

Optimizing fungicide application frequency and interval for improved white mold management in pinto beans

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MAJOR FINDINGS:

- (1) The optimal application interval (number of days between applications) changes with the number of applications being made and severity of white mold pressure.** In pinto beans, three-application fungicide programs were optimized when applications were made 7 to 11 days apart; within this range, the tighter application interval (7 days) was optimal when white mold risk was highest. Two-application fungicide programs were optimized when applications were made 9 to 13 days apart, depending on white mold risk; within this range, the tighter application interval (9-11 days) was optimal when white mold risk was highest. Optimal application interval was consistent irrespective of the fungicide applied (Topsin/generic versus Endura).
- (2) White mold management (disease control, yield) improves as the number of fungicide applications increases.** Realizing the full gain from an additional fungicide application requires adjustments in application timing and application interval. Three-application fungicide programs were most effective when the first application was made at initial bloom and 0-5% of plants had initial pin-pods and when the interval between applications was tight.
- (3) Rotating fungicide chemistries in two- and three-application fungicide programs improves white mold management.** When including Topsin/generic or ProPulse in a fungicide program targeting white mold, field testing conducted on pinto and kidney beans in 2026 and prior testing suggests that the efficacy of Topsin is sharply increased as the application rate increases from 30 to 40 fl oz/ac and that ProPulse is most effective when it is applied first (and other products applied second and/or third) in a fungicide rotation program.

When conditions favor white mold as dry beans enter bloom, the optimal application timing of fungicides targeting white mold changes with the number of applications being made. The optimal application timing for a single fungicide application is different than the optimal timing of the first application of a two- or three-application fungicide program. For details, please reference the report on optimizing fungicide application timing in kidney beans.

Impact of fungicide application interval, frequency and timing on management of white mold in pinto beans; Carrington, ND (2025).

Impact of fungicide application interval, frequency and timing for management of white mold in pinto beans; Carrington, ND (2025)

Average response to the fungicide across five application timings

'ND Rodeo' pinto beans, 14' row spacing, 90,000 viable seeds/ac
Endura 8 oz/ac applied in each application with a tractor at 6 mph, 15 gal/ac spray volume

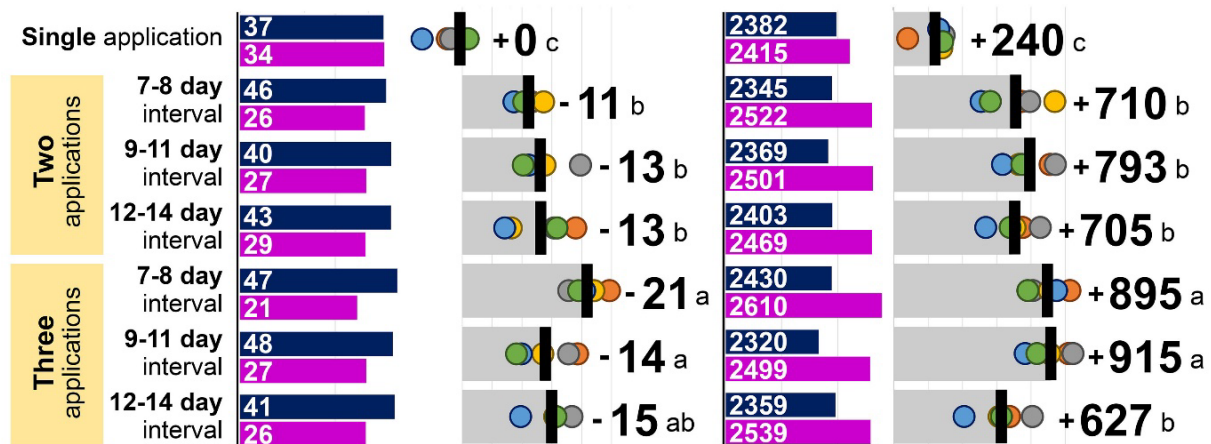
	White mold % of canopy	Yield lbs/ac	Yield gain conferred by the fungicide (lbs/ac)
Non-treated control	75 b*	1759 c*	
Single application	72 b	2100 b	+ 341 a
Two applications	7-8 days apart 62 a	2492 a	+ 733 a
	9-11 days apart 63 a	2507 a	+ 748 a
	12-14 days apart 62 a	2494 a	+ 735 a
Three applications	7-8 days apart 58 a	2672 a	+ 913 a
	9-11 days apart 63 a	2461 a	+ 702 a
	12-14 days apart 62 a	2470 a	+ 711 a
	F, P>F: 9.24, <0.0001 CV: 9.0	25.46, <0.0001 7.4	8.21, <0.0001 23.2

Response to the fungicide versus control in each application timing

BARS = average response across application timings, CIRCLES = response in each applic. timing

'ND Rodeo'
PINTO BEANS

White mold (% of canopy) Yield (lbs/ac; 13.5% moisture)
average response and response across five different application timings



Bar graphs: non-treated (blue), average across all five application timings (pink)

Scatter plots: average (bar), response observed in each application timing

orange = 19% of plants with an open blossom, 0% of plants with initial pin-pods; **gray** = 66% bloom, 6% pin-pod;

yellow = 73% bloom, 12% pin-pod; **blue** = 84% bloom, 42% pin-pod; **green** = 92% bloom, 69% pin-pod

Fungicide applied: Endura, 8 oz/ac; spray vol., 15 gal/ac; driving speed, 6.0 mph **Row spacing:** 14 inches **Seeding rate:** 90,000 pls/ac

Fungicide droplet size: first application across all application timings, medium droplets (TeeJet XR11006, 35 psi);

second and third applications across all application timings, coarse droplets (TeeJet XR11010, 30 psi)

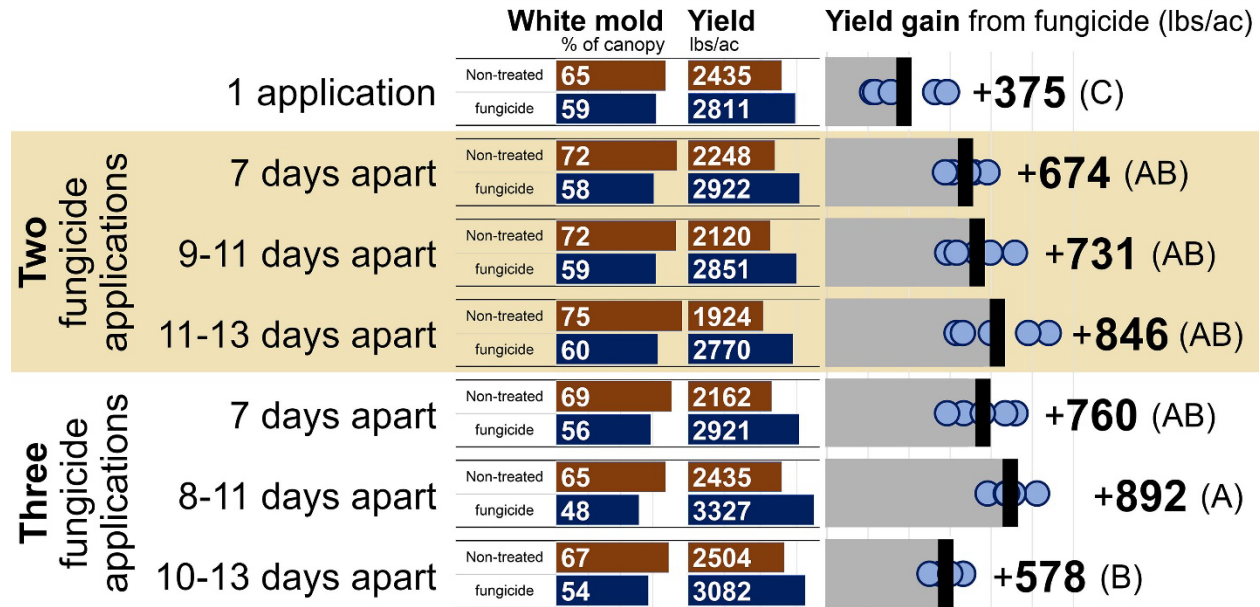
Within-column means followed by different letters are significantly different ($P < 0.05$; Tukey multiple comparison procedure)

Impact of fungicide application interval, frequency and timing on management of white mold in pinto beans; Carrington, ND (2024).

Impact of fungicide application interval, frequency and timing for management of white mold in pinto beans; Carrington, ND (2024)

Response to the fungicide across five application timings

'Torreon' pinto beans, 14' row spacing, 90,000 viable seeds/ac
 Endura 8 oz/ac applied in each application; tractor-mounted sprayer; 6 mph, 15 gal/ac spray vol.
 BARS = average response across application timings, CIRCLES = response in each applic. timing



Bar graphs: non-treated control (brown), average across all five application timings (blue)
Scatter plots: BAR = average response across fungicide applic. timings, CIRCLES = response in each of five fungicide applic. timings
Fungicide applied: Endura, 8 oz/ac; spray vol., 15 gal/ac; driving speed, 6.0 mph **Row spacing:** 14 inches **Seeding rate:** 90,000 pls/ac
Fungicide droplet size: first application across all application timings, medium droplets (TeeJet XR11006, 35 psi);
 second and third applications across all application timings, coarse droplets (TeeJet XR11010, 30 psi)
 Within-column means followed by different letters are significantly different ($P < 0.05$; Tukey multiple comparison procedure)

Impact of fungicide application program on optimal application interval; Carrington, ND (2025). Applications made with a hand-held boom; 15 gal/ac spray volume.

	WHITE MOLD			YIELD
	INCIDENCE	SEVERITY	SEV. INDEX	13.5% moisture
	% of plants	%	% of canopy	lbs/ac
'ND Rodeo' pinto beans Carrington, ND (2025) Row spacing = 14", seeding rate = 90,000 pls/ac				
Non-treated	97 b*	82 b*	79 b*	1319 b*
7 to 8 DAY FUNGICIDE APPLICATION INTERVAL				
Endura 8 oz / Endura 8 oz / Topsin 40 fl oz	85 a	69 a	59 a	2262 a
Topsin 30 fl oz / Topsin 30 fl oz / Endura 8 oz	91 ab	72 a	65 a	2246 a
9 to 11 DAY FUNGICIDE APPLICATION INTERVAL				
Endura 8 oz / Endura 8 oz / Topsin 40 fl oz	90 ab	71 a	65 a	2346 a
Topsin 30 fl oz / Topsin 30 fl oz / Endura 8 oz	86 a	72 a	62 a	2414 a
12 to 13 DAY FUNGICIDE APPLICATION INTERVAL				
Endura 8 oz / Endura 8 oz / Topsin 40 fl oz	92 ab	74 ab	69 ab	2174 a
Topsin 30 fl oz / Topsin 30 fl oz / Endura 8 oz	91 ab	74 ab	67 a	2117 a
	F, P>F:	4.26, 0.0020	5.03, 0.0006	5.85, 0.0002
	CV:	6.3	7.0	11.3
				20.7

* Within-column means followed by different letters are significantly different ($P < 0.05$; Tukey multiple comparison procedure)

Impact of fungicide rotation sequence in two- and three-application fungicide programs on management of white mold in pinto and kidney beans: ‘Pink Panther’ light-red kidney beans, ‘ND Rodeo’ pintos; Carrington, ND (2025). Row spacing = 14”, seeding rate = 90,000 pls/ac.

	White mold (% of canopy)						Yield (lbs/ac)	
	Market class		Average across both market classes		Market class		Average across both market classes	
	PINTO	KIDNEY	PINTO	KIDNEY	PINTO	KIDNEY	PINTO	KIDNEY
Non-treated control	79 d*	49 d*	64 c*	1196 d*	2422 c*	1809 b*		
TWO APPLICATIONS (kidney beans, 9 days apart; pinto beans, 13 days apart)								
Topsin 30 fl oz / Topsin 30 fl oz	66 bcd	34 bcd	50 bc	1904 bc	2890 ab	2397 ab		
Topsin 40 fl oz / Endura 8 oz	60 abc	31 a-d	46 ab	2162 abc	2894 ab	2528 ab		
ProPulse 10.3 fl oz / Topsin 40 fl oz	60 abc	19 abc	39 ab	2281 abc	3062 ab	2672 ab		
THREE APPLICATIONS with Topsin @ 30 fl oz/ac applied twice								
Topsin 30 fl oz / Topsin 30 fl oz / Endura 8 oz	62 abc	30 a-d	46 abc	2311 abc	2772 bc	2541 ab		
Topsin 30 fl oz / Endura 8 oz / Topsin 30 fl oz	70 cd	25 abc	48 abc	1838 cd	3029 ab	2434 ab		
Endura 8 oz / Topsin 30 fl oz / Topsin 30 fl oz	58 abc	29 a-d	43 ab	2346 abc	2897 ab	2622 ab		
THREE APPLICATIONS with Topsin @ 40 fl oz/ac applied once								
Topsin 40 fl oz / Endura 8 oz / Endura 8 oz	57 abc	37 cd	47 abc	2371 abc	2926 ab	2648 ab		
Topsin 40 fl oz / Endura 8 oz / ProPulse 10.3 fl oz	56 abc	20 abc	38 ab	2217 abc	3082 ab	2649 ab		
Omega 8 fl oz / Topsin 40 fl oz / Endura 8 oz	50 ab	17 abc	34 ab	2457 abc	3071 ab	2764 ab		
Omega 8 fl oz / Topsin 40 fl oz / ProPulse 10.3 fl oz	56 abc	16 abc	36 ab	2682 a	3079 ab	2880 ab		
ProPulse 10.3 fl oz / Topsin 40 fl oz / Endura 8 oz	48 a	12 ab	30 a	2543 ab	3168 a	2856 ab		
ProPulse 10.3 fl oz / Endura 8 oz / Topsin 40 fl oz	49 a	11 a	30 a	2711 a	3101 ab	2906 a		
	F, P>F: 6.43, <0.0001	5.79, <0.0001	8.72, <0.0001	8.18, <0.0001	6.13, <0.0001	2.79, 0.0442		
	CV: 16.3	47.4	10.6	17.9	7.1	6.7		

* Within-column means followed by different letters are significantly different ($P < 0.05$; Tukey multiple comparison procedure)

Growth stage at the first fungicide application: Pinto beans: 80% of plants with an open blossom, 50% with initial pods, 85% canopy closure.
 Kidney beans: 100% of plants with an open blossom, 95% with initial pods, 95% canopy closure.

Number of days between fungicide applications: Two-application programs: fungicides were applied 9 days apart in kidney beans; 13 days apart in pinto beans.
 Three-application programs: fungicides were applied 6-7 days apart in kidney beans; 9-11 days apart in pintos.

Impact of fungicide application timing, interval and frequency on white mold management in pinto beans

Carrington, ND (2025)

PINTO BEANS: 'ND Rodeo', a slow-darkening type

Row spacing = 14 inches; seeding rate = 90,000 viable seeds/ac

Application date	Canopy closure (%)	Plants in bloom (%)	Pin-pods (% plants)	Canopy height (in.)	White mold		Yield 13.5% moisture	Test weight lbs/bu
					Incidence Sept. 17 - Oct. 1; R8-R9	Sev. Index		
Non-treated control					94 a*	72 a*	1860 a*	58.2
July 23	88	19	0	17.0	97 a	74 a	1940 a	58.1
July 26	90	66	6	19.3	95 a	74 a	2153 a	58.6
July 28	90	73	12	18.1	96 a	71 a	2139 a	58.7
July 30	90	84	42	17.9	97 a	71 a	2122 a	58.8
July 31	90	92	69	18.3	95 a	71 a	2144 a	58.8
					0.50, 0.7737	0.34, 0.8849	2.15, 0.0793	
					4.0	10.7	12.6	
Non-treated control					96 a*	73 a*	1782 c*	56.9
July 23	88	19	0	17.0	91 a	61 a	2528 ab	58.5
July 26	90	66	6	19.3	93 a	62 a	2574 ab	58.8
July 28	90	73	12	18.1	86 a	59 a	2721 a	59.3
July 30	90	84	42	17.9	91 a	64 a	2290 b	58.9
July 31	90	92	69	18.3	90 a	63 a	2345 b	58.6
					1.75, 0.1453	2.34, 0.0589	14.41, <0.000*	
					8.4	14.8	11.0	
Non-treated control					98 b*	79 b*	1778 b*	57.8
July 23	88	19	0	17.0	82 a	54 a	2804 a	59.5
July 26	90	66	6	19.3	90 ab	61 a	2588 a	59.4
July 28	90	73	12	18.1	85 a	57 a	2684 a	59.0
July 30	90	84	42	17.9	85 a	58 a	2727 a	59.1
July 31	90	92	69	18.3	87 ab	59 a	2559 a	59.3
					3.62, 0.0085	6.94, <0.0001	22.43, <0.000*	
					10.1	16.4	9.4	

* Within-column means followed by different letters are significantly different ($P < 0.05$; Tukey multiple comparison procedure)

Fungicides were applied with a tractor-mounted, PTO-driven sprayer with a pulse-width modification system (Capstan Ag, Topeka, KS). Fungicides were applied with TeeJet XR11006 nozzles @ 35 psi (medium droplets) on July 23-31 when average canopy closure <90% and XR11010 nozzles @ 30 psi (coarse droplets) on later dates when canopy closure >90%. Spray volume = 15 gal/ac; driving speed = 6.0 mph. For ease of application, the fungicide Endura (8.0 oz/ac) was applied at each application.

White mold	Incidence Sept. 17 - Oct. 1; R8-R9	Sev. Index	Yield 13.5% moisture	Test weight lbs/bu	White mold		Yield 13.5% moisture	Test weight lbs/bu
					Incidence Sept. 17 - Oct. 1; R8-R9	Sev. Index		
					97 b*	75 b*	1789 b*	58.3
					87 a	56 a	2539 a	58.9
					87 a	60 a	2643 a	59.0
					93 ab	67 ab	2496 a	59.2
					93 ab	68 ab	2325 a	59.1
					85 a	60 a	2467 a	59.1
					4.95, 0.0013	6.25, 0.0002	11.90, <0.000*	
					6.6	13.2	11.2	
					97 b*	77 b*	1843 c*	58.1
					91 a	62 a	2519 ab	59.3
					90 a	59 a	2651 a	59.5
					90 a	62 a	2457 ab	59.0
					91 a	68 ab	2253 b	59.1
					88 a	62 a	2471 ab	58.9
					2.28, 0.0646	4.93, 0.0013	3.87, <0.000*	
					6.5	14.0	9.7	

Impact of fungicide application timing, interval and frequency on white mold management in pinto beans

Carrington, ND (2024)

Disease pressure was highly variable across the footprint of the study, resulting in elevated variability in disease and yield data

PINTO BEANS: cv. 'Torreón'

Row spacing = 14 inches; seeding rate = 90,000 viable seeds/ac

Application date	Canopy closure (%)	Plants in bloom (%)	Pin-pods (% plants)	Canopy height (in.)	White mold		Yield 13.5% moisture	Test weight
					Incidence Sept. 9-20; R9	Sev. Index		
Non-treated control					86	65 b*	2435 a*	58.7
July 17	73	3	0	15.7	86	63 ab	2655 a	58.5
July 19	75	19	0	17.3	81	56 ab	2962 a	58.7
July 22	78	76	3	20.5	87	65 b	2670 a	58.5
July 24	83	100	49	19.1	79	55 a	3020 a	58.4
July 26	89	100	81	21.3	78	57 ab	2746 a	58.0

F, P>F: 2.54, 0.0436 2.39, 0.0544

CV: 14.5 15.2

Date, growth stage; application #1	TWO APPLICATIONS, 7 days apart	
	Incidence Sept. 9-20; R9	Yield 13.5% moisture
Non-treated control	93	72 b*
July 17	73	77
July 19	75	81
July 22	78	83
July 24	83	81
July 26	89	81

F, P>F: 4.18, 0.0039 8.4, <0.0001

CV: 14.8 10.5

Date, growth stage; application #1	THREE APPLICATIONS, 7 days apart	
	Incidence Sept. 9-20; R9	Yield 13.5% moisture
Non-treated control	89	69 b*
July 17	73	76
July 19	75	72
July 22	78	78
July 24	83	80
July 26	89	78

F, P>F: 5.99, 0.0003 9.5, <0.0001

CV: 12.6 11.6

Date, growth stage; application #1	TWO APPLICATIONS, 9-11 days apart		THREE APPLICATIONS, 8-11 days apart	
	Incidence Sept. 9-20; R9	Yield 13.5% moisture	Incidence Sept. 9-20; R9	Yield 13.5% moisture
Non-treated control	91	72 b*	85	65 b*
July 17	73	81	66	44 a
July 19	75	86	74	53 a
July 22	78	82	70	49 a
July 24	83	81	68	47 a
July 26	89	78	70	49 a

F, P>F: 5.09, 0.0011 8.1, <0.0001

CV: 12.7 12.3

Date, growth stage; application #1	TWO APPLICATIONS, 10-13 days apart		THREE APPLICATIONS, 10-13 days apart	
	Incidence Sept. 9-20; R9	Yield 13.5% moisture	Incidence Sept. 9-20; R9	Yield 13.5% moisture
Non-treated control	94	75 b*	90	67 b*
July 17	73	85	70	49 a
July 19	75	84	77	56 a
July 22	78	82	78	54 a
July 24	83	80	78	56 a
July 26	89	86	79	57 ab

F, P>F: 6.80, 0.0001 8.9, <0.0001

CV: 12.0 14.0

* Within-column means followed by different letters are significantly different (P < 0.05; Tukey multiple comparison procedure)

Fungicides were applied with a tractor-mounted, PTO-driven sprayer with a pulse-width modification system (Capstan Ag, Topeka, KS). Fungicides were applied with TeeJet XR11000 nozzles @ 35 psi (medium droplets) on July 17-26 when canopy closure <90% and XR11010 nozzles @ 30 psi (coarse droplets) in subsequent applications (canopy closure ≥90%). Spray volume = 15 gal/ac; driving speed = 6.0 mph. For ease of application, the fungicide Endura (8.0 oz/ac) was applied at each application.

METHODS SUMMARY for study conducted in 2024:

Row spacing = 14 inches **Seeding rate** = 90,000 viable seeds/ac

Fungicide spray volume = 15 gal/ac.

Application method: PTO-driven tractor-mounted sprayer; application speed = 6.0 mph.

Fungicide spray droplet size: calibrated relative to canopy density and lodging; all application timings of the single-application treatments and first application of the two- or three-application treatments, medium droplets (TeeJet XR11006 nozzles, 35 psi); all application timings of the second and third applications of the two- and three-application sequences (TeeJet XR11010 nozzles, 30 psi)

Number of experimental replicates = 9

White mold assessment: Assessed at or near dry bean maturity by evaluating every plant individually in half of the rows per plot for percent of the plant impacted by white mold.

Harvest: To ensure that variability in dry bean standability (lodging) across the study did not bias yields, plants were clipped at base concurrent with disease assessments, wind-rowed to dry, and manually lifted into the combine.

Supplemental irrigation: Supplemental overhead irrigation was applied as needed to establish the white mold disease pressure needed to evaluate fungicide performance.

DETAILED METHODS: fungicide application interval, frequency and timing study conducted in 2025

LOCATION OF STUDY: GPS Coordinates, 47.5011, -99.1213 (southwest corner; plot 101); Description, North Dakota State University Carrington Research Extension Center approximately 3 miles north of Carrington, ND
AGRONOMICS

Variety 'ND Rodeo', a slow-darkening pinto; 'Epic', a dark-red kidney

Tillage Disked October 2024; cultivated once on May 25, 2025 and twice on June 4, 2025

Previous crop field peas (southern approx. two-thirds); winter wheat (northern approx. third)

Soil fertility - southern third (last year = peas) 18 lbs/ac nitrogen (10 lbs in top 6 inches + 8 lbs at 6 to 18 inches deep); 16 ppm phosphorous; 222 ppm potassium; 58 lbs/ac sulfur (18 lbs in the top 6 inches + 40 lbs at 6 to 18 inches deep); 0.91 ppm zinc; 1.2 ppm boron; 3.1% organic matter; 0.29 mmho/cm soluble salts in the top 6 inches; 0.29 mmho/cm soluble salts at 6 to 18 inches deep; pH = 8.0 in the top 6 inches; pH = 8.1 at 6 to 18 inches deep; Soil fertility - middle third (last year = peas) 60 lbs/ac nitrogen (34 lbs in top 6 inches + 26 lbs at 6 to 18 inches deep); 24 ppm phosphorous; 234 ppm potassium; 44 lbs/ac sulfur (16 lbs in the top 6 inches + 28 lbs at 6 to 18 inches deep); 1.19 ppm zinc; 0.9 ppm boron; 4.1% organic matter; 0.29 mmho/cm soluble salts in the top 6 inches; 0.26 mmho/cm soluble salts at 6 to 18 inches deep; pH = 7.6 in the top 6 inches; pH = 7.9 at 6 to 18 inches deep; Soil fertility - northern third (last year = winter wheat) 22 lbs/ac nitrogen (12 lbs in top 6 inches + 10 lbs at 6 to 18 inches deep); 21 ppm phosphorous; 218 ppm potassium; 32 lbs/ac sulfur (8 lbs in the top 6 inches + 24 lbs at 6 to 18 inches deep); 0.94 ppm zinc; 0.9 ppm boron; 3.9% organic matter; 0.27 mmho/cm soluble salts in the top 6 inches; 0.26 mmho/cm soluble salts at 6 to 18 inches deep; pH = 7.7 in the top 6 inches; pH = 7.9 at 6 to 18 inches deep

Fertilization: Southern third: 196 lbs/ac urea = 90 lbs of nitrogen applied May 25 and incorporated the same day; Middle third: 98 lbs/ac urea = 45 lbs of nitrogen applied May 25 and incorporated the same day; Northern third: 196 lbs/ac urea = 90 lbs of nitrogen applied May 25

Planting date, June 6; **Row spacing**, 14 inches; Rows per plot, four; **Plot size at planting**, 5 feet wide (center-on-center) x 30 feet long; **Plot size at harvest**, 5 feet wide x average 21.4 feet long. **Seeding rate**, 90,000 pure live seeds/acre

Experimental design Randomized complete block with 9 replicates. Established with 10 replicates, but thistle patches on the southern third of the study required destruction of some of the plots. Replicates 9 and 10 on the southern end of the study were combined, with averages taken of all plots for which two plots were available. In two of the fungicide timing data sets (response to fungicide timing within a given application frequency and interval), a full set of plots was available for replicates 9 and 10 but there was harvest error resulting in missing data in another replicate. In these two data sets, the replicate with the missing data point was combined with replicate 10.

Herbicide applications Pre-plant incorporated: June 4; Sonalan (ethalfuralin, 3 lbs/gal; Gowan Company, Yuma, AZ) @ 2 pt/ac + Eptam 7EC (EPTC, 7 lbs/gal; Gowan Company, Yuma, AZ) @ 4 fl oz/ac; spray volume = 20 gal/ac **Pre-emergence:** June 6; Imazethapyr 2SL (Ammonium salt of imazethapyr, 2 lbs free acid per gal; Willowood USA) @ 2 fl oz/ac; spray volume = 12 gal/ac **Post-emergence grass herbicide:** July 1; Targa (quizalofop-p-ethyl, 0.88 lb ai/gal; Gowan Corp., Yuma, AZ) @ 12 fl oz/ac + Trizenta 3EC (clethodim, 3 lbs ai/gal; Arysta LifeScience, Cary, NC) @ 5 fl oz/ac + COC @ 12 fl oz/ac (1% v/v); spray volume = 20 gal/ac **Post-emergence broadleaf herbicide:** July 7; Vulture (ammonium salt of imazamox, 1 lb ai/gal) @ 4 fl oz/ac + Basagran 5L (sodium salt of bentazon, 5 lbs ai/gal) @ 12 fl oz/ac + Outlook (dimethenamid-P, 6.0 lbs/gal) @ 18 fl oz/ac + COC @ 12 fl oz/ac + AMS 8.5 lbs/100 gal; spray volume = 20 gal/ac

Harvest date Sept. 29, 30; Oct. 1, 2 **Yield assessment** Dry beans were manually clipped concurrent with disease assessments and wind-rowed to facilitate even dry-down (simulating knifing). In order to exclude transition areas where spraying was initiated or ended, the first and last 2 to 3 feet at each end of each plot was excluded from harvest. The harvested plot length was measured for each plot. Grain was cleaned after harvest, and moisture was assessed on the cleaned grain. Yields are reported at 13.5% moisture.

DISEASE ESTABLISHMENT This research trial was planted on land with a prior history of Sclerotinia epidemics. Because of recurrent rains and heavy dews during bloom, no supplemental irrigation was applied to the study. An irrigation system with micro-sprinklers established on a 20-foot offset grid was established over this study during late vegetative growth, but the irrigation system was not utilized.

FOLIAR FUNGICIDE APPLICATIONS Fungicide treatments were applied with a PTO-driven tractor-mounted sprayer equipped with a pulse-width modulation system (Capstan AG, Topeka, KS). Pulse width was modified as needed to maintain a constant driving speed, the same nozzles, and the same application pressure across spray volume treatments, with pulse width manually adjusted and set on the basis of the measured spray output. Non-harvested plots were established between treatment plots to facilitate a transition zone for turning on or off the sprayer between treatment plots while maintaining full driving speed. To avoid edge effects, alleys were not established on plot ends until dry bean maturity. Fungicide treatments were applied to a 10-foot width consisting of a pair of 5-foot-wide plots, one seeded to 'Epic' dark-red kidney beans and one seeded to 'ND Rodeo' slow-darkening pinto beans. Applications were made with a 7-nozzle boom with 20-inch spacing, with the boom centered over the 10-foot application width such that there was complete nozzle overlap throughout the 10-foot treatment width.

Nozzles with a 110-degree spray pattern were utilized, and boom height was set 20 inches above the canopy (average height across the study). To facilitate overspray of treatments, capture any fungicide drift and to establish an acceptable width for driving the tractor to apply treatments, treatment plots were separated by 10-foot wide non-harvested filler plots on both sides of the treatment plots. A tractor with a 5-foot wheelbase was used to apply fungicide treatments, and this tractor was driven in the center of every second 10-foot wide filler plots. To ensure that the driving pass for the tractor was smooth, the wheel tracks were tilled and smoothed during dry bean mid-vegetative growth with a cultivator originally designed for cultivating between strawberry beds.

Application	Date	Time	Nozzle	Pressure	Pulse Width	Speed	Product
1	23 July	3:42p	XR11006	35 psi	51%	6.0 mph	Endura, 8 oz/ac
2	26 July	1:32p	XR11006	35 psi	51%	6.0 mph	Endura, 8 oz/ac
3	28 July	3:05p	XR11006	35 psi	51%	6.0 mph	Endura, 8 oz/ac
4	30 July	5:10p	XR11006	35 psi	51%	6.0 mph	Endura, 8 oz/ac
5	31 July	6:40p	XR11006	35 psi	51%	6.0 mph	Endura, 8 oz/ac
6	2 Aug.	8:48a	XR11010	30 psi	36%	6.0 mph	Endura, 8 oz/ac
7	4 Aug.	2:57p	XR11010	30 psi	36%	6.0 mph	Endura, 8 oz/ac
8	7 Aug.	10:30a	XR11010	30 psi	36%	6.0 mph	Endura, 8 oz/ac
9	10 Aug.	4:05p	XR11010	30 psi	36%	6.0 mph	Endura, 8 oz/ac
10	12 Aug;	6:01p	XR11010	30 psi	36%	6.0 mph	Endura, 8 oz/ac
11	14 Aug.	9:56a	XR11010	30 psi	36%	6.0 mph	Endura, 8 oz/ac
12	18 Aug.	2:00p	XR11010	30 psi	36%	6.0 mph	Endura, 8 oz/ac
13	21 Aug.	2:27p	XR11010	30 psi	36%	6.0 mph	Endura, 8 oz/ac
14	21 Aug.	10:20a	XR11010	30 psi	36%	6.0 mph	Endura, 8 oz/ac

Spray droplet size: Droplet size was calibrated relative to canopy closure. Medium droplets were utilized in the first application, when the canopy was nearing closure but still open. Coarse droplets were utilized in the second application, when the canopy was at or near closure.

IN-SEASON DATA COLLECTION Sclerotinia disease assessments: All plants in the second row of each four row plot (counting from the west) were individually assessed for the percent of the plant exhibiting white mold symptom. A 0 to 10 scoring system was utilized, where 0 = no disease, 1 = 1-10% of the plant diseased, 2 = 11-20% of the plant diseased, ... 10 = 91-100% of the plant diseased. The plant-level data were utilized to calculate plot-level Sclerotinia incidence, severity and severity index levels. Sclerotinia incidence = percent of plants exhibiting white mold symptoms; Sclerotinia severity = average percent of plant tissue exhibiting white mold symptoms among plants with the disease; Sclerotinia severity index = percent of canopy exhibiting white mold symptoms. Disease assessments were conducted on Sept. 17 to October 1 at the R8-R9 growth stage (at or near maturity). An average of 38 plants per plot were individually scored for white mold severity in each plot.

STATISTICAL ANALYSIS Data were evaluated with analysis of variance with the assumptions of constant variance, normality, and additivity of main-factor effects across replicates tested. Analyses were conducted with replicate and treatment as main factor effects, and they were implemented in PROC UNIVARIATE and PROC GLM of SAS (version 9.4; SAS Institute, Cary, NC).

DETAILED METHODS: fungicide application rotation sequence study, 2025

LOCATION OF STUDY

GPS Coordinates, kidney bean study: 47.5034, -99.1182 (northwest corner; plot 101)

GPS Coordinates, pinto bean study: 47.5027, -99.1199 (northwest corner; plot 101)

Description: North Dakota State University Carrington Research Extension Center approximately 3 miles north of Carrington, ND

AGRONOMICS

Variety 'Pink Panther' light-red kidney, 'Torreon' pinto bean

Tillage Disked October 2024; cultivated once on May 25, 2025 and twice on June 4, 2025

Previous crop: field peas (kidney beans), soybeans (pinto beans)

Soil fertility: 42 lbs/ac nitrogen (30 lbs in top 6 inches + 12 lbs at 6 to 18 inches deep); 31 ppm phosphorous; 230 ppm potassium; 86 lbs/ac sulfur (26 lbs in the top 6 inches + 60 lbs at 6 to 18 inches deep); 0.97 ppm zinc; 1.0 ppm boron; 3.7% organic matter; 0.34 mmho/cm soluble salts in the top 6 inches; 0.30 mmho/cm soluble salts at 6 to 18 inches deep; pH = 7.9 in the top 6 inches; pH = 8.2 at 6 to 18 inches deep

Fertilization: 98 lbs/ac urea = 45 lbs of nitrogen applied May 25 and incorporated the same day

Planting date: June 9 (kidney beans), June 10 (pinto beans)

Row spacing: 14 inches; **Rows per plot:** four **Seeding rate:** 90,000 pure live seeds/acre

Plot size at planting: 5 feet wide (center-on-center) x 30 feet long, **Plot size at harvest:** 5 feet wide x average 21.4 feet long.

Experimental design Randomized complete block with 7 replicates (kidney beans), 8 replicates (pinto beans)

Herbicide applications Pre-plant incorporated: June 4; Sonalan (ethalfluralin, 3 lbs/gal; Gowan Company, Yuma, AZ) @ 2 pt/ac + Eptam 7EC

(EPTC, 7 lbs/gal; Gowan Company, Yuma, AZ) @ 4 fl oz/ac; spray volume = 20 gal/ac Pre-emergence: June 11; Imazethapyr 2SL

(Ammonium salt of imazethapyr, 2 lbs free acid per gal; Willowood USA) @ 2 fl oz/ac; spray volume = 12 gal/ac Post-emergence grass

herbicide: July 1; Targa (quizalofop-p-ethyl, 0.88 lb ai/gal; Gowan Corp., Yuma, AZ) @ 12 fl oz/ac + Trizenta 3EC (clethodim, 3 lbs ai/gal;

Arysta LifeScience, Cary, NC) @ 5 fl oz/ac + COC @ 12 fl oz/ac (1% v/v); spray volume = 20 gal/ac Post-emergence broadleaf herbicide: July

7; Vulture (ammonium salt of imazamox, 1 lb ai/gal) @ 4 fl oz/ac + Basagran 5L (sodium salt of bentazon, 5 lbs ai/gal) @ 12 fl oz/ac + Outlook

(dimethenamid-P, 6.0 lbs/gal) @ 18 fl oz/ac + COC @ 12 fl oz/ac + AMS 8.5 lbs/100 gal; spray volume = 20 gal/ac

Harvest date: Sept. 24 (kidney beans), Oct. 20 and 22 (pinto beans)

Yield assessment Dry beans were manually clipped concurrent with disease assessments and wind-rowed to facilitate even dry-down (simulating knifing). In order to exclude transition areas where spraying was initiated or ended, the first and last 2 to 3 feet at each end of each plot was excluded from harvest. The harvested plot length was measured for each plot. Grain was cleaned after harvest, and moisture was assessed on the cleaned grain. Yields are reported at 13.5% moisture.

DISEASE ESTABLISHMENT

This research trial was planted on land with a prior history of Sclerotinia epidemics. Because of recurrent rains and heavy dews during bloom, no supplemental irrigation was applied to the study. An irrigation system with micro-sprinklers established on a 20-foot offset grid was established over this study during late vegetative growth, but the irrigation system was not utilized.

FOLIAR FUNGICIDE APPLICATIONS – KIDNEY BEANS

Study evaluating fungicide rotation sequence in 2- and 3-application fungicide programs

- fungicide application 1, 100% of plants with an open blossom, 95% of plants with initial pin-pods, canopy closure approx. 95%; AIXR110015 50 psi, Aug. 1 at 11:30 am to 1:30 pm
- fungicide treatments at target 7d interval (actual = 6d); AIXR110015, 50 psi, Aug. 7, 3:30-5:00 pm
- fungicide treatments at target 10d interval (actual = 9d); AIXR110015, 40 psi, Aug. 10, 8:30-9:05 pm; kidney beans upright, canopy closure 100%, full bloom and early to mid pod
- fungicide treatments at target 14d interval (actual = 13d); AIXR110015, 40 psi, Aug. 14, 11:15 am - 12:30 pm; kidney beans partially lodged, canopy closure 100%, full bloom and mid pod

Study evaluating fungicide application interval for Topsin/Topsin/Endura vs. Endura/Endura/Topsin application programs

- fungicide application 1, 100% of plants with an open blossom, 95% of plants with initial pin-pods, canopy closure approx. 95%; AIXR110015 50 psi, Aug. 1 at 11:30 am to 1:30 pm
- fungicide treatments at target 7d interval (actual = 6d); AIXR110015, 50 psi, Aug. 7, 3:30-5:00 pm
- fungicide treatments at target 10d interval (actual = 9d); AIXR110015, 40 psi, Aug. 10, 8:30-9:05 pm; kidney beans upright, canopy closure 100%, full bloom and early to mid pod
- fungicide treatments at target 12d interval (actual = 11d); AIXR110015, 40 psi, Aug. 12, 8:35-8:55 pm; kidney beans upright, canopy closure 100%, full bloom and early to mid pod
- fungicide treatments at target 14d interval (actual = 13d); AIXR110015, 40 psi, Aug. 14, 11:15 am - 12:30 pm; kidney beans partially lodged, canopy closure 100%, full bloom and mid pod
- fungicide treatments at target 20d interval (actual = 18d); AIXR110015, 40 psi, Aug. 19, 6:30-6:55 pm; kidney beans partially lodged, end of bloom with only 20-30% of plants still in bloom
- fungicide treatments at target 24d interval (actual = 23d); AIXR110015, 40 psi, Aug. 24, 1:35-1:55 pm; bloom complete
- Spray droplet size: Droplet size was calibrated relative to canopy closure. Medium droplets were utilized in the first application, when the canopy was nearing closure but still open. Medium droplets on the coarser end of the medium spectrum were utilized in the second application, when the canopy was closed.

FOLIAR FUNGICIDE APPLICATIONS – PINTO BEANS

Study evaluating fungicide rotation sequence in 2- and 3-application fungicide programs

- fungicide application 1, 80% of plants with an open blossom, 50% of plants with initial pin-pods, canopy closure approx. 85%; AIXR110015 60 psi, July 30 at 5:00-8:00 pm
- fungicide treatments at target 10d interval (actual = 11d); AIXR110015, 40 psi, Aug. 10, 9:10-10:05 pm; full bloom and early to mid-pod, canopy closure 100%, pinto beans lodged at an average approx. 30 degree angle;
- fungicide treatments at target 12d interval (actual = 13d); AIXR110015, 40 psi, Aug. 12, 9:00-9:50 pm; full bloom and early to mid-pod, canopy closure 100%, pinto beans lodged at an average approx. 30-45 degree angle;
- fungicide treatments at target 20d interval (actual = 20d); AIXR110015, 40 psi, Aug. 19, 7:00-8:20 pm; pinto beans 45-degree lodged, late bloom with 100% of plants in bloom

Study evaluating fungicide application interval for Topsin/Topsin/Endura vs. Endura/Endura/Topsin application programs

- fungicide application 1, 80% of plants with an open blossom, 50% of plants with initial pin-pods, canopy closure approx. 85%; AIXR110015 60 psi, July 30 at 5:00-8:00 pm
- fungicide treatments at target 7d interval (actual = 8d); AIXR110015, 50 psi, Aug. 7, 5:10-5:30 pm
- fungicide treatments at target 10d interval (actual = 11d); AIXR110015, 40 psi, Aug. 10, 9:10-10:05 pm; full bloom and early to mid-pod, canopy closure 100%, pinto beans lodged at an average approx. 30 degree angle;
- fungicide treatments at target 12d interval (actual = 13d); AIXR110015, 40 psi, Aug. 12, 9:00-9:50 pm; full bloom and early to mid-pod, canopy closure 100%, pinto beans lodged at an average approx. 30-45 degree angle;
- fungicide treatments at target 14d interval (actual = 15d); AIXR110015, 40 psi, Aug. 14, 12:35-1:15 pm; pinto beans lodged about 45 degrees, canopy closure 100%, full bloom and early to mid pod
- fungicide treatments at target 20d interval (actual = 20d); AIXR110015, 40 psi, Aug. 19, 7:00-8:20 pm; pinto beans 45-degree lodged, late bloom with 100% of plants in bloom
- fungicide treatments at target 24d interval (actual = 25d); AIXR110015, 40 psi, Aug. 24, 2:05-2:25 pm; end of bloom with 10% of plants in bloom

IN-SEASON DATA COLLECTION

Sclerotinia disease assessments: All plants in the second row of each four-row plot (counting from the north) were individually assessed for the percent of the plant exhibiting white mold symptoms. A 0 to 10 scoring system was utilized, where 0 = no disease, 1 = 1-10% of the plant diseased, 2 = 11-20% of the plant diseased, ... 10 = 91-100% of the plant diseased. The plant-level data were utilized to calculate plot-level Sclerotinia incidence, severity and severity index levels. Sclerotinia incidence = percent of plants exhibiting white mold symptoms; Sclerotinia severity = average percent of plant tissue exhibiting white mold symptoms among plants with the disease; Sclerotinia severity index = percent of canopy exhibiting white mold symptoms.

Kidney beans: Disease assessments were conducted on September 8-10 at the R9 growth stage (maturity). An average of 47 plants per plot were individually scored for white mold severity in each plot.

Pinto beans: Disease assessments were conducted on October 16, 17, 20, and 21 at the R9 growth stage (maturity). An average of 120 plants per plot were individually scored for white mold severity in each plot.

STATISTICAL ANALYSIS

Analysis of variance Data were evaluated with analysis of variance. (1) The assumption of constant variance was assessed with Levene's test for homogeneity of variances and visually confirmed by plotting residuals against predicted values. (2) The assumption of normality was assessed the Shapiro-Wilk test and visually confirmed with a normal probability plot. (3) The assumption of additivity of main-factor effects across replicates (no replicate-by-treatment interaction) was evaluated with Tukey's test for nonadditivity. If data did not meet model assumptions, a systematic natural-log transformation was applied to correct deviations from normality and/or homoskedasticity, and analysis of variance was conducted on the transformed data. Data subjected to a systematic natural-log transformation are identified by the symbol '†' placed at the top of the applicable column of data in the summary table; for ease of transformation, treatments for non-transformed data are presented in the summary table. Single-degree-of-freedom contrasts were performed for all pairwise comparisons of isolates; to control the Type I error rate at the level of the experiment, the Tukey multiple comparison procedure was employed. Analyses were conducted with replicate and treatment as main factor effects, and they were implemented in PROC UNIVARIATE and PROC GLM of SAS (version 9.4; SAS Institute, Cary, NC).