



Maintaining the Efficacy of Foliar Fungicides for Tobacco Disease Management

Emily Pfeufer

Extension Tobacco Plant Pathologist

Bob Pearce

Extension Tobacco Agronomist

One of the best examples of the development of fungicide resistance in tobacco is the case of Ridomil Gold for management of blue mold. Before 1979, blue mold (FIGURE 1) was primarily a disease of the transplant bed, and was preventatively managed using protectant fungicides such as ferbam, copper, and sulfur. After the blue mold epidemic of 1979 and within three years of the labeling of the systemic fungicide Ridomil Gold, over 70% of tobacco growers were spraying Ridomil pre-planting¹. Even though standard protectant fungicides like mancozeb were still available, few growers took advantage of these chemistries¹, and resistance to Ridomil Gold in blue mold pathogen populations was reported as early as 1986, within six years of its labeling². It is likely that spraying the same fungicide back-to-back played a role in developing Ridomil-resistant populations of the blue mold fungus.

Fungicides are organized into groups based on their **mode of action**, which is the mechanism by which a pesticide or chemical affects its target pest. Fungicide groupings are determined by an agrochemical industry group known

as the Fungicide Resistance Action Committee (FRAC), and the groupings are referred to as FRAC Groups or FRAC Codes. While fungicides may have different product names, if they are in the same group, they essentially cause the same challenge to the fungus.

HOW RESISTANCE TO FUNGICIDES DEVELOPS

When a fungicide with a particular mode of action is first introduced, most target fungi in the

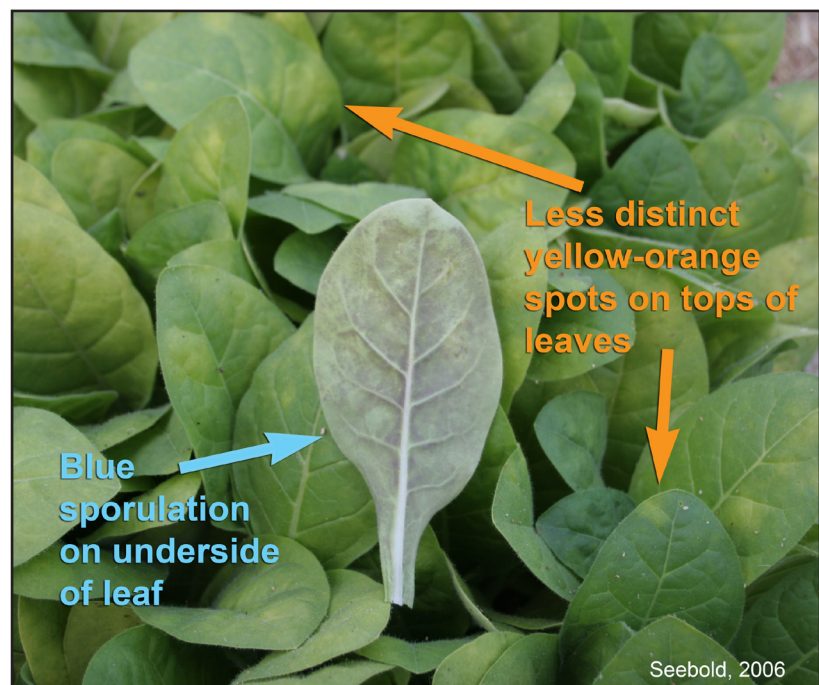


FIGURE 1. ORANGE-YELLOW BLUE MOLD SYMPTOMS ON TOPS OF TOBACCO TRANSPLANT LEAVES, WITH BLUE-GRAY SPORULATION APPARENT ON UNDERSIDE OF LEAF.

¹Nesmith, 1984. *Plant Disease* 68: 933-937. ²Tuzun et al., 1986. *Phytopathology* 96: 938-941.

environment are very sensitive to it, but there may be one or two individuals that are naturally resistant, or even just slightly less sensitive to the fungicide mode of action. As this mode of action is used repeatedly, most sensitive target fungi are suppressed, but the naturally resistant fungi are less affected. These resistant fungi contribute relatively more descendants to the next pathogen generation, gradually building up a population that overall is less sensitive to the fungicide. After many applications of the same mode of action, the population becomes composed of more and more descendants of resistant fungi, and fewer and fewer descendants of sensitive fungi, which results in poorer disease control when using that mode of action.

FUNGICIDE RESISTANCE MANAGEMENT

Management of resistance to fungicides is based on **alternating the use of particular modes of action**, or FRAC groups, which essentially presents multiple **different** challenges to the fungal population. Overall, fungi that are naturally resistant to a mode of action are very rare in the environment. Challenging a

population with multiple **different** modes of action will reduce the chance of developing widespread resistance, which will prolong the efficacy of these chemicals.

There have been many recent advances in fungicide chemistries since the early 1980s, and tobacco growers may now choose from seven modes of action for foliar disease management (TABLE 1). At a minimum, growers are encouraged to **alternate FRAC codes** to maintain fungicide efficacy. However, when only two FRAC codes are in use, there still may be potential to develop resistance to both modes of action, especially if the fungicides used are prone to resistance development. Proneness for development of resistance is based on whether fungicides have single-site or multi-site modes of action. Fungicides with **single-site** modes of action are effective on a very specific part of the fungal lifecycle, which reduces effects on nontarget organisms, and these often have systemic activity, meaning the chemical actually enters the plant tissue and may have some curative activity if present at infection. Unfortunately,

TABLE 1. FUNGICIDES LABELED FOR IN-SEASON MANAGEMENT OF FOLIAR DISEASES OF TOBACCO.

Product	Active ingredient(s)	Mode of action	FRAC group	Diseases on label
Actigard	Acibenzolar-S-methyl	Induces systemic acquired resistance	P1	Blue mold
Agri-mycin 17, Ag streptomycin, Harbour	Streptomycin	Inhibit protein synthesis	25	Wildfire, blue mold
Aliette WDG	Fosetyl-Al	Unknown	33	Blue mold
Forum, Revus	Dimethomorph, Mandipropamid	Inhibit cell wall formation	40	Blue mold
Manzate ProStick	Mancozeb	Multi-site, contact fungicide	M3	Blue mold, anthracnose, target spot, stem rot
Presidio	Fluopicolide	Inhibits cell division	43	Blue mold
Quadris, Satori, AzoxyStar, Azoxy 2SC	Azoxystrobin	Inhibit cellular respiration	11	Target spot, frog-eye, blue mold

these fungicides are more prone to development of resistance in pathogen populations, and include fungicides in groups 11, 43, and 40. Fungicides with **multi-site** modes of action, such as those in group M3, are effective on multiple points of the pest lifecycle, and are less prone to development of resistance, yet many of these are protectant fungicides with no systemic activity. An exception is Actigard, which induces the plant's own defenses against infection by pathogens, resulting in systemic activity yet a low potential for resistance.

PRACTICAL EXAMPLE: BLUE MOLD MANAGEMENT

Guidelines for designing a tobacco fungicide program for blue mold management are shown as an example in TABLE 2. Several products are listed for the 'sample program choice,' with the single best choice based on individual

farm choices. For example, growers whose last application in the floathouse was Quadris (to manage target spot) would be ill-advised to use any azoxy fungicide as their first field application, for concerns about developing resistance to the azoxystrobins. However, a grower with frogeye pressure would want to incorporate an azoxystrobin product by the second application, to address both blue mold and frogeye disease concerns (TABLE 1). Other fungicides, such as Manzate ProStick, are not recommended close to harvest as a result of concerns about residues and the mandatory preharvest interval (TABLE 2). The preharvest interval, which is found on the product label, should be adhered to for all fungicides used.

By using alternate modes of action, growers may preserve the efficacy of fungicides as powerful disease management tools for many growing seasons to come.



FIGURE 2. ORANGE-YELLOW LESIONS ON TOP SURFACES OF TOBACCO LEAVES IN THE FIELD.

TABLE 2. SAMPLE FOLIAR DISEASE MANAGEMENT PROGRAM FOR BURLEY FIELDS UNDER MODERATE TO HIGH THREAT OF TOBACCO BLUE MOLD. LABEL INSTRUCTIONS, INCLUDING SAFETY PRECAUTIONS AND TANK MIX PARTNERS, SHOULD ALWAYS BE FOLLOWED IN THE USE OF ANY PESTICIDE, AND SUPERSEDE INFORMATION PRESENTED HERE.

Timing	Potential product choices	Sample program choice	Rate	FRAC group
1-2 weeks post-transplant	Manzate ProStick, Agri-Mycin, Ag Streptomycin, Harbour, Aliette, Forum, Revus, Presidio, Quadris, Satori, AzoxyStar, Azoxy 2SC	Forum/Revus <u>OR</u>	8 oz / A	40
		Presidio <u>OR</u>	4 oz / A	43
		Quadris/Satori/Azoxy	8 oz / A	11
CHANGE FRAC GROUP				
3 weeks post-transplant	Actigard, Aliette, Agri-Mycin, Ag Streptomycin, Harbour, Manzate ProStick, Forum, Revus, Presidio, Quadris, Satori, AzoxyStar, Azoxy 2SC	Manzate ProStick <u>OR</u>	1.5 lb / A	M3
		Quadris/Satori/Azoxy <u>OR</u>	8 oz / A	11
		Presidio <u>OR</u>	4 oz / A	43
		Forum/Revus	8 oz / A	40
CHANGE FRAC GROUP				
5 weeks post-transplant	Actigard, Aliette, Agri-Mycin, Ag Streptomycin, Harbour, Manzate ProStick, Forum, Revus, Presidio, Quadris, Satori, AzoxyStar, Azoxy 2SC	Actigard	0.5 oz / A	P1
CHANGE FRAC GROUP OR RETURN TO GROUP USED IN FIRST APPLICATION				
7 weeks post-transplant	Actigard, Aliette, Agri-Mycin, Ag Streptomycin, Harbour, Forum, Revus, Presidio, Satori, AzoxyStar, Azoxy 2SC	Forum/Revus <u>OR</u>	8 oz / A	40
		Presidio <u>OR</u>	4 oz / A	43
		Manzate ProStick	1.5 lb / A	M3
CHANGE FRAC GROUP OR RETURN TO GROUP USED IN SECOND APPLICATION				
9 weeks post-transplant	Aliette, Agri-Mycin, Ag Streptomycin, Harbour, Forum, Revus, Presidio, Quadris, Satori, AzoxyStar, Azoxy 2SC	Quadris/Satori/Azoxy <u>OR</u>	8 oz / A	11
		Presidio <u>OR</u>	4 oz / A	43
		Forum/Revus	8 oz / A	40

ADDITIONAL RESOURCE

Some Principles of Fungicide Resistance (PPFS-MISC-02)

<https://plantpathology.ca.uky.edu/files/ppfs-misc-02.pdf>

By Dr. Paul Vincelli; provides detailed information on the general topic of resistance to fungicides.

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