Hort Innovation

Final Report

Pest and disease management and research services

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Project code:

MU16003

Project:

Pests and disease management and research services (MU16003)

Disclaimer:

Funding statement:

This project has been funded by Hort Innovation, using the mushroom research and development levy and contributions from the Australian Government. Hort Innovation is the grower-owned, not-for-profit research and development corporation for Australian horticulture.

Publishing details:

ISBN 978-0-7341-4814-8

Published and distributed by: Hort Innovation

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Public summary

Mushrooms lack a protective outer layer such as the skin and cuticle of many fruits and vegetables and they grow indoors in warm, humid conditions where new crops grow adjacent to older crops, making them susceptible to pests and diseases which impact yield and quality resulting in a loss of income for the grower. Because the cropping cycle is so short, conventional agrichemicals cannot be applied when a disease expresses mid-cycle, leaving the grower with few satisfactory options for disease control. The most effective way therefore of mitigating the impact of pests and diseases is to prevent them establishing in the first place.

Information on both current and emerging mushroom pests and pathogens, early disease symptom recognition, pest and disease management issues and hygiene strategies was gathered from a variety of sources such as the industry's pest and disease online library AGORA, international literature and from national and international networking. But the greatest source of topical and relevant information was mushroom growers themselves. Direct grower engagement, most often by email or phone, was the driving force behind the successful delivery of MU16003 ensuring topics addressed by the resources were current and relevant to the industry. Issues raised by one grower were often experienced by another, so information presented to one grower was relevant to many. While many grower enquiries were easy to satisfy, some growers requested help with a longstanding pest or disease issue which had defied the grower's best efforts and had begun impacting the farm's profitability. By assisting the grower address the problem the Project Team identified which resources worked for the farm, how the farm staff were able to use the resources to their advantage and which resources needed to be developed or modified for the wider industry. In addition to published journal articles and direct email, pest and disease management resources were delivered at both face-to-face and online workshops and to individual farms that requested a webinar on a specific topic or who accepted an offer from the Project Team to deliver a webinar on a specific topic.

At the completion of MU16003, the mushroom industry has a suite of available resources which will assist growers and their staff to recognize disease symptoms early, make good decisions at the right time and to prevent pests and diseases establishing through application of effective hygiene and up-to-date pest and disease management strategies. As a result, growers will be equipped to mitigate the impact of pests and diseases on farm profitability.

During the project, 37 articles were published in the Australian Mushrooms Journal and eight factsheets and 11 grower alerts were sent directly to growers through the project's pest and disease management contact database. In terms of digital resources, four instructional videos were produced in cooperation with the industry's communications project MU18001 and two short pest and disease symptom recognition presentations were recorded to video. Responding to positive grower feedback, a Dry Bubble management wallchart and Dry Bubble symptom recognition pocketbook were updated and the revised versions sent to all farms as part of an industry-wide mailout which also included supporting information such as the Dry Bubble Factsheet, Chemical Summary Tables and examples of recommended signage for farms managing Dry Bubble.

All resources produced during MU16003 remain available on AGORA which is password-protected and readily accessible by requesting login details from the Project Team.

Keywords

Agaricus bisporus; *Cladobotryum mycophilum*; Cobweb; Dry Bubble; Farm; Green mould; Hygiene; Integrated Pest and Disease Management; *Lecanicillium fungicola*; mushrooms; MVX Syndrome; *Trichoderma*; Virus

Introduction

The challenges surrounding pest and disease management in mushroom crops are unique. Mushrooms lack a resilient outer layer such as the waxy cuticle of fruits and leaves and they are grown indoors under controlled conditions where new crops grow adjacent to older, potentially diseased crops. Mushrooms are therefore very susceptible to pest and disease outbreaks which significantly reduce mushroom yield and quality, resulting in a loss of income for the mushroom grower. Simply put, growers cannot afford the effects of pests and diseases.

The financial impact of pests and diseases varies. A mismanaged Dry Bubble (*Lecanicillium fungicola*) infection can result in crop losses approaching 20% while losses in the vicinity of 1-5% are more common (1). When it expressed in epidemic proportions in Europe in the mid-1990s, Cobweb disease (*Cladobotryum* spp.) was responsible for up to 40% of crop loss (2) while *Trichoderma aggressivum* compost mould generates losses of between 60% and 100% (3). Brown Cap Mushroom Disease, a viral infection associated with MVX Syndrome, results in losses of up to 80% due to rejection and downgrading of product caused by discolouration and post-harvest degradation (4). Losses due to insect activity are more difficult to estimate. Due to their role as disease vectors, they are responsible for losses far in excess of direct damage, but it has been determined that a single Sciarid larva in 125g of compost will cause 0.5% crop loss by directly feeding on

mushroom mycelium (5). There are also indirect costs due to pest and disease outbreaks to be considered – purchase of more pesticides and salt, labour costs of monitoring and applying treatments, increased air filtration and the social costs of fewer mushrooms to pick, smaller pay packets for harvesters and low morale on the farm leading to poor decisions.

The impact of pests and diseases extends far beyond the affected rooms – the likelihood of spread from the infected beds to other parts of the farm is very high. Vectors, including invertebrates such as mites and flies, are a significant factor in disease persistence and in-farm reinfection cycles. But most significantly, farm personnel and the standard cultivation practices that they perform like watering and harvesting are the greatest vectors of disease. Spores of pathogenic fungi form reservoirs in outside soil or nooks and crannies in buildings and cracked concrete. Pathogenic bacteria form resilient biofilms wherever moisture and organic material accumulate. Therefore, vector controls must also be considered in an effective pest and disease management strategy.

Because of the rapid growth cycle of the mushroom crop, the capacity of mushrooms to bioaccumulate residues and the withholding period stipulated by pesticide manufacturers, there is a very narrow window for the grower to apply chemical control products. If a disease expresses mid-cycle, the only management options available are to terminate the crop early, or try to contain the infection by applying salt, an operation that if not done with scrupulous care and attention will spread the disease.

Because of the lack of sustainable treatment options available, the most successful and cost-effective pest and disease management strategy is to recognize disease symptoms early and control the infection by making correct decisions and to prevent pests and pathogens establishing by embracing holistic whole-farm IPDM principals. The aim of MU16003 is to provide growers with the tools to help reduce the risk of pest and disease by developing farm-friendly information packages in different formats and ensuring access to relevant and up-to-date resources on mushroom pests and diseases, their symptomology and their management.

Building on the outcomes of previous projects MU13014 – *implementing industry risk management systems and capability* and MU12007 – *development of a pilot mushroom farm disease monitoring scheme*, the project has an end of project SIP-aligned outcome such that *growers experience improved product quality and yield by mitigating the impacts of pests and diseases.* This will be achieved by satisfying two intermediate outcomes which will ensure:

- that growers have access to new and re-packaged information on effective pest and disease management
- and that the project generates a positive change in growers' KASA

Methodology

MU16003 developed and delivered new and re-packaged and updated farm-friendly extension resources on pest and disease management strategies direct to growers, farm principals and nominated key farm pest and disease personnel.

1. DEVELOPMENT OF EXTENSION RESOURCES

New information was developed into a range of extension resources in different formats, each with a specific purpose and encompassed:

industry journal articles | factsheets | grower alerts | voice-over-PowerPoint videos (VoP) | instructional videos | symptom recognition resources

Older but still relevant information was reviewed and re-packaged into modern formats as above. In addition to being distributed to industry, these resources were all filed on AGORA, the Australian mushroom industry's password-protected online pest and disease library, to ensure industry access in times of need.

2. INFORMATION GATHERING

2.1 Direct Grower Engagement

The first point of engagement with a grower was most often by email or phone and was encouraged by the Project Team by displaying contact details on all outputs. While some enquiries were relatively easy to satisfy, the majority were a request for assistance for a longstanding pest or disease issue which had defied the grower's best efforts. By the time the problem had been brought to the attention of the Project Team, it was firmly entrenched and impacting the farm's profitability.

2.1.1 Workshops: Nine face-to-face workshops were scheduled over the life of the project. The content of the first round of workshops was aimed at basic concepts of farm hygiene and disease management, with a particular focus on management strategies for the two most prevalent diseases, Cobweb and Dry Bubble, based on the different reproductive biology of the pathogens. The emphasis of all presentations was *why* certain things were done rather than just *what* things needed to be done in a disease management plan.

2.1.2 Farm visits: The ultimate grower engagement occurs on the farm and is where and the Project Team were able to

fully understand issues. While the same pest and disease issues may arise on different farms, the contributing factors are usually different and are influenced by such variables as the age of the facility, materials flow and management priorities. Farm visits had been removed from the original project proposal but were reinstated later through a project variation. Unfortunately, COVID prevented all planned farm visits from going ahead but the Project Team managed to get onto four farms in a COVID travel window.

2.1.3 Conference: The biennial AMGA conference was an opportunity to engage with growers and industry stakeholders such as local and international suppliers and manufacturers who exhibit both established and new pest and disease management products and technologies. The pest and disease presentation is usually very well attended and the conference offered the chance for the Project Team to establish new relationships and refresh old ones.

2.1.4 AGORA: The hub of MU16003 was AGORA, the online resource library for all things related to pests and diseases for the mushroom industry such as articles, videos and factsheets produced through MU16003, significant past and current international research publications and issues of the Australian Mushrooms Journal. Established in earlier levy-funded work, AGORA is a password-protected website that can be accessed by growers and nominated farm personnel and it contains the necessary resources required for growers to understand and manage pest and disease issues they may be facing on their farm. As a central library, it is also extensively used by the Project Team when troubleshooting a pest and disease problem during grower engagement. Access is easily obtained by contacting the Project Team. AGORA content was constantly reviewed and updated throughout MU16003 so that this online resource remains a highly significant asset to the Australian mushroom industry beyond this project.

2.2 Research

Information gained through the research component of MU16003 was funneled directly into pest and disease extension resource materials and distributed to industry. Research topics were farm-based and focused on critical areas contributing to effective pest and disease management strategies – pest/pathogen identification, foot dip management and improvement of spot treatment outcomes.

2.2.1 Literature review – New and emerging threats to the Australian mushroom industry: A significant risk the Australian mushroom industry is currently facing is from the incursion by new pathogens – those that have not occurred in Australia – and emerging or known pathogens that are expressing a different symptomology or with greater vigour. There is limited ability on-farm to recognise the symptoms or know the remedial actions required should an outbreak of a new and emerging disease occur. Although some of these threatening pathogens have been observed within the Australian mushroom industry, none of them have been reported on mushroom crops. A literature review was undertaken to identify the knowledge gaps and gather information from international literature about the biology, symptomology and management of the identified threats.

2.2.2 Diagnostic capacity: The first step towards an effective pest and disease management strategy is to identify the target. Treatments are often species-specific so to achieve good control, the correct product or strategy must be applied. But pathogen identification in mushroom crops is difficult – laboratory processing of compost and casing samples is particularly problematic for modern molecular diagnostic techniques. The Project Team explored the capacity of commercial diagnostic laboratories to effectively deliver mushroom diagnostics.

Unusual symptoms which sometimes expressed on mushroom crops and were not familiar to growers were sent to the Project Team to investigate. Often these symptoms were a result of environmental stress while some were caused by a breakdown in the composting or cultivation system resulting in some moulds growing where they normally do not. These unusual symptoms were written up as case studies, anonymized and formed the basis for industry journal articles.

2.2.3 Improving management of foot dips: Mushroom growers make most of their decisions and formulate adoption strategies based on evidence. Foot dips are a tool critical in maintaining farm hygiene, particularly as more and more information indicates that the concrete floor plays a significant role in pathogen survival and spread but there is little available evidence to show how often foot dip disinfectants need replacing. Observation on-farm demonstrated that the usage of foot dips and their effective management need to improve. This exercise, aimed at informing growers how much organic material in a foot dip is too much, tested the efficacy of a registered foot dip disinfectant by determining the killing capacity of the disinfectant with increasing organic load against the Dry Bubble pathogen *L. fungicola*. The organic content of foot dip disinfectant samples obtained from farms was also determined as a benchmark for foot dip cleanliness and the killing power of each sample was tested against *L. fungicola* spores.

2.2.4 Spot treatment: Because of the rapid growth cycle of mushrooms and their ability to bioaccumulate chemical residues, the only treatment available to a grower when a disease expresses mid-crop, other than terminating the crop early, is spot treatment. If done well, current best practice spot treatment with salt will only contain the disease. If not done well, spot treatment will spread the disease and make the situation worse. One of the activities of MU16003 was to investigate methods of improving the salting technique. But a fatty acid product that was developed in the UK specifically

for spot treatment in mushroom crops became available and, through consultation with the PRG, it was decided to investigate the new product. A trial was performed on a Dry Bubble-affected crop at the Marsh Lawson Mushroom Research Unit (MLMRU) at the University of Sydney.

2.2.5 PDMS culture collection: The Pest and Disease Management Service (PDMS) culture collection is a valuable asset to the Australian mushroom industry as it contains pathogens and compost moulds collected since 2012 as well as isolates recovered during an earlier mushroom industry project. Currently, the collection is housed on agar slopes and is checked regularly and maintained as required.

2.3 Technical Expertise

With more than 80 years combined experience in many different aspects of mushroom cultivation, the Project Team have accrued a valuable body of knowledge unique to the industry. Throughout MU16003, this expertise was applied to the benefit of growers in a number of ways such as:

- maintaining pesticide access for the mushroom industry though input into SARP
- providing expert input to help the introduction of minor use permits
- providing expert comment on and input into other Hort Innovation-funded mushroom industry projects
- serving on industry committees and project PRGs
- obtaining current overseas updates through international networking

3. RESOURCE DELIVERY

Early in the project, a contact database was established through Constant Contact, comprising farm principals, growers and key farm staff dealing with on-farm pest and disease issues. Because of the small number of growers, it was possible to have at least one contact for each farm subscribed. The contact database was used to deliver Factsheets and Grower Alerts direct to the target audience. Journal articles were published in the Australian Mushrooms Journal while instructional and symptom recognition resources were variously delivered at both face-to-face and online workshops, on-farm and by mailout. All resources produced were lodged on AGORA so they are available at all times for growers and stakeholders who have received login details from the Project Team.

4. CLOSING PROJECT EVALUATION

To determine how the project had contributed to the end of project outcome, a grower was interviewed and a case study written. To gain an industry-wide opinion of the value of the project, an *e*survey was distributed to all farms via the project contact database.

Results

1. EXTENSION RESOURCES

Information gathered from numerous sources, headed mainly by issues arising from direct grower engagement were developed into a variety of extension resource types each with a specific purpose:

Australian Mushrooms Journal articles | items ranged from short notices and announcements to in-depth treatments of individual pests and diseases, symptoms, their management strategies and aspects of whole farm hygiene and IPDM. Articles deliver detailed information on mushroom pest and disease topics covering activities and research both within Australia and internationally. Furthermore, journal articles are an effective vehicle to address issues that occur within the industry, which growers can use to apply to their farms. Topics for AMJ articles often result from growers' enquiries

Factsheets | information bulletins that contain new information, often from international sources, to assist growers in pest and disease management or which present a comprehensive summary of pests, diseases and their symptoms and hygiene and management protocols. Disease action plan checklists for rapid application on-farm began to be incorporated into later factsheets which were well-received from growers

Grower Alerts | short, rapid communications which quickly deliver information in response to industry issues. Grower Alerts have been issued to provide timely links to pest and disease information such as announcements of minor use permits; to alert growers to urgent industry issues and to raise awareness of upcoming international mushroom research webinars

Voice-over-PowerPoint videos (VoP) recordings | are short, (<10min) focused recordings addressing disease symptom recognition and pest identification. With VoP, important illustrative slides can be displayed for as long as required and viewers can run the presentation back or halt the presentation at critical points much easier than with video

Instructional videos | produced in cooperation with Project MU18001 – *mushroom industry communication program* covered topics of farm hygiene, farm sampling techniques, correct spot treatment procedures and navigating AGORA

Symptom recognition resources | such as a disease symptom recognition pocketbook and a symptom recognition and

disease management wall chart

Chemical summary tables present the basic information gathered from labels of APVMA-registered products and minor use permits to help the grower decide which product is most appropriate for their on-farm situation. These tables were requested by the AMGA and are regularly updated

PowerPoint presentations were delivered face-to-face at workshops and on-farm and later at online workshops. These were delivered 'live' and were created for each specific interaction. The audience reaction and questions in a live presentation are very valuable and steer the presentations

The developed resources delivered to industry, are summarized in the Extension Resources Table (**Table 1**) and can be accessed as described. Major outputs only are listed in the Outputs Summary Table (**Table 3**). All outputs are detailed in the Supplementary Outputs Table, attached as **Appendix 1**.

Table 1 Summary of extension resources produced and M&E parameters

Item	M&E KPI	Output	KPI met	Access
Industry journal articles	Two published articles every 6 months	37	✓	**Appendix 2**
Factsheets	One factsheet every 6 months	8	✓	**Appendix 3**
	Open rate to exceed 40%		✓	
Grower alerts	As required	11	✓	**Appendix 4**
Voice-over-PowerPoint	None set	2	—	Links in **Appendix 1**
Instructional videos	None set	4	—	Links in **Appendix 1**
Symptom recognition resources *(other than video and VoP)*	None set	1	—	**Appendix 5**
Chemical summary tables	None set	2	—	**Appendix 6**

2. INFORMATION GATHERING

2.1 Direct Grower Engagement

Direct grower engagement was the foundation upon which MU16003 was built and delivered ensuring pest, disease and hygiene issues addressed in the resources produced were current and relevant. Some enquiries were dealt with immediately, while others took significant time and effort over a long period to satisfy. A list of grower enquiries is attached (**Appendix 7**). Note that many of the listed issues were raised by multiple farms which is not reflected in the list. Three examples of the types of issue arising from multiple farms are:

- confirmation of pesticide application rates - a seemingly minor query quickly dealt with but one which has ramifications for industry risk management and protection of the mushroom 'brand'
- assistance with fly identification which lead to the production of a VoP recording (link in Supplementary Outputs Table **Appendix 1**)
- a query about Smokey Mould which resulted in a Factsheet being written and distributed (Factsheet #3 **Appendix 3**)

Two major issues the Project Team faced were first recorded outbreaks of *Trichoderma aggressivum* f. aggressivum (Compost Green Mould) and a virus disease resembling Mushroom Virus X (MVX) Syndrome. While *T. aggressivum* had been isolated in Australia previously, this was the first report from a farm outbreak. A timeline of how the Project Team dealt with this outbreak is attached (**Appendix 8**). The MVX-like virus disease was the first time the syndrome had been reported in Australia and the Project Team assisted the affected farm with an immediate response and management plan through exchange of information by email and by online workshops and resulted in the production of a VoP describing virus disease symptomology (link in Supplementary Outputs Table **Appendix 1**). The Project Team liaised with a commercial diagnostic laboratory to establish capacity to test for the correct virus particles and moderated an online meeting between the commercial laboratory and the leading international researcher on mushroom virus disease, Dr Helen Grogan of Teagasc, Ireland. The conclusion of this meeting was that Australia has a unique viral disease expressing. A nationwide industry survey was conducted by the Project Team through Crop Health Services Victoria, offering free virus testing for any grower that was interested in taking part. The MVX Syndrome report with action timeline (**Appendix 9)** and industry survey result (**Appendix 10)** are attached.

2.1.1 Workshops: Ten face-to-face workshops were delivered over five states attracting attendees from nearly 50% of levy-paying farms. The KPIs set for workshops for LoP were either met or exceeded in the 18 months during which travel was possible before the COVID epidemic shut down interstate travel. It was possible to exceed the number of required workshops by delivering multiple workshops in the same state for different farms and in one case delivering multiple workshops to the same farm so that more staff could attend (**Table 3**).

Workshop content

1. Introduction
- presenters introduce themselves and describe past and present involvement in the industry.
- participants introduce themselves and their role on the farm and how long they have been performing that role

2. Mushroom pathology 101 *(live presentation)*
- introduces the different types of organisms that cause diseases on-farm and their basic biology

3. Case study 1: Dry Bubble biology *(live presentation)*
- biology of the causal organism particularly how it reproduces – the scientific evidence

4. Case study 1: Dry Bubble management *(live presentation)*
- how to control the disease with emphasis on spot treatment according to the biology of the pathogen – the on-farm evidence

5. Vectors *(live presentation)*
- identifying the ways that pathogens travel around the farm

6. Spot treatment training *(interactive practical exercise)*

7. Case study 2: Cobweb biology *(live presentation)*
- biology of the causal organism particularly how it reproduces – the scientific evidence

8. Case study 2: Cobweb management *(live presentation)*
- how to control the disease with emphasis on spot treatment according to the biology of the pathogen – the on-farm evidence

9. Sampling on-farm *(video presentation)*
- introduces new techniques to make farm sampling achievable. Includes sampling video produced in MU16003

10. Scheduled Q&A session

11. Satisfaction survey

At the conclusion of each face-to-face workshop, an anonymous exit satisfaction survey was completed by each attendee which asked for comments about pest and disease management on their farm in light of the workshop presentation and two 'scoring' questions rating content and relevance. Two examples from each workshop have been anonymized and attached as **Appendix 11**.

Table 2 Cumulative figures for 10 face-to-face workshops

State	Workshops	Participants	Farms rep.	Feedback	Rating[1]	Relevance[2]
South Australia	2	18	3	18	8.7	8.9
Victoria	4	46	5	41	9.1	8.8
New South Wales	1	17	5	17	8.7	9.0
Queensland	2	24	5	23	9.1	9.3
Western Australia	1	14	1	13	7.9	7.5
TOTALS & MEANS	**10**	**119**	**19**	**112**	**8.7**	**8.7**

[1] A score out of 10 which reflects the participants' opinion of the workshop as a whole
[2] A score out of 10 which reflects the relevance of the content to the participants

While face-to-face interactions were the most productive form of engagement, it was impossible to maintain through the peak of the COVID pandemic when travel restrictions were in force and so many farms suffered from staff shortages. To overcome this, the project embraced remote delivery by presenting online workshops. Online workshops were offered to farms on a topic of their choice by the project or were delivered to assist a farm request to workshop a disease issue. In shifting to a remote delivery model, the Project Team evolved an effective two-way information system which proved productive for example in dealing with an outbreak of suspected Mushroom Virus X Syndrome which is described in a remote workshop report (**Appendix 12**). Details of further remote workshops are presented in **Table 3** and the Supplementary Outputs Table **Appendix 1**.

2.1.2 Farm visits: The capability to visit farms was established through a variation and was aimed at examining vulnerabilities of different farms to pests and diseases. One of the major on-farm tasks was to undertaking some strategic sampling from sites identified during project MU12007 – *development of a pilot mushroom farm disease monitoring scheme*, highlighting disease hotspots and assisting farms to develop better management strategies. COVID restrictions largely prevented this activity from proceeding, but in a COVID travel window, the Project Team did manage to visit four farms. From this limited opportunity on-farm, it was apparent that COVID-enforced staff shortages were severely impacting the hygiene regime and farms would not benefit from sampling results. Staff normally tasked with crop monitoring and supervising cleaning were either unavailable because they were busy filling gaps on other critical processes, or they were only able to dedicate a small amount of time to hygiene and crop monitoring.

2.1.3 Conference: Under the theme of 'a Bridge to Success', the 43rd biannual AMGA conference was held in Sydney from 11th-13th October 2018 and was attended by 128 delegates, speakers and exhibitors. The project delivered a pest and disease presentation entitled "Pest and disease management – it's a numbers game" describing some of the numbers involved in mushroom growing and how they relate to pest and disease management. The presentation is attached as a PDF (**Appendix 13**). The presentation was also reproduced in the industry journal (*Allan J, Gill W (2018) Pest and disease by the numbers AMJ 4: 28-31*; Article #7 **Appendix 2**). A subsequent industry conference scheduled for 2020 was canceled due to COVID restrictions.

2.1.4 AGORA: As the central library of mushroom pest, disease and hygiene information, AGORA is an invaluable industry asset which has proven time and time again to be reliable, relevant and extremely appropriate for the role it plays in grower engagement and disease management. After each interaction with a grower, the appropriate section is reviewed for content relevancy measured against how the grower was able to use the resources. The library is then updated accordingly with new material as it becomes available.

AGORA has played a significant role in helping two farms manage their way through two serious diseases which have been responsible for many business closures around the world. By having the resources in one central hub, the Project Team were able to collect and deliver to the farm within minutes the most appropriate resources that were needed at that time. Further resources appropriate to where the farm was in managing the outbreak were sent at a later time. This was to ensure that growers received the correct information at the right time and were not overwhelmed by the volume of material. There are of course some growers who devour information and will read anything relevant to their situation. In one interaction with such a grower, his issue had not been fully resolved, but his response was to say that he was very satisfied with the outcome because he appreciated all the information that was fed to him from AGORA.

At the other end of the scale, AGORA is also a significant asset when dealing with newcomers into the mushroom industry. The Project Team have developed a method to drip-feed relevant information to those new to the industry, so they do not become daunted by the sheer volume of information available. At the end of one such interaction the new grower was very complimentary about the way information from AGORA was fed to them and how they were going to change practices as a result (grower feedback email – grower details redacted; **Appendix 14**).

2.2 Research

2.2.1 Literature Review – New and emerging threats to the Australian mushroom industry: Three fungi, five bacteria and one virus complex were identified by the Literature Review as posing a threat to the Australian mushroom industry as new and emerging diseases. Of these, six were considered to be new, not having been recorded in Australia previously, one had been isolated previously in Australia but had not caused a disease issue on-farm, and two were known pathogens which have caused problems overseas by expressing different symptoms and greater vigour than when previously encountered here.

From the review, two journal articles: *Gill W (2020) Mushroom virus disease – biology and epidemiology AMJ 4:14-19* (Article #24 **Appendix 2**); *Gill W (2021) Mycetocola. An emerging soft rot disease of cultivated Agaricus bisporus AMJ 1:26-28* (Article #25 **Appendix 2**) and three Factsheets: *Syzygites megalocarpus – Troll Doll* (Factsheet #1 **Appendix 3**); *Internal Stipe Necrosis* (Factsheet #7 **Appendix 3**); *Mushroom Virus X Syndrome – Patch disease and Brown Cap Mushroom disease* (Factsheet #8 **Appendix 3**) were published and delivered to growers.

Two pathogens highlighted in the literature review – fungal *T. aggressivum* and viral MVX Syndrome – established on-farm for the first time in Australia during the course of MU16003 and were addressed by the Project Team working closely with affected farm staff. Both pathogens caused many businesses to close when overseas industries were hit, but both affected Australian businesses are recovering their lost productivity.

As part of the review, a chapter detailing exotic diseases of *A. bisporus* mushrooms on international crops that have not expressed here and diseases of cultivated mushrooms other than *A. bisporus* was written. This chapter, called 'The Disease Watchlist' will be extracted from the literature review as a stand-alone document and will be used to monitor impending industry biosecurity issues. Like the Literature Review, the Disease Watchlist is a living document which will be updated as new information arises. The Literature Review is attached as **Appendix 15**.

2.2.2 Diagnostic capacity: The first request for diagnostic assistance during MU16003 came from a farm experiencing an unusual grey/green mycelium growing sporadically over mushroom beds (Farm case study #1 **Appendix 16**). The grower was advised to submit a sample to a commercial diagnostic laboratory for identification, but the interaction with the laboratory was problematic requiring the Project Team to intervene and facilitate a satisfactory conclusion. This experience demonstrated the need for the capacity for mushroom diagnostics to be examined and reviewed regularly. Further growers' diagnostic requests submitted to laboratories were followed by the Project Team and a relationship was established with Crop Health Services Victoria where the reception staff and diagnosticians are very knowledgeable and very approachable. This laboratory is the recommended laboratory for mushroom diagnostics of fungal, bacterial, viral

and nematode issues. The capacity to address entomological issues will be determined in the future as farm problems arise.

Grower engagement by email or telephone sometimes resulted in an unusual symptom on mushrooms or compost and/or casing being sent to the Project Team for investigation. This required a compost sample to be grown out and the pathogen identified by its micromorphology or sent to the diagnostic laboratory for identification. On other occasions, the symptom was determined to be caused by abiotic issues and not because of a pest or pathogen. The investigations of unusual symptomology have been anonymized and presented as farm case studies, some of which have been published as journal articles: *Gill W, Allan J (2019) When relations go bad: navigating uncharted waters. AMJ 4:20-26* (Farm case study #2 **Appendix 16**; Article #16 **Appendix 2**); *Gill W (2020) Nematodes: a fly-in-fly-out pest of mushroom crops. AMJ 1:26-28* (Farm case study #3 **Appendix 16**; Article #17 **Appendix 2**); *Gill W (2020) Peak fly season is nearly upon us… are you ready? AMJ 3:22-23* (Farm case study #4 **Appendix 16**; Article #21 **Appendix 2**); *Gill W (2022) Abnormal mushroom development. AMJ 1:14-15* (Farm case study #6 **Appendix 16**; Article #36 **Appendix 2**). Significantly for industry, the capacity to diagnose unusual symptomology allowed MU16003 to monitor for new and emerging diseases and other potential biosecurity concerns.

2.2.3 Improving management of foot dips: This exercise demonstrated that as little as 8g of casing soil in 100ml of a fresh solution of a registered disinfectant made to manufacturer's instructions was enough to severely reduce the efficacy of the disinfectant against *L. fungicola* (Dry Bubble) spores. The organic content of foot dip disinfectant samples taken from five farms was also measured and in four of the five samples, the efficacy of the disinfectant against *L. fungicola* was lower than fresh, clean disinfectant. These results will increase growers' awareness for the need to replenish foot dip disinfectant more often. This work was published in the Australian Mushrooms Journal as: *Gill W (2021) Organic material affects foot dip efficacy. AMJ 4:22-23* (Article #33 **Appendix 2**)

2.2.4 Spot treatment: The results if the *in planta* trial of a non-synthetic alternative to salt were encouraging. The report has been submitted under an embargo due to the regulatory conditions that must be met before the product can be legally applied to a mushroom crop. A document describing current spot treatment has been attached as **Appendix 17**.

2.2.5 PDMS culture collection: The PDMS culture collection is an assemblage of 58 accessions isolated from Australian mushroom farms comprising *Lecanicillium fungicola* (31 isolates), *Cladobotryum mycophilum* (6 isolates), *Trichoderma* spp. (13 isolates) and various weed moulds (8 isolates). The collection is maintained on 1/5th strength PDA slopes in screw-capped McCartney bottles in triplicate and stored at 4°C. The collection has been accessed by industry stakeholders and other industry projects which have used isolates for pesticide and disinfectant trials and to simulate disease outbreaks in the MLMRU. As it also includes some strains isolated from a previous project, the collection is valuable as a historical record should pesticide resistance trials, for example, be undertaken at a later date.

2.3 Technical Expertise

Technical input from the Project Team helped secure and/or obtain renewal of minor use permits for salt, Carbendazim, *Bacillus amyloliquefaciens* (Serifel®), Prochloraz and Vivando® (**Appendix 18**). Technical papers (**Appendix 19**), written to address topical industry issues, were re-worked into a reader-friendly format and published in the industry journal.

The mushroom industry highly benefited from the Project Team's international networking and collaboration with Dr Helen Grogan, the world's leading mushroom virus researcher, to work through the MVX Syndrome issue that arose during MU16003 (detailed in section 2.1 above). The Project Team liaised between Dr Grogan and Crop Health Services Victoria culminating in an international online meeting to discuss the Australian virus issue and to map out a way forward.

Throughout the project, the team continually monitored and evaluated new developments in pest and disease management arising overseas and brought these to the attention of industry, such as publicizing the international webinar sponsored by Teagasc, Ireland, earlier this year.

3. RESOURCE DELIVERY

The contact database established using Constant Contact comprising farm principals, growers and key farm staff dealing with on-farm pest and disease issues was critical in delivering significant pest and disease information in a quick and timely manner to a targeted audience. Because of the small number of growers, it was possible to have at least one contact for each farm. This contact database was used to primarily distribute the Factsheets and Grower Alerts.

Journal articles were published in the Australian Mushrooms Journal which was distributed to a wider national and international audience though the industry communications project MU18001.

Instructional videos were used as training aids during face-to-face workshops and are available from AGORA or direct from the Project Team either as a link or file transfer when a farm requires to use them for training purposes.

The Voice-over-PowerPoint digital pest and disease identification resources are also available from AGORA or direct from the Project Team either as a link or file transfer when a fam requires to use them for training purposes.

Symptom recognition and disease management resources, such as the Dry Bubble laminated wallchart and Dry Bubble symptom recognition pocketbook were sent to all farms in a mailout which included other Dry Bubble management information such as the Dry Bubble factsheet, chemical summary tables and example door signage.

Some presentations created specifically as educational/instructional tools for face-to-face workshops (described in 2.1.1 above) and on-farm delivery are not filed on AGORA and are not appended here. Because their impact relies on live delivery and the presenter/audience interaction, making these available to industry is of no value.

All resource outputs are stored on AGORA and are available at all times to industry stakeholders who have received login details from the Project Team.

4. CLOSING PROJECT EVALUATION

A grower case study and the results of the *e*survey are attached (**Appendix 20** and **Appendix 21** respectively).

Discussion

MU16003 has delivered a suite of farm-friendly resources to the Australian mushroom industry to help growers and their staff identify pests and diseases early, allowing them to make good, informed decisions about all facets of pest and disease management, hygiene practices and chemical application to help mitigate the impact of pests and diseases on farm profitability. The project has embraced different media and modes of delivery to ensure the information, gathered from research, international literature, national and international networking but primarily by engaging with growers, reached its target audience and was fit for purpose. As summarized by one grower (Grower case study **Appendix 20**) the pest and disease project was about supporting industry capacity, acting as an insurance policy that was open to being used as required.

Aligning with one of the intermediate outcomes, MU16003 has delivered 37 industry journal articles, 8 factsheets, 11 grower alerts and seven digital/video products presenting new information to growers and industry stakeholders over the course of the project (**Table 3**). In response to positive feedback, two Dry Bubble management resources were updated and revised and included in a mailout package to all levy-paying farms. The package also included new resources such as example door signs to assist traffic management and reduce vectoring when Dry Bubble was expressing. These resources are all available on AGORA and can be accessed at all times by growers with login details. Growers not 'subscribed' can easily get in touch with the Project Team (contact details are prominent on all articles, factsheets and grower alerts) and be issued with personal login details.

From satisfaction surveys completed at the end of face-to-face workshops (**Appendix 11**), the majority of attendees were able to list something they learnt from the workshop which they could apply or use to make changes on their farms. One grower, after receiving material from the Project Team off AGORA relevant to his issue, was extremely grateful to have new information to assimilate although it did not fully resolve his issue. He was, nonetheless, very satisfied at the outcome. In another instance, a new entrant into the industry with no previous experience was extremely grateful to receive so much relevant information from AGORA in a progressive manner (grower email, **Appendix 14**). Furthermore, an experienced grower (grower case study on Hort Innovation's website accessible at: https://www.horticulture.com.au/growers/help-your-business-grow/research-reports-publications-fact-sheets-and-more/defending-aussie-mushrooms-against-pests-and-disease/) commenting on the appropriateness of the instructional videos said that he used them to train staff. These resources are not only increasing growers' and farm staff knowledge of pests, diseases and hygiene in alignment with a second intermediate project outcome, but also upskilling them in disease management practices and instilling the confidence to manage pest and disease incursions effectively.

In as far as the farms that experienced severe outbreaks of *Trichoderma* Compost Green Mould and MVX Syndrome are still in business and recovering lost production where many farms worldwide have succumbed to these diseases, the end of project outcome has been satisfied. Early attempts at surveying growers by 'cold calling' were unproductive and this has continued throughout, culminating in the poor but not unexpected response to the end-of-project *e*survey (**Appendix 21**) which was intended to capture evidence that the end of project outcome has been satisfied. The Australian mushroom industry is very small (about 40 growers), insular and competitive – growers tend not to want their disease status to be known. As mushrooms crop weekly and multiple rooms are cropping at the same time, growers have always time-poor and under pressure, but the post-pandemic hangover of continued labour shortages is continuing to put farms under more and more pressure. Some farms have resorted to reducing pinning so that short-staffed harvesting and pack room teams can keep up with production and minimize both waste and pest and disease risks due to spoilage on the beds. Under these conditions, it would be difficult to determine if a farm has improved product quality and yield.

AGORA has been central to the successful delivery of MU16003 and it continues to be the hub of the Australian mushroom industry's pest and disease management strategy. As such, it played a pivotal role in assisting farms manage the first outbreaks in Australia of *Trichoderma* Compost Green Mould (**Appendix 8**) and MVX Syndrome (**Appendices 9, 10, 12**). From two severe diseases that have closed hundreds of businesses around the world, both farms are recovering

their production and the diseases have been contained and have not spread to other farms. Established nearly 20 years ago from a HAL-funded project, the AGORA website has morphed into a library where all information and resources concerned with pest and disease management is stored. There is nothing fancy about AGORA - it is a working 'blue-collar' website that is available at all times to all growers. As summarized by one grower (Grower case study **Appendix 20**), accessing AGORA is his first action when addressing an issue, noting the wide span of information available and direct access to the Project Team helps protect businesses and the industry as a whole. From a user satisfaction survey (Final Report: MU1800 – Mushroom industry communication program, 2022; Hort Innovation website) AGORA was highly valued by 70% of respondents while 80% ranked it as somewhat or very valuable and 70% were satisfied with AGORA.

Outputs

The output summary table (**Table 3**) lists the major outputs only. Please refer to the **Supplementary Outputs Table** in **Appendix 1** for details of all outputs and links to audio-visual resources where appropriate.

Table 3. Output summary table

Output	Description	Detail
SUPPLEMENTARY OUTPUTS TABLE ***Appendix 1***	Supplementary table with detailed descriptions of all outputs delivered	
JOURNAL ARTICLES ***Appendix 2***	**Australian Mushrooms Journal** is a quarterly publication distributed to levy payers and others involved in, or with an interest in, the operations of the Australian mushroom industry	The project KPI of two published articles per six-monthly reporting period has been exceeded. For article details, refer to the supplementary outputs table, **Appendix 1**
FACTSHEETS ***Appendix 3***	**Factsheets** were distributed to farm principals and farm personnel who had been identified as key farm pest and disease contacts	The project KPI of one factsheet per six-monthly milestone reporting period has been achieved. The opening rate KPI of 40% has been exceeded for all factsheets For factsheet details, refer to the supplementary outputs table, **Appendix 1**
GROWER ALERTS ***Appendix 4***	**Grower alerts** were distributed to farm principals and farm personnel who had been identified as key farm pest and disease contacts	Grower Alerts are rapid communications which quickly deliver information in response to industry issues .and which may immediately change the way growers treat their crop. For grower alert details, refer to the Supplementary Outputs Table **Appendix 1**
SYMPTOM RECOGNITION RESOURCES ***Appendix 5***		Dry Bubble recognition and management wallchart and symptom recognition pocketbook were revised and distributed as part of a Dry Bubble management mailout package
CHEMICAL SUMMARY TABLES ***Appendix 6***		The development of chemical summary tables was requested by the AMGA to help growers make the correct pesticide decisions. The information contained was gathered from the APVMA website
GROWER ENQUIRIES ***Appendix 7***		Grower enquiries drove MU16003. The list of the issues addressed is appended, noting that most of these issues were presented by multiple farms
WORKSHOPS ***Face-to-Face***	Face-to-face workshops were targeted at growers and harvest supervisors but staff from all roles were welcomed as it is important that QA, marketing and accounting staff also recognize the impact that pests and diseases have on their jobs and what is involved in managing outbreaks	Presentations were live PowerPoint deliveries, allowing the focus of the presentation to be dictated by audience questions and the P&D status of the farms. None of these presentations have been attached to this report as they are only of value when delivered live. A confidential exit survey was conducted at the conclusion of each workshop which involved some questions to evaluate the effect on participants' KASA, a comment section and a rating for content and relevance. For workshop details, refer to the Supplementary Outputs Table **Appendix 1**
WORKSHOPS ***Remote***	Due to COVID-enforced travel restrictions, delivery of face-to-face workshops was not possible. MU16003 turned to online remote workshops to continue extension and engagement. Online workshops were both requested by farms and offered by MU16003	Farms determined the content of requested online workshops while for workshops offered by MU16003, content was determined from on-farm observations. One of the outputs of these remote workshops was a short voice-over-PowerPoint presentation which has subsequently been released to industry. Total attendance was not counted as many participants accessed single computers. The number of registrants replying to webinar invitations was recorded. For workshop details, refer to the Supplementary Outputs Table **Appendix 1**

INSTRUCTIONAL VIDEOS	**Instructional videos** are often used in workshops or sent to farms dealing with a relevant issue	The videos were produced in collaboration with project MU18001 and Team Rowley. Details and links are available in the Supplementary Outputs Table **Appendix 1**
VOICE-OVER-POWERPOINT RECORDINGS	**Vice-over-PowerPoints** (VoP) are short (<10min) focused, narrated PowerPoint slide presentations that have been recorded	VoP are particularly useful when presenting issues relating to pest and disease symptom recognition or to pest and pathogen identification. With VoP, viewers can run the presentation back or halt the presentation at critical points for discussion. Details and links are available in the Supplementary Outputs Table **Appendix 1**

Outcomes

MU16003 project outcomes align with **SIP 2017-2021 OUTCOME 2** such that: *Mushroom growers are profitable and sustainable through increased yields, reduced costs and effective risk management* with the **End of Project Outcome** such that: *Growers experience improved product quality and yield by mitigating the impacts of pests and diseases*. Two **Intermediate Outcomes** align with the SIP such that: *Growers have access to new and re-packaged information on effective pest and disease management* and *Positive change in growers' KASA.*

Table 4. Outcome summary table

Outcome	Alignment to fund outcome, strategy and KPI	Description	Evidence
Intermediate outcome: Positive change in growers' KASA	This outcome aligns with Outcome 2 of the Mushroom Strategic Investment Plan 2017-21	If nothing changes on a mushroom farm, diseases don't go away because the growing system is enclosed and intense. Growers will try everything they know to eradicate pests and diseases but if unsuccessful, they will engage with the Project Team. For the Project Team, effective grower engagement is about understanding farm processes, identifying where change needs to be made and providing the resources from AGORA, or developed new resources to effect that change on-farm. The Project Team monitored progress and evaluated the impact of resources and revised or developed new ones as necessary	Grower feedback from: workshop satisfaction surveys, grower case study, industry survey, emails, observation on farm and personal comments during grower engagement
Intermediate outcome: Growers have access to new and re-packaged information on effective pest and disease management	This outcome aligns with Outcome 2 of the Mushroom Strategic Investment Plan 2017-21	Information was gathered from many sources including applied research, international literature, national and international networking. But the most valuable source was through direct grower engagement ensuring that the resources developed were relevant to the Australian mushroom industry. All products are stored on AGORA and are accessible to growers	MU16003 delivered to growers 37 journal articles, 8 factsheets (both exceeding their set KPIs), 4 instructional videos and 2 VoP recordings which increased hygiene, pest and disease management and symptom recognition capabilities on-farm. Growers were presented further information by grower alerts, chemical summary tables and face-to-face and online workshops
End of project outcome: Growers experience improved product quality and yield by mitigating the impacts of pests and diseases	This outcome aligns with Outcome 2 of the Mushroom Strategic Investment Plan 2017-21	MU16003 focused on a proactive approach to pest and disease management strategies to reduce chances of infection and identifying where pathogen reservoirs establish on-farm. Of course, reactive strategies were also important as some infections still evade detection	Difficult to determine as growers are reluctant to disclose disease status of their farms. Reduced cropping in response to staff shortages are blurring this outcome. But the farms that suffered MVX and *Trichoderma* Compost Green Mould are recovering lost production indicating that some growers are improving quality and yield by changing practices due to the influence of MU16003

Monitoring and evaluation

Table 5. Key Evaluation Questions

Key Evaluation Question	Project performance	Continuous improvement opportunities
Effectiveness: To what degree has the new information presented to growers influenced a change in growers' KASA?	A positive change in growers' KASA has been documented from comments on workshop satisfaction surveys	Satisfaction surveys continue to be completed after a grower enquiry
Effectiveness: Has a change in KASA flowed on to the end-of-project outcome so that farms have mitigated loss due to pest and disease?	The farms that suffered *T. aggressivum* and MVX Syndrome outbreaks have recovered much of their productivity lost during their outbreaks	Post-enquiry/direct engagement outcomes need to be documented to capture grower feedback and level of satisfaction for better M&E
Relevance: Do growers feel more empowered or better equipped to manage on-farm pest and disease risks?	Comments on workshop satisfaction surveys indicate that attendees have learnt a lot from the workshops and are confident of managing pests and diseases	Direct grower engagement must continue but grower response needs to be better documented for informative M&E
Process appropriateness: How relevant was the project to the needs of growers?	Grower engagement, via phone, email and face to face was a key factor in delivery. The issues raised by growers were addressed as either factsheets distributed through the contact database or journal articles, distributed to the wider industry and stakeholders. Because they were initiated by growers, issues were always relevant and current	Grower engagement, topics of currency and the confidence that growers had in the Project Team to treat their information confidentially were, without doubt, key aspects that contributed to the successful delivery of MU16003. 'Cold-calling' was unproductive, but growers are always keen to talk about their situation face-to-face, particularly when they are on their own farm
Process appropriateness: Have delivery strategies reached the greatest number of growers?	The project created a database of key farm pest and disease personnel and farm principals for resources distribution. With a small industry of approximately 40 growers, we are confident we have reached most, if not all growers	The ability to contact key personnel from all farms and deliver information to them directly was very important. In previous projects information was only distributed through the industry journal which often did not reach the key pest and disease personnel
Process appropriateness: Growers are very practical people. How better engaged would growers have been if delivery included engagement on-farm?	Farm visits went ahead after a variation was executed	Engaging with growers on their own farm is critical to understand industry issues. Some workshops were held on-farm allowing for a practical session on-site
Efficiency: Were there any aspects of the project that could have made more efficient use of resources?	By keeping project resources on AGORA, they are always available to growers and stakeholders who have received login details	Relevant and appropriate resources were produced and distributed directly to key farm personnel and are always available on AGORA. It is difficult to imagine a more efficient use of resources
Other: Is there a system in place by which growers are continuously updated with new and international mushroom pest and disease management information and their access to an updated AGORA is maintained?	Growers are updated with new and international pest and disease management information through the project contact database. A recent example is a webinar presented by Teagasc, Ireland which featured international researchers presenting their recent work on mushroom pest and disease management strategies. Growers were informed of the webinar by a Growers' Alert (GA #10 **Appendix 4**) issued by the project which contained a link to the recorded webinar and listed the presenters and the topics covered. Factsheets and journal articles cover international issues such as the recent emergence of the new mushroom pathogens *Mycetocola* (Art #25 **Appendix 2**) and *Syzygites (*FS #1 **Appendix 3**)	The current system by which growers are continuously updated with new and international mushroom pest and disease management information and their access to an updated AGORA is maintained must continue into the next pest and disease management project

Recommendations

The target audience for the outcomes of MU16003 is mushroom growers. The outputs which assist them to make good, informed decisions of pest and disease management and hygiene practices remain available on AGORA and for industry to receive the full benefit of MU16003, growers need to take advantage of the materials produced by the project. The first step the grower featured in the case study (**Appendix 20**), takes when facing a pest and disease issue on-farm is to use the AGORA website to look through the available information. He strongly suggests that growers "…jump on the AGORA website and familiarize themselves with what is available." In addition to resources addressing pests, diseases and hygiene issues, there are useful references to assist growers select the appropriate chemical to suit their situation and avoid potential residue detections and QA concerns.

For delivery partners of subsequent pest and disease management projects, it is important that direct grower engagement is continued as this is the only way that the actual disease status of the industry can be determined. But grower engagement can be very time-consuming and can become very involved. Some inquiries can be satisfied immediately but at the other end of the scale, one phone call can lead to weeks of intense work involving international agencies and multiple online farm meetings as was the case with the *Trichoderma* Compost Green Mould and the MVX syndrome outbreaks. In reviewing grower engagement, the MU16003 Project Team concluded that the outcomes and resolutions of grower interactions need to be documented better. Not only will this help with project M&E but will also better monitor how a farm responds to different resources and how they can be improved or altered to suit different farms and different situations. Grower engagement occurs when growers are under pressure to resolve an issue that is usually affecting them financially. They are then open about their on-farm situation, revealing the true pest and disease status of the industry and are more responsive than when cold calling with a phone or email survey seeking information.

The response from stakeholders and individual growers indicates that the Australian mushroom industry is satisfied with the outcomes of MU16003. Although there are many more grower resources available now than there were before the start of the project, there is great scope for delivery of many further products. Being under pressure from staff shortages, now more than ever farms are taking short cuts with their hygiene practices and 'adapting' pest and disease management and hygiene strategies to reduce investment in time and farm resources. The biggest challenge for the team delivering the next version of mushroom pest and disease management will be to maximize adoption of *correct* work practices.

AGORA must be controlled and maintained by the next pest and disease management project team. During the outbreaks of *Trichoderma* Compost Green Mould and MVX, the ability to instantly access and distribute the correct information n the correct timeframe to the farms in need allowed them to manage the infections and remain operating when so many businesses around the world have succumbed to these diseases.

References

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[4] Grogan H, Green J, Burton K, Eastwood D (2009) *Technology Updates – Crops, Environment and Land Use*. Project 5515, Teagasc, Ireland

[5] https://www.afbini.gov.uk/articles/insect-pests-mushrooms-sciaridae

Intellectual property

There is no project IP or commercialisation to report

Appendices

Appendix 1: Supplementary outputs table
Appendix 2: AMJ articles
Appendix 3: Factsheets
Appendix 4: Grower Alerts
Appendix 5: Symptom recognition resources
Appendix 6: Chemical Summary Tables
Appendix 7: Grower enquiries
Appendix 8: *Trichoderma aggressivum* timeline
Appendix 9: Virus report
Appendix 10: Virus survey
Appendix 11: Workshop satisfaction surveys
Appendix 12: Remote workshop report
Appendix 13: AMGA conference presentation
Appendix 14: Grower feedback email
Appendix 15: Literature review
Appendix 16: Farm case studies
Appendix 17: Spot treatment trial
Appendix 18: Minor use permits
Appendix 19: Technical papers
Appendix 20: Grower case study
Appendix 21: Closing industry survey