Final report

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Marsh Lawson Mushroom Research Centre of Excellence

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Delivery partner:

The University of Sydney

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MU21004

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Contents

Public summary

The aim of the project is to provide management services to run the Marsh Lawson Mushroom Research Centre (MLMRC) as a world-class research facility. This facility is intended to assist the mushroom industry in several key areas:

- Driving innovation.
- Facilitating sustainable business practices.
- Adapting to climate change.
- Encouraging new expertise in the industry through R&D pathways.

The project is delivered jointly by Applied Horticultural Research (AHR), which provides management services, and The University of Sydney, which is responsible for providing and maintaining the facilities and employing growers. These project partners handle the day-to-day management of the research centre and carrying out research trials.

Direction for the MLMRC is provided by an industry-focused Independent Steering Committee, with members of the Committee coming from all areas of the Australian mushroom industry. The committee offers support and guidance to the project, in the form of highlighting research priorities and providing technical expertise.

The MLMRC suffered a major mechanical breakdown in late 2023, with both the air conditioning system and boiler failing. This led to a 6 month period of repairs, where no trials were able to be completed. Excluding the 6 months of downtime, the MLMRC ran at near full utilisation, with 24 research trials being completed in the MLMRC over the course of the project.

Designs for new air handling units, ducting, heating, and cooling systems have been completed, and manufacturing is underway, with installation and commissioning planned for late 2025 to ensure the MLMRC is able to consistently serve the needs of the Australian mushroom industry.

Communication with industry has been a core focus of the project, with findings shared through the MushroomLink magazine, podcasts, webinars, and national and international conferences. The Centre also engaged with global partners to exchange knowledge and inform best practice.

Keywords

Mushrooms; production; pest; disease; Integrated Pest Management; Agaricus bisporus; white mushroom; fungi; compost;

Introduction

The Marsh Lawson Mushroom Research Unit (MLMRU) is located at the University of Sydney's Darlington campus and has played a key role in supporting the Australian mushroom industry for many years.

The MLMRU facility is owned by the University of Sydney, which provides water, communications and energy to the facility. The Australian mushroom industry has contributed funds to equip and maintain the facility. Applied Horticultural Research (AHR) managed the MLMRU from 2011 to 2025—initially under contract with the Australian Mushroom Growers Association (AMGA), then through the Hort Innovation projects MU16004 and MU21004.

The MLMRU is equipped with two independent, fully controllable growing rooms, each with a capacity for 72 phase 3 compost blocks, and a large preparation/analysis space. The independent growing rooms provide ideal facilities for experiments that cannot be easily done on commercial farms, such as pathogen detection and control, pesticides and new growing media.

Experiments in the research unit have provided the data needed for registration and permit of many of the crop protection products available to mushroom growers, including treatments for sciarid and phorid flies, mites and the transmission of Dry Bubble and Cobweb by flies. The unit has been used for evaluating spot treatments for disease, and the effectiveness of sanitation methods and products. It was a key facility in developing molecular disease identification tools (MU12007), in studies of the microbial ecology of compost and casing in cropping (MU10021), and in analysis of nitrogen transformations during cropping (MU17004). It has been used for evaluating alternative compost ingredients, casing materials, lime in casing for yield and whiteness and Trichoderma and Cobweb control, in projects funded by Hort Innovation, NSW EPA and a range of commercial partners.

In 2017 the research unit was incorporated into the broader Marsh Lawson Mushroom Research Centre (MU16004/MU21004), under the control of the MLMRC Steering Committee. This Steering Committee was responsible for the selection and review of projects in the unit and also had a role in identifying key issues for the industry where scientific progress was important for achieving the aims of the Mushroom Industry Strategic Plan. These issues included developments in production such as new casing materials, food safety issues, disease threats, and improvements in sustainability.

The MLMRC Steering Committee provided input into ideation sessions with the Hort Innovation Strategic Investment Advisory Panel (SIAP). From 2025 onwards, a new Hort Innovation advice mechanism means that this advisory role to the industry will be taken over by an AMGA Research Committee, including the Mushroom RD&E Coordinator.

In late 2024, the climate control and air handling systems were reviewed and redesigned to meet current industry standards. The AMGA has pledged $50,000 towards the upgrade, and the University of Sydney will also contribute funds. By the end of 2025, the MLMRU will be again operating reliably and at commercial standards, ensuring that the needs of the industry can be met.

Figure 1. MLMRU growing environment

Methodology

Applied Horticultural Research (AHR) has managed the MLMRU from 2011 to 2025—initially under contract with the AMGA, then through the Hort Innovation project MU16004, and most recently under this project: MU21004.

Under this project, the AHR technical and administrative staff took primary responsibility for the day-to-day operations of the mushroom growing facility, ensuring it remained fully operational. In collaboration with the MLMRC Steering Committee, AHR maintained a structured program of trials at the unit to support near-full utilisation. The project team actively engaged with mushroom levy-funded projects, private research initiatives from within the mushroom industry, and promoted student involvement in mushroom research. Project staff provided technical support to researchers within the scope of the project budget, with additional support offered as needed and funded by individual projects. PhD student and former lead picker at Regal Mushrooms, Sandra Evangelista, was employed and received training alongside AHR's Umberto Calvo from Australian and international experts (Tim Adlington and Erik De Groot, respectively) so that they could effectively setup research trials, grow the mushroom crop, and collect yield and quality data.

The University of Sydney's maintenance team was frequently liaised with to ensure that the MLMRU was running as efficiently as possible and to ensure that the downtime from the air conditioner and boiler failures were minimised.

The trials that were run in the MLMRC focussed on four broad areas:

- Driving innovation.
- Facilitating sustainable business practices.
- Adapting to climate change.
- Encouraging new expertise in the industry through R&D pathways.

The project engaged with the local and international mushroom research community and commercial international organisations via:

- Webinars with international speakers.
- Membership of international experts on the Steering Committee.
- Involvement in the International Society for Mushroom Science conference.
- Encouragement of international research students.

The benefits of the MLMRC and the outcomes of trials were shared with the mushroom industry via collaboration with the Mushroom MU21003 project team

Another key part of the project was the independent, industry led group, the Marsh Lawson Mushroom Research Centre Steering Committee. This committee played a vital role in advising the SIAP and Hort Innovation on the research priorities of the mushroom industry. It also helped build connections between the industry, both within Australia and internationally. The Steering Committee's key roles and responsibilities were:

- Identification of research priorities for the Australian mushroom industry and communication to growers.
- Selection and programming of research projects to be carried out in the Research Unit.
- Establishment of an innovation fund to cover the cost of 'proof of concept' and demonstration trials.
- Preparation of research project briefs for proposed funding by Hort Innovation.
- Promotion of the activities of the research unit both nationally and internationally.

Results and discussion

Table 1. MLMRU Research trials conducted

	Completion date	Trial	Client/funding source
1	May 2022	Testing new irrigation setup, casing method and providing grower training	MU21004
2	August 2022	Effect of bacterial inoculation on Agaricus hyphal growth rate (race tubes) – trial 1	MU17004
3	September 2022	Growth of Oyster mushrooms on mixed substrates including coffee chaff	University of Sydney
4	September 2022	Microbial consortia in spawn-run	MU17004
5	September 2022	Testing new irrigation setup, casing method and providing grower training	MU21004
6	December 2022	Nitrogen transformation – trial 1	MU17004
7	December 2022	Growth of king oyster mushrooms on mixed substrates including coffee chaff	University of Sydney
8	December 2022	Effect of bacterial inoculation on Agaricus hyphal growth rate (race tubes) – trial 2	MU17004
9	December 2022	Drip irrigation trial	MU17004
10	April 2023	Nitrogen transformation – trial 2 – fertigation for nitrogen supplementation during cropping (urea)	MU17004
11	April 2023	Microbial consortia in spawn-run trial 2	MU17004
12	July 2023	Nitrogen transformation – trial 3 - fertigation for nitrogen supplementation during cropping (amino acid powder)	MU17004
13	August 2023	Spawn run and cropping in white tubs - investigating causes of uneven pinning	MU17004
14	September 2023	Nitrogen transformation – trial 4	MU17004
15	November 2023	Oyster bags	University of Sydney
16	November 2023	Developing small scale composting processes	University of Sydney
17	November 2023	Nitrogen transformation – trial 5	MU17004
18	October 2024	Risk analysis and management strategies for mushroom compost – trial 1	MU21001
19	November 2024	Risk analysis and management strategies for mushroom compost – trial 2	MU21001
20	December 2024	Risk analysis and management strategies for mushroom compost – trial 3	MU21001
21	December 2024	Risk analysis and management strategies for mushroom compost – trial 4	MU21001

22	April 2024	Oyster mushrooms on coffee-derived substrates	University of Sydney
23	May 2025	Pseudo-commercial crop	University of Sydney
24	May 2025	Effect of calcium on mushroom quality	University of Sydney

Upgrade to current facilities

The development of a new research unit has been postponed by the Steering Committee in favour of upgrading the current facilities due to the aging components of the unit resulting in periodic operational issues. The most recent issue was the breakdown of the air conditioning unit and the boiler, rendering the unit unusable for trials for over six months while repairs were made. The PC interfacing with the room controls has been upgraded to guarantee remote monitoring and management of the growing rooms' conditions, and an uninterruptible power supply has been installed, to ensure electricity supply issues don't affect the operation of the PC.

To guard against future operational disruptions, the team consulted with Raymon Teeuwen, a recognised expert in mushroom growing room operations. Raymond identified major design limitations in the existing MLMRU system, which need to be rectified to guarantee reliable operation in the future. Based on his findings, airflow and climate control specialist Jan Gielen was engaged to develop a new system for airflow, heating, and cooling. The design phase is now complete, and manufacturing is in progress. The University of Sydney's infrastructure team has been actively involved and will support the installation of the new climate control system.

The Australian Mushroom Growers Association (AMGA) has demonstrated strong industry support by committing $50,000 toward the upgrade. The renovation is set for completion in 2025. Additionally, the University is implementing new maintenance strategies and planning further system improvements at the MLMRU to ensure the upgraded growing systems continue to perform at their highest potential after the upgrade is complete.

Visits to the MLMRU

The MLMRU has hosted a diverse range of visitors in recent years, contributing to ongoing international collaboration and knowledge exchange. In October 2022, Dr Ralph Noble from Microbiotech (UK) visited the unit, followed shortly by Dr Aimee McKinnon, Research Scientist at Agriculture Victoria, in November 2022. In May 2023, Professor Ilmi Hewajulige from Sri Lanka's Industrial Technology Institute toured the facilities.

Engagement with Korean stakeholders followed later in the year. In September 2023, a delegation from the Korean Mushroom Spawn Association visited, including the Association's President, research officers from the Korean Seed & Variety Service, and a group of mushroom growers. This was followed by a visit in November 2023 from staff representing the Gyeonggi-do Agricultural Research and Extension Services and the Gyeonggi-do Regional Specialised Crop Development Association.

In 2024, the unit welcomed two visitors through AHR's partnerships via CGIAR: Dr Rose Catiempo from the University of the Philippines Mindanao and PhD candidate Pramodi Sewwandi from the Industrial Technology Institute in Sri Lanka. In September 2024, Stéphane Doutriaux of Mycosense visited the unit, following initial contact during the AU + NZ Mushroom Growers Conference in Auckland. Each of these visits has played a role in strengthening the MLMRC's national and internation research connections.

Outputs

Table 2. Output summary

Output	Description	Detail
Completed MLMRU trials		
Risk analysis and management strategies for mushroom compost (MU21001)	Four trials were completed for the compounds selected for investigation. The project has been finalised successfully.	Appendix 1
Nitrogen transformations/fertigation trials	Ten trials were completed investigating nitrogen processes in mushroom cultivation and the effect of fertigation with different nitrogen compounds at varying rates	Appendix 1
University of Sydney research projects	Seven trials have been carried out by University of Sydney researchers, honours students and PhD students focusing on both Agaricus and oyster mushroom projects.	Appendix 1
PhD student trial	A PhD student has been investigating the effects of in-crop calcium additives on post-harvest quality	Appendix 1
Growing mushroom for teaching activities	A mushroom crop was grown by students of the University of Sydney course HORT3005 *Production Horticulture*. This teaching activity was used to showcase the Unit to undergraduate horticulture students and train them in the growing of *A. bisporus* mushrooms.	Appendix 1
Webinars/podcasts/videos		
Video interview	Mycosense Spotlight technology with Stéphane Doutriaux.	Published - link
Video interview	Researcher and PhD student on using the Unit for their research and teaching activities	Not released
Podcast	Ralph Noble - Peat alternatives	Published - link
Podcast	Stuart Whitehall and Umberto Calvo on drip irrigation & supplements	Published - link
Podcast	Geoffrey Price - American Mushroom Institute – Part 1	Published - link
Podcast	Geoffrey Price - American Mushroom Institute – Part 2	Published - link
Podcast	The Mycionics robotic harvesting system	Published - link
Podcast	Global perspectives from Erik De Groot	Published - link
Video interview/ Podcast	Serifel trial with Warwick Gill. Recorded the day of first setup. It was decided not to release it due to the trial being aborted soon after	Not released
Webinar	Serifel trial with Warwick Gill. Postponed, to be run while the trial is in the growing room. Pending upgrade of the Unit.	Planned
Articles in MushroomLink magazine		
Article	Mycosense Spotlight with Stéphane Doutriaux	Appendix 2
Article	Effects of Nitrogen	Appendix 2
Article	Feeding Mushrooms	Appendix 2
Article	Inside the Marsh Lawson Mushroom Research Centre	Appendix 2
Article	What's New at the Marsh Lawson Mushroom Research Unit	Appendix 2
Article	PCR Testing	Appendix 2
Conference presentations		Appendix 2
Conference presentation	Update on the MU21004 project provided to industry at the AMGA Conference, Adelaide, 28 October 2022	Appendix 3
Conference presentation	MLMRU update at the Australian and New Zealand Mushroom Conference, Auckland, 22-24 October 2024	Appendix 4
Media		
Sky News interview	Sky News interview, 11th August, 2023. Public warned over dangers of death cap mushrooms.	Link

Outcomes

Table 3. Outcome summary

Outcome	Alignment to fund outcome, strategy and KPI	Description	Evidence
Hort Innovation and privately contracted projects completed at Unit	Aligned to SIP 2022-2026: Outcome - *The Australian mushroom industry has improved profitability, efficiency and sustainability through innovative production systems, reduced costs, and effective risk management.*; Strategy - *Support an Australian mushroom centre of excellence for compost and mushroom production RD&E;* KPI - *Evidence of industry support and engagement for driving RD&E*	Five trials for project MU21001 completed. Ten trials for project MU17004 completed. Unit used for teaching and University research activities.	Appendix 1
Improved industry understanding of project outputs from the MLMRC	As above.	Seven videos, webinars & podcasts delivered during the project, with 3 more awaiting release. Close involvement with communications project MU21003. Updates presented on the project at AMGA Conference 2022 and AU+NZ Mushroom conference 2024.	Videos and podcasts distributed through MU21003 – MushroomLink website with average of 100 views per video/podcast. MushroomLink magazine physical copies distributed to 140 people, with additional digital reach of 500 people (Appendix 2)
Enhanced Australian-based research and appropriate mushroom growing facilities available	As above.	24 trials conducted in the unit across multiple Australian projects and funding sources. The unit was maintained via repairs and replacements (upgrade to PC and UPS). The unit is scheduled to receive major upgrades, with new air handling units designed specifically for the Unit to ensure that the unit is in the best possible condition to serve the Australian mushroom industry's research requirements.	Linkages with AHR, Michael Kertesz, Warwick Gill and Aimee McKinnon projects for potential MLMRC trials. Steering Committee minutes, milestone report MS106

National recognition of research leadership through the steering committee	As above.	The Steering Committee provided technical advice, leadership and oversaw projects conducted in the Unit.	Steering Committee minutes, milestone report MS106
Preparation for transition to a new research facility, if required.	As above.	The development of a new, expanded research facility to upgrade the existing MLMRU. The need for a new facility has now been deemed to not be a major priority, but engagement has been made with designers to upgrade the current facility	Steering Committee minutes, milestone report MS106

Monitoring and evaluation

Table 4. Key Evaluation Questions

Key Evaluation Question	Project performance	Continuous improvement opportunities
To what extent have the trials and outputs improved the knowledge of the Australian mushroom industry regarding new R&D	The completion of trials under the projects MU21001 and MU17004 contributes important knowledge regarding novel techniques for providing nitrogen to a mushroom crop as well as risk management in the industry	Ensuring consistent operation of the unit would allow for more sensitive trials to be carried out.
To what extent has the project met the needs of industry levy payers?	The inclusion of levy payers from competing farms in the Steering Committee ensures that the project prioritises the needs of industry levy payers	Further engagement with farms not represented within the Steering Committee.
To what extent were the target engagement levels of industry levy payers achieved through the magazine and webinar series?	MushroomLink magazine physical copies distributed to approximately 140 people, with additional digital distribution to 500 people. This represents a wide range of levy payers. Videos and podcast distributed through MushroomLink had an average of 100 views per video/podcast. Regular industry updates in Mushroom Link concerning activity in the Unit.	Surveys within articles and webinars could be included to see what forms of media content are preferred in order to maximise reach to levy payers.
Did the project engage with industry levy payers through their preferred learning style?	Industry communications produced in a wide range of formats: written articles, podcasts, videos and conference presentations.	The same content can be reproduced in multiple different formats to improve access
What efforts did the project make to improve efficiency?	Casual labour was used wherever possible to set up trials and pick mushrooms with supervision from a grower to allow full time staff to focus on higher level tasks.	Create simple protocols or checklists for casual staff tasks to improve consistency and reduce onboarding time for new workers.

Recommendations

- Continue to operate the MLMRC and the current research unit as a mushroom research growing facility
- Support the renovation of the current research facility to ensure that high quality trials can be effectively carried out
- Continue to investigate the possible transition to a new facility in the future, with the possible inclusion of a small scale composting facility
- Continue to invest in the innovation fund to facilitate small scale, proof-of-concept trials.
- Engage with the AMGA Research Committee for technical advice and leadership for the Research Unit

Refereed scientific publications

Journal article

Research for the following journal articles made some use of the MLMRU as part of other Hort Innovation projects, and have been reported in the respective project reports.

Noble, R., Thai, M., and **Kertesz, M. A.,** 2023. Nitrogen balance and supply in Australasian mushroom composts. Applied Microbiology and Biotechnology, *108,* Article 151 (DOI: 10.1007/s00253-023-12933-2); https://link.springer.com/article/10.1007/s00253-023-12933-2

Thai, M., Bell, T.L., and **Kertesz, M. A.,** 2024. *Mycovorax composti* gen. nov. sp. nov., a member of the family *Chitinophagaceae* isolated from button mushroom compost. International Journal of Systematic and Evolutionary Microbiology, *74,* Article 6496 (DOI 10.1099/ijsem.0.006496); https://www.microbiologyresearch.org/content/journal/ijsem/10.1099/ijsem.0.006496

Shamugam, S. and **Kertesz, M. A.** (2022) Bacterial interactions with the mycelium of the cultivated edible mushrooms *Agaricus bisporus* and *Pleurotus ostreatus. J Appl Microbiol 134*, lxac018 (DOI 10.1093/jambio/lxac018); https://doi.org/10.1093/jambio/lxac018

Thai, M., Safianowicz, K., Bell, T. L., and **Kertesz, M. A.,** 2022. Dynamics of microbial community and enzyme activities during preparation of *Agaricus bisporus* compost substrate. ISME Communications 2, Article 88 (DOI: 10.1038/s43705-022-00174-9); https://www.nature.com/articles/s43705-022-00174-9

Kertesz, M. A. and Thai, M., 2018. Compost bacteria and fungi that influence growth and development of *Agaricus bisporus* and other commercial mushrooms. Applied Microbiology and Biotechnology *102*, 1639-1650. (DOI: 10.1007/s00253-018-8777-z); https://link.springer.com/article/10.1007/s00253-018-8777-z

Chapter in a book or paper in conference proceedings

Gough, P., Perera, P. B., **Kertesz, M. A.** and Withana, A. (2023) Design, Mould, Grow!: A Fabrication Pipeline for Growing 3D Designs Using Myco-Materials. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems (CHI '23*), Hamburg, Germany: ACM, New York, USA. (DOI 10.1145/3544548.3580958); https://dl.acm.org/doi/abs/10.1145/3544548.3580958 https://dl.acm.org/doi/abs/10.1145/3544548.3580958

Intellectual property

No project IP or commercialisation to report

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Appendices

Appendix 1 MLMRU trial schedule

Appendix 2 MushroomLink Articles

Appendix 3 Marsh Lawson Mushroom Research Centre update – presentation at AU+NZ Mushroom

Appendix 4 MLMRC presentation at the AMGA mushroom conference

No	Trial Name	Project/client	Room no.	Trial lead	Start date	End date
1	Testing new irrigation setup, casing method and providing grower training	MU21004	1	Umberto	24/05/2022	1/07/2022
2	Effect of bacterial inoculation on Agaricus hyphal growth rate (race tubes) – trial 1	MU17004	2	Meghann (Shiva)	27/07/2022	11/08/2022
3	Growth of Oyster mushrooms on mixed substrates including coffee chaff	University of Sydney	2	Meghann	12/07/2022	15/09/2022
4	Microbial consortia in spawn-run	MU17004	2	Meghann (Shiva)	2/08/2022	15/09/2022
5	Testing new irrigation setup, casing method and providing grower training	MU21004	1	Umberto	2/08/2022	15/09/2022
6	Nitrogen transformation – trial 1	MU17004	1	Meghann (Phil)	2/11/2022	16/12/2022
7	Growth of king oyster mushrooms on mixed substrates including coffee chaff	University of Sydney	2	Meghann	16/10/2022	16/12/2022
8	Effect of bacterial inoculation on Agaricus hyphal growth rate (race tubes) – trial 2	MU17004	2	Meghann	16/10/2022	16/12/2022
9	Drip irrigation trial	MU17004	1	Umberto	2/11/2022	16/12/2022
10	Nitrogen transformation – trial 2 – fertigation for nitrogen supplementation during cropping (urea)	MU17004	1	Umberto	15/02/2023	1/04/2023
11	Microbial consortia in spawn-run trial 2	MU17004	2	Meghann	13/02/2023	4/04/2023
12	Nitrogen transformation – trial 3 - fertigation for nitrogen supplementation during cropping (amino acid powder)	MU17004	1	Henry	10/05/2023	21/07/2023
13	Spawn run and cropping in white tubs - investigating causes of uneven pinning	MU17004	2	Meghann	27/06/2023	21/08/2023
14	Nitrogen transformation – trial 4	MU17004	1	Henry	27/07/2023	7/09/2023
15	Oyster bags	University of Sydney	2	Meghann	5/09/2023	4/11/2023
16	Developing small scale composting processes	University of Sydney	2 + oven	Meghann	Unknown	4/11/2023
17	Nitrogen transformation – trial 5	MU17004	1	Umberto	3/10/2023	21/11/2023
18	Risk analysis and management strategies for mushroom compost – trial 1	MU21001	1	Umberto Calvo	10/09/2024	20/10/2024
19	Risk analysis and management strategies for mushroom compost – trial 2	MU21001	2	Umberto Calvo	2/10/2024	9/11/2024
20	Risk analysis and management strategies for mushroom compost – trial 3	MU21001	1	Umberto	29/10/2024	5/12/2025
21	Risk analysis and management strategies for mushroom compost – trial 4	MU21001	2	Umberto	13/11/2024	21/12/2024
22	Oyster mushrooms on coffee-derived substrates	University of Sydney	1	Meghann	6/02/2025	11/04/2025
23	Pseudo-commercial crop	University of Sydney	1	Umberto	15/04/2025	25/05/2025
24	Effect of calcium on mushroom quality	University of Sydney	1	Umberto	15/04/2025	25/05/2025

TESTING THE EFFECTS OF NITROGEN AT THE MLMRU

Project MU17004 (*Optimising nitrogen transformations in mushroom production*), led by Professor Michael Kertesz at the University of Sydney, aims to understand the influence of soil microbes on nitrogen transformations occurring in compost and casing during mushroom production. The objective of this ongoing project is to optimise nitrogen management, reducing losses from compost and improving yield and quality.

Nothing grows without nitrogen. It is a key building block of DNA, a component of the amino acids that form proteins, and is essential for growth. It is also necessary for respiration, the process by which all living cells break down carbon compounds to produce energy.

The ability of fungi to use a wide variety of nitrogen sources is one of the factors that allows them to colonise so many challenging environmental niches, outcompeting microbes such as bacteria and yeasts in low nitrogen conditions.

Nitrogen is added at the start of composting to stimulate microbial activity. Additional nitrogen supplements may be incorporated with spawn or added at casing. However, such protein-rich supplements generally provide a transient pulse in ammonia (NH_4^+), followed by a continual rise in nitrite (NO_2^-) and nitrate (NO_3^-) in the casing during cropping. As *Agaricus* mycelia are intolerant to ammonia and do not absorb nitrate well, this is not an efficient process. There must be a better way.

A series of trials is currently being conducted at the MLMRU examining use of fertigation to add nitrogen during cropping, looking to determine the best form and concentration of nitrogen to improve yield without increasing disease pressure.

Trial One - Urea

Method

The aim of this trial was to observe the effect of applying urea at pinning on yield and quality. Twenty-four blocks of un-supplemented compost and peat (Elf Farm Supplies and Elf Mushrooms) were set up in the MLMRU growing room, with half allocated for the urea treatment.

Figure 1. Installation of drip lines between mature Phase 3 compost and casing.

Drip lines were installed on top of the 'treated' compost blocks prior to casing. However, they were not used immediately, with both treated and control blocks initially irrigated using a watering wand (Figure 1).

Once the beds started pinning, 100g of urea (46% nitrogen) dissolved in 3L of water was applied across the 12 treated blocks using the installed drip lines. The same amount of water was added to the control block casing using a small watering can. This process was repeated at pinning prior to both the second and third flushes. The quantity of nitrogen in the form of urea applied throughout the trial equates to the amount of nitrogen generally applied via a slow-release protein-based supplement at the end of the spawn run, while the 3L correspond to the total volume of the piping system, to be flushed completely to deliver the above-mentioned amount of urea.

Mushrooms were harvested daily during flushing, then weighed and graded as P/A+ (grade 1); A/A- (grade 2); or B/C (grade 3).

Trichoderma appeared during the second flush. Diseased areas were treated by removing the affected mushrooms, applying salt, and covering with plastic. The number of diseased patches were counted as they appeared.

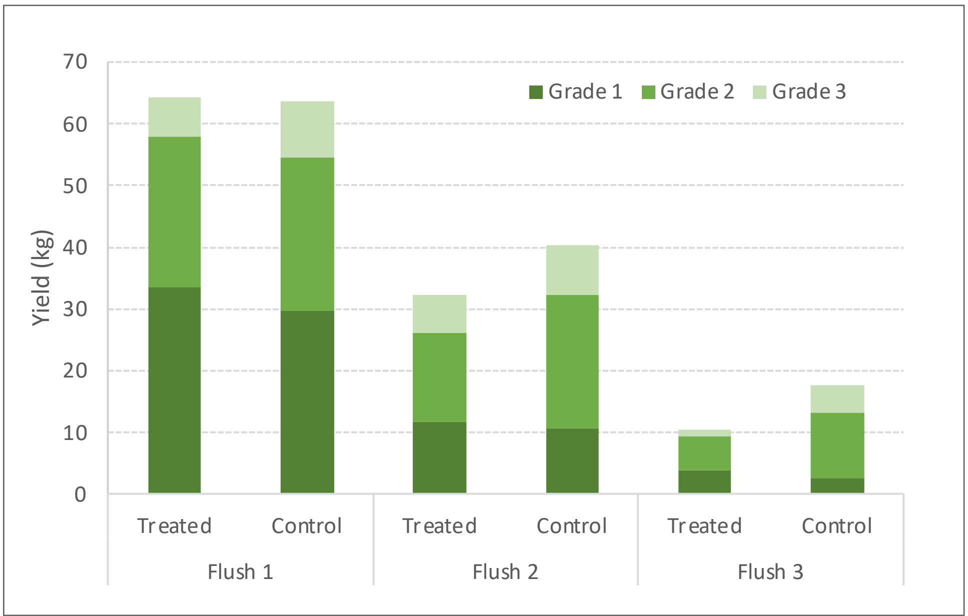


Figure 2. Yield from flushes 1, 2 and 3, divided into three quality grades, from blocks fertigated with urea at pinning or irrigated with water only.

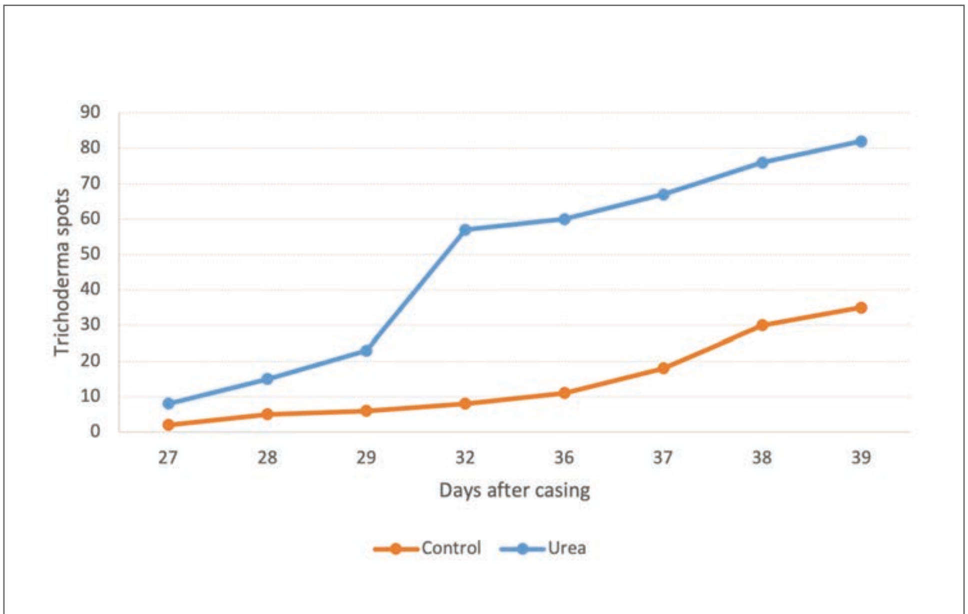


Figure 3. Cumulative outbreaks of Trichoderma on blocks fertigated with urea at pinning or irrigated with water only at pinning.

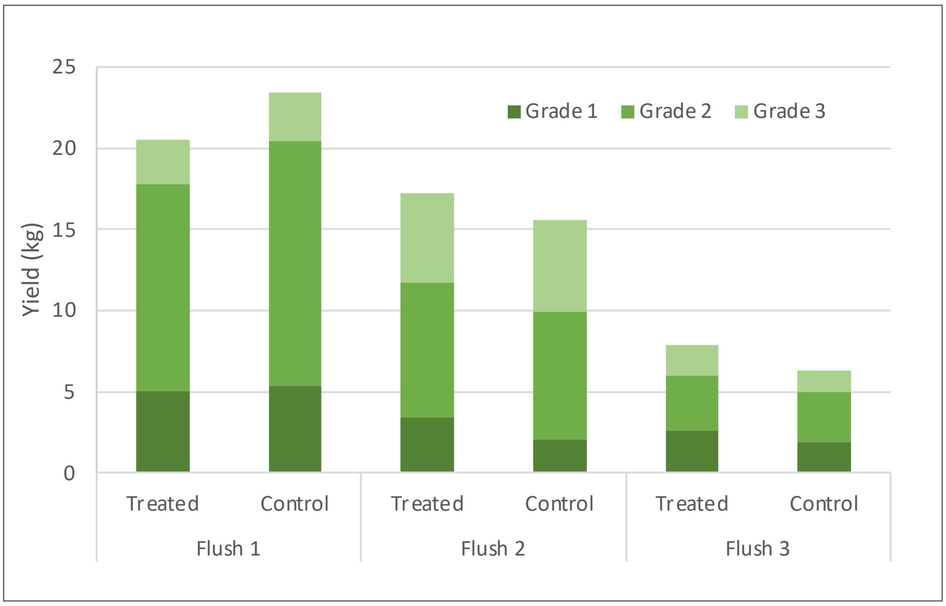


Figure 4. Yield from flushes 1, 2 and 3, divided into three quality grades, from blocks fertigated with amino acids at pinning or irrigated with water only

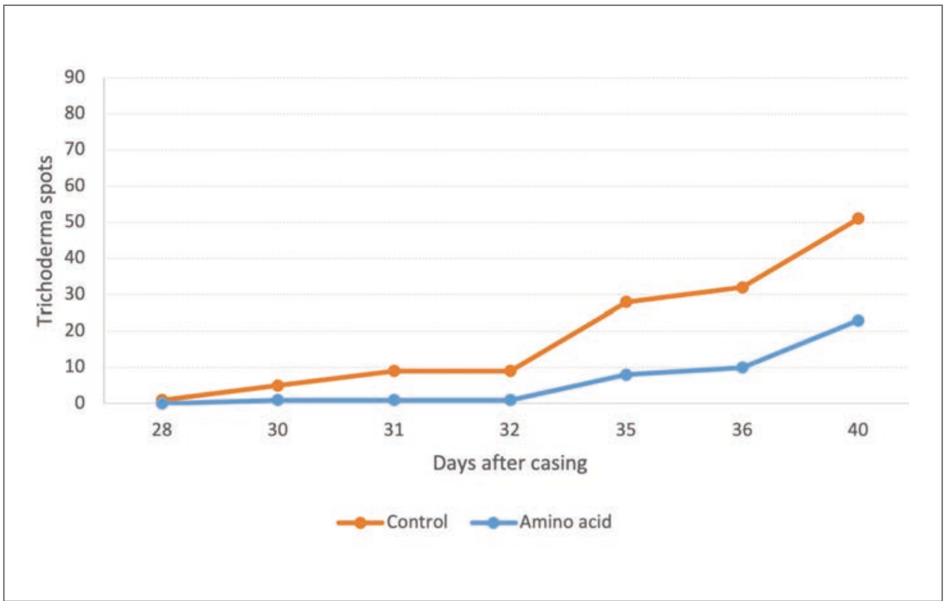


Figure 5. Cumulative outbreaks of Trichoderma on blocks fertigated with amino acid solution or irrigated with water only at pinning.

Results

Total yield over the three flushes was slightly lower for the treated blocks than for the controls (Figure 2). This can be attributed in part to the high incidence of *Trichoderma* in the treated blocks. It was estimated that 5% of flush 2 and 40% of flush 3 mushrooms were lost due to *Trichoderma* in the urea-treated blocks. While *Trichoderma* also appeared in the untreated blocks, they were less affected. (Figure 3).

Trial Two – Amino acid powder

Method

In this trial, urea was replaced with powdered amino acids with a lower nitrogen content (13.9% vs 46%). As nitrogen from amino acid powder is released slowly, it was hypothesised that this could avoid the stimulation of disease observed in trial 1.

In a further change to the experimental design from the previous trial, the 24 blocks were divided into four plots of six blocks each and set up with drip irrigation systems. Each system consisted of 6 x 1.8m drip lines, with downward-facing drippers staggered at 30cm spacings to provide even coverage over the compost.

The amino acid powder was applied at its maximum solubility of 250g/L for the same volume of water per block as in the urea trial, delivering a total amount of nitrogen of around six times the standard rate. This was done to force a response from the mushroom crop.

The treatment was applied during pinning prior to each flush. At 15-, 24- and 33-days post-casing, freshly

Third flush mushrooms fertigated with a solution of amino acids.

prepared amino acid solution was pumped into the system and delivered to the treated blocks. The control blocks were run with water only for the same amount of time. All systems were then purged with clean water, ensuring the nitrogen solution was fully discharged.

Results

In this trial, total yield was almost identical for the blocks fertigated with amino acids and those irrigated with water alone. However, it was noted that the controls tended to yield more in first flush, with the amino acid treated blocks catching up in later flushes (Figure 4). Trichoderma was less of an issue in this trial, particularly in the treated blocks (Figure 5), even though the total amount of nitrogen delivered was much higher than in Trial 1. This suggests that the form of nitrogen applied and its complexity are important not only for the mushroom mycelium, but also for the parasitic green mould.

While yield (kg) benefits of the amino acid treatment were only apparent in the later flushes, mushrooms from the treated blocks appeared to be firmer and heavier than the controls. If this can be verified, it would mean that fewer mushrooms are needed to fill a 250g punnet – a potential benefit to growers.

While the low pH of the amino acid solution (4.2) seemed to have no obvious ill-effects on yield, further verification is required.

Further studies

Subsequent trials at the unit will explore further optimisation of the added N via amino acid powder. This will include reducing the concentration of the solution to more accurately mimic the N-release profile of supplements. Nitrogen via fertigation might also be delivered in later flushes only, trying to improve the declining yield, as the first flush the mushroom mycelium can easily utilise the nitrogen in the compost and supplementation might not have an economically relevant result.

Seaweed extract is another option that might be interesting to explore. As the nitrogen concentration is very low, it would not be used as a fertiliser, but rather as a stimulant, to help the mycelium takeup more of the nitrogen already present in the compost.

Hort Innovation MUSHROOM FUND

This project has been funded by Hort Innovation using the mushroom research and development levy and funds from the Australian Government. For more information on the fund and strategic levy investment visit horticulture.com.au

FEEDING MUSHROOMS

The 'ins' and 'outs' of nitrogen in mushroom compost

By Meghann Thai and Michael Kertesz

Remember the slogan "Meat for Vegetarians"? Button mushrooms contain around 3 g/100 g protein. This is similar to mung bean sprouts and slightly lower than chickpeas, but considerably higher than most vegetables.

While protein is a valuable portion of the dry matter (DM) in mushrooms, its content is quite variable, ranging from 14-30%. Dry matter itself ranges from a low as 7% up to 14%. High DM content and, therefore, high protein content, is associated with firmer mushrooms and improved shelf life.

Important amino acids, such as leucine, lysine, and tyrosine, are the building blocks of the majority of protein in mushrooms. Nitrogen is an essential component in all of these compounds. It is therefore unsurprising that the nutritional content of mushrooms is strongly correlated to the nutritional quality of the substrate on which they have been grown.

Nitrogen is one of the most important elements in mushroom composting and cropping. Button mushrooms are grown on a composted substrate made from wheat straw, poultry manure, and gypsum.
See p24 for more on nitrogen in poultry litter.

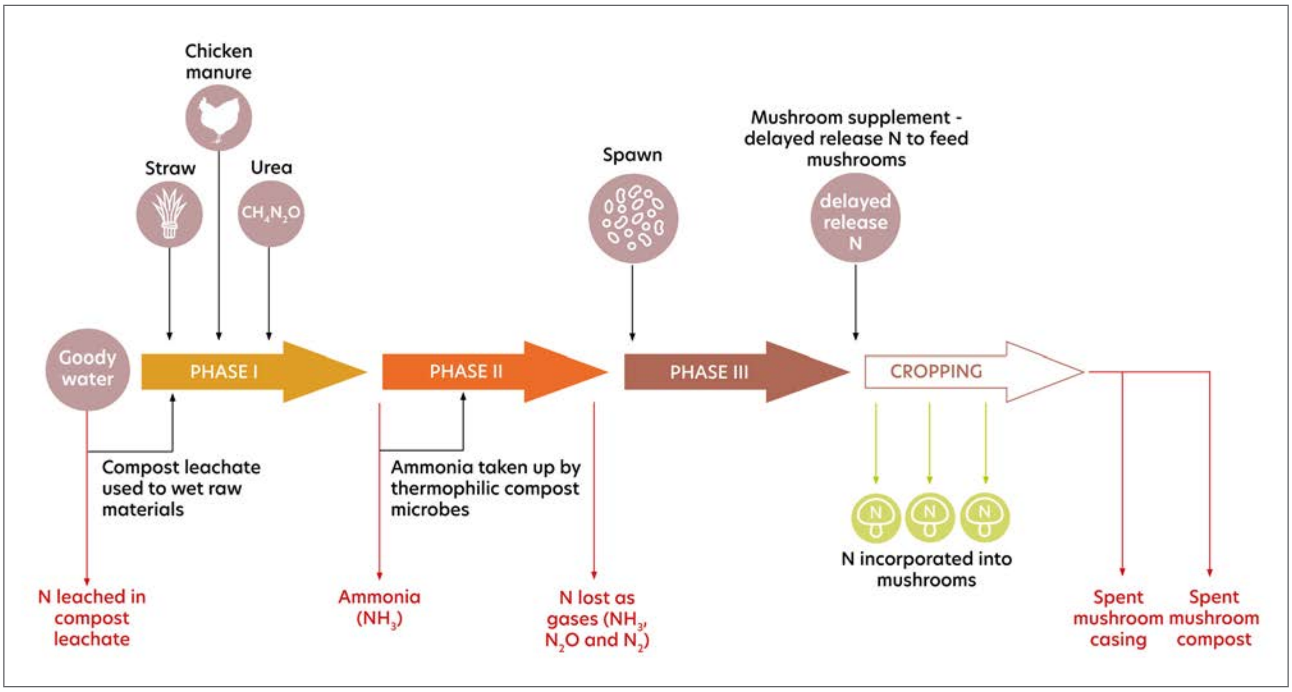


Figure 1. Nitrogen transformation throughout mushroom composting and cropping. Nitrogen inputs, losses and outputs are indicated by the black, red, and green arrows, respectively.

The inputs and outputs of nitrogen in mushroom composting are summarised in Figure 1.

At the start of composting, composters adjust the ratios of their raw mixtures to meet the desired C:N ratio of 35:1. Poultry manure is the primary source of nitrogen in mushroom compost, contributing approximately 40-50% of the total nitrogen in the initial feedstocks. Wheat straw adds another 20-25% of the total nitrogen, and additional nitrogen can be provided using organic sources such as cottonseed meal or soybean meal.

Inorganic nitrogen sources such as ammonium nitrate, ammonium sulphate or urea can also be used. These additional nitrogen feedstocks usually contribute approximately 3-5% of the total nitrogen at the start of composting.

Compost leachate ('goody water'), which is recycled from the previous compost crop, is used to wet the raw materials and makes up the remainder of the nitrogen balance. Although some nitrogen is potentially lost during prewetting as goody water runoff, adding this to the next compost batch means the net loss of nitrogen is likely minimal.

There are several ways in which nitrogen is lost during the composting process. During Phase I, the microbially intense process of composting is typically characterised by a strong ammonia (NH_3) odour. The NH_3 is released due to proteolysis (enzymic breakdown of proteins into amino acids) and heat generated by the microbes in the feedstocks.

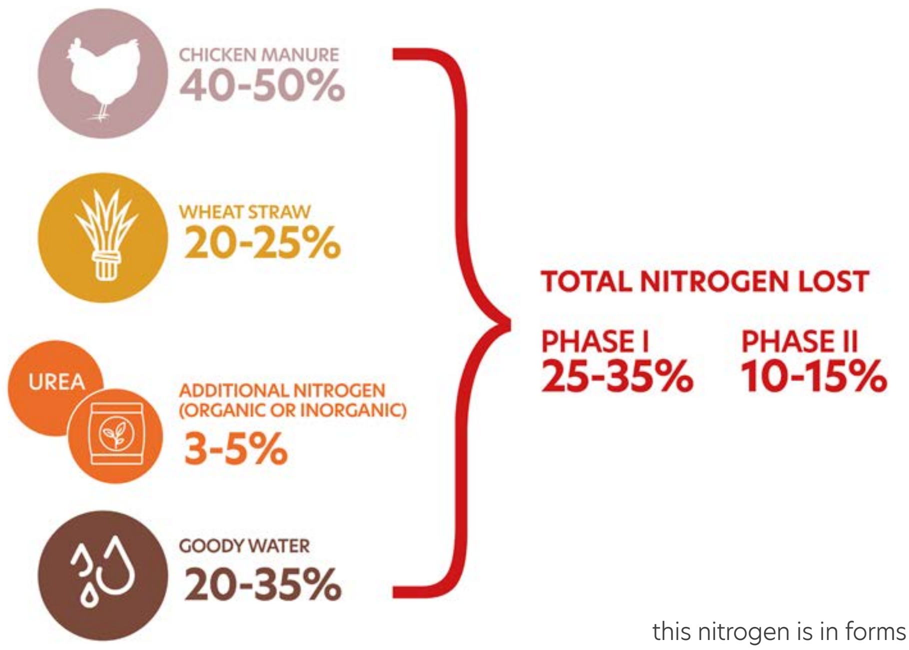
By the end of Phase I, approximately 25-35% of the nitrogen inputs from the start of composting have been lost. However, it is difficult to fully quantify how much of the nitrogen loss during Phase I is from ammonia volatilisation or due to goody water runoff.

During Phase II, the free ammonia from Phase I is used to aid in pasteurisation. It is then re-assimilated back into the compost by thermophilic microbes during conditioning, producing biomass. Although this stage of composting is conducted inside an enclosed tunnel, a further 10-15% of nitrogen is lost during Phase II, most likely in the form of nitrogenous gases.

By the end of Phase II, only 40-50% of the total nitrogen from the initial feedstocks remains. During Phase III, protein from the grain in mushroom spawn offers a small amount of nitrogen. However, the mushrooms gain most of their nitrogen from the microbial biomass in the compost.

After Phase III, commercial supplements contribute approximately 10-15% of nitrogen used during cropping. Commercial supplements are designed to release

NITROGEN INPUTS AT THE START OF COMPOSTING



nitrogen slowly over time. This maximises nitrogen availability for the mushrooms during consecutive flushes.

Nitrogen becomes an output when mushrooms are harvested. Total nitrogen in button mushrooms increases over consecutive flushes; total nitrogen content of first flush and third flush mushrooms is approximately 5% and 7% of dry weight respectively.

When total nitrogen is converted to approximate protein content, 5-7% total nitrogen corresponds to approximately 30-33% protein in the mushrooms. By the end of cropping, approximately 50% of the nitrogen inputs from composting and cropping are left over in the spent mushroom casing and compost. However, most of this nitrogen is in forms that cannot be accessed by the mushroom mycelium.

Improving nitrogen management throughout composting could provide a major financial benefit for the mushroom industry, improving efficiency of nitrogen uptake and accumulation of dry matter. Unfortunately, not enough is known about where and how nitrogen is lost during composting.

Research on developing a mass balance model on nitrogen inputs and losses during composting is currently underway. This includes measuring nitrogenous gases during Phase II and maximising nitrogen output in mushrooms.

This project was funded through Hort Innovation project MU17004 *Optimize nitrogen transformations in Mushroom production*.

Further reading

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Hort Innovation Strategic levy investment | MUSHROOM FUND

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INSIDE THE MARSH LAWSON MUSHROOM RESEARCH CENTRE

By Paulette Baumgartl

Research and development underpin new technology. For the mushroom industry this is no different. A dedicated research centre is one driver of important developments, as industry seeks ways to adapt and respond to challenges.

Research is a systematic mechanism by which we can answer questions and understand processes. Data and discovery facilitate an evidence-based approach to solving problems. Research can optimise processes on farms, ultimately improving both their economic and environmental bottom lines.

The Australian mushroom industry has long enjoyed a fruitful relationship with researchers. Systems and processes directing current mushroom growing practice are based on efforts from past research, including studies into compost, pest and disease control, and harvest and post-harvest technology.

In this context, it is welcome news when universities and industry collaborate. This is exemplified by the Marsh Lawson Mushroom Research Centre (MLMRC), situated within The University of Sydney.

Dr Gordon Rogers, Director of Applied Horticultural Research, reminded the mushroom community of this unique facility at the AMGA conference, highlighting its capacity to support growers and the industry as a whole.

The aim of the centre is to contribute to a strong research capacity for the Australian mushroom industry and operate a world class research unit.

"The centre provides research leadership, engages with global leaders in mushroom research, and communicates its findings," Dr Rogers said.

As issues are similar around the world, Dr Rogers believes it makes sense to engage with global researchers and include international members on the steering committee.

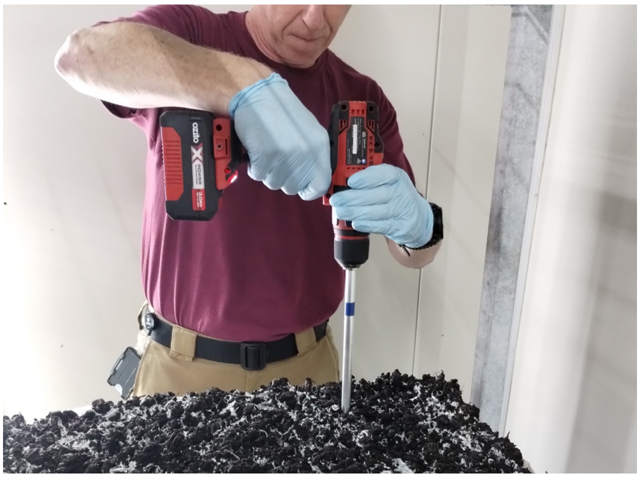
"We plan to pursue international research collaborations, including students. This will help us become more involved in the International Society for Mushroom Science," he said.

Activities at the MLMRC are guided by a steering committee, which includes researchers, growers, and composters. This group approves and prioritises activities, as well as identifying and directing research at the centre.

The unit itself

The unit has existed in one form or another for 30 years. It was originally a simple growing facility in a building basement. Its has been in its current form for the last 10. Located within the grounds of the University of Sydney, it has two growing rooms, each with a 72- block capacity and full environmental controls including a boiler for cookout; it is an ideal testing facility for industry.

Drip irrigation trial before (left) and after (right) casing



Dr Phil Butterworth collecting a sample of compost + casing

Sandra Evangelista and Tyler Kristensen assess dry bubble

Adjacent to the growing rooms is a well-equipped laboratory, with sample storage freezers.

Two trained growers (AHR agricultural scientist Umberto Calvo and PhD student Sandra Evangelista), supervised by Tim Adlington (Steering Committee Chair), currently operate the facility.

The University of Sydney has provided ongoing support to the unit with maintenance, new equipment and running costs, including a new boiler, humidifiers, and an overhaul of the cooling system.

"The industry is well-supported by the university, and we are lucky to have this ongoing assistance," Dr Rogers said.

The growing rooms are well maintained and highly climate controlled, with PCR testing between crops ensuring cleanliness and other commercial standards are upheld.

"While not a farm, the unit is similar enough to a growing room to conduct trials with a fair amount of confidence that on-farm conditions are being simulated," Dr Rogers emphasised.

"It is there for the industry, and we want more people to know about it."

Previous studies

Traditionally, the unit has been used for pesticide registration efficacy studies to support permit applications. In the last five years, 37 trials have been conducted in the unit, including the successful permit application of Vivando® based on efficacy and residue trials.

Other highlights include:

- PCR disease diagnostic project (MU12007)
- Casing replacement and improvement trials
- Alternative nitrogen sources research
- Investigations into cold plasma treated irrigation water

- Compost supplementation trials
- Impact of calcium on mushroom whiteness trials
- Impact of CO_2 concentration on flush timing, yield and quality

Current and planned trials

Collaborations are currently underway with researchers from around Australia. These include digitally monitoring compost moisture, evaluation of nitrogen forms under the casing layer, and the novel work of Dr Kertesz that is investigating nutrient seeding and its potential to fortify the nutritional value of mushrooms.

Dr Kertesz's team is also evaluating the impact of different substrates on microbial populations during the spawn run.

The *Pest and Disease project* team Judy Allan and Warwick Gill run regular spot sanitiser treatment trials in the unit, and a further project is working to establish threshold levels of potential compost contaminants (e.g., pesticide residues) that find their way into the edible part of the mushrooms.

The unit will also soon welcome Dr Aimee McKinnon from Agriculture Victoria as she commences evaluations into non-synthetic (biological) controls for the mushroom industry.

Transitioning to a new facility

The current unit is situated on prime university real estate in the middle of the univertsity's inner city campus and, unsurprisingly, is under some pressure.

A move would provide an opportunity to grow and modernise the facility, with current plans including four growing rooms with a 5-tonne capacity, fitted out with Dutch shelves, a rack system, and an industry standard environmental control system.

A new site, potentially further out of the city towards the new Western Sydney Airport Precinct, could also host a compost research facility to research Phase I, II and III compost.

The world standard design would include Phase I bunkers and Phase II/III tunnels, with full pasteurisation spawn run facilities including heating elements in the walls of the Phase II/III tunnels to maintain temperature.

Dr Ralph Noble discussing trials with Meghann Thai and student Juno Bennet.

The unit currently sits on prime real estate in the middle of The University of Sydney's main Darlington campus

Get involved

The Marsh Lawson Mushroom Research Unit is available to the industry for research projects and small proof-of-concept trials.

The team of researchers and technicians can tailor support packages to your needs, including trial designs, growing and harvesting, treatment applications, data collection, analytical services, and reporting.

For more information contact Umberto Calvo (umberto.calvo@ahr.com.au) or Adam Goldwater (adam.goldwater@ahr.com.au)

Hort Innovation
Strategic levy investment
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WHAT'S NEW AT THE MARSH LAWSON MUSHROOM RESEARCH UNIT

Optimising nitrogen in compost

A new trial, managed by AHR in collaboration with Dr Michael Kertesz, has been set up in the unit to examine the benefits of fertigation. The study is an integral part of the Hort Innovation project *Optimise nitrogen transformations in mushroom production* (MU17004)).

This trial marks the first time nitrogen (N) fertigation has been tested in the unit. Urea will be used as the nitrogen source to deliver the same amount of N that would be available in a slow-release supplement.

The main difference between fertigation and slow-release fertiliser is timing - in this fertigation study the N will be delivered into the colonised compost right before each flush, when the mushrooms need it the most. The trial is based on the work of Dr Michael Kertesz who discovered that there was a spike in N consumption just prior to the flush, and that targeted addition of N can increase both yield and N content, especially in later flushes.

While urea is currently being used, there is potential to explore other fertilisers such as ammonium salts, amino acids, protein hydrolysates, or protein-based fertilisers that are soluble in water. The trial is operating on normal overhead irrigation for both the control and fertigation side, with drip irrigation used only for fertiliser input. Water inputs are accounted for in the overhead irrigation.

Impact of bacteria to speed up spawn run

In a recent project at the University of Sydney, Dr Meghann Thai and colleagues have added compost bacteria to compost during the spawn run in an effort to speed up the process. The aim is to shorten the colonisation process by a few days and thereby increase production efficiency.

The bacteria used in the project were originally isolated from mushroom compost, so they are well equipped to survive in the compost bed. They were grown in a laboratory before being diluted to a specific number of cells per gram of compost and added to the compost at the start of spawn run. This facilitated accurate and consistent application of the bacteria during the spawn run.

This project is part of a larger initiative by Hort Innovation to improve the efficiency and sustainability of mushroom production.

Set up of the nitrogen fertigation trial in the MLMRU with drip irrigation for the fertiliser input. - Umberto Calvo

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A VISION FOR THE FUTURE OF MUSHROOM HARVESTING

Instead of fully replacing human labour with robotics, Swiss company MycoSense is pioneering tools that enhance efficiency for human harvesters.

Co-founded by engineer and entrepreneur Stéphane Doutriaux, MycoSense focuses on growth and harvest optimisation through advanced 3D scanning, specialised sensors, and data integration.

Their standout innovation is the *Spotlight*, a system that shows pickers which mushrooms are ready for harvest and which mushrooms need more time. This simplifies decision-making for workers and improves accuracy of grading.

A UNIQUE INDUSTRY WITH COMPLEX CHALLENGES

Stéphane Doutriaux became involved in the mushroom industry through evaluating a robotic harvesting system. As a potential investor, he wanted to understand more about the challenges in picking and packing mushrooms.

"One of the things that has struck me most is how many challenges there are every day, challenges that need to be solved immediately. Not next week, not tomorrow, but within the hour. Every day is different, and every day things have to be solved quickly. Going high tech is not necessarily the main thing on growers' minds…." explains Stéphane.

Mushroom farms, often family-run enterprises spanning generations, are characterised by a mix of traditional methods and emerging technologies. Some farms work with older growing systems, others are fully modernised and there is everything in between.

While there are many exciting new technologies available, even some newer farms are still choosing to build with standard flat shelves – keeping it simple and avoiding extra cost.

As Stéphane commented, "Over the past six years, I've had the opportunity to visit nearly 80 or 100 farms. It's been a rich experience because every farm is different, and there are often good reasons for that. New technology needs to fit old infrastructure. You can't just replace everything, or change the people, we need to ease ourselves in."

BRIDGING THE TECHNOLOGY GAP

Artificial intelligence driven robotic pickers are truly the holy grail of fully automated mushroom farms. Robots don't need to be paid shift allowances, have holidays or take time off and are available any time day or night.

Unfortunately, robotic systems frequently struggle to match the ability of humans. A robotic arm is a poor substitute for the dexterity of the human hand, with its ability to gently bend, twist and stretch during picking. Sometimes pickers use two hands, keeping neighbouring mushrooms in place while plucking out the central leader.

Moreover, it is difficult to design robots that can adapt to the constraints inherent in mushroom harvesting.

These include the difficulty of extracting mushrooms from tightly packed beds (without damaging them!), customer-specific packaging and the ever-present need for flexibility in harvest planning and dispatch.

With human resources an ongoing struggle, anything that can optimise mushroom harvesting and make it easier for the pickers is welcome.

As an example of his thinking, Stéphane cited the development of self-driving cars.

"Did the car industry develop a robot to drive your car? No. They started by building a navigation system to help you drive your car better."

Recognising this reality, Stéphane (together with several Swiss and Dutch mushroom businesses) established MycoSense. Essentially, they aimed to develop the navigation system for mushroom harvesting.

While this could potentially be used by robots in the future, the immediate need was to make picking easier, and more efficient, for humans.

Other 'low hanging fruit' for growers included improving harvest forecast, centralising data collection, putting people where they are needed most and automating where it is easiest and cheapest to do so.

SHINING A LIGHT ON THE RIGHT SIZED MUSHROOM

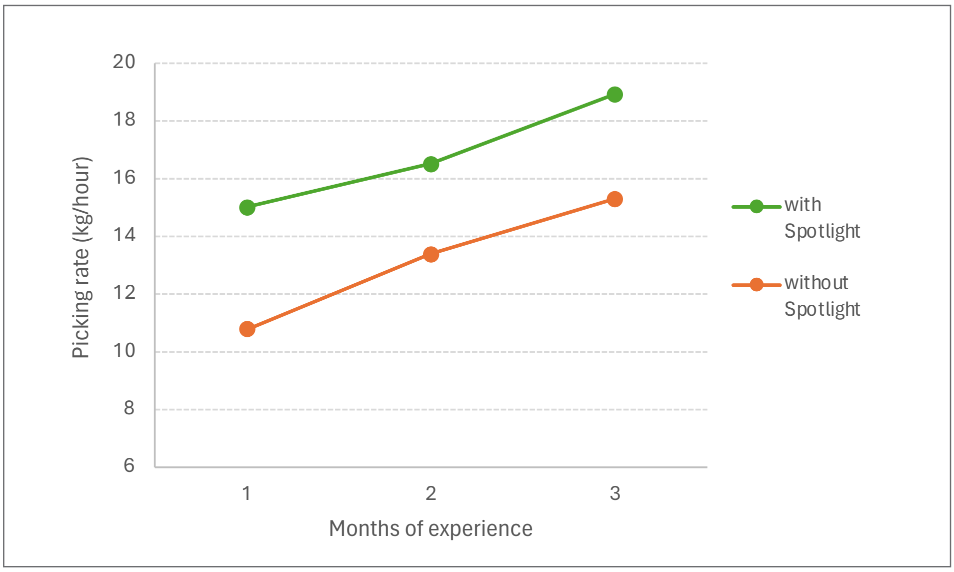
The company's flagship product, *Spotlight*, revolutionises the harvesting process by identifying mushrooms ready for picking. It projects size onto the mushroom caps, coding them green for mushrooms at the required size for harvest, while those not yet ready

Training new pickers using the Spotlight system. According to Waldemar Schuller (Dohme, Germany), pickers were initially sceptical, but were positive after getting used to the system. Even expert pickers found the devices useful, and were less tired at the end of the day.

are marked with red lights. Potential benefits from the system include;

- Size harmonisation
- Boosted picking speed
- Less concentration needed, so workers are less tired
- Improved autonomy of new workers (days to train instead of weeks or months)

However, the projector is just the visible tip of the system. As Stéphane explained, "Underneath the Spotlight is floating a whole iceberg. This is a very powerful piece of software called Harvest Manager." The software collates information from many sources around the farm and integrates it with information coming from harvesting - size, volume and so on, as well as orders and future forecasting.



Average picking rates of new mushroom harvesters. Harvesters targeted 40-55mm mushrooms and thinning clusters. Rates recorded at Wauwiler Champignons, Switzerland, 2024. Using the Spotlight not only helped new trainees pick faster, sooner, it also improved size consistency in punnets.

The Harvest Manager software includes both a desktop display and mobile app.

"We're using this to optimise harvest and yields, as well as helping to manage teams of pickers…. for example, if a room needs to be picked by 11am, then the fastest team may be dispatched there".

Computer dashboards allow farm managers to analyse scan data for better forecasting, team management, and informed decision-making. A complementary mobile and tablet app ensures seamless coordination, delivering information directly to harvest and packing managers. Used in combination with the Spotlight system, this can tell harvest teams exactly what they need to pick, into what container and where from.

While Spotlight is compatible with older growing systems, it can also increase the speed and quality of picking for farms with new technology. For example, the company is currently working on controlling the speed of self-driving trolleys used for graze picking according to the number of harvestable mushrooms detected using the Spotlight system.

"The way we see ourselves is as a bridge," Stéphane said.

"Getting the most out of existing infrastructure, while also getting ready for the future with simple, easy to implement technology".

IN SUMMARY

Stéphane Doutriaux's presentation highlighted a practical approach to modernisation that acknowledges the intricate nature of the industry while addressing key challenges. He believes that a sound technology roadmap is not about replacing people with machines but about enabling people to work more effectively. This means assigning workers to the roles where they can have the greatest impact, keeping systems simple to minimise disruptions, and designing technology that integrates seamlessly into daily operations.

All technologies are prone to occasional failures. The more complex the technology, the greater the chance that things will go wrong. MycoSense is therefore focused on creating tools that can be quickly and easily replaced. Repair should ideally use universally accessible parts, reducing downtime.

As a bridge between traditional practices and future automation, the Spotlight is definitely an impressive innovation.

By scanning the mushroom beds, Spotlight and the supporting software can help managers plan which rooms need to be picked and when, to both meet supply requirements and optimise yield.

A picker using the Spotlight system at Deckers (Germany).

IN PRACTICE: RESULTS FROM FARMS TRIALLING THE TECHNOLOGY

- Spotlight started shipping in March 2024
- Ten farms have been equipped and trained, with over 100 Spotlights running

Some examples

Cabane & Compagnie (France)

- Three-year old GTL tilting beds farm with six pinning rooms, 12 pickings rooms (600m2)
- Four rooms harvested at any given time
- Two 8-hour shifts/day using 16 Spotlights
- Produce 27kg/m^2 very high quality mushrooms
- Mainly 60mm-80mm, multiple thinning passes to prepare the bed
- Harvesting speed: avg 47.5kg/hr (55kg/hr imposed maximum to keep quality level (speed measured on total average both flushes including thinning)
- Benefits:
  - Standardised sizes picked, while maintaining picking speed
  - Increased yield thanks to picking proper size (i.e. bigger mushrooms)
  - Simplifies management of inexperienced pickers (within one week, total picking autonomy)

Dohme Germany

- Increase in speed of all pickers
- 4.87kg/hr speed increase for low-performance pickers
- 3.75kg/hr speed increase for average pickers
- 3.6kg/hr increase for better-than-average pickers

Pilzland in Germany

- New modern facility equipped with GTL tilting shelves
- 50t/week, expanding to 150t/week Challenges: All pickers on 3-month rotation form Ukraine, Romania with no time to train
- Training period went down from three weeks (min) to three days.
- Standardised sizes is a major advantage
- Increased yield due to better respect of picking instructions (bigger mushrooms picked, graze picking)

Watch Stéphane Doutriaux discuss the Spotlight

A NEW DIAGNOSTIC TOOL GIVES GROWERS THE UPPER HAND IN CONTROLLING DISEASE

By Dr Gordon Rogers

A mushroom industry-funded project has delivered a commercially available early disease detection service which has revolutionised the way growers manage disease.

Growers can now identify disease early, whether in compost, grow room, or the crop itself, facilitating timely action to manage diseases and minimise losses.

For example, the system can identify *Trichoderma aggressivum,* a species of green mould that is highly damaging to yield but nearly impossible to distinguish visually from other less serious green moulds.

Interestingly, the PCR test used to detect *Trichoderma* uses the same technology as the gold standard PCR test for detecting COVID-19.

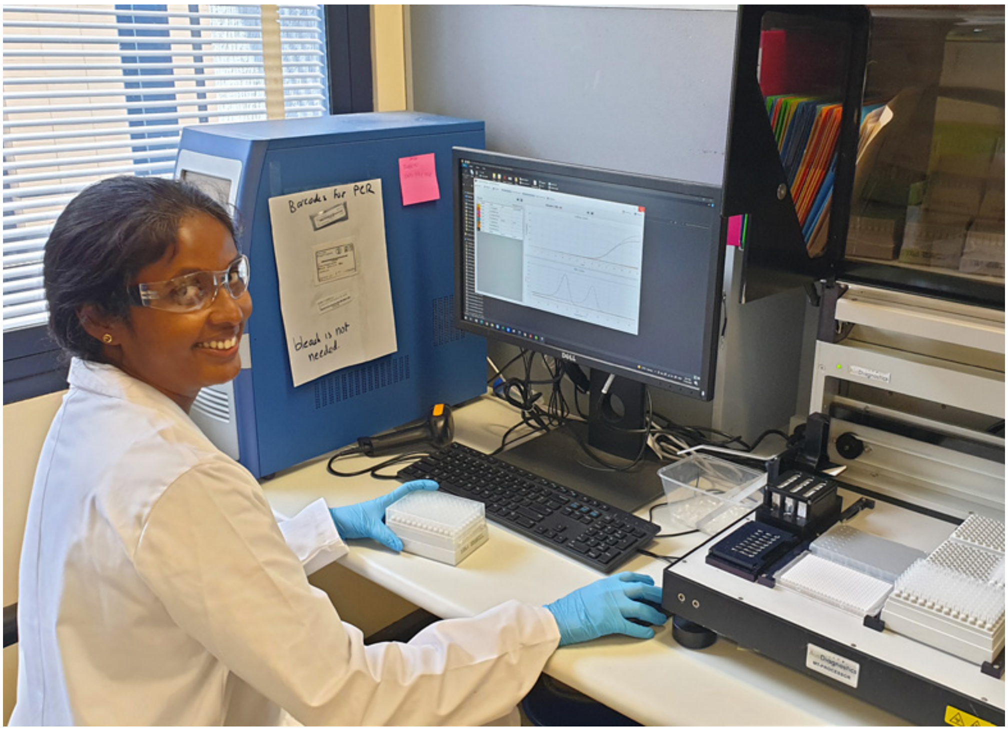
The PCR test can also identify Dry Bubble (*Lecanicillium fungicola*), Cobweb (*Cladobotryum* sp.) and Bacterial Blotch. All four diseases are included in the same testing 'panel', meaning that a single test can detect any of the diseases above in any one sample provided.

The results from a single sample give a positive or negative for a range of species (see Table 1), as well as an indication of how much disease is present.

Quick turnaround of test results, early detection before symptoms are evident, and cost-effectiveness are all major benefits of the new testing service.

The PCR-based testing service was developed by a Hort Innovation project (MU12007) and is now fully operational.

Trichoderma (left) and dry bubble (right) are just two of the diseases that can be tested for using the PCR testing service



AHR employee Samali Perera runs mushroom samples through the PCR machine

The development team was led by Associate Professor Michael Kertesz from the University of Sydney. Partners included AusDiagnostics, who provided the PCR delivery platform, and disease experts Judy Allan and Dr Warwick Gill. Trials were carried out by the Marsh Lawson Mushroom Research Unit (MLMRU).

The project was managed by Applied Horticultural Research (AHR) who are now also providing the testing service commercially from their Sydney laboratory.

The table below shows the diseases which can be detected using the PCR testing service developed by Hort Innovation project MU12007.

Testing and control measures on farm are effective at controlling disease

The mushroom disease testing service has already proved popular, with over 5,000 samples processed since August 2020.

As well as identifying disease, testing after cookout can provide vital information on whether control measures taken at the farm have been effective.

AHR has seen some encouraging trends in the testing results, showing that PCR testing for disease, coupled with corrective action, is effective at controlling disease.

COMMON NAME OF DISEASE	SCIENTIFIC NAMES
Cobweb	*Cladobotryum mycophilum (Hypomyces odoratus)*
	Lecanicillium spp.
Dry bubble	*Lecanicillium fungicola (Verticillium fungicola)*
	Trichoderma spp.
Green mould	*Trichoderma aggressivum*
Bacterial blotch	*Pseudomonas tolaasii* *Pseudomonas gingeri*

Table 1. The diseases which can be detected using the PCR testing service developed by Hort Innovation project MU12007

AHR principal, Dr Gordon Rogers says “Farms using this service see a steady decline in positives for diseases they are targeting.”

“This means the control measures on farms are working, and testing is confirming their effectiveness.”

How to get your samples tested

PCR testing, developed during the Hort Innovation project, is now being offered as a commercial service by AHR, using a methodology commercialised by AusDiagnostics.

The PCR technique is highly sensitive at detecting diseases. A sample containing even the smallest amount of the disease can usually be detected before any symptoms are evident in the crop.

Very importantly, the way the sample is collected is critical.

A video produced by Judy Allan and Warwick Gill demonstrates how to collect samples for disease testing from growing rooms, equipment, work areas, mushroom caps and compost. Click here to view the video or visit the AGORA website for both the video and appropriate control measures.

Samples being prepared for PCR testing

To test for the presence of Trichoderma, Cobweb, Dry Bubble or Blotch disease, send your samples by express post to the AHR diagnostic laboratory in Sydney to:

Applied Horticultural Research
PO Box 917 Alexandria NSW 1435

For more information on how to collect and send samples to the laboratory, visit the AHR website https://ahr.com.au/mushroom-disease-diagnosis-service

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.

Hort Innovation Strategic levy investment | MUSHROOM FUND

This project has been funded by Hort Innovation using the mushroom research and development levy and funds from the Australian Government. For more information on the fund and strategic levy investment visit horticulture.com.au

Marsh Lawson Mushroom Research Centre update

Project MU21004 - Delivered jointly by the University of Sydney and Applied Horticultural Research (AHR)

Umberto Calvo (AHR)

Manager and Assistant grower at the MLMRU

Hort Innovation MUSHROOM FUND

This project has been funded by Hort Innovation using the mushroom research and development levy and funds from the Australian Government. For more information on the fund and strategic levy investment visit horticulture.com.au

Marsh Lawson Mushroom Research Centre (MLMRC)

Aim: To contribute to a strong research capacity for the Australian Mushroom industry and operate the Mushroom Research Unit as a world-class facility.

Objectives of the project

1. Operate the Mushroom Research Unit (MLMRU)
2. Provide research leadership
3. Engage with global leaders in mushroom research
4. Communicate research findings to industry
5. Support transition to a new research facility

1. Marsh Lawson Mushroom Research Unit (MLMRU)

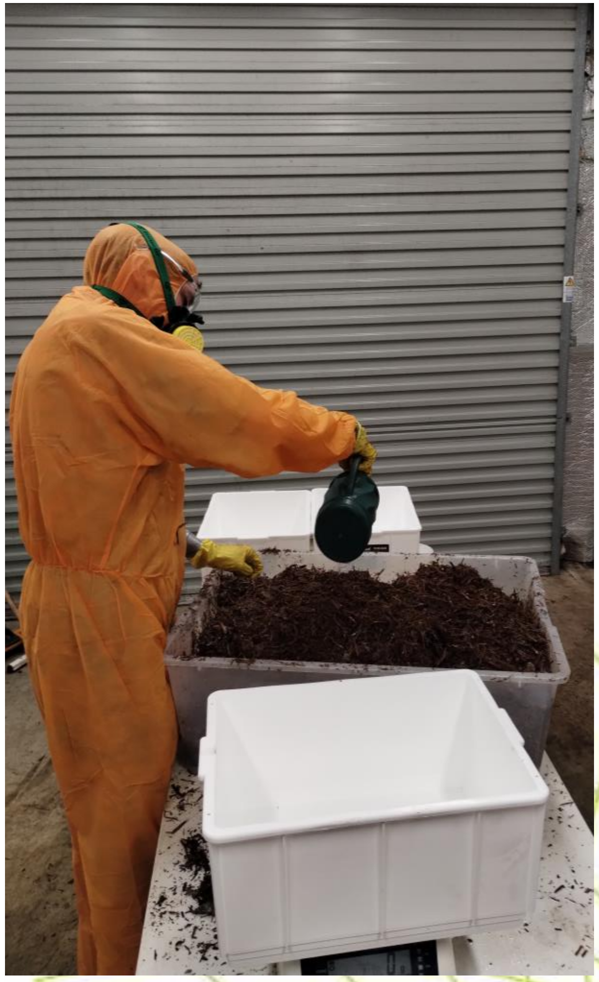
- University of Sydney – 10 min walk from Redfern station
- 2 independent growing rooms and shared lab space
- Full environmental controls
- Ideal test facility for industry
- Growers under continuous training and supervision
- High student involvement

Sandra Evangelista
Grower

Umberto Calvo
Manager and Assistant Grower

1. Marsh Lawson Mushroom Research Unit (MLMRU)

- New boiler, humidifiers, cooling systems overhauled
- Growing facility cleaned, sanitised, sampled for PCR disease testing after every crop
- Always improving procedures to best represent commercial farm conditions



Achievements of the Mushroom Research Unit

- **PCR disease diagnostic service**
- Studies on
  - Chemicals efficacy and residues
  - Irrigation and treated irrigation water
  - Nitrogen transformations and supplements
  - Microbial communities in compost
- Many Sydney University student trials

Mushrooms irrigated with tap water (left) or 0.3% $CaCl_2$ (right) following 6 days storage at $3^{o}C$ (AHR data).

Planned trials at the MLMRU

Contracted by other R&D projects OR proposed by Steering Committee

1. Establish threshold levels of potential compost contaminants
2. Casing alternatives, reuse of spent compost and spent casing
3. Comparison studies
    1. commercially available compost supplements
    2. effectiveness of sanitiser treatments
    3. currently registered fly control
    4. currently registered fungicides

2. Mushroom Research leadership

- Steering Committee to direct and prioritise MLMRU activities
- Assist in the identification of industry research priorities and formulation of projects
- Proof of concept trials / small reviews
- Promote the activities of the MLMRC

3. Engage with global leaders in mushroom research

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- Facilitate webinars and podcasts with international researchers
- Pursue international research collaborations
- Trial new technologies from abroad
- Involvement in the International Society for Mushroom Science
- Encourage international guests to visit

4. Communicate results to industry

- Close collaboration with MushroomLink - MU21003
- Case studies, podcasts and webinars
- Demonstration trials and ‘live’ webinars from the Unit
- Present at Mushroom Conferences

5. Transition to a new facility

Upgrade of current facility planned for early 2025 - Led by AMGA and University of Sydney

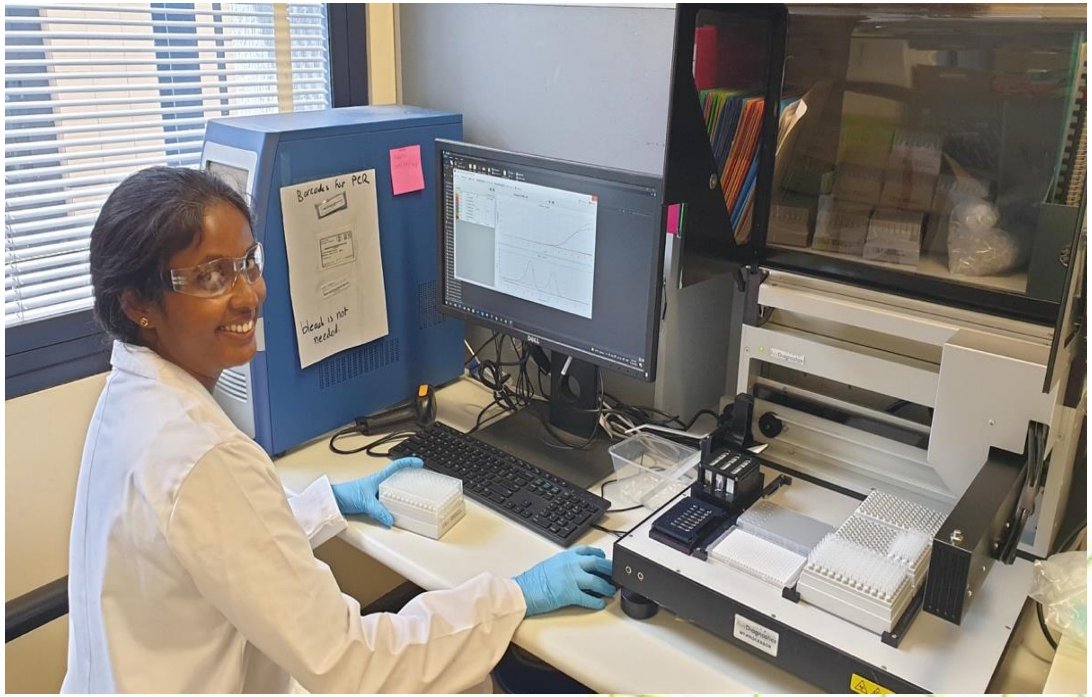
Fancom control system – FungiClima Consulting to design new AHUs

Proposed specifications of new facility:

- **Grow rooms**: 4 growing rooms 25-40m³, with Dutch shelves and a rack system. Industry standard controls
- **Compost research facility**: Phase 1 bunkers and Phase 2 & 3 tunnels
- **Location**: TBD
- Similar to other world-class facilities

PCR Disease Testing

- HIA project MU12007
- Identify disease during compost production, in grow rooms, around the facilities or on workers
- Monitor effectiveness of disease management and outbreaks
- Results are **STRICTLY CONFIDENTIAL**



Hort Innovation Strategic levy investment MUSHROOM FUND

THE UNIVERSITY OF SYDNEY

AMGA

AusDiagnostics

What can be detected?

Disease	Scientific names
Cobweb	*Cladobotryum mycophilum* (*Hypomyces odoratus*)
Dry Bubble	*Lecanicillium* spp.
	Lecanicillium fungicola (*Verticillium fungicola)*
Green mould	*Trichoderma* spp.
	*Trichoderma aggressivum** specific test
Bacterial blotch	*Pseudomonas tolaasii*
	Pseudomonas gingeri

Trichoderma

Dry Bubble

Testing is quick, reliable, and a great way to monitor the effectiveness of farm disease management strategies

How to collect the samples

Collect the samples from your farm using a range of methods:

- Rollers
- Cotton buds
- Cotton pads
- Compost samples
- Casing samples
- Straw, chicken manure

Video: How to sample

PCR Disease Testing

Contact *Applied Horticultural Research*

PO Box 917 Alexandria NSW 1435

02 8627 1040 www.ahr.com.au

- Tyler Kristensen tyler.kristensen@ahr.com.au
- Umberto Calvo umberto.calvo@ahr.com.au

Pricing

1	**sample**	**$155 each**
2-7	**samples**	**$90 each**
8-15	**samples**	**$75 each**
16+	**samples**	**$65 each**

DNA extraction for dirty samples always included

Currently testing 100-120 samples per month at the AHR lab

Marsh Lawson Mushroom Research Centre

Gordon Rogers (AHR)
Michael Kertesz (Uni of Sydney)

Marsh Lawson Mushroom Research Centre (MLMRC)

Aim: To contribute to a strong research capacity for the Australian Mushroom industry and operate the Mushroom Research Unit as a world class facility:

1. Operate the Mushroom Research Unit (MLMRU)
2. Provide research leadership
3. Engage with global leaders in mushroom research
4. Communicate research findings to industry
5. Support transition to a new research facility

Hort Innovation project MU21003

Delivered jointly by the University of Sydney and Applied Horticultural Research (AHR).

1. Marsh Lawson Mushroom Research Unit (MLMRU)

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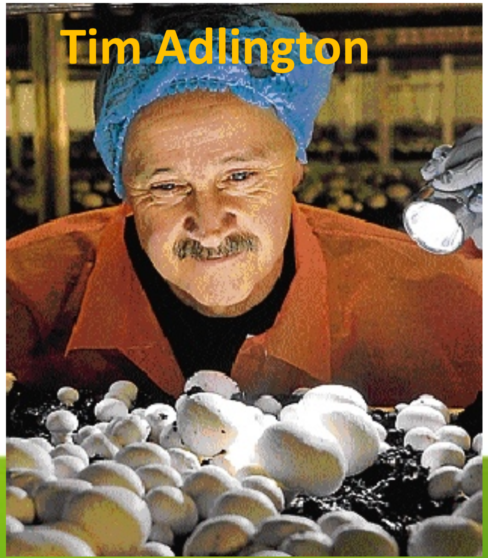
- Located at **University of Sydney**
- **2 independent growing rooms**: 72 block capacity
- **Trained growers**, supervised by Tim Adlington
- **Full environmental controls** (AEM)
- **Ideal test facility for industry**
- **5+ students now active in the mushroom industry**

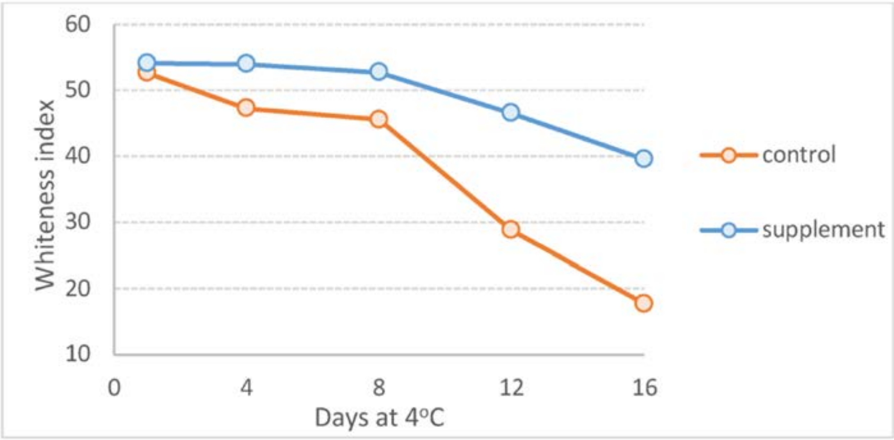
Recent improvements to the Mushroom Research Unit

- New dedicated growers (Umberto Calvo and Sandra Evangelista) trained by Tim Adlington
- New boiler, humidifiers, cooling systems overhauled
- Whole facility cleaned, sanitised with PCR disease testing after every crop
- Commercial standards for growing, harvesting, grading.



Past achievements of the Mushroom Research Unit

- 37 trials run over the last 5 years (8 per year)
- **Vivando®** efficacy and residue trials
- **PCR disease diagnostic** project (MU12007)
- **Casing replacement** and improvement trials
- **Alternative nitrogen sources**
- **Cold plasma treated irrigation water**
- **Compost supplementation** trials
- **Calcium** in compost, casing and irrigation on whiteness
- **Casing run CO_2 conc.** on flush timing, yield and quality
- Many **Sydney University student trials**

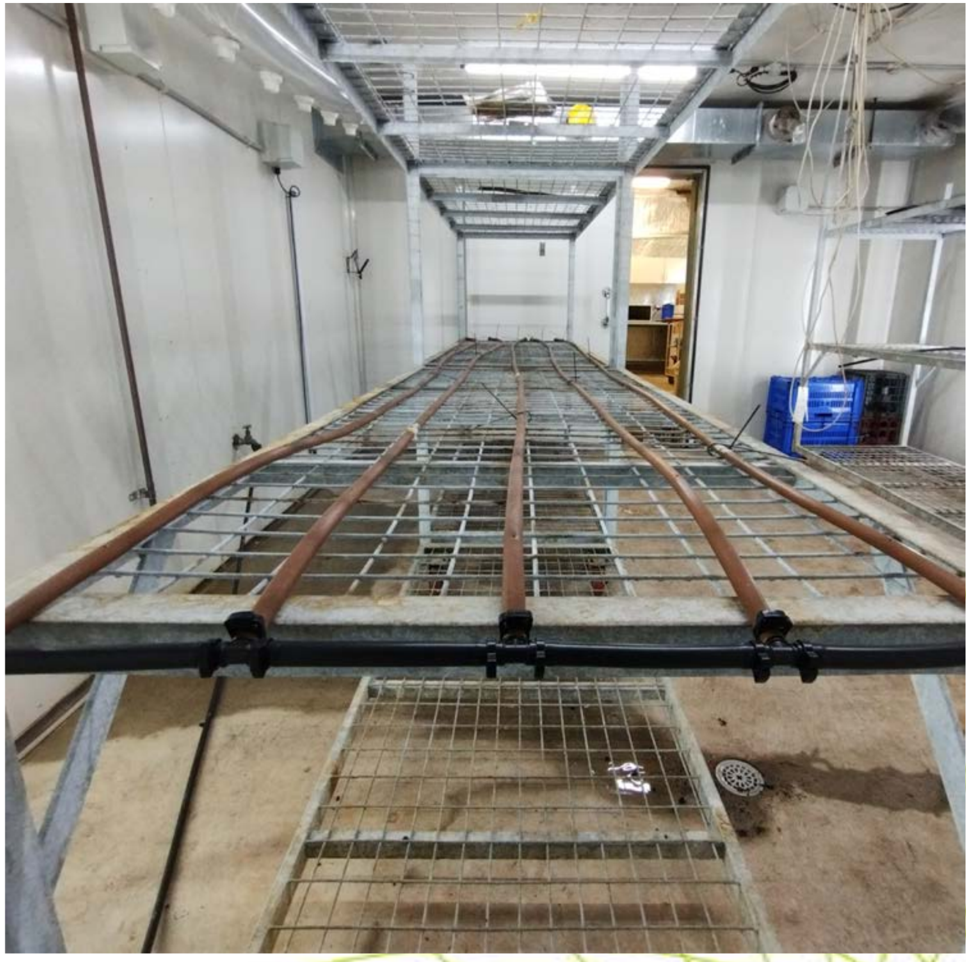


Effect of supplementing casing with 10g/kg corn or soybean meal (average of both treatments) on the whiteness index of stored mushrooms. Derived from Adibian and Mami, 2015.

Mushrooms irrigated with tap water (left) or 0.3% $CaCl_2$ (right) following 6 days storage at 3°C (AHR data).

Current and planned MLMRU trials…

1. **Compare drip irrigation** with overhead irrigation with **digital monitoring of compost moisture**
2. **Evaluate applying nitrogen forms** in-crop under the casing layer (Drip + fertigation)
3. **Spot sanitiser treatments** (Judy and Warwick)
4. **Evaluate non-synthetic (biological) controls** Vic DPI
5. **Evaluate microbials in spawn run** with different substrates (Sydney Uni)
6. Establish threshold levels of **potential compost contaminants** (e.g. pesticide residues)



2. Mushroom Research leadership

- **Marsh Lawson Steering Committee** to provide leadership and direction
- **Direct MLMRU studies** and activities
- **Undertake small proof of concept trials** /small reviews using an innovation fund directed by the steering committee
- **Promote the activities of the MLMRC** to industry and internationally
- **Assist in the identification of industry research priorities** and formulation of projects

3. Engage with global leaders in mushroom research

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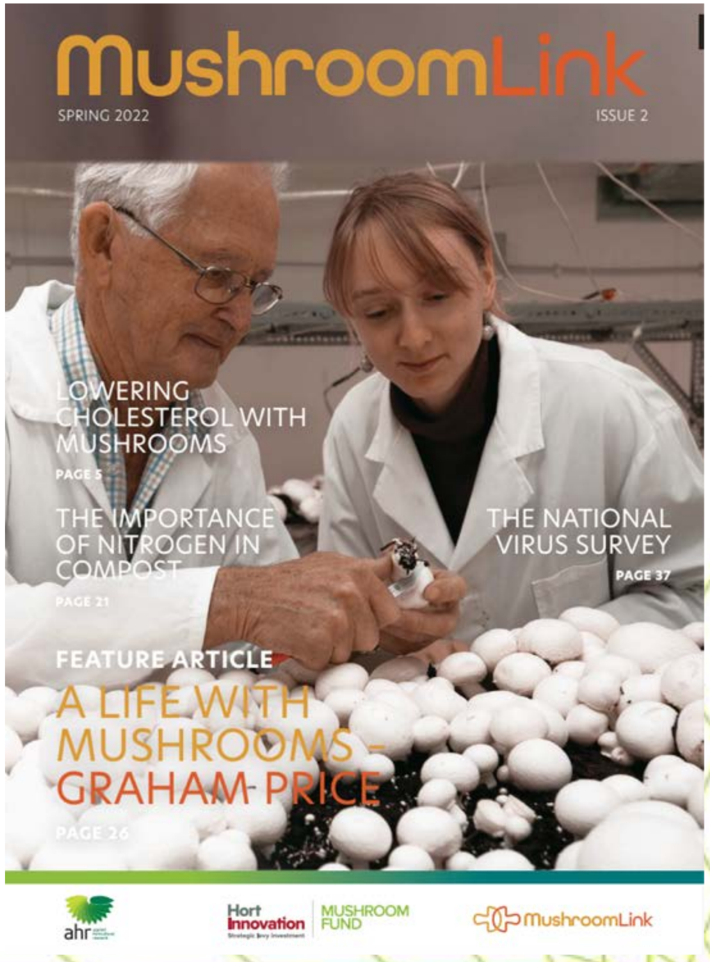
- **International members** on Steering Committee
- **Webinars** by international researchers
- Pursue **international research collaborations**
- Get involved in the **International Society for Mushroom Science**
- Encourage **international research students**

inagro
ONDERZOEK & ADVIES IN LAND- & TUINBOUW

ISMS The International Society for Mushroom Science

4. Communicate results to industry

- Link to **mushroom communications project (MU21003)**
- **Four case studies per year** on MLMRC-related achievements, including “proof of concept” trial outcomes
- **Webinar series** - 6 per year with a focus on international speakers and outputs of the MLMRC
- Run **Demonstration Trials** at the research and ‘live’ webinars at the unit, showing the results of the trials for extension.
- Present at at **Australian Mushroom Conferences** featuring trials and achievements.



5. Transition to a new facility

Current site not viable long term. New facility specs:

- **Growing rooms**: 4 growing rooms 25-40m^3 (e.g. 5 x 5m) with 5 tonne capacity. Dutch shelves and a rack system. Industry standard control system.
- **Compost research facility**: Compost research facility for research on Phase 1, 2 and 3 compost. Phase 1 bunkers and Phase 2/3 tunnel designed for for pasteurization and spawn run. Heating elements in the walls of the Phase 2/3 tunnels to maintain temp.
- Model on Inagro, PennState, Teagasc (Dublin). https://inagro.be/edible-mushrooms

Current mushroom research projects

Production	**Communications, industry development**
• Bio-markers for compost quality control to maximise yield	• Mushroom industry communications program
• Optimising nitrogen transformations in mushroom production	• Marsh Lawson Mushroom Research Centre of Excellence
• Recycling spent mushroom substrate (SMS) for fertiliser	• Mushroom industry conference
Pests, disease, biosecurity	**Market research**
• Pest and disease management for the Australian mushroom industry	• Consumer demand spaces for horticulture
• Development of a biosecurity plan for Australian mushrooms	• Consumer usage, attitude and brand tracking (pilot program)
• Data for pesticide permits/ Minor use program / SARPs	• Consumer behavioural data program
• Desktop review of pathway risks for the mushroom industry: imports	• Mushroom price elasticity of demand
• Non-synthetic alternatives for pest and disease management	• Foodservice foundational market insights
Food safety and risk	**Human nutrition, education**
• Extension and Adoption: Food Safety, Quality and Risk Management	• Educating the food industry about Australian Mushrooms
• Mushroom industry crisis and reputation risk management	• Mushrooms and health benefits of lowering blood cholesterol
	• Mushroom education resources
	• Evaluate (vitamin D2) health claims for mushrooms