage) include the pesticides Calypso (thiacloprid) and Hallmark (lambda-cyhalothrin), the fungicides Bravo 500 (chlorothalonil), Rovral WG (iprodione), Filex (propamocarb hydrochloride) and Fubol Gold WG (mancozeb + metalaxyl-M) and the herbicide Roundup (glyphosate). However, bifenthrin is harmful to biological control agents and thus does not represent a major loss to growers using full ICM programmes. The identification of suitable ICM-compatible replacement products and the securing of on-label or EAMU approvals for them are required.

An examination of regulations within the SUD alongside information on current industry practice gained in this project indicates that UK HNS growers should have no difficulty demonstrating compliance.

Guidance on ICM practices to maintain/improve production efficiency in an environmentally sustainable way

A wide range of specific ICM practices were identified by which growers can maintain/improve production efficiency in an environmentally sustainable way. These are listed under Action Points for Growers.

Additionally, this project identified many knowledge transfer and research and development activities that are likely to increase the uptake and level of ICM by UK HNS growers. These are listed in full in the Science section of this report and summarised below.

Key points are:

Knowledge transfer

- Demonstration sites of ICM programmes under commercial conditions including e.g. Integrated Pest Management (IPM), water cleaning, and irrigation control
- Regular workshops across the country on optimising ICM, with updates on new products and methods e.g. improved monitoring techniques
- Regional based training in ICM methods and management for various staff levels
- Crop-specific guidelines for ICM
- More factsheets e.g. on aphid control within IPM programmes
- Greater use of Smartphones for information dissemination and tips for recognition of pests, diseases and weeds

Research and development

- Improved monitoring for pests and pathogens
- Control of leaf and bud nematode, scale insects, capsid bugs and phormium mealybug
- Banker plants and parasitoid/predator dispersal
- Disease suppressive growing media
- Control of bacterial diseases
- Application of disease and pest forecasting
- Seed meals, bark mulches and growing media composition for weed and liverwort control

Financial Benefits

The prevention of pests and diseases by monitoring for early detection and avoiding conditions so as to not favour their development, will reduce plant damage, save on pesticide application and overall will maintain a higher quality crop.

The greater use of biocontrols rather than chemical pesticides will remove hazardous material from use on the nursery and prevent the need for out-of-hours application by spray operators and subsequent re-entry restriction periods.

Action Points

All action points have been assessed for their impact on improving the control of pests, diseases and/or weeds in HNS on nurseries and their importance within ICM. Whether or not the measures could be implemented, or at least tested, immediately on nurseries has been noted, with any constraints such as the purchase of new equipment noted. Most measures require some additional work to substitute or integrate them on the nursery and the main inputs have been noted. Action points have been divided into knowledge transfer and practical measures against pests, diseases and weeds both as integrated approaches and individually. Opportunities for research and development are given in the Science section.

1) Knowledge Assimilation and Training

Impact - High
Importance - High
Timeframe for implementation – Immediate

1.1 Up-to-date pesticide information

- It is important that nurseries check the current approval status of individual products (expiry, withdrawals or use-up) on the CRD website www.pesticides.gov.uk, (or LIAISON website if a subscriber) and contact their consultant if further guidance is required.
- All the plant protection products being used on nurseries should be reviewed at least annually to ensure they are the best currently available (effective mode of action/low risk to biocontrols).
- Growers should be set up to receive weekly e-mails from the HDC as this will notify them of any new SOLAs/EAMUs and provide the document for the required downloading and on-site filing.

Constraints – None.
Additional work required – Time dedicated by grower and consultant to seek and review.

1.2 Staff training and pest and disease identification

- Ensure that all staff members are given training so they can be alert for pests and diseases and that as many as possible can identify them and know what action can be taken against them.
- Distinction between fungal, bacterial, nematode, pest feeding damage, scorch, nutrient deficiency and other causes of discolouration or necrosis is not easy and growers may need to use a plant clinic or external advisor to ensure that the correct control measures are used.

Constraints – Training takes time and may not be seen as relevant for production staff. Cost and extra work involved in sending off samples and the associated paperwork.
Additional work required – Training in-house or obtaining an external trainer/advisor. Time to collect appropriate samples of the damage for plant clinic diagnosis. Early correct diagnosis will, however, allow good control and save time on repeated treatments.

1.3 Grower sharing of knowledge on biocontrol agent deployment

- Growers who do not use biocontrol agents (BCAs) against pests should see their use on another nursery and seek more information from suppliers of the products.

Constraints – Availability of a demonstration nursery to visit with the same crop types/systems as the home nursery.
Additional work required – Arrangement with another nursery for a visit.

Impact - Medium
Importance - Medium
Timeframe for implementation – Immediate

1.4 Spray application

- The HDC distributed DVD on the use of plant protection products and application equipment should be viewed by all spray operators, those in charge of operators and site safety to refresh themselves on the techniques and management required.

Constraints – Time, opportunity and computer or DVD player and screen.
Additional work required – Viewing and discussion of DVD.

- Growers need to be aware of the benefits of DNA-based detection and quantification of pest and pathogen presence and ongoing developments in these techniques.

Constraints – Information would be best sourced at a training workshop although information on projects using this technology is available from the HDC.
Additional work required – Attendance at a workshop and ongoing updating.

2) Practical Activities on the nursery
Integrated Programmes:

Impact – High
Importance - High
Timeframe for implementation – Immediate

2.1 Monitoring for pests and diseases

- Nurseries without a monitoring procedure for bought-in stock should adopt one.
- Where possible, a quarantine area should be set aside for in-coming plants.

Constraints – Staff with the ability to pick out unhealthy plants are required and they will need extra time for detailed inspections. Some pests, diseases and weeds may not show at delivery. There may not be space to keep old and new plants apart and if plants are moved twice after delivery then this adds extra labour costs.
Additional work required – Time and staff for inspection and possibly for moving plants a second time if a quarantine area is established.

2.2 Staff training

- Production staff (including seasonal workers) moving and watering plants should also be encouraged to look out for problems and to report them.

Constraints – Lack of knowledge of staff, particularly temporary staff.
Additional work required – Staff training on arrival and at regular intervals thereafter.

2.3 Prompt and contained removal of affected material

- Removal of affected tissue/plants or spot treatment should be implemented to prevent explosions in the occurrence of pest, diseases or weeds.
- Procedures for the regular contained removal of pest, disease and weed affected material should be agreed with staff and monitored.
- Small amounts of diseased or pest infested waste should be bagged in-situ.

Constraints – Staff will need to be able to recognise problems and notify someone else or to have the authority to carry out treatment/plant disposal themselves. Provision of disposal bags.
Additional work required – Staff training and clear procedures for control actions.

2.4 Plant waste disposal

- Nurseries should review and, if necessary, make improvements to their plant waste disposal areas to ensure pests, disease and weeds are killed and/or contained.
- Where the aim is to compost plant waste, the regular management and monitoring of a series of heaps needs to be put in place.

Constraints – Alternative arrangements for disposal may need to be set up and use of an unmanaged open disposal heap cease.
Additional work required – Provision of covered disposal areas or skips and the giving of instructions to all workers on waste management.

2.5 Target setting

- Each nursery should consider the range of ICM measures that might reasonably be carried out on their crops and produce their own targets for substituting or adopting additional measures.
- Non-chemical plant protection methods including cultural and biological control should be the first course of action if effective methods are available.
- Growers should determine whether there are ICM measures they or their staff could do easily now or, could do with changes to equipment or with technical assistance, or would require major changes and the likely investments required and benefits to be gained.

Constraints – Information required on the measures available and their likely success on the crops grown at the home nursery.
Additional work required – A review of ICM measures and the seeking of advice on pest biocontrol leading to nursery tests to determine the most appropriate organisms to be used.

2.6 Managing pesticide resistance

- Growers should ensure that they are using a mixture of plant protection products with varying modes of action to reduce the chance of resistance developing.

Constraints – Knowledge of the different modes of action will need to be sought from product labels and/or websites and guidance may need to be sought on how products should be alternated.
Additional work required – Checking the modes of action of products and then the creation of spray programmes.

2.7 Managing irrigation

- Growers should investigate the use of electronic sensors for water management in their crops to save wasted water, run-off and unsuitable conditions for healthy root growth.

Constraints – Lack of information on products and their selection. While water is not too expensive the use of devices has not been a priority.
Additional work required – Sourcing information and ideally visiting a nursery with functioning monitoring. Fitting of devices and training of staff in their use.

Impact - Medium

Importance - Medium

Timeframe for implementation – Immediate

2.8 Use of less susceptible varieties

- Growers should determine whether particular species or cultivars have known susceptibility to particular diseases and pests and try to alter selections accordingly.
- If susceptible cultivars need to be grown then they should be known to staff and given extra checks.

Constraints – Variety selection is not always possible as markets may demand a particular one.
Additional work required – Records to be kept of problem cultivars. Clients to be persuaded that an alternative line is as good/better than their normal one.

2.9 Selecting effective plant protection products

- Growers should continue to try out new plant protection products and note their effectiveness, crop safety and any possible reasons for any poor control seen in order to be able to select the most effective products.

Constraints – Time to keep records and to review them.
Additional work required – Record keeping after each pesticide application and then review of the information at the end of the year.

2.10 Managing unsold stock

- Growers should ensure that unsold stock is either consciously kept and maintained or disposed of to prevent pest, disease and weed spread to new stock.

Constraints – Time to decide which plants to dispose of and the worry that there might still be a future demand for them.
Additional work required – The unwanted plants will need to be moved or disposed of.

2.11 Testing new pest and disease monitoring technologies

- Growers should seek information on new pest and disease monitoring technologies and take time to weigh-up whether any might save them time/money on their nursery.

Constraints – Information from research projects needs to be applied to greater areas of commercial crops and so measures are likely to require periods of testing and evaluation. Investment in new monitoring equipment.
Additional work required – Ongoing interest in new developments such as HDC commissioned research. Records will need to be kept and the measures adapted to suit the cropping systems and crops on the nursery.

2.12 Learning form other crops

- Information on ICM directed at other crops should be examined by HNS growers and their consultants with a view to adoption.

Constraints – Seeking information on ICM in other crops and judgement on whether measures might be utilisable on the nursery.
Additional work required – Awareness of ICM work on other crops, possibly by requesting factsheets or annual summaries of other horticultural sectors from HDC.

2.13 Pest monitoring records

- A crop pest, disease and weed recording form should be utilised by all growers which can be printed off or used on a palm-top for use in the crop to record problems.

- Information should also be noted on the activity of any introduced or natural BCA e.g. the presence of a number of aphid mummies.

Constraints – None except agreement of all to use the same recording method.
Additional work required – Creation of the monitoring form.

2.14 Rapid on site identification

- Smartphones could be used with a magnification application. There could be a photograph of the pest/pathogen next to the magnified image to check identification.
- An "IPM Scope CAM" with a LED-lighted unit to magnify objects 3-25x on the unit display and up to 300x digitally on the computer can be purchased.
- Digital images can be e-mailed to advisors for assistance with identification.

Constraints – Not all growers have Smart phones, and Scope CAMs require funds. Compilation and verification of key pest/disease identification pictures.
Additional work required – Time to set the system up, but then time spent identifying pests and diseases may be saved compared with use of hand lenses and identification guides.

Impact – Low
Importance - Low
Timeframe for implementation – Immediate

2.15 Utilising beneficials

- Growers should consider maintaining some particular areas of crop or wild plants on site to be reservoirs of native biocontrol agents.

Constraints – Knowledge of which plants are most suitable for encouraging native predators and parasitoids but without being weed seed sources or pest hosts. Information on the area and distribution required to ensure significant pest reduction.
Additional work required – Retaining areas of crop plants or sowing wild flower mixes on waste areas or within lawns.

Practical Activities on the nursery
3) Pest control:

Impact - High
Importance – High
Timeframe for implementation – Immediate

3.1 Indicator plants for pest monitoring

- Staff awareness of the different susceptibilities of particular crops to particular pests should be increased to aid monitoring and prompt control of spread.

Constraints – Knowledge of pest host preferences and willingness to learn from observations made on nurseries.
Additional work required – Pest records (if not already done) for different crops and cultivars throughout the year. Once information is available, then staff dispersing BCAs or spot spraying will need to be trained to target their use on specific plant species/cultivars.

3.2 Improving TSSM control

- Growers using only chemicals to control TSSM should try BCAs as good control can be achieved by predatory mites.
- TSSM infestation is usually worse indoors than outside, but nurseries with outdoor infestations should consider BCA use.

- Where BCA use has not given good control, growers should examine the distribution pattern and application density of the predatory mites and determine whether this needs to be improved.

Constraints – Unfamiliarity with the use of BCAs, costs of BCAs (although savings will be made on pesticides).
Additional work required – Determination of the best BCAs to use and when and how to use theme. Staff time will be required for BCA distribution and monitoring.

3.3 Improving aphid control

- Growers should consider using parasitoid mixtures Aphidsure or Fresa Protect against aphids, particularly if there a mixture of aphid species present, or the identity of those present is uncertain.

Constraints – None, other than growers receiving information on the products.
Additional work required – None, if single parasitoid species are currently being used.

3.4 Multiple biological control agents for improved pest control

- Growers should consider utilising more than one BCA for a pest where they are effective at different stages of the pest lifecycle or have different abilities to attack the pests and so will give complementary control.

Constraints – Unfounded concern that some BCAs may feed on others, lack of information on other BCAs and the need to re-organise the existing programme of BCA introductions.
Additional work required – Growers and consultants should consult BCA producers' websites to determine whether their current BCA purchasing should be amended.

Impact - Medium
Importance - Medium
Timeframe for implementation – Immediate

3.5 Reasons for sub-optimal control with IPM

- If biological control is not as effective on a nursery than reported from others then growers should work with their crop consultants to determine why and to carry out improvements.

Constraints – Knowledge that BCA use on the nursery could be more effective.
Additional work required – Records (if not already done) for different crop areas throughout the seasons for the use of BCAs, with further record keeping as procedures are changed. BCA companies may need to be consulted for advice.

3.6 Managing pesticide resistance

- Management of pesticide resistance (e.g. to Aphox) is improved by the use of bio-controls as this ensures that there is no selective survival of resistant aphid types.

Constraints – None other than lack of confidence in BCA effectiveness if pesticides have only been used previously. If BCA use is adopted, then care will be required in the selection of pesticides for the control of other pests as these might affect BCA survival.
Additional work required – Time required to deploy BCAs

3.7 Use of biological control agents in outdoor crops

- Growers should try out parasitoids and predators against pests in their outdoor crops during the warmer months when the activity of both pests and the control agents are most active.

Constraints – Requirement to set aside an area from pesticide application, availability of consultants, purchase of BCAs, uncertainty of rates and BCA distribution pattern.
Additional work required – Marking out a test area, monitoring of pests and BCAs.

3.8 Learning from biological control on other crops

- Information from BCA use in other crops e.g. glasshouse tomatoes can be utilised by HNS growers.

Constraints – Time to review the information and consider any differences between the crops that could affect the BCAs e.g. a smaller crop canopy in HNS.
Additional work required – Review of BCAs not already used on the nursery, monitoring of any additional/different BCA use.

Practical Activities on the nursery
4) Disease control:

Impact - High
Importance - High
Timeframe for implementation – Immediate

4.1 Reducing conditions that favour disease

- Production staff need to be aware of what environmental conditions favour disease development and to take action to ensure that temperatures, humidity and wetness are as good as possible for each crop type.

Constraints – Possible limited environment manipulation with the current structures and systems and the cost of making changes. Staff will require training on conditions which favour particular diseases. Agreement on staff responsibilities/procedures for e.g. any changing of computer settings.
Additional work required – Training courses. Agreed acceptable environmental conditions for particular crops or growing areas and action to be taken if conditions become unfavourable.

4.2 Treatment of recycled water

- Growers should beware re-using water collected from infected plants without the water being treated for plant pathogens and should install treatment methods.

Constraints – Information required on the best treatment method, finance will be needed for the treatment equipment.
Additional work required – Installation of the treatment facility.

Impact - Medium
Importance - Medium
Timeframe for implementation – Immediate

4.3 Monitoring of irrigation water for pathogens

- Leaf-baiting for *Pythium* and *Phytophthora* pathogens in irrigation water should be more widely adopted by nurseries and could be used to take the place of water sampling for laboratory testing.

Constraints – Knowledge of bait construction and placement and the use of lateral flow devices for diagnosis.
Additional work required - Training in the baiting process, deployment and retrieval of baits

4.4 Biological methods to treat recycled water

- More use should be made by growers of slow sand filters, iris or reed beds to remove pathogens from water collected from contaminated sources.

Constraints – Information required on the types of slow sand filter and/or filter beds.
Additional work required – Installation and then maintenance of the filter.

4.5 Utilising disease forecasting models

- Rose growers should try out the powdery and downy mildew disease forecasting programmes to see if they can make better timed/less frequent fungicide applications.
- Other growers should keep aware of any developments in forecasting for other crops.

Constraints – Potential worry about changing from sprays at regular intervals to spraying according to forecasted risks.
Additional work required – Information to be assimilated, purchase of humidity loggers and use of a decision support system computer programme.

Practical Activities on the nursery
5) Weed control:

Impact - Medium
Importance - Medium
Timeframe for implementation – Immediate

5.1 Growing media composition to reduce liverwort

- Growers should try the inclusion of a proportion of composted woodfibre or sterilised loam in potting mixes to aid liverwort reduction, particularly in short term crops.

Constraints – Some plants may not grow as well in mixes different from their usual mix.
Additional work required – Small-scale test batches potted and observed in comparison with the usual mix over the period of a year.

5.2 Mulches to suppress weeds

- Bark mulches should be used, particularly on larger pots, to suppress weed growth in containers and so eliminate the use of herbicides.

Constraints – Purchase of bark topping machinery or dedication of staff to hand-topping.
Additional work required – Topping with bark will add an extra process but herbicide application will not be necessary. It may be necessary to improve the roadways between the potting area and the beds, otherwise the mulch may shake out during transport.

5.3 Identifying “windows” for herbicide treatment

- Growers not currently determining herbicide programmes based on an awareness of the spray window for both the weed and crop should do so to obtain optimum control.

Constraints – Knowledge of weed biology and herbicide product activity/selectivity.
Additional work required – Information required on the activity of herbicides and yearly spray programmes will then need to be devised.

Knowledge and Technology Transfer

Presentations were given by Erika Wedgwood and John Buxton on disease and pest ICM measures at an HDC growers' meeting held at Bransford Webbs nursery on 28 July 2011. Knowledge transfer was carried out during visits to participating nurseries as part of the process of assessing what ICM measures were in place or which had, or had not, been considered for use by the growers.

"The survey used as part of this project was undertaken during 2011 and approval status of the products discussed may have changed since submission of the project report. Only products officially approved as plant protection products should be applied to control pest, disease and weed problems or uses as plant growth regulators. Before using any such substances, growers should refer to product approval and label documents. Regular changes occur in the approval status of pesticides arising from changes in the pesticides legislation or for other reasons."

SCIENCE SECTION

1. Introduction

This review brings together information on what is available for Integrated Crop Management (ICM) in the UK and the current level of uptake and satisfaction amongst growers. Practices currently in use on some nurseries with good results should be economically viable on others with the same crop types, growing systems and market and in many instances they are likely to have a wider application.

Grower confidence in the likely future benefits from developing and adopting new ideas will be increased by the review of ICM practices available, including those of crops other than HNS and measures in use by overseas producers. Examples of successful adoption on nurseries are given, where available, to assist evaluation of the likely benefits.

Nursery profitability has been considered, utilising work on case studies. The costs and benefits of ICM in terms of time, money, crop quality and sales versus more conventional control methods relying on pesticides has been assessed.

The future needs of the industry and knowledge gaps requiring further work for improved HNS crop protection in the UK have been identified by the review, based on the views of growers and those involved with research and development.

The UK Hardy Nursery Stock (HNS) industry needs to demonstrate by 2014 that it has met the general principles of ICM set by the EC Sustainable Use Directive (SUD). This review and the strategies it presents will help to establish the current position and identify the future steps required to achieve this aim.

2. Methods

Establishing the current management procedures for pests, diseases and weeds and the extent of ICM in UK HNS production was achieved by two methods: a survey form and visits to a selection of nurseries. Twelve nurseries with a range of crop types across the country were visited by ADAS crop consultants to see management practices and speak with the person with overall responsibility for crop protection. It was thus possible to determine the strengths and weaknesses of currently used measures and identify gaps in ICM programmes for HNS.

The survey of nurseries placed a strong emphasis on the use of ICM because the implementation of the SUD will require all growers to demonstrate that they are using ICM techniques by 2014. Given environmental, legislative and market pressures to reduce the use of higher risk products, coupled with the diminishing range of products available to growers, the ICM approach, which helps to reduce their use, is essential to safeguarding the industry's future.

A survey form (Appendix 1) to assess the crop management practices in use amongst UK HNS growers was developed by ADAS in conjunction with members of the HDC HNS panel and others working within the industry. At the end of March 2011 the survey form was placed on the HDC website, promoted in HDC News and ADAS Technical Notes and posted to all UK nurseries registered with the HDC as producing hardy nursery stock, with the final deadline for replies by the end of June 2011.

The survey's front page stated that ICM aims to reduce the use of 'conventional' crop protection products and to select products of lower risk to human and animal health and the environment. It described ICM as a combination of non-chemical and chemical techniques to achieve effective pest, disease and weed control. ICM techniques were said to include:

- Nursery hygiene, water management and other cultural methods
- Pest and disease forecasting and monitoring
- Biological controls, including predators, parasitoids and 'biopesticides' (i.e. products containing biological control agents, such as microbials, pheromones or plant extracts).
- Some 'natural' physically-acting products such as plant extracts and oils, currently exempt from the pesticide regulations

Researchers and consultants working in horticulture were also consulted and ongoing work was examined to gain information on any particular aspects of crop management related to crop protection that would benefit from further work. Their suggestions are used in the action points and incorporated in the Discussion section. Information was also collated from scientific publications and websites, particularly where there was evidence that the ICM described was being used by growers. Details of ICM in practice in arable and non-ornamental crops were also examined for methods that might be utilised or developed for use in HNS ICM.

Information in the next sections includes the results of surveys, consultations and literature reviews presented under topic headings in order to be able to relate problem areas on nurseries to potential solutions. Appendix 2 provides a summary table of the principal division of the objectives between the report sections. Action points are used throughout the text thus:

- These bullet points direct growers to changes to their crop management that could be carried out now to improve their pest, disease and weed control
- ➢ These bullet points highlight areas where further research or development is required before a measure may be able to be introduced to HNS crops

The action points relevant to growers, their likely impact, importance, likely timeframe for implementation, constraints and additional work required have been collated in the Grower Summary. Action points highlighting knowledge transfer gaps and research and development opportunities have been summarised at the end of the report.

3. The Introduction of the Sustainable Use Directive and the Potential Impact on UK HNS Growers

3.1 The Sustainable Use Directive

The Directive on the Sustainable Use of Pesticides (the Directive) 2009/128/EC led the HNS Panel to add IPM/ICM to the 2010 – 2011 HNS Strategy as a high priority for research and development and knowledge transfer.

Article 1 of the Sustainable Use Directive (SUD) explains that the Directive's objective is to establish:

"..a framework to achieve a sustainable use of pesticides by reducing the risks and impacts of pesticide use on human health and the environment and promoting the use of integrated pest management and of alternative approaches or techniques such as non-chemical alternatives to pesticides"

Article 14 of the SUD introduces a number of requirements for the implementation of Integrated Pest Management (IPM) by all professional users of pesticides.

Each Member State will be required to:

- Take all necessary measures to promote low pesticide-input pest management, with priority being given to non-chemical methods wherever possible;
- Establish or support the establishment of the conditions needed to implement IPM, particularly ensuring that monitoring and decision making tools and advisory services on IPM are available;
- Ensure the general principles of IPM set out in Annex III of the Directive [included at the end of this section] are implemented by all professional users by 1 January 2014;
- Establish appropriate incentives to encourage users to implement voluntary crop or sector specific guidelines.

The IPM definition provided in Article 3 of the Directive [Annex I] (see below for the full definition) will be adopted by Defra:

"..integrated pest management means the careful consideration of all available plant protection methods and subsequent integration of appropriate measures that discourage the development of the populations of harmful organisms and keep the use of plant protection

products and other forms of intervention to levels that are economically and ecologically justified and reduce or minimise risks to human health and the environment. Integrated Pest Management emphasises the growth of a healthy crop with the least possible disruption to agro ecosystems and encourages natural pest control mechanisms”

Defra also state that:

“It should be noted that although this definition confines itself to IPM specifically, in reality it is extremely difficult, if not impossible, to practise IPM without also practising ICM (integrated crop management) a more holistic approach which, in addition, to pests encompasses weeds and diseases as well.”

Defra interpret ‘pest’ as insect pests. However, the EU definition of IPM uses the term “pest” to include the management of pest, diseases and weeds. In this report we have chosen to use the term ICM as most growers are familiar with the term IPM in association with the commercial supply of biological control organisms for the control of invertebrate pests which damage crops.

DIRECTIVE 2009/128/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 21 October 2009 (Article III)

This seeks to establish a framework for Community action to achieve the sustainable use of pesticides which will include integrated pest management.

The general principles of integrated pest management (called ICM in the current report) are defined as;

1. The prevention and/or suppression of harmful organisms should be achieved or supported among other options especially by:

    - Crop rotation.
    - Use of adequate cultivation techniques (e.g. stale seedbed technique, sowing dates and densities, under-sowing, conservation tillage, pruning and direct sowing).
    - Use, where appropriate, of resistant/tolerant cultivars and standard/certified seed and planting material.
    - Use of balanced fertilisation, liming and irrigation/drainage practices.
    - Preventing the spreading of harmful organisms by hygiene measures (e.g. by regular cleansing of machinery and equipment).
    - Protection and enhancement of important beneficial organisms, e.g. by adequate plant protection measures.
    - Utilisation of ecological infrastructures inside and outside production sites.

2. Harmful organisms must be monitored by adequate methods and tools, where available. Such adequate tools should include observations in the field as well as scientifically sound warning, forecasting and early diagnosis systems, where feasible, as well as the use of advice from professionally qualified advisors.

3. Based on the results of the monitoring the professional user has to decide whether and when to apply plant protection measures. Robust and scientifically sound threshold values are essential components for decision making. For harmful organisms threshold levels defined for the region, specific areas, crops and particular climatic conditions must be taken into account before treatments, where feasible.

4. Sustainable biological, physical and other non-chemical methods must be preferred to chemical methods if they provide satisfactory pest control.

5. The pesticides applied shall be as specific as possible for the target and shall have the least side effects on human health, non-target organisms and the environment.

6. The professional user should keep the use of pesticides and other forms of intervention to levels that are necessary, e.g. by reduced doses, reduced application frequency or partial applications, considering that the level of risk in vegetation is acceptable and they do not increase the risk for development of resistance in populations of harmful organisms.

7. Where the risk of resistance against a plant protection measure is known and where the level of harmful organisms requires repeated application of pesticides to the crops, available anti-resistance strategies should be applied to maintain the effectiveness of the products. This may include the use of multiple pesticides with different modes of action.

8. Based on the records on the use of pesticides and on the monitoring of harmful organisms the professional user should check the success of the applied plant protection measures.

Following public consultation in 2010 on the UK implementation of the SUD, the UK Government's response was that it will make those changes necessary to ensure that the UK's already comprehensive controls for plant protection products comply with the requirements of the Directive. Additional regulation will thus be introduced only in the few areas where this is necessary to bring the UK regime in line with the SUD (Mason, 2011). A scoping study of non-chemical pest, disease and weed control measures has recently been commissioned by the Chemicals Regulation Directorate (CRD) which includes HNS crops and will help to inform their decision making in relation to the SUD (Jonathan Blake, pers. comm., 2012). For diseases of outdoor HNS, the measures with the greatest effectiveness, widest spectrum of use across the different pathogens and economic viability may be the use of resistant cultivars, seed and young plant testing and hygiene/disinfection.

There are a number of provisions e.g. sales of pesticides, inspection of application equipment (many of which are already covered by existing UK plant protection product legislation and voluntary initiatives) which apply at various dates between 26 November 2011 and 2016. One provision is the presentation of a National Action Plan to the European Commission by November 2012 and a draft will be released by CRD for public consultation in spring 2012 (Mason, 2011).

3.2. Measures available towards the sustainable use of pesticides

Alternatives to conventional pest control techniques (pest, disease and weed) in the UK were considered in a scoping study of the potential for their wider use by a sub-group of the Advisory Committee on Pesticides (ACP) (Edward-Jones, G. *et al.*, 2003). The scope included alternatives such as crop breeding and glasshouse environment control, natural predator management and forecasting as well as products such as pheromones, antifeedants / eating deterrents, plant extracts and commodity chemicals. All of these were stated as having high potential for future use. Antagonistic fungi were said to have medium potential at this date. The potential for mycoherbicides and antifeedants was considered to be small. Efficacy, cost and risks to the health and environment of alternatives to chemical control were considered as far as was possible. Recommendations were made on the regulatory framework for products to become available as plant protection products, and concluded that more public sector support was needed to bring alternative controls to commercial fruition and that improvements were needed in the communication to crop producers on situations where alternatives could solve particular problems.

The International Organisation for Biological and Integrated Control of Noxious Animals and Plants, West Palaearctic Region Section (IOBC/WPRS) published Technical Guideline III

"Guidelines for Integrated Production of Arable Crops in Europe" (Boller, Malavolta and Jörg, 1997). This is intended as a framework for the formulation of specific national and regional Integrated Production guidelines and standards and to promote their harmonisation throughout Europe. The basic requirements for all crops fall within the headings of;

1. Biodiversity and ecological infrastructures
2. Choice of cultivars
3. Crop rotation
4. Irrigation
5. Soil protection
6. Nutrient management
7. Crop protection

There are specific tables of recommendations for each crop. In sugar beet, for example, flea beetles (*Chaetocnema* spp.) and other pests may only be treated according to damage thresholds. No insecticides are allowed against Collembola. No nematicides are allowed, with nematodes instead being controlled by not growing sugar beet or *Chenopodiaceae* crop/weeds more than one year in four. Fungal leaf diseases and vectors of virus diseases may only be treated according to prediction models or thresholds.

A briefing note prepared for the European Parliament gives information on technologies that complement, or can be used as alternatives to, the application of synthetic pesticides (Chandler, 2008). This includes information on the augmentation of biological control using species that are native to that country, including pest, disease and weed control agents.

In the UK, there are Assured Produce protocols (www.assuredproduce.co.uk) for vegetable and fruit crops which give information on good husbandry, including tables of suitable plant protection products. For ornamentals, members of the British Ornamental Plant Producers (BOPP) Certification Scheme adhere to procedures on crop quality which include pest, weed and disease management. The BOPP crop husbandry (particularly outdoor growing and soil-grown crops) is often different for HNS growers. General guidance is available on ICM on protected ornamentals from the ADAS/Defra guide (Buxton, J. *et al.* 2006). HNS growers could utilise the detailed information on disease identification, epidemiology and control available for herb growers on the HDC website.

- General information on ICM directed at other crops should be utilised by HNS growers

➢ Specific crop guidelines are required for ICM in HNS

4. Crop Types and Land Areas Surveyed

Completed survey forms were received from 30 nurseries growing a range of HNS crops, with a variety of both container and field grown areas (Figure 4.1). The management programmes reported on apply to 73 ha of protected container plants and 149 ha of outdoor containers. In total, across the 30 nurseries surveyed, there were 165 ha of field grown crops, of which 117 ha were trees. Shrubs and herbaceous crops were the next largest ornamental cropping areas, covering 65 and 50 ha, respectively (Figure 4.2). Most crops (except hedging, conifers and field grown trees) had areas grown under protection (Figure 4.3).

Finals or near finals

Most pots, or plants in field locations, being grown-on for sale were herbaceous or shrubs. Of the 30 nurseries surveyed, the major types of plants that were being produced were:

- Herbaceous plants by 64% of nurseries
- Shrubs by 68% of nurseries
- Climbers by 32% of nurseries
- Container grown trees by 29% of nurseries
- Roses by 21% of nurseries
- Other crop types were each grown by less than 15% of the nurseries surveyed

Young plants

Fewer respondents produced young plants (e.g. plugs, liners, intermediate pots, seedlings, transplants and tree-whips to be grown on). Of the 30 nurseries surveyed, the proportion of nurseries producing young plants for each of the commonest crop types was;

- 32% produced shrubs
- 19% produced herbaceous plants
- 18% produced climbers
- 14% produced container-grown roses

The survey thus fulfilled an objective of including information from the major crop areas based on HDC levy income. Growers were not asked about turnover but the nurseries involved are known to include smaller businesses (although possibly fewer in proportion to the number of HDC levy payers).

In addition to the surveys, twelve nurseries were interviewed on site by ADAS Consultants to discuss their ICM practices and review how crop pest, disease and weed management was being carried out. Primarily, this was to see which measures are working well and if there

may be aspects that could benefit from a change in working practices or additional research. The nurseries were geographically spread across England and between them utilised a range of consultants (or none) so that the practices reported showed variation.

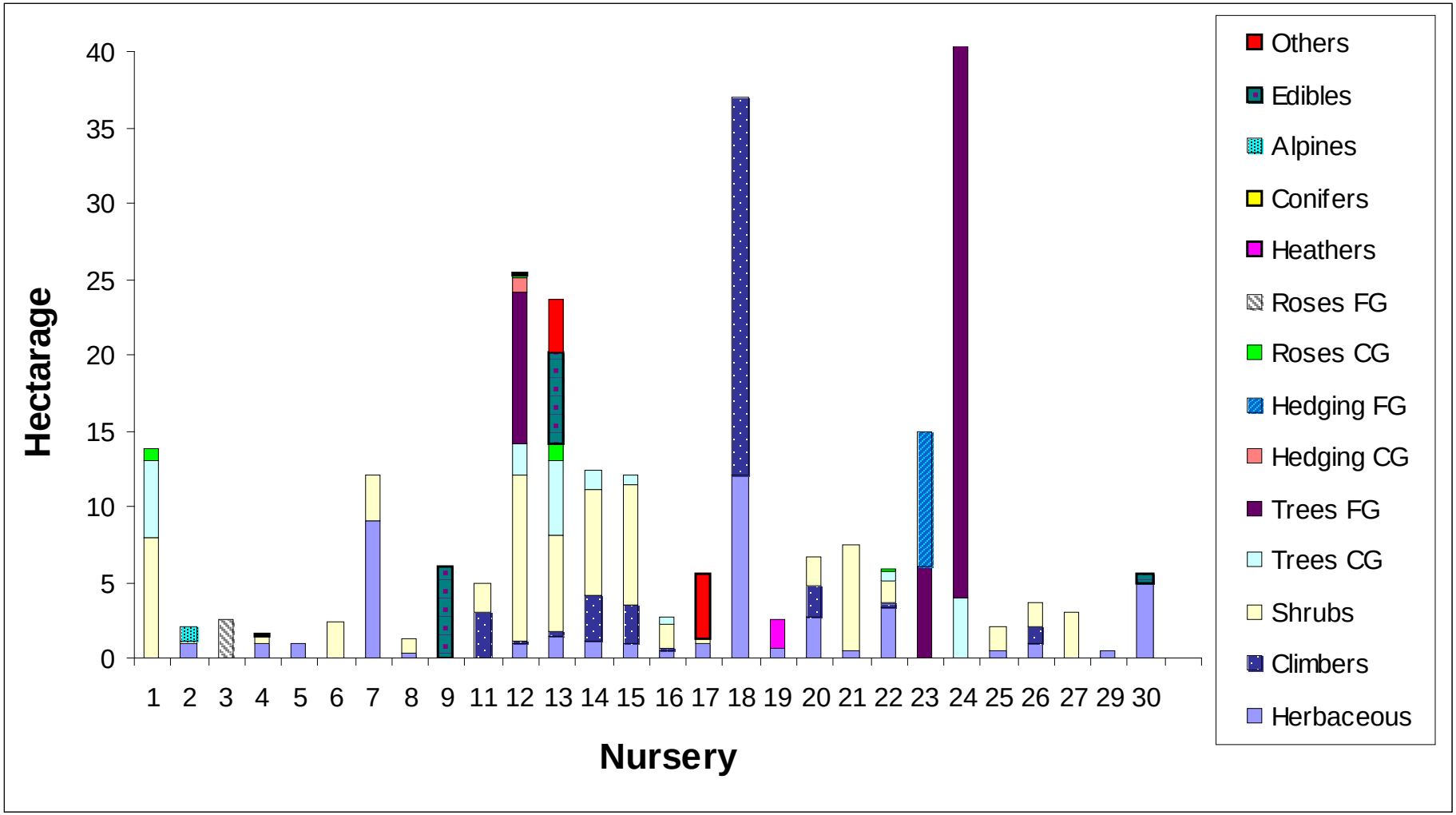


Figure 4.1: The total production areas of nurseries (shown by a code number) responding to the survey. The major crop types grown by each nursery are shown. Each nursery's use of ICM measures was calculated for their main crop to produce the percentage adoptions shown in Figure 6.1. N.B. the bar for nursery code 24 (a major producer of field grown trees) has been foreshortened from 89 ha to aid presentation.

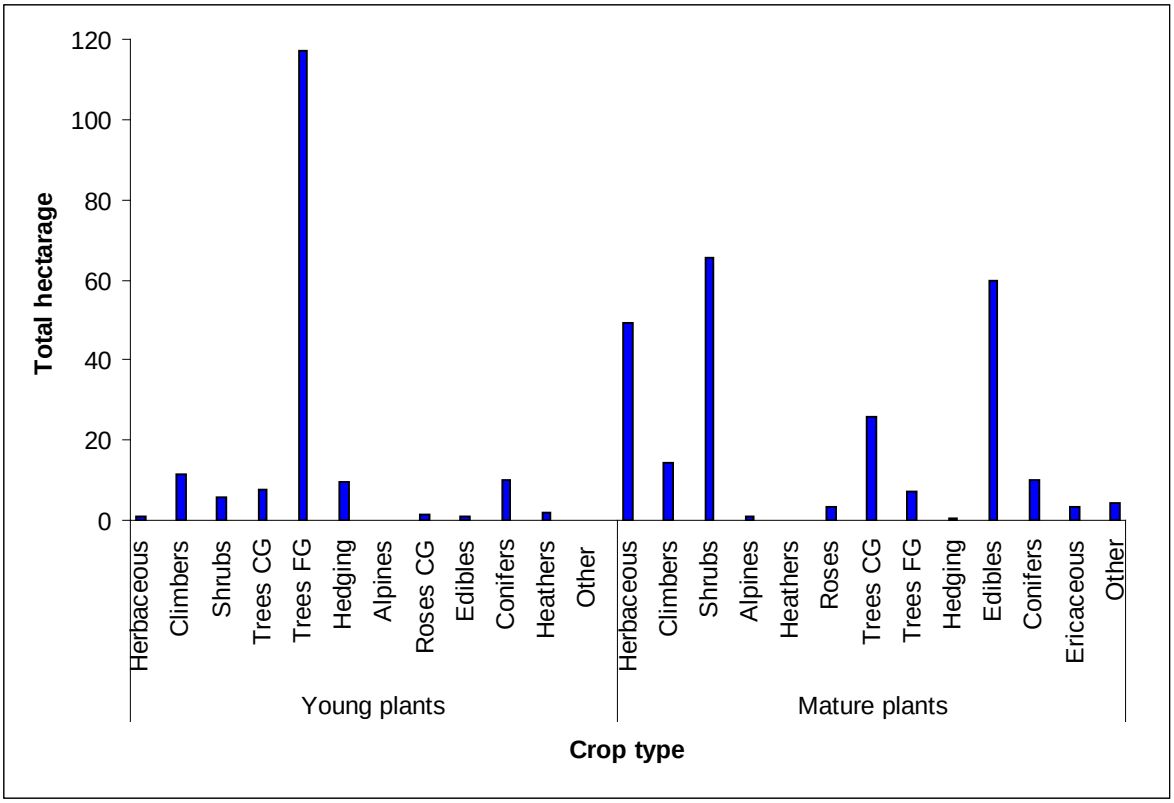


Figure 4.2: The total production area in 2011 per crop type across 30 surveyed nurseries (CG – container grown; FG – field grown).

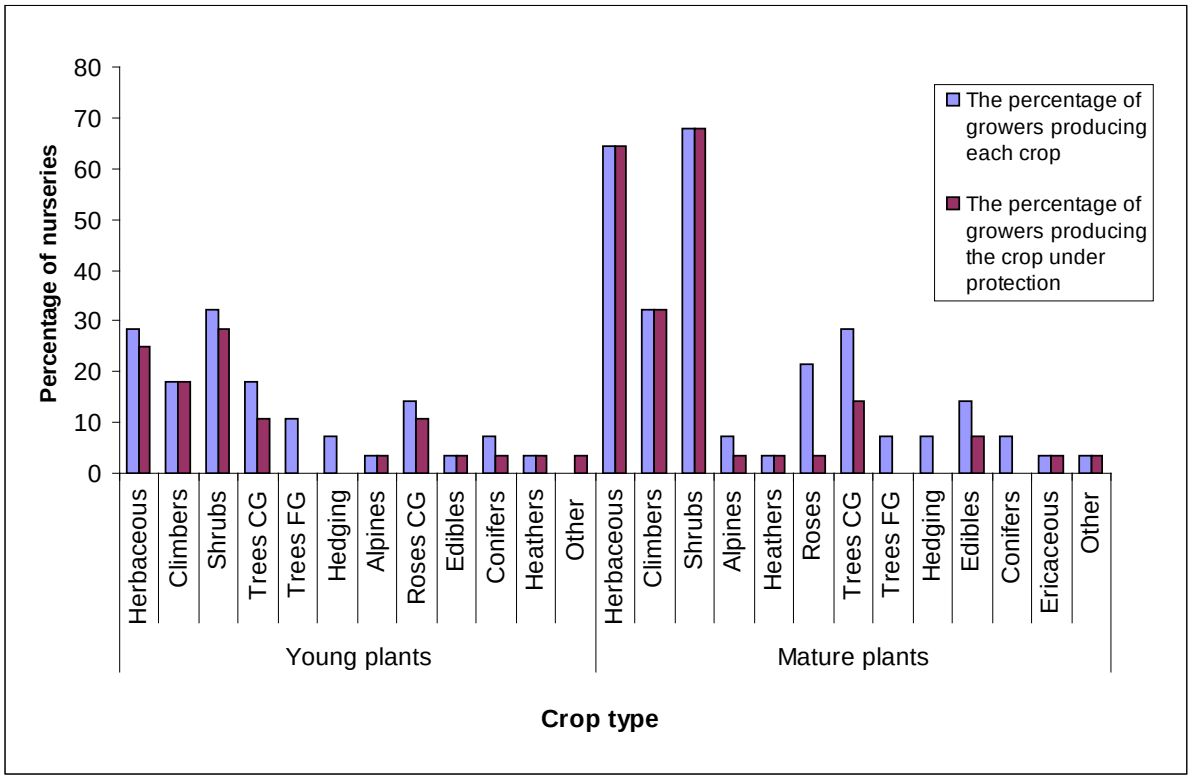


Figure 4.3: The percentage of nurseries (of the 28 providing information) growing each crop type and whether any of the crops were grown under protection in 2011

5. Knowledge Transfer

A high level of understanding of ICM was reported by the majority of survey respondents (Figure 5.1). This was probably related to the high amount of information sourcing being carried out by them. Of 24 information sources listed, a total of 17 sources were each used by at least half of the growers (Figures 5.2 & 5.3).

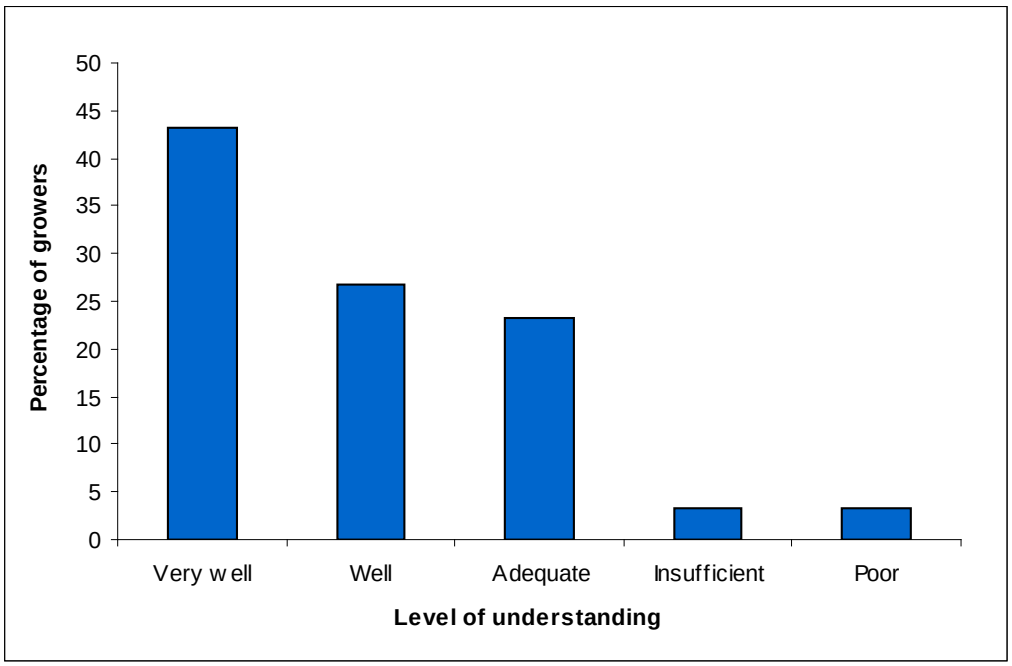


Figure 5.1: Respondents' perceived understanding of what ICM is and what it involves.

5.1. Information sources

At least two thirds of nurseries used information from one or more HDC source:

- Factsheets and project reports were rated the most useful in decision making on crop protection by over 75% of those using them
- Events and HDC News were considered good by around 65%
- The HDC website was relevant to 58%, but 25% of those using it found it of least benefit in decision making

ADAS Technical Notes, containing monthly updates on current and forecast pest, disease and weed problems and product information, were listed by half the nurseries, with 88% finding them of high relevance to their decision making (Figure 5.2).

Two thirds of growers used a horticultural consultant (nursery visits) and/or received information from one, with 75% valuing their information highly. Fewer nurseries received visits or gained information from product marketing agents, with biocontrol, plant protection

product suppliers and merchants' information of importance to 58% to 40%, in that order (Figure 5.3).

Around half of growers answered that they used one or other of the plant protection product websites by CRD, Liaison, and Resistance Action. There was some dissatisfaction with the information provided by these sites, with around 40% finding them poor sources.

Several growers said that they valued seeing how things worked on other nurseries. One research establishment considered demonstration farms to be critical. The advantage of experimental set-ups away from commercial nurseries is that measures can be compared and that nurseries are not asked to give access to their site to potential competitors.

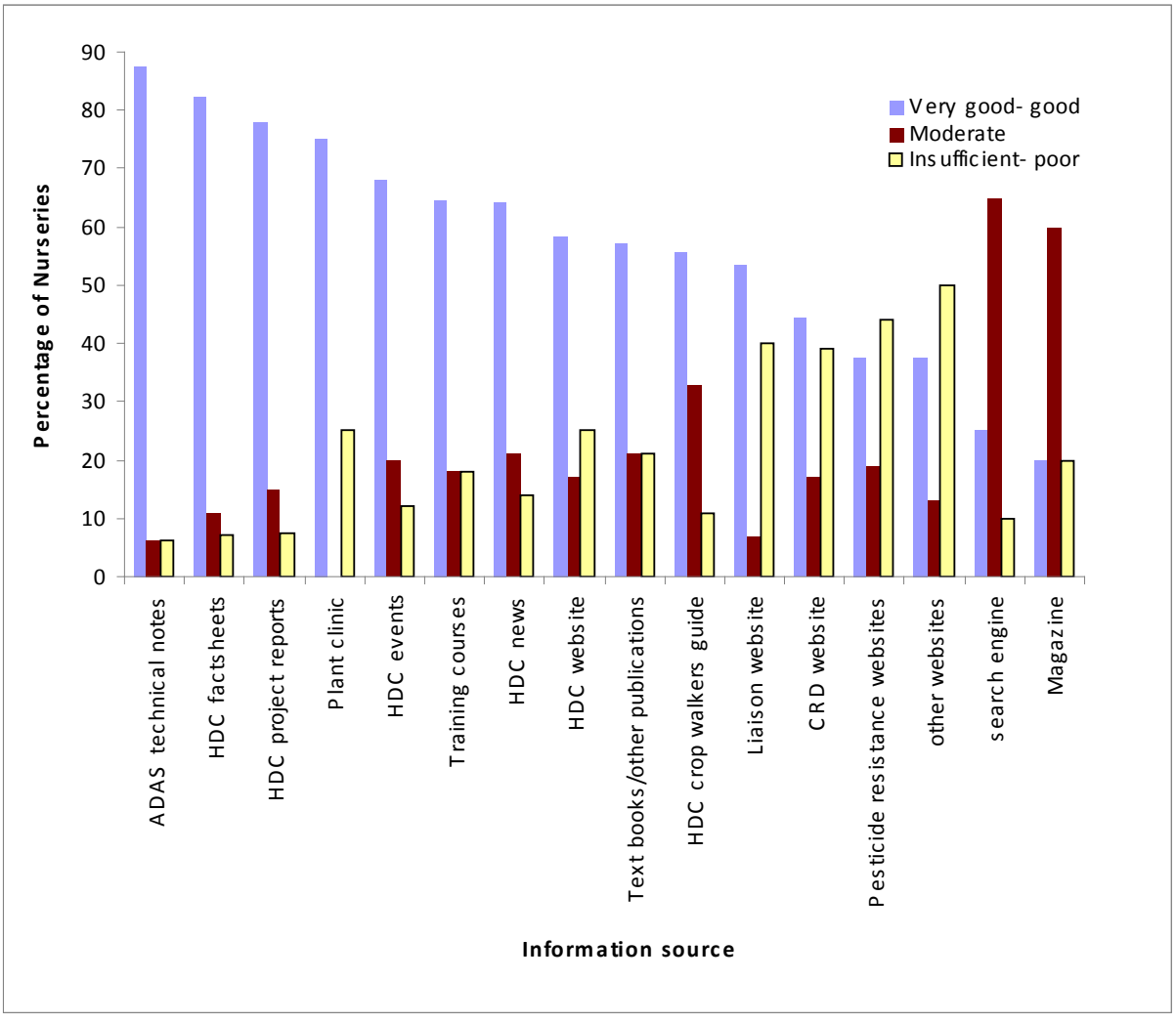


Figure 5.2: Sources of crop protection information used by 30 growers and the proportion using each who thought of the sources as either good or of little relevance to their decisions on crop protection.

In France, Astredhor has 13 regional stations which carry out horticultural experiments related to the crops grown in that area. In the USA, the different states have Extension Services based in the Universities which carry out experiments and provide free advice to farmers and growers.

In the UK, the regional stations of the government advisory service and the specialist crop institutes have been shut down over the last thirty years, with current research and advisory activity funded mainly by farmer and grower levies to the AHDB with projects contracted-out to research companies or Trusts.

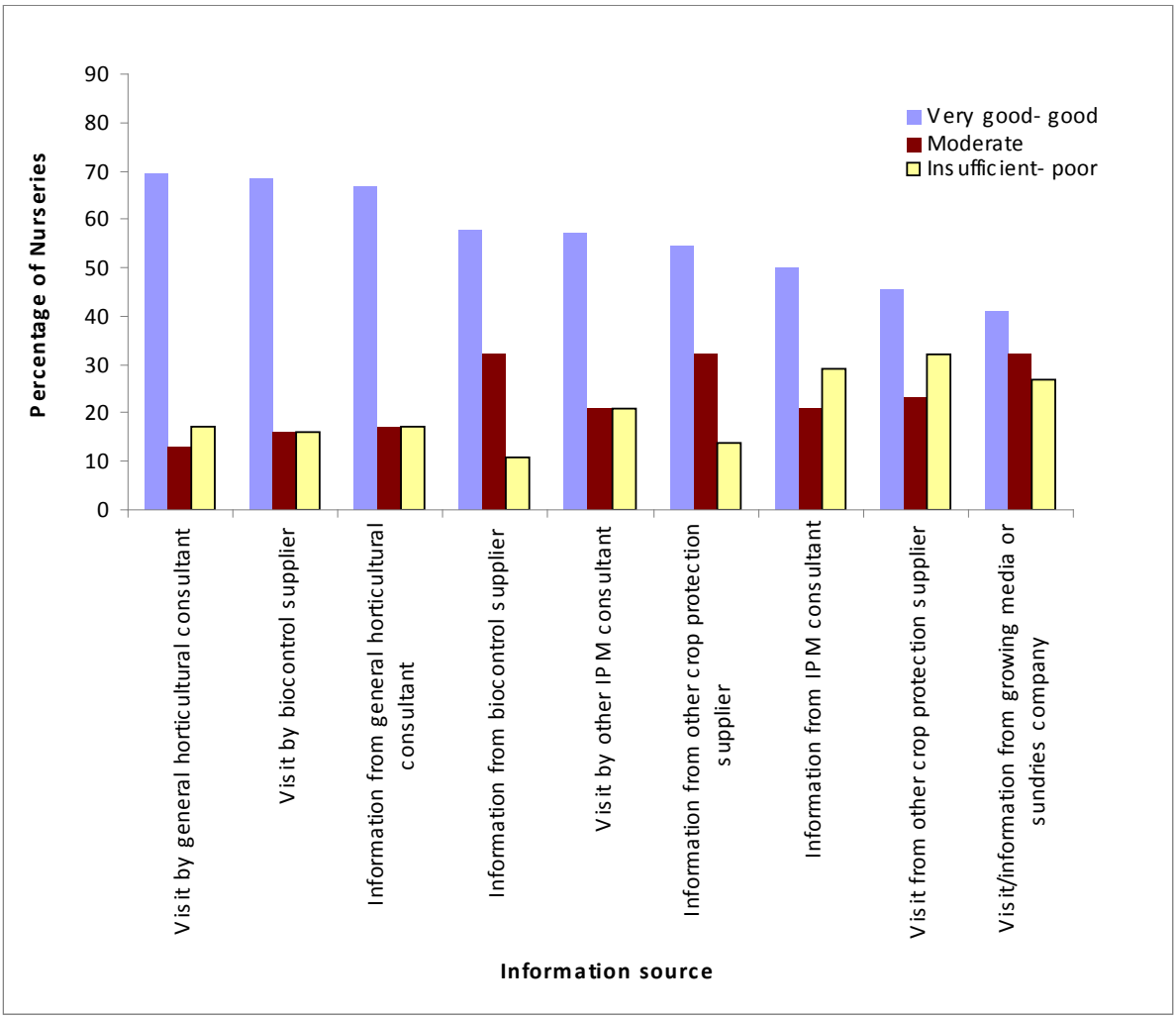


Figure 5.3: Sources of crop protection information used by 30 growers and the proportion using each who thought of the sources as either good or of little relevance to their decisions on crop protection.

5.2. Training

Training was given to staff at all nurseries. Team leaders and regular team members most often received crop protection training, with 80% of nurseries providing it more often

occasionally or at most yearly to these staff (Figure 5.4). Senior managers received a little less training. The least likely to be trained were the seasonal staff, with 44% of nurseries providing no training for them, although 26% are likely to give occasional training, almost exclusively by nursery staff. 18% of nurseries provide no ongoing training for senior managers and 7% allow none for regular team members.

Training was provided in a number of ways across the different staff levels (Figure 5.4) with senior managers most likely to be updated by a visiting consultant. Visiting experts also tend to communicate with the team leaders more than the staff under them. Around a third of nurseries will use training courses, a third using an external provider on-site. Most levels of staff most commonly receive training on-site by the nursery's own staff.

Nursery managers who were interviewed supported training, as staff were needed who recognised the importance of identifying and controlling pests, diseases and weeds. At one nursery it was said that using ICM often requires a cultural change across the business, which can take time and require persistence to see change brought about.

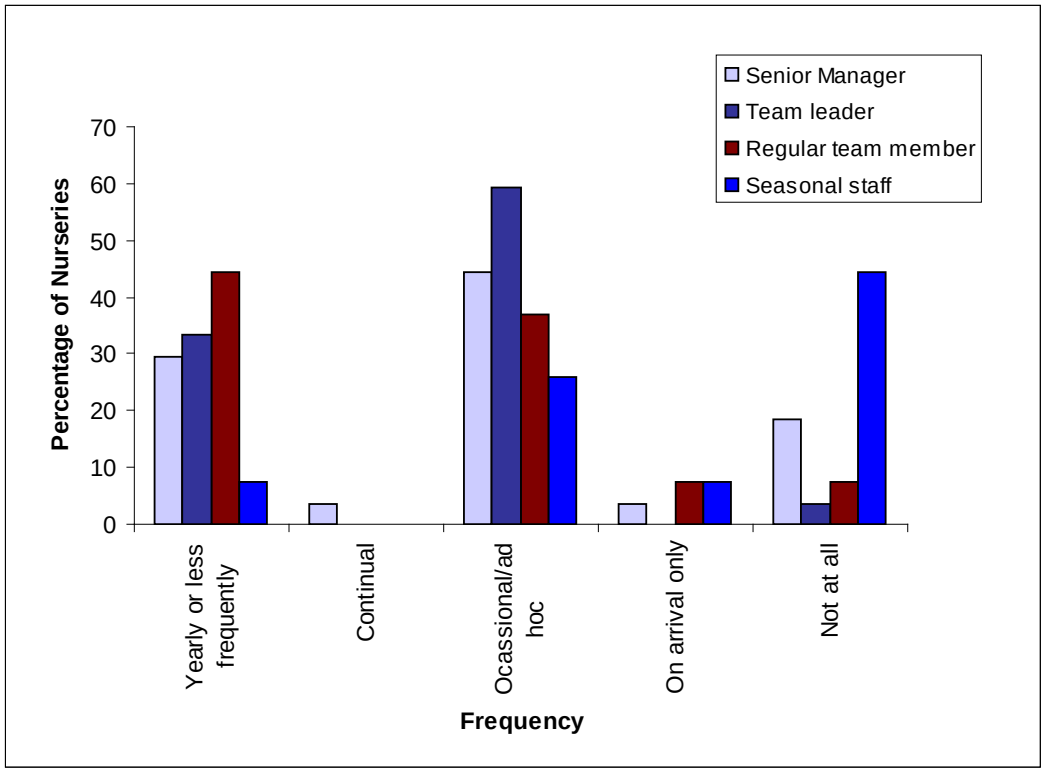


Figure 5.4: The frequency of training of different staff members in pest, disease and weed identification and crop protection.

Particularly among the smaller nurseries visited it was seen that ICM would be hard to develop much further because they lacked the advice/reassurance of a consultant. Although

training courses on (e.g. on crop inspection) are useful to establish the idea of ICM and provide background details, it was strongly felt by crop advisors and researchers that growers would benefit from seeing how things worked on nurseries over a period of time with the opportunity for discussion with someone more familiar with the measures.

- Smaller nurseries would benefit from a series of visits by a consultant to put ICM into practice on their holdings
- Regional training events could be run, with perhaps follow-up telephone advice made available (as is offered by Defra to farmers for nutrient management advice)

Growers wish to keep abreast of new technical developments and to be aware of new plant protection products. Changes in approvals for their existing chemicals can happen with only short notice. This information can be obtained from regular checks of websites and reading e-mails from the HDC, and ADAS Technical Notes. However, most of the larger nurseries have a number of visits a year by private consultants and seek information from them.

- A booklet, DVD or website on IPM should be produced so that information is available in one place, with the latter source easiest to keep up to date

Only three of the growers had BASIS certification and three were on the National Register of Spray Operators (NRoSO), yet many had attended HDC courses. There are no other well known national schemes within horticulture to record training. One of the growers had helped to facilitate a LANTRA training day for women which had resulted in them gaining greater confidence in applying their horticultural knowledge. It would be useful to have some documented evidence of training for staff if they do not officially collect continuing professional development points, as well as for the nursery quality assurance record.

- More skills training should be offered, in particular hands-on at various levels
- Certificates of Attendance could be issued to participants on training courses

6. The Extent of Integrated Crop Management in UK Hardy Nursery Stock

When respondents were asked about their level of understanding of what ICM is and what it involves, 70% stated that they had a good understanding (Figure 5.1). In the survey form, growers were given a range of measures for pest, disease and weed control not involving pesticides, which experience by ADAS consultants and members of the HDC Steering Group for this project had shown to be useable / used on ornamental plant nurseries (Appendix 1; Q11, 16 and 22).

In order to evaluate whether the survey respondents' perceived understanding of ICM was reflected in the measures carried out on their nurseries, an index of ICM measure usage was calculated. This index was devised using information on control measures provided by each nursery for their main crop by area (falling principally within herbaceous, climbers, shrubs roses and trees) for pests, diseases and weeds. The "on the ground" information from nurseries of ICM uptake was compared with what the consultants considered to be relevant measures for that crop type. Not all possible ICM measures could be considered to be important/particularly relevant for particular crops (e.g. pest bio-controls in submerged aquatics). This means that, for example, a grower of edible crops could be advised to carry out 47 ICM measures relevant to that crop type, whereas for herbaceous finals this would be 44, heathers 38 and field grown trees 31. For shrubs, there are potentially 38 to 47 measures depending on the crop (Table 6.1), although some shrubs e.g. *Choisya, Ceanothus* and *Lavandula* have fewer pest problems and so fewer control measures are necessary. The more measures carried out considered appropriate to the crop type, the wider the integration of control methods and so potentially the greater likelihood of success in managing pest, disease and weed populations on crops. Care is needed in interpretation, as this evaluation does not discriminate between nurseries with and without a pest, disease or weed on site on which to use a particular ICM measure.

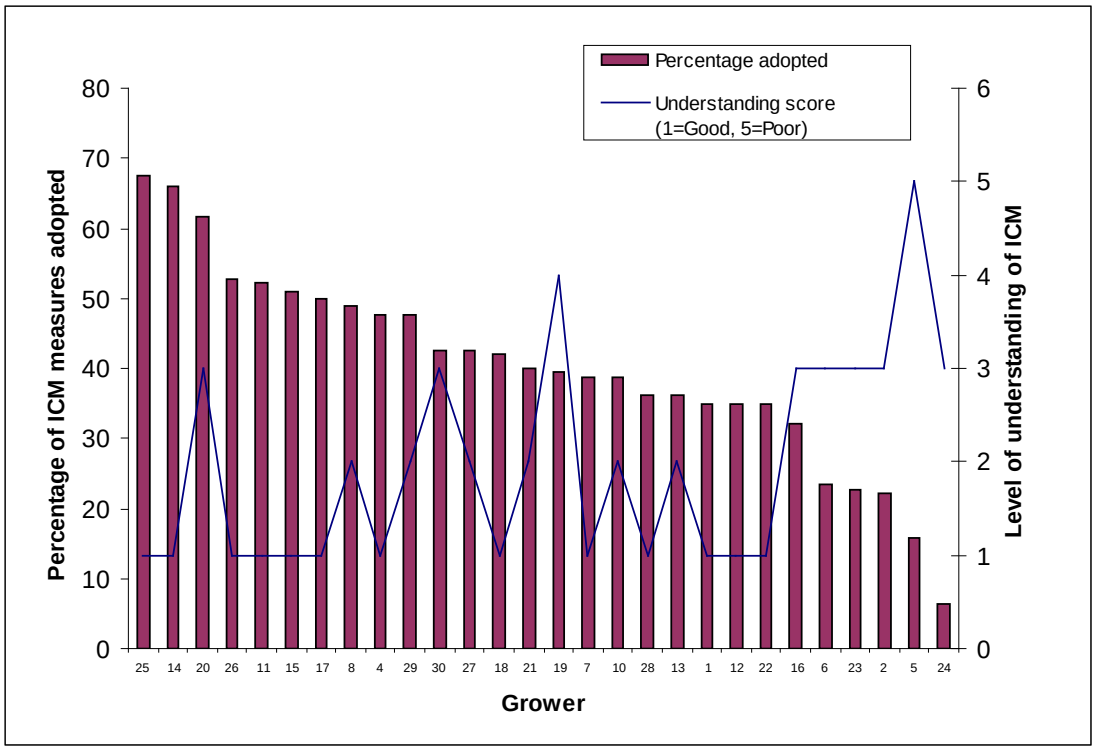


Figure 6.1: The percentage of suitable measures followed on nurseries (identified as number 1 to 30) set against the survey respondents' stated understanding of ICM

Figure 6.1 shows that in general most respondents' perceived understanding of ICM (the best being index 1) was reflected in the plant management techniques they reported using.

- Growers with a "good understanding index" of 1 or 2 generally carried out nearly 50% of "appropriate" measures for their crop.
- The number of measures carried out on three nurseries (numbers 1, 12 and 22) fell below what might have been expected by growers with a good understanding of ICM.
- Growers who credited themselves with medium to poor understanding of ICM (indices 3 to 5) mainly worked on nurseries within the low (10% to 30%) ICM measure application range.
- Nursery number 19 carried out more ICM measures on heathers than expected from the grower's claimed understanding of ICM. This understanding may relate to the terminology, not the concept.

Nurseries which operated 66% of measures reported a well managed pest, disease and weed situation and almost half the other nurseries are not far below this adoption level. "Lower adopting" nurseries could be advised to adopt some of the more popular measures (see Figure 6.2) to improve their ICM index. Each crop type differs in the total number of measures believed most relevant.

If around 50% application of ICM measures is taken as the goal (already achieved by a third of growers), then for each grower the following number of extra adoptions could be advised (Table 6.2). Improvement involving more than one measure is thus suggested for two thirds of the nurseries.

N.B. there will be nurseries where growers have considered particular measures e.g. pot toppers or mulches, but they would not be practical in their systems. In addition, the use of biocontrol products for individual pests "requires" that the pest is present on that nursery. The adoption of ICM on these nurseries may therefore be higher than indicated by our assessment method.

- Each nursery should consider the range of ICM measures that might reasonably be carried out on their crops and produce their own targets for substituting or adopting additional measures

Table 6.2: The number of additional measures that growers could adopt in order to improve their uptake of ICM measures according to the proposed guidelines in Table 6.1

Nursery code number	Main crop (by area)	% Increase needed to reach 50%	Additional measures needed to reach 50%
25	Shrubs	0	0
14	Shrubs	0	0
20	Shrubs	0	0
26	Shrubs	0	0
11	Climbers	0	0
15	Shrubs	0	0
17	Herbaceous	0	0
8	Shrubs	1	0.5
4	Herbaceous	2	1
29	Herbaceous	2	1
30	Edibles	7	3.5
27	Shrubs	8	3
18	Trees FG	8	2.5
21	Shrubs	10	4
19	Heathers	11	4
7	Climbers	11	5
10	Herbaceous	11	5
28	Shrubs	14	6.5
13	Shrubs	14	6.5
1	Shrubs	15	6
12	Shrubs	15	6
22	Shrubs	15	6
16	Shrubs	18	6
6	Shrubs	27	12.5
23	Trees FG	27	8.5
2	Herbaceous	28	12.2
5	Herbaceous	34	15
24	Trees FG	44	13.5

- It would be beneficial to discuss these results with individual growers following on from this work in order to determine whether they under-reported what they do or if there are sound reasons why particular measures are not being used on their nurseries.

Further analysis (Figures 6.2 & 6.3) showed which measures were being used by the majority of nurseries for pest, disease and weed control for their main crop type. Measures such as removing infected material, using clean cuttings, spot watering and regular inspections were common but not universal. Such measures could be targeted on nurseries not doing them currently. Grouping of crops by water need, irrigation scheduling, ventilation of tunnels and bio-pesticide application were used by slightly fewer nurseries. These measures probably require more specific knowledge of crop requirements and technical experience/support than the more commonly used measures. Measures to restrict the movement of pathogens between areas (common in edible glasshouse crop growing) such as boot dips, restricted access, removing outdoor clothing or wearing a disposable coat were not said to be used even in propagation areas. Where crops are grown under protection, the risk of pathogen or pest movement from outdoors on people requires assessment on individual nurseries.

- Growers should review the prevention and control measures they are currently taking and determine whether there are things they or their staff could do easily now, could do with some changes to equipment or with technical assistance, or would require major changes and the benefits gained are unlikely to justify the investment in time and or money.

Measures aimed specifically at pest control included the use of sticky or pheromone traps, and biocontrol products for specific pests with several growers using a range of biocontrol products. Most growers had some of each crop type under protection where these measures would normally be common (e.g. in glasshouse crops and soft fruit polytunnels).

From the case studies, one of the constraints to adopting more ICM measures was the extra time which could be involved in putting out biocontrol products. However, one grower in Denmark (G. Christensen, see Section 12.2) uses these products on his outdoor HNS and has calculated that, among other benefits, there is a cost saving as applications do not require trained spray operators working outside of normal hours or staff exclusion periods.

It would not be expected that two thirds of growers never have the pests on which to use the biocontrol products and it is likely that they are instead using plant protection products (with half saying that they use selective pesticides). From the minority of case studies where biocontrols were little used, at one nursery (code 30) with mainly protected cropping this was because selective pesticides are used, with spot treatments being deployed in order to preserve natural predators (e.g. ladybirds feeding on aphids within ferns), an assessment of the numbers of naturally occurring predators also being made prior to the decision of whether to apply an insecticide or not. At one site (nursery code 5), if whiteflies occur under protection the plants are moved outdoors to cooler temperatures. Another grower (nursery 10) had tried *Phytoseiulus persimilis* against two-spotted mite and has not continued to do so due to poor results, choosing instead to use physically acting products such as Majestik (maltodextrin) and SB Plant Invigorator (urea, di-amide of carbonic acid). However, this grower was willing to visit a demonstration site or nursery where planned introductions were giving excellent control. More information on particular biocontrol measures are given in report Section 9.

Some of the measures are likely to be more easily adopted (i.e. without training or with minimal changes to current working practices), such as ensuring clean pots are used from covered storage, or could be considered less costly than others, such as fitting lids to disposal bins rather than removing each small batch of waste from the growing area. The measures most suitable to be recommended to those using few ICM practices are probably those that most other growers of the same crop type already use, as shown in Figures 6.2 and 6.3.

Species/cultivar selection for lower pest or disease susceptibility was not included in the matrix (Table 6.1) as this is often dictated by the client, but should take place as an ICM measure before any crop is grown.

Table 6.1: ICM measures for pests, diseases and weeds considered to be relevant to different crop types (A-U, see key below) shown blocked

ICM measure	Crops																				
1. Pests	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**P**	**Q**	**R**	**S**	**T**	**U**
Monitoring:																					
Sticky traps	■		■	■	■	■	■		■	■		■			■	■	■		■	■	■
Pheromone traps	■		■	■	■		■		■	■		■			■	■	■		■	■	■
Inspection and records	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Indicator plants	■		■	■	■		■	■	■			■	■	■							
Quarantine areas	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Bio-controls for:																					
Aphids	■		■	■	■	■			■	■		■					■		■	■	■
Caterpillars	■		■		■				■	■		■			■	■	■	■	■	■	■
Leaf miner			■		■				■	■		■					■				
Sciarid	■		■	■	■	■			■			■			■	■	■	■	■	■	■
Slugs / snails	■		■		■				■	■		■			■	■	■	■	■	■	■
TSSM	■		■		■				■			■			■	■	■	■			
Vine weevil	■		■	■	■	■	■		■	■		■	■								
Whiteflies	■		■		■				■	■		■			■		■			■	
Western flower thrips			■		■				■			■				■	■			■	
Other:																					
Crop rotation								■			■			■							
Selective products (e.g. Chess WG)	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Pot toppers and mulches	■		■	■	■	■	■		■	■		■	■		■	■	■	■	■	■	■
Banker plants	■		■	■	■	■			■	■		■					■		■	■	■

2. Diseases	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
Husbandry:																					
Growing media selection																					
Clean seed, cuttings, stock etc																					
Cleaned water																					
Sub-irrigation / drip-point																					
Water monitoring (electronic)																					
Spot watering (autumn-winter)																					
Irrigation scheduling																					
Crop grouping by water need																					
Spacing																					
Diagnostic kits																					
Environment Control																					
Products:																					
Bio-stimulants																					
Bio-pesticides																					
Microbial products (Revive, Trianum, Compost Tea etc)																					

2. Diseases contd.	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**P**	**Q**	**R**	**S**	**T**	**U**
Other:																					
Weather records / forecasts																					
Disease forecasting																					
Water sampling																					
Water baiting																					
Hygiene:																					
Sweeping																					
Covered disposal																					
Pressure-washing																					
Removal of infected material																					
Disinfection beds etc																					
Sterilise trays/pots																					
3. Weeds																					
Nursery hygiene																					
Bio-fumigants																					

Key to crops / crop categories:

A – Alpines	**B – Aquatics**	**C – Climbers**	**D – Conifers**	**E – Edibles / herbs**
F – Heathers	**G - Hedging (CG)**	**H – Hedging (FG)**	**I – Herbaceous**	
J - Roses (CG)	**K – Roses (FG)**	**L – Shrubs**	**M – Trees (CG)**	**N – Trees (FG)**
O – Ceanothus (shrubs)	**P – Choisya (shrubs)**	**Q – Clematis (climbers)**	**R – Cordyline & Phormium (shrubs)**	**S – Hebe (shrubs)**
T – Photinia (shrubs)	**U – Lavandula (shrubs)**			

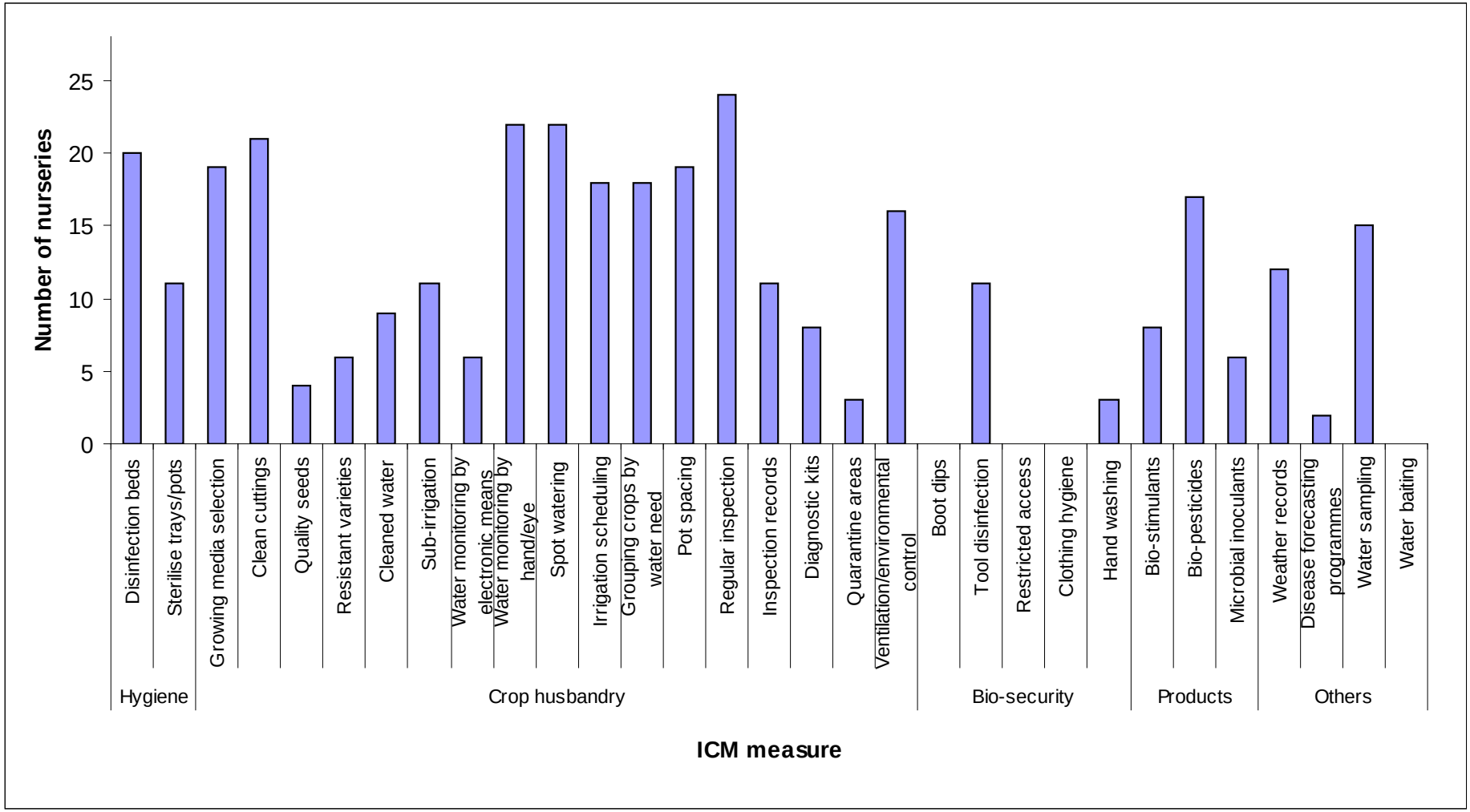


Figure 6.2: The number of growers using particular ICM measures for cleaning, crop husbandry, containment and plant protection products

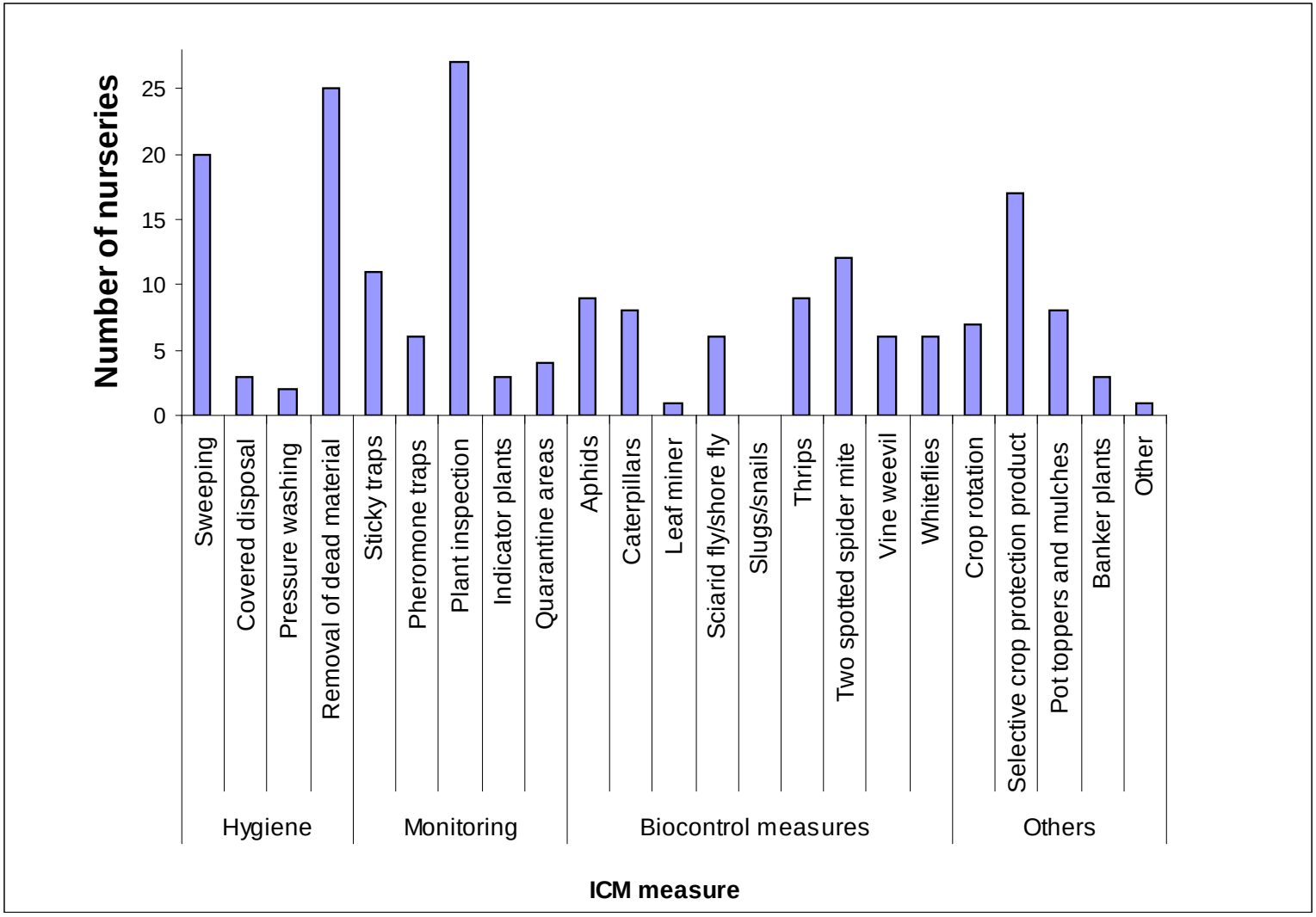


Figure 6.3: The adoption of ICM measures against pests by growers for their main crop

7. Monitoring and Forecasting

7.1. Monitoring

Monitoring to provide information on the incidence of pests and diseases and the severity of damage is one of the most important aspects of successful ICM. During monitoring, accurate diagnosis of any problems is essential in order to aid decisions in managing the IPM programme. Knowledge that certain problems are likely to occur at a particular time and on a particular crop can also be critical when planning preventive cultural and biological control strategies. Once biological control agents have been released, these should be monitored in addition to the pests to ensure that they are establishing and giving the required level of control. Forecasting (which is covered more fully in the next chapter), usually utilises weather data combined with a knowledge of the life cycle of a pest or disease and will often also involve monitoring, particularly if management action is based on a threshold.

Growers on most nurseries (88%) reported a weekly, or more frequent, crop monitoring programme (Figure 7.1). This should pick up the majority of problems in the early stages of infestation or infection.

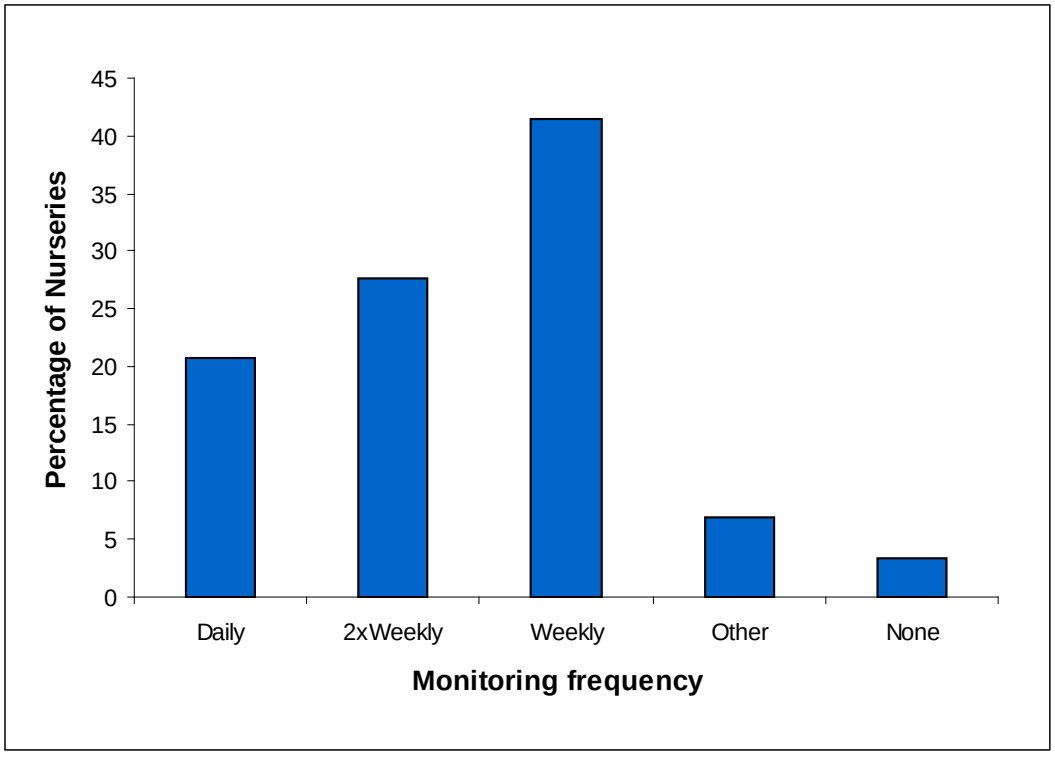


Figure 7.1: The percentage of nurseries with each interval between inspections

Regular monitoring was highlighted as the cornerstone of ICM, with protected crops in spring and summer requiring the most checking. In some nurseries, regular checks by a senior staff member occur as well as frequent inspections by the staff responsible for a particular production area.

- Production staff (including seasonal workers) moving and watering plants should also be trained to recognise pests, diseases and damage symptoms and encouraged to look out for problems and to report them.
- Prompt removal of affected tissue/plants or spot treatment can often prevent explosions in the occurrence of pest, diseases or weeds.

There were a range of recording methods reported, with only a few nurseries using a specific recording form. Having a standard form ensures that key information is noted down such as the bench or bed number and problem incidence and facilitates the re-checking of plants if required. Records are usually compiled on most nurseries to decide on any control measures. At one nursery, manual records from a form are entered onto a computer so that trends over the years can be compared, understood and predicted.

- A crop pest, disease and weed recording form should utilised by all growers which can be printed off or used on a palm-top for use in the crop to record problems. An example of a version currently in use on one nursery is shown in Table 7.1.

Table 7.1: Crop husbandry, pest, disease and weed monitoring diary

SEEN Date / Initials	**Location*** e.g. bed & position within	**Crop**	**Observation**	**Severe Obvious Monitor**	**Action Required**	**DONE Date / Initials**

* Site position should be sufficiently detailed to allow other staff to locate the problem and beds and benches may benefit from sub-division number-labelling

- Other records could include numbers of pests on sticky traps and pheromone traps and presence of biological control agents. For example, percentage aphid parasitism (indicated by the proportion of 'mummies' in aphid colonies, percentage of parasitized whitefly scales, presence of *Phytoseiulus* predatory mites or eggs in

spider mite colonies, etc. These records will enable the IPM programme to be managed accordingly.

As monitoring is so critical for successful IPM, staff should be trained and experienced enough to be able to detect problems quickly, diagnose the cause of the problems and have confidence in methods for checking that biological control is working well. Staff should also be given adequate time to carry out weekly monitoring.

A crop walker's guide for pot and bedding plants to aid recognition by growers of crop problems was published by the HDC in 2008 and a similar one for HNS growers was published in 2012. However, knowledge/experience is needed to know which plant species or varieties are likely to be affected by particular pest or diseases, where on a plant to look for pests and diseases and the most likely locations in a production area. For top fruit, there is an Integrated Pest and Disease Management (IPDM) Best Practice Guide developed by EMR available on the HDC website. This has a pest and disease action calendar with a checklist of IPDM tasks and detailing when and how to sample, the thresholds and action to be taken.

- A Guide to Crop Walking for ICM in HNS should be produced with information on how different crops should be inspected for various pest and disease problems and how monitoring can be done to check the progress of biological control.

Guidelines for monitoring and diagnosis of pest and disease problems in IPM programmes are given in the HDC website 'HDC Herb Best Practice Guide' in protected herbs and these are also relevant to HNS - see http://herbs.hdc.org.uk/ under the tab 'A. General Information'. ICM is particularly relevant where it is necessary to minimise pesticide residues on edible crops grown on HNS nurseries. Key actions on spider mite, botrytis and powdery mildew cultural control and pesticide selection and timing to minimise pesticide residues have been given to tomato growers in a government report (Caspell *et al.*, 2006), and some of this information will also be relevant to HNS growers. High standards of glasshouse and crop hygiene, environmental control, effective crop monitoring and attention to detail were key factors in achieving successful disease control and minimal use of fungicides.

In this project, some of the survey reports of poor crop protection may have resulted from mis-identifications of pests, diseases and weeds on nurseries. This could be avoided by the availability of readily available reference photographs. There are a number of HDC resources available to growers which can be viewed or downloaded from the website or

received through the post, including various factsheets and crop walker guides. However, some publications are quite bulky to carry around the nursery. An option for the future could be smart phone “apps” to aid recognition and correct diagnosis of problems.. For arable crops, ADAS and BASF have recently developed a weed identification “App” for smart phones and something similar for pests and diseases could be developed for HNS growers:

- Smartphones could be sent information on specific pests/diseases for each month
- The phone could be used with a magnification application. There could be a photograph of the pest/pathogen next to magnification to check identification
- An “IPM Scope CAM” is available with a LED-lighted unit to magnify objects 3-25x on the unit display and up to 300x digitally on the computer (www.specmeters.com)
- Digital images can be e-mailed to growers or consultants for assistance with identification
- Information gathering on potential invasions/epidemics could be developed and dissemination funded by the AHDB cross-sector as some invasions/epidemics related to weather conditions e.g. aphids, moths and powdery mildew may apply to several arable and outdoor and protected horticultural crops simultaneously within particular regions of the UK

Another important aspect of growers gaining knowledge of the biology of pests, diseases or weeds likely to damage their crops is knowing when the different life/growth stages and damage is most likely to occur. This will allow timely preventive cultural and biological control agents to be put in place and extra effort can be put into monitoring susceptible crops at appropriate times so that curative control measures can be implemented at an early stage.

- A monthly wall chart or calendar listing the risk of various pest and disease incidence (including photographs to aid recognition) could be produced for HNS growers

7.1.1. Assisted monitoring

It is possible to use measures that assist crop inspection for pests and diseases. This is a rapidly developing area with new electronic and molecular technologies allowing the development of devices and techniques. The miniaturisation and cheaper production costs of equipment mean that growers have the opportunity (e.g. with the use of smart phones and Lateral Flow Devices (LFDs)) to use products to diagnose problems rapidly on the nursery and to take rapid action to maintain and improve crop quality. The HDC, Association of Applied Biologists (AAB), International Organisation for Biological and Integrated Control (IOBC) and trade are active in knowledge transfer within the grower or scientific

communities. Review articles are produced in publications such as Horticulture Week (e.g. Tilley, 2012) and on various horticultural websites. There is, however, a problem that not all growers will be aware of new technologies when they are first made available and those that do need to then make a commercial decision to try them, often without the benefit of seeing them working on a commercial nursery.

- Growers should seek information on new pest and disease monitoring technologies and take time to weigh-up whether any might save them time/money on their nursery
- HDC should continue to fund research on assisted monitoring and seminars for growers and consultants
- Demonstration areas / test periods on nurseries (or in as near to commercial growing situations as possible) should be set up for the most promising technologies. Ideally these should be at more than one location on several dates, to be reasonably easily accessible to as many growers as possible. There could be opportunities for combined levy/manufacturer funding

The EU project Q-DETECT, which involves the Food and Environment Research Agency (Fera) and is due to finish in 2013, has been developing field sampling and detection methods to aid plant health inspectors. Methods include the detection of pest or pathogen DNA, acoustic detection of wood-boring pests, the detection of diseases from the volatiles they produce, remote imaging to identify disease-prevalent areas and “smart traps” with cameras to identify pests without collecting in the traps. The DNA testing is the closest to deployment with devices allowing tests to be conducted in the field within 15 minutes (Tilley, 2012).

Indicator plants

Growers responding to this survey were aware that specific crop species are more likely than others to be attacked by particular pathogens (e.g. hollyhocks by rust) or pests (e.g. *Choisya* by TSSM, *Clematis* by WFT). Crops susceptible to particular pests have been recorded by Buxton *et al.* (2006). When crop walking for monitoring purposes, these plants should be checked first as they can often show up problems before they occur on other plant species. As a precaution against these very susceptible plants becoming breeding grounds for pests, extra biological control agents can be applied and monitored regularly. Plant species other than those grown in the crop can also be used as Indicator plants, for example, potted primulas can be used to indicate adult vine weevil feeding activity.

Trapping

Sticky traps were used by a third of the survey growers for monitoring flying pests, e.g. whiteflies and thrips. They could be more widely used immediately outside glasshouses and poly tunnels, to give warning of incoming pests. However, with non-baited traps in particular, there is more chance of other insects being trapped than when set up under cover, also sticky traps outdoors tend to get covered in debris as well as incidental insects.

HNS growers may not be using all the pest specific monitoring tools that are available. They are mainly only using pheromone traps for light brown apple moth and carnation tortrix. Other pheromone traps are available for HNS pests, e.g. those for monitoring European tarnished plant bug and common green capsid. A sex pheromone trap for western flower thrips (Thripline AMS, from Syngenta Bioline) and a lure based on plant volatiles effective for all thrips species (Lurem-TR, available through Koppert) are available. Both are being investigated in HortLINK project HL01107 on integrated thrips control in strawberry.

- Pheromones and semiochemicals for additional pest-specific monitoring on HNS nurseries requires research

Baited traps could be of particular benefit if used on plants that are to be moved from a region with a particular pest population to one that is not affected.

It would be very useful to monitor vine weevil adult activity and, if the current HDC project SF/HNS 112 looking at attractants leads to the development of a commercial lure, this should be considered by growers. As the weevils are female, a sex pheromone cannot be developed, although there may be an aggregation pheromone. Adult feeding activity can currently be monitored using indicator plants and presence of adults can be monitored using simple refuges in which the adults shelter during the day. In CRD-funded project PS2134, simple refuges such as plastic cockroach traps were shown to be effective daytime refuges for vine weevils (Pope, 2012). They can currently be monitored using indicator crops or simple homemade traps such as a tile on the ground under which the adults will seek shelter when not feeding within the crop.

- If vine weevil attractants are developed then commercial development should follow

It is possible to use light traps set up at night for moth pests (particularly now there are cheaper to run Light-Emitting Diode (LED) versions). However, light traps will attract all

night-flying moths and thus knowledge of moth identification would be needed to interpret the catches. A blue light (Ferolite) with a blue trap combined with a pheromone has been found to be most effective for trapping *Tuta absoluta* moth infesting tomatoes (Hassan, 2011). In the UK, a pheromone lure is used for trapping this pest in tomatoes, in conjunction with lights and water traps. In the USA, the Agricultural Research Service has developed a Light-emitting Diode Equipped CC Trap (LAD-CC) which utilises a green LED in a trap that looks like an overturned plastic cup with a ring on the bottom. It attracts large numbers of Silverleaf Whiteflies *(Bemisia tabaci)* and kills them without the use of pesticides, working especially well at night. It is effective outdoors as an alternative to yellow sticky traps (which trap other insects and dust) (Elstein, D., 2002). However, in the UK, the use of traps for mass trapping i.e. for control purposes rather than monitoring, requires registration and this is currently inhibiting the development of the use of pheromones for strategies such as mating disruption and 'lure and kill'.

- The use of LED light traps requires investigation and HDC Project CP 88 on enhancing the monitoring and trapping of protected crops by incorporating LED technology into existing traps will be completed in September 2013

In New Zealand and Hungary remote trap catching and monitoring has been developed for pests such as moths, and this technology could have potential in the UK.

Volatile detection

All plants emit a mixture of volatile organic compounds (VOCs) in response to environmental factors, e.g. a plant can give off an 'alarm' signal when attacked by a pest. In nature, predators and parasitoids that attack crop pests can use these plant signals as a cue to detect their prey. Work to allow humans to detect pest and disease-affected plant tissue by detecting VOCs using hand-held electronic noses ("e-noses") has been carried out (Laothawornkitkul, 2008, Laothawornkitkul *et al.* 2008; Jansen *et al.*, 2011; Paul *et al.*, 2011). Discrimination has been shown between physically-damaged, caterpillar-damaged and powdery-mildew damaged leaves. The sensitivity of the devices is improving (they are also used for searches of containers by Customs Officers). Detection across a floor area of around 1000 m^2 is possible. There is potential to develop them for real- time pest and disease monitoring systems. One aim is to be able to monitor for the presence of problems before visible damage appears.

- More work should be carried out on "e-noses" as an aid to crop monitoring, particularly to give early warning of an attack

Image analysis

Pests and diseases affect plant transpiration and can cause plant temperature anomalies. Temperature effects may appear before visual symptoms and this can provide an early warning of pest or disease damage. Multispectral imaging has been demonstrated on motorised rigs for use either in glasshouses or the field (Edmonson, 2008). Interpretation of the images requires a visual image to be captured (by a machine or a human) in order to be able to examine the location of any heating and judge whether it is, for example, the difference between the flower and a leaf or an attack. Image analysis can allow automated inspection of crops, facilitating routine crop surveillance. The most immediate applications are considered to be in glasshouse and bedding crops (Edmonson, 2008). Thermal imaging on motorised rigs may be less likely to have immediate use in mixed HNS cropping environments where plant size and architecture is more variable.

Plant stress can lead to increased pest and disease susceptibility. Plants that are well-watered produce a blue thermal image, whilst those experiencing drought conditions show red. This can pick out a stress problem within a production area. High plant tissue temperature can, however, be caused by sunlight alone (Adams, 2008). Thermal images could be utilised as an occasional check of the evenness of overhead irrigation/drainage and could assist the positioning of water sensors across the crop area. However, human checking of growing media moistness is probably currently more appropriate.

Leaf baiting

It is possible to use leaves such as rhododendron or fruit such as apple in bags suspended in water or buried in soil to attract the zoospores of *Pythium* and *Phytophthora*. The technique has been used in the detection of *Phytophthora ramorum*, and for root rots pathogens (HDC Project HNS 181). The baits can then be tested by growers with a LFD for either *Pythium* or *Phytophthora.* However, no growers surveyed used leaf baits even though 70% of growers never treat their water and many use non-mains or borehole water (see information from Q18 later in this report).

- Leaf baiting for Oomycete pathogens in water should be more widely adopted by nurseries, especially those recycling water for crop irrigation
- ➢ Workshops on the use of water-baiting are required

Molecular-based diagnostics

Real-time polymerase-chain reaction (PCR) has been used in recent years to monitor fungal, bacterial, viral and nematode pests of crops, and more recently for the quantification of fly

egg populations (Rogers *et al*., 2011). The quantity of DNA in each sample is measured and related to standard curves for known quantities of e.g. eggs, spores or sclerotia in order to be able to estimate the density of the relevant pest or pathogen propagules in plant tissue, soil, solid or liquid growing media or air. Molecular techniques are quicker than traditional methods of pest and disease detection, involving various ways of separating out/isolating the pest or pathogen followed by identification and counting. Air sampling integrated with DNA-based diagnostics can be used to identify and quantify the presence of pathogen inoculum to guide spray decisions at key times. There is continual development in this technology and automated on-site diagnostics or biosensors could in the future detect pests or pathogens and be used to send out a warning to growers (West, 2011). A technique known as terminal restriction fragment length polymorphism (T-RFLP) can permit simultaneous identification of micro-organisms in a single test. It has been used in HDC Project PC 281 with tomatoes grown in various media and detected more than 100 species of fungi and bacteria (some of which would not normally be able to be cultured) (O'Neill, 2011). This technique can be used to determine the population of beneficial microbes in growing media as well as that of pathogenic species.

- Growers need to be aware of the benefits of DNA-based detection and quantification of pest and pathogen presence and ongoing developments in these techniques
- ➢ Development of molecular diagnostics techniques and work on their utilisation in crops should continue

7.2. Pest, disease and weed forecasting

Forecasting (i.e. predicting something is likely to happen) can include the following methods:

1. Use of weather data to indicate that conditions e.g. temperature, rainfall or humidity have been favourable for infection and/or development of a particular disease.

2. Use of “accumulated day degrees” above a threshold for development of a particular pest e.g. before eggs hatch or adults emerge from pupae.

Two nurseries reported having used disease forecasting programmes but this was in association with research projects. Others said that forecasting was something that they had considered but not carried out and would be interested in knowing more about. Forecasting need not involve electronic equipment, in its basic form it may only require records or a memory of previous seasons and when pests, diseases and weeds were active. This information can be used to predict the most likely time, conditions or crop growth stage that damage might occur in the coming season.

- An HDC workshop would be justified for researchers and scientists to examine the use of pest, disease and weed forecasting and their integration for use by HNS growers

7.2.1. Functioning forecasting programmes on nurseries

ICM

The Groiefax (Growth Fax) pest and disease warning system is operated by a group of consultants to inform tree, shrub and container stock growers in Belgium and the Netherlands of the actions that they need to take for major pest and disease outbreaks. Meteorological data from nurseries plus Met Office data is collated and fed into computer modelling programmes based on research and development projects e.g. on rose powdery mildew, fireblight and leafspots. Information is also given on weeds, soil and nutrient management. Around 30 emails a year are sent to around 200 growers (to arrive on a Monday morning), targeting information relevant to the cropping type of each nursery. The aim is to reduce chemical usage. They also have a trials area to investigate new products, techniques and technologies. The scheme is funded by an annual grower subscription of €170 (www.boomteeltkenniscentrum.nl).

Since 1996 a pest and disease warning system for ornamentals nurseries has been operated by the Research Centre of Ornamental Plants (PCS) in Belgium, with membership of the scheme including identification pests and diseases using clinic samples. The centre carries out research on integrated control, focusing on minimising the use of chemical products and also the recycling of water and fertilisers in closed culture systems (www.pcsierteelt.be).

- A pest and disease warning service for UK nursery stock growers should be possible and investigations should be made into grower interest and the economic and practical feasibility of setting up and running a scheme.

7.2.2. Development of forecasting programmes on nurseries

Diseases

In HDC project HNS 173 (Xu, 2011), forecasting programmes are under investigation for both downy and powdery mildew in rose. The powdery mildew model was originally developed within HDC project HNS 165 (Xu, 2010). The computer programme is supplied to the user and run in conjunction with in-crop temperature and humidity loggers, which are downloaded to the computer. The programme creates a threshold index which then requires decisions based on information such as when the last fungicide was applied to inform the timing of any fungicide application. There is potential to extend the application of this to other HNS crops.

- Verification of the rose mildew forecasting programmes should be carried out on other crops
- Rose growers should be prepared to try out the disease forecasting programmes to see if they can make better timed/less frequent fungicide applications

Spore trapping equipment is currently still only a research tool because checking visually for spores on sticky tapes takes time and expertise. More recently, air suction samplers have been developed with a revolving barrel containing a vial for each sampling period but molecular diagnostics of the vial contents is required, which is speedy but at present costly.

Disease forecasting has traditionally been used with outdoor crops where leaf wetness and, to a lesser extent, temperature and humidity are under grower control. Research on Botrytis has taken place on protected raspberries (LINK project HL0175LSF; O'Neill *et al.*, 2011) and strawberries (LINK project HL0191; Xu, X. *et al.*, 2011) where temperature and humidity

records, provided by weekly downloads from loggers in the crop, have been used in the BOTEM decision support computer programme to determine whether or not conditions have been suitable for flower infection. However, if flowers are not given fungicide protection, they can develop latent botrytis which will infect the fruit. If flowers are likely to be infected based on the forecast, colder storage or quicker marketing could be targeted at the resulting fruit.

There has been work on forecasting in cucumber crops. This has involved immunoassay spore trapping for *Mycosphaerella* (HDC Project PE 001, McPherson, 2011). This testing is, at present, costly because of the price of reagents. This approach could be of benefit, however, to monitoring for non-indigenous pathogens such as *P. ramorum;* a greater volume of air can probably be sampled than would be "sampled" in the rain falling into a water collection trap. The crop loss scenarios from quarantine organisms would make this method worthwhile but it is not currently economically viable for general use.

Current benefits and limitations to the use of forecasting

The benefit of these forecasts is that they can cut down the number of fungicide applications as some would otherwise be put on at weekly intervals in the at-risk period for each crop. If conditions were not right for disease development, a curative fungicide application would not be needed. This is particularly relevant to edible crops as this reduces the chance of pesticide residues being found at harvest. A reduced number of powdery mildew sprays were used in an ICM management programme on strawberries and in 2011 kept the disease as controlled as did multiple sprays in the standard crop management (LINK project HL0191). In addition, potassium bicarbonate was used rather than e.g. Systhane 20 EW.

When forecasting that conditions have been right for a disease to attack, curative products are required as infection will have happened by the time the record has been made. Curative products are usually less effective than protectants. Protectants may, however, be used within forecasting programmes if the disease is known to have rapid multiplication, so that spores are produced not long after infection (e.g. powdery mildews and rusts), then the application of a product will prevent re-infection of other areas on the plant or other plants.

If weather forecasting could be sufficiently accurate and could be related to the micro-climate conditions in the crop, then this information could be harnessed together with the parameters for disease development to make the prevention of initial establishment feasible.

One of the difficulties with using forecasting in HNS is where nurseries have a mixture of crops and hence diseases to contend with. However, although programmes for powdery and

downy mildews have mainly been developed on a particular crop, the environmental conditions required for spore germination, infection and sporulation are likely to be similar for the different species of the same pathogen family. For pathogens, such as *Botrytis* with a wide host range, it is probable that forecasting programmes devised in other crops can be utilised in HNS. For example, potato blight (*Phytophthora infestans*) forecasting provided on the internet by the Potato Marketing Organisation is used by the plant health inspectors in the South West of England to give an indication of when weather conditions have been good for sporulation and infection of *Phytophthora ramorum* on hardy nursery stock such as *Rhododendron, Camellia, Pieris* and *Magnolia* (Ann Payne, PHSI pers. comm.).

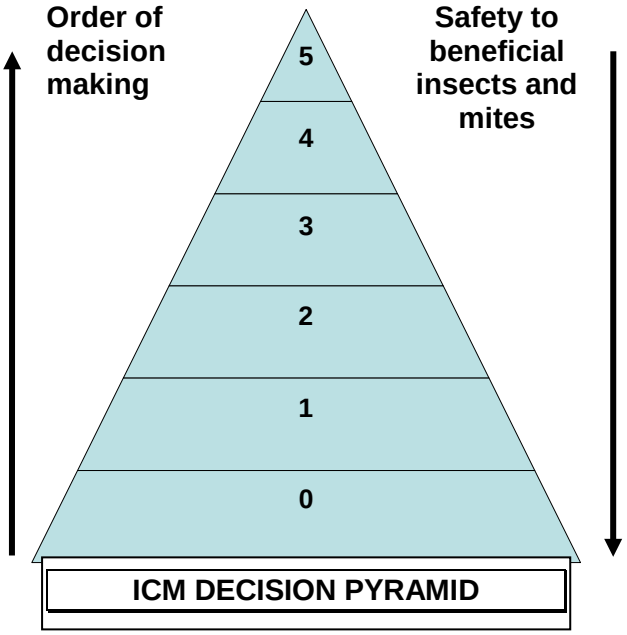
Forecasting programmes can be used to both warn that weather conditions outside have been suitable for particular diseases and that conditions have become favourable under protection. The development of computer programmes is required that can utilise incoming environmental records and continually match them to disease development parameters and so allow an early warning alarm to be given. In the meantime, however, grower/production staff awareness of, and reaction to, the range of temperature, wetness and humidity conditions favouring particular pathogens can go some way to reducing disease risk.

- Further investigations on monitoring and forecasting would be of benefit, in particular the utilisation of existing models for the same pests and diseases as on HNS
- Assistance to growers with running models (initially or ongoing) would be of benefit
- Production staff need to be aware of the favourable environmental conditions for disease development and to put in place measures to stop them occurring

8. The Selection of Plant Protection Products by Growers

8.1. Current practices on HNS nurseries

One aspect of SUD compliance will be the requirement of growers to demonstrate to regulators that they have carried out a decision making process which leads to the selection of the most appropriate control measure. A decision tree for pesticide use is shown in Figure 8.1. The factors considered and the high proportion of growers who said they considered each is shown In Table 8.1, with most nurseries having a management plan to guide decisions on the monitoring, reporting and the control measures to be taken (Figure 8.2).



Conventional chemical pesticide, e.g. Decis
IPM compatible chemical pesticide, e.g. Conserve, Chess
Biorational pesticide needed, e.g. Majestik
Biopesticide needed, e.g. Serenade
Use appropriate biological control
Crop inspection, no action needed

Figure 8.1: Diagram to show how pest control options should start at the base of a pyramid, with most control measures being carried out here. Control measures at levels 2 to 5 should only follow due consideration and possibly follow initial use of measures 0 to 2.

Table 8.1: The proportions of growers considering various factors before the use of chemical plant protection products

Factor to be considered	Yes (%)	No (%)	Do not know (%)
Has the problem been accurately identified?	100	0	0
Does the level of damage or potential damage justify need for treatment?	100	0	0
Is chemical control the most effective solution?	97	3	0
Is the alternative to chemical control an option?	90	10	0
Are non-target organisms (beneficial insects) at risk?	84	13	3
Can a safer (e.g. for the environment) chemical option be considered?	90	10	0

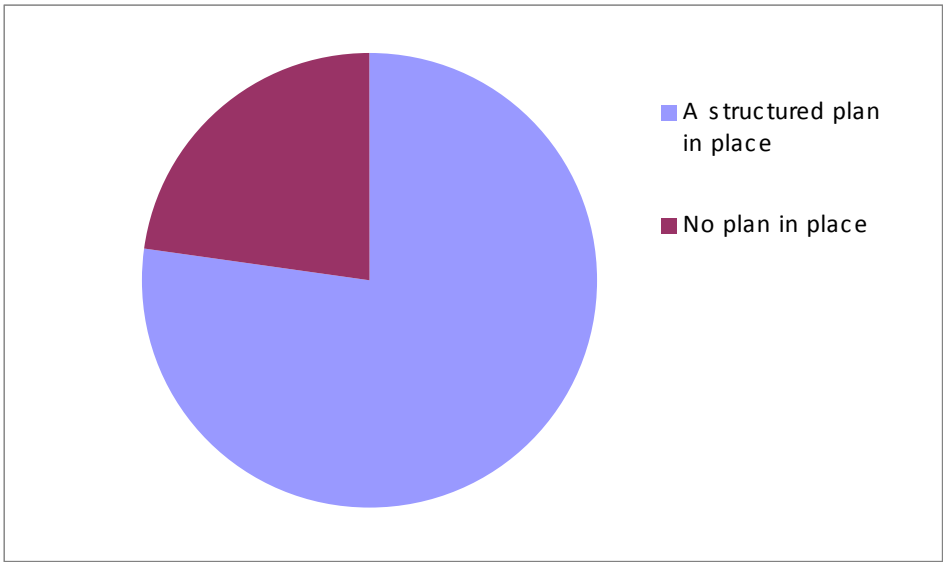


Figure 8.2: The proportion of growers (out of 22 responding) having a management plan for pests, disease and weed control on their nursery.

8.2. The selection and sustainable use of chemical pesticides and alternative plant protection products

Plant protection products approval for use on ornamentals

It is not necessary for growers or staff to be BASIS-qualified (i.e. qualified to give advice on pesticide use) in order to select products to be used on their own nursery. However, most of the survey respondents were visited by a horticultural consultant (Figure 5.3) who should be BASIS-qualified.

Any pesticide used needs to be approved for use on that crop, in that location (i.e. outdoors or under protection). Pesticides can have full approval for this use or a special approval to include crops not on the label (what was previously called a Specific Off-label Approval or 'SOLA', now referred to as an Extension of Authorisation for Minor Use or 'EAMU'). Existing SOLAs will remain valid until they are reviewed, when they will be replaced by EAMUs, if considered appropriate. There are also the Long Term Arrangements for Extension of Use (LTAEUs), whereby growers can use on ornamental crops a product approved on an edible crop, subject to certain restrictions. These restrictions include the field of use (i.e. approval for use is needed on a protected edible crop to extrapolate to a protected ornamental crop). In addition, the active ingredient must not be on the list of active ingredients for which extrapolation is prohibited. The list of active ingredients for which extrapolation is prohibited is gradually increasing as products are granted (or refused) EAMUs for use on ornamental crops. The status of particular products can be checked through the HDC website via a special link to the LIASON pesticide approval database. Approvals and SOLAs / EAMUs are also listed on the CRD website (www.pesticides.gov.uk) and can be filtered by crop (select 'ornamental plant production' for HNS).

It is a legal requirement for growers to have either an electronic or paper copy of any SOLAs /EAMUs that they use and to comply with any conditions which may differ from the main label. Such off-label use is also entirely at the users own risk. Only pesticide products with UK MAPP numbers should be used in the UK. Growers should make sure that they keep up to date with changes in pesticide approvals, e.g. by using the following methods:

- Consult a BASIS-qualified consultant
- Growers should check that they receive weekly e-mails from the HDC as these will notify them of any new EAMUs.
- Information relating to product withdrawals / approval expiry or use-up dates is sent to subscribers of ADAS Hardy Ornamental Plant Notes
- All of the plant protection products being used on nurseries should be reviewed at least annually

The safe use of pesticides

Table 8.1 showed that most growers carefully consider whether or not chemical control is needed and are aware that some products are more harmful than others, to non-target organisms and the environment, by consulting product labels. It is a legal requirement in the UK to have knowledge of the safe use and storage of pesticides. Inspection of the application equipment is required by the EU Sustainable Use Directive (SUD). For example,

application methods include hand held applicators, knapsack sprayers and hydraulic sprayers with booms (tractor or ATV mounted). The SUD requirement for spray operators to be trained for the equipment type they use has been satisfied for some years in the UK. The UK Voluntary Initiative scheme ensures crop spraying equipment is regularly checked and certified to be in good working order.

- The HDC produced a DVD ('Spray Check'), which all nurseries should have received during 2011 on the safe and efficient use of plant protection products using hand held sprayers. All spray operators and nursery managers should view this to update themselves on techniques and best practice.

Pesticide resistance management

Pesticide resistance is when a pesticide fails to achieve the expected level of control of a pest, disease or weed, when used according to the label recommendation. The risk of resistance development is increased by the repeated use of the same pesticide or pesticides in the same chemical group. This leads to the selection for individuals in the pest population which are resistant to the applied pesticide. These resistant survivors then multiply so that the whole population becomes resistant. For example, the melon-cotton aphid, *Aphis gossypii*, which is common on some HNS plants is always resistant to carbamate pesticides such as pirimicarb (e.g. Aphox). Resistance tends to develop faster in protected crops as pest reproduction is faster due to the higher temperatures, pest populations are isolated and pesticide application is often frequent. Pests can often be resistant to pesticides in more than one chemical group. For example, the melon-cotton aphid is also resistant to the pyrethroid insecticides such as deltamethrin (e.g. Bandu). However, this aphid should be susceptible to pesticides in some other chemical groups, including pymetrozine (e.g. Chess) and the neonicotinoid pesticides such as acetamiprid (e.g. Gazelle).

Key action points for resistance management are:

- Use alternatives to pesticides i.e. cultural or biological control methods whenever possible
- Follow any resistance management guidelines on the product label. For example, only two applications of any neonicotinoid pesticide (e.g. Gazelle, Intercept) may be used on any crop.
- Do not rely on the same pesticide, or pesticides in the same chemical group, for control of any pest, disease or weed. Alternate pesticides from different chemical groups which have different modes of action, selecting pesticides that the target pest, disease or weed should be susceptible to.

- To help fungicide resistance management, select products formulated as mixtures, where both active ingredients are effective against the target disease, e.g. Switch (cyprodimil plus fludioxonil), used for Botrytis control.

Information on the mode of action groups and occurrence of resistant pests is available from http://www.pesticides.gov.uk/guidance/industries/pesticides/advisory-groups/Resistance-Action-Groups website. However, most HNS growers responding to this survey felt the website was not grower-friendly. The Action Groups are informal groups of UK experts for weeds, fungicides and insecticides (WRAG, FRAG and IRAG, respectively) and there are also International Action Committees. The British Crop Production Council, BCPC "Green book" (UK Pesticide Guide 2012) also lists mode of action groups together with the active ingredient at the top of each entry. From discussions with a grower during a case study, it seems likely that the information needs to be provided to growers in a much simpler format so that they can see at a glance which products should/should not be used in alternation.

- An easily updatable, electronic information sheet, one each for insecticides, fungicides and herbicides, should be produced for HNS growers, listing mode of action groups for the most common products used for control of the main pests, diseases and weeds. These sheets will allow quick and easy selection of the most appropriate pesticides to ensure good resistance management. The sheets would supplement the information on the principles of resistance management in the pesticide resistance factsheet for HNS growers that has been commissioned by the HDC and is in preparation by ADAS.
- These information sheets could also include lists of biological control agents and biopesticides that can be used for each pest or disease, as an alternative to using a chemical pesticide, as using biological control is a key strategy in resistance management.

Product selection for lower "risk"

Lower risk products include chemical pesticides and biopesticides of minimal or no hazard to humans, beneficial insects and the environment. Although a product may contain natural ingredients or micro-organisms found naturally in the environment, it is not necessarily safe to all non-target organisms and thus companies seeking registration for natural products as pesticides need to produce evidence of the type of activity expected from the ingredients and their metabolites. All pesticides also require results to be presented showing that they control the organisms that they claim to.

'Grey-area' products e.g. 'growth enhancers' and others that do not specifically claim direct pesticidal activity but infer an incidental pest or disease control benefit from, for example, enhanced disease resistance, do not require evidence of pesticidal activity to be submitted to regulators. Nor is it a requirement to list the ingredients and hazards to the operator or environment on the product label or to produce the material safety data sheet required for pesticides.

Integration of pesticides with biological control agents within an IPM programme

Some of the biological control agent suppliers (Biobest, Koppert) have databases on their websites giving information on the side-effects of pesticides on biological control organisms. This information is also available as a mobile app (Biobest) and for pda access (Koppert). Where available, the persistence of the pesticide against the biocontrol agent is included. For example, pesticides with long-term harmful side-effects include the pyrethroid insecticides such as cypermethrin (e.g. Toppel 100 EC) and deltamethrin (e.g. Bandu), which are harmful to most biocontrol agents for up to three months and are therefore incompatible with IPM. The databases use the IOBC (International Organisation for Biological Control) scheme for categorising the percentage mortality to beneficial species i.e. 'safe' (S) (0-25%); 'slightly harmful' (25-50%), 'moderately harmful' (50-75%) and 'harmful' (75-100%).

Table 8.2 lists some 'safe' pesticides that can be integrated with IPM (taken from Buxton *et al.*, 2006, but updated for those still available in 2012). Some active ingredients will be contained in products other than those listed. Many of these products were mentioned by HNS growers in this survey as commonly being used on their nurseries.

Table 8.2: Examples of 'safe' pesticides compatible within IPM programmes

'Safe' insecticides / acaricides
Bacillus thuringiensis (Dipel DF)
clofentezine (Apollo 50SC)
diflubenzuron (Dimilin Flo)
fatty acids (Savona)
maltodextrin (Majestik, Eradicoat)
pymetrozine (Chess WG)
spinosad (Conserve)
Lecanicillium lecanii (Mycotal)

'Safe' fungicides
azoxystrobin (Amistar)
iprodione (Rovral WG)
myclobutanil (Systhane 20EW)
propamocarb hydrochloride (Filex)
tolclofos-methyl (Basilex)

When using IPM, the programme for each crop should be planned in advance, including the selection of pesticides to be integrated for control of each pest or disease if required. The help of the biological control supplier or an IPM consultant should be sought, if needed. The least harmful and shortest persistence pesticide should be selected whenever possible, to avoid disruption of the IPM programme.

Biopesticides

Biopesticides include semiochemicals (such as pheromones), micro-organisms and natural chemicals (such as plant extracts). These products have many established uses for pest control and are increasingly being used by growers in the USA and mainland Europe (Gwynn 2009a, b). European Directives (SUD and the Water Framework Directive (WFD)) and increasing occurrences of pest resistance, health and safety concerns and market demand are also driving factors for the development of biological alternatives to pesticides.

The UK government has taken an active role in encouraging the development and implementation of biopesticides. However, they remain a very small part of the UK pesticide market: very few new active substances are registered each year and to date, only 16 bio-pesticide active substances are available in the UK as registered products and, of these, only a few are used in practice. Product gap analyses carried out for the HDC (Gwynn, 2009a & 2009b) show that more products exist that could be of benefit to UK growers. Three bio-fungicide products are currently used in UK horticulture (Contans WG, *Coniothyrium minitans*, Prestop, *Gliocladium catenulatum* and Serenade ASO, *Bacillus subtilis* QST713). The biopesticide Met 52, *Metarhizium anisopliae* strain F52, became available in the UK in 2011 and joins various entomopathogenic (and slug-parasitic nematode products), including DiPel DF, *Bacillus thuringiensis* var *kustaki*, Naturalis-L, *Beauveria bassiana* ATC74040, Mycotal, *Lecanicillium lecanii* (formerly *Verticillium lecanii*) and a virus and pheromone used in codling moth control. Citronella oil is registered as the herbicide product Barrier H (Gwynn, 2009a).

In 2010, a four-year HortLINK project known as SCEPTRE (HL 01109/CP 77) was set up in order to support UK approval of new products (label and off-label) and devise integrated pest management (IPM) programmes, i.e. utilisation of both chemical and biological products where appropriate against specific pests, diseases and weeds. The focus is on problems having the greatest financial impact on the profitability of crop production and where the likelihood of achieving a crop protection solution is good. As the ranges of major pests affecting edibles and ornamentals are similar, it is believed that ornamental growers will also benefit through more rapid identification of potentially useful novel products. In Year 1, a

total of 76 chemical pesticides, 57 biopesticides and 23 botanical pesticides were offered for screening against disease, pest and weed problems in soft and top fruit, field vegetable and protected edible crops.

The diseases being studied within the SCEPTRE project are powdery mildew, downy mildew, rust, *Botrytis*, *Phytophthora, Phomopsis*, *Pythium*, leaf and cane spots (*Alternaria, Didymella, Leptosphaeria, and Elsinoë*) and Mucor/Rhizopus. The pests selected are aphids, caterpillars, spider mites, thrips, capsid bugs, whitefly and cabbage root fly. New herbicides and alternative treatments for various common annual and perennial weeds are being examined. From the first year results, control was demonstrated against most of the pests and diseases, with a greater number of chemical rather than biological or other treatments showing efficacy. Further information can be found on the HDC website.

In the USA, more than 115 projects have been funded and more than 200 bio-pesticide clearances have been granted with help of the United States Department of Agriculture (USDA) under the Interregional Research Project Number 4 (IR-4) set up in 1963 to help with the registration of new, reduced risk pest control products for speciality crops. In the Netherlands, the 'Genoeg' project (translation: using plant protection products of natural origin more effectively) began in 2003 and includes co-financing of registration fees, extra trial costs and a bio-pesticide-specific regulatory body.

The European Network for Durable Exploitation of crop protection strategies (ENDURE) has been bringing together representatives of industry and scientists from several European countries to examine the use of chemical pesticides and other approaches to pest, disease and weed control. The website holds a large number of information documents and project reports related to ICM www.endure-network.eu. Policy Brief No. 3 of November 2010 gives a summary of biocontrol opportunities in the implementation of IPM (with "pest" referring to pests, diseases and weeds and "biocontrol" referring to agents against all these pests). The main findings were;

1. Biocontrol is one of the major IPM tools and should be further developed in Europe.
2. Biocontrol agents are usually specific and well used for certain crops, particularly covered crops, but there are significant opportunities for their use in other sectors.
3. Their specificity presents significant challenges for biocontrol producers, who do not benefit from the return on investment seen in the chemical control industry.
4. Increased use of biocontrols will require support from policy makers. In particular, support for research, education and extension, and in adapting the regulatory framework.

In December 2009, ENDURE produced a 234 page review www.endure-network.eu/endure_publications/deliverables of factors influencing the success or failure of biocontrol, and recommended orientation for new research and development projects (Deliverable DR4.7). They concluded that there were five key research needs;

1. To devise better strategies for the screening of biocontrol agents (i.e. faster screening and the pertinence of criteria leading to commercialisation).
2. To improve knowledge on efficacy-related issues (e.g. to recognise that biocontrol use will promote a biological balance rather than eradicate pests and diseases).
3. To promote multidisciplinary approaches to integrate better biocontrol with IPM (ICM) and other production issues (e.g. to integrate biocontrol with genetically modified plants).
4. To develop adapted delivery technologies (e.g. low pressure spray equipment)
5. To safeguard the durability of biocontrol (i.e. not to assume this will be higher than that of chemical control).

Three key issues were identified by ENDURE in terms of development;

1. The training of advisers and farmers.
2. The development and dissemination of Decision Support Systems (DSS).
3. The establishment of demonstration schemes and development of farmer' networks.

One reason for the lack of biopesticide development and uptake in the UK has been regulatory obstacles (Chandler *et al.,* 2008). The 'REBECA' study was an EU Commission funded project which reviewed the risks of biocontrol agents (biopesticides and macro-organisms), compared regulation in the EU and the USA and proposed alternative regulation procedures which would see EU data requirements made more specific to biopesticides (Anon, 2007) (currently the data requirement is the same for biopesticides and chemical pesticides). With the implementation of Regulation 1107/2009, the UK will be in the largest of three zones within Europe (central) and zonal authorisation should allow companies to gain a single approval from one authority that will cover the product in multiple member states. For protected crops there is only one zone.

"Grey-area" products

There are many 'grey-area' products and some examples are given below. They are often marketed as 'plant strengtheners' or 'invigorators' or function as inducers of resistance, also known as elicitors or defence activators. These include chitosan, salicylic acid analogues, living or processed fungal products and seaweed extracts. Pheromone products that are

used for insect monitoring rather than control are also included. All of them are currently exempt from registration requirements but their continued use under these alternative descriptions is becoming increasingly uncertain because of use within pest and disease control programmes.

The product Seagold is derived from shrimp and crab meal and seaweed, for incorporation in potting compost as an organic fertiliser. It is said to control nematodes and the viruses they carry. Seagold would increase the chitin content of the soil which may increases the population of bacteria, actinomycetes and fungi in the soil which produce the enzyme chitinase. Chitinase dissolves chitin, a constituent of cell walls of some fungi (not Oomycetes) and nematodes.

Biosept All Clear is a formulation of plant extracts and grapefruit oil that is claimed to "activate plant flavonoids". It is said to stimulate all plant growing areas so that plants treated before infection by pathogens or infestation by insects will be stronger and therefore less susceptible to attack.

TKO Phosphite 0-29-26 is a Phosphate / Potassium nutrient solution. Phosphorous acid (phosphonate or phosphite) is the anionic metabolite of the systemic fungicide aluminium tris-O-ethyl phosphonate (fosetyl-Al), which is the active ingredient of Aliette 80WG (facing withdrawal by 31 October 2012). Both phosphorous acid and fosetyl-Al are effective in controlling diseases caused by Oomycetes. Fosetyl-Al has been shown to reduce the severity of downy mildew (*Peronospora sparsa*) on boysenberry (Tate & Van der Mespel, 1983), rose and blackberry (O'Neill *et al.,* 2002). The mode of action is reported to be direct antifungal activity of phosphonate toward mycelial growth and also, perhaps, indirect stimulation of host defences. The compounds are systemic in both a basipetal and acropetal direction (Johnson *et al.,* 2004).

Orophyte is an example of a product sold as a supplemental foliar feed. The potassium in it is said to be important in speeding the healing of wounds, with its effect on plant vigour providing plants with increased disease resistance. The anti-evaporant and dispersive properties are said to reduce moisture build-up on foliage, enabling leaves to dry faster and leaving less time available for fungal spores to germinate. The product is also claimed to protect against pathogen penetration into damaged areas of the plant by drying and sealing sap-sucking insect punctures.

There are many microbial supplements and mycorrhiza for soil treatments to improve root health e.g. Revive, Wormcast, Rootgrow, EndoRoots. Some products are applied to the leaves instead or as well e.g. compost teas. HDC Project CP 82 is investigating whether phylloplane bacteria have potential to be used as biocontrol agents for aphids and other pests in strawberry (HDC, 2011). As well as microbial products there are various salts that have been used to control powdery and downy mildews.

Field studies on the biological control of bacterial pathogens have been carried out over seven years in France on the biological control of the bacterial blight of walnuts caused by *Xanthomonas arboricola* p.v. *juglandis* in comparison with copper derivates (which provide very poor protection). The elicitors Stimula (containing micronutrients B, Zn and N and amino acids) and Laminarine (algae extract) gave 25% reduction in nut fall. The efficacy of the Laminarine was improved substantially by mixture with the product Yeast BPAS (strain FZB 24) but the yeast alone was ineffective. The bacterial antagonist *Bacillus subtilis* MBI 600 in Subtilex provided 43% control (although Serenade *Bacillus subtilis* strain QRD132 gave no control). The best, 53% reduction, was given by PC10c containing *Pantoea agglomerans.* The application of Trichover (*Trichoderma viridie*) to the soil, or over the trees as for the other products tested, had no effect. The temperature in the orchard, rainfall and leaf wetness period had important effects on the disease development (Blum *et al.*, 2009).

Research searching for biocontrol agents for bacteria is ongoing. For example, *Pantoea agglomerans* strain 48b/90 (Pa48b) is a leaf epiphyte bacteria, which produces toxins and also acts by antibiosis, competes for resources with pathogenic bacteria and induces host plant defence. *In vitro,* it inhibits the growth of various *Pseudomonas syringae* and *Xanthomonas campestris* pathovars and *Agrobacterium tumefaciens* (Sammer *et al*., 2009). Other strains of *P. agglomerans* do not produce toxin; generally when considering the efficacy of biocontrol agents, the results relate to the particular strain used.

Oils from various plant species have been found to inhibit the growth of potato blight (*Phytophthora infestans*) in culture. These include lemon balm (*Melissa officinalis*), yarrow (*Achillea millefolium*) and coriander (*Coriandrum sativum*). Some essential oils such as from hyssop (*Hyssopus officinalis*) and thyme (*Thymus vulgaris*) have also been shown to reduce disease severity on potato plants using a 1:500 dilution in water. Caraway (*Carum carvi*) and dill (*Anethum graveolens*) did not reduce fungal growth in culture but did reduce plant infection severity. Peppermint (*Mentha x piperita*) caused inhibition in potato blight, *Phytophthora infestans* cultures but did not reduce disease severity on plants when applied pre- and post-inoculation (Quintanilla *et al.*, 2002). However, some effect of peppermint oil

has been found on downy mildew of brassicas (*Peronospora parasitica*) (Lawson *et al.,* 1998). A commercial formulation of mint oil (Funga-stop) is available in the USA to help control soilborne pathogens. Basil oil can inhibit growth of soilborne pathogens (Quarles, 2005). Rapeseed oil gave good control of lettuce downy mildew in field trials (Defra, 2002).

An extract of the Giant Knotweed (*Fallopia sachalinensis*) (formerly *Reynoutris sachalinensis*) is going to be marketed in the UK by Syngenta as the product Regalia (Shamash, 2012). According to a US Environment Protection Agency factsheet, when sprayed on plants the extract causes the plants to activate an internal defence system that prevents growth of certain fungi, especially powdery mildew and grey mould. The extract is approved in the USA for use on ornamental plants grown in greenhouses (Benmhend, 2005). Italian researchers have found that the extract sold as Milsana (not registered as a pesticide) reduced powdery mildew infection on cucumber by 50%. Sprays protected roses from powdery mildew, but were less effective than oils and soaps, and repeated sprays induced a greener and glossier colouration of the leaves, but they became brittle to the touch (Quarles, 2005).). Research in the UK in Defra-funded project HH3118TPC / HDC project PC 210 on protected herbs showed that weekly applications of Milsana ® plus a wetter checked powdery mildew development on mint, even under high disease pressure (Bennison & Green 2007).

8.3. Economic criteria for the selection of biological and chemical plant protection products used

The SUD states that the sustainable use of biological, physical and other non-chemical methods must be preferred to chemical methods if they provide satisfactory pest control. Biological control agents are available for most of the common pests of hardy nursery stock, with examples listed in Question 13 of the survey (Appendix 1). The cost of using these products in an Integrated Pest Management (IPM) programme instead of pesticides, or together with the minimal use of selective pesticides, varies with crop, nursery and individual conditions e.g. pest density, temperature and humidity. It is possible that certain crops or growing areas with particular pest problems could be targeted for the use of bio-controls, rather than the whole nursery, particularly if the grower is new to using IPM and needs to gain confidence. An example costing is given below for *Choisya ternata* in 3 L pots in a polytunnel.

There will be costs for both the time for carrying out the operations and the purchase of the products. Costs have been calculated per hectare, excluding VAT.

It is assumed that the crop is subject to attack from:

- Vine weevil
- Two-spotted spider mite (TSSM)
- Aphids
- Carnation tortrix / light brown apple moth (LBAM)

Annual cost of pesticide application to the crop

Table 8.3: Annual labour costs/ha incurred from pesticide application to *Choisya*

Activity carried out	**Hours duration / application**
Ensuring COSHH, EAMU, spray records are available	0.25 h
Measuring/mixing/preparing the sprayer	0.25 h
Post-application cleaning up	0.25 h
Applying a pesticide at high volume, using a trolley sprayer applying approx 1500 L water/ha (to point of run-off)	3.00 h
Total	3.75 h

Table 8.4: Annual cost/ha of insecticide/acaricide application (product & labour) on *Choisya*

Pesticides required (and reason for use)	**Product cost for 1500 L spray / ha**	**No. of applications needed per year**	**Annual cost of product / ha**	**Annual cost of labour / ha***	**Annual Total costs / ha**
Abamectin (Dynamec) for TSSM	£90	2	£180.00	£112.50	£292.50
Pymetrozine (Chess) for aphids	£45	1	£ 45.00	£ 56.25	£101.25
Indoxacarb (Steward) for tortrix/LBAM	£45	3	£135.00	£168.75	£303.75
Totals			**£360.00**	**£337.50**	**£697.50**

* based on spray operator @ £15 / hour

Table 8.5: Annual cost of growing media treatment against vine weevil per hectare of 3 L Choisya pots

Pesticide required (and reason for use)	**Growing media volume* / ha to be treated**	**Cost of media treatment @£25 / m^3**
Imidasect (vine weevil)	30 m^3	**£750**

*Based on 10,000 3 L pots / ha (pot thick)

Table 8.6: Annual costs of personal protective clothing for use with pesticides

Re-useable disposable Personal Protective clothing	Price (March 2012)
Spray suit (e.g. Microchem 3000)	£13.66
Nitrile gauntlets	£ 6.91
Box of face masks (e.g. FFP3 valved respirator)	£14.00
Total	**£34.57**

Therefore, the total cost for a season long chemical programme would be:

- **£1,482.07 / ha** (Pesticide product costs alone £1110 / ha excluding VAT)

Annual cost of biological control programme for the crop

Table 8.7: Annual labour costs/ha incurred by deploying three biocontrol agents

Labour cost to deploy biocontrols @ £15 / hour / ha*	Annual labour cost / ha of crop
5 applications of *Phytoseiulus* to prevent TSSM	£ 75
5 applications of *Aphidius colemani* for aphid control	£ 75
6 applications of *Trichogramma* for tortrix/LBAM control	£ 90
Total	**£240**

* Seasonal staff might be used at a lower cost

Table 8.8: Annual cost of purchasing biocontrol agents against TSSM, aphids and tortix per hectare of crop

Products required (and reason for use)	Product costs	Use rate	No. required /ha	Intro-ductions needed	Total annual cost
Phytoseiulus (TSSM preventative)	2000 @ £8.90	2/m^2	20,000	5	£445
Aphidius colemani (aphids)	1000 @ £17.45	0.1/m^2	1,000	5	£ 87.25
Trichogramma (tortrix/LBAM)	Pack of 10,000 @ £7.00	10/m^2	100000 (10 pks)	6	£420
Total					**£952.25**

Table 8.9: Annual cost of growing media treatment with Met 52 against vine weevil for a hectare of 3 L Choisya pots

Product required (and reason for use)	**Growing media volume* / ha to be treated**	**Cost of media treatment @£13 / m^3**
Met 52 (vine weevil)	30 m^3	**£390**

Therefore the total cost for the biocontrol programme would be:

- **£1,582.25 / ha** (Biocontrol products cost alone £1342.25 / ha excluding VAT) or,
- **£1,486.35 /ha** if less skilled labour (not spray operator certified) was used at £9/hr

Table 8.10: Summary of the annual cost / ha to control pests using either pesticides or biocontrol agents on a 3 L Choisya polytunnel crop

Conventional pest control		**Pest control by biocontrol products**	
Cost of pesticides	**PPE and labour***	**Cost of biocontrols**	**Labour cost***
£1 100	£372	£1 342	£240
£1 482		**£1 582**	

*Labour costs for both programmes calculated at £15 / hour

The biocontrol programme could work out cheaper, because if the earlier introductions of *Phytoseilus* worked well, further introductions might not be needed, but the "worst case " scenario has been assumed. Also note that Met 52 is less expensive for vine weevil protection than Imidasect.

N.B. these are example costings. Costs will vary according to choice of pesticides or biological control agents e.g. entomopathogenic nematodes could be used as an alternative to Met52.

8.4. The relative importance of various pest, diseases and weeds on HNS nurseries and the efficacy of the control products used

Growers were asked to comment on any particular pests, diseases or weeds that they found difficult to control on their nursery site (survey Questions 10, 15 and 21). The frequencies with which specific problems were mentioned are shown in Figures 8.6, 8.9 and 8.12 as a proportion of the total number of all pests, diseases or weeds reported.

In the survey, (Question 7), growers were asked to list the plant protection products (both chemical and macro/microbiological) they most commonly used and what pests, diseases and weeds they were used against, together with how effective (using a 1 to 5 index) each control measure was. For each of the four most commonly used pesticide, fungicide and herbicide products, growers reported the main target for each and how effective that product was against that problem. There were some differences in the level control achieved for particular types of pest, disease or weed and these are detailed in Figures 8.7, 8.10 and 8.13, respectively. It is not known whether growers achieving poor control were, for example, using an inappropriate product, application timing or technique.

Figures 8.3, 8.4 and 8.5 highlight which products were more commonly used, and were either found effective by growers against the specific target, or had given poor results (based on answers to Question 7 of the survey). The number of growers who said that a plant protection product either eliminated the particular pest, disease or weed problem or was very good (index 1 or 2), or conversely was poor/gave no or little effect (index 4 or 5) is shown. These results indicate that most products that are used give control of the target problem. Few reports were given of products that had been used and found unsatisfactory. It is possible that some such products had been tried but are not now used in management programmes because they proved ineffective and were thus not reported. Growers were also asked (in Questions 13 and 19) for specific information on any use of pest biocontrols (Figure 8.8) and biofungicides and natural products (Figure 8.11) and their satisfaction with the control achieved. Comments on the popularity and effectiveness of individual products have been given within each of the following sub sections on pests, diseases and weeds. Further information on the control given by different products and particular crop protection problems has been reported in the case studies of nurseries in Section 12.

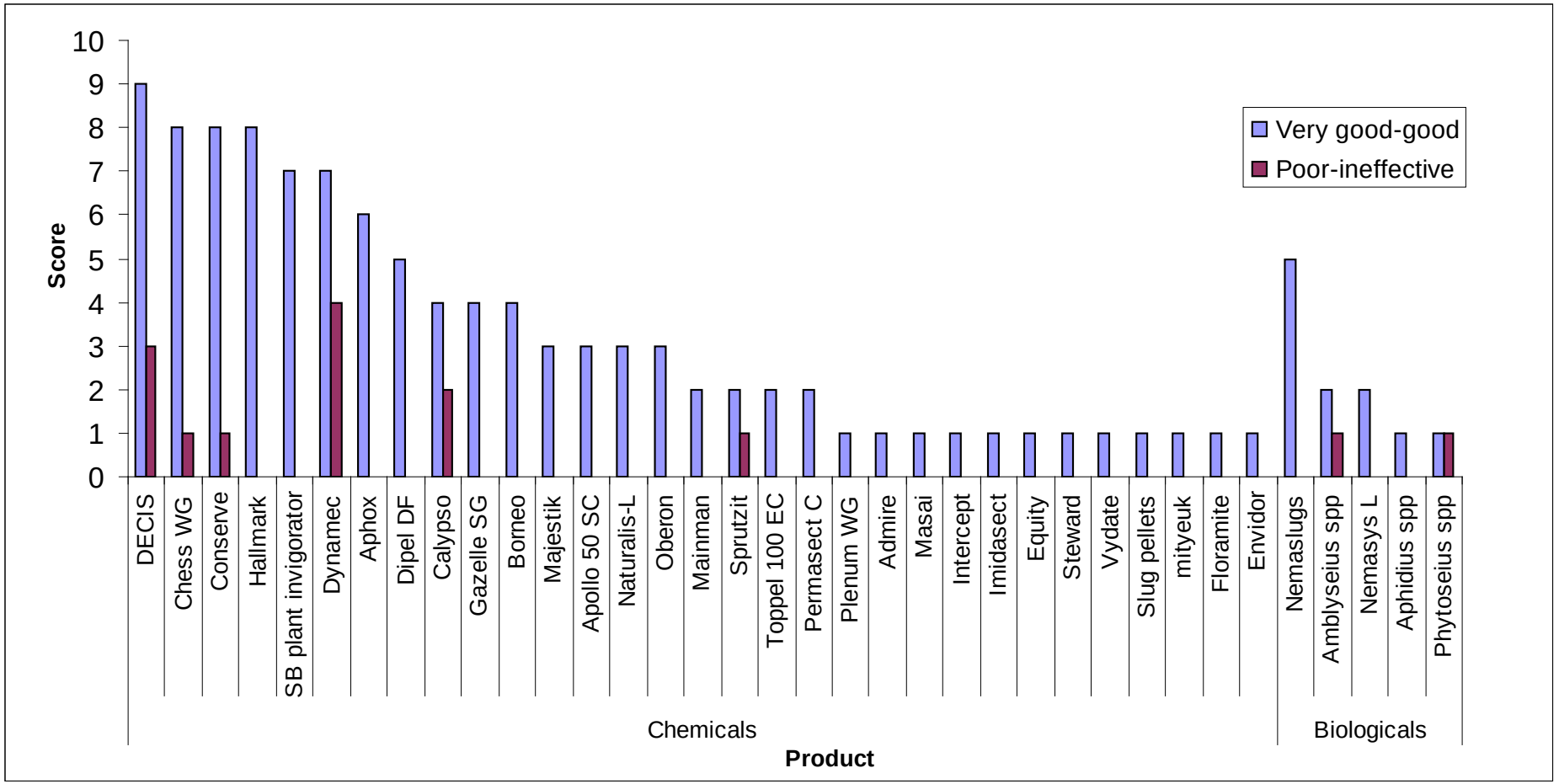


Figure 8.3: Pest control products most commonly used by 30 growers and the perceived efficacy of the product on one or more insect, mite or mollusc targets (Score = the number of rankings for a particular product i.e. a grower using it for more than one pest could give multiple scores)

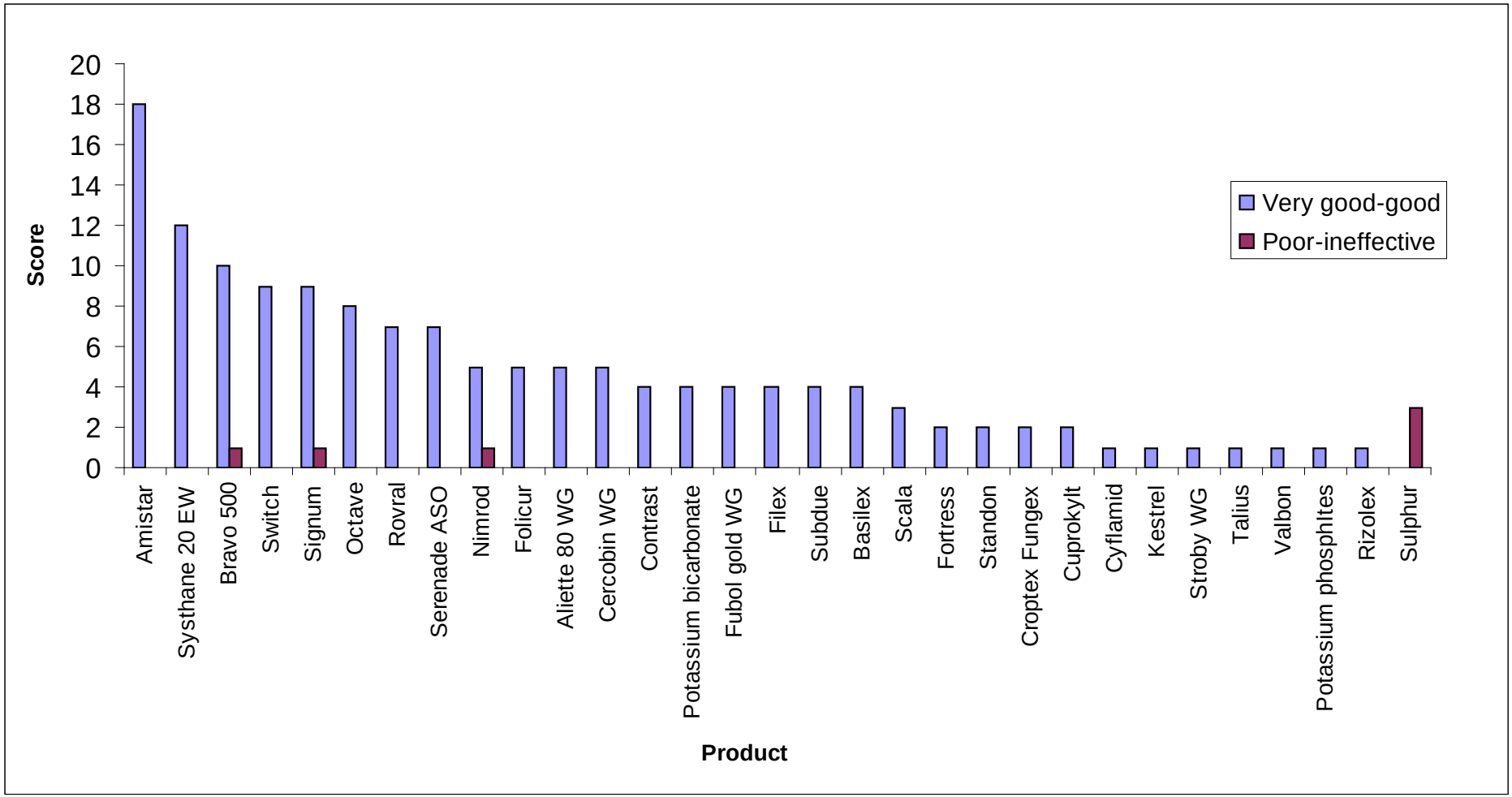


Figure 8.4: Disease control products most commonly used by 30 growers and the perceived efficacy of the product on one or more disease targets (Score = the number of rankings for a particular product i.e. a grower using it for more than one pathogen could give multiple scores)

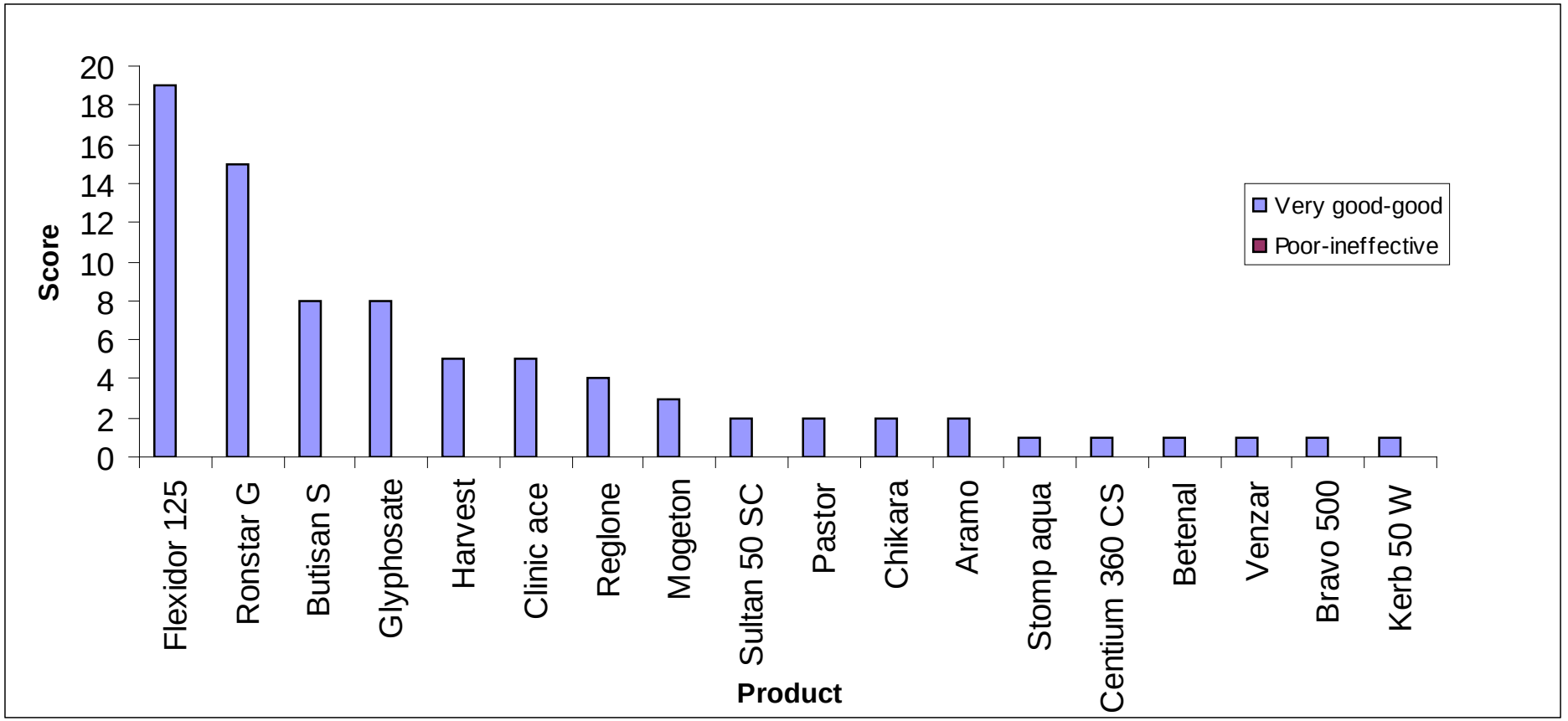


Figure 8.5: Weed control products most commonly used by 30 growers and the perceived efficacy of the product on one or more weed targets (Score = the number of rankings for a particular product i.e. a grower using it for more than one pathogen could give multiple scores). Products used by growers which contained glyphosate were Clinic Ace, Roundup and Roundup Biactive

8.4.1. The importance of different pests, and control success

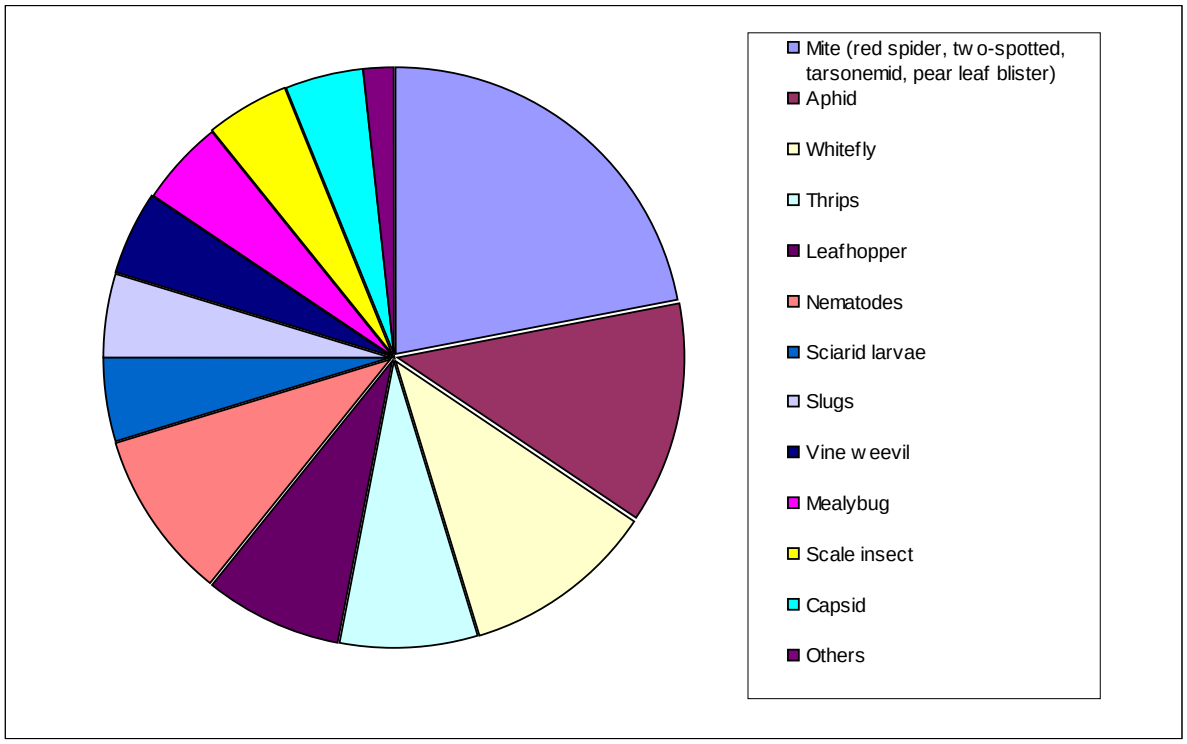


Figure 8.6: The relative importance of each of the pests reported by 30 growers as difficult to control based on the frequency with which they were listed under Question 10 of the survey.

Pest importance

Various mites, mainly two-spotted spider mite (*Tetranychus urticae*), formed nearly a quarter of the pest problems of growers (Figure 8.6). Aphids (unspecified species, but likely to include the potato aphid, *Macrosiphum euphorbiae,* and at least three other species), whiteflies (most likely the glasshouse whitefly, *Trialeurodes vaporariorum*), thrips (not specified by most growers, but likely to be mainly *Thrips tabaci* and, potentially, western flower thrips (WFT) (*Frankliniella occidentalis*), leaf and bud nematode (*Aphelenchoides* species) and leafhoppers (species not specified by growers) were the next most problematic with each causing around 10% of pest problems on particular crops such as herbs. All growers reported one or more pests as difficult to control.

Overall success at controlling each pest by all available products

Figure 8.7 shows which pests were reported to be either well or poorly controlled (Question 7 in the survey) based on the index of control success given by growers for the different products used against their four main pests. The number of respondents shown is greater than the number of growers as some growers commented on the efficacy of several

products to control the same pest. The overall efficacy of particular products, rather than the control by any product of particular pests, is shown in Figure 8.3.

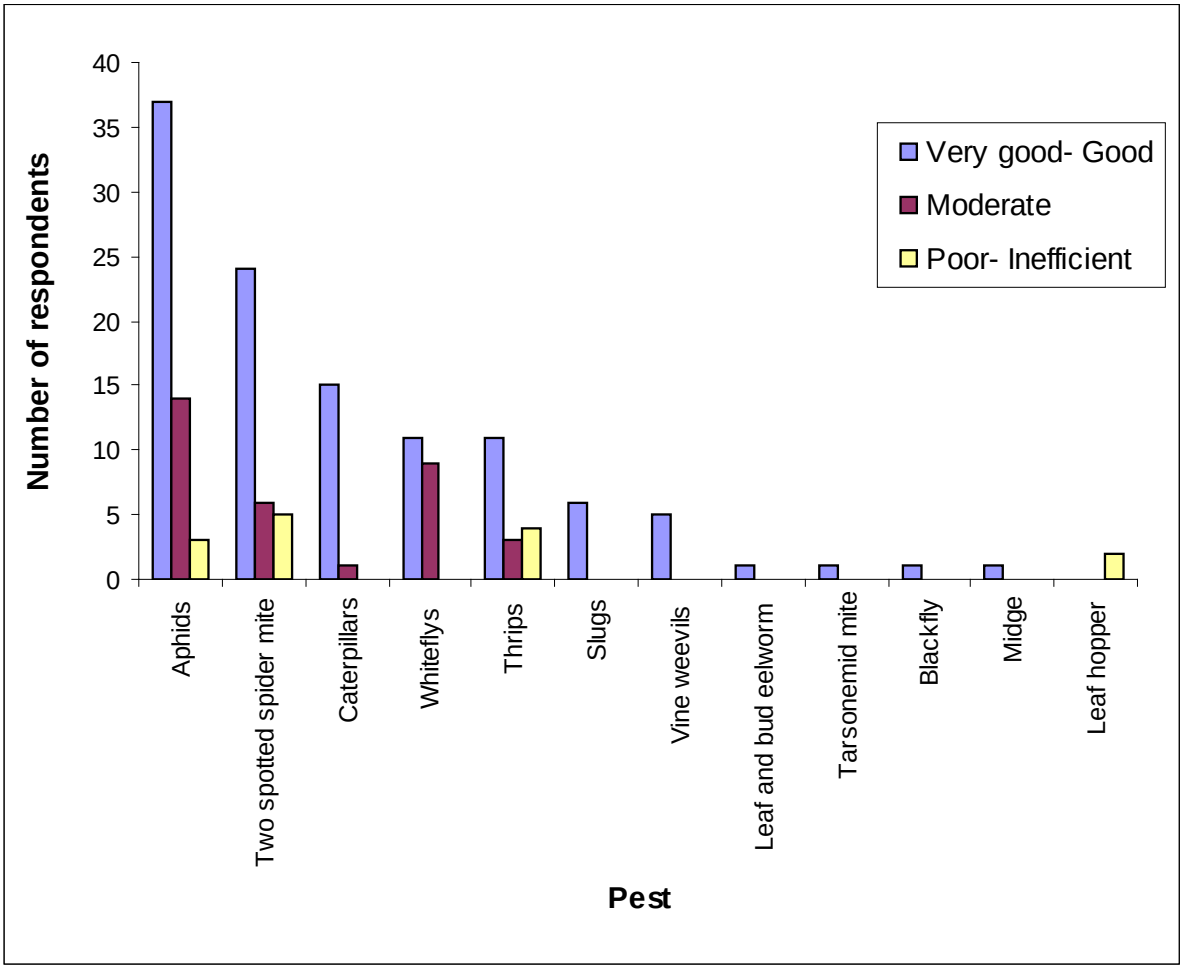


Figure 8.7: The efficacy of all crop protection products (chemical pesticides and biopesticides) used by the nurseries surveyed at controlling each specific pest

Chemical control measures against aphids were common and of the different products used by growers they were principally very effective (Figure 8.7). For two-spotted spider mites, thrips and aphids a few growers were not satisfied with the control given by the products they had used. Only a few growers included pests such as midge amongst their four main pest problems, but control was good, except against leafhopper.

Efficacy of individual plant protection products

A wide range of insecticidal / acaricidal products were used by growers (Figure 8.3). Those most commonly reported as being used and found very good or good (by nearly a quarter (seven) of the growers surveyed) were Chess WG (pymetrozine), Decis (deltamethrin), SB Plant Invigorator (physically acting), Conserve (spinosad), Hallmark (lambda-cyhalothrin), and Dynamec (abamectin). All of these products except SB Plant Invigorator (used for the

control of aphid, TSSM, thrips and whitefly) also had a smaller number of growers using them who were unhappy with the control given. Problems with the efficacy of Dynamec were reported by the greatest number of growers. Of the products used by three or fewer growers, most were found to give very good or good control e.g. Majestik (maltodextrin – a physically-acting plant extract), Mainman (flonicamid – a selective feeding blocker aphicide) and others with various other modes of activity. One out of three growers using it found Spruzit (pyrethrins + oil) found it to be ineffective. None of the effective products have a final use date within the next two to three years, but it is difficult to say beyond this with current uncertainties concerning e.g. listing on Annex I (more details on continuing approval dates are given in the next section).

- Comparative evaluation of the efficacy of the less used insecticides giving good control with those more commonly used by growers is required to ensure that the best IPM- compatible products are used on HNS

Pest biocontrol products and their effectiveness

Various pest biocontrol agents are used by HNS growers under protection, with information available to growers from suppliers' websites and an HDC Crop Walkers' Guide (Brough *et al.*, 2008). A Guide for HNS has recently been produced (Hewson *et al.*, 2012).

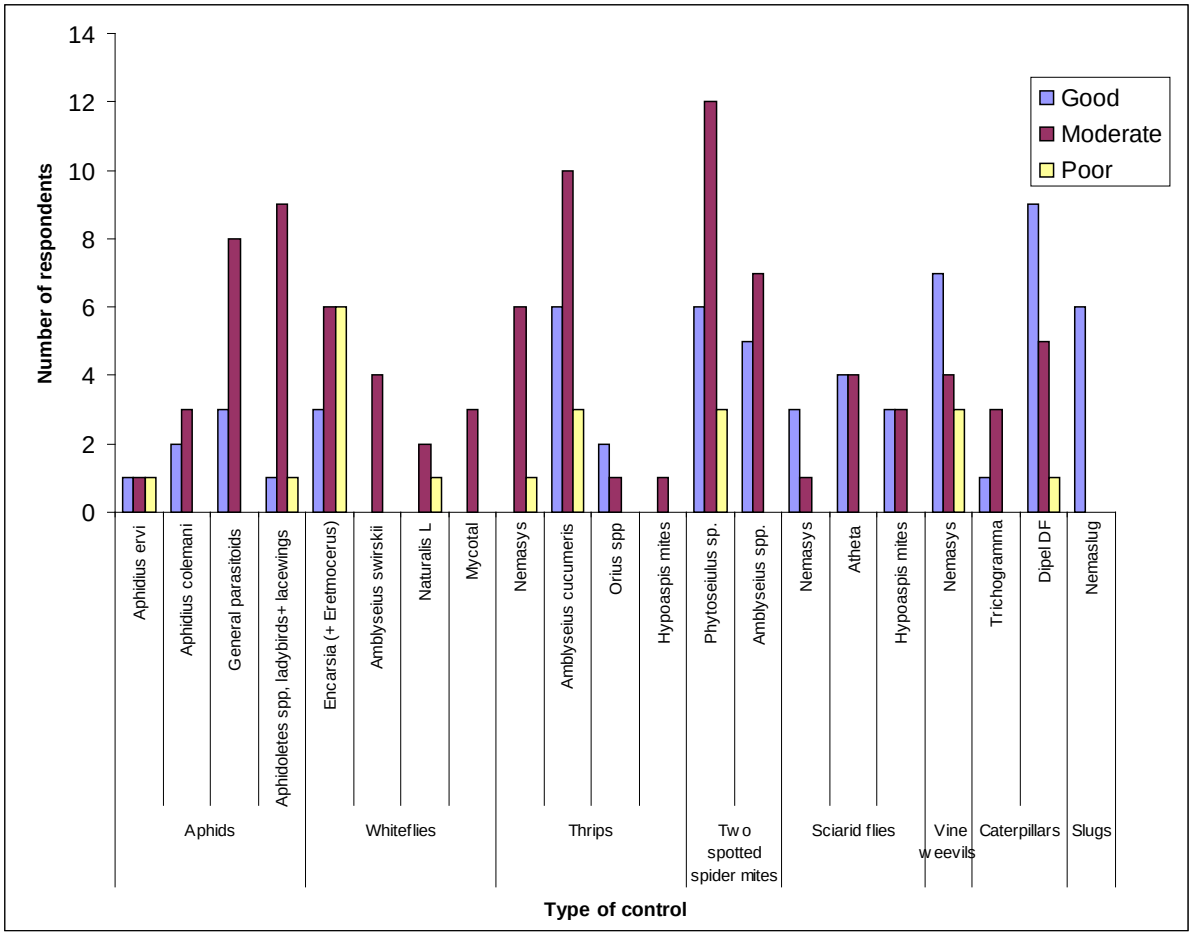


Figure 8.8: The effectiveness of pest biocontrol agents (parasitoids, predators and microbial) for specific pests as reported in replies to Q13 of the grower survey

A sample of the growers' replies to their use, or otherwise, of biocontrols is given in Table 8.11 with comments on the organisms' effectiveness at control. Figure 8.8 shows the number of growers using biocontrol products against one or more pests, with the maximum utilisation of biocontrol being against two-spotted spider mite, where it was used by 12 out of the 28 growers who responded to this question.

Table 8.11 shows that a number of growers used pest biocontrols widely and mostly successfully (e.g. nursery codes 1, 8, 13, 17 and 26). These nurseries were using either a biocontrol consultant and / or had regular visits from a general horticultural consultant. Biocontrol suppliers are less likely to visit smaller nurseries and nurseries of up to 1 ha are unlikely to fund the cost of a private consultant.

- Detailed regular advice on the nursery is key to successful uptake of ICM by growers

- There is further need for knowledge transfer activity to help dispel common misunderstandings about ICM, to cascade research results and to build confidence that ICM can work well

Table 8.11: Use of pest biocontrol products by a sample of 13 nurseries visited taken to represent a range of crop areas growing protected containers (PC), outdoor containers (OC) and/or field grown (F) stock together with sources of advice and grower comments on the levels of control achieved: *Poor, **Moderate or *** Good.

ID code & Crop type	Crop area & location	Crop monitoring & advice	Main pests	Biocontrols used	Grower comments on control achieved
ID 5 Herb-aceous	1 ha Mainly OC, rest PC.	No consultants used. Crops walked occasionally.	Vine weevil. Aphid. Caterpillar. Leaf & bud nematode.	Not used as pests rarely a problem and then pesticides used to spot treat	Not tried biologicals yet.
ID 28 Mixed HNS	1 ha Half F, rest PC & OC.	No formal crop walking system.	TSSM. Whitefly. Vine weevil. Aphids.	*Phytoseiulus*. *Encarsia*. Nematodes. Tried parasitoids.	* Tried, but not successful. * Almost useless. Not used, too labour intensive. ** Worked OK.
ID 29 Herb-aceous	1 ha PC, OC & F.	Twice weekly.	Thrips. Leaf & bud nematode.	Not used.	Tried in past but pest problems not enough to warrant usage.
ID 8 Mixed HNS	2 ha Mainly OC, rest PC.	Visits from biocontrol supplier and ADAS consultant monthly	Aphids. Whitefly. TSSM. Vine weevil. Caterpillar.	Parasitoids. *Encarsia*. *Phytoseiulus*. Nemasys L. Dipel DF.	** ** *** * ***
ID 27 Mixed HNS	3 ha PC & OC	Twice weekly ADAS consultant used	TSSM. Thrips. Caterpillar.	Phytoseiulus. *Amblyseius cucumeris*. None, Decis used.	*Tried, could not keep up with mite population. Used every 2 weeks, on all protected crops. Not compatible with biocontrol. Bios not fully effective but may be due to lack of skilled staff.
ID 26 Mixed HNS	4 ha PC & OC	Twice weekly plus regular visits by Biocontrol consultant.	Aphid. Caterpillar. Sciarid	Aphid parasitoids. Dipel DF.	** ***

ID code & Crop type	Crop area & location	Crop monitoring & advice	Main pests	Biocontrols used	Grower comments on control achieved
			larvae. TSSM. Thrips. Whitefly.	Nemasys. *Phytoseiulus.* *Amblyseius* *Encarsia*.	*** ** *** *** Wide variety of bios used and generally pretty successful.
ID 30 Mixed HNS	6 ha Mainly PC, rest OC	Daily. ADAS consultant used	TSSM. Aphids. Whitefly.	Not used.	Bios not used due to time pressures, also fast throughput on some crops.
ID 22 Mixed HNS some trees	6 ha More PC than OC	Daily by nursery staff in own areas. Biocontrol consultant plus ADAS consultant.	TSSM. Whitefly. Aphids. Vine weevil. Leaf & bud nematode.	*Phytoseiulus* widely used. *Encarsia* cards. Parasitoids. Nemasys L. No biocontrols available.	*** ** *** ***
ID 17 Mixed HNS	7 ha Mainly PC, rest OC	Twice weekly. Info from Biocontrol supplier.	Aphid. Caterpillar. Sciarid larvae.	Parasitoids. Dipel DF. *Tricho-gramma*. Nemasys	** *** ** ***
ID 4 Mixed HNS	7 ha, More PC than OC	Info from biocontrol supplier and ADAS consultant.	Thrips. Aphids. Caterpillar. Sciarid fly larvae.	*Amblyseius*. Parasitoids. Dipel DF Nemasys.	** ** *** *** Biocontrols costly and extra time needed to put them out.
ID 23 Tree & hedge	15 ha F	Twice weekly. A German consultant used	No major problems. Regular use broad-spectrum insecticides.	Not used.	Bios not suitable for outdoor production.
ID 1 Mixed HNS & trees	20 ha Mainly OC, F some PC	Biocontrol supplier visits regularly, less frequent visits by ADAS consultant.	Aphids. Whitefly. Vine weevil. TSSM.	Parasitoids. *Encarsia*. Nemasys L. *Phytoseiulus*.	*** * * ***
ID 13 Mixed HNS	24 ha Mainly OC, rest	ADAS consultant visits monthly, some visits by	Vine weevil. Aphids. Whitefly.	Nemasys L. Parasitoids.	* **

ID code & Crop type	Crop area & location	Crop monitoring & advice	Main pests	Biocontrols used	Grower comments on control achieved
	PC	Biocontrol supplier	TSSM.	*Encarsia*.	*
				Phytoseiulus.	**

8.4.2. The main pests and pest biocontrols used by growers surveyed and comments on the control reported to have been achieved by their use

The biological control products available to UK growers were listed in Q13 of the questionnaire sent to growers (Appendix 1) and grower use is summarised in Figure 8.8. An IPM guide is available on the pests and some of the biocontrol agents and other control methods (Buxton *et al*., 2006), although more products are now available.

Two-spotted spider mites and predatory mites

Most, but not all the growers with two-spotted spider mites (TSSM) on crops said they achieved good control with predatory mites (Figure 8.8). Thus, the problems reported with the control of this pest may be related to timings, release rates and predator species choice This indicates the need for more technical advice to growers, in order to improve the success of their biocontrol strategies. There may also be an opportunity for improved cultural measures such as the control of TSSM at the end-of-season prior to diapause and the quarantining of bought-in material. However, with HNS production schedules there is often much less opportunity for thorough cleaning of structures between crops than there is in other protected crops e.g. pot and bedding. The use of the predatory mite *Phytoseiulus persimilis* is already very common (21 of the growers surveyed) with species of *Amblyseius,* such as *Amblyseius californicus* used to a lesser extent for mite control. *Amblyseius cucumeris* were, however, commonly used for thrips control (19 of the growers surveyed).

Most of the growers who used predatory mites obtained good or moderate control with only three users of each reporting poor control. There are sometimes advantages to using more than one bio-control agent for control of a pest. For example, *Amblyseius californicus* can be used earlier in the season than *Phytoseiulus persimilis*, due to its tolerance of lower temperatures. However, *Amblyseius californicus* is currently only licensed in the UK for release in fully enclosed glasshouses, not poly tunnels, therefore it is not as widely used as *P. persimilis*. Experience from crop consultants has shown that some growers are not clear that acaricides only control certain stages of the pest's life cycle e.g. Dynamec does not kill TSSM eggs; therefore a repeat spray is required to kill the mites hatching from these eggs.

- Good control can be achieved using predatory mites and so growers using only chemicals to control TSSM should try some biocontrol control
- Improved grower knowledge is needed for the successful use of predatory mites (such as timing of introduction, release rates, distribution within the crop and possibly the use of fleece covers to aid movement between non-touching crops)
- Growers need to be aware of the advantages of using more than one bio-control agent for a pest if available and if this can improve control, rather than resorting to a pesticide.

Aphids and parasitoids and predators

Aphicides dominated the use of plant protection products against leaf pests, with a variety of products used (Figure 8.3) and control was generally stated to be very good or good (Figure 8.7). For aphid biocontrol, there are both parasitoids (parasitic wasps e.g. *Aphidius ervi* and *Aphidius colemani*) which were used by few growers and various predators (the predatory midge *Aphidoletes aphidimyza,* ladybirds and lacewing larvae) which were used by a third of growers (Figure 8.8).

One difficulty with using the parasitoids available at the time of the survey was that growers needed to identify the aphid species present in order to select the right parasitoid species, (not all parasitoids control all aphid species). As many nurseries grow a wide range of crops, many aphid species could occur. Not knowing which species is present can also result in control failures when using pyrethroids or products such as Aphox as resistant *Aphis gossypii* or *Myzus persicae* can be a problem.

In 2011 however, products became available containing a mixture of up to six species of parasitoids. These products give control of a wide range of aphid species, without as much need for aphid identification by growers. These products (initially the BCP Certis product Aphidsure mix) were initially tested in protected strawberry (e.g. in Horticulture LINK project HL0191) but have been used since in commercial crops of protected HNS and ornamental pot plants, where they have given improved control of a range of aphid species. The mix has also been shown to give promising control of two 'problem' aphid species on protected herbs (HDC-funded project PE 006). They are particularly suited for use in crops that are attacked by several species of aphid and in mixed cropping situations.

- A factsheet or website on aphid identification is required, with a table showing which crops the different aphid species are most likely to occur on

- Growers should consider using the parasitoid mixes available for more reliable aphid control where there is do ubt over the identity of the aphid species present or in mixed cropping situations
- Although growers are using a range of chemical active ingredients against aphids to manage pesticide resistance, the use of bio-controls should be increased to avoid resistance selection pressure.

Whiteflies and parasitoids and pathogens

Whitefly biocontrol was mainly reported as effective (Figure 8.8), with no adverse comments received from those using *Amblyseius swirskii* (relatively recently marketed in the UK). However, it should be noted that this predatory mite species is not native to the UK and thus is only licensed for release in glasshouses, not in polytunnels, thus its use in protected HNS is currently limited. Some growers obtained good control with the parasitic wasp *Encarsia formosa*, but nearly half the growers reported poor control. Whitefly control with *Encarsia* was reported as giving the poorest control of all biocontrol agents used. Control failures are likely to be due to too few parasitoids being released, too late, or to temperatures being too low for effective parasitism. Problems with biological control of whiteflies on protected herbs were investigated in HDC-funded project PC 178, and many of the factors discussed in this project will also be appropriate for protected HNS.

- Crop consultants and growers need to determine why biological control of whitefly is not as effective on some nurseries as on others
- ➢ Research may be required to improve the level of control given by bio-control products for whitefly on HNS

Researchers at the Ontario Ministry of Agriculture have monitored the use of tomato or aubergine trap plants amongst fuchsias and poinsettias respectively (both are common whitefly hosts), in combination with the parasitic wasp *E. formosa* www.omfra.gov.on.ca. Aubergines were found to be more attractive to glasshouse whitefly than tomato and proved to be a good trap/banker plant for whitefly and *E. formosa* respectively. However, the trap/banker plants need to be monitored carefully to avoid them becoming sources of pests, as aubergines are attractive and good host plants for many other pests such as TSSM, thrips and aphids. Thus appropriate biological control agents should be released to trap plants to avoid this problem.

Leaf and bud nematode

This pest spreads from plant to plant either during propagation, where cuttings are taken from infested mother plants, or in water-splash during overhead irrigation or rainfall. Therefore, cultural control methods include taking cuttings only from uninfested plant material, avoiding overhead watering and keeping susceptible plants under protection. There is currently no biological control option for this pest. HDC-funded project HNS 131 investigated alternatives to aldicarb (Temik) for control of leaf and bud nematodes and only oxamyl (Vydate) was found to be effective. Various non-chemical controls were tested, including garlic and extract of *Tagetes*. A literature review on alternatives to Vydate is currently being done in the HDC/HTA/EMRA-funded IPM Fellowship, CP 89. If any potential new chemical or non-chemical control measures are identified, HDC funding will be sought to test their efficacy on HNS. There has been investigation of the use of antagonistic fungi such as *Arthrobotrys dactyloides* to trap and parasitise plant pathogenic nematodes (Ellis *et al.*, 2008), but these live in soil and so would be ineffective against leaf and bud nematode.

- Research is required to find an alternative control measure to Vydate, that can be used for control of leaf and bud nematode within IPM programmes

Thrips biocontrol measures

Amblyseius cucumeris is the most widely used predatory mite for control of thrips. *Amblyseius swirskii* and *A. montdorensis* are also available for both thrips and whitefly control, but are only licensed for release in glasshouses, not in polytunnels, therefore their use in protected HNS is limited. The predators feed only on young thrips larvae. The majority of growers found them to give good or moderate control of their thrips. The species of thrips was not requested in this project survey, but was likely to be to be mainly western flower thrips, *Frankliniella occidentalis* (WFT).

Research in strawberries (HDC project SF 80) showed *Amblyseius cucumeris*, although successful in protected strawberry, was less reliable against WFT in open-sided 'Spanish' tunnels. Horticulture LINK project (HL0191) is investigating methods for improved IPM methods for WFT. This pest is becoming increasingly resistant to all approved pesticides on some strawberry farms. The research includes using the flower bug *Orius laevigatus* (which feeds on thrips adults and larvae) to supplement *A. cucumeris*, testing novel pesticides and biopesticides, and to investigate improved trapping and monitoring techniques. The latter techniques include using sticky traps together with the commercially available WFT sex pheromone lure or the plant volatiles lure attractive to all thrips species. Some of the results of this project will also be applicable to other crops including HNS.

Prevalence of different pest species

Although the most commonly mentioned pest problems during the survey were TSSM, aphids and whitefly, the list varied between nurseries. Bio-controls are available for all these pests and some growers said that good control was achieved on their nurseries. There are, however, a number of pests which still need to be controlled by pesticides and further research is needed to determine alternative or more effective actives. Work is particularly needed on an alternative to Vydate for control of leaf and bud nematode and on improved control of Phormium mealybug.

- Scale insects, capsid bug, phormium mealybug, leaf and bud nematode and woolly aphid all require further work on control methods
- Demonstration sites would be useful to allow commercial evaluation of ICM programmes throughout the year, including monitoring key crops. Any problems in pest or disease control could be investigated and methods sought to improve the success of the ICM programmes

8.4.3. The importance of different diseases, and control success

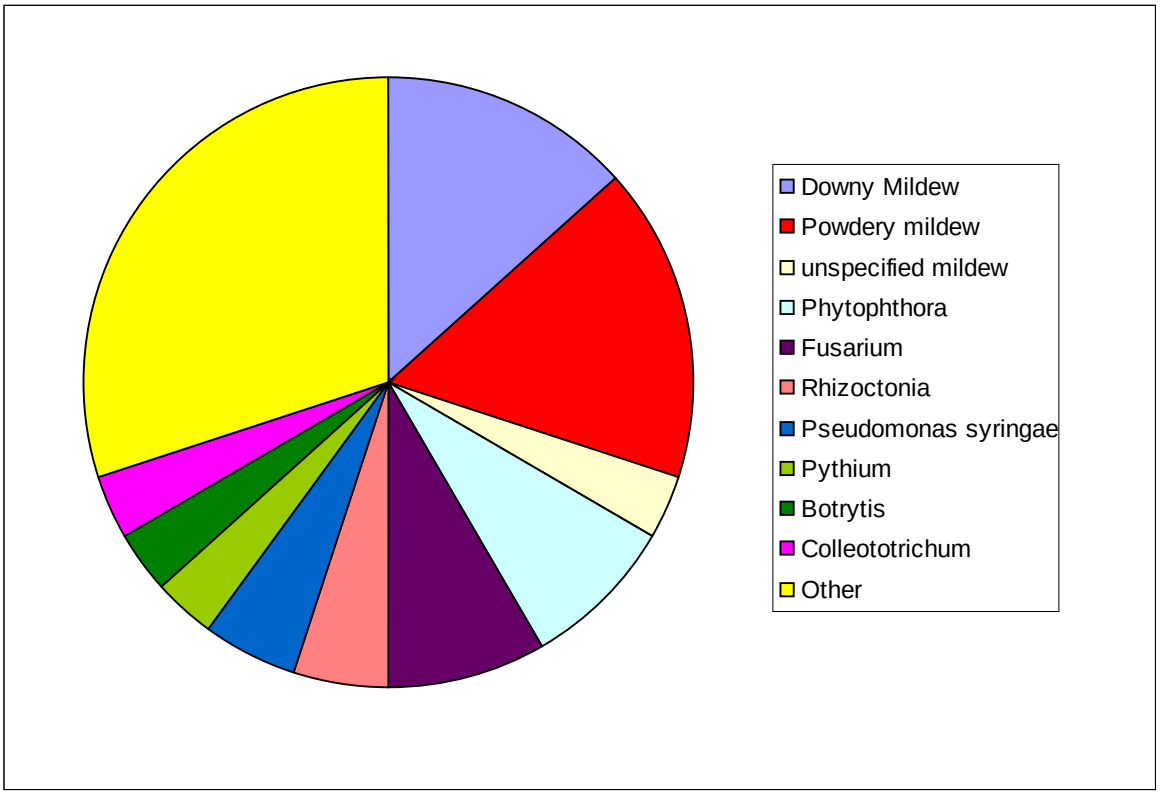


Figure 8.9: The relative importance of each of the diseases reported by growers as difficult to control based on the frequency with which they were listed under Question 15 of the survey.

Disease incidences

Powdery mildews caused 18% of the growers' disease problems. Downy mildews caused 15% of all the problems. *Fusarium* and *Phytophthora* root infections were each mentioned by 5 out of 30 growers and so formed 9% of growers' problems. *Botrytis* was only mentioned as a problem by two growers, possibly because control has largely been effective, either by chemical or cultural methods (Figure 8.9). The "other" fungi mentioned were each reported by once and comprised a wide range of leaf spots and a rust. Four growers said they found no diseases difficult to control.

Success at controlling each disease by all available products (chemical and biological)

The highest total number of products were used for *Botrytis* or powdery mildew control and found to be mainly effective (Figure 8.10). Downy mildew control was the next most frequently carried out, mainly successfully. Some of the commonly used products did not give good control of *Botrytis* and powdery mildew. Some products are known to be less

effective against some of the pathogens listed on the label and it is possible that the products selected were not the best choice for control of those pathogens. None of the other pathogens were poorly controlled by the products commonly used against them.

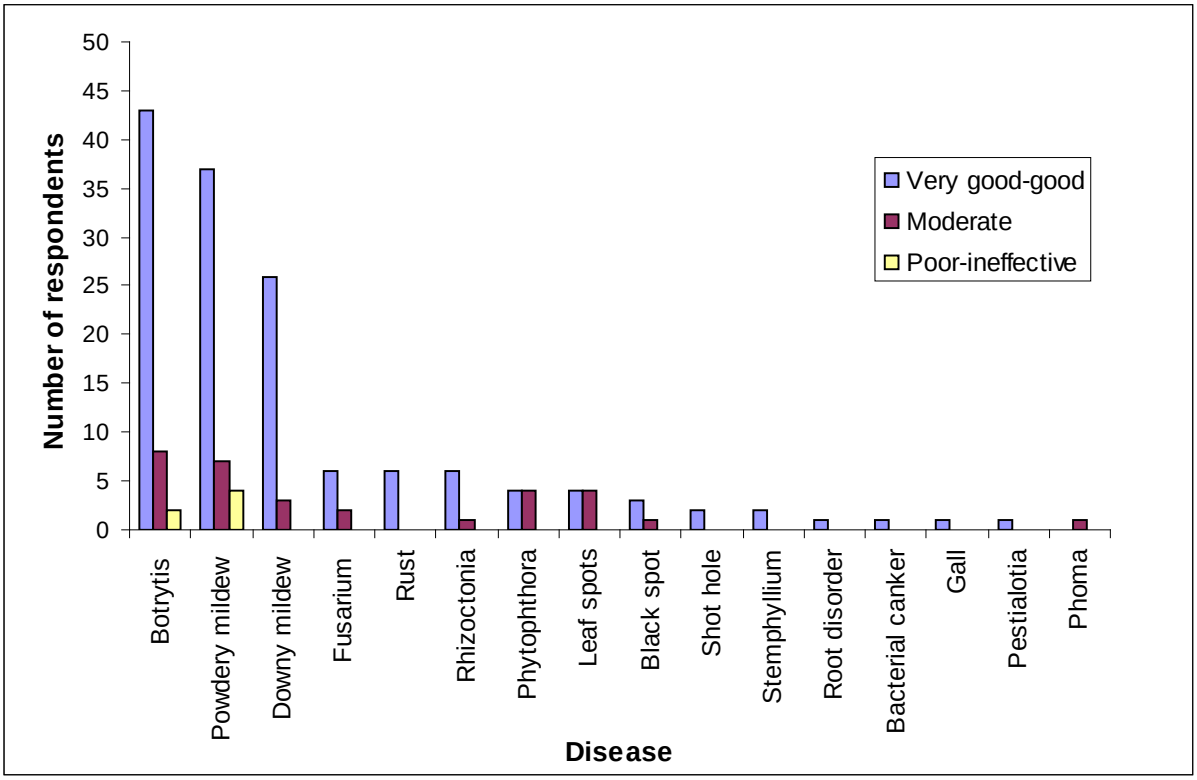


Figure 8.10: The efficacy of all crop protection products overall at controlling each specific pathogen.

Efficacy of individual plant protection products

Figure 8.4 showed the products that were used by growers to treat various diseases (as reported in Q7) and ranked by them for their effectiveness. This shows that the majority of products which have been used gave control of the problem they were used against, demonstrating that growers are already carrying out the SUD by selecting effective products and applying them correctly. The fungicide product most used and found effective (Figure 8.4) was Amistar, with 18 reports of it being very good/good and none of any poor control even though it was used for a broad range of problems (*Botrytis*, powdery mildew, downy mildew, rust, *Stemphylium* and *Colletotrichum)*. Systhane 20EW also had a high number of supporters (12). Fortunately, neither product has a final use date within the next few years Table 9.2). Other products found most effective by nearly a quarter (seven) of the growers surveyed were Rovral WG, Serenade ASO, Switch, Signum, Octave and Bravo 500 and of these Rovral WG and Bravo 500 are approaching current final use dates. Sulphur, a protectant fungicide, used by respondents against powdery mildew on oak, was noted as

ineffective, although other growers in answer to Q19 (Figure 8.11) reported principally good control by this plant protection product.

Natural and biocontrol products and their effectiveness against pathogens

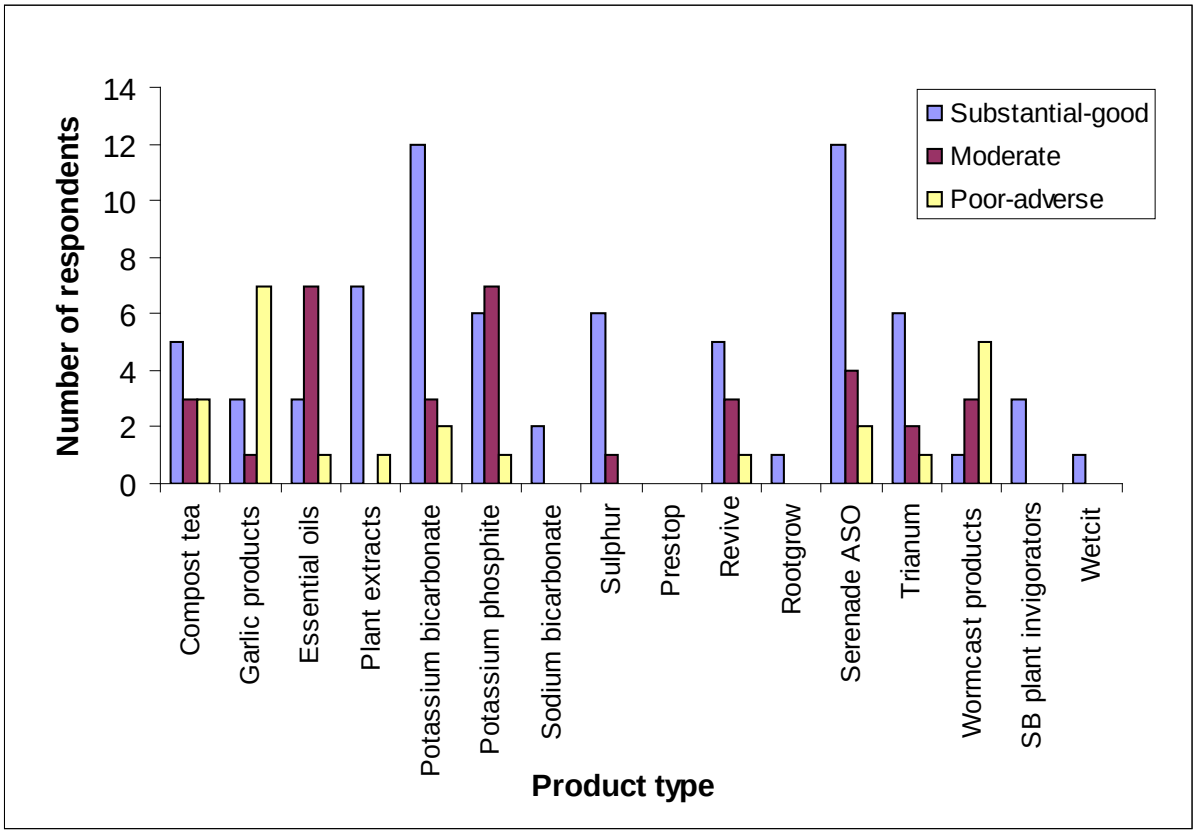


Figure 8.11: The number of respondents who used each product and their scoring of the effectiveness of each product.

Information on these “Grey-area” products was given in Section 8.2.

Products with the highest proportion of growers using them and having good efficacy were potassium bicarbonate (for powdery mildew control) and Serenade ASO (a strain of *Bacillus subtilis* with enzyme activity). A report has been produced for the HDC supporting the efficacy of potassium bicarbonate against powdery mildew (Tiffin and Green, 2005). Potassium bicarbonate and other inorganic salts were shown to be safe to *Amblyseius cucumeris* and *Aphidius colemani* (Pope *et al*, 2011). Serenade ASO has label recommendations as a foliar spray against *Botrytis*, and effectiveness known against powdery mildews, had given good results on 12 nurseries. The product has recent registration in the UK and independent replicated trial results will become available through HDC projects in progress such as SCEPTRE.

Potassium phosphite had been used by half the growers surveyed, and had give principally good effects, although not all use was totally effective. The product would have been directed at root rots, and application of the similarly acting fungicide fosetyl-aluminium can also be moderate if applied once infection has become established, or if drench volume is insufficient and/or the required repeat applications are not given.

Good powdery mildew control on roses was shown by both potassium phosphites and potassium bicarbonate (HDC Project 165). One potassium phosphite product has been submitted for Annex I listing. If successful, only potassium phosphite products registered as plant protection products could be used on crops.

Trianum (*Trichoderma harzianum)* was used by a number of nurseries and Revive (*Bacillus subtilis*) was used on 9 nurseries with most reporting some benefit. When microbial products used as growing–media drenches, such as Trianum and Revive, are incorporated into growing media, the activity of the micro-organisms may be affected by the conditions in which the plants are held. Comparative studies under controlled conditions could give a better idea of the effectiveness of these products.

Compost tea has been used by 11 of the 30 growers, with good effects reported by 5 of them (Figure 8.11). Compost tea is a water extract of either humic or green compost, brewed and then applied usually to the foliage but sometimes to the compost within 12 hours to provide nutrients and beneficial micro-organisms (bacteria and fungi) to the crop. The constituents used in the “brew” will differ between suppliers and the natural brewing process can result in different tea compositions and it is not intended as a curative treatment. Several growers had used both essential oils and potassium phosphate and achieved only moderate control. Growers visited who supported the use of compost teas said that its use had reduced their pesticide applications. There has been ongoing debate within the horticultural industry about compost teas, with a division into supporters and those who remain to be convinced of their benefit. The variability of the product has hampered the commissioning of replicated trials.

Sulphur (against powdery mildew) would also be recommended by several growers. A significant proportion of users of garlic products and Wormcast products reported either poor or adverse effects, but did not give any further details. In contrast, eleven growers had used essential oils and most had reported moderate improvements in plant health. Eight of the growers had used plant extracts and all but one reported substantial benefits. There appears to be potential for more growers to benefit from the use of essential oils and plant extracts on

their crops, perhaps in crop management programmes to reduce plant protection product usage.

- On the basis of reports by a number of growers, other growers should consider trying potassium bicarbonate and Serenade ASO
- There are several potassium phosphite products available and these might be worth comparative evaluation (subject to confirmation they are legal to use on crops).
- The beneficial effects of essential oils and plant extracts would be worth further investigation

8.4.4. The importance of different weeds, and control success

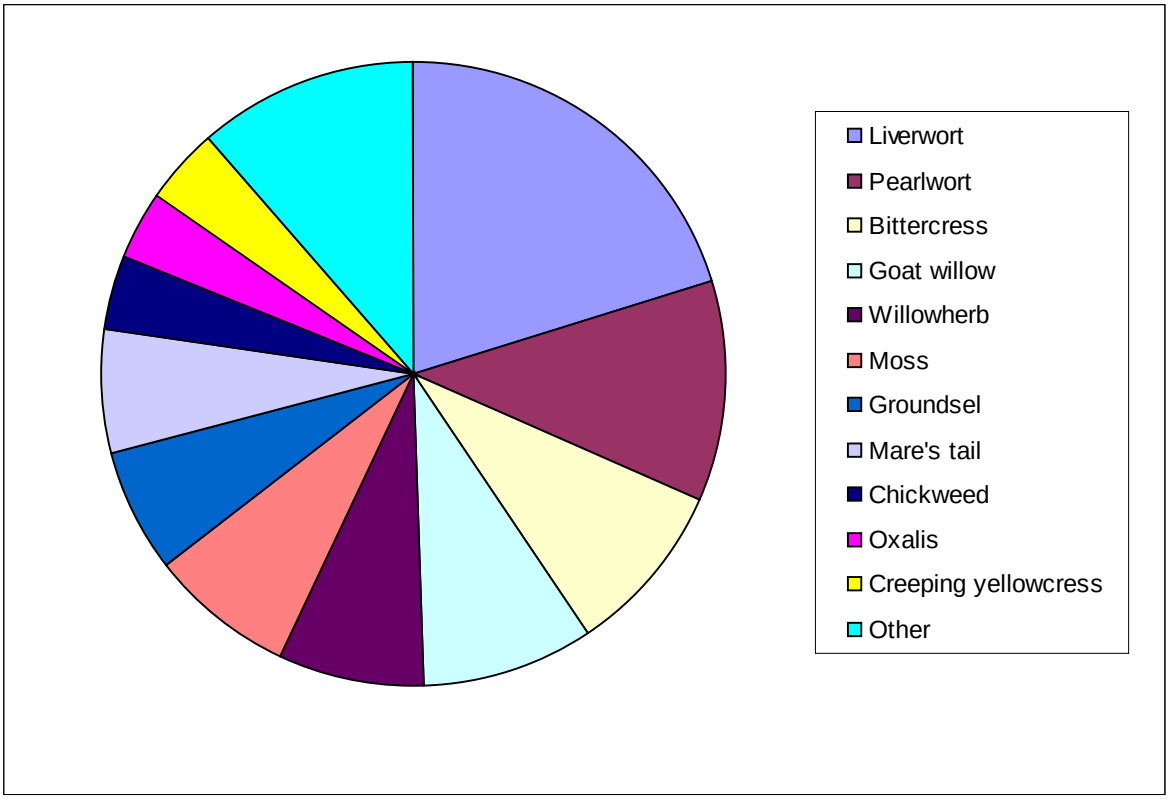


Figure 8.12: The relative importance of each of the weeds reported by growers as difficult to control based on the frequency with which they were listed under Question 21 of the survey

Weed importance

Liverwort caused nearly a quarter of all the weed control problems mentioned by growers (Figure 8.12). Liverwort growing on the surface of growing media is a major problem to the horticulture industry, affecting both protected and outdoor grown hardy nursery stock; the cost of hand removal of moss, liverwort and weeds at dispatch has been estimated at 4% of total annual production costs (Scott and Hutchinson, 2001), equating to £1,763 per hectare

based on 2008-9 figures (Crane and Vaughan, 2009). Zero tolerance of liverwort in certification schemes and a lack of approved chemical products make its control a technical priority for growers.

In HDC report HNS 175, investigations were carried out on the herbicidal effect of glucosinolate (GSL) hydrolysis products found in oil seeds on liverwort, and the suppression of liverwort growth by unknown biological or physical factors within certain growing media components. *Sinapis alba*, *Brassica napus* '00' and *Camelina sativa* significantly reduced liverwort establishment, whilst amendment of the growing media with composted wood fibre and sterilised loam significantly reduced liverwort establishment. *Sinapis alba* seed meal combined with bark to cover the surface of the growing media was particularly effective.

- The inclusion of a proportion of composted wood-fibre or sterilised loam in potting mixes could be tried by growers to aid liverwort reduction, particularly in short term crops

- Further work on seed meal and bark mulches across a range of plant species is required to clarify some issues of phytotoxicity
- Further work using composted wood-fibre and sterilised loam is needed in combination with seed meal mulches to see if dose rates of the latter can be reduced

From the survey, pearlwort and bittercress were the principal annual weeds causing problems, each comprising 10% of all the different weed problems. These are well known in the growing of containerised ornamentals. Moss, mare's tail and chickweed were also noted as causing problems. Moss establishment is favoured by the moist conditions in propagation and carried with the plants at potting-on. Mare's tail spreads in soils, aided by underground rhizomes which are difficult to control while the stem segments above ground can root if cut down.

One of the key weeds was goat willow, with 7 out of the 30 growers saying it was a problem for them. Its germination may be prevented by a well timed application of Flexidor 125, however, crop growth stages at this time may be susceptible to herbicide damage.

Weed control often goes awry when there is insufficient time to carry out essential hand weeding due to other pressures, e.g. despatch, and it is also an expense. Once weeds have

set seed within the crop, weed pressure will be higher. A campaign to “keep on top of” weeds can, however, pay off as weed pressure will be reduced over a period of years as seeds germinate and plants are removed before seeding. Only one grower said that he had no weeds that were difficult to control.

At one nursery it was said that the grower can recognise the source of the bought-in plants by the weeds which start to germinate on the pot surfaces. Many nurseries spend time at despatch hand-removing weeds and top-dressing with more growing media or bark to make the pots look clean. The timely and correct use of residual herbicide treatments is able to help control weed germination. This will ensure that when plants are sold they will not produce growth on the retail bench or allow weeds to contaminate landscape planting areas. A comprehensive weed control handbook is available from the HDC for growers with regular updates on the products available for use.

- Herbicide programmes should be determined for each crop with awareness of the spray window for the weed and the crop

Overall success at controlling each weed by all available products

None of the products commonly used by growers against weeds gave them poor control of their target species (Figure 8.13). The highest number of products in total that were described as being very good were used against hairy bittercress, with willowherb and groundsel given the next highest number of effective products.

There is a fear amongst growers of losing effective herbicide products owing to changes in regulations (see later section for more details), because physical control is often less effective and more costly in terms of labour. The number of new herbicide active ingredients being developed is also much smaller than that of insecticides and fungicides and has been reflected in the fewer herbicide products offered for testing under SCEPTRE.

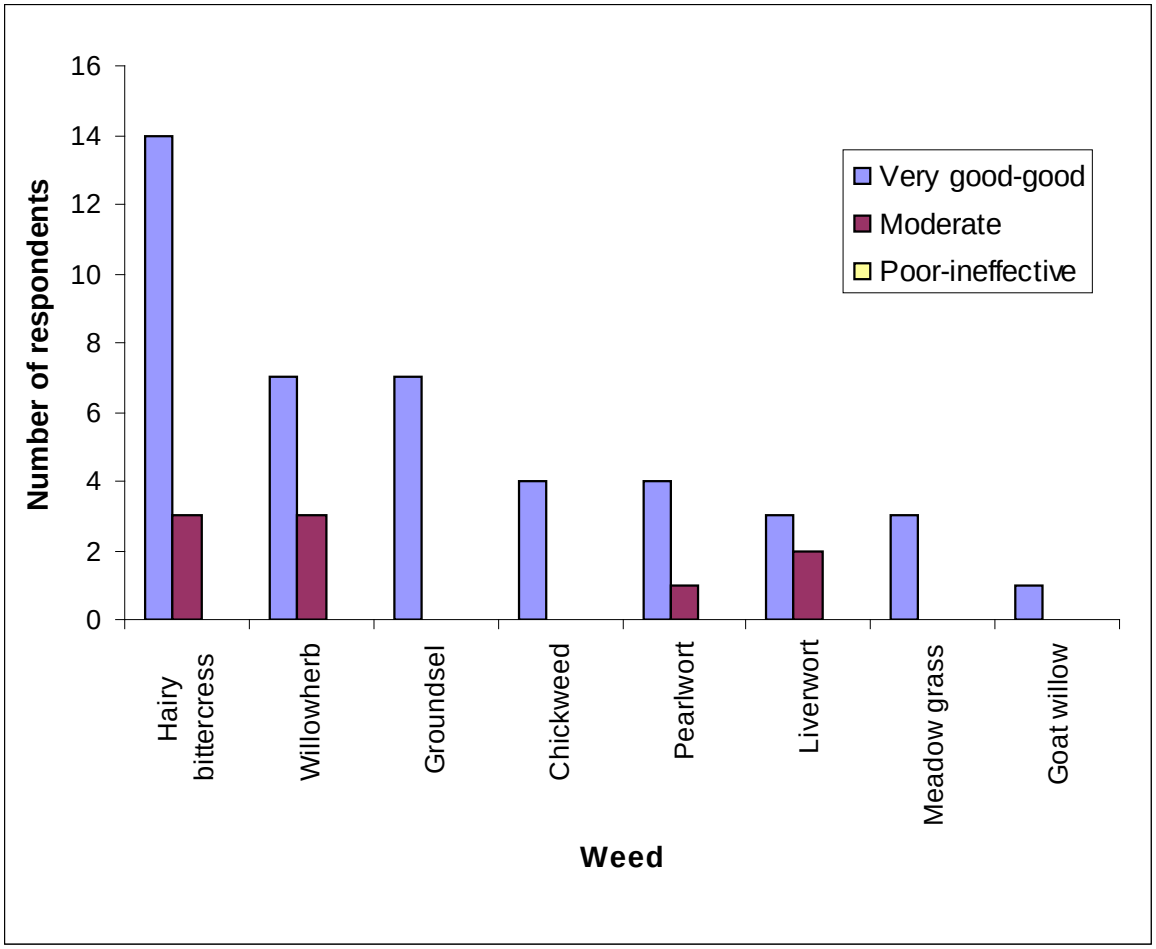


Figure 8.13: The efficacy reported by growers of all crop protection products (chemicals) at controlling each specific weed.

Efficacy of individual plant protection products

Figure 8.5 showed that the herbicides Flexidor 125 (isoxaben) and Ronstar 2G (oxadiazon) are clearly found to be very effective by growers. Butisan S (metazachlor) was also proving to be a good tool in outdoor situations, and restrictions on the number of applications of it (see below) will make its use difficult on ornamentals. Also, current approvals no longer permit use of metazachlor products on container grown HNS. No products were reported to give poor or non-existent control of any weeds, which suggests that growers have a good knowledge of the spectrum of weeds controlled by each product and select what they use according to their particular weed population. In terms of contact acting herbicides for non-crop situations, Harvest (glufosinate-ammonium) was used by a number of growers. A number of herbicide products have end-use dates (Table 9.3) and this is likely to make weed control more difficult for growers in the future.

Weed biocontrol products and their effectiveness

No weed biocontrol products were used by growers. Citronella is available in the UK against ragwort, but this weed is usually only a problem in pasture.

There is a lot of interest in bio-herbicides because of the environmental issues surrounding conventional herbicides and their diminishing availability. Most bio-herbicide products on the market contain plant extracts or bacterial enzymes rather than a micro-organism. The SCEPTRE HortLINK project includes bio-herbicides and all the candidates that might get registration in the UK have been identified and are to be screened for efficacy on annual and perennial weeds. Most are broad spectrum contacts. A review of non-chemical weed control methods (e.g. electrocution and germination enhancers) has recently been commissioned by CRD (PS 2809, Blake, 2012) and the report is likely to be made available to the industry.

Work with buckwheat has shown it to suppress weeds. As part of the EMT/HDC/HTA Fellowship Scheme to develop new scientists to work in the horticultural industry, ADAS have started work to develop new techniques of weed control in tree fruit, including work on electrocuting weeds, and suppression by buckwheat (see HDC website).

8.4.5. Pest, disease and weed control on aquatic ornamental plant nurseries

No responses to the current survey were received from aquatic plant growers, but an earlier HDC survey (HNS 145) of pest, disease and weed problems and their control in aquatic plant production (both submerged and marginal plants) (Wedgwood *et al.,* 2007) looked at this sector and the findings from this work for the plants grown out of water are in line with those of the other ornamental plant growers who responded to the 2011 survey.

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 sometimes infested some protected marginal and aquatic species. Whorled pond snails damaged 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 occurred on water lilies towards the end of the growing season. Water lily crown rot (*Phytophthora* sp.) was less prevalent that it was in the late 1980s when the source of infection was attributed to certain imports.

In terms of control measures, physical intervention was commonly used, including hosing larger plants with water, washing plants or roots, hand-picking snails and removing damaged leaves. Hygiene measures were commonly used, including the segregation of separate

batches of plant stocks and cleaning tanks and benches between batches. Natural products, e.g. garlic as a spray treatment to improve vigour, and barley straw in water to reduce algal growth, were also used. Biological pest control was sometimes used, e.g. entomopathogenic nematodes against vine weevil and parasitic wasps (*E. formosa*) against glasshouse whitefly in marginal plants. Chemical control of pests and disease was used on marginals where other measures failed.

One conclusion from this work was that that there should be greater use of slow sand filters (Pettitt and Hutchinson, 2005) for treating recirculating irrigation water on nurseries producing ornamental plants as the physical and biological filters are able to remove weed propagules (including algae), bacteria and fungi. The actual space and filter maintenance requirements require clarification with growers to improve the adoption of the system.

- More use should be made by growers of slow sand filters to remove pathogens from water collected from contaminated sources
- Demonstrations of slow sand filters, with information on construction and maintenance, needs be provided for growers who currently use or are thinking of using recycled water

8.4.6. Overview of the pest, disease and weed control being achieved by HNS growers

When considering growers' comments on the efficacy of plant protection products, thought needs to be given as to whether the products always achieved the required spray coverage, drench penetration, or biocontrol density. The HDC workshops on "Optimising Pest and Disease Control" aimed at optimising the application of both chemical plant protection products and biological control measures. These workshops included interactive demonstrations and have been popular with growers/staff who apply products on nurseries. The presentations from the workshops are available to growers on the HDC website, but comments from growers in this project have indicated that making time for "DIY viewing" is not easy and that participatory events are preferred.

In summary, individual growers state that they are using chemicals commonly against one or more of a range of pests, diseases and weeds and few report poor control. Many were using more than one product against a particular problem.

- Non-chemical plant protection methods including cultural and biological control should be the first course of action if effective methods are available.
- If a pesticide is required, growers should note its effectiveness and crop safety and any possible reasons for any poor control seen, in order to be able to select the most effective products
- Using a mixture of products, either in a programme or as fungicides with more than one active ingredient with different modes of action is a wise policy to reduce the chance of resistance developing
- Where the range of available active ingredients is being reduced for control of particular problems, then research on suitable alternatives needs to continue, with application for EAMUs if needed

From the summary of control measures carried out by growers (Figures 6.2 and 6.3), there is room for greater adoption of non-chemical control measures. Growers listed the problem pests (Figure 8.6), diseases (Figure 8.9) and weeds (Figure 8.12) on their nursery. Problem organisms are those that require repeated control measures, either because the problem seen is not completely eradicated by the control measures used or because there is a re-infestation or re-infection. The percentage of the 30 growers who mentioned each problem was calculated and these percentages have been presented in pie charts to show their predominance compared with other problems named by growers. Greater pest control is likely to be achieved when growers are confident about the stages of the life-cycle that require targeting by both the chemical and biological control agents.

- Growers need information on the pest life cycle stages which are controlled by various plant protection products and bio-control agents to help them plan IPM programmes

- Growers need information on release rates for bio-controls, how these should be adjusted according to pest density and when additional bio-controls should be used for improved control in the IPM programme

- Growers need regular updates on new bio-controls available for pests, diseases and weeds in agriculture and horticulture, and information on how to integrate them into their ICM programmes

- Workshops on optimising pest and disease control should be offered to growers across the country on e.g. on a three year cycle to cater for new staff, new products and improved application equipment

- Staff on each nursery need training in recognition and monitoring of pests and diseases and of biocontrol agents.

8.5. The development of ICM programmes for pest, disease and weed control on UK HNS nurseries

8.5.1. ICM programme development

- ICM programmes are already being used by the major growers of protected HNS in the UK. These programmes are constantly developing as a result of research to answer specific pest, disease or weed problems or gaps in knowledge within ICM. This research is done on a range of crops in addition to HNS, and many of the results are applicable cross-sector.

- HDC and Defra (either individually or together in Horticulture LINK projects) have commissioned a large number of research projects investigating non-chemical control methods for the management of pests, diseases and weeds in various crops, and summaries are available on their websites: www.hdc.org.uk and www.randd.Defra.gov.uk (on the latter website, search e.g. on 'biological control').

- The SCEPTRE project is an example of a current co-funded HDC/Defra/Industry project. This project will deliver applied research to help secure both label and off-label approvals for new and safer pesticides and biopesticides, and develop sustainable IPM programmes for use on edible crops. Many of the results will also be applicable to ornamental crops including HNS, but further development may be needed before adoption on ornamentals. See www.hdc.org.uk/sceptre.

- Other non-chemical methods have been developed by private companies such as biological control suppliers, and details are available on their websites.

- Relevant research on biological control methods has been done in various crops in other countries and a good source of information on these projects is the IOBC (International Organisation for Biological Control) website: www.iobc-wprs.org Detailed reports are only available on-line to IOBC members, however the biological

control suppliers and many IPM consultants including ADAS are IOBC members and thus have access to these reports.

- European research on ICM/IPM has often been carried out at universities, and the knowledge transfer route to advisors and growers is not always strong. 'ENDURE' (European Network for durable exploitation of crop protection strategies) gives information on several hundred ICM research projects summarised by ENDURE which have been carried out in the EU on pests, diseases and weeds on edible horticultural and arable crops, and states whether the results are "ready to use" on the crop which was experimented on. See the ENDURE website http://www.endureinformationcentre.eu/. The findings of Deliverable DR4.7 reviewing the factors influencing the success or failure of biocontrol and the recommended orientation for new research and development projects (ENDURE, 2009) were reported earlier in the current project (Section 8.2).

8.5.2. Guidelines on the adoption of ICM measures

When adopting ICM techniques, it is important to consider all pest, disease and weed problems that are likely to occur during the production of each crop and to plan an ICM programme for each crop, including the use of cultural and biological control methods together with the minimal use of compatible pesticides. New methods developed in research can then be integrated into the programme as required. Help from an ICM consultant is often needed, particularly for growers who are less experienced in techniques such as biological control. Information on putting together programmes is available from biological control suppliers and consultants, and also in factsheets, booklets and websites. Examples of these are given below:

- Integrated Pest Management in Protected Ornamental Crops – A Best Practice Guide for UK Growers. A booklet was produced by ADAS with Defra funding, in 2006. This booklet was well-received by growers but is now out of print. Funding the production of an updated booklet or website would be justified.
- Best Practice Guidelines for Integrated Management of pests and diseases on protected herbs, see www.hdc.org.uk/herbs/ . This website was the final output of a Defra/HDC-funded project, HH3118TPC / PC 210. Much of the information is relevant for pests and diseases of HNS. Information is given on recognition of the major pests and diseases of protected herbs (many of which are the same as those of HNS), details of biological control methods, monitoring techniques and integration of pesticides.

- A robust IPM programme for organic tomato – HDC Factsheet 14/10. Some of the information in this factsheet is also relevant to HNS.

Some research projects in the UK and overseas have been done specifically on HNS but many others have been done on other horticultural crops. Some of these methods could be used by HNS growers immediately, but like the results of SCEPTRE, many would need further development work before they could be reliably adopted on HNS. Examples of some recent research projects developing ICM on HNS or on other horticultural crops are given below, in relation to specific pests, diseases and weeds.

8.5.3. Research on biological aphid control

- *Potential of a new mix of six aphid parasitoid species*. BCP Certis/grower trials tested this mix against a wide range of aphid species on protected HNS, strawberry and ornamental pot plants. Building on these results, HDC-funded project PE 006: "Protected herbs, improved biological control of 'problem' aphid species" has tested the potential of the mix against the hawthorn-parsley aphid and mint aphid. The mix is also being tested on tunnel-grown strawberry in Horticulture LINK project HL0191, "Minimising pesticide residues in strawberry through integrated pest, disease and environmental crop management". The mix is now being used successfully on protected HNS by several UK growers. Development work would be needed to test the method on outdoor HNS; however the mix will be tested for control of aphids on outdoor lettuce in 2012, in the current HDC/HTA/EMRA funded IPM Fellowship project CP 89.

- *Management of the risk of hyperparasitsm of aphid parasitoids*. The risk of hyperparasitoids attacking parasitised aphid 'mummies' was first identified on outdoor HNS in MAFF-funded project HH1812 (1995-1997). More recently in HDC-funded project PC 295b, "Sweet pepper: further development of IPM solutions for aphid infestations" is investigating the problem of hyperparasitoids threatening biological control of aphids in protected pepper crops. The incidence and species of hyperparasitoids is also being studied on various horticultural crops including protected HNS, strawberry and outdoor lettuce in the HDC/HTA/EMRA funded IPM Fellowship project CP 89.

8.5.4. Research on biological sciarid and shore fly control

- *Use of a grower DIY system for rearing the predatory beetle Atheta coriaria*. HDC-funded projects PC 239, PC 239a and PC 261 investigated the use of an on-nursery system for rearing *A. coriaria* for reduced cost biological control of sciarid and shore flies in protected ornamentals, herbs and celery. HDC Factsheet 06/10 summarised the method and research results. Several growers of protected HNS are now using the system, particularly in propagation houses.

- *New approaches to microbial control of insect pests in protected crops and their interaction with waste-based growing media.* This Horticulture LINK funded project, HL 0193 investigated the natural infection of sciarid and shore flies with entomopathogenic fungi, and the comparative attractiveness and suitability for peat-alternative growing media for sciarid and shore fly development. The research was done on protected ornamentals and herbs but the results are useful for growers of HNS. Further development work is needed to identify methods for encouraging the natural fungal infections and to identify growing media that do not encourage fly problems.

8.5.5. Research on biological vine weevil control

- *Use of entomopathogenic nematodes and an entomopathogenic fungus to control vine weevil larvae.* The Horticulture LINK funded project, HL0171 has investigated a strain of the entomopathogenic fungus *Metarhizium anisopliae* for control of vine weevil larvae in soft fruit and hardy nursery stock crops. This strain is now marketed as a granular formulation (Met52), which can be incorporated into substrates or soil before planting. Further work has indicated that Met52 may be combined with entomopathogenic nematodes, *Heterorhabditis bacteriophora* or *Steinernema kraussei*, for improved control of vine weevil larvae. Entomopathogenic nematodes are already used widely on their own by growers to control this pest. The different entomopathogenic nematodes currently available will be tested for comparative efficacy against vine weevil, with or without Met52, in the current HDC/HTA/EMRA funded IPM Fellowship project CP 89.

- *Exploiting the behaviour of adult vine weevil*. CRD-funded project PS2134 investigated the potential of exploiting vine weevil behaviour to achieve control through use of an entomopathogenic fungus. This approach is based on the fact that adult vine weevils aggregate in refuges during the day. By placing artificial refuges

containing spores of a suitable entomopathogenic fungus within the crop it may be possible infect weevils using these refuges and to spread the pathogen through the weevil population. Results from HDC-funded project SF/HNS 127 may make this approach more effective by identifying and synthesising the vine weevil aggregation pheromone.

- *Evaluation of insecticides for control of adult vine weevil.* HDC-funded project SF/HNS 112 compared the efficacy of several insecticides in controlling adult vine weevils under laboratory and semi-field conditions. The project identified two insecticides, indoxacarb (Steward) and pymetrozine (Chess) that gave useful control of adult vine weevil. These insecticides are compatible with biological control agents used for control of other pests in IPM programmes, unlike the 'standard' pyrethroid insecticide, lambda-cyhalothrin (Hallmark).

8.5.6. Research on disease control

- *Molecular diagnostic techniques for the improved detection of soil-borne pathogens.* The rapid detection and quantification of pathogens such as *Verticillium* spp. and *Phytophthora* spp. is important, allowing various control measures before a crop is planted such as seeking another site, containerisation, soil sterilisation, or the substitution of a less susceptible variety. Recent HDC-funded research (SF 97) developed quantitative polymerase chain reaction (abbreviated to QPCR) tests that enabled the detection and quantification of *V. dahliae* and *V. albo-atrum* DNA in soil. Although the research was carried out for strawberry growers, this technique could prove useful for field grown trees. The use of Terminal Restriction Fragment Length Polymorphism (T-RLFP), as utilised in HDC Project PC 281, allows detection and quantification of a wide range of species of micro-organisms and this could be utilised in research on developing optimum symbiotic relationships in the rhizosphere or determining the microbial population in situations of replant sickness.

- *Utilisation of biopesticides.* The SCEPTRE project CP 77 has included a number of biopesticides put forward by companies seeking information on product efficacy against selected pathogens. The first year results are due for release to HDC members, but the products will not be named in order to respect the confidentiality of the companies. There will be a further two years of testing and it is anticipated that products to control pathogens common to both edible and ornamental crops will be found from this work.

- *Disease forecasting.* The availability of relatively inexpensive electronic in-field weather recording devices has made the utilisation of forecasting models based on the conditions in the crop (not a remote station) more realistic. Work on raspberries, strawberries and roses (HDC Projects SF 74, SF 94 and HNS 173, respectively) have already proved that fungicide applications can be reduced when conditions are not right for disease development. In the long-term, this data might be coupled with automatic molecular detection of air-borne spores, or the use of e-noses to detect volatiles produced by crops in the early stages of infection, rather than requiring field inspections of symptoms.

8.5.7. Research on weed control

- *Liverwort and weed control using novel techniques*. The potential for oil seed meals as a control for liverwort was identified in HDC Project HNS 93c. HDC Project HNS 175 used both incorporated treatments and mulches and showed effective liverwort control following mulch application of *Sinapis alba* seed meal (England, 2011). HDC Project CP 86 sowed groundsel and annual meadow grass seeds both above and below the mulch and obtained control, suggesting the seed meal may act by e.g. an allelopathic affect of the glucosinolates in the meal rather than by physical suppression (Atwood, 2011).

- *The control of perennial weeds using an electronic weeder*. This has been investigated as part of the SCEPTRE project CP 77. Operation of the hand-held weeder at 3.5 kV and travelling at slow speed gave almost complete control of creeping thistle. Both docks and nettles appeared initially to be killed, but regrowth occurred.

9. The Continuing Availability of Plant Protection Products

Information on the reduced availability of plant protection products coming about through changes to EU legislation and the implementation of existing legislation on plant protection products is available at:
www.eppo.org/PPPRODUCTS/information/new_eu_regulations.htm

Losses are also occurring through influences from commercial pressures, particularly in the supply of products for speciality crops such as ornamentals. The regulatory changes are predominantly as a result of the revision of 91/414/EEC (plant protection product approvals legislation) now replaced by The Plant Protection Products Regulation 1107/2009 and the implementation of the Water Framework Directive (WFD). The changing availability of plant protection products in Europe will have impacts on all areas of UK agriculture and horticulture with a reduced number of plant protection products available for use on a wide range of crops. ADAS have produced and published a series of reports looking at the economic and production impacts of changing plant protection product availability on a range of crops. In addition, in 2010, HDC (via project CP 70 conducted by ADAS) and Defra have funded the collation of data looking at the yield implications of plant protection product losses due to the revision of 91/414/EEC on 15 specified horticultural crops.

In March 2011, ADAS completed a report (IF01100) for Defra on “The Impact of changing pesticide availability on horticulture and an assessment of all impacts and priorities on a range of arable, horticultural and forage crops.” This includes a section specifically on HNS.

http://randd.Defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=17126

According to Defra report IF01100, meeting the water quality requirements, such as of the Water Framework Directive (2000/60/EC) (WFD) and Drinking Water Directive (1998/83/EC) (DWD), is likely to impact on a number of important active substances, particularly in catchments with high usage rates of a particular active ingredient. A number of approaches to minimising active substances reaching water are being adopted including farm advice and voluntary measures (e.g. English Catchment Sensitive Farming Delivery Initiative), including the use of buffer zones and unsprayed areas. In the future, the introduction of restrictions in use (timing, crop or rate) of specific active substances in affected catchments may be necessary. Ultimately, if these restrictions on use are not sufficiently effective approval may be withdrawn although this is a last resort and unlikely to occur unless mitigation measures

completely fail to prevent active substances entering water in concentrations which lead to failure of WFD objectives for surface and groundwater, including failure of Drinking Water Protected Area (DrWPA) objectives. The loss of active substances as a result of needing to meet water quality requirements would be additional to any losses from the changing plant protection product legislation.

The active substances that are most likely to be affected by water quality requirements are those that are used on a large area (i.e. on broad acre crops such as cereals) and or used at high rates at regular intervals such as those used in some horticultural crops. However, any reduction in the availability of active substances for use within a crop may risk displacement of the problem with other active substances. Many horticulture crops rely on Specific Off-label Approvals (SOLAs) for minor use, (now Extension of Authorisation for minor use, EAMUs), which may not be supported if a major use is withdrawn. In particular, Defra report IF01100 highlighted that the potential restriction in use or complete loss of any herbicides could have significant effects on horticultural crops, as the number of herbicides that are available are limited.

The IF01100 report found that in the absence of plant protection products, major losses in hardy nursery stock when using sensible non-pesticide mitigation measures would be caused by grass and broad-leaved weeds due predominantly to increased costs associated with controlling grass weeds (£128M), broad-leaved weeds (£128M), aphids (£108M) and powdery mildew (£86M) with other pests and diseases each below £60K, with many losses calculated as around £2K. With ICM, growers work to integrate chemical, biological and cultural control; the aim is not to specifically totally replace chemicals.

The greatest economic losses for HNS (as for other crops) are forecast to be due to poor weed control, especially of broad leaved weeds, mainly resulting from the possible loss of the herbicides pendimethalin and flumioxazin for residual weed control in field production and glufosinate ammonium for contact treatment. For fungicides, the possible loss of the *Botrytis* control product iprodione in HNS (and *Rhizoctonia* and *Sclerotinia* in protected crop) and downy mildew control product mancozeb in protected crops would be important. The recent loss of bifenthrin for weevil control in protected ornamentals, and chlorpyriphos for weevil and capsid bug control could be difficult for growers. However, the chlorpyriphos that used to be the active in SuSCon Green is due to be replaced with another active ingredient and so the loss of this active may not now be as important in container production. The potential loss of metaldehyde because of water quality requirements could be important on

nurseries with a slug and snail problem because methiocarb cannot be used under protection.

Regulatory update 24/2010 (www.pesticides.gov.uk/approvals) gives information about an extension to back-stop expiry dates for Control of Pesticides Regulations Approvals (COPR) products. COPR product approvals had previously been issued with 'backstop' expiry dates of 31 December 2012 for advertisement, sale and supply, and 31 December 2013 for storage and use because of decisions required on inclusion in Annex I (of Directive 91/414 EC) to be made for all existing active substances. However, some decisions on Annex I inclusion have yet to be made; CRD require additional time for the re-registration of products containing the included active substances. In order to take account of the longer period required for Annex I inclusion, the CRD are changing the 'back-stop' expiry date for products still approved (now authorised) under COPRA to 31 December 2020. This change will be reflected in the Pesticides Register shortly.

An Amendment Notice of Approval has been issued which extends the expiry date for COPR approvals to 31 December 2020 for advertisement, sale and supply by any persons (www.pesticides.gov.uk/uploadedfiles/Web_Assets/PSD/roll10_web.doc) and gives an additional 12 months until 31 December 2021 to allow for storage and use of existing stocks in the supply chain by any persons. This Amendment Notice highlights that product approvals will be revoked prior to this date if an earlier decision is taken which impacts upon the COPR approval.

The Amendment Notice will be applied to all provisional and full approvals granted under COPR. However, where products are already under phased revocation (wind down); the existing revocation dates will remain unchanged.

COPR approvals may only continue up to the final deadline for re-registration of the active substance(s), as detailed in the Inclusion Directive(s). Further revocation action will therefore be taken six months prior to the final re-registration deadline. Where actives are registered on Annex 1, a new final use date will be issued in due course.

The sum effect of the current situation is that it is possible that growers will suddenly find that they are losing actives (and hence products) that they thought they would still be able to use until 2021.

- It is important that growers check the current status of individual products on the CRD website www.pesticides.gov.uk or contact their consultant if further guidance is required.

In order to help the industry understand and manage crop protection and plan for the future, the plant protection product usage data from the HNS grower survey for the current project has been checked against EU legislation on continued active ingredient registration. Information is current to 2 December 2011 and does not include products not commonly used by the growers questioned.

The tables below (9.1, 9.2 & 9.3) show the products which growers reported having used. Final use dates prior to December 2015 (which applied to them to 2 December 2011) have been given. Some products may be able to continue in use pending decisions on their actives. The dates apply to the current MAPP numbers - it is possible for products to be re-registered under a new number. Information is also presented on active ingredients in the tabulated products which are under threat of being excluded from Annex I.

9.1. Insecticides used on nurseries and their future availability

The loss of any insecticide increases the challenge for growers of achieving pest control whilst managing insecticide resistance. This has the greatest impact when controlling key pests where resistance is already prevalent, such as with some aphid and thrips species, two-spotted spider mite and whitefly populations (IF01100 report).

Microbial products registered as plant protection products have been included in Table 9.1 as they were included in the list of crop protection products listed by growers. There are no issues with final use dates with microbial plant protection products. Nemasys L has been listed although it is not a registered plant protection product.

Table 9.1: Insecticides and acaricides used on the nurseries surveyed and the pests the products have been used against on these nurseries and any near future end dates before 2021 of authorised use (information correct at 19 January 2012)

Product used by growers	Active ingredient	Authorisation expiry date if due before 2021	Grower-stated target pests as given on survey form
Admire	imidacloprid		Aphid
Aphox	pirimicarb		Aphid, Blackfly
Apollo	clofentazine		TSSM
Borneo	etoxazole	31/05/15	TSSM
Calypso	thiacloprid	31/12/14	Aphid, Thrips, Whitefly, Caterpillars
Chess WG	pymetrozine	31/12/15	Aphid, Leaf hopper
Conserve	spinosad		Aphid, Thrips, Whitefly, Caterpillars
Decis	deltamethrin		Aphid, Whitefly, Caterpillars, TSSM, Leafhopper
Dipel DF	*Bacillus thuringiensis*		Caterpillars
Dynamec	abamectin		TSSM, Thrips, Tarsonemid mite
Envidor	spirodiclofen	31/07/13	TSSM
Equity	chlorpyriphos		Vine weevil
Floramite	bifenazate		TSSM
Gazelle	acetamiprid		Aphid, Whitefly
Hallmark	Lambda-cyhalothrin	31/12/15	Aphid, TSSM, Thrips, Whitefly, Midge
Imidasect	imidacloprid		Vine weevil
Intercept	imidacloprid		Aphid, Whitefly, Vine weevil
Mainman	flonicamid		Aphid, Whitefly
Majestik	Physically acting	31/01/14*	Aphid, Whitefly
Masai	tebufenpyrad		TSSM
Naturalis-L	*Beauveria bassiana*	01/04/13*	TSSM, Whitefly
Nemasys L	Nematodes		Vine weevil
Nemolt	teflubenzuron	30/01/12	Thrips
Oberon	spiromesifen	30/04/13	TSSM, Whitefly
Permasect C	cypermethrin		Caterpillars
Plenum	pymetrozine	31/12/15	Aphid,
SB Plant Invigorator	Physically acting		Aphid, TSSM, Thrips, Whitefly
Spruzit	pyrethrins + oil		Aphid, Thrips, Whitefly
Steward	indoxacarb		Caterpillars
Toppel 100 EC	cypermethrin		Aphid
Vydate	oxamyl		Leaf and bud nematode
Naturalis L	*Beauveria bassiana*		Thrips

*these products are low risk and likely to be able to continue in use

Calypso has a final use date of 31/12/14 and may be at risk after this date as thiacloprid is a potential endocrine disruptor.

The following actives are being detected in water at levels exceeding 0.1µg/L and are therefore at risk of restricted use: cypermethrin, chlorpyriphos and metaldehyde.

Any restrictions on cypermethrin use would affect crops grown on a field scale more than container producers, however, other pyrethroids are available as alternatives.

SuSCon Green (chlorpyriphos) had a final use date of 31/12/11, but it is likely that a new formulation is to be produced for growing media incorporation in ornamentals which will be based on a different active ingredient. In practice, however, growers have tended to use parasitic nematode products instead as these fit better within IPM systems.

Metaldehyde has approval until 31/12/21. This active is currently in a stewardship scheme. Metaldehyde has principally caused problems in field crops where there has been some overdosing and application too near to water-carrying ditches and the Metaldehyde Stewardship Guidelines have been developed to promote best practice which should help to prevent this problem occurring (see www.getpelletwise.com). Field-grown crops such as trees and roses are not normally affected by molluscs, and the use of ferric phosphate based slug pellets are seen as part of the solution as they can be used in high risk areas e.g. next to ditches/water courses; thus continued availability of ferric phosphate (with approved use until June 2018) is important.

Although methiocarb is listed as a UK specific pollutant it is approved for use in non edible crops until 2021. In practice, it is rarely used in the production of ornamentals as it impacts upon naturally occurring predators. If methiocarb became the only formulation of slug pellets available to growers it is likely that methiocarb usage would increase (largely in agriculture); under this scenario it is thought that it would only be a matter of time before methiocarb became an issue in water. Methiocarb is currently only listed as UK specific pollutants for outdoor crops.

9.2 Fungicides used on nurseries and their future availability

A number of products are due to expire (in terms of final use) prior to December 2015 and the actives are deemed to be under threat (Table 9.2).

Table 9.2: Fungicides used on the nurseries surveyed and the pathogens the products have been used against on these nurseries and any near future end dates before 2021 of authorised use (information correct at 2 December 2011). *Updated with information from Abbot (2012) on 28 January 2012, following a delay in the EU approvals process.

Product used by growers	Active ingredient	Authorisation expiry date if due before 2021	Grower-stated target diseases as given on survey form
Aliette 80WG	fosetyl-aluminium	31/10/12	Downy mildew, Powdery mildew
Amistar	azoxystrobin		Botrytis, Powdery mildew, Downy mildew, Rust, Stemphylium, Colletotrichum
Basilex	tolclofos-methyl		Rhizoctonia
Bravo 500	chlorothalonil	03/03/15	Downy mildew, Botrytis, Leaf spots
Cercobin WG	thiophanate-methyl		Fusarium, Phytophthora
Cuprokylt	copper oxychloride		Shot hole, Gall
Cyflamid	cyflufenamid	03/04/14	Powdery mildew
Filex	propamocarb hydrochloride	31/03/13	Downy mildew, Phytophthora
Folicur	tebuconazole		Powdery mildew, Rust, Black spot
Fortess	quinoxyfen	01/09/14	Powdery mildew
Fubol Gold WG	mancozeb + metalaxyl-M	30/07/13	Downy mildew
Nimrod	bupirimate		Powdery mildew
Scotts Octave	prochloraz		Botrytis, Fusarium, Leaf spots
Potassium bicarbonate	potassium bicarbonate		Powdery mildew
Potassium phosphites	potassium phosphite		Downy mildew
Rizolex 50 WP	tolclofos-methyl		Rhizoctonia
Rovral WG	iprodione	31/12/13	Botrytis, Rhizoctonia, Leaf spots
Scala	pyrimethanil		Botrytis
Serenade ASO	*Bacillus subtilis*		Botrytis, Powdery mildew
Signum	boscalid + pyraclostrobin		Botrytis, Powdery mildew, Downy mildew
Standon Fullstop	fosetyl-aluminium	31/10/12	Downy mildew
Stroby WG	kresoxim-methyl		Powdery mildew
Subdue	metalaxyl-M	30/09/12 *now 30/06/18	Phytophthora
(not stated)	sulphur		Powdery mildew
Switch	cyprodinil + fludioxonil	01/11/14 new MAPP	Botrytis, Powdery mildew
Systhane 20EW	myclobutanil		Powdery mildew, Rust, Black spot
Talius	proquinazid	29/07/11	Powdery mildew
Valbon	benthiavalicarb-isopropyl + mancozeb		Downy mildew

Products controlling Botrytis and other fungi

Eight products were stated by growers to be commonly used against Botrytis, most products also having activity against other pathogens.

Rovral WG has a final use date of 31/12/13. This active is being detected in water at levels exceeding 0.1µg/L and is therefore at risk of restrictions on use being imposed. Other chemistry is available for control of *Botrytis*, however, relying on fewer fungicides is not sustainable from a resistance management point of view.

Switch is authorised until 2021 under MAPP 13185 (this is probably the back stop date referred to above under the regulatory update, as a newer MAPP number is authorised it is likely that the earlier MAPP number will be subject to revocation shortly). Switch MAPP 15129 has a final use date of 01/11/14.

Use of Bravo 500 is restricted to outdoor crops and has a final use date of 03/03/15. The active (chlorothalonil) is classed as a UK specific pollutant which may result in further restrictions on used. This multisite inhibitor protects against a wide range of pathogens and is useful from a resistance management point of view. It is a significant loss not being able to use this active under protection.

Products controlling powdery mildews

Fourteen products were reported as being commonly used by growers against powdery mildew. Fortress (quinoxyfen) use is only authorised until 01/09/14. This will be one less active to use in alternation within fungicide resistance management programmes which are particularly important with powdery mildew. Quinoxyfen is at risk in 2014 due to perceived hazard criteria.

Cyflamid has a SOLA which approves use until 30/04/14. The parent approval authorises use until 30/09/22 and so the HDC is seeking to obtain a SOLA/EAMU in line with the parent authorisation.

The biofungicide, Serenade ASO (containing *Bacillus subtilis*) became available in 2010 and has since been found by one major nursery to give effective control of *Botrytis* and powdery mildew under protection.

Products controlling rusts

Only three products (Amistar, Folicur and Systhane 20EW) are commonly used by growers against rust, and none lose authorisation within the next few years.

Products controlling downy mildews

Nine products were stated to be commonly used by growers. Fubol Gold WG is authorised for use until 30/07/13. One of the actives (mancozeb) in this fungicide mixture is at risk in 2016 due to hazard criteria. Fubol Gold WG and Fenomenal will become the main eradicant fungicides for use against downy mildew post 31/10/12 – loss of either product would be likely to compromise disease control in the long term.

Products controlling leaf spots

With Bravo 500 and Rovral WG having listed final use dates and Fubol Gold being at risk of loss this will leave only Octave and Systhane 20EW of the products usually used by growers against leaf spots.

Products controlling root rots

Aliette 80WG is being withdrawn by the manufacturers in 2012 (and consequent loss of equivalent products containing the same active ingredient). Filex remains, but this has a final use date of 31/03/13. Proplant MAPP 15422 has the same active as Filex, propamocarb hydrochloride, and would be an alternative along with Octave. Fenomenal (a mixture of fosetyl-aluminium and fenamidone) (MAPP 15494) has become available for use on ornamentals (Approval 2427/2011) for use as a container drench or for incorporation in growing media used in propagation, and will provide cover with current registration up to 2016. In addition, the controlled release granule containing fosetyl-aluminium, Plant Trust, also recently become available, and particularly where plants (e.g. *Chamaecyparis* cultivars, *Taxus baccata* or *Araucaria*) are known to be susceptible to root rots then it could be incorporated into the growing medium at potting, or dibbed into pots. Surface scattering of Plant Trust would also be possible, but can be less effective (Andrew Wilson, Everiss pers. comm.)

- Growers should consider small-scale evaluation of Fenomenal and/or Plant Trust where cultural measures against root rots on particular crops do not give sufficient control

➢ An EAMU would be worth seeking for Proplant (MAPP 15422)

Products controlling bacteria

There was only one product, Cuprokylt, in common use. Croptex Fungex used to be a popular product, but this cannot now be used. Copper based products are the only ones available in Europe against leaf spot and rot bacteria. In the USA, antibiotics such as streptomycin can be used, but they are not allowed in Europe.

Bacterial leaf spotting can easily be confused with fungal spots and fungicide applications (e.g. Octave) will not have any affect. Information from projects HNS 71 and HNS 91 has been used in Factsheet 04/10 and details bacterial shot-hole of cherry laurel, with further work now carried out in project HNS 179. A factsheet on bacterial disease of ornamentals was prepared in December 2011 as part of HDC project PC 291 and is due to be published shortly.

- Growers need to be aware of the symptoms of bacterial leaf spot so that the correct treatments can be carried out

An ionising water treatment unit (Aqua-Hort) which added 2ppm copper to irrigation water was tested in HDC Project 142 and gave some control of *Pseudomonas* and *Xanthomonas* leaf spots.

- Growers should beware re-using water collected from infected plants without treatment
- More products to apply against bacteria need to be developed, with curative action being the most important

There has been UK interest in the use of bacteriophages, also known as phages, (virus-like organisms infecting bacteria) since a 2010 HDC meeting for bedding and pot plant growers when information was presented (Jill England pers. comm.). Work is being carried out in the USA, but it has been necessary to apply the material daily. The phages have specific conditions for growth on plants and each species of bacteria requires a specific phage and the phages are not easy to produce. Research on bacteriophages is starting to be carried out. They have, for example, been tested *in vitro* for their ability to infect and kill *Erwinia amylovora*, the causative agent of fireblight. Different phages were isolated from soil samples of *E. amylovora* infected orchards. (Fieseler *et al*., 2009). It is considered unlikely that they will become registered for use as plant protection products in the UK within the short to medium term (T. O'Neill, pers. comm.).

9.3. Herbicides used on nurseries and their future availability

Weeds are controlled with a combination of residual herbicides, some post-emergence herbicides and hand weeding.

The products highlighted here (Table 9.3) are those due to expire (in terms of final use) in the next decade and the actives deemed to be under threat.

Table 9.3: Herbicides used on the nurseries surveyed and the pathogens the products have been used against on these nurseries and known end dates of authorised use before 2021 (information correct at 2 December 2011)

Product used by growers	Active ingredient	Authorisation expiry date if due before 2021	Grower-stated target weeds as given on survey form
Aramo	tepraloxydim	31/05/15	
Betanal Flow	phenmedipham	28/02/15	
Betanal Expert	desmedipham + ethofumesate + phenmedipham	28/02/13	
Butisan S	metazachlor		Liverwort, Willowherb, Groundsel
Centium 360 CS	clomazone		
Chikara Weed Control	flazasulfuron	31/05/14	
Clinic Ace	glyphosate	30/06/18	Willowherb, Hairy bittercress, Groundsel, Meadow Grass
Dual Gold	S-metolachlor		Pearlwort
Flexidor 125	isoxaben		Pearlwort, Hairy Bittercress, Groundsel
Harvest	glufosinate-ammonium	2017	Willowherb, Hairy Bittercress, Groundsel, Meadow grass
Kerb Flo	propyzamide	30/09/16	
Kibosh	glufosinate-ammonium		
Pastor	clopyralid + fluroxypyr + triclopyr		
Reglone	diquat	End of 2015 this MAPP*	
Ronstar Liquid or 2G	oxadiazon		Willowherb, Hairy Bittercress, Groundsel, Goat Willow, Meadow grass
Roundup	glyphosate	30/06/18	
Roundup Biactive	glyphosate	30/06/18	
Stomp Aqua	pendimethalin	03/09/13 this MAPP	
Sultan 50 SC	metazachlor		
Venzar Flowable	lenacil		Liverwort

* delays in the EU approval process means that diquat will now still be approved until 30/06/18 (Abbot, 2012)

The active in Kerb Flo is being detected in water at levels exceeding 0.1µg/L and is therefore at risk of restrictions on use being imposed. This is one of the few residual herbicides that can be used on light soils so restrictions on use would compromise weed control on many field nurseries.

Butisan S (metazachlor) is also being detected in water so a limit of 1 application every 3 years has been imposed on the label and further restrictions might still be imposed.

Glyphosate is the active ingredient in the products Roundup, Roundup Biactive and Clinic Ace commonly used by growers. There are many different generic products which all have final use dates of 30/06/18. This would be a big loss to growers as they have experience of its crop safety when used on dormant or woody subjects to give broad-spectrum systemic weed control. Glyphosate is also a UK specific pollutant so may be at risk in the future.

Harvest (glufosinate ammonium) is also considered at risk (because of hazard criteria) in 2017. This would be a huge loss as it is the mainstay for controlling established weeds in non-cropped areas and is used as an inter row spray by tree and hedging producers as it is the safest, most effective option. Glyphosate is not as good on willowherb, an important nursery weed. Other contact herbicides are only really effective on weed seedlings.

Although both Reglone and Stomp Aqua have final use dates, it is probable that the new MAPP numbers expected will come through before expiry of the original. The situation with pendimethalin may be more complex, as this active is generally thought to be under threat with loss possibly in 2013 (because of hazard criteria and as it is a UK specific pollutant). Pendimethalin is one of the main residual herbicides so this loss is one of the highest causes for concern along with glufosinate ammonium.

Betanal Flow and Betanal Expert have final use dates, but are already no longer available in most supply chains. Goltix Flowable M12851 or Goltix WG M11359 can be used as a substitute in most cases and can currently be used under the LTAEU until 31/12/21.

- An Extension of Authorisation for minor use is needed for HNS for one of the formulations of Goltix

Chikara is a useful residual herbicide in non cropped areas and a replacement would be needed after 2014.

Aramo is a selective graminicide and its loss in 2015 would leave a big gap, as this herbicide controls annual meadow grass, the predominant grass weed on some nurseries.

9.4. Biocides

Biocides/disinfectants were used for algal control and for sterilising pots and structures, e.g. Jet 5 (peroxyacetic acid). These should not be used on crops unless they are also registered as plant protection products. This is an area where there can be different interpretation of the regulations, for example the cleansing of irrigation lines and disposal over the crop. Biocide run-off and disposal is of environmental concern as if it enters ditches, drains and sewage treatment system, the microflora can be killed affecting the food chain and the breakdown of organic material.

- Plant protection products need to be produced, or existing biocides put through the pesticide registration process in order to provide registered products against algae and bacteria for use on crops or over cropped areas
- A new factsheet on biocides/disinfectants is required so that growers can select the safest and most effective active ingredient for the specific contamination problem

10. Hygiene and Cultural Control

10.1. Crop and nursery hygiene

Hygiene procedures are a key of ICM, are relatively straightforward and should be carried out by everyone day to day on the nursery, with extra measures in place when stock is received (Buxton *et al.*, 2006 ; Hewson and Perkins, 2008; Fera, 2011). Hygiene measures being carried out by nurseries were given in Figures 6.2 and 6.3.

- Managers should ensure that staff are aware how pests, diseases and weeds spread and that time spent carrying out hygiene measures is part of the production process.

Clean equipment and staff hygiene

Few nurseries reported containment measures to stop the spread of pests and diseases by staff themselves, such as changing to clean overalls and hand and boot washing when moving from outside to covered growing areas or after clearing out an infected or infested crop. Tool disinfection was carried out by a third of nurseries, and would principally involve the cleaning of secateurs when taking cuttings and after pruning out diseased stems. Hygiene measures can add a little extra time to tasks, but can save time in the long run if a pest or disease outbreak is averted. HDC Factsheet 15/05 gives information on disinfectant use, although a revision is due (O'Neill *et al.*, 2005).

One grower mentioned the problem of dirty Danish trolleys coming onto the nursery and that cleaning them was difficult. Trolleys can pass through many nurseries across various borders within a short time.

At least one nursery (code 22) visited re-uses pots without washing and has not had problems, but they record if a root pathogen has been seen and throw away the pots when the plants are potted on. Another (nursery code 5) had re-used large pots at times, and had infrequently had weed seeds germinate from around the pot rim. Pot re-use is environmentally beneficial, particularly where disposal to waste occurs because of poorly developed recycling in Britain, but new pots are easier to work with. On smaller nurseries pot washing and stacking by hand is time consuming and exposure to disinfectants or their vapours a possibility, with a final issue of disposal of the used solution.

Clean stock

Most growers stated that they seek to use clean cuttings. There is considerable problem with the potential transmission of leaf and bud nematode inside cuttings of *Anemone, Penstemon, Phlox* etc and at least two nurseries purchase plants micro-propagated to ensure that they are not harbouring the pest. Most pathogens (fungi, water-moulds, bacteria and viruses) are present in plant tissue beyond the location of visible symptoms, with some pathogens able to spread rapidly in the water-conducting vessels from the roots towards the leaves. It is thus unwise for cuttings to be taken from mother plants with disease symptoms on older tissue. With molecular diagnostics, it is becoming increasingly apparent that micro-organisms can be present in tissue causing latent/symptomless infection, with the symptoms only expressed if triggered by some external or internal factor.

- Further research is required to provide guidelines on the propagation of disease-free material, including the use of on-site diagnostic tests and their utilisation with latent infections
- There is a particular need to find a control method for leaf and bud nematode

Most nurseries clear away infected material. On one protected crop nursery (not surveyed for this project) affected plants are taken off benches directly into specially coloured plastic sacks, sealed and incinerated. Practices that should be avoided are the bringing of affected plants to the front of the bed for later collection or leaving them *in situ* when healthy plants are taken for sale, or walking through the nursery collecting material for disposal in an open barrow or trolley for placing on the waste heap. Open disposal sites allow pathogens, pests and weed seeds to survive and to be carried back to the crop by agents including wind, flies or on wheels or boots leaving the site. If there is an intention to compost the waste, e.g. for use on field crops, then the process should be managed and monitored to ensure that the correct temperatures are reached to kill pests and diseases and that all staff are aware of which bin is for new waste and what materials are acceptable.

One grower visited (nursery code 5) highlighted that problems with pests, diseases and weeds that can arise through the retention of unsold nursery stock from one year to the next. Material is often produced without knowing how much will be sold, and unlike crops such as bedding plants, the plants remain saleable and, if plants are potted on, larger plants may be sold for more money.

- Nurseries should make improvements, if necessary, to their plant waste disposal areas to ensure pests, disease and weeds are killed and/or contained
- Proper procedures should be put in place if material is to be composted
- Procedures for the regular contained removal of pest, disease and weed affected material should be agreed with staff and monitored
- Growers should ensure that unsold stock is either consciously kept and maintained or disposed of to prevent pest, disease and weed spread to new stock

Only a small proportion had a quarantine area for purchased stock, most going directly into their growing-on positions. It is likely that plants will at times be dispatched following application of plant protection products used to treat pests, diseases or weeds have had an effect and the receiving nursery will not be aware that there could be a resurgence of the problem, particularly in the case of some insecticides. Some of those questioned had established suppliers and did not recall having had problems with previous deliveries. With most growers regularly inspecting their crops, problems should be noticed. Growers in the south west of England had been issued by with LFDs for *Phytophthora* spp. by Plant Health and Seeds Inspectors and were checking for and testing any foliage blight-like symptoms.

- Nurseries without a monitoring procedure for bought-in stock should adopt one

Species and cultivar selection

Another way of reducing the amount of disease in crops on nurseries is the selection of species and varieties that have a lower susceptibility or resistance to particular diseases. This is sometimes not possible if a particular named plant is popular, but several growers reported that they had stopped growing “problem” plants. There are for example differences between conifer species and cultivars in their susceptibility to root rot (Wedgwood, 2011), rose cultivars to blackspot and downy mildew, and hollyhocks to rust. Reduced fungicide application would be needed if resistance was exploited. Pest preference/survival on certain plant species also occurs, and has been utilised (conversely) in work on encouraging beneficial insects to areas.

- Growers should determine whether particular species or cultivars have known susceptibility to particular diseases and pests and try to alter selections accordingly
- ➢ Testing the relative susceptibility/resistance of cultivars of some of the more popular HNS with particular problems with diseases or pests would be worthwhile

Clean beds

Bed or bench disinfection was carried out on two thirds of the nurseries (Figure 6.2), with most scraping the woven ground-cover on standing-areas between crops. Cleaning beds was not carried out by some HNS producers as, in contrast to pot and bedding, they are less likely to clear off a whole length of standing area of mixed crops, and some or all plants in a batch can remain where they are for two years or more. Effective disinfection of gravel/sand construction beds is difficult because drainage water can be drawn upwards from below the treated depth. There were indications in monitoring experiments in the 1980s that Efford sand beds built up a microflora that helped in the control of zoospore producing root pathogens, similar to the bio-filter effect in slow sand filters for water purification (M. Wainwright pers. comm.).

- Updating of the HDC factsheet 15/05 on disinfectants, giving information on the best products for particular problems is required

10.2. Substrates and nutrition.

Adequate and balanced nutrition of crops and the provision of well structured and balanced growing media /substrates are important elements of ICM. The use of controlled release fertilisers is common in HNS production and so there is less nutrient leaching and consequent environmental impact than when liquid feeds are used. Plant protection product incorporation into growing media allows measured use of pesticides into pots with potentially reduced environmental impact (Hewson and Perkins, 2008).

Many nurseries have their own growing media blends or favour a particular product, having observed how their crops grow best. The reduction of peat in composts will mean that growers will need to spend time determining how each of their crops grows in various blends. Only one nursery visited currently uses composted green waste in their compost mix. Another nursery did use composted green waste but was worried by the reports of herbicide residues in it and so the grower is producing his own conifers to ensure they will be able to secure sufficient bark for their future needs.

The HDC carried out surveys on root rots of *Choisya* for HNS 169 (Talbot and Wedgwood, 2009) and conifers for HNS 181 (Wedgwood, 2011) and how the growing media used might affect the problem. Root rot pathogens, particularly the water-moulds (*Pythium* and *Phytophthora*) are favoured by growing media that is less free-draining so mixes with higher bark content or perlite were being used by growers to reduce these problems. However, both

surveys concluded that potting-on of liners when the roots were not actively growing gave a greater chance of root rot developing, with overwatering being a contributory cause of losses.

Growing media does not only provide a medium from which water and nutrients can be taken up, but also can include products that kill or reduce pest and disease populations. In 2011, growers were able to order growing media containing the fungicide fosetyl-aluminium in a controlled release granule (Plant Trust), rather than apply the chemical as an Aliette WG80 drench (which was not commonly done, Figure 8.4). The current survey was too early in 2011 to determine use of this product. Other chemical drench products are still available. A Fera booklet sponsored by the manufacturers of Plant Trust (Fera, 2011) emphasises the need for good hygiene and growing conditions for the crop. In theory nursery hygiene should negate the need for the preventative use of this product, but in reality "reservoirs" of *Pythium* and *Phytophthora* species are likely to be present in most field and container growing nurseries, or can be in bought-in on stock. If susceptible subjects are fungicide treated then the multiplication and potential spread of these pathogens will be reduced.

Microbial products to improve root health such as Revive (*Bacillus subtilis*) and Trianum (*Trichoderma harzianum*) have also been used by growers for incorporation or drenching into compost prior to potting. The bio-fungicide Prestop (*Gliocladium catenulatum*) became available during the current survey period. A microbial insecticide, MET 52 (*Metarhizium anisopliae* strain F52) became available in 2011 for compost incorporation with activity against vine weevils and other insects with a life stage in growing media.

Plants that are under stress through nutrient deficiency, or have soft growth induced by excessive or unbalanced nutrition, are more liable to succumb to pest and disease infestation and may also be less competitive against weeds. With mixed HNS, nutrition (often in the form of controlled release granules) needs to be suitable for a range of container grown crops. Alternatively crop specific mixes can be used.

Correlation between plant vigour and "phenological" (i.e. not inherited) plant resistance is however, unclear. This paves the way for the production of various "plant strengtheners" that e.g. affect the calcium or silicon in or on the leaves, or stimulants that e.g. increase the production of chemicals such as anthocyanins and jasmonates that may impede pathogen entry or repel/resist or physiologically affect pests. There are also growing media applied products that are attributed with controlling root pathogens e.g. crab shell, or of out-

competing them e.g. mycorrhiza and fungi such as *Trichoderma* spp. and *Gliocladium* sp. and strains of bacteria such as of *B. subtilis.* Products such as Compost Tea include both micro-organisms and nutritional components.

There has been research on disease suppressive media in field soil and containers, and also studies of the composting procedures required to ensure that pathogens are not introduced. This was reviewed by Noble and Roberts (2003). Work has principally been on field vegetables or protected edibles, but has included species of pathogens such as *Pythium, Phytophthora, Fusarium* and *Rhizoctonia* which are also found in HNS, with bark, green waste and paper mill sludge among composted materials tested.

- A review of disease suppressive media would be worthwhile for growers, highlighting the main conclusions and giving recommendations for their use
- Research studies to evaluate the effect of different growing media on HNS crops with particular diseases would be worthwhile, preferably defining activity with reference to the physical, chemical and biological parameters of the media

10.3. Environment control

Ensuring air movement in glasshouses and polytunnels will reduce humidity in the crop and lower the chance of pathogen spore germination and infection (HDC, 2008). This will include managing the ventilation in glasshouses and polytunnels, particularly to avoid temperature stress to plants and conditions that create humidity and condensation and so favour disease establishment. Watering using sub-irrigation or using overhead irrigation early in the day to reduce moisture on plants is also important (Hewson and Perkins, 2008).

HDC Factsheet 23/11 (O'Neill, 2011) summarises current information on the biology of tomato grey mould (*Botrytis cinerea*) in glasshouse crops. It provides practical advice on how to minimise losses to the disease with minimal use of fungicides and has relevance to HNS crops even if they are not grown under heated glass.

10.4. Irrigation

Other than for field grown trees, irrigation was used by all nurseries. Mains water was used by half the nurseries, but 40% had boreholes and 40% used reservoir water. A reasonably large proportion (37%) used roof collected water, with 23% using recycled (Figure 10.1). A mean number of two sources were used by nurseries, with four sources not being uncommon (Figure 10.2).

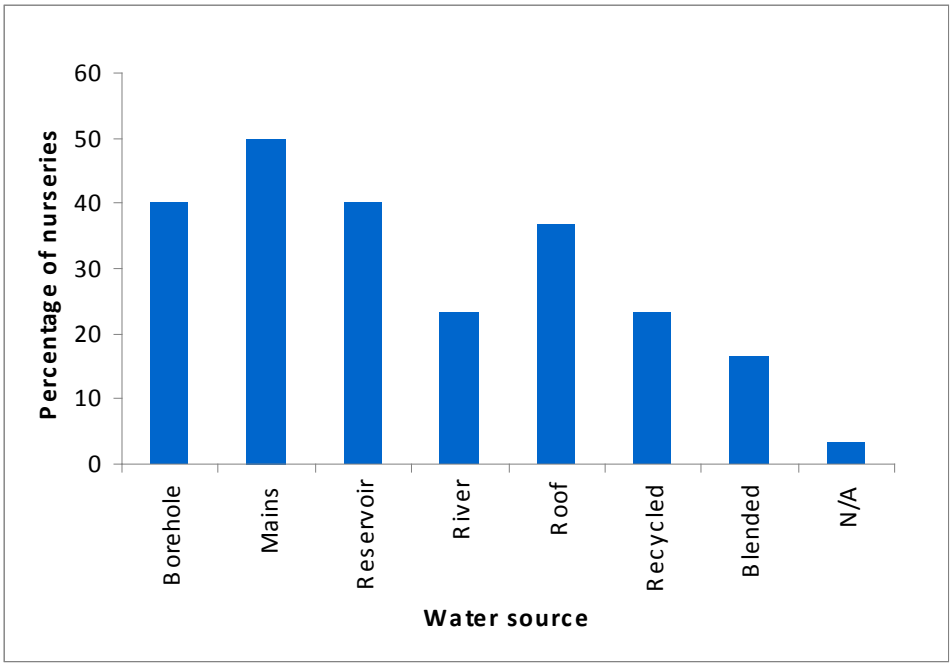


Figure 10.1: Sources of irrigation water on the HNS nurseries responding to the survey

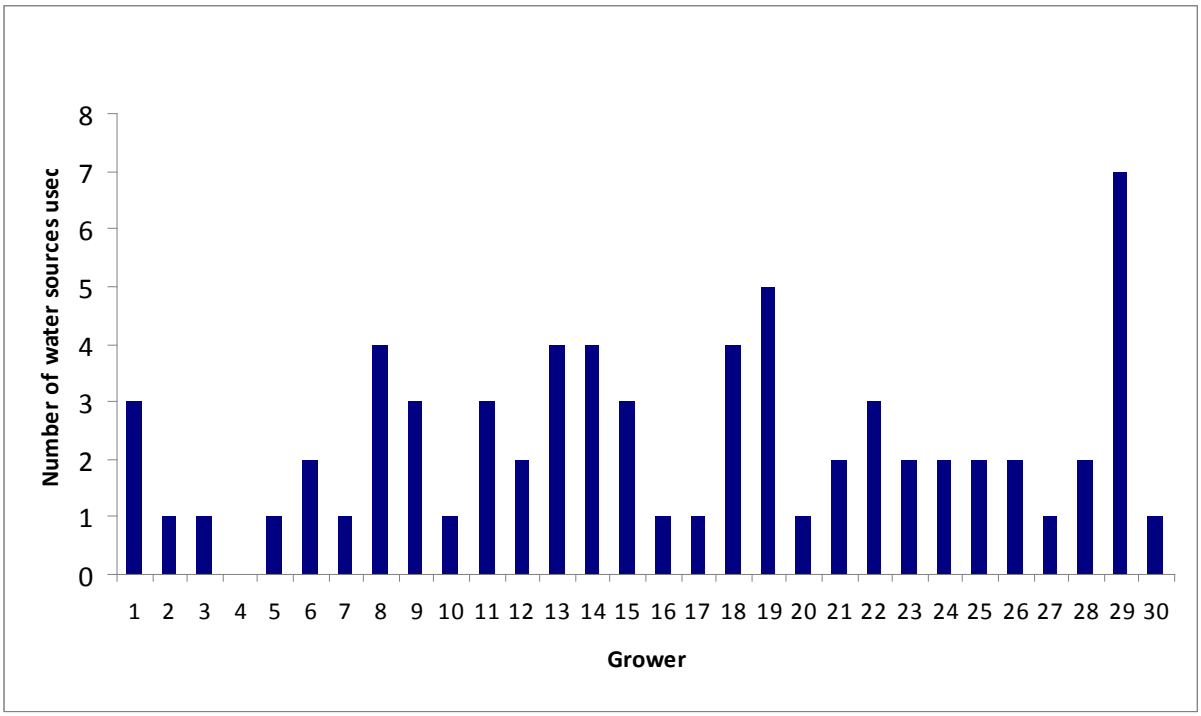


Figure 10.2: The number of different water sources used by the nurseries surveyed. Individual nurseries are shown by their project identification code numbers.

Considering the relatively high number of nurseries using water other than mains or bore-hole (which would normally be free of plant pathogens), a high proportion, 21 out of the 30 nursery sites (70%), were using no water treatment (Figure 10.3). Not treating water, particularly if it has been recycled form beds and benches, would usually be considered to be likely to result in a high risk of transmitting root rot pathogens such as *Pythium,*

Phytophthora and possibly *Thielaviopsis basicola* and *Fusarium* species. Advice was given on the detection within water (using leaf baits) and the decontamination of water (using disinfectants and slow sand filters) of *Phytophthora* species on nurseries in the HDC project HNS 134 (Jennings, 2008).

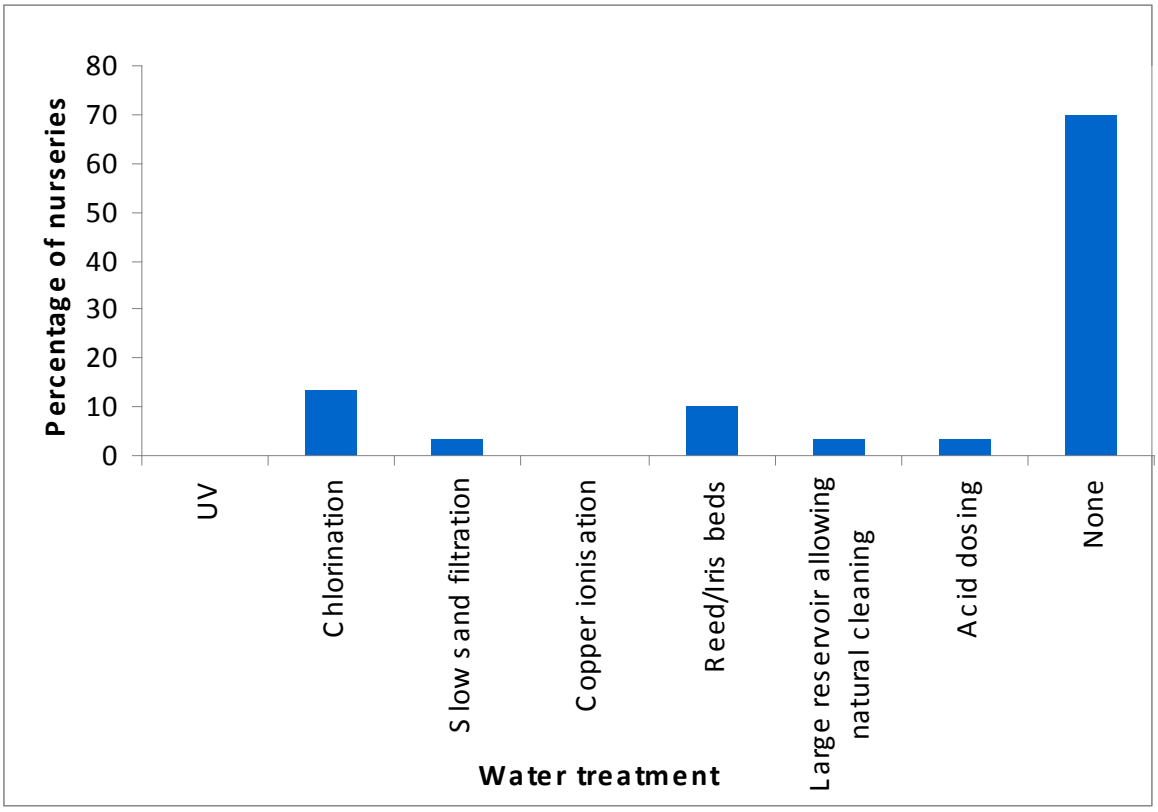


Figure 10.3: The number of different water treatment methods used by the nurseries surveyed

Water samples were taken for testing by a number of the nurseries and if these indicated no pathogens present at the time of sampling then this presumably supported their decision not to carry out routine treatment of the water. It is, however, likely that pathogens could arrive in reservoirs or recycled water in run-off from infected plants and when this happens may depend on environmental factors which influence both the run-off and the release of the pathogen spores from infected tissue. An HDC project starting in 2012 (HNS/PO 188) is to investigate the use of leaf baits and diagnostic kits (LFDs) to enable growers to monitor *Pythium* and *Phytophthora* more regularly on site and at minimal cost (project leader Erika Wedgwood).

In addition to carrying pathogens, water remaining on leaves from overhead irrigation can increase the likelihood of fungal and bacterial infection. Splashing and water retention by compost is also key to the dispersal of liverwort propagules. If pots are overwatered, there is

a high risk of root rot developing. The use of evaporation sensors was uncommon in the survey. Sensors allow the irrigation to be stopped if sufficient is received from rain or little has been taken up by the plants. Nursery Code 31 benefited from using sensors to allow a drier propagation environment than in conventional mist operated systems and had noticeably less moss and liverwort. Guides on water management in ornamentals, including improving efficiency and reducing pollution is available (Hewson and Perkins, 2008; Caspell, 2010).

Methods of irrigation scheduling and control are varied (Caspell, 2010) and include;

1. Rain gauges
2. Assessment of weather conditions and use of Met Office data
3. Knocking out pots and examining moisture levels in the rootball
4. Timeclock controllers
5. Capacitance probes
6. Mini-tensiometers
7. Evaposensors
8. Computer bases systems
9. Use of experienced staff
10. Staff training measures to improve the level of understanding

- Growers should investigate the use of electronic sensors for water management in their crops to save water, reduce run-off and minimise unsuitable moisture conditions for healthy root growth

11. Natural Beneficials for Pest Control and Wildlife Conservation

One of the ways in which the SUD says the prevention and/or suppression of harmful organisms should be achieved is by the utilisation of ecological infrastructures inside and outside production sites. Only a few growers had actively set up wildlife conservation areas or structures on their nurseries (Figure 11.1).

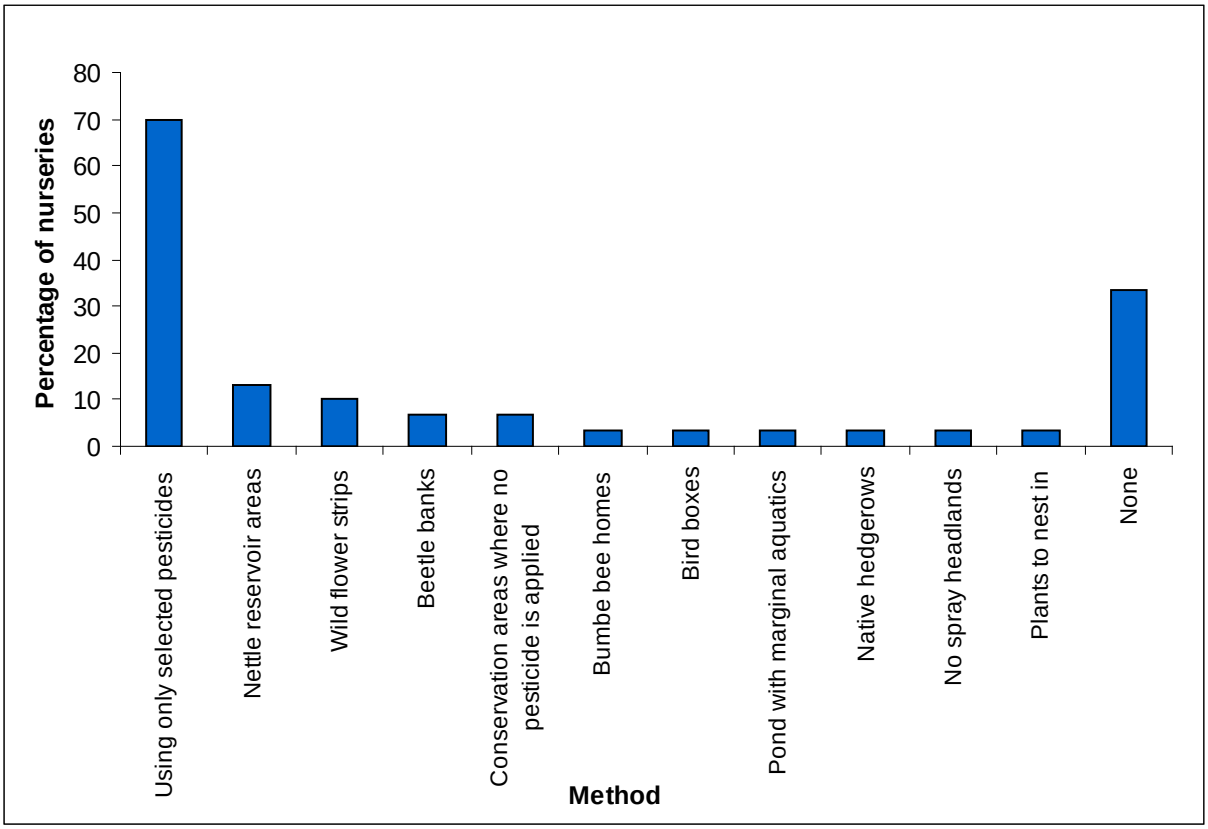


Figure 11.1: Methods available to growers to encourage beneficials and conserve wildlife and the extent of their use on the nurseries surveyed.

In edible crop growing, there is a Conservation Grade Protocol where growers must be part of a farm assurance scheme, participate in conservation training, have a farm environment plan, give 10% of area over to managed wildlife habitats and pass an independent annual audit. The 10% area might be more than many ornamental nurseries feel they can spare, particularly when growers are generally advised to remove weeds that can harbour pests and diseases and spread seeds in to the crop from locations close to standing areas, tunnels and glasshouses (McEwan, 2011b).

VHB herbs have become the first glasshouse growers to work to the Conservation Grade Protocol and can now use the Nature Friendly Farming bee logo on their products. This

company has not used any insecticides on the crop for 14 years and has now developed a water meadow and native tree woodland on the site (McEwan, 2011b).

One way to improve pest control on outdoor ornamentals would be to boost beneficial invertebrate populations either on crops or to provide hosts within for example grassed areas around buildings or around boundaries. Native beneficial invertebrates include hoverflies, lacewings, ladybirds, hymenopteran parasitoids and predatory mites. Other beneficials include bumble and honey bees. Further wildlife species such as butterflies and birds are also valued, but may also cause plant damage. The provision of host plants for adults and larvae can attract beneficial invertebrates into an area and encourage colonisation which may include overwintering. Care will be needed in the selection of hosts so that pest species are not attracted without their predator or parasite in sufficient numbers. Similarly, some plants can harbour diseases e.g. willowherb rust which attacks *Fuchsias*. Hardy perennials are ideal as most provide a continual habitat. There are opportunities for the use of some hardy nursery stock species (including grasses, sedums, herbs, ground cover and flowering species) as “plant partners” in planting schemes to encourage beneficial invertebrates

There are internet sites recording garden plants favoured by bees and other declining pollinators (RHS Perfect for Pollinators) and for wild areas within gardens (Garden Organic www.gardenorganic.org.uk), wild flower / grass mixes in arable field margins to help game birds by providing seeds and insects as food, beetle banks to encourage predatory ground beetles, and amenity or landscape plantings for wildlife (the British Association for Shooting and Conservation (BASC), RSPB, British Beekeepers Association, Bumble Bee Conservation Trust, Hymettus www.hymettus.org.uk, LEAF, Natural England, SAC, Stockbridge Technology Centre Ltd www.stockbridgeonline.co.uk Defra and ADAS). Operation Bumblebee has seen landscape planting and “hotels” created for solitary bees around a supermarket www.j-sainsbury.co.uk. In the UK, at least one nursery, Bransford Webbs, is working to market plants beneficial to pollinators. The START Initiative for sustainable living set up by Prince Charles acknowledges that people require assistance in sifting out measures they can follow.

Various university extension services in the USA provide information on plants favoured by American beneficial insects and their utilisation in crop protection. In France, the Station de l’Institut technique de l’horticulture is starting to provide information (in French) to their growers.

Banker plants allow the continuous self-introduction of bio-controls to the crop, with

parasitoids emerging from aphids that feed only on the bankers. This differs from trap plants where plants more susceptible than the crop to a pest are used to draw in the pest from the crop and the pest is preferably controlled on the trap by destruction or parasitism. Cornell University have found that pollen from *impatiens* banker plants can support the predator *Orius insidiosus* instead of aphids or thrips so that the predators are ready for when WFT arrive (www.reeis.usda.gov). The university has also funded work to look at different host banker plants for the aphid predator midge, *Aphidoletes aphidimyza (*http://nesare.org). The University of Maryland have worked with a grower to establish bird cherry oat aphid on banker pots of barley which are then put out in the glasshouse as a an initial food source for the parasitoid *Aphidius colemani* which then moved to parasitise melon aphid, *Aphis gossypii,* and peach potato aphid, *Myzus persicae,* arriving to infest the crop.

At one nursery visited in the UK, the use of wildlife areas to support beneficials which could then migrate to feed on crop pests was discussed. Spare land was available that could be used that currently required weed maintenance. It was queried how many predators/parasites are needed to be effective in biocontrol considering that commercial release rates are very high. More information would be needed on dispersal distances. Information would be needed on the best plants to use.

- Work is required on the optimum banker plant species and density and distribution for use with released predators or parasitoids in HNS
- Information needs to be collated/researched on the dispersal and host-finding behaviour of parasitoids and predatory insects in the outdoors

Much of the information on planting for wildlife in commercial crops relates to field margins in arable cropping systems where flowering plants have been selected to provide nectar, pollen, seed and refuge for invertebrates and birds. Defra Project AR0408 (Defra 2005b), however, focussed on the higher biodiversity value weed species of fat hen, annual meadow grass, groundsel, charlock, common chickweed and scentless mayweed within crops and preserving them by selective herbicide use. Similarly within the horticultural sector, HortLINK project HL0192 is developing selections of flowering plant species that provide combined agronomical and ecological benefits. HDC studentship CP 61 is looking at the benefits of crop combinations in improving naturally occurring predators.

The use of purchased biocontrol agents such as predatory or parasitic insects or predatory mites by nurseries involves regular expenditure. Some nurseries already breed their own *Atheta beetles* and banker plants have been used as mini-rearing systems for beneficial

invertebrates. Nurseries could extend this by producing a wide range of plants, both indoor and outdoor species (native and/or non-native) that are known to attract and host native parasitoids and/or predators of invertebrates. These would have a beneficial effect while on the nursery and their benefits could be promoted to customers for use in gardens and sustainable landscape plantings including the increasingly popular living walls and roofs.

- Lists of crop and weed plants known to be good sources of beneficials and not of pests or diseases are required
- Growers should consider maintaining some crop or wild plants on site to be reservoirs of native biocontrol agents

12. Case Studies of HNS Nurseries

12.1. English nurseries visited in 2011

ADAS consultants visited ten nurseries of varying sizes across England to encompass a range of crops (young and mature plant production). The majority of nurseries had already returned a survey form and by speaking with the managers and seeing the growing systems, it was possible to determine the relative use of plant protection products, biocontrol products and cultural control measures for crop pest, disease and weed control. The number of ICM measures recorded on seven nurseries based on their survey forms is given, with around 40% adoption of all feasible ICM measures being the commonest.

The case studies have been presented in full and opinions expressed are those of the growers interviewed. Observations on growing practices were made by ADAS advisers. Each study has been approved as a correct record by the person interviewed. For ease of comparison each study has been divided into the following sections:

- Nursery area and crops grown
- Training and advice sources
- Crop management
- Crop husbandry (growing media/nutrition and irrigation)
- Pests (plus pest control products)
- Diseases (plus disease control products)
- Weeds (plus weed control products)
- Hygiene and crop monitoring
- Key Points for healthy plant production given by the grower

All nursery managers were using a wide range of sources of advice and information to keep up to date with plant protection products and alternative control methods. Crop monitoring was routine and the information was used to determine control measures necessary on particular crops. When insecticides were used, they were often as spot-sprays to crops that were susceptible.

As shown by results from the 30 nurseries who returned questionnaires, pest (macro) biocontrol products (either deployed on plants or in growing media) are commonly in use on HNS nurseries and several of the case study nurseries had programmes in place (e.g. codes 22 and 34). Nursery code 22 used biocontrols routinely through from propagation to liners so

that predators such as *Phytoseiulus* were carried to the final crop and continued their control. Nursery code 31 was pleased with the newly available aphid parasitoid mix as it solved the problem of having to identify the aphid species in order to obtain the correct parasitoids product. However, some growers (e.g. code number 10) had ceased using particular biocontrols after not achieving satisfactory control. Some smaller sized nurseries (e.g. code number 33) had not tried to use biocontrols and this appeared to be because they lacked the help of an advisor. The microbiological control product Met52, *Metarhizium anisopliae* strain F52, only become available to growers in 2011, but was already in use on nurseries (code numbers 5, 27, 31 and 32). Physically acting products such as Majestik and SB Plant Invigorator were widely used at nursery code 10, with nursery code 34 using them on hotspots of aphid activity when biocontrols had been introduced.

Diseases were in general controlled by fungicide application, but all the nurseries visited appreciated the importance of good husbandry, crop hygiene and exercising care with irrigation to prevent pathogen establishment in the first place. Examination of a number of nursery plant protection product records (John Buxton, pers. comm.) showed fungicide applications were carried out more often than those of either pesticides or herbicides. The dominance of fungicides was particularly noticeable on nurseries with good pest bio-control programmes. The protectant, rather than significantly curative, activity of many fungicides (in contrast to insecticides/acaricides) leads nurseries towards having a routine spray programme for the diseases they know can be a problem on particular crops. Grower experience, or consultant advice (site related or via e.g. ADAS, Dove Associates/Horticulture Week bulletins), will be used to highlight periods of greater risk (based on environmental conditions and/or crop growth stage) and so target when fungicides are used. Several nurseries (e.g. code numbers 10, 22 and 31) had used microbial products (either the biopesticide Serenade ASO or growth stimulants, principally Revive and Trianum), with two nurseries (code numbers 27 and 34) being regular users of compost tea, the latter nursery also using compost tea as a growing media drench against root rot as well as by regular foliar application to protected containers Other growers who had used Revive (nursery codes 8 and 22) were not convinced of any benefits.

Weed control was largely carried out using herbicide applications to standing areas, field areas and containers. However, several nurseries (e.g. nursery codes 30 and 31) were successfully using bark mulch to top pots instead of herbicide applications.

Overall, all nurseries were carrying out the cultural aspects of ICM with many only using plant protection products when necessary in order to produce crops to the quality required by their markets.

12.1.1. Key advice by UK growers for successful crop management

All growers were able to highlight particularly well performing aspects of their crop production programmes that could be utilised by other growers, including the following:

Crop monitoring

- Production staff should be given the opportunity to attend a local training day on basic pest and disease recognition and control.
- Where the staff are well trained, informed and motivated ICM becomes well established, and the IPM programme very successful and well implemented.
- Regular, informed crop monitoring is key. Develop a 'start clean, stay clean' mindset - end-of-season and start-of-season pest and disease clean-ups are vital, particularly prior to the commencement of biological control programmes.
- Monitoring crops at least weekly for pest and disease problems is essential, particularly during the spring and summer months under protection, and acting promptly when problems are spotted.

Providing good hygiene and good growing conditions as part of ICM

- Keep production areas clean to avoid problems and to prevent carry over between crops. Paying attention to the fundamental basics ensures that the foundations are in place to produce a good crop.
- Keep things as simple as possible, get the basics such as the correct substrate, adequate ventilation and appropriate irrigation for the crop in question.
- It is important to concentrate on all the basics of crop production in order to produce good plants. ICM encompasses these core strategies, such as regular crop monitoring.
- It is important to try to put the 'right crop in the right place' in line with its cultural requirements (i.e. outdoor, under glass, under polythene, shade, dry regime etc).
- Investing time in matching growing media to the requirements of particular crops will improve crop quality; for example, the additional buffering properties of humic compost can benefit *Choisya*.
- ICM works well. There is a need to monitor the crop and take swift action when pest to predator ratios change. Technical support is vital for success e.g. changing the species of predator to suit the conditions, otherwise bad experiences with biological control can tempt a reversion to spraying. Staff need technical understanding of how ICM works –

aim to ensure that those responsible for crop monitoring know as much as possible and work as a team.

- ICM often requires a cultural change across the business, which can take time, so it requires managers to be patient and stay with it. Managing change can be challenging, but rewarding, work.
- ICM is the way forward given the diminishing range – and in some cases effectiveness – of synthetic plant protection products.
- ICM is the way ahead and essential in order to comply with the requirements of industry certification schemes and legislation, notably the Sustainable Use Directive, which will require all nursery businesses to show that they are using ICM by 2014, to reduce plant protection product use.

Water use

- Use electronic monitoring and control of irrigation water as this will save wasting water and prevent the overwatering that increases the chance of root rots.
- Iris bed treatment of recirculated water is effective.
- Close attention should be paid to water management e.g. using low-level irrigation, particularly with moisture sensitive crops such as *Choisya, Phormium* and *Hebe*.
- Clear beds of old stock prior to standing down new crops as water requirements can be very different. Group crops with similar cultural requirements.
- Pay close attention to water quality – monitor quality of water sources and blend with other water sources if necessary.

Reduction of pesticide use / alternative products

- Be aware of crop specific problems, treat them if you need to and take a proactive approach where necessary. Avoid applying treatments for pest, disease or weed control where they are not necessary.
- With the diminishing range of suitably approved plant protection products available, explore alternative approaches as part of a wider, more strategic and co-ordinated approach to crop protection.
- Biofungicides and microbial products such as Revive, Prestop, Serenade have proved successful in disease control.
- Compost tea can work well and is worth considering by other growers, depending on the type of crops they grow and their associated problems, e.g. it can help improve the quality and robustness of *Choisya* and *Hebe* crops.
- With close monitoring of crops, compost tea works well providing that fungicides are used where needed.

- Try to expand biological control programmes every year to embrace new products. Look at biological pest and disease control as one and get the basics right to ensure success. Ensure that good pest, disease and weed control programmes are in place before problems get out of control and monitor and adapt programmes as required.
- Larvanem is very effective against vine weevil larvae; although it is time consuming to apply it can be used on all crops (both edible and ornamental lines).
- Ensuring a sufficient depth of bark mulch on containers is the key to weed control without herbicides, provided that regular hand weeding is carried out and weeds are not allowed to set seed.

Crop management for profit

- Manage production against sales and understand your markets. Time potting in line with sales to limit the need to cut too much stock back – aim for a succession of smaller batches of stock coming through as bedding plant growers do.
- Do not produce more stock than you have a market for as you may be tempted to retain old crops until the following year; pest disease and weed problems tend to be worst in older crops.
- BOPP audited compliance can be of great benefit as a nursery management tool, helping to balance cost effectiveness with the need to be environmentally responsible and legally compliant
- If unsure about the cause of a particular problem, get it checked out promptly to ensure that the most suitable – and effective – treatments are chosen.
- Try new products and approaches, listen to other growers experiences. Keep up to date with publications, technical advice and keep staff up to date. Work with others to keep tabs on what others in the industry are up to.

Nursery Case Study ID Code 5 (7 ICM measures reported out of 44 = 16% score)

Nursery area and crops grown

The nursery is based in the South East and grows for the landscape market and specialises in herbaceous plants and also has a range of alpines and ferns. There are no shrubs. The site covers 1 ha with 5 full time employees, plus the 2 owners who contribute 1.5 units of labour and management. There are several polytunnels and standing areas with overhead irrigation. There is a propagation glasshouse, half of which has a heat-coil heated floor. Plants are started in cell trays (larger ones use Jiffy pots inside the cells for ease of removal) and then moved on directly to final pots (2 L). There is a holding area for plants in propagation trays that have been moved out of the glasshouse, but have not been potted on.

Because the plants are grown for the landscape market they do not need to be visually perfect. The market requires a sturdy plant. Foliage will be cut off before dispatch if the landscapers do not want to transport and handle pots with top-growth. Picture labels are not wanted. The majority of plants are picked and sent out to purchasers by nursery staff, rather than being selected by customers on site.

There have been some sales for living walls, but these usually require numbers in the 1000s and it is not likely that this number will have been grown on the "off-chance" of a request.

Training and advice sources

HDC News was felt to be too general to be of relevance. Something like the annual research summaries produced for fruit would be more useful. Growers don't have time to read a lot of text – 1 side of A4 is the optimum amount. Information on managing pesticide resistance should give a table of 2 types that should be switched between- there is no need to define the different activities of the products.

Nursery staff across nurseries may not all readily "take to" reading information. They would benefit from local (half hour drive) courses demonstrating e.g. hygiene measures. DVDs/videos are not a good substitute. As many have family responsibilities, they would find staying away from home difficult. It would be good if they could bring home a certificate from the course to display at work. The grower's partner helped to set up a course for women in horticulture with LANTRA.

Crop management

Attention is paid to good crop husbandry and hygiene and as this results in few pest problems there is no use of introduced biocontrols.

Crop husbandry

Growing media/nutrition

The compost used for the final plants is quite open, with 70% peat, 15% wood chip, 5% bark in the finals. Met 52 has just been added into the current bulk delivery of compost. In prop the mix is 50% fine bark and 50% peat.

Irrigation

The irrigation of the outside container beds and the production tunnel is regulated using Skye Evaposensors, one for each type of growing system. This device is not fitted into the pot, but instead monitors evaporation from a wick coming from a water container. There is also a rain gauge. This allows the length of the irrigation to be varied automatically by the irrigation controller from a calculated standard setting depending on the weather and the amount of evaporation of irrigation/rain water. There is still some need for grower checking outside of the summer period. Water use was previously calibrated using a bucket evaporimeter.

There is no need to give as much water to plants as often given on most nurseries. It is, however, not easy to define overwatering. From work with strawberries, it is possible to train plants to need less water. Many nurseries claim that their watering is done by skilled staff, but the reality is perhaps not so good.

Pests

The main pests seen are Solomon's Seal sawfly, leaf and bud nematode on Japanese anemones, a caterpillar on *Euphorbia* and *Aquilegia*, aphids, rabbits, and mice in propagation.

Vine weevil is something that customers easily recognise; other problems are less likely to cause complaints. Vine weevil can be active all the time in the glasshouse. Is it day-length the controls the lifecycle or temperature? Bamboos, amongst other plants can harbour vine weevil larvae but not show obvious damage, thus helping to maintain a population.

If there are e.g. whitefly problems in the glasshouse, this can be resolved by moving the affected plants to the colder temperatures outside.

Pest control products
Few pest biocontrol organisms are used because the relevant pests are not a problem. When there are serious pests, e.g. leaf and bud nematode, these are dealt with by cutting off the affected tissue, or in extreme cases throwing out the plant. If a type of plant is seen to be particularly affected by particular pests or diseases then it may not be grown again.

Before the product was withdrawn from sale, fipronil was used against vine weevil and this meant the plants were free from weevil for a year, maybe two. The biocontrol agent MET52 is now being used. Nematode drenching has also been used for the first time this year.

There is an area of land that is not used for growing and this has weeds on it. It is important that the weeds are cut down before they go to seed. They could be acting as hosts of natural biocontrols, but the effectiveness of biocontrol "banker areas" was questioned. The grower requested more information on how many predators/parasitoids are needed to be effective in biocontrol. Commercial release rates are very high, is this what is needed for wild biocontrols? What dispersal distances can be expected from the biocontrol source to crop plants? What plants are the better ones to have?

Diseases
Although powdery mildew can be present on plants, for the landscape trade this is acceptable at low levels and so treatment is not always necessary. Control is complicated as ideally there needs to be fungicide use before it is seen as it can already be systemically present.

Disease control products
Compost tea is not used. It is not clear that this really is beneficial to plants. Trianum is used in the compost in propagation, but it is not certain that this is having any effect. No biofungicides are used.

Weeds
The principal weeds were willowherb, pearlwort, hairy bittercress and liverwort.

Weed control products
Ronstar 2G is used on pots. Weeds are kept in check on the woven ground cover / gravel hard-standing. In winter, Roundup herbicide application to the beds can be done over the plants after raking-up. Flexidor or Devrinol is then used.

The main problem that comes with bought-in plants is weeds. It is usually possible to identify the plant supplier by the weeds that grow out of the pot.

Liverworts can cause a problem on the pots, however, these are not commonly seen surviving once plants are transplanted into gardens. Once the pot surface is buried in the garden soil, the liverworts do not come back. There is a problem with them on the nursery as they can restrict the emergence of new growth after winter.

Hygiene and crop monitoring
There is no quarantine area for bought-in stock. The nursery has four suppliers and there are not concerns about the material sent by them. The plants are usually put down together in a whole bed, but there is no specific after-arrival monitoring. All plants have a potting-on label, and although the supplier is not identified on the label, it would be easy to check this if a problem arose.

There is no bed disinfection between crops.

There is a certain amount of cleaning up (removing damaged leaves and weeds from the pot) but not as much as on nurseries selling to garden centres/shops. A lot of time/expense is spent on many nurseries at dispatch removing diseased bits and taking off weedy tops of pots and adding fresh compost/bark. However, it is possible that the disease is in the plant beyond the visual symptoms and quite likely that there will still be weed seeds present that will grow again through the dressing.

There should be a greater understanding that plants get pests and diseases. With some e.g. hollyhocks and rust they can be expected to be seen with disease. If plants are clean, they are likely to have been fungicide treated. Once the fungicide wears off the disease can show again.

Pots are mainly used new, rather than washed, as this is most economically viable. A few larger ones are used again without washing. The only problem that has been seen as a result is a ring of seedlings around the pot edge, but only on occasion. There is no easy way of recycling pots – a company that took them before was only storing them. Only 25% of a recycled pot can be used material.

With hardy nursery stock, there will always be surplus stock "hanging around" as the production of the material has to be predicted at least a year, often two years in advance. It is then common to round up the numbers needed as well. It was acknowledged that these plants can act as disease and pest reservoirs.

Mains water is used for irrigation so there is a very low risk of pathogens being carried to plants. The expenditure on mains water is not sufficient to make investment in collecting water worthwhile. Some growers mix mains with recycled water and may believe that the chlorine in the mains water will treat the recycled component.

Waste compost and plant material is spread by licence on the waste ground, or put in skips. Composting on site would require proper bays and the material to be shredded and so it is not easy to do this without extra investment.

Key Points from the grower

- Use electronic monitoring and control of irrigation water. This will save wasting water and prevent the overwatering that increases the chance of root rots.
- Production staff should be given the opportunity to attend a local training day on basic pest and disease recognition and control.

Nursery Case Study ID Code 8 (23 ICM measures reported out of 47)

Nursery area and crops grown

The nursery is based in the South East produces a wide range of nursery stock and herbaceous perennials for the amenity landscape sector. Mature plants are grown, with 0.5 ha protected and 1.2 ha outdoor containers.

Training and advice sources

Nursery staff and managers access a wide range of information, advice and training from several sources, notably bio-control suppliers, the HDC, technical notes and various consultants. Spray programmes are reviewed and updated annually to ensure they are legally compliant and, where necessary, IPM compatible. Product approvals and SOLA's are also reviewed regularly throughout the year.

Crop management

Interest in Integrated Crop Management (ICM) has evolved gradually in recent years, largely in response to environmental concerns generally, and the diminishing range of

approved pesticides available to ornamentals growers for crop protection. The business is also BOPP Certificated and the adoption of ICM links well with helping to satisfy the requirements of this scheme, particularly in respect of reduced pesticide use and best practice.

ICM is widely practiced at one site, where a range of HNS shrubs and herbaceous perennials are grown both outdoors and under protection. This includes the use of capillary sand-bed irrigation, reed-beds, reservoir storage, beetle banks to encourage native beneficial insects, and the use of biological control agents / Integrated Pest Management (IPM).

Crop husbandry
Growing media/nutrition

Irrigation
Careful water management is considered pivotal to successful ICM at the nursery, in terms of controlling background weed and disease pressure and reducing water consumption. To this effect, capillary sand-beds are used at one site, where bore-hole water is the principal source of supply. A lagoon fed by rainfall and nursery run-off (filtered through a reed-bed) helps bolster storage reserves for use during dry periods. Water samples are taken twice a year to check for pathogens and ensure stored water is of an acceptable quality for crop irrigation.

Environment manipulation
Adequate side ventilation aids air movement and helps reduce summer temperatures to help control problems such as powdery mildew, downy mildew and leaf pests, for example spider mite. Fan ventilation is also used to good effect amongst tunnel crops.

The company places a high priority on good crop husbandry, disciplined nursery hygiene and diligent crop monitoring across each of its production sites. Where possible, crops are spaced as required rather than grown pot-thick, to improve quality, control leaf wetness and reduce leaf diseases, notably *Botrytis*, downy mildew (*Hebe*) and powdery mildew.

Pests
Two-spotted spider mite, leaf and bud nematode and vine weevil cause problems.

Pest control products
A comprehensive biological pest control programme is used under protection for the safe and effective control of leaf pests, notably aphids, thrips and two-spotted spider mite, linked to the judicious use of compatible spray products to control pest ‘hot-spots’, for example Chess WG (aphids), Conserve (thrips and caterpillar), Majestik and SB Plant Invigorator.

Less (IPM) compatible products such as Gazelle and Dynamec are used by way of support but usually as spot sprays, to minimise damage to non-target organisms. Spot treatments of insect pathogenic nematode product Nemasys L (*Steinernema kraussei)* are used to control vine weevil as required and the bio-insecticide Met-52 (*Metarhizium anisopliae* var. *anisopliae* strain 52) will also be used during 2011.

Occasionally, more persistent broad-spectrum (pyrethroid) insecticides are used as spot sprays to control difficult pests in outdoor situations, notably beech aphid and caterpillars. Usually one or two sprays suffice, if well timed.

Beetle banks have been established to encourage background populations of native beneficial insects to establish; for example, ground beetles are an effective vine weevil predator.

Diseases
Shot hole and downy mildew are particular problems.

Disease control products
There has been some experimentation with microbial products (e.g. Revive) amongst plugs and crops prone to root decay pathogens such as *Choisya* but results have been inconclusive. Potassium bicarbonate is used for powdery mildew control but primarily as an end of season clean-up (unsightly leaf deposits are a concern, particularly with evergreen subjects). Potassium phosphate products are included in routine spray programmes for *Hebe* downy mildew, to bolster the control provided by fungicides.

Weeds
Problems exist with *Equisetum arvense, Rorippa sylvestris, Marchantia* and *Salix caprea.*

Weed control products
Roundup is used on beds and Ronstar on pots.

Hygiene and crop monitoring
Crop walking is undertaken each week by site managers using a standard recording sheet and cascaded back to nursery staff as required.

Key points from the grower

- ICM is very much a behavioural thing, a 'mindset', and often requires a cultural change across the business, which can take time, so it requires managers to be patient and stay with it. Managing change can be challenging, but rewarding, work.
- Regular, informed crop monitoring is also key and the nursery is keen to develop a 'start clean, stay clean' mindset, hence end-of-season and start-of-season pest and disease clean-ups are vital, prior to the commencement of our biological control programme, for example.
- It is important to try to put the 'right crop in the right place' in line with its cultural requirements (i.e. outdoor, under glass, under polythene, shade, dry regime etc). *Skimmia* is perhaps a good example of this, as the crop struggled with summer heat under protection but has responded well since being moved to a cooler, more shaded environment with a slightly drier regime and more open growing media.
- ICM is the way ahead and essential in order to comply with the requirements of industry certification schemes and legislation, notably the Sustainable Use Directive, which will require all nursery businesses to show that they are using ICM by 2014, to reduce pesticide use. The nursery is keen to build on the progress made so far with ICM in order to meet the requirements of this Directive.
- Being a commercial concern, it is important to balance cost effectiveness with the need to be environmentally responsible and legally compliant, and BOPP has been of great benefit as a nursery management tool.
- The grower has concerns over the diminishing range of suitably approved pesticides available and is keen to explore alternative approaches as part of a wider, more strategic and co-ordinated approach to crop protection.
- Disease forecasting may be of interest to the nursery, but the diversity of HNS crops could be problematic and whilst 'soft' bio-products are attractive, prompt use is essential for them to work well (hence monitoring) – and repeat treatments are sometimes needed, which can pose problems logistically.
- The grower would welcome the arrival of more bio-friendly products but felt that more independent research is needed before commercial uptake.

Nursery Case Study ID Code 10 (17 ICM measures reported out of 44 = 39% score)

Nursery area and crops grown

The family owned nursery, based in the West, occupies an area of 5 ha, plus stock beds of approximately 1 ha. It specialises in unusual and rare shrubs and grafted tree species and cultivars, although they also grow a wide range of "bread and butter" varieties of shrubs, but no herbaceous plants. They sell to garden centres, and a few other nurseries as wholesale. They do not supply the multiples.

The Prop unit is the only heated area (by oil fired boiler) on the nursery. All other areas of tunnels and glasshouses are unheated and use fleece and other insulation for winter protection.

Training and advice sources

ADAS advice is rated highly, by the grower who also values and uses HDC Factsheets and project reports. It would be useful if e.g. ADAS technical notes could contain a summary of important research areas being carried out abroad from time to time, such as by the research institutes in Holland. Horticulture Week is read regularly. Advice from the local agrochemical distributor is not rated highly.

The grower is interested in new developments in the HNS industry both in the UK and abroad and considers and tries out new techniques. Disease forecasting techniques, such as the rose downy mildew programme being developed with EMR at present, have been considered, but the grower believes that, under protection at least, all that is needed to minimise foliar pathogens is the regular use of biopesticides and relative humidity sensors to activate fans and move air around, to eliminate moist air pockets and minimise foliar moisture.

Crop management

The nursery does not have an ICM programme, but although the grower is dubious of biological pest control (having spent money on it and achieved only poor results) he has evaluated, and now uses routinely, several biopesticides based on beneficial microorganisms.

Crop husbandry

Growing media/nutrition

An 80% peat based compost, with 10% loam and 10% composted conifer bark is mixed on site and used for all stock. This is unusual, as the majority of nurseries now buy in ready mixed compost. With reference to DEFRA's plan to phase out peat entirely by 2030, the grower stated that peat would always be the substrate of choice. He has tried 20% Bulrush woodfibre in some mixes, and has had some success, but in future will continue to use his own recipe. To ensure continuity of supply for conifer bark, he has planted a 5 acre field with Giant Redwoods, which will be coppiced in rotation for bark production.

The grower has tried a % of green waste in the media and sees this as having potential, as it offers disease suppressive tendencies. However, having heard about problems with persistent herbicide residues in some batches of green waste, he will not be using this again, unless he can control the supply himself.

Irrigation

From 1985 until 2009, water from a small reservoir was used and this was chlorinated to control any pathogens and acidified with nitric acid to reduce the bicarbonate and pH to acceptable levels. This was OK but was expensive in terms of the treatment costs and also it was felt that chloride levels in the water and then the compost were too high, causing reduction in plant growth.

After studying methods used by some Dutch growers, a large reservoir was excavated (4 acres in size) and pipes installed so that all runoff water from the nursery was recirculated into the reservoir, and an Iris bed constructed which filters all the water before it is used for irrigation. The original Dutch system was much smaller and only partially treated the irrigation water. This nursery's system utilises the natural slope of the site, with a zig zag system of ditches constructed and lined with black polythene, with Iris plants densely planted in polystyrene blocks which float on the top of the water. The roots of the Iris reach down approx 1 metre, and form a dense mat so that the recycled water is slowly passed through the system and filtered and cleaned.

Tests for pathogens in the Iris bed system are done regularly by Tim Pettitt at the Eden project. Recent results had levels of organisms quantified in colony forming units/ml. The water entering the Iris system showed 25 cfu/ml, mainly fast growing Pythium species (tentatively identified as *P. ultimum*), whereas a sample taken from water emerging from the end of the system showed no fast growing *Pythium* species.

There are two small areas down to subirrigation, otherwise all plants are watered from above, either with drippers for larger pots such as trees, or overhead irrigation. The results of the HDC project HNS 97b, which looked at automatic irrigation controlled by a sensor run on moisture deficit readings, have been taken up. A DeltaT sensor is placed in the compost, and controls the timing and duration of irrigation, depending on the settings adopted. This system was initially tried just on one bed, but was so successful that it is now in place on a total of 9 different zones. The result has been improved plant quality, more flexible use of water and a reduction in total water usage.

<u>Pests</u>
The main pests on the nursery which are difficult to control include leaf and bud nematode, western flower thrips (WFT) and two-spotted spider mite (TSSM).

Although WFT are difficult to control, thrips damage only occurs on some subjects, such as *Chaenomeles*.

Spider mite has been a major problem on subjects such as *Wisteria, Choisya, Skimmia* and *Crinodendron*.

Pest control products
The grower is looking into heat treatment of dormant woody plants for nematode control. He doubts the efficacy and value of treatment with toxic granular products such as Vydate and believes this will be withdrawn by the EC before long.

WFT control is a priority as it has been difficult to get control by conventional insecticides. Has just tried Nemasys foliar application, after discussions with ADAS and Becker Underwood. Earlier this year Naturalis-L was tried for thrips control, with three applications as per label, but the grower was extremely disappointed with the lack of control.

Phytoseiulus predatory mites have been extensively tested in the past against TSSM, but with poor results. Concern about the cumulative effect of fungicide usage on the predators was expressed. The exact reasons for the poor results with *Phytoseiulus* at this site were not known, as other nurseries have had excellent control of spider mite, using a planned programme of introductions. The grower would be interested in any demonstration site/nursery that was set up in the future, to show the best way to use predators to ensure success.

Conventional acaricides, such as Borneo, Masai (poor control was gained with this product, probably due to resistance) and Dynamec have been used. Oberon was considered but not

used because of fears about phytotoxicity following the *Cordyline* "twisting" syndrome incidents which caused significant crop losses in nurseries a few years ago.

Physically acting products such as Majestik and SB Plant Invigorator are widely used for general pest control, including spider mite. The grower believes that both these products reduce the level of powdery mildew on the crop, and has had good success from using them on *Clematis* under protection.

Diseases

These include *Rhizoctonia* (from time to time as fungal strands on the surface of the compost), *Botrytis* and powdery mildew. The grower uses STC for pathogen identification rather than using LFD devices to test on site.

The Iris bed system ensures that water borne pathogens are minimised.

Disease control products

Several biopesticides are extensively used, including Prestop, which is used on all cuttings once they are rooted and weaned. Prestop must not be used earlier as it inhibits rooting. He is aware of the high cost of the product but sees the benefits as outweighing the costs. Effectiveness against *Rhizoctonia* and *Pythium* in the compost has been seen.

Compost tea has been considered, but it is seen as too formulaic, and unproven. He prefers to use products such as Serenade (for Botrytis and mildew control) that have been tested and gone through the Approval system at CRD. He has also tested Revive and Trianum as compost drenches, with good results. Agricarb (potassium bicarbonate) has been used for powdery mildew control on *Clematis* with good results, but some scorch was seen on soft growth after using this product. These products are primarily used on plants under protection, whereas once placed outside, plants are treated with conventional fungicides such as Systhane, Amistar, etc.

A bark topping is used on all pots after rooting as aid to weed control, but also believes it has some disease suppressive effects. The grower is very interested in the microflora of compost and ways to help improve its biodiversity. Ways to increase the disease suppressive nature of growing media is a topic he feels needs further research work.

Weeds

The main weed problems were bittercress, liverworts, pearlworts and mosses.

Weed control products

Weed control is achieved mainly by herbicide use, although some physical means are used, such as growing stock plants through Mypex in the field grown stock beds. The grower stated that, with the SUD directive coming from the EU, the loss of herbicides would have a greater adverse effect on the nursery than any loss of insecticides or fungicides. He saw biocontrol of weeds as a research priority in the future.

Hygiene and crop monitoring

No specific measures were mentioned.

Key points from the grower

- Iris bed treatment of recirculated water has been effective.
- Biofungicides and microbial products such as Revive, Prestop, Serenade have proved successful in disease control.

Nursery Case Study ID Code 22 (14 ICM measures reported out of 40 = 35% score)

Nursery area and crops grown

The nursery is based in the West and grows approximately 60% herbaceous and 40 % shrubs. Major lines of shrubs grown include *Hebe*, *Ceanothus* and *Lonicera*, while herbaceous subjects include *Phormium*, *Dianthus* and *Primula*. Plants are sold to garden centres, excluding those attached to national chain stores.

Training and advice sources

The nursery has a system whereby growers are given responsibility for a section of the nursery, and it is their job to monitor their crops on a daily basis. They have a paper based system to record findings a "QMS" form. The results from these forms are entered onto computer so that trends over the years can be compiled and understood. The standard of growers at this nursery is generally high, and they are keen to implement ICM/IPM measures as much as possible. The technical supervisor collates the QMS forms every week and takes action dependent on the results. He is in charge of the overall spray and IPM programme for the whole nursery.

The Pocket Diagnostic kits are used, but they feel that a laboratory sample (they use Fera) is actually the most reliable way to identify a problem. Samples are sent to Fera when there is any doubt as to identity of a pathogen; otherwise it is felt that the incorrect fungicide may be applied. On average, about 10-12 pathology samples are sent to Fera annually.

Advice is given by ADAS, agrochemical distributors Hutchinsons and Koppert. ADAS visit reports are sent to all grower staff after each monthly visit so they are kept up to date. Propagators also supply advice on crop husbandry, but as the nursery is moving towards producing all its own cuttings, plugs and liners, this will become less important in future years. They find the HDC website, factsheets and ADAS technical notes to be useful sources of information. The Green Book is used regularly for pesticide information, as is the new HDC Liaison website for ornamental pesticide approvals/SOLAS.

A crop protection programme is drawn up every year, reviewed in conjunction with ADAS, and including any new products that are suitable or have relevant SOLAS, e.g. Movento, this season. Separate programmes exist for *hellebores*, *hebes*, *lupins*, *dahlias*, *dianthus*, cuttings and trees. Programmes for grey leaf plants (e.g. lavenders) also exist.

Crop management

The nursery's philosophy has been to be as "green" as possible and their environmental policy is detailed and extensive. They have been given the BS 8885 kite mark (not common in the nursery industry) and as part of this scheme they are inspected annually by independent auditors

An ICM policy is also part of their environmental approach, and as part of this their IPM programme is well developed and very successful. Fungicides are widely used however, as it is felt that ICM methods alone are inadequate to control pathogens such as powdery and downy mildews, which can cause serious crop losses/ quality reduction in a short space of time if not controlled.

Crop husbandry

Growing media/nutrition

CRF is incorporated into the Scotts compost used, and liquid feed, using Peters or Vitax feed for hard water areas, also applied as needed. When crops appear less vigorous, e.g. *Echinacea*, which is a tricky crop to grow, top up liquid feeds are applied using a Dosatron dilutor.

Irrigation
Water is abstracted from the nearby river, using an abstraction licence, and pumped into a 4 million gallon reservoir, topped up as needed. Water is not treated for pathogens, or with acid to soften it (pH is about 7.5) and no problems seem to result. Water quality is however tested annually.

Over 70 % of the crops are grown with sub-irrigation, which keeps the crop foliage dry and so helps limit disease outbreaks.

Pests
Main pests on the nursery are TSSM, thrips, tortrix, aphids and whitefly, although the latter is confined to certain subjects, such as *Abelia*.

Pest control products
Insecticides used include: Savona, Majestic, Conserve, Aphox and Gazelle.
Pyrethroids are rarely used as they are not compatible with IPM. Over the month of March 2011 (when the visit was made) only three insecticide applications were made (two of Conserve, used for tortrix control, and one of Aphox for aphid control) and one PGR (Bonzi for growth regulation on hebe). An application of Nemasys L was made for control of vine weevil larvae in one crop.

An active biocontrol programme is in place throughout the nursery for TSSM, (*Phytoseiulus*), thrips (*Amblyseius*) and whitefly (*Encarsia*). Naturalis L (*Beauveria bassiana*) is in stock but has not been used yet against whitefly. The most important part of this programme is the fact that biocontrols are used routinely throughout the propagation unit, from plugs to liners. Thus, plants are potted on, e.g. *Phormium* splits, with predators active on them and this is carried on with further *Phytoseilus* on the final pot crop. Results this year have been excellent, with control of spider mite on susceptible *Phormium* varieties such as Jester better than ever. Monitoring recently showed that, although spider mite could be found, in every case, *Phytoseiulus* adults and nymphs were present in equal or higher numbers.

Koppert supplies the biocontrol products and their technical specialist visits every 3-4 weeks in season to check progress and provide advice in addition to ADAS advice. A detailed introduction programme is in place with quantities of biocontrols week by week, BUT the order is varied depending on the results of crop monitoring, and amounts adjusted accordingly.

Vine weevil is routinely controlled using the chemical pesticides Exemptor or Intercept in the growing media, which also gives some aphid control. The nursery is considering the biopesticide Met 52 but have not used it yet, although they have the technical information about the product. Nemasys L nematodes are used on old stock or whenever vine weevil larvae are found.

Slugs are an occasional problem on *Phormium* and so Nemaslug is used every spring and autumn. It is hard to tell how well it has performed, and sometimes slug pellets are used in addition.

Pyrethroids are only used on the outdoor tree crop, when the complex of caterpillar / capsid / aphid etc causes problems. One year there was a resurgence of Fruit tree red spider mite on Sorbus as a direct result of using a pyrethroid, but this has not been the case the last few years.

Tortrix (both light brown apple moth and carnation tortrix) are low level pests on some crops such as *Choisya*, but pheromone traps are used and Conserve applied if needed.

Trichogramma has been considered against the caterpillars but the problem is not great enough to justify widespread use of this parasitoid.

Diseases

The main pathogens are *Fusarium* (in *Hebe* and *Dianthus*), powdery mildew, downy mildew, botrytis, (especially in winter/spring), and leaf spots on some subjects, such as *Leucanthemum* and *Hebe.*

Disease control products

The main fungicides used were; Bravo (now stopped since the SOLA lapsed), Amistar, Fungex, Switch, Signum, Systhane, Rovral and Fubol Gold. An active resistance management plan is in place, with actives rotated to reduce chance of resistance. The IRAC code for each product is listed to help staff choose the correct product and to avoid using products in the same chemical class.

A study of the pesticide application records over the month of March 2011 showed that a total of 21 fungicide applications were made to various individual crops, mainly for powdery mildew, downy mildew and leaf spot protection, compared with only 3 insecticide applications. The overwhelming majority of pesticide usage at this nursery was thus fungicides.

Biopesticides / microbials have been tried, including Revive, Serenade and Trianum, but the manager is not convinced that efficacy is high. However, trials with routine drenches of Trianum on *Dianthus* plugs are in progress, as part of the *Fusarium* control programme. This pathogen has caused significant losses in some varieties (e.g. Showgirl) in previous years.

Prestop was considered for root rot control but its price is very high (about 10 X the cost of e.g. Subdue) and on this basis was not used.

Biorationals such as Agricarb have been used with some success in the past, although it did cause some scorch of soft growth in some subjects. The nursery is considering the use of Phorce (potassium phosphite) in trials as part of the downy mildew programme.

Compost tea is not used as the nursery is not convinced of its overall effectiveness and practicality. Crops such as hebe are grown on a sand bed to reduce leaf wetness and therefore problems with downy mildew, and so spraying the crop weekly with compost tea, thus increasing humidity and leaf wetness seems counter-productive.

Weeds

The principal weeds are groundsel, willowherb, meadow grass and bittercress.

Weed control products

Harvest and Clinic Ace are used on the Mypex/gravel beds. Flexidor and Ronstar 2G or Ronstar Liquid are used on the pots.

Hygiene and crop monitoring

As well as the use of fungicides, crop rotation, excellent hygiene and varietal choice are exercised to try and reduce pathogen problems. Hygiene procedures are well developed; all crops are grown on Mypex and each year, the Mypex is swept using a special machine which beats and sweeps the debris up, before a disinfectant biocide such as Jet 5 is applied. The cleaning machine is very thorough and as a consequence the Mypex is worn out within 3 seasons, whereas on some nurseries it is not renewed for many years.

Key points from the grower

- ICM is well established at this nursery, and the IPM programme is very successful and

well implemented. Staff are well trained, informed and motivated. However, because of the risk of rapidly spreading pathogens, such as downy and powdery mildews which have caused serious problems in the past, fungicide usage is high.

- If disease forecasting techniques were more highly developed, the nursery would be keen to take them up and use them, which might allow routine fungicide use to be reduced. The possibility of using simple recording devices such as Tinytags to record % RH, temperature etc., linked to a computer programme that could alert growers to e.g. periods of leaf wetness, would be of great interest. Ideally the computer sensors would send an alert directly to the grower's desk so that action could be taken immediately. Further research work is clearly required here, but might be of interest to HDC as possible future projects.

Nursery Case Study ID Code 27 (17 ICM measures reported out of 40 = 42% score)

Nursery area and crops grown

This nursery business in the North-East produces a wide range of nursery stock and herbaceous perennials for the amenity landscape sector and retail garden market. Currently, the use of ICM is focused at the site visited (covering 3 ha), where container production is geared to towards major retailers, mainly under protection but with some outdoor beds. Principal crops on this site include *Ceanothus, Choisya, Convulvulus cneorum, Hebe* and *Phormium.*

Training and advice sources

Advice, publications and information are used from several sources, notably various crop consultants, the HDC, product suppliers (e.g. growing media) and external training providers (occasionally). Information is also cascaded down regularly through senior and site managers to nursery staff. Plant Clinic diagnostic services are also used as required for problem solving and accurate identification of crop problems (to be more specific than the results from Pocket Diagnostic kits).

Crop management

Whilst the use of ICM is not formalised within a structured programme as such - nor driven by any particular ideology – it has evolved gradually at the site and now comprises an essential part of nursery's philosophy and approach to crop protection, building as it does on the company's long standing interest in biological pest control and the integrated management of pests. Whilst environmental concerns and a desire to pursue a more sustainable approach to production have played a part, the adoption of ICM is also helping to address nursery problems created by the diminishing range of approved pesticides available to ornamentals growers.

Crop protection has an especially high priority at this site, driven by a market requirement for zero tolerance of pests, diseases and weeds.

Crop husbandry

Growing media/nutrition

With some crops, notably *Choisya* and *Phormium*, considerable emphasis is placed in matching growing media specifications to their particular requirements. For example, humic compost is blended with peat and coir to give a well drained but moisture – and nutrient – retentive mix.

Clay minerals are used in the growing media for conifers and have conferred an effective buffering quality.

Irrigation
Drip-point irrigation is used with specimen grade *Phormium* to help control leaf disorders and crown rot, whilst capillary mat irrigation is in place for other moisture sensitive crops, notably *Choisya* and *Convulvulus cneorum*. Close attention is paid to water management (inc. irrigation timings). The nursery has also been involved in piloting new approaches to irrigation scheduling in an effort to improve water use efficiency and are especially interested in the potential of thermal imaging technology, should this become available and economically feasible for commercial use.

A blend of pond and bore-hole water is used for crop irrigation, acid dosed to moderate alkalinity. Chlorination was used for water disinfection but has ceased, in favour of a more natural and sustainable approach to disease control including the using of compost tea.

Environment manipulation
Crops are spaced and ventilated as required to facilitate adequate air movement, control temperature and humidity and in turn help to reduce leaf wetness and disease problems.

Pests
Of particular concern are leaf pests, notably two-spotted spider mite, thrips, caterpillar, whiteflies and various aphids.

Slug control remains an increasingly difficult problem to resolve (pellets are largely unsuccessful and those based on metaldehyde environmentally undesirable), as are the control of mice, without resorting to poisons (reluctantly). To a lesser degree, spider mite is also an ongoing problem.

Mealy bug on *Phormium* can also prove troublesome and difficult to control.

Pest control products
Where possible, short persistent spray products such as Chess WG, Majestik and SB Plant Invigorator, each of which can be used with IPM, are used to control pest outbreaks, usually as spot sprays, to minimise collateral damage to non-target insects, for example naturally occurring aphid parasitoids. Broad-spectrum pyrethroids are only used if necessary, for example to control caterpillars (a frequent pest of *Choisya, Euonymus* and *Photinia*), and as spot sprays well away from biological controls.

A growing media incorporated insecticide is added to the *Phormium* mix for mealy bug control.

Although vine weevil is not a particular problem, the new bio-insecticide product Met 52 (*Metarhizium anisopliae* var *anisopliae* strain 52) will be used in 2011.

Biological pest control and with it Integrated Pest Management (now an essential component of ICM) has been deployed at the site for several years, primarily for the control of two-spotted spider mite and thrips. Whilst the use of *Amblyseius cucumeris* predators has proved effective at controlling the latter (more so in fact than using insecticide products), biocontrol of spider mite has been less successful, with key crops such as *Berberis, Choisya* and *Phormium* suffering high infestations and damage during the mid-summer period. Whilst some of these difficulties could be linked to a lack of monitoring, shortage of time and deployment of insufficient predators at key times, a requirement for zero tolerance of leaf pests means the nursery currently relies solely on chemical control for this particular problem. Effective biocontrol of aphids and whiteflies has also proved difficult, for the same reasons and so the nursery has resorted to spot sprays to control any outbreaks, linked to twice weekly crop monitoring.

Spraying is not habitually the first option when confronted by a problem; accurate identification and alternatives to conventional synthetic insecticides are considered first, as are the use of 'soft' rather than persistent broad-spectrum treatments to mitigate any harm to non-target organisms such as beneficial insects.

Diseases

In terms of diseases, *Hebe* downy mildew and leaf-spot, and various root decay pathogens, namely *Phytophthora, Pythium* and *Thielaviopsis basicola* can pose problems. *Botrytis* can be a concern too under protection during the autumn and winter months, particularly amongst deciduous crops, notably climbers in tunnels.

Disease control products

Compost tea is used across the site for the control of disease problems, principally *Botrytis*, *Hebe* downy mildew and various leaf-spot fungal pathogens. It is applied fortnightly via overhead irrigation in summer and by spray application in winter. Whilst this provides valuable crop protection, especially when linked to good crop husbandry, hygiene and regular crop monitoring it is augmented where necessary with appropriate fungicide treatments, especially during the autumn-winter period. Fubol Gold is used against downy mildew and Nimrod, Systhane or Signum against powdery mildews. *Phytophthora* can be a problem on *Choisya* and they receive Subdue. *Rhizoctonia* is treated using Basilex or Rhizolex.

Microbial products, namely Trianum (*Trichoderma harzianum*) and Revive (*Bacillus subtilis*) have also been tried to help control *Pythium* and *Phytophthora* at the nursery's propagation unit nearby. While compost tea has proved "a real winner" with the range of crops on the site and helped reduce the site's fungicide inputs significantly, the Production Manager is a little more sceptical about some of the other novel products / bio-pesticides which have given variable results on the nursery and can be quite costly.

Elsewhere, potassium bicarbonate has been used in powdery mildew spray programmes but it can leave an unsightly leaf deposit on finished crops and scorching of soft growth is a concern, although the former problem may be resolved by earlier treatments and latter with lower application rates. The nursery is also interested in the use of potassium phosphate, and silicon based products to bolster disease control in crops prone to leaf diseases, notably at this site, potassium phosphate with *Hebe* for downy mildew control.

Weeds

Groundsel, willowherb, bittercress and liverwort are problems.

Weed control products

Groundsel was treated with Butisan S, willowherb controlled by using Ronstar 2G and liverworts by Venzar. Whilst residual herbicides are used to control weeds such as groundsel, willowherb and bittercress, the nursery has trialled pot toppers with some crops, for example those difficult to hand weed such as *Berberis* and *Genista*. However, whilst successful to a degree, pot toppers were time consuming to apply and not suitable for all crops (e.g. herbaceous perennials and plants with an overtly suckering habit. Cost (c10p per pot) is also a concern although there may be scope to re-use the better quality mats such as those made from coir and jute. Mechanisation may be the way forward with pot toppers and the nursery are following the development of a Dutch prototype machine with interest.

Loose-fill mulches are deemed unsuitable on account of spillage from pots (due to uneven road surfaces) and failure to provide lasting control of broad-leaf weeds, notably bittercress. However, some top-dressing of pots is done for 'cosmetic' purposes when cleaning up pots prior to despatch.

Hygiene and crop monitoring

Disease control using compost tea is augmented with good husbandry (grading, crop monitoring, dry regimes where appropriate and prompt removal of diseased plant material).

Both *Choisya* and *Phormium* crops are carefully graded at potting and 'culled' promptly as and when root or crown decay problems are spotted on the beds.

Whilst disciplined nursery hygiene is regarded as crucial in order to reduce background problems – and so bed sweeping and prompt removal of nursery waste are undertaken – a 'sterile' environment is discouraged in order to enable beneficial microbes to survive and develop, in line with the use of compost tea. Disinfectant products are not used as it is felt these may destroy beneficial compost tea residues. However, pruning tools are disinfected when working with crops deemed to be most at risk from disease transfer, e.g. *Choisya* and *Convulvulus cneorum*.

Crop monitoring is carried out twice weekly by the Site Manager and fortnightly by the Production Manager.

Key points from the grower

- ICM is the way forward given the diminishing range – and in some cases effectiveness – of synthetic pesticides and the need for all nursery businesses to be environmentally responsible, particularly, going forward, with the need to comply with the requirements of the Sustainable Use Directive (2014). ''ICM is a cultural thing and whilst we have not set out to devise and implement structured programmes – an overly prescriptive approach might be difficult to achieve given the diversity of crops and ICM measures involved – we are gradually moving in that direction''
- Whilst trying to maintain good nursery hygiene, the nursery doesn't go overboard and seek a completely sterile environment – preferring to not use disinfectants as these might counteract the beneficial effects of the compost tea programme.
- Compost tea has worked well on this site and is worth considering by other growers, depending on the type of crops they grow – and their associated problems. Whilst it's not a remedy to cure all ills, it – alongside other measures outlined – has certainly helped improve the quality and robustness of e.g. the *Choisya* and *Hebe* crops.
- Biocontrol has given effective thrips control under protection. Its low success for spider mite and whiteflies on this site may be due to a lack of time and focus due to other work pressures, rather than any inherent failing with the technique, which is generally well proven.
- Monitoring crops at least weekly for pest and disease problems is essential, particularly during the spring and summer months under protection, and acting promptly when problems are spotted.
- Investing time in matching growing media to the requirements of particular crops has improved crop quality; for example, the additional buffering properties of humic compost have worked well with *Choisya*.
- Close attention is paid to water management e.g. using low-level irrigation, particularly with moisture sensitive crops such as *Choisya, Phormium* and *Hebe*.
- If unsure about the cause of a particular problem it is checked out promptly to ensure that the most suitable – and effective – treatments are chosen. The local Plant Clinics are used and the Manger consults widely if required.

Nursery Case Study ID Code 30 (20 ICM measures out of 47 = 43% score)

Nursery area and crops grown

This multi-sited business in the west midlands produces a wide range of herbaceous perennials (including ferns). Principle crops include *Geranium, Hosta, Heuchera, Iris, Peony*

and various grasses; however, the range of stock includes herbs, young vegetable plants and alpines. Stock is produced primarily for the retail sector which accounts for two thirds of sales; the remaining stock is sold within the landscape and amenity sector which remains an important sector.

The nurseries are on several sites, on over 5.5 ha of production beds. The majority of beds are protected (nearly 4 ha), including tunnels where the polythene can be removed in late spring or summer, removing the need to move crops outdoors or to apply growth regulators. Outdoor beds are also an important production facility with a current total of 1.6 ha. New outdoor beds are currently being installed to increase the area of outdoor beds to 2 ha. A further 400 square meters are planned in 2012. Longer term, 5000 square meter of glass will be constructed in two blocks.

Training and advice sources

There is support from the ADAS Notes and visits from an ADAS consultant, together with the HDC (HDC News, workshops/events and the weekly email). Information is also obtained from the trade e.g. Horticulture Weekly.

Crop management

Crop protection is considered important in order to meet customer specifications. The business has grown by 50% since 2007 in terms of production volumes, with significant increases in crops such as herbs, and this has limited the amount of time that is available to devote to the implementation of ICM systems. ICM is currently focused on the use of selective pesticides and commodity substances such as potassium bicarbonate, however, the nurseries are increasing their use of ICM.

Crop husbandry

Growing media/nutrition

Optimising plant nutrition is considered an important technique to help to prevent diseases, and fertilisers containing potassium phosphite and seaweed extracts are utilised to strengthen plant growth. This is particularly important in herb crops where pesticide applications are kept to a minimum as spray applications (and associated harvest intervals) can disrupt sales.

Irrigation

All irrigation is overhead. Water sources include bore hole and mains supplies. The new nursery beds have been designed with water recycling in mind (these beds have been plumbed into a water recycling system, although the water recycling system is not operational as yet). Attention is paid to water use and efficiency; this has been identified as an area where improvements could be made by capturing and storing rainwater which is better quality in terms of irrigation than either mains or borehole water. Acid dosing is not carried out as it is not necessary.

Environment manipulation

Crops are spaced and ventilated and / or moved outside in line with crop need and the growing conditions. Managing the crop in this way prevents excessive humidity, temperature and Improves air movement.

The overhead watering is carried out in the morning where possible, particularly under protection. This aids leaf drying, which limits the risk and severity of a range of foliar diseases.

Crops are produced in the most appropriate location to meet the crops requirements e.g. ferns are produced under shading to prevent foliar scorch

Pests

Leafhoppers are a problem on a range of stock including herbs such as *Salvia officinalis.* Because this pest is so mobile it is difficult to eradicate as new infestations seem to move in from hedgerows and surrounding non cropped areas. Spraying herbs can render them unsalable for up to 14 days due to harvest intervals, depending upon which product is used. Therefore controlling leaf hopper can be difficult within saleable crops, especially when they are growing rapidly as removing herb crops (particularly those grown under glass) from sale for 14 days can result in crops going over at certain times of year.

Other more visible pests such as aphids and caterpillars are problematic. Outbreaks of two-spotted spider mite (TSSM) tend to occur in midsummer as temperatures increase and are linked to a lack of time to monitor crops.

Rabbits can also cause problems. Although all production sites are fenced, the rabbits soon find holes in fences. Where burrows occur within the fenced production site, control and eradication is difficult.

Pest control products

Spray programmes work around naturally occurring predators e.g. an influx of Ladybirds controlled aphids in the fern crop and only a couple of hotspots of pest activity had to be sprayed out.

Short persistence insecticides are used where possible e.g. Aphox, Chess WG, Spruzit and Dynamec to minimise impacts upon naturally occurring predators such as aphid parasitoids, Ladybirds and hoverfly larvae. Broad spectrum pyrethroids are only generally used to control caterpillars and leafhoppers.

Diseases

Powdery mildew can affect a range of crops grown, as can downy mildew which is problematic on key crops such as *Digitalis and Salvia.* Root pathogens such as *Pythium* and *Phytophthora* can cause problems on *Euphorbia, Helleborus* and *Penstemon* at certain times of year and are often linked to stress caused by the weather, e.g. high temperatures under protection, particularly following potting.

Whilst the usual diseases such as powdery and downy mildews cause problems on a range of stock these pathogens can be prevented by utilising good cultural controls. These diseases do not cause too much of a problem providing that fungicide programmes can be put in place if needed. *Rhizoctonia* is a problem on some batches of stock, the disease is difficult to predict and often causes crop losses by the time symptoms have been detected and controls applied.

Disease control products

Rovral is the main fungicide control product against *Rhizoctonia*; it would be useful to have other effective fungicides that are reasonably priced. Prestop has not been used to date because of its high price.

Potassium bicarbonate is used in powdery mildew spray programmes and is used as the main control on herb crops (*Salvia* and *Rosmarinus* in particular) as there is no harvest interval. Potassium phosphite is also used to help prevent diseases such as downy mildew on a range of hosts, particularly *Salvia.* Serenade ASO is used in disease control programmes and is used on herbs prone to *Botrytis* such as oregano. Stimulate and or Maxicrop are used to give plants a boost, particularly plugs that have not been potted as quickly as intended.

The nursery is investigating getting Trianum incorporated into the growing media by their

supplier.

Weeds
Potting new batches of stock adjacent to older stock infested with willowherb, bittercress and groundsel can increase weed pressure in some instances.

Weed control products
The majority of mature crops, excluding herbs, are top dressed with bark. 9cm's and plugs are not top dressed as they would be smothered. The bark mulch prevents moss and liverwort establishing on the surface of pots and reduces the time taken to process orders. Plants are potted centrally and are transported on Danish trolleys, rubber trolley tracks are used where concrete paths do not separate beds, because trolleys are not transported for a long way over uneven internal roads the loose fill bark works well.

Some Ronstar 2G is used on newly potted batches of stock and Flexidor 125 is used at 1 litre per hectare where crop safety is known. The business is looking at the results of HNS 166 ("Hardy ornamentals: herbicide screening for herbaceous perennials and grasses") and plan to make more use of residual herbicides such as Devrinol and applications in late winter.

Hygiene and crop monitoring
Beds are swept and sprayed with Jet 5, where possible between batches, before new stock is stood down. During the height of the season, when potting is in full spring and resources are stretched due to the need to dispatch high volumes, the stock beds are not always sprayed between batches. Beds are always swept even if it is not possible to spray them.

Iris crops can be prone to bacterial infections therefore infected plants are promptly rouged which prevents disease spread. Geranium crops that have not sold before they have gone over are promptly cut back to promote new growth and flowers to facilitate swift sales.

The production manager walks crops daily on the three main sites. However, crop monitoring on the satellite sites is the responsibility of the site managers. Key people within the business are always keeping an eye open to look for and react to problems.

Key points from the grower
- It is important to concentrate on all the basics of crop production in order to produce good plants. ICM encompasses these core strategies such as regular crop monitoring.
- Clear beds of old stock prior to standing down new crops as water requirements can be very different. Group crops with similar cultural requirements.
- Pay close attention to water quality – monitor quality of water sources and blend with other water sources if necessary.
- Manage production against sales and understand your markets. Time potting in line with sales to limit the need to cut too much stock back – aim for a succession of smaller batches of stock coming through as bedding plant growers do.

Nursery Case Study ID Code 31 (no questionnaire completed)

Nursery area and crops grown
These nurseries based in the South are primarily a liner producer. The production of hardy nursery stock liners for the trade makes up 65 percent of production. The remaining 35 percent of sales are of specimen shrubs, containerised trees and containerised soft fruit for independent garden centres.

The nursery site visited comprised 100 acres, much of which is used for the field production of trees. Grass leys are sown to rest land between tree crops. At any one time 4.5ha is in field production whilst 3.6 ha is used for the production of young plants and liners, there are 3.4 ha of outdoor container beds and 1.5 ha of stock beds.

Training and advice sources

The production director places great emphasis on training staff to recognise the importance of identifying and controlling pests, diseases and weeds.

To keep up to date with pesticide changes, new biological controls and techniques there are one or two advisory visits per annum from Dove Associates. The business also subscribes to the ADAS Hardy Ornamental notes and obtains additional information from the following sources: ADAS, FAST (for soft fruit), Fruit focus, local talks and events, HDC training / technical days, HDC news (which helps them to keep abreast of developments within other sectors that may be transferable), HDC SOLAs, IPPS Meetings and workshops, Hort Week & The Green Book. Spray operators are NROSO registered.

Crop management

The business has progressed ICM a lot in the last ten years. The nurseries evaluate lots of different products, which has given them the confidence to fully utilise cultural controls and minimise spray inputs where other solutions can be used. They continue to look at ways of preventing pests, diseases and weeds impacting upon production; the correct timing of key tasks such as propagation and potting helps to avoid problems. Embracing new technologies and products helps drive the business forward; including the use of the increasing range of bio-pesticides that suit the ICM based system The production director is confident that few changes will be required to ensure compliance with the Sustainable Use Directive.

ICM is utilised at both sites, with cultural controls being seen as an important first step. A structured biological control programme is in place, mainly at the glasshouse site, but also at the main site under protection e.g. in propagation.

Crop husbandry

Growing media/nutrition

A well drained rooting substrate with a high perlite content is used; this helps to keep the substrate open whilst maintaining the air filled porosity of the rooting medium and preventing the medium sitting wet and cold. This has resulted in less sciarid; a common problem in propagation; switching from the incorporation of Suscon Green to Met 52 has also undoubtedly contributed to control.

Individual crops are managed in order to meet the crop needs to minimise potential pest and disease problems.

Irrigation

An Evaposensor controls irrigation in propagation, but other crops are controlled by Heron, with percentage reduction up and down used frequently. Some liners are on capillary beds whilst the rest are watered overhead. Drip irrigation is used to water container grown trees whilst field grown trees are watered by boom irrigators.

The nurseries have an abstraction licence for water from a natural lake on the site, but this cannot meet demand alone. Water is pumped into a 250,000 gallon butyl lined reservoir. Mains water tops up the reservoir in order to meet demand. The water is treated with nitric acid prior to chlorination. At another site, rain water is collected from the glasshouse roofs and is stored in tanks prior to use. The tanks only hold a certain volume of water and overflow into a drainage ditch.

Environment manipulation
Ventilation is considered an important ICM technique in relation to disease control, ventilation of glasshouses is automated whilst tunnel ventilation is manual. They aim to get as much air through crops as possible, with team leaders responsible for ventilation. Generally vents are only closed when temperatures drop to 6°C or 7°C although vents on some crops are closed before temperatures get this low. Crops are watered carefully during the winter in relation to the weather to ensure that the foliage does not stay wet for longer than is necessary. Trees are spaced to ensure sufficient airflow through the crop canopy. Spacing is not appropriate for liner crops as pots are placed in plastic trays.

Evaposensors are used to control the mist system in propagation. Because conditions vary so much It has been found necessary to have two Evaposensors within each house to achieve optimum results; one on the north and one on the south side. The propagation environment is drier than conventional leaf operated mist systems, with less moss and liverwort pressure due to reduced water usage. These drier conditions have helped to reduce pest and disease problems within the propagation environment.

Pests
A diverse range of crops is grown in order to provide the required range for customers therefore no particular pest, disease or weed issue affects all crops. Pest problems tend to vary from season to season, in 2011 aphids were more prominent than in previous years.

Rust mites and Tarsonemid mites are becoming more of a problem on crops such as *Azalea, Euonymus, Itea* and *Sambucus.* While TSSM is not an uncommon pest, control is not considered difficult. Thrips and sciarids are not much of a problem,

Apple leaf curling midge and pear blister mite are two of the most difficult pests to control. Leaf and bud nematode is seen as the biggest problem going forward. To reduce the risk of problems *Anemone* that have been micro propagated are bought in to ensure that stock is clean; these are then used as mother stock. All *Penstemon* cuttings are bought in as cuttings, taken from micro propagated mother plants for the same reason.

Pest control products
Few broad spectrum pesticides are now used. These which may have previously controlled or suppressed rust mites and tarsonemid mites. Acaricides are now used to achieve control.

The new mix of aphid parasitoids from BCP has given us the confidence to control aphids with biological controls as there is no need to identify individual aphid species, Intercept 70 WG used to be the main control. Less chemical controls are available to control Two – spotted spider mite (TSSM), *Phytoseiulus persimilis* is used where possible under protection. *Amblyseius californicus* is used under protection instead of *Phytoseiulus persimilis* during spells of hot weather.

Planned releases of predators are increased if need be in order to achieve success where pests are getting away from predators but a corrective insecticide is not required.

Vydate 10G is the only real control for leaf and bud nematode and has caused problems with phytotoxicity on *Buddleja, Penstemon* and *Phlox.*

Met 52 is used against Vine weevil and should also help to suppress other pests such as Thrips and sciarids with a soil / compost dwelling stage to the lifecycle.

In contrast to under protection, insecticides are normally used to achieve control in outdoor crops; although biological controls have been used outdoors to some success in trees where

the canopy is touching.

As there are fewer pesticides approved for use on fruit than on ornamentals, the preferred strategy is to apply chemical controls as soon as these pests are seen. Insecticide groups are rotated to prevent resistant populations developing.

Key lines of some stock plants are planted directly into the soil within glasshouses and are planted in groups in line with crop susceptibility to pests and diseases so that controls can be effectively targeted at key areas.

Diseases

The main disease problem is bacterial canker on *Prunus* (Fruit trees) and ornamentals e.g. *Prunus* 'Stella'. Problems can arise from the rootstocks which are thought to be infected, but without symptoms prior to planting (the pathogen is latent).

Disease control products

A 10 day fungicide programme is in place in propagation and other areas for mildew and scab control.

Where crops are susceptible to a particular disease e.g. *Phytophthora,* proactive approaches are sought e.g. incorporation of Plant Trust into growing media. IPM compatible products are used where possible to minimise the risk of damaging biological controls.

Trianum is used both as a compost incorporated treatment and as a drench, use is targeted at key crops e.g. *Cistus, Lavandula* etc. In addition, Trianum *(Trichoderma harzianum)* is used; other biological products including Prestop are also being trialled to determine their effectiveness. Serenade ASO (ref. SOLA 0246/09) is used preventatively, particularly in propagation; Serenade ASO (ref. SOLA 0246/09) is also used in conjunction with copper fungicides as a tank mix to control bacterial infections.

Mycorrhiza and bio-stimulants have helped to reduce fungicide inputs; this has helped to reduce operator exposure to pesticides which is seen as a positive step forward.

Weeds

The main weeds in field production that cause problems are mare's tail, docks, dandelion and fat hen. In liner production moss and liverwort can cause a problem, but applying a mulch of bark has reduced the extent of the problem, although where the bark topping falls away from the edge of the pot the mosses and liverworts can take hold. Bark topping is applied to liners by a tray topper (machine) to prevent moss and liverwort establishing. Bigger pots are topped with bark by hand as it is difficult to justify the cost of another machine given the number of larger pots handled. Chickweed, bittercress, and willowherb are common container weeds. Oxalis can be a problem on some bought in plugs; young Oxalis seedlings are removed with care to ensure complete removal of the root system to prevent weeds re-generating.

Weed control products

Weeds in propagation are controlled by regular hand weeding. Some (limited) use of Ronstar 2G is applied to certain liner crops. Roundup is used to spot treat perennial weeds and to kill grass leys prior to cultivations whilst Harvest is used as a contact herbicide. Chikara is used in non crop areas and the nursery is looking at using this herbicide on sand beds. Stomp, Butisan S, Flexidor 125 and Devrinol are the main residual herbicides, although there is interest in making more use of Lenacil and Linuron. Weed control in soft fruit is achieved by top dressing with bark. Flexidor 125 is the main residual herbicide, depending on the specific crop.

Panacide used to be used for moss and liverwort control and bark topping liners has removed the need for the use of pesticides to control mosses and liverworts. Bark topping liners has also streamlined the dispatch process, with less time being spent cleaning up product prior to sending it out. The bark topping prevents moss and liverwort growing on the surface of liners after delivery to customers; this prevents them having to spend as much time cleaning up liners prior to potting.

Hygiene and crop monitoring

Beds are cleared, (scraped if necessary), swept and sterilised if necessary with either Jet 5 or Menno Florades. Chlorine is used to sterilise the sand where crops with root disease have been grown prior to standing following crops down. A tank mix of Ronstar liquid and Flexidor 125 is used to provide residual weed control on beds prior to standing crops down. Crop losses are rogued out and disposed of to prevent disease spread.

The nursery has very competent staff that take an interest in pest, disease and weed control. Crop monitoring is delegated to the three supervisors with individuals responsible for the following areas: tree production, liner production at the main site and off site liner production. Supervisors report to the production director. Weekly crop monitoring is linked to weekly spraying needs, with planned applications of fungicides adjusted in line with current disease pressure; insecticides may also be applied depending on levels of pest activity. The production director and supervisors adopt a team effort with regard to crop monitoring and implementing the most appropriate controls.

Key points from the grower

- Try to expand biological control programme every year to embrace new products. Look at biological pest and disease control as one and get the basics right to ensure success. Ensure that good pest, disease and weed control programmes are in place before problems get out of control and monitor and adapt programmes as required.
- Keep things as simple as possible, get the basics such as the correct substrate, adequate ventilation and appropriate irrigation for the crop in question.
- Do not produce more stock than you have a market for as you may be tempted to retain old crops until the following year; pest disease and weed problems tend to be worst in older crops.
- Keep production areas clean to avoid problems and to prevent carry over between crops. Paying attention to the fundamental basics ensures that the foundations are in place to produce a good crop.
- Be aware of crop specific problems, treat them if you need to and take a proactive approach where necessary. Avoid applying treatments for pest, disease or weed control where they are not necessary.

Nursery Case Study ID Code 32 (no questionnaire completed)

Nursery area and crops grown

This nursery is based in the South West and sells a wide range of usual and less usual nursery stock species and varieties, and the business is about 60% retail, plus sales to landscapers and other nurseries and independent garden centres in the South West region. They take advantage of the mild climate to grow many species of shrub and tree that are not normally hardy except in the South and South West. In addition, they grow small quantities of over 40 varieties of *Fuchsia*. The stock area is about 2 ha, composed of 0.5 ha field grown stock, and 1.5 ha of container ground, with 0.5 ha under protection. The site is sheltered but sloping, so heavy rainfall in the winter months is a problem, with leaching of nutrients and excess water in container stock left outside.

Most stock is unheated, although there is spare tunnel space if needed for winter protection. Two glasshouses are heated using a Biomass boiler running on wood pellets. This boiler also heats the retail area and café. The prop unit uses a Hotbox electric system, installed under the benches.

Training and advice sources

The main source of advice is HDC fact sheets, HDC News, and workshops, although it was noted that there were rarely any events held in the south west where there is a large density of smaller growers. The HDC was rated highly overall. The RHS website is found valuable for technical information. The local agrochemical distributor was rated as OK but not specialist enough. There was no regular contact with ADAS. Horticulture Weekly magazine is found useful, in particular Dove Associates' technical page which features topical problems.

Visits to other growers were felt to be extremely valuable, and the grower would welcome HDC events held on growers' holdings.

Crop management

The manager had heard of ICM, but was more familiar with the older term IPM. There is a strong emphasis on good environmental practices. There has been discussion with the landowner about the possibility of moving to Organic production, but the manager does not believe this is feasible at present, given the wide range of pests and diseases that attack the crops.

Crop husbandry

Growing media/nutrition

The nursery uses a peat free mix from Petersfield, which is supplied in bulk lorry loads and mixed in batches. The recipe uses composted mixed bark, plus 5 % loam and 10 % green waste. (Green waste use is uncommon amongst HNS nurseries). CRF is added, plus Met52 for vine weevil control, mixing these in using a concrete mixer on site. The manager has been testing Melcourts Silvamix peat free media as an alternative to the Petersfield mix as the latter media tends to be rather too heavy, due to the green waste, and sits wet during the winter months. The Melcourt product has seemed lighter and easier to work with.

Irrigation

The nursery has two boreholes plus a natural spring, all of which provide excellent quality water which is about pH 5.6-6.0, low in salts and ideal for nursery stock. Irrigation is by a mixture of overheads for field grown stock, hand watering for smaller containers, and drip lines for larger specimen plants in containers. There can be problems with customers removing the drip lines from the pots. There is no water recirculation and so excess water drains down the slope to ground.

Environment manipulation

Tunnels all have vented sides which can be rolled up to increase ventilation and allow air circulation and make conditions less favourable to diseases.

Pests

Vine weevil is adequately controlled by compost incorporated treatment, but it would become a very serious problem if left for a season or more. Capsid bugs (probably common green capsid) were very damaging to *Fuchsia*, *Caryopteris, and Magnolia.*

Scale insects were a problem, especially on high value subjects like *Camellia*. Tortrix moths have caused damage. Spider mite has been a sporadic pest. Aphids require control.

Pest control products

Spider mite has been a sporadic pest but Dynamec has given good control of spider mite.

Chess insecticide has given good aphid control. Certis spraying oil has been used for scale control, with reasonable results.

Vine weevil became a major problem on the nursery some years ago, in the period after Aldrin was withdrawn and before Intercept was approved. Since then, Intercept was routinely incorporated in the media before potting, but as soon as Met 52 became available in 2011, the nursery moved completely over to this bioinsecticide. So far, the results from using the Met 52 have been good.

Encarsia was tried for several seasons on the fuchsias, but black scales were never found and the results were disappointing. Instead of biocontrol use, knowledge has been built up of which species and varieties of e.g. fuchsia are most susceptible to whitefly, and they are monitored and treated if necessary with spot sprays of Gazelle or SB Plant Invigorator. Predators for TSSM have not been used and the manager felt that he would need further back up and advice to make their use work.

Diseases

In the past few years, *Phytophthora ramorum* was a very serious problem, and caused large quantities of stock to be destroyed. Now, the nursery is free of this pathogen. Nevertheless, as the nursery is surrounded by woodland, the risk is always present. All larches in the immediate vicinity have been felled, and all if not most of the wild *Rhododendron ponticum* was removed some years ago. PHSI inspectors visit the nursery regularly to monitor for infection. The manager knows which cultivars of rhododendron are susceptible and does not grow these anymore, and believes that many cultivars, including the small leaved hybrids, are resistant. LFD test kits (supplied by PHSI inspectors) are used regularly. The stock is constantly monitored for any signs of leaf or stem infection, and immediately rogued out and burnt.

Other diseases highlighted were powdery mildew and botrytis (mainly a problem in the winter months in tunnels).

Disease control products

Fungicide drenches are not used against *Phytophthora ramorum*. Fungicides are not used regularly for powdery mildew and botrytis, but products such as Systhane, Rovral and Cercobin have been used.

Prestop is in stock but has not been tried yet. Serenade has not been used so far. The manager is keen to use biopesticides but wishes there was more practical, unbiased information on their use as he finds the label claims confusing.

Weeds

The main weeds were hairy bittercress in pots and rosebay willow herb on paths and uncultivated ground.

Weed control products

Unlike many nurseries, Ronstar granules are not used after potting. Instead, the woven ground cover beds are kept clean, growing media is kept under cover and weed control is carried out by hand as far as possible to reduce weed problems.

Herbicides are used outdoors, including Roundup (glyphosate) and Kaspar (glufosinate-ammonium), but usually as spot sprays in problem areas.

Hygiene and crop monitoring

No rhododendrons or any species, such as *Viburnum*, which are susceptible to *P. ramorum* infection, are bought in and all propagation is from the nursery's own stock plants.

Susceptible plants are constantly checked for *P. ramorum*.

Key points from the grower

- The threat of *Phytophthora ramorum* requires constant monitoring of susceptible material and measures to prevent the introduction of the disease on bought-in plants
- The use of Ronstar herbicide on pots can be avoided by maintaining weed-free standing areas supplemented by hand weeding of pots

Nursery Case Study ID Code 33 (no questionnaire completed)

Nursery area and crops grown

The nursery is based in the South West and sells a wide range of HNS subjects, mainly shrubs and trees, with special emphasis on ericaceous subjects such as *Camellias* and *Rhododendrons*, with a small herbaceous section. Total area is only 2 ha, with about half this area under protection (polythene tunnels). The nursery is unheated except for the prop unit and one small glasshouse, which are heated by LPG.

About 70% of their plants are sold by mail order to retail customers, with only 15 % on nursery sales, with the rest wholesale to local landscapers

Training and advice sources

The grower had little or no contact with crop advisors, and relied on visits to other growers and the agrochemical distributor Monroes for advice. He read Hort. Week, with Dove Associates' technical update column being particularly worthwhile. HDC fact sheets etc were useful but the HDC website was not rated highly.

Crop management

The nursery manager was not aware of the concept of ICM, although he had heard of IPM from using biological controls in a previous job as manager of a strawberry farm. It is likely that without regular visits and /or technical advice by phone, there will be little uptake of ICM methods on this nursery in the future.

Crop husbandry

Growing media/nutrition

Scotts 70% peat/ 30% mixed bark nursery stock compost is used, with CRF and Intercept incorporated and delivered in 50m3 bulk lorry loads. Compost is stored under cover until needed. There is no pressure to reduce peat usage as present.

Irrigation

The nursery has a borehole, with soft water of excellent quality, although analysis has shown high Fe levels. There are no restrictions on abstraction levels from the Environment Agency. Irrigation is mainly by hand, plus a small amount of drip lines in specimen container stock. No recirculation is carried out, excess water runs to ground.

Environment manipulation

Some tunnels on this site have vented sides, but not all as some tunnels were quite old. The grower was aware of the benefits of ventilation in reducing diseases such as *Botrytis*.

Pests

The main pests encountered are scale insects, especially on *Camellias*, *Ilex,* laurels and other evergreen subjects. This is probably because the nursery takes cuttings from its own stock plants, which have low levels of scale present, thus perpetuating the problem. Intercept is incorporated into the compost, but does not provide complete control.

TSSM is a problem from late summer onwards under protection. The most important pest problem at present was phormium mealy bug (*Balanococcus diminutus*), which has proved extremely difficult to control. Glasshouse whitefly is a problem on some subjects under protection.

Pest control products
Pesticides used against TSSM included Dynamec, and Talstar. Biological control had not been tried as the grower felt that insufficient technical back up was available. Drenches of Intercept 70WG, and Certis spraying oil have been tried against phormium mealy bug, but the pest has not been eradicated. Physically acting products such as Savona and SB Plant Invigorator had been sprayed for whitefly control, but the grower was not sure if they were as effective as conventional pesticides.

The nursery is surrounded by woodland and the grower felt that, without the Intercept, vine weevil would rapidly become a major problem. The grower had not heard of Met 52, and was interested in the product when described, but valued the incidental control of aphids and other sap sucking pests given by Intercept.

Diseases
Phytophthora ramorum was a constant threat, as expected on a nursery in this region. Crops are inspected by the local PHSI officer who also distributes free LFD test kits for the grower to use. Larch and *R .ponticum* in the vicinity have been largely eradicated as they posed reservoirs of *P. ramorum* infection. The grower and staff have been given training by PHSI in symptom recognition and monitor crops regularly.

Other disease problems included the problems common on many nurseries - powdery mildew on *Acers* and *Lonicera*, and rust on hollyhock and *Hypericum.*

Disease control products
No biopesticides have been used, and the grower was not aware of products such as Serenade and Prestop. This may reflect the fact that they have not been promoted by the local agrochemical distributor (Monroes).

Weeds
The main weed problems are hairy bittercress, rosebay willow herb, chickweed and groundsel. On non cropped areas such as paths, control of rosebay willow herb from Roundup is inadequate.

Weed control products
After potting, container stock is treated with Ronstar granules, (in keeping with most nursery stock growers). Follow up applications of Flexidor are sometimes made, especially on stock that is slow growing. Roundup is used on paths.

Hygiene and crop monitoring
All crops are grown on Mypex, which is cleaned between crops, but on some long term crops in tunnels, a build up of peat, moss and liverwort was noted.

Key points from the grower
- Technical support on the use of pest biocontrol products is needed before they would be tested on the nursery as alternatives to the conventional pesticides in use at present

Nursery Case Study ID Code 34 (no questionnaire completed)

Nursery area and crops grown

This nursery is in the West and primarily a tree nursery with a strong background in fruit although ornamentals are an important component of the catalogue. Up to 60% of production is field grown which is supplied to commercial growers, farm shops and other nurseries. The bulk of field grown stock is containerised on site for the container unit.

The nursery covers a total of 400 acres; There are: 30 acres of established mother trees and hedges for propagation material, 8 acres of established stool beds, 50 acres of field production. The container unit container unit spans a further 10 acres. Remaining land is rested in grass leys. Grass is sprayed off and the land is sterilised prior to being brought into production. Oats are sown on sterilised land in the autumn and are ploughed in prior to planting in spring. This stimulates some biological activity within the soil, compared to bare ground green cover helps to give more control over planting as evapo-transpiration helps to dry the soil, particularly after a wet winter.

Most crops are budded or grafted, some rootstocks are produced via hardwood and semi ripe cuttings taken in autumn e.g. *Prunus* Colt, St Julian A & Pixie. Most production from stool beds is graded and sold / used in house. Some are planted out and are graded prior to use / sale. Some rootstocks (ornamental subjects in particular) are bought in e.g. *Acer, Crataegus* and *Fraxinus.*

Training and advice sources

The manager engages in continued professional development, attending Voluntary Initiative / UAP events and collecting NOROSO points too. Staff also attend relevant courses run by IPPS and HDC. HDC news, SOLAs / Extension of Authorisation for Minor Uses (EAMU) and The UK Pesticide Guide are used to keep up to date.

Crop management

The nursery manager believes that the nursery is well placed to meet the requirements of the Sustainable Use Directive with a return to the use of biological controls in 2012, cultural control of weeds within the container unit and the use of compost tea.

Crop husbandry

The growth tips of trees are frequently removed when pruning and heading back is carried out; this is often the type of growth that insects favour so pruning provides a degree of cultural control.

Growing media/nutrition

Irrigation

In the container unit, irrigation is supplied predominately through drip lines (in order to minimise disease pressure) with some hand watering. Rain guns are used for field scale irrigation. The nursery has a licence to abstract water and rain water and surface run off is collected in reservoirs. Water is chlorinated and dosed with nitric acid prior to use. The nursery has 3 reservoirs; 2 of which are butyl lined, the smallest of the 3 reservoirs is clay lined.

Environment manipulation

Protected crops are ventilated at all times unless frosty conditions prevail. Overhead watering is applied during the first two hours of the morning to ensure that the crops foliage is kept as dry as possible; many container grown trees are produced on drip lines. Crops are spaced far apart as possible to ensure sufficient return per square meter whilst maximising airflow. Tree lines are based on double rows with 1 meter between rows.

Pests

Key pests cause similar problems most years, the seasons / weather can dictate when

certain pests become problematic.

Two-spotted spider mite (TSSM) is the main pest under protection. Aphids frequently cause problems both outdoors and under protection. Woolly aphid, beech aphid and cherry blackfly are the most troublesome species. Thrips occasionally cause problems on cherries (both ornamentals and fruit lines). Capsid occasionally causes problems but as growth tips are frequently pruned out it is rarely an issue. Apple leaf rolling midge is also problematic– Movento appears to be the most effective chemical control. Minor pests include leaf miner, scale insects and rust mites.

Pest control products
The nursery has tried pheromone traps for apple leaf rolling midge but the height of traps seems fairly critical. The key to achieving control is to catch the pest early.

Until recently, biological controls have been used on protected crops for two-spotted spider mite, vine weevil, aphid and thrips control. For various reasons, biological controls were not used during 2011 but will be used again next year. A new sprayer operative will be trained in the use of biological control.

Although biological controls have not been used this year, IPM compatible insecticides have been used (Apollo (at the start of the season) Aphox, Dynamec, Chess and Sequel) which allows natural predators to build up.

Phytoseiulus persimilis, Feltiella acarisuga and *Amblyseius californicus* are used to control TSSM; different predators are use at different times of year in line with pest pressure and temperatures. Where aphids occur in high numbers early in the season, Aphox is normally applied prior to predator introductions. Hotspots of aphid activity are normally treated with Majestik when introductions of biological controls have commenced to minimise detrimental side effects on predators. Hoverfly larvae have not been used as crop canopies often do not touch. Banker plants have been used in each house in the past. Aphids are found to be much easier to control than TSSM which increases rapidly during spells of high temperatures. *Amblyseius cucumeris* are used for thrips control.

Nematodes (*Heterorhabditis bacteriophora*) in the product Larvanem are applied as a drench in the autumn to control vine weevil larvae.

<u>Diseases</u>
Bacterial canker is the main problem on field grown crops, particularly *Prunus.* It is possible that bacterial canker may infect crops from surrounding hedgerows however it is thought that losses are linked to cultural issues.

Powdery and downy mildews, *Botrytis* and rust are the most problematic diseases that occur both under protection and in field production.

Disease control products
Fungicide programmes (based on a 7 – 10 day programme) are in place for control of blossom wilt, scab and powdery mildew. As many fungicides from different fungicide groups are used as possible in spray programmes to help prevent fungicide resistance becoming a problem. Insecticides are added to fungicides if crop monitoring determines a need to do so.

Potassium bicarbonate and potassium phosphite are used

Serenade ASO is used as a protectant against bacterial canker.

Compost tea is used on a fortnightly programme on container grown crops and is IPM compatible, where disease problems occur fungicides are used in line with disease pressure. The use of compost tea has resulted in a reduction in fungicide use on container grown crops by at least 50%. Compost tea is not applied to field grown crops as in house trials comparing compost tea to a standard fungicide programme have indicated that there is little benefit gained from the application of compost tea to field grown crops. Pests are not controlled biologically outdoors so there is less concern of fungicide application impacting upon the performance of biological controls. Although the majority of compost tea is applied to the crop foliage it is also used as a pot drench to help protect stock from *Phytophthora.* Field grown stock that is containerised is treated in this way. Copper is applied at the end of the season to protect points of leaf abscission and to help to harden wood prior to winter.

Weeds

Generally, couch grass, annual meadow grass, fat hen, dandelion, buttercup and redshank are the most common field weeds. Creeping yellow cress can be problematic in stool beds; however this weed is controlled culturally by cultivations. Hedge bindweed has been a problem in stool beds however new stool beds are being established on ground that is free of bindweed.

Bittercress, groundsel and sow thistle are the most common weeds in container production.

Weed control products

Grass leys are sprayed off with glyphosate two weeks prior to commencing soil preparation. Residual herbicides are utilised within field production; Generally Flexidor 125 is either tank mixed with Butisan S or Devrinol (Butisan S can only be used once every 3 years on the same land). Occasionally, a tank mix of Stomp and Devrinol is applied. Ronstar liquid is also used occasionally. Weeds are spot sprayed in field production with Harvest, applied via a knapsack approximately every 3 weeks.

Glyphosate is used to kill any weeds that establish over winter on woven matting. Harvest is used periodically through the growing season in line with weed pressure. Most pots are mulched with bark to conserve water and minimise weed pressure; no residual herbicides are used in containers.

Hygiene and crop monitoring

Dead leaves are cleaned up to help prevent *Botrytis* and other foliar diseases.

Woven matting is scraped and swept to remove debris between batches and is treated with Jet 5. Irrigation lines are treated with Jet 5 at the end of the season. Hand weeding is carried out at least once a fortnight and whenever staff are working through the crops. Crop losses are rogued and burnt where pathogens are suspected (rather than composted) to prevent disease spread within the nursery.

The Pest and Disease Manager and Container Manager spray operator are responsible for crop monitoring which is carried out weekly. Different people have responsibility for field and container grown crops. The crop monitoring team are also responsible for inputs of biological controls; close attention is also paid to the effectiveness of spray applications. A team of three staff are responsible for weed monitoring and herbicide applications. Staff are encouraged to report pest, disease and weed problems when working through crops.

Key points from the grower

- Finished stock is stacked up on outside beds during winter so that the root zones are insulated by surrounding pots, this also frees up bed space prior to stock being sold.

- Compost tea has been used for approximately 7 years; providing crops are closely monitored it works well providing that fungicides are used where needed.
- ICM has worked very well in the past, there is a need to monitor the crop and take swift action when pest to predator ratios change. Technical support is vital for success e.g. changing the species of predator to suit the conditions. Bad experiences with biological control can tempt people to revert to spraying. Staff need technical understanding of how ICM works – aim to ensure that those responsible for crop monitoring know as much as possible and work as a team.
- Bark mulches have been used for 4 years in the container production unit, ensuring a sufficient depth of bark is the key to success. Providing that regular hand weeding is carried out and weeds are not allowed to set seed, this will give adequate weed control. Not all customers like bark mulches as they make a mess in retailer's customer's cars.
- Larvanem has been used for vine weevil larvae control for several years; although it is time consuming to apply it can be used on all crops (both edible and ornamental lines) and is very effective.
- Try new products and approaches, listen to other growers experiences. Keep up to date with publications, technical advice and keep staff up to date. Work with others to keep tabs on what others in the industry are up to.

12.2. Danish nursery case study

A case study was also carried out by telephone with a nursery growing HNS outdoors in Denmark. This study shows a greater outdoor use at this particular nursery of the same pest biocontrol products as used on protected UK crops. Many of the biocontrols are already in use in monocrop outdoor UK fruit production. Although use in Denmark was only between May and August, when temperatures there are suitable for biological control agents, this is when the pest problems will be most active.

A nursery of 11 hectares in Denmark run by the Christensen family with flowering shrubs and perennials grown in containers from 2 L to 10 L has been using biological pest control in the propagation area and glasshouses for 20 years. Since 2009, they have been working with the Danish Nursery Owner Association to investigate the use of bio-controls on outdoor production. The Danish crop advisor to this grower was interviewed for the current project by Jude Bennison, an expert in IPM in the UK to obtain practical details on the deployment of pest predators and parasites.

The products used are the same as used on protected crops in the UK. The measures were mainly used in Denmark from May to August when temperatures in Denmark are suitable for biological control agents. The pest problems are likely to be most active during these months.

Tables 12.1, 12.2 and 12.3 summarise the ICM strategies used and their varying success. Comments have been made on why they may or may not have been successful, in order to give guidance to UK growers considering following some of the strategies.

Table 12.1: Successful ICM strategies on outdoor HNS on the Christensen nursery

Pest	ICM strategy	Comment
Aphids	Parasitoids (*Aphidius colemani* & *A. ervi*)	Only certain aphid species attacked. Occasional hyperparasitism observed.
	Predatory midges (*Aphidoletes aphidimyza*)	Used to supplement parasitoids. Can work well but variable success.
	Predatory bugs (*Orius majusculus*)	Used to supplement parasitoids and *Aphidoletes*. Feed on beech aphids. Tend to establish on early flowering crops e.g. *Potentilla.* Will also feed on thrips and mites.
	Naturally-occurring predators	High incidence due to very few, selective pesticides used. Ladybirds, lacewings, hover flies.
Spider mites	Predatory mites (*Phytoseiulus*	*Amblyseius cucumeris* (used for

Pest	ICM strategy	Comment
	persimilis)	thrips) also give some control of spider mite but *P. persimilis* gives the main control.
Thrips	Predatory mites (*Amblyseius cucumeris*)	Not a big problem outdoors, occur later in the season.
Whiteflies	Parasitoids (*Encarsia formosa*)	Whiteflies not a big problem outdoors.
Vine weevil	Entomopathogenic nematodes (*Heterorhabditis bacteriophora*)	Applied in irrigation water in spring and early September, when soil temperatures at least 12°C.
Caterpillars	*Bacillus thuringiensis* (Dipel)	
Slugs & snails	Ferric phosphate (Ferramol)	
Ground-dwelling pests	Predatory mites (*Hypoaspis miles*)	Used against sciarid fly and thrips larvae in substrate.
Disease	**ICM strategy**	**Comment**
All leaf pathogens	Minimise insecticide use	It was claimed that the organic solvents in insecticides strip the wax layer and increase susceptibility to fungi.
All	Fungicides applied if monitoring showed need. Biofungicides not known of. Significantly fewer fungicides needed since using IPM (see note 10 below)	Tebuconazole (Folicur), azoxystrobin (Amistar), propamocarb hydrochloride (Proplant), fenhexamid (Teldor), and Tilt all said to be compatible with predators.
Weed	**ICM strategy**	**Comment**
Various	Pots covered with bark to prevent weeds and also to reduce evaporation and water consumption Larger beds used to increase production area so less space to get weedy	

Table 12.2: Moderately successful ICM strategies (some improvement / pesticides needed) in use on the Christensen nursery

Pest	ICM strategy	Comment
Aphids	Teppeki (flonicamid)	Used occasionally. IPM compatible.
Spider mite	Nisserun (hexythiazox)	Used if needed, IPM-compatible.
Caterpillars, beetles, leaf miners	Spruzit (pyrethrum)	Used if needed, IPM-compatible if used infrequently as short persistence.
Disease	**ICM strategy**	**Comment**
None mentioned		

Table 12.3: Unsuccessful ICM strategies or those not currently used on the Christensen nursery

Pest	**ICM strategy**	**Comment**
Capsids and leafhoppers	None available	Not yet a problem on this nursery.
Disease	**ICM strategy**	**Comment**
Root diseases	Prestop (*Gliocladium catenulatum*)	Not available in Denmark.
Botrytis	Serenade (*Bacillus subtilis*)	Still new in Denmark.

12.2.1. Key advice by a Danish grower for successful ICM in HNS

Factors which contributed to ICM success on the Danish nursery:

1. Dedication of the grower and the propagation manager, who had 20 years of experience in using IPM in the propagation area before trying it outdoors. The propagation manager is also responsible for production planning, daily work management, plant health (pest, disease and weed control), irrigation and nursery staff health & safety.
2. Starting on a small area first to gain experience and confidence.
3. Back-up visits, information and advice given by the biological control supplier consultant is considered key to success as he is very experienced in IPM (several other HNS growers would like to adopt ICM outdoors but the consultant has limited time available and this is inhibiting further uptake).
4. There was both better pest control and a better working environment when using biological control rather than pesticides.
5. Good advance planning of the ICM programme according to plant susceptibility to each pest and disease and time of year problems tend to occur.
6. Grouping together of plants with similar pest or disease problems.
7. Good weekly monitoring and recording programme.
8. Staff training in knowledge and understanding of biological control, and in recognising early symptoms of pest attack.
9. Careful release strategy for biological controls, e.g. in the morning, avoiding release in the hot, sunny times of day. Air-assisted knapsack used for fast release of some predators, this has been checked to calibrate release rates. Entomopathogenic nematodes applied through irrigation water.
10. Since adopting IPM on this nursery and using far fewer insecticides, the need for fungicides has been significantly reduced. This is attributed to insecticides being formulated with organic solvents that destroy the wax layer on the leaves, which exposes the leaf to fungal infection.

11. It was important to have a good relationship with customers so that they can understand about biological control and IPM (in particular if batches had to be delayed because the biocontrol agents had not finished their work).

Key benefits reported by the grower of using ICM

1. A better working environment – this is very important in Denmark. This helps to attract new horticultural staff.
2. Better pest control than when using insecticides (due to insecticide resistance).
3. High incidence of naturally-occurring predators and beneficial insects e.g. ladybirds against aphids and powdery mildew, lacewings, spiders, predatory midges, hoverflies, parasitoids, bumble bees and honeybees. Increased biodiversity.
4. Fewer fungicides needed.
5. Better quality plants.
6. Releasing biological control agents can be done in normal working hours, rather than spraying pesticides in the evening when overtime needs to be paid.
7. No spray certificate required to release biological controls.
8. Use of biological control agents is a good selling point.

- Research on the efficacy of bio-controls on outdoor HNS in the UK, perhaps looking first at those that are native e.g. *Amblyseius*, should be carried out.
- The side effects of pesticides on beneficials requires further research.

- UK growers should consider whether they might now test the use of biocontrol products outdoors, particularly if pesticide application on their nurseries involves application staff working after hours or problems with restricted entry to the crop for the period after spraying.

13. Knowledge Transfer and Research and Development Targets

Research and development opportunities are identified and discussed in detail within the main body of the report. This section assesses their relative importance for improving ICM, and the nature of the additional work required. Research will often involve collaboration between research organisations and/or crop consultants and commercial companies and the assistance of nurseries.

Opportunities have been assessed for their impact on improving the control of pests, diseases and/or weeds in HNS on nurseries and their importance within ICM. An indication is given of the period of research or development required before the measure would be

ready for use (probably initially as test-runs by commercial nurseries). Any constraints, other than the requirement for funding, are noted. Additional work required to substitute or integrate them on the nursery is noted. Action points have been divided into knowledge transfer and research and development.

Knowledge Transfer

1) Consultancy and demonstration:

Impact - High
Importance - High
Timeframe for implementation – Immediate
1.1 Demonstration sites ➢ Demonstration areas / test periods on nurseries should be set up for the most promising technologies (e.g. pheromone light traps, water sensors, slow sand filters). Ideally these should be at more than one location to be reasonably easily accessible to as many growers as possible. There could be opportunities for combined levy/manufacturer funding. There should be several open-day dates ➢ Demonstration sites would also be useful to allow commercial evaluation of pest and disease programmes as a whole throughout the year with monitoring various crops across the nurseries. Records would then exist to investigate why any failures arise and to seek to improve the effectiveness ➢ Certificates of Attendance should be issued to participants on training courses **Constraints** – Agreement of nurseries or other facilities to act as demonstration sites, funding for record keeping and demonstration days **Additional work required** – Selection of sites and funding of the work and ensuring effective knowledge transfer
1.2 Nursery consultancy ➢ Nurseries who do not currently employ a consultant (principally smaller ones) would benefit from a series of visits to put ICM into practice on their holdings, as detailed regular advice on the nursery is key to successful uptake of ICM amongst growers **Constraints** – Lack of suitably qualified consultants and cost **Additional work required** - None

Impact - Medium
Importance – Medium
Timeframe for implementation – Immediate
1.3 Using forecasting models ➢ Assistance to growers with running forecasting models (initially or ongoing) would be of benefit **Constraints** – Funding/finance would be required for consultation. Purchase of on-site weather recording equipment and support software **Additional work required** – Downloading and interpretation of data using decision support models
1.4 Using microbial products ➢ Growers should be given updates on the use of microbial biocontrols (both those registered as pesticides and others) for pests, diseases and weeds in agriculture and

edible horticultural crops so that they have information on how to integrate them into their HNS ICM programmes

Constraints – Lack of sound information on the efficacy of biocontrols not registered as plant protection products ("Grey-area" products)
Additional work required – Collation of and dissemination of information

1.5 Using molecular diagnostics

- Promotion of the benefits of molecular diagnostics techniques to growers and their utilisation in crops is required

Constraints – None
Additional work required – Comparison of the results from conventional and molecular diagnostics

2) Preparation of Publications:

Impact - High
Importance – High
Timeframe for implementation – A year from commissioning of work

2.1 Implementing IPM

- A booklet, DVD or website on IPM should be produced
- An information sheet / web source summarising the pest lifecycle stages which are controlled by various plant protection products and biocontrol products should be made available to growers
- A guide on how to Crop Walk should be produced with information on how different crops should be inspected for various pest and disease problems
- Specific crop guidelines are required for ICM in addition to measures which apply across all crops

Constraints – None, other than collaboration between writers and product suppliers
Additional work required – Information needs to be collated and inspection protocols agreed between experts

Impact - Medium
Importance - Medium
Timeframe for implementation – A year from commissioning of work

2.2 Avoiding pesticide resistance

- An information sheet each for insecticides, fungicides and herbicides should be provided for growers displaying mode of groups for the most common products used on HNS nurseries. This will facilitate selections for good resistance management. This would supplement the information on the principles of resistance already commissioned by the HDC

Constraints – None
Additional work required – Extraction from existing databases required

2.3 Timeliness of treatment

- A monthly wall chart/calendar listing the risk of various pests activity (including pictures of the pests) could be produced
- The chart could be provided as a spreadsheet to allow grower use alongside spray programmes
- Smart phones could be sent information on specific pests and diseases to look out

for each month

Constraints – None
Additional work required – Gathering of information on lifecycles/generations and agreement of experts on how these are affected under protection

2.4 Optimising bio-control deployment

- Information on the numbers of bio-controls to be released and how the numbers should be adjusted according to the situation in the crop, together with recommendations for combinations of bio-controls to improve effectiveness

Constraints – Co-operation of the biocontrol companies to agree rates of application and situations where rates would benefit from being changed
Additional work required – Subsequent monitoring by nurseries utilising the information

2.5 Aphid identification

- A factsheet and website and/or Smartphone "App" on aphid identification is required, with a table of which crops the different aphid species are most likely to occur. This should include details of which bio-control organisms are effective against each species

Constraints – None
Additional work required – Production of additional pictures of aphid species

2.6 Biocide/disinfectant selection

- An updated HDC factsheet on biocides/disinfectants is required so that growers can select the safest and most effective active ingredient for the specific contamination problem

Constraints – None
Additional work required – Collation of information on product efficacy, and possibly some comparative tests of biocidal activity

Impact - Low
Importance - Low
Timeframe for implementation – A year from commissioning of work

2.7 Do suppressive growing media help?

- A review of disease suppressive media for container and field grown crops

Constraints – None
Additional work required – Review of research, possibly leading to comparative trials

Research and Development:
1) Integrated programmes:

Impact - High
Importance - High
Timeframe for implementation – A year from commissioning of work (for initial results)

1.1 Capitalising on SCEPTRE results

- Results on biopesticides and non-chemical crop protection measures found effective

against specific pests, diseases and weeds of edible crops in the in the SCEPTRE project (CP 77) need to be examined to identify the new developments most relevant to HNS crops

Constraints – Availability of products showing sufficient efficacy to pathogens present on HNS
Additional work required – Testing of products for phytotoxicity and efficacy on HNS

1.2 Filling pesticide gaps

- Where the range of active ingredients is being reduced for particular pest, disease or weed problems then research on suitable alternatives (plant protection products, cultural and biological etc) needs to continue, with the submission of applications for EAMUs for plant protection products if needed

Constraints – None
Additional work required – Research projects will be needed for various crops and problems

1.3 Optimising biocontrol on HNS

- Research is required to maximise the control given by biological control products of pests and diseases
- Specific research on biocontrol focussed on individual HNS crops is needed to get the best results

Constraints – None
Additional work required – Targeted work on specific pests and diseases and key crops, with additional separate focus on outdoor crops. The majority of the work could be within commercial crops, but some specific trials would be required. Integrated programmes need to be devised so that actions to improve control of one problem do not make others worse

1.4 Development and validation of molecular diagnostics

- Further development of molecular diagnostics techniques for identifying and quantifying pathogens and pests (e.g. in soil), followed by validation in crops

Constraints – None
Additional work required – Development of techniques and research to validate the results in crops

Impact – High (for outdoor crops) Lower (for protected crops)

Importance – Medium

Timeframe for implementation – Two years (for initial results)

1.5 Develop better forecasting of pests and diseases

- Further investigations on monitoring and forecasting would be of benefit, in particular the utilisation of existing models on other crops for the same pests and diseases as on HNS
- Information gathering on potential invasions/epidemics could be developed and dissemination funded by the AHDB cross-sector as some invasions/epidemics related to weather conditions e.g. aphids and powdery mildew may apply to several arable and outdoor horticultural crops at once within particular regions of the UK

Constraints – Interpretation of monitoring results and use in forecasting by growers will require training. Growers may need to purchase traps. Some web based forecasting systems are run with non-HDC grower levys or plant protection company funding and agreements will need to be reached with these before the models can be utilised. Once

information is collated from other crops there would need to be validation work on HNS nurseries

Additional work required – Collation of information, comparison of lifecycles on different crops, production and ongoing administration of ideally a website to disseminate the information

Impact – Medium

Importance – Medium

Timeframe for implementation – A year from commissioning of work (for initial results)

1.6 Smartphone pest and disease identification

- Information and photographs on specific pests/diseases for each month could be sent to growers to be read on Smart phones. Smart phones could be used with a magnification application to aid identification of the problem

Constraints – More widespread purchase of Smartphones. Ongoing funding of consultant/s to prepare crop information on pests and diseases likely to be important in the coming month unless a fixed pest/disease/weed "likely problem period" calendar is used

Additional work required – Ongoing downloading by the grower if a one-off set calendar warning programme is not used. Promotion to growers and utilisation of feedback

Impact – Low

Importance - Medium

Timeframe for implementation – A year from commissioning of work (for literature review)

1.7 Enhancing populations of beneficials

- Work to compile lists of crop e.g. herbs and weed plants known to be good sources of beneficials and not of pests or diseases is required

Constraints – Availability of some of the information on pests of native flora

Additional work required – Information on hosts for beneficials is mainly available from farmland, grassland and garden research, but linking with information on host plant pest and disease susceptibilities is required. Testing of plants as reservoirs of pests and disease and the conditions that favour these and the balance with beneficials is required

Impact – Low

Importance – Low

Timeframe for implementation – Two years for the first crops/varieties

1.8 Identifying resistant/tolerant varieties

- Resistance/tolerance testing of cultivars of some of the more popular HNS with particular problems with diseases or pests would be worthwhile

Constraints – This would be an ongoing programme to include an increasing number of HNS crops, varieties and pest and disease problems

Additional work required – Replicated trials and/or collation of information from nurseries for crops with particular disease or pest problems where cultivar resistance is suspected

Research and Development:

2) Pests:

Impact – Medium

Importance – Medium

Timeframe for implementation – One to two years from commissioning of work (initial

results)

2.1 E-nose pest monitoring

- More work should be carried out on "e-noses" as an aid to crop monitoring, particularly to give early warning of an attack

Constraints – Cost of e-noses. Uncertainty as to whether all models of e-noses are sensitive enough to detect insect and pest presence in a protected structure
Additional work required – Testing of the existing models in cropping situations so that improvements can be made in the devices and/or the way they are used and the interpretation of the results

2.2 Pheromone pest monitoring

- Pheromones for pest specific monitoring require further research

Constraints – Pheromone traps are pest species specific and with mixed HNS there is likely to be a wider range of pests to consider than for mono-cropping. Traps will need to be purchased by growers
Additional work required – Research to identify and prepare pheromones and to establish the best release rates. Nursery validation testing of traps would be needed

2.3 Vine weevil attractants for monitoring

- If vine weevil attractants are developed then commercial development should follow

Constraints – Time to try out various methods in different types of cropping areas
Additional work required - Setting up of experiments on nurseries to allow regular monitoring

2.4 LED lights for pest monitoring

- The use of LED light traps is under investigation and use in commercial situations needs to be tested

Timeframe for implementation – After existing project completion in September 2013
Constraints – Purchase of traps. Time for growers to test out the traps and record results
Additional work required – Deployment, emptying and recording of traps

2.5 Control of leaf and bud nematode

- There is a particular need to find a control method for leaf and bud nematode

Constraints – Ideas required on methods. The pest is only confined to particular crops
Additional work required – Research on e.g. biological or chemical control

2.6 Control of less common pests

- Scale insects, capsid bug, phormium mealybug and woolly aphid control methods require investigation

Constraints – None, other than finding methods that are effective
Additional work required – Research is required on a variety of techniques

2.7 Dispersal range of predators/parasitoids outdoors

- Information needs to be collated and researched on the dispersal and host-finding behaviour of parasitoids and predatory insects in the outdoors, in mixed-cropping and mono-cropped areas
- This would increase the confidence of growers and give information on release rates/spacing and geographical location in the crop

Target for Action – HDC, researchers, possibly biocontrol companies
Constraints – Increased confidence of growers to use biocontrols outdoors where the insects could potentially disperse from the areas of deployment
Additional work required – Determining if the density and distribution required for various biocontrol agents to achieve pest control differs from when the same plants are grown under protection

Impact – Low
Importance – Medium
Timeframe for implementation – A year from commissioning of work (initial results)

2.8 Optimising use of banker plants

- Work is required on the optimum banker plant species and density of distribution for use with released predators or parasitoids

Constraints – Willingness of growers to utilise bankers to aid early multiplication of biocontrol species
Additional work required – Testing of various species for their ability to produce food sources (e.g. pollen or aphids) which can maintain biocontrol organisms which will then disperse in to the crop

Research and Development:
3) Diseases:

Impact – High
Importance – High
Timeframe for implementation – A year from commissioning of work (initial results)

3.1 High health propagation material

- Further research is required to provide guidelines on the propagation of disease-free material, including the use of on-site diagnostic tests and their utilisation with latent infections

Constraints – The co-operation of propagators to stop affected plants being produced. Where micro-prop is to be used then controlled temperature and lighting is required. Lateral flow devices (LFDs) are available for only a restricted range of pathogens (fungi, bacteria and viruses)
Additional work required – More information is required on the latency of diseases and the extension of pathogens e.g. in vascular tissue beyond visible infection. Development of additional LFDs e.g. for *Phomopsis*

3.2 Identifying bactericides

- More products against bacterial plant pathogens need to be developed, with curative action being the most important

Constraints – Bactericides exist for surface sterilisation but cannot be used on crops unless registered as a plant protection product
Additional work required – Efficacy testing of chemical products and potential biocontrols including bacteriophages

3.3 Extending the use of forecasting models

- Verification of the rose downy and powdery mildew forecasting programmes should be carried out on other crops

Constraints – Grower acceptance of forecasting as a way to reduce fungicide use
Additional work required – The testing of products in commercial crops and the creation of an understanding of how to manipulate the disease based on changing environmental conditions

3.4 Improvement in soil/root health through utilisation of molecular diagnostic techniques

- Utilisation of molecular techniques, such as T-RFLP, to identify and quantify micro-organisms in soil and growing media to gain information on both the beneficial microbial compositions in rhizospheres and the populations in areas of replant sickness. This could lead to improved root health by subsequently carrying out the manipulation of rhizosphere communities

Constraints – Initial work may need to focus on a small number of species across a range of soil types and geographical locations to provide comparative information on the microbial population
Additional work required – The sampling of rhizospheres to build up a database on the compositions of microbial communities from around healthy and weak/diseased root systems. Work on selective control of particular microbial species or the supplementation and/or multiplication of beneficials would then need to follow.

Impact - Medium
Importance - Medium
Timeframe for implementation – A year from commissioning of work (initial results)

3.5 Making use of disease suppressive growing media

- Research studies to evaluate disease suppressive media for specific HNS crops know to have problems with particular diseases

Constraints – The suitability of the suppressive growing media for all crops
Additional work required – Trials with different growing media and crops

3.6 Use of essential oils and other natural products for disease control

- Further research on natural products to improve plant health

Constraints – Legislative difficulties in testing "Grey-area" materials and products for their efficacy against pathogens, as showing that a "plant health promoter" gives direct control of an organism can lead to requirements for the active ingredient to be registered as a pesticide and the product will then require plant protection registration.
Additional work required – Review of existing information before commencing trials with various materials, ornamental crops and diseases

Research and Development
4) Weeds:

Impact - High
Importance - High
Timeframe for implementation – Two years from commissioning of work

4.1 Algae and liverwort herbicides

- Plant protection products need to be produced, or existing biocides put through the pesticide registration process, in order to provide registered products against algae and liverworts for use on crops or over cropped areas

Constraints – The availability of products for testing
Additional work required – Laboratory testing of specific products against a range of organisms

Impact - Medium
Importance - Medium
Timeframe for implementation – Two years from commissioning of work

4.2 Alternatives to herbicides

- Further work on seed meal, composted woodfibre, bark mulches and sterilised loam is required across a range of plant species to investigate dose rates for liverwort and weed seedling control and to clarify some issues of phytotoxicity

Constraints – Different products of the same type may produce different results because of the varying source material and percentage compositions of components
Additional work required – Research with a range of growing media supplements and mulches and various weeds

Discussion

This discussion incorporates comments on ICM given by growers, consultants and researchers during the course of this project and seeks to highlight the next stages in the development of ICM for HNS and other ornamental crops in the UK. It is clear that there has been a significant amount of government and levy money spent on many individual horticultural projects which have covered specific pests and diseases or weed problems. In crops such as oilseed rape, soft fruit and organic vegetables, there has been work to integrate pest and disease control, but there has not, until the current project, been an attempt to bring together the many strands of ICM knowledge and to combine these with current best or 'better' practice amongst HNS growers.

It was seen from this work that "low pesticide-input pest management practices (strategies)", with the integration of both non-chemical and reduced or alternative plant protection product options for the effective, practical, economically viable and environmentally-sustainable management of pests, diseases and weeds, were taking place. The majority of nurseries were using good growing conditions and husbandry (e.g. removing infected/infested material, clean cuttings, careful watering and pot spacing) and monitoring pest and disease problems. Nearly all stated that they went through the stages of considering if treatment was necessary and if there was no alternative to chemical use then consideration of the product's safety to the environment was considered. Growers listed a number of products that they used against pests and diseases, coming from a range of activity groups to minimise resistance. A couple of nurseries made greater use of a range of bio-control organisms for pest control than the others with, in general, two-spotted spider mite predators being the most frequently utilised, and this seemed to be related to the growers' greater knowledge of ICM. Many nurseries have some or all of their crop outdoors and, as purchased, biocontrols are more usually thought of as being for use under protection; their use outdoors on a Denmark nursery could be of interest.

Although this project has dealt specifically with the management of pests, diseases and weeds, for integrated crop management to be effective it is necessary to ensure that plants are growing strongly and to consider the sustainability of ornamental plant production systems. Nutrition and water management are important and work on these areas will be critical in the future. The use of slow release fertilisers and fertiliser applied as top dressing needs to be examined, as there may be issues of run-off, in which case there is a need to determine the extent of the problem and the associated pollution risks.

An adequate supply of water will be important and there needs to be more investment in water harvesting and recycling on many nurseries. Phytophthora infections of the foliage and roots can be spread by contaminated water and although there was research carried out a decade ago on the construction of slow sand filters for water treatment, the uptake on nurseries has been minimal. To aid growers' decisions relating to the investment of time and money on in order to improve their irrigation and drainage systems it would be sensible to have demonstration facilities, probably with sites in the north, south and southwest to allow for differences in rainfall and climate. Demonstration sites would also be useful to show the effective use of biocontrols and the use of monitoring and forecasting tools to improve pest and disease control.

With the current concern about the UK government's insistence on peat replacement in England in commercial horticulture by 2030 there is an opportunity for the development of peat alternative composts with disease suppression benefits; with activity coming either from the certain compost components, or from the inclusion of microorganisms such as certain strains of *Trichoderma*.

It is possible that, as with fruit growing, there will be a move to more protected cultivation of ornamentals to improve the growth predictability/quality of crops. Recent hard winters and wet summers have caused plant losses to frost, foliar and root diseases. The presence of *Phytophthora ramorum* in rainfall has caused problems for growers of susceptible species of HNS. However, production under protection may increase certain pest problems. With protected crops there is the possibility of using LED lighting to enhance rooting which may impact on pest and disease control. A new facility for LED research is being developed at STC.

The importance of alternating fungicide products in order to minimise the risk of fungicide resistance is clear. However, much of the information on cases of fungicide resistance in ornamentals is anecdotal (M McPherson pers comm.). Information on fungicide resistance is passed to the FRAC by the arable sector as part of the Stewardship of the product because there is a regulatory requirement to monitor resistance to be able to justify the continued use of products. However, no monitoring is carried out within ornamentals and insufficient coverage is often the cause of poor control rather than resistance. The recent reporting of metalaxyl resistance in *Impatiens* downy mildew has been the first official record from ornamentals in the UK. Work has been done on insecticide resistance by Rothamsted Research, but similar work is required for fungicides. If chemical plant protection product use

is to be integrated with other control methods then more research is required to enable the correct fungicide choices for effective control of particular pathogens.

One thing that stood out during the collation of replies to the survey and whilst on nursery visits was that, although opportunities had been taken up for the replacement of insecticides/acaricides by biocontrol organisms at a number of nurseries, the use of fungicides was still high. Investment by companies in biocontrol organisms, and development work on their use on nurseries, has meant that the control of most pests is possible without the use of pesticides. However, more ways to give growers the confidence to reduce the quantity of fungicide applications still need to be found. With more accessible technologies such as in-crop loggers, improved computer memory capacity and on-site diagnostic devices, there should be more opportunities to use fungicides only where monitoring and/or forecasting shows it to be necessary. Greater use of fungicidal biocontrol agents or antagonists or other products that make plant tissue less hospitable to pathogens could also help to reduce the use of the more environmentally harmful fungicides. More research needs to be carried out on alternative methods of disease management.

A sensible way forward for future research commissioning by the HDC would be an increase in cross-sector projects. This might also allow more funding of longer strategic projects, in particular those bringing together the expertise and facilities of researchers from different organisations. The current pool of experts in the UK is not large and collaboration is currently limited by the perceived need to compete for funding. In addition to longer-term collaborative projects, there needs to be a mechanism of fast response to requests for the funding of short term “crisis” projects so that effort is not expended on preparing detailed bids and delays experienced during the prolonged bid procedure. Where there is clearly grower support for work, or information from overseas where urgent action is needed, this should speed acceptance. The industry needs to be increasingly proactive in order to be aware of developing problems, to allow procedures that minimise the risk from new pests, diseases and weed from abroad, so that there is less need for crisis action.

It is clear from literature reviews and attending conferences that there are bodies of scientists carrying out research that is never heard about in the horticultural industry. There needs to be more linking of pure and applied research and then, most importantly, extension work so that new ideas can be put into practise on nurseries. Most people try things out after seeing how they perform for someone else and more needs to be done to demonstrate techniques to growers. If demonstration events are held, they should be repeated to be within reasonable travel distance of most nurseries, with an effort made to attract more

participants from smaller nurseries. Increasing the amount of knowledge transfer via the HDC could necessitate a greater funding stream for researchers/advisors separate to research costs. Some areas of horticulture are more technologically advanced than others, and as was seen in the current project, some nurseries are closer to reduced pesticide inputs than others. Effort need to be made to give growers the support they would like in order to achieve the level of ICM practicable on their own nursery.

Conclusions

- From postal surveys of 30 nurseries and visits to 12 HNS nurseries (contact with 34 nurseries), it was shown that all were carrying out a mixture of measures against pests, diseases and weeds involving crop husbandry and the selection of plant protection products
- A few nurseries were carrying out a very wide range of measures and recommendations have been made suggesting wider adoption by others of certain measures
- Pest biocontrols were in use on many nurseries, but not the full range, and more widespread information on these products for growers and assistance with their utilisation is recommended
- The majority of HNS growers will have no difficulty in satisfying the requirements of the Sustainable use Directive.

Glossary

Acaricide: A pesticide product with activity against mites

BCA: Macro-biocontrol agents, i.e. not microbial, for the control of invertebrate pests. Parasitoids (e.g. wasps) and predators (e.g. mites) are used for specific pest targets.

Biopesticide: Biological plant protection product involving the use of beneficial micro-organisms/microbes. Their active ingredient will have been registered on Annex I as a pesticide. These are more usually bacteria or fungi, but can be viruses. These may be used live or the product can be an extract of the material (e.g. an enzyme or metabolite) produced by the organism that is effective against the target pest, pathogen or weed.

Biologicals: This term can be used to distinguish products containing beneficial micro-organisms that are not registered for use in plant protection products/biopesticides. Such products can also be described as biostimulants or antagonists and there should be no claims on the label that the product kills/controls pathogens. The term can also include natural products such as plant extracts. Products that claim to improve plant health may also be called "grey-area" products, particularly if there is some evidence that pathogens can be killed following use of the product.

ICM: Integrated Crop Management - the integration of biological, chemical and cultural control methods to achieve sustainable invertebrate pest, pathogen and weed control.

IPM: Integrated Pest Management – the integration of biological, chemical and cultural control methods to achieve sustainable pest control.

Leaf bait: Pieces of leaves, e.g. of rhododendron, that are put in irrigation water (usually suspended in a porous bag) to attract the swimming spores (zoospores) of *Phytophthora* and *Pythium* species in order to monitor (e.g. by use of an LFD) water contamination.

LFD: Lateral flow device - part of a commercial diagnostic kit that includes buffer to enable extraction of the pathogen from the plant tissue so that it can react with the assay strip in the LFD to produce a coloured line indicating a positive detection. Separate LFDs are required for *Phytophthora* and *Pythium,* and further testing (molecular) is required for determination of the species.

Parasitoid: An insect that kills by developing inside or on a host's body.

PCR: Polymerase chain reaction - a technique for the multiple duplication of a length of molecular material (DNA or RNA) in order to produce sufficient for detection and identification ("fingerprinting"). Developments in molecular diagnostics have allowed the production of faster results, better quantification, detection of more species and of multiple species in one sample. Smaller equipment for use in crops has been produced.

Pheromone: A chemical attractant usually specific to one particular insect species.

Plant protection product: Product to protect crop plants from damage by pests and diseases and competition with weeds/plants growing where they are not wanted.

Predator: An insect or mite that attacks and eats prey.

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Websites

A sample of websites with IPM/ICM specific content is given here, but there is a vast range of material available (particularly from the Extension Services of many USA Universities);

http://www.endureinformationcentre.eu European network for durable exploitation of crop protection strategies

http://ec.europa.eu/sanco_pesticides/public/index.cfm Links to the European Union database on approved active substances including toxicological information. The data can be searched and exported to Excel.

http://www.eppo.org/PPPRODUCTS/information/new_eu_regulations.htm New EU Plant Protection Products Legislation with document downloads on The Plant Protection Products Regulations, The Directive on the Sustainable Use of Pesticides and the Directive with regard to machinery for pesticide application.

http://www.greenhousemanagementonline.com/new-greenhouse-production-manual-available.aspx
An IPM manual is available for download

http://www.greenhousemanagementonline.com/Default.aspx
Greenhouse Management magazine (GIE Media, Ohio, USA) with advice and links

http://www.ipmnet.umd.edu/index.htm
University of Maryland IPM factsheets and research

http://www.weatheronline.co.uk/weather/agriculture?LANG=en&COUNTRY=UK&WMO=u3764&MENU=801&CROP=3&STAGE=3&DTG=0&AZ=A
Disease forecasting for various horticultural crops

http://www2.warwick.ac.uk/fac/sci/lifesci/wcc/hdcpestbulletin/brassicas/cabbage_root_fly/
HDC Pest Bulletin provided by Warwick to 2010. Cabbage root fly egg-laying forecasting. This moved to the Syngenta website in June 2011 www.syngenta-crop.co.uk/pestupdate/

Appendices

Appendix 1

Survey questions sent to by the HDC to all nurseries growing HNS.

Dear Grower,

Help to shape the future of crop protection activities in the HNS Sector

Background

The Hardy Nursery Stock (HNS) Panel receives numerous requests to fund crop protection research and communication activities. This survey has been designed to assist the Panel's decision making when deciding how best to invest the levy. It aims to gather 'baseline' information on current approaches to crop protection along with pest, disease and weed control concerns. This information will help us to promote economically-viable and practical 'better practice' crop protection methods and to identify future research priorities. Needless to say; the more replies we receive, the better the decision-making process will become.

Integrated Crop Management

The survey places a strong emphasis on Integrated Crop Management (ICM), as the implementation of the EC Sustainable Use Directive (SUD) will require all growers to demonstrate that they are using ICM techniques by 2014.

ICM aims to reduce the use of 'conventional' crop protection products and to select products of lower risk to human and animal health and the environment. Therefore ICM is a combination of non-chemical and chemical techniques to achieve effective pest, disease and weed control. ICM techniques include:

- Nursery hygiene, water management and other cultural methods
- Pest and disease forecasting & monitoring
- Biological controls, including predators, parasitoids and 'biopesticides' (i.e. products contain biological control agents, such as microbials, pheromones or plant extracts).
- Some 'natural' physically-acting products such as plant extracts and oils, currently exempt from the pesticide regulations

Given environmental, legislative and market pressures to reduce our use of higher risk products, coupled with the diminishing range of products available to growers, this new approach, which helps to reduce their use, is essential to safeguarding the industry's future.

Completing the survey

This survey has been sent out via hardcopy and electronic copy (which is also available on the HDC website: www.hdc.org.uk).

The full survey should take about an hour to complete. However, partially-completed surveys can also be returned. ADAS have been commissioned to conduct this survey (as part of project HNS 185). The surveys will be held by ADAS and the information reported without identifying individual nurseries (unless you permit us to do so). You may complete the survey anonymously.

PLEASE SEND REPLIES BACK TO:

Dr Erika Wedgwood, ADAS Boxworth, Battlegate Road, Boxworth, Cambridge CB23 4NN by post or E-mail to erika.wedgwood@adas.co.uk.

For support or to complete the survey over the telephone, please call 01954 268231.

HNS Crop Protection (ICM) Survey

Background Information

Optional information

Name	
Nursery name and address	
Telephone number/s	
e-mail	

Q1

How well do you feel you **understand what ICM is and what it involves**? (An explanation was given on the front page) Please put a **X** in one of the boxes				
1 very well	2	3	4	5 poorly

Please confine your subsequent answers to activities on a single site.

Please use separate forms if you are able to complete details for other sites.

Q2

Production area	Approximately, how big is your hardy nursery stock production area (hectares)?		
	Protected container	Outdoor	
		Container	Field

Q3

Crop type and area grown FG = Field Grown CG = Container Grown	Young plants (e.g. plugs, liners, intermediate pots, seedlings, transplants and tree whips to be grown-on)		Mature plants (e.g. in final or near final pots, or final field locations being grown-on for sale)	
	Approximate area in **ha**	**%** grown under protection	Approximate area in **ha**	**%** grown under protection
Herbaceous				
Climbers				
Shrubs				
Trees (CG)				
Trees (FG)				
Hedging (CG)				
Hedging (FG)				
Roses (CG)				
Roses (FG)				
Heathers				

Conifers				
Alpines				
Aquatics				
Edibles				
Other (please state)				

Crop Protection information and training

Q4

Information sources Where do you get crop protection information from?	**Score** importance to your decisions **1**= high relevance **to 5** = little benefit Leave blank, if not used	
	Score	Further details (e.g. frequency)
Visit by biocontrol supplier		
Information from biocontrol supplier by post/phone/email/website		
Visit from other crop protection product supplier		
Information from other crop protection product supplier by post/phone/email/website		
Visit or information from growing media or sundries company		
Visit by other IPM consultant		
Information from IPM consultant by post/phone/email/website		
Visit by general horticultural consultant		
Information from general horticultural consultant by post/phone/email/website		
Training courses (please state)		
Plant Clinic (please state)		
HDC Events		
HDC News		
HDC Factsheets		
HDC Crop Walkers Guides		
HDC project reports (including Grower Summaries)		
HDC website		
CRD website		
Liaison Website		
Pesticide resistance websites (e.g. FRAC/FRAG)		
Other websites (please state)		
Search engine (e.g. Google) (Please state)		
Magazines (Please state)		
Text books/other publications (Please state)		
ADAS Technical Notes		
'Other' (please state)		

Q5

Training	How often are people trained in pest, disease and weed identification and crop protection tools? Mark frequency with an **X**			
Frequency	Senior manager	Team Leader	Regular team member	Seasonal staff
Not at all				
On arrival only				
Occasional / *ad hoc*				
Yearly or less frequently				
	Where is the training received from? Mark combinations with an **X**			
	Senior manager	Team leader	Regular team member	Seasonal staff
Visiting crop walker (trade)				
Visit from supplier				
Visit from consultant				
On-site training by external provider				
Off-site training by external provider				
On-site training by own staff				
College (before or in employment)				
'Other' (please state)				

Approaches to crop protection

Q6

Crop monitoring	How frequently are the majority of crops walked in the growing season to check on pests, disease & weeds? Mark with an '**X'**		
Daily	Twice-weekly	Weekly	Other

How do you keep records of crop monitoring? e.g. notebook/standard pro-forma stored on computer or hard copy (If you use a standard pro-forma, it would be helpful if you could enclose a copy when returning this form)

Q7

Products	Which crop protection products do you most commonly use? Are treatments used preventatively (**P**) or curatively (**C**)? How effective is it? **1** = eliminates problem **to 5** = no/little effect				
	Main pest Pest target	Product name	On which main crops	**P** or **C**	Score **1- 5**
Pests					
1					
2					
3					
4					
Diseases					
1					
2					
3					
4					
Weeds					
1					
2					
3					
4					

Q8

Decisions on product use	How many of the following points do you usually consider when deciding whether or not to use chemical crop protection products against pests, diseases or weeds? State **Y**es or **N**o
	Y / N
Has the problem been accurately identified?	
Does the level of damage or potential damage justify the need for treatment?	
Is an alternative to chemical control an option?	
Is chemical control the most effective solution?	
Are non-target organisms (such as beneficial insects) at risk?	
Can a safer (e.g. for the environment) chemical option be considered?	

Q9

Main crops	Questions 11, 16 and 22 should be answered in reference to your main crops. Please list up to 4 of your main crops (e.g. *Clematis, Choisya, Hebe, Phormium)* or up to 4 of your main crop categories (e.g. shrubs, herbaceous, alpines, conifers climbers)			
Crop or crop categories	Crop 1	Crop 2	Crop 3	Crop 4

Pest Control

Q10

Please comment on any <u>pests</u> (including slugs, snails and nematodes) you find difficult to control on this nursery site.

Q11

Pest control within ICM	Which ICM <u>pest</u> control measures do you already practice on your main crops (as specified in Q9)? What <u>approximate</u> percentage (%) of the total crop is included within the ICM measure? • Please mark percentage with an asterisk ***** if it includes crops grown outdoors. • Mark as '**?**' if you do not understand what the measure is.			
Main Crop	Crop 1	Crop 2	Crop 3	Crop 4
ICM measure (%):				
Sweeping				
Covered disposal				
Pressure-washing				
Removal of infected material				
Monitoring:				
Sticky traps				
Pheromone traps				
Plant inspection				
Indicator plants				
Quarantine areas				
Bio-control measure against:				
Aphids				
Caterpillars				
Leaf miner				
Sciarid fly/shore fly				
Slugs/snails				
Thrips				
Two-spotted spider mite				

Vine weevil				
Whiteflies				
Other				
Others:				
Crop Rotation				
Selective crop protection product (e.g. Chess)				
Pot toppers and mulches				
Banker plants				
'Other' (please state)				

Q12

Do you have a structured control programme in place? If so, please provide further details (e.g. what type of programme and who designs it?)

Q13

Biological control products	How effective have you found biological control products at controlling pest problems? **1**= Good control **2**= Moderate control (occasional integration of pesticides) **3**= Poor control (resorted to pesticide use) Please score with an asterisk ***** if it includes crops grown outdoors.			
	1	**2**	**3**	Which biological control was mainly used/comments? State if **No** experience
Aphid parasitoids (these lay eggs in the pest, e.g. *Aphidius ervi*)				
Aphid predators (these eat the pest, e.g. lacewing larvae)				
Whitefly parasitoids (e.g. *Encarsia*)				
Whitefly pathogen *Naturalis-L* (+ on thrips)				
Mycotal (+ on thrips)				
Thrips predators (e.g. *Amblyseius*)				
Thrips pathogenic nematodes				

(e.g. Nemasys F)				
Two-spotted spider mite predators (e.g. *Phytoseiulus*)				
Sciarid fly predator (e.g. *Hypoaspis, Atheta*)				
Sciarid pathogenic nematodes (e.g. Nemasys)				
Vine weevil pathogenic nematodes (e.g. Nemasys L)				
Caterpillar control *Bacillus thuringiensis* (Dipel DF*)* *Nematodes*				
Caterpillar parasitoid (e.g. *Trichogramma*)				
Slug pathogenic nematodes (e.g. Nemaslug)				

Q14.

What ICM measures for <u>pest</u> control have been considered/used but not adopted?

What were the reasons for not adopting or using these?

Disease Control

Q15

Please comment on any <u>diseases</u> you find difficult to control on this nursery site.

Q16

Disease control within ICM	Which ICM <u>disease</u> control measures do you already practice on your main crops (as specified in Q9)? • What <u>approximate</u> percentage of the total crop is included within the ICM measure? • Please mark percentage with an asterisk ***** if it includes crops grown outdoors. • Mark as '**?**' if you do not understand what the measure is.			
Main Crop	Crop 1	Crop 2	Crop 3	Crop 4
ICM measure (%):				
Disinfection beds etc				
Covered disposal				
Crop rotation				
Sterilise trays/pots				
Removal of infected material				
Crop husbandry:				
Growing media selection (e.g. for structure)				
Clean cuttings				
Quality seed				
Resistant varieties				
Cleaned water				
Sub-irrigation				
Water monitoring by electronic means				
Water monitoring by hand/eye				
Spot watering				
Irrigation scheduling				
Grouping crops by water need				
Pot spacing				
Regular inspection				
Inspection records				
Diagnostic kits				
Quarantine areas				
Ventilation / environment control				
Hygiene:				
Boot dips				
Tool disinfection				
Restricted access				
Clothing hygiene				
Hand washing				
Products:				
Bio-stimulants				
Bio-pesticides (e.g.				

Serenade ASO)				
Microbial inoculants or similar (e.g. Revive)				
Others:				
Weather records				
Disease forecasting programmes				
Water sampling				
Water baiting				
'Other' (please state)				

Q17

Water sources	Which water sources do you use? Please record all those that apply by marking with an **X**. Mark the main volume source over the whole year with an **XX**.					
Borehole	Mains	Reservoir	River	Roof	Recycled	Blended

Q18

Water treatment	How is the water treated on the nursery in terms of disinfection or purification (mark **X** to all that apply)?					
UV	Chlorination	Slow sand filtration	Copper ionisation	Reed/Iris beds	Other	None

Q19

Natural products	How effective have you found natural or microbial products (e.g. plant stimulants)? 1 = Substantial increase in plant quality or loss reduction 2 = Noticeable improvement 3 = Some effect or sometimes 4 = No improvement 5 = Adverse effect Please mark answers with an **X**					
	Not used	1	2	3	4	5
Compost Tea						
Garlic products						
Essential oils (e.g. Biosept)						
Plant extracts (e.g. Orosorb)						
Potassium bicarbonate (e.g. Agricarb)						
Potassium phosphite						

(e.g. Farm-Fos)						
Sodium bicarbonate						
Sulphur						
Prestop						
Revive						
Rootgrow						
Serenade ASO						
Trianum						
Wormcast products						
Other (name)						
Other (name)						

Q 20

What ICM measures for <u>disease</u> control have been considered/used but not adopted on this nursery site?

What were the reasons for not adopting or using these?

Weed Control

Q 21

Please comment on any <u>weeds</u> (including mosses, liverworts and algae) you find difficult to control on this nursery site.

Q22

Weed control within ICM	Which ICM <u>weed</u> control measures do you already practice on your main crops (as specified in Q9)? What <u>approximate</u> percentage of the total crop is included within the ICM measure? Please mark percentage with an asterisk ***** if it includes crops grown outdoors. Mark as '**?**' if you do not understand what the measure is.

Main crop	Crop 1	Crop 2	Crop 3	Crop 4
ICM measure (%):				
Disinfection (e.g. of beds, pots)				
Nursery hygiene				
Water management				
Pot toppers				
Bark mulch (pots)				
Other mulch (pots)				
Mulches (field)				
Bio-fumigants (field)				
Others (name)				

Q 23

What ICM measures for <u>weed</u> control have been considered/used but not adopted on this nursery site?
What were the reasons for not adopting or using these?

Encouraging wildlife

Q24

Do you try to encourage native beneficial insects to build up on the nursery, and if so how? Please mark with a '**X**' to all those that apply							
Not carried out	Using only selective pesticides	Wild flower strips	Nettle reservoir areas	Beetle-banks	Bumble bee homes	Bird boxes	Other (what?)

Q25

Have you any other comments on aspects of pest, disease or weed control measures in relation to ICM?

If you have any queries, or would like to comment more fully on some of the questions, then please contact Erika Wedgwood on 01954 268231

THANK YOU VERY MUCH FOR COMPLETING THIS SURVEY

Appendix 2

Appendix Table 2.1: Summary of how the project objectives have been covered within the report sections. In addition, there is some overlap of objectives between sections.

Report section and title	Main objectives covered*
Grower Summary Action Points	2,4
3. The Introduction of the Sustainable Use Directive and the Potential Impact on UK HNS Growers	3
4. Crop Types and Land Areas Surveyed	1,2
5. Knowledge Transfer	1,2
6. The Extent of Integrated Crop Management in UK Hardy Nursery Stock	1,2,4
7. Monitoring and Forecasting	1,2
8. The Selection of Plant Protection Products by Growers	1,2,3
9. The Continuing Availability of Plant Protection Products	3
10. Hygiene and Cultural Control	1,2
11. Natural Beneficials for Pest Control and Wildlife Conservation	1,2
12. Case Studies of HNS Nurseries	1,2,4
13. Knowledge Transfer and Research and Development Targets	4

*The objectives were:

1. To establish the current extent of use of ICM and determine the strengths and weaknesses of available strategies and identify gaps in current ICM programmes for HNS.

2. To identify, list and assess the feasibility and practicality of current ICM practices.

3. To briefly describe the potential impact on HNS growers from ongoing changes to plant protection product legislation and the implementation of the EC Sustainable Use Directive (SUD).

4. To provide guidance on the ICM practices required to improve – or at least maintain at present levels - production efficiency in an environmentally sustainable way.

5. To create a publication for the HNS sector on practical, cost-effective ICM practices currently available and guidance on how to adopt them.

It is anticipated that Objective 5 will be covered by a full article in HDC News based on the findings of this report.