IT'S A WRAP ON MU16003 **PEST AND DISEASE MANAGEMENT AND RESEARCH SERVICES**

By Dr Jenny Ekman and Paulette Baumgartl

Like all crops, mushroom yields can be adversely impacted by pests and diseases. However, mushrooms lack protective skins, as well as the defence compounds often produced by parent plants. Moreover, treating disease with fungicide is clearly problematic for a fungus! Added to this is a short cropping cycle, leaving little time to treat diseases mid cycle.

Prevention is better than cure very much applies here.

Over the last five years, Warwick Gill from the University of Tasmania and Judy Allan have led the levy funded project MU 16003 *Pest and disease management and research services*, creating an exhaustive and detailed body of knowledge for the Australian mushroom industry.

The team has researched and collated information on current and emerging mushroom pests and pathogens, as well as how to recognise, treat and manage them. They have also focussed strongly on communicating their findings through a variety of engaging formats. The legacy is an impressive and invaluable information resource.

Most of the resources created through the project are available via the AGORA website (agora.australianmushrooms.com.au, note that this is password protected), with a few highlights presented here.

THE MU16003 CATALOGUE

Information collected via scientific literature, AGORA's own pest and disease library, national and international networks, and the growers themselves, has been disseminated and distributed to growers in a variety of forms, including fact sheets, case studies, articles, and digital resources.

The catalogue includes

37 INDUSTRY JOURNAL ARTICLES PUBLISHED IN AMJ

8 FACT SHEETS

11 GROWER ALERTS

2 VOICE OVER POWER POINT PRESENTATIONS

4 INSTRUCTIONAL VIDEOS

6 CHEMICAL SUMMARY TABLES

RESEARCH HIGHLIGHTS

Research projects focussed on critical areas that would have the greatest impact on effective pest and disease management strategies.

Improving management of foot dips

Once disease is present on a mushroom farm, the grow room floor becomes a significant disease reservoir. Normal farm practices can spread pathogens between grow rooms, potentially contaminating the entire farm. They can also transfer virus contaminated spores and mycelium of *Agaricus* spreading viral disease.

While the usefulness of foot dips is widely known, the factors effecting their efficacy on mushroom farms is less certain.

Top tips:

1. Replenish the foot dip often and make sure it is CLEAN
    - For example, only 8g of casing soil (approx. a tablespoon) in 100ml of a fresh registered disinfectant solution (mixed according to manufacturer's instructions) severely reduced efficacy of the disinfectant against L. fungicola (Dry Bubble) spores
2. Make sure the person mixing the solutions understands how to mix to the correct concentration
3. Do not simply "top up" partly used solutions, especially if dirty; dispose of the old mix (as much as possible) and replace the solution
4. If a foot dip is not being used, empty it, clean it and put it away.
    - Neglected foot dips pushed into a corner when not needed can become a breeding ground for pests and diseases
    - If the organic material dries out, it can spread around the farm
5. Depending on the amount of dirt or casing build-up in the foot dip, replenishment may be required more than daily.

Make sure footbaths are replenished regularly with fresh disinfectant

Getting the best from cookout (fact sheet 5)

As mushroom crops mature, so do pests and pathogens within the crop. Effective termination when cropping has finished is the best way to 'start clean' when the new materials are introduced. Steam provides an effective way to heat compost, and is still the best way to prevent cross contamination, killing pests within the compost as well as on the structures and equipment in the growing rooms.

However, cookout clearly requires large amounts of energy. With energy costs rising it is ever more important to maximise effectiveness. This is where it helps to understand what pests or pathogens are present, and the time + temperature combinations needed to kill them.

Fact sheet 5 includes a quick reference table showing the time and temperature combinations needed to kill a number of pests and pathogens, summarised in Table 1. However, it is important to understand that these are based on laboratory trials. Moreover, times to kill dry spores can be much longer than those needed to kill fresh material – another reason to cook out promptly once the crop is finished. Cookout times will also be affected by:

- Rate and uniformity of heat penetration
- Compost and casing structure, density and moisture content
- Production system (trays or shelves)
- Age and integrity of the grow rooms

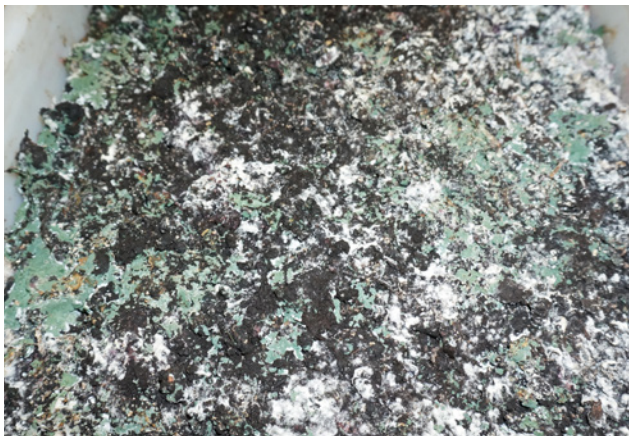
For a routine cookout, holding compost at 65 to 70°C for 9 hours is generally sufficient for a shelf farm, increasing to 70°C for 12 hours or more in an older farm using timber trays.

	TEMPERATURE						TIME (Hours)
	46°C	50°C	55°C	60°C	65°C	70°C	
***Agaricus* spores**					X		72
						X	3
Bacterial blotch		X					0.15
Brown plaster mould				X			4
Cecid adults and larvae	X						1
Cobweb		X					4
				X			2
Dry bubble			X				4
				X			2
False truffle				X			>3
Lipstick mould		X					16
				X			6
Mat disease				X			2
		X					16
Mites			X				5
Nematodes			X				5
Olive green mould				X			6
Phorid adults and larvae			X				5
Sciarid adults and larvae			X				5
Wet bubble		X					4
				X			2

Table 1. Time and temperature combinations needed to kill mushroom pests and diseases. From Overstijns, 1998.

A notable absentee from Table 1 is the green mould fungus *Trichoderma* spp., particularly *Trichoderma aggressivum*. Depending on the strain, *Trichoderma* is exceptionally hard to kill. For example, it has been shown to survive nearly 30 hours at 74°C. The fungus can penetrate and survive in timber trays, especially if heated while containing compost.

If *Trichoderma* is a problem it may be necessary to cook twice – both before and after the room is emptied – as well as extend heating times considerably.



Severe Trichoderma (green mould) in a mushroom crop.
- Photo by R. Hall

Top tips for successful room sanitation:

- Don't cut cookout short, especially if using timber trays
- Make sure floor cracks and joins are sealed, as these can act as havens for disease, and often remain cooler than compost
- Empty grow rooms downwind from new rooms, and never empty old rooms while new rooms are being filled or cased
- Remove spent mushroom compost from the farm as soon as possible
- Follow cookout with;
    - Gross cleaning to remove soil and debris
    - Pre-rinsing with low pressure water
    - Mechanical washing using a detergent (e.g. broom, brush)
    - Post rinsing to remove detergent
    - Disinfection using a sanitiser
    - Final rinse then drying

After the room is emptied, the next step is gross cleaning to remove soil and debris; start at the top and move down.

NEW AND EMERGING THREATS TO THE MUSHROOM INDUSTRY

This comprehensive review identified three fungi, five bacteria and one virus complex as new, emerging and re-emerging (in more virulent form) diseases in the Australian mushroom industry.

Of these, six had not 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 that have caused greater problems overseas that in Australia.

Fact sheets on the more concerning diseases were sent to all members.

Mushroom Virus X Syndrome - Patch Disease and Brown Cap Mushroom Disease (fact sheet 8)

Mushroom Virus X syndrome (MVX) describes a range of symptoms including delayed opening, reduced yields, distorted mushrooms, and cap browning. Initially a bit of a puzzle, researchers now know that it is a combination of two separate virus diseases – Patch Disease and

After the room is emptied, the next step is gross cleaning to remove soil and debris; start at the top and move down.

Symptoms of MVX, with bare patches 'spiralling' along an affected bed. Photo supplied by farm

Brown Cap Mushroom Disease. The two diseases can occur together, with variable and complex expression of symptoms.

Farm operations where compost is exposed, especially during Phase II, Phase III and casing are particularly vulnerable to infection.

Top tips:

- Don't ignore sporadic 'off white' or 'brown' mushrooms appearing – it might be an early warning that virus is replicating on your farm
- MVX syndrome symptoms may appear similar to symptoms expressed by other diseases
- If you suspect a virus infection, send samples for PCR testing immediately
- MVX syndrome viruses can be spread by mushroom spores and mycelium
- Consider reducing the proportion of open mushrooms grown to reduce the number of mushroom spores moving around the farm
- Reduce dust levels around the farm
- Protect vulnerable operations – Phase II, Phase III and casing – from dust
- Stringent hygiene based on efficient cook out and effective cleaning is the most successful management tool

Yellowing troll doll mycelium colonising a portobello mushroom.
- Photo Kerry O'Donnell

Syzygites megalocarpus – Troll Doll (fact sheet 1)

Troll doll is caused by a common mould (*Syzygites megalocarpus*) that colonises a diverse variety of dead or ailing mushrooms.

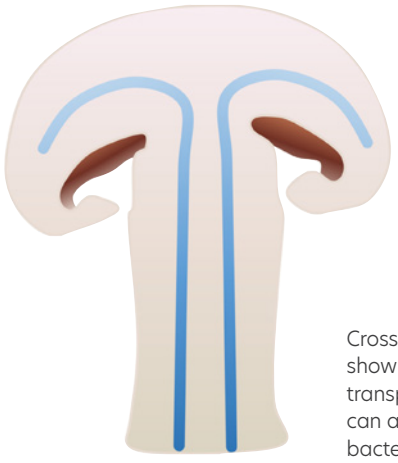
First thought to be confined to late flushes of brown portobello strains of *Agaricus bisporus, Syzygites* has since been observed on earlier flushes and on both brown and white strains of *A. bisporus*. Due to the mould's tolerance to low temperatures, it can also develop postharvest in packaged product, with the mould appearing while on the retail shelf.

Top tips:

- Symptoms may occur postharvest
- Treat infection as for cobweb – cover with moist paper town, salt edges then the middle
- Do not water areas of infection
- Avoid disturbing the area to prevent the spread of airborne spores
- Sanitisers are effective against Syzygites spores and mycelium, as is an effective cookout
- Hygiene is key – keep beds and floors clear of dead tissue, stumps and knock downs

Internal Stipe Necrosis (fact sheet 7)

Internal Stipe Necrosis has been observed sporadically on Australian mushroom farms over the past 10 years. It tends to be associated with use of wetter and heavier black peat as a significant component of mushroom casing.



Cross section of mushroom showing the key water transport vessels, which can also transport bacteria

Internal stipe necrosis, showing typically variable symptoms.
- Photo Judy Allan

As the name implies, symptoms are largely confined to the stipe. As the bacteria is carried within the water conductive tissues of the mushroom, it mainly affects the ring of tissue surrounding the inner soft central column of the stipe. This becomes brown and necrotic, with dying areas sometimes extending towards the outer edge of the stipe. Affected tissue dries and completely collapses, leaving a column of dead, corky tissue attached to the base of the mushroom cap.

There is no outward symptomology, however some affected mushrooms may appear wet during early development.

Top tips:

- Internal Stipe Necrosis is characterised by browning and necrosis of affected stipe tissue.
- The disease is associated with the bacterium *Ewingella americana* and can affect a large range of mushroom species, not just *Agaricus*.
- Symptoms are more pronounced when there is an imbalance in water relations, particularly if casing remains wet.
- The impact of Internal Stipe Necrosis can be reduced by managing the room environment; ensure compost temperatures are regulated and there is sufficient evaporation to avoid water pooling.
- Ensure irrigation water is clean.

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

GROWER ENGAGEMENT

The team actively engaged with growers and took considerable effort to encourage uptake of the resources and expertise that was being made available.

Despite COVID-19 disruptions, ten face-to-face workshops were delivered over five states, attracting attendees from nearly 50% of levy-paying farms. There were also numerous "phone a friend" online consultations.

Workshop topics included mushroom pathology 101, dry bubble biology and management, vectors, spot treatment training, cobweb biology and management, and on farm sampling.

Four on-farm visits allowed the team to examine vulnerabilities of different farms to pests and diseases, as well as undertake some strategic sampling from sites identified during project MU12007 – *development of a pilot mushroom farm disease monitoring scheme*. These visits highlighted disease hotspots, and assisted farms to develop better management strategies.

Over 120 delegates, speakers and exhibitors attended the 43rd Biannual AMGA conference in 2018, 'a Bridge to Success'. The team delivered a 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.

AGORA

One of the key activities of the project team has been to maintain and update the AGORA website, making it the central library of mushroom pest, disease and hygiene information. Hundreds of resources are available, including both locally produced fact sheets and articles and publications from around the world. There are also videos demonstrating sampling methods, spot treatments and pest and disease identification.

The information on AGORA provides an invaluable industry asset for understanding and managing not just pest and diseases, but the important roles of compost quality, farm hygiene and other factors.

Having such information available through AGORA has helped numerous farms manage their way through serious diseases.

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Information for this article has been sourced from articles and fact sheets published through the AMGA by Judy Allan and Warwick Gill, and the MU16003 final report.