

# Optimizing fungicide droplet size for improved management of foliar diseases of chickpeas, field peas and lentils

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## THIS IS A RESEARCH UPDATE ON A CONTINUING PROJECT

- Funding is being sought from the Northern Pulse Growers Association to continue fungicide droplet size studies on chickpeas in 2020.
- Funding for follow-up research on lentils and/or field peas will be sought after multi-year research on chickpeas is completed.

## OBJECTIVE & RATIONALE

- Due to the limited systemic movement by fungicides within plants, fine to medium spray droplets are generally recommended for fungicides so as to optimize fungicide coverage to the upper canopy.
- For diseases that are initiated in the lower canopy, such as anthracnose and white mold of lentils, agricultural engineers often recommend the use of medium or even coarse droplets for fungicides, as fine droplets lack the velocity to penetrate crop canopies and are predominately deposited in the upper canopy.
- **Recommendations on optimizing spray droplet size with fungicides are based largely on theory**, and data quantifying the impact of spray droplet size on fungicide performance are limited.
- **When producers switch from spraying herbicides to fungicides, they do not always change droplet size.** With the emphasis on reducing herbicide drift, the need to apply herbicides (which exhibit much greater systemic movement than fungicides) with coarse, very coarse or ultra-coarse droplets has been emphasized. The impacts of applying fungicides with coarse droplets on disease control and crop yield have not been well documented, and the cost of applying fungicides with sub-optimal droplet sizes is poorly understood.

## MAJOR FINDINGS

- 1. Fine droplets optimized fungicide performance against *Ascochyta* blight in chickpeas**, minimizing disease and maximizing chickpea yield (Tables 1, 2, 3, and 4).
- 2. The impact of droplet size on was similar across fungicides tested.**
  - Applying fungicides with fine droplets (vs. coarse or medium-coarse) conferred average yield gains of 151 lbs/ac for Proline and 143 lbs/ac for Proline + Bravo WeatherStik.
  - Applying fungicides with fine droplets (vs. medium) conferred average yield gains of 132 lbs/ac for Proline and 78 lbs/ac for Proline + Bravo WeatherStik.
- 3. Applying fungicides with fine droplets optimized *Ascochyta* management and field pea agronomic performance under *Ascochyta* pressure**, minimizing disease and maximizing field pea yield (Tables 5 and 6).
  - Applying fungicides with fine droplets (vs. coarse) conferred average yield gains of 3.1 bu/ac for Priaxor and 1.5 bu/ac for Proline.
  - Applying fungicides with fine droplets (vs. medium) conferred average yield gains of 0.3 bu/ac for Priaxor and 0.6 bu/ac for Proline.
- 4. Applying fungicides with medium droplets optimized anthracnose and white mold management in lentils**, minimizing disease and maximizing lentil yield (Table 7).
  - Applying fungicides with medium droplets (vs. fine) conferred average yield gains of 106 lbs/ac.
  - Applying fungicides with medium droplets (vs. coarse) conferred average yield gains of 60 lbs/ac.

## METHODS

- **Application methods**, studies conducted in Carrington: Fungicides were applied with a tractor-mounted R&D sprayer equipped with a pulse-width modulation system (Capstan AG; Topeka, KS). Driving speed = 8.9 mph (studies conducted in 2019), 3.6 mph (study conducted in 2018). Spray volume = 15 gal/ac. Constant driving speed and constant spray volume were maintained across tips differing in output by adjusting pulse width.
- **Application methods**, study conducted in Williston/Hofflund: Fungicides were applied with a 60-inch hand-held boom equipped with four nozzles, each 20 inches apart. Wilger manufactures nozzles that differ in droplet size without changing output, and spray volume was kept at a constant 15 gal/ac across treatments.
- Row spacing (lentils, field peas, and chickpeas): 7.0 or 7.5 inches
- Plot size: 5 ft x 30 ft at planting (Carrington); 5 ft x 25 ft at planting (Williston).
- Experimental design: randomized complete block with six replicates (chickpeas, Carrington 2018 and Williston/Hofflund 2019), seven replicates (lentils and chickpeas, Carrington 2019), eight replicates (field peas, Wilger tips, Carrington 2019), or ten replicates (field peas, TeeJet tips, Carrington, 2019).
- In studies conducted in Carrington in 2019: Two varieties were evaluated in each droplet size study, with the varieties were planted back-to-back and sprayed concurrently.
- Disease establishment: For chickpeas and field peas, infested crop residues were spread in non-harvested buffer and guard plots adjacent to the treatment plots during early to mid-vegetative growth. For lentils, no supplemental pathogen inoculation was conducted.
- Disease assessment, chickpeas: The percent of the canopy diseased was estimated twice after fungicides were applied, including once shortly before crop maturity. Due to uneven senescence associated with good versus poor disease control in Carrington in 2019, the second disease assessment in chickpeas was conducted by assessing the percent of pods exhibiting *Ascochyta* symptoms. In each quarter of each plot, all of the pods on 2 to 4 plants, with the number of plants adjusted as needed such that a minimum of 50 pods assessed per quarter of the plot.
- Disease assessment, field peas: The percent of the canopy diseased and the height up the canopy that severe disease symptoms extended was assessed twice (Wilger tips) or once (TeeJet tips) after fungicides were applied, with the last assessment conducted prior to senescence at mid- to late pod-fill.
- Disease assessment, lentils: The percent of the canopy exhibiting anthracnose and white mold was assessed prior to senescence at mid- to late pod-fill.
- Yields were calculated on the basis of the measured plot length and reported at a standard 13.5% moisture. Grain was cleaned prior to yield assessment.

**FIGURE & TABLE 1.**  
**Impact of fungicide spray droplet size, chickpeas.** TeeJet extended-range flat-fan tips; Carrington, 2019.

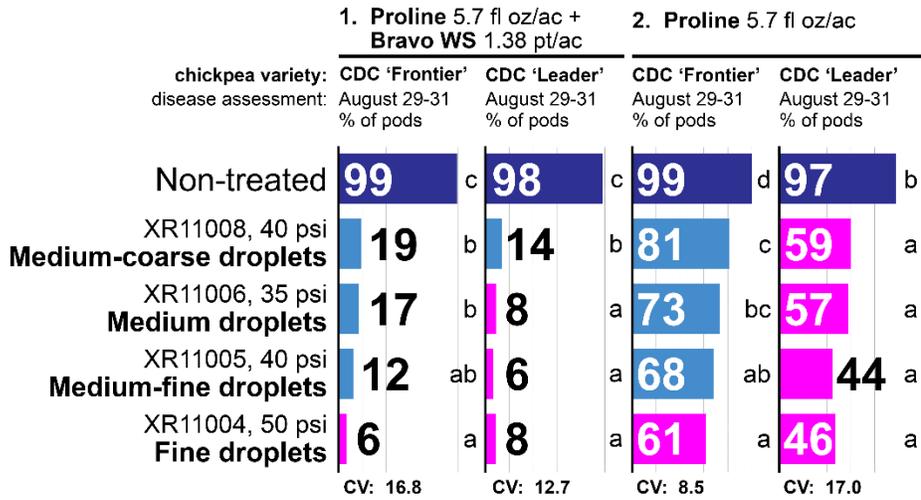
Fungicides were applied with a tractor-mounted R&D sprayer equipped with a pulse-width modulation system. Driving speed = 8.9 mph. Spray volume = 15 gal/ac. Pulse width was modified as needed to maintain constant spray volume across tips differing in output.

Five fungicide applications were made 10-14 days apart from first appearance of disease symptoms (shortly before bloom) until early senescence.

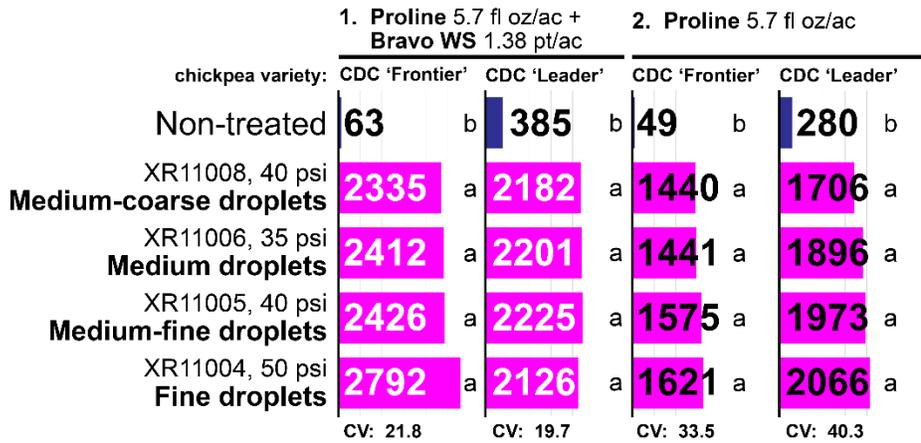
Within-column means followed by different letters are significantly different ( $P < 0.05$ ; Tukey multiple comparison procedure).

Key results (right):  
 Full results (below):

**Ascochyta blight severity**



**Chickpea Yield (pounds/acre)**



**CDC Frontier<sup>1</sup> chickpeas**

|  | Ascochyta severity | Ascochyta severity | Ascochyta rAUDPC | Yield             |
|--|--------------------|--------------------|------------------|-------------------|
|  | July 29-31         | Aug. 26-31         | June 19- Aug. 31 | 13.5% moisture    |
|  | % necrosis         | % of pods          | 0 to 100         | lbs/ac            |
| <b>Proline 480SC 5.7 fl oz/ac + Bravo WeatherStik 1.38 pt/ac + Preference 0.125% v/v</b> |                    |                    |                  |                   |
| 1 Non-treated  | 68 <sup>b*</sup>   | 99 <sup>c*</sup>   | 55 <sup>b*</sup> | 63 <sup>b*</sup>  |
| 2 XR11004, 50 psi (fine droplets)  | 6 <sup>a</sup>     | 6 <sup>a</sup>     | 4 <sup>a</sup>   | 2792 <sup>a</sup> |
| 3 XR11005, 40 psi (medium-fine droplets)   | 6 <sup>a</sup>     | 12 <sup>ab</sup>   | 6 <sup>a</sup>   | 2426 <sup>a</sup> |
| 4 XR11006, 35 psi (medium droplets)  | 4 <sup>a</sup>     | 17 <sup>b</sup>    | 6 <sup>a</sup>   | 2412 <sup>a</sup> |
| 5 XR11008, 40 psi (medium-coarse droplets)   | 8 <sup>a</sup>     | 19 <sup>b</sup>    | 8 <sup>a</sup>   | 2335 <sup>a</sup> |
|  | F: 246.11          | 424.10             | 489.78           | 43.76             |
|  | P>F: < 0.0001      | < 0.0001           | < 0.0001         | < 0.0001          |
|  | CV: 24.8           | 15.7               | 16.3             | 21.8              |

**CDC Leader<sup>1</sup> chickpeas**

|   | Ascochyta severity | Ascochyta severity | Ascochyta rAUDPC | Yield             |
|---|--------------------|--------------------|------------------|-------------------|
|   | July 29-31         | Aug. 26-31         | June 19- Aug. 31 | 13.5% moisture    |
|   | % necrosis         | % of pods          | 0 to 100         | lbs/ac            |
| <b>Proline 480SC 5.7 fl oz/ac + Preference 0.125% v/v</b> |                    |                    |                  |                   |
| 1 Non-treated   | 60 <sup>b*‡</sup>  | 98 <sup>c*</sup>   | 50 <sup>b*</sup> | 385 <sup>b*</sup> |
| 2 XR11004, 50 psi (fine droplets)                         | 4 <sup>a</sup>     | 8 <sup>a</sup>     | 4 <sup>a</sup>   | 2126 <sup>a</sup> |
| 3 XR11005, 40 psi (medium-fine droplets)                  | 2 <sup>a</sup>     | 6 <sup>a</sup>     | 2 <sup>a</sup>   | 2225 <sup>a</sup> |
| 4 XR11006, 35 psi (medium droplets)                       | 3 <sup>a</sup>     | 8 <sup>a</sup>     | 3 <sup>a</sup>   | 2201 <sup>a</sup> |
| 5 XR11008, 40 psi (medium-coarse droplets)                | 2 <sup>a</sup>     | 14 <sup>b</sup>    | 4 <sup>a</sup>   | 2182 <sup>a</sup> |
|   | F: 33.23           | 911.14             | 744.03           | 35.03             |
|   | P>F: < 0.0001      | < 0.0001           | < 0.0001         | < 0.0001          |
|   | CV: 37.9           | 12.7               | 15.8             | 19.7              |

**Proline 480SC 5.7 fl oz/ac + Preference 0.125% v/v**

|  | Ascochyta severity | Ascochyta severity | Ascochyta rAUDPC  | Yield             |
|--|--------------------|--------------------|-------------------|-------------------|
|  | July 29-31         | Aug. 26-31         | June 19- Aug. 31  | 13.5% moisture    |
|  | % necrosis         | % of pods          | 0 to 100          | lbs/ac            |
| 1 Non-treated                              | 67 <sup>b*</sup>   | 99 <sup>d*</sup>   | 55 <sup>c*‡</sup> | 49 <sup>b*</sup>  |
| 2 XR11004, 50 psi (fine droplets)          | 15 <sup>a</sup>    | 61 <sup>a</sup>    | 20 <sup>a</sup>   | 1621 <sup>a</sup> |
| 3 XR11005, 40 psi (medium-fine droplets)   | 26 <sup>a</sup>    | 68 <sup>ab</sup>   | 27 <sup>ab</sup>  | 1575 <sup>a</sup> |
| 4 XR11006, 35 psi (medium droplets)        | 31 <sup>a</sup>    | 74 <sup>bc</sup>   | 31 <sup>b</sup>   | 1441 <sup>a</sup> |
| 5 XR11008, 40 psi (medium-coarse droplets) | 33 <sup>a</sup>    | 81 <sup>c</sup>    | 33 <sup>b</sup>   | 1440 <sup>a</sup> |
|  | F: 16.41           | 35.02              | 14.97             | 18.22             |
|  | P>F: < 0.0001      | < 0.0001           | < 0.0001          | < 0.0001          |
|  | CV: 37.3           | 8.6                | 7.5               | 33.5              |

**Proline 480SC 5.7 fl oz/ac + Preference 0.125% v/v**

|  | Ascochyta severity | Ascochyta severity | Ascochyta rAUDPC | Yield             |
|--|--------------------|--------------------|------------------|-------------------|
|  | July 29-31         | Aug. 26-31         | June 19- Aug. 31 | 13.5% moisture    |
|  | % necrosis         | % of pods          | 0 to 100         | lbs/ac            |
| 1 Non-treated                              | 56 <sup>b*‡</sup>  | 97 <sup>b*</sup>   | 49 <sup>b*</sup> | 280 <sup>b*</sup> |
| 2 XR11004, 50 psi (fine droplets)          | 4 <sup>a</sup>     | 46 <sup>a</sup>    | 12 <sup>a</sup>  | 2066 <sup>a</sup> |
| 3 XR11005, 40 psi (medium-fine droplets)   | 6 <sup>a</sup>     | 51 <sup>a</sup>    | 14 <sup>a</sup>  | 1973 <sup>a</sup> |
| 4 XR11006, 35 psi (medium droplets)        | 9 <sup>a</sup>     | 60 <sup>a</sup>    | 17 <sup>a</sup>  | 1896 <sup>a</sup> |
| 5 XR11008, 40 psi (medium-coarse droplets) | 7 <sup>a</sup>     | 59 <sup>a</sup>    | 16 <sup>a</sup>  | 1706 <sup>a</sup> |
|  | F: 35.19           | 27.32              | 91.97            | 9.59              |
|  | P>F: < 0.0001      | < 0.0001           | < 0.0001         | 0.0001            |
|  | CV: 21.0           | 16.1               | 19.0             | 40.3              |

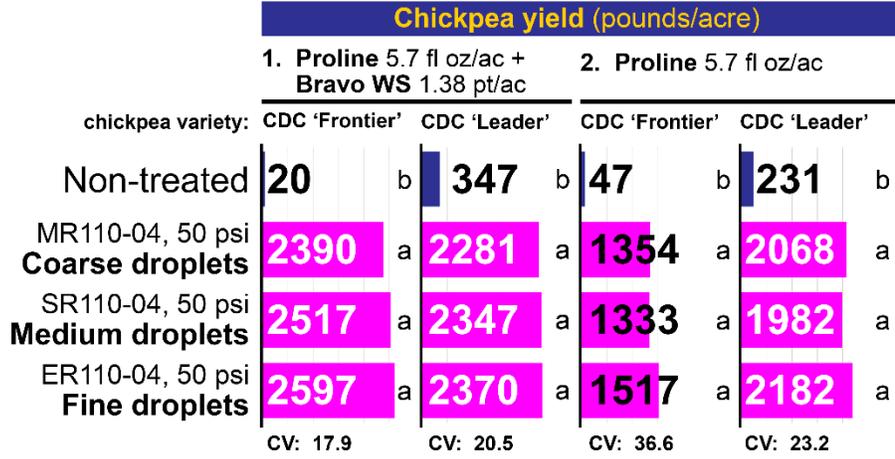
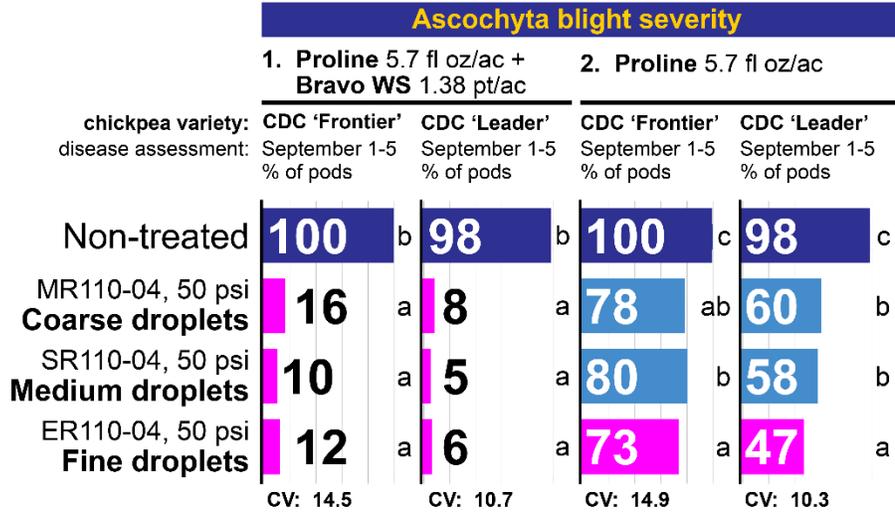
**FIGURE & TABLE 2.**  
**Impact of fungicide spray droplet size, chickpeas.** Wilger flat-fan tips; Carrington, 2019.

Fungicides were applied with a tractor-mounted R&D sprayer equipped with a pulse-width modulation system. Driving speed = 8.9 mph. Spray volume = 15 gal/ac. Wilger manufactures tips that differ in droplet size while maintaining constant output, and all applications were made with 100% pulse width.

Five fungicide applications were made 10-14 days apart from first appearance of disease symptoms (shortly before bloom) until early senescence.

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

Key results (right):  
 Full results (below):



|  | 'CDC Frontier' chickpeas               |  |   |                             | 'CDC Leader' chickpeas                 |  |  |                             |
|--|--|--|---|-----------------------------|--|--|--|-----------------------------|
|  | Ascochyta severity August 1 % necrosis | Ascochyta severity Sept. 1-5 % of pods | Ascochyta rAUDPC June 19- Sept 5 0 to 100 | Yield 13.5% moisture lbs/ac | Ascochyta severity August 1 % necrosis | Ascochyta severity Sept. 1-5 % of pods | Ascochyta rAUDPC June 19- Sept. 5 0 to 100 | Yield 13.5% moisture lbs/ac |
| <b>Proline 480SC 5.7 fl oz/ac + Bravo WeatherStik 1.38 pt/ac + Preference 0.125% v/v</b> |  |  |   |                             |  |  |  |                             |
| 1 Non-treated  | 74 <sup>c*#</sup>                      | 100 <sup>b*</sup>                      | 58 <sup>b*</sup>                          | 20 <sup>b*</sup>            | 62 <sup>b*</sup>                       | 98 <sup>b*</sup>                       | 52 <sup>b*</sup>                           | 347 <sup>b*</sup>           |
| 2 ER110-04, 50 psi (fine droplets)   | 3 <sup>ab</sup>                        | 12 <sup>a</sup>                        | 4 <sup>a</sup>                            | 2597 <sup>a</sup>           | 1 <sup>a</sup>                         | 6 <sup>a</sup>                         | 2 <sup>a</sup>                             | 2370 <sup>a</sup>           |
| 3 SR110-04, 50 psi (medium droplets)   | 3 <sup>a</sup>                         | 10 <sup>a</sup>                        | 3 <sup>a</sup>                            | 2517 <sup>a</sup>           | 1 <sup>a</sup>                         | 5 <sup>a</sup>                         | 2 <sup>a</sup>                             | 2347 <sup>a</sup>           |
| 4 MR110-04, 50 psi (coarse droplets)   | 4 <sup>b</sup>                         | 16 <sup>a</sup>                        | 5 <sup>a</sup>                            | 2390 <sup>a</sup>           | 1 <sup>a</sup>                         | 8 <sup>a</sup>                         | 3 <sup>a</sup>                             | 2281 <sup>a</sup>           |
| F:   | 464.03                                 | 54.88                                  | 2026.16                                   | 95.73                       | 587.38                                 | 1505.14                                | 1323.15                                    | 48.60                       |
| P>F:   | < 0.0001                               | < 0.0001                               | < 0.0001                                  | < 0.0001                    | < 0.0001                               | < 0.0001                               | < 0.0001                                   | < 0.0001                    |
| CV:  | 9.9                                    | 14.5                                   | 8.9                                       | 17.9                        | 20.4                                   | 10.7                                   | 12.5                                       | 20.5                        |
| <b>Proline 480SC 5.7 fl oz/ac + Preference 0.125% v/v</b>                                |  |  |   |                             |  |  |  |                             |
| 1 Non-treated  | 72 <sup>b*</sup>                       | 100 <sup>c*#</sup>                     | 58 <sup>b*</sup>                          | 47 <sup>b*</sup>            | 60 <sup>b*</sup>                       | 98 <sup>c*</sup>                       | 51 <sup>b*</sup>                           | 231 <sup>b*</sup>           |
| 2 ER110-04, 50 psi (fine droplets)   | 12 <sup>a</sup>                        | 73 <sup>a</sup>                        | 22 <sup>a</sup>                           | 1517 <sup>a</sup>           | 5 <sup>a</sup>                         | 47 <sup>a</sup>                        | 13 <sup>a</sup>                            | 2182 <sup>a</sup>           |
| 3 SR110-04, 50 psi (medium droplets)   | 10 <sup>a</sup>                        | 80 <sup>b</sup>                        | 23 <sup>a</sup>                           | 1333 <sup>a</sup>           | 3 <sup>a</sup>                         | 58 <sup>b</sup>                        | 14 <sup>a</sup>                            | 1982 <sup>a</sup>           |
| 4 MR110-04, 50 psi (coarse droplets)   | 14 <sup>a</sup>                        | 78 <sup>ab</sup>                       | 24 <sup>a</sup>                           | 1354 <sup>a</sup>           | 3 <sup>a</sup>                         | 60 <sup>b</sup>                        | 15 <sup>a</sup>                            | 2068 <sup>a</sup>           |
| F:   | 291.32                                 | 182.76                                 | 298.47                                    | 21.54                       | 1184.72                                | 77.06                                  | 757.77                                     | 42.78                       |
| P>F:   | < 0.0001                               | < 0.0001                               | < 0.0001                                  | < 0.0001                    | < 0.0001                               | < 0.0001                               | < 0.0001                                   | < 0.0001                    |
| CV:  | 17.0                                   | 14.9                                   | 8.4                                       | 36.6                        | 12.3                                   | 10.3                                   | 7.8  | 23.2                        |

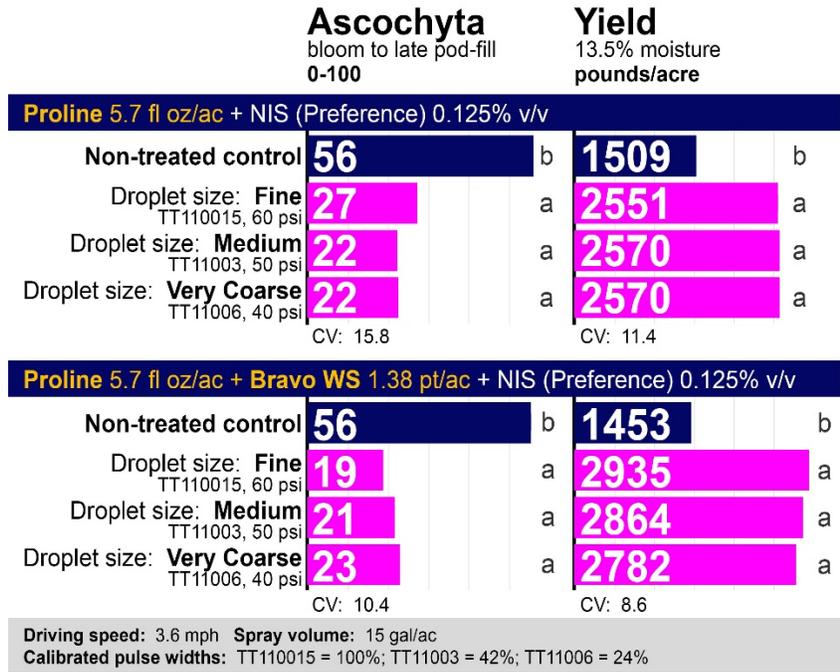
**FIGURE & TABLE 3. Impact of fungicide spray droplet size, chickpeas.** TeeJet TurboTee flat-fan tips; Carrington, 2018.

Fungicides were applied with a tractor-mounted R&D sprayer equipped with a pulse-width modulation system. Driving speed = 3.6 mph. Spray volume = 15 gal/ac. Pulse width was modified as needed to maintain constant spray volume across tips differing in output.

Five fungicide applications were made 10-14 days apart from first appearance of disease symptoms (shortly before bloom) until early senescence.

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

Key results (right):  
Full results (below):



| 'CDC Frontier' chickpeas   |                                      |                       |                       |                          |                          |
|--|--------------------------------------|-----------------------|-----------------------|--------------------------|--------------------------|
| Nozzle   | Droplet Size                         | Ascochyta severity:   |                       | Yield                    | Test Weight              |
|  |                                      | July 20<br>% necrosis | Aug. 14<br>% necrosis | 13.5% moisture<br>lbs/ac | 13.5% moisture<br>lbs/bu |
| <b>Proline 5.7 fl oz/ac + NIS (Preference) 0.125% v/v</b>                                |                                      |                       |                       |                          |                          |
| 1  | Non-treated                          | 82 b*                 | 69 b*                 | 1509 b*                  | 63.1 b*                  |
| 2  | TT110015-VP 60 psi fine-medium       | 46 a                  | 17 a                  | 2551 a                   | 64.2 a                   |
| 3  | TT11003-VP 50 psi medium-coarse      | 36 a                  | 17 a                  | 2570 a                   | 64.3 a                   |
| 4  | TT11006-VP 40 psi very coarse-coarse | 37 a                  | 14 a                  | 2570 a                   | 64.2 a                   |
|  | <i>F</i> :                           | 34.31                 | 104.73                | 24.45                    | 6.82                     |
|  | <i>P&gt;F</i> :                      | < 0.0001              | < 0.0001              | < 0.0001                 | 0.0040                   |
|  | <i>CV</i> :                          | 18.0                  | 21.5                  | 11.4                     | 0.9                      |
| <b>Proline 5.7 fl oz/ac + Bravo WeatherStik 1.38 pt/ac + NIS (Preference) 0.125% v/v</b> |                                      |                       |                       |                          |                          |
| 1  | Non-treated                          | 81 b*                 | 68 b*                 | 1453 b*                  | 62.5 b*                  |
| 2  | TT110015-VP 60 psi fine-medium       | 33 a                  | 5 a                   | 2935 a                   | 64.6 a                   |
| 3  | TT11003-VP 50 psi medium-coarse      | 40 a                  | 5 a                   | 2864 a                   | 64.6 a                   |
| 4  | TT11006-VP 40 psi very coarse-coarse | 42 a                  | 5 a                   | 2782 a                   | 64.7 a                   |
|  | <i>F</i> :                           | 75.82                 | 1331.86               | 64.48                    | 11.62                    |
|  | <i>P&gt;F</i> :                      | < 0.0001              | < 0.0001              | < 0.0001                 | 0.0003                   |
|  | <i>CV</i> :                          | 12.5                  | 10.2                  | 8.6                      | 1.2                      |

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

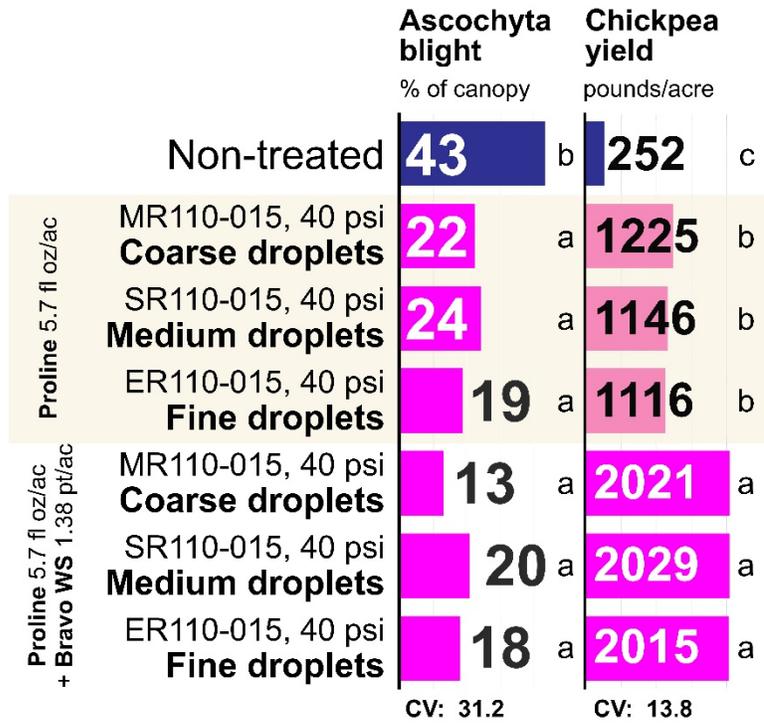
**FIGURE & TABLE 4. Impact of fungicide spray droplet size, chickpeas.** Wilger flat-fan tips; Hofflund, ND (30 miles east of Williston), 2019.

Fungicides were applied with a hand-held boom. Spray volume = 15 gal/ac. Wilger manufactures tips that differ in droplet size while maintaining constant output, and all applications were made with 100% pulse width.

Three fungicide applications were made 10-14 days apart from first appearance of disease symptoms (shortly before bloom) until late pod-fill.

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

Key results (right):  
Full results (below):



**CDC Frontier' chickpeas**

| Replicate |   | Canopy necrosis                     | Canopy necrosis                   | rAUDPC                                | Yield                 | Test Weight           |
|-----------|---|-------------------------------------|-----------------------------------|---------------------------------------|-----------------------|-----------------------|
|           |   | July 11; R2/R3 growth stage percent | August 5; R6 growth stage percent | June 25 (R1) - August 5 (R6) 0 to 100 | 13.5% moisture lbs/ac | 13.5% moisture lbs/bu |
| 1         | Non-treated control   | 10 b*                               | 43 b*                             | 18 b*                                 | 252 c*                | 61.2 c                |
| 2         | Proline 5.7 fl oz/ac ER110-015, 40 psi, fine droplets                         | 4 a                                 | 22 a                              | 9 a                                   | 1225 b                | 62.6 b                |
| 3         | Proline 5.7 fl oz/ac SR110-015, 40 psi, medium droplets                       | 2 a                                 | 24 a                              | 9 a                                   | 1146 b                | 62.3 bc               |
| 4         | Proline 5.7 fl oz/ac DR110-015, 40 psi, coarse droplets                       | 3 a                                 | 19 a                              | 7 a                                   | 1116 b                | 62.4 bc               |
| 5         | Proline 5.7 fl oz/ac + Bravo WS 1.38 pt/ac ER110-015, 40 psi, fine droplets   | 2 a                                 | 13 a                              | 5 a                                   | 2021 a                | 63.8 a                |
| 6         | Proline 5.7 fl oz/ac + Bravo WS 1.38 pt/ac SR110-015, 40 psi, medium droplets | 3 a                                 | 20 a                              | 8 a                                   | 2029 a                | 63.3 ab               |
| 7         | Proline 5.7 fl oz/ac + Bravo WS 1.38 pt/ac DR110-015, 40 psi, coarse droplets | 2 a                                 | 18 a                              | 7 a                                   | 2015 a                | 63.4 ab               |
|           | F:  | 10.01                               | 11.21                             | 17.83                                 | 70.72                 | 9.17                  |
|           | P>F:  | < 0.0001                            | < 0.0001                          | < 0.0001                              | < 0.0001              | < 0.0001              |
|           | CV:   | 59.2                                | 31.2                              | 27.8                                  | 13.8                  | 1.0                   |

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

‡ To meet model assumptions of normality and/or homoskedasticity, analysis of variance was conducted on data subjected to a systematic natural-log transformation. For ease of interpretation, treatments means are presented for the non-transformed data.

**FIGURE & TABLE 5. Impact of fungicide spray droplet size, field peas. TeeJet extended-range and Wilger flat-fan tips; Carrington, 2019.**

Fungicides were applied with a tractor-mounted R&D sprayer equipped with a pulse-width modulation system. Driving speed = 8.9 mph. Spray volume = 15 gal/ac. For TeeJet tips, pulse width was modified as needed to maintain constant spray volume across tips differing in output. For Wilger tips, all applications were made at 100% pulse width

One fungicide application was made when peas had 100% of plants with an open blossom and first pods were full-length and flat.

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

|   |                 | 'LG Koda' green peas |                |                   | 'Nette 2010' yellow peas |                |                   |
|---|-----------------|----------------------|----------------|-------------------|--------------------------|----------------|-------------------|
|   |                 | TeeJet nozzles       | Wilger nozzles | Combined analysis | TeeJet nozzles           | Wilger nozzles | Combined analysis |
| <b>Ascochyta severity (% of canopy; mid to late pod-fill)</b> |                 |                      |                |                   |                          |                |                   |
| <b>Non-treated control</b>                                    |                 | <b>19</b>            | <b>12</b>      | <b>16</b>         | <b>18</b>                | <b>10</b>      | <b>14</b>         |
| Headline  | Medium droplets | 14                   | 10             | 12                | 12                       | 7              | 10                |
| Proline   | Fine droplets   | 11                   | 6              | 9                 | 13                       | 6              | 10                |
| Proline   | Medium droplets | 11                   | 7              | 9                 | 10                       | 8              | 9                 |
| Proline   | Coarse droplets | 11                   | 7              | 9                 | 12                       | 7              | 10                |
| Priaxor   | Fine droplets   | 13                   | 8              | 11                | 11                       | 8              | 10                |
| Priaxor   | Medium droplets | 12                   | 8              | 10                | 11                       | 6              | 9                 |
| Priaxor   | Coarse droplets | 15                   | 10             | 13                | 10                       | 7              | 9                 |
|   |                 | CV: 9.0              | CV: 12.7       | CV: 10.3          | CV: 11.8                 | CV: 10.1       | CV: 11.6          |
| <b>Yield (bushels/acre)</b>                                   |                 |                      |                |                   |                          |                |                   |
| <b>Non-treated control</b>                                    |                 | <b>46</b>            | <b>46</b>      | <b>46</b>         | <b>48</b>                | <b>52</b>      | <b>50</b>         |
| Headline  | Medium droplets | 51                   | 54             | 52                | 56                       | 58             | 57                |
| Proline   | Fine droplets   | 55                   | 52             | 54                | 54                       | 56             | 55                |
| Proline   | Medium droplets | 52                   | 51             | 52                | 54                       | 57             | 56                |
| Proline   | Coarse droplets | 53                   | 47             | 50                | 55                       | 57             | 56                |
| Priaxor   | Fine droplets   | 56                   | 51             | 54                | 54                       | 57             | 55                |
| Priaxor   | Medium droplets | 56                   | 51             | 54                | 54                       | 56             | 55                |
| Priaxor   | Coarse droplets | 51                   | 48             | 50                | 53                       | 54             | 53                |
|   |                 | CV: 12.4             | CV: 10.9       | CV: 11.9          | CV: 9.1                  | CV: 8.7        | CV: 8.7           |

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

|                                    |   | Ascochyta severity          |                   | Ascochyta severity           |                   | Lodging           | Yield             | Test Weight         |                 |
|------------------------------------|---|-----------------------------|-------------------|------------------------------|-------------------|-------------------|-------------------|---------------------|-----------------|
|                                    |   | July 19                     |                   | July 25                      |                   |                   |                   |                     |                 |
|                                    |   | 60-75% of pods fully filled |                   | 95-100% of pods fully filled |                   | Aug. 7-8 maturity | 13.5% moisture    | 13.5% moisture      |                 |
|                                    |   | % severity                  | % up canopy       | % severity                   | % up canopy       |                   |                   |                     | % from vertical |
| Non-treated                        | Non-treated                                   | 12 c <sup>+</sup>           | 48 d <sup>+</sup> | 32 e <sup>+</sup>            | 92 a              | 91 a <sup>+</sup> | 46 a <sup>+</sup> | 62.9 a <sup>+</sup> |                 |
| SR110-04, 50 psi (medium droplets) | Headline 6.0 fl oz/ac + Preference 0.125% v/v | 10 bc                       | 45 cd             | 32 de                        | 97 a              | 82 a              | 54 a              | 62.9 a              |                 |
| ER110-04, 50 psi (fine droplets)   | Proline 5.7 fl oz/ac + Preference 0.125% v/v  | 6 a                         | 31 a              | 18 ab                        | 91 a              | 87 a              | 52 a              | 63.0 a              |                 |
| SR110-04, 50 psi (medium droplets) | Proline 5.7 fl oz/ac + Preference 0.125% v/v  | 7 ab                        | 32 ab             | 17 a                         | 85 a              | 90 a              | 51 a              | 63.4 a              |                 |
| MR110-04, 50 psi (coarse droplets) | Proline 5.7 fl oz/ac + Preference 0.125% v/v  | 7 ab                        | 36 abc            | 21 abc                       | 96 a              | 73 a              | 47 a              | 63.5 a              |                 |
| ER110-04, 50 psi (fine droplets)   | Priaxor 4.0 fl oz/ac + Preference 0.125% v/v  | 8 abc                       | 46 cd             | 26 b-e                       | 94 a              | 86 a              | 51 a              | 63.1 a              |                 |
| SR110-04, 50 psi (medium droplets) | Priaxor 4.0 fl oz/ac + Preference 0.125% v/v  | 8 abc                       | 43 bcd            | 24 a-d                       | 90 a              | 75 a              | 51 a              | 63.4 a              |                 |
| MR110-04, 50 psi (coarse droplets) | Priaxor 4.0 fl oz/ac + Preference 0.125% v/v  | 10 bc                       | 46 cd             | 28 cde                       | 92 a              | 89 a              | 48 a              | 62.6 a              |                 |
|                                    |   | F:                          | 4.59              | 6.35                         | 10.25             | 1.54              | 1.79              | 1.99                | 1.73            |
|                                    |   | P>F:                        | 0.0005            | < 0.0001                     | < 0.0001          | 0.1769            | 0.1109            | 0.0756              | 0.1240          |
|                                    |   | CV:                         | 12.7              | 18.5                         | 21.0              | 9.6               | 16.8              | 10.9                | 1.0             |
|                                    |   | Ascochyta severity          |                   | Ascochyta severity           |                   | Lodging           | Yield             | Test Weight         |                 |
|                                    |   | July 19                     |                   | July 25                      |                   |                   |                   |                     |                 |
|                                    |   | 60-75% of pods fully filled |                   | 95-100% of pods fully filled |                   | Aug. 7-8 maturity | 13.5% moisture    | 13.5% moisture      |                 |
|                                    |   | % severity                  | % up canopy       | % severity                   | % up canopy       |                   |                   |                     | % from vertical |
| Non-treated                        | Non-treated                                   | 10 b <sup>†</sup>           | 42 b <sup>†</sup> | 37 d <sup>†</sup>            | 96 a <sup>†</sup> | 83 b <sup>†</sup> | 52 a <sup>†</sup> | 63.1 a <sup>†</sup> |                 |
| SR110-04, 50 psi (medium droplets) | Headline 6.0 fl oz/ac + Preference 0.125% v/v | 7 ab                        | 38 ab             | 26 abc                       | 98 a              | 59 ab             | 58 a              | 62.7 a              |                 |
| ER110-04, 50 psi (fine droplets)   | Proline 5.7 fl oz/ac + Preference 0.125% v/v  | 6 a                         | 29 a              | 20 ab                        | 99 a              | 74 ab             | 56 a              | 63.1 a              |                 |
| SR110-04, 50 psi (medium droplets) | Proline 5.7 fl oz/ac + Preference 0.125% v/v  | 8 ab                        | 33 ab             | 21 abc                       | 98 a              | 80 ab             | 57 a              | 63.0 a              |                 |
| MR110-04, 50 psi (coarse droplets) | Proline 5.7 fl oz/ac + Preference 0.125% v/v  | 7 a                         | 31 a              | 22 abc                       | 100 a             | 78 ab             | 57 a              | 62.9 a              |                 |
| ER110-04, 50 psi (fine droplets)   | Priaxor 4.0 fl oz/ac + Preference 0.125% v/v  | 8 ab                        | 41 b              | 27 bc                        | 99 a              | 58 ab             | 57 a              | 63.2 a              |                 |
| SR110-04, 50 psi (medium droplets) | Priaxor 4.0 fl oz/ac + Preference 0.125% v/v  | 6 a                         | 36 ab             | 17 a                         | 93 a              | 52 a              | 56 a              | 63.2 a              |                 |
| MR110-04, 50 psi (coarse droplets) | Priaxor 4.0 fl oz/ac + Preference 0.125% v/v  | 7 ab                        | 38 ab             | 29 cd                        | 98 a              | 77 ab             | 54 a              | 63.1 a              |                 |
|                                    |   | F:                          | 4.23              | 4.33                         | 9.27              | 0.63              | 3.46              | 1.29                | 0.65            |
|                                    |   | P>F:                        | 0.0010            | 0.0008                       | < 0.0001          | 0.7266            | 0.0043            | 0.2752              | 0.7165          |
|                                    |   | CV:                         | 10.1              | 18.1                         | 23.4              | 7.7               | 25.4              | 8.7                 | 1.0             |

**TABLE 6. Impact of fungicide spray droplet size, field peas.** TeeJet extended-range flat-fan tips; Carrington, 2019. Fungicides were applied with a tractor-mounted R&D sprayer equipped with a pulse-width modulation system. Driving speed = 8.9 mph. Spray volume = 15 gal/ac. Pulse width was modified as needed to maintain constant spray volume across tips differing in output. One fungicide application was made when peas had 100% of plants with an open blossom and first pods were full-length and flat. Within-column means followed by different letters are significantly different ( $P < 0.05$ ; Tukey multiple comparison procedure).

| 'LG Koda' green peas                      |   | Ascochyta severity          |              | Lodging         | Yield        | Test Weight  |
|---|---|-----------------------------|--------------|-----------------|--------------|--------------|
|   |   | July 22                     |              | Aug. 8-9        | 13.5%        | 13.5%        |
|   |   | 80-90% of pods fully filled |              | maturity        | moisture     | moisture     |
|   |   | % severity                  | % up canopy  | % from vertical | bu/ac        | lbs/bu       |
| Non-treated                               | Non-treated   | 19 c*‡                      | 54 c*        | 90 b*           | 46 b*        | 63 a*        |
| <b>XR11006</b> , 35 psi (medium droplets) | <b>Headline</b> 6.0 fl oz/ac + <b>Preference</b> 0.125% v/v | <b>14 ab</b>                | <b>48 c</b>  | <b>78 ab</b>    | <b>51 ab</b> | <b>63 a</b>  |
| <b>XR11004</b> , 50 psi (fine droplets)   | <b>Proline</b> 5.7 fl oz/ac + <b>Preference</b> 0.125% v/v  | <b>11 a</b>                 | <b>37 a</b>  | <b>85 ab</b>    | <b>55 ab</b> | <b>63 a</b>  |
| <b>XR11006</b> , 35 psi (medium droplets) | <b>Proline</b> 5.7 fl oz/ac + <b>Preference</b> 0.125% v/v  | <b>11 a</b>                 | <b>37 ab</b> | <b>88 b</b>     | <b>52 ab</b> | <b>63 a</b>  |
| <b>XR11010</b> , 30 psi (coarse droplets) | <b>Proline</b> 5.7 fl oz/ac + <b>Preference</b> 0.125% v/v  | <b>11 ab</b>                | <b>34 a</b>  | <b>87 b</b>     | <b>53 ab</b> | <b>63 a</b>  |
| <b>XR11004</b> , 50 psi (fine droplets)   | <b>Priaxor</b> 4.0 fl oz/ac + <b>Preference</b> 0.125% v/v  | <b>13 ab</b>                | <b>48 c</b>  | <b>78 ab</b>    | <b>56 a</b>  | <b>63 a</b>  |
| <b>XR11006</b> , 35 psi (medium droplets) | <b>Priaxor</b> 4.0 fl oz/ac + <b>Preference</b> 0.125% v/v  | <b>12 ab</b>                | <b>45 bc</b> | <b>82 ab</b>    | <b>56 a</b>  | <b>63 a</b>  |
| <b>XR11010</b> , 30 psi (coarse droplets) | <b>Priaxor</b> 4.0 fl oz/ac + <b>Preference</b> 0.125% v/v  | <b>15 bc</b>                | <b>47 c</b>  | <b>71 a</b>     | <b>51 ab</b> | <b>63 a</b>  |
|   | <i>F</i> :  | 7.83                        | 13.14        | 3.43            | 2.45         | 1.10         |
|   | <i>P&gt;F</i> :   | < 0.0001                    | < 0.0001     | 0.0036          | 0.0274       | 0.3730       |
|   | <i>CV</i> :   | 9.0                         | 14.0         | 13.1            | 12.4         | 1.0          |
| 'Nette 2010' yellow peas                  |   | Ascochyta severity          |              | Lodging         | Yield        | Test Weight  |
|   |   | July 22                     |              | Aug. 8-9        | 13.5%        | 13.5%        |
|   |   | 80-90% of pods fully filled |              | maturity        | moisture     | moisture     |
|   |   | % severity                  | % up canopy  | % from vertical | bu/ac        | lbs/bu       |
| Non-treated                               | Non-treated   | 18 b*‡                      | 50 ab*       | 80 b*           | 48 b*        | 63 b*        |
| <b>XR11006</b> , 35 psi (medium droplets) | <b>Headline</b> 6.0 fl oz/ac + <b>Preference</b> 0.125% v/v | <b>12 ab</b>                | <b>52 b</b>  | <b>52 ab</b>    | <b>56 a</b>  | <b>64 ab</b> |
| <b>XR11004</b> , 50 psi (fine droplets)   | <b>Proline</b> 5.7 fl oz/ac + <b>Preference</b> 0.125% v/v  | <b>13 ab</b>                | <b>40 ab</b> | <b>51 ab</b>    | <b>54 a</b>  | <b>64 ab</b> |
| <b>XR11006</b> , 35 psi (medium droplets) | <b>Proline</b> 5.7 fl oz/ac + <b>Preference</b> 0.125% v/v  | <b>10 a</b>                 | <b>39 a</b>  | <b>56 ab</b>    | <b>54 ab</b> | <b>63 ab</b> |
| <b>XR11010</b> , 30 psi (coarse droplets) | <b>Proline</b> 5.7 fl oz/ac + <b>Preference</b> 0.125% v/v  | <b>12 ab</b>                | <b>45 ab</b> | <b>58 ab</b>    | <b>55 a</b>  | <b>64 ab</b> |
| <b>XR11004</b> , 50 psi (fine droplets)   | <b>Priaxor</b> 4.0 fl oz/ac + <b>Preference</b> 0.125% v/v  | <b>11 a</b>                 | <b>49 ab</b> | <b>39 a</b>     | <b>54 ab</b> | <b>64 ab</b> |
| <b>XR11006</b> , 35 psi (medium droplets) | <b>Priaxor</b> 4.0 fl oz/ac + <b>Preference</b> 0.125% v/v  | <b>11 a</b>                 | <b>48 ab</b> | <b>48 a</b>     | <b>54 ab</b> | <b>64 a</b>  |
| <b>XR11010</b> , 30 psi (coarse droplets) | <b>Priaxor</b> 4.0 fl oz/ac + <b>Preference</b> 0.125% v/v  | <b>10 a</b>                 | <b>41 ab</b> | <b>46 a</b>     | <b>53 ab</b> | <b>64 ab</b> |
|   | <i>F</i> :  | 4.73                        | 3.18         | 3.45            | 2.85         | 1.04         |
|   | <i>P&gt;F</i> :   | 0.0003                      | 0.0061       | 0.0035          | 0.0121       | 0.4135       |
|   | <i>CV</i> :   | 11.8                        | 20.0         | 39.1            | 9.1          | 0.9          |

**TABLE 7. Impact of fungicide spray droplet size, lentils.** Wilger flat-fan tips; Carrington, 2019. Fungicides were applied with a tractor-mounted R&D sprayer equipped with a pulse-width modulation system. Driving speed = 8.9 mph. Spray volume = 15 gal/ac. Wilger manufactures tips that differ in droplet size while maintaining constant output, and all applications were made with 100% pulse width. Two fungicide applications were made 11 days apart; see details below the table. Within-column means followed by different letters are significantly different ( $P < 0.05$ ; Tukey multiple comparison procedure).

| <b>'CDC Invincible CL' small-green lentil</b> |  |                                   |                                      |  |
|---|--|-----------------------------------|--------------------------------------|--|
|   | <b>Anthraco</b><br>July 30, late bloom and mid to late pod-fill<br>% of canopy | <b>Sclerotinia</b><br>% of canopy | <b>Foliar disease</b><br>% of canopy | <b>Yield</b><br>13.5% moisture<br>lbs/ac |
| Non-treated                                   | <b>15 b*</b>   | <b>3.1 b*‡</b>                    | <b>18 b*</b>                         | <b>1399 b*</b>                           |
| ER110-04, 50 psi (fine droplets)              | <b>5 a</b>   | <b>0.3 a</b>                      | <b>5 a</b>                           | <b>1539 ab</b>                           |
| SR110-04, 50 psi (medium droplets)            | <b>3 a</b>   | <b>0.1 a</b>                      | <b>3 a</b>                           | <b>1681 a</b>                            |
| MR110-04, 50 psi (coarse droplets)            | <b>5 a</b>   | <b>0.9 a</b>                      | <b>6 a</b>                           | <b>1652 a</b>                            |
| <i>F:</i>                                     | 8.81   | 10.36                             | 16.16                                | 4.23                                     |
| <i>P&gt;F:</i>                                | 0.0008   | 0.0003                            | < 0.0001                             | 0.0233                                   |
| <i>CV:</i>                                    | 68.7   | 88.6                              | 55.3                                 | 10.7                                     |
| <b>'CDC Impress CL' medium-green lentil</b>   |  |                                   |                                      |  |
|   | <b>Anthraco</b><br>July 30, late bloom and mid to late pod-fill<br>% of canopy | <b>Sclerotinia</b><br>% of canopy | <b>Foliar disease</b><br>% of canopy | <b>Yield</b><br>13.5% moisture<br>lbs/ac |
| Non-treated                                   | <b>20.7 b*‡</b>  | <b>1.4 a*‡</b>                    | <b>22.1 b*‡</b>                      | <b>1267 b*</b>                           |
| ER110-04, 50 psi (fine droplets)              | <b>3.0 a</b>   | <b>0.1 a</b>                      | <b>3.1 a</b>                         | <b>1512 a</b>                            |
| SR110-04, 50 psi (medium droplets)            | <b>2.6 a</b>   | <b>0.3 a</b>                      | <b>2.9 a</b>                         | <b>1583 a</b>                            |
| MR110-04, 50 psi (coarse droplets)            | <b>3.6 a</b>   | <b>0.5 a</b>                      | <b>4.1 a</b>                         | <b>1490 a</b>                            |
| <i>F:</i>                                     | 14.14  | 2.09                              | 14.89                                | 8.00                                     |
| <i>P&gt;F:</i>                                | < 0.0001   | 0.1378                            | < 0.0001                             | 0.0020                                   |
| <i>CV:</i>                                    | 39.4   | 156.9                             | 36.6                                 | 8.4                                      |

**Application A: Proline 5 fl oz/ac + Headline 6 fl oz/ac;** July 1 at 2:00-3:00 pm, 95-100% canopy closure, 11 in. canopy height, 100% of plants with an open blossom, 10% of plants with initial pods

**Application B: Endura 6 oz/ac + Headline 6 fl oz/ac;** July 12 at 4:44-5:20 pm, 100% canopy closure, 12-13 in. canopy height, full bloom, first pods flat and unfilled