MY PESTICIDE DOESN'T WORK!

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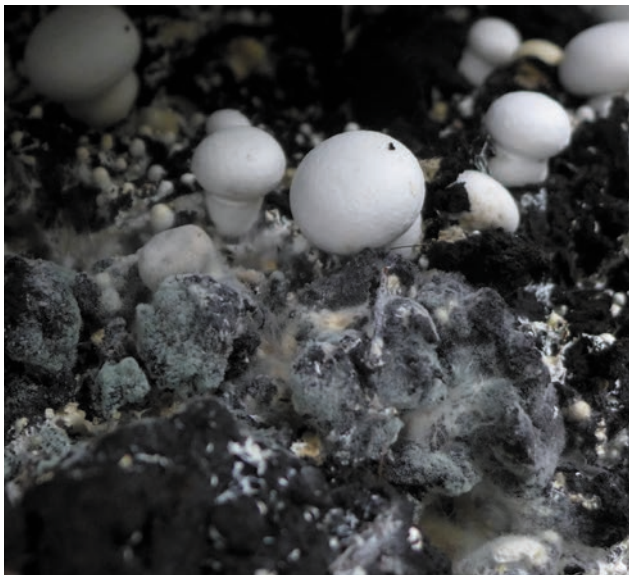
INTRODUCTION

When applied correctly, pesticides are a very effective component of a mushroom farm's IPDM (Integrated Pest and Disease Management) strategy, rapidly reducing pest and pathogen populations. When a pesticide seems no longer to work, or appears to work less effectively than before, it is very concerning. The purchase of pesticides is a significant expense for mushroom farms particularly when faced with increasing costs across the board. It is important from an economic perspective that pesticide effectiveness is optimised and that growers see a good return on their investment.

Faced with control failures, it is easy to presume that the target organism has become resistant, particularly if reduced control is an on-going issue. But there are many reasons, other than resistance, why pesticides may not control pests or pathogens. In this article, we will identify some of the on-farm practices associated with pesticide application that can lead to perceived resistance and offer ways to mitigate these deficiencies.

WHAT IS RESISTANCE?

Before the 1970s, pesticides tended to be broad-spectrum poisons with multiple modes of action, killing the target pest but also its natural enemies and many beneficial organisms. Pesticide resistance was uncommon within agriculture and virtually unknown in mushroom cultivation. But with the development of newer pesticides with a single mode of action, specific organisms and even certain life stages of those organisms can now be targeted, confining the kill to the causal pest or pathogen. The downside is that targeted organisms only need a single mutation to acquire resistance.



Accurate identification of the target is essential for effective pesticide use. - *Photo: Farm supplied*

Resistance is not a genetic mutation caused by repeated exposure to a pesticide. It is a naturally occurring phenomenon. In any natural population, there are some individuals with genes allowing them to resist a pesticide and some individuals with genes expressing a level of tolerance to it. Exposing that population repeatedly to the same pesticide will kill all the individuals that do not have the resistance gene and will allow the resistant individuals to survive and multiply, passing on their resistance genes to successive generations. If that same pesticide is applied in a sublethal dose, those individuals which are tolerant will also survive and pass on their tolerance genes to successive generations.

Because of the rapid turnaround in mushroom crops and the short generation time of mushroom pests and pathogens, the repeated application of a single pesticide, especially at a sublethal rate, will rapidly select a resistant population that cannot be controlled by the pesticide.

ON-FARM CONTROL FAILURES

The failure to control an infestation or disease is most often due to exposing the pest or pathogen to a sublethal concentration. As well as the observed reduced level of control which gives the grower the perception of resistance, the repeated failure to deliver the manufacturer's recommended pesticide rate drives resistance development.

When a pesticide fails to control a pest or pathogen outbreak, it is tempting for a grower to apply more pesticide either at a higher concentration or more frequently. Increased costs aside, this is impractical in mushroom cultivation as higher concentrations of a fungicide can reduce the yield and possibly result in residue detections exceeding the MRL. Similarly, increasing the number of applications can conflict with withholding periods and risk residue detection.

When a farm experiences an ongoing control failure, an overall audit of pesticide management to identify possible breakdowns in farm systems is the first step. To assist, we have identified some farm practices that may lead to 'perceived resistance' and poor pesticide performance (Table 1).

Pesticide control failures are not only a result of farm practices. In a later article, we will address how water quality, pesticide persistence, adsorption and microbial degradation can reduce the impact of pesticides, and offer strategies to mitigate the influence of these properties.

SUMMARY

Synthetic pesticides are becoming increasingly difficult to access for many agriculture industries. It is vital for the Australian mushroom industry to protect the products currently available and to manage pesticides effectively to ensure the longevity of efficacious control chemicals. Once a pest or pathogen population acquires resistance, it is irreversible, and the product becomes ineffective.

Most of the control failures experienced on-farm are due to a sublethal rate of pesticide being delivered to pests and pathogens. This is a significant driver of resistance development. By identifying and correcting flawed farm practices, the chances of developing resistance can be greatly reduced, and farms can maximise their return on the significant investment they make in pesticides.

The major pesticide resistance mitigation strategies that can be addressed on-farm can be summarised as follows:

1. Reduce exposure of pests or pathogens to the active ingredient
    - Do not use pesticides routinely
    - Restrict their usage to when most required or when symptoms express
    - Reduce the disease pressure and pesticide requirement by establishing stringent hygiene standards throughout the farm

Apply pesticide to the bed and not the floor. - *Photo by Judy Allan*

There is a Code of Practice for the storage and handling of pesticides. - *Photo by Judy Allan*

All application equipment must be fit-for-purpose, clean, well-maintained and calibrated. - *Photo by Judy Allan*

2. Accurately identify the target pest or pathogen

   - Send appropriate samples and sample types to the most suitable diagnostic laboratory
   - Select the most appropriate formulation to treat the confirmed target
   - The Hort Innovation levy-funded project MU21007 (*Pest and disease management for the Australian mushroom industry*) project team can help you with this

3. Apply the pesticide at the correct rate

   - Confirm the manufacturer's recommended rate before application, particularly when opening a new container of pesticide

4. Apply the pesticide at the right time

   - Apply pesticides at the most appropriate time, not the most convenient time
   - Coordinate pesticide application with the susceptible life stage
   - Consider pesticide withholding periods before application

5. Apply the pesticide at the right location

   - Incorporating pesticide into the compost is not effective if the pest lays eggs in the casing
   - Apply onto the bed and not the floor

6. Apply pesticides evenly

   - Check the spray pattern on automatic watering systems
   - Prevent overspray by watering trees or other manual spray applicators
   - Keep the pesticide in the spray tank agitated as required

7. Using a mixture of active ingredients in a single application is a recognised technique to reduce resistance developing. But with so few registered or permitted actives available, this is generally not a luxury open to the mushroom industry.

   - If you do combine products in a single application, make sure they are compatible and are mixed in the correct order to prevent them falling out of solution

For effective disease control, being familiar with the biology and ecology of mushroom pests and pathogens, producing a selective compost from an efficient Phase II, maintaining whole-farm stringent hygiene and applying the basic IPDM principals of exclusion and containment will reduce the disease pressure on the farm and minimise the need to resort to pesticides. After all, the total eradication of all pests and pathogens from a mushroom farm is impractical. The aim is to keep pest and pathogen populations below the disease threshold on your farm.

HOW CAN WE HELP?

The MU21007 project team has developed a workshop on effective pesticide management to avoid resistance. The presentation addresses resistance management in pesticides generally but focusses on Vivando® as an example product. This will help growers adopt this newly available fungicide effectively and avoid resistance developing. The workshop can be delivered either face-to-face or remotely. So, if you would like a presentation delivered to your farm, please contact Judy or Warwick.

We are also able to assist you with sampling issues – what to sample, where to sample and where best to send the samples for appropriate testing. Once you have the results, we are happy to help you plan and develop your farm's management strategy. Check out our contact details below.

FURTHER READING

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GLOSSARY

IPDM

IPDM (Integrated Pest and Disease Management) is the broad-based approach that combines both chemical and non-chemical practices for the control of pests and diseases.

Sublethal dose

A sublethal dose of a pesticide has an effect short of death but may cause physiological and molecular changes in the exposed organism which are not fatal.

MRL

The MRL (Maximum Residue Limit) is the maximum concentration of a residue resulting from the APVMA approved use of an agricultural or veterinary chemical which is legally permitted or recognised as acceptable to be present in or on a food, agricultural commodity or animal feed.

Withholding period

The withholding period is the length of time that must elapse between the last application of a pesticide to a crop and the harvest of that crop. The withholding period (if required) is stated on the pesticide label.

Table 1: Farm practices that can result in control failure and lead to 'perceived resistance'

PRACTICE	ISSUE(S)	IMPACT(S) and CONSEQUENCE(S)	MITIGATION STRATEGY(IES)
Target organism not identified correctly	Pests and pathogens are treated with an ineffective and/or inappropriate product.	• The organism responsible for the disease or infestation is not controlled • Disease-causing pests and pathogens multiply and spread to other crops • Quality and yield are reduced throughout the facility, impacting farm income • Expense of purchasing ineffective product is incurred • Expense for labour to apply and monitor crop is incurred	• Take appropriate samples of affected substrate or mushrooms, send to diagnostic laboratory for an accurate identification of the causal pest or pathogen • Determine which disease control product is best for the identified target • Apply product according to manufacturer's directions
Pesticides applied to crops routinely	The routine application of pesticides to crops in the absence of disease selects for naturally resistant mutants, driving resistance development in pest and pathogen populations.	• Expense of purchasing unnecessary product is incurred • Expense of labour to apply and monitor is incurred • Drives development of resistance in pest and pathogen populations	• Apply pesticides only to control pest or disease outbreaks • Investigate alternative non-synthetic pesticide options • Ensure stringent IPDM principals are being applied on-farm to maintain pest and pathogen populations below disease and economic thresholds
Pesticides not rotated	Pests and pathogens are exposed to chemicals with the same mode of action for an extended period. Being relatively small, the mushroom industry does not have access to the wide range of pesticide products available to some other industries.	• Growers achieve less and less control over the disease or infestation • Tendency for growers to apply higher concentrations more often • Growers achieve little or no control for the money spent on pesticides • Drives development of resistance in pest and pathogen populations	• Rotate pesticides of different chemical groups or different modes of action to a predetermined schedule wherever and whenever possible • Investigate alternative non-synthetic pesticide options to include in the rotation or to replace a synthetic product
Incorrect pesticide rate applied	Formulations of pesticides may change without warning, resulting in a change to manufacturers' recommended label rate. The label rate on some products is difficult to interpret and may use volume expressions no longer current. In times of rapid personnel turnover, instructions 'handed down' over the years may not reflect current label rate.	• Incorrect dose of active ingredient may be applied to crop • A higher than recommended application rate: – risks accumulation of chemical residues in mushrooms – may cause yield reduction • A lower than recommended application rate delivers a sublethal dose of pesticide to pests and pathogens resulting in: – poor or no control – resistance development	• When opening a new drum or batch of pesticide, check that the formulation is the same as the previous container • New staff must check label rates for themselves and not rely on oral instructions that may have been passed down from operator to operator over many years • Growers must familiarise themselves with label expressions and how they relate and apply to their farm procedures
Pesticide solutions over-sprayed	When watering a pesticide on to a crop, the pesticide solution can be sprayed onto the floor and walls.	• Pests and pathogens on the bed receive a sublethal dose of pesticide resulting in: – poor control of the disease or infestation – resistance development	• Check the spray pattern of automatic watering system nozzles • Ensure that all the solution is applied to the beds and not the floor and walls when manually applying
Pesticide applied unmonitored through automatic watering systems	Some pesticide formulations are prone to clogging spray nozzles. The application pattern of clogged or partially clogged spray nozzles will be uneven and inconsistent across the bed and throughout the room. This results in areas of both low and high pesticide concentration.	• Pests and pathogens on the bed receive a sublethal dose of pesticide resulting in: – poor control of the disease or infestation – resistance development • Disease will flourish in under-dosed places and spread to other parts of the bed that were under-dosed, and to other parts of the farm • Areas of the bed receiving a high dose are at risk of: – accumulating pesticide residues in harvested mushrooms – impacting yield	• Check that nozzles are clear and replace/clean those that are clogged • Consider applying those formulations known to clog nozzles manually with a watering tree

PRACTICE	ISSUE(S)	IMPACT(S) and CONSEQUENCE(S)	MITIGATION STRATEGY(IES)
Pesticides incorporated into the peat at casing are not mixed sufficiently	Pesticides are not evenly distributed through the casing resulting in varying concentrations of active ingredient being delivered to the target organism. This may be a significant issue for farms that use a pre-wet casing as even a short mixing time will affect the structure and function of the casing. Farms that use deep-dug peat may find difficulty in mixing evenly.	• Pesticide concentrations vary throughout the casing from high to none • Pests and pathogens on the bed receive a sublethal dose of pesticide resulting in: – poor control of the disease or infestation – resistance development • Areas of the bed receiving a high dose are at risk of: – accumulating pesticide residues in harvested mushrooms – impacting yield	• Ensure enough water is added at casing and that pesticide suspensions are thoroughly mixed through the peat for a sufficient period of time • For persistent pest infestations, consider moving away from pre-wet casing temporarily • Consider reducing the proportion of deep-dug peat temporarily
Two or more pesticides combined in one tank	Incompatible products or products mixed in the wrong order may flocculate, falling out of solution. This reduces the amount of pesticide delivered to the mushroom bed.	• Pests and pathogens on the bed receive a sublethal dose of pesticide resulting in: – poor control of the disease or infestation – resistance development	• Ensure mixtures comprise pesticides of different chemical groups • Follow manufacturers' guidelines for compatible pesticides that may be mixed together • Follow recommendations for the order of mixing to avoid flocculation and other adverse interactions
Pesticide settles out of solution	Some pesticide formulations are more prone than others to fall out of solution unless they are continually agitated in the tank.	• Pests and pathogens on the bed receive a sublethal dose of pesticide resulting in: – poor control of the disease or infestation – resistance development	• If sedimentation is an issue with a particular pesticide, ensure tank contents are continually mixed during application and tank is rinsed out at completion of operation • Rinse pesticide residues out of lines and application nozzles
Pesticide storage not appropriate	Some pesticides have a narrow storage temperature range, particularly biological products eg VectoBac® Pesticides have a limited 'shelf life.'	• Active ingredient degrades over time resulting in a lower concentration in the container • Pests and pathogens on the bed receive a sublethal dose of pesticide resulting in: – poor control of the disease or infestation – resistance development	• Ensure pesticides are stored in dry conditions and are not subjected to high temperatures, particularly biological products • Rotate pesticide containers in the chemical store so that older stock is used first • Do not use pesticide that has exceeded its use-by date
Apply pesticides at the wrong time	A modern insecticide is formulated to act on a specific life stage of the pest. A larvicide will give no control if the larvae have already emerged and mated.	• Pest is not exposed to the pesticide during its susceptible life stage	• Learn about the target's life cycle and ecology • There are ways of calculating when emergence is due and when oviposition is due
Apply pesticides in the wrong place	Incorporating fungicide into the casing to control dry bubble disease is a waste of resources. Apply as a drench because the fungus causes symptoms when it is on the casing surface.	• Pathogen is vulnerable to fungicides on the casing surface	• Learn about the target's life cycle and ecology

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FOR FURTHER INFORMATION CONTACT THE PROJECT TEAM

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