SDSU Extension

agronomy

JANUARY 2019

SOUTH DAKOTA STATE UNIVERSITY®
AGRONOMY, HORTICULTURE & PLANT SCIENCE DEPARTMENT

Fungicide Resistance: Risk and Management

Emmanuel Byamukama | Assistant Professor & SDSU Extension Plant Pathologist Dalitso Yabwalo | Research Associate
Shaukat Ali | Associate Professor, Small Grains Plant Pathology Connie Tande | SDSU Extension Plant Diagnostician
Connie Strunk | SDSU Extension Plant Pathology Field Specialist Ryan Hopkins | Graduate Research Assistant
Nathan Braun | Senior Ag Research Tech Febina Mathew | Assistant Professor

What is fungicide resistance?

Fungicide resistance can be defined as when a pathogen population is no longer sensitive or has reduced sensitivity to the fungicide that used to control the same pathogen.

How does fungicide resistance develop?

Figure 1 shows an example of how fungicide resistance develops. As seen in the first pentagon, spores produced by the pathogen are present in two different colors. The difference in spores arises naturally through random processes such as mutation. The blue spores represent those that are sensitive to a fungicide and the red spores are those that are resistant to the fungicide. When the fungicide is applied to the field, it applies a selection pressure and fewer blue spore are seen (as shown in the third pentagon). The red spores remain and can re-infect the host to cause disease. Upon repeated application of the same fungicide, the red spores are not affected by the fungicide applied but blue spores get killed. Eventually, the fungicide resistant individuals dominate the population and the fungicide will no longer be effective.

Do all pathogens have the same potential/likelihood to develop resistance

Fungicide resistance may develop due to two main factors: the pathogen factors and the fungicide factors.

Pathogen factors - Fungicide resistance may develop in pathogens that have one or more of these factors – (1) produce a large number of spores; (2) go through sexual recombination; or (3) have a short generation time. These factors allow for high levels of genetic diversity and a greater chance of mutation within the pathogen population that could result into reduced sensitivity of the pathogen to a fungicide.

Fungicide factors - Examples of factors associated with fungicide that may increase the chances of pathogen developing resistance include: (1) the site of action, (2) frequency of application, (3) time of application, and (4) dose applied. Fungicides that have one mode of action tend to have a higher risk for resistance to develop (Table 1). Fungicides with multiple modes of action tend to have very low risk for fungicide resistance because when one site of action is avoided, the other sites will still be effective. Frequency of application can also increase probability for resistance to develop because with each application, only certain members of the population

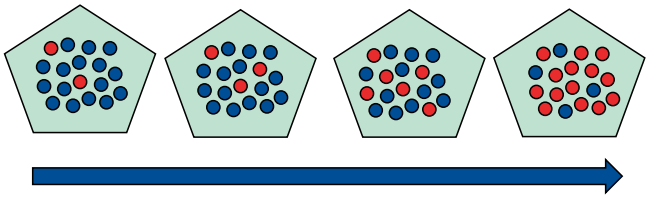

Figure 1. Illustration of how resistant isolates develop and increase as a result of selection pressure from repeated applications of fungicides.

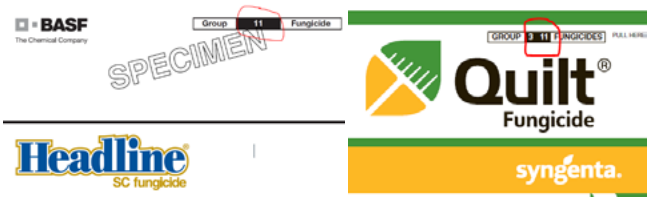

Figure 2. Examples of fungicide FRAC Codes (marked with red pen) for easy grouping of fungicides based on their modes of action.

are removed from the equilibrium. Similarly, applying a low dose or applying too late will also increase selection pressure.

The Fungicide Resistance Action Committee (FRAC), a group of scientists representing different chemical companies, was formed to provide fungicide resistance management guidelines for sustainable use of fungicides. This committee provides the likely risk of a given fungicide to become less effective based on the mode of action of the fungicide. The mode of action group or FRAC codes is always indicated on the fungicide label first page (Figure 2). Mode of action refers to the biochemical process through which the fungicide interferes with the normal functioning of a fungal cell. Fungicides that affect only a single site (single mode of action) tend to have a higher risk of resistance to develop while those with multiple sites tend to have a lower risk. Examples of common ingredients in fungicides registered in South Dakota, their groups and the risk for resistance fungicides to develop are shown in Table 1.

Do we have fungicide resistance in South Dakota?

While a comprehensive survey to detect fungicide resistant pathogen isolates has not yet been done, one soybean pathogen, *Cercospora sojina*, which causes frogeye leaf spot has been found to be resistant to QoI fungicides (quinone outside inhibitor, strobilurin, e.g. active ingredients in Headline and Quadris). The fungicide resistant isolates of *Cercospora sojina* were found in two fields in southeast South Dakota after repeated application of the QoI fungicide did not control the disease.

Based on USDA-NASS estimates, only a few acres of corn and soybean are treated with a fungicide compared to wheat in South Dakota. However, given that just three classes of fungicides or mixtures: FRAC code 11 (QoI, strobilurin), FRAC Code 7 (SDHI) and FRAC code 3 (DMI, including triazoles) (Table 1) are the most frequently used fungicides, it is possible that fungicide resistant pathogen population may exist but perhaps in low numbers to be detected or to cause total fungicide failure at this time. The continued use of the same modes of action over time may lead to further fungicide resistance development in the state.

How to avoid or delay fungicide resistance development

- Use agronomic practices such as planting resistant varieties, crop rotation, drainage, proper soil fertility levels, in order to reduce the severity of diseases with less use of fungicides.
- Rotate different modes of action. Applying one group of fungicides exclusively can lead to selection pressure allowing the less sensitive fungal population to dominate. Use pre-mixed or tank mix fungicides with different modes of action to delay or avoid development of fungicide resistance.
- Avoid multiple applications within the same season. Scout regularly and apply a timely treatment when warranted to avoid re-application. Applying too late or applying too early may reduce the effectiveness of the fungicide. Follow the label instructions for resistance management and which fungicide should be applied for repeat treatment.
- Follow manufacturer's recommended application rate. Applying a reduced rate may knock off weaker members of the population, leading to insensitive members of the population to thrive.
- Scout fields that were treated with a fungicide to determine if the disease was controlled as expected or if there are signs of reduced sensitivity. Send a sample to the SDSU Plant Diagnostic Clinic for suspected fungicide resistance development. Clinic mailing address: SDSU Plant Diagnostic Clinic, Plant Science Building 153, Jackrabbit drive, Brookings SD 57007.

Table 1. FRAC Codes and risk of fungicide resistance for some of common active ingredients registered in South Dakota

FRAC Code	Mode of action	Fungicide group	Resistance risk	Ingredient examples	Examples of trade products with active ingredient
1	Mitosis and cell division interference	Methyl Benzimidazole Carbamates (MBC)	High	thiabendazole	Mertect 340-F, Agri-Star
				thiophanate-methyl	Incognito 85 WDG, Protocol, Topsin M 70WP, Topsin M WSB
3	Demethylase enzyme in sterol biosynthesis inhibition	DeMemethylation Inhibitors (DMI, triazoles)	Medium	cyproconazole	Alto 100 SL, Aproach Prima, Azure
				difenoconazole	Dyna-Shield, CruiserMaxx, Dividend Extreme, Miravis Top,
				flutriafol	Topguard, Fortix
				ipconazole	Acceleron DX-509, Inovate, Rancona, Warden Cereals
				metconazole	Caramba, Quash, Nipsit Suite Cereals
				myclobutanil	Acceleron DT-510, Agri-Star
				tebuconazole	AmTide Tebuconazole, Evito T, Monsoon, Onset 3.6L, Prosaro 421 SC, Raxil 2.6F, Sativa 309 FS
				tetraconazole	Affiance, Priaxor D
				prothioconazole	Delaro 325 SC, Proline 480 SC, Propulse, Stratego YLD
				propiconazole	AmTide Propiconazole, Avaris, Fitness, PropiMax, Tilt, Topaz
4	Nucleic acid synthesis interference	PhenylAmides (PA)	High	metalaxyl	Acquire, Allegiance FL, Belmont 2.7 FS, Dyna-Shield Metalaxyl, Dyna-Shield Metalaxyl 318 FS, MetaStar ST, Sebring 318 FS, Sebring 480 FS
				mefenoxam	Apron XL, Ridomil Gold GR, Ridomil Gold SL
7	Respiration interference	Succinate dehydrongenase inhibitors (SDHI)	Medium to High	boscalid	Endura, Pristine
				carboxin	Enhance, Rancona, Vitaflo-280
				fluopyram	ILeVo, Luna, Propulse
				fluxapyroxad	Systiva XS, Acceleron DX-612, Nexcor, Priaxor D
				penflufen	Evergol
				penthiopyrad	Fontelis, Vertisan
				sedaxane	Vibrance, Warden
11	Respiration interference	Quinone outside Inhibitors (QoI, strobilurin)	High	azoxystrobin	Aframe, Amstar, Azoxystar, Dynasty, Quadris, Quilt, Satori, Trevo
				fluoxastrobin	Aftershock, Evito 480 SC, Fortix, Zolera
				picoxystrobin	Aproach, Aproach Prima
				pyraclostrobin	Headline, Acceleron DX-109, Priaxor, Pristine, Stamina
				trifloxystrobin	Acceleron DX-709, Compass, Stratego, Trilex Flowable
12	Signal transduction interference	PhenylPyrroles (PP)	Low to medium risk	fludioxonil	Dyna-Shield Fludioxonil, Maxim, Spirato 480 FS
44	Microbial disrupters of pathogen cell membranes	Microbial	Resistance not known	bacillus spp	Aveo EZ, Poncho/VoTiVo, Clariva

FRAC Code	Mode of action	Fungicide group	Resistance risk	Ingredient examples	Examples of trade products with active ingredient
49	Lipid metabolism interference	Oxysterol binding protein homologue inhibition (OSBPI)	Medium to High	oxathiapiprolin	Lumisena, Plenaris
M	Multi-site activity	Multi-site	Low	copper	Badge SC, Champ WG, Kocide 2000,
				mancozeb	Dithane 75DF, Dithane M-45, Manzate Pro Stick, Penncozeb 75DF
				thiram	42-SThiram, Protector-D, Signet 480 FS, Vitaflo-280
				maneb	Dithane M-45;
				chlorothalonil	Bravo, Chloronil 720. Equus, Muscle
				captan	Captan 4L, Captan 80 WDG, Enhance