

# Reducing Spray Drift and Its Effects

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[www.ag.ndsu.edu/potatoextension](http://www.ag.ndsu.edu/potatoextension)



# Today's Presentation

- New technology
- Off-site movement of herbicides
- Response of soybean to 2,4-D
- Response of soybean to Dicamba
- Effect of glyphosate on potatoes

# Glyphosate-Resistant Weeds

- Glyphosate-resistant soybean became commercially available in 1996.
- Since 1996, 24 weeds have been documented to be glyphosate resistant ([www.weedscience.org](http://www.weedscience.org)).





# New Genetically Engineered Technology

- Resistance to:
  - 2,4-D (+ triclopyr, fluroxypyr, and fops - ACCase inhibitors)
  - Dicamba
  - ALS
  - HPPD



# Synthetic Auxin Herbicides

- 2,4-D and dicamba resistant soybean will be available in the next few years.
- Low amounts of auxin mimic herbicides can cause epinasty.
  - Epinasty: leaf crinkling, bubbling, strapping, and/or twisting and bending of petioles, branches, and stems.





# Epinasty

- Epinasty can lead to reduced leaf area, changed leaf angle, and malformed growth.
- The greater the amount of epinasty is often associated with a reduction in yield potential.



# Inadvertent Exposure to Herbicides

- Particle drift (including inversions)
- Volatilization
- Contamination of spraying equipment
- Misapplication



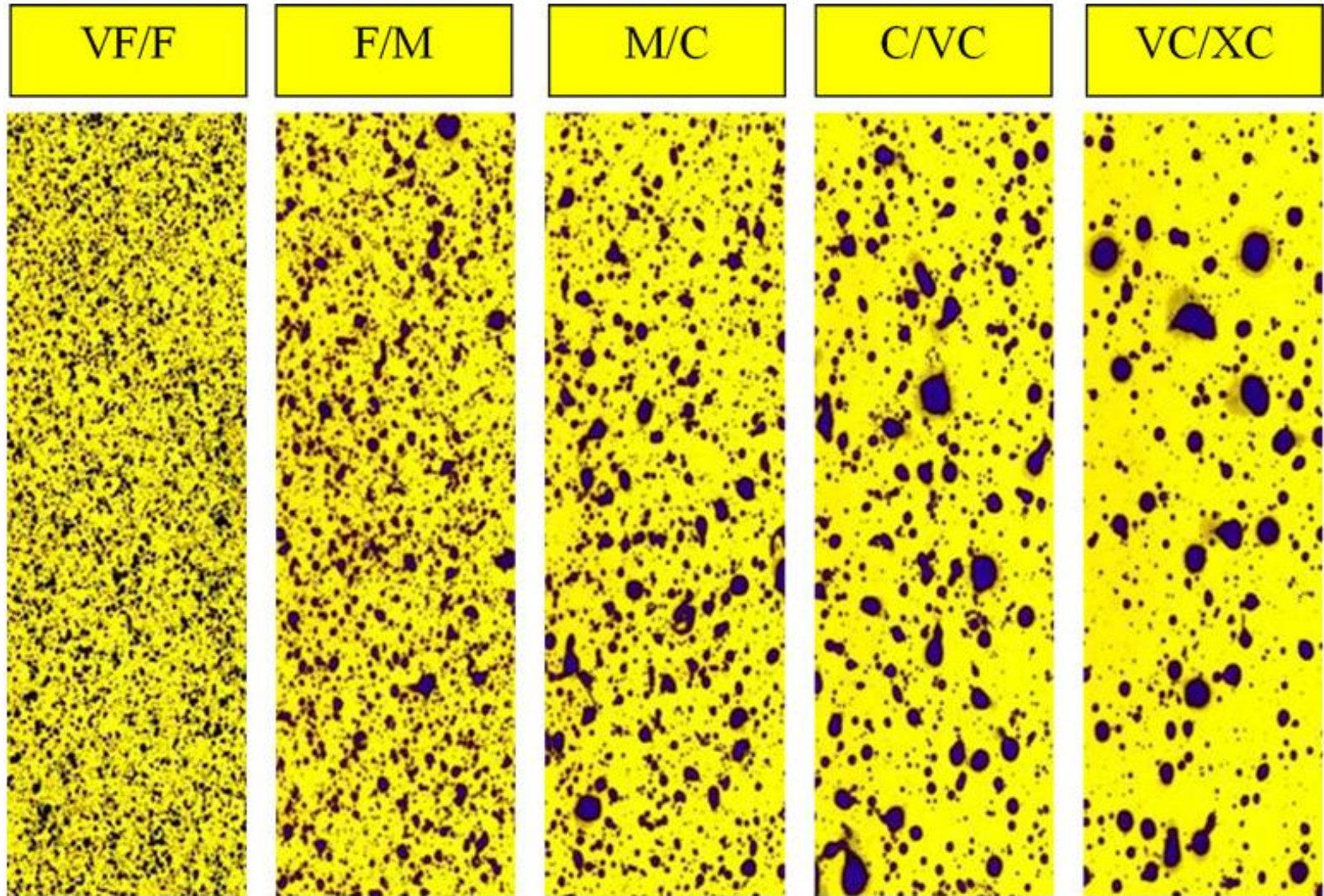


# Drift – Particle Size

## Influence of droplet size on potential distance of drift

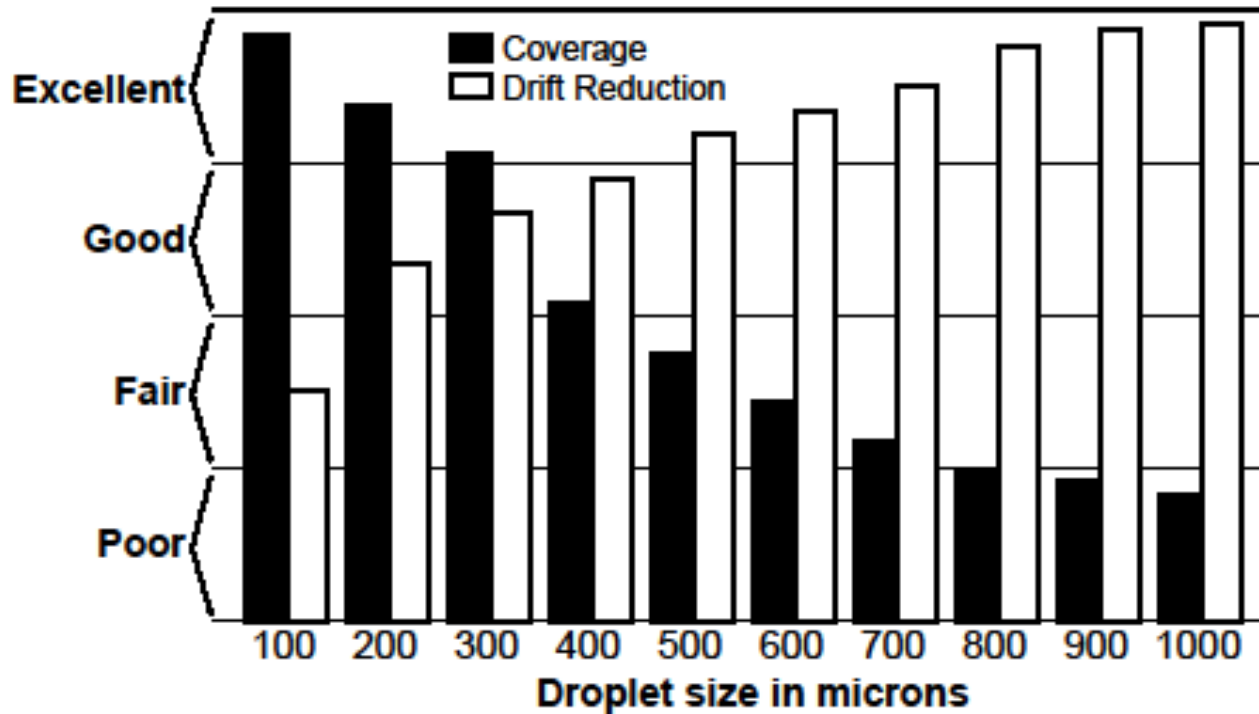
| <b>Droplet diameter (microns)</b> | <b>Type of droplet</b> | <b>Time required to fall 10 feet</b> | <b>Lateral distance droplets travel in falling 10 feet in a 3 mph wind</b> |
|-----------------------------------|------------------------|--------------------------------------|--|
| <b>5</b>                          | Fog                    | 66 minutes                           | 3 miles  |
| <b>20</b>                         | Very fine spray        | 4.2 minutes                          | 1,100 feet   |
| <b>100</b>                        | Fine spray             | 10 seconds                           | 44 feet  |
| <b>240</b>                        | Medium spray           | 6 seconds                            | 28 feet  |
| <b>400</b>                        | Coarse spray           | 2 seconds                            | 8.5 feet   |
| <b>1,000</b>                      | Fine rain              | 1 second                             | 4.7 feet   |

# Coverage of Droplets



# What's the Trade-Off?

**The Trade-Off Between  
Spray Coverage and Drift Reduction**





# Herbicide Volatilization



# Tank Contamination

- Tank Contamination
  - Soybean injury can occur from 0.01% of 8 fl oz/A dicamba
- Incomplete clean-out
  - 0.01% = 6.4 oz left after 16 fl oz/A Clarity in 500 gallon spray tank
  - 0.1% = 2 quarts left after 16 fl oz/A Clarity in 500 gallon spray tank
- Contaminated jugs or equipment
  - 0.01% = 0.05 oz or 1.5 mL Clarity in 500-gallon load

# Tank Residue Case Study

| Water source               | Dicamba (ppb) | Use rate (%) |
|----------------------------|---------------|--------------|
| Spray tank                 | 945           | 0.024%       |
| Spray tank after overnight | 822           | 0.021%       |
| Spray boom                 | 24,800        | 0.63%        |

Based on 1 pt/A Clarity applied in 15 gal/A.  
Spray tank cleaned out prior to test.

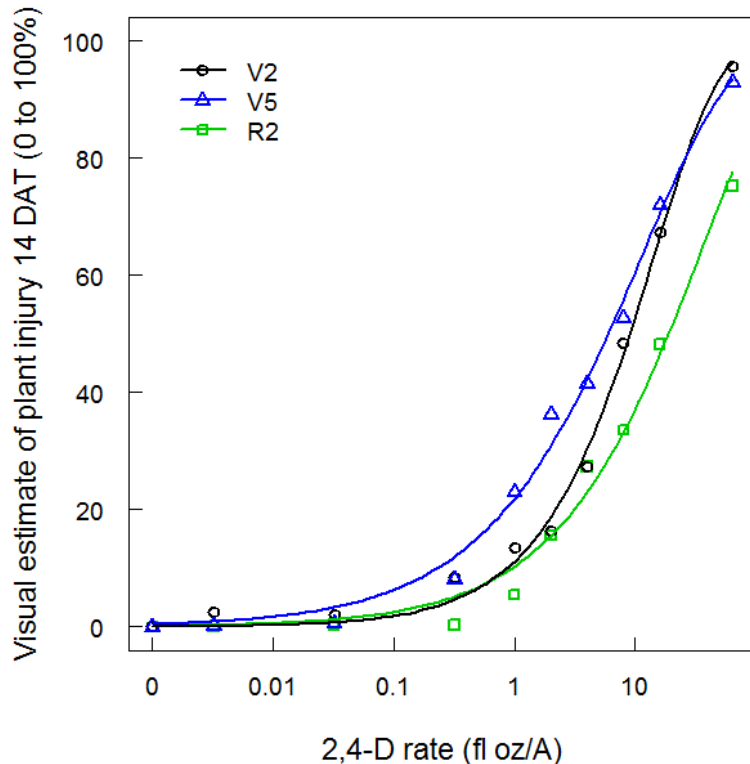
(Boerboom, 2004)



# Response of Glyphosate-resistant Soybean to 2,4-D



# Soybean Injury from 2,4-D at 14 DAT



Estimated 2,4-D dose that caused soybean injury (ED) at 14 DAT.

| ED %             | Soybean growth stage |      |      |
|------------------|----------------------|------|------|
|                  | V2                   | V5   | R2   |
|                  | ----- fl oz/A -----  |      |      |
| ED <sub>20</sub> | 2.19                 | 0.84 | 3.11 |
| ED <sub>50</sub> | 9.02                 | 5.97 | 18.8 |

- Soybean injury of 20% would need 3 to 10% of 32 fl oz/A 2,4-D solution drifting.



14 DAT V2

0 fl oz/A

0.003 fl oz/A

0.03 fl oz/A

0.3 fl oz/A

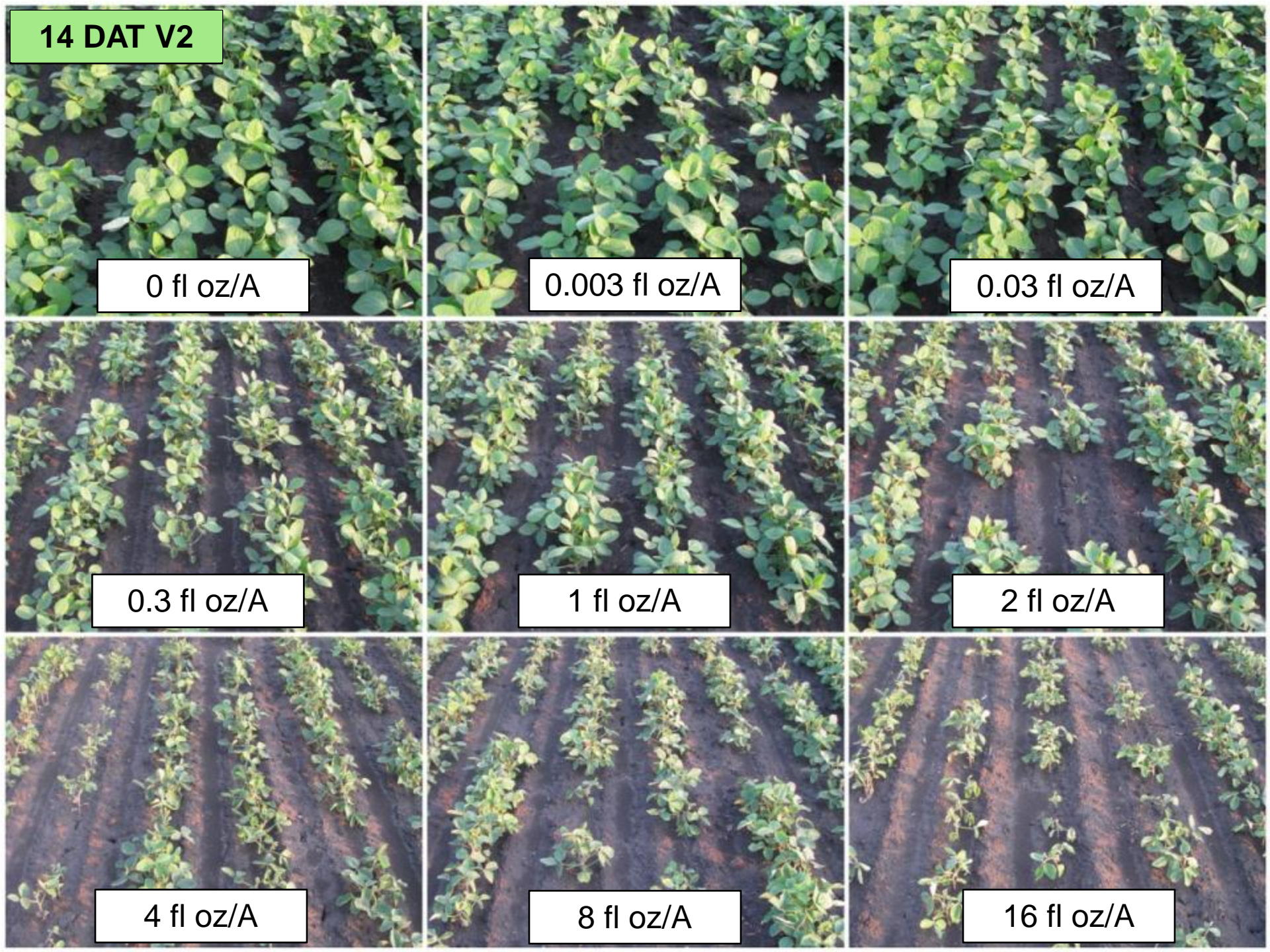
1 fl oz/A

2 fl oz/A

4 fl oz/A

8 fl oz/A

16 fl oz/A

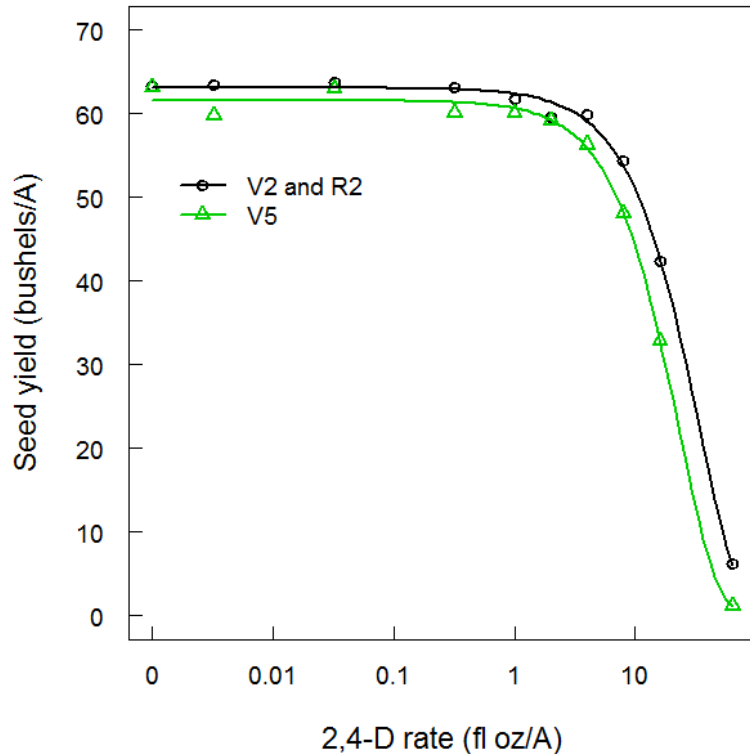




# Reduction in Plant Height from 2,4-D



# Yield Reduction



Estimated 2,4-D dose (ED) resulting in yield reduction.

| ED %             | Soybean growth stage |                  |
|------------------|----------------------|------------------|
|                  | V2 and R2            | V5               |
|                  | ----- fl oz/A -----  |                  |
| ED <sub>10</sub> | 5.8<br>(0.36 pt)     | 4.2<br>(0.26 pt) |
| ED <sub>20</sub> | 10.4<br>(0.65 pt)    | 7.4<br>(0.46 pt) |

- A 10% reduction in seed yield would need 13 to 18% solution drift of 32 fl oz/A 2,4-D.



# Yield Reduction

- Reduction in the number of:
  - Main stem nodes
  - Reproductive nodes
  - Pods
  - Seeds

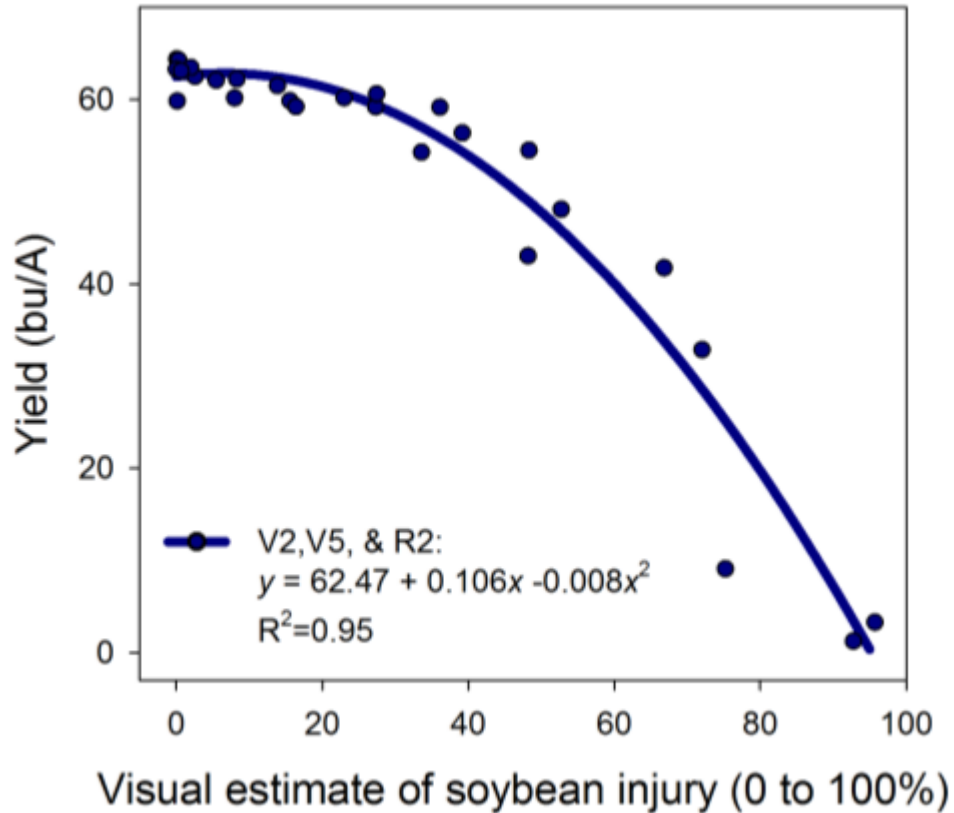




# Can Yield Loss be Estimated from Injury Symptomology?



# Soybean Yield Loss and Injury



Soybean injury from 2,4-D causing soybean yield loss (YL).

|                  | Soybean growth stage |
|------------------|----------------------|
| YL%              | V2, V5, & R2         |
|                  | ----- % injury ----- |
| YL <sub>10</sub> | 35                   |
| YL <sub>20</sub> | 47                   |

# Implications of 2,4-D Drift

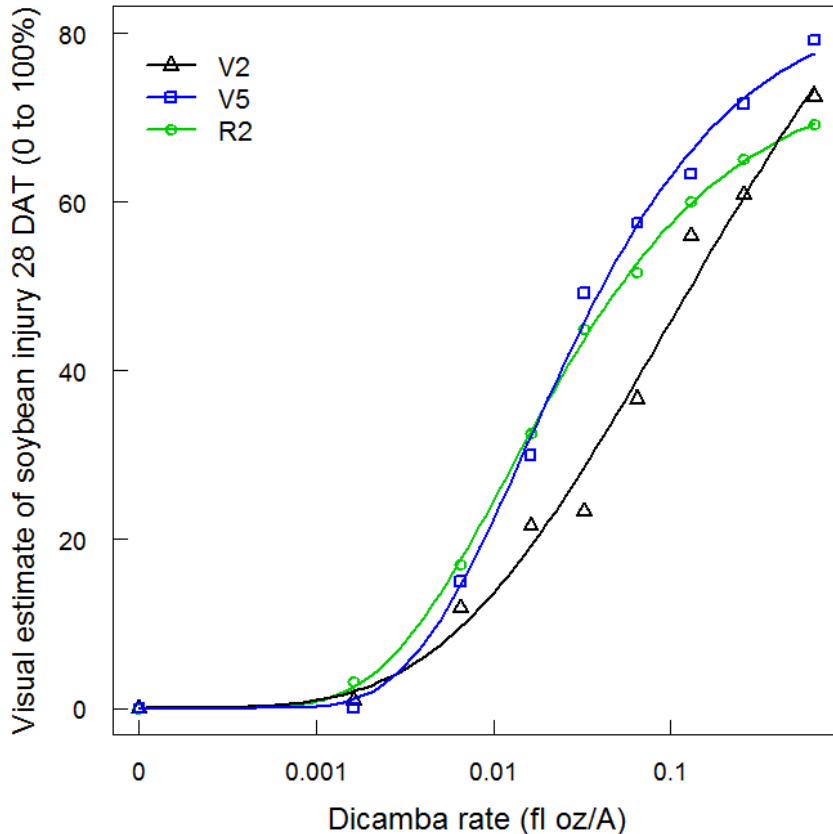
- Injury symptoms can be difficult to detect.
- Soybean was most sensitive to 2,4-D at the V5 growth stage.
- Crop injury and yield loss take a fairly high amount of 2,4-D (13 to 18%) to cause yield loss.
- Greatest injury from 2,4-D will likely occur as a result of misapplication or tank contamination, but cultivars may vary in sensitivity.
- Soybean injury can be used as a quick and easy method to estimate yield loss, but environment and human error can result in variable estimates.



# Response of Glyphosate-resistant Soybean to Dicamba Exposure



# Soybean Injury from Dicamba at 28 DAT

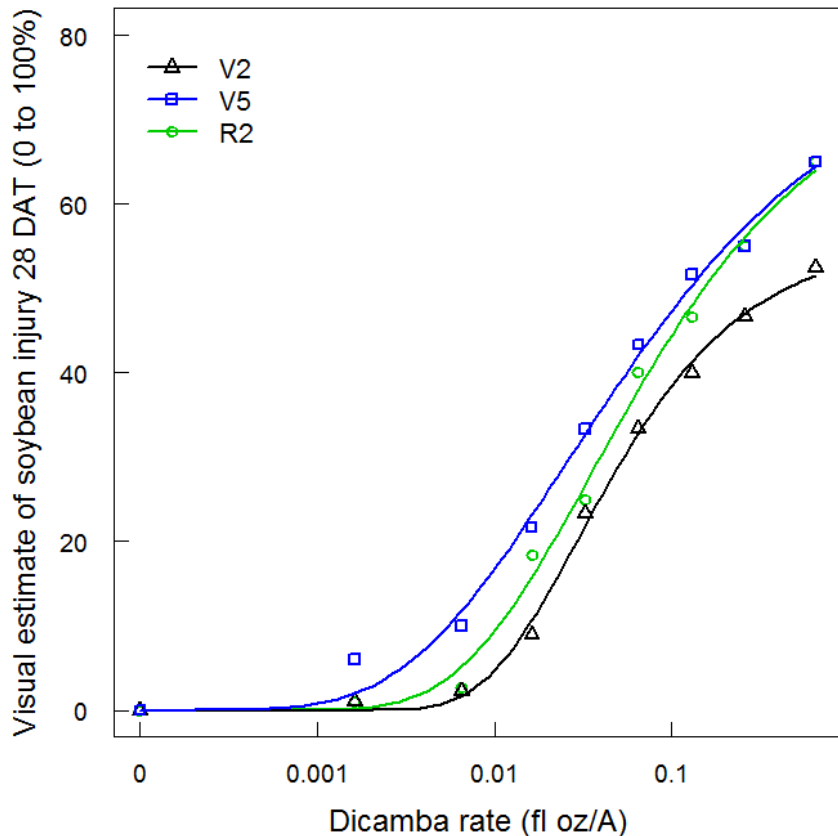


Estimated dicamba dose that caused soybean injury (ED) at 28 DAT in 2009.

| ED %             | Soybean growth stage |      |      |
|------------------|----------------------|------|------|
|                  | V2                   | V5   | R2   |
|                  | ----- fl oz/A -----  |      |      |
| ED <sub>20</sub> | 0.03                 | 0.01 | 0.01 |
| ED <sub>50</sub> | 0.13                 | 0.04 | 0.05 |

- Soybean injury of 20% would need 0.06 to 0.2% of 16 fl oz/A dicamba solution drifting.

# Soybean Injury from Dicamba at 28 DAT

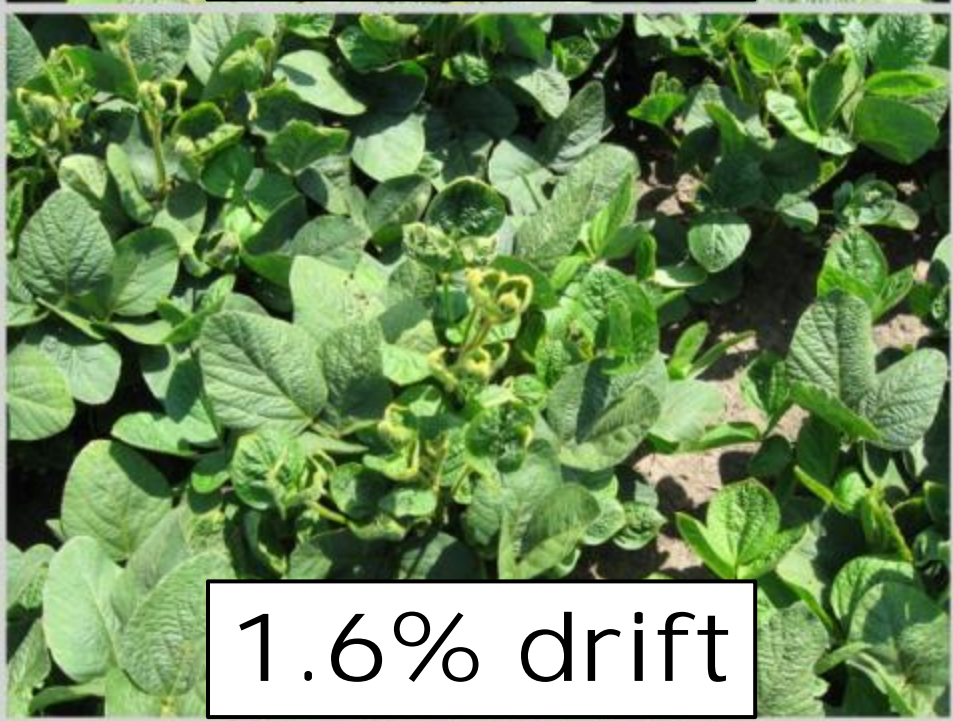
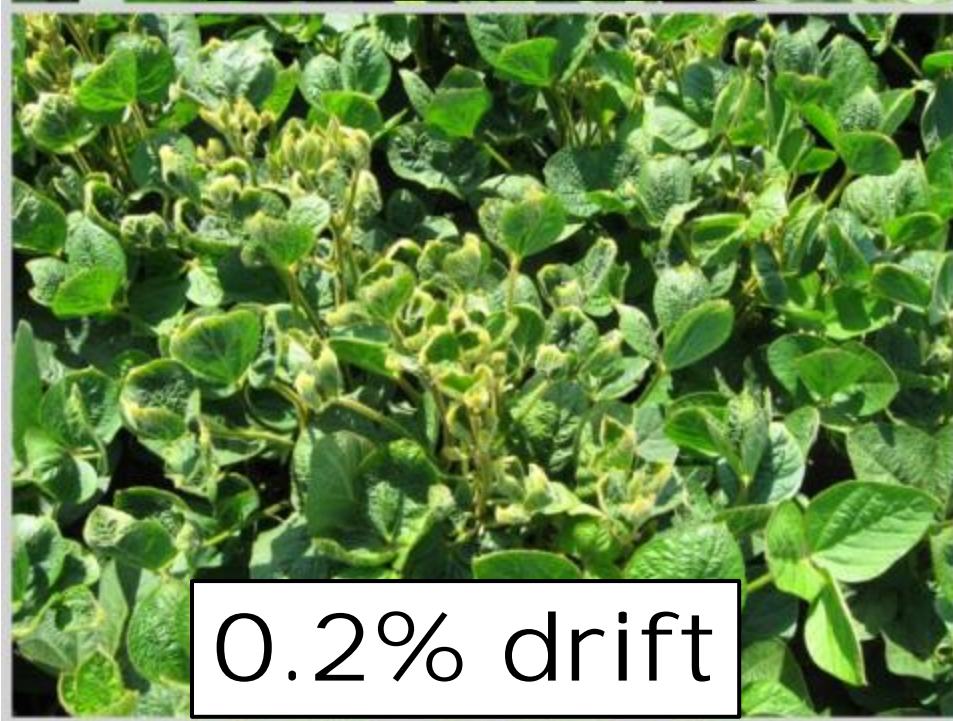


Estimated dicamba dose that caused soybean injury (ED) at 28 DAT in 2010.

| ED %             | Soybean growth stage |      |      |
|------------------|----------------------|------|------|
|                  | V2                   | V5   | R2   |
|                  | ----- fl oz/A -----  |      |      |
| ED <sub>20</sub> | 0.04                 | 0.02 | 0.03 |
| ED <sub>50</sub> | 0.45                 | 0.13 | 0.15 |

- Soybean injury of 20% would need 0.1 to 0.3% of 16 fl oz/A dicamba solution drifting.







28 DAT V5

0 fl oz/A

0.002 fl oz/A

0.007 fl oz/A

0.02 fl oz/A

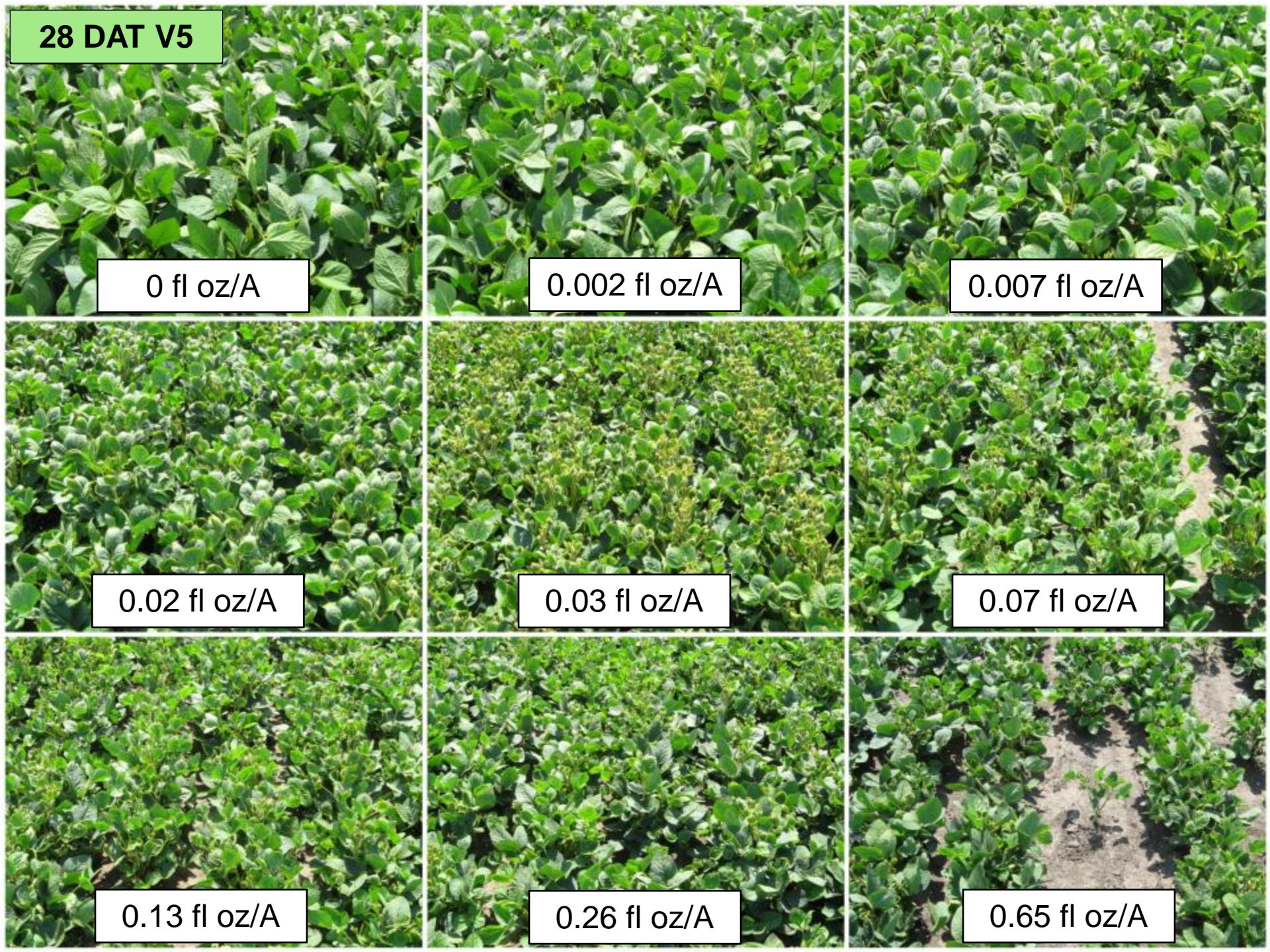
0.03 fl oz/A

0.07 fl oz/A

0.13 fl oz/A

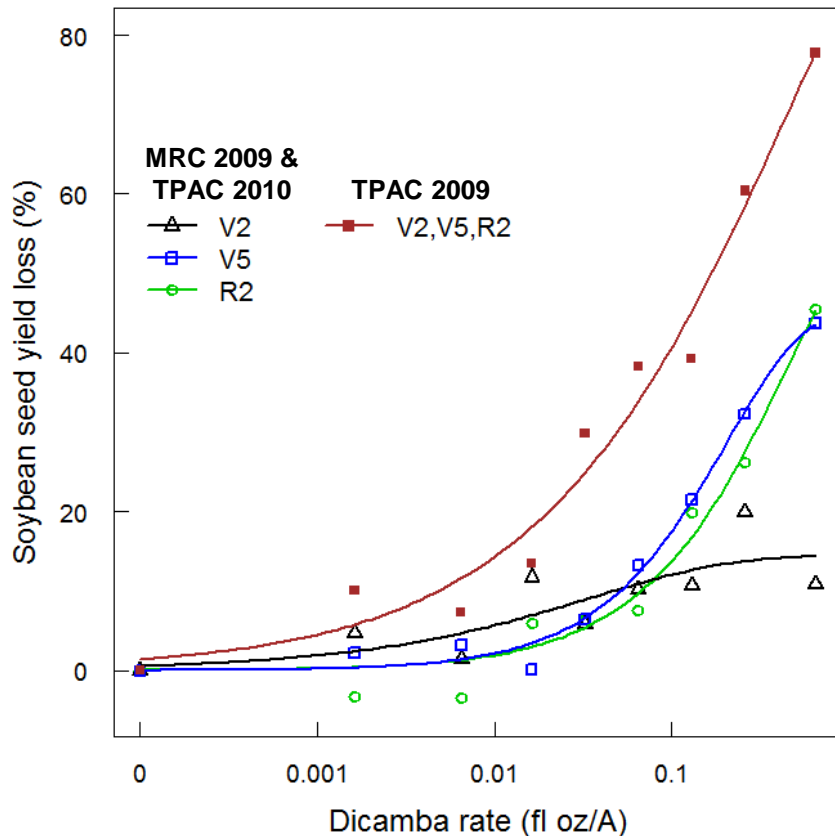
0.26 fl oz/A

0.65 fl oz/A





# Soybean Yield Loss from Dicamba



Estimated dicamba dose that caused soybean yield loss.

|                  | Soybean growth stage |      |      |            |
|------------------|----------------------|------|------|------------|
|                  | MRC 2009 & TPAC 2010 |      |      | TPAC 2009  |
| ED %             | V2                   | V5   | R2   | V2, V5, R2 |
|                  | ----- fl oz/A -----  |      |      |            |
| ED <sub>10</sub> | 0.02                 | 0.31 | 0.02 | 0.005      |
| ED <sub>20</sub> | -                    | 0.07 | 0.03 | 0.02       |

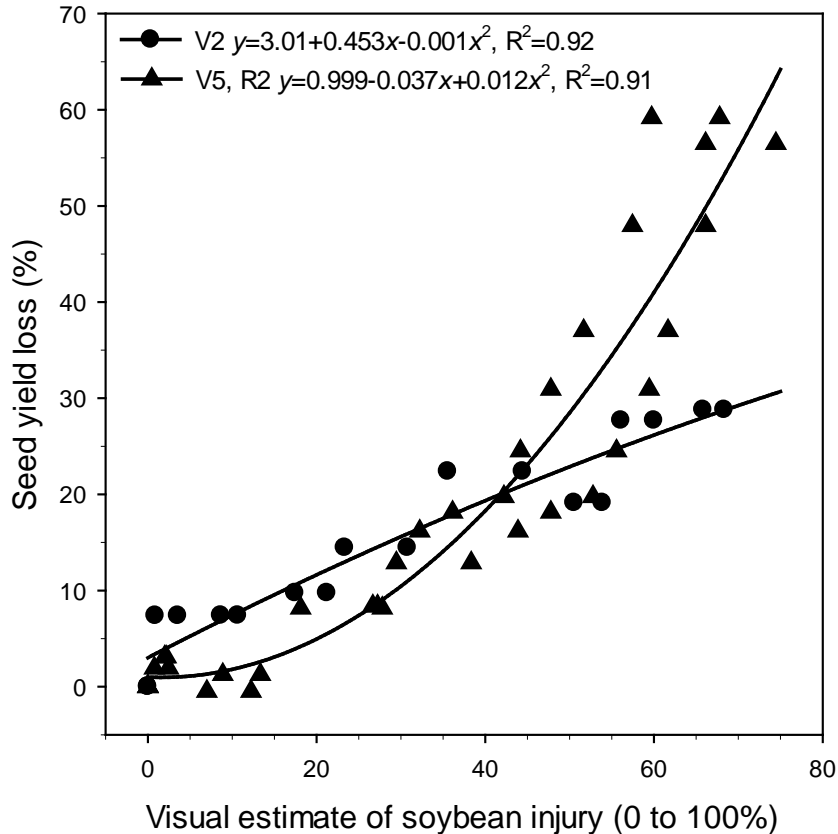
- Soybean yield loss of 10% would need 0.03 to 1.9% of 16 fl oz/A dicamba solution drifting.



# Can Yield Loss be Estimated from Injury Symptomology?



# Soybean Yield Loss and Injury



Soybean injury from dicamba causing soybean yield loss (YL).

| YL%              | Soybean growth stage |         |
|------------------|----------------------|---------|
|                  | V2                   | V5 & R2 |
|                  | ----- % injury ----- |         |
| YL <sub>10</sub> | 16                   | 29      |
| YL <sub>20</sub> | 42                   | 42      |

# Implications of Dicamba Drift

- Injury symptoms are easy to identify with dicamba. Leaf puckering is a predominate symptom.
- Soybean are sensitive to dicamba, and a small amount of drift (0.06 to 1.9% dicamba) can cause injury and yield loss.
- Soybean plants under drought stress are more sensitive to dicamba exposure.
- Soybean injury can be used as a quick and easy method to estimate yield loss, but environment and human error can result in variable estimates.





**NO DRIFT  
ZONE**

 **driftwatch**  
www.driftwatch.org



# Glyphosate and Potatoes



# Glyphosate on Potatoes

- Potatoes are sensitive to low concentrations of glyphosate.
- In seed potatoes, glyphosate will move to tubers and the residues accumulate in the eyes causing sprouting problems the next year.
- Commercial potatoes can become malformed and unmarketable.





# Symptoms of Glyphosate Carryover in Seed Potatoes

- Erratic and slow emergence pattern
- Bending, twisting, and yellowing of leaves
- Multiple shoots from an eye
- Cauliflower or candelabra formation of shoots
- Enlarged shoots
- Prolific roots or reduced rooting





# Glyphosate Levels

- Amount: 0.007 to 0.036 ppm glyphosate

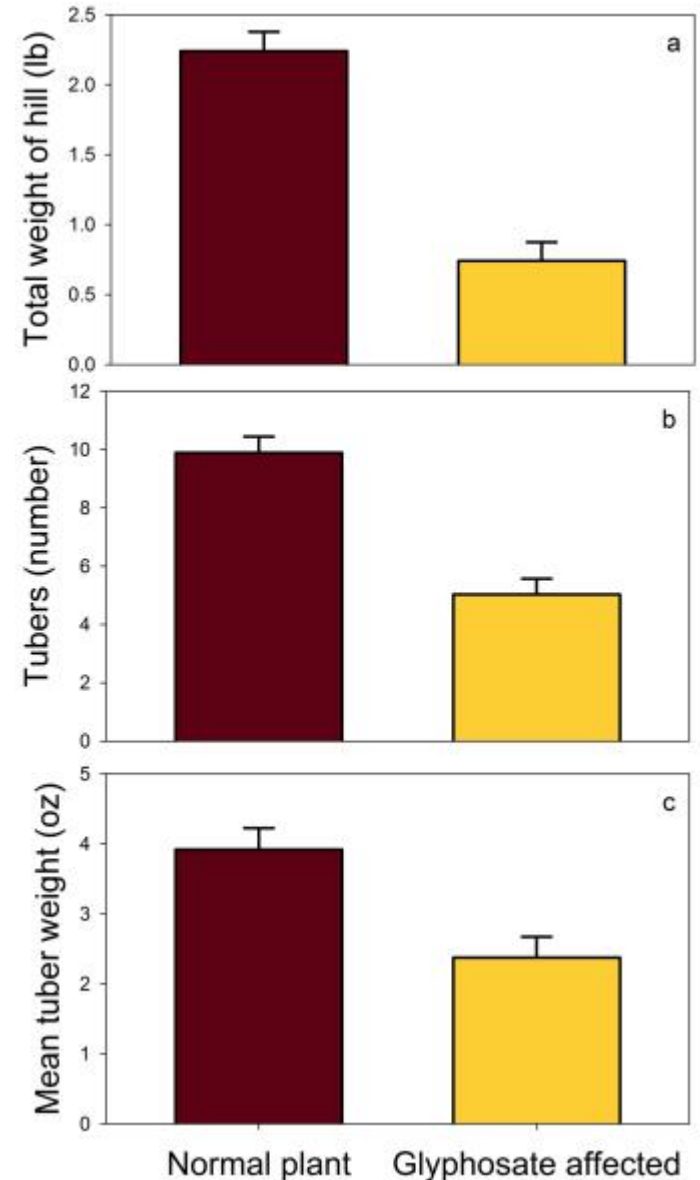




# Glyphosate Residues in Seed Potato

Seed pieces with glyphosate residues had a:

- 67% reduction in total yield (from 2.25 to 0.75 lb/hill)
- 50% reduction in tuber number (10 to 5 tubers/hill)
- 38% reduction in mean tuber weight (3.92 to 2.40 oz/tuber)



# Cost of Production

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## Total operating and overhead costs per acre in 2013

| Corn  | Soybean | Wheat | Barley | Potatoes |
|-------|---------|-------|--------|----------|
| \$648 | \$421   | \$300 | \$447  | \$3,000  |

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- 100 acres of potatoes is worth **\$300,000**.
- Damaging a potato crop is **EXPENSIVE!**



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# 2,4-D and Dicamba Drift Studies

- Studies conducted in Indiana and Illinois in 2009 and 2010.
- Rates
  - 2,4-D: 0, 0.003, 0.03, 0.3, 1, 2, 4, 8, 16, 64 fl oz/A (dimethylamine salt)
  - Dicamba: 0, 0.002, 0.007, 0.02, 0.03, 0.07, 0.13, 0.26, 0.65 fl oz/A (diglycolamine salt)
- Application timings: V2, V5, R2
- Maturity Group 3.4 (Becks brand 342NRR)

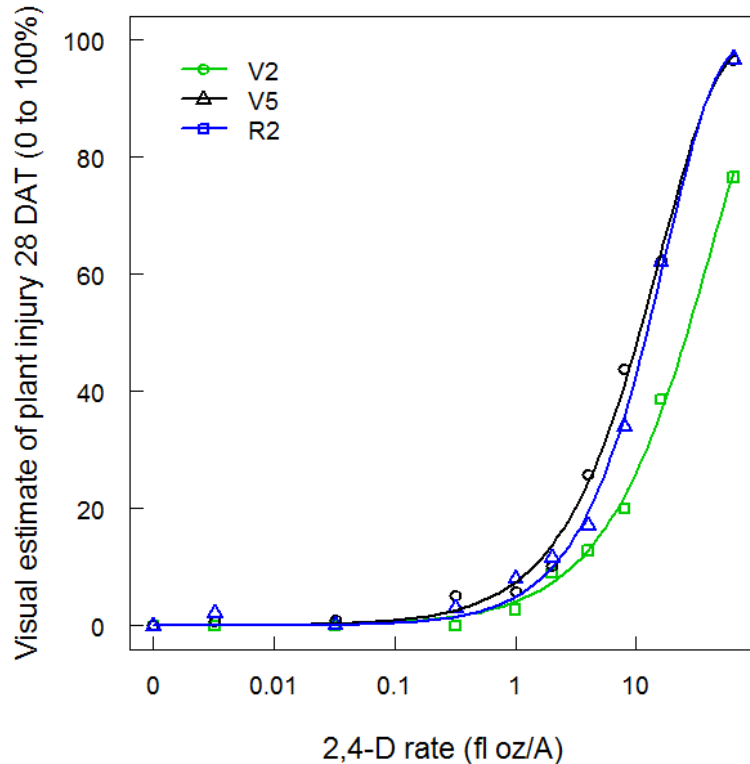


# Rating Injury

Rating scale for visual estimate of soybean injury affected by synthetic auxin herbicides.

| Rating (%) | Description  |
|------------|--|
| 0          | No injury, plant growth is normal.   |
| 10         | Slight reduction in height or canopy volume, cupped or bubbled leaves on $\leq$ upper 10% of the plant, bent petioles, and chlorosis or necrosis.  |
| 20         | Moderately crinkled leaflets (extended across $\leq$ upper 20% of the plant), curled petioles, reduced height and canopy volume, cupped terminal leaflets.   |
| 30         | Moderate to high reduction of height and canopy, compacted internodes and plants begin to have an abnormal appearance, malformation with drawstring, fiddleneck, or cupped effects on $\leq$ upper 30% of the plant, many petioles curled and main stems may be bent.            |
| 40         | Highly stunted plants ( $\leq$ 40% of the plant), petioles curled and main stems bent and/or starting to curl upper leaves exhibit severe malformation and expansion of new leaves suppressed, plant may have patches of necrotic tissue.  |
| 50         | Very high reduction of plant height ( $\leq$ 50% of the plant) with little likelihood of recovery from the apical meristem, new growth suppressed, formation of pods reduced or malformed, some leaf and stem tissue becomes necrotic, petioles, and stems show severe twisting. |
| 60         | Severe height and canopy reduction, including any new growth from axillary buds, leaves severely cupped or fiddlenecked on $\leq$ 60% of the plant, petioles and stems twisted, swollen, and splitting, more extensive die back of tissue.                                       |
| 70         | Severe to very severe reduction of plants, new growth callused and inhibited, most leaves severely deformed and mostly necrotic, extensive petiole bending.  |
| 80         | Very severe soybean injury, $\leq$ 80% of the plants mainly prostrate, petioles twisted with leaves drooping, leaves are chlorotic or necrotic, stems severely twisted, swollen, and split.  |
| 90         | Plant dying, $\leq$ 90% of the plants mainly prostrate, leaves and stems mostly chlorotic or necrotic, all petioles severely twisted, swollen, or split.   |
| 100        | All plants dead.   |

# Soybean Injury from 2,4-D at 28 DAT



Estimated 2,4-D dose that caused soybean injury (ED) at 28 DAT.

| ED %             | Soybean growth stage |      |      |
|------------------|----------------------|------|------|
|                  | V2                   | V5   | R2   |
|                  | ----- fl oz/A -----  |      |      |
| ED <sub>20</sub> | 3.12                 | 4.13 | 6.99 |
| ED <sub>50</sub> | 10.6                 | 12.2 | 26.3 |

- Soybean injury of 20% would need 10 to 22% of 16 fl oz/A 2,4-D solution drifting.



14 DAT V5

0 fl oz/A

0.003 fl oz/A

0.03 fl oz/A

0.3 fl oz/A

1 fl oz/A

2 fl oz/A

4 fl oz/A

8 fl oz/A

16 fl oz/A



# Symptoms of Soybean Injury from 2,4-D

- Reduction in growth and plant height.
  - Primarily seen at V5 growth stage when plants were growing rapidly.
- Rates  $\geq 8$  fl oz/A (0.5 pt/A) caused bending of petioles and callusing of stem.
- Potential yield loss from off-site movement of 2,4-D may be difficult to detect.

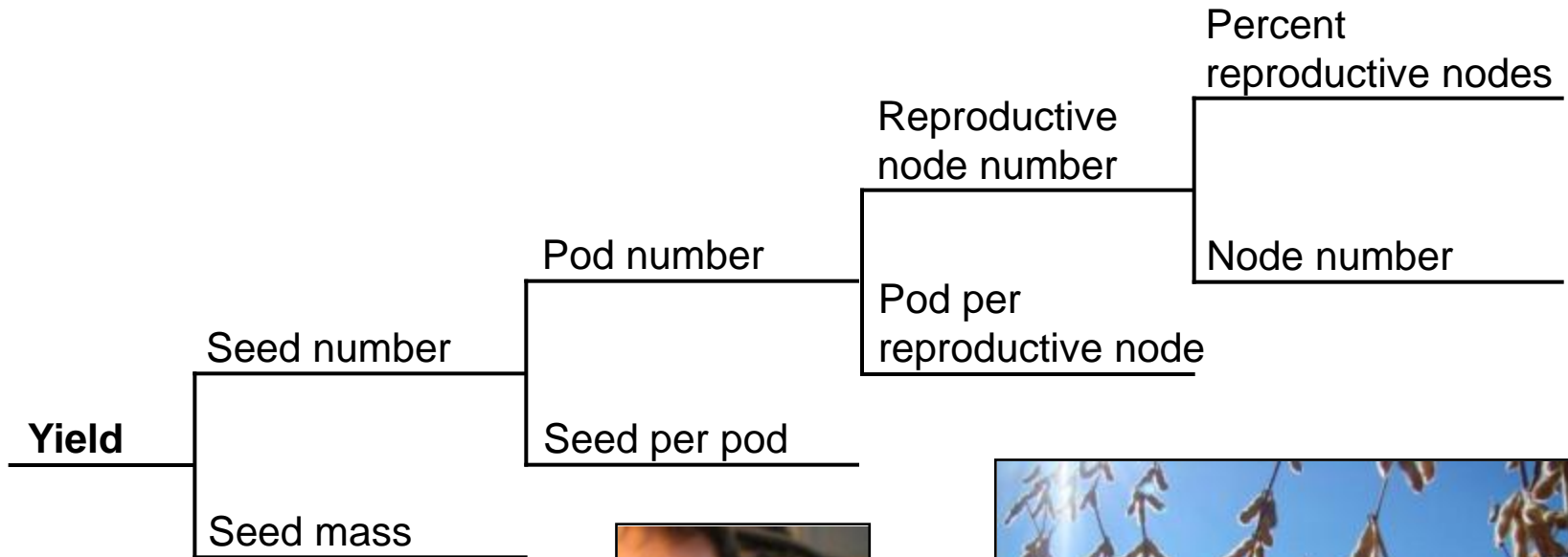
# Yield Components

Primary

Secondary

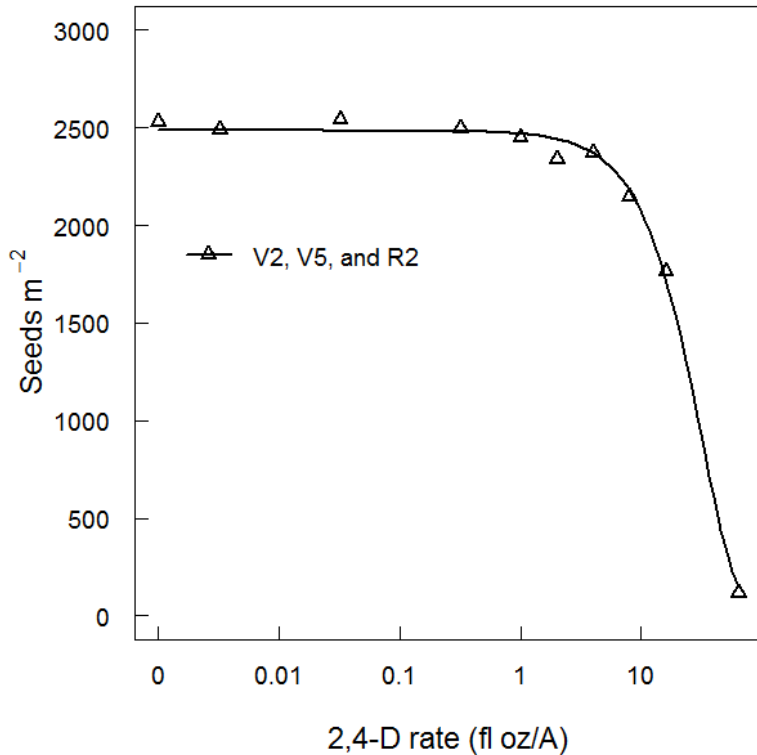
Tertiary

Quaternary





# Seed Number Affected by 2,4-D

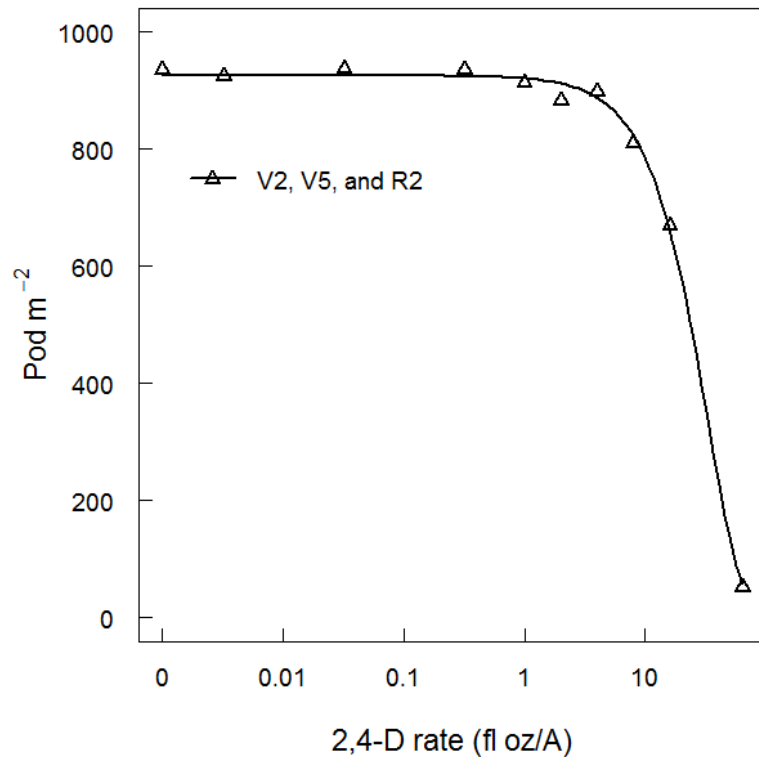


Estimated 2,4-D dose that caused soybean seed loss.

| Soybean growth stage |             |
|----------------------|-------------|
| ED %                 | V2, V5 & R2 |
| ----- fl oz/A -----  |             |
| ED <sub>10</sub>     | 6.88        |
| ED <sub>20</sub>     | 11.4        |

- Soybean seed loss of 10% would need 43% of 16 fl oz/A 2,4-D solution drifting.

# Pod Number Affected by 2,4-D



Estimated 2,4-D dose that caused soybean pod loss.

| ED %             | Soybean growth stage |
|------------------|----------------------|
|                  | V2, V5 & R2          |
|                  | ----- fl oz/A -----  |
| ED <sub>10</sub> | 7.44                 |
| ED <sub>20</sub> | 12.2                 |

- Soybean pod loss of 10% would need 47% of 16 fl oz/A 2,4-D solution drifting.



14 DAT V2

0 fl oz/A

0.002 fl oz/A

0.007 fl oz/A

0.02 fl oz/A

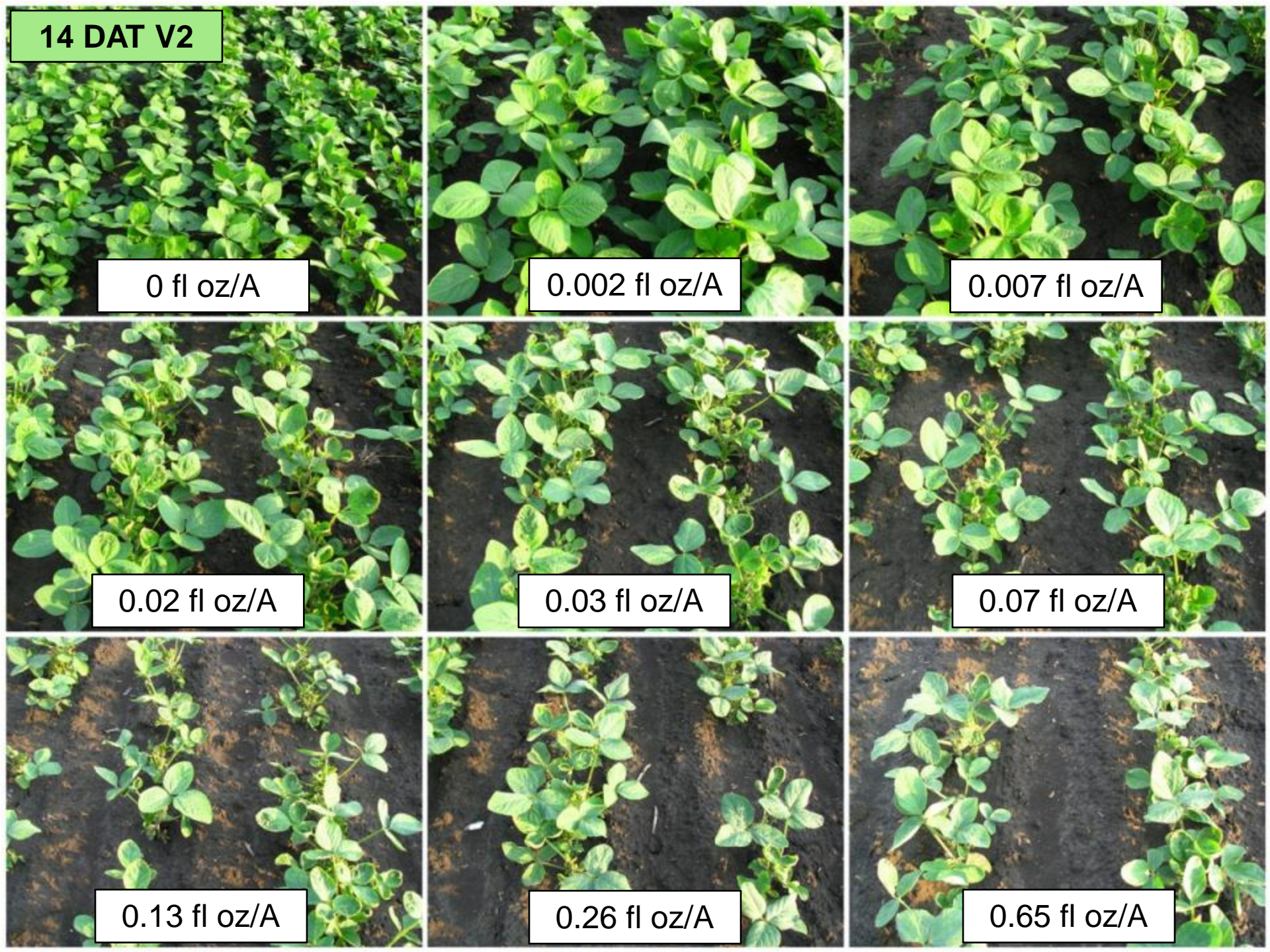
0.03 fl oz/A

0.07 fl oz/A

0.13 fl oz/A

0.26 fl oz/A

0.65 fl oz/A





**V5 application  
2,4-D: 0.02 fl oz/A**



**V5 application  
dicamba: 0.13 fl oz/A**





# Measuring Soybean Injury

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0% = No injury, plant growth is normal.



# 10% Soybean Injury

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10% = Slight reduction in height or canopy volume, cupped or bubbled leaves on  $\leq$  upper 10% of the plant, bent petioles, and chlorosis or necrosis.



10% injury



# 20% Soybean Injury

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Moderately crinkled leaflets (extended across  $\leq$  upper 20% of the plant), curled petioles, reduced height and canopy volume, cupped terminal leaflets.



20% injury





# 30% Soybean Injury

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Moderate to high reduction of height and canopy, compacted internodes and plants begin to have an abnormal appearance, malformation with drawstring, fiddleneck, or cupped effects on  $\leq$  upper 30% of the plant, many petioles curled and main stems may be bent.

30% injury





# 40% Soybean Injury

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Highly stunted plants ( $\leq 40\%$  of the plant), petioles curled and main stems bent and/or starting to curl upper leaves exhibit severe malformation and expansion of new leaves suppressed, plant may have patches of necrotic tissue.

40% injury





# 50% Soybean Injury

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Very high reduction of plant height ( $\leq 50\%$  of the plant) with little likelihood of recovery from the apical meristem, new growth suppressed, formation of pods reduced or malformed, some leaf and stem tissue becomes necrotic, petioles, and stems show severe twisting.

50% injury





# 50% Soybean Injury

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# 60% Soybean Injury

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Severe height and canopy reduction, including any new growth from axillary buds, leaves severely cupped or fiddlenecked on  $\leq$  60% of the plant, petioles and stems twisted, swollen, and splitting, more extensive die back of tissue.



60% injury





# 60% Soybean Injury

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# 70% Soybean Injury

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Severe to very severe reduction of plants, new growth callused and inhibited, most leaves severely deformed and mostly necrotic, extensive petiole bending.

70% injury





# 70% Soybean Injury

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# 80% Soybean Injury

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Very severe soybean injury,  $\leq 80\%$  of the plants mainly prostrate, petioles twisted with leaves drooping, leaves are chlorotic or necrotic, stems severely twisted, swollen, and split.



80% injury





# 90% Soybean Injury

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Plant dying,  $\leq 90\%$  of the plants mainly prostrate, leaves and stems mostly chlorotic or necrotic, all petioles severely twisted, swollen, or split.



90% injury





# 100% Soybean Injury

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All plants dead.





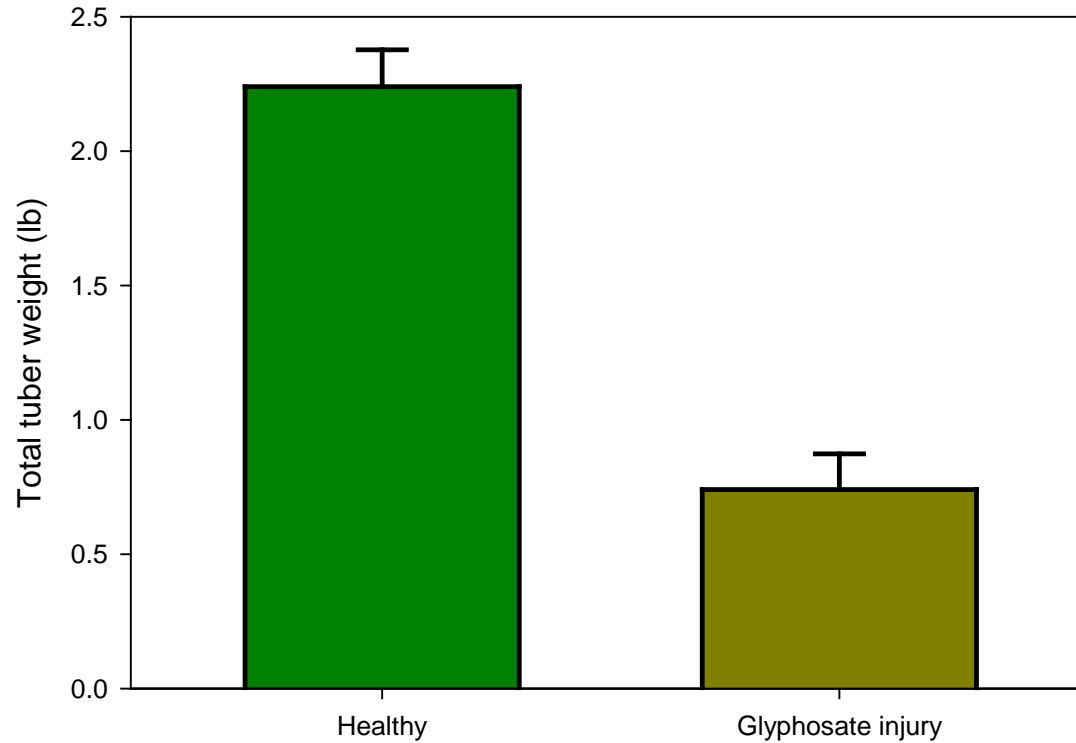




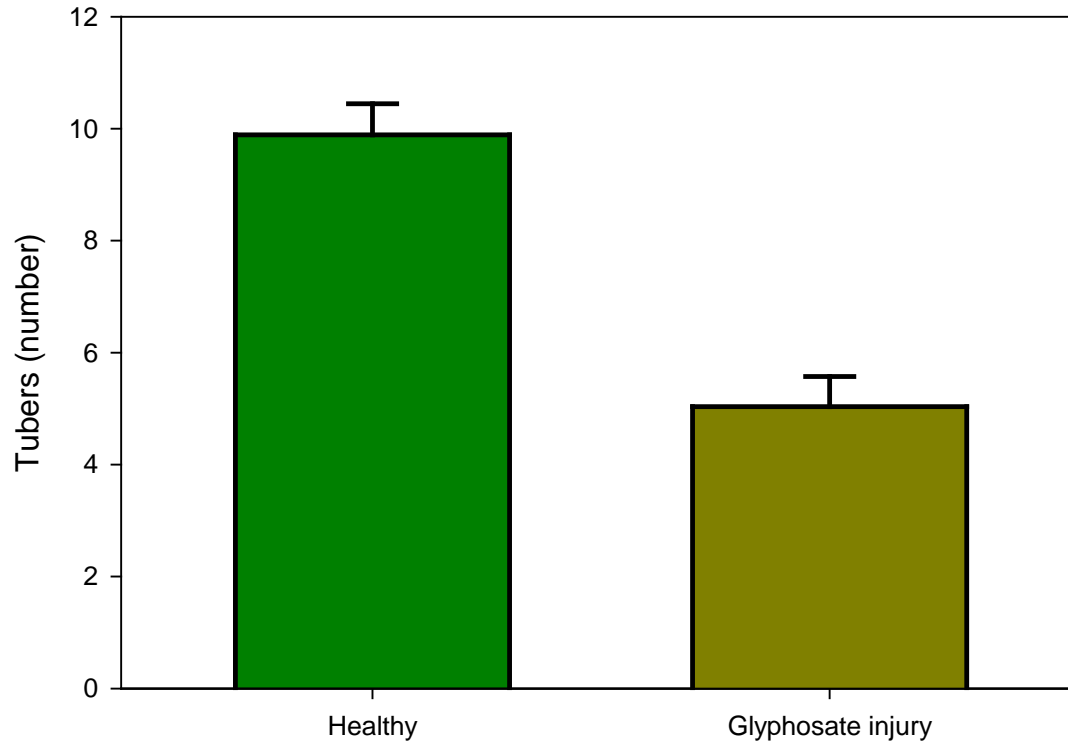




# Total Tuber Weight



# Tuber Number





# Average Tuber Weight

