Improving management of white mold in **kidney beans**: Optimizing **fungicide spray droplet size**

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Optimizing fungicide droplet size

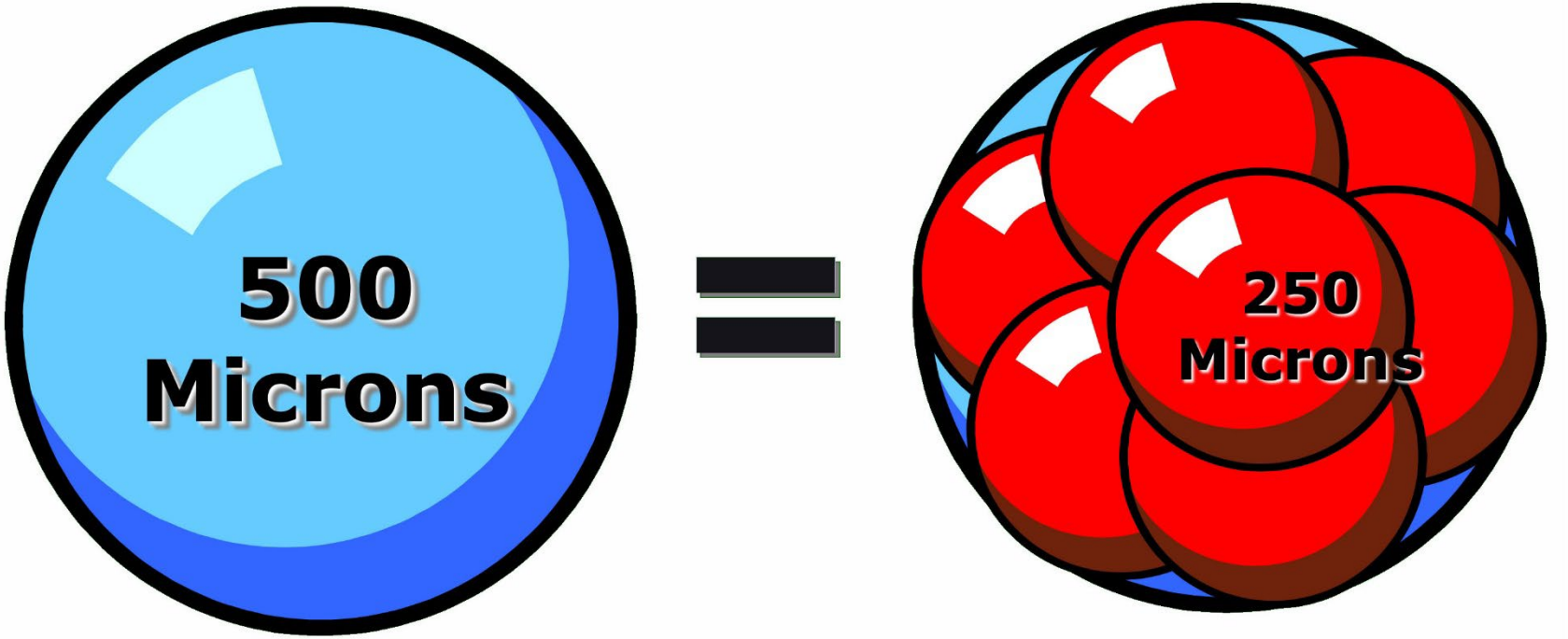
Research question:
How do we optimize fungicide droplet size relative to canopy characteristics to improve white mold management in kidney beans?

- *White mold develops in the interior of the canopy*
- *Fine droplets provide excellent coverage to the upper canopy but do not have the velocity to penetrate a dense canopy*
- *Sharp improvements in white mold management have been observed by calibrating fungicide droplet size relative to canopy closure in soybeans*

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)

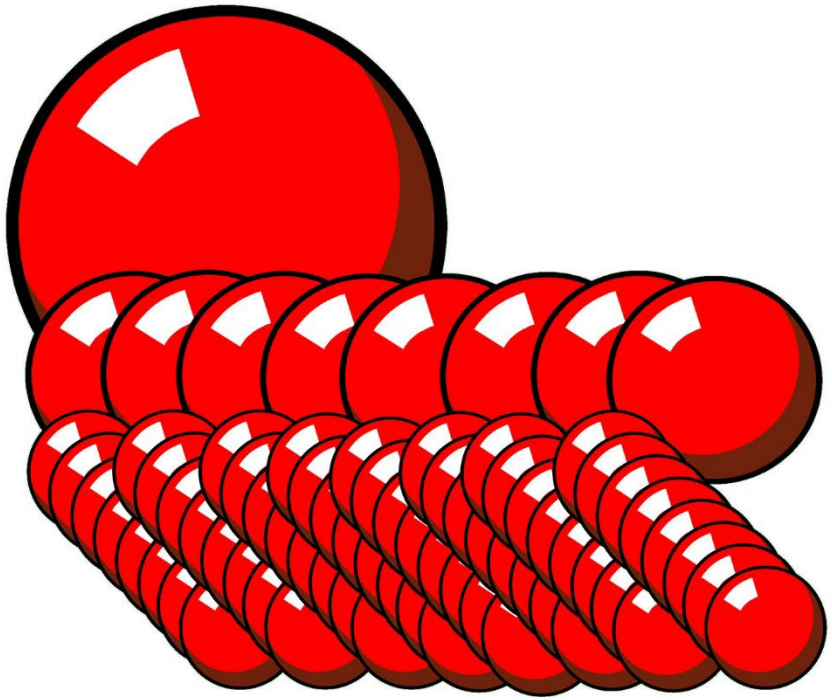
Droplet size

0.065 mm^3 spray volume =

one 500-um diameter droplet

eight 250-um diameter droplets

sixty-four 125-um diameter droplets



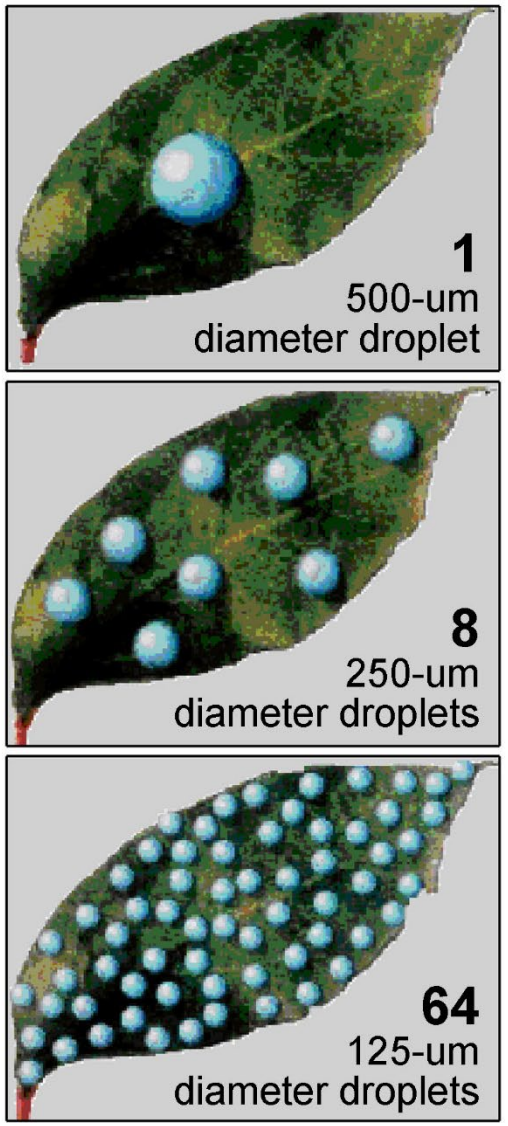
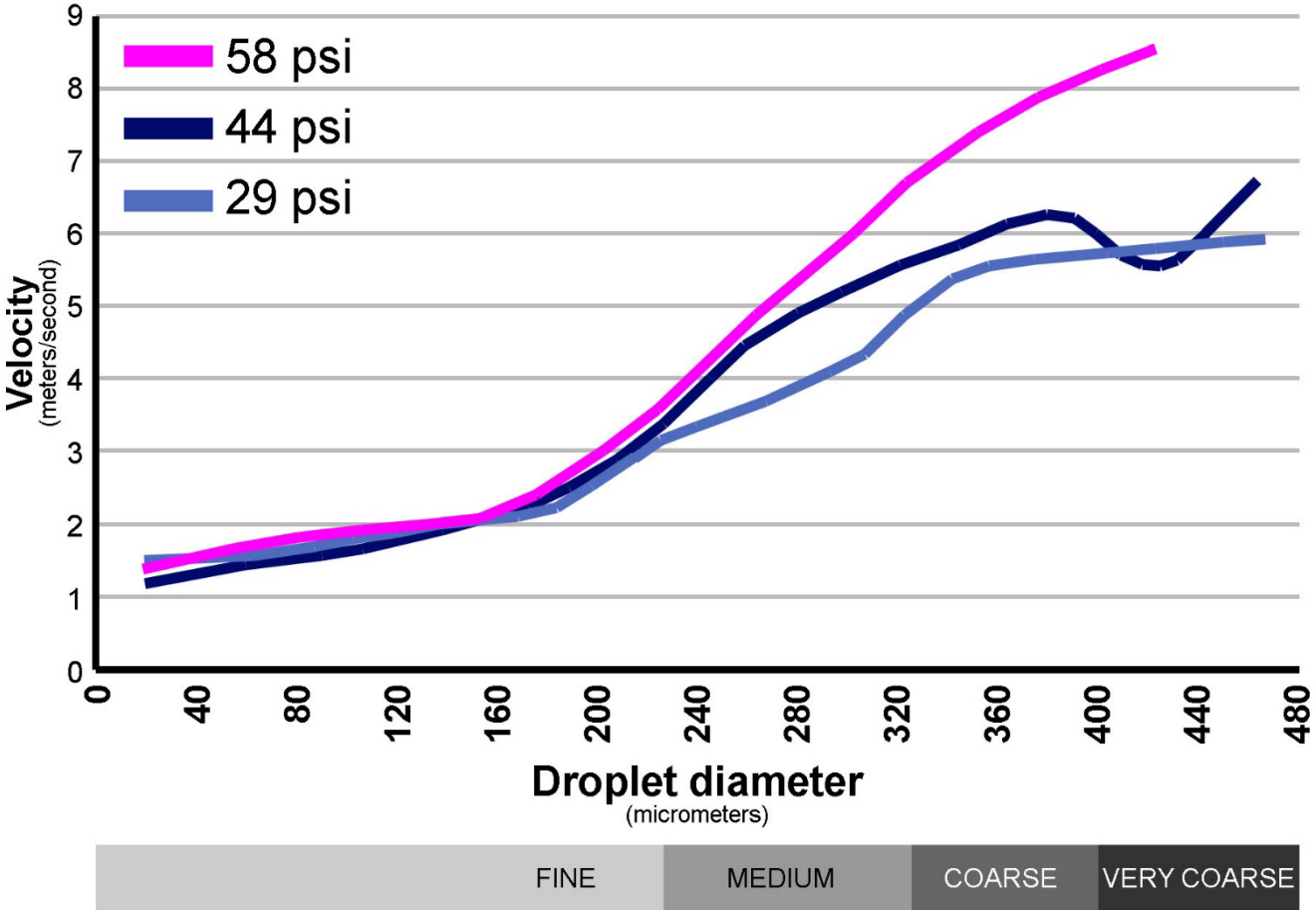


Image adapted from a presentation by Bob Wolf (Kansas State Univ.); Bobby Grisso and Pat Hipkins (Virginia Tech Univ.); and Tom Reed (TeeJet)

Droplet size

… but larger droplets have greater velocity, drift less.

Increased velocity and reduced drift improves canopy penetration.



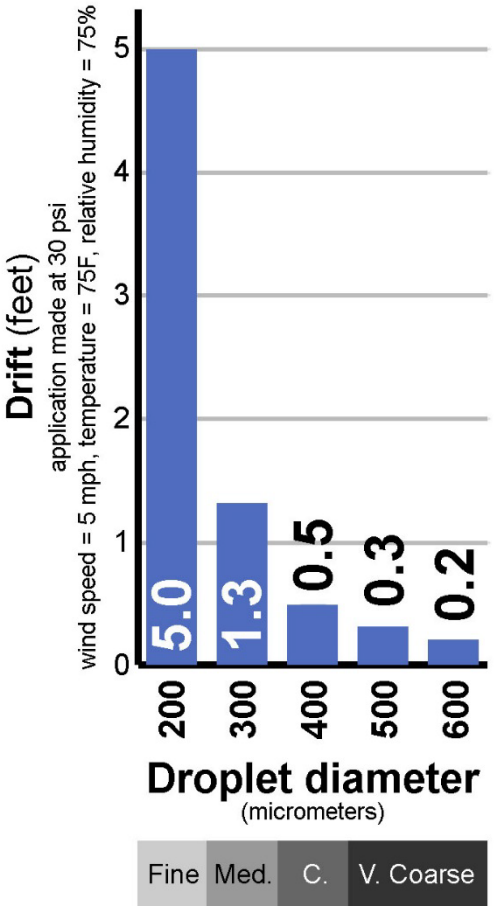


Image adapted from a presentation by Bob Wolf (Kansas State Univ.); Bobby Grisso and Pat Hipkins (Virginia Tech Univ.); and Tom Reed (TeeJet)

Experimental Methods

TeeJet extended-range (XR) flat-fan nozzles were used in these studies

Nozzles and application pressures were selected on from the charts in the TeeJet nozzle catalog

The droplet size spectrum was characterized with a laser-based system in the wind tunnel at Winfield United's R&D facility in River Falls, WI

Nozzle, pressure	Droplet size TeeJet catalog	DV50 (µm) and droplet size Characterized in wind tunnel
XR11004, 60 psi	Fine	247.3 = fine
XR11005, 60 psi	Fine	269.0 = medium
XR11006, 35 psi	Medium	339.5 = medium
XR11010, 30 psi	Coarse	393.1 = coarse

Improving white mold management in dry beans:
Fungicide spray volume – methods

Study location: Carrington

Row spacing = 14 or 28 inches

Seeding rate = 90,000 viable seeds/ac

Fungicide spray volume = 15 gal/ac.

Driving speed = 6.0, 10.0 or 10.5 mph, depending on the study

Driving speed and spray volume were kept constant across droplet size treatments differing in spray output by modifying pulse width.

Number of experimental replicates = 8 to 17, depending on the study year

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

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

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

Improving white mold management in dry beans:
Fungicide droplet size – methods

Methods - Fungicide droplet size studies, kidney beans

Location	Oakes	Carrington	Carrington	Carrington	Carrington
Year	2021	2024	2021	2022	2023
Driving speed	6.0 mph	6.0 mph	10.5 mph	10.0 mph	10.0 mph
Fine droplets	XR11004, 60 psi		XR11005, 60 psi		
Medium droplets	XR11006, 35 psi		XR11006, 35 psi		
Coarse droplets	XR11010, 30 psi		XR11010, 30 psi		
Application #1	Topsin 40 oz	Topsin 40 oz	Topsin 40 oz	Topsin 40 oz	Topsin 40 oz
Application #2	Endura 8 oz	Endura 8 oz	Endura 8 oz	Endura 8 oz	Endura 8 oz
Applic. interval	14 days	7 days	12 days	11 days	10 days
Plot size (average)	5 x 15.0 ft	5 x 22.7 ft	5 x 16.4 ft	5 ft x 15.6 ft	10 ft x 13.9 ft
Experimental reps	17	8	12	8 or 10	10

Plot size = Harvested plot size. The planted plot size and sprayed area were larger.

Non-harvested plots were established on either side and either end of sprayed plots to permit overspray of treatments and facilitate turning on and off the spray boom between treatment plots while maintaining full driving speed.

Calibration

Pulse width was modified as needed to maintain the same driving speed and spray volume across droplet size treatments.

Pulse-width calibration was manually conducted in the field (with the fungicide in the tank) **immediately before application.**

Objectives:

1. **Ensure the precise target spray volume.** Manual adjustments to pulse width were made as needed.
2. **Confirm that all nozzles are operating correctly** – consistent output across all nozzles; no plugs.

Calibration

A pulse width modulation system from Capstan AG that permits manual pulse width calibration was utilized.

- Immediately before applying treatments (after the fungicide was added to the tank), the sprayer was run for 10.0 seconds. Spray output was measured for each nozzle.
- Pulse width was manually adjusted until the correct output was achieved for the driving speed and spray volume

Application methods

Applications were made with a tractor-mounted, PTO-driven spray equipped with a pulse width modulation system

Fungicide droplet size
KIDNEY BEANS
seeded to wide rows (28”)

Fungicide efficacy against white mold was optimized with

APPLICATION #1: coarse droplets

APPLICATION #2: coarse droplets

Location		Carrington	Carrington	Carrington
Year		2022	2022	2024
Variety		Pink Panther	Red Hawk	Pink Panther
Row spacing		**28"**	**28"**	**28"**
Applic. #1	Canopy closure	**81%**	**81%**	**47%**
	Canopy height			20.3
Applic. #2	Canopy closure	**88%**	**92%**	**52%**
	Canopy height	19.5 in.	22.1 in.	23.2 in.
	Lodging (%)			36%

Bar graphs: combined analysis across studies

WHITE MOLD (% of canopy)

Non-treated control	38 b	57 b	17 ab	**37** b
Fine f.b. **fine** droplets	25 a	37 a	18 b	**27** ab
Fine f.b. **medium**	21 a	42 ab	14 ab	**26** ab
Fine f.b. **coarse**	22 a	40 a	12 ab	**25** ab
Medium f.b. **medium**	30 ab	31 a	12 ab	**24** a
Medium f.b. **coarse**	26 ab	42 a	16 ab	**28** ab
Coarse f.b. **coarse**	20 a	37 a	9 a	**22** a
CV:	28.1	26.4	45	16.8

Applications were made with a tractor-mounted, PTO-driven sprayer. Pulse width was modified as needed to maintain constant driving speed and spray volume of 15 gal/ac; 6 mph (2024, Oakes 2021); 10 mph (2022, 2023); 10.5 mph (Carrington 2021). **Testing was conducted with TeeJet extended-range flat fan-nozzles.**
FINE: XR11004 or XR11005, 60 psi
MEDIUM: XR11006, 35 psi
COARSE: XR11010, 30 psi

YIELD (pounds/acre)

Non-treated control	2863 b	2237 b	3070 a	**2724** b
Fine f.b. **fine** droplets	3119 ab	2663 a	3339 a	**3040** a
Fine f.b. **medium**	3222 ab	2525 ab	**3429** a	**3059** a
Fine f.b. **coarse**	3042 ab	2514 ab	3341 a	**2966** ab
Medium f.b. **medium**	2964 ab	2748 a	3409 a	**3040** a
Medium f.b. **coarse**	3237 ab	2591 a	3374 a	**3067** a
Coarse f.b. **coarse**	**3268** a	**2768** a	**3427** a	**3154** a
CV:	8.7	9.0	7.3	2.9

Yield gain (lbs/ac)
conferred by fungicide

317 (A)
335 (A)
242 (A)
317 (A)
344 (A)
431 (A)

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

Fungicide droplet size

KIDNEY BEANS seeded to **narrow rows** (14-15”); **canopy near closure at 1st application,** canopy dense or lodged at 2nd app.

Fungicide efficacy optimized with
Application 1: medium or coarse droplets
Application 2: coarse droplets

	Location	Carrington	Oakes	Carrington
	Year	2021	2021	2023
	Variety	Pink Panther	Dynasty	Pink Panther
	Row spacing	**14"**	**15"**	**14"**
Applic. #1	Canopy closure	**91 %**	**95 %**	**92 %**
	Canopy height	18 in.	21 in.	20 in.
Applic. #2	Canopy closure	99 %	96 %	94 %
	Canopy height	**22.0** in.	**19.9** in.	**21.5** in.
	Lodging (%)	no data	no data	32

WHITE MOLD (% of canopy)

Non-treated control	53 a	36 a	27 a	**31** a
Fine f.b. **fine** droplets	46 a	34 a	26 a	**28** a
Fine f.b. **medium**	52 a	31 a	22 a	**27** a
Fine f.b. **coarse**	49 a	33 a	25 a	**27** a
Medium f.b. **medium**	48 a	31 a	29 a	**28** a
Medium f.b. **coarse**	42 a	30 a	27 a	**26** a
Coarse f.b. **coarse**	46 a	31 a	18 a	**25** a
CV:	23.9	33.6	34.1	8.1

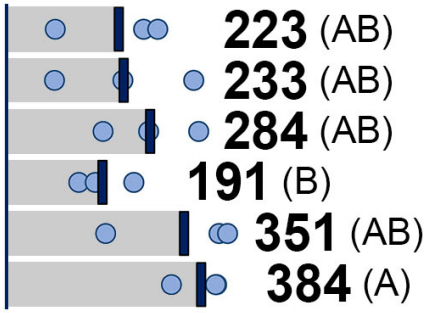
Applications were made with a tractor-mounted, PTO-driven sprayer. Pulse width was modified as needed to maintain constant driving speed and spray volume of 15 gal/ac; 6 mph (2024, Oakes 2021); 10 mph (2022, 2023); 10.5 mph (Carrington 2021). **Testing was conducted with TeeJet extended-range flat fan-nozzles.**
FINE: XR11004 or XR11005, 60 psi
MEDIUM: XR11006, 35 psi
COARSE: XR11010, 30 psi

YIELD (pounds/acre)

Non-treated control	2659 b	3110 b	2936 b	**2902** b
Fine f.b. **fine** droplets	2931 ab	3409 ab	3035 ab	**3125** a
Fine f.b. **medium**	2757 ab	3479 a	3167 ab	**3134** a
Fine f.b. **coarse**	2941 ab	3489 a	3128 ab	**3186** a
Medium f.b. **medium**	2804 ab	3362 ab	3113 ab	**3093** ab
Medium f.b. **coarse**	**3078** a	**3545** a	3134 ab	**3252** a
Coarse f.b. **coarse**	**3074** a	3522 a	**3262** a	**3286** a
CV:	8.9	9.1	9.0	2.3

Yield gain (lbs/ac)

conferred by fungicide



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

Fungicide droplet size

KIDNEY BEANS seeded to **narrow rows** (14-15"); **canopy near closure at 1st application;** canopy mostly upright at 2nd application

		Carrington	Carrington
	Location		
	Year	2021	2023
	Variety	Dynasty	Red Hawk
	Row spacing	**14"**	**14"**
Applic. #1	Canopy closure	**87** %	**95** %
	Canopy height	18.5 in.	21.0 in.
Applic. #2	Canopy closure	100 %	97 %
	Canopy height	**23.5** in.	**23.0** in.
	Lodging (%)	no data	25

Bar graphs: **combined analysis across studies**

WHITE MOLD (% of canopy)

Non-treated control	56 b	43 a	**49** a
Fine f.b. **fine** droplets	46 a	38 a	**42** a
Fine f.b. **medium**	51 ab	37 a	**44** a
Fine f.b. **coarse**	50 ab	38 a	**44** a
Medium f.b. **medium**	49 ab	39 a	**44** a
Medium f.b. **coarse**	50 ab	41 a	**45** a
Coarse f.b. **coarse**	47 a	40 a	**43** a
CV:	13.7	23.4	4.0

YIELD (pounds/acre)

Non-treated control	2431 a	2295 a	**2363** b
Fine f.b. **fine** droplets	2723 a	2548 a	**2636** a
Fine f.b. **medium**	2645 a	2577 a	**2611** a
Fine f.b. **coarse**	2619 a	2609 a	**2614** a
Medium f.b. **medium**	**2740** a	**2667** a	**2704** a
Medium f.b. **coarse**	2644 a	2514 a	**2579** a
Coarse f.b. **coarse**	2706 a	2552 a	**2629** a
CV:	8.9	8.7	1.6

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

Fungicide efficacy against white mold was optimized with

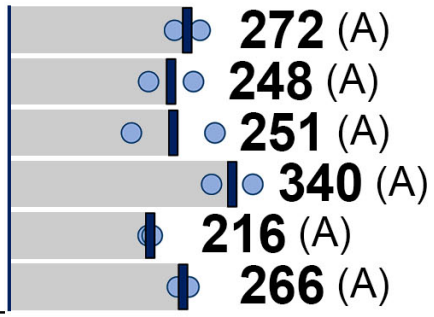
Application #1: medium droplets

Application #2: medium droplets

Applications were made with a tractor-mounted, PTO-driven sprayer. Pulse width was modified as needed to maintain constant driving speed and spray volume of 15 gal/ac; 6 mph (2024, Oakes 2021); 10 mph (2022, 2023); 10.5 mph (Carrington 2021). **Testing was conducted with TeeJet extended-range flat fan-nozzles.**

FINE: XR11004 or XR11005, 60 psi
MEDIUM: XR11006, 35 psi
COARSE: XR11010, 30 psi

Yield gain (lbs/ac) conferred by fungicide



Location	Carrington	
Year	2024	
Variety	Pink Panther	
Row spacing	**14"**	
Applic. #1	Canopy closure	**80** %
	Canopy height	20.2 in.
Applic. #2	Canopy closure	**85** %
	Canopy height	**22.6** in.
	Lodging (%)	36

WHITE MOLD (% of canopy)

Non-treated control	**10** b
Fine f.b. **fine** droplets	**7** ab
Fine f.b. **medium**	**5** ab
Fine f.b. **coarse**	**4** a
Medium f.b. **medium**	**4** ab
Medium f.b. **coarse**	**6** ab
Coarse f.b. **coarse**	**4** a
CV:	64.7

YIELD (pounds/acre)

Non-treated control	**3885** b
Fine f.b. **fine** droplets	**4121** ab
Fine f.b. **medium**	**4262** a
Fine f.b. **coarse**	**4120** ab
Medium f.b. **medium**	**3997** ab
Medium f.b. **coarse**	**4208** ab
Coarse f.b. **coarse**	**4029** ab
CV:	5.8

Fungicide droplet size
KIDNEY BEANS seeded to **narrow rows** (14-15"); **canopy open at 1st application;** canopy open at 2nd application

Fungicide efficacy optimized with
Application #1: fine droplets
Application #2: medium droplets

Applications were made with a tractor-mounted, PTO-driven sprayer. Pulse width was modified as needed to maintain constant driving speed and spray volume of 15 gal/ac; 6 mph (2024, Oakes 2021); 10 mph (2022, 2023); 10.5 mph (Carrington 2021).

Testing was conducted with TeeJet extended-range flat fan-nozzles.
FINE: XR11004 or XR11005, 60 psi
MEDIUM: XR11006, 35 psi
COARSE: XR11010, 30 psi

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

Decision-making chart

Optimizing fungicide droplet size with TeeJet nozzles for improved white mold management in kidney beans

(1) Kidney beans seeded to wide (28”) rows:

- Coarse droplets in application #1
- Coarse droplets in application #2.

Fungicide droplet size: **kidney beans**

Decision-making chart

Optimizing fungicide droplet size with TeeJet nozzles for improved white mold management in kidney beans

(2) Kidney beans seeded to narrow (14”) rows with the **canopy near closure** at the 1st fungicide application and the canopy dense and/or lodged at the 2nd application:

- Medium or coarse droplets in application #1
- Coarse droplets in application #2.

In application #1, medium droplets are most likely to be optimal if the canopy is not very dense in the first application; otherwise, coarse droplets will optimize

Canopy near closure: >90% of ground covered by canopy

Fungicide droplet size: **kidney beans**

Decision-making chart

Optimizing fungicide droplet size with TeeJet nozzles for improved white mold management in kidney beans

(3) Kidney beans seeded to narrow (14”) rows with the **canopy near closure** at the 1st fungicide application and the canopy mostly upright at the 2nd application:

- Medium droplets in application #1
- Medium droplets in application #2.

Canopy near closure: >90% of ground covered by canopy

Decision-making chart

Optimizing fungicide droplet size with TeeJet nozzles for improved white mold management in kidney beans

(4) Kidney beans seeded to narrow (14”) rows with the **canopy open** at the 1st and 2nd fungicide applications:

- Fine droplets in application #1
- Medium droplets in application #2.

Canopy open: ≤85% of ground covered by canopy

Optimizing fungicide droplet size for improved white mold management in kidney beans:

- These should be considered **preliminary** recommendations.
- Statistical separation is rarely achieved with combined analyses across just 2 or 3 droplet size studies.
- Results from 5 to 6 studies in each row spacing and canopy closure grouping will be needed to develop rigorous recommendations.

Fungicide droplet size: **kidney beans**

Optimizing fungicide droplet size for improved white mold management in kidney beans:

- These are results obtained from testing conducted with **TeeJet extended-range flat-fan** nozzles.
- Similar results should be expected for all nozzles manufactured by TeeJet.
- Droplet size optimums for other nozzle manufacturers can differ.




People

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Collaborators – Oakes: Heidi Eslinger, Spencer Eslinger, Leonard Besemann, Kelly Cooper




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