FUNGICIDE RESISTANCE MANAGEMENT IN PRACTICE; MIXTURES, ALTERNATIONS AND CROSS RESISTANCE PATTERNS

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Evolved resistance to fungicides is a critical issue for global food security. Resistance has emerged rapidly in some cases, and some so it is vital that the effective life of actives is prolonged as much as practicable. Recent theoretical models to account at least qualitatively for resistance evolution are backed up by extensive experimental data (reviewed in van den Bosch *et al.* 2014, Ann Rev Phytopath 52 175-195). The models revolve around the resistance factor associated with the resistance mutation and the fitness cost incurred in the absence of the fungicide.

The challenge now is to combine these models with practical realities. The models suggest three general tactics to prolong the useful life of a threatened fungicide; -1- reduce the amount of fungal inoculum; -2- reduce to a minimum the time the fungicide is in contact with the fungus consistent with disease control; -3- use other fungicides in mixtures or alternations with the threatened fungicide.

The third tactic (mixtures and alternations) is believed to be effective if either neutral or negative cross resistance operates. Neutral cross resistance applies when there is no correlation between EC50s of strains to the first and second fungicides; negative cross resistance applies if there is a negative correlation between the EC50s. Mixtures and alternations would not be effective if positive cross resistance applied.

Mixtures and alternations can theoretically apply on timescales from zero to years and on areas from one field to entire countries and continents. Mixtures are alternations with zero time and single field area scales. Various models can be used to design the optimum resistance management mixture or alternation tactics and these will vary depending on the nature of the cross resistance found in the relevant pathogen populations and many other factors. Furthermore, like tactics 1 and 2 (minimum inoculum and minimum dose) the tactics recommended must still deliver adequate disease control and must be acceptable to farmers, regulators and the crop protection industry.

Negative cross resistance presents the attractive scenario of using solo products on large areas for long periods until the resistant population has built up to a large enough level to warrant switching en masse to the second fungicide. The new fungicide is then used until resistance develops and the first fungicide is used again; the Merry Dance. This scenario has severe sociological and regulatory hurdles but may apply advantageously under certain circumstances. In many regions, the pathogen population has already developed resistance to different fungicides with a complex pattern of positive, zero and negative cross resistance. In these cases I will argue that prolongations of effective fungicide life can still be achieved by tactical use of fungicides to pull fungal populations into evolutionary dead ends. To maximise these possibilities, fungicides with enhanced negative cross resistance should be developed and encouraged by regulatory authorities.