Evaluation of fungicides for their efficacy against Phomopsis stem canker of sunflower using remote sensing technology

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Introduction

Phomopsis stem canker is a worldwide major fungal disease of sunflower (*Helianthus annuus* L.) production causing yield losses up to 40% and oil reduction by 15 to 20% (Mathew et al. 2015; Aćimović 1986; Debaeke and Moinard 2010). In the United States, the disease is prevalent in the state of North Dakota, South Dakota, and Minnesota, where ~75% of the sunflower production takes place in the country (Mathew et al. 2015). Phomopsis stem canker is caused by many species of *Diaporthe*, however, *D. helianthi* (Munt.-Cvetk., Mihaljč. & Petrov), *D. gulyae* (Thompson et al. 2011) and *Diaporthe stewartii* Harrison (Mathew et al. 2015; Olson et al. 2017) are predominant in the U.S. To manage the disease in the United States, the fungicides registered for foliar disease management of sunflower belong to three FRAC (Fungicide Resistance Action Committee) groups. (1) FRAC 11 (QoI) Quinone outside inhibitors. (2) FRAC 3 (DMI) DeMethylation inhibitors. (3) FRAC 7 (SDHI) Succinate dehydrogenase inhibitors (Olson, 2017).

Previous fungicides study from Europe by Debaeke and Estragnat (2003) has reported Phomopsis stem canker severity reduction when protectant fungicides were sprayed at early growth stage of sunflower development. In the United States, Olson (2017) observed Phomopsis stem canker incidence decrease and sunflower yield increase when a single application of protectant fungicide was sprayed at R1 (bud formation rather than a cluster of leaves; Berglund 2007) growth stage.

Traditionally, Phomopsis stem canker severity is accessed using rating scale and based on symptoms identification. Using precision agriculture for disease assessment, remote sensing could be a relevant tool to access plant disease because it reduces the variation between accessors, and it provides a repetitive observation of the same object with a larger spectral range than human eye. Plant pathogens infect plant modifying the radiative properties of the crop canopy and remote sensing can detect these changes in the crop canopy prior to the human eyes. Pathogens infect the plant increasing the reflectance in the absorption bands of the leaf pigments and decrease the reflectance in the near infrared bands. The most used vegetation index is the Normalized Difference Vegetation Index NDVI = (NIR-R)/(NIR-R), where NIR is the near infrared reflectance and R the red reflectance (Nicolas, 2004). The objective of this study was to compare the fungicides efficacy against Phomopsis stem canker of sunflower at R1 growth stage using remote sensing technology.

Materials and Methods

The 2020 experiment to evaluate the efficacy of fungicides against Phomopsis stem canker of sunflower was planted on June 2nd at South Dakota State University Research Farm in Brookings, SD. The oil type hybrid (Nuseed) used for the study was seeded at 18,000 seeds per acre. The plot size was twenty feet long by four rows spacing thirty inches, where the outer two rows was border and the inner two rows were used for evaluations. The trial was established using a randomized complete block design, containing ten treatments and one non-treated control (Table 1), and four replications per treatment. The treatments were applied a single spray when the sunflower plants were at R1 growth stage using a highboy sprayer on July 21st (Figure 1). All fungicides were sprayed at the recommended rate from the manufacturer (Table 1) and mixed with adjuvant (3 pints per 100 gallon), 40 psi of pressure, TeeJet (Spraying Systems Co., Wheaton, IL) flat fan nozzle and 30 gallons of water per acre.

Phomopsis stem canker severity was evaluated on September 23rd when the sunflower plants were at R7-R8 (back of the head turning pale yellow to yellow and green bracts) growth stage using a scale 0 to 5 for disease severity, where zero means no infection and 5 means lodged plants. For disease severity ratings, 10 plants per plot were randomly selected from the inner 2 rows. The NDVI values we collected using the GreenSeeker® handheld sensor (Trimble Navigation Limited, Westminster, CO) and Unmanned aerial vehicle (Drone - Phantom 4 Pro V2.0) with multispectral sensor attached. The GreenSeeker values were collect from all the plants in the inner two rows held approximately 1-2 feet above the sunflower canopy (Figure 3) on July 30th and Drone imagery were collected on August 17th. The disease development occurred manly in August and September. The average weather condition in August was temperature of 74.83 ˚F, precipitation 0.04 inches, and humidity 66.7 %, and in September was temperature of 63.38 ˚F, precipitation 0.01 inches, and humidity 61.6 % (www.wunderground.com). The disease severity index (DSI) was calculated from the disease severity ratings DSI (%) = $\sum\left\{\frac{(P\times Q)}{(M\times N)}\times 100\right\}$ where, P = class frequency, Q = score of rating class, M = total number of plants and N = maximal disease index (Chiang et al. 2017). The plots were harvested and yield data recorded on October 14th. Disease severity index, normalized difference vegetation index and yield were analyzed separately using analysis of variance (ANOVA) in R studio (v2.11.1; https://www.rstudio.com/), the treatment means comparation using Fisher's LSD test (α = 0.05) using *agricolae* (deMendiburu 2016), and the correlations between DSI and NDVI, DSI and yield, NDVI and yield was done with Pearson's correlation.

Results and Conclusions

We observed significant differences in NDVI (GreenSeeker and multispectral sensor) and DSI among the fungicides and non-treated control (Figure 3, 4, 5, 6 and Table 2). Treatment six (Approach prima) had significant lower DSI compared to the non-treated control. NDVI values recorded with GreenSeeker showed six treatments (Endura + Folicur, Folicur, Headline, Trivapro, Miravis, and Priaxor) with higher values compared to the non-treated control. NDVI values from multispectral sensor showed treatment eleven (Endura + Folicur) with greater value compared to the non-treated control. Correlations between DSI and NDVI (multispectral sensor) was (r=0.29; *p*=NS). Correlations between sunflower yield and NDVI (multispectral sensor) was (r=0.23; *p*=NS). Correlations between sunflower yield and NDVI (GreenSeeker) was significant positive (r=0.41; *p*=0.01). Correlation between multispectral sensor and GreenSeeker was significant positive (r=0.53; *p*=0.001). The correlation between DSI and NDVI (GreenSeeker) significant positive (r=0.58; *p*=0.00035) show that Phomopsis stem canker severity was associated with a decrease in NDVI values.

Future work

Evaluate fungicides against Phomopsis stem canker of sunflower using remote sensing technology under field conditions in South Dakota in 2021.

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Table 1. Treatments used in this study to determine the efficacy of fungicides against Phomopsis stem canker of sunflower.

Treatments		FRAC code	Rate oz/a
1	NTC	-	-
2	Headline	11	6
3	Priaxor	7+11	4
4	Miravis NEO	3+7+11	13.7
5	Trivapro	3+7+11	13.7
6	Aproach Prima	3+11	6.8
7	Endura	7	9
8	Folicur 430F	3	4
9	Headline + Folicur 430F (tank-mix)	11+3	6+4
10	Headline + Endura (tank-mix)	11+7	6+9
11	Endura + Folicur 430F (tank-mix)	7+3	9+4

Figure 1. Highboy sprayer.

Figure 2. GreenSeeker held above the sunflower canopy.

Table 2. Phomopsis stem canker severity index (DSI), normalized difference vegetation index (NDVI), sunflower yield in pounds per acre (lb/A), and significant difference with Fisher's LSD test ($\alpha = 0.05$).

Treatments	NDVI [a]	0.05	DSI [c]	0.05	NDVI [b]	0.05	lb/A [d]	0.05
Endura + Folicur	0.78	a	94.37	a	0.75	a	2021.64	a
Control	0.75	ab	84.37	ab	0.72	ab	2210.21	a
Folicur	0.77	ab	66.25	ab	0.70	ab	2193.83	a
Endura	0.73	b	70	ab	0.68	ab	2006.92	a
Headline	0.77	ab	60	abc	0.72	ab	2546.64	a
Trivapro	0.76	ab	60	abc	0.64	b	2519.80	a
Miravis	0.77	ab	73.12	ab	0.70	ab	2112.18	a
Priaxor	0.77	ab	52.5	bc	0.68	ab	2580.28	a
Headline + Folicur	0.75	ab	57.5	bc	0.70	ab	2021.64	a
Headline + Endura	0.75	ab	53.12	bc	0.65	b	2094.46	a
Aproach Prima	0.72	b	30.62	c	0.66	b	2379.14	a

[a] **NDVI**, normalized difference vegetation index values collected on July 30th using GreenSeeker and Fisher's LSD analyzed in R Studio.

[b] **NDVI**, normalized difference vegetation index values obtained from ArcGIS (V10.7.1) collected on August 17th using multispectral sensor and Fisher's LSD analyzed in R Studio.

[c] **DSI**, disease severity index values collected on September 23rd using rating scale 0 to 5 (Mathew et al. 2015) and Fisher's LSD analyzed in R Studio.

[d] **lb/A**, sunflower yield in pounds per acre values collected on October 10th and Fisher's LSD analyzed in R Studio.

Figure 3. DSI values collected on 9/23 using rating scale 0 to 5 (Mathew et al. 2015)

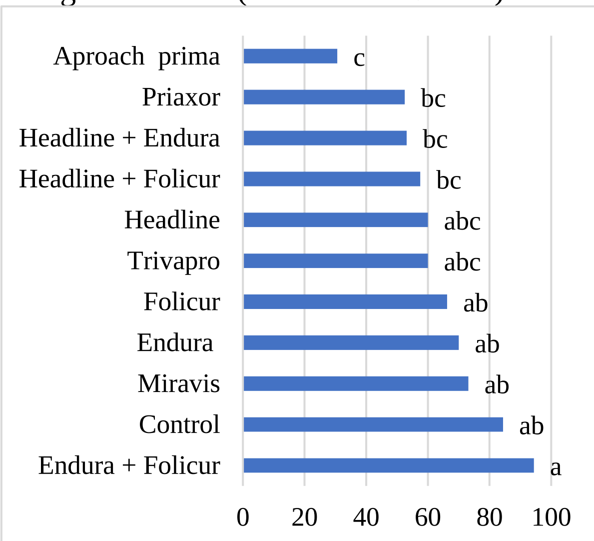

Figure 4. NDVI values collected on 7/30 using GreenSeeker

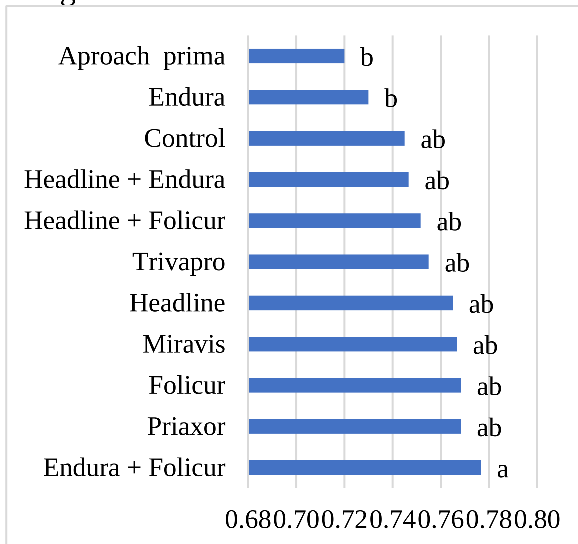

Figure 5. NDVI values collected on 8/17 using UAV multispectral sensor

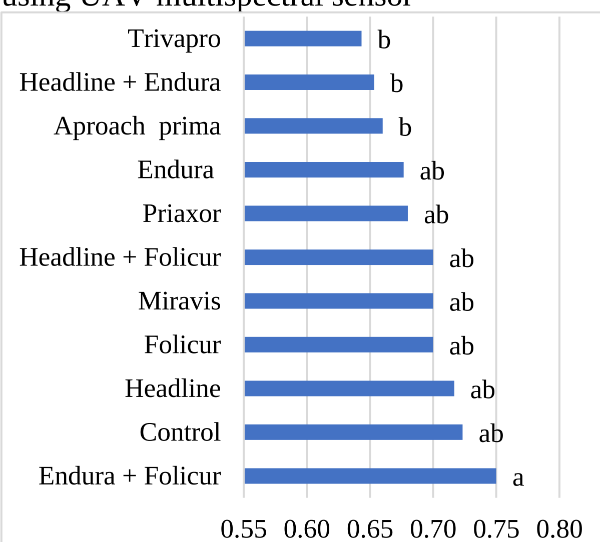

Figure 6. Sunflower yield (lb/A) values collected on 10/14