Are fungicides effective against Phomopsis stem canker?

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BACKGROUND

- Phomopsis stem canker caused by multiple species of *Diaporthe* (Mathew et al. 2018)

- Cause yield losses ≥40% (Debaeke et al. 2003) and oil content up to 25% (Acimovic 1986).

Picture by Dr. Sam Markell
North Dakota State University

BACKGROUND

- Current management options (Mathew et al. 2018):
  - Commercial hybrids with partial resistance
  - A four-year crop rotation with non-hosts
  - Weed management
  - Tillage

BACKGROUND

- On sunflower, three foliar fungicide groups labeled for in the U.S. (Friskop et al. 2017)
  - FRAC 3 (DeMethylation inhibitors, DMI),
  - FRAC 7 (Succinate-dehydrogenase inhibitors, SDHI),
  - FRAC 11 (quinone outside inhibitors, QoI).

RESEARCH JUSTIFICATION

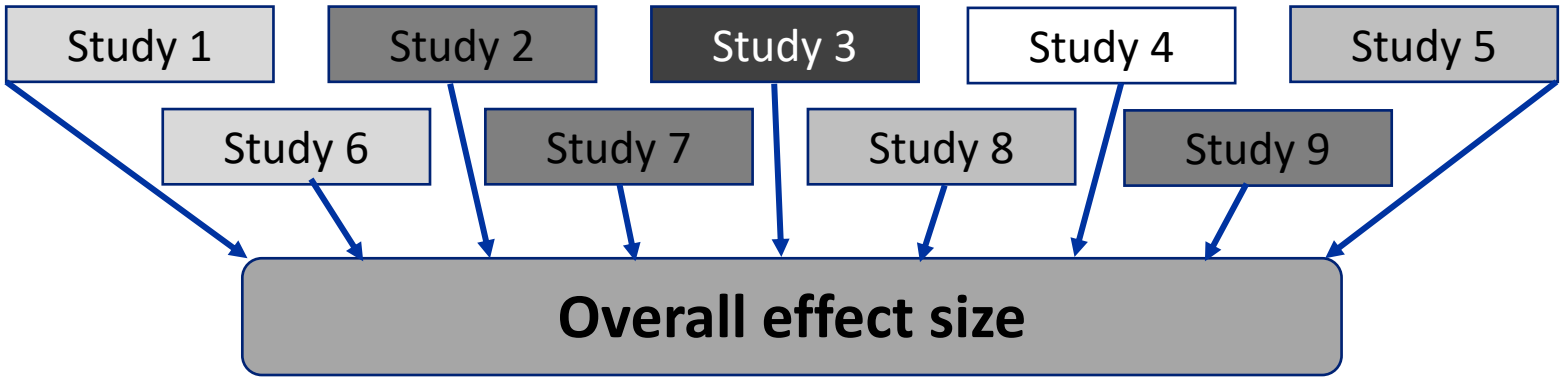
- Prophylactic application
  - Increase production costs
  - May reduce “return on investment”
- Yield gains from foliar fungicide applications **not consistent** across locations-years or fungicide products

RESEARCH JUSTIFICATION

- Meta-analyses used to synthesize results from several field trials to determine the fungicide effectiveness against Phomopsis stem canker.

Meta-analysis

- Meta-analysis combines a large number of studies to analyze results
- Increases the statistical power.



OBJECTIVES

(i) Evaluate the efficacy of multiple fungicide groups against Phomopsis stem canker

(ii) Evaluate the probability of effective fungicide application in the presence of Phomopsis stem canker.

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MATERIALS AND METHODS

Field experiments

- Fungicide trials conducted in Minnesota, Nebraska, North Dakota, and South Dakota
- Year 2009, 2015 - 2020
- Hybrids - susceptible and partially resistant oils
  - susceptible and partially resistant non-oils
- A total of 79 location-years.

MATERIALS AND METHODS

Field experiments

- Trials in rain-fed areas.
- Each trial : RCBD, replication ≥ 3.
- 6 fungicide groups (21 individual active ingredients) and no-fungicide control (NTC)
- Fungicide application at R1

Picture by Dr. Sam Markell
North Dakota State University

MATERIALS AND METHODS

Field experiments.

- All fungicides applied at labelled rates with a non-ionic surfactant [Induce]
- CO_2-powered backpack sprayer (flat-fan nozzle, nozzle pressure of 30 psi and water volume of 20GPA to 30 GPA) or a tractor drawn boom sprayer (flat-fan nozzle, nozzle pressure of 30 psi and water volume of ~30 GPA)
- Followed a common protocol

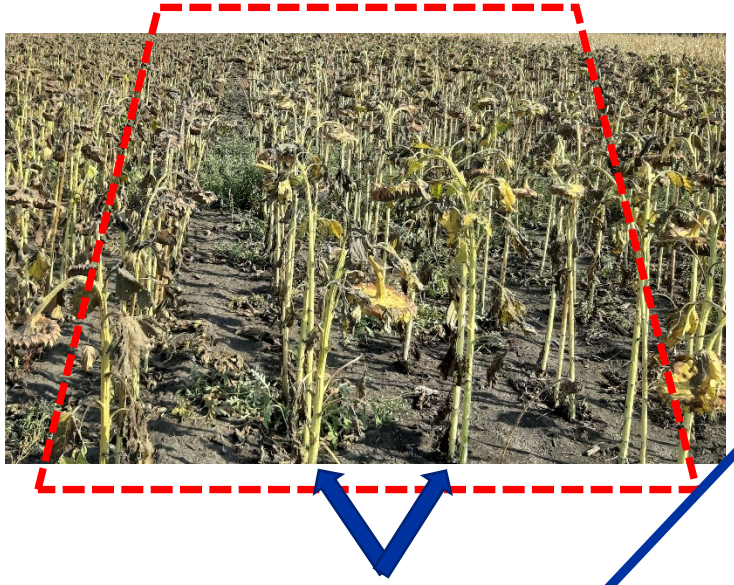
MATERIALS AND METHODS

Field experiments.

- Natural pressure of Phomopsis stem canker.

- Disease
  - 10-20 plants
  - R7 - R9
  - Disease rating scale: 0-to-4 (Debaeke et al. 2003) or 0-to-5 (Mathew et al. 2015).

MATERIALS AND METHODS



Disease scoring

and harvesting

- Disease severity index (DSI) calculated as

$$\text{DSI (\%)} = \frac{\sum(P \; x \; Q)}{(M \; x \; N)} \times 100$$

- For yield, grain moisture content adjusted to 10% (Duffeck et al. 2020).

MATERIALS AND METHODS

- Each field trial was considered an independent study.

- Selection criteria:
  a) DSI was at least 5% in one or more NTC plots
  b) Both DSI and yield were recorded at each plot
  c) The range of DSI and yield was at least 2% between the largest and smallest value (Madden and Paul 2009).

MATERIALS AND METHODS

- Among the 79 trials, 49 trials were used for data analyses

Effect size for DSI and yield calculated

- Effect size is a quantitative measure of the magnitude of the experimental effect.

- A significant *p*-value tells us that an intervention works, whereas an effect size tells us how much it works.

"**metafor**" package of R

McLeod, S. A. (2019). What does effect size tell you? Simply psychology: https://www.simplypsychology.org/effect-size.html

Cohen's *f*

$$f = \frac{\sigma_m}{\sigma} \qquad \sigma_m = \sqrt{\frac{\sum(m_i - \bar{m})^2}{k}}$$

Where, *k* = number of sample groups, m_i = mean of group *i*, $\bar{m}$= mean of k sample means, and σ = pooled SD of k sample groups

Cohen's f is interpreted as how many standard deviation units the means are from the grand mean

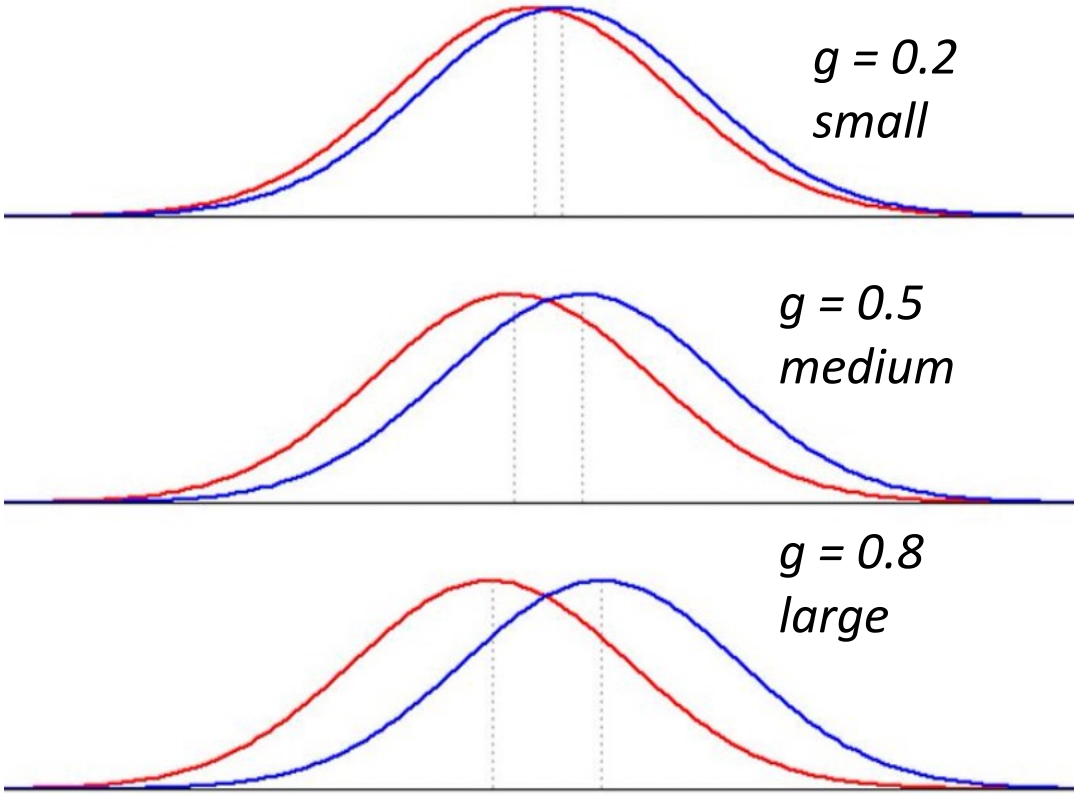
f	effect
0.10	small
0.25	medium
0.40	large

(Cohen 1988)

Hedges' g

- $g = \frac{\mu_T - \mu_{NTC}}{\sqrt{\sigma_{Pooled}}}$ $\quad S_{pooled} = \sqrt{\frac{(n_T - 1)SD_T^2 + (n_{NTC} - 1)SD_{NTC}^2}{n_T + n_{NTC} - 2}}$

For Cohen's d or Hedges g



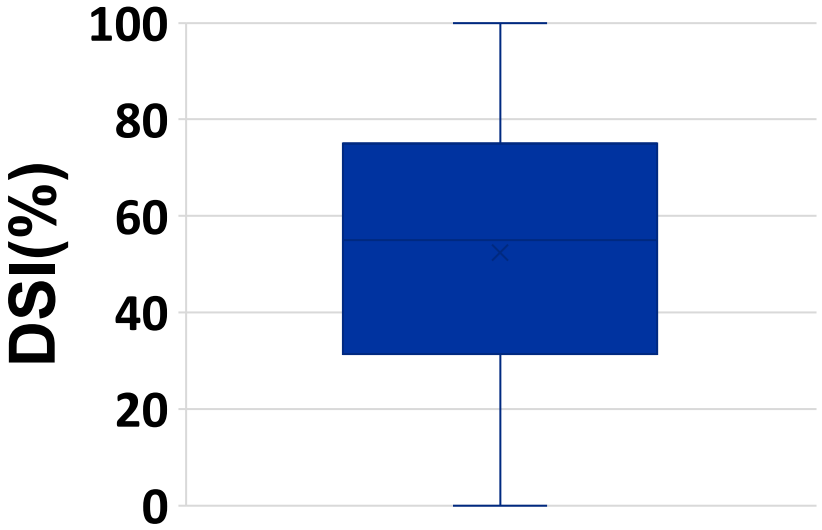
A *g* of 1 indicates the two groups differ by 1 standard deviation and so on.

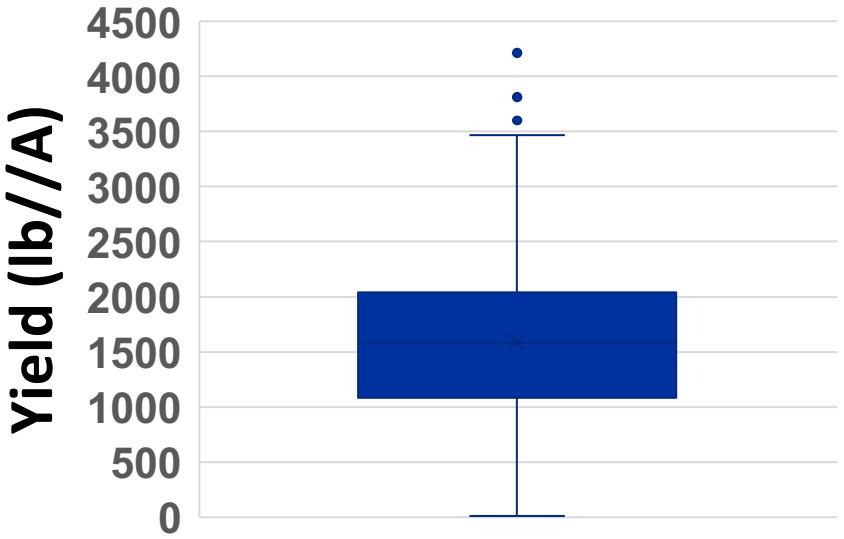
If g<0.2 standard deviations, the difference is negligible.

(Cohen 1988).

RESULTS

DSI and grain yield on NTC plots





Av. DSI= 52.4%

Av. yield = 1588 lb/A

RESULTS

- For DSI, the extent of disease severity reduction varied among trials, *f* ranging from -0.09 to -1.95.

- Of the 48 trials, 70.83% had large effect of disease reduction when fungicides were applied.

Summary table for Hedges' *g* on DSI

Fungicide group[a]	k[b]	Hedges' g	95% CI
QoI	**45**	**-0.47**	**[-0.70; -0.24]***
DMI	7	-0.10	[-0.75; 0.54]
SDHI	9	-0.21	[-0.71; 0.29]
QoI + DMI	4	-1.04	[-2.51; 0.42]
DMI + SDHI	2	-0.73	[-1.60; 0.15]
SDHI + QoI	13	-0.32	[-0.87; 0.22]
DMI + SDHI + QoI	**3**	**-0.79**	**[-1.53; -0.05]***
Others	3	-0.54	[-2.15; 1.07]

[a]QoI= Quinone inside inhibitors; DMI= DeMethylation inhibitors; SDHI= Succinate dehydrogenase inhibitors; Others included Quinone outside inhibitor, stigmatellin binding type (QoSI), CAA= Carboxylic acid amides (CAA) or Amines.

[b]k is the number of studies combined to determine the effect size.

RESULTS

- For yield, the extent of yield increase varied among trials, with *f* ranging from 0.05 to 1.44.

- Of the 49 trials, 71.43% of the trials had large effect of yield increase when fungicides were applied.

Summary table for Hedges' *g* on yield

Fungicide group[a]	k[b]	Hedges' g	95% CI
QoI	**46**	**0.41**	**[0.18; 0.63]***
DMI	7	0.10	[-0.51 0.70]
SDHI	9	0.03	[-0.55; 0.60]
QoI + DMI	4	0.26	[-0.52; 1.04]
DMI + SDHI	2	-0.50	[-1.65; 0.64]
SDHI + QoI	13	0.25	[-0.10; 0.60]
DMI + SDHI + QoI	**3**	**0.94**	**[0.18; 1.70]***
Others	3	-0.21	[-1.42; 1.01]

[a]QoI= Quinone inside inhibitors; DMI= DeMethylation inhibitors; SDHI= Succinate dehydrogenase inhibitors; Others included Quinone outside inhibitor, stigmatellin binding type (QoSI), CAA= Carboxylic acid amides (CAA) or Amines.

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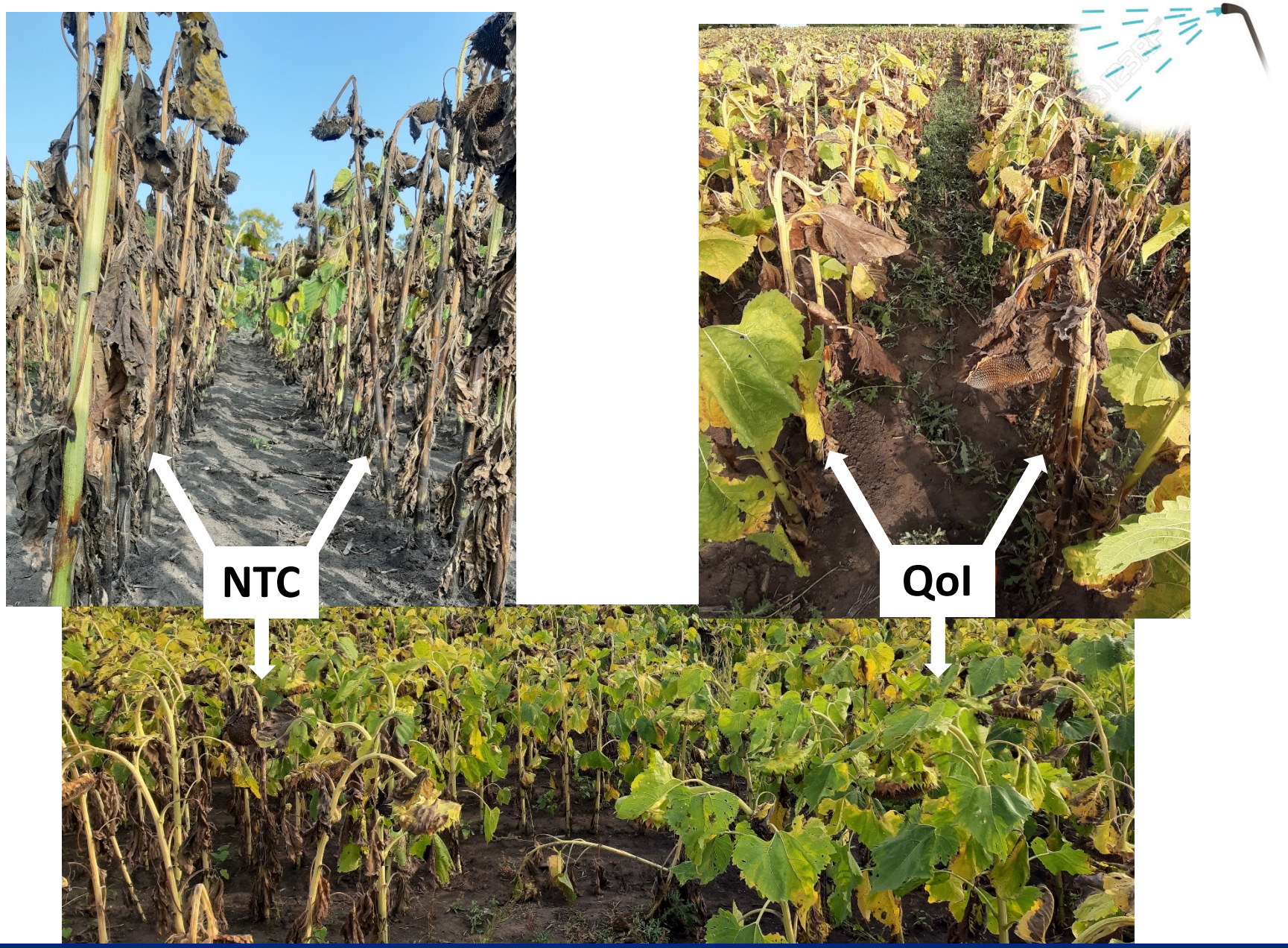
NTC
QoI

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PROBABILITY OF EFFECTIVE FUNGICIDE APPLICATIONS

- Price for Headline averaged across three SD retailers ($128/gal)

- Estimated machinery and labor costs
  ground applications: **$6.8/A**
  aerial applications **$10.5/A**

(Courtesy: South Dakota Oilseeds Council)

PROBABILITY OF EFFECTIVE FUNGICIDE APPLICATIONS

- Price of sunflower for the year 2020 was **$18.7/cwt for oil type** and **$26.3/cwt for non-oil type** (USDA-NASS 2021).

$$\textbf{Break-even yield } (lb/A) = \frac{Cost_{Fung} + Cost_{App}}{Price}$$

$Cost_{Fung}$ = fungicide cost (in $/A)
$Cost_{App}$ = machinery and labor cost for fungicide application (in $/A)
Price = Sunflower grain price (in $/A)

(Acharya et al. 2019)

PROBABILITY OF EFFECTIVE FUNGICIDE APPLICATIONS

$$\boldsymbol{Net\ return}\ (\$/\boldsymbol{A}) = \boldsymbol{Price}\ (\boldsymbol{Yi_{Fung}} - \boldsymbol{Yi_{NTC}}) - (\boldsymbol{Cost_{Fung}} + \boldsymbol{Cost_{App}})$$

Price = Sunflower grain price (in $/lb)
Yi_{Fung} = yield obtained from fungicide application (in lb/A)
Yi_{NTC} = yield obtained from nontreated control (in lb/A)
$Cost_{Fung}$ = fungicide cost (in $/A)
$Cost_{App}$ = machinery and labor cost for fungicide application (in $/A)

(Acharya et al. 2019; Lopez et al. 2015)

PROBABILITY OF EFFECTIVE FUNGICIDE APPLICATIONS

- Break-even yield (lb/A) for Headline 6 oz/A ($128/gal)

	Ground (lb/A)	Aerial (lb/A)
Non-oil	48.5	62.7
Oil	68.2	88.2

PROBABILITY OF EFFECTIVE FUNGICIDE APPLICATIONS

- Net-return ($/A) for Headline 6 oz/A ($128/gal)

Oil	Ground ($/A)	Aerial ($/A)
Susceptible	7.5 to 144.8 (77.8%)	3.7 to 141.0 (77.8%)
Partially-resistant	11.9 to 117.9 (80%)	8.1 to 114.2 (80%)

PROBABILITY OF EFFECTIVE FUNGICIDE APPLICATIONS

- Net-return ($/A) for Headline 6 oz/A ($128/gal)

Non-oil	Ground ($/A)	Aerial ($/A)
Susceptible	3.0 to 304.8 (75%)	13.1 to 301.1 (65%)
Partially-resistant	13.2 to 228.6 (50%)	9.5 to 224.8 (50%)

SUMMARY

- Application of foliar fungicides reduced DSI and increased yield

- Among the FRAC groups, application of QoI or QoI+DMI+SDHI is effective

SUMMARY

In oils, application of QoI resulted in:

- Positive break-even yield [68.2 lb/A (ground) and 88.2 lb/A (aerial)]
- Positive net return ($7.5 to $144.8/A)

In non-oils, application of QoI resulted in:

- Positive break-even yield [48.5 lb/A (Ground) and 62.7 lb/A (aerial)]
- Positive net return ($3.0 to 304.8/A).

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Acknowledgement

Ally Binger

Brian Kontz

Mackayln Fulton

Ruchika Kashyap

Nathan Braun

Renan Guidini

Karthika Mohan

Bijula Sureshbabu

Clay Carlson

Taylor Elverson

Scott Fitterer

Bryan Hansen

Michelle Gilley

Jessica Halvorson

Tyler Patrick

Allison Rickey

NDSU