Final report: **Optimizing fungicide application frequency and application interval relative to soybean maturity for improved white mold management in soybeans**

Principal investigator: Michael Wunsch, NDSU Carrington Research Extension Center
Co-PI: Kelly Cooper, NDSU Robert Titus Research Farm, Oakes

Objectives of the research:

1. Quantify the profitability of making a single versus two sequential fungicide applications targeting white mold in soybeans of early, mid or late 0-maturity.
2. Optimize the interval between successive fungicide applications (7, 10, 12 or 14 days).
3. Evaluate whether the low-cost, off-patent fungicide thiophanate-methyl (Topsin and generics) applied at 40 fl oz/ac can confer satisfactory white mold control in soybeans applied as a single application or with an optimized application interval when applied in rotation with Endura.

Methods:

Agronomics: Planting was conducted May 4, 2021 in Oakes and May 17, 2021 in Carrington. Experimental design was a randomized complete block with a split-plot arrangement (main factor = soybean variety, sub-factor = fungicide treatment) and eight replicates. The varieties Asgrow 'AG009X8' (00.9 maturity), Asgrow 'AG06X8' (0.6 maturity), and Asgrow 'AG09F0' (0.9 maturity) were planted in Carrington and the varieties 'AG06X8', 'AG09F0' and Asgrow 'AG11X8' (1.1 maturity) were planted in Oakes. In Carrington, plots consisted of four rows, each 14 inches apart; in Oakes, plots consisted of three rows, each 21 inches apart. Seeding rate was 165,000 pure live seeds/ac. Plots were 25 feet long at seeding and an average 18.6 feet long at harvest (Carrington) or 21.0 feet long at harvest (Oakes). To facilitate overspray of fungicides, all treatment plots were separated by unharvested plots. Studies were harvested on October 5-6 (Carrington) and October 7-8 (Oakes). Yield was calculated on the basis of the measured plot length and is reported at a standard 13% moisture.

Fungicide treatment imposition: Fungicides were applied in 15 gal/ac with a hand-held boom equipped with four AIXR110015 air-induction flat-fan nozzles spaced 19 inches apart (Spraying Systems Co.; Wheaton, IL). Application pressure was 50 psi, which produced coarse droplets; the canopy was at or near closure in all applications conducted at both study locations, and previous research has shown that coarse droplets optimize fungicide performance against white mold in soybeans when the canopy is at or near closure. The first application was made on July 23 at the full R2 growth stage (Carrington) and on July 5 at the early to full R2 growth stage, depending on the variety (Oakes). The second application was wade 7, 10, 12 or 14 days later, depending on the experimental treatment.

Disease establishment: The research studies were planted on land with a prior history of Sclerotinia epidemics, and supplemental overhead irrigation was applied as needed facilitate white mold disease pressure. In Oakes, irrigation was delivered with a linear irrigator, and in Carrington, irrigation was applied with micro-sprinklers established on a 20-foot offset grid.

White mold was assessed October 4 to 5 in Carrington and October 7 to 9 in Oakes when soybeans were at maturity. Each plant in the second row of each four-row plot (Carrington) or the middle row of each three-row plot (Oakes) was individually assessed for Sclerotinia stem rot, with disease severity evaluated using a 0 to 5 scale: 0 = 0% of the plant diseased or impacted by white mold, 1 = 1-25%, 2 = 26-50%, 3 = 51-75%, 4 = 76-99%, 5 = 100%. Plant tissue was considered to be impacted by white mold if it exhibited disease symptoms or bore poorly filled or unfilled pods due to Sclerotinia lesions that girdled stem tissue below the pods.

Results and discussion:

Disease pressure: White mold pressure was high across all soybean varieties in Oakes and in the 0.6- and 0.9-maturity soybean varieties but not the 00.9-maturity variety in Carrington (**Table 1**). The low disease pressure observed in the 00.9-maturity variety is consistent with previous research that showed that, while individual varieties differ in susceptibility to white mold, on average susceptibility to white mold increases with soybean maturity. Because nearly all white mold infections occur during bloom and the length of the bloom period increases with soybean maturity, longer-maturity soybeans are susceptible to white mold for a longer period of time.

Profitability of a second fungicide application and optimal interval between successive applications (objectives 1 and 2): The optimal number of days between sequential fungicide applications was contingent on soybean maturity (**Figure 1**). The length of the bloom period increases with soybean maturity, and delaying the second application until 14 days after the first application leaves the soybeans under relatively low levels of residual fungicide 8 to 13 days after the first application but extends the period in which fungicides provide protection. This extension of protection outweighed the relatively low residual levels at 8 to 13 days only in the longest-maturity soybeans which have the longest period of susceptibility to white mold.

- *Discussions of profitability of the second fungicide application (Endura @ 5.5 oz/ac) are based on the following assumptions: $30/ac total cost (fungicide + application) for Endura and $24/ac total cost for Topsin and $15 bu/ac soybean price at the elevator. This translates into a minimum 2.0 bu/ac yield gain for Endura and 1.6 bu/ac yield gain for Topsin as the break-even for each fungicide application.*
- In the 00.9-maturity variety (tested in Carrington only), fungicide applications targeting white mold were not profitable due to low disease pressure.
- In the 0.6-maturity variety (tested in Oakes and Carrington), the second fungicide application was consistently profitable when the second application was made 7 days after the first but not when the second application was delayed to 10-14 days later.
- In 0.9-maturity varieties (tested in Oakes and Carrington), the second fungicide application was profitable irrespective of whether it was applied 7, 10, 12 or 14 days after the first application, but making the second application 7 days after the first application maximized the yield gain from the second application.
- In the 1.1-maturity variety (tested in Oakes only), the second fungicide application was profitable irrespective of whether it was applied 7, 10, 12 or 14 days after the first application, but making the second application 14 days after the first application maximized the yield gain from the second application.

Efficacy of the low-cost generic fungicide thiophanate-methyl (objective 3): Although statistical separation between Endura (5.5 oz/ac) and Topsin (40 fl oz/ac) was not observed in any individual study, Topsin was consistently less effective than Endura in all varieties in which white mold pressure was economically relevant (**Table 1**). The reductions in disease control and yield were observed irrespective of whether Topsin was applied once or applied as the first application in a two-application sequence.

Outreach: A user-friendly summary of results was online at the NDSU Carrington website in March 2022: see 'updated recommendations for white mold management in soybeans' at https://www.ndsu.edu/agriculture/ag-hub/research-extension-centers-recs/carrington-rec/research/plant-pathology. Outreach to growers was conducted at the Minnesota Crop Production Retailers and University of Minnesota Extension Short Course in Minneapolis, MN in December 2021, at the Best of the Best in Wheat and Soybean Research meetings in

Moorhead, MN and Grand Forks, ND in February 2022, and at a grower meeting organized by Monty's Plant Foods in Jamestown, ND in March 2022.

Table 1. Impact of fungicide application frequency and application interval on white mold management in soybeans; Carrington and Oakes, ND (2021). *Within-column means followed by different letters are significantly different (P< 0.05)*

	Sclerotinia severity index (percent of canopy)			**Sclerotinia severity index** (percent of canopy)		
	OAKES, ND (2020)			**CARRINGTON, ND** (2020)		
Soybean variety:	**AG06X8**	**AG09F0**	**AG11X8**	**AG009X8**	**AG06X8**	**AG09F0**
Soybean maturity:	**0.6**	**0.9**	**1.1**	**00.9**	**0.6**	**0.9**
Non-treated control	**38** b*	**29** c*	**34** c*	**4** b*	**49** c*	**37** c*
Endura 5.5 oz/ac **(R2 growth stage)**	**40** b	**18** abc	**30** bc	**2** ab	**30** ab	**19** ab
Endura 5.5 oz/ac **(R2 + 7 days)**	**27** ab	**8** a	**19** ab	**1** a	**17** a	**6** a
Endura 5.5 oz/ac **(R2 + 10 days)**	**27** ab	**13** a	**23** abc	**1** a	**19** a	**12** a
Endura 5.5 oz/ac **(R2 + 12 days)**	**15** a	**7** a	**19** abc	**1** a	**19** a	**14** a
Endura 5.5 oz/ac **(R2 + 14 days)**	**27** ab	**9** a	**10** a	**1** a	**25** ab	**17** ab
Topsin 40 fl oz/ac **(R2 growth stage)**	**42** b	**26** bc	**36** c	**1** a	**37** bc	**31** bc
Topsin 40 fl oz f.b. **Endura** 5.5 oz **(R2 + 7 days)**	**29** ab	**16** ab	**26** bc	**1** a	**15** a	**15** a
Topsin 40 fl oz f.b. **Endura** 5.5 oz **(R2 + 10 days)**	**31** ab	**12** a	**29** bc	**1** a	**19** a	**16** ab
Topsin 40 fl oz f.b. **Endura** 5.5 oz **(R2 + 12 days)**	**30** ab	**14** ab	**22** abc	**1** a	**20** a	**19** ab
Topsin 40 fl oz f.b. **Endura** 5.5 oz **(R2 + 14 days)**	**37** b	**13** ab	**16** ab	**0** a	**25** ab	**16** ab
CV:	36.2	52.1	17.1	117.1	39.4	49.0
	Yield (bushels/acre)			**Yield** (bushels/acre)		
	OAKES, ND (2020)			**CARRINGTON, ND** (2020)		
Soybean variety:	**AG06X8**	**AG09F0**	**AG11X8**	**AG009X8**	**AG06X8**	**AG09F0**
Soybean maturity:	**0.6**	**0.9**	**1.1**	**00.9**	**0.6**	**0.9**
Non-treated control	**60** a*	**67** ab*	**68** c*‡	**58** a*	**42** c*	**41** c*
Endura 5.5 oz/ac **(R2 growth stage)**	**64** a	**72** ab	**68** bc	**59** a	**55** ab	**53** bc
Endura 5.5 oz/ac **(R2 + 7 days)**	**67** a	**76** a	**77** abc	**58** a	**59** a	**58** abc
Endura 5.5 oz/ac **(R2 + 10 days)**	**66** a	**74** ab	**75** abc	**58** a	**56** ab	**56** abc
Endura 5.5 oz/ac **(R2 + 12 days)**	**65** a	**72** ab	**77** abc	**59** a	**55** ab	**53** abc
Endura 5.5 oz/ac **(R2 + 14 days)**	**66** a	**74** ab	**85** a	**58** a	**55** ab	**52** a
Topsin 40 fl oz/ac **(R2 growth stage)**	**58** a	**66** b	**68** bc	**60** a	**48** bc	**43** bc
Topsin 40 fl oz f.b. **Endura** 5.5 oz **(R2 + 7 days)**	**65** a	**73** ab	**72** abc	**58** a	**58** a	**53** abc
Topsin 40 fl oz f.b. **Endura** 5.5 oz **(R2 + 10 days)**	**63** a	**73** ab	**72** abc	**58** a	**55** ab	**51** abc
Topsin 40 fl oz f.b. **Endura** 5.5 oz **(R2 + 12 days)**	**63** a	**72** ab	**77** abc	**57** a	**55** ab	**50** abc
Topsin 40 fl oz f.b. **Endura** 5.5 oz **(R2 + 14 days)**	**61** a	**73** ab	**82** ab	**60** a	**57** a	**53** ab
CV:	14.7	8.0	11.5	6.1	9.1	9.0

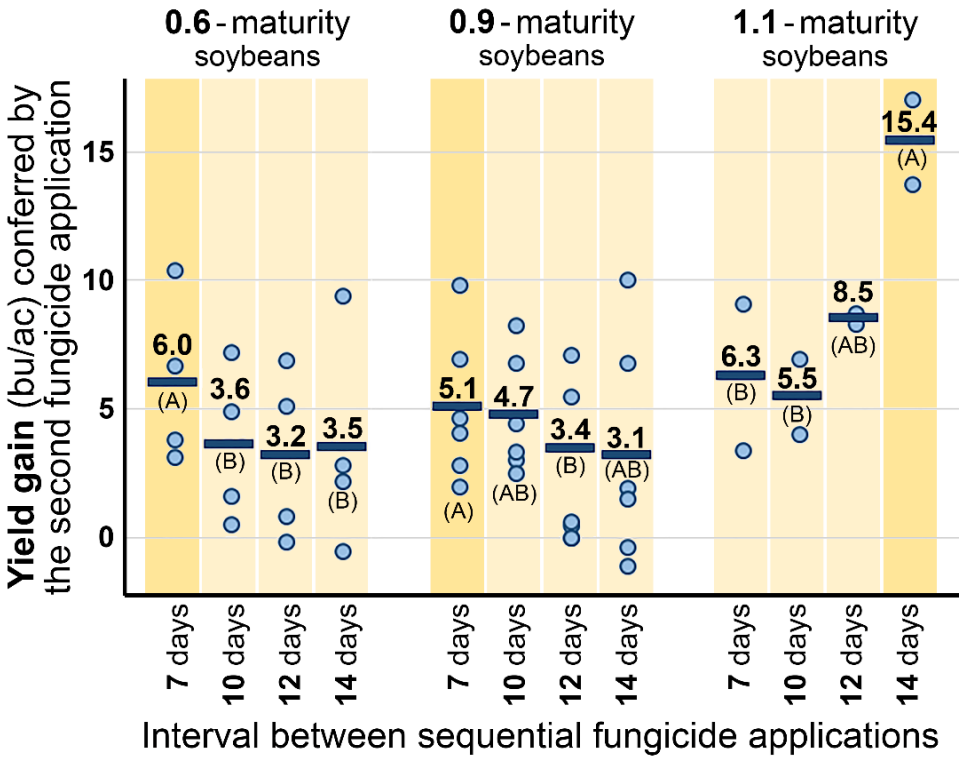

Figure 1. Yield gain conferred by a second fungicide application made 7, 10, 12, or 14 days after the first application; Carrington and Oakes, ND (2020-21). *Dots represent results from individual studies; bars represent average values. Different letters denote statistical separation ($P < 0.05$; Tukey multiple comparison procedure).*