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Fungicide resistance

Fungicides are often used as a critical part of an integrated pathogen control strategy as pathogenic fungi have the ability to significantly reduce the yield and quality of plant stock if left untreated. However with incorrect management there is potential for fungicide resistance to develop. In this month's Nursery Paper Industry Development Officer David Reid investigates fungicide resistance and explores suitable methods for controlling this.

Preventing fungicide resistance

The reduction of fungicide efficacy, coupled with a further reduction of an already small array of chemicals used to control particular diseases, is of significant concern for the nursery industry and without effective management the likelihood of increased resistance could occur. A pathogen's resistance to chemical control is characterised by a change in the sensitivity of their population, which often results in a failure to control disease symptoms. This reduction in a fungal population's fungicide sensitivity is often the result of genetic mutations, or of a further invasion of naturally occurring sub-populations of resistant individuals.

Chemical groups

Fungicides are grouped either by similarities in mode of action, how they biologically act upon a pathogen, their chemical structure or their method of protecting plants.

- *Translaminar* - move from one side of a leaf through to the other
- *Locally systemic* – are able to translocate a short distance through a plant
- *Xylem mobile* - move throughout a plant via water conducting plant tissue
- *True systemic* - move both up through the xylem and down through the phloem
- *Curative fungicides* - are known to stop the early stages of inoculation from spreading further.
- *Contact fungicides* - prevent inoculum from entering the plant by forming a protective or preventative barrier and generally act on multi-sites

A mode of action describes how the fungicide affects the pathogen, such as disrupting cell wall synthesis or a particular enzyme on a metabolic pathway. The development of resistance is generally influenced by how these fungicides act within the pathogen, specifically if they act on single or multiple sites.

- *Multi-site*

Many of the original contact fungicides are known to act on multiple sites, preventing fungal pathogens from completing numerous chemical reactions and interfering with their cellular processes. These are considered at low risk for resistance because for a pathogen to develop a resistance to a multi-site fungicide a synchronised genetic mutation at the target sites would need to occur.

- *Single-site or site-specific*

Site-specific fungicides are known to disrupt specific metabolic processes or structural sites of the pathogen such as DNA or RNA synthesis, cell division or sterol synthesis and may have differing degrees of translocation throughout a plant. With most systemic fungicides utilising a single-site mode of action, they are considered to be at high risk of resistance when not applied with prudence, as their effectiveness can be reduced by mutation of a single gene. Resistance has been found in certain dicarboximides, benzimidazoles, strobilurins, sterol demthylation inhibitors (DMIs) and phenylamides. Mutations of a single gene in the pathogen were enough to prevail over these fungicides, illustrating the possibility of a population of fungal spores shifting from sensitivity to a single-site chemical to a majority of resistant inoculum within a short period of time.

To help identify their resistance risk potential, modes of action are labeled on all fungicides sold in Australia. Details can be found at: http://www.croplifeaustralia.org.au/default.asp?V_DOC_ID=1953

Selection Pressure

The evolutionary mechanism of selection generally drives the development of resistance, characterised by a proportion of a fungal population surviving chemical exposure and its genetic traits being subsequently conferred onto its progeny. This survival may be due to inadequate application, repeated treatment with a single chemical or one with the same mode of action, coupled with numerous environmental variables and specific pathogen traits.

Reproductive rate is a further variable, with those pathogens expressing a high fecundity showing greater resistance potential. The more of the pathogen that is exposed to the fungicide and thus

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exposed to selection pressure, the higher the chance that mutations will reveal themselves, leading to resistance. However, there is a high probability that a mutated individual will not reproduce and it is likely that a number of these mutations will need to occur before a resistant strain emerges from a population.

As the fungicide begins to show signs of resistance, increasing application frequency at higher rates or using other fungicides utilising similar modes of action, will only see the pathogen multiply and pass on the resistant gene(s) to its progeny. The use of high doses or increased frequency will not slow emergence or selection, nor will it extend the effective life of a particular fungicide. Resistance is essentially influenced by the difference between the resilient and sensitive strain's reproductive fitness. To prevent resistance, management focusses on reducing this disparity, without escalating the fitness of the sensitive strain too.

Cellular mechanisms that influence resistance.

1. *Altering of the target site upon which the fungicide acts. The disruption of certain chemical process or function can cause a treatment to no longer bind and exercise its toxicity.*

2. *Increased metabolism within the pathogen. A degradation of fungicidal compounds can inactivate them before reaching their target.*

3. *Removal of fungicide from a pathogen Some pathogens have been known to export fungicides from cells prior to it having its desired effect on the site of action.*

4. *A pathogen can resist fungicidal action by slowing the chemicals absorption*

Identification of resistance

Fungicide resistance is often first recognised when the expected application's results are not achieved, with pathogens expressing reduced sensitivity. At this stage of identifying a problem a genetic based resistance has become dominant in the pathogens population and appropriate management of the resistance is required.

To determine if you have a resistance problem the elimination of other factors that could potentially be confused with resistance is required. Incorrect pathogen ID, inappropriate chemical usage, large infestations, natural fungicide oxidation/degradation and even further invasions may be incorrectly identified as proof of fungicide resistance.

If you think you have identified a resistance problem:

1. *Cease using the resistant fungicide and also those in the same chemical group or using the same mode of action.*

2. *Begin using another fungicide, with a different mode of action, suitable for controlling the particular pathogen. Chemical heterogeneity is an ideal formula for resistance.*

Preventing resistance

Management to prevent resistance fundamentally aims at preventing or interrupting the spread and proliferation of fungicide sensitive pathogens and preserving the effectiveness of the chemical. Preferably, a strategy to combat resistance should be employed well before resistance is considered an issue and one way of mitigating risk is to use fungicides that could be considered 'at-risk' with prudence. However, this may be impractical as many of these same chemicals are effective at broad-spectrum pathogen control.

A resistance management strategy may vary for mode of action, particular pathogens and plant type and ideally will incorporate both best management of chemical usage and cultural practices. Fundamentally, the plan is to reduce the selection pressure by minimising the time of exposure and the magnitude of the pathogen population to the 'at-risk' fungicide. Please refer to the NGIA Australian Nursery Industry Myrtle Rust Management Plan 2012 for an example fungicide rotation program.

Ensure personal protective equipment is used and operators are properly trained to apply fungicide treatments.

What can you do to prevent fungicide resistance?

1. *Can you justify all your fungicide usage?*
   Fungicide application can increase selection pressure so employ cultural measures and bio-controls where possible. Limit number and timing of applications, have your staff properly trained to apply chemicals, ensure thorough spray coverage (even with systemics) and maintain your spray equipment.
2. *Do you have preventative measures in place and do you have a procedure in place when first detecting a pathogen?*
   Spraying late will expose more of the pathogen to the chemical and increase selection pressure.
3. *Do you have a fungicide rotation program in place?*
   Avoid 'at-risk' chemicals or repetitive use of those with same modes of action.
4. *Do you follow label recommendations?*
   When mixing products ensure that they are compatible and not phytotoxic as resistance management may be different for specific plant types or different fungicide groups
5. *Have you implemented appropriate nursery hygiene protocols?*
   Reduce the need to apply treatments by managing overcrowding, leaf wetness and overhead irrigation and be aware that enclosed or greenhouse systems, if not properly managed, may encourage spread and induce selection pressure.

Clear chemical application instructions and storage such as this will aid in the prevention and detection of fungicide resistance issues.

Fungicide resistance reduces the number of fungicides available to manage pathogen populations in your nursery and may contribute to loss of quality and yield due to inadequate fungal control. Even when disease management practices are implemented inoculation may still occur, however by employing the previous principles the risks are mitigated. Management of pathogen populations hinges on the ongoing management of fungicide resistance levels.

Managing fungicide resistance is key in continuing to produce healthy crops

Keep your sprayers calibrated and in good condition

Ensure overhead irrigation is monitored as excessive wetness can contribute to fungal problems.

Impatiens downy mildew a common fungal disease, has the potential to develop resistance to fungicides.

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