Optimizing fungicide application timing for improved white mold management in pinto beans

Research funded by the North Dakota Crop Protection Product Harmonization and Registration Board and the Northarvest Bean Growers Association

Principal Investigator: Michael Wunsch, Ph.D., plant pathologist, North Dakota State University Carrington Research Extension Center / Tel. 701-652-2951 / michael.wunsch@ndsu.edu **Key contributing staff:** Jesse Hafner, research specialist (tractor-applied fungicide applications, agronomics); Suanne Kallis, research specialist (agronomics); Aaron Fauss, research technician (agronomics); Thomas Miorini, former postdoctoral research associate (assistance with application timing studies in 2020, 2021); NDSU Carrington Research Extension Center.

MAJOR FINDINGS: **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.** In research studies conducted utilizing supplemental irrigation to create conditions favoring white mold as dry beans enter bloom, white mold management in pinto beans was optimized with a single fungicide application by delaying the application until 70-100% of plants had initial pin-pods. Two-application fungicide programs were optimized by applying the first application a few days earlier: 10-20% of plants with initial pin-pods when white mold risk was very high and 40-85% of plants with initial pin-pods when white mold risk was more moderate. Three-application fungicide programs were optimized by applying the first application at early bloom when 0-5% of plants had initial pin-pods.

EXPLANATION FOR THE OBSERVED RESPONSE:

Fungicide applications only protect the canopy that is present at the time of the application. Fungicides applied to foliar tissues do not translocate into new growth and do not protect the new growth that occurs after the fungicide is applied. Most fungicides do not have the ability to cure existing infections, and those with some degree of curative activity can generally only stop an infection within 24 hours of the pathogen penetrating the plant (when infections are at a microscopic level and disease is not yet present).

If you are making a single fungicide application, there is a tradeoff: Do you protect against a few early infections or do you delay the application such that more of the canopy is protected as the dry beans enter full bloom? Susceptibility to white mold is highest at full bloom, not bloom initiation and initial pin-pod. The data from our field studies show that the yield loss conferred by allowing some early infections is lower than the yield loss associated with leaving a significant proportion of the canopy unprotected (due to new growth) as the dry beans enter full bloom.

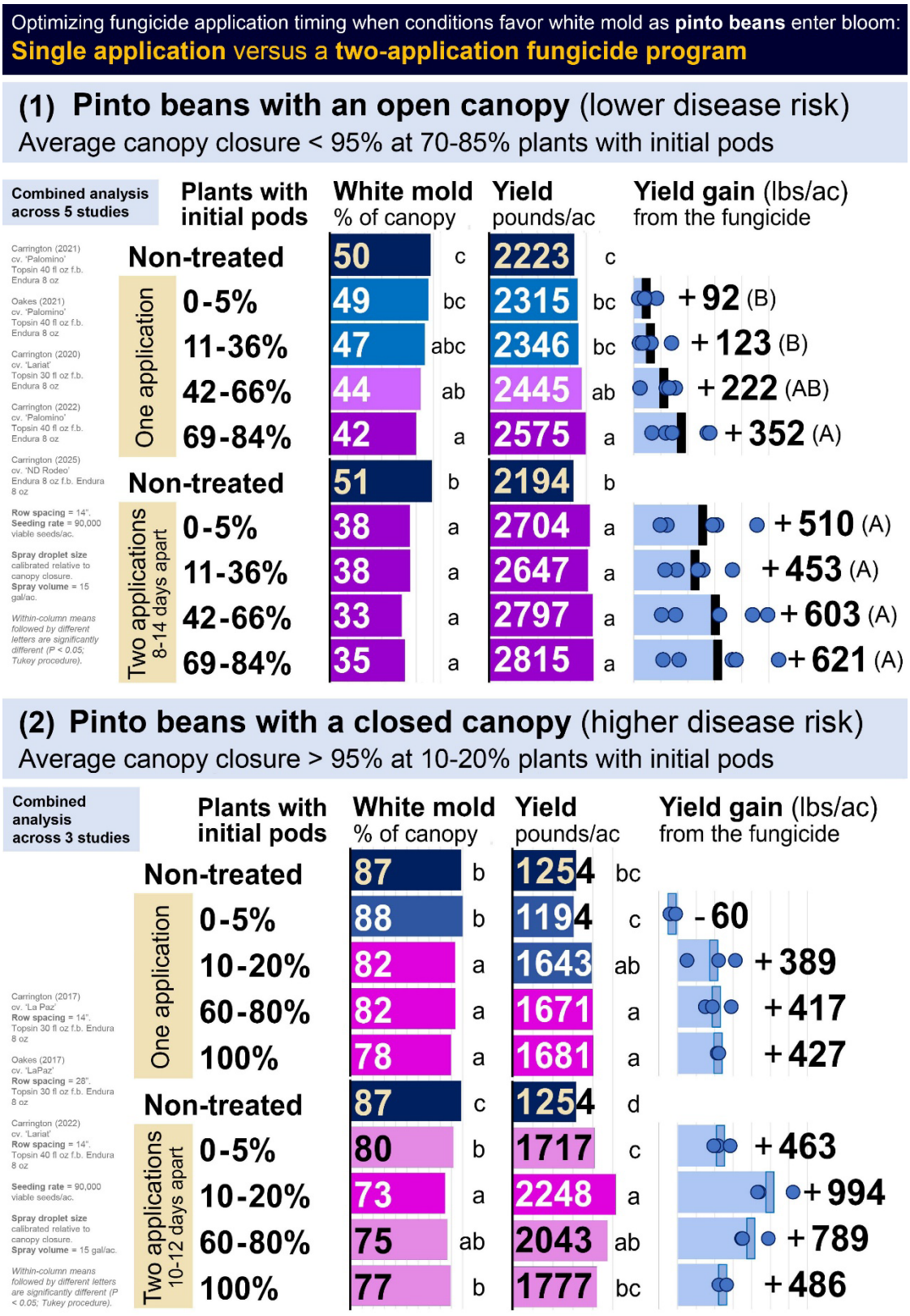
When you are making two fungicide applications, the second fungicide application will protect new growth, which means that now you can afford to protect the crop against early white mold infections. However, applying too early still carries a penalty for the same reason: The new growth that occurs between the first and second applications is unprotected until the second application is made.

With a three-application program, fungicide applications #2 and #3 protect the new growth, and our data show that the fungicide program is optimized by applying the first fungicide at early bloom just as the plants first become susceptible to white mold (<5% of plants with initial pin-pods). In a three-application program, you can afford to protect against the earliest infections because you are making subsequent applications on a tight interval that protects the new growth.

CAUTIONARY NOTE:

These studies were conducted by using overhead irrigation to create conditions favorable for white mold as dry beans entered bloom. **When conditions do not favor white mold until full bloom or early pod-fill, applications should be delayed until conditions favor white mold.** Foliar fungicide applications only protect the canopy to which they are applied, not the new growth, and applying fungicides before there is any significant risk of pathogen infection will result in a significant portion of the canopy being unprotected when conditions become favorable for disease.

Impact of application timing on white mold management in pinto beans: bars denote average response across multiple studies, circles denote response within individual studies.



Impact of application timing on white mold management in pinto beans, Carrington, ND (2024 and 2025). Row spacing = 14 inches, seeding rate = 90,000 viable seeds/ac.

Optimizing fungicide application timing when conditions favor white mold as **pinto beans** enter bloom:

Three-application fungicide program - pinto beans (Carrington, ND)

Endura (8.0 oz/ac) was applied at each application; spray volume = 15 gpa; driving speed = 6.0 mph

3 applications approx. 7 days apart

PINTO BEANS **(2025)**
cv. **'ND Rodeo'**

Date of first application	Plants in bloom (%)	Plants with pin-pods (%)	White mold % of canopy	Yield lbs/ac
			3 applications **7-8 days apart**	
Non-treated			79 b*	1778 b*
July 23	19	0	54 a	2804 a
July 26	66	6	61 a	2588 a
July 30	84	42	58 a	2727 a
July 31	92	69	59 a	2559 a
F, P>F:			6.94, <0.0001	22.43, <0.0001
CV:			31.5	6.7

PINTO BEANS **(2024)**
cv. **'Torreon'**

Date of first application	Plants in bloom (%)	Plants with pin-pods (%)	White mold % of canopy	Yield lbs/ac
			3 applications **5-8 days apart**	
Non-treated			69 b*	2162 b*
July 17	3	0	54 a	3080 a
July 19	19	0	51 a	3030 a
July 24	100	49	59 ab	2921 a
July 26	100	81	59 ab	2747 a
F, P>F:			5.99, 0.0003	9.46, < 0.0001
CV:			12.6	11.6

Combined analysis across studies

Plants in bloom (%)	Plants with pin-pods (%)	White mold % of canopy	Yield lbs/ac	Yield gain conferred by fungicide (lbs/ac)
		3 applications **5-8 days apart**		
Non-treated		74 b	1970 b	
3-19%	0%	54 a	2942 a	+ 973
19-66%	0-6%	56 a	2809 a	+ 839
84-100%	42-49%	58 ab	2824 a	+ 854
92-100%	69-81%	59 ab	2653 a	+ 683
F, P>F:		8.30, 0.0322	46.74, 0.0013	
CV:		6.3	3.0	

3 applications approx. 10 days apart

PINTO BEANS **(2025)**
cv. **'ND Rodeo'**

Date of first application	Plants in bloom (%)	Plants with pin-pods (%)	White mold % of canopy	Yield lbs/ac
			3 applications **9-11 days apart**	
Non-treated			76 b*	1546 b*
July 23	19	0	57 a	2566 a
July 26	66	6	59 a	2591 a
July 30	84	42	67 ab	2312 a
July 31	92	69	67 ab	2381 a
F, P>F:			4.17, 0.0039	13.26, <0.0001
CV:			15.9	13.9

PINTO BEANS **(2024)**
cv. **'Torreon'**

Date of first application	Plants in bloom (%)	Plants with pin-pods (%)	White mold % of canopy	Yield lbs/ac
			3 applications **8-11 days apart**	
Non-treated			65 b*	2435 b*
July 17	3	0	44 a	3458 a
July 19	19	0	53 a	3217 a
July 24	100	49	47 a	3343 a
July 26	100	81	49 a	3312 a
F, P>F:			7.58, < 0.0001	15.79, < 0.0001
CV:			15.5	8.8

Combined analysis across studies

Plants in bloom (%)	Plants with pin-pods (%)	White mold % of canopy	Yield lbs/ac	Yield gain conferred by fungicide (lbs/ac)
		3 applications **8-11 days apart**		
Non-treated		71 b	1991 b	
3-19%	0%	51 a	3012 a	+ 1021
19-66%	0-6%	56 ab	2904 a	+ 913
84-100%	42-49%	57 ab	2828 a	+ 837
92-100%	69-81%	58 ab	2847 a	+ 856
F, P>F:		7.24, 0.0406	30.21, 0.0030	
CV:		6.7	3.9	

Impact of fungicide application timing on white mold management in pinto beans

(1) **studies with a closed canopy at initial pod** (≥95% closure when 10-20% of plants had pin-pods)

			Pinto bean variety	La Paz	La Paz	Lariat
			study location **(year)**	Carrington **(2017)**	Carrington **(2017)**	Carrington **(2022)**
			row spacing, number of **experimental replicates**	14 inches, **15**	28 inches, **15**	14 inches, **10**
Fungicide application #1			fungicide	**Topsin** 30 fl oz	**Topsin** 30 fl oz	**Topsin** 40 fl oz
			nozzles, pressure	XR110015, 35 psi	XR110015, 35 psi	DG110015, 40 psi
			droplet size	fine	fine	fine
Fungicide application #2			fungicide	**Endura** 8 oz	**Endura** 8 oz	**Endura** 8 oz
			nozzles, pressure	XR110015, 35 psi	XR110015, 35 psi	AIXR110015, 50 psi
			droplet size	fine	fine	medium-coarse
			Interval between applications	12 days	12 days	10 to 11 days
Fungicide application date			Application timing #1	July 20	July 20	July 18
			Application timing #2	July 22	July 22	July 21
			Application timing #3	July 25	July 25	July 24
			Application timing #4	July 27	July 27	NOT TESTED
Plants with an open blossom			Application timing #1	80%	80%	16%
			Application timing #2	100%	100%	72%
			Application timing #3	100%	100%	90%
			Application timing #4	100%	100%	NOT TESTED
Plants with initial pin-shaped pods			Application timing #1	0%	0%	2%
			Application timing #2	15%	15%	16%
			Application timing #3	60%	60%	76%
			Application timing #4	100%	100%	NOT TESTED
Canopy closure: % of ground covered by the canopy, range and average			Application timing #1	95% (average)	70% (average)	95-98% (ave. 97%)
			Application timing #2	99% (average)	95% (average)	95-98% (ave. 97%)
			Application timing #3	100% (average)	98% (average)	97-100% (ave. 99%)
			Application timing #4	100% (average)	100% (average)	NOT TESTED
WHITE MOLD (% of canopy diseased)						
Non-treated control				**83** ab*	**86** ab*	**92** a*
SINGLE fungicide application	growth stage at application	16-80%	0-2%	70-97%	**85** b	**88** b	**92** a
		72-100%	15-16%	95-99%	**75** a	**80** a	**90** a
		90-100%	60-76%	98-100%	**77** ab	**81** a	**88** a
		100%	100%	100%	**75** a	**80** a	NOT TESTED
F, P>F:		Plants in bloom	Plants with initial pods	Canopy closure (%)	4.47, 0.0033	5.35, 0.0010	1.63, 0.2063
CV:					11.2	7.1	5.9
Non-treated control					**83** b*	**86** b*	**92** c
TWO fungicide applications	growth stage, 1st application	16-80%	0-2%	70-97%	**75** a	**79** ab	**87** bc
		72-100%	15-16%	95-99%	**70** a	**74** a	**74** a
		90-100%	60-76%	98-100%	**70** a	**74** a	**79** ab
		100%	100%	100%	**77** ab	**78** ab	NOT TESTED
F, P>F:		Plants in bloom	Plants with initial pods	Canopy closure (%)	7.6,<0.0001	4.40, 0.0038	11.9,<0.0001
CV:					10.3	11.4	9.0
YIELD (pounds per acre)							
Non-treated control					**1285** b*	**1297** bc*	**1180** a*
SINGLE fungicide application	growth stage at application	16-80%	0-2%	70-97%	**1209** b	**1215** c	**1159** a
		72-100%	15-16%	95-99%	**1908** a	**1739** a	**1281** a
		90-100%	60-76%	98-100%	**1864** a	**1595** abc	**1555** a
		100%	100%	100%	**1671** ab	**1691** ab	NOT TESTED
F, P>F:		Plants in bloom	Plants with initial pods	Canopy closure (%)	6.38, 0.0003	6.60,0.0007	11.9,<0.0001
CV:					31.3	25.7	9.0
Non-treated control					**1285** c*	**1297** c*	**1180** b*
TWO fungicide applications	growth stage, 1st application	16-80%	0-2%	70-97%	**1719** b	**1686** bc	**1746** ab
		72-100%	15-16%	95-99%	**2163** a	**2158** a	**2423** a
		90-100%	60-76%	98-100%	**1974** ab	**1997** ab	**2158** a
		100%	100%	100%	**1729** b	**1825** ab	NOT TESTED
F, P>F:		Plants in bloom	Plants with initial pods	Canopy closure (%)	13.8,<0.0001	9.5,<0.0001	8.29, 0.0005
CV:					19.4	23.0	31.7

all applications were made with a hand-held boom

all applications were made with a hand-held boom

Combined analysis across 3 studies

Non-treated control				**87** b		
SINGLE fungicide application	growth stage at application	16-80%	0-2%	70-97%	**88** b	
		72-100%	15-16%	95-99%	**82** a	
		90-100%	60-76%	98-100%	**82** a	
		100%	100%	100%	**78** a	
F, P>F:		Plants in bloom	Plants with initial pods	Canopy closure (%)	12.66, 0.0025	
CV:					2.0	
Non-treated control					**87** c	
TWO fungicide applications	growth stage, 1st application	16-80%	0-2%	70-97%	**80** b	
		72-100%	15-16%	95-99%	**73** a	
		90-100%	60-76%	98-100%	**75** ab	
		100%	100%	100%	**77** b	
F, P>F:		Plants in bloom	Plants with initial pods	Canopy closure (%)	25.29, 0.0003	
CV:					2.5	
Non-treated control					**1254** bc	
SINGLE fungicide application	growth stage at application	16-80%	0-2%	70-97%	**1194** c	
		72-100%	15-16%	95-99%	**1643** ab	
		90-100%	60-76%	98-100%	**1671** a	
		100%	100%	100%	**1681** a	
F, P>F:		Plants in bloom	Plants with initial pods	Canopy closure (%)	8.17, 0.0090	
CV:					9.3	
Non-treated control					**1254** d	
TWO fungicide applications	growth stage, 1st application	16-80%	0-2%	70-97%	**1717** c	
		72-100%	15-16%	95-99%	**2248** a	
		90-100%	60-76%	98-100%	**2043** ab	
		100%	100%	100%	**1777** bc	
F, P>F:		Plants in bloom	Plants with initial pods	Canopy closure (%)	51.53, <0.0001	
CV:					5.0	

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

Impact of fungicide application timing on white mold management in pinto beans

(2) **studies with an open canopy at initial pod** (<95% canopy closure through 80% or more of plants with initial pin-pods)

				Pinto bean variety	Palomino	Palomino	Lariat	Palomino	ND Rodeo	
				Location	Carrington	Oakes	Carrington	Carrington	Carrington	
				Year	2021	2021	2020	2022	2025	
				Row spacing	14"	14"	14"	14"	14"	
				Experimental replicates	6	7	16	10	9	
				Application method	hand-held boom	hand-held boom	hand-held boom	hand-held boom	tractor, 6.0 mph	
				fungicide	**Topsin** 40 fl oz	**Topsin** 40 fl oz	**Topsin** 30 fl oz	**Topsin** 40 fl oz	**Endura** 8 oz	
Fungicide application #1				nozzles, pressure	DG110015, 40 psi	AIXR110015, 50 psi	AIXR110015, 60 or 70 psi (medium)	DG110015, 40 psi	XR11006, 35 psi	
				droplet size	fine	medium-coarse		fine	medium	
				fungicide	**Endura** 8 oz	**Endura** 8 oz	**Endura** 8 oz	**Endura** 8 oz	**Endura** 8 oz	
Fungicide application #2				nozzles, pressure	AIXR110015, 50 psi	AIXR110015, 50 psi	AIXR110015, 50 or 6	AIXR110015, 50 psi	XR11010, 30 psi	
				droplet size	medium-coarse	medium-coarse	medium or med-cc	medium-coarse	coarse	
				Interval between applications	14 days	8 to 10 days	10 days	10 to 11 days	10 or 11 days	
Fungicide application date				Application timing #1	July 9	July 12	July 10	July 16	July 23	
				Application timing #2	July 12	July 13	July 14	July 18	July 28	
				Application timing #3	July 16	July 17	July 16	July 21	July 30	
				Application timing #4	July 19	July 19	July 18	July 24	July 31	
Plants with an open blossom				Application timing #1	39%	50%	34%	23%	19%	
				Application timing #2	55%	71%	81%	64%	73%	
				Application timing #3	84%	97%	83%	86%	84%	
				Application timing #4	88%	100%	92%	92%	92%	
Plants with initial pin-shaped pods				Application timing #1	0%	0%	0%	5%	0%	
				Application timing #2	15%	15%	11%	36%	12%	
				Application timing #3	56%	64%	53%	66%	42%	
				Application timing #4	73%	78%	84%	76%	69%	
Canopy closure: % of ground covered by the canopy, range and average				Application timing #1	30-50% (40%)	15-67% (50%)	83 to 96% (89%)	40-75% (59%)	88% average	
				Application timing #2	35-60% (45%)	20-75% (60%)	85 to 96% (91%)	50-75% (63%)	90% average	
				Application timing #3	35-80% (53%)	40-70% (60%)	87 to 95% (92%)	65-80% (72%)	90% average	
				Application timing #4	50-85% (67%)	55-80% (73%)	87 to 89% (93%)	60-80% (69%)	90% average	
										Combined analysis across 5 studies
WHITE MOLD (percent of canopy diseased)										
Non-treated control					**14** b*	**30** a*	**77** b*	**58** a*	**72** a*	**50** c*
SINGLE fungicide application	growth stage at application	19-50%	0-5%	40-91%	**14** b	**22** a	**73** b	**62** a	**74** a	**49** bc
		55-81%	11-36%	45-91%	**7** ab	**22** a	**73** ab	**62** a	**71** a	**47** abc
		83-100%	42-66%	53-92%	**4** a	**23** a	**70** ab	**54** a	**71** a	**44** ab
		88-100%	69-84%	67-93%	**4** a	**19** a	**66** a	**50** a	**71** a	**42** a
F, P>F:		Plants in bloom	Plants with initial pods	Canopy closure (%)	7.71, 0.0006	1.88, 0.1460	5.58, 0.0007	2.37, 0.0718	0.34, 0.8849	7.15, 0.0017
CV:					28.2	34.7	9.5	19.2	10.7	CV: 6.1
Non-treated control					**14** b*	**30** b*	**77** c*	**58** c	**76** b*	**51** b
TWO fungicide applications	growth stage, 1st application	19-50%	0-5%	40-91%	**4** a	**16** a	**61** b	**44** b	**65** ab	**38** a
		55-81%	11-36%	45-91%	**3** a	**16** a	**62** b	**49** bc	**62** ab	**38** a
		83-100%	42-66%	53-92%	**3** a	**18** a	**53** b	**29** a	**65** ab	**33** a
		88-100%	69-84%	67-93%	**4** a	**21** a	**43** a	**42** ab	**65** ab	**35** a
F, P>F:		Plants in bloom	Plants with initial pods	Canopy closure (%)	4.27, 0.0116	8.04, 0.0003	27.2<0.0001	11.57, <0.0001	2.85, 0.0273	8.04, 0.0009
CV:					51.3	27.6	16.2	22.1	17.7	CV: 13.9
YIELD (pounds per acre)										
Non-treated control					**2898** a*	**2747** a*	**1901** b*	**1709** b	**1860** a*	**2223** c*
SINGLE fungicide application	growth stage at application	20-50%	0%	40-90%	**2996** a	**2783** a	**2070** ab	**1788** b	**1940** a	**2315** bc
		55-89%	11-36%	45-94%	**2999** a	**2875** a	**1943** b	**1773** b	**2139** a	**2346** bc
		83-97%	53-66%	53-96%	**2945** a	**2999** a	**2141** ab	**2016** ab	**2122** a	**2445** ab
		88-100%	73-84%	67-93%	**3033** a	**2983** a	**2450** a	**2266** a	**2144** a	**2575** a
F, P>F:		Plants in bloom	Plants with initial pods	Canopy closure (%)	0.22, 0.9216	1.81, 0.1595	5.17, 0.0012	4.30, 0.0062	2.15, 0.0793	8.36, 0.0008
CV:					9.2	7.8	18.2	18.4	12.6	CV: 4.4
Non-treated control					**2898** a*	**2747** a*	**1901** d	**1709** c	**1714** b*	**2194** b
TWO fungicide applications	growth stage, 1st application	20-50%	0%	40-90%	**3144** a	**2942** a	**2514** bc	**2292** b	**2626** a	**2704** a
		55-89%	11-36%	45-94%	**3217** a	**2978** a	**2411** c	**2183** b	**2444** a	**2647** a
		83-97%	53-66%	53-96%	**3207** a	**2953** a	**2780** ab	**2700** a	**2348** a	**2797** a
		88-100%	73-84%	67-93%	**3233** a	**2963** a	**2973** a	**2447** ab	**2460** a	**2815** a
F, P>F:		Plants in bloom	Plants with initial pods	Canopy closure (%)	1.52, 0.2339	1.28, 0.3069	28.2,<0.0001	13.81, <0.0001	17.86, <0.0001	9.83, 0.0003
CV:					8.8	7.7	11.9	13.8	10.3	CV: 6.9

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

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	Test weight
					Incidence	Sev. Index	13.5% moisture	
					Sept. 17 - Oct. 1; R8-R9			
					% of plants	% of canopy	lbs/ac	lbs/bu
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	

Application date	Canopy closure (%)	Plants in bloom (%)	Pin-pods (% plants)	Canopy height (in.)	White mold		Yield	Test weight
					Incidence	Sev. Index	13.5% moisture	
					Sept. 17 - Oct. 1; R8-R9			
					% of plants	% of canopy	lbs/ac	lbs/bu
Non-treated control					**96** a*	**76** b*	**1714** b*	**57.9**
July 23	88	19	0	17.0	**92** a	**65** ab	**2626** a	**59.5**
July 26	90	66	6	19.3	**84** a	**56** a	**2656** a	**59.2**
July 28	90	73	12	18.1	**86** a	**62** ab	**2444** a	**59.3**
July 30	90	84	42	17.9	**90** a	**65** ab	**2348** a	**59.2**
July 31	90	92	69	18.3	**89** a	**65** ab	**2460** a	**58.9**
					2.01, 0.0983	2.85, 0.0273	17.86, <0.000	
					10.0	17.7	10.3	

Application date	Canopy closure (%)	Plants in bloom (%)	Pin-pods (% plants)	Canopy height (in.)	White mold		Yield	Test weight
					Incidence	Sev. Index	13.5% moisture	
					Sept. 17 - Oct. 1; R8-R9			
					% of plants	% of canopy	lbs/ac	lbs/bu
Non-treated control					**97** b*	**75** b*	**1789** b*	**58.3**
July 23	88	19	0	17.0	**87** a	**56** a	**2539** a	**58.9**
July 26	90	66	6	19.3	**87** a	**60** a	**2643** a	**59.0**
July 28	90	73	12	18.1	**93** ab	**67** ab	**2496** a	**59.2**
July 30	90	84	42	17.9	**93** ab	**68** ab	**2325** a	**59.1**
July 31	90	92	69	18.3	**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	

Application date	Canopy closure (%)	Plants in bloom (%)	Pin-pods (% plants)	Canopy height (in.)	White mold		Yield	Test weight
					Incidence	Sev. Index	13.5% moisture	
					Sept. 17 - Oct. 1; R8-R9			
					% of plants	% of canopy	lbs/ac	lbs/bu
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	12.43, <0.000	
					10.1	16.4	9.4	

Application date	Canopy closure (%)	Plants in bloom (%)	Pin-pods (% plants)	Canopy height (in.)	White mold		Yield	Test weight
					Incidence	Sev. Index	13.5% moisture	
					Sept. 17 - Oct. 1; R8-R9			
					% of plants	% of canopy	lbs/ac	lbs/bu
Non-treated control					**97** b*	**76** b*	**1546** b*	**57.7**
July 23	88	19	0	17.0	**85** a	**57** a	**2566** a	**59.3**
July 26	90	66	6	19.3	**86** a	**59** a	**2591** a	**59.6**
July 28	90	73	12	18.1	**90** ab	**63** ab	**2455** a	**59.0**
July 30	90	84	42	17.9	**91** ab	**67** ab	**2312** a	**58.9**
July 31	90	92	69	18.3	**94** ab	**67** ab	**2381** a	**58.7**
					4.45, 0.0026	4.17, 0.0039	13.26, <0.000	
					7.2	15.9	13.9	

Application date	Canopy closure (%)	Plants in bloom (%)	Pin-pods (% plants)	Canopy height (in.)	White mold		Yield	Test weight
					Incidence	Sev. Index	13.5% moisture	
					Sept. 17 - Oct. 1; R8-R9			
					% of plants	% of canopy	lbs/ac	lbs/bu
Non-treated control					**97** a*	**77** b*	**1843** c*	**58.1**
July 23	88	19	0	17.0	**91** a	**62** a	**2519** ab	**59.3**
July 26	90	66	6	19.3	**90** a	**59** a	**2651** a	**59.5**
July 28	90	73	12	18.1	**90** a	**62** a	**2457** ab	**59.0**
July 30	90	84	42	17.9	**91** a	**68** ab	**2253** b	**59.1**
July 31	90	92	69	18.3	**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	

* Within-column means followed by dfiferent 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.

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. 'Torreon'

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 Incidence Sept. 9-20; R9 % of plants	White mold Sev. Index Sept. 9-20; R9 % of canopy	Yield 13.5% moisture lbs/ac	Test weight lbs/bu
					SINGLE APPLICATION			
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			
Non-treated control					**93**	**72** b*	**2248** b*	**59.0**
July 17	73	3	0	15.7	**77**	**56** a	**2859** a	**58.4**
July 19	75	19	0	17.3	**81**	**57** a	**2963** a	**58.0**
July 22	78	76	3	20.5	**83**	**59** a	**3030** a	**58.7**
July 24	83	100	49	19.1	**81**	**58** a	**2936** a	**58.1**
July 26	89	100	81	21.3	**81**	**59** a	**2823** a	**58.2**
				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			
Non-treated control					**89**	**69** b*	**2162** b*	**59.1**
July 17	73	3	0	15.7	**76**	**54** a	**3080** a	**57.6**
July 19	75	19	0	17.3	**72**	**51** a	**3030** a	**58.6**
July 22	78	76	3	20.5	**78**	**57** a	**2828** a	**58.1**
July 24	83	100	49	19.1	**80**	**59** ab	**2921** a	**58.7**
July 26	89	100	81	21.3	**78**	**59** ab	**2747** a	**58.3**
				F, P>F:		5.99, 0.0003	9.5,<0.0001	
				CV:		12.6	11.6	

Application date	Canopy closure (%)	Plants in bloom (%)	Pin-pods (% plants)	Canopy height (in.)	White mold Incidence Sept. 9-20; R9 % of plants	White mold Sev. Index Sept. 9-20; R9 % of canopy	Yield 13.5% moisture lbs/ac	Test weight lbs/bu
					TWO APPLICATIONS, 9-11 days apart			
Non-treated control					**91**	**72** b*	**2120** b*	**57.9**
July 17	73	3	0	15.7	**81**	**57** a	**3035** a	**58.2**
July 19	75	19	0	17.3	**86**	**64** ab	**2705** a	**58.0**
July 22	78	76	3	20.5	**82**	**58** a	**2848** a	**58.3**
July 24	83	100	49	19.1	**81**	**59** a	**2752** a	**57.8**
July 26	89	100	81	21.3	**78**	**56** a	**2915** a	**58.7**
				F, P>F:		5.09, 0.0011	8.1,<0.0001	
				CV:		12.7	12.3	
					THREE APPLICATIONS, 8-11 days apart			
Non-treated control					**85**	**65** b*	**2435** b*	**59.0**
July 17	73	3	0	15.7	**66**	**44** a	**3458** a	**58.0**
July 19	75	19	0	17.3	**74**	**53** a	**3217** a	**58.4**
July 22	78	76	3	20.5	**70**	**49** a	**3305** a	**58.2**
July 24	83	100	49	19.1	**68**	**47** a	**3343** a	**58.3**
July 26	89	100	81	21.3	**70**	**49** a	**3312** a	**58.1**
				F, P>F:		7.6,<0.0001	15.8,<0.0001	
				CV:		15.5	8.8	

Application date	Canopy closure (%)	Plants in bloom (%)	Pin-pods (% plants)	Canopy height (in.)	White mold Incidence Sept. 9-20; R9 % of plants	White mold Sev. Index Sept. 9-20; R9 % of canopy	Yield 13.5% moisture lbs/ac	Test weight lbs/bu
					TWO APPLICATIONS, 11-13 days apart			
Non-treated control					**94**	**75** b*	**1924** b*	**58.7**
July 17	73	3	0	15.7	**85**	**61** a	**2888** a	**58.0**
July 19	75	19	0	17.3	**84**	**59** a	**3002** a	**58.8**
July 22	78	76	3	20.5	**82**	**59** a	**2607** a	**57.9**
July 24	83	100	49	19.1	**80**	**57** a	**2767** a	**58.8**
July 26	89	100	81	21.3	**86**	**63** a	**2585** a	**58.1**
				F, P>F:		6.80, 0.0001	8.9,<0.0001	
				CV:		12.0	14.0	
					THREE APPLICATIONS, 10-13 days apart			
Non-treated control					**90**	**67** b*	**2504** b*	**58.6**
July 17	73	3	0	15.7	**70**	**49** a	**3167** a	**58.6**
July 19	75	19	0	17.3	**77**	**56** a	**3056** a	**58.2**
July 22	78	76	3	20.5	**78**	**54** a	**3080** a	**58.6**
July 24	83	100	49	19.1	**78**	**56** a	**3004** a	**58.2**
July 26	89	100	81	21.3	**79**	**57** ab	**3105** a	**58.3**
				F, P>F:		5.30, 0.0008	4.92, 0.0013	
				CV:		13.4	11.0	

* Within-column means followed by dfiferent 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 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 studies conducted in 2020-2024:

Row spacing = 14 inches in most studies; 28 inches in some studies
Seeding rate = 90,000 viable seeds/ac
Fungicide spray volume = 15 gal/ac.
Fungicide application method: Fungicides applied with a hand-held boom pressurized by CO2 (2020, 2021, 2022) and with a PTO-driven tractor-mounted sprayer (2024).
Fungicide spray droplet size: medium in study conducted in 2017; fine, medium or coarse, calibrated relative to canopy characteristics, in 2020-2024.
Interval between sequential applications: 8 to 14 days, depending on study
Number of experimental replicates = 6, 7, 9, 10, 15 or 16, depending on study
White mold assessment: Assessed at or near dry bean maturity by evaluating every plant individually in minimum 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 for 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 combiend with replicate 10.
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 6; Imazethapyr 2SL (Ammonium salt of imazethapr, 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).