

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

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

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MAJOR FINDINGS: When conditions favor white mold as dry beans enter bloom, the optimal application timing of fungicides targeting white mold changes with the number of applications being made. In research studies conducted utilizing supplemental irrigation to create conditions favoring white mold as dry beans enter bloom, white mold management in kidney beans was optimized with a single fungicide application by delaying the application until 80-100% of plants had initial pin-pods. Two-application fungicide programs were optimized by applying the first application a few days earlier: 20-40% of plants with initial pin-pods. Three-application fungicide programs were optimized by applying the first application at early bloom when 0-5% of plants had initial pin-pods.

EXPLANATION FOR THE OBSERVED RESPONSE:

Fungicide applications only protect the canopy that is present at the time of the application.

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

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

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

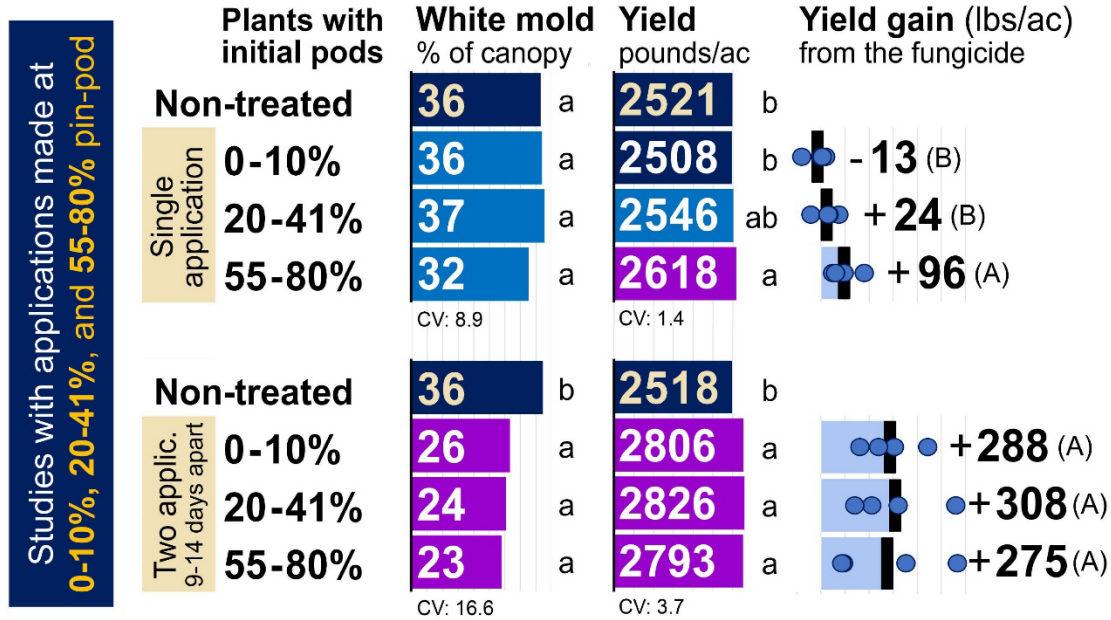
With a three-application program, fungicide applications #2 and #3 protect the new growth, and our data show that the fungicide program is optimized by applying the first fungicide at early bloom just as the plants first become susceptible to white mold (<5% of plants with initial pin-pods). In a three-application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

CAUTIONARY NOTE:

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

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

Optimizing fungicide application timing when conditions favor white mold as kidney beans enter bloom:
Single application versus a two-application fungicide program



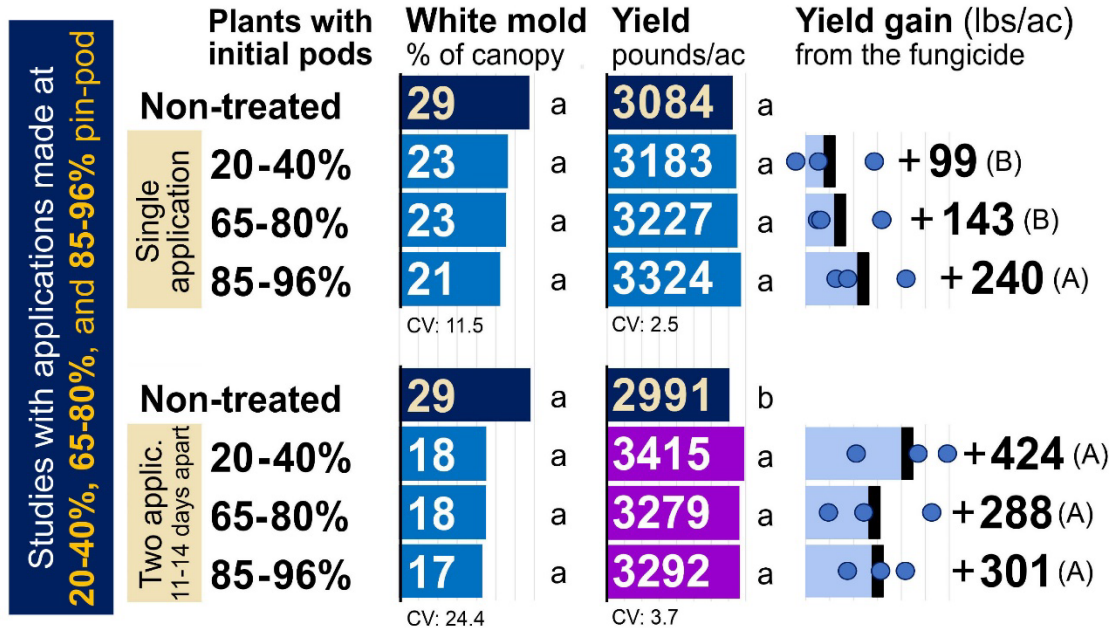
KIDNEY BEANS

'Dynasty' DR kidney, Carrington, ND (2020); 'Dynasty' DR Kidney, Carrington, ND (2020); 'Red Hawk' DR Kidney, Carrington, ND (2022); 'Epic' DR Kidney, Carrington, ND (2025)

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

2020-2022: Topsin (30 or 40 fl oz) or Topsin (30 or 40 fl oz) followed by Endura (8 oz) 10, 12 or 14 days later

2025: Endura (8 oz/ac) or Endura f.b. Endura 9-11 days later. All years: Row spacing = 14". Spray volume = 15 gal/ac.



KIDNEY BEANS

'Dynasty' DR kidney, Carrington, ND (2021); 'Pink Panther' LR Kidney, Carrington, ND (2022); 'Pink Panther' LR Kidney, Carrington, ND (2024)

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

2021-2022: Topsin (40 fl oz) or Topsin (40 fl oz) followed by Endura (8 oz) 12 or 14 days later

2024: Endura (8 oz/ac) or Endura f.b. Endura 11-13 days later. All years: Row spacing = 14". Spray volume = 15 gal/ac.

Impact of application timing on white mold management in kidney beans: results from a field study conducted in Carrington, ND in 2025. Row spacing = 14 inches, seeding rate = 90,000 viable seeds/ac.

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

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

Three applications, either approx. 7 days apart or approx. 10 days apart

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

| | | | | KIDNEY BEANS | | | | | | | |
|---|--------------------|-------------------|----------------------------|---------------------------------------|----------------|--|--------------|--|----------------|--|--------------|
| | | | | cv. 'Epic', a dark-red type | | | | | | | |
| Growth stage when first fungicide application was made | | | | White mold | | Yield | | White mold | | Yield | |
| Application date | Canopy closure (%) | Plants in bloom % | Plants with initial pods % | % of canopy | | lbs/ac | | % of canopy | | lbs/ac | |
| | | | | 3 APPLICATIONS, 7-8 days apart | | 3 APPLICATIONS, 9-11 days apart | | 3 APPLICATIONS, 9-11 days apart | | 3 APPLICATIONS, 9-11 days apart | |
| Non-treated control | | | | 47 a* | | 2430 a* | | 48 c* | | 2320 b* | |
| July 23 | 92% | 27% | 0% | 17 a | | 2595 a | | 22 a | | 2489 ab | |
| July 26 | 90% | 57% | 7% | 17 a | | 2611 a | | 24 ab | | 2499 ab | |
| July 28 | 93% | 80% | 14% | 21 a | | 2601 a | | 26 ab | | 2471 ab | |
| July 30 | 94% | 95% | 41% | 25 a | | 2551 a | | 29 ab | | 2573 a | |
| July 31 | 94% | 99% | 63% | 26 a | | 2694 a | | 33 b | | 2465 ab | |
| | | | | <i>F, P>F:</i> | 16.67, <0.0001 | | 2.32, 0.0607 | | 19.33, <0.0001 | | 2.50, 0.0462 |
| | | | | <i>CV:</i> | 31.5 | | 6.7 | | 20.8 | | 6.3 |

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

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

(1) studies evaluating application timings of 0-8%, 22-41% and 56-80% of plants with initial pin-pods

| | | Kidney bean variety Dynasty | Dynasty | Red Hawk | Epic | | | | |
|---|-------------------------------|-----------------------------------|------------------------|------------------------|--------------------|----------------|---------------|---------------|----------------|
| | | Location Carrington | Carrington | Carrington | Carrington | | | | |
| | | Year 2020 | 2021 | 2022 | 2025 | | | | |
| | | Row spacing 14" | 14" | 14" | 14" | | | | |
| | | Experimental replicates 16 | 7 | 10 | 9 | | | | |
| | | Application method hand-held boom | hand-held boom | hand-held boom | tractor, 6 mph | | | | |
| Fungicide application #1 | fungicide | Topsin 30 fl oz | Topsin 40 fl oz | Topsin 40 fl oz | Endura 8 oz | | | | |
| | nozzles, pressure | AIXR110015, 70 psi | DG110015 40 or 30 psi | DG110015, 40 psi | XR11006, 35 psi | | | | |
| | droplet size | medium | fine or medium | fine | medium | | | | |
| Fungicide application #2 | fungicide | Endura 8 oz | Endura 8 oz | Endura 8 oz | Endura 8 oz | | | | |
| | nozzles, pressure | AIXR110015, 60 psi | AIXR110015, 50 psi | AIXR110015, 50 psi | XR11010, 30 psi | | | | |
| | droplet size | medium | medium-coarse | medium-coarse | coarse | | | | |
| Interval between applications | | 10 days | 14 days | 12 days | 9 to 11 days | | | | |
| Fungicide application date | | | | | | | | | |
| Application timing #1 | July 7 | July 7 | July 12 | July 26 | | | | | |
| Application timing #2 | July 14 | July 9 | July 14 | July 30 | | | | | |
| Application timing #3 | July 16 | July 12 | July 18 | July 31 | | | | | |
| PLANTS WITH AN OPEN BLOSSOM (%) | | | | | | | | | |
| Application timing #1 | 10% | 65% | 28% | 57% | | | | | |
| Application timing #2 | 64% | 90% | 54% | 95% | | | | | |
| Application timing #3 | 86% | 96% | 78% | 99% | | | | | |
| PLANTS WITH INITIAL PIN-SHAPED PODS (%) | | | | | | | | | |
| Application timing #1 | 0% | 8% | 6% | 7% | | | | | |
| Application timing #2 | 38% | 32% | 22% | 41% | | | | | |
| Application timing #3 | 61% | 80% | 56% | 63% | | | | | |
| CANOPY CLOSURE (percent of the ground covered by the canopy) | | | | | | | | | |
| Application timing #1 | 75-93% (ave. 87%) | 75-85% (ave. 80%) | 60-85% (ave. 73%) | average 90% | | | | | |
| Application timing #2 | 84-95% (ave. 90%) | 80-95% (ave. 87%) | 70-90% (ave. 81%) | average 94% | | | | | |
| Application timing #3 | 88-96% (ave. 93%) | 85-97% (ave. 91%) | 85-97% (ave. 94%) | average 94% | | | | | |
| White mold (% of canopy) | | | | | | | | | |
| Non-treated control | | 46 a* | 19 a* | 40 a* | 37 a* | 36 a* | | | |
| SINGLE fungicide application | growth stage at application | 10-65% | 0-8% | 73-90% | 48 a | 24 a | 38 a | 33 a | 36 a |
| | | 54-95% | 22-41% | 73-94% | 47 a | 18 a | 40 a | 43 a | 37 a |
| | | 78-100% | 56-80% | 80-94% | 45 a | 13 a | 37 a | 31 a | 32 a |
| <i>F, P>F:</i> | Plants in bloom | Plants with initial pods | Canopy closure (%) | 0.46, 0.7147 | 2.65, 0.0798 | 0.68, 0.5707 | 1.94, 0.1085 | 2.14, 0.1646 | |
| <i>CV:</i> | | | | 14.8 | 40.9 | 14.5 | 30.1 | 8.9 | |
| Non-treated control | | 46 c* | 19 b* | 40 c | 40 b* | 36 b* | | | |
| TWO fungicide applications | growth stage, 1st application | 10-65% | 0-8% | 73-90% | 41 bc | 9 a | 30 b | 22 a | 26 a |
| | | 54-95% | 22-41% | 73-94% | 36 b | 11 ab | 24 ab | 26 a | 24 a |
| | | 78-100% | 56-80% | 80-94% | 27 a | 13 ab | 21 a | 30 ab | 23 a |
| <i>F, P>F:</i> | Plants in bloom | Plants with initial pods | Canopy closure (%) | 20.38, <0.0001 | 3.50, 0.0385 | 19.17, <0.0001 | 4.45, 0.0026 | 7.15, 0.0093 | |
| <i>CV:</i> | | | | 18.4 | 46.6 | 21.3 | 29.4 | 16.6 | |
| Yield (lbs/ac) | | | | | | | | | |
| Non-treated control | | 2181 a* | 3517 a* | 2005 a* | 2382 a* | 2521 b* | | | |
| SINGLE fungicide application | growth stage at application | 10-65% | 0-8% | 73-90% | 2201 a | 3438 a | 2005 a | 2388 a | 2508 b |
| | | 54-95% | 22-41% | 73-94% | 2256 a | 3475 a | 2039 a | 2412 a | 2546 ab |
| | | 78-100% | 56-80% | 80-94% | 2278 a | 3566 a | 2185 a | 2443 a | 2618 a |
| <i>F, P>F:</i> | Plants in bloom | Plants with initial pods | Canopy closure (%) | 0.67, 0.5771 | 0.33, 0.8012 | 1.91, 0.1520 | 0.32, 0.8985 | 7.98, 0.0066 | |
| <i>CV:</i> | | | | 10.0 | 7.2 | 9.6 | 5.5 | 1.4 | |
| Non-treated control | | 2181 b* | 3517 b* | 2005 b* | 2369 a* | 2518 b* | | | |
| TWO fungicide applications | growth stage, 1st application | 10-65% | 0-8% | 73-90% | 2486 a | 3757 a | 2448 a | 2531 a | 2806 a |
| | | 54-95% | 22-41% | 73-94% | 2502 a | 3728 ab | 2565 a | 2510 a | 2826 a |
| | | 78-100% | 56-80% | 80-94% | 2534 a | 3612 ab | 2572 a | 2456 a | 2793 a |
| <i>F, P>F:</i> | Plants in bloom | Plants with initial pods | Canopy closure (%) | 6.65, 0.0008 | 4.45, 0.0175 | 14.31, <0.0001 | 1.13, 0.3589 | 8.2, 0.0061 | |
| <i>CV:</i> | | | | 10.5 | 3.9 | 9.3 | 6.7 | 3.7 | |

Combined analysis across four studies

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

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

(2) studies evaluating application timings of 24-40%, 66-80% and 85-96% of plants with pin-pods

| Kidney bean variety | | Dynasty | Pink Panther | Pink Panther | | | |
|---|-------------------|--------------------------|------------------------|--------------------|----------------|---------------|---------------|
| Location | | Carrington | Carrington | Carrington | | | |
| Year | | 2021 | 2022 | 2024 | | | |
| Row spacing | | 14" | 14" | 14" | | | |
| Experimental replicates | | 7 | 10 | 9 | | | |
| Application method | | hand-held boom | hand-held boom | tractor, 6 mph | | | |
| Fungicide application #1 | fungicide | Topsin 40 fl oz | Topsin 40 fl oz | Endura 8 oz | | | |
| | nozzles, pressure | fine or medium; | DG110015, 40 psi | XR11006, 35 psi | | | |
| | droplet size | calibrated vs canopy | fine | medium | | | |
| Fungicide application #2 | fungicide | Endura 8 oz | Endura 8 oz | Endura 8 oz | | | |
| | nozzles, pressure | AIXR110015, 50 psi | AIXR110015, 50 psi | XR11010, 30 psi | | | |
| | droplet size | medium-coarse | medium-coarse | coarse | | | |
| Interval between applications | | 14 days | 12 days | 11 to 13 days | | | |
| Fungicide application date | | | | | | | |
| Application timing #1 | July 9 | July 12 | July 17 | | | | |
| Application timing #2 | July 12 | July 14 | July 22 | | | | |
| Application timing #3 | July 14 | July 18 | July 24 | | | | |
| PLANTS WITH AN OPEN BLOSSOM (%) | | | | | | | |
| Application timing #1 | 90% | 74% | 64% | | | | |
| Application timing #2 | 96% | 78% | 100% | | | | |
| Application timing #3 | 100% | 100% | 100% | | | | |
| PLANTS WITH INITIAL PIN-SHAPED PODS (%) | | | | | | | |
| Application timing #1 | 32% | 40% | 24% | | | | |
| Application timing #2 | 80% | 66% | 68% | | | | |
| Application timing #3 | 95% | 96% | 85% | | | | |
| CANOPY CLOSURE (percent of the ground covered by the canopy) | | | | | | | |
| Application timing #1 | 80-95% (ave. 87%) | 65-85% (ave. 77%) | average 73% | | | | |
| Application timing #2 | 85-97% (ave. 91%) | 70-90% (ave. 79%) | average 80% | | | | |
| Application timing #3 | 87-98% (ave. 94%) | 85-95% (ave. 90%) | average 82% | | | | |
| White mold (% of canopy) | | | | | | | |
| Non-treated control | | 19 a* | 37 a* | 30 b* | 29 a* | | |
| SINGLE fungicide application | 64-90% | 24-40% | 73-87% | 18 a | 35 a | 18 a | 23 a |
| | 78-100% | 66-80% | 79-91% | 13 a | 35 a | 21 ab | 23 a |
| | 100% | 85-96% | 82-94% | 11 a | 34 a | 19 ab | 21 a |
| <i>F, P>F:</i> | Plants in bloom | Plants with initial pods | Canopy closure (%) | 1.94, 0.1586 | 0.47, 0.7049 | 2.74, 0.0326 | 4.18, 0.0646 |
| <i>CV:</i> | | | | 48.7 | 20.7 | 8.9 | 11.5 |
| Non-treated control | | 19 b* | 37 c* | 31 b* | 29 a* | | |
| TWO fungicide applications | 64-90% | 24-40% | 73-87% | 11 ab | 26 b | 16 a | 18 a |
| | 78-100% | 66-80% | 79-91% | 13 ab | 15 a | 24 ab | 18 a |
| | 100% | 85-96% | 82-94% | 7 a | 20 ab | 23 ab | 17 a |
| <i>F, P>F:</i> | Plants in bloom | Plants with initial pods | Canopy closure (%) | 5.59, 0.0075 | 11.78, <0.0001 | 2.68, 0.0355 | 4.35, 0.0596 |
| <i>CV:</i> | | | | 46.0 | 35.4 | 39.8 | 24.4 |
| Yield (lbs/ac) | | | | | | | |
| Non-treated control | | 3517 a* | 2414 a* | 3321 a* | 3084 a* | | |
| SINGLE fungicide application | 64-90% | 24-40% | 73-87% | 3475 a | 2466 a | 3607 a | 3183 a |
| | 78-100% | 66-80% | 79-91% | 3566 a | 2477 a | 3639 a | 3227 a |
| | 100% | 85-96% | 82-94% | 3644 a | 2589 a | 3740 a | 3324 a |
| <i>F, P>F:</i> | Plants in bloom | Plants with initial pods | Canopy closure (%) | 0.98, 0.4289 | 1.22, 0.3220 | 2.04, 0.0986 | 4.56, 0.0544 |
| <i>CV:</i> | | | | 5.5 | 8.5 | 8.9 | 2.5 |
| Non-treated control | | 3517 a* | 2414 b* | 3043 a* | 2991 b* | | |
| TWO fungicide applications | 64-90% | 24-40% | 73-87% | 3728 a | 2883 a | 3634 a | 3415 a |
| | 78-100% | 66-80% | 79-91% | 3612 a | 2940 a | 3285 a | 3279 a |
| | 100% | 85-96% | 82-94% | 3691 a | 2830 a | 3355 a | 3292 a |
| <i>F, P>F:</i> | Plants in bloom | Plants with initial pods | Canopy closure (%) | 2.65, 0.0819 | 16.35, <0.0001 | 2.15, 0.0800 | 6.76, 0.0237 |
| <i>CV:</i> | | | | 4.2 | 6.8 | 11.7 | 3.7 |

Combined analysis across three studies

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

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

Carrington, ND (2025)

KIDNEY BEANS: 'Epic', a dark-red type

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

| Application date | Canopy closure (%) | Plants in bloom (%) | Pin-pods (% plants) | Canopy height (in.) | White mold | | Yield | Test weight |
|---|--------------------|---------------------|---------------------|---------------------|----------------------------------|--------------|----------------|-------------|
| | | | | | Incidence | Sev. Index | | |
| | | | | | Sept. 17 - Oct. 1; R8-R9 | | 13.5% moisture | |
| | | | | | % of plants | | lbs/ac | |
| | | | | | % | | lbs/bu | |
| SINGLE APPLICATION | | | | | | | | |
| Non-treated control | | | | | 75 ab* | 37 a* | 2382 a* | 54.9 |
| July 23 | 92 | 27 | 0 | 17.3 | 70 ab | 31 a | 2399 a | 55.4 |
| July 26 | 90 | 57 | 7 | 18.9 | 73 ab | 33 a | 2388 a | 54.6 |
| July 28 | 93 | 80 | 14 | 17.4 | 66 b | 30 a | 2435 a | 55.0 |
| July 30 | 94 | 95 | 41 | 18.1 | 84 a | 43 a | 2412 a | 55.1 |
| July 31 | 94 | 99 | 63 | 19.5 | 70 ab | 31 a | 2443 a | 55.3 |
| | | | | | <i>F, P>F:</i> 2.56, 0.0420 | | 1.94, 0.1085 | |
| | | | | | 15.7 | | 0.32, 0.8985 | |
| | | | | | CV: | | 30.1 | |
| | | | | | | | 5.5 | |
| TWO APPLICATIONS, 7-8 days apart | | | | | | | | |
| Date, growth stage; application #1 | | | | | 85 b* | 46 c* | 2345 a* | 54.4 |
| Non-treated control | | | | | 85 b* | 46 c* | 2345 a* | 54.4 |
| July 23 | 92 | 27 | 0 | 17.3 | 52 a | 21 a | 2529 a | 55.1 |
| July 26 | 90 | 57 | 7 | 18.9 | 59 a | 24 ab | 2504 a | 54.7 |
| July 28 | 93 | 80 | 14 | 17.4 | 64 a | 28 ab | 2506 a | 55.1 |
| July 30 | 94 | 95 | 41 | 18.1 | 67 a | 31 b | 2540 a | 54.4 |
| July 31 | 94 | 99 | 63 | 19.5 | 67 a | 28 ab | 2533 a | 54.8 |
| | | | | | <i>F, P>F:</i> 7.18, <0.0001 | | 13.28, <0.0001 | |
| | | | | | 19.2 | | 2.27, 0.0653 | |
| | | | | | CV: | | 24.7 | |
| | | | | | | | 5.9 | |
| THREE APPLICATIONS, 7-8 days apart | | | | | | | | |
| Date, growth stage; application #1 | | | | | 84 b* | 47 a* | 2430 a* | 54.7 |
| Non-treated control | | | | | 84 b* | 47 a* | 2430 a* | 54.7 |
| July 23 | 92 | 27 | 0 | 17.3 | 48 a | 17 a | 2595 a | 55.1 |
| July 26 | 90 | 57 | 7 | 18.9 | 49 a | 17 a | 2611 a | 55.7 |
| July 28 | 93 | 80 | 14 | 17.4 | 54 a | 21 a | 2601 a | 55.2 |
| July 30 | 94 | 95 | 41 | 18.1 | 61 a | 25 a | 2551 a | 54.9 |
| July 31 | 94 | 99 | 63 | 19.5 | 59 a | 26 a | 2694 a | 54.9 |
| | | | | | <i>F, P>F:</i> 11.28, <0.0001 | | 16.67, <0.0001 | |
| | | | | | 20.0 | | 2.32, 0.0607 | |
| | | | | | CV: | | 31.5 | |
| | | | | | | | 6.7 | |

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

Fungicides were applied with a tractor-mounted, PTO-driven sprayer with a pulse-width modification system (Capstan Ag, Topeka, KS). Fungicides were applied with TeeJet XR11006 nozzles @ 35 psi (medium droplets) on July 23-31 when canopy closure <95% and XR11010 nozzles @ 30 psi (coarse droplets) on later dates (canopy closure ≥95%). Spray volume = 15 gal/ac; driving speed = 6.0 mph. For ease of application, the fungicide Endura (8.0 oz/ac) was applied at each application.

| White mold | Incidence | Sev. Index | Yield | Test weight | White mold | | Yield | Test weight |
|---|---------------|--------------|----------------|-------------|---------------------------------|------------|----------------|-------------|
| | | | | | Incidence | Sev. Index | | |
| | | | | | Sept. 17 - Oct. 1; R8-R9 | | 13.5% moisture | |
| | | | | | % of plants | | % of canopy | |
| | | | | | % | | lbs/ac | |
| | | | | | % | | lbs/bu | |
| TWO APPLICATIONS, 9-11 days apart | | | | | | | | |
| | 79 b* | 40 b* | 2369 a* | 54.9 | | | | |
| | 61 a | 29 ab | 2500 a | 55.0 | | | | |
| | 55 a | 22 a | 2531 a | 55.5 | | | | |
| | 61 a | 26 a | 2508 a | 54.8 | | | | |
| | 59 a | 26 a | 2510 a | 54.9 | | | | |
| | 64 ab | 30 ab | 2456 a | 55.1 | | | | |
| | | | | | <i>F, P>F:</i> 5.06, 0.0011 | | 4.45, 0.0026 | |
| | | | | | 17.5 | | 1.13, 0.3589 | |
| | | | | | CV: | | 29.4 | |
| | | | | | | | 6.7 | |
| THREE APPLICATIONS, 9-11 days apart | | | | | | | | |
| | 85 bc* | 48 c* | 2320 b* | 55.3 | | | | |
| | 55 ab | 22 a | 2489 ab | 55.2 | | | | |
| | 60 ab | 24 ab | 2499 ab | 54.5 | | | | |
| | 61 ab | 26 ab | 2471 ab | 55.1 | | | | |
| | 67 ab | 29 ab | 2573 a | 54.7 | | | | |
| | 72 b | 33 b | 2465 ab | 55.0 | | | | |
| | | | | | <i>F, P>F:</i> 8.97, <0.0001 | | 19.33, <0.0001 | |
| | | | | | 16.2 | | 2.50, 0.0462 | |
| | | | | | CV: | | 20.8 | |
| | | | | | | | 6.3 | |
| THREE APPLICATIONS, 12-14 days apart | | | | | | | | |
| | 77 a* | 41 b* | 2359 b* | 55.4 | | | | |
| | 60 a | 26 a | 2537 ab | 54.7 | | | | |
| | 59 a | 22 a | 2454 ab | 55.4 | | | | |
| | 58 a | 23 a | 2569 ab | 54.2 | | | | |
| | 71 a | 32 ab | 2616 a | 55.0 | | | | |
| | 63 a | 27 a | 2519 ab | 55.2 | | | | |
| | | | | | <i>F, P>F:</i> 2.27, 0.0656 | | 4.93, 0.0013 | |
| | | | | | 23.4 | | 1.92, 0.1116 | |
| | | | | | CV: | | 28.9 | |
| | | | | | | | 7.1 | |

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

Carrington, ND (2024)

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

KIDNEY BEANS: 'Pink Panther', a light-red type

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

| Application date | Canopy closure (%) | Plants in bloom (%) | Pin-pods (% plants) | Canopy height (in.) | White mold | | Yield 13.5% moisture | Test weight |
|---------------------|--------------------|---------------------|---------------------|---------------------|--------------------------|------------|----------------------|-------------|
| | | | | | Incidence Sept. 9-20; R9 | Sev. Index | | |
| Non-treated control | | | | | 56 | 30 b* | 3321 a* | 53.4 |
| July 17 | 73 | 64 | 24 | 16 | 38 | 18 a | 3607 a | 53.5 |
| July 19 | 75 | 91 | 60 | 16.6 | 40 | 21 ab | 3464 a | 53.3 |
| July 22 | 80 | 100 | 68 | 20.1 | 44 | 21 ab | 3639 a | 52.6 |
| July 24 | 82 | 100 | 85 | 19.1 | 37 | 19 ab | 3740 a | 53.6 |
| July 26 | 88 | 100 | 86 | 20.1 | 47 | 24 ab | 3418 a | 54.1 |

F, P>F: 2.74, 0.0326 2.04, 0.0946

CV: 35.7 8.9

| Date, growth stage; application #1 | TWO APPLICATIONS, 7 days apart | | Yield 13.5% moisture | Test weight |
|------------------------------------|--------------------------------|--------------------|----------------------|-------------|
| | % of plants | % of canopy lbs/ac | | |
| Non-treated control | 60 | 32 b* | 3179 a* | 53.3 |
| July 17 | 73 | 64 | 24 | 16 |
| July 19 | 75 | 91 | 60 | 16.6 |
| July 22 | 80 | 100 | 68 | 20.1 |
| July 24 | 82 | 100 | 85 | 19.1 |
| July 26 | 88 | 100 | 86 | 20.1 |

F, P>F: 4.28, 0.0034 1.56, 0.1930

CV: 44.9 10.6

| Date, growth stage; application #1 | THREE APPLICATIONS, 7 days apart | | Yield 13.5% moisture | Test weight |
|------------------------------------|----------------------------------|--------------------|----------------------|-------------|
| | % of plants | % of canopy lbs/ac | | |
| Non-treated control | 68 | 38 b* | 2889 b* | 53.8 |
| July 17 | 73 | 64 | 24 | 16 |
| July 19 | 75 | 91 | 60 | 16.6 |
| July 22 | 80 | 100 | 68 | 20.1 |
| July 24 | 82 | 100 | 85 | 19.1 |
| July 26 | 88 | 100 | 86 | 20.1 |

F, P>F: 13.58, <0.0001 3.6, 0.0079

CV: 25.9 11.3

| Date, growth stage; application #1 | TWO APPLICATIONS, 9-11 days apart | | Yield 13.5% moisture | Test weight |
|------------------------------------|-----------------------------------|--------------------|----------------------|-------------|
| | % of plants | % of canopy lbs/ac | | |
| Non-treated control | 66 | 40 b* | 3125 a* | 53.0 |
| July 17 | 73 | 64 | 24 | 16 |
| July 19 | 75 | 91 | 60 | 16.6 |
| July 22 | 80 | 100 | 68 | 20.1 |
| July 24 | 82 | 100 | 85 | 19.1 |
| July 26 | 88 | 100 | 86 | 20.1 |

F, P>F: 5.16, 0.0010 1.66, 0.1674

CV: 34.1 12.8

| Date, growth stage; application #1 | THREE APPLICATIONS, 8-11 days apart | | Yield 13.5% moisture | Test weight |
|------------------------------------|-------------------------------------|--------------------|----------------------|-------------|
| | % of plants | % of canopy lbs/ac | | |
| Non-treated control | 52 | 27 b* | 3307 a* | 53.2 |
| July 17 | 73 | 64 | 24 | 16 |
| July 19 | 75 | 91 | 60 | 16.6 |
| July 22 | 80 | 100 | 68 | 20.1 |
| July 24 | 82 | 100 | 85 | 19.1 |
| July 26 | 88 | 100 | 86 | 20.1 |

F, P>F: 2.94, 0.0236 1.85, 0.1253

CV: 39.1 9.4

| Date, growth stage; application #1 | THREE APPLICATIONS, 10-13 days apart | | Yield 13.5% moisture | Test weight |
|------------------------------------|--------------------------------------|--------------------|----------------------|-------------|
| | % of plants | % of canopy lbs/ac | | |
| Non-treated control | 56 | 28 a* | 3452 a* | 55.4 |
| July 17 | 73 | 64 | 24 | 16 |
| July 19 | 75 | 91 | 60 | 16.6 |
| July 22 | 80 | 100 | 68 | 20.1 |
| July 24 | 82 | 100 | 85 | 19.1 |
| July 26 | 88 | 100 | 86 | 20.1 |

F, P>F: 2.68, 0.0355 2.15, 0.800

CV: 39.8 11.7

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

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

METHODS SUMMARY for studies conducted in 2020-2024:

Row spacing = 14 inches in most studies; 28 inches in some studies

Seeding rate = 90,000 viable seeds/ac

Fungicide spray volume = 15 gal/ac.

Application method: Fungicides applied with a hand-held boom pressurized by CO₂ (2020, 2021, 2022) and with a PTO-driven tractor-mounted sprayer (2024).

Fungicide spray droplet size: fine, medium or coarse, calibrated relative to canopy characteristics

Interval between sequential applications: 10 to 14 days, depending on study

Number of experimental replicates = 7, 9, 10 or 16, depending on study

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

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

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

DETAILED METHODS for study conducted in 2025:

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

AGRONOMICS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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