



Effect of Off-site Movement of Dicamba and 2,4-D on Soybean

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www.ag.ndsu.edu/potatoextension



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).

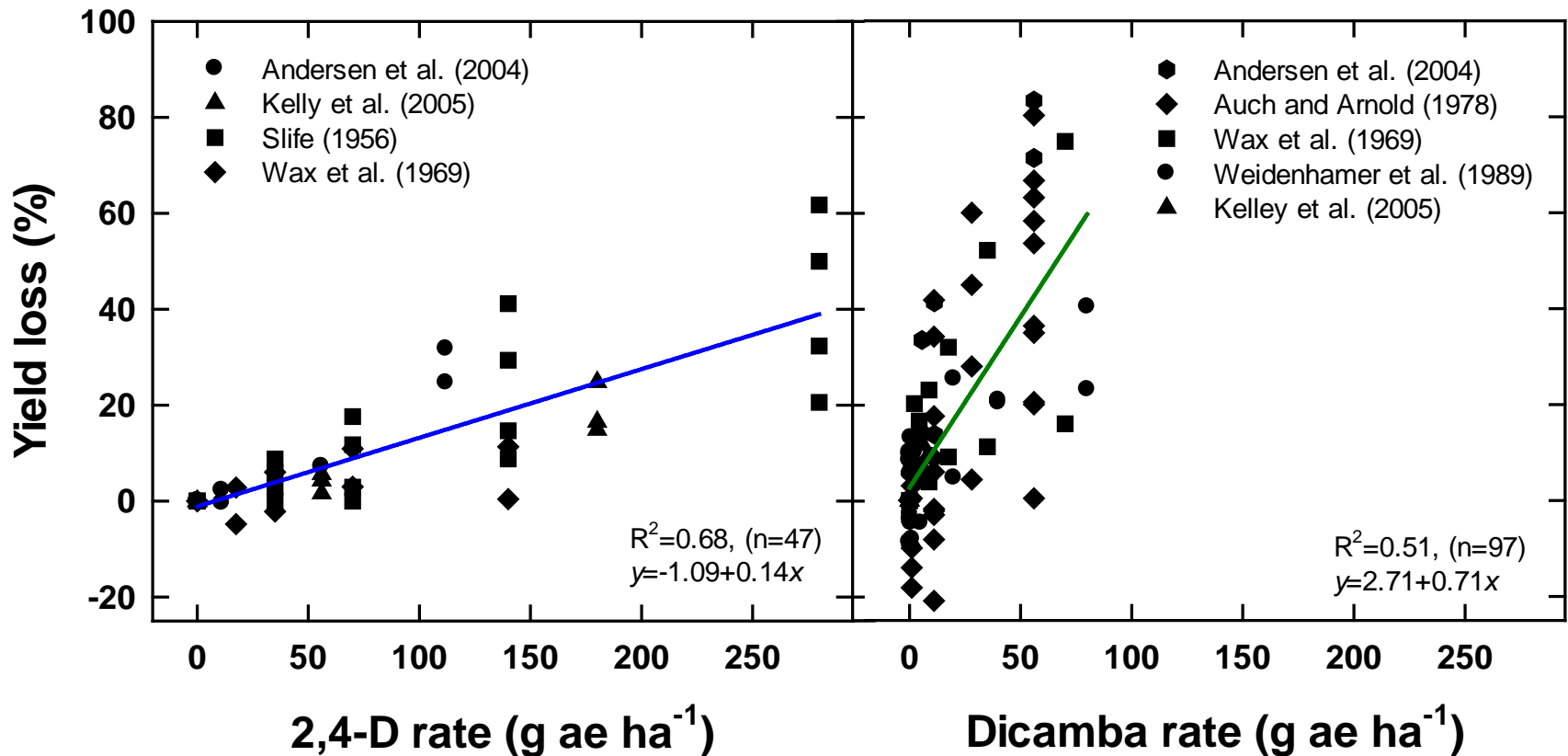


New Genetically Engineered Technology

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



2,4-D vs. Dicamba



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 Auxin Herbicides

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

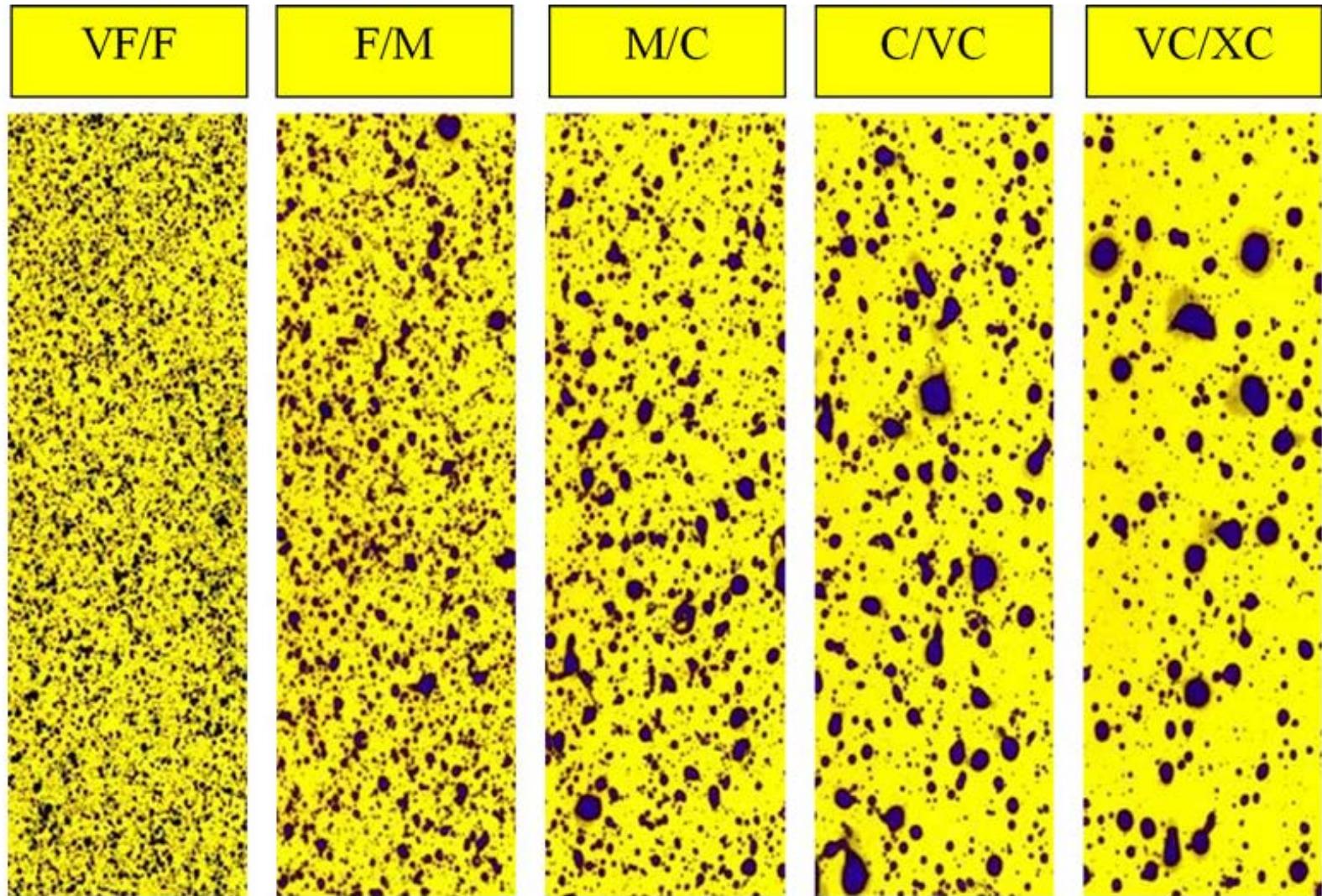


Drift – Particle Size

Influence of droplet size on potential distance of drift

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

Coverage of Droplets





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)

Misapplication



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



2,4-D Drift Study

- Location: Lafayette, IN (2009 and 2010); Fowler, IN (2009); and Urbana, IL (2009 and 2010)
- Design: Randomized complete block
 - 2,4-D: 0, 0.003, 0.03, 0.3, 1, 2, 4, 8, 16, 64 fl oz/A (dimethylamine salt)
 - Application timings: V2, V5, or R2
 - 140 L carrier volume at 138 kPa and 3.1-m-wide boom using XR flat-fan nozzles
- Becks 342NRR seeded at 420,000 seeds ha⁻¹ in 38 cm rows

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.

Rating Injury

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

Rating (%)	Description
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.

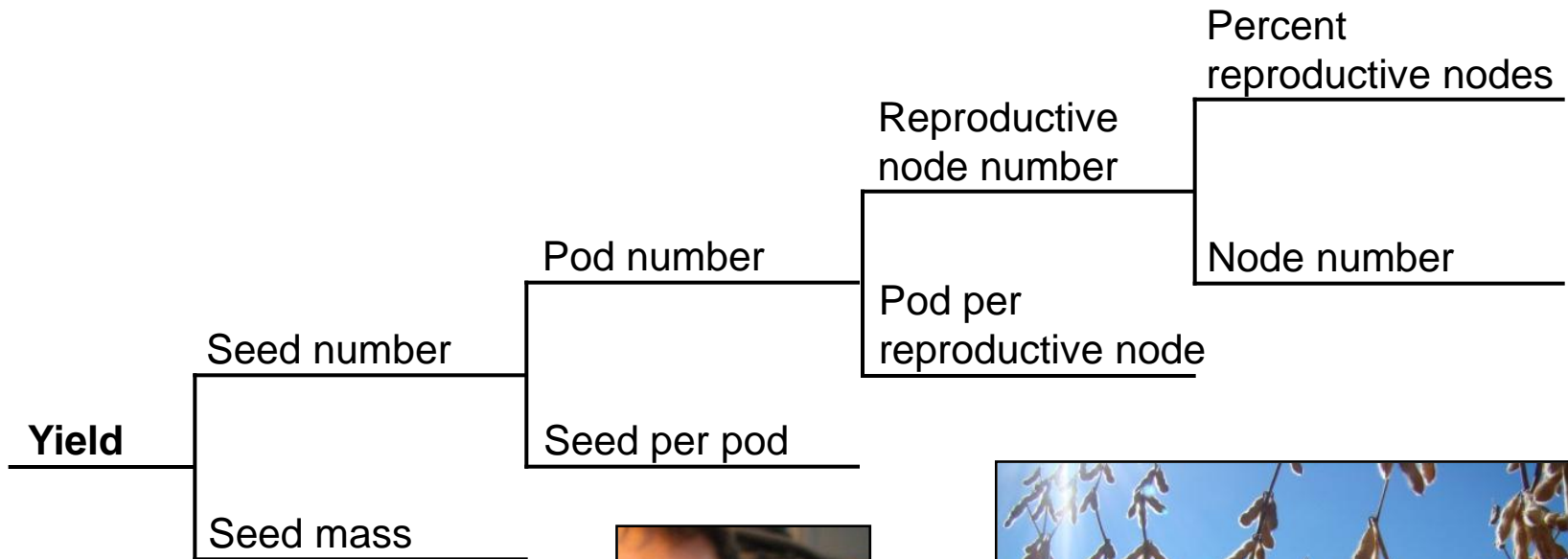
Yield Components

Primary

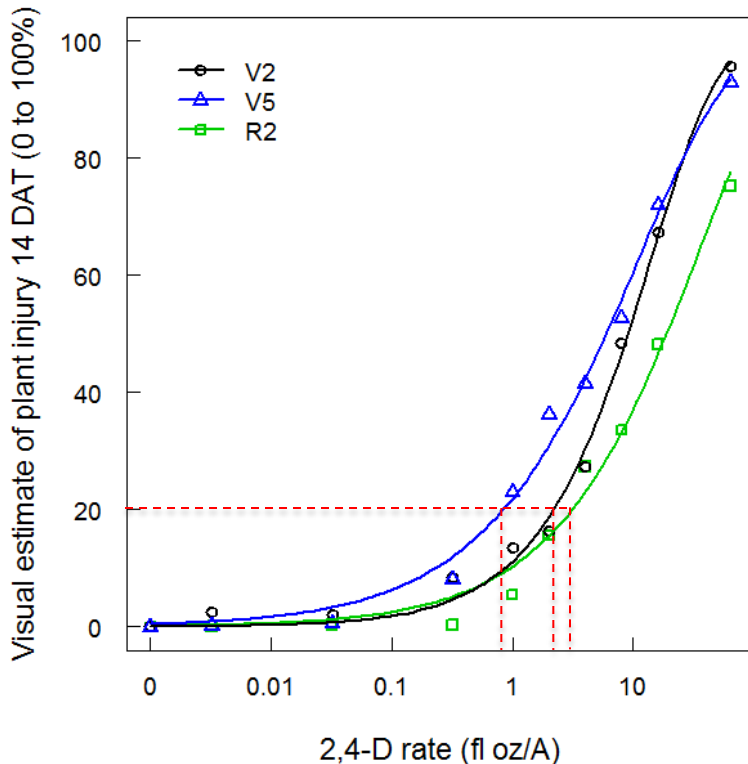
Secondary

Tertiary

Quaternary



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 ₂₀	2.19	0.84	3.11
ED ₅₀	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

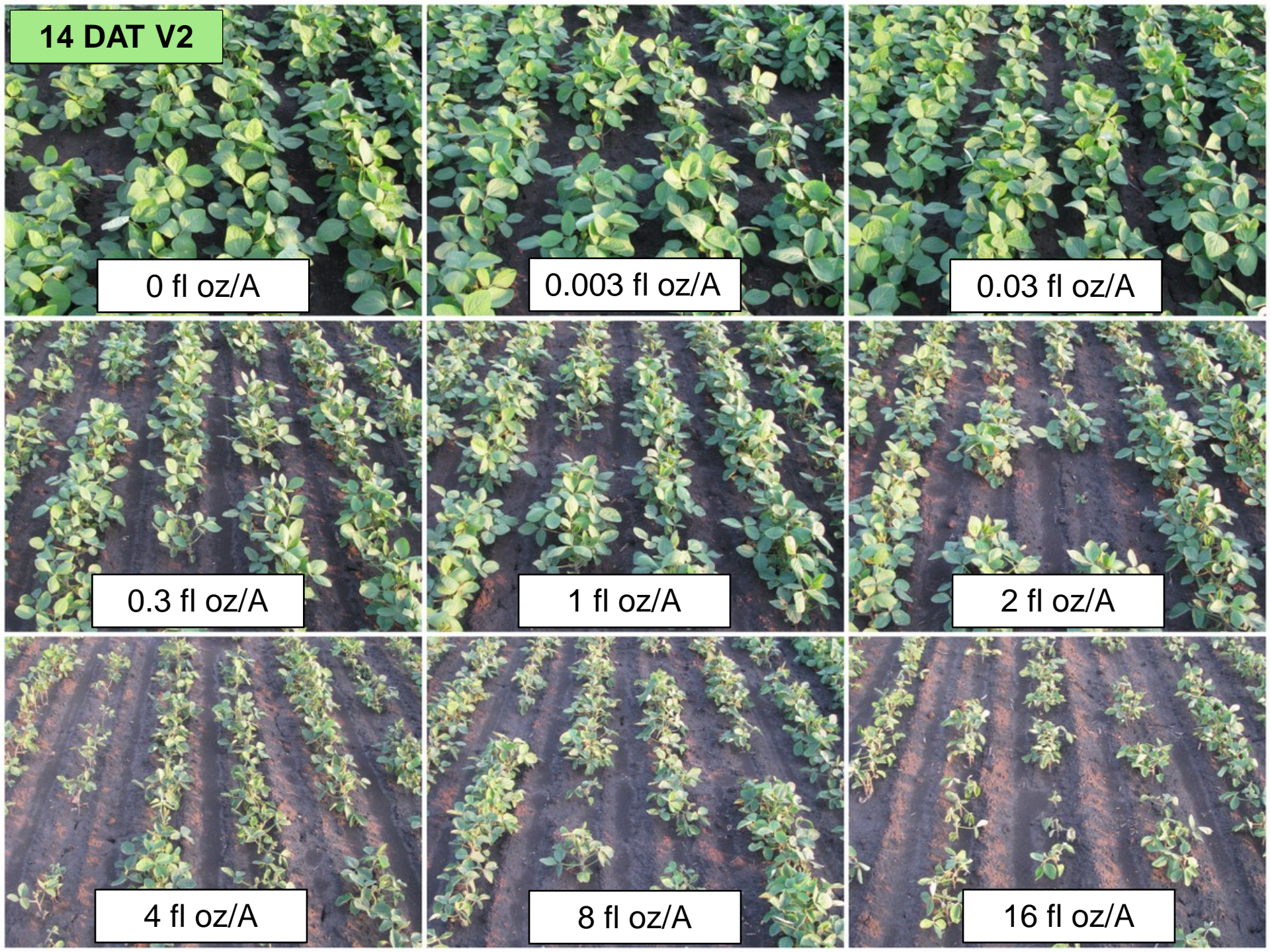
1 fl oz/A

2 fl oz/A

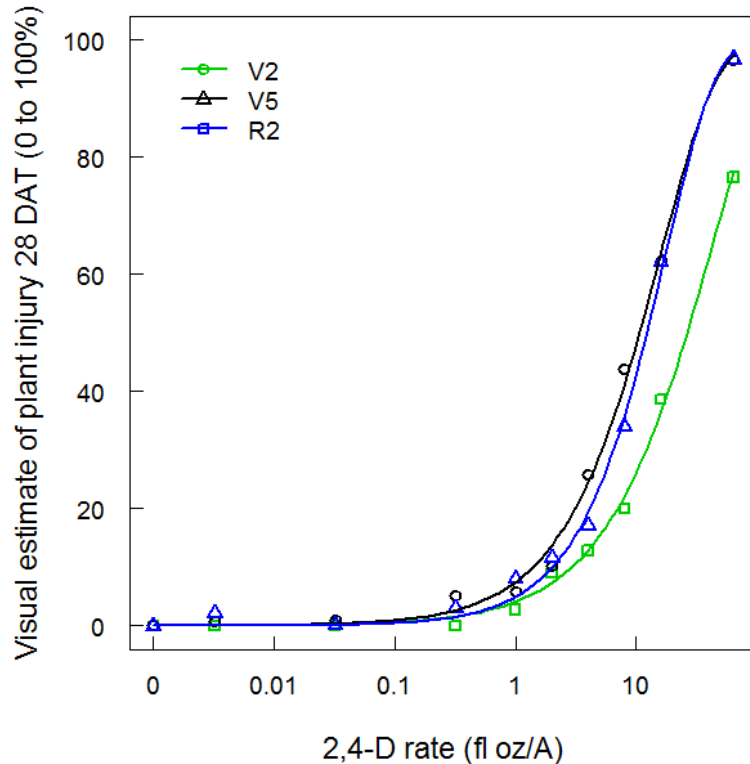
4 fl oz/A

8 fl oz/A

16 fl oz/A



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 ₂₀	3.12	4.13	6.99
ED ₅₀	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

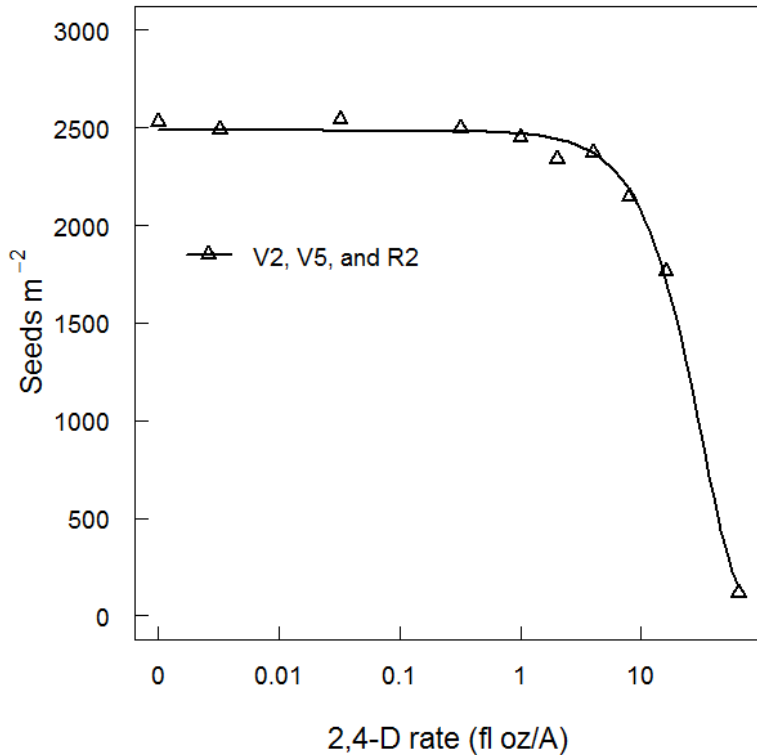
8 fl oz/A

16 fl oz/A

Reduction in Plant Height



Seed Number Affected by 2,4-D

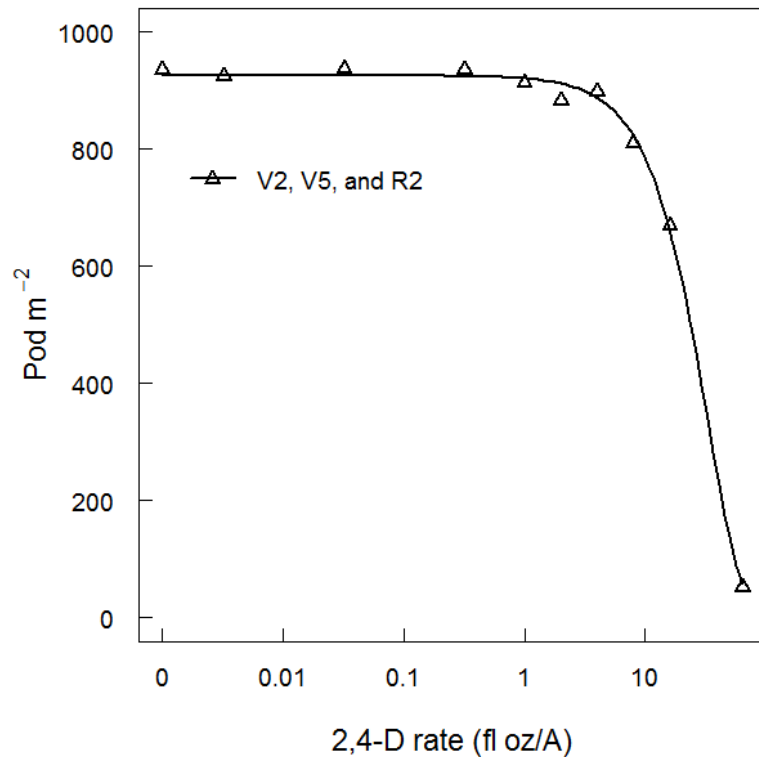


Estimated 2,4-D dose that caused soybean seed loss.

ED %	Soybean growth stage
	V2, V5 & R2
	----- fl oz/A -----
ED ₁₀	6.88
ED ₂₀	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

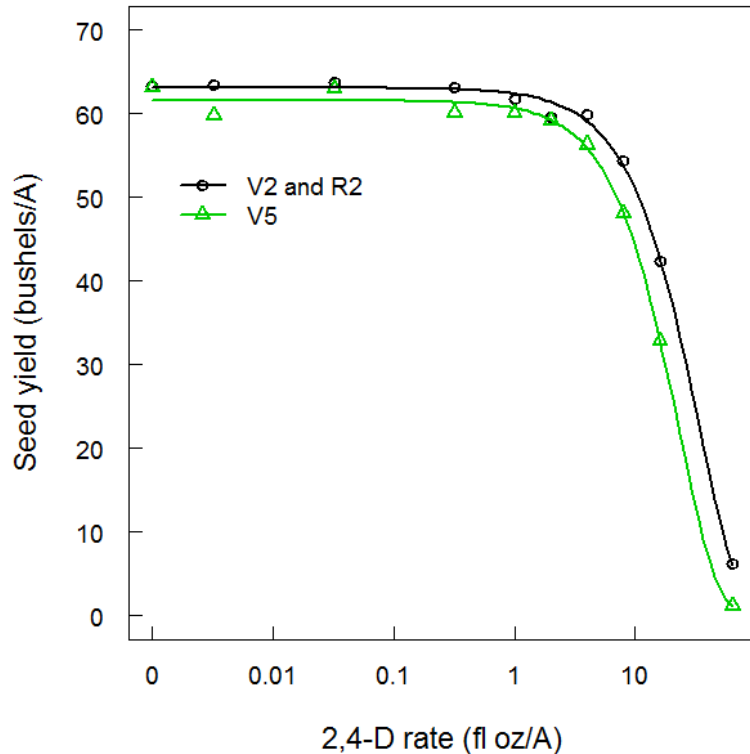


Estimated 2,4-D dose that caused soybean pod loss.

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

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

Yield Reduction



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

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

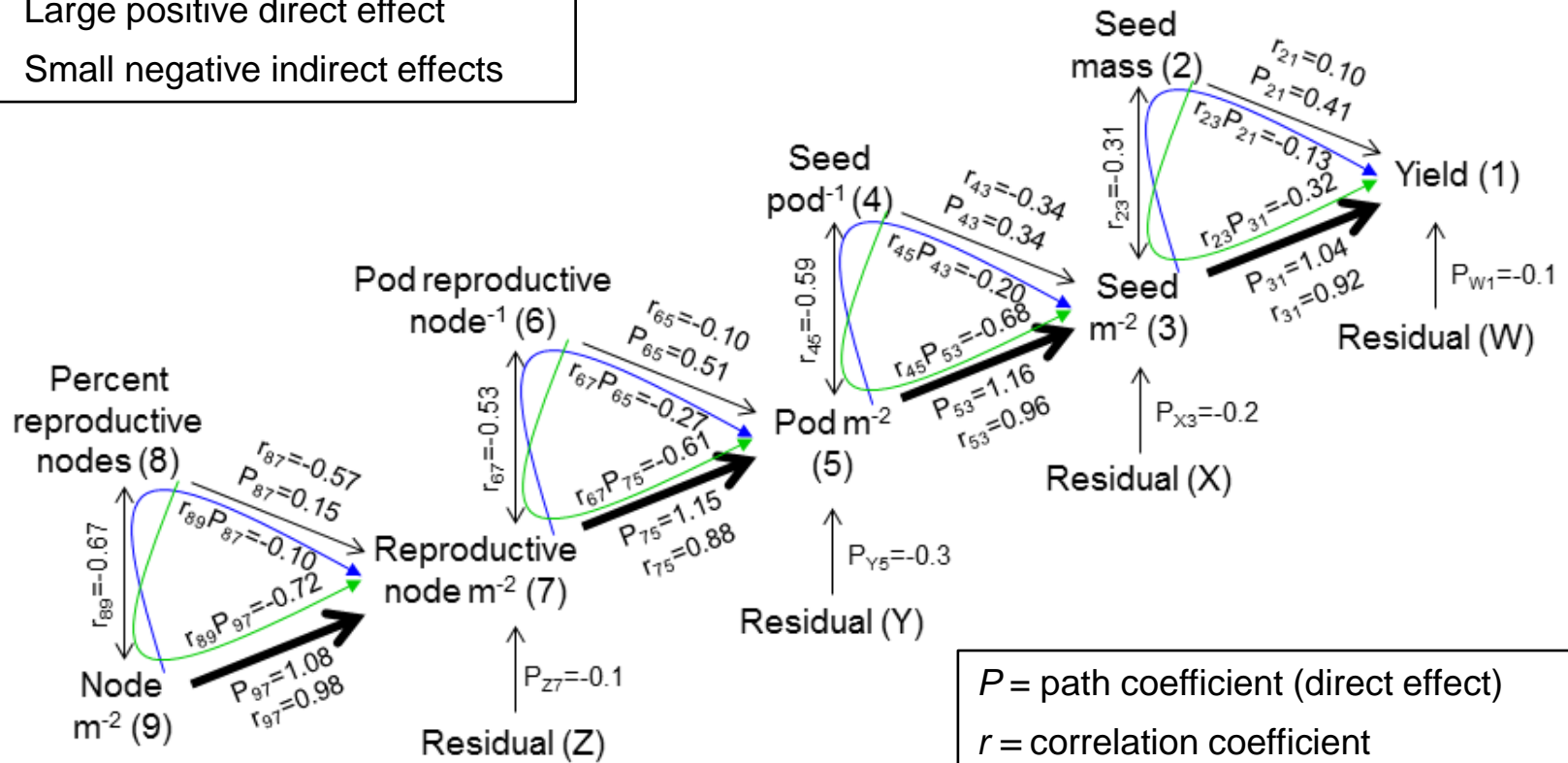
- Reduction in the number of:
 - Main stem nodes
 - Reproductive nodes
 - Pods
 - Seeds



Path Analysis – 2,4-D Rates

Criteria for identifying an important trait affecting its response variable:

1. Positive correlation
2. Large positive direct effect
3. Small negative indirect effects

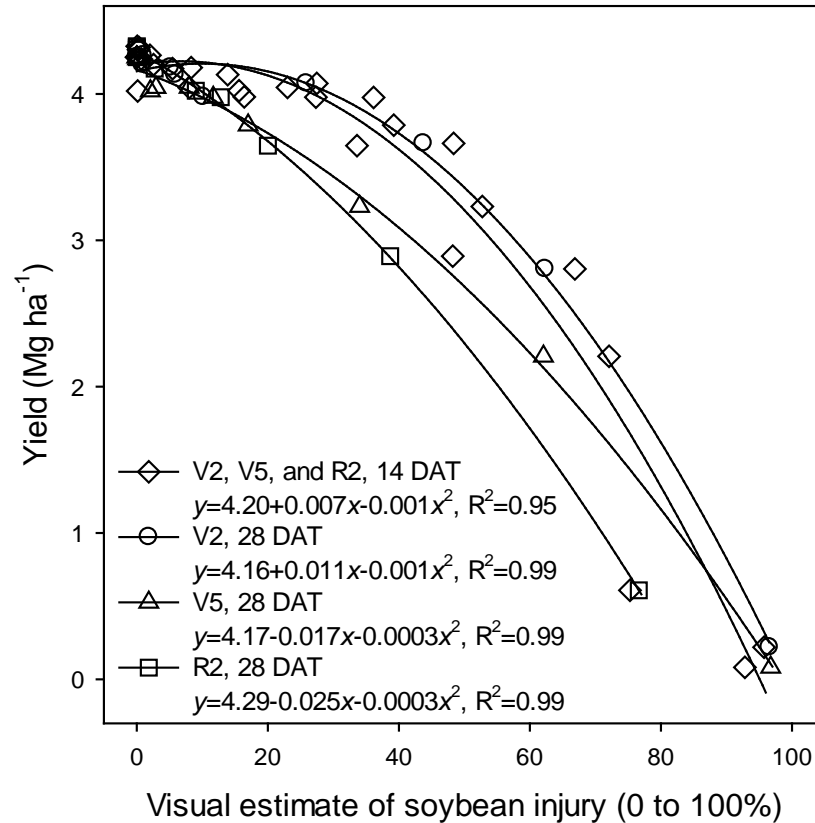


P = path coefficient (direct effect)
 r = correlation coefficient
 $r \times P$ = indirect effect of the path coefficient \times correlation coefficient

Can Yield Loss be Estimated from Injury Symptomology?



Soybean Yield Loss and Injury



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

YL %	Soybean growth stage			
	14 DAT	V2 28 DAT	V5, 28 DAT	R2, 28 DAT
	----- % injury -----			
YL ₁₀	35	40	19	15

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.

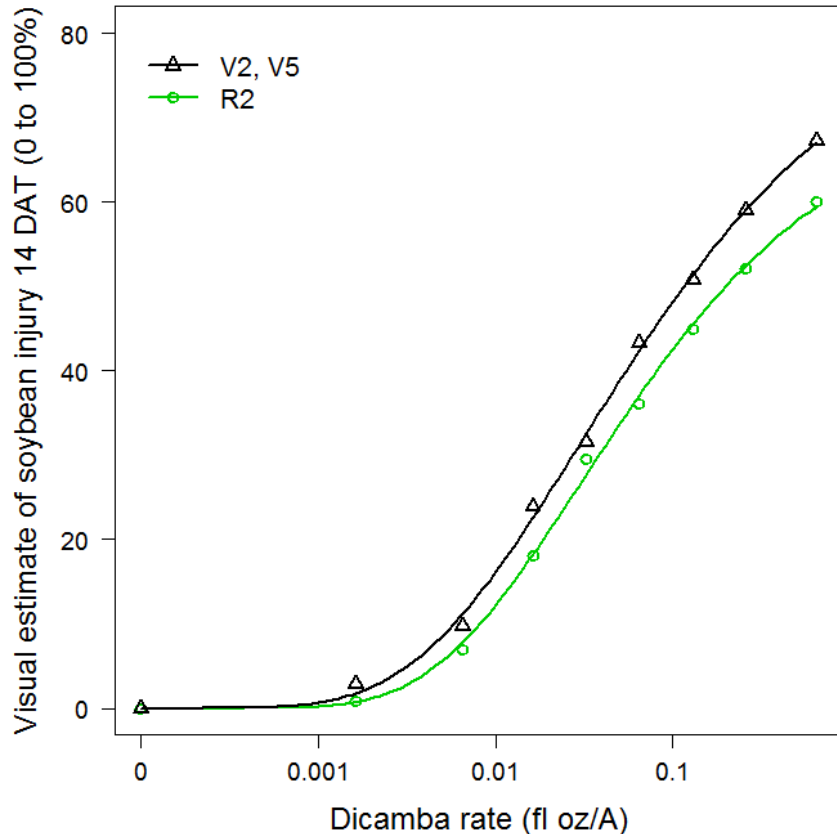
Response of Glyphosate-resistant Soybean to Dicamba Exposure



Dicamba Drift Study

- Location: Lafayette, IN (2009 and 2010) and Fowler, IN (2009)
- Design: Randomized complete block
 - 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, or R2
 - 140 L carrier volume at 138 kPa and 3.1-m-wide boom using XR flat-fan nozzles
- Becks 342NRR seeded at 420,000 seeds ha⁻¹ in 38 cm rows

Soybean Injury from Dicamba at 14 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 ₂₀	0.02	0.03
ED ₅₀	0.12	0.20

- Soybean injury of 20% would need 0.1 to 0.2% of 16 fl oz/A dicamba 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

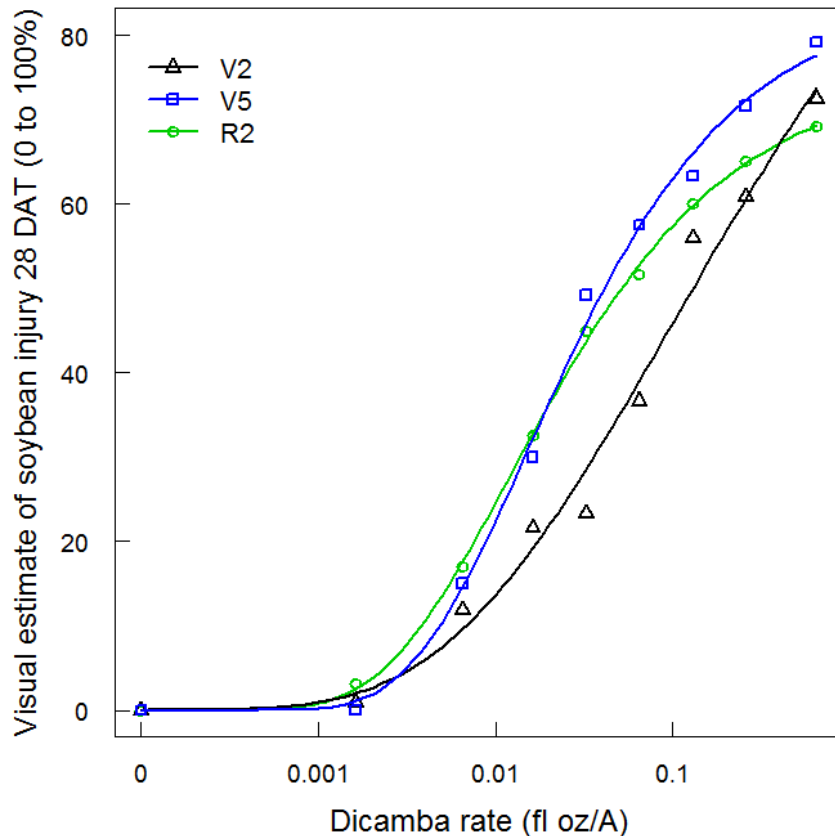
0.07 fl oz/A

0.13 fl oz/A

0.26 fl oz/A

0.65 fl oz/A

Soybean Injury from Dicamba at 28 DAT

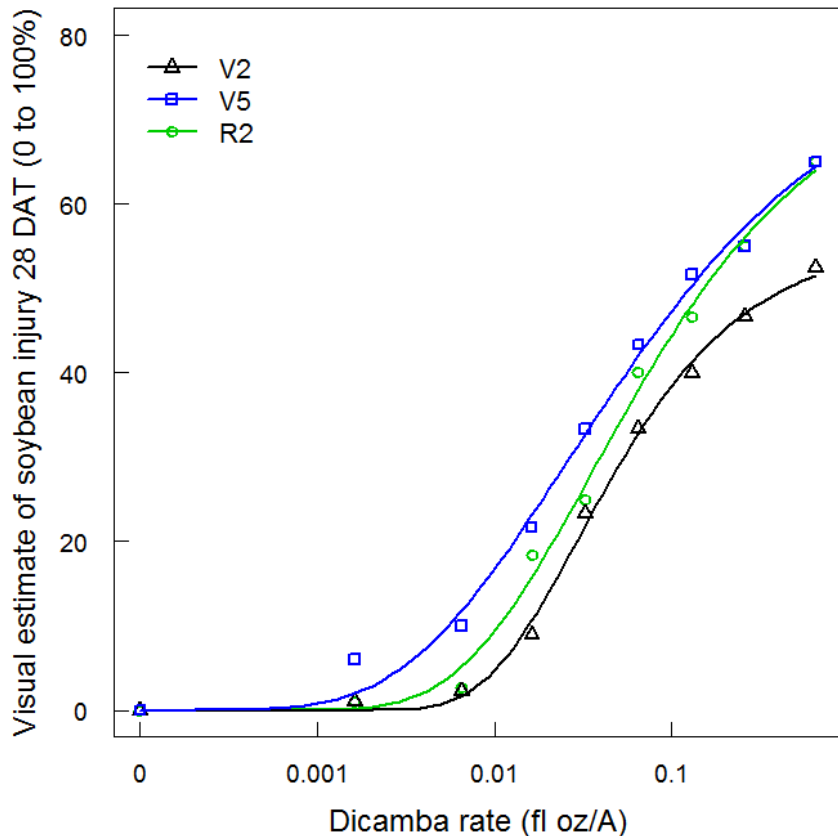


Estimated dicamba dose that caused soybean injury (ED) at 28 DAT in 2009.

ED %	Soybean growth stage		
	V2	V5	R2
	----- fl oz/A -----		
ED ₂₀	0.03	0.01	0.01
ED ₅₀	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.

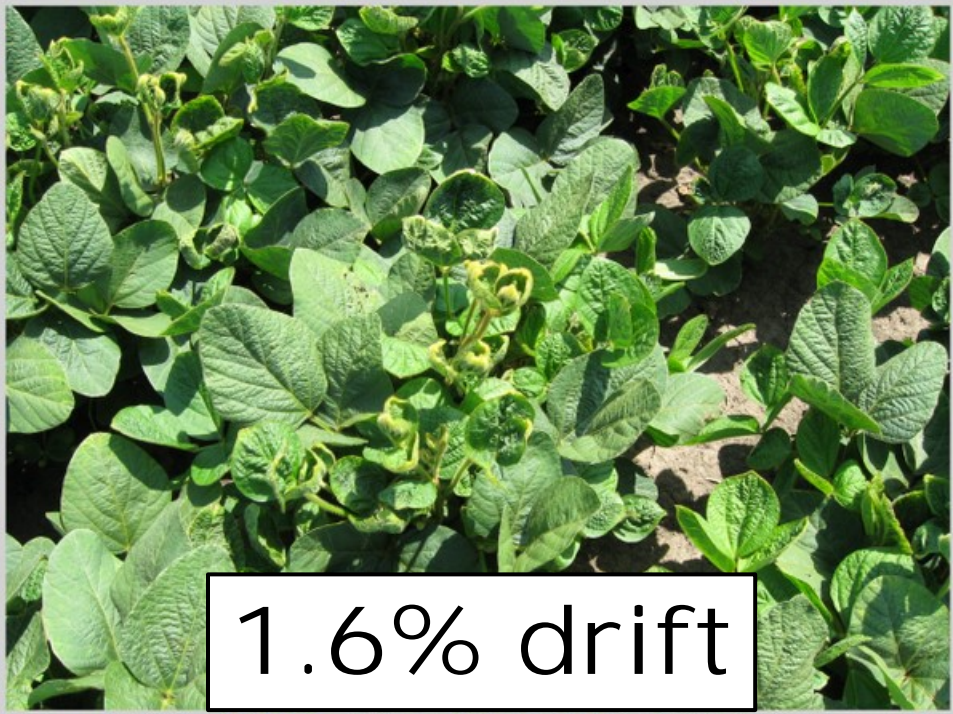
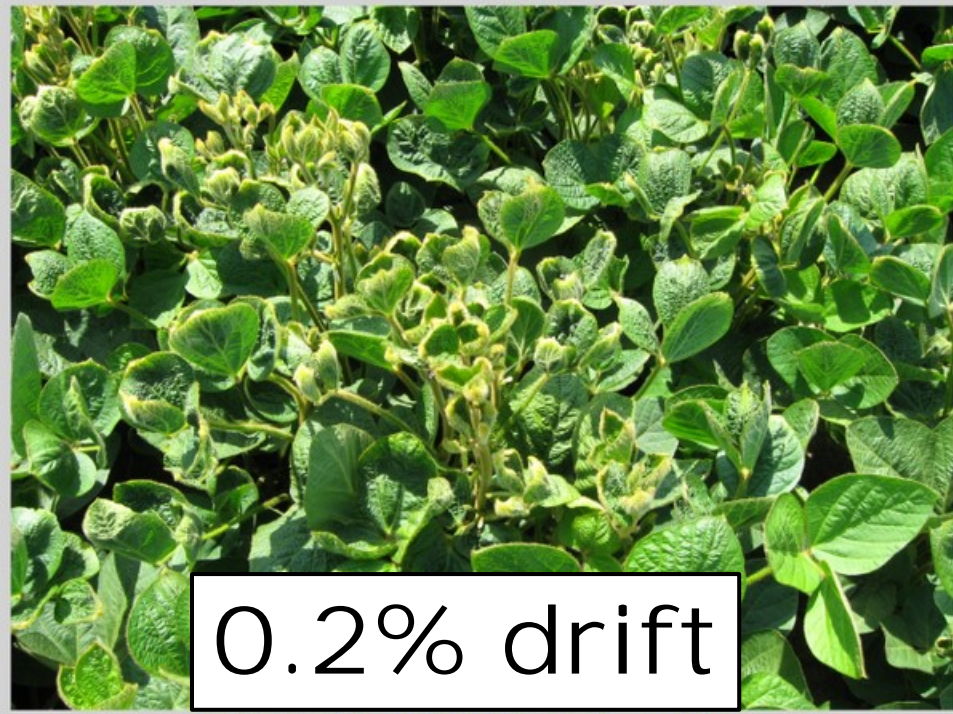
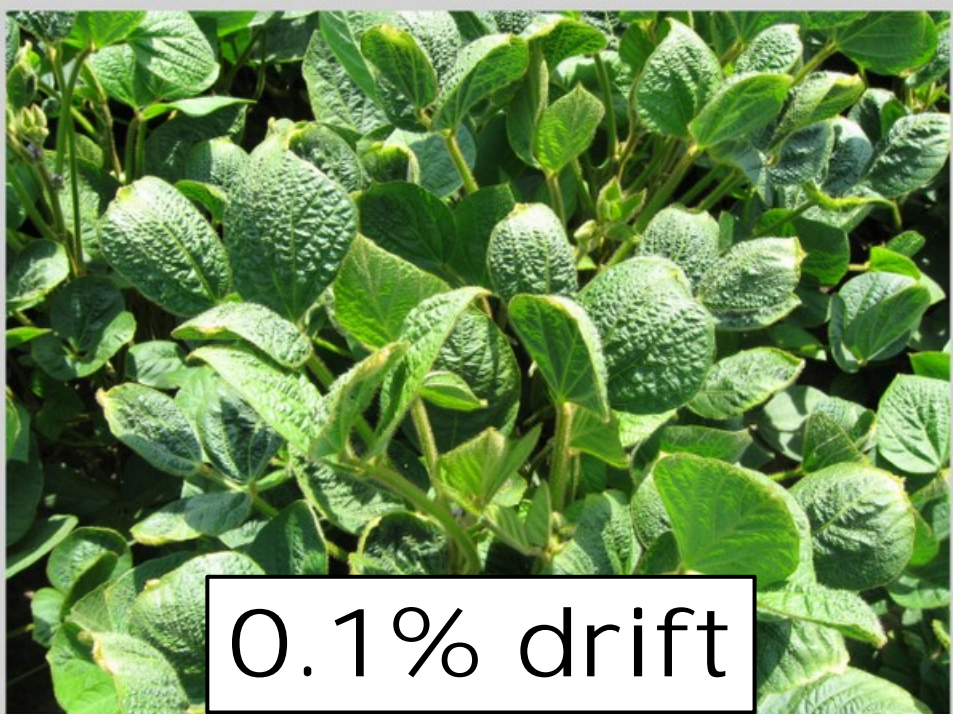
Soybean Injury from Dicamba at 28 DAT



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

ED %	Soybean growth stage		
	V2	V5	R2
	----- fl oz/A -----		
ED ₂₀	0.04	0.02	0.03
ED ₅₀	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

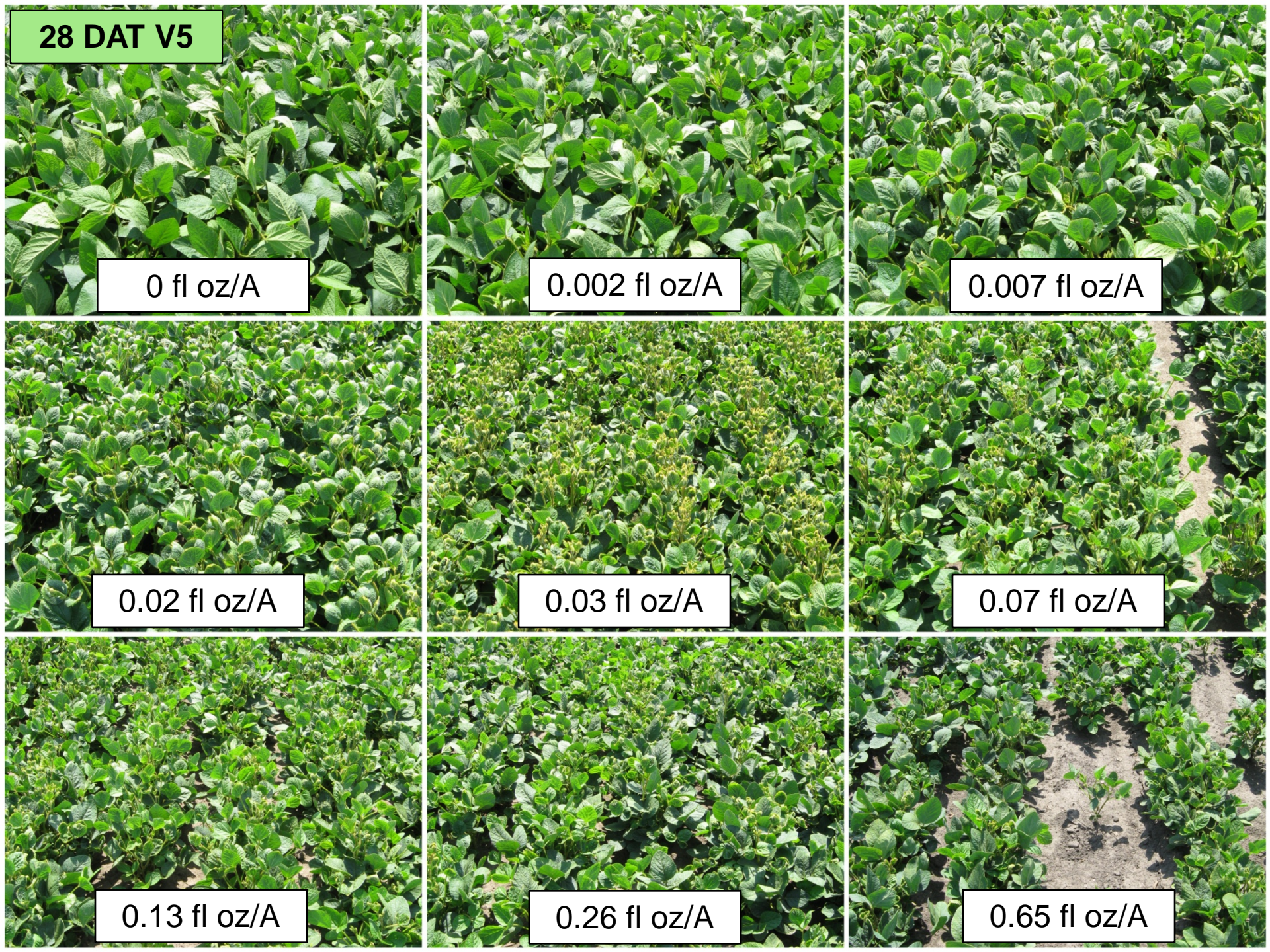
0.03 fl oz/A

0.07 fl oz/A

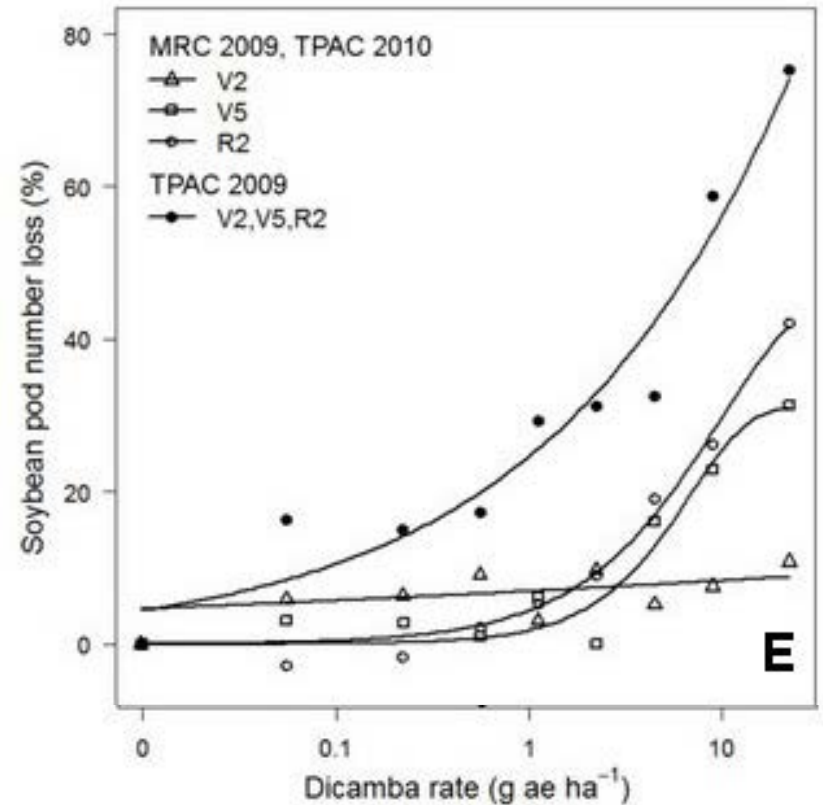
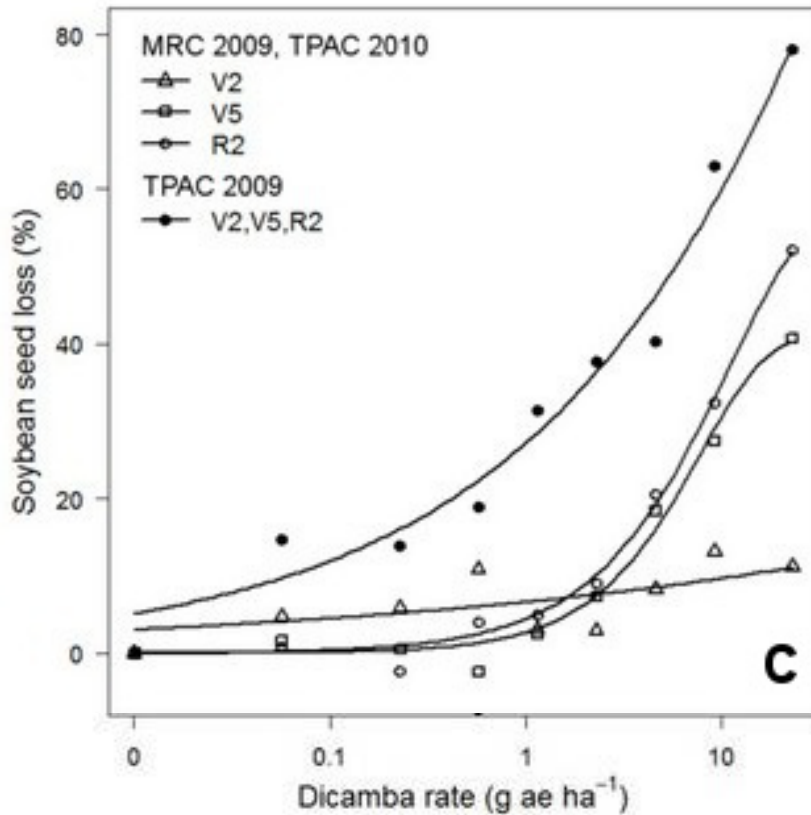
0.13 fl oz/A

0.26 fl oz/A

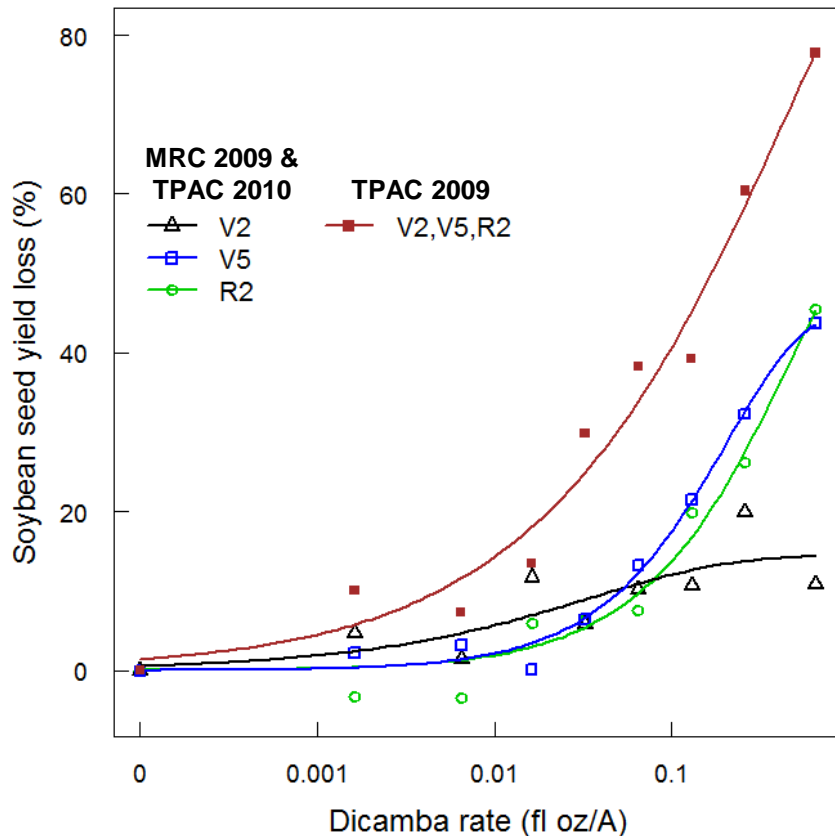
0.65 fl oz/A



Dicamba Dose Response Curves



Soybean Yield Loss from Dicamba



Estimated dicamba dose that caused soybean yield loss.

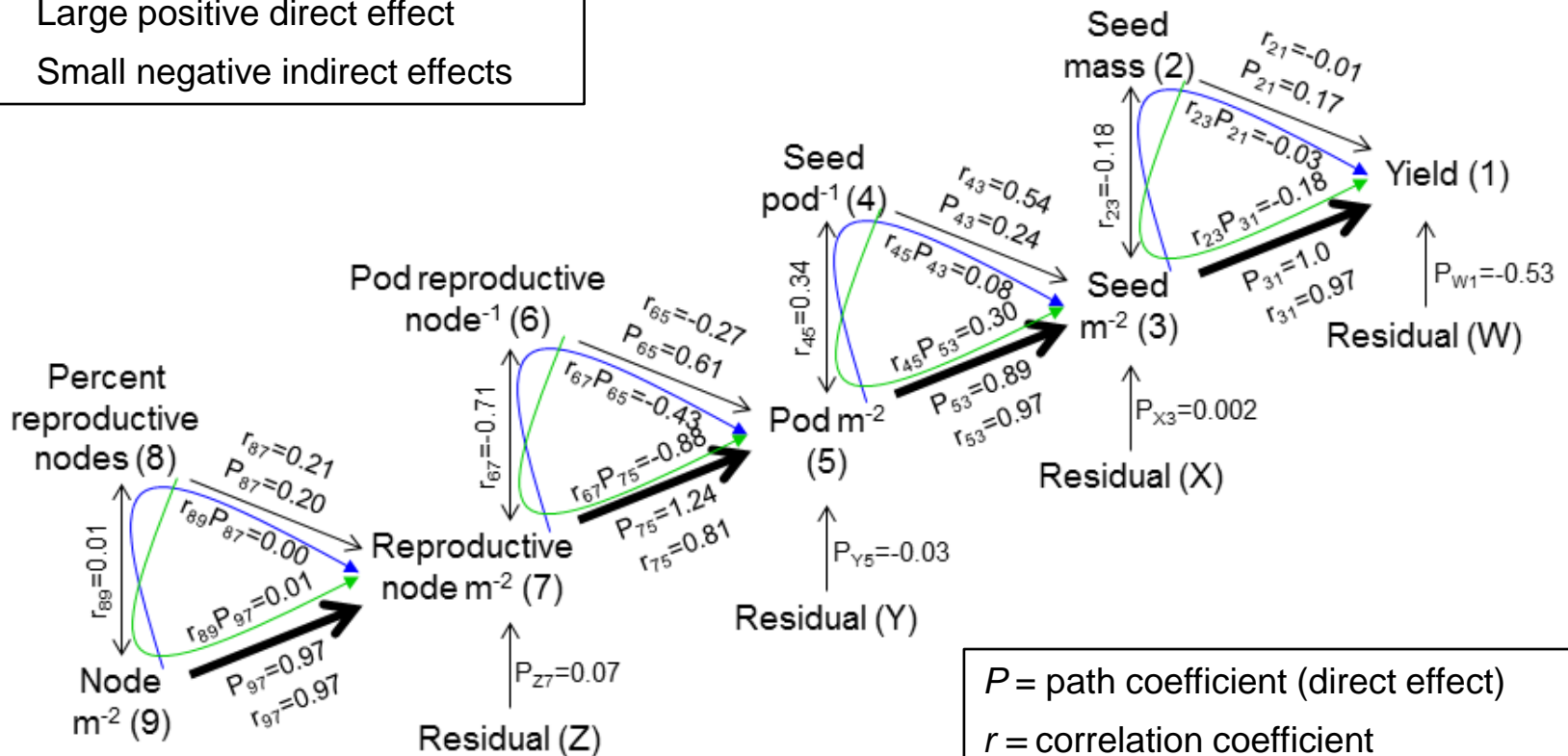
	Soybean growth stage			
	MRC 2009 & TAPC 2010			TPAC 2009
ED %	V2	V5	R2	V2, V5, R2
	----- fl oz/A -----			
ED ₁₀	0.02	0.31	0.02	0.005
ED ₂₀	-	0.07	0.03	0.02

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

Path Analysis on Dicamba Rates

Criteria for identifying an influential trait affecting its response variable:

1. Positive correlation
2. Large positive direct effect
3. Small negative indirect effects

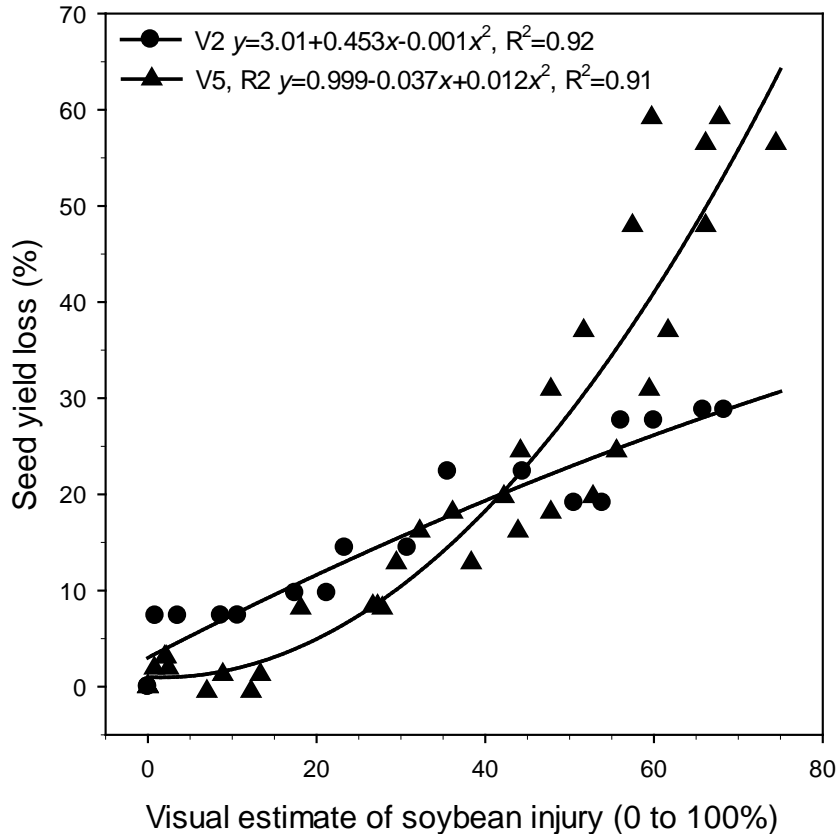


P = path coefficient (direct effect)
 r = correlation coefficient
 $r \times P$ = indirect effect of the path coefficient \times correlation coefficient

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 ₁₀	16	29
YL ₂₀	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.

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



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



Effect of Yield Components

- Yield components were affected at all levels:

↓ Node number (quaternary)

↓ Reproductive node number (tertiary)

↓ Pod number (secondary)

↓ Seed number (primary)

↓ **Yield**



Effects of Dicamba & 2,4-D Drift

- Many other plants and crops are sensitive to dicamba and 2,4-D.
- Because a low amount causes epinasty, concerns will likely arise when a small amount of product drifts or is misapplied.
- To avoid off-site movement of herbicides follow the label and any recommended practices recommended by University Extension and chemical companies.
- If a drift incident occurs follow the instructions in “Documentation for Suspected Herbicide Drift Damage” (<http://www.ag.ndsu.edu/pubs/plantsci/weeds/wc751.pdf>)

Questions?



[www.ag.ndsu.edu/
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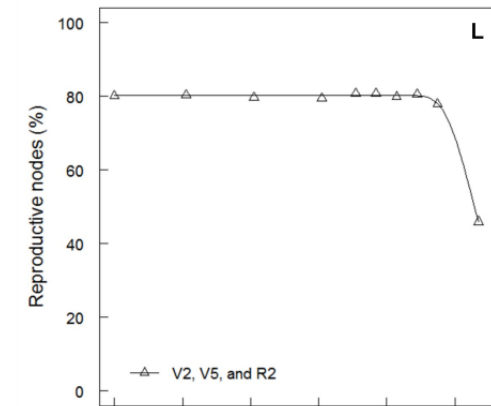
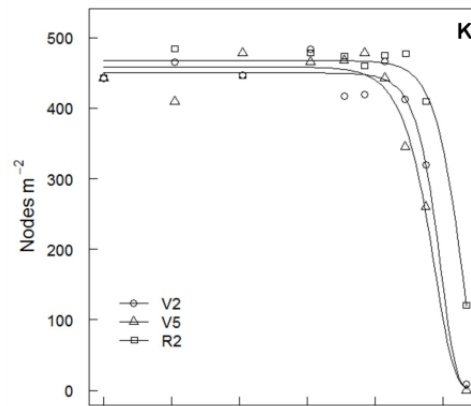
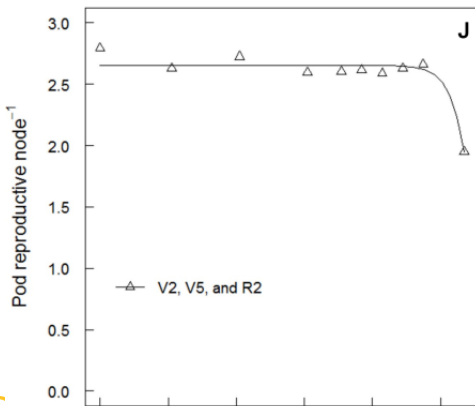
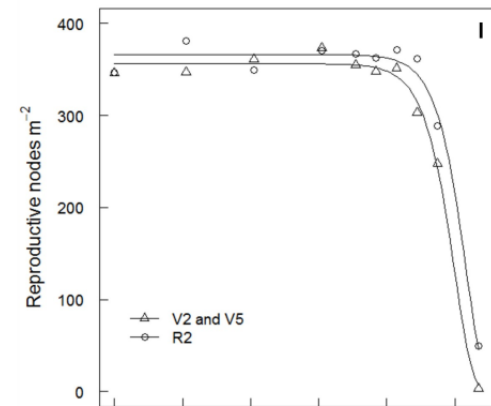
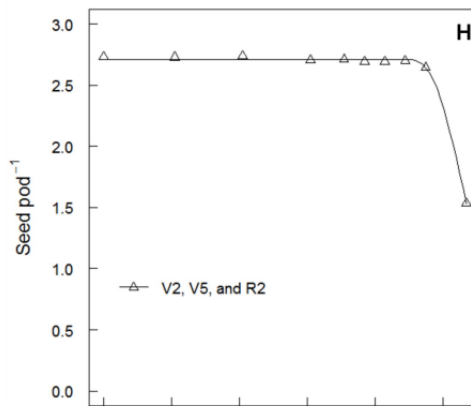
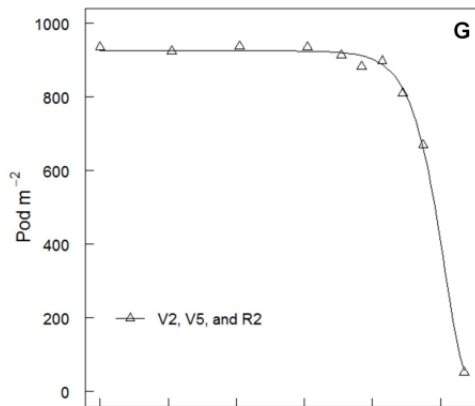
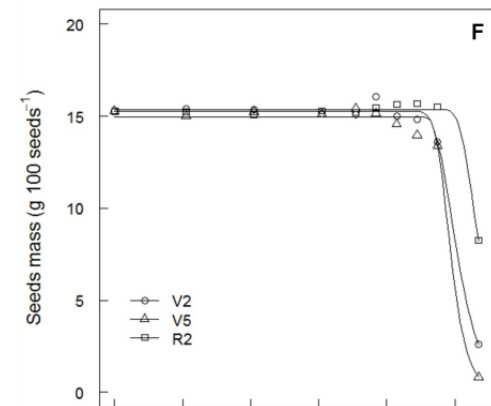
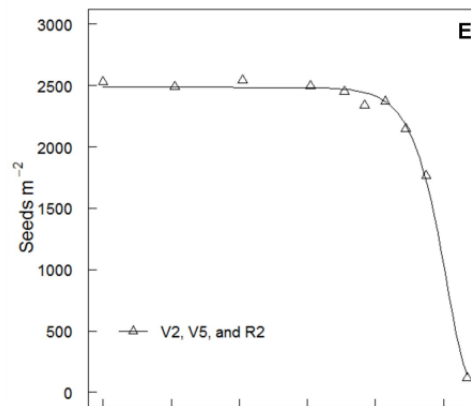
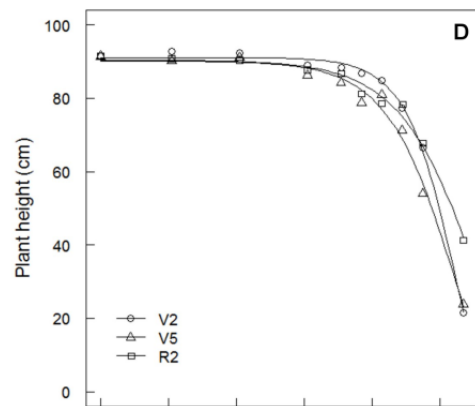
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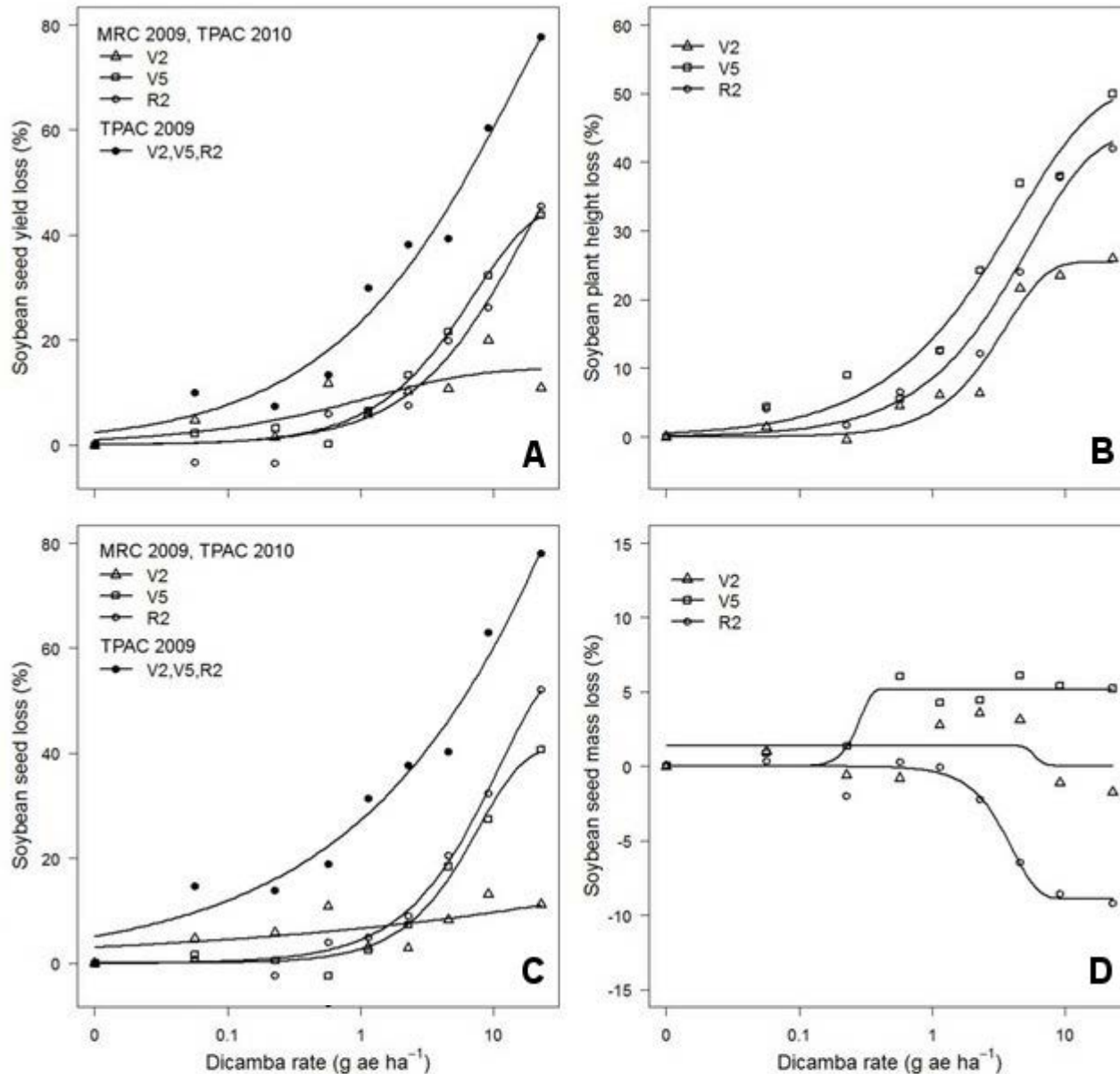
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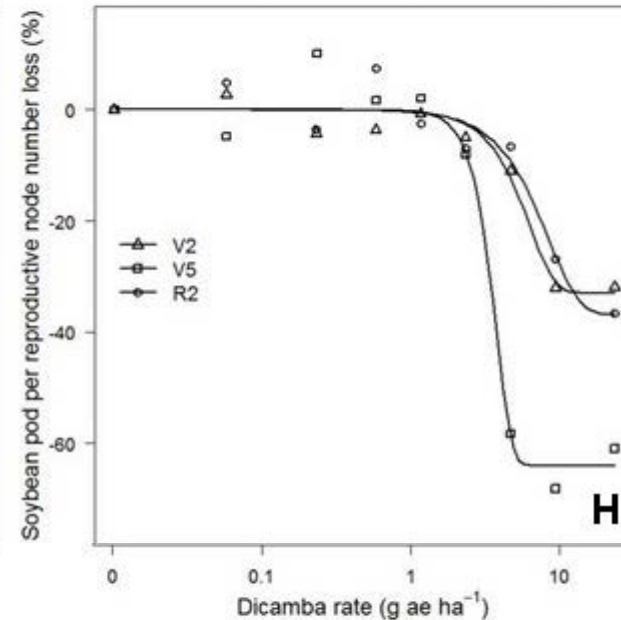
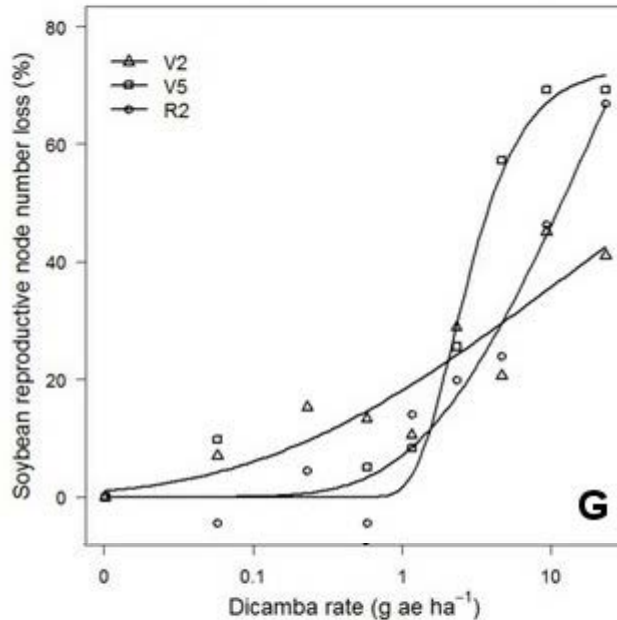
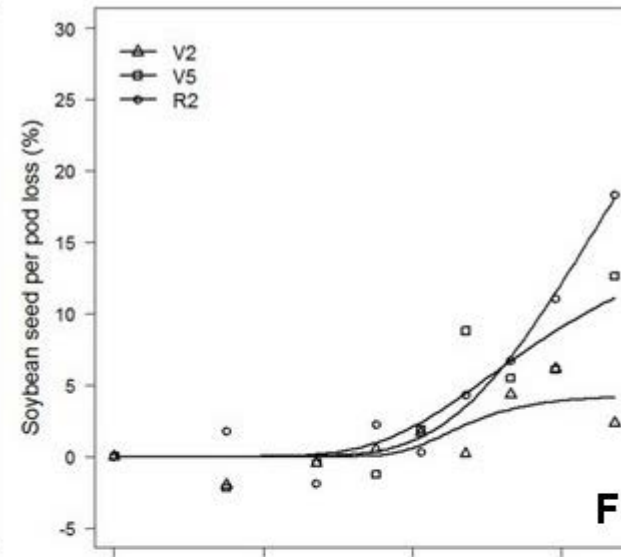
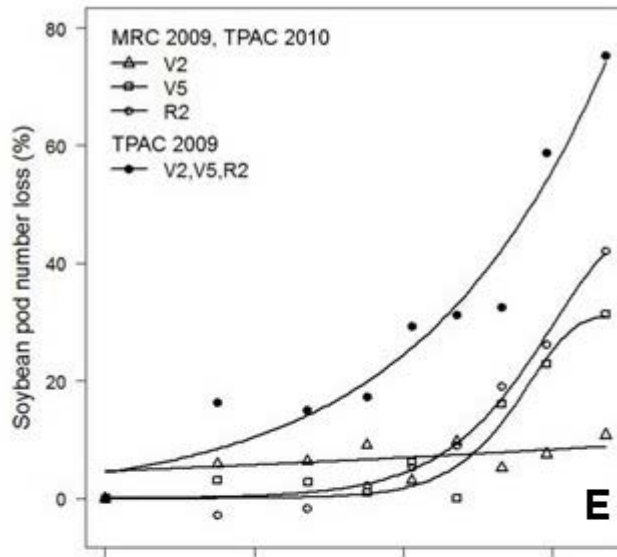
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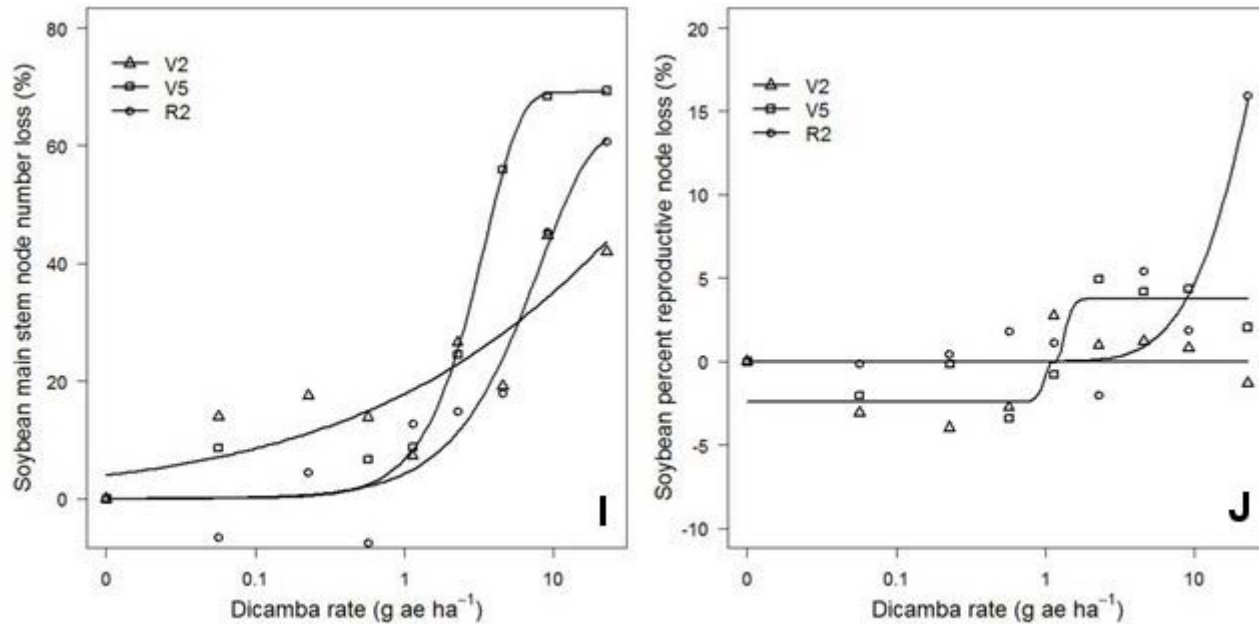
Dicamba Dose Response Curves



Dicamba Dose Response Curves



Dicamba Dose Response Curves



0% injury – Unt. check



10% injury



20% injury



30% injury



40% injury



50% injury



50% Soybean Injury



60% injury



60% Soybean Injury



70% injury



70% Soybean Injury



80% injury



90% injury



100% injury

