Efficacy of foliar fungicides against *Phomopsis* in sunflower

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Outline

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Phomopsis stem canker

- Economically important disease of sunflower worldwide

(Harveson et al. 2016)

- Primarily caused by *Phomopsis gulyae* and *P. helianthi* in MN, ND and SD

(Elverson et al. 2020)

- More than 40% yield loss

(Mathew et al. 2015)

- Up to 25% reduction in oil content

(Acimovic 1986)

- Average prevalence – 58% in 2025

- North Dakota – 64% disease prevalence

(NSA Survey 2025)

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Symptoms of Phomopsis stem canker

Lesions on leaf

Stem lesions

Pith damage

Pictures by: Karthika Mohan
(Survey 2024 and 2025)

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Rationale

- Fungicides containing pyraclostrobin (QoI) are effective in the field, however, QoI fungicides possess high risk for fungicide resistance

(Kashyap et al. 2023; FRAC 2025)

- To accurately assess fungicide efficacy, essential to understand the relationship between the Phomopsis stem canker disease severity and yield

Research Objective

To evaluate the efficacy of fungicides with different modes of action within different yield environments under field conditions across MN, ND, NE, and SD

Objective 1

To characterize the relationship between Phomopsis stem canker severity and yield, and classify trials into yield environments

Details of trials

- Fungicide efficacy field trials between 2009 and 2021 (Kashyap et al. 2023; Dangal et al. 2023)
- Rain-fed areas (MN, ND, and SD) or irrigated areas (NE)
- At university farms or in farmer fields
- Fields with a history of Phomopsis stem canker
- Type of sunflower hybrid used and the weather variables varied

Field trials 2022 to 2025

- Field trials
    - Four states (MN (Crookston), ND (Grandin/Carrington), NE (Scottsbluff), and SD (Brookings)) in 2022, 2023, 2024 and 2025
- Using *Phomopsis*-susceptible sunflower hybrid
- In 2025 – Partially resistant hybrids also included at all locations
- Randomized complete block with ten treatments, including a non-treated control (NTC)
- Four replications per treatment

Treatments

Treatment	Active ingredients	Product	Company	Growth stage	Rate (fl oz/ A (mL/ha))
T1	-------	No fungicide control		---	---
T2	Pyraclostrobin (QoI)	Headline		R1	6 (438)
T3	Fluopyram (SDHI) + tebuconazole (triazole/DMI)	Luna experience	Bayer	V8	9 (658)
T4	Fluopyram + tebuconazole	Luna experience	Bayer	V8	9 (658)
	Pyraclostrobin	Headline		R1	6 (438)
T5	Fluopyram + tebuconazole	Luna experience	Bayer	R6	9 (658)
	Pyraclostrobin	Headline		R1	6 (438)
T6	Fluopyram + tebuconazole	Luna experience	Bayer	R1	9 (658)
T7	Fluopyram + tebuconazole	Luna experience	Bayer	R6	9 (658)
T8	Tebuconazole	Folicur	Bayer	V8	4 (292)
T9	Tebuconazole	Folicur	Bayer	R6	4 (292)
T10	Fluopyram + tebuconazole	Luna experience	Bayer	R1	9 (658)
	Pyraclostrobin	Headline		R6	6 (438)

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All the fungicide treatments were sprayed with adjuvants [NIS (0.25% V/V, Induce) and Crop oil (0.08% V/V, Interlock)]

Fungicide application

- Water volume of 15 gal/A (140 L ha^{-1})
- MN, NE, ND – Backpack sprayer, and SD - High-clearance sprayer
- Application speed - 3 km/h and boom height - 1.3 meters above the canopy)
- TeeJet (Spraying Systems Co., Wheaton, IL) flat fan nozzle tips with 40 psi pressure

Backpack sprayer

High-clearance sprayer

Disease rating and yield estimation

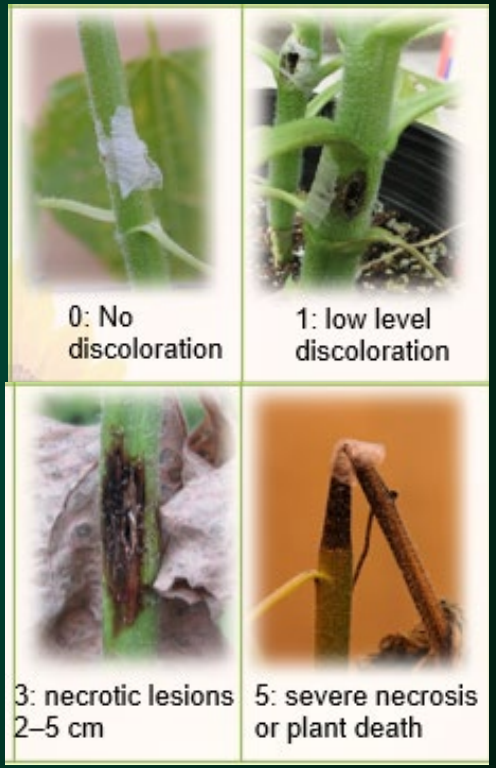
- After R6 growth stage
- Ten random plants from the two middle rows
- Disease scoring scale of 0 to 5 (Mathew et al. 2015)
- Disease severity index (DSI) was calculated

$$DSI\ (\%) = \sum \{[(P \times Q)/(M \times N)] \times 100\}$$

where, P = class frequency, Q = score of rating class,

M = total number of plants and N = maximal disease index (Chiang et al. 2017)

- Yield estimated after adjusting to 10 % moisture



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Data analysis

Relationship between DSI and Yield

- Fit a linear regression of yield on DSI using NTC data across 81 trials
- Includes field trials
  - From (2009–2021) (Kashyap et al. 2023; Dangal et al. 2023)
  - 18 trials (2022–2025)
- For each trial, calculate the residual = (observed yield – predicted yield)

Data analysis

Classification to yield environments

- Classify trials by residual standard deviation (SD)
  - Low-yield environment: residual < –1 SD (yield much lower than predicted)
  - High-yield environment: residual > +1 SD (yield much higher than predicted)
  - Moderate-yield environment: residual within ±1 SD (yield near predicted)

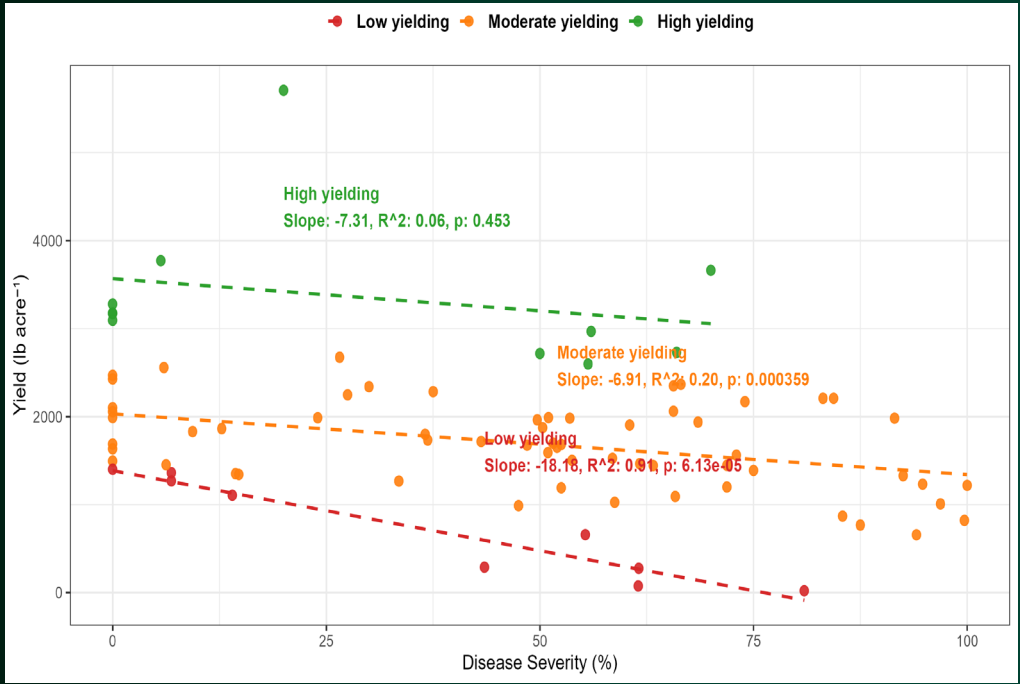
Relationship between DSI and yield

- Across the NTC plots (n = 81), yield decreased with increasing disease severity
- Overall relationship

$$\text{Yield (lbs acre}^{-1}) = 2277.31 - 10.38 \times \text{DSI} \; [R^2 = 0.135 \; (P<0.001)]$$

- Residual standard deviation = 816.4 lbs acre^{-1}
- Trials classified into three yield environments
  - Low yield (n=9) → residual was less than −816.4,
  - Moderate yield (n=61) → residual fell between −816.4 and +816.4
  - High yield (n=11) → residual was greater than +816.4

Residual defined yield environments



Fitted regression lines

- High yield [Yield=3567.76−7.31×DSI (%)] ($R^2 = 0.06$, $P = 0.453$)
- Moderate yield [Yield=2032.26−6.91×DSI (%)] ($R^2 = 0.19$, $P = 3.59\times10^{-4}$)
- Low yield [Yield=1386.08−18.18×DSI (%)] ($R^2 = 0.91$, $P = 6.13\times10^{-5}$)

In the low and moderate yield environment, one-unit increase in DSI resulted in significant yield reduction of 18.18 and 6.91 lbs acre^{-1} (P <0.0001) respectively

Yield environments of trials (2022 - 2025)

High yield environments	Moderate yield environment	Low yield environment
Crookston 2023 Grandin 2023 Grandin 2024 Scottsbluff 2022 Scottsbluff 2023	Brookings 2022 Brookings 2023 Brookings 2024 Brookings 2025 (Sus) Brookings 2025 (Res) Crookston 2022 Crookston 2024 Crookston 2025 (Sus) Crookston 2025 (Res) Scottsbluff 2024	Carrington 2025 (Sus) Carrington 2025 (Res)

Objective 2

To evaluate the efficacy of fungicide treatment within different yield environments under field conditions across MN, ND, NE, and SD

Analysis of data

- Separately for yield environments
- Linear mixed-effects model in R (using lme4) (Bates et al. 2015)
- Treatment as fixed effect
- Random effects: trial, block and treatment × trial interaction
- Models fit by restricted (residual) maximum likelihood (Patterson and Thompson, 1971; Harville, 1977)

Analysis of high yield environment trials

Treatments	Estimated marginal means	
	Yield (lbs acre^{-1})	DSI (%)
T1 - Non-treated control (NTC)	3174.0	58.40 a
T2 - Pyraclostrobin (6 fl oz/ A) at R1 growth stage	2790.0	50.55 abc
T3 - Fluopyram+ tebuconazole (9 fl oz/ A) at V8 growth stage	2921.0	47.20 bcd
T4 - Fluopyram+ tebuconazole (9 fl oz/ A) at V8 growth stage + pyraclstrobin (6 fl oz/ A) at R1 growth stage	3000.0	39.25 d
T5 - Pyraclostrobin (6 fl oz/ A) at R1 growth stage + fluopyram+ tebuconazole (9 fl oz/ A) at R6 growth stage	3107.0	43.85 bd
T6 - Fluopyram+ tebuconazole (9 fl oz/ A) at R1 growth stage	2893.0	41.40 d
T7 - Fluopyram+ tebuconazole (9 fl oz/ A) at R6 growth stage	2818.0	47.25 bcd
T8 - Tebuconazole (4 fl oz/ A) at V8 growth stage	2736.0	53.05 ac
T9 - Tebuconazole (4 fl oz/ A) at R6 growth stage	2820.0	51.45 abc
T10 - Fluopyram+ tebuconazole (9 fl oz/ A) at R1 growth stage + pyraclostrobin (6 fl oz/ A) at R6 growth stage	2764.0	47.05 bcd
Pr>F	**0.254**	**0.0002**

Treatments with fluopyram +tebuconazole at either V8/R1/R6 growth stage significantly reduced DSI (P=0.0002) by up to 33%

Analysis of moderate yield environment trials

Treatments	Estimated marginal means	
	Yield (lbs acre^{-1})	DSI (%)
T1 - Non-treated control (NTC)	1527.0 abc	49.5 ab
T2 - Pyraclostrobin (6 fl oz/ A) at R1 growth stage	1520.0 ab	43.3 c
T3 - Fluopyram+ tebuconazole (9 fl oz/ A) at V8 growth stage	1671.0 cde	49.5 ab
T4 - Fluopyram+ tebuconazole (9 fl oz/ A) at V8 growth stage + pyraclstrobin (6 fl oz/ A) at R1 growth stage	1762.0 e	42.2 c
T5 - Pyraclostrobin (6 fl oz/ A) at R1 growth stage + fluopyram+ tebuconazole (9 fl oz/ A) at R6 growth stage	1729.0 de	44.6 ac
T6 - Fluopyram+ tebuconazole (9 fl oz/ A) at R1 growth stage	1607.0 acd	44.5 ac
T7 - Fluopyram+ tebuconazole (9 fl oz/ A) at R6 growth stage	1520.0 ab	54.2 b
T8 - Tebuconazole (4 fl oz/ A) at V8 growth stage	1485.0 ab	48.0 abc
T9 - Tebuconazole (4 fl oz/ A) at R6 growth stage	1454.0 b	50.8 b
T10 - Fluopyram+ tebuconazole (9 fl oz/ A) at R1 growth stage + pyraclostrobin (6 fl oz/ A) at R6 growth stage	1597.0 abcd	43.7 ac
Pr>F	**0.0002**	**0.0007**

- Fluopyram+tebuconazole at either V8/R6 with pyraclostrobin (QoI) at R1 significantly increased yield (*P*=0.0002) by up to 15%.
- Pyraclostrobin (QoI) at R1 or with fluopyram+tebuconazole at R6 significantly reduced DSI (*P*=0.0007) by up to 12%.

Analysis of low yield environment trials

Treatments[w]	Estimated marginal means	
	Yield (lbs acre^{-1})	DSI (%)
T1 - Non-treated control (NTC)	280.0 a	66.5 a
T2 - Pyraclostrobin (6 fl oz/ A) at R1 growth stage	348.0 ab	56.0 ac
T3 - Fluopyram+ tebuconazole (9 fl oz/ A) at V8 growth stage	296.0 a	53.5 ac
T4 - Fluopyram+ tebuconazole (9 fl oz/ A) at V8 growth stage + pyraclstrobin (6 fl oz/ A) at R1 growth stage	271.0 a	55.5 ac
T5 - Pyraclostrobin (6 fl oz/ A) at R1 growth stage + fluopyram+ tebuconazole (9 fl oz/ A) at R6 growth stage	345.0 ab	37.0 b
T6 - Fluopyram+ tebuconazole (9 fl oz/ A) at R1 growth stage	268.0 a	58.8 ac
T7 - Fluopyram+ tebuconazole (9 fl oz/ A) at R6 growth stage	347.0 ab	58.8 ac
T8 - Tebuconazole (4 fl oz/ A) at V8 growth stage	282.0 a	52.5 ac
T9 - Tebuconazole (4 fl oz/ A) at R6 growth stage	280.0 a	49.8 bc
T10 - Fluopyram+ tebuconazole (9 fl oz/ A) at R1 growth stage + pyraclostrobin (6 fl oz/ A) at R6 growth stage	436.0 b	36.8 b
Pr>F	**0.02**	**0.001**

Fluopyram+tebuconazole at R1 with pyraclostrobin (QoI) at R6 significantly increased yield (*P*=0.02) and reduced DSI (*P*=0.001) by up to 55% and 45% respectively.

Summary

- Across the NTC plots of trials (n = 81), yield decreased with increasing severity of Phomopsis stem canker (R^2 = 0.135, P<0.001)
  - one-unit increase in DSI resulted in significant yield reduction of 10.38 lbs acre^{-1} (P <0.001)
- One-unit increase in DSI resulted in yield reduction of 18.18 (low yield environment) and 6.91 lbs acre^{-1} (moderate yield environment)
- Consider field history, disease pressure, and environmental conditions to maximize effectiveness of fungicide application

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THANK YOU