Factors in the Success or Failure of Foliar Fungicide Application

Many factors may affect the success of a foliar fungicide application. Decisions made before or during the application can affect the response to the fungicide, and the environmental conditions present during and after the application also can affect the outcome. The following sections address possible factors in the success or failure of a fungicide application.

Preapplication Factors

Lack of Yield-Limiting Disease

Some fungicides are applied in the absence of significant disease pressure or disease threat. Research indicates that foliar fungicide applications made in low-disease environments may not result in economic yield increases. Additionally, preventive applications may not be profitable if the disease does not develop because of unfavorable weather conditions following application.

For example, the response to foliar fungicides applied to corn varies depending on the disease level. Fungicide applications increased yield by almost 10 bushels per acre (629 kg/ha) when disease severity was greater than 5% on the ear leaf at the early dent stage of corn development. In contrast, yield returns from fungicide applications averaged less than 2 bushels per acre (126 kg/ha) when disease severity was below 5% at the same stage of development (Table 5).

Moreover, not all of the diseases present on a plant may be of economic consequence. Some diseases are common yet rarely cause yield loss. Examples include common rust on corn and peanut and brown spot on potato and soybean (Fig. 24).

![Fig. 24. Some diseases, such as brown spot on soybean, are common yet rarely cause yield loss. (Courtesy Daren S. Mueller)](image-url)

**TABLE 5.** Corn yield response to quinone outside inhibitor (QoI) fungicides: 2008–2010

<table>
<thead>
<tr>
<th>Disease Severity of Untreated Crop</th>
<th>Mean Yield Response</th>
<th>Total Treatments</th>
<th>Treatments with Break-Even Yield Response&lt;sup&gt;c&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;5%</td>
<td>1.5 bushels/acre (94.4 kg/ha)</td>
<td>347</td>
<td>31.6%</td>
</tr>
<tr>
<td>&gt;5%</td>
<td>9.6 bushels/acre (603.8 kg/ha)</td>
<td>266</td>
<td>59.0%</td>
</tr>
</tbody>
</table>

<sup>a</sup>Used with permission from Wise and Mueller (2011).

<sup>b</sup>Data are pooled across all treatments that included a QoI mode of action and were applied between V15 and R3 growth stages. Data include only trials for which disease severity ratings were submitted.

<sup>c</sup>Break-even yield response = 6.0 bushels/acre (377.4 kg/ha).
**Incorrect Diagnosis**

One reason for foliar fungicide failure is inaccurate disease diagnosis. With an incorrect diagnosis, a fungicide may be selected that does not manage the targeted disease. Common problems that may be misidentified as fungal diseases include insect damage, chemical injury, bacterial disease, root damage from nematodes, genetically induced leaf spots, and environmental damage (Fig. 25).

**Fungicide Storage**

Maintaining proper storage conditions is important, because outdated or improperly stored fungicide materials may lose their activity and fail to work (Fig. 26). Fungicides stored longer than 2 years or under improper conditions (such as extreme cold) may lose their activity. Some flowable fungicides tend to settle out in containers over time (Fig. 27). To help ensure the proper dosage of active ingredient, container contents must be mixed thoroughly before dispensing the fungicide into the sprayer.

**Fungicide Selection**

Even if the problem is accurately diagnosed as a fungal disease, foliar fungicides do not manage all fungal diseases or vary in the level of efficacy with which they control specific diseases. Product labels specify the disease organisms that may be managed by particular fungicides, and resources from extension services are available to help select the fungicides that are most effective against certain diseases.

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**Fig. 25.** Disease look-alikes, such as herbicide injury (top) and physiological symptoms (bottom), make correct diagnosis important. (Courtesy Kiersten A. Wise)

**Fig. 26.** Maintaining proper storage conditions is important for ensuring fungicide viability. (Courtesy Nicholas S. Dufault)

**Fig. 27.** Some flowable fungicides tend to settle out in containers over time. (Courtesy Kiersten A. Wise)
Factors During the Spraying Process

Fungicide Rates
Fungicides should be used at the recommended rates for effective disease management. Product labels may list a range of rates, and a specific recommended rate may be available that falls within this range. These rates or ranges are based on multiple-year and multiple-location testing to establish the most effective amount of product to use under a wide variety of environmental conditions. Given this, recommended rates may vary based on the disease or geographic location. Applying a fungicide below the recommended rate may result in inadequate disease control in some situations and possibly the development of resistant strains of the pathogen.

Proper Mixing
The treatment area and the amount of product to add to the mixing tank should be carefully calculated. Errors in calculation can result in ineffective disease control, damage to crops, and excessive fungicide costs.

Mixing fungicides with water that is too acidic or too alkaline can reduce fungicidal activity, especially for water with a pH greater than 8. Ideally, water with a pH near 7 should be used for mixing pesticides. If water pH is not favorable, it can be corrected with pH buffers, which are added to the water before mixing in fungicides.

Mixing multiple pesticides in a spray tank can save time, but the compatibility of the products should be tested. Incompatibility can result in the formation of insoluble precipitates in the spray tank. Product labels often contain information on mixing compatibility. If a label does not address compatibility, a small volume of the spray mix should be tested in a glass jar for 30 minutes; separation or settling of pesticides in the jar indicates incompatibility.

Fungicides begin to lose their activity if they sit too long in the spray tank. Fungicide activity often declines within 12 hours after mixing, and this process is accelerated by poor water quality (for instance, sediment, high or low pH).

Sprayer Calibration and Application
The most common cause of foliar fungicide application failure is likely incorrect sprayer calibration. If a sprayer is not properly calibrated, too much or too little fungicide can be applied, resulting in plant injury or poor disease management. To avoid these problems, sprayers should be recalibrated after any modification to the nozzle, pressure, or speed (Fig. 28). Calibrating and adjusting a sprayer takes time and effort, but doing so can save money and make fungicide applications more effective.

Order for Adding Formulations
The order in which pesticides of different formulations are added to the tank can affect compatibility. Different formulations should be added to the tank in the following order:

1. activators or compatibility agents
2. wettable powders (WP) and dry flowables (DF)
3. water-soluble concentrates (WSC or SC)
4. emulsifiable concentrates (EC)
5. soluble powders (SP)
6. adjuvants or spray additives

Fig. 28. Sprayers should be properly calibrated before use. (Courtesy Tristan Mueller)
Factors in the Success or Failure of Foliar Fungicide Application

Fungicides should be applied in the recommended volume of water, as well as at a constant speed and at the recommended pressure. Spray pressure should be adjusted for the type of nozzle used. It is important to note that the recommended pressures for fungicide applications are often different from the recommended pressures for herbicides. When preparing to apply a fungicide with equipment that is used to apply both herbicides and fungicides, the applicator should verify that the pressure and nozzle have been adjusted to optimize fungicide application. Excessively high sprayer pressure produces small droplets (less than 100 microns), which may drift from the targeted area. To avoid sprayer misses or overlap between field passes, boom width and height must be measured carefully and drive rows must be adjusted.

Application Timing

Avoiding yield loss requires applying fungicides at an appropriate time to limit disease development. Foliar fungicides typically have 14–21 days of activity, so they must be applied at the correct growth stage and prior to or at the onset of disease to maximize efficiency.

The application window varies by crop and disease, and in some instances, only a narrow window may be available for the fungicide to be effective. Examples include the wheat disease Fusarium head blight (Fig. 29) and the soybean disease white mold. In each case, a specific growth stage must be protected, and applications that are not made at that stage will be less effective or ineffective. Fungicides that are applied too early may break down prior to disease development or not provide coverage on new growth that requires protection. Fungicides that are applied after diseases can easily be found may not provide satisfactory or economical disease control.

Environmental Considerations

Environmental conditions during or immediately after foliar fungicide applications influence the final outcome. Applications made when temperatures exceed 90°F (32°C) and when humidity is low (less than 50%) may result in excessive evaporation of small droplets as they leave the nozzle. Also, spraying during windy conditions decreases efficacy because of product drift from the targeted area.

Foliage should be dry at the time fungicides are applied, as dew or rain on foliage can cause the product to become diluted or run off. Rain or irrigation within a few hours after application may wash off some product; fungicides differ in how quickly they become rainfast. A general rule for the amount of time needed between application and a rainfall event is that systemic fungicides need a minimum of 3 hours to dry on the plant surface. Contact fungicides are always sensitive to rain removal but more so before drying occurs on plant surfaces.

Postapplication Factors

Resistance

Fungicide resistance is a cause of fungicide failure but not the most likely reason a fungicide fails to control a disease. The only way to be certain of the presence of a fungicide-resistant pathogen in the field is to have the pathogen tested in a qualified lab. (A more complete discussion of fungicide resistance is provided in Part III.)

Phytotoxicity

Excess rates of fungicides and applications of fungicides under extreme environmental conditions can burn leaves or stunt plants in some field crops. Phytotoxicity can be avoided by applying fungicides at the recommended rates and according to label directions. Fungicides applied during hot weather can cause plant damage, in some instances.

Fig. 29. Fungicides should be applied at the appropriate time to maximize effectiveness, especially for diseases such as Fusarium head blight. (Courtesy Marcia McMullen)
The additives included in fungicide applications can also cause damage in field crops that is sometimes perceived as fungicide failure. A recent example of this is arrested ear development in corn (Fig. 30), which has been linked to pretassel applications of nonionic surfactants. Fungicide and additive product labels must be checked before application to determine the proper rates and uses of additives.

**Field Variability**

In some cases, farmers may feel that fungicides have failed, because yields of treated areas or fields are not higher than those of untreated areas or fields. This lack of perceived success occurs most frequently in fields with greater spatial variability and when disease severity is minimal. When natural variability in a field is greater than the expected yield response, it is difficult to sort out small yield responses or perceived yield losses caused by fungicide application.

The discrepancy in corn yield responses in low- and high-disease environments (Table 5, page 20) exemplifies how difficult it is to identify a small yield response if the spatial variability of a particular field exceeds 2 bushels per acre (126 kg/ha), which is the average yield response when foliar disease severity is low. If variability in a field is much greater than that, then the perception may be that fungicide application has caused a yield loss, depending on where the treated areas lie within the field.

*Fig. 30. Arrested ear syndrome on corn caused by additives for foliar applications. (Courtesy Nathan Stetzel)*