The impact of peat-free growing media and the emergence of sciarid flies (Sciaridae) as a pest or just a nuisance in Scotland

Project Final Report

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Content

1 Executive Summary

Reducing peat use in horticulture is critical for the future health of Scotland's peatland habitats (IUCN UK Peatland Programme, 2024). More sustainable peat-free growing media options are available (Holmes & Bain, 2021; Royal Horticultural Society, 2024a), but the biosecurity status of some of these materials is currently unclear. In response to anecdotal stakeholder reports of higher numbers of fungus gnats (Sciaridae) in peat-free materials, this study engaged with stakeholders to understand their perceptions on fungus gnat (Sciaridae) prevalence in the growing media they are using and also reviewed the evidence available in literature.

Fungus gnats (*Bradysia* spp.) (also commonly known as sciarid fly) are small, black, slow-flying insects which are commonly encountered in the glasshouse environment (Marín Cruz, 2022), although for most people they are best known as a nuisance on houseplants. There are at least 250 species of fungus gnat in the UK (Royal Horticultural Society, 2024b), and their larvae are small and transparent which makes them difficult to identify on, or in, growing media and other organic material.

In UK horticulture, fungus gnats have long been thought of as a nuisance and a low-level pest, but little research has been conducted on fungus gnats in the UK. This scoping study therefore:

- Interviewed stakeholders who are growing plants in the glasshouse context to understand the impacts that they are seeing with fungus gnat infestations.
- Reviewed the literature to establish what is known about fungus gnat issues in Scotland, the UK, and internationally.
- Engaged with biological control suppliers to establish what species are currently deployed to manage fungus gnats.

1.1 Results

This project made several important observations and findings:

- Stakeholders confirmed experiencing an increase in sciarid flies in glasshouses and polytunnels compared to previous years. Interviewees suggested that the incidence of sciarid flies had risen recently, with 92% believing the flies were introduced through purchased growing media.
- The literature review revealed that sciarid flies not only cause direct damage to plants but can also transmit plant diseases, including fungal spores and potentially viruses. This finding supports the need to regard sciarid flies as a pest and not just as a mere nuisance.

- Both the literature review and stakeholder observations indicate that some conditions are more conducive to sciarid fly development including higher moisture content in growing media and warmer temperatures.
- No direct link has been identified in the literature or by stakeholders between increased sciarid fly numbers and specific components of peat-containing or peat-free growing media. The relevant properties of the range of growing media ingredients commonly used should be assessed for their ability to inhibit or support sciarid fly development.
- Effective control or management of sciarid flies is likely associated with good hygiene practices, as the flies are attracted to organic material. Adjusting moisture levels in growing media or plant growing conditions could also help manage sciarid fly populations, however these measures are limited by the need to maintain conditions suitable for plant growth.
- Chemical control is unlikely to be a viable option due to the limited availability of pesticides.
- Stakeholders reported using sticky traps to reduce adult fly numbers, baits such as potato sections on the surface of the growing media to target larvae, and hot water treatments.
- Some biological control options are available and in use by stakeholders, primarily involving parasitic nematodes and rove beetles. However, many stakeholders lack the knowledge needed to select the most suitable biocontrol for their specific situation. This challenge is compounded by the high cost of biocontrols.
- A key observation is the lack of Scottish and UK-specific scientific literature on sciarid flies. Most findings on sciarid fly species and control measures are derived from US literature, much of which is decades old.
- Consequently, there is no definitive knowledge about the specific sciarid fly species causing issues in the UK. As a result, it cannot be confidently stated that the findings from the literature review pertain to the species present in the UK.

1.2 Recommendations

In order to provide accurate advice for stakeholders in the future, this scoping study revealed that experimental work is required to:

- Identify the species of sciarid fly in Scotland and whether some species are more damaging than others. Currently, all sciarid fly species are treated in the same way which may be ineffective.

- Establish which components of growing media are more attractive to fungus gnats. This would enable growers to make more informed decisions around growing media choice as a means of sciarid population control.
- Clarify the most effective horticultural management strategies in the glasshouse context in Scotland (e.g. watering regimes) to lower sciarid fly populations.
- Identify which disease-causing pathogenic species can be spread by sciarid fly in Scotland.
- Increase consumer confidence in peat-free growing media by clarifying the provenance of the constituents and their biosecurity status in comparison to peat mixes.

2 Introduction

Peat has long been a primary component in plant-growing media due to its affordability, wide availability, and unique physicochemical properties. Its high water-holding capacity and inert nature make it particularly suitable for horticultural applications (Taparia et al., 2021). However, in recent decades, the importance of peatlands has been increasingly recognised. These ecosystems are not only home to diverse wildlife but also serve as some of the largest carbon stores on Earth, playing a crucial role in combating climate change.

Peat extraction is associated with significant ecological damage, contributing to greenhouse gas emissions and the destruction of critical habitats. Due to these environmental concerns, EU and UK regulations strongly discourage peat use, and both regions are moving towards a ban on peat in horticultural growing media (RHS, 2024). Currently, the UK alone sells nearly three million cubic meters of peat annually for horticultural purposes, with about one-third of that coming from domestic peatlands. The majority of this peat is used by amateur gardeners (66%), followed by the horticultural industry (34%), and a small percentage by local authorities (less than 1%) (IUCNUK Peatland Programme, 2024). Most commercially produced horticultural growing media uses a mix of peat or peat-free replacement in combination with higher fertility / nutrient rich components depending on purpose (Litterick, 2022).

A ban on peat in plant-growing media would provide significant environmental benefits, allowing peat bogs to recover and continue functioning as vital carbon sinks. To address this, various government-commissioned and scientific studies have identified several viable alternatives to peat (Taparia et al., 2021). These alternatives vary in their advantages and disadvantages, which are important to consider as the industry moves away from peat. Table 1, lists some of the most common peat alternatives and also typically minor mix components used in horticulture along with their advantages and disadvantages, illustrating how they compare to peat in different aspects of plant growth (Taparia et al., 2021, Department for Environment, Food & Rural Affairs [Defra], 2022, Litterick, 2022).

Table 1 – Non-peat components of plant growing media and their advantages and disadvantages

Main Component	Advantage	Disadvantage
Coir (coconut coir)	Sustainable and renewable. Good water retention and pH neutral. Durable, decomposes slowly.	High salinity requires pre-treatment. Environmental impact due to transportation from tropical regions
Wood fibres/barks	Renewable and offers good aeration for roots.	Low in nutrients, requiring supplementation Some wood species are highly acidic Poor water holding capacity
Minor Component	**Advantage**	**Disadvantage**
Perlite	Excellent drainage to prevent waterlogging. Lightweight, making it easy to handle.	No nutrients require combination with other materials. Non-renewable, though abundant Poor water-holding capacity.
Vermiculite	Holds water well and pH neutral.	Compacts over time, reducing aeration. Less effective for aeration on its own.
Biochar	Improves soil health and sequesters carbon. Helps retain moisture and supports microbial life.	Expensive to produce on a large scale. Limited water retention, compared to peat.
Composted green waste	Widely available and reduces landfill. Nutrient-rich for plant growth.	Variable quality depends on the composting process. May contain weed seeds or pests if improperly processed.

Water-holding capacity and aeration are considered to be the most common issues with the majority of the materials. Biosecurity is often overlooked but was recognised and reviewed in Plant Health Centre Report PHC2021/02, with recommendations on hygiene and best practice in a further report PHC2023/03 which sets out the processes required to reduce the biosecurity risks associated with plant waste material (Elliot et al., 2023, Elliot, 2023).

Anecdotally, stakeholders observed an increase in the sciarid flies / fungus gnats in glasshouses after the use of peat-free media and in some instances, the authors have observed sciarid flies directly feeding on the live plants. However, the potential of sciarid flies to be a primary pest is unknown. Hence the project aimed to seek evidence to address this knowledge gap by critically reviewing the available literature and by conducting semi-structured with various stakeholders involved in horticulture production.

3 Material and methods

3.1 *Literature review*

The aim of the literature review was to concentrate on literature published only in the UK and Europe. However, it was soon discovered that there was very limited literature from the UK and Europe and that significant work had been conducted in the United States. The literature review was therefore widened to encompass any international research that had been conducted. In order to cover both scientific and grey literature, search engines such as Google, Google Scholar, Semantic Scholar and Gov.UK were utilised. Words such as sciarid flies, fungus gnats, *Bradysia* spp., pest, plants and glasshouse were used. The combination of words with the 'AND' Boolean term was used to collect the respective articles.

3.2 *Semi-structured interviews*

To improve our understanding of the issues that stakeholders are encountering with sciarid fly, we conducted semi-structured interviews with 18 relevant stakeholders. Stakeholders were initially identified through the existing professional networks of the authors and contacted via email. Stakeholders included:

- Plant growers from the horticultural sector who are managing sciarid fly on a daily basis
- Biocontrol companies that produce and sell products to control sciarid fly
- Researchers that are specifically working on sciaridae (e.g. evolutionary biologists), or are growing plants in the glasshouse context for experimental reasons

These interviews were scripted (see appendix A) so that we could gather data to understand:

- If sciarid fly are an issue and to what extent
- Have stakeholders noted any differences when using peat-free/reduced growing media
- Do they have any management processes in place to lower the prevalence of sciarid fly in their particular context

We also allowed time for general discussion (hence semi-structured) to gather information which we may not have foreseen.

An ethics assessment was carried out using the ethics approval process at SRUC. Interviews were conducted on Teams and recorded so that we could refer back to them if needed. Data was held on SRUC servers in line with current GDPR and were deleted upon the completion of the project.

Considerations when analysing the data:

The data only captured the views of those who participated in the interviews. We contacted many more people than replied, the data therefore represents a cross-section of the sectors involved and not the views of the sectors as a whole.

The results analysed are those received from respondents. No attempt was made to verify the data reported.

4 Results

4.1 Review of Literature

The majority of articles published on sciarid fly are concerning non-Mendelian inheritance systems. Most of the literature is from work conducted in the United States (US). This is because the US are interested in soilless media research due to pressing issues like water conservation, climate resilience, urbanization, food security, and economic innovation. Each state's individual environmental, economic, and social conditions have driven a tailored approach to embracing soilless agriculture as a key area for research and development.

4.1.1 Sciarid fly biology

Sciarid flies are generally described as small, dark-coloured gnats with unmarked wings. They are considered the least well-known family of Diptera in the British fauna. Sciarid flies are not frequently studied among British dipterists, in part due to difficulty in the identification and uniform appearance of most species. In 2005, 263 species were confirmed, including many species new to the British Isles: 111 new to Great Britain and 32 new to Ireland (Menzel et al., 2006).

The sciarid flies are commonly found in a variety of habitats, particularly where conditions are favourable for their development. The most common habitats are mushroom houses, greenhouses and protected cultivation, woodlands and forests, soils and compost. Table 2 shows the most common and most notable genera of sciarid flies relevant to the UK with a particular focus on controlled production (Menzel et al., 2006, Kapongo et al., 2020).

Table 2 - Common Sciarid flies in the glasshouse setting

Genus	**Habitat and comments**
Bradysia	The most common genus in the glasshouse and it is encouraged by the moist and organic-rich materials. Some of the notable and common Bradysia species are • *Bradysia impatiens*- Fig-1 (a) • *Bradysia coprophila* - Fig-1 (b) • *Bradysia paupera*
Sciara	The second most common genus which is similar to *Bradysia*.
Lycoriella	The most common species in mushroom houses but also found in glasshouses.

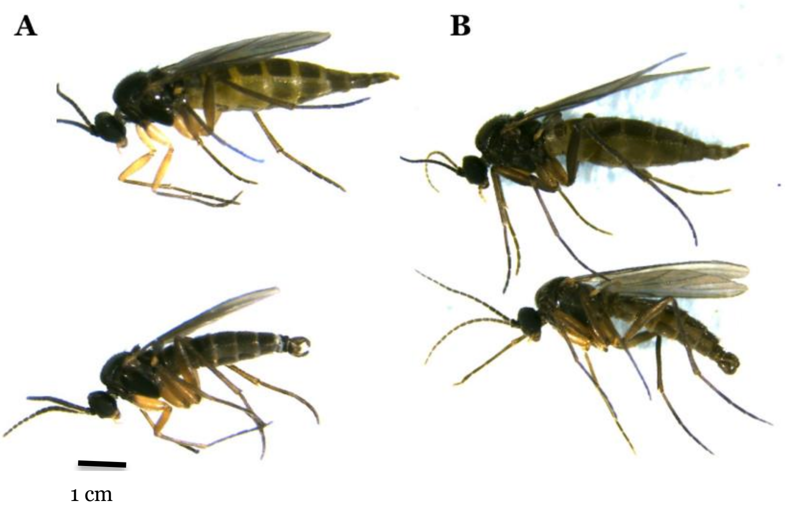

Figure 1 - Shows the males and female of the most common sciarid flies in the glasshouse settings, the top ones are the females and the bottom ones are the males (A) Bradysia impatiens (B) Bradysia coprophila

Figure 2 illustrates the lifecycle of sciarid flies which starts with an adult fly. Sciarid flies, particularly those in the family Sciaridae, generally exhibit semelparity, meaning they typically engage in a single reproductive cycle before dying. In many species, females lay a large number of eggs in a brief lifespan, after which they do not survive long, and they are monogenic, (produce all male or all female offsprings) (Gerbi et al., 1986).

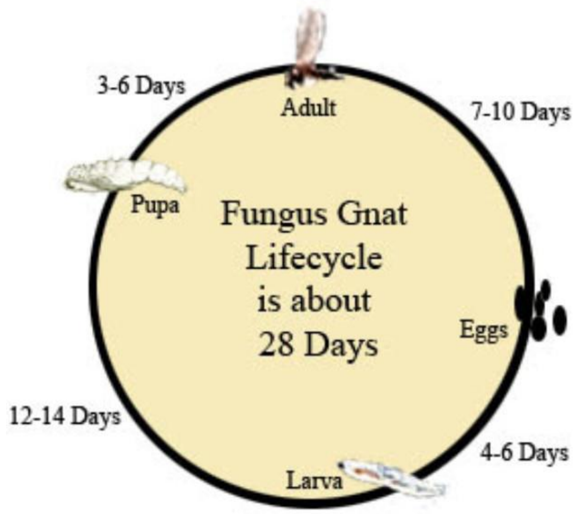

Figure 2 - Life cycle of sciarid flies. Source British Gardeners

Within 4-6 days, larvae hatch from the egg, and it has four instar (developmental stages) before it pupates. The four instars are considered the active stages where the larvae feed on fungi, algae, organic materials and living plant roots (Katumanyane et al., 2018). This is the most crucial stage concerning pest activity and sciarid flies act as direct pests during this life stage. The duration of this stage depends on the availability and the type of nutrient source. The larvae take around 12-14 days to pupate, depending on the nutrient source available. For instance, sciarid flies fed on the fungi *Trichoderma spp.* exhibited a better survival rate and a shorter lifecycle compared to those fed on *Phytophthora spp.* (Zin & Badaluddin, 2020). This might be due to the nutrient content and the also the secondary metabolites produced by the fungi. The pupation lasts for about 3-6 days. The final stage of the life cycle is the adult fly and it can act as a vector for various fungal and viral diseases in a glasshouse settings (Budziszewska et al., 2021; Braun, 2011).

Generally, the life cycle of a sciarid fly takes approximately 28 days to complete but, as above, the full life cycle is greatly influenced by the availability and type of nutrient sources and the environmental conditions. In summary, temperature (20°C to 25°C) and moisture content (70% to 90%) are key environmental factors influencing the life cycles and reproductive success of sciarid flies. Eggs, numbering between 40 and 100 per female, are laid in moist, organic-rich environments, with the full life cycle lasting about 20 to 30 days (Harris et al., 1996).

4.1.2 Pest status

Sciarid files are common insects in the glasshouse setting, and initially, were considered only as a nuisance. However, the direct damage caused to plant roots, along with a recognition of the role these insects may play in pathogen dissemination, has elevated them to pest status (Kapongo et al., 2020). It is considered an important glasshouse pest and if not controlled it has the potential to cause 50% yield loss (Agriculture and Horticulture Development Board [AHDB], 2021, Greenwood Plants, 2023).

The sciarid fly larvae not only cause direct damage to the living plants by feeding on their roots but also make the plants vulnerable to various soil-borne pathogens by creating wounds in their root system (Gillespie & Menzies, 1993). Furthermore, it has been reported that larvae are capable of directly transmitting certain fungal diseases including *Pythium spp.*, *Fusarium spp.*, and *Verticillium spp.*, from diseased to non-infected plants (Gillespie & Menzies, 1993). Studies revealed that oospores of certain species of *Pythium* were viable even after their passage through the digestive system of *B. impatients* (the most common species in the glasshouse) and this can be introduced to the young healthy plants during the feeding process (Kapongo et al., 2020). Laboratory studies on geranium seedlings showed their susceptibility to *Pythium* infection increased when they were subjected to sciarid fly feeding (Daughtrey & Buitenhuis, 2020).

Although the adult sciarid flies don't fly high or very far, they are capable of acting as vectors for various plant diseases such as *Botrytis cinerea*, *F. avenaceum*, *F. acuminatum* (Ellis &

Everhart), *T. basicola*, *V. dahliae*, and *V. albo-atrum* (Marín Cruz et al., 2022). The adult flies carry the spores/inoculum of these plant pathogens on their body and then spread them to healthy plants (Cloyd, 2008). A study has revealed that sciarid flies were able to transmit the peanut stunt virus transstadially (transfers from one stage to another) in their lifecycle and act as a vector for this disease (Budziszewska et al., 2021).

The ability of both life stages of fungus gnats to transmit diseases implies that the acceptable threshold for this pest may be quite low (Budziszewska et al., 2021). As a result, rigorous plant protection measures, including alternative management strategies, must be employed.

4.1.3 UK research

Sciarids have previously been identified as a pest in the UK. It was mentioned in several grey literature sources such as the AHDB Crop Walker guide for cut flowers bedding and pot plants, AHDB report 'Cultural control of sciarid and shore flies in protected ornamental' and in, various commercial biocontrol company's promotional literature. Most of the research conducted in the UK was on *L. ingenua*, the mushroom pest.

Although this study has confirmed that sciarid flies are a glasshouse pest, investigations into contributing factors such as aggressiveness and choice of plants is lacking. There may also be other factors that need to be identified and considered.

4.1.4 *Sciarid fly management*

4.1.4.1 Growing media

The composition and structure of growing media plays a critical role in influencing fungus gnat populations. Media with high porosity, created by components like organic matter and large particles, provide ideal conditions for adult female fungus gnats to lay eggs. These spaces, often found in more porous, less uniform media, maintain higher humidity levels, which enhance egg survival and larval development (Binns, 1973; Anas and Reeleder, 1988). The presence of decaying organic matter, especially in media like composted hardwood bark, creates favourable breeding sites for fungus gnats due to the increased microbial activity, which provides a food source for larvae and adults (Freeman, 1983; Kennedy, 1974).

Different types of growing media vary in their attractiveness to fungus gnats. Media rich in organic components, like peat moss and composted bark, tend to attract more gnats due to higher moisture retention and microbial activity, which promotes fungal growth that gnats feed on (Baker, 1994; Gardiner et al., 1990).

Extreme wetness or dryness reduces gnat survival, with the optimal moisture content for fungus gnat development being around 52% (Olson et al., 2002). Commercially produced bagged growing media and plant plugs can serve as sources for introducing fungus gnats into greenhouses, prompting recommendations for pasteurising growing media to prevent infestation (Cloyd and Zaborski, 2004).

A second study conducted in the US indicated that bagged soilless growing media and rooted plant plugs from wholesale distributors could be sources of fungus gnat introductions into greenhouses. Samples of these materials were incubated in the lab, revealing that fungus gnats emerged from both stored and delivered soilless media, as well as from rooted plant plugs. Hence the authors suggest pasturing the soilless media before bagging it up can control the sciarid fly population (Cloyd & Sutherland, 2004). Once planted up, it is difficult to pasteurise the equipment which holds the rooted plants, so treating the media before it is used is much more effective.

4.1.4.2 Chemical control

Insecticides are a common method for managing fungus gnats in greenhouses and nurseries, primarily targeting larvae through drench applications since larvae cause the most plant damage (Hamlen & Mead, 1979; Lindquist et al., 1985). Globally, insect growth regulators (IGRs) like pyriproxyfen and cyromazine are widely used, but need to be applied early, before gnat populations grow (Ludwig & Oetting, 2001). In the US neonicotinoid insecticides, such as imidacloprid and thiamethoxam, have been shown to be effective against larval stages (Cloyd & Dickinson, 2006) and can be applied as a soil drench. However, in the UK cyromazine, imidacloprid and thiamethoxam are not approved for use. Pyrethroid-based insecticides can control adult fungus gnats but may negatively affect beneficial organisms, disrupting biological control efforts (Croft & Whalon, 1982; Smith & Stratton, 1986).

Other options for chemical control are also limited as many neonicotinoids are banned in the UK and pyrethroid-based insecticides are highly regulated. Soil drenches are no longer approved and therefore there are few chemical options available.

4.1.4.3 Cultural control

Water management is crucial in controlling fungus gnats in greenhouses and nurseries. Sites with poor drainage or algae buildup are more prone to higher fungus gnat populations, leading to significant damage, particularly to seedlings. It has also been observed that greenhouses with soil floors are more susceptible compared to those with cement floors (Keates et al., 1989). One strategy to manage larvae is allowing the growing medium to dry out, which reduces attractiveness to egg-laying females and inhibits egg hatching. However, this approach is difficult to apply after planting up without risking plant growth. Other suggested techniques include incorporating diatomaceous earth (powdered soft, siliceous sedimentary rock), which disrupts insect cuticles, or applying sand to deter egg laying, but studies have shown these methods to be ineffective against fungus gnats (Cloyd and Dickinson, 2005; Cloyd et al., 2007).

Monitoring is a key aspect of fungus gnat management, enabling early detection before populations grow. This typically involves using yellow sticky cards for adult fungus gnats or discs of potato placed on the surface of the growing medium to detect larvae, as the larvae tend to congregate under these disks (Harris et al., 1995). While potato disks recover more larvae than other materials, no consistent relationship has been established between adult populations as caught on sticky cards and larval abundance in the growing medium. Moreover, no threshold levels have been developed to guide when control measures are necessary, making it challenging for growers to make informed decisions on pest control strategies (Cabrera et al., 2003; Harris et al., 1995).

4.1.4.4 Biological control

Biological control methods for managing fungus gnats have gained traction among greenhouse producers in the UK, owing to the availability of effective natural enemies. Predatory mites, beetles and entomopathogenic nematodes are commonly utilised to control fungus gnat larvae in horticultural settings (Cloyd, 2008). Among these, the soil-dwelling predatory mite *Hypoaspis miles* is commercially accessible and is used to manage fungus gnat larvae; however, it does not target the eggs and pupae (Walter and Campbell 2003). The rove beetle *Atheta coriaria* has been explored as a potential biological control agent, showing a preference for fungus gnat larvae in laboratory tests (Carney et al. 2002). However, further research is necessary to fully understand its impact on fungus gnat populations in greenhouse environments.

Entomopathogenic nematodes, particularly *Steinernema feltiae*, are also available through various distributors in the UK and have proven effective against fungus gnat larvae (Gouge and Hague 1995). They must be applied before gnat populations reach damaging levels, and their efficacy is influenced by factors such as application rate, timing, host plant, and moisture content of the growing medium (Cloyd, 2008). However, there are concerns regarding the quality and cost of commercial nematode products. When deploying multiple biological control agents in a system, interactions between them can complicate their use, e.g. when using *S. feltiae* in parallel with arthropods that predate on fungus gnats (like *A. coriaria)* there is the potential for issues with compatibility (Carney et al. 2002). Additionally, preliminary research suggests that entomopathogenic fungi such as *Beauveria bassiana* may provide another avenue for managing fungus gnat populations in the UK (Filotas et al. 2005). Continued investigation into these biological control strategies is essential for developing integrated pest management practices in greenhouse systems.

4.2 *Stakeholder interviews*

A total of 19 interviews were conducted across industry, science and biocontrol providers. These were semi-structured in nature, i.e. they were asked a set of questions (see appendix A) but were also given space to talk about anything that they felt was relevant.

4.2.1 *Prevalence of sciarid fly*

A significant number of respondents (94%) stated that they had noticed an increased prevalence of fungus gnats recently, although none had been carrying out systematic surveys (i.e. it was anecdotal). This was across the different sectors interviewed.

When asked where they think that the fungus gnats come from, the majority (92%) responded that they believed that it was via the growing media (Fig-3). Eight percent thought other sources were responsible; for example, gnats blowing in on the wind. Once again, this was just through their own observations rather than systematic surveying or experimentation. It is important to note that they also named the growing media (where they knew it), and there were a wide range of products being used (we have not named the providers for reasons of confidentiality). No contributors identified a specific growing media component which they believed made the issue worse.

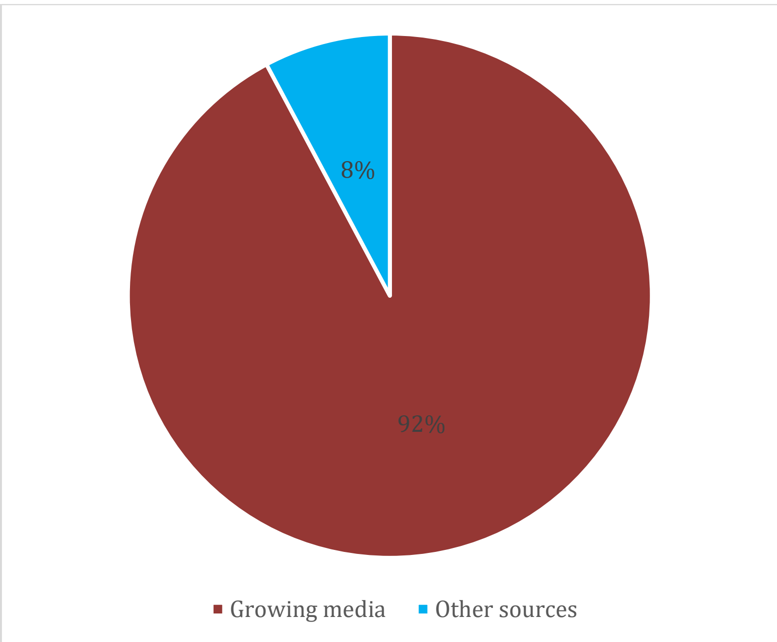

Figure 3 - Response to the question What is the main source of sciarid flies in your facilities?

It is important from a plant health and biosecurity perspective to establish whether fungus gnats are a primary pest (i.e. they are consuming live parts of a host thereby causing poor health or death) or just a nuisance. We therefore asked interviewees whether they had observed damage which they attributed to fungus gnats. Ninety percent of respondents reported that they had lost plants due to fungal gnat damage and they therefore considered them to be a pest, a further 5% were unsure, and 5% replied no, they did not believe that they were a pest (Fig-4).

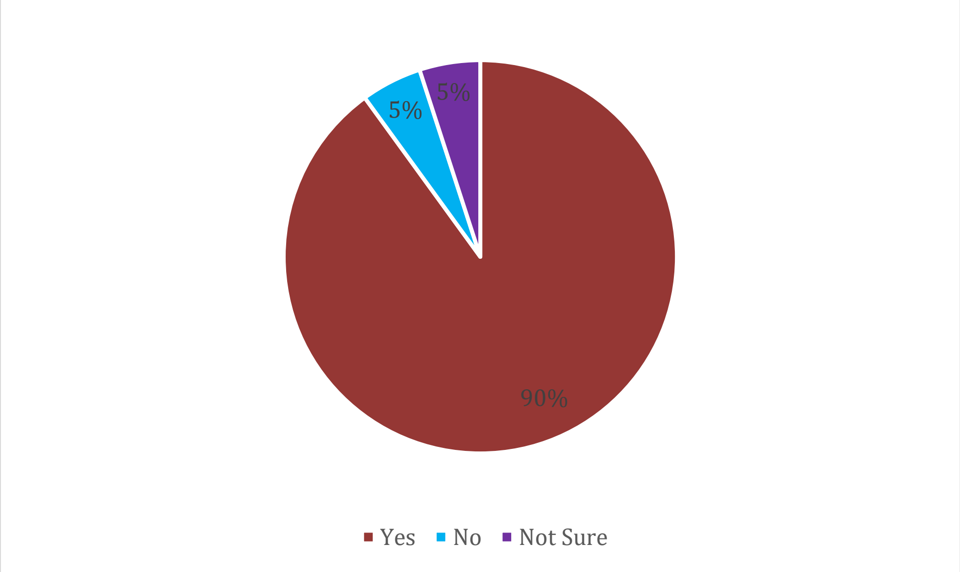

Figure 4 - Response to the question Do you consider them as a pest?

We asked interviewees whether they had noted any factors that they believed affected fungal gnat prevalence. The most reported factor was the moisture content of the growing media. If media is kept wet, users noted that there were more fungus gnats. In addition, plants that require a longer growing period under glass (e.g. Poinsettia) were reported to be impacted more by fungus gnats. Seedlings were also reported to be highly impacted by fungus gnat presence, particularly if they were kept wet. Time of year was thought to be less influential although some glasshouse growers reported higher numbers in summer.

Apart from the entomologists who were interviewed, there was no recognition among interviewees of the specific sciarid fly species which were present.

4.2.2 Reported Management Options

Interviewees were asked what actions they take to manage fungus gnats in their growing facilities. A range of answers were provided:

- Avoid over-watering plants, just provide enough water for healthy growth
- Yellow sticky traps are commonly deployed
- Biological control products (nematodes and predatory beetle larvae)
- Pouring hot water through the pots containing growing media reduces fungus gnats

- Potato peelings on the surface of potted plants can act as a lure for fungus gnats which can be removed after a period, therefore lowering the population of larvae. These peelings should be disposed of carefully so as not spread the infestation or any other disease.
- Good plant hygiene procedures (especially the reduction of plant debris lying around growing facilities)

Discussions with biocontrol providers revealed that products are available, but more than one organism is required to be deployed at a time as applying just one biocontrol agent does not necessarily provide sufficient control. Nematodes (e.g. *Steinernema feltiae*), predatory beetle larvae (particularly rove beetle, *Dalotia coriaria*), and mites (*Stratiolaelaps scimitus*) were reported as frequently used for the control of fungus gnats.

Interviewees were asked where they get their fungus gnat management information from. There were no specific resources named, responses were "the internet", "word of mouth", and "consultants" (particularly the biocontrol companies).

4.3 Knowledge gaps

Most of the scientific studies on sciarid flies are conducted in the US, and many are decades old. This study did not reveal any literature which clarified the sciarid species of concern to Scotland, how damaging they are, and whether they transmit diseases in the glasshouse context.

The horticulture industry is aware of sciarid fly and anecdotally acknowledge that there is an increase in the emergence of sciarid flies after using peat alternatives (organic matters such as composted bark). Knowledge exists on biological and procedural controls (e.g. good hygiene) but it is largely anecdotal, information derived from experimental studies in the glasshouse context is severely lacking. In addition, most of the biocontrol agents are tested on *Lycoriella spp*. which are more prevalent in mushroom houses rather than in glasshouse facilities.

5 Conclusions and Recommendations

This project made some important observations and findings. Stakeholders confirmed that they are experiencing more sciarid flies in glasshouses and polytunnels compared to previous years. Interviewees suggested that sciarid fly incidence had increased recently, with 92% believing the flies came in on purchased growing media.

The literature review indicates that sciarid flies cause direct damage to plants and can also transmit virus and other plant diseases, which indicates that sciarid flies should be considered as a pest and not just (as commonly thought) as a nuisance.

Both the literature review and stakeholders observations indicate that some conditions are more conducive to sciarid fly development including higher moisture content in growing media and warmer temperatures.

No direct link has been identified in the literature or by stakeholders between increased sciarid fly numbers and specific components of peat containing or peat free growing media. The relevant properties of the range of growing media ingredients commonly used should be assessed for their ability to inhibit or support sciarid fly development.

Control or better management of sciarid flies is likely tied to good hygiene practices, as the flies are attracted to organic material. Respondents emphasised that good horticultural practices, such as clean glasshouses and work areas, was an effective way of reducing sciarid fly populations. This aligns with the fact that sciarid fly will lay eggs in any organic material and the larvae can reach maturity within a small amount of organic material.

Adjusting the moisture levels of growing media and the temperature of plant growing conditions could also help manage sciarid fly populations. However, these measures will be limited by the need maintain conditions suitable for plant growth.

Chemical control is unlikely to be a viable option due to the limited availability of pesticides.

Stakeholders reported using sticky traps to reduce adult fly numbers, baits such as potato sections on growing media surfaces to target larvae, and hot water treatments. Yellow sticky traps not only reduce populations, but also provide a visual means of monitoring fly numbers within a specific area, and may be useful in guiding the deployment of biological controls.

Some biological control options, such as parasitic nematodes, are already in use by stakeholders. These are commonly applied in combination with other measures, such as rove beetles, to enhance effectiveness.

A key observation is the lack of Scottish and UK-specific scientific literature on sciarid flies. Most findings on sciarid fly species and control measures are derived from US literature, much of which is decades old.

Consequently, there is no definitive knowledge about the specific sciarid fly species causing issues in the UK. As a result, it can’t be confidently stated that the findings from the literature review pertain to the species present in the UK.

There is an urgent need to test and confirm some of the observations in this report. No direct link was made between the observed increase in sciarid populations and peat free growing media so, rigorous experimental work is required before definitive conclusions can be drawn. This should include identifying specific components of growing media and environmental conditions that attract sciarid flies to help growers make more informed choices around which growing media to use and what conditions to maintain.

In addition, adjusting the type and moisture content of growing media are key strategies in managing fungus gnat populations in greenhouse environments. Most of the media in the UK currently use various organic materials as peat alternatives which could have had an impact on sciarid fly prevalence. Growers should be encouraged to experiment with available components and mixtures to find what works well in their context, to optimise plant growth while lowering pest issues. Steam sterilising growing media before use can significantly reduce sciarid fly populations.

Biological controls, in combination with the measures mentioned above, can offer an effective management option. However, further experimentation to establish the effectiveness of these controls in Scottish glasshouses is required.

Experimental investigations would be useful to establish exactly which management measures are effective. Testing each growing media component in combination with each management approach (e.g. allowing growing media to dry out, sticky traps, biological controls) would be beneficial to move from anecdotal evidence to scientifically validated practices.

It is clear that if populations of sciarid fly are not controlled there is a risk of plant health issues, particularly with seedlings and young plants. There is some evidence that sciarid flies can transmit diseases via propagules attached to their bodies, but this needs further experimental investigation.

This scoping study revealed that sciarid fly is under-researched in the glasshouse context in Scotland, the UK, and Europe. The impact of sciarid fly in glasshouses and on protected crops in Scotland remains unknown and requires further investigation. Additionally, there is limited information on sciarid fly diversity in Scotland. Identifying sciarid fly to species level is a specialist task, and understanding which species are present, as well as their relative impact, would improve management strategies. Currently, all sciarid fly infestations are treated the same way, but there may be some subtle differences between species that warrant tailored approaches.

Therefore, more research is needed to identify the damaging sciarid fly species present in Scottish glasshouses to develop more effective management strategies.

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7 Appendix A

Interview Questions

Introduce the study:

This study is conducted by SRUC and Royal Botanic Garden, Edinburgh funded by the Plant Health Centre, Edinburgh. It is seeking to collect information about the prevalence of fungal gnats and better understand have any impacts on plant growth/production. In the first part of the study, we are speaking with key stakeholders in the Agri and/or horticulture sector to gather the accounts and experiences of users with the above-mentioned focus.

Sample questions

1. Could you please introduce yourself and your experience/involvement with [Agri/horticulture sector specifically on growing plants in protected/controlled conditions]?

Growth medium - content

2. Name the types of growth media that you use more frequently. It would be helpful if you send me the list later if you need some time.

Prevalence of fungal gnats

3. How often do you encounter fungal gnat in protected/controlled situations?

4. Have you noticed if there are any changes in the prevalence of fungal gnats in the recent years? Could you elaborate on it a bit more?

Factors

5. Are there any factors (e.g. time of year, growth media content, environmental conditions, plant husbandry, crop type etc.) that affect the prevalence of fungal gnats you see??

6. Were you able to identify fungal gnats at the species level? If so, what are the most common ones you observe?

7. Were you able to identify fungal gnats at the species level, and say which are most common? Or can you describe their general size and colour?

8. What, do you think the source of fungal gnats is?

Any impacts on plant growth

9. Do you see any different effects on the crops or plants being grown when fungal gnat numbers are high or low? If so, could you please explain what you have noticed

10. Do you have any records of crop loss and in your experience do any impacts from fungal gnats differ by crop type? Can you expand on any difference you see?

Management

11. Do you take any actions to manage fungal gnats in protected /controlled conditions? Can you expand on this?

12. Any 'best practices' to prevent or avoid fungal gnats and could you please elaborate on these?

Evidence

13. What kind of source do you use for information on fungal gnats and management practices? (e.g. Institutes, grower bodies, consultants, booklets, videos, scientific papers, word of mouth etc.)

Further input

14. Is there anything else you would like to share with us that you think might be relevant to this study?

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