Improving management of white mold in soybeans and dry beans:

1. Impact of row spacing

Michael Wunsch

North Dakota State University Carrington Research Extension Center

Impact of row spacing on dry bean agronomic performance under white mold pressure

Carrington and Oakes, ND

2019, 2020

WHITE MOLD SEVERITY (% of canopy)

Row spacing (inches)	Seeding rate, pure live (viable) seeds (pls/ac)	Pinto beans: Plant population, end-of-season (at maturity) (plants/ac)	Pinto beans: Low disease pressure, <20% of canopy (30-inch rows), 12 studies	Pinto beans: Intermediate disease pressure, 20-40% of canopy (30-inch rows), 8 studies	Pinto beans: High disease pressure, >40% of canopy (30-inch rows), 7 studies	Kidney beans: Plant population, end-of-season (at maturity) (plants/ac)	Kidney beans: Low disease pressure, <20% of canopy (30-inch rows), 6 studies	Kidney beans: Intermediate disease pressure, 20-40% of canopy (30-inch rows), 5 studies	Kidney beans: High disease pressure, >40% of canopy (30-inch rows), 7 studies
30	70,000	50,894	9 a	29 a	53 a	52,559	5 ab	34 a	46 a
22.5	70,000	52,427	11 ab	36 ab	60 a	50,606	4 ab	32 a	47 a
15	70,000	52,818	11 ab	38 b	59 a	53,488	5 b	33 a	49 a
7.5	70,000	53,144	13 b	35 ab	55 a	55,979	2 a	35 a	46 a
			CV: 27.7	CV: 17.7	CV: 10.2		CV: 19.2	CV: 14.9	CV: 11.0

YIELD (pounds/acre)

Row spacing (inches)	Seeding rate (pls/ac)	Pinto beans: Plant population (plants/ac)	Pinto beans: Low	Pinto beans: Intermediate	Pinto beans: High	Kidney beans: Plant population (plants/ac)	Kidney beans: Low	Kidney beans: Intermediate	Kidney beans: High
30	70,000	50,894	3015 b	2596 a	1919 a	52,559	3015 ab	1799 b	1446 a
22.5	70,000	52,427	3022 b	2424 a	1836 a	50,606	3022 b	1878 b	1514 a
15	70,000	52,818	3398 a	2522 a	1876 a	53,488	3398 a	2309 a	1632 a
7.5	70,000	53,144	3305 a	2482 a	1738 a	55,979	3305 ab	2054 ab	1466 a
			CV: 7.4	CV: 8.1	CV: 8.0		CV: 6.4	CV: 10.6	CV: 13.1

Data are from studies conducted in Carrington and Oakes, ND in 2019 and 2020 with no foliar fungicide, one or two fungicide applications (Topsin at 40 fl oz/ac or Topsin followed by Endura at 8 oz/ac 10-14 days later), fallow ground, direct-seeded into winter rye terminated 10-14 days prior to planting, or direct-seeded into rye terminated 0-3 days after planting.

Plots were 10 feet wide and 25 feet long at seeding. The middle 5 feet by 20 feet were assessed for disease and yield.

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

Optimizing row spacing

Impact of row spacing on white mold:

PINTO BEANS:

- White mold severity was minimized in wide (30-inch) rows at all levels of disease pressure.
- When less than 20% of the canopy was diseased at the end of the season, pinto bean yield was maximized when pinto beans were grown in narrow (7.5-inch or 15-inch) rows.
- When more than 20% of the canopy was diseased at the end of the season, there was no statistical difference in yields across row spacings but a trend of higher yield in wide (30-inch) rows.

Impact of row spacing on white mold:

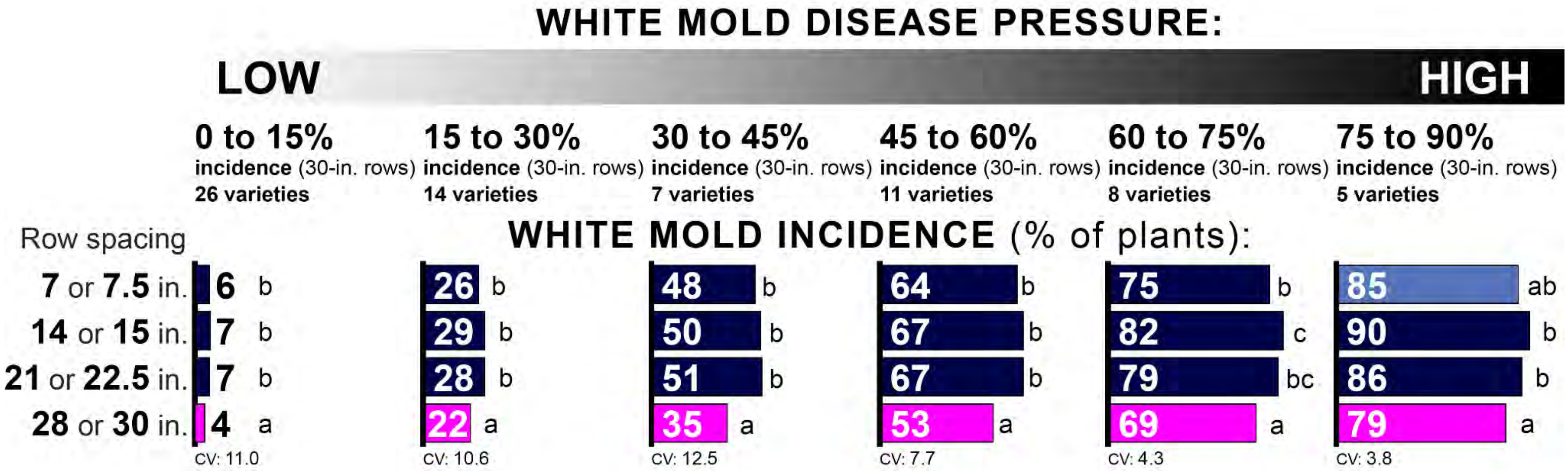
KIDNEY BEANS:

- When less than 20% of the canopy was diseased at the end of the season, white mold severity was minimized in narrow (7.5-inch) rows that maximized the spacing between adjacent plants.
- When more than 20% of the canopy was diseased at the end of the season, row spacing had little or no impact on white mold severity in kidney beans.
- At all levels of white mold pressure, yields were maximized when kidney beans were seeded to 15-inch rows.

Impact of row spacing on soybean agronomic performance under white mold pressure

Carrington, Hofflund, Langdon and Oakes, ND

2013-2017



Soybean maturity: 00.5 to 0.9 **Two to fourteen varieties evaluated per study location per year**

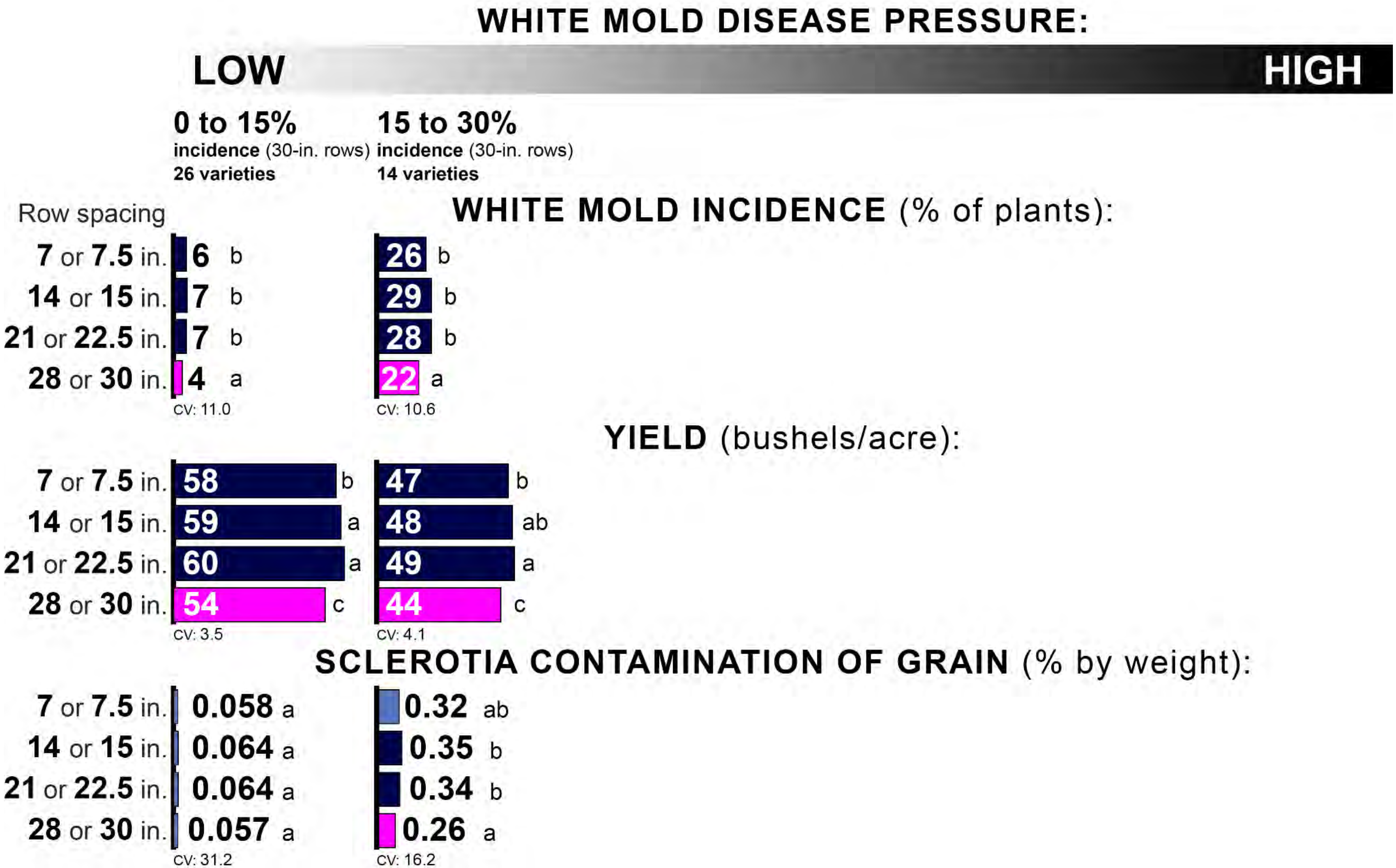
2013-2014: Carrington only. Single seeding rate (165,000 viable seeds/ac)

2015-2017: All study locations. Combined analysis across three seeding rates (132,000; 165,000; 198,000 viable seeds/ac)

Impact of row spacing on soybean agronomic performance under white mold pressure

Carrington, Hofflund, Langdon and Oakes, ND

2013-2017



Soybean maturity: 00.5 to 0.9 **Two to fourteen varieties evaluated per study location per year**

2013-2014: Carrington only. Single seeding rate (165,000 viable seeds/ac)

2015-2017: All study locations. Combined analysis across three seeding rates (132,000; 165,000; 198,000 viable seeds/ac)

Impact of row spacing on soybean agronomic performance under white mold pressure

Carrington, Hofflund, Langdon and Oakes, ND

2013-2017

WHITE MOLD DISEASE PRESSURE:

LOW → **HIGH**

	0 to 15% incidence (30-in. rows) 26 varieties	**15 to 30%** incidence (30-in. rows) 14 varieties	**30 to 45%** incidence (30-in. rows) 7 varieties	**45 to 60%** incidence (30-in. rows) 11 varieties

WHITE MOLD INCIDENCE (% of plants):

Row spacing	0 to 15%	15 to 30%	30 to 45%	45 to 60%
7 or **7.5** in.	6 b	26 b	48 b	64 b
14 or **15** in.	7 b	29 b	50 b	67 b
21 or **22.5** in.	7 b	28 b	51 b	67 b
28 or **30** in.	4 a	22 a	35 a	53 a
	CV: 11.0	CV: 10.6	CV: 12.5	CV: 7.7

YIELD (bushels/acre):

Row spacing	0 to 15%	15 to 30%	30 to 45%	45 to 60%
7 or **7.5** in.	58 b	47 b	41 a	35 a
14 or **15** in.	59 a	48 ab	43 a	35 a
21 or **22.5** in.	60 a	49 a	42 a	37 a
28 or **30** in.	54 c	44 c	41 a	37 a
	CV: 3.5	CV: 4.1	CV: 5.7	CV: 8.1

SCLEROTIA CONTAMINATION OF GRAIN (% by weight):

Row spacing	0 to 15%	15 to 30%	30 to 45%	45 to 60%
7 or **7.5** in.	0.058 a	0.32 ab	0.66 a	1.27 ab
14 or **15** in.	0.064 a	0.35 b	0.62 a	1.33 ab
21 or **22.5** in.	0.064 a	0.34 b	0.75 a	1.48 b
28 or **30** in.	0.057 a	0.26 a	0.50 a	1.07 a
	CV: 31.2	CV: 16.2	CV: 19.4	CV: 14.4

Soybean maturity: 00.5 to 0.9 **Two to fourteen varieties evaluated per study location per year**

2013-2014: Carrington only. Single seeding rate (165,000 viable seeds/ac)

2015-2017: All study locations. Combined analysis across three seeding rates (132,000; 165,000; 198,000 viable seeds/ac)

Impact of row spacing on soybean agronomic performance under white mold pressure

Carrington, Hofflund, Langdon and Oakes, ND

2013-2017

WHITE MOLD DISEASE PRESSURE:

LOW → HIGH

	0 to 15%	15 to 30%	30 to 45%	45 to 60%	60 to 75%	75 to 90%
	incidence (30-in. rows)	incidence (30-in. rows)	incidence (30-in. rows)	incidence (30-in. rows)	incidence (30-in. rows)	incidence (30-in. rows)
	26 varieties	14 varieties	7 varieties	11 varieties	8 varieties	5 varieties

WHITE MOLD INCIDENCE (% of plants):

Row spacing	0 to 15%	15 to 30%	30 to 45%	45 to 60%	60 to 75%	75 to 90%
7 or 7.5 in.	6 b	26 b	48 b	64 b	75 b	85 ab
14 or 15 in.	7 b	29 b	50 b	67 b	82 c	90 b
21 or 22.5 in.	7 b	28 b	51 b	67 b	79 bc	86 b
28 or 30 in.	4 a	22 a	35 a	53 a	69 a	79 a
	CV: 11.0	CV: 10.6	CV: 12.5	CV: 7.7	CV: 4.3	CV: 3.8

YIELD (bushels/acre):

Row spacing	0 to 15%	15 to 30%	30 to 45%	45 to 60%	60 to 75%	75 to 90%
7 or 7.5 in.	58 b	47 b	41 a	35 a	32 a	26 a
14 or 15 in.	59 a	48 ab	43 a	35 a	30 a	23 a
21 or 22.5 in.	60 a	49 a	42 a	37 a	32 a	24 a
28 or 30 in.	54 c	44 c	41 a	37 a	31 a	27 a
	CV: 3.5	CV: 4.1	CV: 5.7	CV: 8.1	CV: 8.8	CV: 14.5

SCLEROTIA CONTAMINATION OF GRAIN (% by weight):

Row spacing	0 to 15%	15 to 30%	30 to 45%	45 to 60%	60 to 75%	75 to 90%
7 or 7.5 in.	0.058 a	0.32 ab	0.66 a	1.27 ab	2.17 a	1.91 ab
14 or 15 in.	0.064 a	0.35 b	0.62 a	1.33 ab	2.47 a	2.09 b
21 or 22.5 in.	0.064 a	0.34 b	0.75 a	1.48 b	2.37 a	1.77 ab
28 or 30 in.	0.057 a	0.26 a	0.50 a	1.07 a	1.73 a	1.74 a
	CV: 31.2	CV: 16.2	CV: 19.4	CV: 14.4	CV: 9.0	CV: 12.3

Soybean maturity: 00.5 to 0.9 **Two to fourteen varieties evaluated per study location per year**

2013-2014: Carrington only. Single seeding rate (165,000 viable seeds/ac)

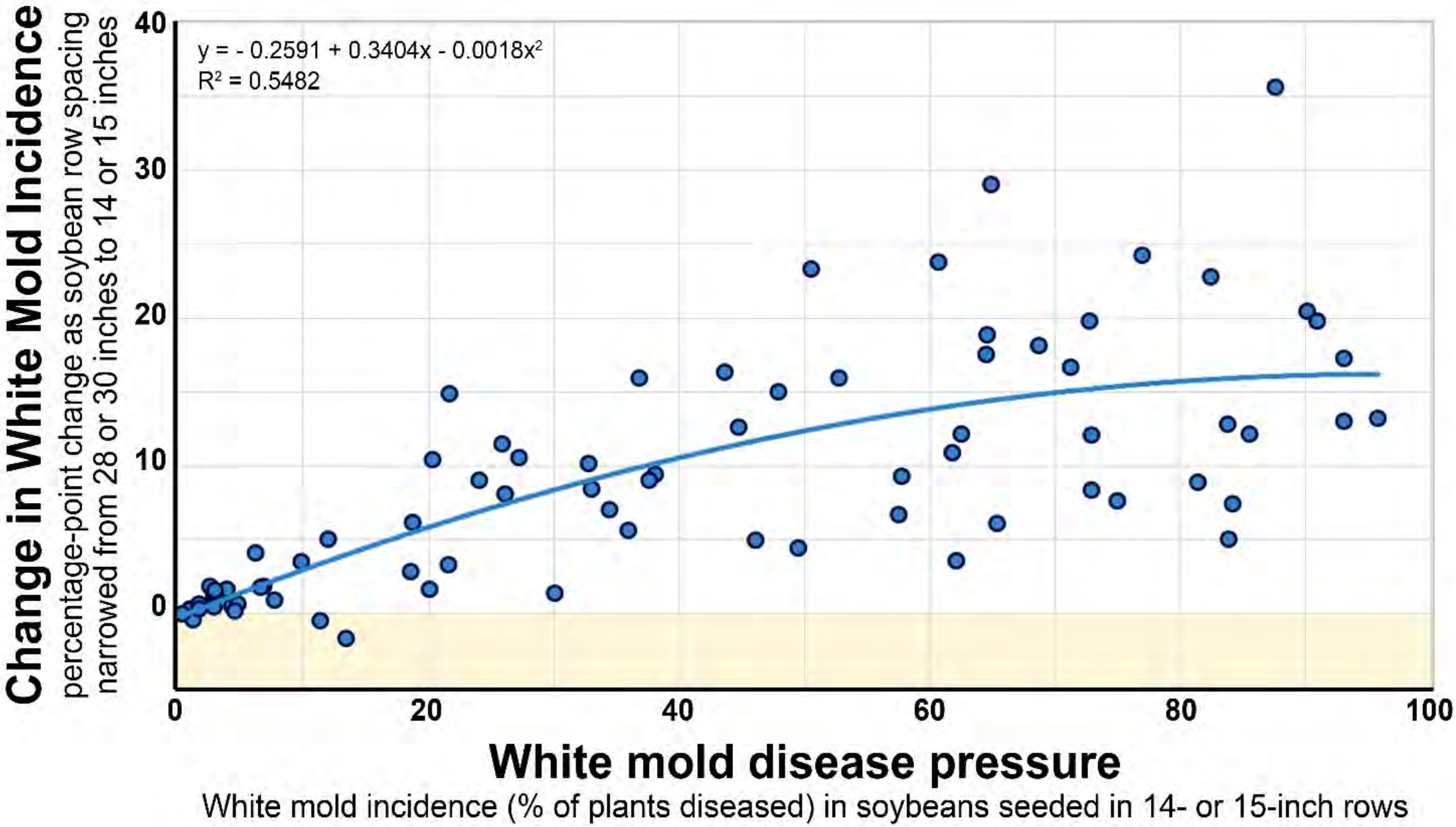
2015-2017: All study locations. Combined analysis across three seeding rates (132,000; 165,000; 198,000 viable seeds/ac)

Impact of narrowing row spacing from **wide** (28-30”) to **narrow** (14-15”) rows

1. **WHITE MOLD INCIDENCE**

Carrington, Hofflund, Langdon and Oakes, ND (2013-2017)

Soybean maturity: 00.5 to 0.9 **Two to fourteen varieties evaluated per study location per year**
2013-2014: Carrington only. Single seeding rate (165,000 viable seeds/ac)
2015-2017: All study locations. Combined analysis across 3 seeding rates (132,000; 165,000; 198,000 viable seeds/ac)

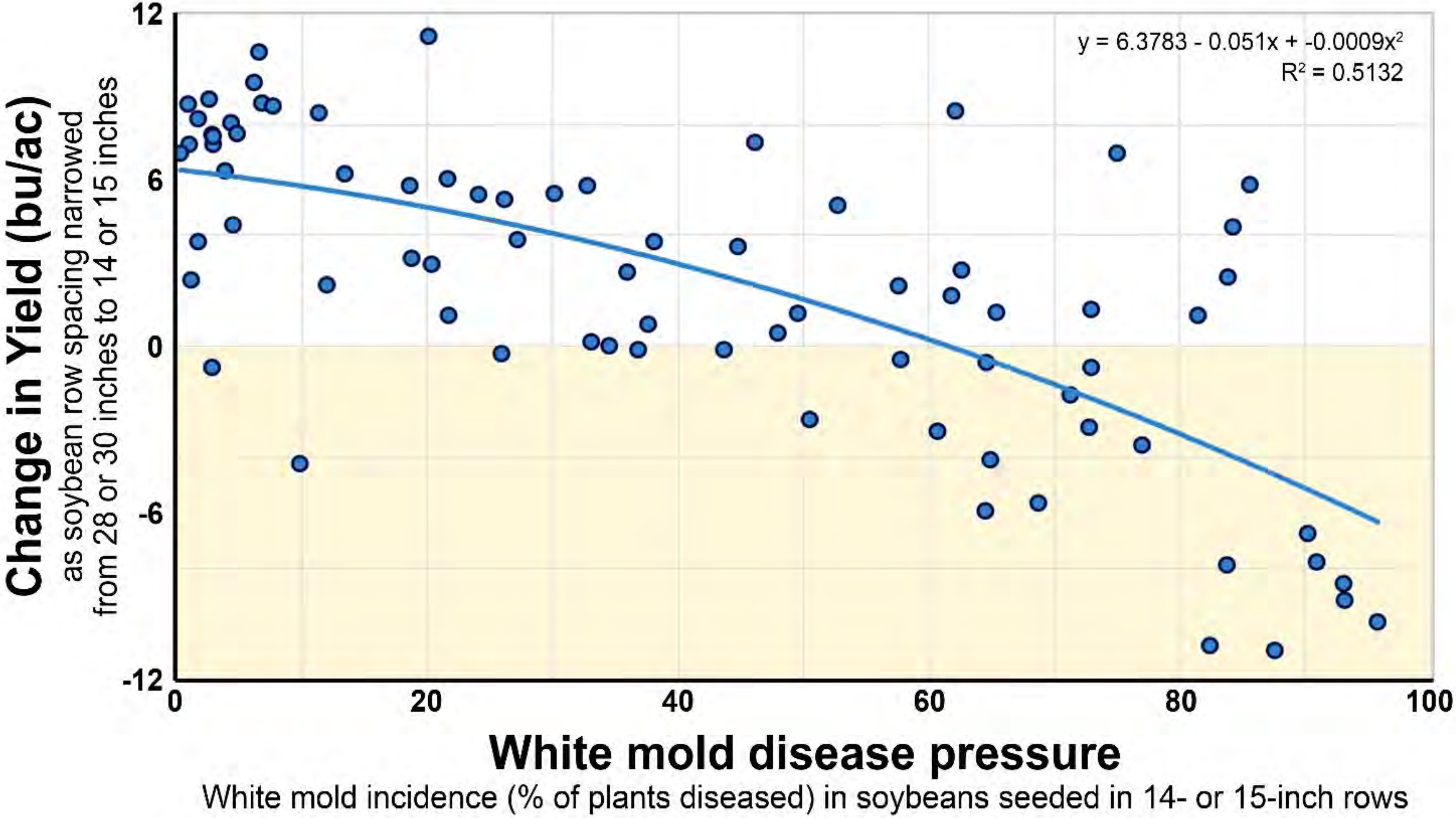


Impact of narrowing row spacing from **wide** (28-30”) to **narrow** (14-15”) rows

2. YIELD

Carrington, Hofflund, Langdon and Oakes, ND (2013-2017)

Soybean maturity: 00.5 to 0.9 **Two to fourteen varieties evaluated per study location per year**
2013-2014: Carrington only. Single seeding rate (165,000 viable seeds/ac)
2015-2017: All study locations. Combined analysis across 3 seeding rates (132,000; 165,000; 198,000 viable seeds/ac)

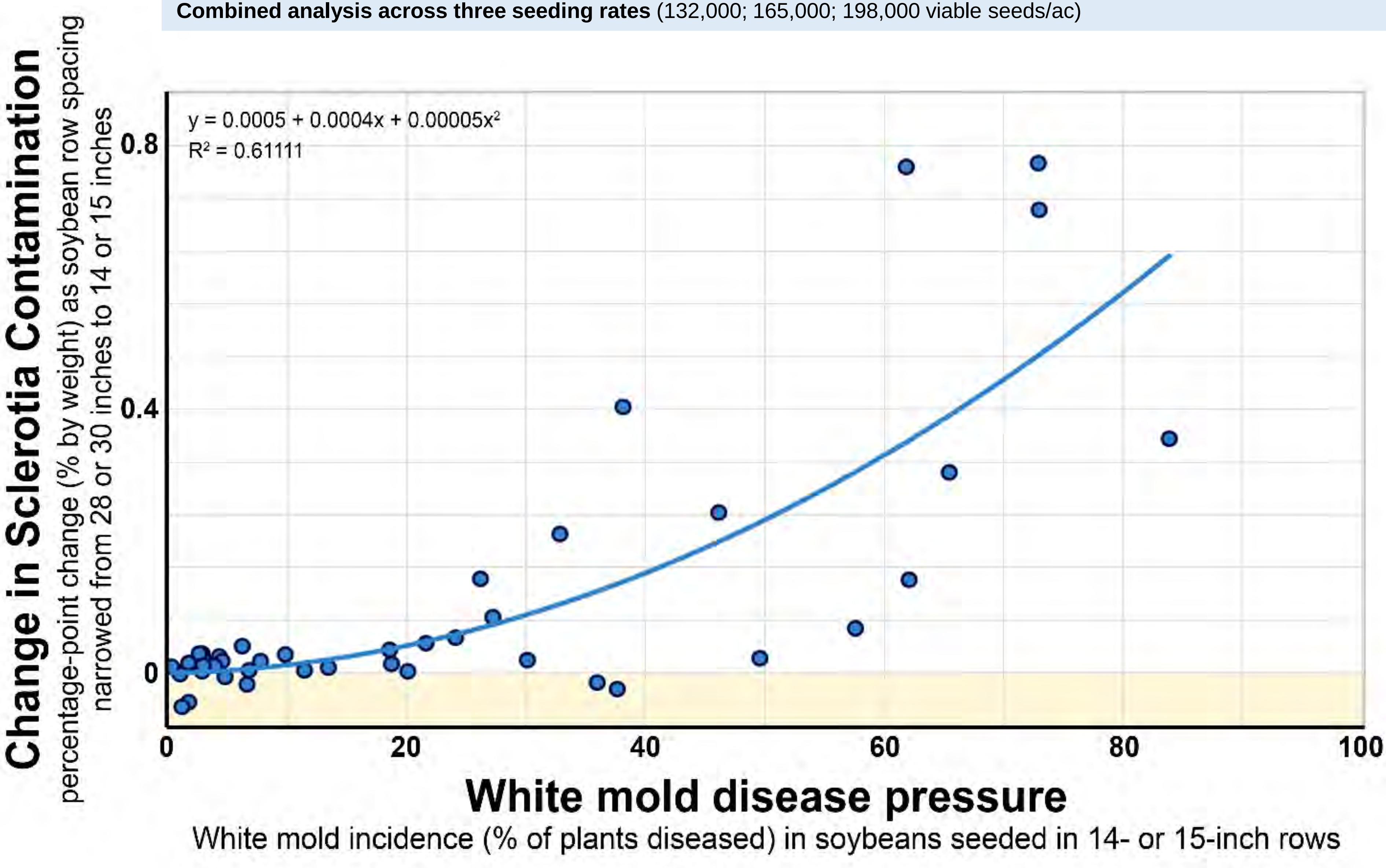


Impact of narrowing row spacing from **wide** (28-30”) to **narrow** (14-15”) rows

3. SCLEROTIA CONTAMINATION in the HARVESTED GRAIN

Carrington, Hofflund, Langdon and Oakes, ND (2015-2017)

Soybean maturity: 00.5 to 0.9 **Two to five varieties evaluated per study location per year.**
Combined analysis across three seeding rates (132,000; 165,000; 198,000 viable seeds/ac)

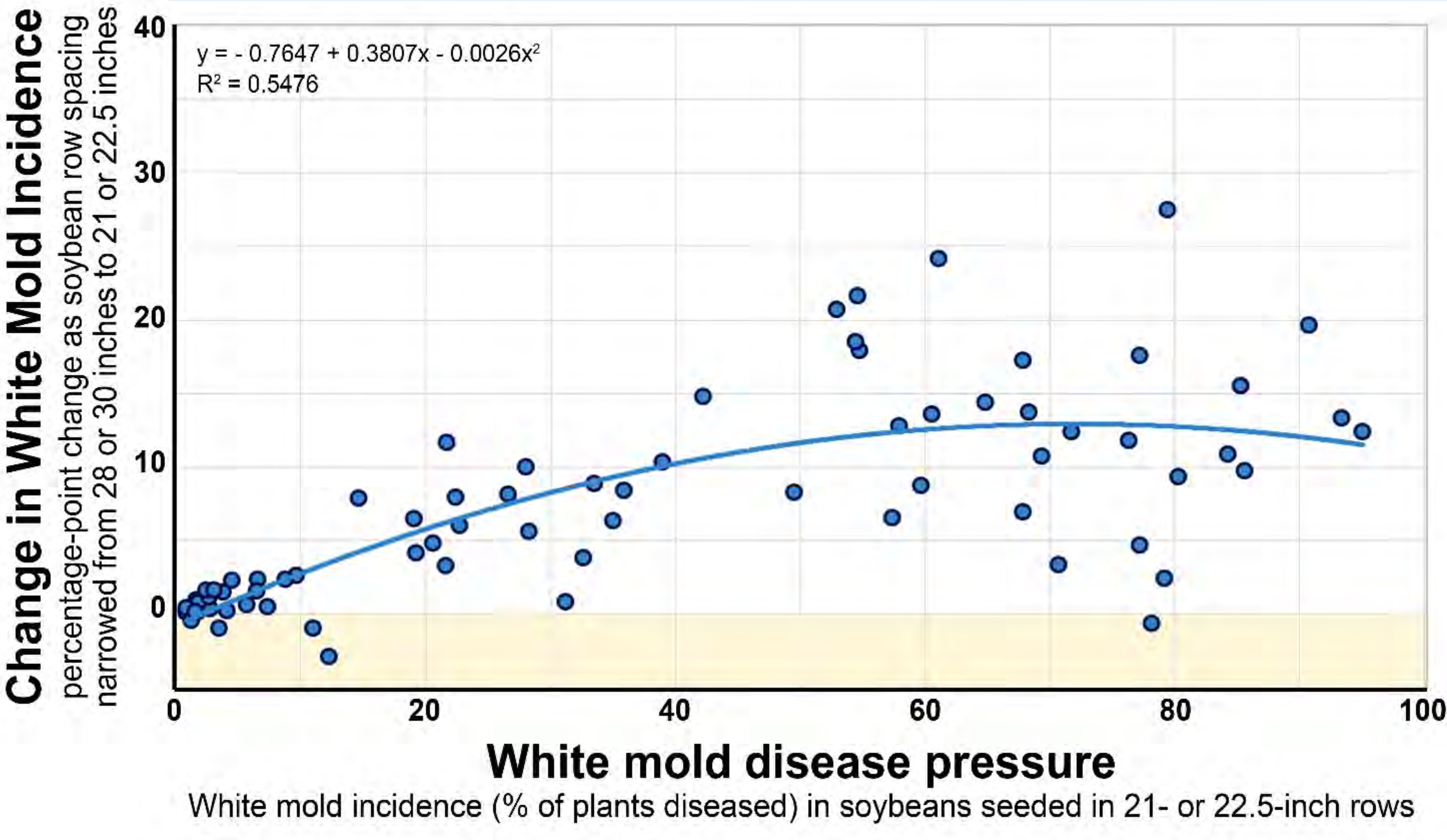


Impact of narrowing row spacing from **wide** (28-30”) to **intermediate** (21-22.5”) rows

1. WHITE MOLD INCIDENCE

Carrington, Hofflund, Langdon and Oakes, ND (2013-2017)

Soybean maturity: 00.5 to 0.9 **Two to fourteen varieties evaluated per study location per year**
2013-2014: Carrington only. Single seeding rate (165,000 viable seeds/ac)
2015-2017: All study locations. Combined analysis across 3 seeding rates (132,000; 165,000; 198,000 viable seeds/ac)

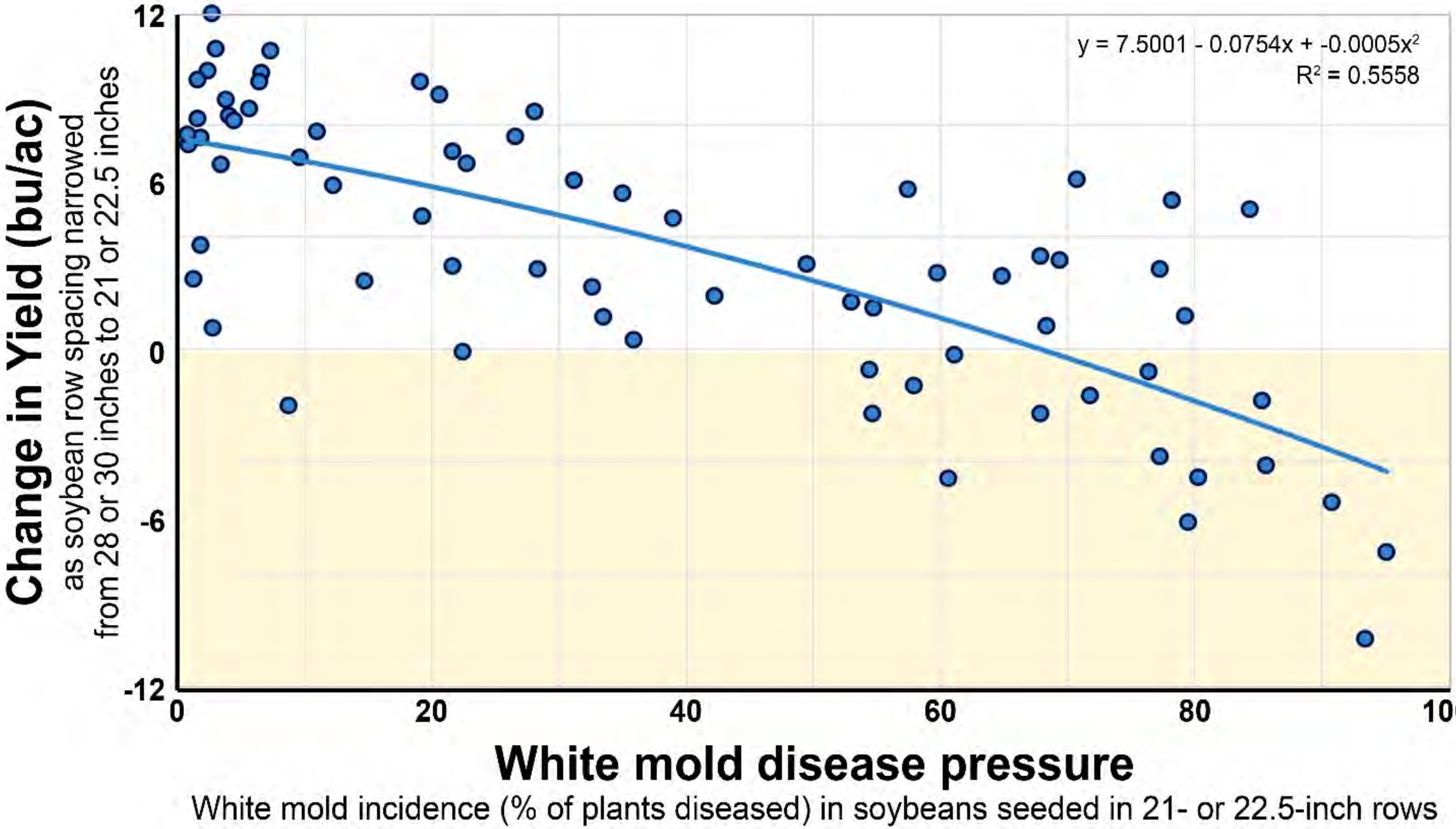


Impact of narrowing row spacing from **wide** (28-30”) to **intermediate** (21-22.5”) rows

2. **YIELD**

Carrington, Hofflund, Langdon and Oakes, ND (2013-2017)

Soybean maturity: 00.5 to 0.9 **Two to fourteen varieties evaluated per study location per year**
2013-2014: Carrington only. Single seeding rate (165,000 viable seeds/ac)
2015-2017: All study locations. Combined analysis across 3 seeding rates (132,000; 165,000; 198,000 viable seeds/ac)

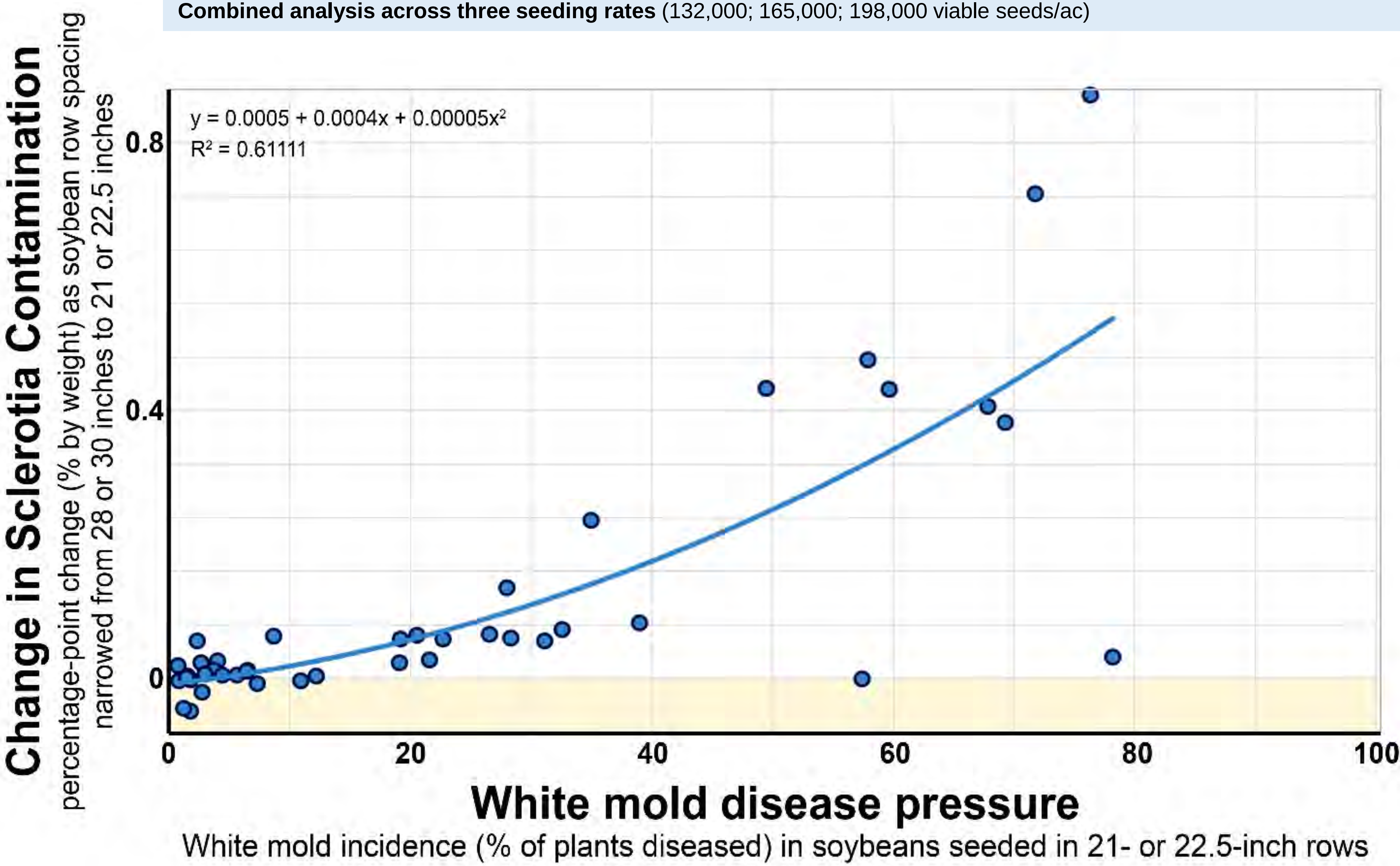


Impact of narrowing row spacing from **wide** (28-30”) to **intermediate** (21-22.5”) rows

3. SCLEROTIA CONTAMINATION in the HARVESTED GRAIN

Carrington, Hofflund, Langdon and Oakes, ND (2015-2017)

Soybean maturity: 00.5 to 0.9 **Two to five varieties evaluated per study location per year.**
Combined analysis across three seeding rates (132,000; 165,000; 198,000 viable seeds/ac)



Optimizing row spacing

Impact of row spacing on white mold:

- When end-of-season white mold incidence was less than 50%, soybean yield was maximized when soybeans were grown in narrow (14- or 15-inch) or intermediate (21- or 22.5-inch) rows.

- **Intermediate row spacing was optimal.** Soybeans seeded to 21- or 22.5-inch rows generally developed less white mold and had higher yields than soybeans seeded to 14- or 15-inch rows.

- The **increase in sclerotia contamination of grain** associated with planting to narrow or intermediate rows was negligible when end-of-season white mold incidence was less than 30% and moderate when white mold incidence was less than 50%.

Improving management of white mold in soybeans and dry beans:

2. Impact of seeding rate

Michael Wunsch

North Dakota State University Carrington Research Extension Center

Impact of seeding rate on dry bean agronomic performance under white mold pressure

Carrington and Oakes, ND
2019, 2020

Row spacing *inches*	Seeding rate pure live (viable) seeds *pls/ac*	Plant population end-of-season (at maturity) *plants/ac*	Low disease pressure <20% of canopy (30-inch rows) 4 studies		Intermediate disease pressure 20-40% of canopy (30-inch rows) 4 studies		High disease pressure 40-60% of canopy (30-inch rows) 1 study	
WHITE MOLD (% of canopy)								
30	120,000	96,439	11	a	36	ab	57	ab
30	70,000	48,536	8	a	22	a	58	ab
22.5	120,000	85,054	12	a	44	b	60	ab
22.5	70,000	42,646	8	a	28	ab	51	ab
15	120,000	90,750	10	a	42	b	75	b
15	70,000	48,972	8	a	35	ab	56	ab
7.5	120,000	115,454	10	a	36	ab	72	b
7.5	70,000	49,513	9	a	37	ab	46	a
			CV: 26.7		CV: 20.4		CV: 15.0	
YIELD (pounds/acre)								
30	120,000	96,439	3182	de	2846	ab	2403	a
30	70,000	48,536	3083	e	2937	a	2267	a
22.5	120,000	85,054	3614	bcd	2439	b	2318	a
22.5	70,000	42,646	3326	cde	2653	ab	2345	a
15	120,000	90,750	3867	ab	2849	ab	2041	a
15	70,000	48,972	3737	abc	2772	ab	2430	a
7.5	120,000	115,454	4148	a	2826	ab	1888	a
7.5	70,000	49,513	3937	ab	2643	ab	2173	a
			CV: 6.1		CV: 6.4		CV: 13.6	

Impact of increasing **seeding rate** from 70,000 to 120,000 viable seeds/ac on white mold severity and yield in pinto beans. Data are from studies conducted in Carrington and Oakes, ND in 2019 with no foliar fungicide, one or two fungicide applications, fallow ground, direct-seeded into winter rye terminated 10-14 days prior to planting, or direct-seeded into rye terminated 0-3 days after planting. *Within-column means followed by different letters are sign. different (P < 0.05; Tukey procedure).*

Impact of seeding rate on dry bean agronomic performance under white mold pressure

Carrington and Oakes, ND

2019, 2020

WHITE MOLD (% of canopy)

		Pinto beans		Kidney beans		
Row spacing *inches*	**Seeding rate** pure live (viable) seeds *pls/ac*	**Plant population** end-of-season (at maturity) *plants/ac*	**Low** disease pressure: <20% of canopy (30-inch rows) **3 studies** — **WHITE MOLD** (% of canopy)	**Plant population** end-of-season (at maturity) *plants/ac*	**Low** disease pressure <20% of canopy (30-inch rows) **6 studies** — **WHITE MOLD** (% of canopy)	**Intermediate** to **high** disease pressure >20% of canopy (30-inch rows) **6 studies** — **WHITE MOLD** (% of canopy)
30	90,000	76,935	**8** a	60,875	**4** ab	**37** a
30	70,000	60,959	**8** a	53,477	**5** ab	**36** a
22.5	90,000	84,820	**10** a	59,822	**6** b	**37** a
22.5	70,000	70,218	**8** a	51,680	**4** ab	**36** a
15	90,000	85,476	**11** a	65,216	**5** ab	**35** a
15	70,000	65,817	**7** a	53,974	**5** ab	**35** a
7.5	90,000	89,685	**10** a	68,385	**4** ab	**37** a
7.5	70,000	68,483	**8** a	57,744	**2** a	**36** a
			CV: 25.4		CV: 18.3	CV: 12.9

YIELD (lbs/acre) — Pinto beans; **YIELD** (pounds/acre) — Kidney beans

Row spacing	Seeding rate	Pinto plant population	Pinto yield (lbs/acre)	Kidney plant population	Kidney yield, low disease pressure (pounds/acre)	Kidney yield, intermediate to high disease pressure (pounds/acre)
30	90,000	76,935	**3205** b	60,875	**2150** bc	**1916** b
30	70,000	60,959	**3193** b	53,477	**2152** bc	**1920** b
22.5	90,000	84,820	**3166** b	59,822	**2225** abc	**2112** ab
22.5	70,000	70,218	**3142** b	51,680	**2130** c	**2060** ab
15	90,000	85,476	**3356** ab	65,216	**2501** a	**2480** a
15	70,000	65,817	**3494** a	53,974	**2358** abc	**2495** a
7.5	90,000	89,685	**3301** ab	68,385	**2443** ab	**2189** ab
7.5	70,000	68,483	**3265** ab	57,744	**2318** abc	**2182** ab
			CV: 4.1		CV: 7.0	CV: 11.2

Impact of increasing **seeding rate** from 70,000 to 90,000 viable seeds/ac on white mold severity and yield in pinto beans. Data are from studies conducted in Carrington, ND in 2020 (pinto beans) and Carrington and Oakes in 2019 and 2020 (kidney beans) with no foliar fungicide, one or two fungicide applications. *Within-column means followed by different letters are sign. different (P < 0.05; Tukey procedure).*

Optimizing seeding rate

Impact of seeding rate on white mold:

PINTO AND KIDNEY BEANS:

- Increasing seeding rate from 70,000 to 90,000 viable seeds/ac (pinto and kidney beans) was generally associated with higher white mold severity.
- Increasing seeding rate from 70,000 to 120,000 viable seeds/ac (pinto beans) conferred moderate to sharp increases in white mold severity.
- Increasing seeding rate above 70,000 viable seeds/ac was associated with little or no yield gains in pinto and kidney beans grown under white mold pressure.

Impact of seeding rate on white mold management in soybeans

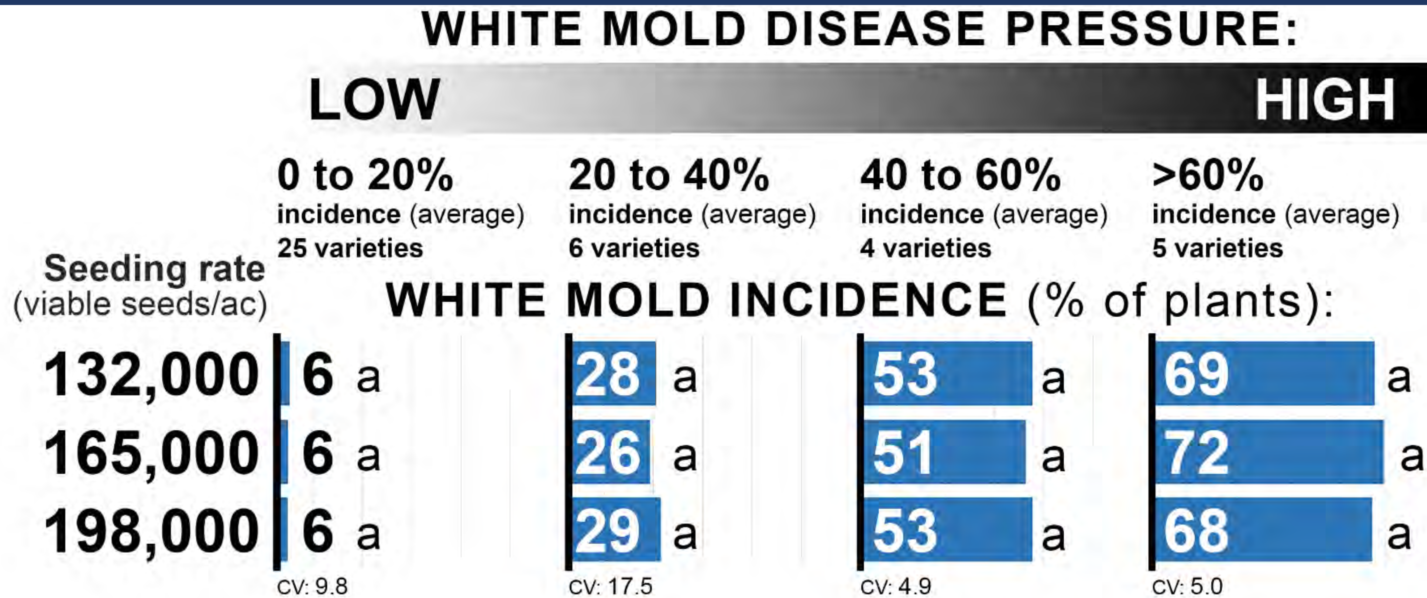
1. WHITE MOLD INCIDENCE

Carrington, Hofflund, Langdon and Oakes, ND (2015-2017)

Soybean maturity:
00.5 to 0.9

Two to five varieties evaluated per study location per year.

Combined analysis across four row spacings
(7, 14, 21, and 28 in. or 7.5, 15, 22.5, and 30 inches)



Impact of seeding rate on white mold management in soybeans

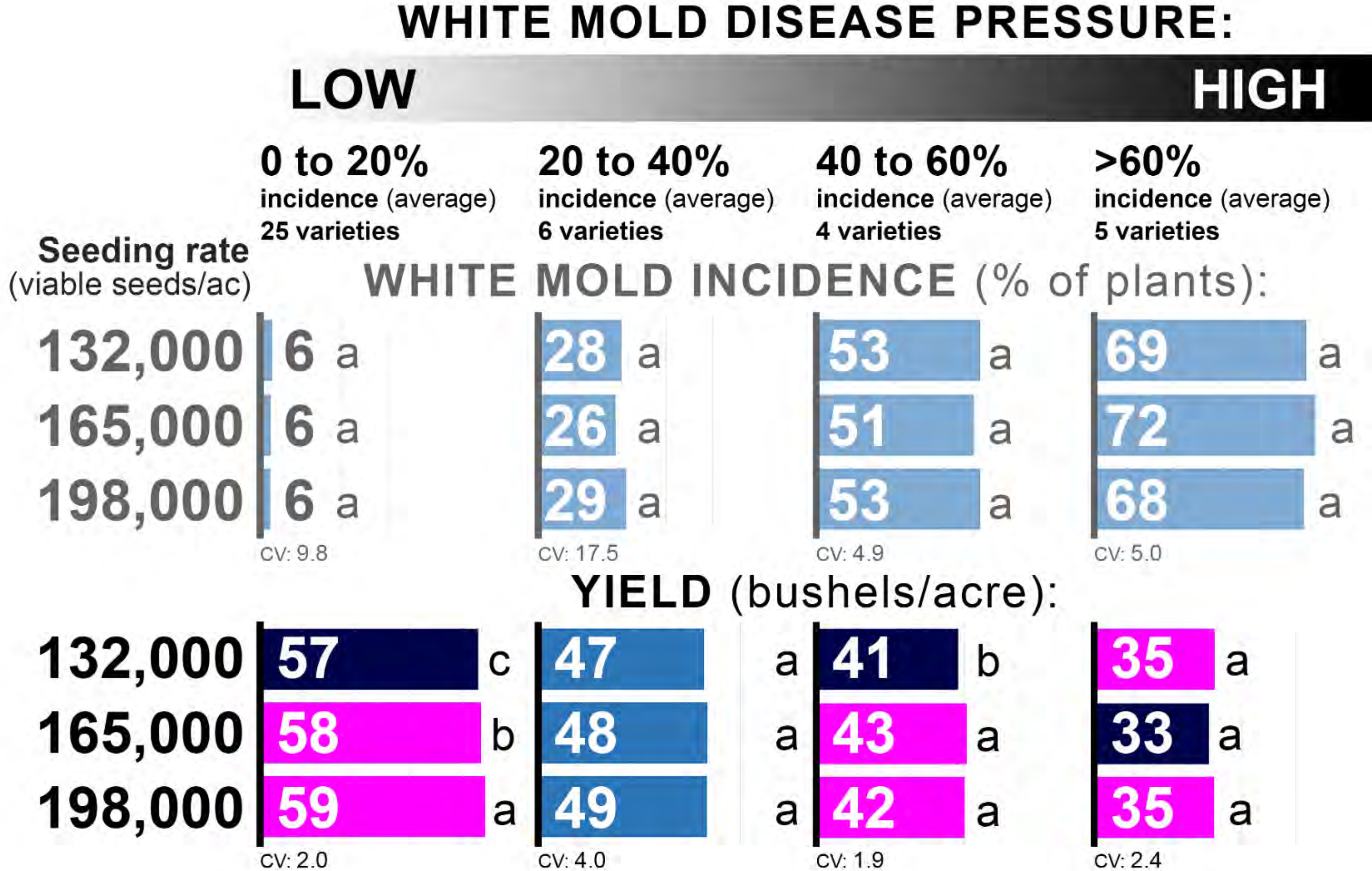
2. SOYBEAN YIELD

Carrington, Hofflund, Langdon and Oakes, ND (2015-2017)

Soybean maturity:
00.5 to 0.9

Two to five varieties evaluated per study location per year.

Combined analysis across four row spacings
(7, 14, 21, and 28 in. or 7.5, 15, 22.5, and 30 inches)



Impact of seeding rate on white mold management in soybeans

3. SCLEROTIA CONTAMINATION in the HARVESTED GRAIN

Carrington, Hofflund, Langdon and Oakes, ND (2015-2017)

Soybean maturity:
00.5 to 0.9

Two to five varieties evaluated per study location per year.

Combined analysis across four row spacings
(7, 14, 21, and 28 in. or 7.5, 15, 22.5, and 30 inches)

WHITE MOLD DISEASE PRESSURE:

LOW → HIGH

WHITE MOLD INCIDENCE (% of plants):

Seeding rate (viable seeds/ac)	**0 to 20%** incidence (average) 25 varieties	**20 to 40%** incidence (average) 6 varieties	**40 to 60%** incidence (average) 4 varieties	**>60%** incidence (average) 5 varieties
132,000	6 a	28 a	53 a	69 a
165,000	6 a	26 a	51 a	72 a
198,000	6 a	29 a	53 a	68 a
	CV: 9.8	CV: 17.5	CV: 4.9	CV: 5.0

YIELD (bushels/acre):

Seeding rate	0 to 20%	20 to 40%	40 to 60%	>60%
132,000	57 c	47 a	41 b	35 a
165,000	58 b	48 a	43 a	33 a
198,000	59 a	49 a	42 a	35 a
	CV: 2.0	CV: 4.0	CV: 1.9	CV: 2.4

SCLEROTIA IN GRAIN (% by weight):

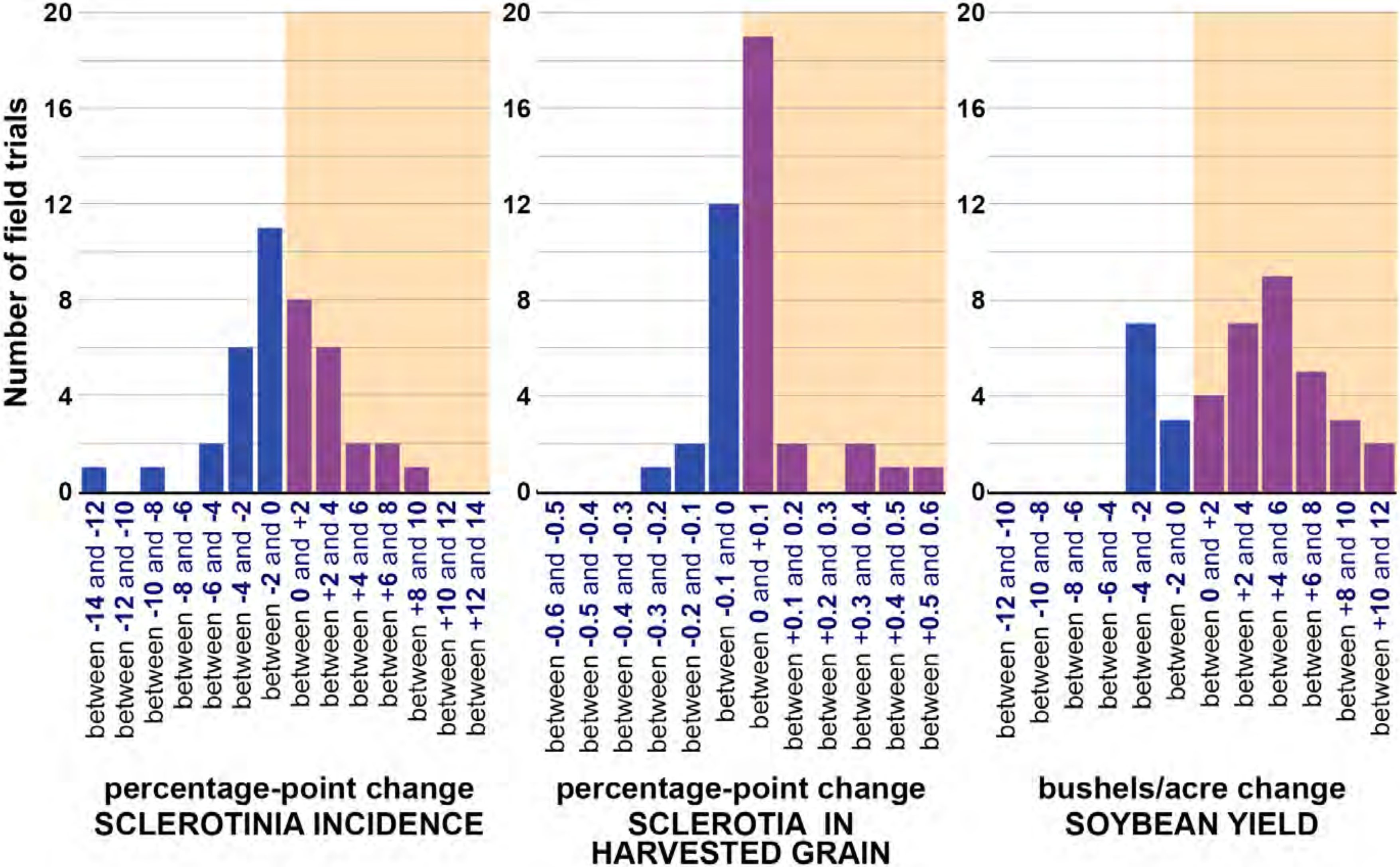
Seeding rate	0 to 20%	20 to 40%	40 to 60%	>60%
132,000	0.059 a	0.21 a	1.14 a	1.67 a
165,000	0.063 a	0.18 a	1.10 a	1.96 a
198,000	0.063 a	0.20 a	1.30 a	1.82 a
	CV: 30.8	CV: 30.0	CV: 12.6	CV: 8.5

IMPACT OF INCREASING SEEDING RATE

on white mold incidence, sclerotia contamination, and soybean yield

as soybean seeding rate increased from 132,000 to 198,000 viable seeds/ac

Carrington, Hofflund, Langdon and Oakes, ND (2015-2017)



Soybean maturity: 00.5 to 0.9 **Two to five varieties evaluated per study location per year.**
Combined analysis across four row spacings (7, 14, 21, and 28 in. or 7.5, 15, 22.5, and 30 inches)

Impact of seeding rate on white mold management in soybeans

Seeding rate may impact white mold in soybeans when conditions are favorable for disease at canopy closure

Carrington, ND (2015)

Soybean maturity: 0.3 **Combined analysis across four row spacings** (7, 14, 21 and 28 inches)
Supplemental irrigation delivered at different growth stages to facilitate early vs. delayed white mold development.

Seeding rate	Canopy Closure *Days after 90% bloom*	Sclerotinia Incidence *Sept. 5-6; R7 %*	Soybean Yield *13% moisture bu/ac*	Sclerotia in Grain *% by weight*
IRRIGATION: R2 to R4 growth stage (July 22 - Aug. 3)				
132,000 pls/ac	**11**	32 a	42 a	0.95 a
198,000 pls/ac	**11**	37 a	41 a	1.53 b
		CV: 22.0	CV: 10.0	CV: 33.8
IRRIGATION: R4 to R7 growth stage (Aug. 8 - 31)				
132,000 pls/ac	**11**	30 a	50 a	0.60 a
198,000 pls/ac	**11**	27 a	51 a	0.68 a
		CV: 19.8	CV: 6.2	CV: 32.1
IRRIGATION: R5 to R7 growth stage (Aug. 16 - 31)				
132,000 pls/ac	**12**	21 a	50 a	**0.37** a
198,000 pls/ac	**11**	20 a	51 a	**0.50** a
		CV: 25.3	CV: 6.0	CV: 34.1

Impact of seeding rate on white mold management in soybeans

Seeding rate may impact white mold in soybeans when conditions are favorable for disease at canopy closure

Carrington, ND (2017)

Soybean maturity: 0.7 **Combined analysis across four row spacings** (7, 14, 21 and 28 inches)
Supplemental irrigation delivered at different growth stages to facilitate early vs. delayed white mold development.

	White mold R9 growth stage **% of canopy diseased**		**Soybean yield** 13% moisture **bushels/acre**		**Sclerotia in grain** contamination **% by weight**	
IRRIGATED FROM **LATE VEGETATIVE GROWTH** TO **FULL POD** (V4/V5 to R4 growth stage)						
132,000 pure live seeds/ac	30	a	38	a	0.97	a
165,000 pure live seeds/ac	31	a	41	a	0.92	a
198,000 pure live seeds/ac	37	a	40	a	1.34	a
	CV: 32.1		CV: 13.9		CV: 42.9	
IRRIGATED FROM **FULL BLOOM** TO **BEGINNING SEED** (R2 to R5 growth stage)						
132,000 pure live seeds/ac	33	a	40	b	0.94	a
165,000 pure live seeds/ac	33	a	43	a	0.85	a
198,000 pure live seeds/ac	32	a	43	ab	0.82	a
	CV: 25.1		CV: 9.2		CV: 34.6	
DRYLAND (no supplemental irrigation)						
132,000 pure live seeds/ac	2	a	53	b	0.02	a
165,000 pure live seeds/ac	1	a	54	ab	0.03	a
198,000 pure live seeds/ac	2	a	55	a	0.03	a
	CV: 46.8		CV: 5.3		CV: 80.6	

Optimizing seeding rate

Impact of seeding rate on white mold:

- Within the range of seeding rates evaluated in this study (132,000 to 198,000 pure live seeds/ac), **seeding rate had little or no effect on white mold.**
- *Possible exception:* Higher seeding rates might be associated with a modest increase in white mold when conditions favor disease at canopy closure. Additional data are needed to confirm.
- Different results may obtained from seeding rates outside of the range tested in this study.




Improving management of white mold in soybeans and dry beans:
3. Optimizing fungicide application timing

Michael Wunsch
North Dakota State University Carrington Research Extension Center

Optimizing fungicide application timing for white mold management in dry beans

1. PINTO BEANS

Carrington and Oakes, ND (2017, 2020, 2021)

Fungicide applied:

SINGLE FUNGICIDE APPLICATION –

- Topsin @ 30 fl oz/ac (studies from 2017, 2020)
- Topsin @ 40 fl oz/ac (studies conducted in 2021)

TWO FUNGICIDE APPLICATIONS –

- Topsin @ 30 fl oz/ac followed by Endura @ 8 oz/ac (2017, 2020)
- Topsin @ 40 fl oz/ac followed by Endura @ 8 oz/ac (2021)

Spray volume: 15 gal/ac

Nozzles & droplet size:

- When average canopy closure was < 80%: TeeJet DG110015 nozzles at 40 psi (fine droplets)
- When average canopy closure was 80-90%: TeeJet DG110015 nozzles at 30 psi (medium droplets)
- When average canopy closure was 90-95%: TeeJet AIXR11015 nozzles at 60 psi (medium-coarse droplets)
- When average canopy closure was 95-100%: TeeJet AIXR nozzles at 50 psi (coarse droplets)

(1) AVERAGE RESULTS
canopy open at initial pod development (10-20% plants with pods)

AVERAGE RESULTS
across all studies

4 studies conducted across 2 years, 2 locations

average **CANOPY CLOSURE**
at 55-100% plants in bloom, 10-20% with pods:
40-95%

SINGLE FUNGICIDE APPLICATION:

Fungicide application timing	Canopy closure	White mold % of canopy		Yield lbs/ac	
Non-treated control		44	b	2470	b
34-80% of plants **in bloom**, **< 5%** of plants with **pods**	**40-89%**	38	ab	2622	ab
55-100% of plants **in bloom**, **10-20%** of plants with **pods**	**45-91%**	36	ab	2624	ab
84-100% of plants **in bloom**, **50-64%** of plants with **pods**	**53-93%**	29	a	2770	a
88-100% of plants **in bloom**, **65-100%** of plants with **pods**	**67-93%**	27	a	2870	a
		CV: 18.3		CV: 4.7	

TWO APPLICATIONS 9 to 14 days apart:

Fungicide application timing - first application	Canopy closure at 1ST application	White mold % of canopy		Yield lbs/ac	
Non-treated control		44	b	2470	b
30-80% of plants **in bloom**, **< 5%** of plants with **pods**	**40-89%**	25	a	2887	a
55-100% of plants **in bloom**, **10-20%** of plants with **pods**	**45-91%**	27	ab	2890	a
84-100% of plants **in bloom**, **50-64%** of plants with **pods**	**53-93%**	21	a	3003	a
88-100% of plants **in bloom**, **65-100%** of plants with **pods**	**67-93%**	20	a	3077	a
		CV: 27.5		CV: 5.6	

Optimizing fungicide application timing for white mold management in dry beans

PINTO BEANS: Carrington and Oakes, ND (2017, 2020, 2021)

Fungicide applied:

SINGLE FUNGICIDE APPLICATION –

- Topsin @ 30 fl oz/ac (studies from 2017, 2020)
- Topsin @ 40 fl oz/ac (studies conducted in 2021)

TWO FUNGICIDE APPLICATIONS –

- Topsin @ 30 fl oz/ac followed by Endura @ 8 oz/ac (2017, 2020)
- Topsin @ 40 fl oz/ac followed by Endura @ 8 oz/ac (2021)

Spray volume: 15 gal/ac

Nozzles & droplet size:

- When average canopy closure was < 80%: TeeJet DG110015 nozzles at 40 psi (fine droplets)
- When average canopy closure was 80-90%: TeeJet DG110015 nozzles at 30 psi (medium droplets)
- When average canopy closure was 90-95%: TeeJet AIXR11015 nozzles at 60 psi (medium-coarse droplets)
- When average canopy closure was 95-100%: TeeJet AIXR nozzles at 50 psi (coarse droplets)

AVERAGE RESULTS: canopy open versus at/near closure at initial pod development (10-20% plants with pods)

AVERAGE RESULTS across all studies

4 studies conducted across 2 years, 2 locations

average **CANOPY CLOSURE** at 55-100% plants in bloom, 10-20% with pods: **40-95%**

SINGLE FUNGICIDE APPLICATION:

Fungicide application timing	Canopy closure	White mold % of canopy		Yield lbs/ac	
Non-treated control		44	b	2470	b
34-80% of plants **in bloom** < **5%** of plants with **pods**	40-89%	38	ab	2622	ab
55-100% of plants **in bloom** **10-20%** of plants with **pods**	45-91%	36	ab	2624	ab
84-100% of plants **in bloom** **50-64%** of plants with **pods**	53-93%	29	a	2770	a
88-100% of plants **in bloom** **65-100%** of plants with **pods**	67-93%	27	a	2870	a
		CV: 18.3		CV: 4.7	

TWO APPLICATIONS 9 to 14 days apart:

Fungicide application timing - first application	Canopy closure at 1ST application	White mold % of canopy		Yield lbs/ac	
Non-treated control		44	b	2470	b
30-80% of plants **in bloom** < **5%** of plants with **pods**	40-89%	25	a	2887	a
55-100% of plants **in bloom** **10-20%** of plants with **pods**	45-91%	27	ab	2890	a
84-100% of plants **in bloom** **50-64%** of plants with **pods**	53-93%	21	a	3003	a
88-100% of plants **in bloom** **65-100%** of plants with **pods**	67-93%	20	a	3077	a
		CV: 27.5		CV: 5.6	

2 studies conducted across 1 year, 1 location

average **CANOPY CLOSURE** at 55-100% plants in bloom, 10-20% with pods: **95-99%**

SINGLE FUNGICIDE APPLICATION:

Fungicide application timing	Canopy closure	White mold % of canopy		Yield lbs/ac	
Non-treated control		84	b	1291	bc
34-80% of plants **in bloom** < **5%** of plants with **pods**	70-95%	87	ab	1212	c
55-100% of plants **in bloom** **10-20%** of plants with **pods**	95-99%	78	a	1823	a
84-100% of plants **in bloom** **50-64%** of plants with **pods**	98-100%	79	a	1729	a
88-100% of plants **in bloom** **65-100%** of plants with **pods**	100%	78	a	1681	ab
		CV: 1.2		CV: 6.0	

TWO APPLICATIONS 9 to 14 days apart:

Fungicide application timing - first application	Canopy closure at 1ST application	White mold % of canopy		Yield lbs/ac	
Non-treated control		84	d	1291	d
30-80% of plants **in bloom** < **5%** of plants with **pods**	70-95%	77	c	1703	c
55-100% of plants **in bloom** **10-20%** of plants with **pods**	95-99%	72	a	2161	a
84-100% of plants **in bloom** **50-64%** of plants with **pods**	98-100%	72	a	1986	b
88-100% of plants **in bloom** **65-100%** of plants with **pods**	100%	77	ab	1777	c
		CV: 1.3		CV: 1.9	

Fungicide application timing

PINTO BEANS

Fungicide applied:

SINGLE FUNGICIDE APPLICATION –

- Topsin @ 30 fl oz/ac (studies from 2017, 2020)
- Topsin @ 40 fl oz/ac (studies conducted in 2021)

TWO FUNGICIDE APPLICATIONS –

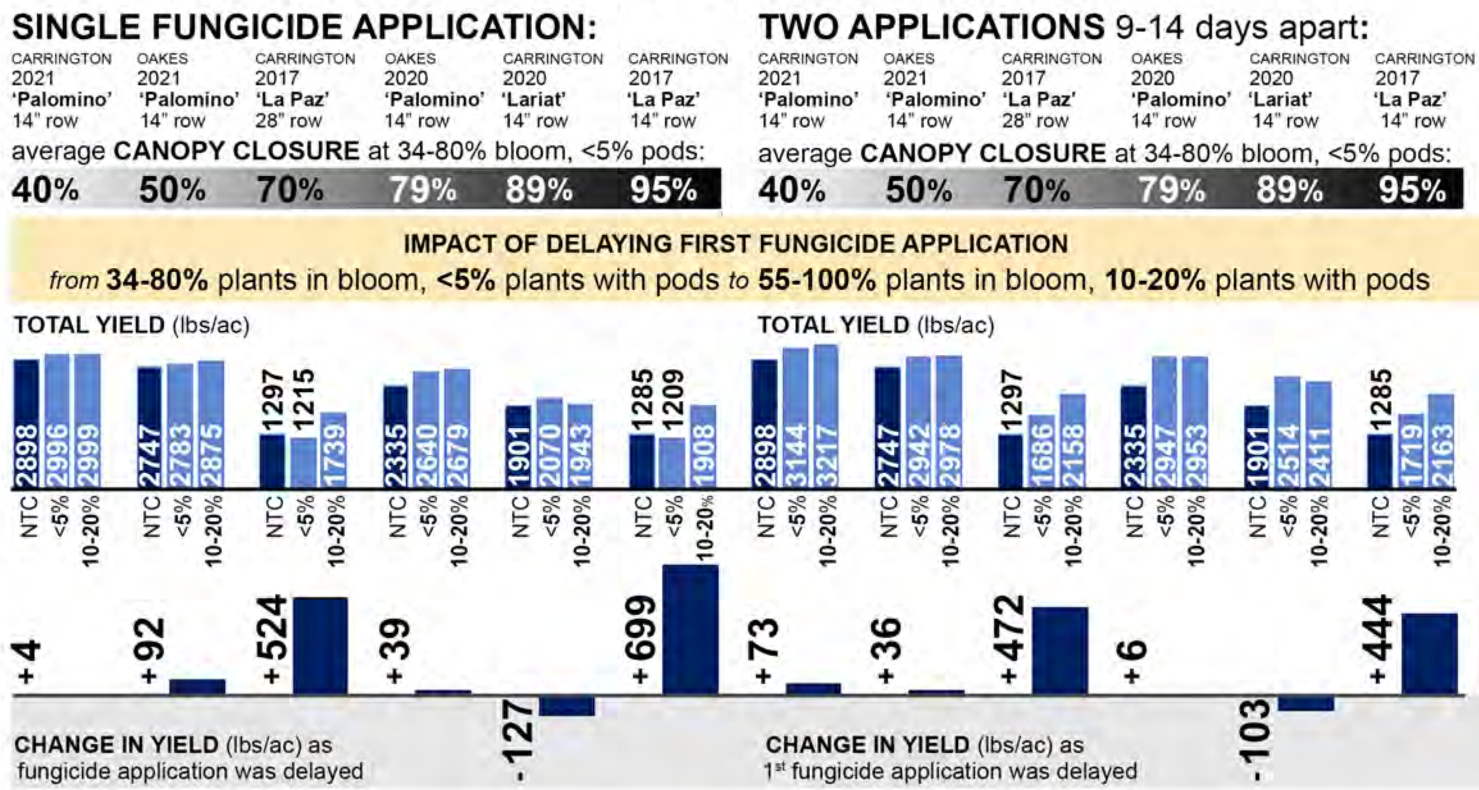
- Topsin @ 30 fl oz/ac followed by Endura @ 8 oz/ac (2017, 2020)
- Topsin @ 40 fl oz/ac followed by Endura @ 8 oz/ac (2021)

Spray volume: 15 gal/ac

Nozzles & droplet size:

- When average canopy closure was < 80%: TeeJet DG110015 nozzles at 40 psi (fine droplets)
- When average canopy closure was 80-90%: TeeJet DG110015 nozzles at 30 psi (medium droplets)
- When average canopy closure was 90-95%: TeeJet AIXR11015 nozzles at 60 psi (medium-coarse droplets)
- When average canopy closure was 95-100%: TeeJet AIXR nozzles at 50 psi (coarse droplets)

RESULTS FROM INDIVIDUAL STUDIES



Fungicide application timing

PINTO BEANS

Fungicide applied:

SINGLE FUNGICIDE APPLICATION –

- Topsin @ 30 fl oz/ac (studies from 2017, 2020)
- Topsin @ 40 fl oz/ac (studies conducted in 2021)

TWO FUNGICIDE APPLICATIONS –

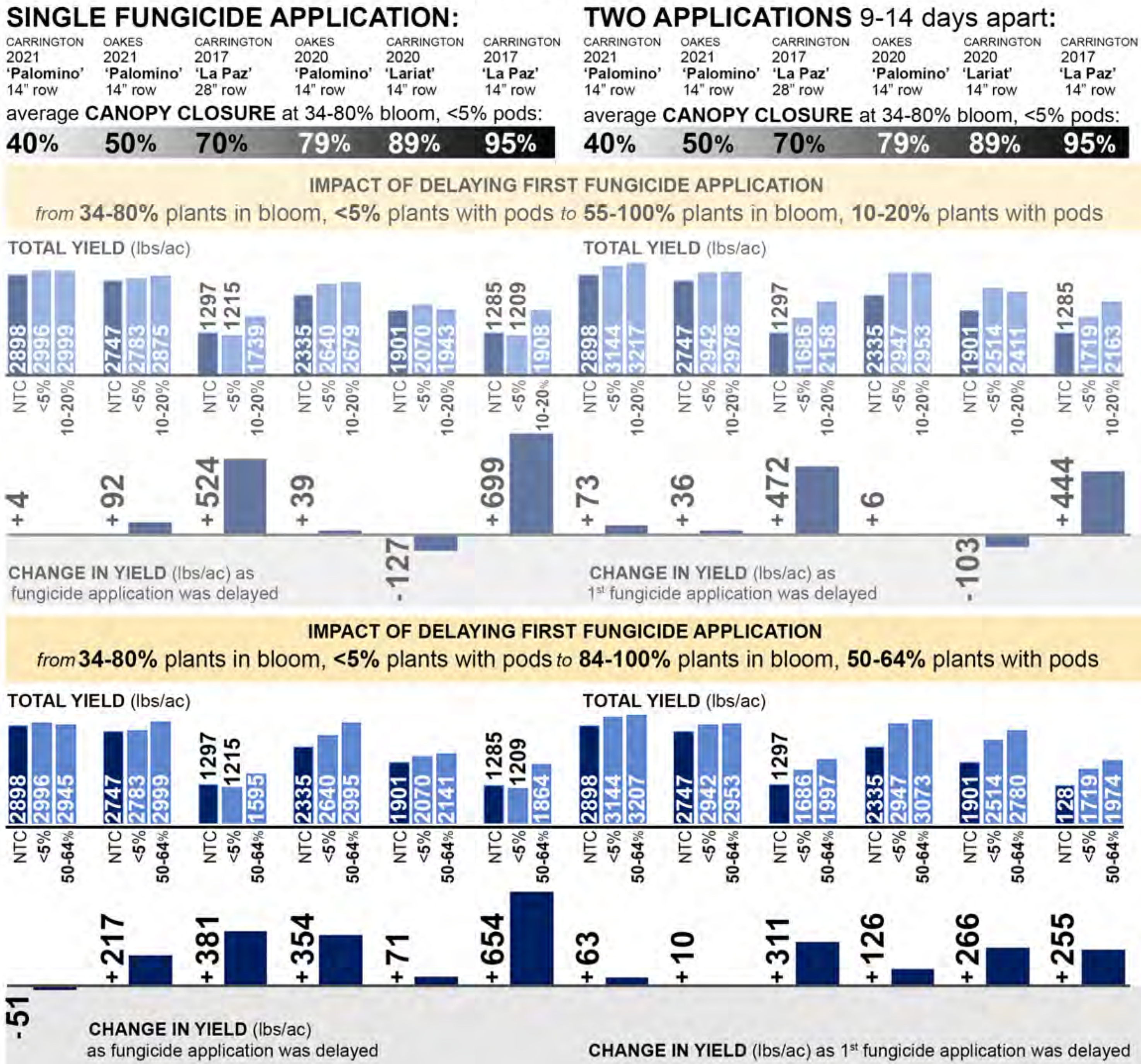
- Topsin @ 30 fl oz/ac followed by Endura @ 8 oz/ac (2017, 2020)
- Topsin @ 40 fl oz/ac followed by Endura @ 8 oz/ac (2021)

Spray volume: 15 gal/ac

Nozzles & droplet size:

- When average canopy closure was < 80%: TeeJet DG110015 nozzles at 40 psi (fine droplets)
- When average canopy closure was 80-90%: TeeJet DG110015 nozzles at 30 psi (medium droplets)
- When average canopy closure was 90-95%: TeeJet AIXR11015 nozzles at 60 psi (medium-coarse droplets)
- When average canopy closure was 95-100%: TeeJet AIXR nozzles at 50 psi (coarse droplets)

RESULTS FROM INDIVIDUAL STUDIES



Fungicide application timing

PINTO BEANS

Fungicide applied:

SINGLE FUNGICIDE APPLICATION –

- Topsin @ 30 fl oz/ac (studies from 2017, 2020)
- Topsin @ 40 fl oz/ac (studies conducted in 2021)

TWO FUNGICIDE APPLICATIONS –

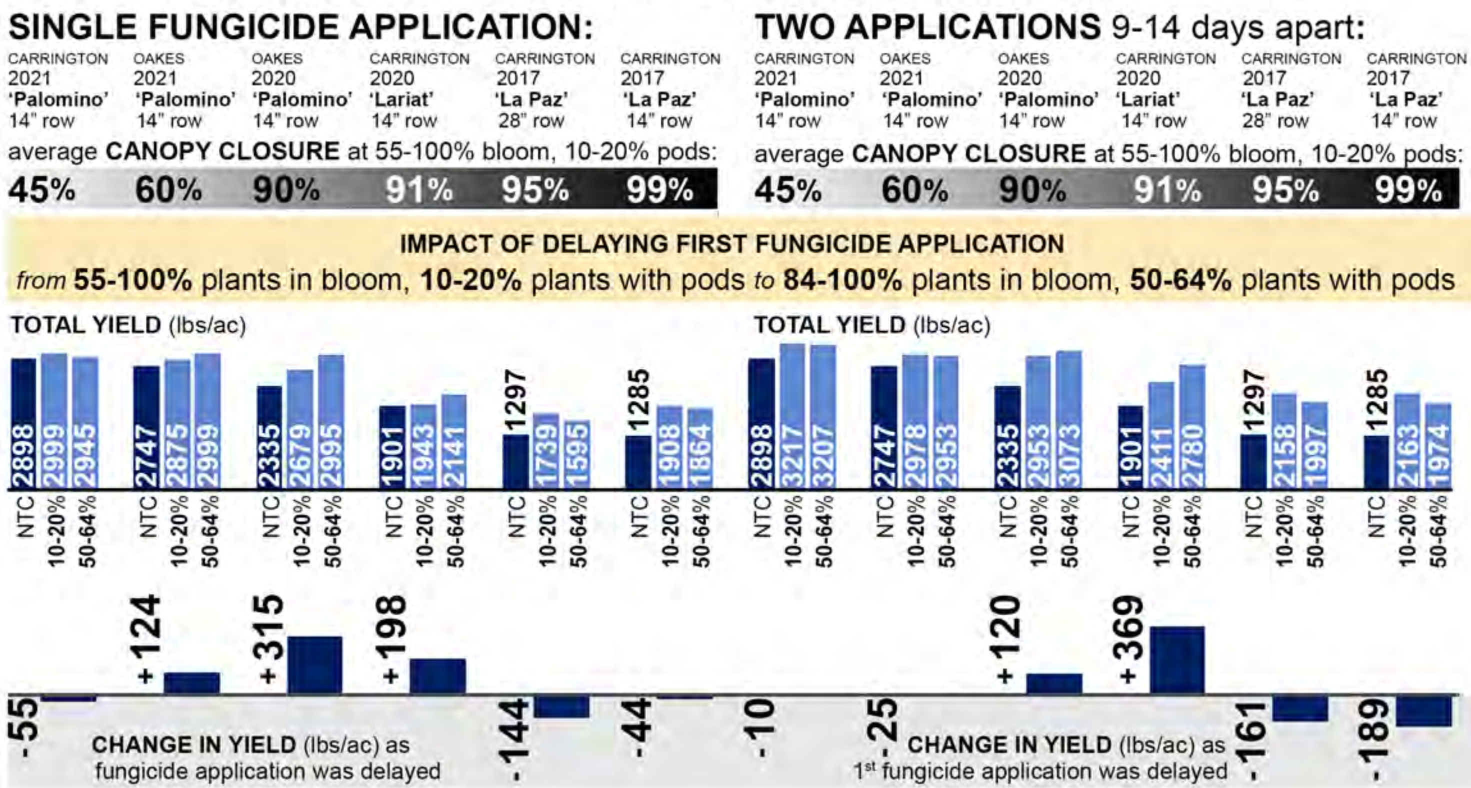
- Topsin @ 30 fl oz/ac followed by Endura @ 8 oz/ac (2017, 2020)
- Topsin @ 40 fl oz/ac followed by Endura @ 8 oz/ac (2021)

Spray volume: 15 gal/ac

Nozzles & droplet size:

- When average canopy closure was < 80%: TeeJet DG110015 nozzles at 40 psi (fine droplets)
- When average canopy closure was 80-90%: TeeJet DG110015 nozzles at 30 psi (medium droplets)
- When average canopy closure was 90-95%: TeeJet AIXR11015 nozzles at 60 psi (medium-coarse droplets)
- When average canopy closure was 95-100%: TeeJet AIXR nozzles at 50 psi (coarse droplets)

RESULTS FROM INDIVIDUAL STUDIES



Fungicide application timing

PINTO BEANS

Fungicide applied:

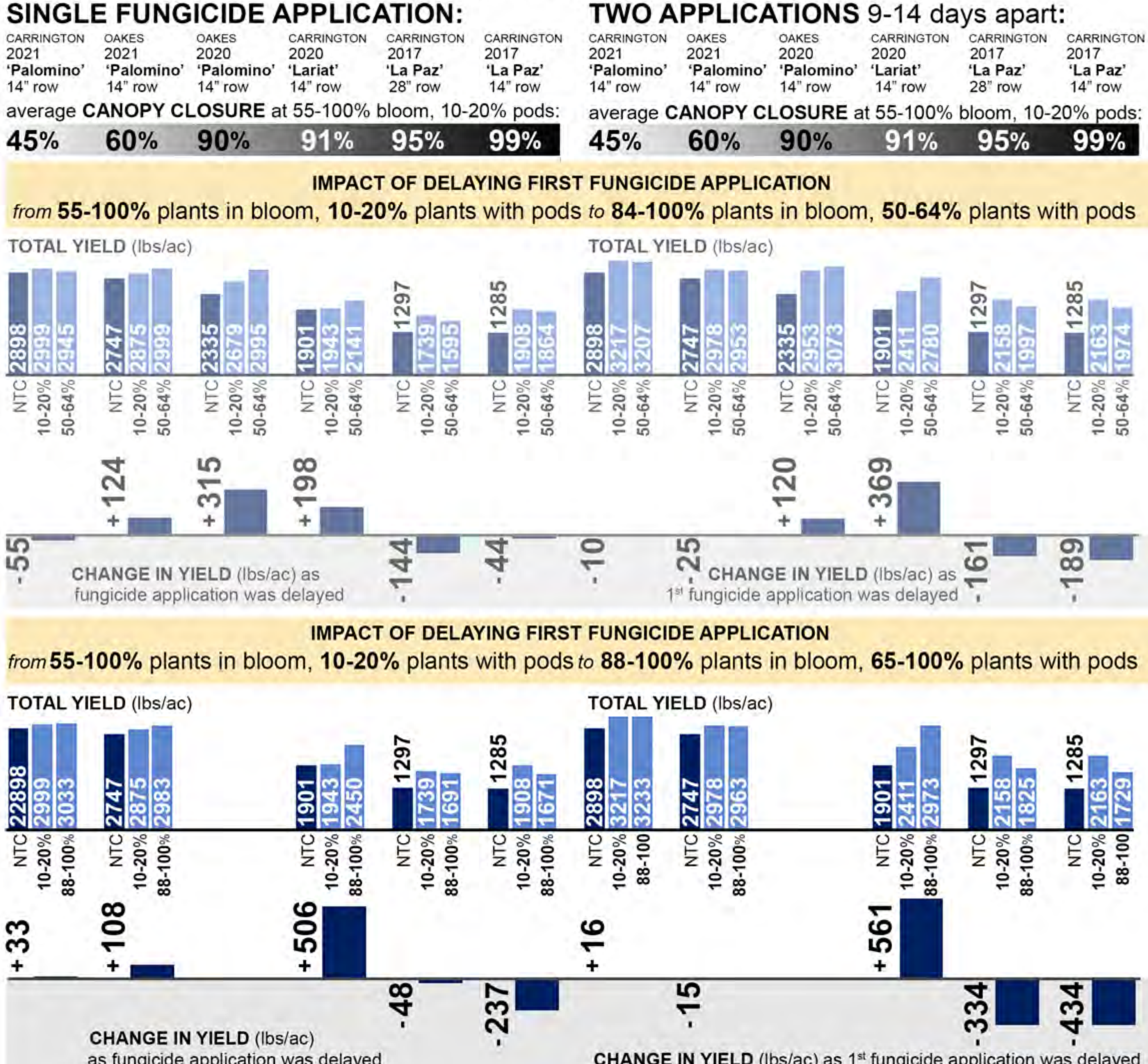
SINGLE FUNGICIDE APPLICATION –
- Topsin @ 30 fl oz/ac (studies from 2017, 2020)
- Topsin @ 40 fl oz/ac (studies conducted in 2021)

TWO FUNGICIDE APPLICATIONS –
- Topsin @ 30 fl oz/ac followed by Endura @ 8 oz/ac (2017, 2020)
- Topsin @ 40 fl oz/ac followed by Endura @ 8 oz/ac (2021)

Spray volume: 15 gal/ac

Nozzles & droplet size:
- When average canopy closure was < 80%: TeeJet DG110015 nozzles at 40 psi (fine droplets)
- When average canopy closure was 80-90%: TeeJet DG110015 nozzles at 30 psi (medium droplets)
- When average canopy closure was 90-95%: TeeJet AIXR11015 nozzles at 60 psi (medium-coarse droplets)
- When average canopy closure was 95-100%: TeeJet AIXR nozzles at 50 psi (coarse droplets)

RESULTS FROM INDIVIDUAL STUDIES



Optimizing fungicide application timing

Impact of fungicide application timing on white mold:

PINTO BEANS:

- Applying fungicides when 10-20% of plants had at least one initial pin-shaped pod was optimal in pinto beans when the canopy was at or near closure (95-99% average closure).
- Applying fungicides when 50-64% of plants had at least one initial pin-shaped pod was optimal in pinto beans when the canopy was open (< 95% average closure) initial pod development.

Optimizing fungicide application timing for white mold management in dry beans

1. BLACK BEANS

Carrington and Oakes, ND (2017, 2020, 2021)

(1) AVERAGE RESULTS

canopy open at initial pod development (10-20% plants with pods)

AVERAGE RESULTS
across all studies

4 studies conducted across 3 years, 2 locations

average **CANOPY CLOSURE**
at 10-60% plants in bloom, <5% with pods:
40-85%

SINGLE FUNGICIDE APPLICATION:

Fungicide application timing	White mold % of canopy		Yield lbs/ac	
Non-treated control	56	a	2419	a
10-60% of plants **in bloom** **< 5%** of plants with **pods**	50	a	2563	a
50-100% of plants **in bloom** **< 20%** of plants with **pods**	44	a	2749	a
75-100% of plants **in bloom** **30-50%** of plants with **pods**	46	a	2718	a
85-100% of plants **in bloom** **65-100%** of plants with **pods**	43	a	2829	a
	CV: 13.6		CV: 9.5	

TWO FUNGICIDE APPLICATIONS 10 to 12 days apart:

Fungicide application timing - first application	White mold % of canopy		Yield lbs/ac	
Non-treated control	56	b	2419	b
10-60% of plants **in bloom** **< 5%** of plants with **pods**	33	a	2924	ab
50-100% of plants **in bloom** **< 20%** of plants with **pods**	31	a	3119	a
75-100% of plants **in bloom** **30-50%** of plants with **pods**	30	a	3128	a
85-100% of plants **in bloom** **65-100%** of plants with **pods**				
	CV: 17.7		CV: 8.8	

Fungicide applied:

SINGLE FUNGICIDE APPLICATION –
- Topsin @ 30 fl oz/ac (studies from 2017, 2020)
- Topsin @ 40 fl oz/ac (studies conducted in 2021)

TWO FUNGICIDE APPLICATIONS –
- Topsin @ 30 fl oz/ac followed by Endura @ 8 oz/ac (2017, 2020)
- Topsin @ 40 fl oz/ac followed by Endura @ 8 oz/ac (2021)

Spray volume: 15 gal/ac

Nozzles & droplet size:
- When average canopy closure was < 80%: TeeJet DG110015 nozzles at 40 psi (fine droplets)
- When average canopy closure was 80-90%: TeeJet DG110015 nozzles at 30 psi (medium droplets)
- When average canopy closure was 90-95%: TeeJet AIXR11015 nozzles at 60 psi (medium-coarse droplets)
- When average canopy closure was 95-100%: TeeJet AIXR nozzles at 50 psi (coarse droplets)

Optimizing fungicide application timing for white mold management in dry beans

1. BLACK BEANS

Carrington and Oakes, ND (2017, 2020, 2021)

(2) RESULTS ACROSS INDIVIDUAL STUDIES

Bloom initiation vs. <20% of plants with initial pods

AVERAGE RESULTS
across all studies

4 studies conducted across 3 years, 2 locations

average **CANOPY CLOSURE**
at 10-60% plants in bloom, <5% with pods:
40-85%

SINGLE FUNGICIDE APPLICATION:

Fungicide application timing	White mold % of canopy		Yield lbs/ac	
Non-treated control	56	a	2419	a
10-60% of plants **in bloom** < **5%** of plants with **pods**	50	a	2563	a
50-100% of plants **in bloom** < **20%** of plants with **pods**	44	a	2749	a
75-100% of plants **in bloom** **30-50%** of plants with **pods**	46	a	2718	a
85-100% of plants **in bloom** **65-100%** of plants with **pods**	43	a	2829	a
	CV: 13.6		CV: 9.5	

TWO FUNGICIDE APPLICATIONS 10 to 12 days apart:

Fungicide application timing - first application	White mold % of canopy		Yield lbs/ac	
Non-treated control	56	b	2419	b
10-60% of plants **in bloom** < **5%** of plants with **pods**	33	a	2924	ab
50-100% of plants **in bloom** < **20%** of plants with **pods**	31	a	3119	a
75-100% of plants **in bloom** **30-50%** of plants with **pods**	30	a	3128	a
85-100% of plants **in bloom** **65-100%** of plants with **pods**				
	CV: 17.7		CV: 8.8	

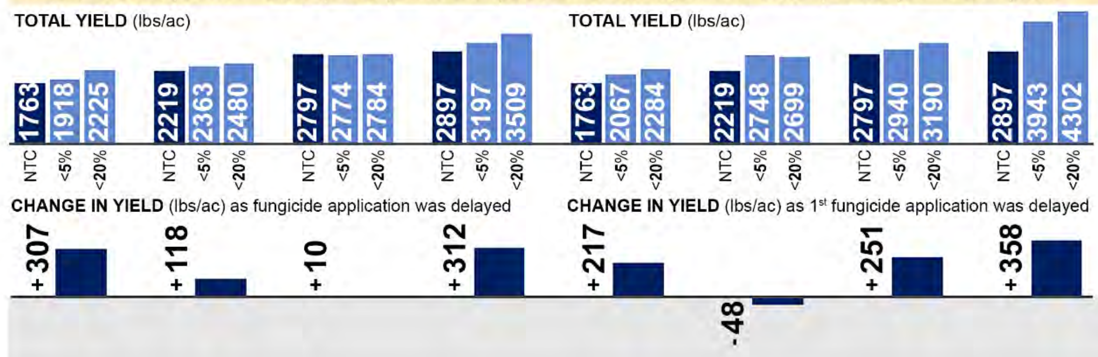
RESULTS FROM INDIVIDUAL STUDIES

SINGLE FUNGICIDE APPLICATION: / **TWO APPLICATIONS** 10-12 days apart:

Carrington 2017 'Eclipse' 28" row; Carrington 2017 'Eclipse' 14" row; Carrington 2020 'Black Bear' 14" row; Oakes 2017 'Eclipse' 14" row

average **CANOPY CLOSURE** at 10-60% bloom, <5% pods: 40% | 50% | 72% | 85%

IMPACT OF DELAYING FIRST FUNGICIDE APPLICATION
from **10-60%** plants in bloom, **<5%** plants with pods *to* **50-100%** plants in bloom, **<20%** plants with pods



Optimizing fungicide application timing for white mold management in dry beans

1. BLACK BEANS

Carrington and Oakes, ND (2017, 2020, 2021)

(2) RESULTS ACROSS INDIVIDUAL STUDIES

Bloom initiation vs. <20% or 30-50% of plants with initial pods

AVERAGE RESULTS
across all studies

4 studies conducted across 3 years, 2 locations

average **CANOPY CLOSURE**
at 10-60% plants in bloom, <5% with pods:
40-85%

SINGLE FUNGICIDE APPLICATION:

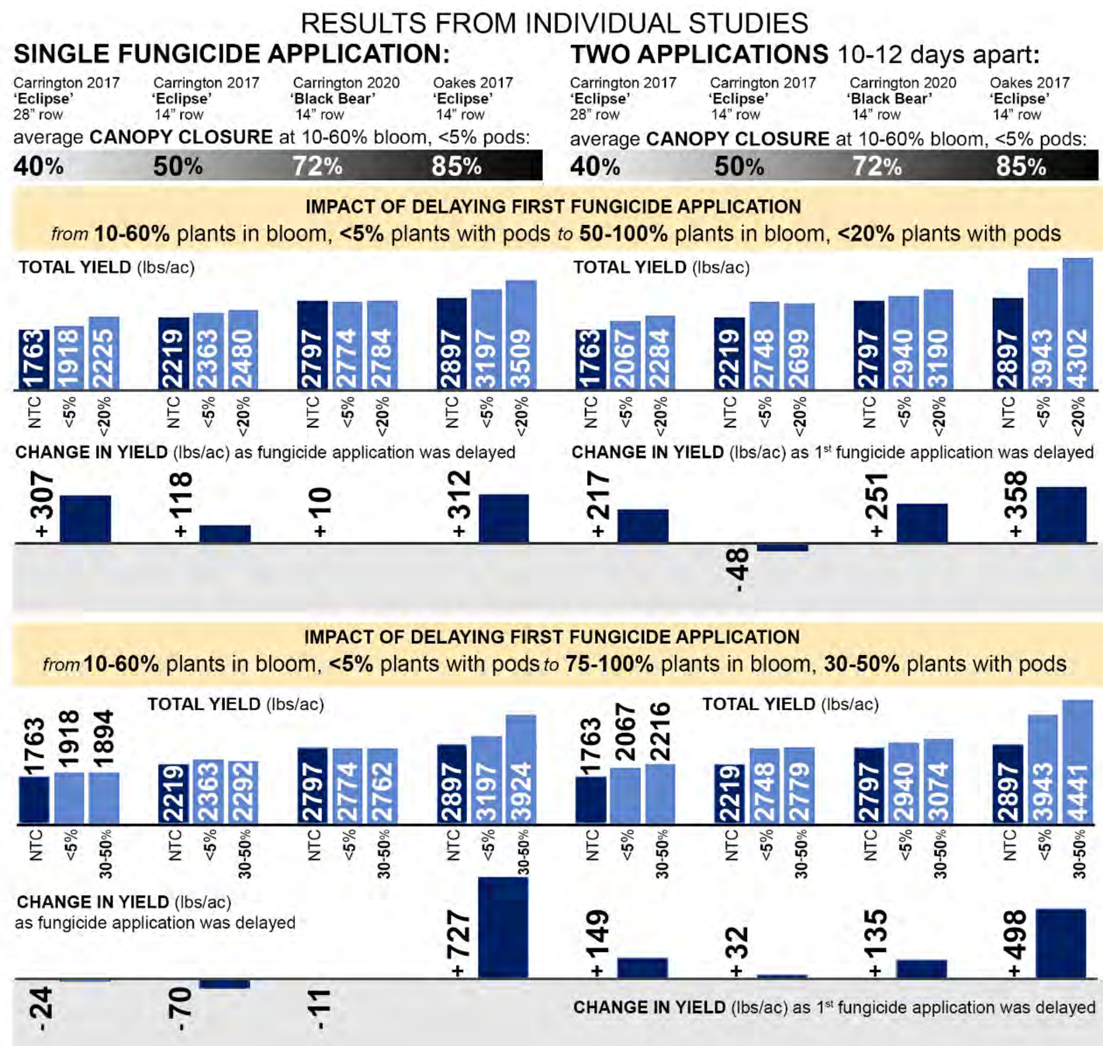
Fungicide application timing

	White mold % of canopy		Yield lbs/ac	
Non-treated control	56	a	2419	a
10-60% of plants **in bloom** < 5% of plants with **pods**	50	a	2563	a
50-100% of plants **in bloom** < 20% of plants with **pods**	44	a	2749	a
75-100% of plants **in bloom** 30-50% of plants with **pods**	46	a	2718	a
85-100% of plants **in bloom** 65-100% of plants with **pods**	43	a	2829	a
	CV: 13.6		CV: 9.5	

TWO FUNGICIDE APPLICATIONS 10 to 12 days apart:

Fungicide application timing - first application

	White mold % of canopy		Yield lbs/ac	
Non-treated control	56	b	2419	b
10-60% of plants **in bloom** < 5% of plants with **pods**	33	a	2924	ab
50-100% of plants **in bloom** < 20% of plants with **pods**	31	a	3119	a
75-100% of plants **in bloom** 30-50% of plants with **pods**	30	a	3128	a
85-100% of plants **in bloom** 65-100% of plants with **pods**				
	CV: 17.7		CV: 8.8	



Optimizing fungicide application timing for white mold management in dry beans

1. BLACK BEANS

Carrington and Oakes, ND (2017, 2020, 2021)

(2) RESULTS ACROSS INDIVIDUAL STUDIES
Initial pod development vs. 30-50% of plants with initial pods

AVERAGE RESULTS
across all studies

4 studies conducted across 3 years, 2 locations

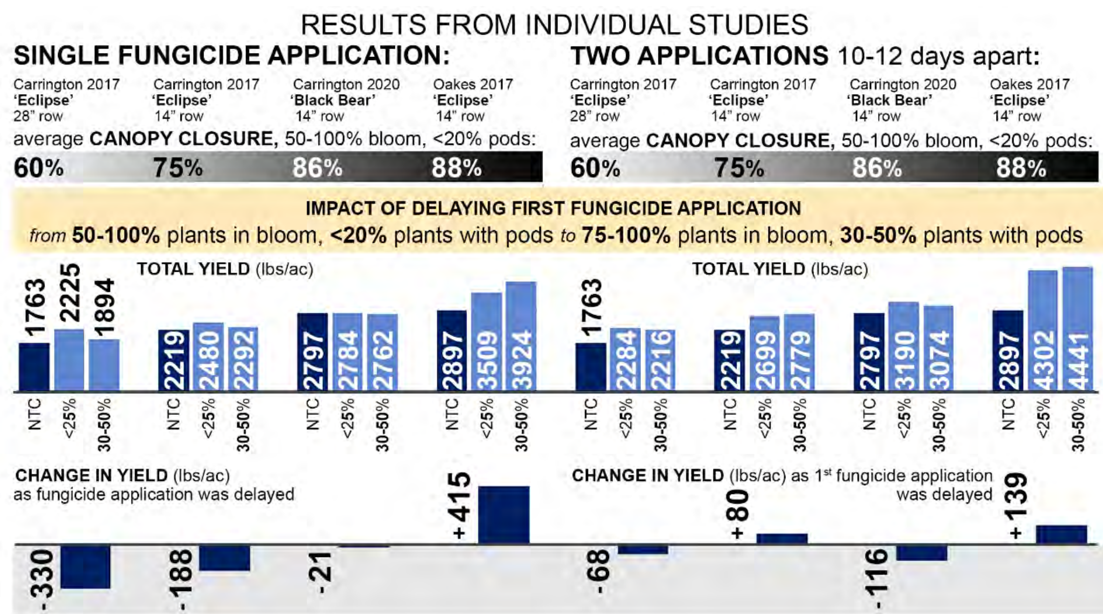
average **CANOPY CLOSURE**
at 50-100% plants in bloom, <20% with pods:
60-88%

SINGLE FUNGICIDE APPLICATION:

Fungicide application timing	White mold (% of canopy)		Yield (lbs/ac)	
Non-treated control	56	a	2419	a
10-60% of plants **in bloom**, < 5% of plants with **pods**	50	a	2563	a
50-100% of plants **in bloom**, < 25% of plants with **pods**	44	a	2749	a
75-100% of plants **in bloom**, 30-50% of plants with **pods**	46	a	2718	a
85-100% of plants **in bloom**, 65-100% of plants with **pods**	43	a	2829	a
	CV: 13.6		CV: 9.5	

TWO FUNGICIDE APPLICATIONS 10 to 12 days apart:

Fungicide application timing - first application	White mold (% of canopy)		Yield (lbs/ac)	
Non-treated control	56	b	2419	b
10-60% of plants **in bloom**, < 5% of plants with **pods**	33	a	2924	ab
50-100% of plants **in bloom**, < 25% of plants with **pods**	31	a	3119	a
75-100% of plants **in bloom**, 30-50% of plants with **pods**	30	a	3128	a
85-100% of plants **in bloom**, 65-100% of plants with **pods**				
	CV: 17.7		CV: 8.8	



Optimizing fungicide application timing for white mold management in dry beans

1. BLACK BEANS

Carrington and Oakes, ND (2017, 2020, 2021)

(2) RESULTS ACROSS INDIVIDUAL STUDIES

Initial pod development vs. 30-50% or 85-100% of plants with initial pods

AVERAGE RESULTS
across all studies

4 studies conducted across 3 years, 2 locations

average CANOPY CLOSURE
at 50-100% plants in bloom, <20% with pods:
60-88%

SINGLE FUNGICIDE APPLICATION:

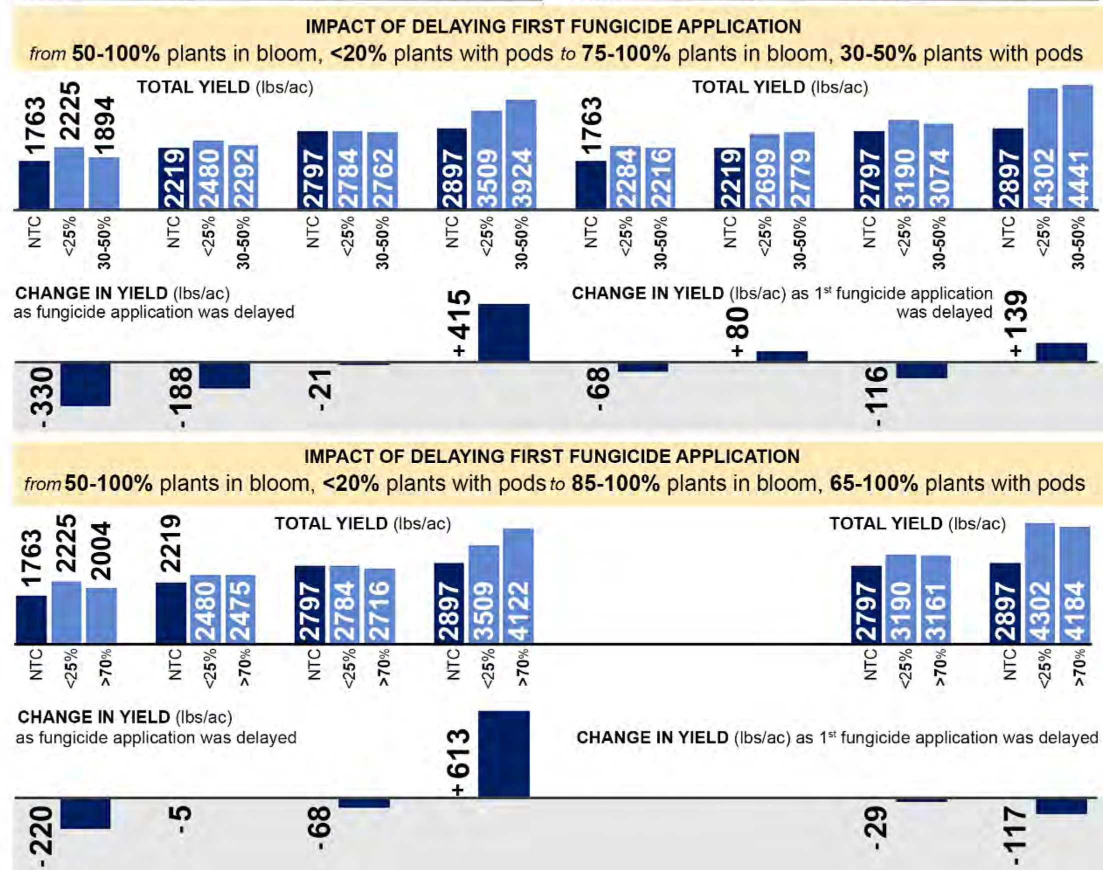
Fungicide application timing	White mold (% of canopy)		Yield (lbs/ac)	
Non-treated control	56	a	2419	a
10-60% of plants **in bloom** **< 5%** of plants with **pods**	50	a	2563	a
50-100% of plants **in bloom** **< 25%** of plants with **pods**	44	a	2749	a
75-100% of plants **in bloom** **30-50%** of plants with **pods**	46	a	2718	a
85-100% of plants **in bloom** **65-100%** of plants with **pods**	43	a	2829	a
	CV: 13.6		CV: 9.5	

TWO FUNGICIDE APPLICATIONS 10 to 12 days apart:

Fungicide application timing - first application	White mold (% of canopy)		Yield (lbs/ac)	
Non-treated control	56	b	2419	b
10-60% of plants **in bloom** **< 5%** of plants with **pods**	33	a	2924	ab
50-100% of plants **in bloom** **< 25%** of plants with **pods**	31	a	3119	a
75-100% of plants **in bloom** **30-50%** of plants with **pods**	30	a	3128	a
85-100% of plants **in bloom** **65-100%** of plants with **pods**				
	CV: 17.7		CV: 8.8	

RESULTS FROM INDIVIDUAL STUDIES

	SINGLE FUNGICIDE APPLICATION:				TWO APPLICATIONS 10-12 days apart:			
Study	Carrington 2017 'Eclipse' 28" row	Carrington 2017 'Eclipse' 14" row	Carrington 2020 'Black Bear' 14" row	Oakes 2017 'Eclipse' 14" row	Carrington 2017 'Eclipse' 28" row	Carrington 2017 'Eclipse' 14" row	Carrington 2020 'Black Bear' 14" row	Oakes 2017 'Eclipse' 14" row
average **CANOPY CLOSURE**, 50-100% bloom, <20% pods:	60%	75%	86%	88%	60%	75%	86%	88%



Optimizing fungicide application timing

Impact of fungicide application timing on white mold:

BLACK BEANS:

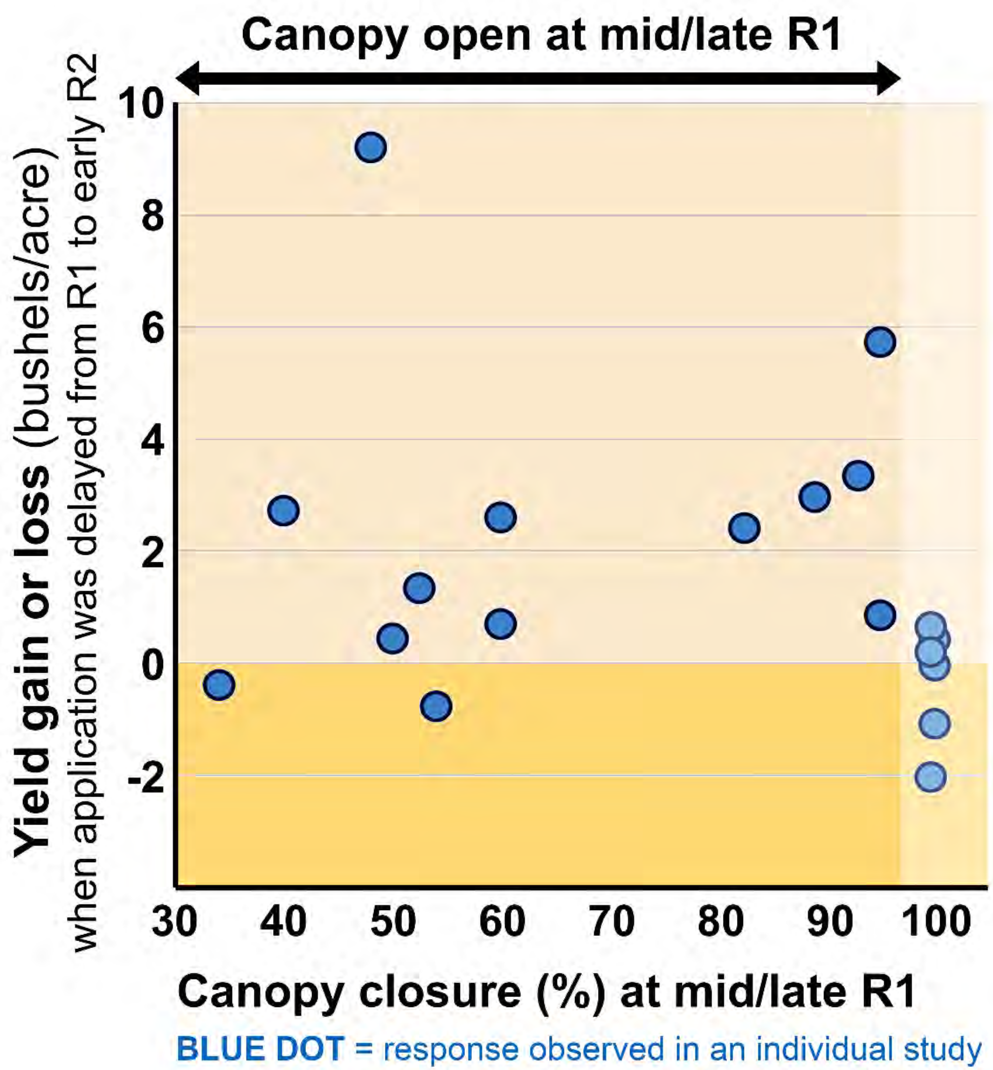
- Applying fungicides when up to 20% of plants had at least one initial pin-shaped pod and 50-100% of plants were in bloom was optimal in black beans when the canopy was open (< 90% average closure) at this growth stage.
- No testing was conducted on black beans with a closed canopy during initial pod development.

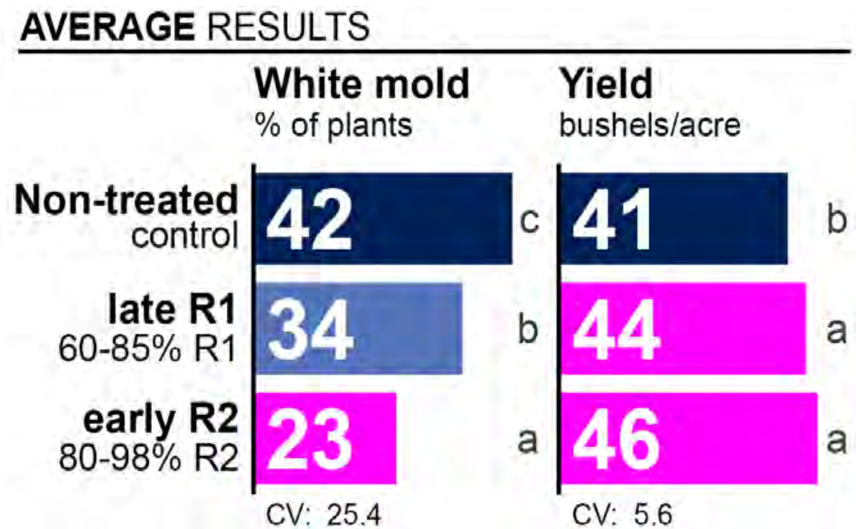
Optimizing fungicide application timing for white mold management in soybeans

1. **mid/late R1** (60-85% R1) **versus early R2** (80-99% R2)

Carrington, Hofflund, Langdon and Oakes, ND (2014-2016)

(1) Impact of delaying applications from mid/late R1 to early R2 **when the canopy was open at the R1 application**





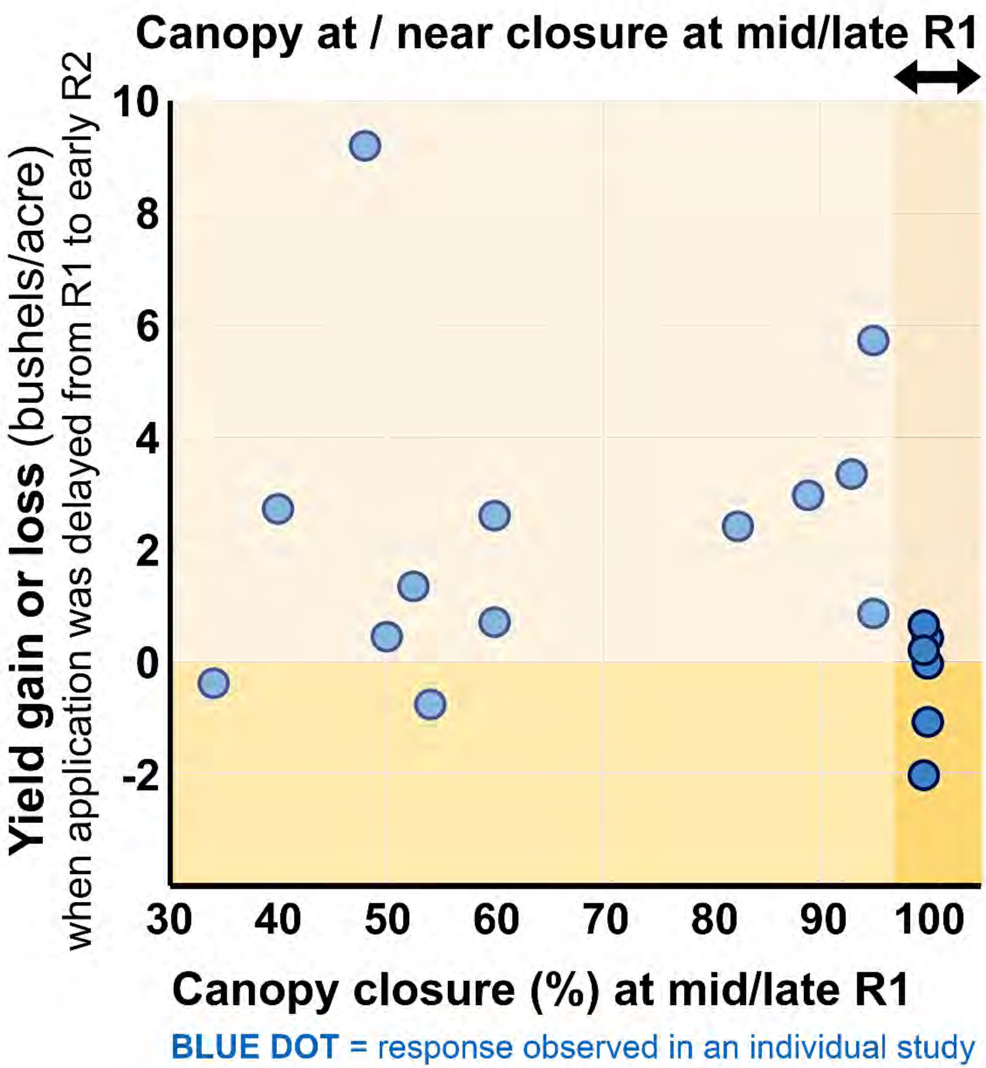
Combined analysis from 13 studies
Fungicide: single application, Endura (5.5 or 8.0 oz/ac)
Soybean row spacing: 7, 7.5, 14, 15, 21, 28 or 30 in.

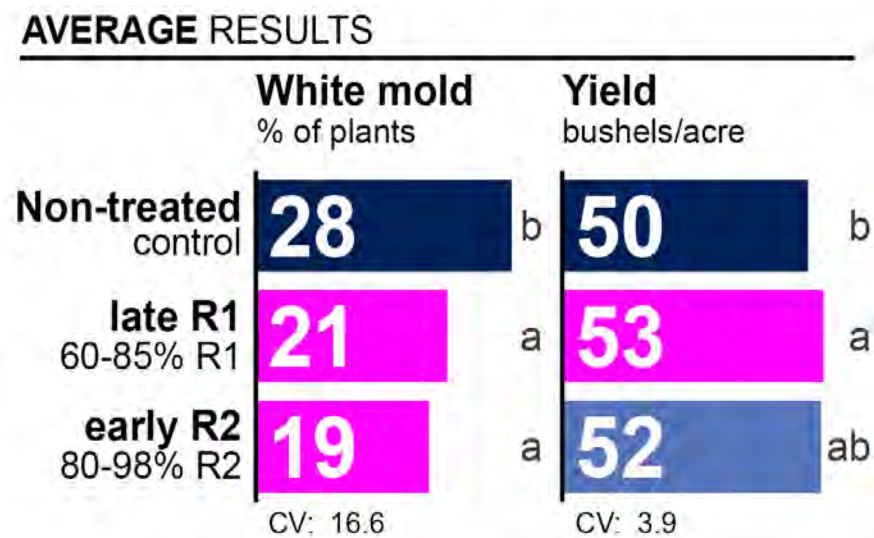
Optimizing fungicide application timing for white mold management in soybeans

1. **mid/late R1** (60-85% R1) **versus early R2** (80-99% R2)

Carrington, Hofflund, Langdon and Oakes, ND (2014-2016)

(1) Impact of delaying applications from mid/late R1 to early R2 **when the canopy was at or near closure at the R1 application**





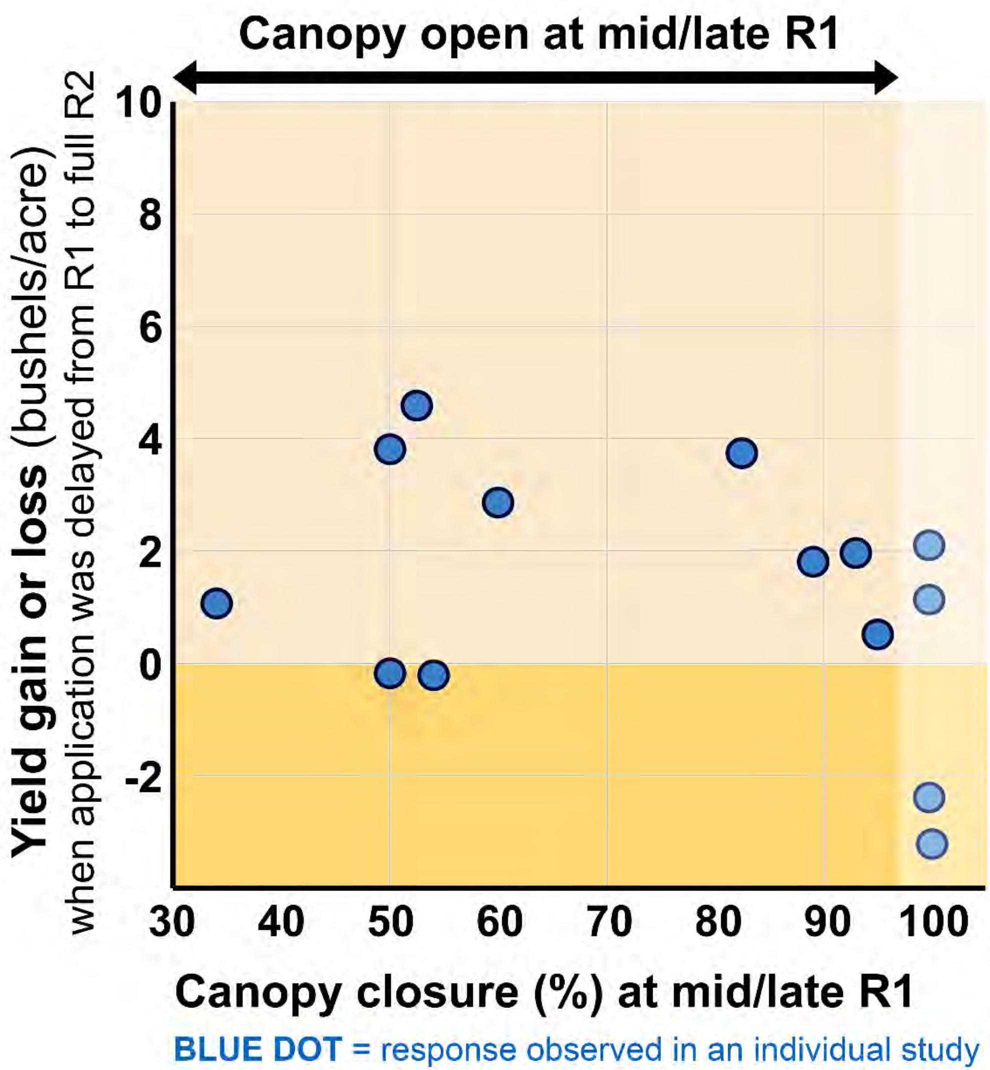
Combined analysis from 6 studies
Fungicide: single application, Endura (5.5 or 8.0 oz/ac)
Soybean row spacing: 7.5 or 14 inches

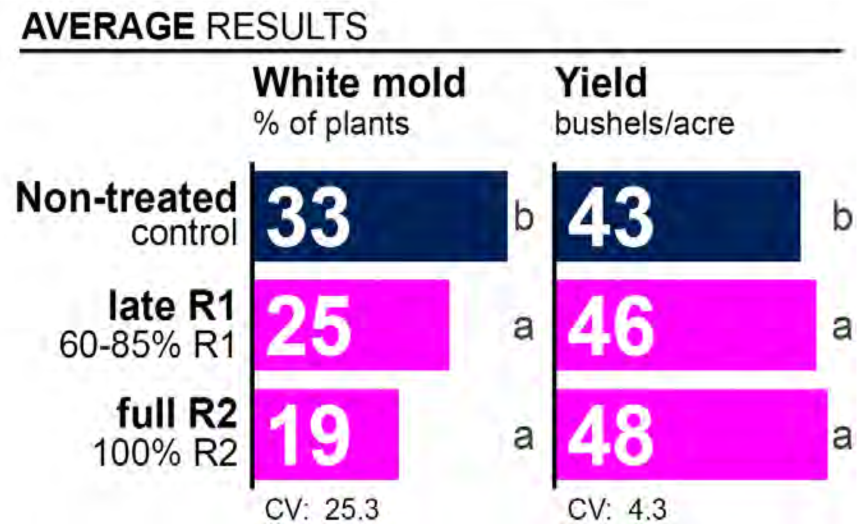
Optimizing fungicide application timing for white mold management in soybeans

2. mid/late R1 (60-85% R1) versus full R2 (100% R2)

Carrington, Hofflund, Langdon and Oakes, ND (2014-2016)

Impact of delaying applications from mid/late R1 to full R2
when the canopy was open at the R1 application





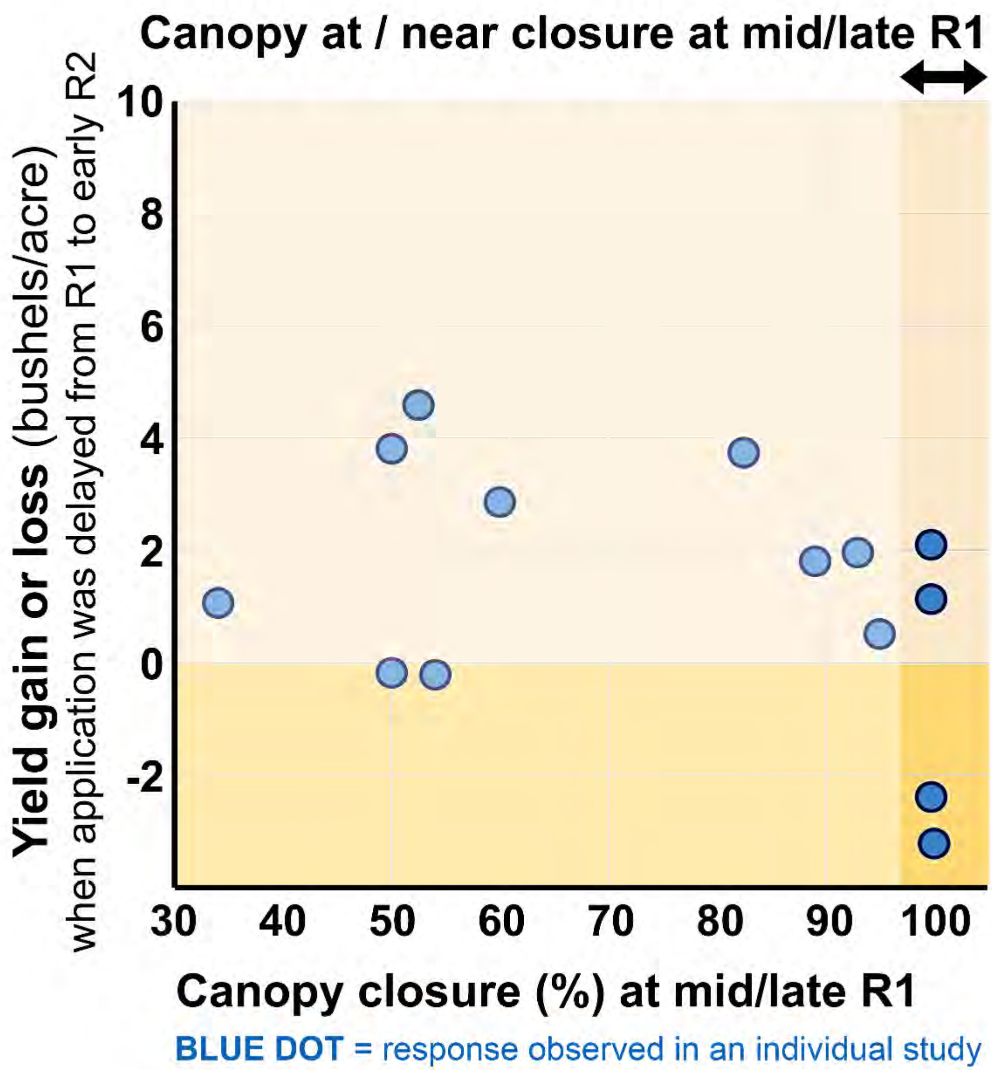
Combined analysis from 10 studies
Fungicide: single application, Endura (5.5 or 8.0 oz/ac)
Soybean row spacing: 14, 15, 21, or 28 inches

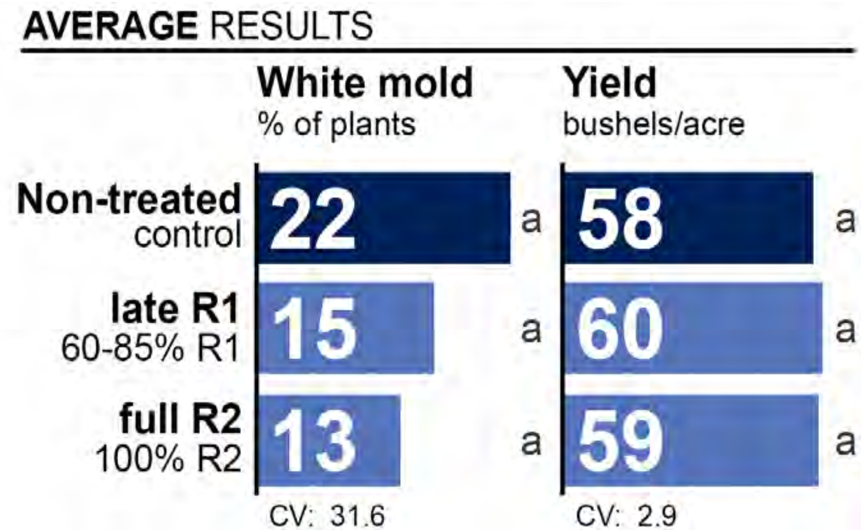
Optimizing fungicide application timing for white mold management in soybeans

2. **mid/late R1** (60-85% R1) **versus full R2** (100% R2)

Carrington, Hofflund, Langdon and Oakes, ND (2014-2016)

Impact of delaying applications from mid/late R1 to full R2
when the canopy was at or near closure at the R1 application





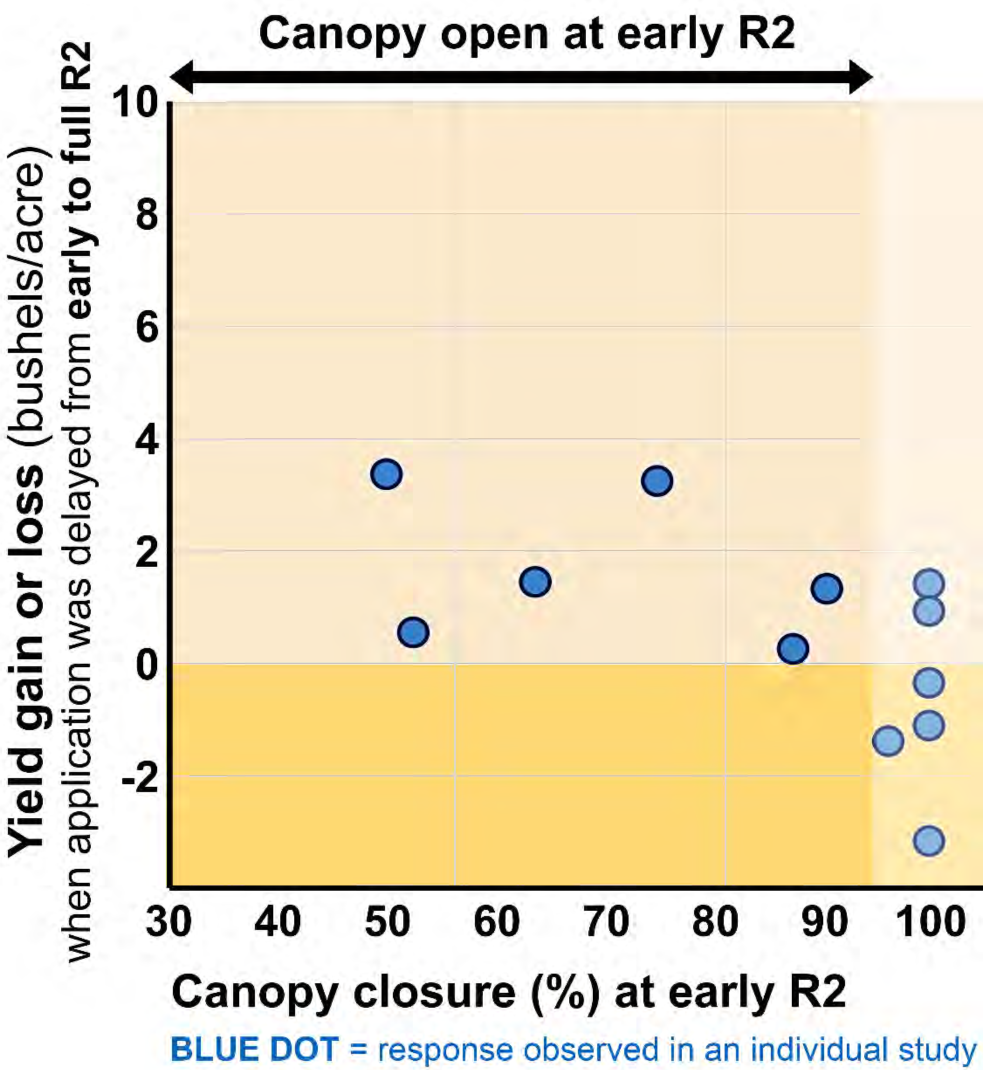
Combined analysis from 4 studies
Fungicide: single application, Endura (5.5 oz/ac)
Soybean row spacing: 14 inches

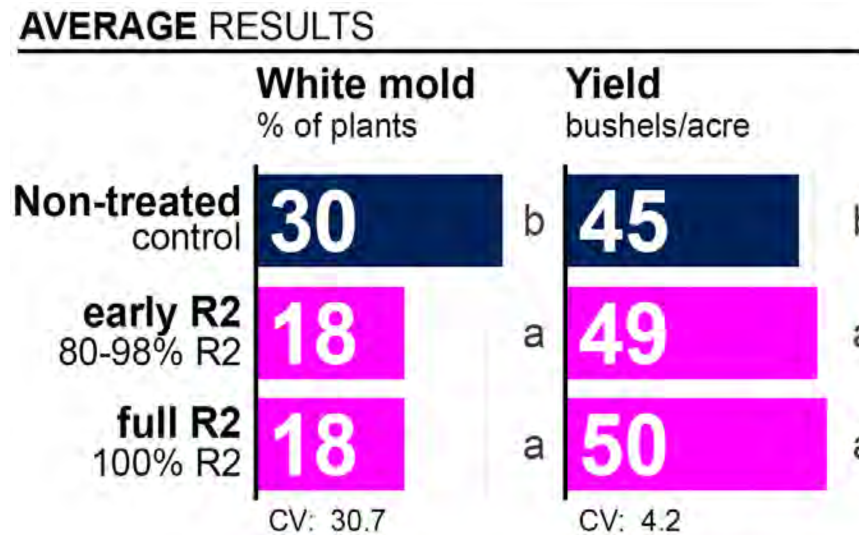
Optimizing fungicide application timing for white mold management in soybeans

3. **Early R2** (80-99% R2) **versus full R2** (100% R2)

Carrington, Hofflund, Langdon and Oakes, ND (2014-2016)

Impact of delaying applications from early R2 to full R2 **when the canopy was open at the early R2 application**





Combined analysis from 6 studies

Fungicide: single application, Endura (5.5 or 8.0 oz/ac)

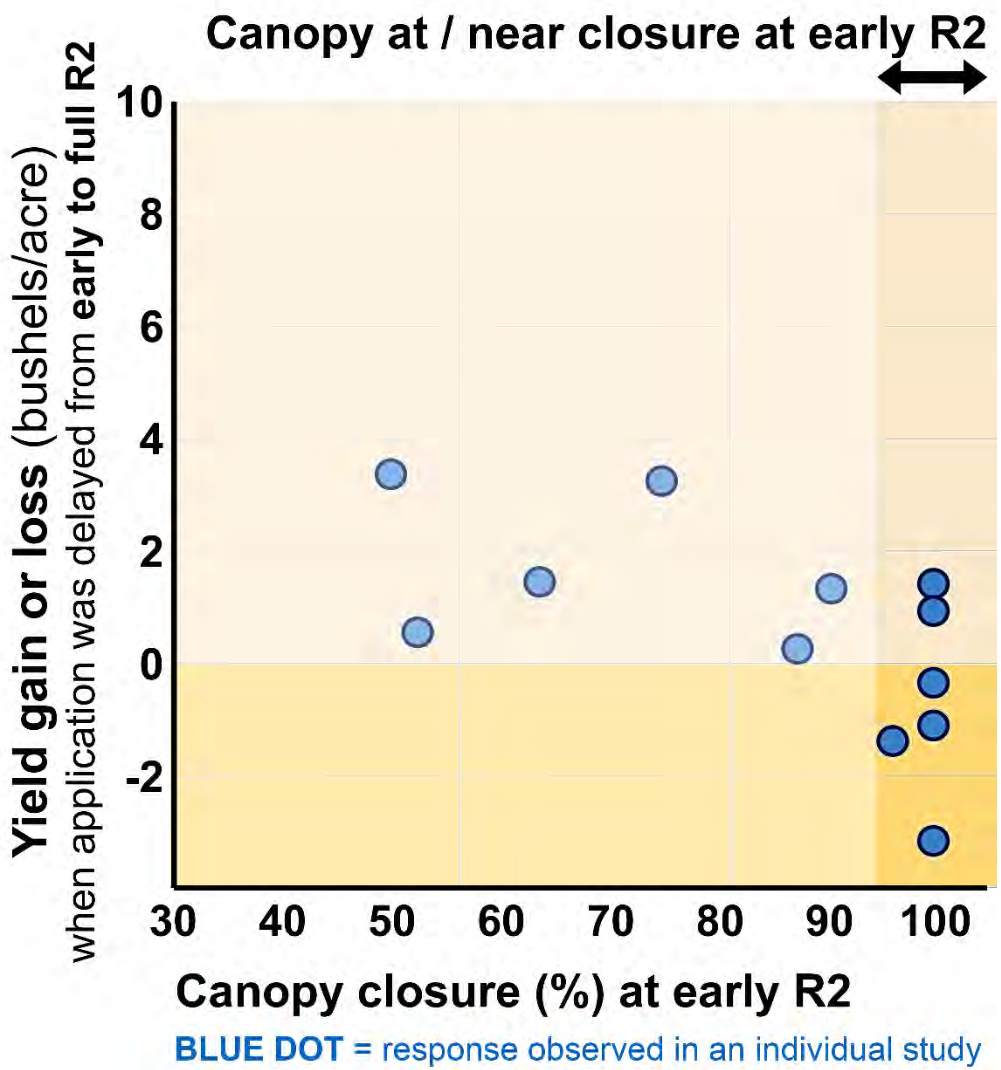
Soybean row spacing: 21 or 28 inches

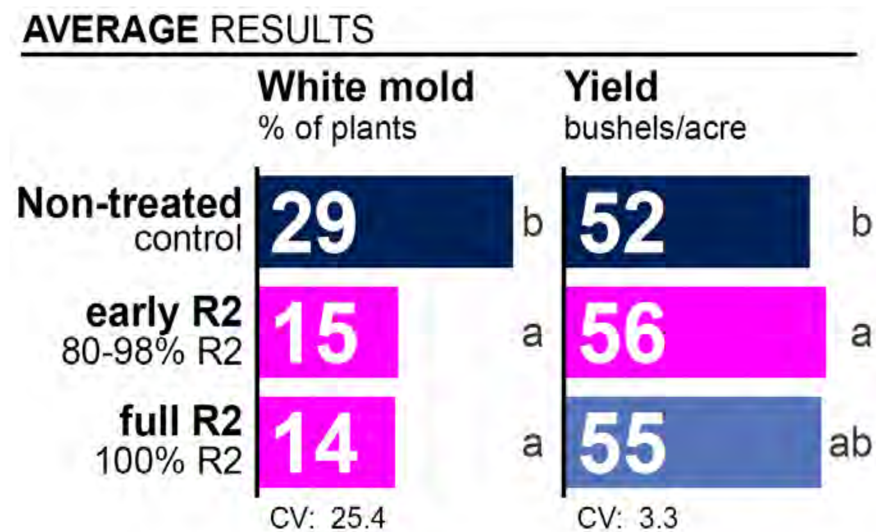
Optimizing fungicide application timing for white mold management in soybeans

3. **Early R2** (80-99% R2) **versus full R2** (100% R2)

Carrington, Hofflund, Langdon and Oakes, ND (2014-2016)

Impact of delaying applications from early R2 to full R2
when the canopy was at or near closure at the early R2 application





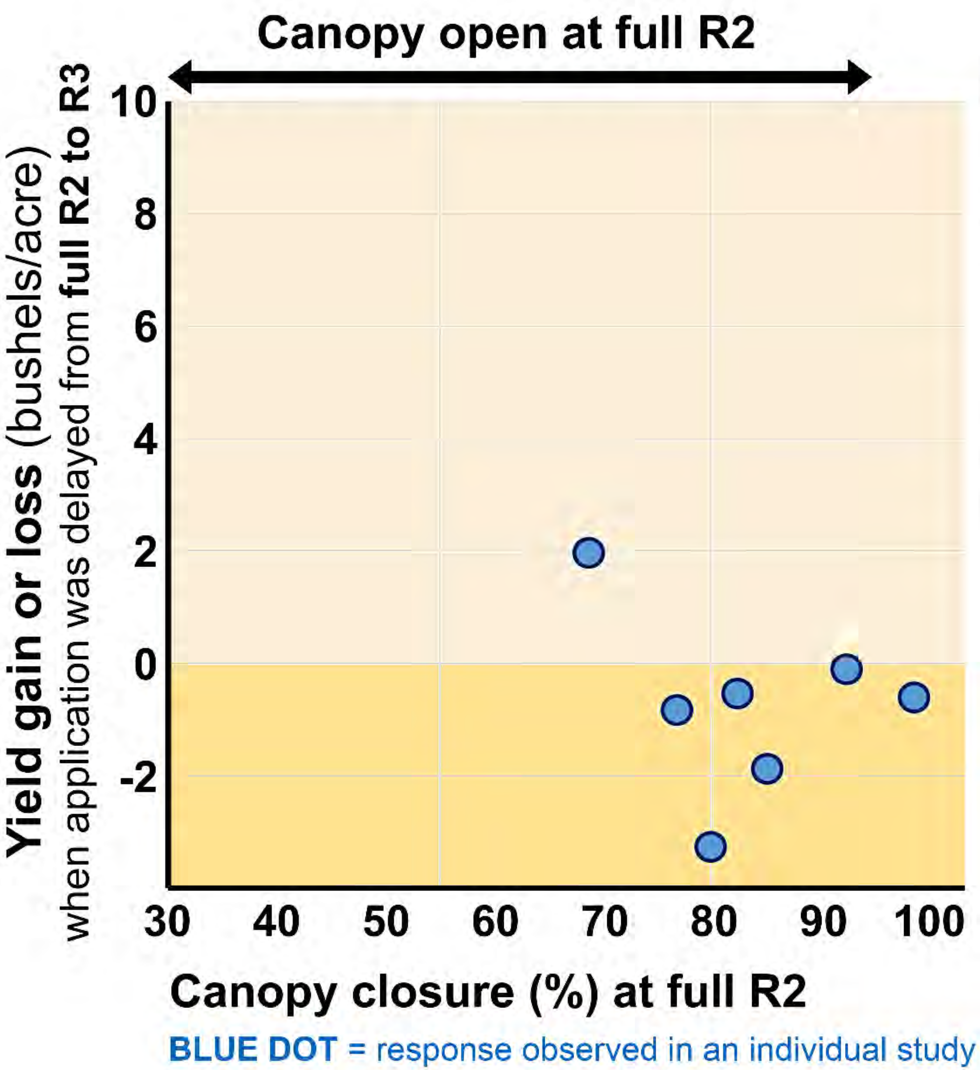
Combined analysis from 6 studies
Fungicide: single application, Endura (5.5 oz/ac)
Soybean row spacing: 14 inches

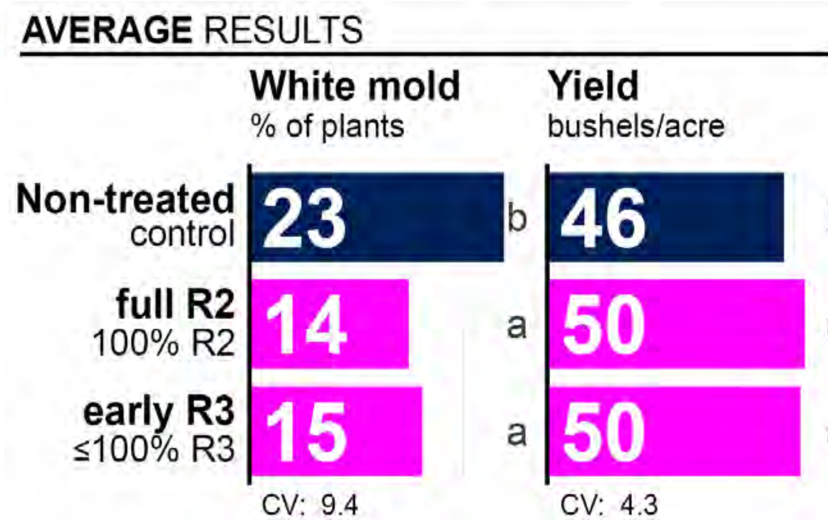
Optimizing fungicide application timing for white mold management in soybeans

4. **Full R2** (100% R2) **versus early R3**

Carrington, Hofflund, Langdon and Oakes, ND (2014-2016)

Impact of delaying applications from full R2 to early R3 relative to canopy closure at full R2





Combined analysis from 7 studies
Fungicide: single application, Endura (5.5 or 8.0 oz/ac)
Soybean row spacing: 15, 28 or 30 inches

Optimizing fungicide application timing

When conditions favor white mold as soybeans entered bloom:

Fungicides should be applied as soon as 100% of plants reach the R2 growth stage unless the canopy closes earlier.

- If the canopy is closed at mid/late R1 (60-85% of plants at R1), fungicides should be applied at mid/late R1.
- If the canopy is closed at early R2 (80-99% R2), fungicides should be applied at early R2.

R1: at least one open blossom on the plant.
R2: at least one open blossom at one of the top two nodes of the plant.

North Dakota Soybean Council
Our World Is Growing.

NDSU NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION

Improving management of white mold in soybeans and dry beans:

4. Optimizing fungicide spray droplet size

NDSU Carrington Research Extension Center
Heidi Eslinger, Kelly Cooper, Seth Nelson NDSU Robert Titus Research Farm, Oakes

RESEARCH FUNDED BY THE **NORTH DAKOTA SOYBEAN COUNCIL**

Droplet size

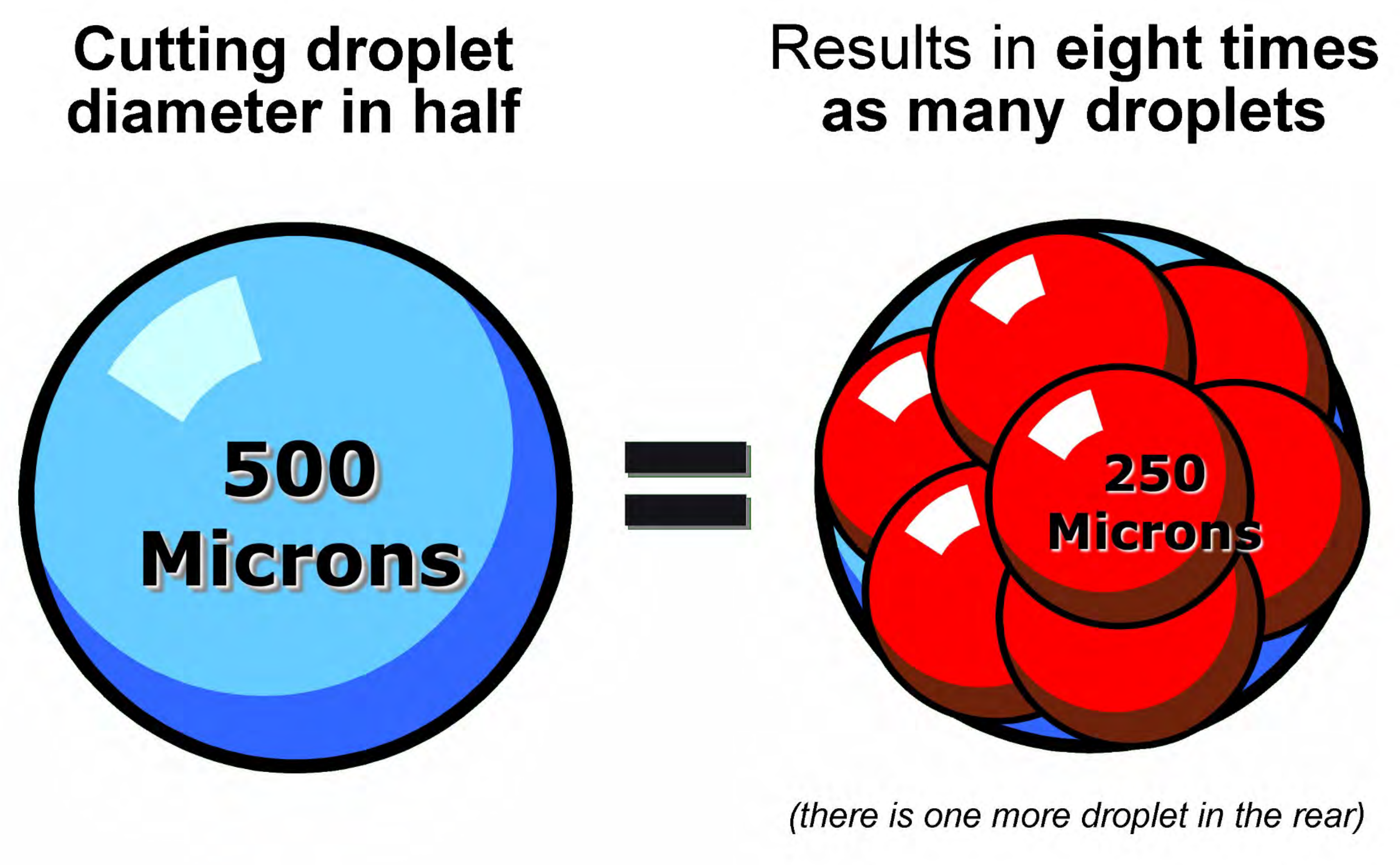


Image adapted from a presentation by Bob Wolf (Kansas State Univ.); Bobby Grisso and Pat Hipkins (Virginia Tech Univ.); and Tom Reed (TeeJet)

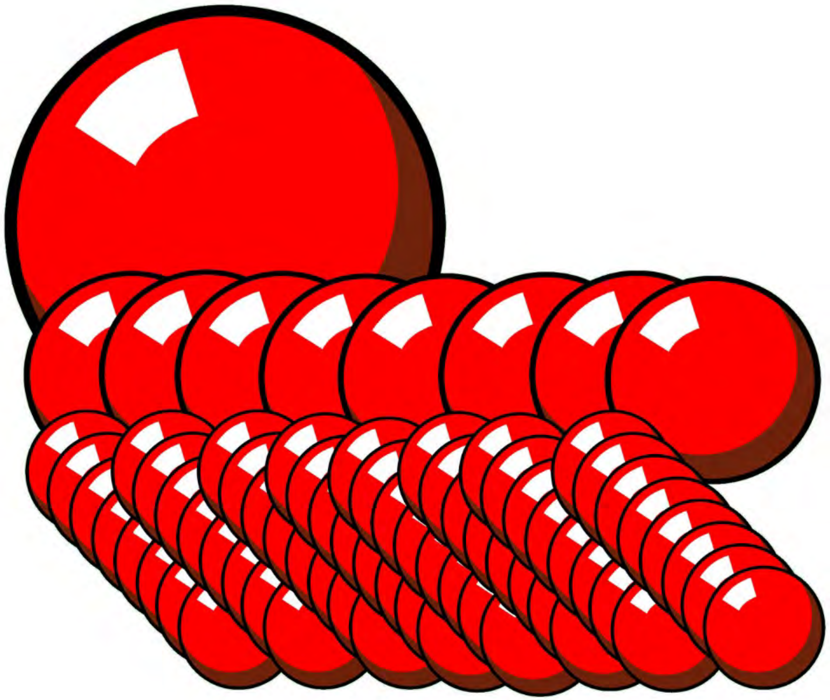
Droplet size

0.065 mm^3 spray volume =

one 500-um diameter droplet

eight 250-um diameter droplets

sixty-four 125-um diameter droplets



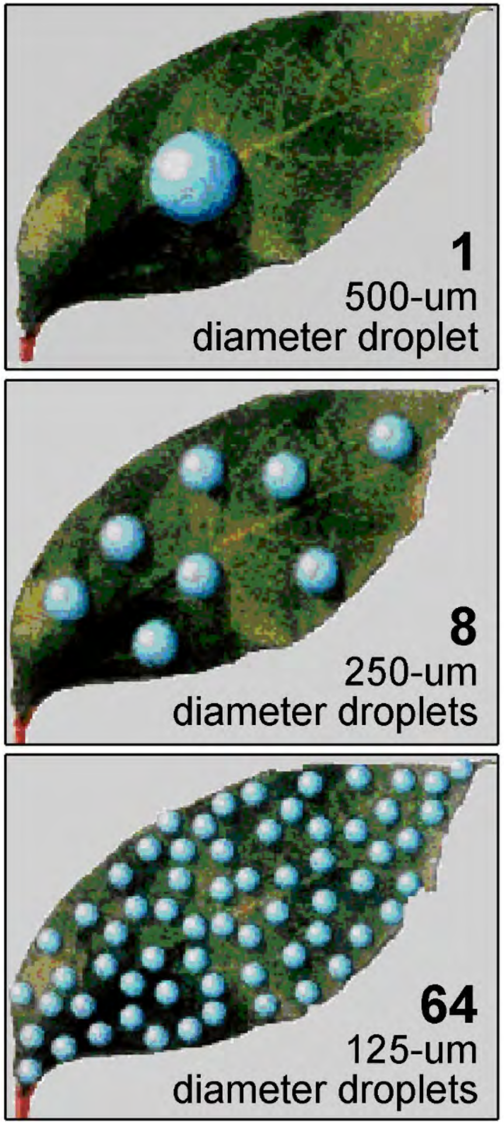


Image adapted from a presentation by Bob Wolf (Kansas State Univ.); Bobby Grisso and Pat Hipkins (Virginia Tech Univ.); and Tom Reed (TeeJet)

Droplet size

… but larger droplets have greater velocity, drift less.

Increased velocity and reduced drift improves canopy penetration.

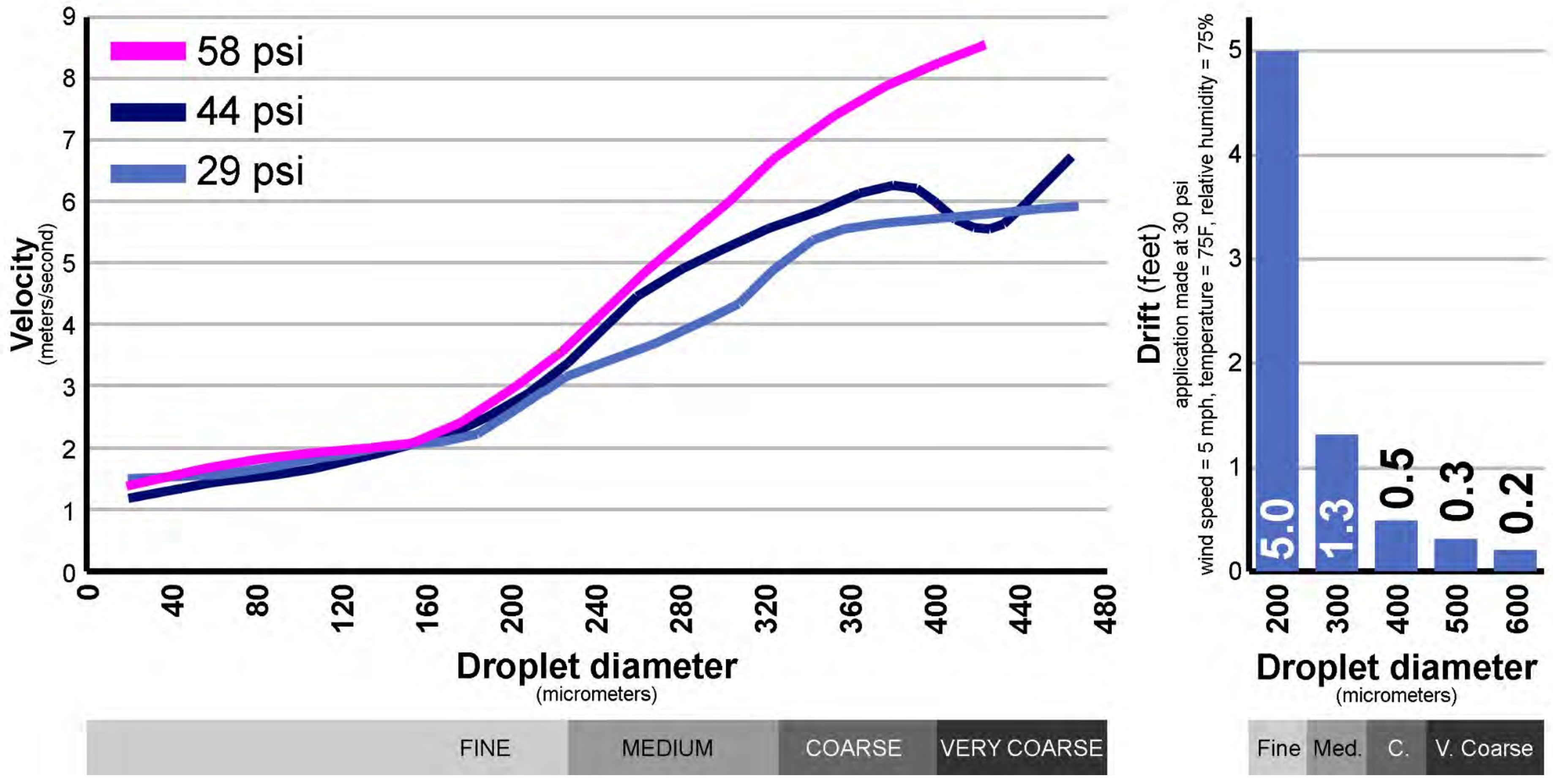


Image adapted from a presentation by Bob Wolf (Kansas State Univ.); Bobby Grisso and Pat Hipkins (Virginia Tech Univ.); and Tom Reed (TeeJet)

Experimental Methods

1. WILGER nozzles

Spray droplet size estimates were based on information provided by the manufacturer.

Recommended Pressure: 25-70 PSI

Recommended Pressure: 30-100 PSI

Recommended Pressure: 30-100 PSI

Recommended Pressure: 35-100 PSI

Tip Cap No.	Flow Rate USGPM	PSI	VMD (Droplet Size in µ); %<141µ (Drift %); %<200µ (Drift %); %<600µ (Small Droplets)															
			110° ER Series				110° SR Series				110° MR Series				110° DR Series			
			VMD	<141	<200	<600	VMD	<141	<200	<600	VMD	<141	<200	<600	VMD	<141	<200	<600
04	0.43	50	209	26%	47%	96%	275	15%	30%	96%	355	8%	17%	91%	447	5%	10%	79%

Fine 106-235µ; Medium 236-340µ; Coarse 341-403µ; Very Coarse 404-502µ

ER110-04
50 psi
FINE DROPLETS

SR110-04
50 psi
MEDIUM DROPLETS

MR110-04
50 psi
COARSE DROPLETS

DR110-04
50 psi
VERY COARSE DROPLETS

Experimental Methods

2. TEEJET nozzles

Spray droplet size estimates were based on information provided by the manufacturer.

XR11004 50 psi
FINE DROPLETS

XR11005 40 psi
MEDIUM-FINE DROPLETS

XR11006 35 psi
MEDIUM DROPLETS

XR11008 40 psi
MEDIUM-COARSE DROPLETS

XR11010 30 psi
COARSE DROPLETS

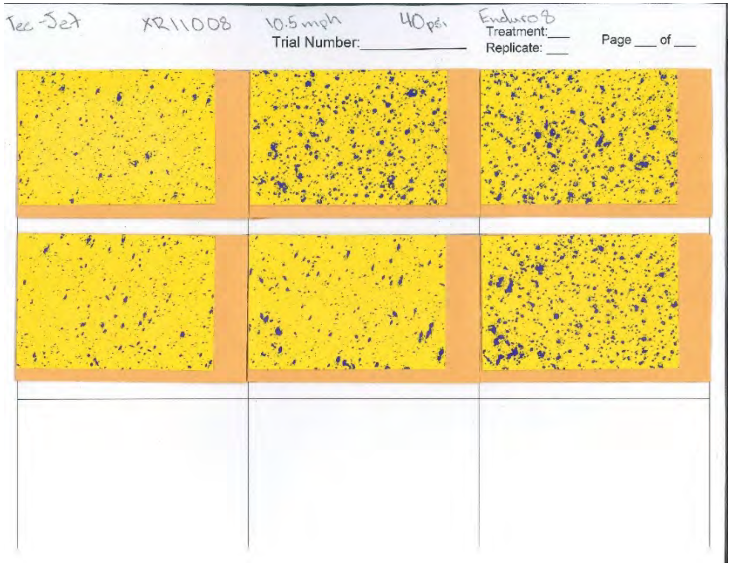
XR TeeJet® (XR)

	PSI						
	15	20	25	30	40	50	60
XR11004	M	M	M	M	M	F	F
XR11005	M	M	M	M	M	F	F
XR11006	C	M	M	M	M	M	F
XR11008	C	C	C	C	M	M	M
XR11010	VC	C	C	C	M	M	M

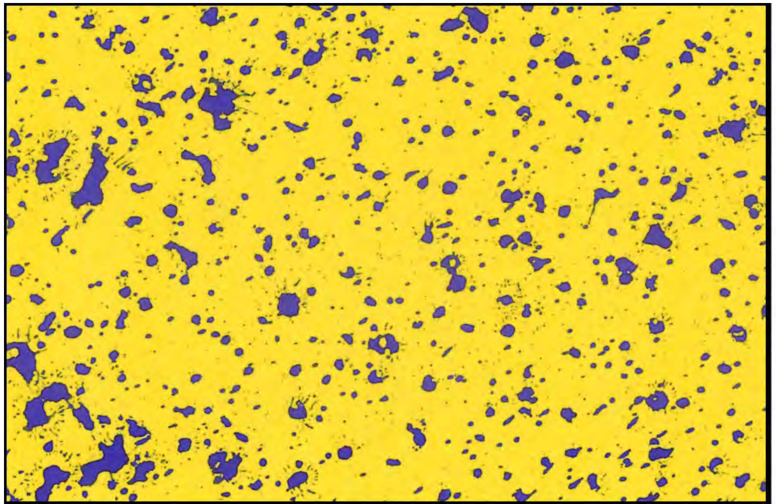
Experimental Methods

Droplet size characterization (water- and oil-sensitive spray cards)

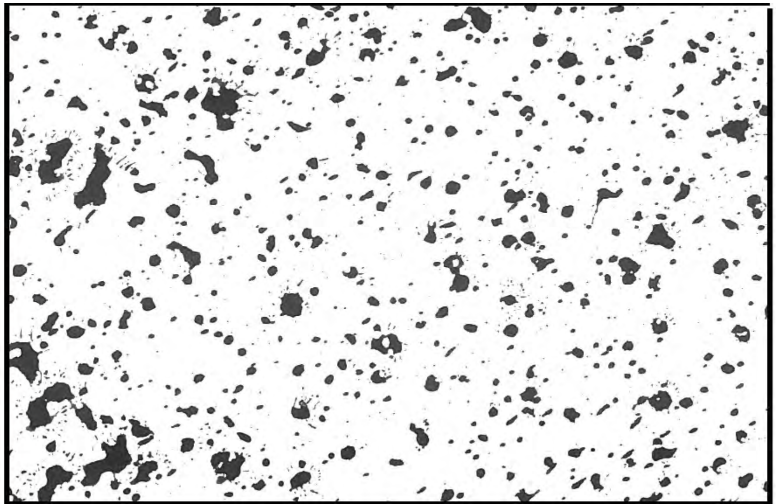
- To reduce problems with coalesced droplets, spray volume reduced to 5 gal/ac for this analysis
- For analysis, yellow background replaced with white and images were converted to grayscale
- <u>A useful tool to evaluate shifts in droplet size spectrum across nozzles</u>, not for accurately characterizing droplet size spectrum due to problems with:
  - coalesced droplets (despite low spray volume)
  - splash-back from large droplets



Original spray card



Yellow replaced with white, image converted to grayscale



Experimental Methods

Droplet size characterization (water- and oil-sensitive spray cards)

	TEEJET NOZZLES				AVERAGE VALUES, TEEJET NOZZLES (2018-2020)	WILGER NOZZLES
	2017	2018	2020	2020		2019, 2020
	Carrington	Carrington	Oakes	Carrington		Carrington, Oakes
	4.0 mph	6.7 mph	6.0 mph	10.5 mph		8.6 mph
	Endura, 5.5 oz/ac	Endura, 5.5 oz/ac	Endura, 5.5 oz/ac	Endura, 8.0 oz/ac		Endura, 5.5 oz/ac
FINE	XR8004, 60 psi	XR8003, 50 psi	XR11004, 60 psi	XR11004, 60 psi		ER110-04, 50 psi
MEDIUM-FINE	XR8004, 40 psi	XR8004, 40 psi	XR11005, 40 psi	XR11005, 40 psi		
MEDIUM	XR8006, 60 psi	XR8006, 40 psi	XR11006, 35 psi	XR11006, 35 psi		SR110-04, 50 psi
MEDIUM-COARSE	not assessed	XR8008, 35 psi	XR11008, 40 psi	XR11008, 40 psi		
COARSE	XR8010, 40 psi	XR8010, 35 psi	XR11010, 30 psi	XR11010, 30 psi		MR110-04, 50 psi
VERY COARSE						DR110-04, 50 psi
	DV 5 (µm) - RAW VALUES					
FINE	387	312	333	351	**332**	**344**
MEDIUM-FINE		447	523	576	**515**	
MEDIUM	445	513	511	546	**523**	**421**
MEDIUM-COARSE		733	679	697	**703**	
COARSE	600	587	819	819	**742**	**543**
VERY COARSE						**641**
	DV 9 (µm) - RAW VALUES					
FINE	652	567	680	607	**618**	**560**
MEDIUM-FINE		797	937	1171	**968**	
MEDIUM	769	971	934	1009	**971**	**715**
MEDIUM-COARSE		1239	1241	1241	**1240**	
COARSE	1065	892	1247	1247	**1128**	**1027**
VERY COARSE						**1074**

Calibration

The initial calibration was conducted with water.

Objectives:

1. **Nozzle selection:** Tips with output deviating from advertised specifications discarded
2. **Initial identification of pulse width** needed to deliver 15 gal/ac spray volume at target driving speed

Spot-On sprayer calibrator model SC-1 (Innoquest, Inc.; Woodstock, IL)

The final calibration was conducted with fungicide in the field immediately before application.

Objectives:

1. **Ensure a precise spray volume of 15 gal/ac.** Manual adjustments to pulse width were made as needed.
2. **Confirm that all nozzles are operating correctly** – consistent output across all nozzles; no plugs.

Applications

Tractor-mounted sprayer equipped with a pulse-width modulation system from Capstan AG.

Spray volume: 15 gal/ac Pulse width manually calibrated to maintain a constant spray volume across tips differing in output.

Driving speed: 4.0 to 10.5 mph, depending on the study.

Optimizing spray droplet size for improved management of white mold in soybeans

Scope of research – soybeans

2019
Carrington – 6 varieties
 * 10-13 replicates/study
 * 8.7 acres
Oakes – 2 varieties
 * 8-9 replicates/study
 * 1.8 acres

2020
Carrington – 4 varieties
 * 12-13 replicates
 * 5.2 acres
Oakes – 2 varieties
 * 15-16 replicates
 * 3.3 acres

PINTO BEANS

canopy open (52-76% average closure) at the 1st fungicide application
canopy at or near closure (91-95% closure) at the 2nd fungicide application

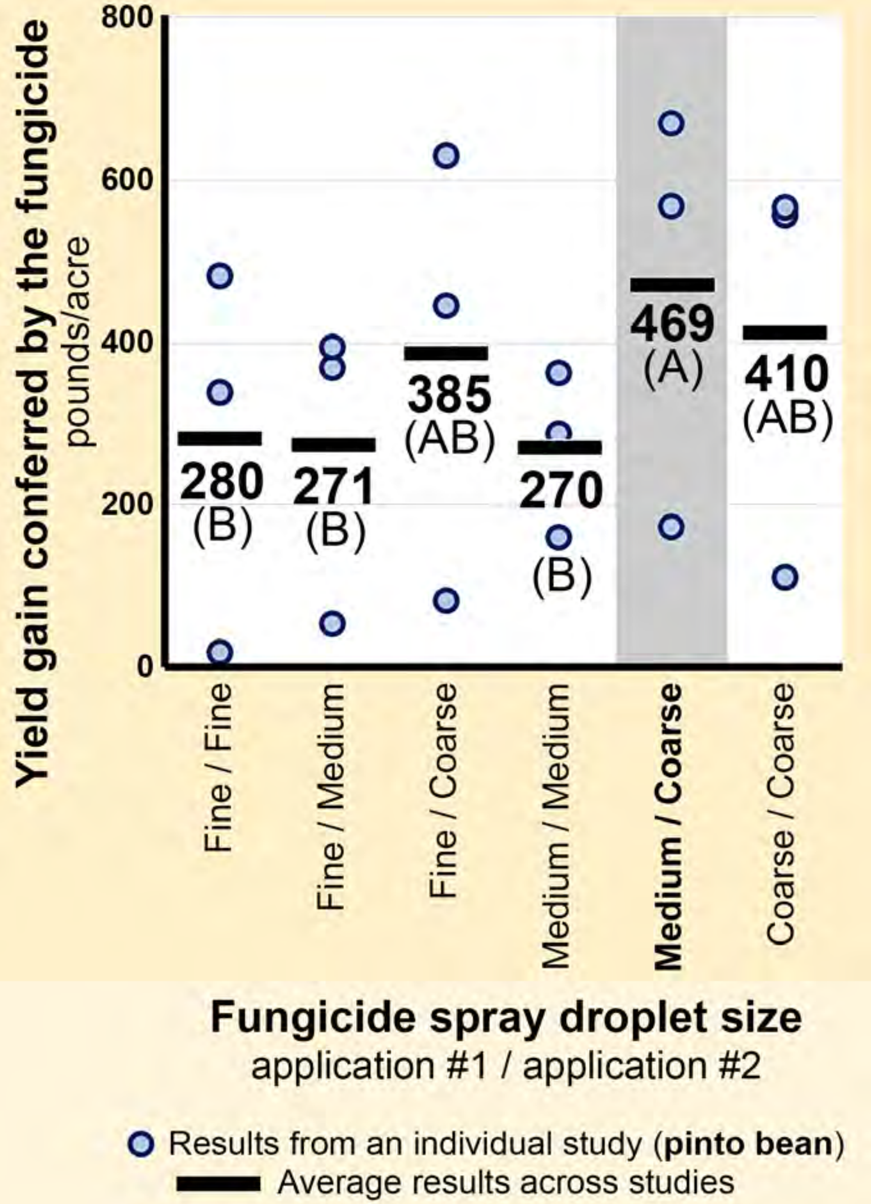
	Carrington 2021	Oakes 2021	Oakes 2021	Combined Analysis
	no cover crop	rye, late term.	rye, early term.	3 studies
variety	'Palomino'	'Palomino'	'Palomino'	
CANOPY CLOSURE when fungicides were applied				
application #1	40-60% (**52%**)	45-85% (**64%**)	45-90% (**76%**)	40-90% (**64%**)
application #2	80-100% (**95%**)	50-100% (**91%**)	75-100% (**92%**)	50-100% (**93%**)

WHITE MOLD (% of canopy)

Fungicide droplet size (1st application / 2nd application)	Carrington 2021	Oakes 2021 (rye, late term.)	Oakes 2021 (rye, early term.)	Combined Analysis
Non-treated	55 a	12 a	27 b	31 b
Fine / Fine	46 a	8 a	12 a	22 a
Fine / Medium	45 a	9 a	14 a	23 a
Fine / Coarse	47 a	10 a	16 a	25 a
Medium / Medium	48 a	10 a	14 a	24 a
Medium / Coarse	43 a	7 a	14 a	21 a
Coarse / Coarse	42 a	7 a	15 a	21 a
	CV: 13.2	CV: 48.4	CV: 34.1	CV: 8.9

YIELD (pounds/acre)

Fungicide droplet size (1st application / 2nd application)	Carrington 2021	Oakes 2021 (rye, late term.)	Oakes 2021 (rye, early term.)	Combined Analysis
Non-treated	2161 a	3363 a	2944 b	2822 b
Fine / Fine	2642 a	3382 a	3282 ab	3102 ab
Fine / Medium	2529 a	3416 a	3337 a	3094 ab
Fine / Coarse	2605 a	3445 a	3573 a	3208 a
Medium / Medium	2522 a	3523 a	3230 ab	3092 ab
Medium / Coarse	2829 a	3536 a	3510 a	3292 a
Coarse / Coarse	2716 a	3473 a	3509 a	3233 a
	CV: 9.8	CV: 7.4	CV: 8.1	CV: 3.7



Fungicide: **Topsin at 40 fl oz/ac followed by Endura at 8 oz/ac** **Application timing:** Early bloom, initial pod development **Spray volume:** 15 gal/ac
Row spacing: 14 inches **Seeding rate:** 90,000 pure live seeds/ac **Driving speed:** 10.5 mph (Carrington); 6.0 mph (Oakes)
Nozzles (Carrington): TeeJet XR11005 nozzles at 60 psi, medium droplets were applied with XR11006 nozzles at 35 psi, and coarse droplets were applied with XR11010 nozzles at 30 psi
Nozzles (Oakes): TeeJet XR11004 nozzles at 60 psi, medium droplets were applied with XR11006 nozzles at 35 psi, and coarse droplets were applied with XR11010 nozzles at 30 psi

IMPACT OF SPRAY DROPLET SIZE: **TEEJET NOZZLES**

PINTO BEANS

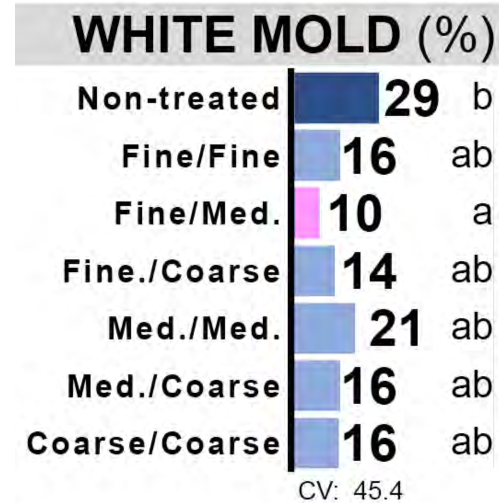
canopy open (68% average closure)
at the 1st fungicide application
canopy open (82% average closure)
at the 2nd fungicide application

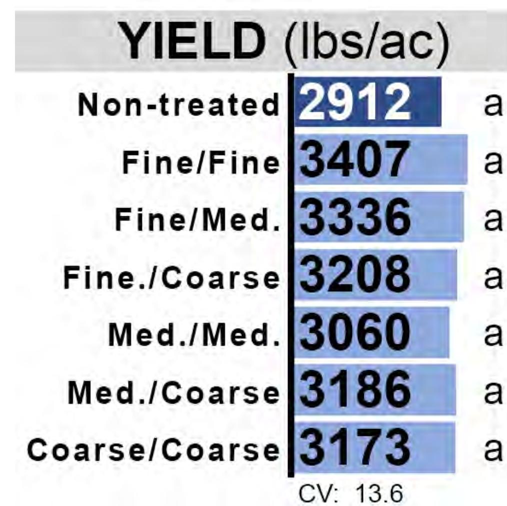
ave. CANOPY < 70%, 1st applic.
ave. CANOPY 80-85%, 2nd applic.

Oakes
2021
no cover crop
variety **'Palomino'**

CANOPY CLOSURE

application #1 45-95% **(68%)**
application #2 40-100% **(82%)**





Fungicide: Topsin at 40 fl oz/ac followed by Endura at 8 oz/ac
Application timing: Early bloom, initial pod development
Spray volume: 15 gal/ac
Row spacing: 14 inches
Seeding rate: 90,000 pure live seeds/ac
Driving speed: 10.5 mph (Carrington); 6.0 mph (Oakes)
Nozzles (Carrington): TeeJet XR11005 nozzles at 60 psi, medium droplets were applied with XR11006 nozzles at 35 psi, and coarse droplets were applied with XR11010 nozzles at 30 psi
Nozzles (Oakes): TeeJet XR11004 nozzles at 60 psi, medium droplets were applied with XR11006 nozzles at 35 psi, and coarse droplets were applied with XR11010 nozzles at 30 psi

Optimizing fungicide droplet size

Impact of fungicide droplet size on white mold:

PINTO BEANS:

- White mold management was optimized when fungicide droplet size was calibrated relative to canopy closure when fungicides were applied
- When canopy closure was open at the first application (<80% average closure) and near closure (91-95% average closure) at the second application, applying fungicides with medium droplets at the first application and coarse droplets at the second application optimized white mold management
- When the canopy was very open at the first application (68% average closure) and open at the second application (82% average closure), applying fungicides with fine droplets at the first application and fine to medium droplets at the second application appeared to optimize fungicide performance.
- This is research in progress, and additional testing is planned for 2022.

KIDNEY BEANS

canopy near closure (87-94% average closure)
at the 1st fungicide application
canopy at or near closure (91-99% closure)
at the 2nd fungicide application

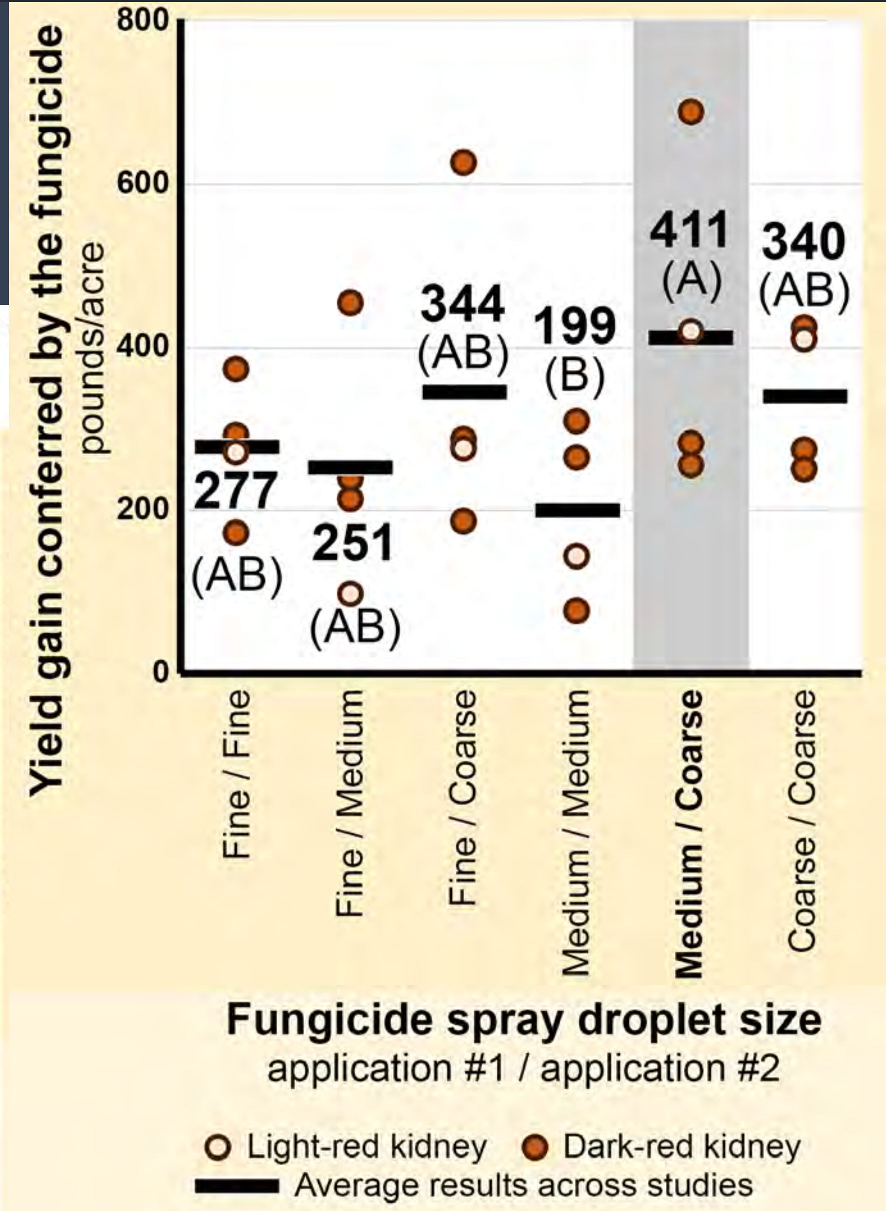
	Oakes 2021 no cover crop	Oakes 2021 rye, late term.	Carrington 2021 no cover crop	Carrington 2021 no cover crop	Combined Analysis 4 studies
variety	'Dynasty'	'Dynasty'	'Dynasty'	'Pink Panther'	
CANOPY CLOSURE when fungicides were applied					
application #1	80-100% (**94%**)	75-100% (**94%**)	60-100% (**87%**)	75-100% (**91%**)	60-100% (**92%**)
application #2	60-100% (**91%**)	95-100% (**99%**)	100% (**100%**)	90-100% (**99%**)	60-100% (**97%**)

WHITE MOLD (% of canopy)

	Oakes 2021 no cover crop	Oakes 2021 rye, late term.	Carrington 2021 no cover crop	Carrington 2021 'Pink Panther'	Combined Analysis
Non-treated	50 a	30 a	56 b	53 a	47 b
Fine/Fine	45 a	30 a	46 a	46 a	42 ab
Fine/Med.	41 a	27 a	51 ab	52 a	43 ab
Fine./Coarse	42 a	28 a	50 ab	49 a	42 ab
Med./Med.	49 a	29 a	49 ab	48 a	44 ab
Med./Coarse	36 a	26 a	50 ab	42 a	39 a
Coarse/Coarse	38 a	25 a	47 a	46 a	39 a
	CV: 26.8	CV: 34.1	CV: 13.7	CV: 23.9	CV: 6.5

YIELD (pounds/acre)

	Oakes 2021 no cover crop	Oakes 2021 rye, late term.	Carrington 2021 no cover crop	Carrington 2021 'Pink Panther'	Combined Analysis
Non-treated	2934 a	3189 a	2431 b	2659 b	2803 b
Fine/Fine	3307 a	3361 a	2723 ab	2931 ab	3080 a
Fine/Med.	3387 a	3429 a	2645 ab	2757 ab	3054 a
Fine./Coarse	3560 a	3470 a	2619 ab	2941 ab	3148 a
Med./Med.	3199 a	3266 a	2740 a	2804 ab	3002 ab
Med./Coarse	3622 a	3470 a	2686 ab	3078 a	3214 a
Coarse/Coarse	3354 a	3439 a	2706 ab	3074 a	3143 a
	CV: 11.7	CV: 6.9	CV: 9.1	CV: 11.4	CV: 3.2



Fungicide: Topsin at 40 fl oz/ac followed by Endura at 8 oz/ac **Application timing:** Early bloom, initial pod development **Spray volume:** 15 gal/ac
Row spacing: 14 inches **Seeding rate:** 90,000 pure live seeds/ac **Driving speed:** 10.5 mph (Carrington); 6.0 mph (Oakes)
Nozzles (Carrington): TeeJet XR11005 nozzles at 60 psi, medium droplets were applied with XR11006 nozzles at 35 psi, and coarse droplets were applied with XR11010 nozzles at 30 psi
Nozzles (Oakes): TeeJet XR11004 nozzles at 60 psi, medium droplets were applied with XR11006 nozzles at 35 psi, and coarse droplets were applied with XR11010 nozzles at 30 psi

IMPACT OF SPRAY DROPLET SIZE: **TEEJET NOZZLES**

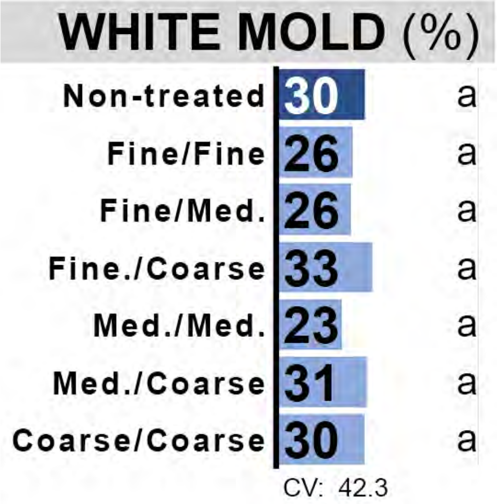
KIDNEY BEANS

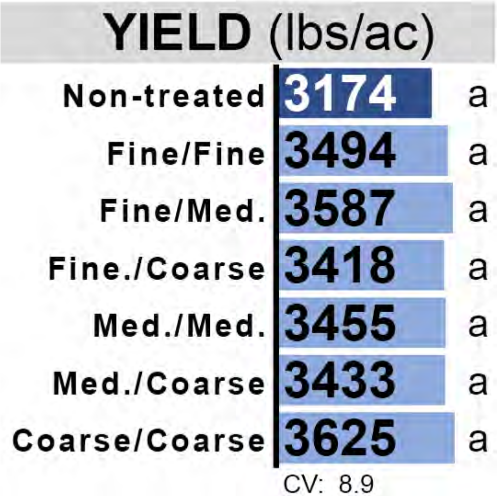
canopy closed (98% average closure)
at both the 1st and 2nd applications

Fungicide: Topsin at 40 fl oz/ac followed by Endura at 8 oz/ac
Application timing: Early bloom, initial pod development **Spray volume:** 15 gal/ac
Row spacing: 14 inches
Seeding rate: 90,000 pure live seeds/ac
Driving speed: 10.5 mph (Carrington); 6.0 mph (Oakes)
Nozzles (Carrington): TeeJet XR11005 nozzles at 60 psi, medium droplets were applied with XR11006 nozzles at 35 psi, and coarse droplets were applied with XR11010 nozzles at 30 psi
Nozzles (Oakes): TeeJet XR11004 nozzles at 60 psi, medium droplets were applied with XR11006 nozzles at 35 psi, and coarse droplets were applied with XR11010 nozzles at 30 psi

ave. CANOPY 98%, 1st applic.
ave. CANOPY 98%, 2nd applic.

Oakes
2021
rye, early term.
variety **'Dynasty'**
CANOPY CLOSURE
application #1 90-100% **(98%)**
application #2 90-100% **(98%)**





Optimizing fungicide droplet size

Impact of fungicide droplet size on white mold:

KIDNEY BEANS:

- White mold management was optimized when fungicide droplet size was calibrated relative to canopy closure when fungicides were applied
- When canopy closure was near closure at the first application 87-94% average closure) and at or near closure (91-99% average closure) at the second application, applying fungicides with medium droplets at the first application and coarse droplets at the second application optimized white mold management
- When the canopy was closed at both applications, applying fungicides with coarse droplets at both applications appeared to optimize fungicide performance.
- This is research in progress, and additional testing is planned for 2022.

IMPACT OF SPRAY DROPLET SIZE: TEEJET NOZZLES

Soybeans

canopy very open when fungicides were applied

Location	Carrington	Oakes	Carrington	Oakes	COMBINED ANALYSIS
YEAR	2020	2019	2020	2019	
soybean variety:	Dairyland 'DSR-0418'	Dairyland 'DSR-1120'	Dairyland 'DSR-0807	Peterson '18X11N'	Four varieties
Canopy Closure Average:	64%	70%	72%	73%	<80%
Canopy Closure Range:	47-80%	60-85%	62-88%	60-85%	

White mold severity index (% of canopy diseased)

	Carrington 2020	Oakes 2019	Carrington 2020	Oakes 2019	COMBINED ANALYSIS
Non-treated	6 a	8 a	14 a	63 b	23 b
Fine DROPLETS	1 a	6 a	10 a	42 a	15 ab
Medium-fine DROPLETS	4 a	6 a	11 a	49 ab	17 ab
Medium DROPLETS	2 a	5 a	9 a	41 a	15 a
Medium-coarse DROPLETS	4 a	6 a	10 a	47 a	17 ab
Coarse DROPLETS	7 a	5 a	10 a	51 ab	18 ab
	CV: 57.9	CV: 62.4	CV: 29.6	CV: 21.8	CV: 19.6

Soybean Yield (bu/ac; 13% moisture)

	Carrington 2020	Oakes 2019	Carrington 2020	Oakes 2019	COMBINED ANALYSIS
Non-treated	58 a	64 a	53 a	37 b	53 a
Fine DROPLETS	57 a	68 a	54 a	50 a	57 a
Medium-fine DROPLETS	58 a	67 a	54 a	50 a	57 a
Medium DROPLETS	58 a	66 a	55 a	48 a	57 a
Medium-coarse DROPLETS	58 a	68 a	55 a	48 a	57 a
Coarse DROPLETS	57 a	67 a	54 a	43 ab	55 a
	CV: 5.2	CV: 19.0	CV: 5.7	CV: 13.4	CV: 4.4

North Dakota Soybean Council
Our World Is Growing.

NDSU NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION

Fungicide: Endura 70WG 5.5 oz/ac except studies in Carrington in 2020, when 8.0 oz/ac was applied **Application timing:** 100% of plants at R2 growth stage **Spray volume:** 15 gal/ac
Row spacing: 21 inches **Seeding rate:** 165,000 pure live seeds/ac **Driving speed:** 10.5 mph (Carrington, 2020); 6.0 mph (Oakes, 2020); 8.9 mph (2019); 6.7 mph (2018); 4.0 mph (2017)
Nozzles (2017): XR8004, 60 psi (fine); XR8004, 40 psi (medium-fine); XR8006, 60 psi (medium); XR8010, 40 psi (coarse)
Nozzles (2018): XR8003, 50 psi (fine); XR8004, 40 psi (medium-fine); XR8006, 40 psi (medium); XR8008, 35 psi (medium-coarse); XR8010, 30 psi (coarse)
Nozzles (Carrington, 2019; Oakes, 2019 and 2020): XR11004, 50 psi (fine); XR11005, 40 psi (med.-fine); XR11006, 35 psi (medium); XR11008, 40 psi (med.-coarse); XR11010, 30 psi (coarse)
Nozzles (Carrington 2020): XR11005, 60 psi (fine); XR11006, 50 psi (medium-fine); XR11006, 35 psi (medium); XR11008, 40 psi (medium-coarse); XR11010, 30 psi (coarse)

IMPACT OF SPRAY DROPLET SIZE: TEEJET NOZZLES

Soybeans

canopy open when fungicides applied

Location	Oakes	Carrington	Carrington	Carrington	Carrington	Oakes	COMBINED ANALYSIS
YEAR	2020	2018	2020	2020	2018	2020	
soybean variety:	Peterson '14R09N'	ProSeed 'XT60-40'	Peterson '18X06N'	Peterson '18X07N'	Peterson '18X06N'	GH '0936X'	**Six varieties**

Canopy Closure

	Oakes 2020	Carrington 2018	Carrington 2020 ('18X06N')	Carrington 2020 ('18X07N')	Carrington 2018 ('18X06N')	Oakes 2020 ('0936X')	COMBINED ANALYSIS
Average:	80.7%	82.5%	84.5%	86.4%	87.5%	88.9%	80.7-88.9%
Range:	65-90%	75-90%	71-93%	75-93%	80-95%	70-97%	

White mold severity index (% of canopy diseased)

	Oakes 2020	Carrington 2018	Carrington 2020 ('18X06N')	Carrington 2020 ('18X07N')	Carrington 2018 ('18X06N')	Oakes 2020 ('0936X')	COMBINED ANALYSIS
Non-treated	2 a	6 b	17 a	26 a	12 a	4 b	11 b
Fine DROPLETS	1 a	4 ab	16 a	19 a	7 a	2 ab	8 ab
Medium-fine DROPLETS	1 a	5 b	14 a	17 a	6 a	1 a	8 a
Medium DROPLETS	1 a	2 a	9 a	11 a	5 a	2 ab	5 a
Medium-coarse DROPLETS	2 a	4 ab	14 a	15 a	7 a	2 a	7 a
Coarse DROPLETS	1 a	4 ab	12 a	14 a	7 a	2 a	7 a
	CV: 60.3	CV: 21.8	CV: 30.2	CV: 27.3	CV: 31.2	CV: 61.1	CV: 24.7

Soybean Yield (bu/ac; 13% moisture)

	Oakes 2020	Carrington 2018	Carrington 2020 ('18X06N')	Carrington 2020 ('18X07N')	Carrington 2018 ('18X06N')	Oakes 2020 ('0936X')	COMBINED ANALYSIS
Non-treated	77 a	64 a	52 a	51 a	64 a	79 a	64 c
Fine DROPLETS	77 a	67 a	52 a	53 a	66 a	81 a	66 bc
Medium-fine DROPLETS	79 a	64 a	53 a	55 a	65 a	82 a	66 b
Medium DROPLETS	80 a	68 a	55 a	56 a	71 a	83 a	69 a
Medium-coarse DROPLETS	78 a	66 a	55 a	53 a	67 a	80 a	66 b
Coarse DROPLETS	78 a	66 a	53 a	53 a	67 a	80 a	66 bc
	CV: 5.6	CV: 4.9	CV: 7.8	CV: 8.7	CV: 8.9	CV: 4.6	CV: 1.5

North Dakota Soybean Council
Our World Is Growing

NDSU NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION

Fungicide: Endura 70WG 5.5 oz/ac except studies in Carrington in 2020, when 8.0 oz/ac was applied **Application timing:** 100% of plants at R2 growth stage **Spray volume:** 15 gal/ac

Row spacing: 21 inches **Seeding rate:** 165,000 pure live seeds/ac **Driving speed:** 10.5 mph (Carrington, 2020); 6.0 mph (Oakes, 2020); 8.9 mph (2019); 6.7 mph (2018); 4.0 mph (2017)

Nozzles (2017): XR8004, 60 psi (fine); XR8004, 40 psi (medium-fine); XR8006, 60 psi (medium); XR8010, 40 psi (coarse)

Nozzles (2018): XR8003, 50 psi (fine); XR8004, 40 psi (medium-fine); XR8006, 40 psi (medium); XR8008, 35 psi (medium-coarse); XR8010, 30 psi (coarse)

Nozzles (Carrington, 2019; Oakes, 2019 and 2020): XR11004, 50 psi (fine); XR11005, 40 psi (med.-fine); XR11006, 35 psi (medium); XR11008, 40 psi (med.-coarse); XR11010, 30 psi (coarse)

Nozzles (Carrington 2020): XR11005, 60 psi (fine); XR11006, 50 psi (medium-fine); XR11006, 35 psi (medium); XR11008, 40 psi (medium-coarse); XR11010, 30 psi (coarse)

IMPACT OF SPRAY DROPLET SIZE: **TEEJET NOZZLES**

Soybeans

canopy near closure when fungicides applied

Location YEAR soybean variety:	Carrington 2017 Dairyland 'DSR-0619'	Carrington 2018 Dairyland 'DSR-0904'	Carrington 2018 Peterson '17X09N'	Carrington 2019 Peterson '17X09N'	Carrington 2019 Dairyland 'DSR-0418'	COMBINED ANALYSIS Four varieties
Canopy Closure Average:	92%	92.5%	92.5%	94.9%	95.9%	92.5-95.8% canopy closure (average, studies with all five droplet size treatments)
Canopy Closure Range:	75-97%	90-95%	90-95%	80-100%	90-100%	

White mold severity index (% of canopy diseased)

	Carrington 2017	Carrington 2018 (DSR-0904)	Carrington 2018 (17X09N)	Carrington 2019 (17X09N)	Carrington 2019 (DSR-0418)	Combined Analysis
Non-treated	12 b	17 b	36 a	92 b	67 b	53 c
Fine DROPLETS	7 ab	16 ab	34 a	87 ab	53 a	48 b
Medium-fine DROPLETS	9 ab	16 ab	34 a	89 ab	58 ab	49 b
Medium DROPLETS	6 a	11 ab	31 a	89 ab	54 a	46 ab
Medium-coarse DROPLETS	NOT TESTED	10 ab	31 a	85 a	53 a	45 ab
Coarse DROPLETS	3 a	9 a	26 a	85 a	50 a	43 a
	CV: 23.1	CV: 39.5	CV: 28.1	CV: 5.2	CV: 16.1	CV: 4.8

Soybean Yield (bu/ac; 13% moisture)

	Carrington 2017	Carrington 2018 (DSR-0904)	Carrington 2018 (17X09N)	Carrington 2019 (17X09N)	Carrington 2019 (DSR-0418)	Combined Analysis
Non-treated	49 a	58 a	51 a	3 b	20 b	33 c
Fine DROPLETS	52 a	58 a	54 a	6 a	30 a	37 abc
Medium-fine DROPLETS	52 a	57 a	53 a	6 ab	28 ab	36 bc
Medium DROPLETS	52 a	60 a	54 a	5 ab	31 a	37 abc
Medium-coarse DROPLETS	NOT TESTED	61 a	58 a	8 a	30 a	39 ab
Coarse DROPLETS	53 a	61 a	59 a	9 a	35 a	41 a
	CV: 5.2	CV: 8.1	CV: 10.9	CV: 27.2	CV: 25.8	CV: 5.3

North Dakota Soybean Council *Our World Is Growing.*

NDSU NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION

Fungicide: Endura 70WG 5.5 oz/ac except studies in Carrington in 2020, when 8.0 oz/ac was applied **Application timing:** 100% of plants at R2 growth stage **Spray volume:** 15 gal/ac

Row spacing: 21 inches **Seeding rate:** 165,000 pure live seeds/ac **Driving speed:** 10.5 mph (Carrington, 2020); 6.0 mph (Oakes, 2020); 8.9 mph (2019); 6.7 mph (2018); 4.0 mph (2017)

Nozzles (2017): XR8004, 60 psi (fine); XR8004, 40 psi (medium-fine); XR8006, 60 psi (medium); XR8010, 40 psi (coarse)

Nozzles (2018): XR8003, 50 psi (fine); XR8004, 40 psi (medium-fine); XR8006, 40 psi (medium); XR8008, 35 psi (medium-coarse); XR8010, 30 psi (coarse)

Nozzles (Carrington, 2019; Oakes, 2019 and 2020): XR11004, 50 psi (fine); XR11005, 40 psi (med.-fine); XR11006, 35 psi (medium); XR11008, 40 psi (med.-coarse); XR11010, 30 psi (coarse)

Nozzles (Carrington 2020): XR11005, 60 psi (fine); XR11006, 50 psi (medium-fine); XR11006, 35 psi (medium); XR11008, 40 psi (medium-coarse); XR11010, 30 psi (coarse)

IMPACT OF SPRAY DROPLET SIZE: **TEEJET NOZZLES**

Soybeans

canopy closed when fungicides applied

Location	Oakes	Carrington	Carrington	Carrington	Carrington	COMBINED ANALYSIS
YEAR	2018	2019	2019	2019	2019	
soybean variety:	Pioneer 'P11A95X'	Peterson '14R09N'	Peterson '18X07N'	Dairyland 'DSR-0807'	Peterson '18X06N'	Five varieties
Canopy Closure Average:	98.5%	98.7%	98.9%	99.6%	99.6%	98.5-99.6% canopy closure (average)
Range:	97-100%	98-100%	97-100%	98-100%	99-100%	

White mold severity index (% of canopy diseased)

	Oakes 2018	Carrington 2019 ('14R09N')	Carrington 2019 ('18X07N')	Carrington 2019 ('DSR-0807')	Carrington 2019 ('18X06N')	Combined analysis
Non-treated	39 b	84 b	79 b	73 b	72 b	69 c
Fine DROPLETS	32 ab	75 a	68 a	63 ab	61 a	60 ab
Medium-fine DROPLETS	28 ab	81 ab	72 ab	68 ab	65 ab	63 b
Medium DROPLETS	30 ab	79 ab	72 ab	67 ab	63 a	62 b
Medium-coarse DROPLETS	29 ab	77 ab	73 ab	60 a	60 a	60 ab
Coarse DROPLETS	25 a	74 a	66 a	61 a	58 a	57 a
	CV: 21.6	CV: 8.8	CV: 10.0	CV: 13.5	CV: 12.2	CV: 3.2

Soybean Yield (bu/ac; 13% moisture)

	Oakes 2018	Carrington 2019 ('14R09N')	Carrington 2019 ('18X07N')	Carrington 2019 ('DSR-0807')	Carrington 2019 ('18X06N')	Combined analysis
Non-treated	53 b	9 b	14 b	18 b	15 b	22 c
Fine DROPLETS	59 ab	17 a	20 ab	27 ab	23 a	29 b
Medium-fine DROPLETS	63 ab	13 ab	18 ab	24 ab	20 ab	27 b
Medium DROPLETS	62 ab	15 a	19 ab	25 ab	20 a	28 b
Medium-coarse DROPLETS	61 ab	15 a	18 ab	27 a	24 a	29 b
Coarse DROPLETS	66 a	18 a	22 a	30 a	24 a	32 a
	CV: 10.5	CV: 16.02	CV: 28.8	CV: 29.3	CV: 25.1	CV: 5.0

North Dakota Soybean Council *Our World Is Growing.*

NDSU NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION

Fungicide: Endura 70WG 5.5 oz/ac except studies in Carrington in 2020, when 8.0 oz/ac was applied **Application timing:** 100% of plants at R2 growth stage **Spray volume:** 15 gal/ac

Row spacing: 21 inches **Seeding rate:** 165,000 pure live seeds/ac **Driving speed:** 10.5 mph (Carrington, 2020); 6.0 mph (Oakes, 2020); 8.9 mph (2019); 6.7 mph (2018); 4.0 mph (2017)

Nozzles (2017): XR8004, 60 psi (fine); XR8004, 40 psi (medium-fine); XR8006, 60 psi (medium); XR8010, 40 psi (coarse)

Nozzles (2018): XR8003, 50 psi (fine); XR8004, 40 psi (medium-fine); XR8006, 40 psi (medium); XR8008, 35 psi (medium-coarse); XR8010, 30 psi (coarse)

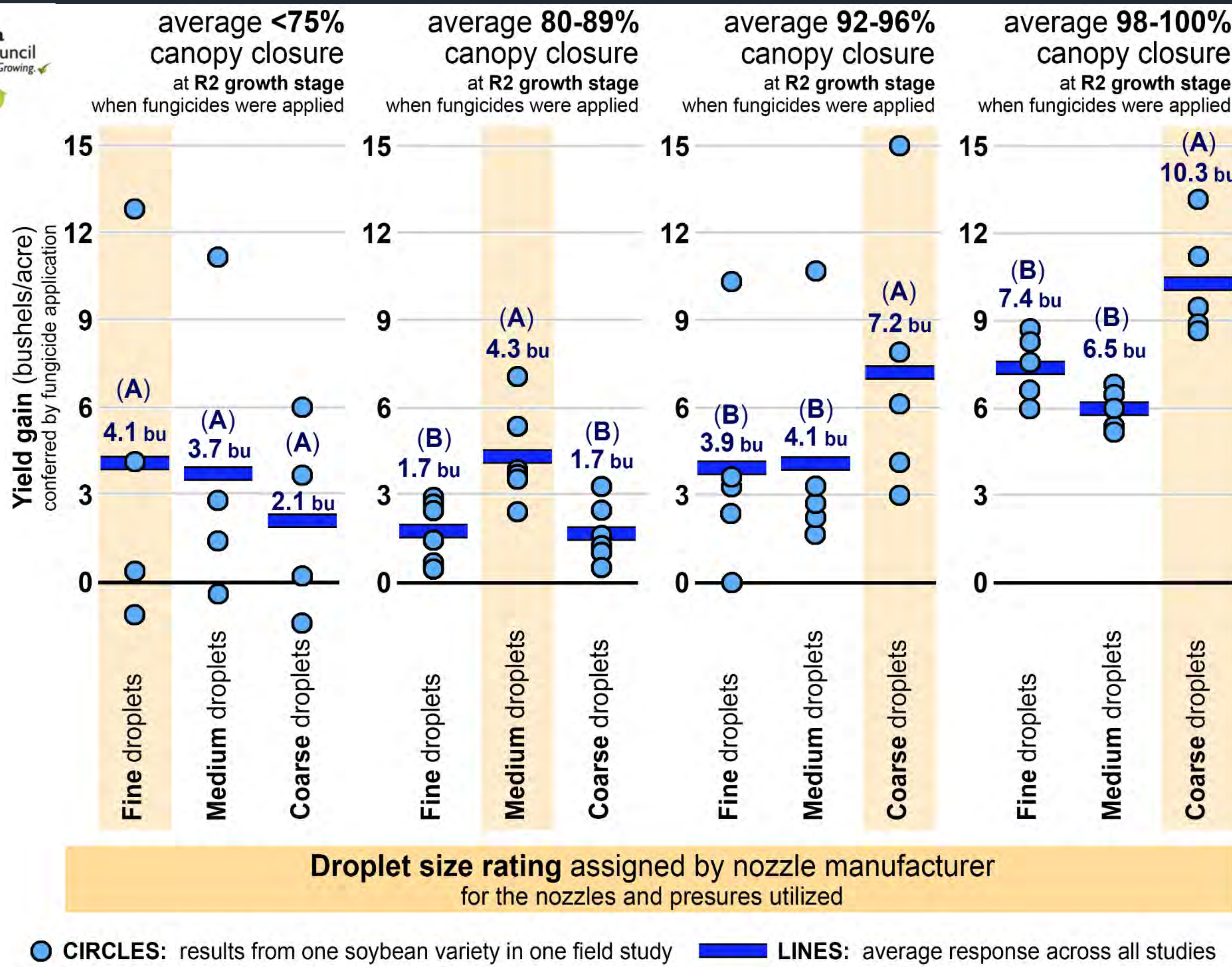
Nozzles (Carrington, 2019; Oakes, 2019 and 2020): XR11004, 50 psi (fine); XR11005, 40 psi (med.-fine); XR11006, 35 psi (medium); XR11008, 40 psi (med.-coarse); XR11010, 30 psi (coarse)

Nozzles (Carrington 2020): XR11005, 60 psi (fine); XR11006, 50 psi (medium-fine); XR11006, 35 psi (medium); XR11008, 40 psi (medium-coarse); XR11010, 30 psi (coarse)

IMPACT OF SPRAY DROPLET SIZE: **TEEJET NOZZLES**

Soybeans

Yield gain conferred by the fungicide relative to canopy closure and spray droplet size



Optimizing fungicide spray droplet size

Soybeans

Soybeans – TeeJet nozzles:

Applying fungicides with **coarse droplets** optimized white mold management in soybeans when the soybean canopy was at or near closure (92-100% average canopy closure).

Applying fungicides with **medium droplets** optimized white mold management in soybeans when the soybean canopy was open (80-90% average canopy closure).

North Dakota Soybean Council
Our World Is Growing.

NDSU NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION

IMPACT OF SPRAY DROPLET SIZE: **WILGER NOZZLES**

Soybeans: **canopy open** when fungicides applied

North Dakota Soybean Council
Our World Is Growing.

Soybean Row spacing: 21 inches

Seeding rate: 165,000 viable seeds/ac

Location / YEAR / soybean variety:	Carrington 2020 Dairyland 'DSR-0418'	Carrington 2020 Dairyland 'DSR-0807'	Oakes 2019 Dairyland 'DSR-1120'	Oakes 2019 Peterson '18X11N'	Carrington 2020 Peterson '18X07N'	COMBINED ANALYSIS
Canopy Closure — Average:	63%	69%	70%	73%	79%	63-79%
Canopy Closure — Range:	42-72%	54-92%	60-85%	60-85%	60-91%	Average across five varieties

White mold severity index (% of canopy diseased)

	Carrington 2020 'DSR-0418'	Carrington 2020 'DSR-0807'	Oakes 2019 'DSR-1120'	Oakes 2019 '18X11N'	Carrington 2020 '18X07N'	COMBINED ANALYSIS
Non-treated control	13 a	26 b	16 a	69 b	38 a	32 b
Fine droplets ER110-04, 50 psi	10 a	20 ab	9 a	51 a	30 a	24 a
Medium droplets SR110-04, 50 psi	10 a	17 a	10 a	50 a	28 a	23 a
Coarse droplets MR110-04, 50 psi	8 a	16 a	7 a	42 a	26 a	20 a
Very Coarse droplets DR110-04, 50 psi	8 a	21 ab	6 a	49 a	29 a	23 a
	CV: 11.9	CV: 14.8	CV: 60.4	CV: 17.3	CV: 28.0	CV: 13.7

Soybean Yield (bu/ac; 13% moisture)

	Carrington 2020 'DSR-0418'	Carrington 2020 'DSR-0807'	Oakes 2019 'DSR-1120'	Oakes 2019 '18X11N'	Carrington 2020 '18X07N'	COMBINED ANALYSIS
Non-treated control	47 a	38 a	67 a	37 b	32 b	44 b
Fine droplets ER110-04, 50 psi	49 a	41 a	68 a	46 ab	36 a	48 ab
Medium droplets SR110-04, 50 psi	49 a	42 a	67 a	48 a	37 a	49 a
Coarse droplets MR110-04, 50 psi	50 a	41 a	71 a	50 a	38 a	50 a
Very Coarse droplets DR110-04, 50 psi	50 a	39 a	66 a	48 a	39 a	48 a
	CV: 7.0	CV: 9.4	CV: 6.1	CV: 17.1	CV: 9.0	CV: 4.6

Fungicide: Endura 70WG 5.5 oz/ac **Application timing:** 100% of plants at R2 growth stage **Spray volume:** 15 gal/ac **Driving speed:** 6.0 mph (2020); 8.9 mph (2019)

IMPACT OF SPRAY DROPLET SIZE: **WILGER NOZZLES**

Soybeans: **canopy open** when fungicides applied

Location	**Carrington**	**Carrington**	**Carrington**	**Carrington**	**Carrington**	**Carrington**	COMBINED ANALYSIS
YEAR	2019	2019	2019	2019	2019	2019	
soybean variety:	Peterson '17X09N'	Dairyland 'DSR-0418'	Peterson '14R09N'	Peterson '18X07N'	Dairyland 'DSR-0807'	Peterson '18X06N'	
Canopy Closure – Average:	**94.9%**	**95.9%**	**98.7%**	**98.9%**	**99.6%**	**99.6%**	**94.9-99.6%**
Canopy Closure – Range:	**80-100%**	**90-100%**	**98-100%**	**97-100%**	**98-100%**	**99-100%**	Average across six varieties

White mold severity index (% of canopy diseased)

Treatment	Peterson '17X09N'	Dairyland 'DSR-0418'	Peterson '14R09N'	Peterson '18X07N'	Dairyland 'DSR-0807'	Peterson '18X06N'	Combined
Non-treated control	90 a	68 a	83 a	76 a	71 b	72 b	76 b
Fine droplets ER110-04, 50 psi	86 a	59 a	79 a	71 a	62 a	60 a	70 a
Medium droplets SR110-04, 50 psi	87 a	55 a	77 a	71 a	66 a	61 a	70 a
Coarse droplets MR110-04, 50 psi	84 a	54 a	75 a	70 a	62 a	60 a	68 a
Very Coarse droplets DR110-04, 50 psi	85 a	52 a	77 a	71 a	57 a	58 a	67 a
	CV: 6.8	CV: 12.4	CV: 7.7	CV: 9.9	CV: 14.8	CV: 11.7	CV: 3.2

Soybean Yield (bu/ac; 13% moisture)

Treatment	Peterson '17X09N'	Dairyland 'DSR-0418'	Peterson '14R09N'	Peterson '18X07N'	Dairyland 'DSR-0807'	Peterson '18X06N'	Combined
Non-treated control	3 b	15 b	8 a	12 a	16 b	13 b	11 c
Fine droplets ER110-04, 50 psi	6 ab	23 a	11 a	14 a	22 ab	20 ab	16 ab
Medium droplets SR110-04, 50 psi	5 ab	24 a	12 a	13 a	19 ab	18 ab	15 b
Coarse droplets MR110-04, 50 psi	6 ab	24 a	12 a	16 a	23 ab	20 ab	17 ab
Very Coarse droplets DR110-04, 50 psi	9 a	26 a	12 a	15 a	26 a	20 a	18 a
	CV: 43.0	CV: 22.6	CV: 16.6	CV: 35.9	CV: 28.7	CV: 33.6	CV: 9.1

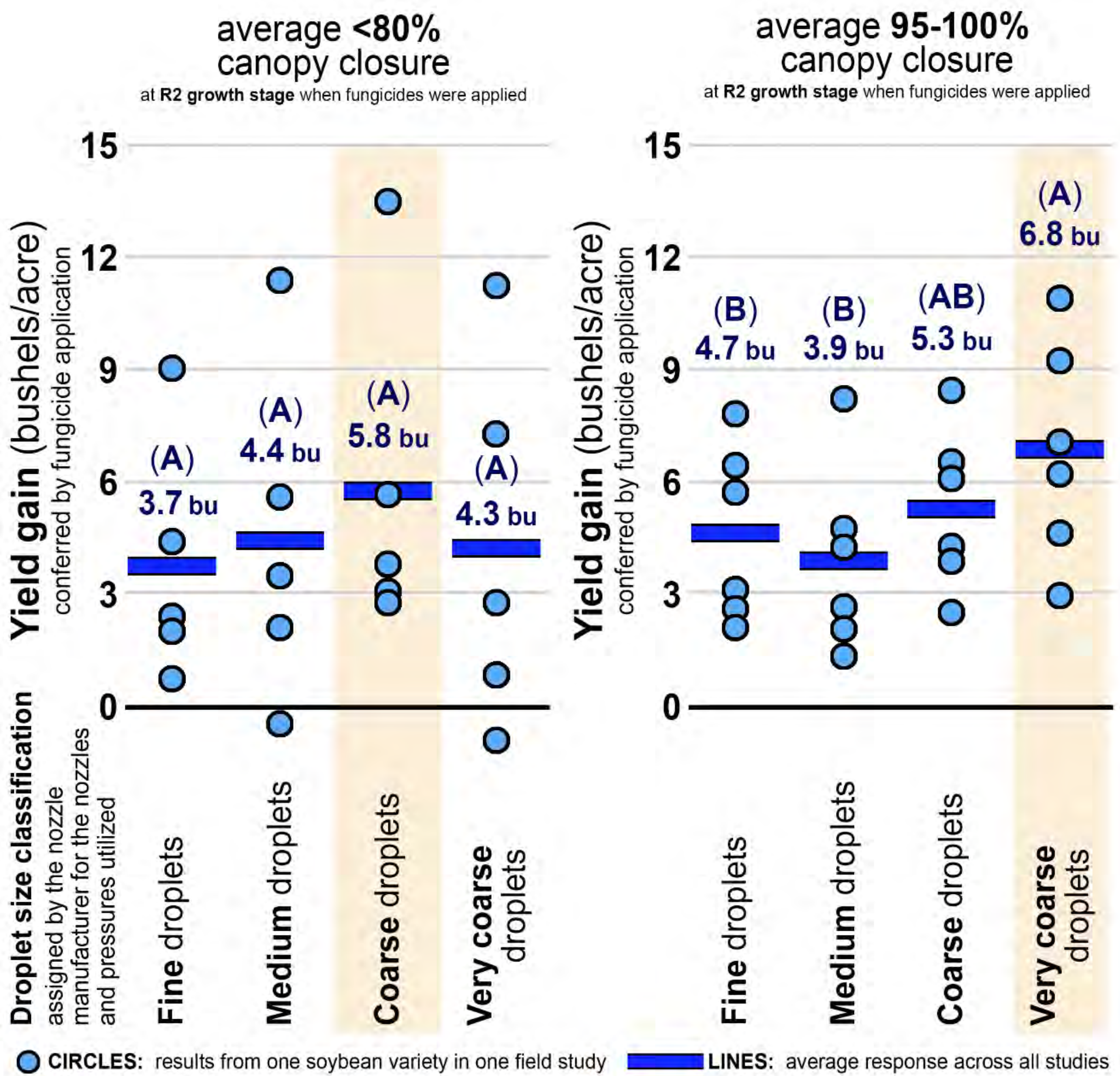
Agronomics - Row spacing: 21 inches **Seeding rate:** 165,000 viable seeds/ac

Fungicide: Endura 70WG 5.5 oz/ac **Application timing:** 100% of plants at R2 growth stage **Spray volume:** 15 gal/ac **Driving speed:** 6.0 mph (2020); 8.9 mph (2019)

IMPACT OF SPRAY DROPLET SIZE: WILGER NOZZLES

Soybeans

Yield gain conferred by the fungicide relative to canopy closure and spray droplet size



North Dakota Soybean Council
Our World Is Growing.

NDSU NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION

Optimizing fungicide spray droplet size

Soybeans

Soybeans – Wilger nozzles:

Applying fungicides with **very coarse droplets** optimized white mold management in soybeans when the soybean canopy was at or near closure (95-100% average canopy closure).

Applying fungicides with **coarse droplets** appeared to optimize white mold management in soybeans when the soybean canopy was open (<80% average canopy closure), but statistical separation was not achieved.

Different optimum droplet sizes were observed for TeeJet versus Wilger nozzles.

The droplet size spectrum considered to be "medium", "coarse", "very coarse", etc. may be different for Wilger vs. TeeJet.

Quantification of droplet size spectrums will be conducted in 2021.




Improving management of white mold in soybeans:
5. Optimizing fungicide application frequency & interval

Michael Wunsch, Thomas Miorini, Suanne Kallis, and Jesse Hafner
NDSU Carrington Research Extension Center
Heidi Eslinger, Kelly Cooper, Seth Nelson NDSU Robert Titus Research Farm, Oakes

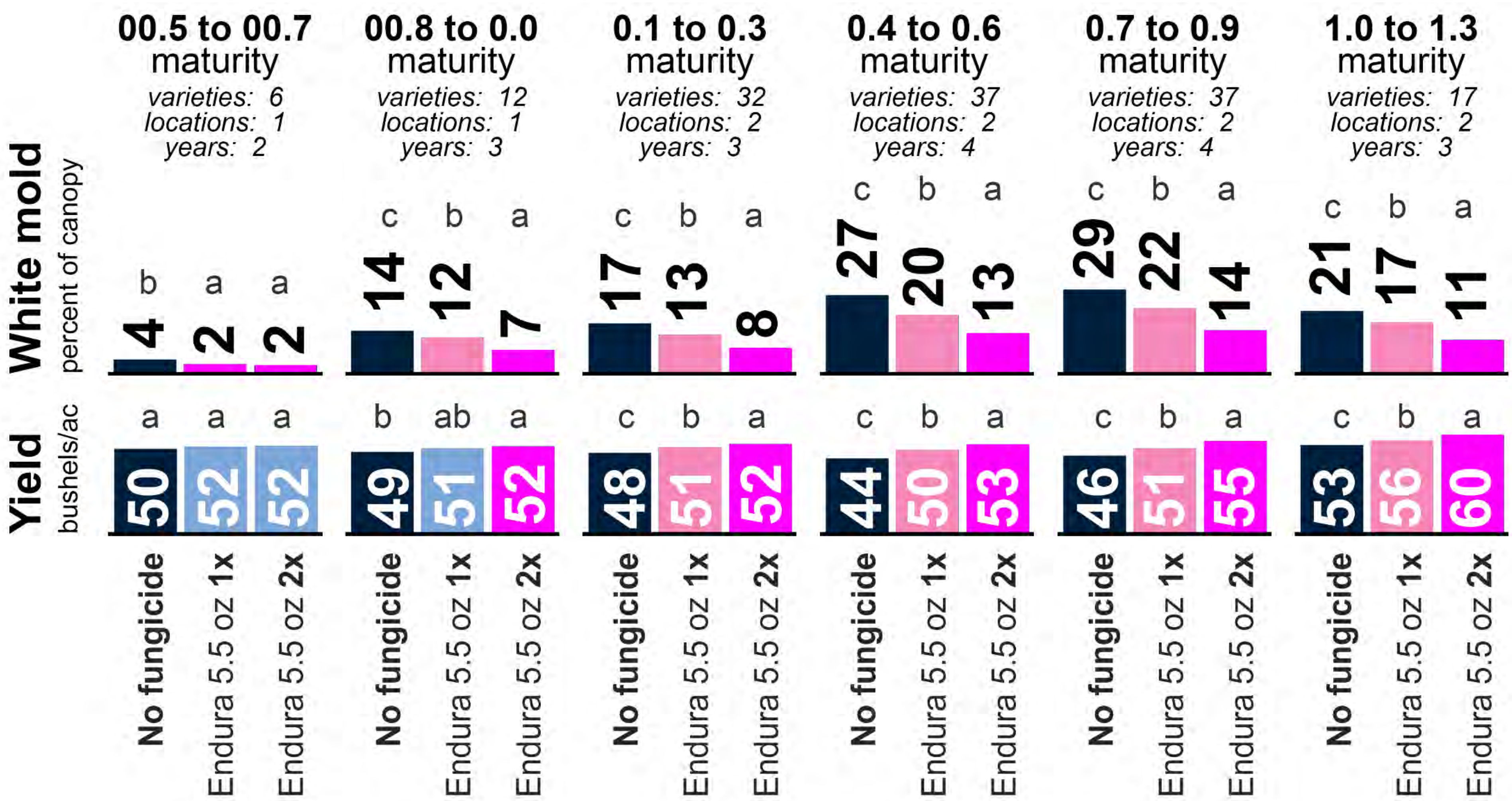
RESEARCH FUNDED BY THE **NORTH DAKOTA SOYBEAN COUNCIL**

What is the profitability of a single versus two sequential fungicide applications targeting white mold relative to soybean maturity?

COMBINED ANALYSIS OF EIGHT STUDIES: Carrington and Oakes, ND (2018-2021)

Fungicide: Endura (5.5 oz/ac) **Application A:** early R2 growth stage **Application B:** 10-14 days later **Soybean row spacing:** 14 or 21 inches

Each study was established as a split-plot or a split-split-plot with 6 or 8 replicates.
main factor = soybean maturity range (6 varieties within each range of maturity), sub-factor = soybean variety, sub-sub-factor = no fungicide, fungicide 1x, fungicide 2x
OR main factor = soybean variety, sub-factor = no fungicide, fungicide 1x, fungicide 2x



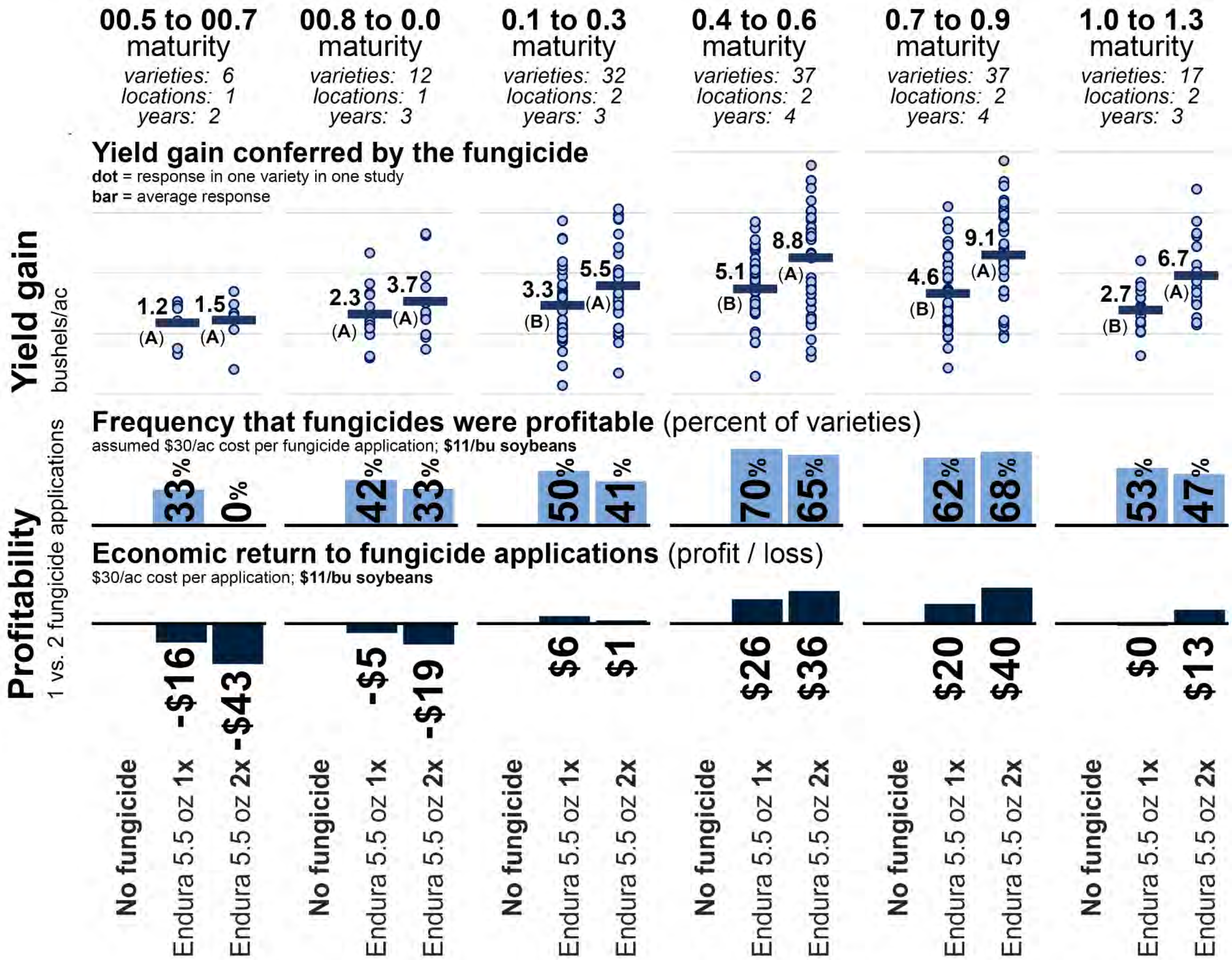
What is the profitability of a single versus two sequential fungicide applications targeting white mold relative to soybean maturity?

COMBINED ANALYSIS OF EIGHT STUDIES: Carrington and Oakes, ND (2018-2021)

Fungicide:
Endura (5.5 oz/ac)

Application A:
early R2 growth stage
Application B:
10-14 days later

Soybean row spacing:
14 or 21 inches



When making two sequential fungicide applications targeting white mold, what is the optimal interval between applications and does the optimal interval change with soybean maturity length?

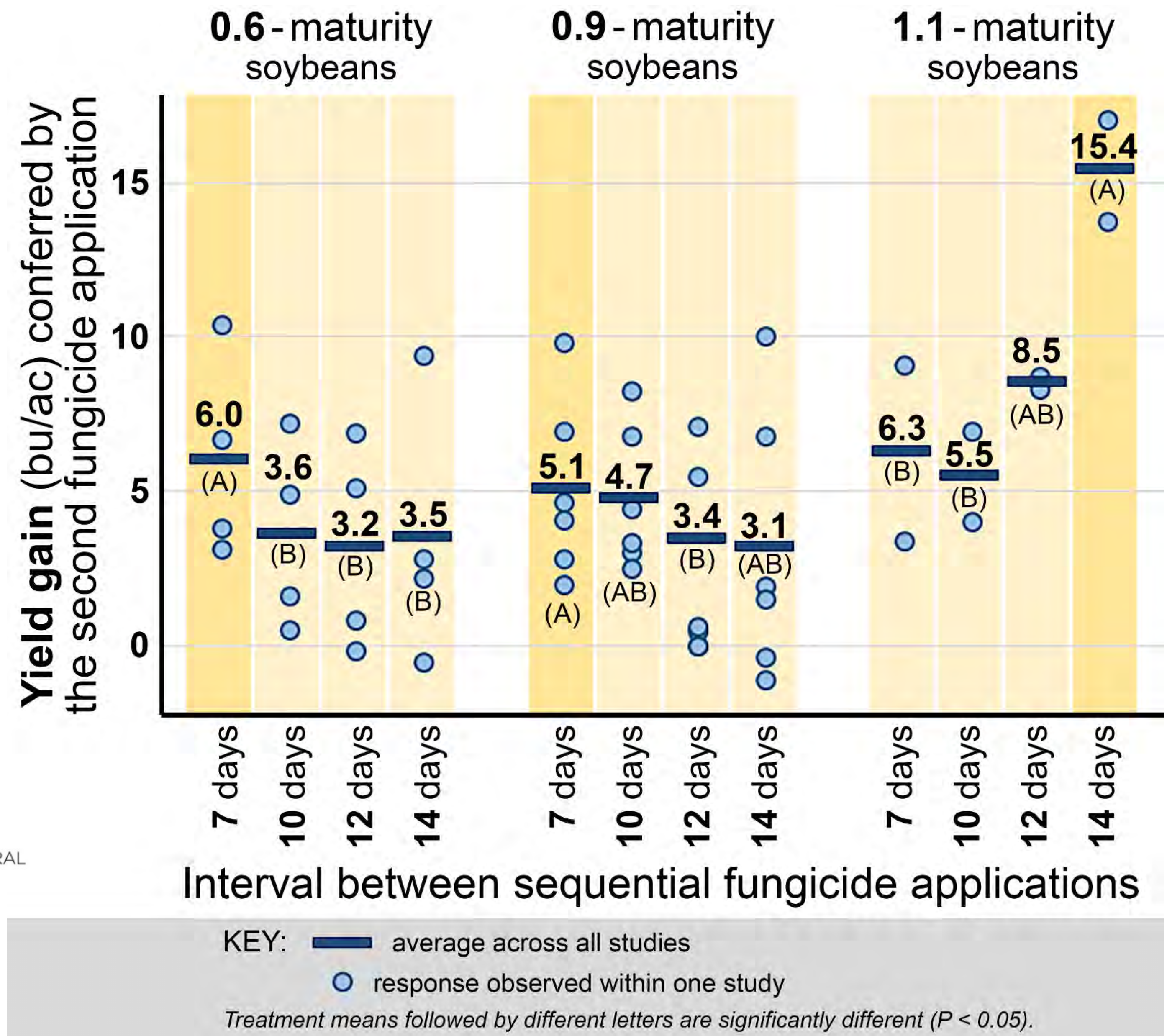
COMBINED ANALYSIS OF THREE STUDIES: Carrington (2020), Carrington (2021), Oakes (2021)

Fungicide:
- Endura followed by Endura (5.5 oz),
- Topsin followed by Topsin (20 fl oz)
- Topsin (40 fl oz) f.b. Endura (5.5 oz)

Application A: R2 growth stage
Application B: 7-14 days later

Soybean row spacing: 14 or 21 in.

Study design: randomized complete block with a split-plot arrangement and 8 replicates.
- Main factor = soybean variety (differing in maturity)
- Sub-factor = fungicide treatments



NDSU NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION

North Dakota Soybean Council
Our World Is Growing.

Applied at 40 fl oz/ac, does the off-patent fungicide **thiophanate-methyl** (Topsin. generics) confer satisfactory management of white mold applied as a single application or the first of two applications?

	White mold % of canopy		**Yield** bu/ac	
Non-treated control	38	d	56	c
Endura 5.5 oz/ac **(R2 growth stage)**	27	bc	62	ab
Endura 5.5 oz/ac **(R2 + 7 days)**	15	a	67	a
Endura 5.5 oz/ac **(R2 + 10 days)**	19	ab	65	a
Endura 5.5 oz/ac **(R2 + 12 days)**	15	a	64	a
Endura 5.5 oz/ac **(R2 + 14 days)**	18	ab	66	a
Topsin 40 fl oz/ac **(R2 growth stage)**	34	cd	57	bc
Topsin 40 fl oz f.b. **Endura** 5.5 oz **(R2 + 7 days)**	20	ab	64	a
Topsin 40 fl oz f.b. **Endura** 5.5 oz **(R2 + 10 days)**	21	ab	63	a
Topsin 40 fl oz f.b. **Endura** 5.5 oz **(R2 + 12 days)**	21	ab	63	a
Topsin 40 fl oz f.b. **Endura** 5.5 oz **(R2 + 14 days)**	22	ab	65	a
	CV: 19.1		CV: 4.2	

North Dakota Soybean Council
Our World Is Growing.

COMBINED ANALYSIS OF FIVE STUDIES: testing conducted on three different soybean varieties in Oakes in 2021 and two different soybean varieties in Carrington in 2021

Application A: R2 growth stage **Application B:** 7-14 days later **Soybean row spacing:** 14 or 21 in.

Thank You!

Michael Wunsch, Jesse Hafner, Thomas Miorini, Kaitlyn Thompson, Suanne Kallis, Billy Kraft, Michael Schaefer NDSU Carrington REC
Heidi Eslinger, Leonard Besemann, Kelly Cooper, Seth Nelson, Walt Albus NDSU Robert Titus Research Farm, Oakes
Venkata Chapara, Amanda Arens, Scott Halley NDSU Langdon Research Extension Center
Tyler Tjelde NDSU Williston Research Extension Center – Irrigated Research Site, Hofflund

RESEARCH FUNDED BY THE **NORTH DAKOTA SOYBEAN COUNCIL**

North Dakota Soybean Council
Our World Is Growing.

NDSU NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION