FUNGICIDE RESISTANCE: AN APPROACH TO THE PROBLEM

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Summary

Benzimidazole-resistant strains of five pathogenic fungi, *Sphaerotheca fuliginea*, *Septoria apiicola*, *Botrytis cinerea*, *Penicillium digitatum*, and *Venturia inaequalis*, have appeared in New Zealand. There is a strong possibility that in all cases where one or two gene mutations can confer resistance to a fungicide, development of resistance will be inevitable in a pathogen exposed continuously to the fungicide. In order to maintain the effectiveness of "specific" fungicides in the field, their use should be moderated, by fitting them into spray programmes at the times when their special properties are of greatest advantage.

INTRODUCTION

Man makes extensive use of antibiotics, fungicides and pesticides to control unwanted microorganisms and other pests. The effect of these attacks may be the selection of strains unaffected by the killing agent. In medicine it is well known that bacterial species may become resistant to antibiotics such as penicillin, and entomologists have to contend with the problem of insects becoming resistant to insecticides. Until 1969 plant pathologists seldom had to consider the possibility that fungal pathogens would become resistant* to fungicides. Since this date the situation has changed, and fungicide-resistant strains are no longer of rare occurrence. The most probable explanation is that prior to 1969 most fungicides in use had a broad toxic action, affecting the fungus at many sites (non-specific fungicides). This means that no single genetic change in the fungus was likely to produce resistance. However since 1969 much more use has been made of fungicides that probably act on specific metabolic steps (specific fungicides) with the result that a single genetic change in the fungus may confer resistance.

In New Zealand, benzimidazole-resistant strains of five important pathogens have appeared in the field. The fungi are *Sphaerotheca fuliginea*, *Septoria apiicola*, *Botrytis cinerea*, *Penicillium digitatum* and *Venturia inaequalis*. Resistant strains, that have appeared in the field after use of one of the benzimidazole group, have proved on laboratory testing to be resistant also to the other members of this group. Resistance to fungicides other than the benzimidazoles has been reported overseas for all the major groups of specific fungicides introduced into New Zealand, with the possible exception of the morpholines. Where these fungicides are in use here it is probable that resistance will become a problem to the grower unless appropriate measures are taken.

DEVELOPMENT OF RESISTANCE

Fungi are variable and adaptable organisms. Most species exist as a number of slightly different strains and it is possible that some of these strains may carry genes conferring resistance to a new fungicide. When

* We use the term resistant although the term tolerant is sometimes used.

the fungicide is used this strain is at a strong advantage and will rapidly build up in numbers. Such a strain would however have to be extremely rare for the fungicide to have passed all the screening tests. Fungi also vary by mutation and it is likely that mutations conferring resistance can arise in the field at the time of spraying. Laboratory experiments show that the rates of mutation to resistance to fungicides like benomyl are similar to those observed for other fungal genes, that is, about one in 10^8 spores is resistant. In the few cases where it has been studied it has been found that resistance in strains isolated in the field is due to alterations in only one or two genes, which is consistent with the hypothesis that the resistant strain arose by mutation.

It has been observed in the field that resistance arises more readily in high-sporing, fast-cycling species. This is to be expected on the mutation hypothesis. Although fungi produce many more than 10^8 spores, it is only those few spores that arrive at the host and cause infection that are subject to selection.

It has often been found that resistant strains have arisen independently at a number of localities within a short space of time. For example strains of *Venturia* resistant to benzimidazoles have been found at two well separated localities in New Zealand, two in Australia and at least one in Japan, after about three seasons successful use of the fungicide. Theoretical calculations show that for *V. inaequalis* the rate of appearance of resistance is about that expected for the mutation hypothesis.

It should be stressed that the difference between sensitive and resistant strains in the amount of fungicide they will tolerate is great. For instance, 0.1 ppm benomyl will prevent growth of sensitive strains of *B. cinerea* and *V. inaequalis*. Resistant strains of *B. cinerea* will grow in the presence of 100 ppm benomyl, and of *V. inaequalis* in the presence of at least 10 ppm benomyl. This difference in susceptibility is so great that a resistant strain can cause an epidemic under a continued benzimidazole programme at much the same rate as normal strains in the complete absence of fungicides. The fact that fungicides, such as benomyl, reduce the saprophytic fungal population will also contribute to the build up of the resistant population as saprophytes often play a role in control of a pathogen population.

The competitive ability of resistant strains in the absence of the selective fungicide is a factor which could influence their long term survival, and work is at present being undertaken on this topic.

TACTICS

Control of many diseases is better with specific fungicides than with the older chemicals, and an attempt should be made to prolong their effective use by growers. Several suggestions can be made.

1. The specific fungicide should be used only when necessary. Where effective control can be obtained with non-specific fungicides these alone should be used. Regular, repeated use of a specific fungicide should be avoided. If needed, the specific fungicide should be put into the control programme at times when its special properties can be used to greatest advantage in reducing the population of the pathogen. A specific fungicide might, for example, best be used in a post-harvest "clean-up" spray, or it might be used occasionally, to cope with emergencies such as the advent of a long period of weather favourable to the disease. Such procedures cannot be implemented unless we have a sound knowledge of disease epidemiology.
2. Where it is economically feasible it is recommended that the specific fungicide is always mixed with a non-specific fungicide. If two or more specific fungicides possessing different modes of action are available (e.g. benzimidazoles and pyrimidines for the control of powdery

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mildews) we do not recommend that they should be used in mixtures. It is unsound to use one specific fungicide until resistance arises and then to switch to the other.

3. There are a few important diseases which are controlled effectively only by use of a specific fungicide. Attempts should be made to find and screen new chemicals so that we possess suitable back-up fungicides should resistant strains of the pathogens arise.

4. Where specific fungicides are already in use in cropping situations, and adequate fungicides are available, the haphazard introduction of new specific fungicides should be discouraged. The development of resistance to several specific fungicides simultaneously should be avoided at all costs.

5. Every effort should be made to keep the total pathogen population as low as possible, to prevent an outbreak of a resistant strain. Established practices of good hygiene should not be neglected, and spray applications should be correctly timed. Growers should not be encouraged to rely on specific fungicides to hold a high inoculum potential in check.

6. Recommended rates of application should not be exceeded. If a grower believes he is losing control of a disease he should seek advice before continuing to apply the specific fungicide, as resistance may have arisen in his crop. If resistance is suspected, an immediate switch must be made to another fungicide.