

Project title: Review of the development and use of trap plant systems for pest control in protected ornamental crops

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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

This is a desk study which outlines the importance, mechanisms and literature base of trap plant approaches to control pests. The report is focused on protected crops, in particular ornamentals. The study provides an overview of trap plants whilst highlighting specific studies of relevance to the UK protected horticulture sector.

Background

The protected ornamental industry faces a range of issues linked to crop protection and production. These include a reduction in the available products approved for use, the potential for increasing resistance in target pest organisms, increasing pressures from consumers and retailers for 'environmentally-friendly' practices and a need to comply with legislation and industry initiatives. These pressures have led to a change in pesticide use and the exploitation of other methods available for maintaining pest populations below the economic damage thresholds, using integrated crop management (ICM).

Trap plants offer a means of manipulating pest behaviour and their use for pest control has been well researched in some arable and horticultural crops. However, the vast majority of successful examples to date are in outdoor crops. In many cases, promising results have been obtained and recent evidence suggests that trap plant systems may be transferable to ornamental crop production where interest in the subject area is increasing.

Trap plants are usually grown either within a crop or around its perimeter. The pest preference for the trap plants over the crop plants, results in reduced pest damage to the main crop. Though most commonly employed against more mobile pests (such as beetles butterflies and moths), research suggests that trap plants can also be used with success against pests displaying more random and/or weak dispersal behaviours, such as thrips, whitefly and aphids, which are of particular interest to protected ornamental growers.

Recent research suggests that a trap plant approach may work in protected ornamental crops as it has in outdoor edible and arable crops. Work with both western flower thrips and glasshouse whitefly, for example, has produced promising trap plant species for use in several ornamental crops.

This desk study aims to bring together the evidence relating to the successful use of trap plants, providing UK growers with an improved evidence base to inform them of which trap plants are most attractive to pests (i.e. which have the potential to work best from the scientific literature). This, combined with feedback from growers through a survey and consultation, will allow growers to assess where trap plant research would benefit from further work.

Summary

There are a number of important conclusions that can be drawn from this desk study on the use of trap plants:

- 1) There are many documented successes of trap plant approaches in outdoor crops, which prove that the mechanism of trap plant control works, on a fundamental level. Current research on the use of trap plants in ornamental crops however was limited to whitefly control in poinsettia and thrips control in chrysanthemums. A body of research supported the use of trap plant approaches for the control of these pests in protected crops. There is huge scope for further applied research into the use of trap plants against other pests and in other protected ornamental crops.
- 2) The literature points to the fact that most of the innovation in the field of trap plant pest control strategies is taking place in the USA. A number of the pests that have been studied in the USA also have a distribution in the UK (including capids, western flower thrips and whitefly). This American collection of studies could be put to further use in this country by applying the theory to commercial trials in the UK.
- 3) There is a large variation in the management and use of trap plants which indicates that trap plants can be a very flexible pest control strategy, forming part of a wider ICM regime which incorporates biological pest control, physical trapping, semiochemicals etc. It is particularly important to look ahead at work which investigates the best methods of deployment of trap plants. Two of the growers surveyed mentioned the management of the trap plants and how this relates to their decision to use them or not. There is a good deal of work to be done looking at the placement of trap plants in the main crop, the number required, the growth stage of the trap plant, and which methods of chemical, cultural, physical and biological pest control can be employed by growers to accompany trap plant strategies.

Financial Benefits

This desk study report is a review of the use of trap plants, their definitions, successes and failings, financial benefits have not been specifically pinpointed, however, the diversification of control methods in the current climate of reduced pesticide availability may have a wide-range of financial benefits for the protected crop industry. If the number of spray applications can be reduced on account of traps plant use within crops, or at least early sprays targeted more accurately because of their use then savings will accrue in terms of reduced pesticide costs and more importantly application time costs.

Action Points

- It is suggested that growers use this study as a foundation for decisions made about future work on trap plants specifically, and ICM approaches to pest control in general.
- To compliment yellow / blue sticky traps, trap plants such as aubergine and nicotinia could be used within 'mono-crop pot plant crops' such as pot chrysanthemums and poinsettias to monitor levels of whitefly and other flying pests.

SCIENCE SECTION

Introduction

The protected ornamental industry faces a range of issues linked to crop protection and production. These include a reduction in the available products approved for use, the potential for increasing resistance in target pest organisms, increasing pressures from consumers and retailers for 'environmentally-friendly' practices and a need to comply with legislation and industry initiatives. These pressures lead to a changing approach to pesticide use and for the full exploitation of the methods available for maintaining pest populations below the economic damage thresholds, using integrated crop management (ICM) where possible.

Trap plants offer a means of manipulating pest behaviour and their use for pest control has been well researched in some arable and horticultural crops. However, the vast majority of successful examples to date are in outdoor crops. Interest in trap cropping, a traditional pest management approach has increased considerably in recent years (Shelton & Badenes-Perez, 2006). In many cases, promising results have been obtained and recent evidence suggests that trap plant systems may be transferable to ornamental crop production (Buitenhuis et al. 2007).

Trap plants are usually grown either within a crop or around its perimeter. The pest preference for the trap plants over the crop plants, results in reduced pest damage to the crop. Though most commonly employed against more mobile pests (such as members of the Lepidoptera and Coleoptera), research suggests that trap plants can also be used with success against pests displaying more random and/or weak dispersal behaviours, such as thrips, whitefly and aphids (Murphy et al. 2002; Buitenhuis & Shipp 2006).

Recent research suggests that a trap plant approach may work in protected ornamental crops as it has in outdoor edible and arable crops. Work with both western flower thrips (*Frankliniella occidentalis*) and glasshouse whitefly (*Trialeurodes vaporariorum*), for example, has produced promising trap plant species for use in several ornamental crops (Lee et al. 2009; Buitenhuis et al. 2007).

This desk study aims to bring together the evidence relating to the successful use of trap plants. This project will provide UK growers with an improved evidence base to inform them of which trap plants are most attractive to pests (i.e. which have the potential to work best

from the scientific literature). This, combined with feedback from growers through a survey and consultation, will allow growers to assess where trap plant research would benefit from further work.

Further benefits of trap plant systems in ornamental crops have been realised where species were identified that function as 'dead-end' trap plants for pests. Dead-end trap plants, whilst being attractive to adult pests, are unsuitable for the development of juveniles; this phenomenon has rarely been found and is thus unlikely in whiteflies, thrips, aphids and caterpillars. However, it may be possible to create artificial dead-end trap plants combining trap plants with other methods to limit pest build-up upon them, such as physical removal, spot treatment or control through the use of combined trap plants and associated biotic (e.g. natural enemies) or abiotic (e.g. sticky traps) control. Discussions with the Chemicals Regulation Directorate led to the conclusion that trap plants can be chemically treated provided there is regulatory approval for the product to be used on the trap plant species itself, rather than the crop. This artificial 'dead-end' would then serve to prevent over-spill of pests from trap plants into crops, and thus, reduce overall pest pressure.

This report summarises the scientific literature related to trap plants and collates the small number of responses from growers about their experience with trap plants. This project aims to highlight the areas where trap plant research has already taken place, as well as the many research areas where there is scope for further research. The specific industry benefits of this project aims to include:

A. Bringing together current research and commercial practices using, trap plants on various ornamental crops. The HDC PO Panel asked for a particular focus on species and varieties against four major pests in protected ornamentals (whitefly, thrips, aphids and caterpillars).

B. This work will develop a scientific evidence base for the use of trap plants on UK ornamentals and will avail growers with current information about which plants and varieties to use within their crops for maximum impact on pest populations. This information could then be used as a foundation for any future trial work, at the growers' discretion.

C. Once trap plant options are established, the summary on current practices in the UK and other countries (particularly Spain, Canada and France) within commercial ornamental crops will allow the industry to assess how best to further research trap plants pest management strategies.

D. The results of this project will better inform growers of the options available when putting together an ICM programme for their ornamental crops. Trap plants are currently being employed on various crops against different pest groups but there is a need for a collated and coordinated view of their benefits and use, this study will provide that.

Overall, this project will aim to answer the following specific questions for the ornamental sector:

- 1) Which trap plant should I use against whitefly?
- 2) Which trap plant should I use against WFT?
- 3) Which trap plant should I use against thrips?
- 4) Which trap plant should I use against caterpillar?
- 5) How these trap plants are being used and managed in a commercial setting, both in the UK and elsewhere?
- 6) Are there any measures I can take to improve the pest reduction achieved by the trap plants (i.e. chemical application, physical removal or ICM combinations)?

To achieve the benefits outlined above, this desk study had the following objectives:

- 1) To consult UK growers (through an HDC survey and direct consultation, driven by suggestions from the PO Panel) about experience with, and use of, trap plants within the industry to date, for all protected ornamental crops with a particular focus on poinsettia, chrysanthemums and bedding plants.
- 2) To collect information on the use of trap plants in countries other than the UK and, where possible, consult growers overseas on current trap plant practices in protected horticulture (successes and failures). It is known that the use of trap plants in Spain, Canada and France is being developed, so focus was drawn on to commercial practices in these countries in particular.
- 3) To perform a review of the scientific literature on trap plants within protected crops generally. This included the identification of “dead-end” trap plants (those plants that pests have a preference for, but cannot fully develop on) and chemical/biopesticide treatments that may be used to simulate a dead-end effect on trap plants (i.e. killing pests before they can develop).

4) To perform a detailed review of the scientific literature relating to plant preferences for egg-laying and feeding of four pest groups, associated with three commercially important ornamental crops, as follows:

- a) Poinsettia and whitefly (*Trialeurodes vaporariorum*)
- b) Chrysanthemums and Western flower thrips (*Frankliniella occidentalis*)
- c) Primroses and aphids (various species)
- d) Primroses and caterpillars (various species)

5) To provide the HDC PO Panel with a detailed report of the findings from objectives 1 to 4, in order to review the results and discuss the most appropriate candidate pest/crop combinations to take forward for further trial work. This will allow the Panel to direct future experimental work.

Materials and methods

Scientific articles were searched for using the search engine, Web of Knowledge (Thomson Reuters), this was used to perform a detailed search for the articles related to trap plants. Web of Knowledge allows users to follow citation records for and to each article. This citation tool decreases the likelihood that any relevant research is missed during a search. The search engine, Google Scholar, was also used to ensure that all articles were captured during searches. The search terms used were broad and exhaustive to ensure that any examples of failure or success using trap plants were not missed. Below is the complete list of search terms used (Table 1)

Table 1 – List of search terms used to acquire literature for review.

BANKER + PLANT
BANKER + PLANT + GLASSHOUSE
BANKER + PLANT + GREENHOUSE
BANKER + PLANT + HORTICULTURE
BANKER + PLANT + ORNAMENTAL
BANKER + PLANT + PROTECTED
BARRIER + PLANT
BARRIER + PLANT + GLASSHOUSE
BARRIER + PLANT + GREENHOUSE

BARRIER + PLANT + HORTICULTURE
BARRIER + PLANT + ORNAMENTAL
BARRIER + PLANT + PROTECTED
BIOLOGICAL + CONTROL + BEDDING
BIOLOGICAL + CONTROL + CHRYSANTHEMUM
BIOLOGICAL + CONTROL + POINSETTIA
BIOLOGICAL + CONTROL + PRIMROSE
COMPANION + PLANT
COMPANION + PLANT + GLASSHOUSE
COMPANION + PLANT + GREENHOUSE
COMPANION + PLANT + HORTICULTURE
COMPANION + PLANT + ORNAMENTAL
COMPANION + PLANT + PROTECTED
DEAD-END + TRAP + PLANT
INDICATOR + PLANT
INDICATOR + PLANT + GLASSHOUSE
INDICATOR + PLANT + GREENHOUSE
INDICATOR + PLANT + HORTICULTURE
INDICATOR + PLANT + ORNAMENTAL
INDICATOR + PLANT + PROTECTED
INSECTARY + PLANT
INSECTARY + PLANT + GLASSHOUSE
INSECTARY + PLANT + GREENHOUSE
INSECTARY + PLANT + HORTICULTURE
INSECTARY + PLANT + ORNAMENTAL
INSECTARY + PLANT + PROTECTED
OVIPOSITION + PEST + PREFERENCE
PEST + OVERSPILL + CROP
REPELLENT + PLANT
REPELLENT + PLANT
REPELLENT + PLANT + GLASSHOUSE
REPELLENT + PLANT + GLASSHOUSE
REPELLENT + PLANT + GREENHOUSE
REPELLENT + PLANT + GREENHOUSE
REPELLENT + PLANT + HORTICULTURE
REPELLENT + PLANT + HORTICULTURE

REPELLENT + PLANT + ORNAMENTAL
REPELLENT + PLANT + ORNAMENTAL
REPELLENT + PLANT + PROTECTED
REPELLENT + PLANT + PROTECTED
SECONDARY + CROP + PEST
SECONDARY + PLANT
SECONDARY + PLANTS
SUICIDE + TRAP + PEST
TRAP + BEDDING
TRAP + CHRYSANTHEMUM
TRAP + CROP
TRAP + CROP + APHID
TRAP + CROP + CATERPILLAR
TRAP + CROP + HEMIPTERA
TRAP + CROP + LEPIDOPTERA
TRAP + CROP + THRIPS
TRAP + CROP + THYSANOPTERA
TRAP + CROP + WHITEFLY
TRAP + CUT + FLOWERS
TRAP + PLANT
TRAP + PLANT + AGRICULTURE
TRAP + PLANT + BIOLOGICAL + CONTROL
TRAP + PLANT + CULTURAL + CONTROL
TRAP + PLANT + EDIBLES
TRAP + PLANT + GREENHOUSE
TRAP + PLANT + HORTICULTURE
TRAP + PLANT + INSECTICIDE
TRAP + PLANT + MANAGEMENT
TRAP + PLANT + NATURAL + ENEMY
TRAP + PLANT + ORNAMENTAL
TRAP + PLANT + PARASITIDS
TRAP + PLANT + PEST
TRAP + PLANT + PEST + CONTROL
TRAP + PLANT + PHEROMONE
TRAP + PLANT + PREDATORS
TRAP + POINSETTIA

The search terms listed in Table 1 provided a vast list of scientific articles of possible interest for inclusion in this study. The list of articles found after each search (Table 1) was briefly studied and all the articles relevant to this study (i.e. those related to the use of secondary plants in any way) were collated for a more detailed examination. Once a basis of potentially relevant literature was established, then the articles were read and reviewed to form the majority of this study.

In order to investigate the pre-existing uses of trap plants in commercial horticulture, a survey was created with advice from the industry representatives. The aim of the survey was to ascertain if, which and how trap plants are being used commercially, and to examine reasons for lack of use. Growers were also targeted individually to try and maximise participation.

The survey was accompanied by a brief cover letter (Appendix 1), explaining the aim of the study, and the questions were as follows (Full survey – Appendix 2):

1) Have you ever used or trialled indicator or trap plants in your protected crops?
(e.g. early flowering varieties, plants or varieties more attractive to pests)

1a) If not, do you have no need for trap plants or does something, such as management or cost, detract you from using them?

1b) If so, what trap plant / crop combinations have you used, and for what pest?

Crop	Crop variety	Trap plant	Trap plant variety	Pest

2) Which of the above do you consider to have been successful and why?

3) Did the trap plant require different management to the crop itself? (e.g. different watering, feeding or some cutting back)

4) If so, how were the trap plants managed differently to the crop?

5) Are you still using any trap plants or indicator plants in your crops, if not why?

6) What crops and pests do you think would most benefit from research into trap plant varieties and management?

7) Your contact details (only used for the purposes of this survey)

The survey was designed, with advice from the industry representatives, to gather as much information using as few questions as possible. This concise format was designed to maximise grower participation whilst answering the questions important to the aim of this study and, therefore, establishing commercial practices.

Results and Discussion

Literature review

Introduction, definitions and examples of success

In order to include all possible areas of interest to UK protected ornamental growers, it is necessary to begin this study with an explanation of the various types of “secondary plants” used in conjunction with main crops. Trap plants are a type of secondary plant. As the term suggests, secondary plants are grown together with main/primary crops for pest management reasons. Parolin *et al.* (2012) offer a diagrammatic summary of secondary plants and their effects on crops, pests and natural enemies (Figure 1).

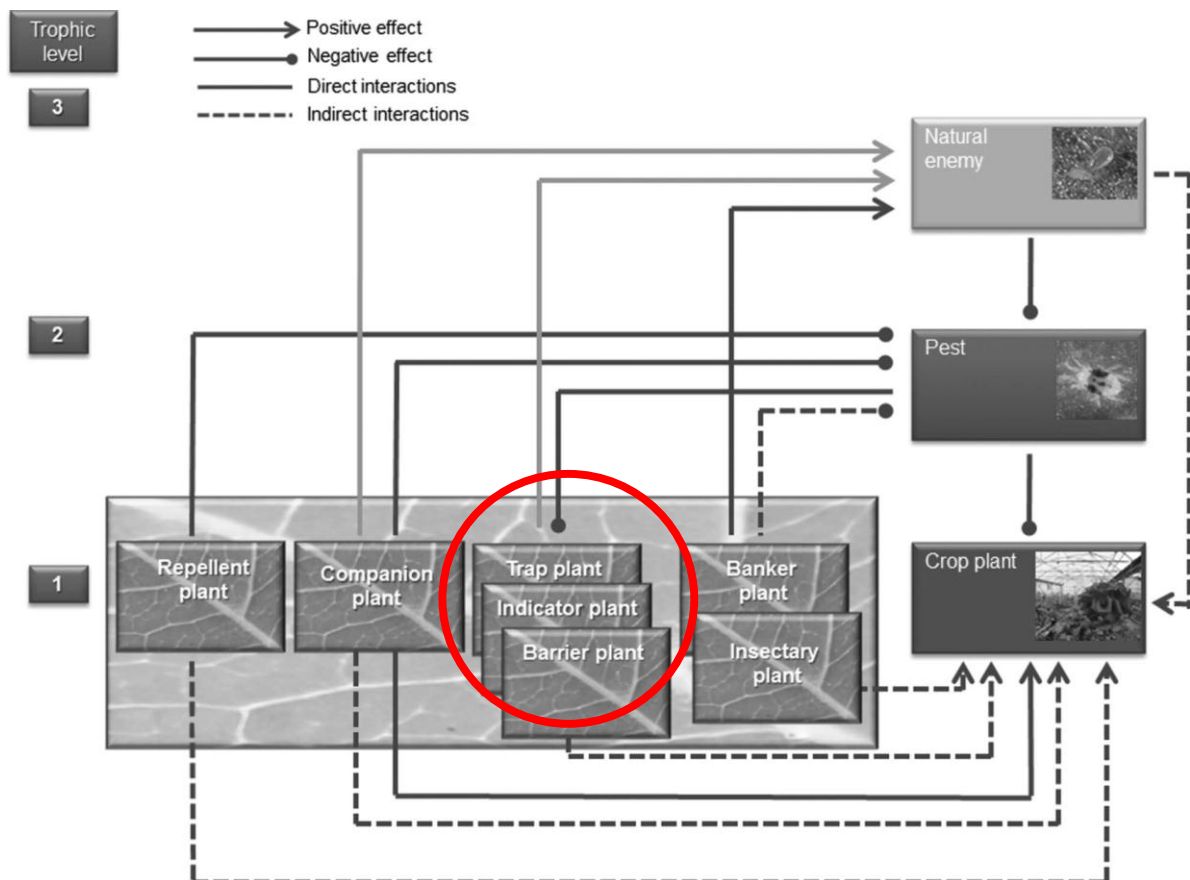


Figure 1 – A diagrammatic explanation of secondary plants and their effects on crops, pests and natural enemies. The lighter grey lines show interactions that occur but are not

considered the main function of the secondary plant (from Parolin *et al.* 2012). The three categories of secondary plant considered in this study are circled in red.

All of the categories of secondary plant were included in the literature search of this study. This ensured that the searches covered all definitions of non-crop plants used in IPM. The categories primarily of interest are trap plants, indicator plants and barrier plants (circled in red in Figure 1). These three terms can sometimes be interchangeable in the literature (Parolin *et al.* 2012), so it is reasonable to consider indicator and barrier plants as a type of trap plant because they all serve to protect the crop from pests by attraction and/or interception, thus “trapping” the pest away from the main crop. Figure 1 shows that all three trap categories (trap, indicator and barrier) indirectly interact with the crop by directly influencing the pest populations. There may also be an additional effect on the natural enemies, resulting from the effect on the pests. The three categories of trap plant can also be used for early detection of pest populations because the secondary plants are either more attractive to the pests or they are the first plants infested before the main crop. To further clarify the definitions of the three categories of trap plant specific definitions are provided below:

Barrier plants – Originally, barrier crops were only researched and considered for disease suppression (Deol & Rataul 1978). Parolin *et al.* (2012) expanded this definition to include pests, “a plant which is used within or bordering a primary crop for the purpose of disease suppression and/or interception of pests and/or pathogens. It has been shown that barrier plants can reduce the potential of aphids to spread viruses (Toba *et al.*, 1977; Difonzo *et al.* 1996). It has been suggested that barrier plants act as a mechanical barrier to the dispersal of insect pests, such as aphids in muskmelon using wheat or Swiss chard as a barrier crop (Toba *et al.*, 1977; Hooks and Fereres 2006). Hooks and Fereres (2006) conducted a review of barrier plants and found successful examples using sunflower, millet, sorghum and sesame to protect outdoor peppers and wheat. Barrier crops are considered to be under-researched and examples of barrier plants from the literature are primarily concerned with disease suppression in outdoor crops (Parolin *et al.* 2012). In fact, no examples of research into barrier crops in protected culture were found during this desk study.

Indicator plants – An indicator plant is simply a species or variety that is more susceptible to an insect or disease than the main crop (Lamb 2006). Indicator plants attract pests more readily than the main crop, making detection of early pest invasion quicker and more cost effective. The preference of a pest for a particular indicator plant over the main crop makes

this type of secondary plant ideal for early detection as well as trapping pests on their preferred host plant, after which a grower may wish to replace the indicator (mechanical removal of pests) or treat the indicator with appropriate biological or chemical agents. Indicator crops are becoming more widely used around the world (Lamb 2006). However, finding commercially driven examples of their use is very difficult; instead most examples are from the research literature.

There are three proven successes of the use of indicator plants in protected horticulture. Firstly, the use of tomato plants in protected poinsettia crops to attract whitefly (*Trialeurodes vaporariorum* and *Bemesia tabaci*) (Lamb 2006; Ferre 2011). Also, the use of aubergine plants in poinsettia, again to attract whitefly (Lamb 2006). The third example is the use of bean plants (*Phaseolus vulgaris*) as an early indicator of spider mite infestation in protected tomatoes (Berlinger et al. 1996). This example also found that the use of beans in tomatoes assisted the release of natural enemies because biological control agents could be released in the period of up to five weeks before the spider mites started to infest the main tomato crop, instead of the indicator beans.

Trap plants – Although in this desk study we consider barrier and indicator plants to be trap plants in their own right, trap plants have a formal definition. Trap plants are plants that are grown to attract, divert, intercept and/or retain targeted insects or the pathogens they vector in order to reduce damage to a main crop (Shelton & Badenes-Perez 2006). A trap plant is a plant of a certain growth stage, cultivar, variety or species that is more attractive to a pest than the main crop (Poveda et al., 2008). Insect pests are less likely to feed or lay eggs on the main crop because they find the trap crop to be more attractive (Vandermeer 1989; Murphy 2004).

An example of a successful trap crop is aubergine in poinsettia to preferentially attract whiteflies, where it has been shown that not only are the aubergine plants preferred by the pest but the pests are significantly less likely to leave the aubergine plants in favour of the main poinsettia crop (Lee et al. 2008; 2009). Therefore, trap plants also limit pest populations to a specific area within the crop, this allows growers to use conventional methods of control (chemical, cultural and biological) in a quick and targeted way, where just the trap plant is treated, at least initially (Hokkanen 1991; Shelton and Nault 2004; Poveda et al., 2008; Shelton & Badenes-Perez 2006). This allows chemical treatment to be localised (and therefore reduced overall), biological control agents to be released in very high densities around the trap plant, and the trap plant can even be removed altogether (Parolin et al. 2012). Managing the trap plants appropriately is very important to prevent

“over-spill” of pests into the main crop. If over-spill occurs then the trap plant becomes an “insectary plant” instead (Figure 1). There is very little in the literature about the specific management requirements of trap plants. Presumably, this is because it very much depends on the pest pressures, varieties grown, environmental conditions and time/financial restraints of the individual site and grower. Therefore, to generalize in the literature would not be productive without further experimental work.

Potted *Chrysanthemum* cultivars have been successfully used as trap plants for western flower thrips (WFT) (*Frankliniella occidentalis*) in protected culture (Murphy 2004; Buitenhuis et al. 2006; Lamb 2006). Cultivars that flower earlier or are more susceptible than the main crop can be used. Gerbera and verbena plants can also be used, interspersed through the crop to attract thrips away from the potted *Chrysanthemum* crop (Lamb 2006).

The use of aubergine plants in poinsettia crops, and other flowering species and varieties in potted chrysanthemums are considered the main successes of trap plant approaches in protected ornamental horticulture.

Methods of trap cropping

From this literature search, methods of trap cropping can be grouped into eight categories that are not mutually exclusive. Categorising the methods of trap cropping using the literature is a particularly useful exercise because it allows growers to assess what might be possible for their particular crop and circumstances. Each is described below, with examples of success from the literature.

Conventional – This is the most general type of trap cropping, where a lower value plant is grown next to the main crop and is naturally more attractive to the pest than the crop itself (Shelton & Badenes-Perez 2006). This can be increased attractiveness for pest feeding or egg-laying (oviposition). Conventional trap plants, therefore, either prevent pests from infesting main crops or they concentrate the pests on the trap plant for economical removal or treatment (Hokkanen 1991; Javaid and Joshi 1995). Examples of usage of conventional trap plants are reasonably well-established and widespread in outdoor arable and horticultural crops. However, examples in protected crops, in particular ornamentals, are few and have already been outlined above (WFT in chrysanthemums, whitefly in poinsettia, spider mites in tomatoes) (Berlinger et al. 1996; Murphy 2004; Buitenhuis et al. 2006; Lamb 2006; Lee et al. 2008; 2009).

The most enduring example of large-scale commercial use of conventional trap plants is the use of alfalfa to protect cotton from *Lygus* sp. bugs. This system was first investigated in the 1960s and is still used across the USA today (Stern 1969; Godfrey & Leigh 1994). It is likely that most trap plant research and implementation has been focused on outdoor large-scale crops because of their economic and environmental importance, which drives innovation for alternative pest management. However, protected crops have shown far more success with biological control agents than outdoor crops because of the enclosed growing area and controllable environmental conditions. This indicates that glasshouse growers may perhaps already be in a strong position to consider pest control alternatives, having already done so a number of years. However, there is a lot of scope for research into conventional trap plants in protected culture (e.g. pest preference studies) because comparatively little research has been conducted compared to trap plants outdoors.

Dead-end (suicide) – Dead-end trap plants are plants that are more attractive to pests than their associated crop but their immature stages are not able to survive and develop on them (Shelton and Nault 2004). This means that such trap plants act as a pest “sink” within a crop (Badenes-Perez et al. 2004). Unfortunately, there are no examples of dead-end trap plants used in protected or ornamental crops. The most cited examples of successful dead-end trap plant use are from field horticultural crops. Yellow rocket can be used against the diamondback moth (*Plutella xylostella*) in field brassicas and sun hemp (*Crotalaria juncea*) used against the bean pod borer, *Maruca testulalis* (Jackai & Singh 1983; Badenes-Perez et al. 2004; 2005; Lu et al. 2004; Shelton & Nault 2004). Dead-end trap plants can be created by growers by using highly attractive plants and treating them with pesticides (Shelton & Badenes-Perez 2006). Very little research has been conducted on the interaction between trap plants, pesticide treatment and the main crop.

Genetically modified – There is a growing body of scientific literature dedicated to the use of genetically modified (GM) trap and barrier plants. However, there are currently no examples from the UK or in protected horticulture, therefore, GM trap plants will not be further discussed in this report. So far, trap plants have been successfully genetically modified to create dead-end host plants for field crop pests such as Colorado beetles in potatoes in the USA (Hoy 1999).

Perimeter – Perimeter trap plants are highly attractive to pests and planted around the edges and borders of the main crop (Boucher et al 2003). They are considered most appropriate in outdoor rather than protected crops, where it is considered more effective to use trap plants interspersed within a crop rather than around the perimeter, primarily

because of the lack of larger landscape effects within glasshouses (Lamb 2006; Shelton & Badenes-Perez 2006). It has also been found that perimeter trap plants may not be the most effective spatial design for pest reduction in outdoor crop (Pair et al 1997).

Sequential – Sequential trap cropping is the planting of crops earlier or later than the main crop to enhance pest attraction. Existing studies have used this approach using early-season potatoes to trap Colorado beetles away from the main crop (Hoy et al 2000), Outdoor strawberries have also benefited from sequential trap plants by planting wheat a week before the strawberries to trap dusky wireworms, *Agriotes obscurus*. Dusky wireworms have a distribution in the UK, so this approach may be useful to UK strawberry growers. Sequential trap cropping could be very useful to the UK protected ornamental industry, particularly to manage pests in flowering species, such as WFT in chrysanthemums. Using early-flowering cultivars of *Chrysanthemum* sp., verbena and gerbera species could be used to attract thrips to the trap plants before the main crop begins to flower (Lamb 2006). This would reduce the size of thrips populations later in the crop, making their numbers easier to manage by conventional means. There is very little research on this approach in protected ornamentals but there is a lot of potential to include sequential trap plants as part of grower IPM strategies. It would also be very interesting to look at the use of multiple trap plant varieties to provide a sequentially attractive growth stage to pests, away from the main crop. Again, this approach could be useful in potted chrysanthemums using a number of varieties to attract pests and reduce damage to the main crop.

Push-pull – This approach is based on a combination of an attractive trap plant (pull) with a repellent intercrop (push) (Figure 1; Khan et al. 2001; Pyke et al. 1987). All examples of this so far are in outdoor crops, particularly cereals in Africa (Poveda et al. 2008). The repellent aspect of this strategy is very much understudied in protected crops. If repellent plant species were found for glasshouse then this strategy could potentially work very well using repellent plants within the protected environment and attractive plants outside. This would deter pests from invading the glasshouse, thus reducing populations within the main crop.

Biological control-assisted – Figure 1 shows that there is a multitrophic interaction occurring between plants, pests and natural enemies, as one would expect given that pests are constantly under pressure from predators and parasitoids. The interaction between trap plants and pest natural enemies/biological control agents should, therefore, not be ignored because it may be a useful component of IPM. It has been shown that the inclusion of trap plants in outdoor crops can increase parasitism of the pests that the trap plants are

designed to control (Khan et al 200), such as sorghum (trap), cotton (crop), cotton bollworm (pest), and *Trichogramma chilonis* (natural enemy) (Virk et al 2004). This represents a double approach to pest reduction. However, much like many of the approaches listed in this report, research focus has been almost exclusively on large-scale outdoor crops. However, the principle of biological control-assisted trap plants remains of interest to researchers worldwide, therefore, it may be applied in protected crops with further research. This is particularly important in protected crops because natural enemies are often bought by growers as biological controls, therefore, if they are released in conjunction with trap plants an additive effect on control could be possible

Trap-assisted – Besides the assistance of biological control to trap plant strategies, it is possible that traditional traps, such as blue and yellow sticky traps can be used in conjunction with trap plants to enhance control (Lamb 2006). The trap plant attracts the pests away from the main crop and the insects become trapped on the sticky trap. In theory, this would increase the control provided, compared to each of the control strategies applied individually.

Semiochemicals have been shown to increase trap plant control efficacy. This is because the principles that underlie trap plant effects on insect behaviour are similar to those of semiochemicals (Foster & Harris 1997; Shelton & Badenes-Perez 2006). The mechanism that underpins the use of trap plants may be due to semiochemicals naturally produced by the trap plant. Therefore, semiochemicals can be used to enhance existing trap-plants or to create trap plants using regular plants within the crop by applying semiochemical attractants (Shelton & Badenes-Perez 2006). A successful example of this is the use of pheromone-baited trees in forestry to control bark beetles and concentrate the pest in areas that can be easily treated (Borden 1995; Borden & Greenwood 2000). The combination of semiochemicals with trap crops is progressing with GM plants, where plants are engineered to produce insect pheromones (Nesnerova 2004). None of these semiochemical approaches have been used in protected crops yet. However, there is potential for their use in the future as more pheromones are identified.

Overall, the literature review of this desk study showed the large number of successful examples of the use of trap plants to reduce pest populations. However, there are very few studies in the scientific literature that trial trap plants in protected crops, particularly few in ornamental protected crops. Table 2 shows a list of all the studies found to include trap plants in protected crops. Over three hundred different examples of trap plant/pest/crop combinations were found in the literature, however, only 14 of these related to protected

crops (Table 2), six different crop in total, only two of which were ornamentals (chrysanthemum and poinsettia). This serves to highlight how much research remains to be done on trap plants in protected crops worldwide.

Table 2 - Articles found during the literature search relating to the use of trap plants in protected crops and pests relevant to UK horticulture.

Crop	Pest species	Country	Trap crop	Reference	Method
Bell pepper	<i>Zonosemata electa</i> Pepper maggot	USA	Cherry pepper	Grubinger et al 2004	Perimeter
Chrysanthemum	<i>Frankliniella occidentalis</i> Western flower thrips	USA	Petunia (cv' Summer Madness, Super Blue Magic, Calypso, Red Cloud)	Lamb 2006	Sequential & conventional
Chrysanthemum	<i>Frankliniella occidentalis</i> Western flower thrips	USA	Gerbera (cv' Jaguar)	Lamb 2006; Syngenta Seeds Ltd	Sequential & conventional
Chrysanthemum	<i>Frankliniella occidentalis</i> Western flower thrips	USA	Verbena (cv' Tapien lavender)	Lamb 2006; Warnock & Loughner 2004	Sequential & conventional
Chrysanthemum	<i>Frankliniella occidentalis</i> Western flower thrips	USA	Early flowering varieties of chrysanthemum	Lamb 2006; Buitenhuis & Shipp 2006	Sequential
Lettuce	<i>Lygus rugulipennis</i> Tarnished plant bug	Sweden	Alfalfa, clover, melilot, mugwort and vetch	Ramert et al. 2001	Conventional

Crop	Pest species	Country	Trap crop	Reference	Method
Lettuce	<i>Frankliniella occidentalis</i> Western flower thrips	USA	Wildflowers	Yudin et al 1988	Conventional
Poinsettia	Whitefly <i>Trialeurodes vaporarium</i> and <i>Bemisia tabaci</i>	USA	Aubergine	Lamb 2006	Conventional
Strawberry	<i>Agriotes obscurus</i> Dusky wireworm	Canada	Wheat and other cereals	Vernon et al 2000; Vernon et al 2002	Sequential
Strawberry	<i>Lygus hesperus</i>	USA	Daisy and Yarrow	Zalom et al 1990	Conventional
Strawberry	European tarnished plant bug	UK	Mayweed and alfalfa	Easterbrook & Tooley 1999	Conventional
Tomato	<i>Leptinotarsa decemlineata</i> Colorado beetle	Canada	Potato	Hunt & Whitfield 1996	Sequential
Tomato	<i>Bemisia tabaci</i>	Lebanon	Cucumber	Al-Musa 1982	Conventional
Tomato	Whitefly	USA	Squash	Schuster 2003; 2004	Conventional

Grower survey and consultation

In order to try and collect some of the more anecdotal evidence on trap plants from growers, a survey was sent out to growers using the HDC broadcast system. Unfortunately, response to this was extremely poor and only three responses were received. This could be indicative of a number of things:

- 1) The growers felt that they had nothing to contribute to this study, meaning that they were not using or considering using trap plants. Given how little research has been done in protected compared to outdoor crops, it is perhaps the case that there is insufficient knowledge about trap plants in the UK protected ornamental industry.
- 2) The distribution system of the survey was flawed and either not looked at by growers or they felt that they had too little spare time to fill out the survey. This may not necessarily be the case because when growers were targeted individually there was no extra interest in the participating.

Even though only three responses were received, some additional and interesting extra information was gathered to add to this desk study. The responses are listed below in full (please see Appendix 2 for the questions):

Responder 1 -

1) Yes

1a) Trap plants have not always been used due to time constraints - felt sometimes too long to check the trap plants and also would like to have more knowledge as to what trap plants are effective and how to manage them.

1b)

Crop	Crop variety	Trap plant	Trap plant variety	Pest
Bedding plants		Fuchsia	Gold Rush Barbara Norton	Greenfly

2) Greenfly were really attracted to the Gold Rush fuchsia but unsure as to how much it reduced the overall greenfly on other plants. Have also found that Verbena are very good in attracting whitefly but have not put this down as it was not used as a trap plant and there was concern about Bemisia Tabacii

3) No different management which meant it was really easy to maintain and could be easily added to system: not difficult to persuade staff!

4) N/A

5) Not at this time of year but there would be potential for the Christmas crops. With such a quick turnaround of bedding plants and plants moving around the greenhouses it could be very difficult to manage.

6) Definite potential for poinsettias and whitefly

Cyclamen? Maybe looking at thrips and mites? Only reasoning behind this is that it is a long term crop and people may be more inclined to install trap plants.

Responder 2 –

1) Yes

1a) N/A

1b)

Crop	Crop variety	Trap plant	Trap plant variety	Pest
Poinsettia	Various	Nicotiana	tabaccum	whitefly

Note we tried several species of Nicotiana and tabaccum seemed the best.

2) Partial success as the plants appeared to be more attractive to Whitefly and other species than the Poinsettia, We ended up using these combined with a sticky trap to boost monitoring. However these required quite a lot of input and we struggled to maintain them.

3) Yes, this was a problem. They became too big, needed more water and feed and took up crop space.

4) They need routine replacement, possibly two or three times during the life of a Poinsettia crop.

5) I'm not convinced they do a much better job than traps alone and have the potential to act as breeding hot spots if not very well managed.

6) Poinsettia- Whitefly, Possibly Cyclamen- Thrips

Responder 3 –

Responder 3 did not submit the survey but sent an email instead after being consulted:

“Until 18 months ago, when I retired, we were growing NFT tomatoes.

Whitefly control had been a problem off and on for 20 years. It was notable that Wood Groundsel, *Senecio sylvaticus*, growing in gravel in an unconcreted part of the boiler house, was very attractive to whitefly.

Over the last couple of years I started to grow it as an indicator plant. The scale was also well parasitized by *Encarsia*.”

Grower survey discussion –

Interestingly, although only three replies were received, each reply contained information novel and useful to this desk study. The combined information from the growers is summarised in Table 3. Nothing related to aphid control arose from the literature review, so a potential trap plant for aphids in bedding plants could be very interesting for future work. The issue of trap plant management was raised by one of the growers. Removal of the trap plants (*Nicotiana tabaccum*) a few times during the life of the main crop (poinsettia) is alluded to as a potential solution to the faster rate of growth of the trap plant compared to the crop. This would also prevent the *Nicotiana* becoming an “insectary plant” within the glasshouse. Cyclamen is mentioned by two of the growers as a potential future focus of trap plant research, particularly in relation to thrips control (and spider mites). Cyclamen is a relatively long-term protected ornamental, which would make it an attractive candidate for future work on trap plants. Although not related to protected ornamentals in this instance, responder 3 definitely captures the aim of the grower survey, in that the use of wood groundsel to attract whitefly away from tomatoes was initially an observation of the uncropped areas of the glasshouse. It would be interesting to test wood groundsel’s attractiveness to whitefly compared to a number of other ornamental crops, such as poinsettia. Overall, although the survey response was very disappointing, the interesting observations of the growers will no doubt help to give future research more direction with regards to commercial demand and novel examples.

Table 3 – Summary of grower information about the commercial use of trap plants

Crop	Pest species	Trap crop	Success	Difficulty	Other crop suggestions
Bedding plants	Aphids (various)	Fuchsia (cv' Golden Rush; Barbara Norton)	Management of trap crop very similar to that of main crop	Short-term crops, such as bedding make trap crop harder to manage	Verbena as a trap crop for whitefly, however concerns about <i>Bemisia</i> sp. Poinsettia would probably benefit from trap plants for whitefly. Longer term cyclamen crop could potentially be a good target for trap cropping, especially for mites and thrips
Poinsettia	Whitefly	<i>Nicotiana tabaccum</i>	Used in combination with traps (trap-assisted)	A good deal of management, requiring more water and feed than the poinsettia. Grower not convinced that trap plant increase control more than conventional trapping alone	Trap crop for thrips in cyclamen crop
Tomato	Whitefly	Wood Groundsel, <i>Senecio sylvaticus</i>	Good parasitism by <i>Encarsia</i> sp. (biological control-assisted)	None reported	None reported

Conclusions

There are a number of important conclusions that can be drawn from this desk study on the use of trap plants. Firstly, each benefit outlined in the introduction of this report will be assessed in turn:

A. Current research on trap plants has been brought together in this report. Unfortunately, there were only a few studies from protected ornamental crops, specifically whitefly control in poinsettia and thrips control in chrysanthemums. Two of the major pests highlighted by the HDC PO Panel (thrips and whitefly) have therefore got a small body of research supporting the use of trap plant approaches for their control (Table 2). The other two pests of protected ornamentals (aphids and caterpillars) are not at all well-described in the literature. However, one of the growers reported that fuchsias may represent viable candidate trap plants for use against aphids in bedding plants, warranting further research, particularly in applied and commercially relevant trials. A number of trap plant studies have been conducted on caterpillars (Lepidoptera) in outdoor crops but there is nothing in the literature on control of lepidopteran pests in protected ornamental horticulture.

B. This study has summarised the scientific evidence base for the use of trap plants on ornamentals. It has highlighted that there is a vast amount of research still to be done if trap plants are to be successfully deployed in ornamental glasshouses. However, this desk study serves to avail growers with current information about some of the plants and varieties that are used in protected edibles (Table 2). This information can now be used as a foundation for any future trial work, after the consideration of growers.

C. The summary of current practices was a disappointing aspect of this work because of the very poor participation of growers in the collection of observational and anecdotal information about trap plants. However, the literature points to the fact that most the innovation in the field of trap plant pest control strategies is taking place in the USA. A number of the pests that have been studied in the USA also have a distribution in the UK (e.g. WFT, whitefly and *Lygus* sp.) (Table 2). This American collection of studies could be put to further use in this country by applying the theory to commercial trials in the UK.

D. The list of trap plant methods (see Discussion) in this report shows the large variation in management and use of trap plants. This indicates that trap plants can be a very flexible pest control strategy, forming part of a wider ICM regime which incorporates biological control, physical trapping, semiochemicals etc. Therefore, this study serves to

show growers how many trap plant options there are to research further. It is particularly important to look ahead at work which investigates the best methods of deployment of trap plants. Two of the growers surveyed mentioned management of the trap plants and how this relates to their decision to use them or not. There is a good deal of work to be done looking at the placement of trap plants in the main crop, the number required, the growth stage of the trap plant, and which methods of chemical, cultural, physical and biological control can be employed by growers to accompany trap plant strategies.

With the exception of the grower survey (B), the benefits of this study can be realized and the evidence base provided here gives growers a vast amount of ideas and scope for future work on trap plants in protected ornamentals.

Now, the objectives of this study can be looked at in turn:

- 1) As benefit B was not wholly realised. The objective to consult UK growers was not entirely achieved because of the very participation in the survey.
- 2) Information and literature was collected from many countries (Table 2). An international approach to trap plant research would be helpful to UK horticulture, and indeed worldwide, because many of the crop/pest combinations are the same in different countries as they are in the UK (Table 2).
- 3) A detailed search and targeted review of the scientific literature on trap plants within protected crops was performed. However, no naturally occurring “dead-end” trap plants were identified for use in protected crops). Therefore, time and money would perhaps be better spent looking at the relationship between other control methods (e.g. chemical treatments) and trap plants. Discussions with CRD concluded that insecticides applied to trap plants need to have approval for that trap plant rather than the main crop itself.
- 4) As outlined above in the benefits of this study (A), there are a few studies on trap plants to control thrips and whitefly, whereas, caterpillars and aphids still require further research in protected crops.
- 5) There are a number of directions that future work on trap plants could take. It is clear from this study that protected crops are underrepresented in the trap plant literature (only 14 studies out of over 300 considered concerned protected compared to outdoor crops and their pests). In particular, there is a good deal of scope for future investigation of how biological control-assisted trap plants might be used in protected ornamentals. Trap plants have been used and studied since the 1960s in outdoor crops but are a comparatively

recent development for protected crops. However, the use of biological control (the release and manipulation of natural enemies) in glasshouses is long-established in protected crops compared to outdoors. Trap plant approaches, and applied research related to them, may represent a natural 'next step' towards expanding IPM strategies in protected crops.

It is hoped that studies such as this one will contribute to the clarification of alternative pest control approaches and the identification of gaps in our knowledge. Gaps which are clear to see in this study. With the difficulties facing the industry in terms of funding and regulatory requirements the trend is towards funding short-term, applied research with better guarantees of results (Parolin et al 2012).

Knowledge and Technology Transfer

Presentation to given by Pat Croft at the BPOA meeting on 4th October at Stockbridge Technology Centre

Glossary

Definitions are provided in the main text (e.g. methods of trap cropping)

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Appendices

Appendix 1 – Survey cover letter



Trap plants for pests survey for protected ornamental growers

Trap plants and indicator plants are species and varieties that are more attractive to a pest than the commercial crop itself; therefore, they can offer a way of influencing pest behaviour to monitor and reduce pest populations.

Stockbridge Technology Centre is conducting a HDC funded study on the use of trap plants in protected ornamentals sector. The aim of this study (PO 009) is to conduct a review of the evidence on trap plants within protected crops, in the UK and other countries, for the benefit of UK ornamental growers.

A fundamental part of this study is to consult UK growers about experience with, and use of, trap and indicator plants. Therefore, we would like to ask if you would be able to spare five minutes to fill-out a brief questionnaire about your experience with trap plants. Even if you have no experience of trap plants then the first two questions still apply.

If you would like to provide any further information about the use of trap and indicator plants in protected ornamentals, or would like to discuss things further please contact Dr Luke Tilley (**email: luke@stc-nyorks.co.uk tel: 01757 268275**)



Trap plant for pests survey for protected ornamental growers

1) Have you ever used or trialled indicator or trap plants in your protected crops?
(e.g. early flowering varieties, plants or varieties more attractive to pests)

1a) If not, do you have no need for trap plants or does something, such as management or cost, detract you from using them?

1b) If so, what trap plant / crop combinations have you used, and for what pest?

Crop	Crop variety	Trap plant	Trap plant variety	Pest

2) Which of the above do you consider to have been successful and why?

3) Did the trap plant require different management to the crop itself? (e.g. different watering, feeding or some cutting back)

4) If so, how were the trap plants managed differently to the crop?

5) Are you still using any trap plants or indicator plants in your crops, if not why?

6) What crops and pests do you think would most benefit from research into trap plant varieties and management?

7) Your contact details (only used for the purposes of this survey)

Name:

Company:

Telephone:

Email:

Thank you for completing this survey. Please return by **31st July** to Dr Luke Tilley by email to **luke@stc-nyorks.co.uk**, or by mail to:

**Luke Tilley
Stockbridge Technology Centre
Cawood, Selby
North Yorkshire
YO8 3TZ**

Alternatively, if you would like to discuss things further please phone Luke Tilley on **01757 268275**