Optimizing the deployment of fungicides for improved management of white mold soybeans and dry beans

Michael Wunsch

North Dakota State University - Carrington Research Extension Center

Fungicide application timing – fundamental concepts

Fungicide applications must be made prior to pathogen infection.

- You cannot eradicate existing disease.
- Some, but not all, modern fungicide exhibit some degree of curative activity, but this curative activity is limited to the first few hours after pathogen infection – when pathogen infection can be seen only with a microscope and before disease lesions are present.

Michael Wunsch
North Dakota State University Carrington Research Extension Center

Fungicide application timing – example from a pathogen that infects via all plant tissues

Powdery mildew of field peas: Applying fungicides preventatively or when disease is at trace levels is critical.

Carrington, ND (2022)

FUNGICIDE APPLICATION TIMING			POWDERY MILDEW SEVERITY				
			Percent of canopy diseased; peas at late pod-fill				
Days after first disease symptoms	Disease severity in non-treated peas		'Navarro' yellow pea		'Empire' green pea		Combined
	'Navarro'	'Empire'	Proline	Azoxystar	Proline	Azoxystar	analysis
Non-treated control			**21** b*	**37** a*	**21** b*	**14** a*	**23** b*
1st disease symptoms	1%	1%	**2** a	**18** a	**1** a	**7** a	**7** a
4 or 7 days later	10-25%	5-15%	**10** ab	**37** a	**6** ab	**19** a	**18** b
5 or 8 days later	10-30%	5-15%	**20** b	**33** a	**9** ab	**14** a	**19** b
6 or 9 days later	15-35%	10-15%	**32** b	**36** a	**13** b	**21** a	**25** b
7 or 10 days later	15-35%	10-20%	**20** b	**38** a	**7** ab	**18** a	**21** b
8 or 11 days later	15-35%	10-20%	**18** b	**38** a	**11** ab	**16** a	**21** b
10 or 13 days later	20-40%	10-25%	**23** b	**32** a	**12** b	**14** a	**20** b
		CV:	28.2	17.0	35.8	18.3	22.5

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

Fungicide application timing – example from a pathogen that infects via all plant tissues

Powdery mildew of field peas: Applying fungicides preventatively or when disease is at trace levels is critical.

Carrington, ND (2022)

FUNGICIDE APPLICATION TIMING			YIELD				
Days after first disease symptoms	Disease severity in non-treated peas		13.5% moisture				
			'Navarro' yellow pea		'Empire' green pea		Combined
	'Navarro'	'Empire'	Proline	Azoxystar	Proline	Azoxystar	analysis
Non-treated control			**55** a*	**54** a*	**55** a*	**54** a*	**55** a*
1st disease symptoms	1%	1%	**57** a	**56** a	**58** a	**55** a	**57** a
4 or 7 days later	10-25%	5-15%	**53** a	**55** a	**56** a	**54** a	**55** a
5 or 8 days later	10-30%	5-15%	**51** a	**56** a	**55** a	**56** a	**55** a
6 or 9 days later	15-35%	10-15%	**56** a	**56** a	**57** a	**53** a	**56** a
7 or 10 days later	15-35%	10-20%	**54** a	**53** a	**57** a	**53** a	**54** a
8 or 11 days later	15-35%	10-20%	**53** a	**54** a	**53** a	**53** a	**53** a
10 or 13 days later	20-40%	10-25%	**55** a	**52** a	**56** a	**51** a	**54** a
		CV:	6.2	6.2	7.1	5.7	2.6

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

Improving crop disease management:

Fungicide application timing – fundamental concepts

When a crop exhibits heightened susceptibility to a disease for 2 weeks or more, a single application is often insufficient.

- New growth that occurs after the fungicide is applied is not protected.
- Within treated tissue, the fungicide breaks down with time.

Michael Wunsch
North Dakota State University Carrington Research Extension Center

Fungicide application timing – example from a pathogen that infects via all plant tissues

Fungicides do not translocate into new growth

- The field peas in the picture were treated with a fungicide at early bloom.
- No follow-up fungicide application was made 7-14 days later.
- At late pod-fill, the upper part of the plant (not present when fungicides were applied approx. 4 weeks earlier) was diseased with powdery mildew

Photo courtesy of Suanne Kallis, NDSU Carrington




Assessing risk of Sclerotinia on basis of environmental conditions

Michael Wunsch

North Dakota State University - Carrington Research Extension Center

Assessing risk of Sclerotinia

1. Soil temperature and moisture favoring apothecia production.

Sclerotia deposited in soil

Ascospores released into soybean canopy

2. Temperature, relative humidity, and rainfall patterns favoring infection and secondary spread.

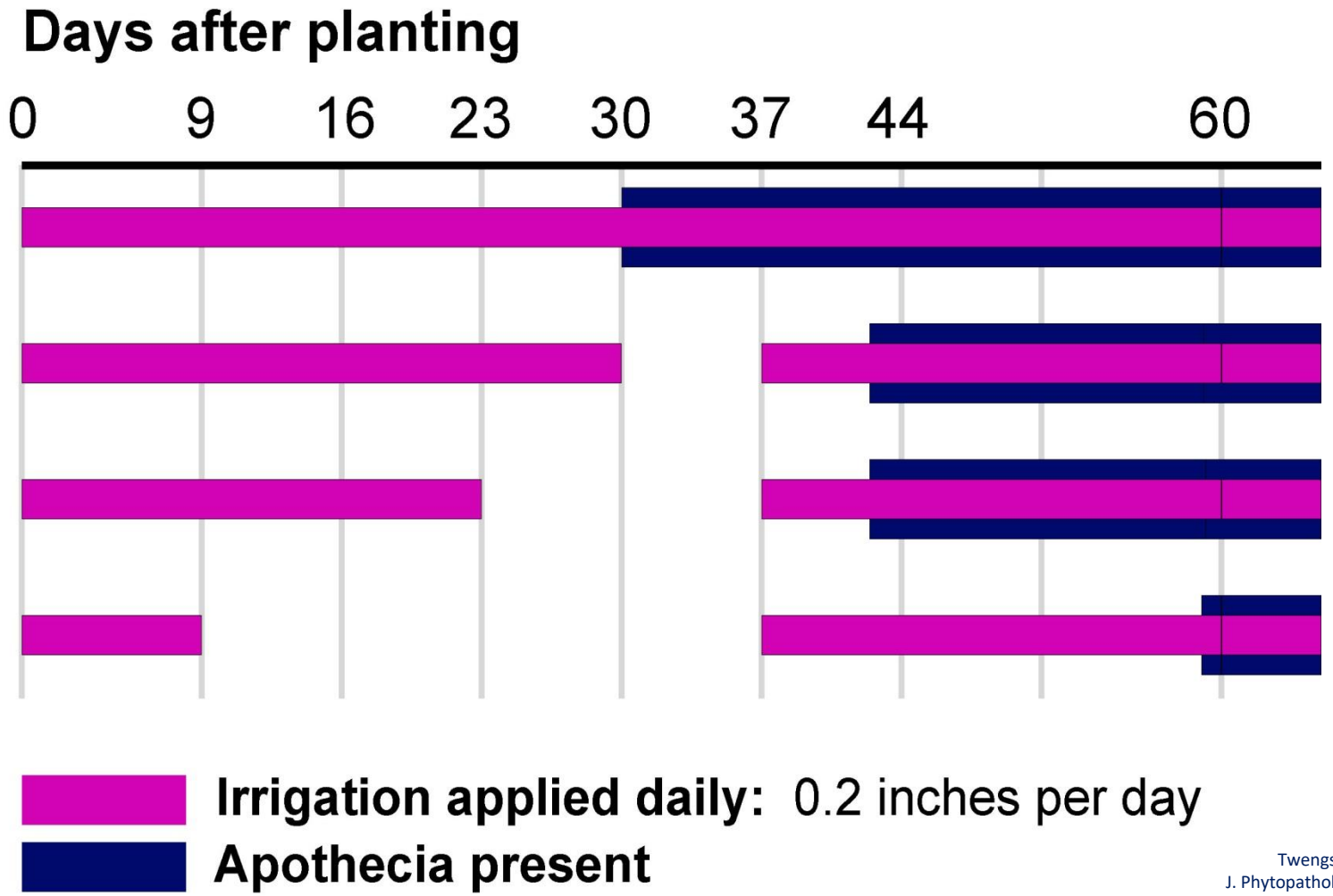
Plant-to-plant spread:
Between plants in direct contact

Initial infection:
Spores colonize dead blossoms

Soil moisture

A period of dry weather delays apothecia production.

UPPSALA, SWEDEN (1992) - Rapeseed (canola); SOIL TYPE = **LOAMY SAND**



Twengstrom et al. 1998
J. Phytopathology 146:487-493.

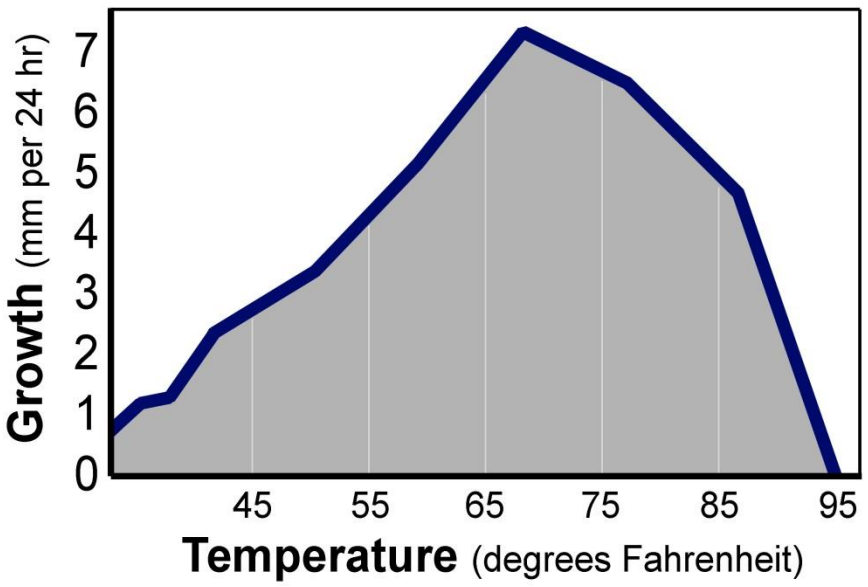
Air Temperature

Cool to moderate air temperatures favor Sclerotinia

Sclerotinia is inhibited as temperatures approach 85 to 90˚F

Sclerotinia growth rates

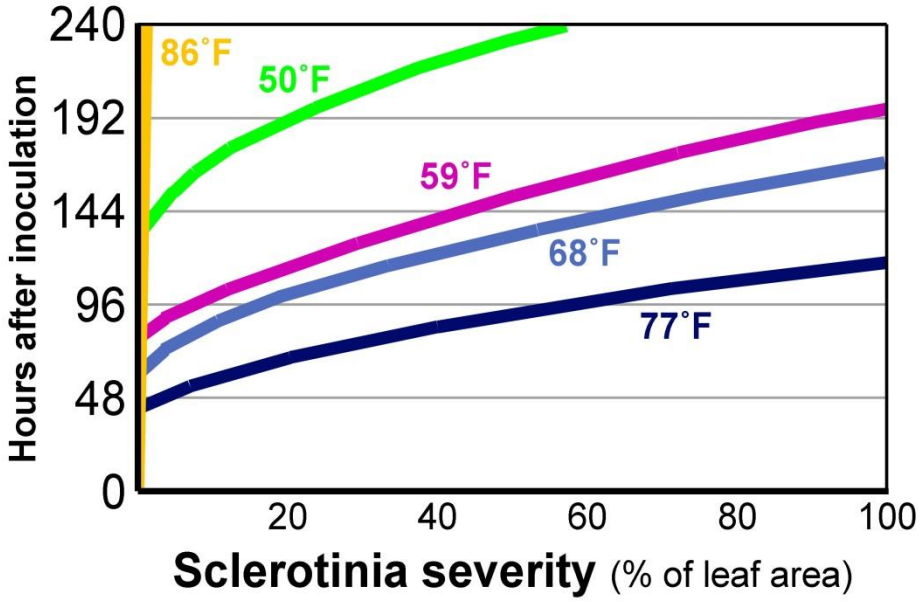
On artificial media in the lab



Berg and Lentz 1968. Can. J. Botany 46:1477-1481

Sclerotinia disease progression

Dry bean plants at 100% relative humidity (greenhouse)



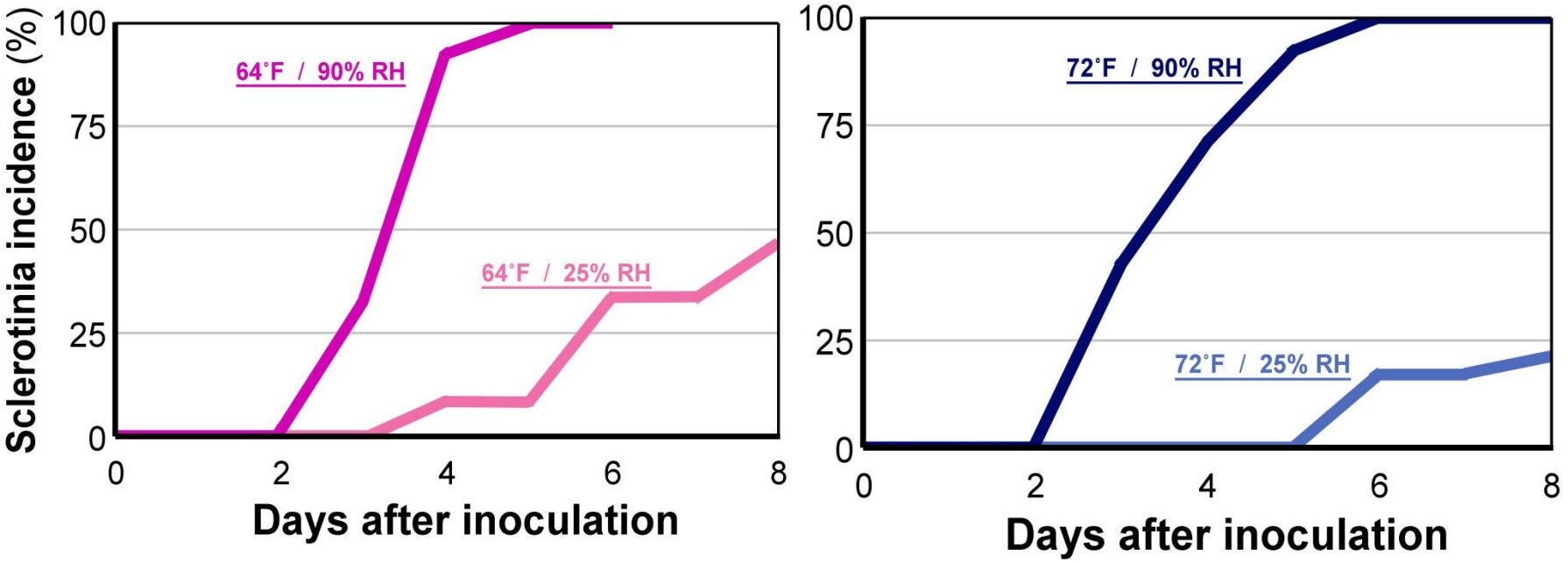
Weiss et al. 1980 Plant Disease 64:757-759

Relative humidity

Under sustained cool temperatures,
Sclerotinia may be able to develop even at low relative humidity

Sclerotinia disease progression

On dry bean plants (greenhouse) - *dead blossom inoculated with spores, placed in lowest node of plant*



Harikrishnan and del Rio 2006. Plant Dis. 90:946-950

Sclerotinia disease development

CONCLUSIONS:

Risk of Sclerotinia is highest when cool temperatures are sustained. When sustained cool temperatures occur, the rainfall and humidity requirements for Sclerotinia disease development are lower.

Sclerotinia is most severe when rainfall events are recurrent. The total amount of rainfall is likely less important than the frequency of rainfall events.




Improving management of white mold in soybeans:

1. Optimizing fungicide application timing

Michael Wunsch

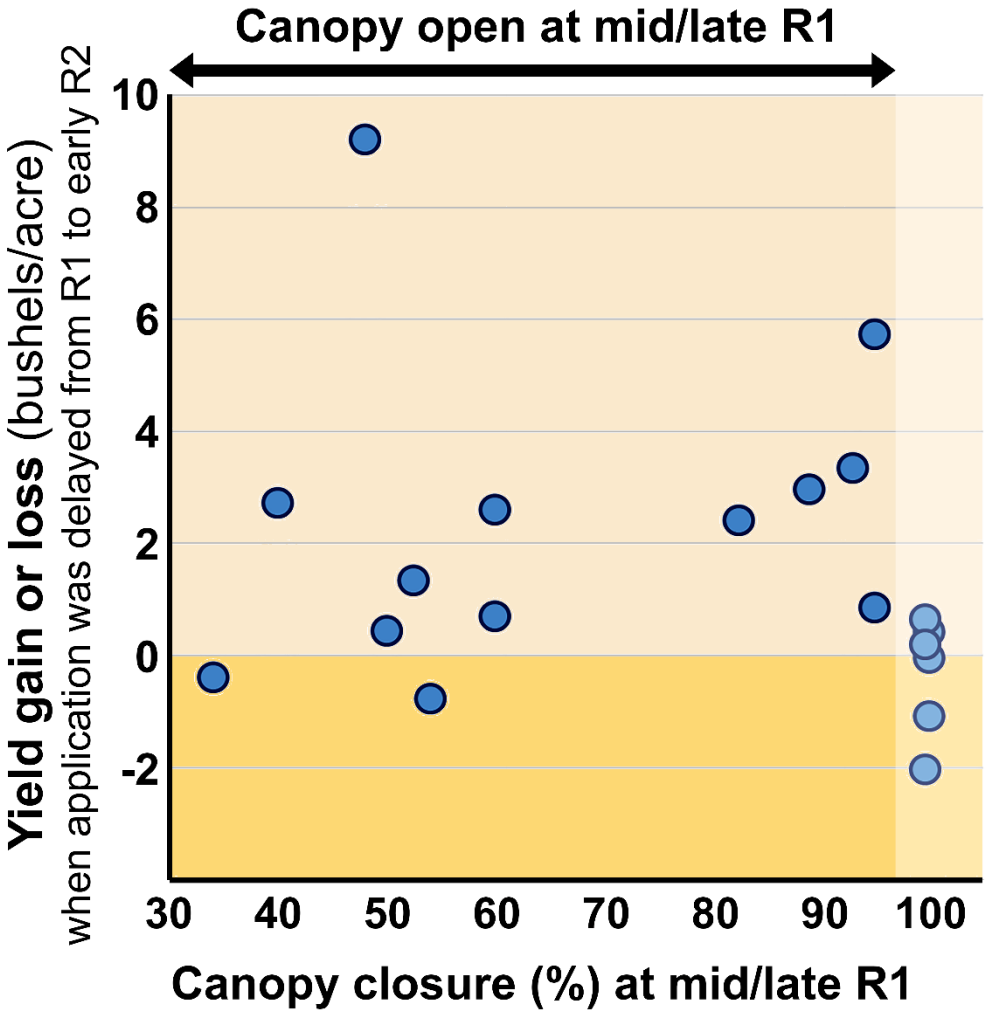
North Dakota State University Carrington Research Extension Center

Optimizing fungicide application timing for white mold management in soybeans

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

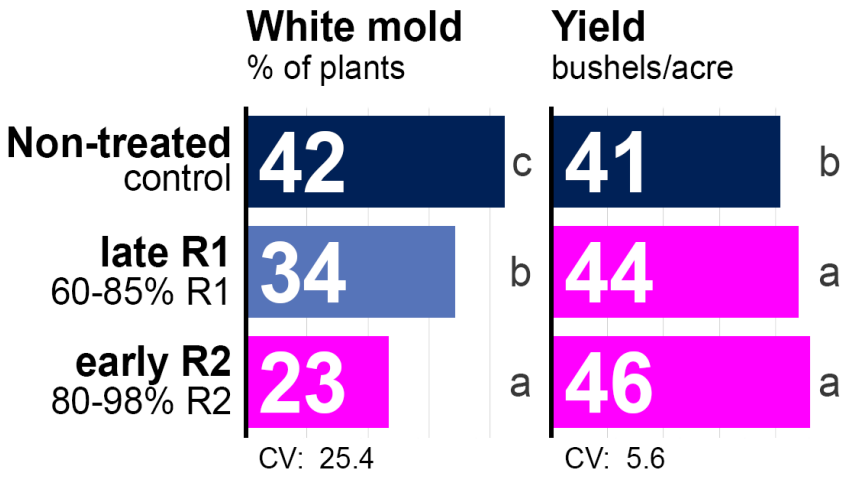
Carrington, Hofflund, Langdon and Oakes, ND (2014-2016)

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



BLUE DOT = response observed in an individual study

AVERAGE RESULTS



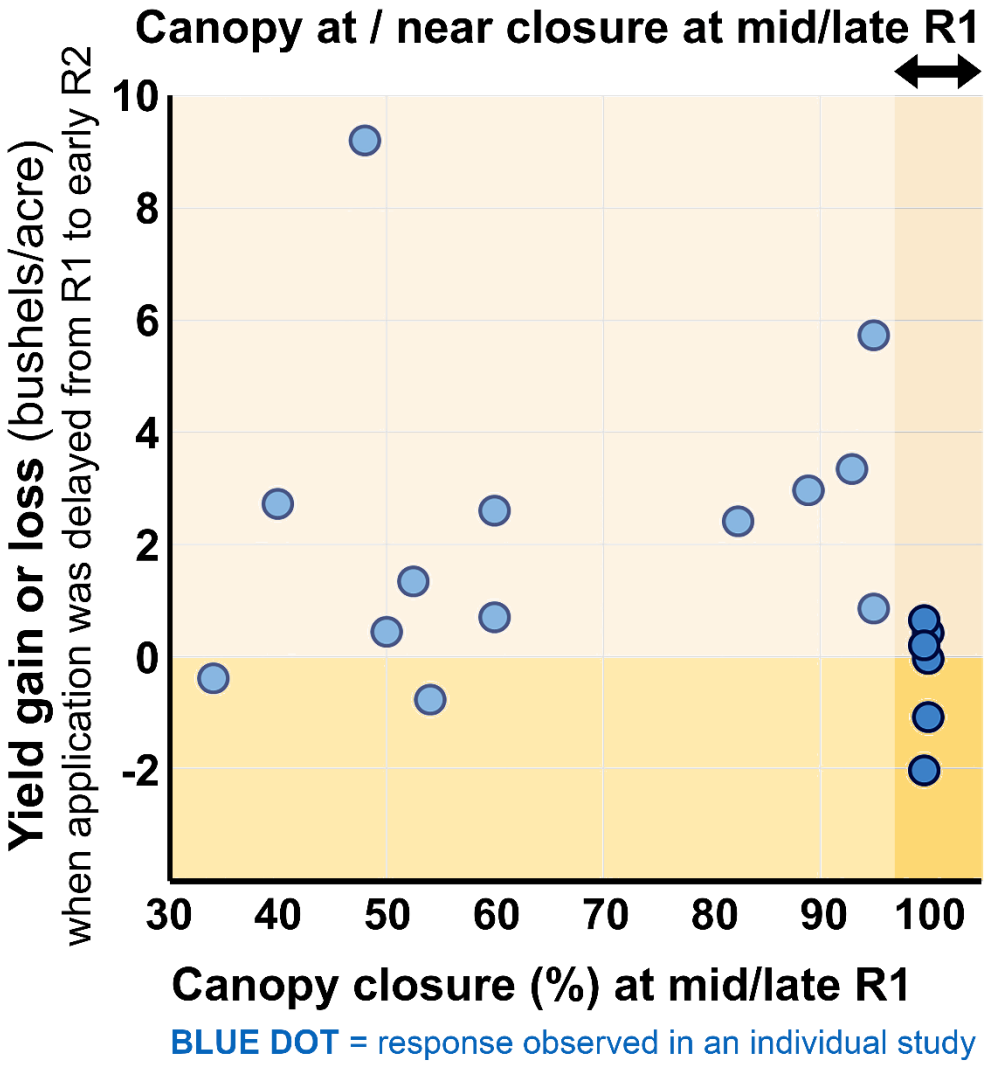
Combined analysis from 13 studies
Fungicide: single application, Endura (5.5 or 8.0 oz/ac)
Soybean row spacing: 7, 7.5, 14, 15, 21, 28 or 30 in.

Optimizing fungicide application timing for white mold management in soybeans

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

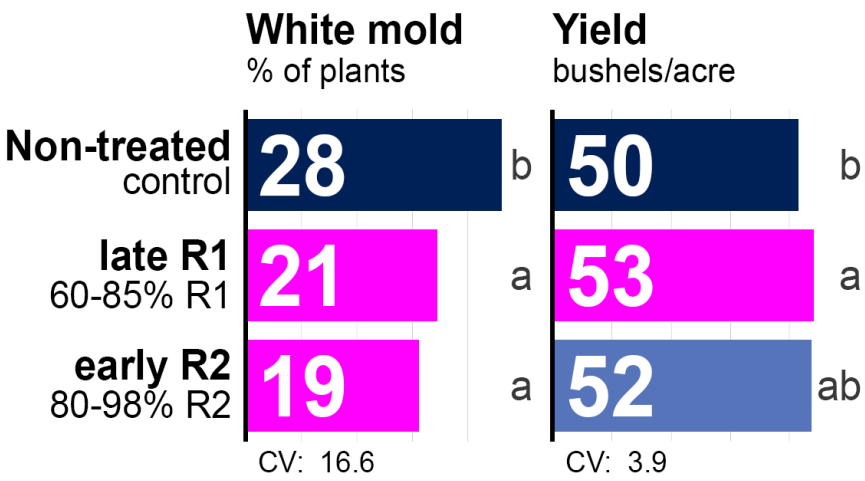
Carrington, Hofflund, Langdon and Oakes, ND (2014-2016)

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



BLUE DOT = response observed in an individual study

AVERAGE RESULTS



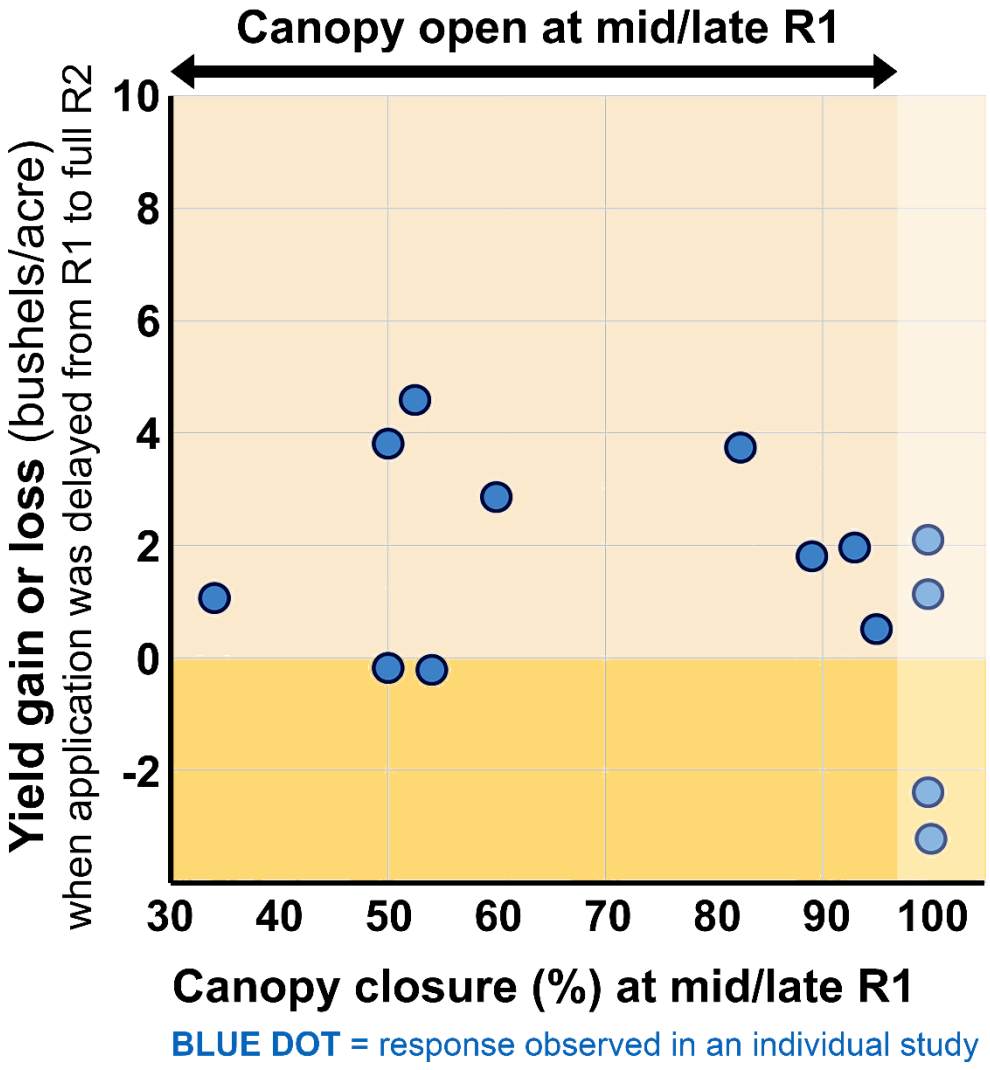
Combined analysis from 6 studies
Fungicide: single application, Endura (5.5 or 8.0 oz/ac)
Soybean row spacing: 7.5 or 14 inches

Optimizing fungicide application timing for white mold management in soybeans

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

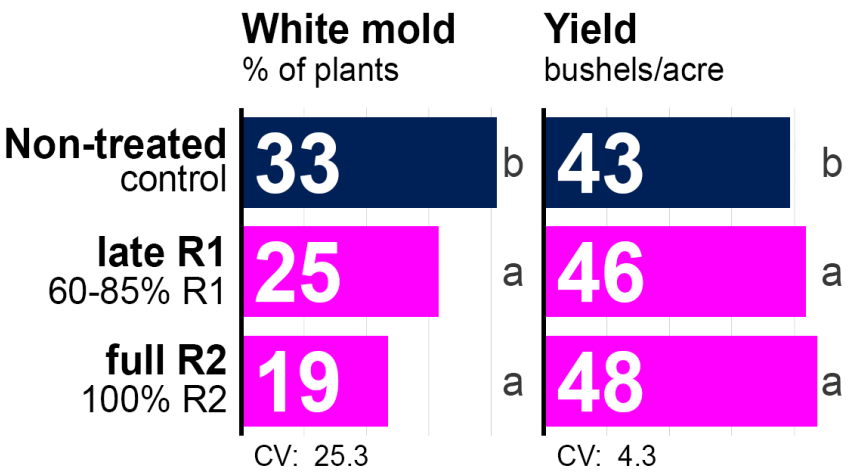
Carrington, Hofflund, Langdon and Oakes, ND (2014-2016)

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



BLUE DOT = response observed in an individual study

AVERAGE RESULTS



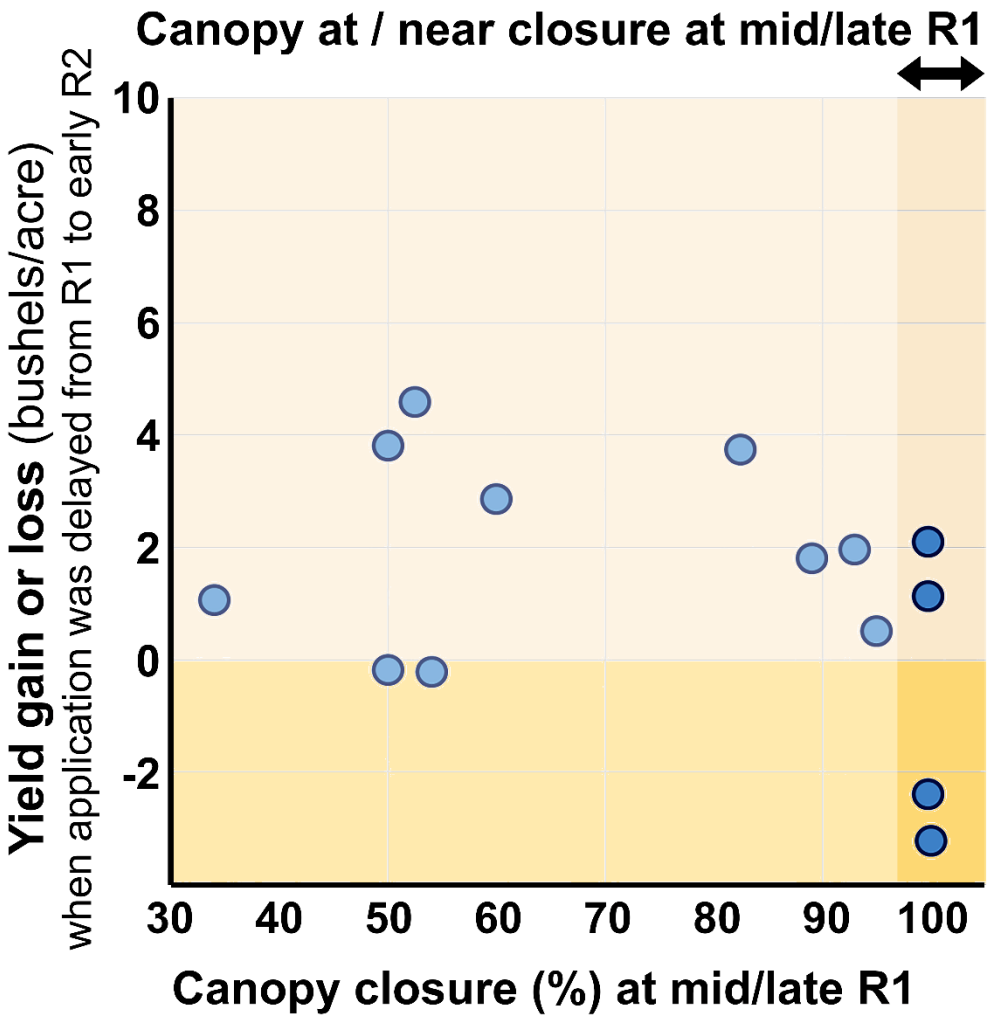
Combined analysis from 10 studies
Fungicide: single application, Endura (5.5 or 8.0 oz/ac)
Soybean row spacing: 14, 15, 21, or 28 inches

Optimizing fungicide application timing for white mold management in soybeans

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

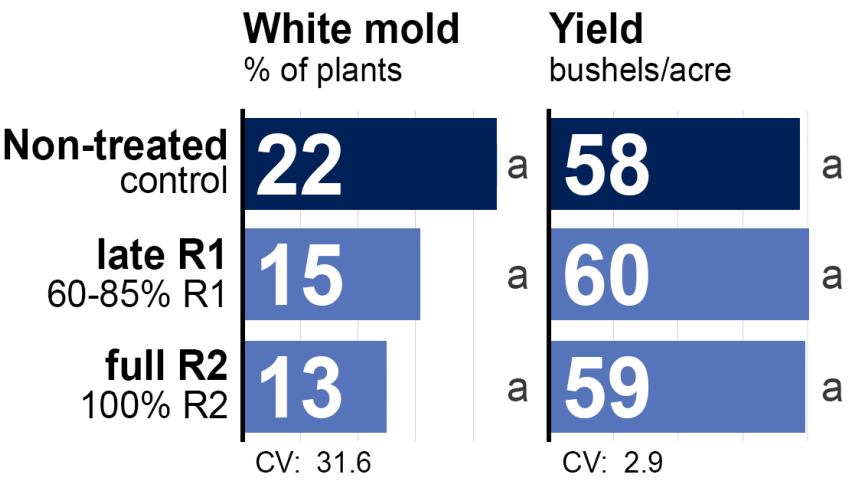
Carrington, Hofflund, Langdon and Oakes, ND (2014-2016)

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



BLUE DOT = response observed in an individual study

AVERAGE RESULTS



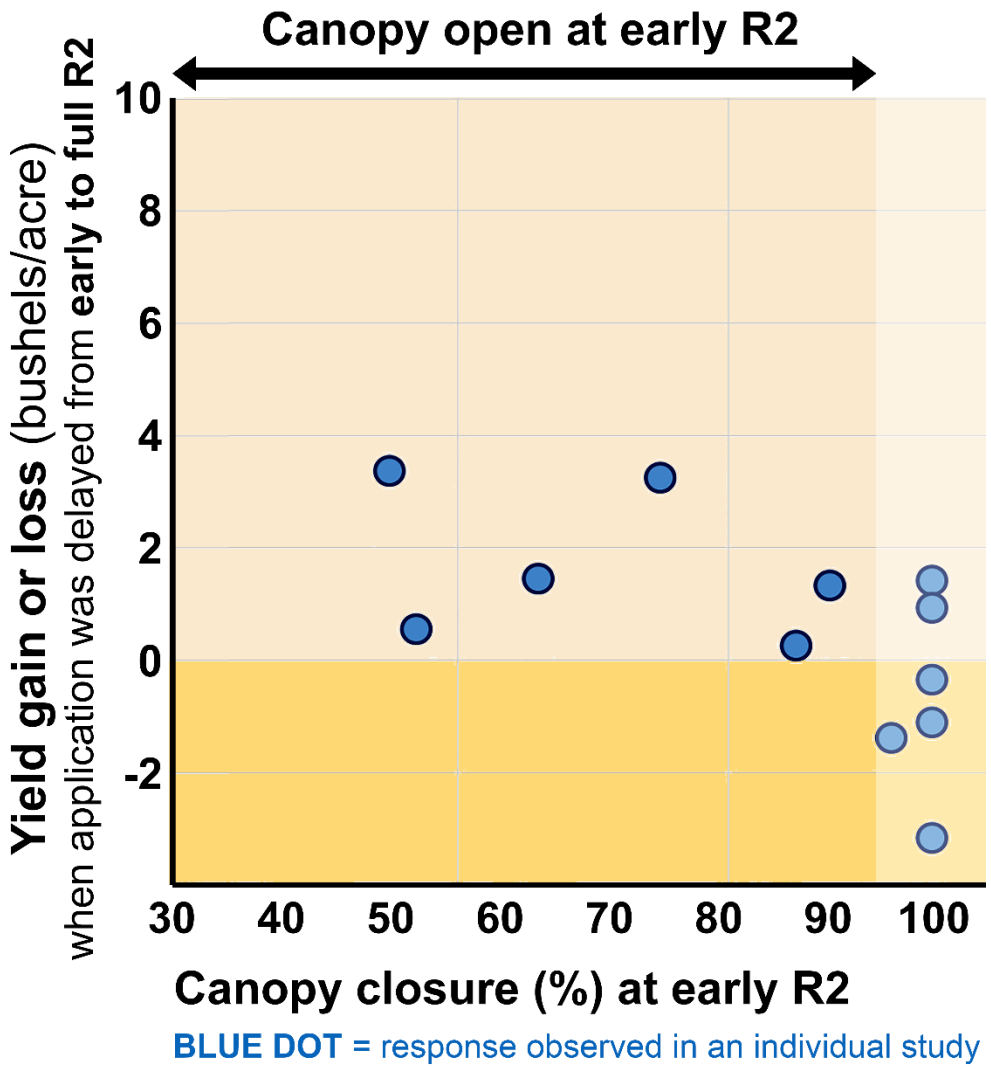
Combined analysis from 4 studies
Fungicide: single application, Endura (5.5 oz/ac)
Soybean row spacing: 14 inches

Optimizing fungicide application timing for white mold management in soybeans

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

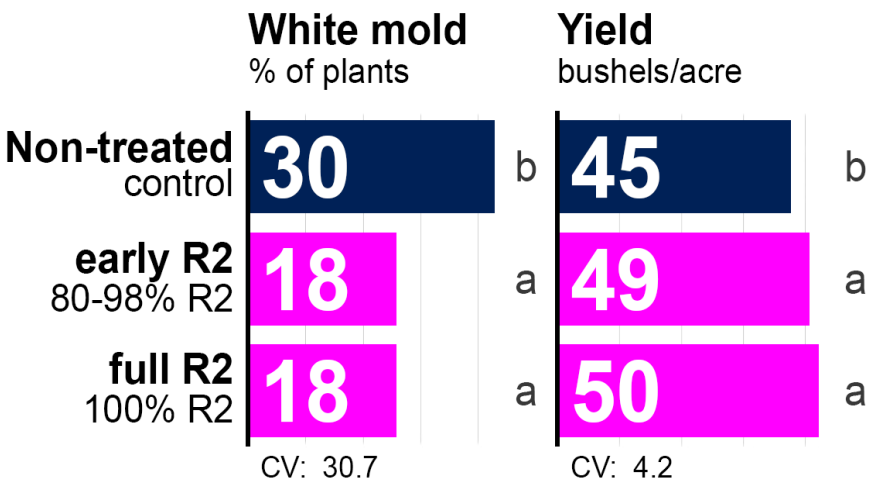
Carrington, Hofflund, Langdon and Oakes, ND (2014-2016)

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



BLUE DOT = response observed in an individual study

AVERAGE RESULTS



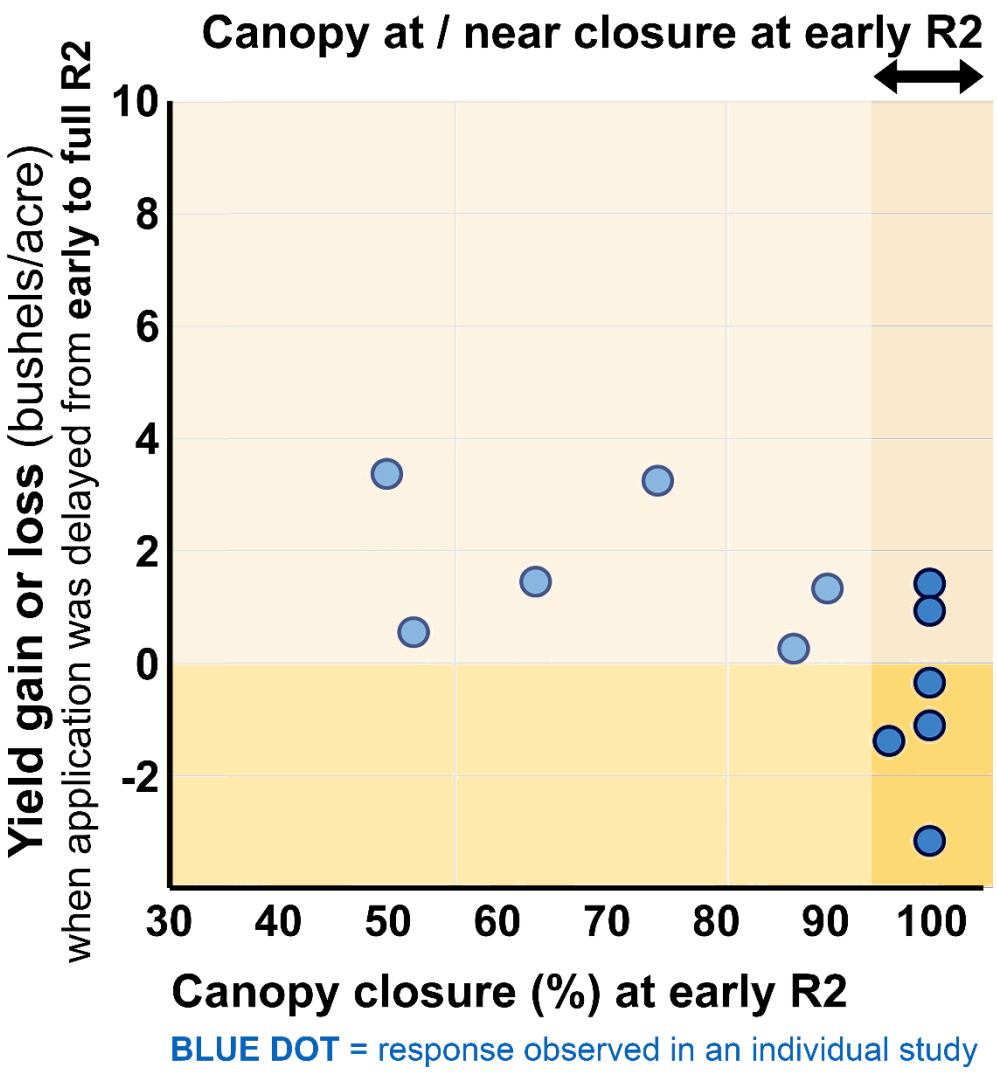
Combined analysis from 6 studies
Fungicide: single application, Endura (5.5 or 8.0 oz/ac)
Soybean row spacing: 21 or 28 inches

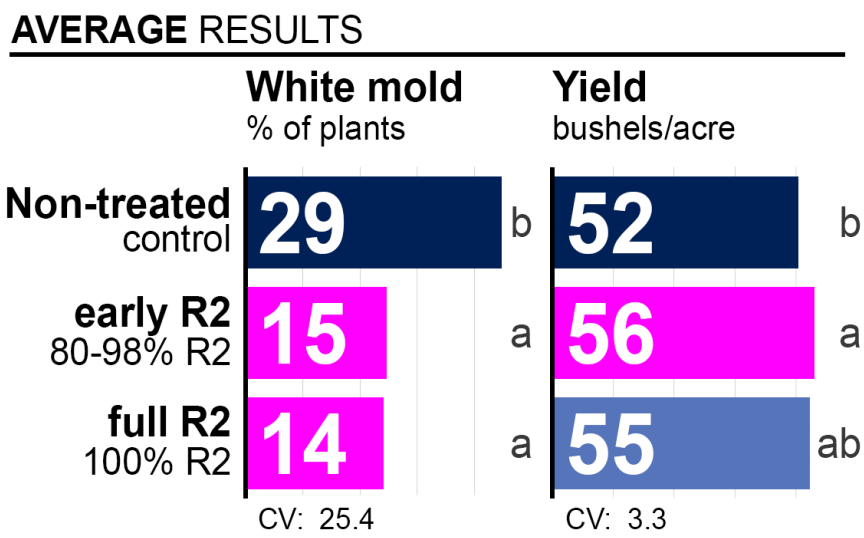
Optimizing fungicide application timing for white mold management in soybeans

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





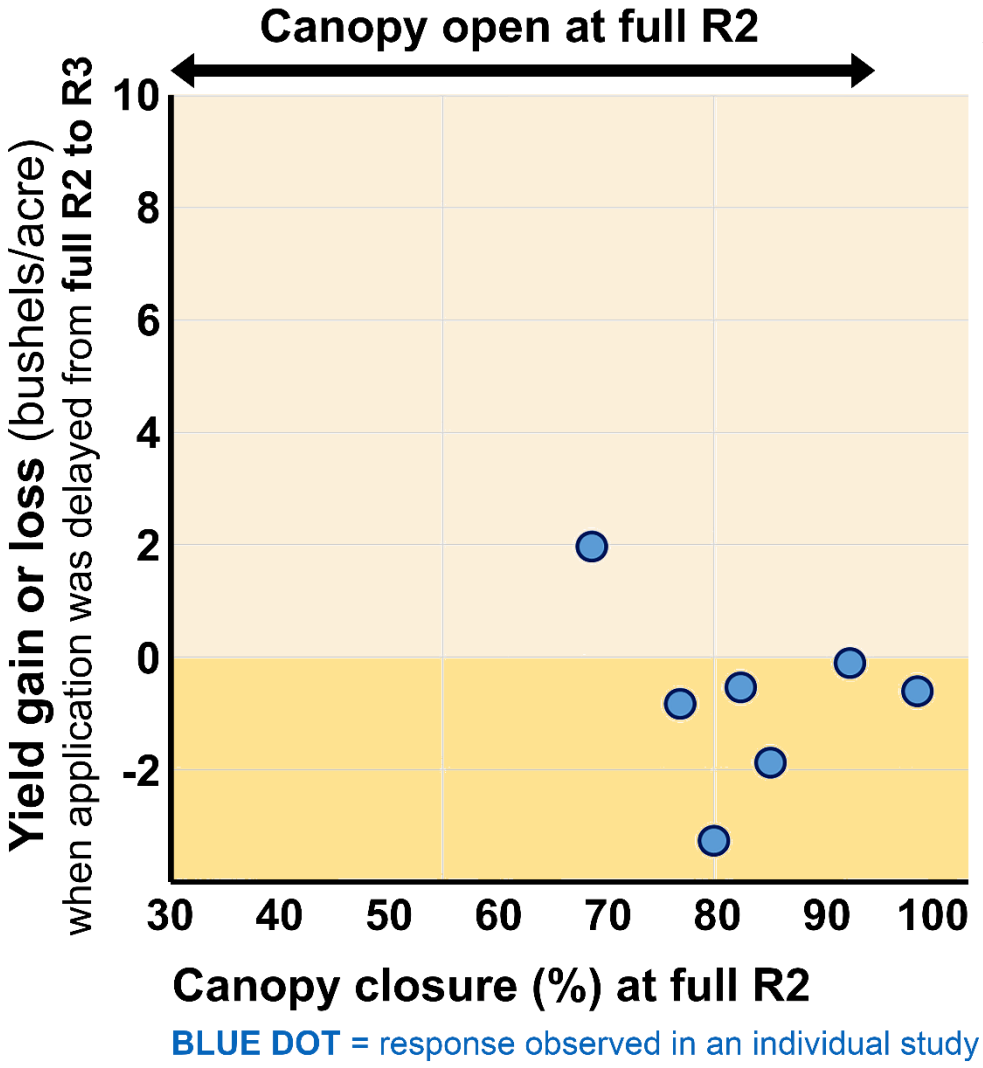
Combined analysis from 6 studies
Fungicide: single application, Endura (5.5 oz/ac)
Soybean row spacing: 14 inches

Optimizing fungicide application timing for white mold management in soybeans

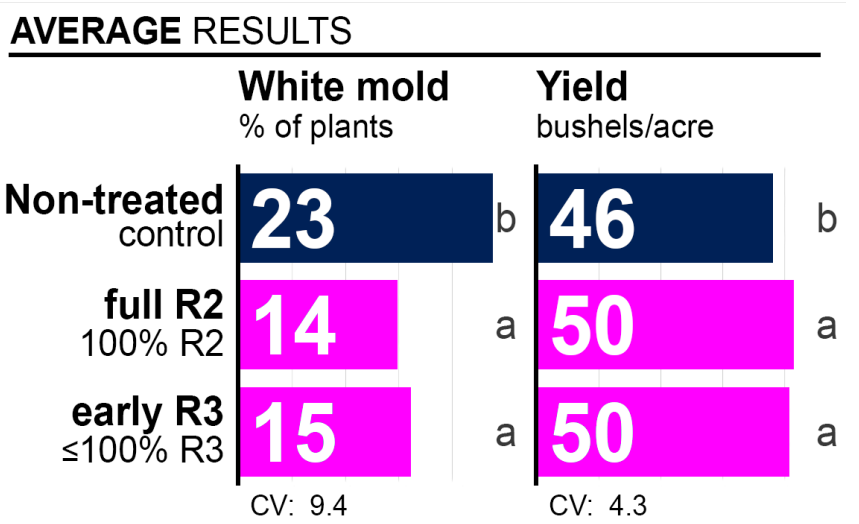
4. **Full R2** (100% R2) **versus early R3**

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



BLUE DOT = response observed in an individual study



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 enter 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 dry edible beans:

1. Optimizing fungicide application timing

Michael Wunsch

North Dakota State University Carrington Research Extension Center

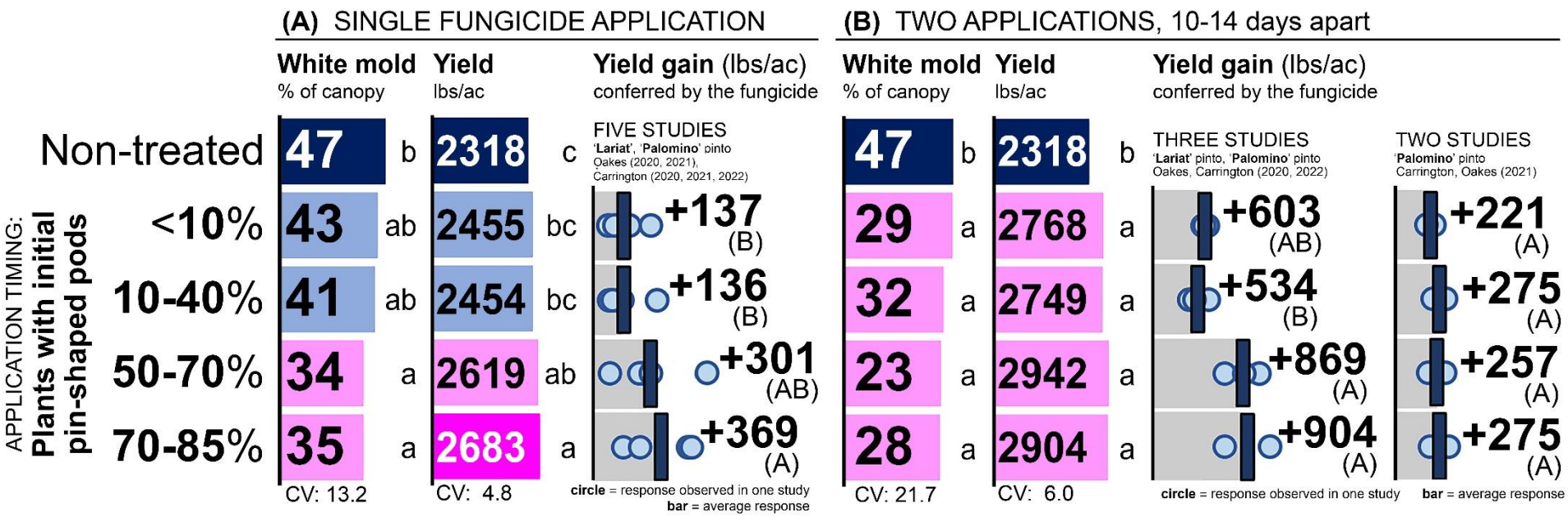
Optimizing fungicide application timing

PINTO BEANS – open canopy, warm temperatures at initial pod

PINTO
open canopy
warm temperatures

<95% canopy closure when 10-20% of plants had initial pods

average daily high observed between 2nd and 3rd application timing: **80-85°F**
average daily high observed between 3rd and 4th application timing: **82-86°F**



'Lariat' and 'Palomino' pinto beans
Carrington and Oakes, ND (2020-2022)
Within-column means followed by different letters are significantly different (*P* < 0.05;
Tukey multiple comparison procedure)

NORTHARVEST BEANS (MINNESOTA / NORTH DAKOTA)

NDSU NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION

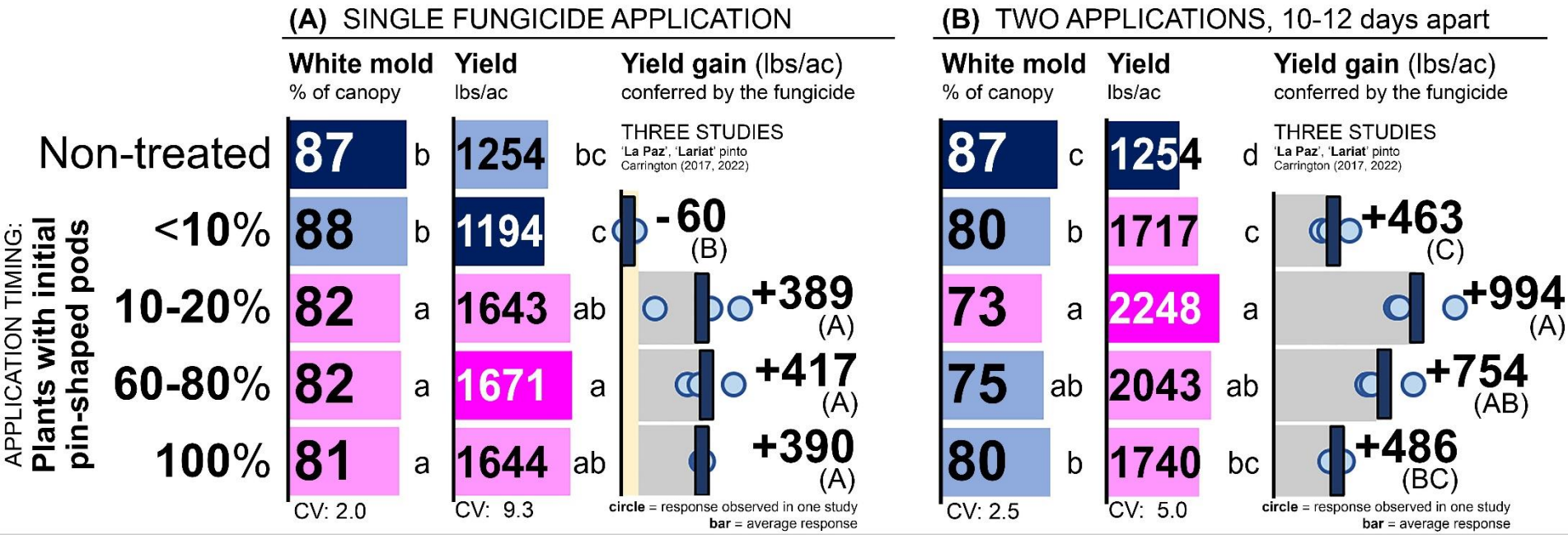
Optimizing fungicide application timing

PINTO BEANS – closed canopy, cool temperatures at initial pod

PINTO
closed canopy
cool temperatures

≥95% canopy closure when 10-20% of plants had initial pods

average daily high observed between 2nd and 3rd application timing: **79-82°F**
average daily high observed between 3rd and 4th application timing: **76-82°F**



'Lariat' and 'La Paz' pinto beans
Carrington, ND (2017, 2022)
Within-column means followed by different letters are significantly different (*P* < 0.05; Tukey multiple comparison procedure)

NORTHARVEST BEANS (MINNESOTA / NORTH DAKOTA)

NDSU NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION

Optimizing fungicide application timing

When conditions favor white mold as **pinto beans** enter bloom:

If it is cool and the canopy is at / near closure, fungicides should be applied when 10-20% of plants have initial pin-shaped pods.

- Can delay to 60-80% of plants with 1st pods if making one application

If it is warm and the canopy is open, fungicides should be applied when 70-85% of plants have initial pin-shaped pods.

There is a significant yield penalty to applying at initial bloom when <10% of plants have initial pin-shaped pods.

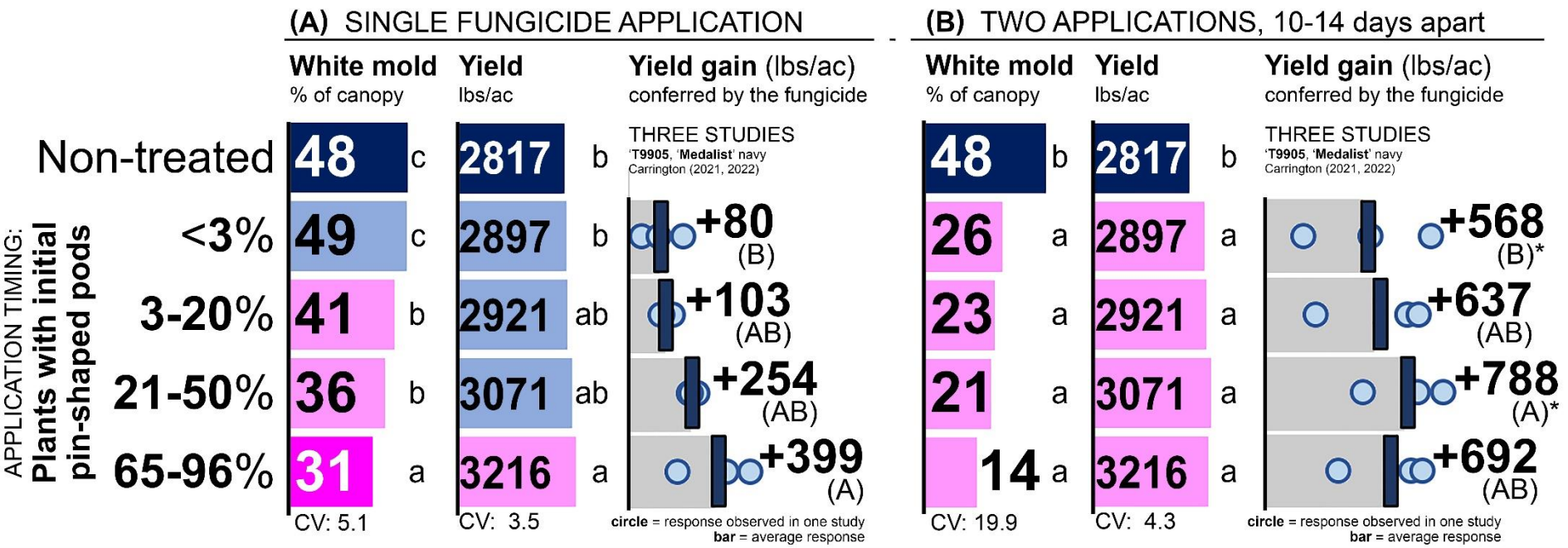
Optimizing fungicide application timing

NAVY BEANS – open canopy, warm temperatures at initial pod

NAVY
warm temperatures

<95% canopy closure when 21-50% of plants had initial pods

average daily high observed between 2nd and 3rd application timing: **88-90°F**
average daily high observed between 3rd and 4th application timing: **84-92°F**



'T9905' and 'Medalist' navy beans
Carrington, ND (2021, 2022)
Within-column means followed by different letters are significantly different (*P* < 0.05; Tukey multiple comparison procedure)

NORTHARVEST BEANS (MINNESOTA / NORTH DAKOTA)

NDSU NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION

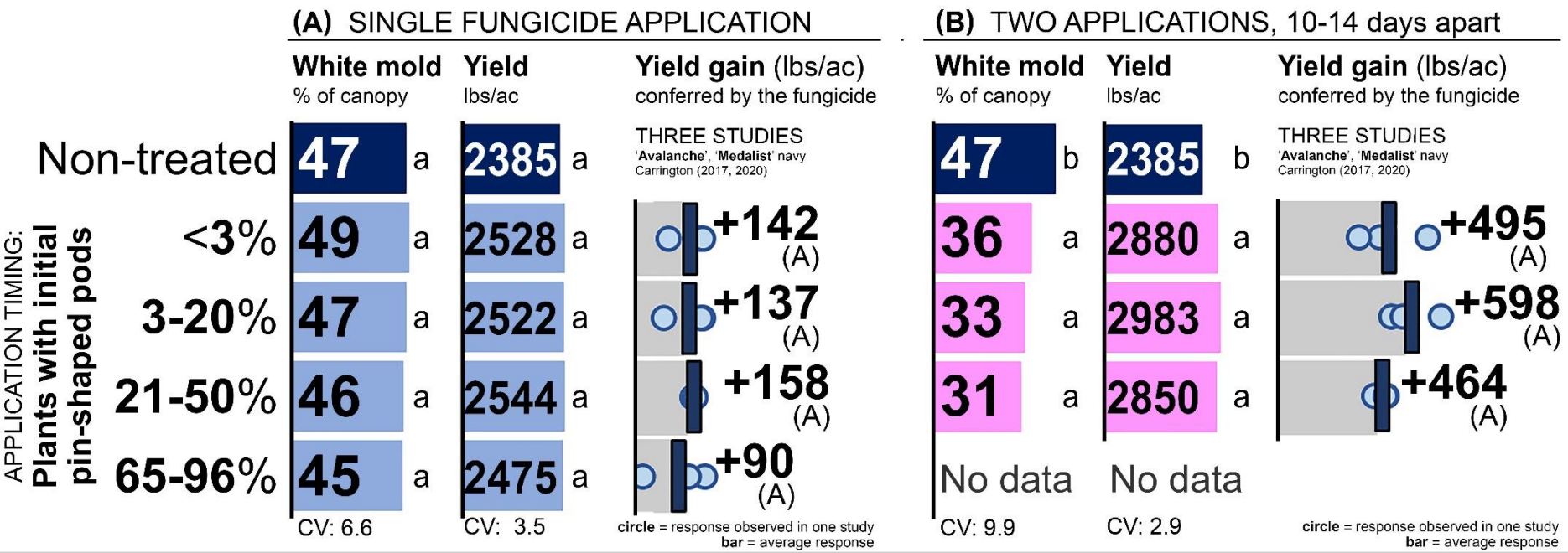
Optimizing fungicide application timing

NAVY BEANS – open canopy, cool temperatures at initial pod

NAVY
cool temperatures

<95% canopy closure when 21-50% of plants had initial pods

average daily high observed between 2nd and 3rd application timing: **79-80°F**
average daily high observed between 3rd and 4th application timing: **80-82°F**



'Avalanche' and 'Medalist' navy beans
Carrington, ND (2017, 2020)
Within-column means followed by different letters are significantly different (*P* < 0.05; Tukey multiple comparison procedure)

NORTHARVEST BEANS MINNESOTA NORTH DAKOTA

NDSU NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION

Optimizing fungicide application timing

When conditions favor white mold as **navy beans** enter bloom:

If it is cool, fungicides should be applied very early in initial pod development (3-20% of plants with pin-shaped pods).

- Two fungicide applications needed; a single application is sufficient.

If it is warm, fungicides should be applied when 21-50% of plants have initial pin-shaped pods (two applications) or 65-96% of plants with initial pin-shaped pods (one application)..

There is a yield penalty to applying at initial bloom (<10% of plants have initial pin-shaped pods) only when it is warm.

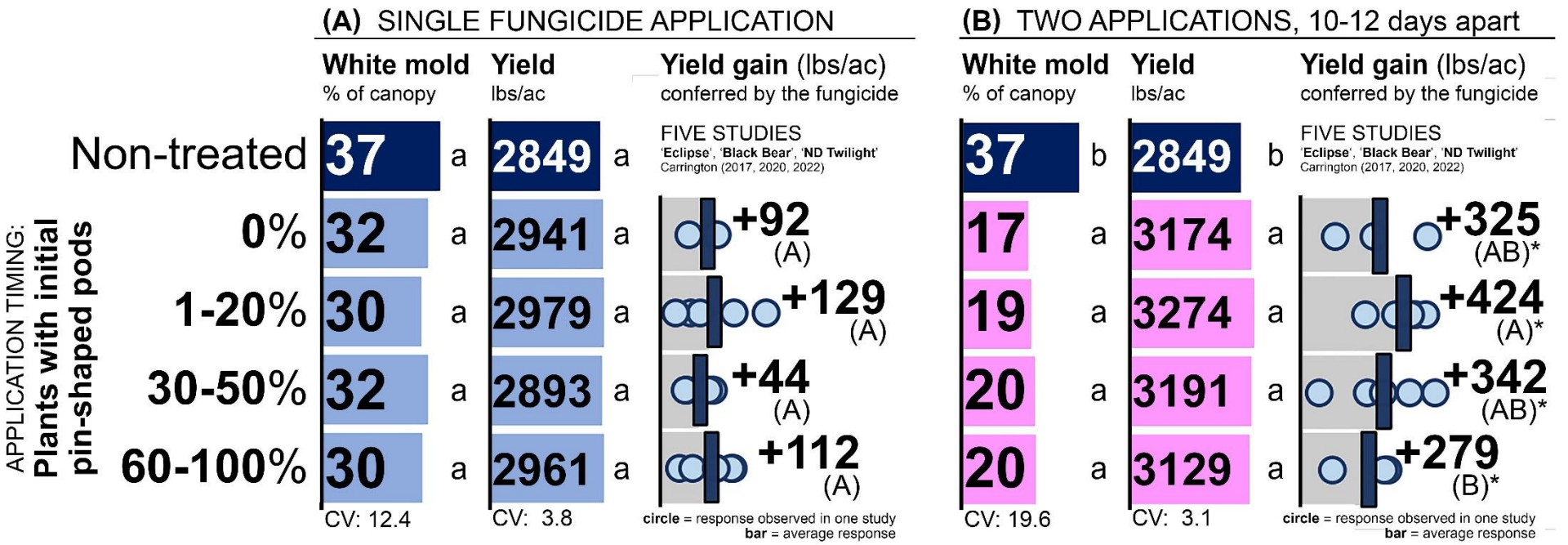
Optimizing fungicide application timing

BLACK BEANS – open canopy, cool temperatures at initial pod

BLACK
open canopy

average **60-86% canopy closure when 1-20% of plants had initial pods**
average **70-90% canopy closure when 60-100% of plants had initial pods**

average daily high observed between 2nd and 3rd application timing: **79-80°F**
average daily high observed between 3rd and 4th application timing: **80-81.5°F** (3 studies), **90°F** (2 studies)



'Black Bear', 'Eclipse' and 'ND Twilight' black beans
Carrington, ND (2017, 2020, 2022)
Within-column means followed by different letters are significantly different ($P < 0.05$;
Tukey multiple comparison procedure)

NDSU NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION

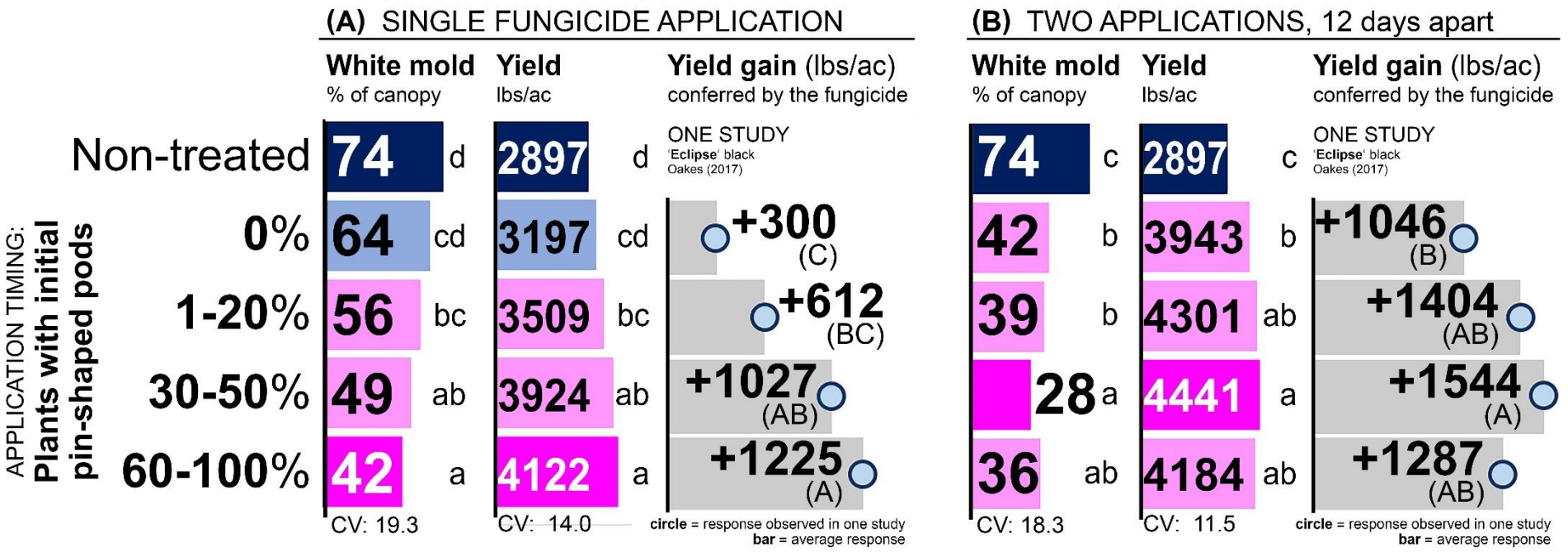
Optimizing fungicide application timing

BLACK BEANS – closed canopy, cool temperatures at initial pod

BLACK
canopy at or near closure

average **88% canopy closure when 1-20% of plants had initial pods**
average **97% canopy closure when 60-100% of plants had initial pods**

average daily high observed between 2nd and 3rd application timing: **79°F**
average daily high observed between 3rd and 4th application timing: **82.5°F**



'Eclipse' black beans
Oakes, ND (2017)

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

NDSU NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION

Optimizing fungicide application timing

When conditions favor white mold as **black beans** enter bloom:

Fungicides should be applied very early in initial pod development (1-50% of plants with pin-shaped pods).

- Delaying applications until 60-100% of plants have initial pods may be possible when making a single fungicide application.
- A single fungicide application often conferred poor disease control and should be utilized only when rainfall and temperatures do not favor white mold in the second half of bloom.

There was often a yield penalty to applying at initial bloom prior to the development of initial pin-shaped pods (0% of plants with initial pin-shaped pods).




Improving management of white mold in soybeans: 4. Optimizing fungicide spray droplet size

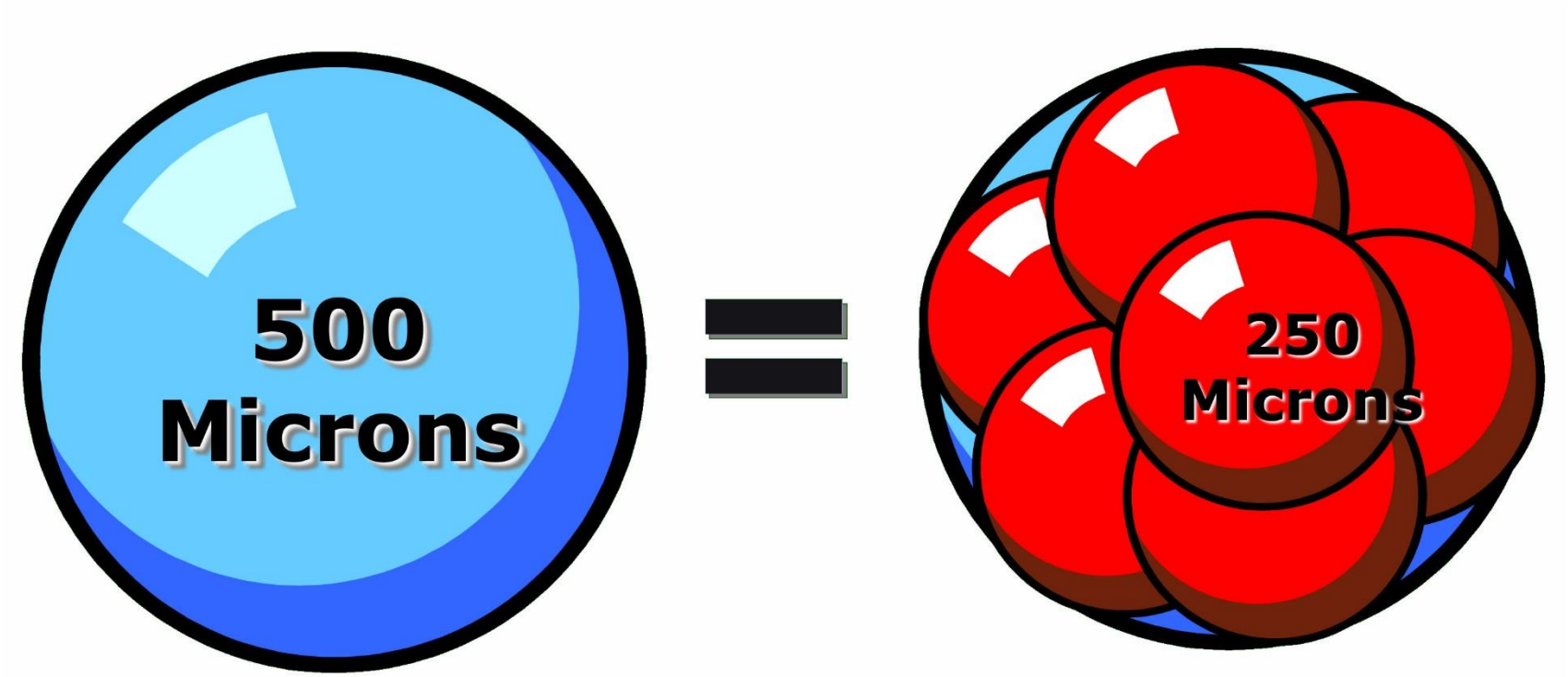
Michael Wunsch, Thomas Miorini, Michael Schaefer, Billy Kraft, Suanne Kallis
NDSU Carrington Research Extension Center
Heidi Eslinger, Kelly Cooper, Seth Nelson NDSU Robert Titus Research Farm, Oakes

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

Droplet size

Cutting droplet diameter in half

Results in **eight times as many droplets**



(there is one more droplet in the rear)

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

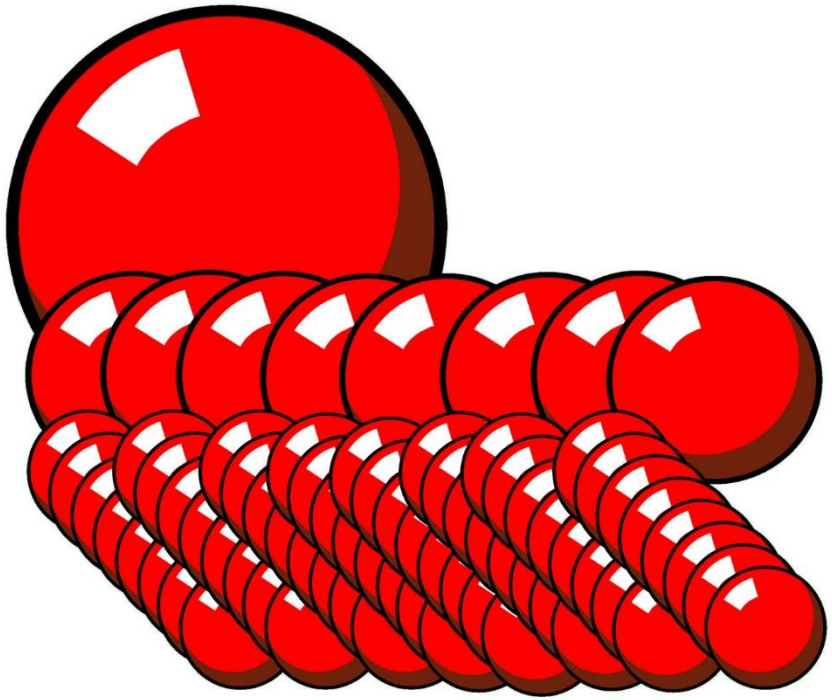
Droplet size

0.065 mm^3 spray volume =

one 500-um diameter droplet

eight 250-um diameter droplets

sixty-four 125-um diameter droplets



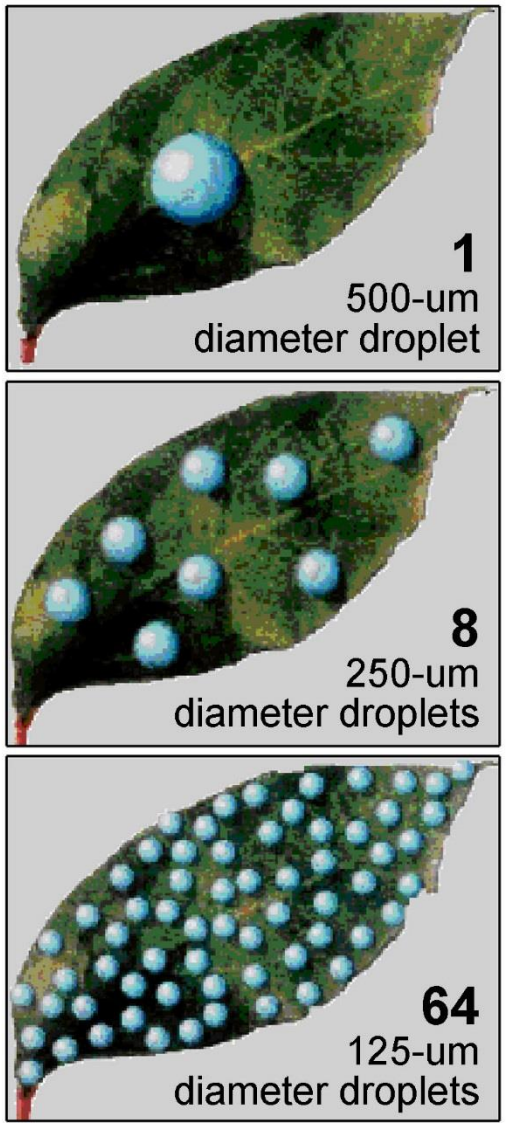
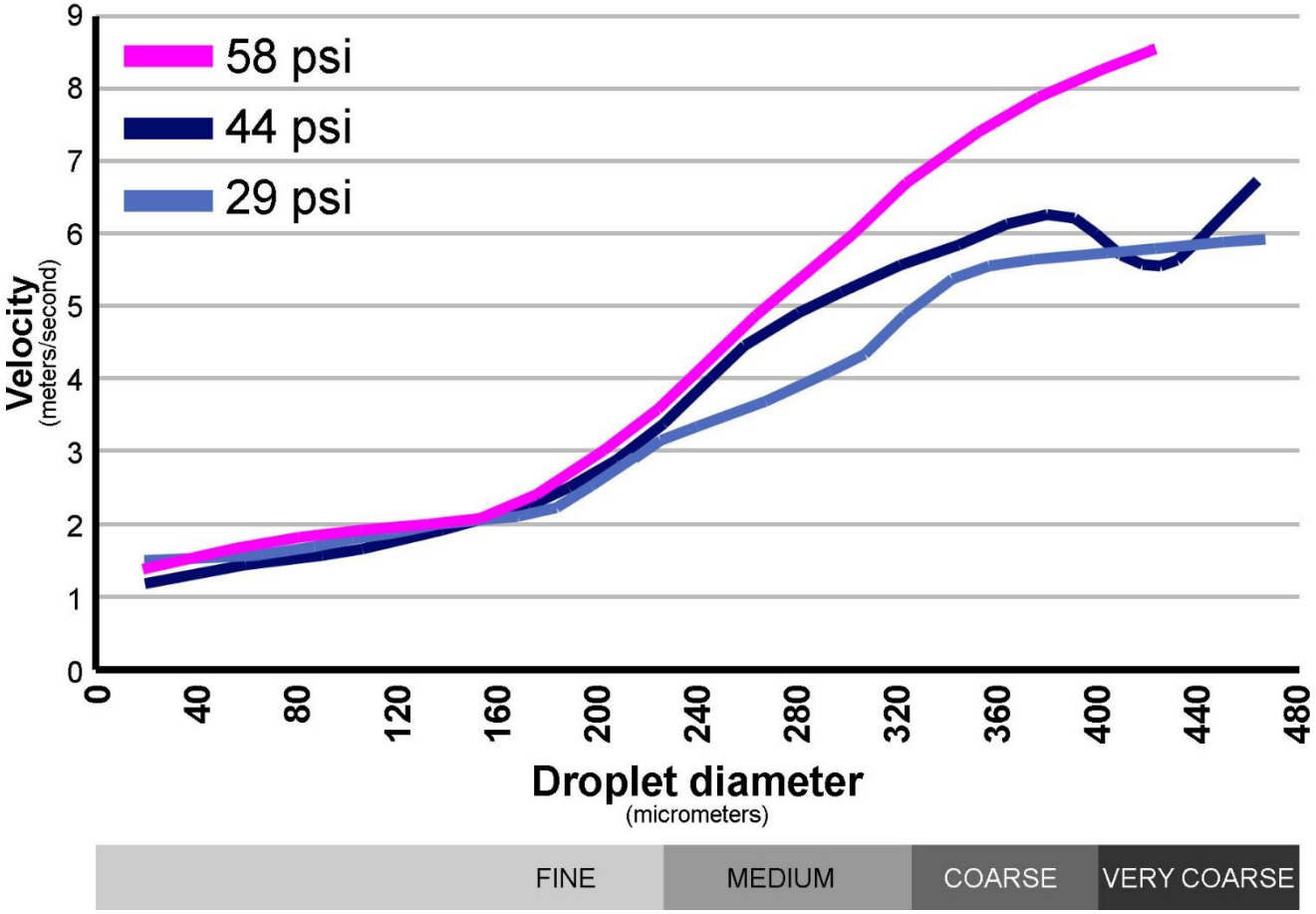


Image adapted from a presentation by Bob Wolf (Kansas State Univ.); Bobby Grisso and Pat Hipkins (Virginia Tech Univ.); and Tom Reed (TeeJet)

Droplet size

… but larger droplets have greater velocity, drift less.

Increased velocity and reduced drift improves canopy penetration.



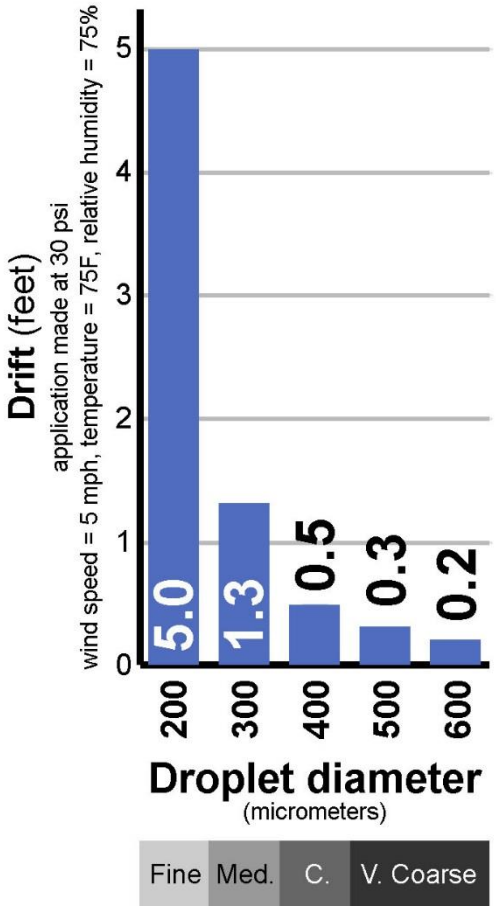


Image adapted from a presentation by Bob Wolf (Kansas State Univ.); Bobby Grisso and Pat Hipkins (Virginia Tech Univ.); and Tom Reed (TeeJet)

Experimental Methods

1. WILGER nozzles

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

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

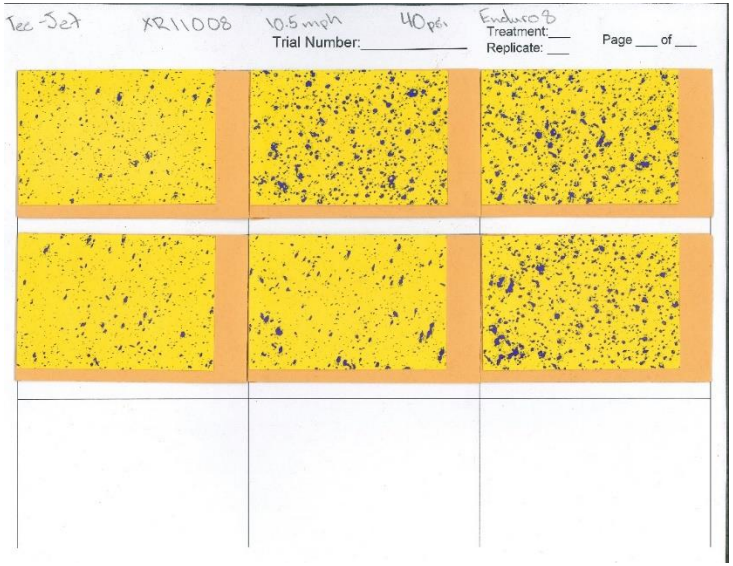
XR TeeJet® (XR)

	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

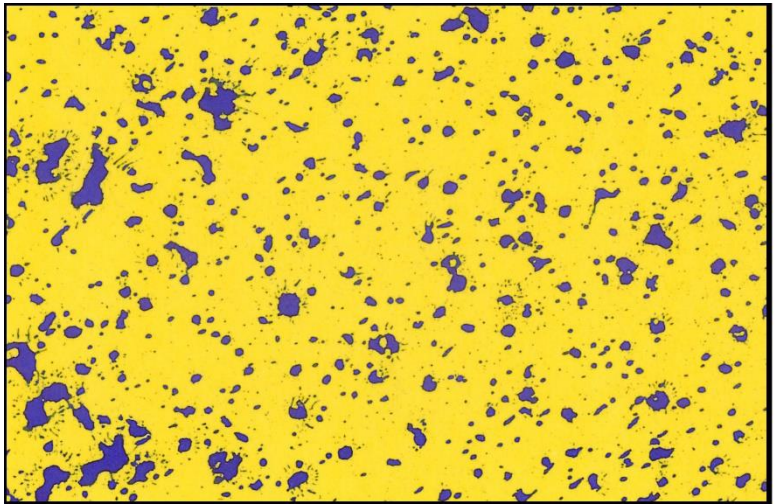
Experimental Methods

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

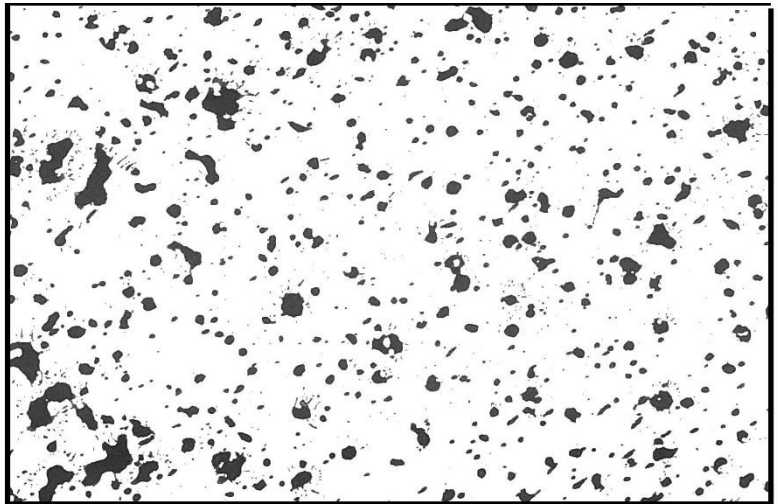
- To reduce problems with coalesced droplets, spray volume reduced to 5 gal/ac for this analysis
- For analysis, yellow background replaced with white and images were converted to grayscale
- A useful tool to evaluate shifts in droplet size spectrum across nozzles, not for accurately characterizing droplet 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					WILGER NOZZLES
	2017 Carrington 4.0 mph Endura, 5.5 oz/ac	2018 Carrington 6.7 mph Endura, 5.5 oz/ac	2020 Oakes 6.0 mph Endura, 5.5 oz/ac	2020 Carrington 10.5 mph Endura, 8.0 oz/ac	**AVERAGE VALUES,** TEEJET NOZZLES (2018-2020)	2019, 2020 Carrington, Oakes 8.6 mph 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.

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

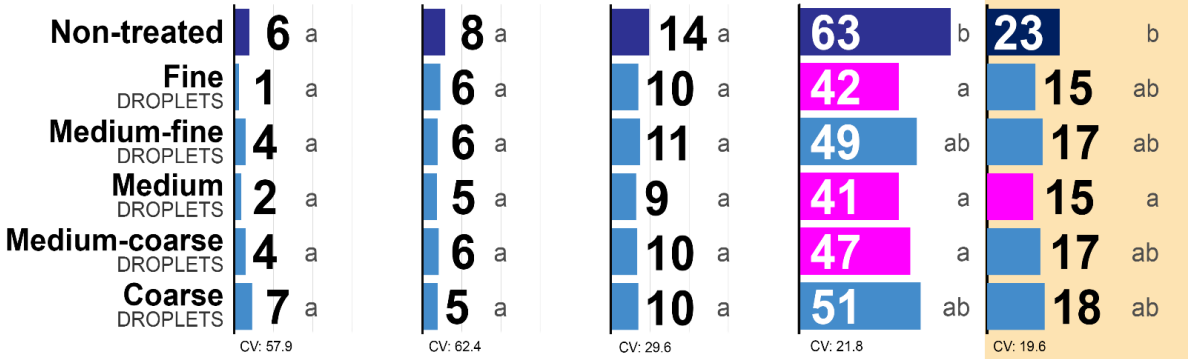
IMPACT OF SPRAY DROPLET SIZE: **TEEJET NOZZLES**

Soybeans

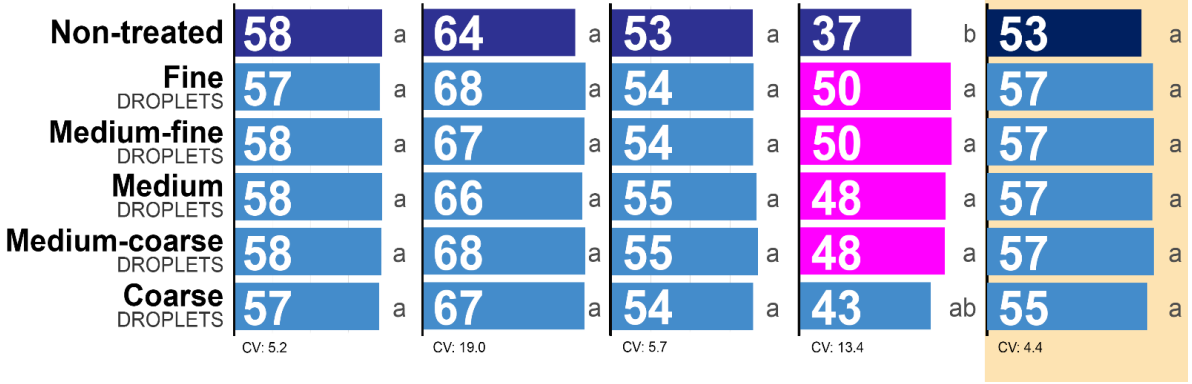
canopy very open when fungicides were applied

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%
Range:	47-80%	60-85%	62-88%	60-85%	

White mold severity index (% of canopy diseased)



Soybean Yield (bu/ac; 13% moisture)



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)

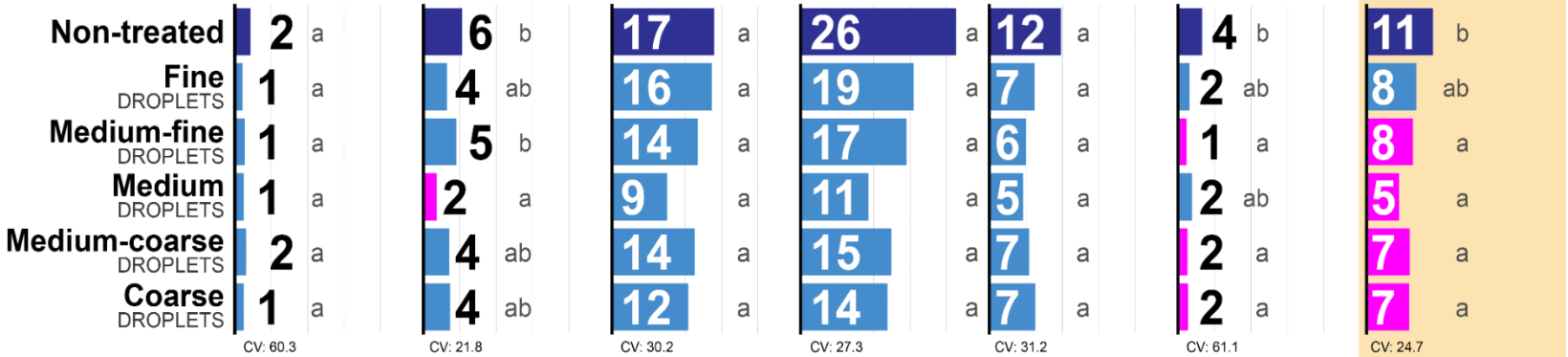
IMPACT OF SPRAY DROPLET SIZE: TEEJET NOZZLES

Soybeans

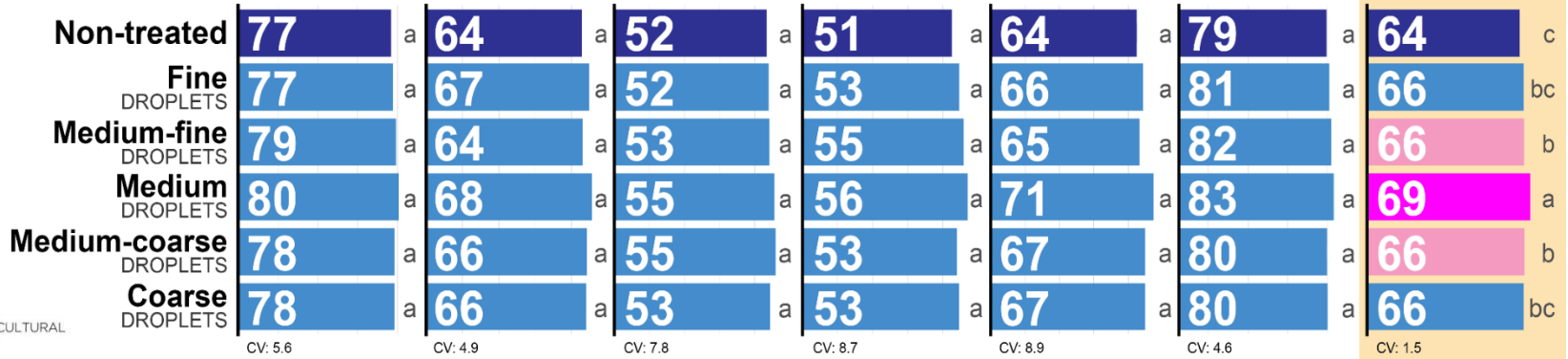
canopy open when fungicides applied

	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	**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)



Soybean Yield (bu/ac; 13% moisture)



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)

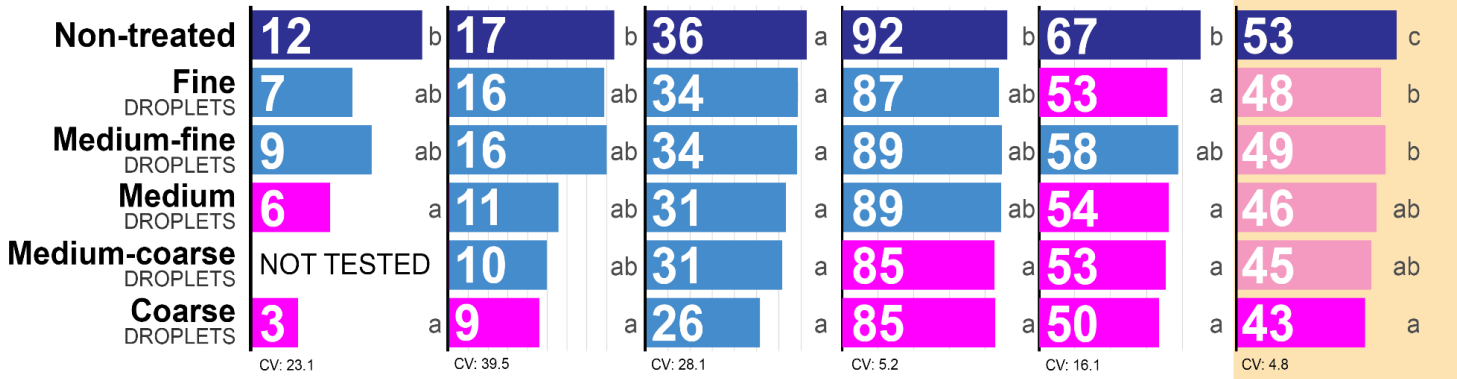
IMPACT OF SPRAY DROPLET SIZE: **TEEJET NOZZLES**

Soybeans

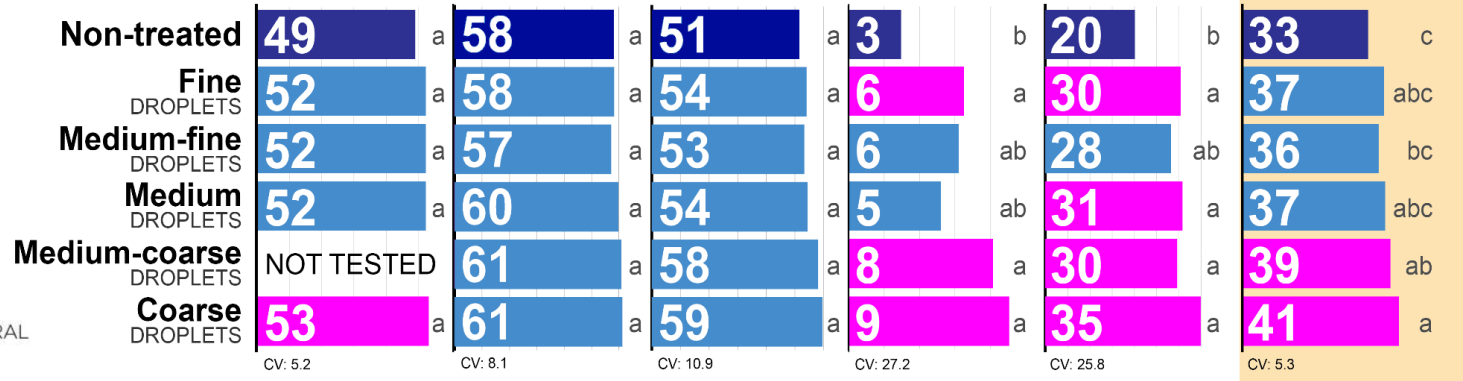
canopy near closure when fungicides applied

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

White mold severity index (% of canopy diseased)



Soybean Yield (bu/ac; 13% moisture)



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)

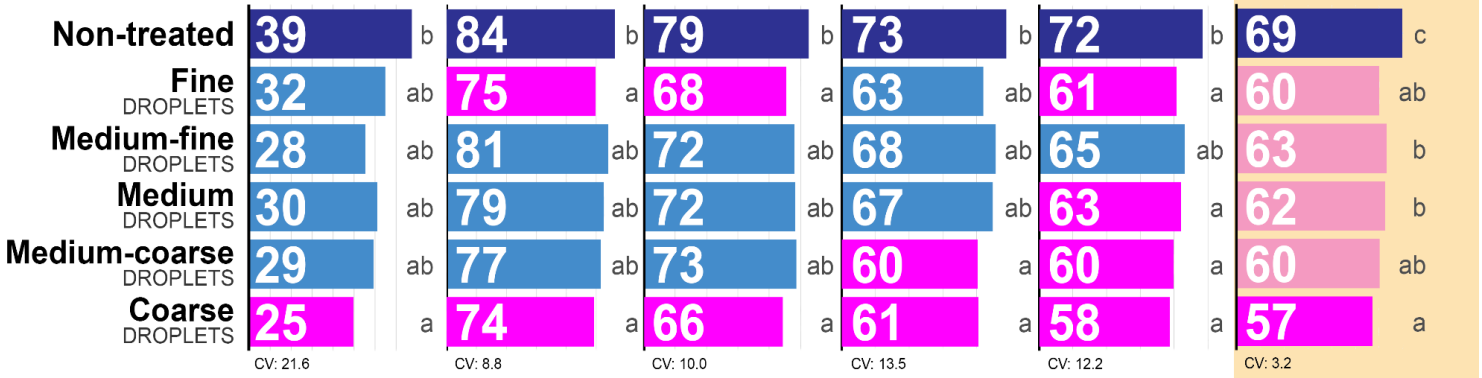
IMPACT OF SPRAY DROPLET SIZE: TEEJET NOZZLES

Soybeans

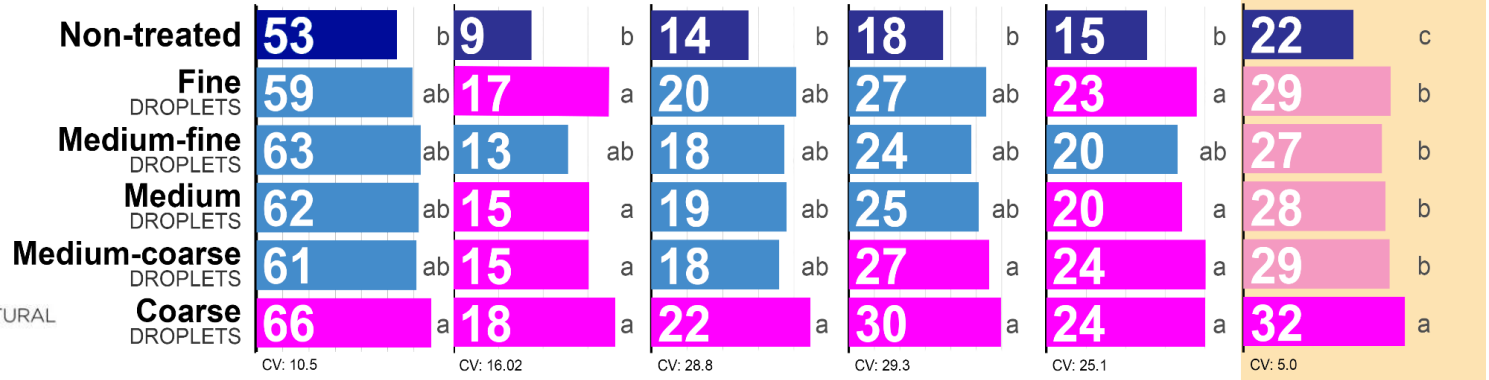
canopy closed when fungicides applied

	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)



Soybean Yield (bu/ac; 13% moisture)



North Dakota Soybean Council
Our World Is Growing.

NDSU NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION

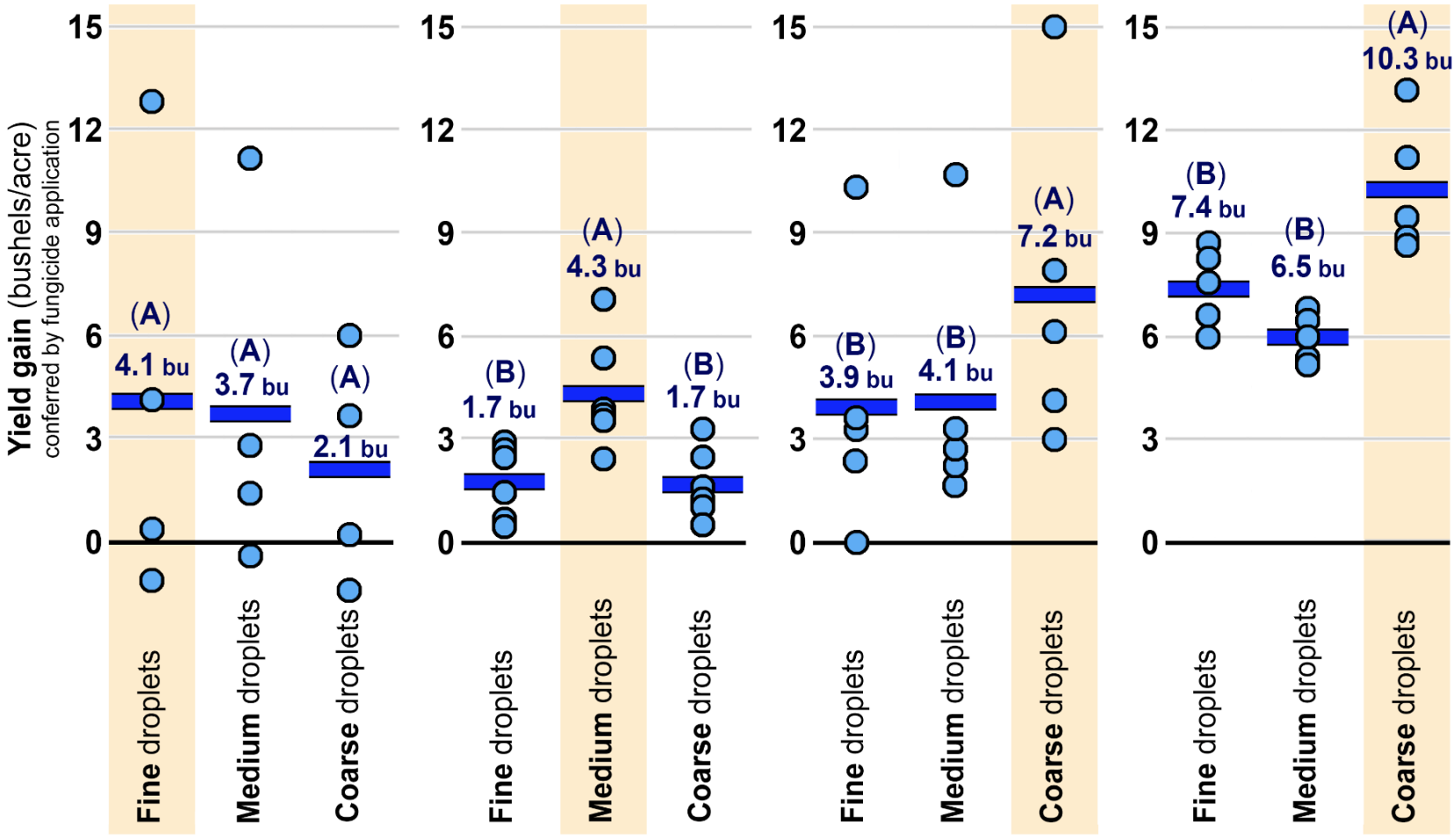
Fungicide: Endura 70WG 5.5 oz/ac except studies in Carrington in 2020, when 8.0 oz/ac was applied **Application timing:** 100% of plants at R2 growth stage **Spray volume:** 15 gal/ac
Row spacing: 21 inches **Seeding rate:** 165,000 pure live seeds/ac **Driving speed:** 10.5 mph (Carrington, 2020); 6.0 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

North Dakota Soybean Council
Our World Is Growing.

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



Droplet size rating assigned by nozzle manufacturer
for the nozzles and presures utilized

CIRCLES: results from one soybean variety in one field study **LINES:** average response across all studies

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	Carrington	Carrington	Oakes	Oakes	Carrington	COMBINED ANALYSIS
	YEAR	2020	2020	2019	2019	2020	
	soybean variety:	Dairyland 'DSR-0418'	Dairyland 'DSR-0807'	Dairyland 'DSR-1120'	Peterson '18X11N'	Peterson '18X07N'	
Canopy Closure	Average:	63%	69%	70%	73%	79%	63-79%
	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 Peterson '18X11N'	Carrington 2020 Peterson '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 Peterson '18X11N'	Carrington 2020 Peterson '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

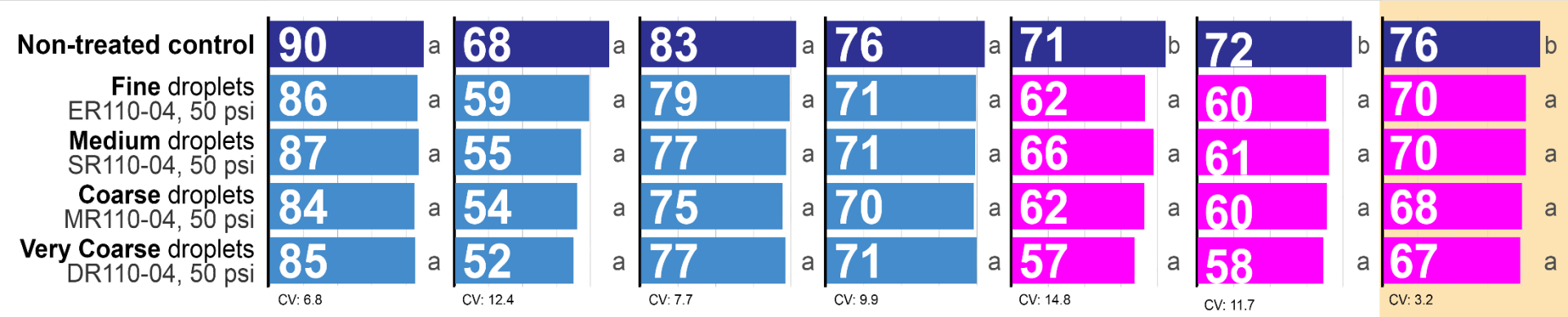
Fungicide: Endura 70WG 5.5 oz/ac **Application timing:** 100% of plants at R2 growth stage **Spray volume:** 15 gal/ac **Driving speed:** 6.0 mph (2020); 8.9 mph (2019)

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

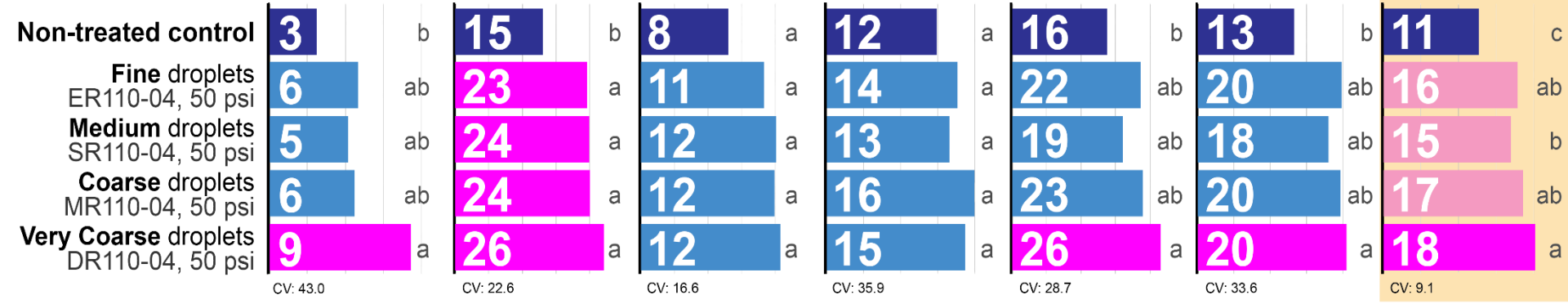
Soybeans: **canopy open** when fungicides applied

	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%
	Range:	80-100%	90-100%	98-100%	97-100%	98-100%	99-100%	Average across six varieties

White mold severity index (% of canopy diseased)



Soybean Yield (bu/ac; 13% moisture)



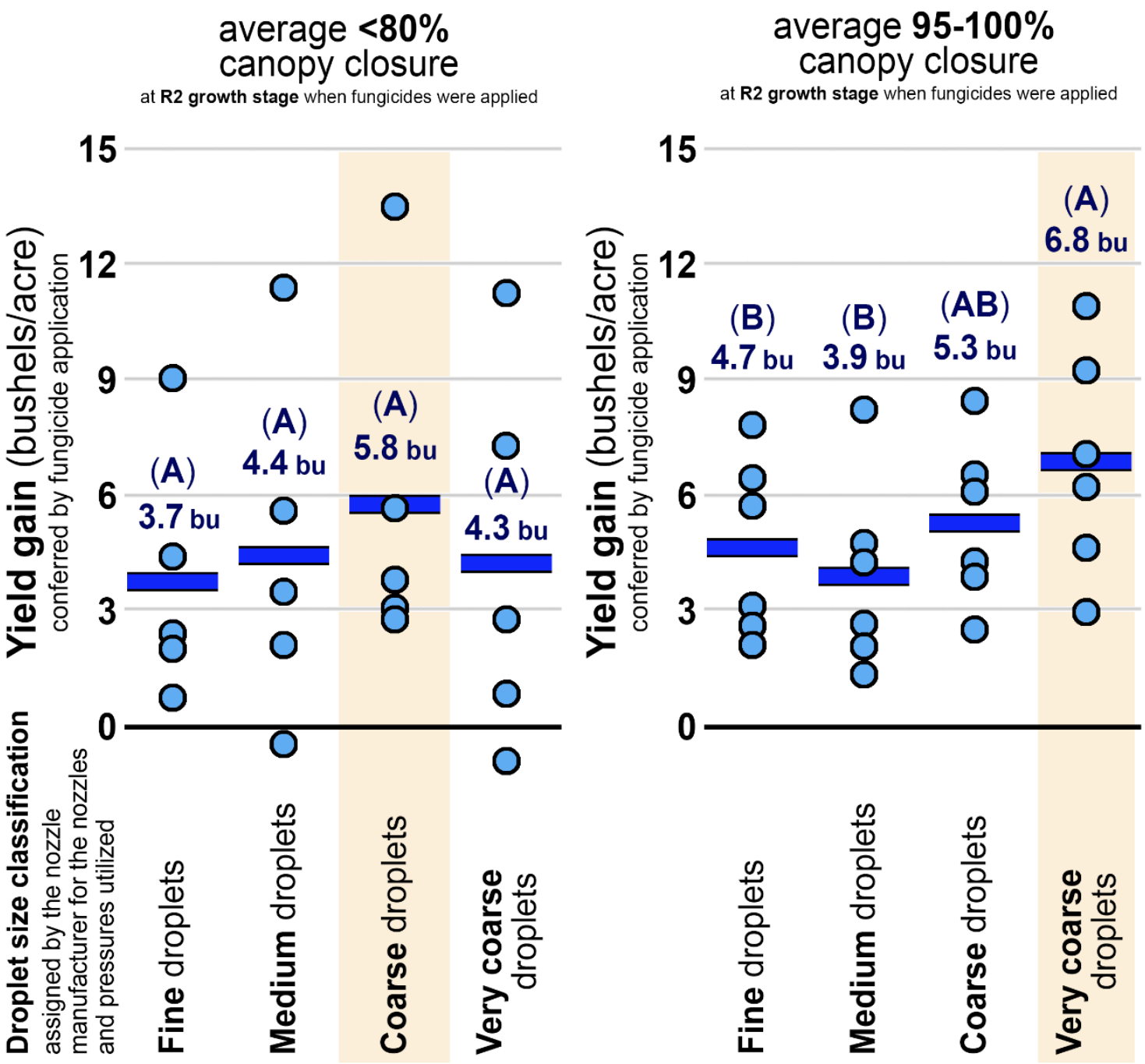
Agronomics - Row spacing: 21 inches **Seeding rate:** 165,000 viable seeds/ac

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

CIRCLES: results from one soybean variety in one field study

LINES: average response across all studies

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 dry edible beans:
2. Optimizing fungicide droplet size

Michael Wunsch
North Dakota State University Carrington Research Extension Center

Optimizing fungicide droplet size

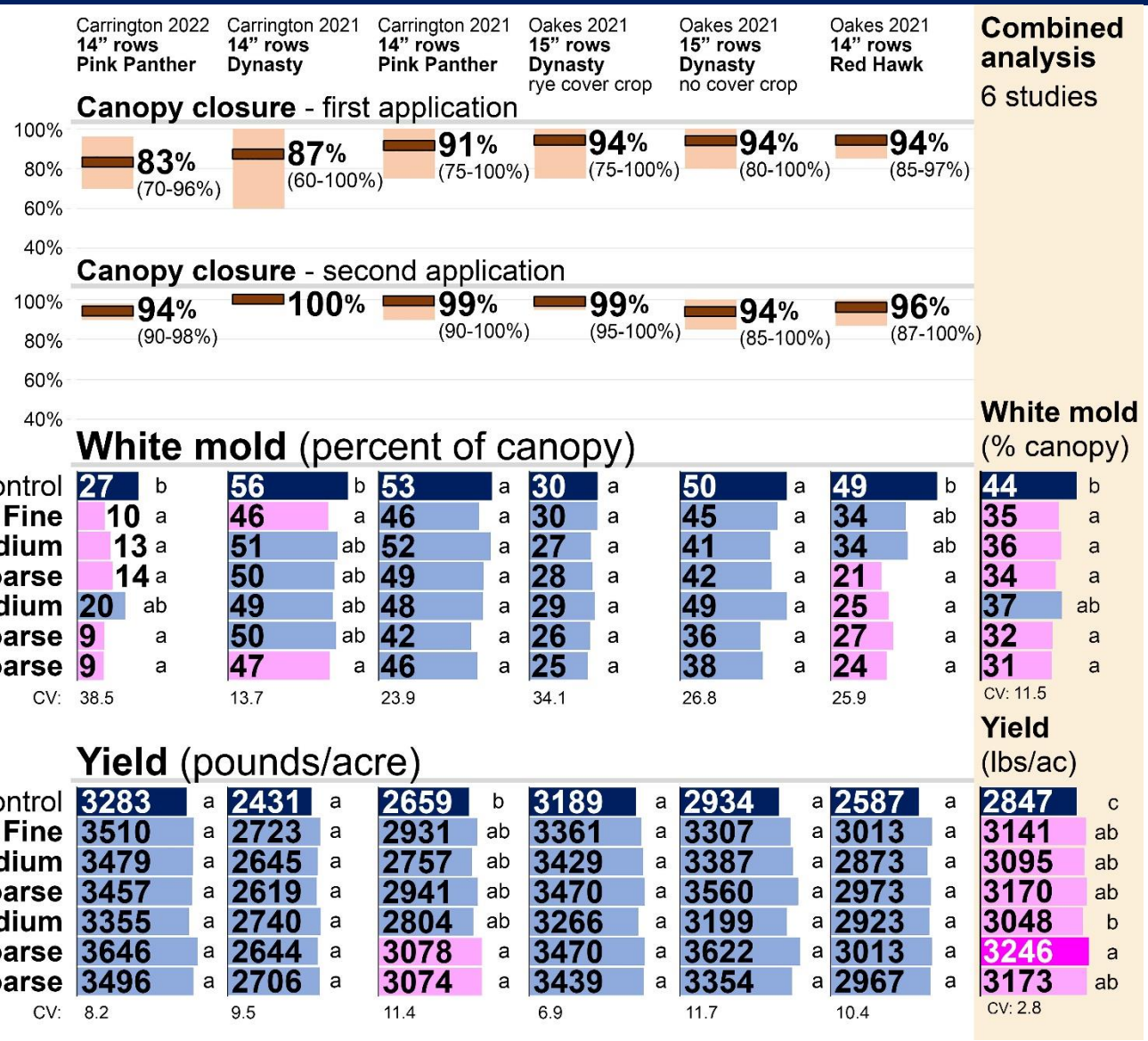
KIDNEY BEANS:

Narrow row spacing; **canopy open at 1st application**, at/near closure at 2nd applic.

Topsin 40 fl oz/ac
f.b. **Endura** 8 oz/ac

Spray volume: 15 gpa
Driving speed: 6, 10, or 10.5 mph

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



Nozzles and pressure: FINE: XR11004 or XR11005 nozzles, 60 psi MEDIUM: XR11006 nozzles, 35 psi COARSE: XR11010 nozzles, 30 psi
Driving speed: 6.0 mph in Oakes (2021), 10.5 mph in Carrington (2021), 10.0 mph in Carrington (2022).

Optimizing fungicide application timing

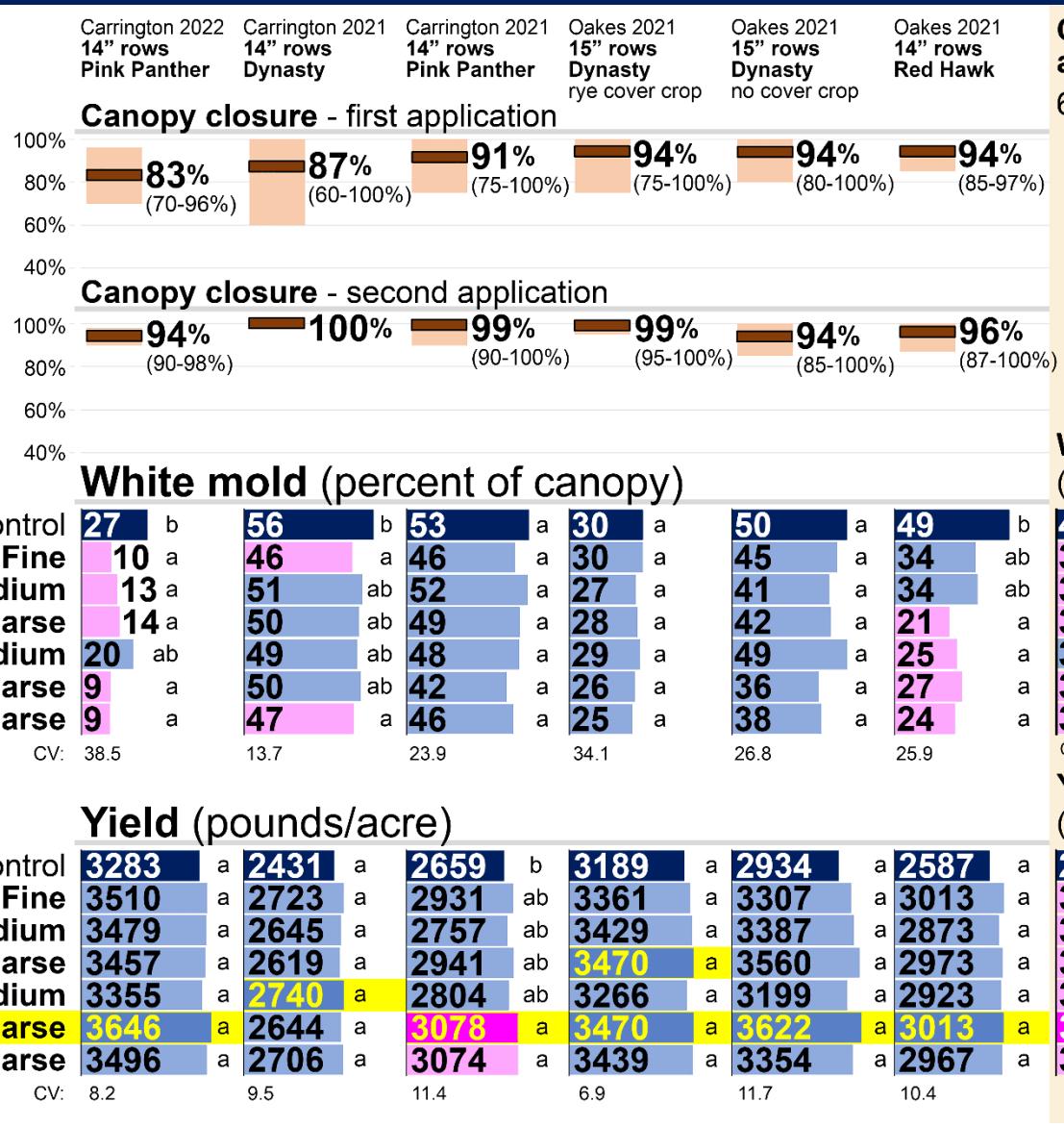
KIDNEY BEANS:

Narrow row spacing; **canopy open at 1st application**, at/near closure at 2nd applic.

Topsin 40 fl oz/ac
f.b. **Endura** 8 oz/ac

Spray volume: 15 gpa
Driving speed: 6, 10, or 10.5 mph

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



Nozzles and pressure: FINE: XR11004 or XR11005 nozzles, 60 psi MEDIUM: XR11006 nozzles, 35 psi COARSE: XR11010 nozzles, 30 psi
Driving speed: 6.0 mph in Oakes (2021), 10.5 mph in Carrington (2021), 10.0 mph in Carrington (2022).

Optimizing fungicide application timing

KIDNEY BEANS:

Narrow row spacing; canopy open at 1st application, at/near closure at 2nd applic/

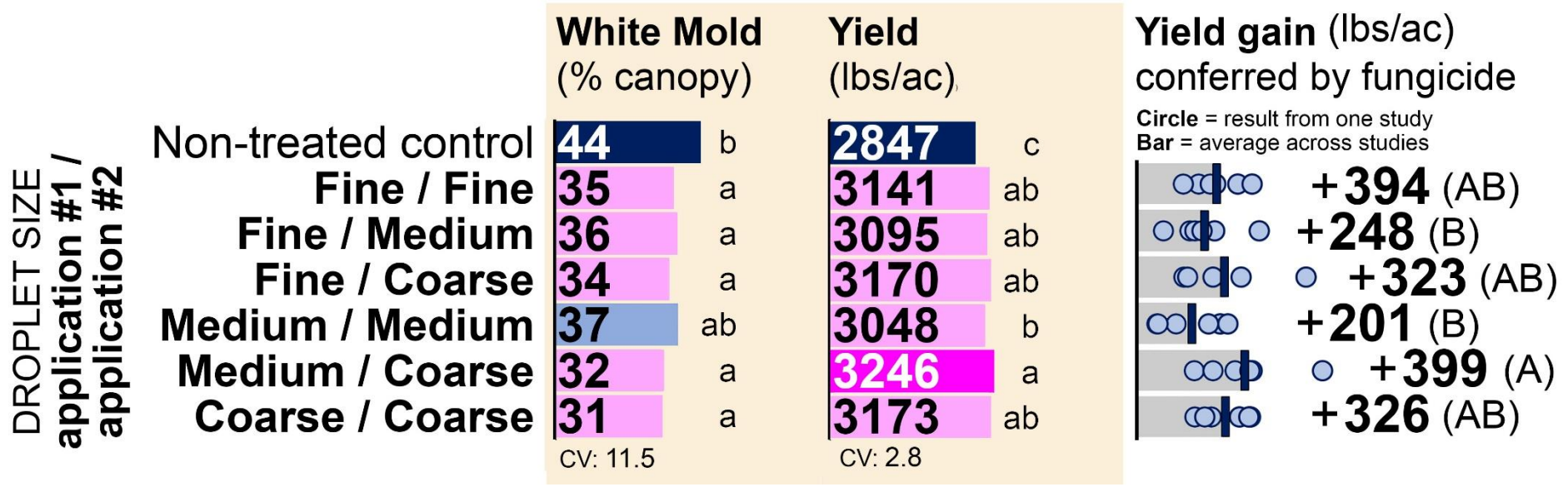
Topsin 40 fl oz/ac f.b. **Endura** 8 oz/ac | Spray volume: 15 gpa | Driving speed: 6, 10 or 10.5 mph (depending on study)

KIDNEY BEAN

combined analysis across 6 studies

14" rows open canopy at 1st application, 'Pink Panther' LR (2 studies)
14" rows open canopy at 1st application, 'Red Hawk' DR (1 study)
14-15" rows open canopy at 1st application, 'Dynasty' DR (3 studies)

Fungicide performance maximized with **medium** droplets (app. #1) **/ coarse** droplets (app. #2)



Carrington and Oakes, ND (2021, 2022)

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

Nozzles and pressure: FINE: XR11004 or XR11005 nozzles, 60 psi MEDIUM: XR11006 nozzles, 35 psi COARSE: XR11010 nozzles, 30 psi
Driving speed: 6.0 mph in Oakes (2021), 10.5 mph in Carrington (2021), 10.0 mph in Carrington (2022).

Optimizing fungicide application timing

KIDNEY BEANS:

Narrow rows with closed canopy at 1st applic.
OR
Wide row spacing with open canopy at 1st app.

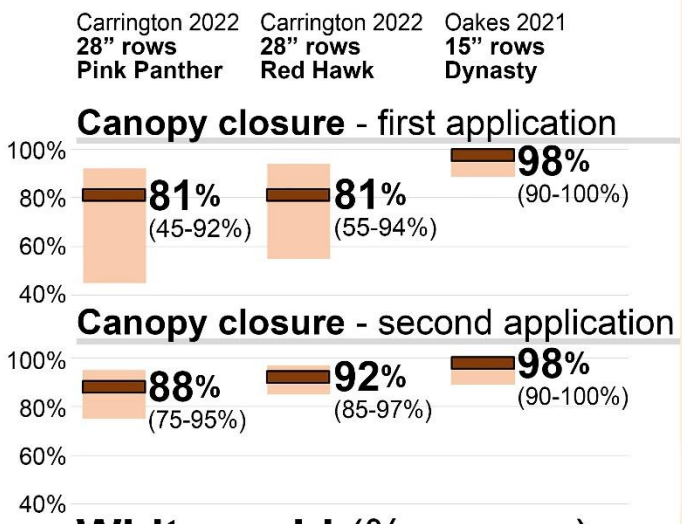
Topsin 40 fl oz/ac
f.b. **Endura** 8 oz/ac

Spray volume: 15 gpa
Driving speed: 10 mph

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

Nozzles and pressure:
FINE: XR11004 or XR11005 nozzles, 60 psi
MEDIUM: XR11006 nozzles, 35 psi
COARSE: XR11010 nozzles, 30 psi

Driving speed:
6.0 mph in Oakes (2021)
10.5 mph in Carrington (2021)
10.0 mph in Carrington (2022).



Combined analysis (3 studies)

White mold (% canopy)

DROPLET SIZE application #1 / application #2							Combined	
Non-treated control	38	b	57	b	30	a	42	a
Fine / Fine	25	a	37	a	26	a	29	a
Fine / Medium	21	a	42	ab	26	a	30	a
Fine / Coarse	22	a	40	a	33	a	32	a
Medium / Medium	30	ab	31	a	23	a	28	a
Medium / Coarse	26	ab	42	a	31	a	33	a
Coarse / Coarse	20	a	37	a	30	a	29	a
CV:	28.1		26.4		38.5		12.1	

Yield (pounds/acre)

DROPLET SIZE application #1 / application #2							Combined	
Non-treated control	2863	b	2237	b	3174	a	2758	b
Fine / Fine	3119	ab	2663	a	3494	a	3092	a
Fine / Medium	3222	ab	2525	ab	3587	a	3111	a
Fine / Coarse	3042	ab	2514	ab	3418	a	2991	ab
Medium / Medium	2964	ab	2748	a	3455	a	3056	a
Medium / Coarse	3237	ab	2591	a	3433	a	3087	a
Coarse / Coarse	3268	a	2768	a	3625	a	3220	a
CV:	8.7		9.0		8.2		3.1	

NORTHARVEST BEANS

NDSU NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION

Optimizing fungicide application timing

KIDNEY BEANS:

Narrow rows with closed canopy at 1st applic.
OR
Wide row spacing with open canopy at 1st app.

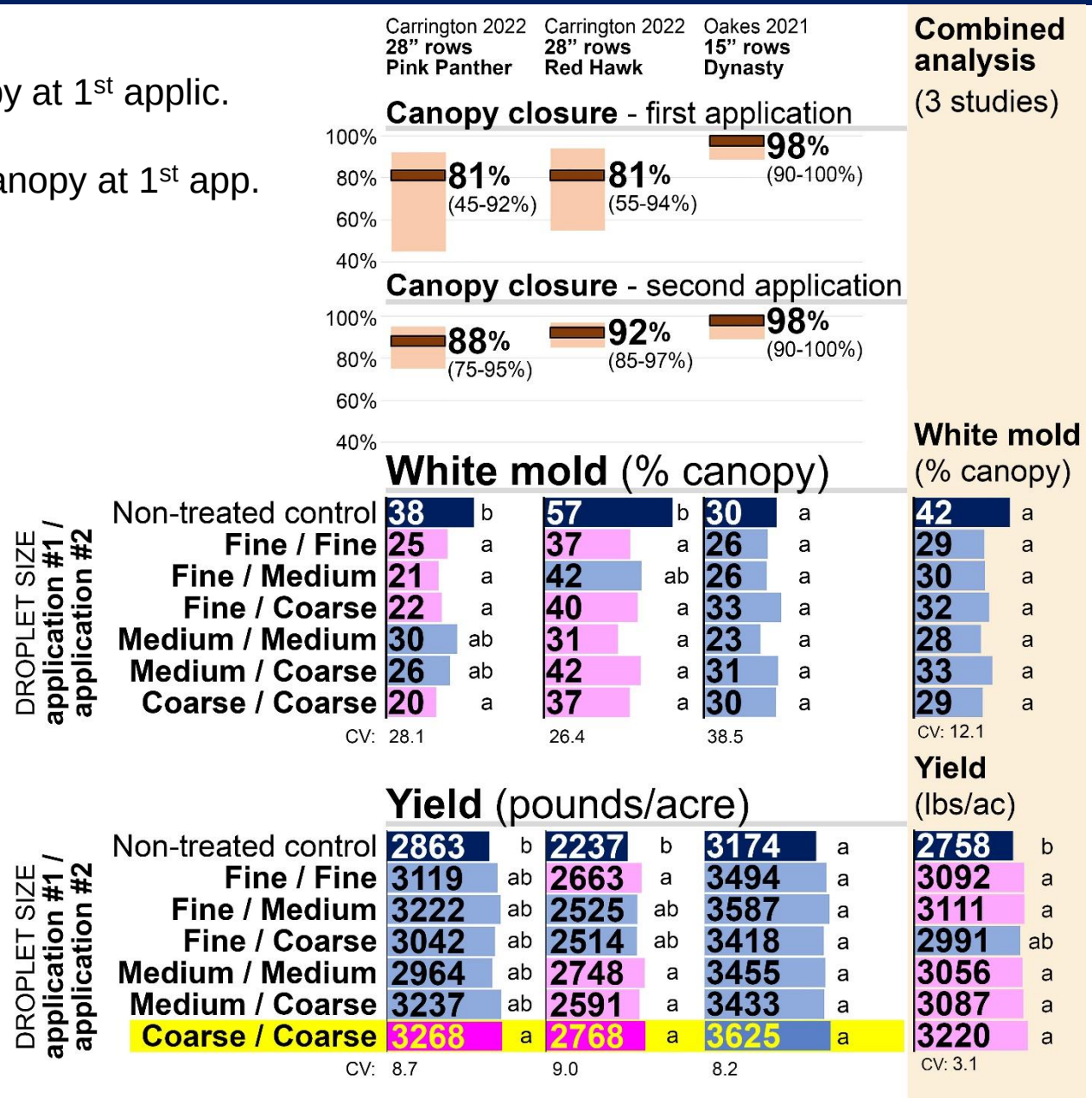
Topsin 40 fl oz/ac
f.b. **Endura** 8 oz/ac

Spray volume: 15 gpa
Driving speed: 10 mph

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

Nozzles and pressure:
FINE: XR11004 or XR11005 nozzles, 60 psi
MEDIUM: XR11006 nozzles, 35 psi
COARSE: XR11010 nozzles, 30 psi

Driving speed:
6.0 mph in Oakes (2021)
10.5 mph in Carrington (2021)
10.0 mph in Carrington (2022).



NORTHARVEST BEANS

NDSU NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION

Optimizing fungicide application timing

KIDNEY BEANS:

Narrow row spacing; canopy closed at 1st application OR
Wide row spacing; canopy open at 1st application

Topsin 40 fl oz/ac f.b. **Endura** 8 oz/ac | Spray volume: 15 gpa | Driving speed: 6 or 10 mph (depending on study)

KIDNEY BEAN

combined analysis across 3 studies

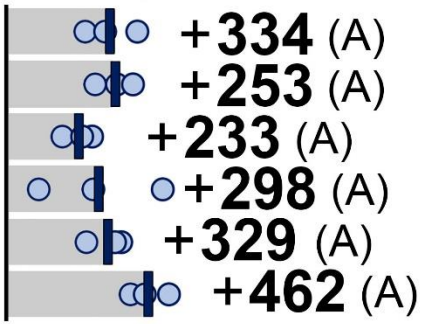
28" rows, 'Pink Panther' LR
28" rows, 'Red Hawk' DR
15" rows closed canopy at 1st application, 'Dynasty'

Fungicide performance maximized with **coarse** droplets (app. #1) **/ coarse** droplets (app. #2)

DROPLET SIZE application #1 / application #2	White Mold (% canopy)		Yield (lbs/ac)	
Non-treated control	42	a	2758	b
Fine / Fine	29	a	3092	a
Fine / Medium	30	a	3111	a
Fine / Coarse	32	a	2991	ab
Medium / Medium	28	a	3056	a
Medium / Coarse	33	a	3087	a
Coarse / Coarse	29	a	3220	a
	CV: 12.1		CV: 3.1	

Yield gain (lbs/ac) conferred by fungicide

Circle = result from one study
Bar = average across studies



Carrington and Oakes, ND (2021, 2022)

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

Nozzles and pressure: FINE: XR11004 or XR11005 nozzles, 60 psi MEDIUM: XR11006 nozzles, 35 psi COARSE: XR11010 nozzles, 30 psi
Driving speed: 6.0 mph in Oakes (2021), 10.5 mph in Carrington (2021), 10.0 mph in Carrington (2022).

Optimizing fungicide droplet size

Kidney beans:

Preliminary findings from ongoing research –

- When kidney beans were seeded into narrow (14-15”) rows and the canopy was open at the first fungicide application, **medium droplets (app. 1) followed by coarse droplets (app. 2)** were optimal
- When kidney beans were seeded into wide (28-30”) rows and the canopy was open at the 1st application or seeded into narrow (14-15”) rows and the canopy was closed at the 1st application, **coarse droplets (app. 1) followed by coarse droplets (app. 2)** were optimal

Warning: This research was done with TeeJet nozzles. The droplet size spectrum considered ‘medium’, ‘coarse’ etc. differs by nozzle manufacturer.

IMPROVING WHITE MOLD MANAGEMENT IN DRY EDIBLE BEANS

Optimizing fungicide application timing

PINTO BEANS

Four studies: fine droplets (1st app.) / medium droplets (2nd app.) optimal **Canopy characteristics favoring these droplet sizes not well understood.**

Topsin 40 fl oz/ac f.b. **Endura** 8 oz/ac

Spray volume: 15 gpa
Driving speed: 6 or 10 mph

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

Nozzles and pressure:
FINE: XR11004 or XR11005, 60 psi
MEDIUM: XR11006 nozzles, 35 psi
COARSE: XR11010 nozzles, 30 psi

Driving speed:
6.0 mph in Oakes (2021)
10.5 mph in Carrington (2021)
10.0 mph in Carrington (2022).

	Oakes 2021 **15" rows Palomino**	Carrington 2022 **14" rows Palomino**	Oakes 2022 **28" rows Palomino**	Oakes 2022 **14" rows Palomino**	**COMBINED ANALYSIS** across 4 studies
Canopy closure - first application	68% (45-95%)	61% (50-75%)	59% (40-80%)	78% (60-100%)	
Canopy closure - second application	86% (60-100%)	90% (75-98%)	96% (90-100%)	98% (95-100%)	

White mold (percent of canopy)

Droplet size application #1 / application #2	Oakes 2021		Carrington 2022		Oakes 2022 28"		Oakes 2022 14"		**White Mold (% of canopy)**	
Non-treated control	29	b	69	b	42	b	37	b	44	b
Fine / Fine	16	ab	54	ab	22	a	24	a	29	a
Fine / Medium	10	a	43	a	25	a	19	a	24	a
Fine / Coarse	14	ab	39	a	28	ab	28	ab	27	a
Medium / Medium	21	ab	40	a	28	ab	20	a	27	a
Medium / Coarse	16	ab	48	a	24	a	19	a	27	a
Coarse / Coarse	16	ab	43	a	24	a	20	a	26	a
CV:	31.8		6.3		38.5		39.0		CV: 14.7	

Yield (pounds/acre)

Droplet size application #1 / application #2	Oakes 2021		Carrington 2022		Oakes 2022 28"		Oakes 2022 14"		**Yield (pounds/acre)**	
Non-treated control	2912	a	2612	b	2987	b	3529	a	3010	a
Fine / Fine	3407	a	3277	a	3461	a	3861	a	3502	a
Fine / Medium	3336	a	3631	a	3426	a	3942	a	3584	a
Fine / Coarse	3208	a	3254	a	3210	ab	3728	a	3350	a
Medium / Medium	3060	a	3411	a	3240	ab	3816	a	3382	a
Medium / Coarse	3186	a	3210	ab	3332	ab	3774	a	3375	a
Coarse / Coarse	3173	a	3606	a	3366	ab	3630	a	3444	a
CV:	13.6		9.0		9.1		8.0		CV: 4.1	

NORTHARVEST BEANS

NDSU NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION

Optimizing fungicide application timing

PINTO BEANS

Four studies: fine droplets (1st app.) / medium droplets (2nd app.) optimal **Canopy characteristics favoring these droplet sizes not well understood.**

Topsin 40 fl oz/ac f.b. **Endura** 8 oz/ac

Spray volume: 15 gpa
Driving speed: 6 or 10 mph

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

Nozzles and pressure:
FINE: XR11004 or XR11005, 60 psi
MEDIUM: XR11006 nozzles, 35 psi
COARSE: XR11010 nozzles, 30 psi

Driving speed:
6.0 mph in Oakes (2021)
10.5 mph in Carrington (2021)
10.0 mph in Carrington (2022).

	Oakes 2021 **15" rows Palomino**	Carrington 2022 **14" rows Palomino**	Oakes 2022 **28" rows Palomino**	Oakes 2022 **14" rows Palomino**	**COMBINED ANALYSIS** across 4 studies
Canopy closure - first application	68% (45-95%)	61% (50-75%)	59% (40-80%)	78% (60-100%)	
Canopy closure - second application	86% (60-100%)	90% (75-98%)	96% (90-100%)	98% (95-100%)	

White mold (percent of canopy)

Droplet size application #1 / application #2	Oakes 2021		Carrington 2022		Oakes 2022 28"		Oakes 2022 14"		**White Mold** (% of canopy)	
Non-treated control	29	b	69	b	42	b	37	b	44	b
Fine / Fine	16	ab	54	ab	22	a	24	a	29	a
Fine / Medium	10	a	43	a	25	a	19	a	24	a
Fine / Coarse	14	ab	39	a	28	ab	28	ab	27	a
Medium / Medium	21	ab	40	a	28	ab	20	a	27	a
Medium / Coarse	16	ab	48	a	24	a	19	a	27	a
Coarse / Coarse	16	ab	43	a	24	a	20	a	26	a
CV:	31.8		6.3		38.5		39.0		CV: 14.7	

Yield (pounds/acre)

Droplet size application #1 / application #2	Oakes 2021		Carrington 2022		Oakes 2022 28"		Oakes 2022 14"		**Yield** (pounds/acre)	
Non-treated control	2912	a	2612	b	2987	b	3529	a	3010	a
Fine / Fine	3407	a	3277	a	3461	a	3861	a	3502	a
Fine / Medium	3336	a	3631	a	3426	a	3942	a	3584	a
Fine / Coarse	3208	a	3254	a	3210	ab	3728	a	3350	a
Medium / Medium	3060	a	3411	a	3240	ab	3816	a	3382	a
Medium / Coarse	3186	a	3210	ab	3332	ab	3774	a	3375	a
Coarse / Coarse	3173	a	3606	a	3366	ab	3630	a	3444	a
CV:	13.6		9.0		9.1		8.0		CV: 4.1	

NORTHARVEST BEANS

NDSU NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION

Optimizing fungicide application timing

PINTO BEANS:

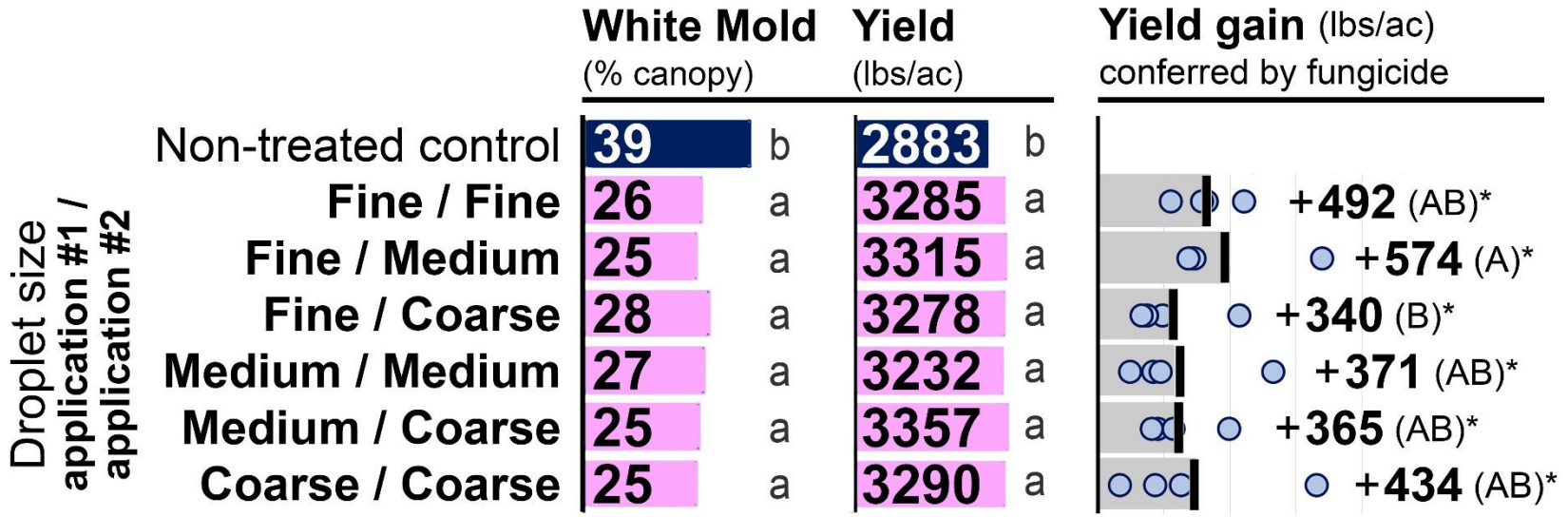
Four studies: fine droplets (1st app.) / medium droplets (2nd app.) optimal

Canopy characteristics favoring these droplet sizes not well understood.

Topsin 40 fl oz/ac f.b. **Endura** 8 oz/ac | Spray volume: 15 gpa | Driving speed: 6 or 10 mph, depending on study

PINTO BEAN

(A) Fungicide performance maximized with **fine** droplets (application #1) **/ medium** droplets (application #2)



Combined analysis of **four studies** seeded to **'Palomino'** pintos:
Oakes, 2021, 15" row spacing; Carrington, 2022, 14" row spacing; Oakes, 2022, 14" and 28" row spacing

Within-column means followed by different letters are significantly different ($P < 0.05$) or ($P < 0.10$) if followed by an asterisk

Nozzles and pressure: FINE: XR11004 or XR11005 nozzles, 60 psi MEDIUM: XR11006 nozzles, 35 psi COARSE: XR11010 nozzles, 30 psi
Driving speed: 6.0 mph in Oakes (2021), 10.5 mph in Carrington (2021), 10.0 mph in Carrington (2022).

IMPROVING WHITE MOLD MANAGEMENT IN DRY EDIBLE BEANS

Optimizing fungicide application timing

PINTO BEANS

Four studies: medium droplets (1st app) / coarse droplets (2nd app.) optimal
Canopy characteristics favoring these droplet sizes not well understood.

Topsin 40 fl oz/ac f.b. **Endura** 8 oz/ac

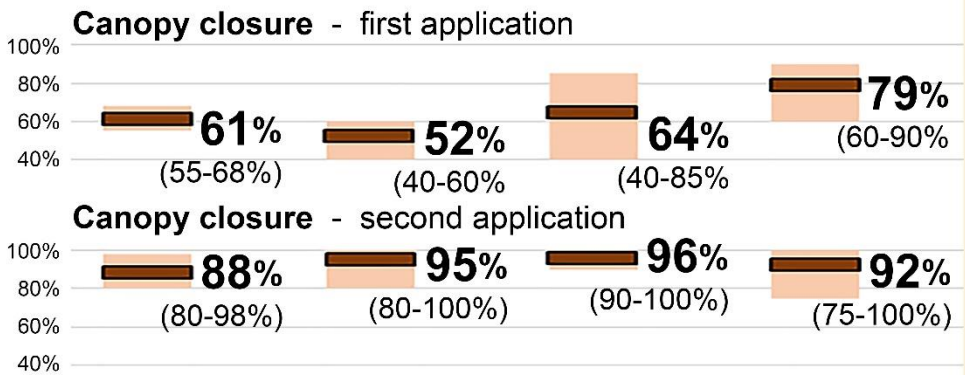
Spray volume: 15 gpa
Driving speed: 6, 10, or 10.5 mph

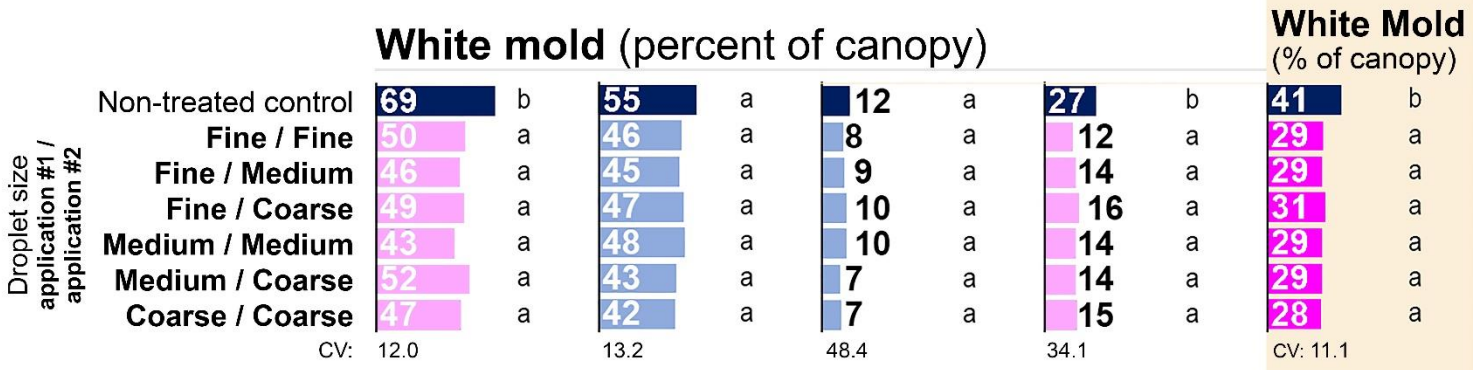
Within-column means followed by different letters are significantly different (*P* < 0.05; Tukey procedure)

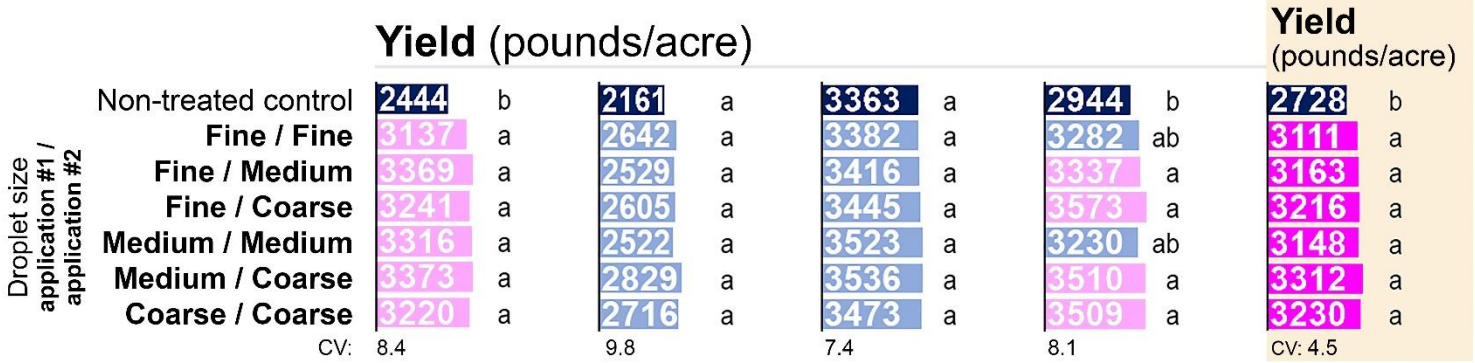
Nozzles and pressure:
FINE: XR11004 or XR11005, 60 psi
MEDIUM: XR11006 nozzles, 35 psi
COARSE: XR11010 nozzles, 30 psi

Driving speed:
6.0 mph in Oakes (2021)
10.5 mph in Carrington (2021)
10.0 mph in Carrington (2022).

	Carrington 2022 **28" rows Palomino**	Carrington 2021 **14" rows Palomino**	Oakes 2021 **15" rows Palomino** late-terminated rye	Oakes 2021 **15" rows Palomino** early-terminated rye	**COMBINED ANALYSIS** across 4 studies







NORTHARVEST BEANS

NDSU NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION

IMPROVING WHITE MOLD MANAGEMENT IN DRY EDIBLE BEANS

Optimizing fungicide application timing

PINTO BEANS

Four studies: medium droplets (1st app) / coarse droplets (2nd app.) optimal
Canopy characteristics favoring these droplet sizes not well understood.

Topsin 40 fl oz/ac f.b. **Endura** 8 oz/ac

Spray volume: 15 gpa
Driving speed: 6, 10 or 10.5 mph

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

Nozzles and pressure:
FINE: XR11004 or XR11005, 60 psi
MEDIUM: XR11006 nozzles, 35 psi
COARSE: XR11010 nozzles, 30 psi

Driving speed:
6.0 mph in Oakes (2021)
10.5 mph in Carrington (2021)
10.0 mph in Carrington (2022).

	Carrington 2022 **28" rows Palomino**	Carrington 2021 **14" rows Palomino**	Oakes 2021 **15" rows Palomino** late-terminated rye	Oakes 2021 **15" rows Palomino** early-terminated rye	**COMBINED ANALYSIS** across 4 studies
Canopy closure - first application	61% (55-68%)	52% (40-60%	64% (40-85%)	79% (60-90%	
Canopy closure - second application	88% (80-98%)	95% (80-100%)	96% (90-100%)	92% (75-100%)	

White mold (percent of canopy)

Droplet size application #1 / application #2	Carrington 2022		Carrington 2021		Oakes 2021 late-terminated rye		Oakes 2021 early-terminated rye		**White Mold** (% of canopy)	
Non-treated control	69	b	55	a	12	a	27	b	41	b
Fine / Fine	50	a	46	a	8	a	12	a	29	a
Fine / Medium	46	a	45	a	9	a	14	a	29	a
Fine / Coarse	49	a	47	a	10	a	16	a	31	a
Medium / Medium	43	a	48	a	10	a	14	a	29	a
Medium / Coarse	52	a	43	a	7	a	14	a	29	a
Coarse / Coarse	47	a	42	a	7	a	15	a	28	a
CV:	12.0		13.2		48.4		34.1		CV: 11.1	

Yield (pounds/acre)

Droplet size application #1 / application #2	Carrington 2022		Carrington 2021		Oakes 2021 late-terminated rye		Oakes 2021 early-terminated rye		**Yield** (pounds/acre)	
Non-treated control	2444	b	2161	a	3363	a	2944	b	2728	b
Fine / Fine	3137	a	2642	a	3382	a	3282	ab	3111	a
Fine / Medium	3369	a	2529	a	3416	a	3337	a	3163	a
Fine / Coarse	3241	a	2605	a	3445	a	3573	a	3216	a
Medium / Medium	3316	a	2522	a	3523	a	3230	ab	3148	a
Medium / Coarse	3373	a	2829	a	3536	a	3510	a	3312	a
Coarse / Coarse	3220	a	2716	a	3473	a	3509	a	3230	a
CV:	8.4		9.8		7.4		8.1		CV: 4.5	

NORTHARVEST BEANS

NDSU NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION

Optimizing fungicide application timing

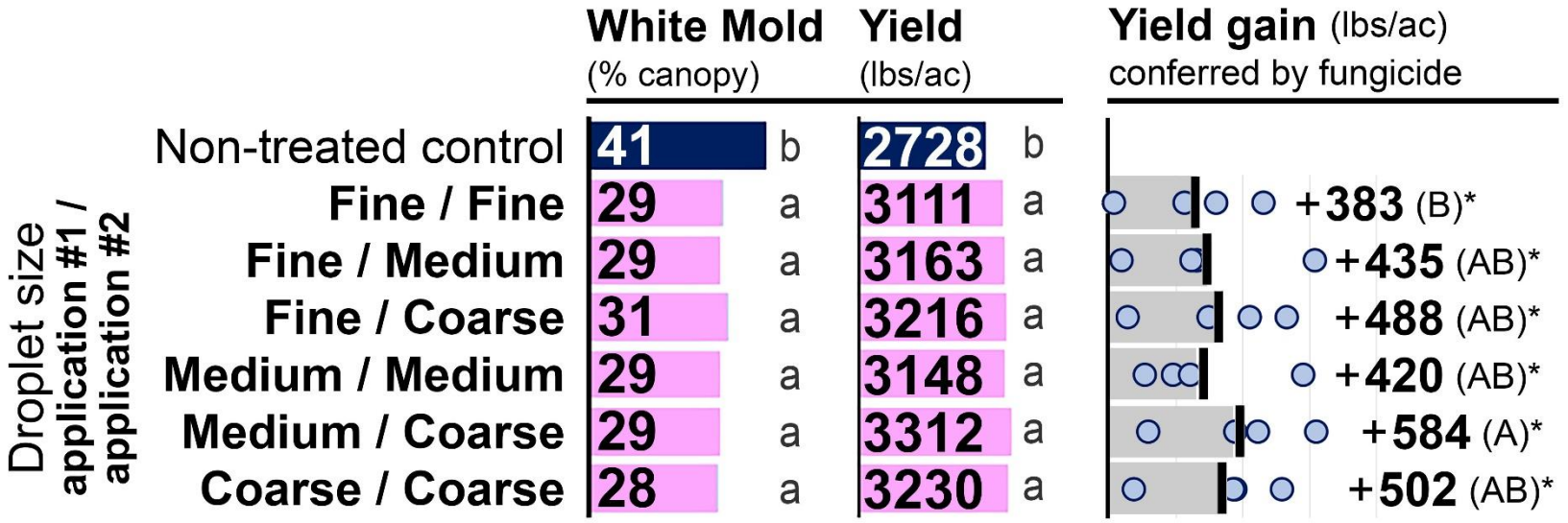
PINTO BEANS:

Four studies: medium droplets (1st app.) / coarse droplets (2nd app.) optimal
Canopy characteristics favoring these droplet sizes not well understood.

Topsin 40 fl oz/ac f.b. **Endura** 8 oz/ac | Spray volume: 15 gpa | Driving speed: 10 mph

PINTO BEAN

(B) Fungicide performance maximized with
medium droplets (application #1) **/ coarse** droplets (application #2)



Circle = result from one study
Bar = average across studies

Combined analysis of **four studies** seeded to **'Palomino'** pintos:
Carrington, 2021, 14" row spacing; two studies, Oakes, 2021, 15" row spacing; Carrington, 2022, 15" row spacing

Within-column means followed by different letters are significantly different ($P < 0.05$) or ($P < 0.10$) if followed by an asterisk

Nozzles and pressure: FINE: XR11004 or XR11005 nozzles, 60 psi MEDIUM: XR11006 nozzles, 35 psi COARSE: XR11010 nozzles, 30 psi
Driving speed: 6.0 mph in Oakes (2021), 10.5 mph in Carrington (2021), 10.0 mph in Carrington (2022).

Optimizing fungicide droplet size

Pinto beans:

Preliminary findings from ongoing research –

- In four studies, **fine droplets (app. 1) followed by medium droplets (app. 2)** were optimal
- In four studies, **medium droplets (app. 1) followed by coarse droplets (app. 2)** were optimal
- In all studies, the optimal droplet size increased as canopy density increased between fungicide applications 1 and 2
- The canopy characteristics at which fine vs. medium droplets are optimal at the first application are not understood yet.

Warning: This research was done with TeeJet nozzles. The droplet size spectrum considered ‘medium’, ‘coarse’ etc. differs by nozzle manufacturer.




Thank you - Your checkoff dollars helped fund this research.

Michael Wunsch, Jesse Hafner, Thomas Miorini, Kaitlyn Thompson, Suanne Kallis, Billy Kraft, Michael Schaefer NDSU Carrington REC
Heidi Eslinger, Spencer 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**
THE **NORTHARVEST BEAN GROWERS ASSOCIATION**
ND CROP PROTECTION PRODUCT HARMONIZATION & REGISTRATION BOARD
ND DEPARTMENT OF AGRICULTURE USDA SPECIALTY CROP BLOCK GRANT PROGRAM

North Dakota Soybean Council
Our World Is Growing.

NORTHARVEST BEANS
MINNESOTA
NORTH DAKOTA

NDSU NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION