
Best Practices for Ground Application

Pesticide Spray Drift Series—3 Parts

- March 15, 2018 webinar: "Strategies for Managing Pesticide Spray Drift"
  - Presented by Dr. Greg Kruger, University of Nebraska-Lincoln
  - Covers fundamentals of pesticide spray particle drift management
  - Materials available: https://www.epa.gov/reducing-pesticide-drift/strategies-managing-pesticide-spray-drift-webinar-materials
- September 27, 2018 webinar: "Best Practices for Aerial Application"
  - Presented by Br. Bradley Fritz, United States Department of Agriculture
  - Dr. Greg Kruger joined for the Q+A discussion
  - Webinar materials will be posted online
- Today's webinar: "Best Practices for Ground Application"
  - Presented by Dr. Greg Kruger, University of Nebraska-Lincoln
  - Dr. Bradley Fritz will join for the Q+A discussion

Joining us for Q+A discussion

- Bradley Fritz, Ph.D
- Agricultural engineer and Research Leader, Agricultural Research Service, US Department of Agriculture
- Research areas: examining the role of spray nozzles, spray solutions, and operational settings in resulting droplet size of spray; exploring the transport and fate of applied spray under field conditions
- Numerous publications: https://www.ars.usda.gov/people-locations/person?person-id=33323

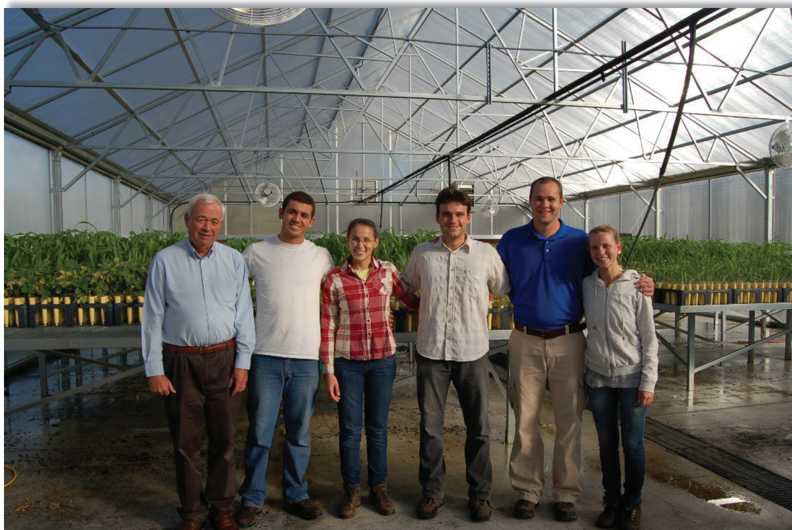
Presenter

Greg Kruger, Ph.D.

- Weed science and pesticide application technology specialist
- University of Nebraska-Lincoln, Department of Agronomy and Horticulture
- Director of the Pesticide Application Technology Laboratory
- Areas of research: droplet size and efficacy, spray drift deposition and canopy penetration, influence of nozzle type, orifice size, spray pressure, and carrier volume rate on spray droplet size
- Weed Science Society of America liaison to EPA

Best Practices for Ground Application

Greg R. Kruger
Weed Science and Application Technology Specialist
WCREC, North Platte, NE




PESTICIDE APPLICATION TECHNOLOGY LABORATORY

Definition of Drift:

Movement of spray particles and vapors off-target causing less effective control and possible injury to susceptible vegetation, wildlife, and people.

Adapted from National Coalition on Drift Minimization 1997 as adopted from the AAPCO Pesticide Drift Enforcement Policy - March 1991

Types of Drift:

Vapor Drift - associated with volatilization (gas, fumes)

Particle Drift - movement of spray particles during or after the spray application

Particle Drift – *Big 4*

1. Wind Speed

Particle Drift – *Big 4*

1. Wind Speed
2. Boom Height

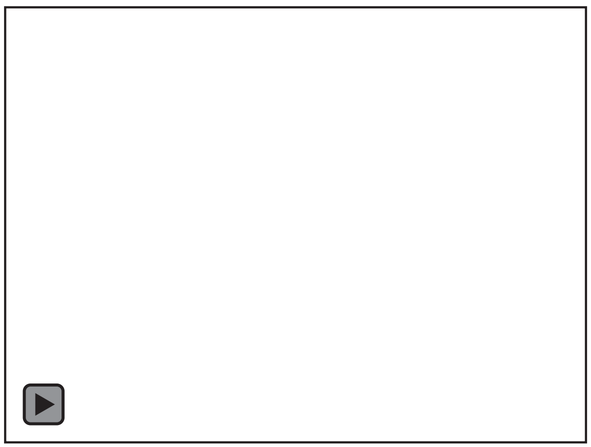
Particle Drift – *Big 4*

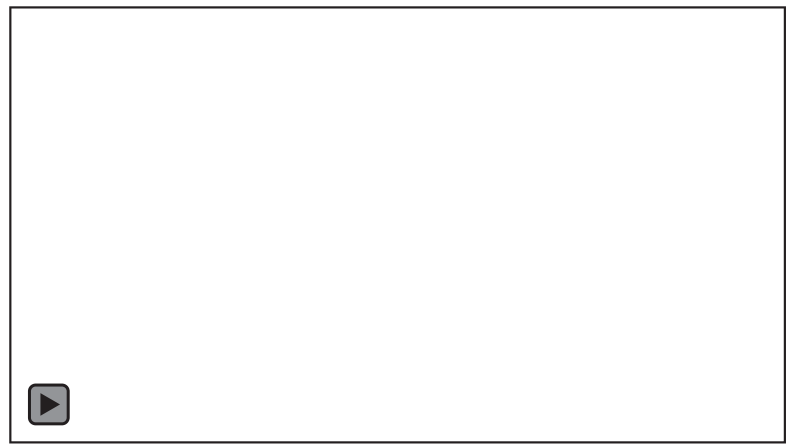
1. Wind Speed
2. Boom Height
3. Distance from Susceptible Vegetation

Particle Drift – *Big 4*

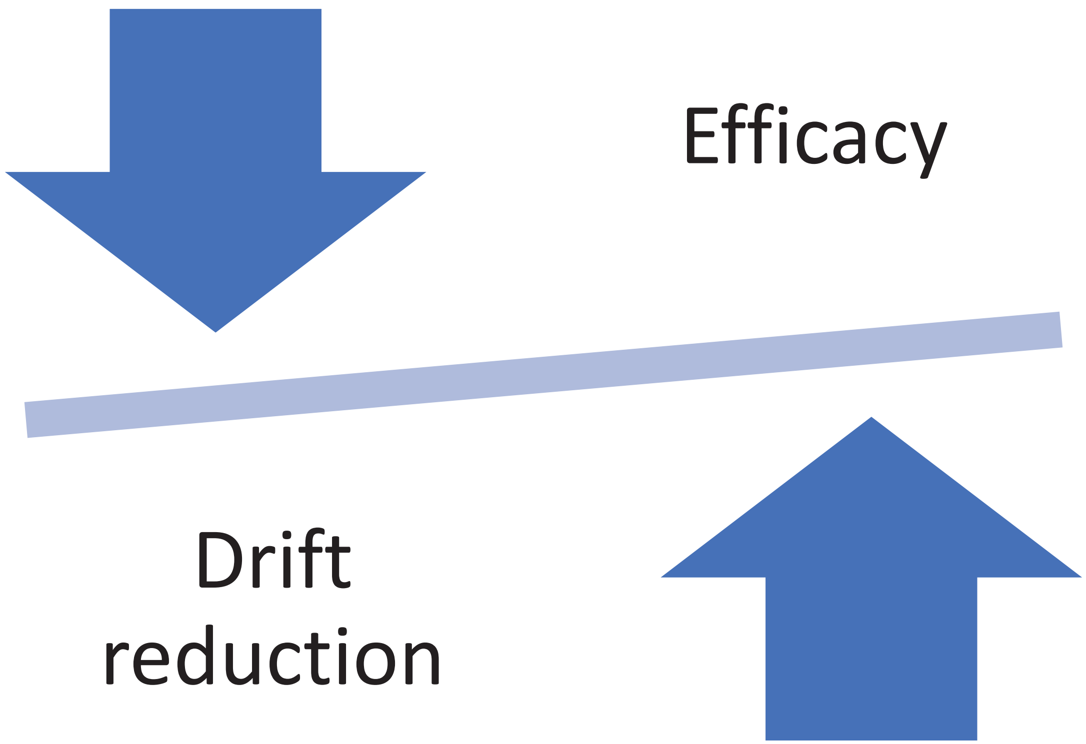
1. Wind Speed
2. Boom Height
3. Distance from Susceptible Vegetation
4. Spray Particle Size

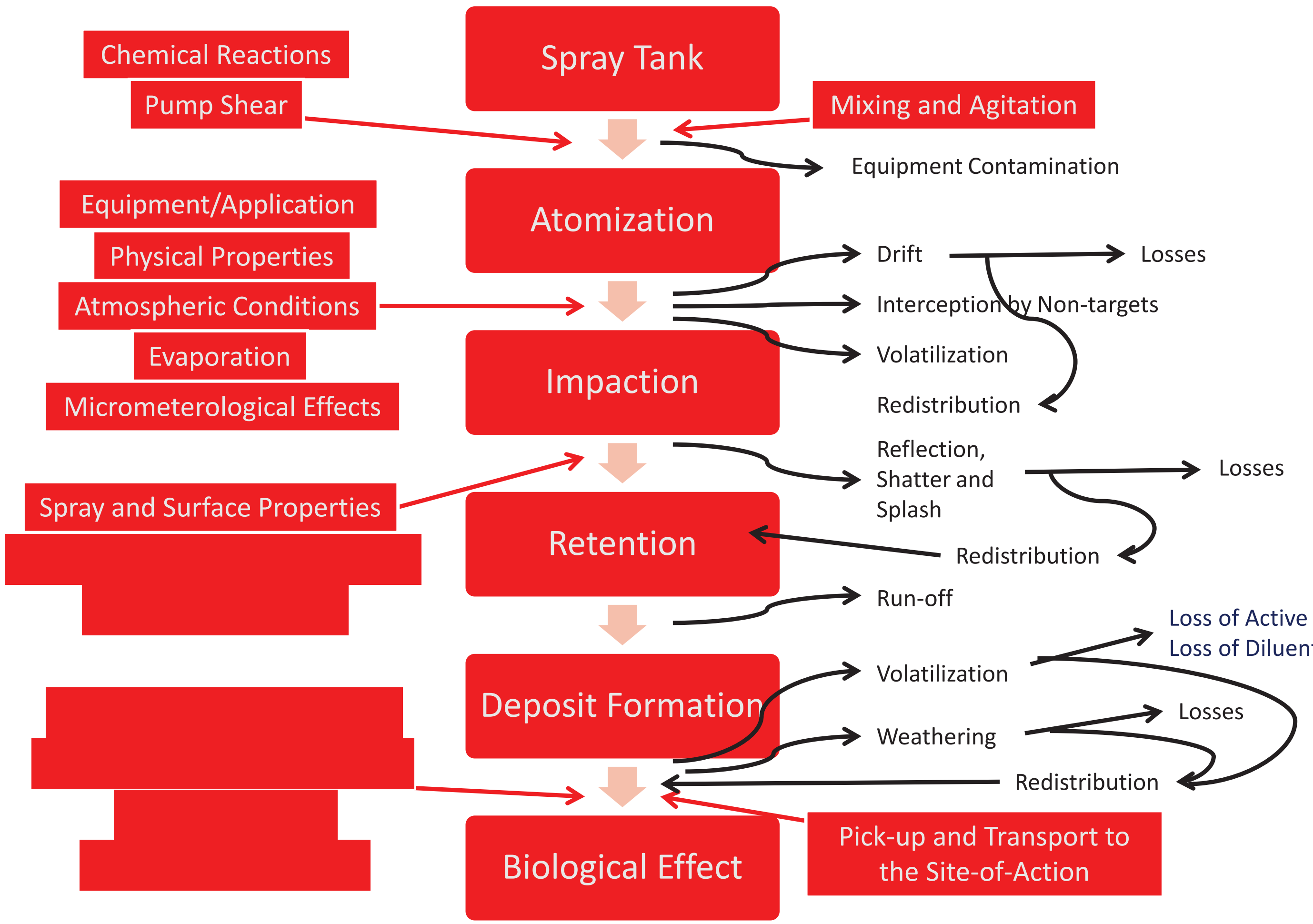
Comparison of Nozzles





Relationship Between Drift and Efficacy



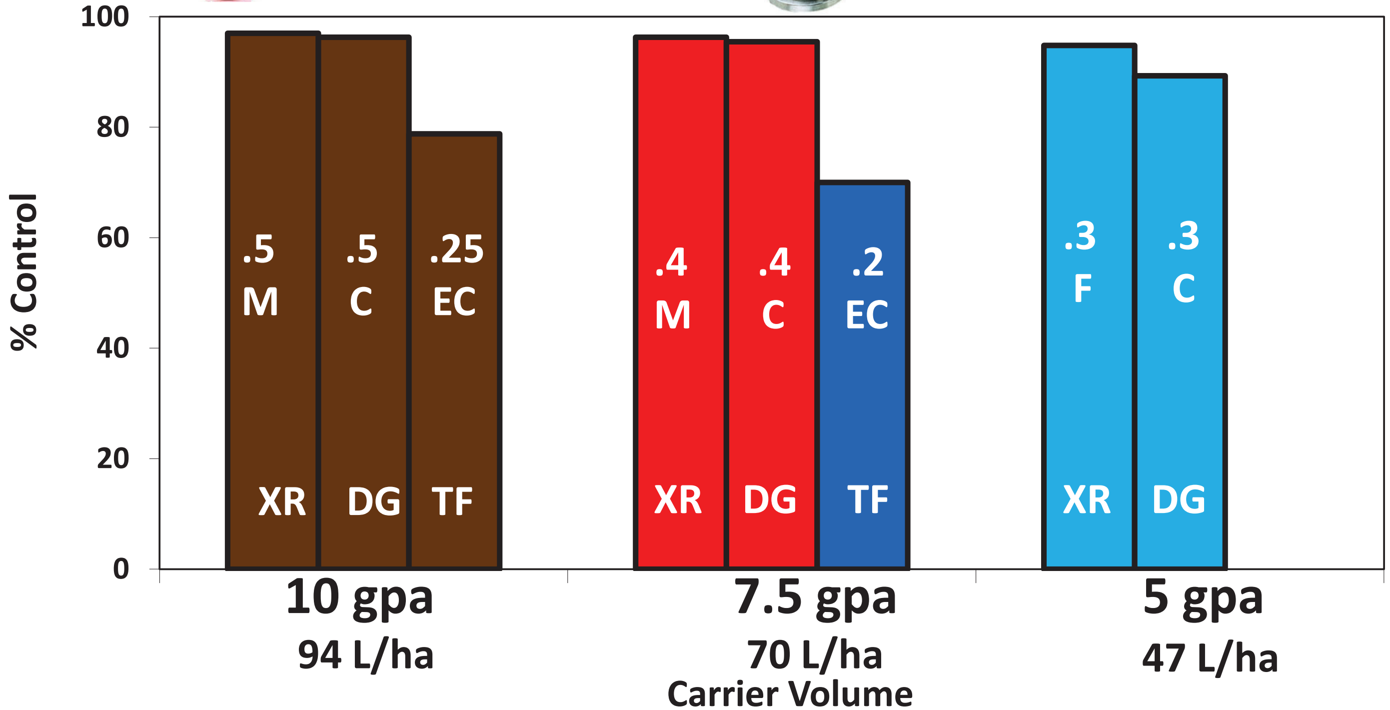


Ebert et al. 1999

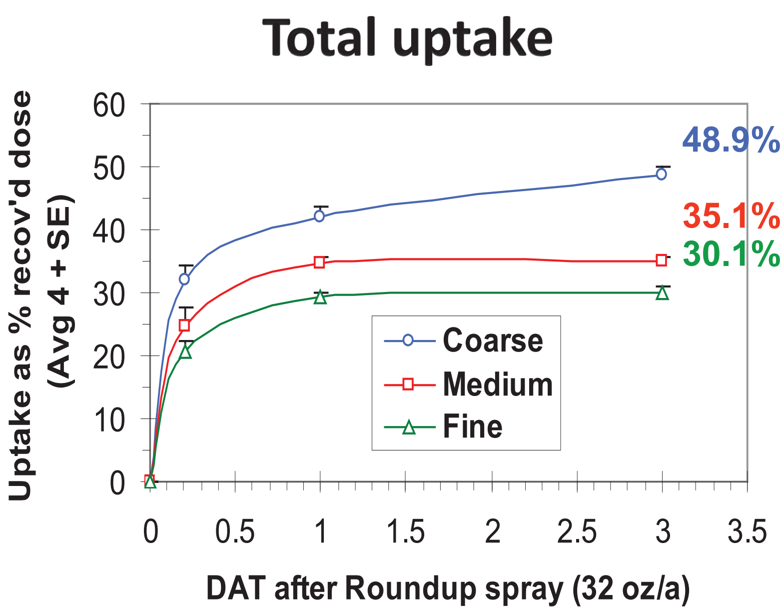
TR Kochia Control 9 DAT

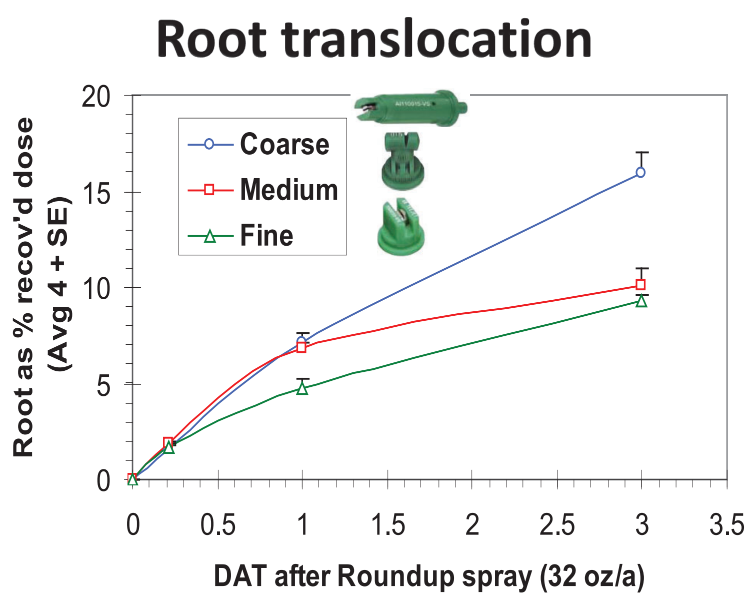
with XR, DG, and TF Nozzles at 30 psi (2 bars)

Paraquat + Atrazine (0.35 + 0.56 kg/ha)



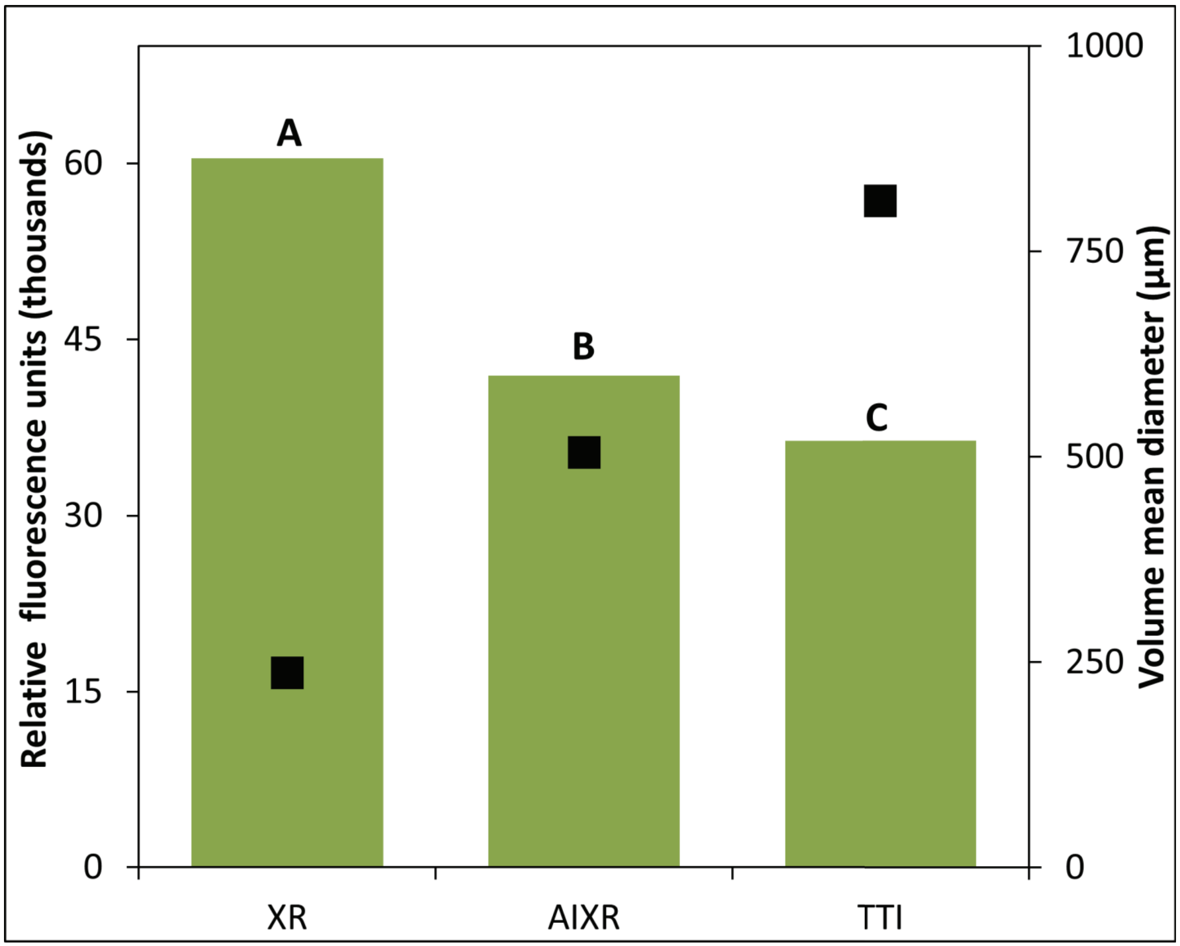
Even at lower retention, large droplets showed uptake & translocation in RR corn



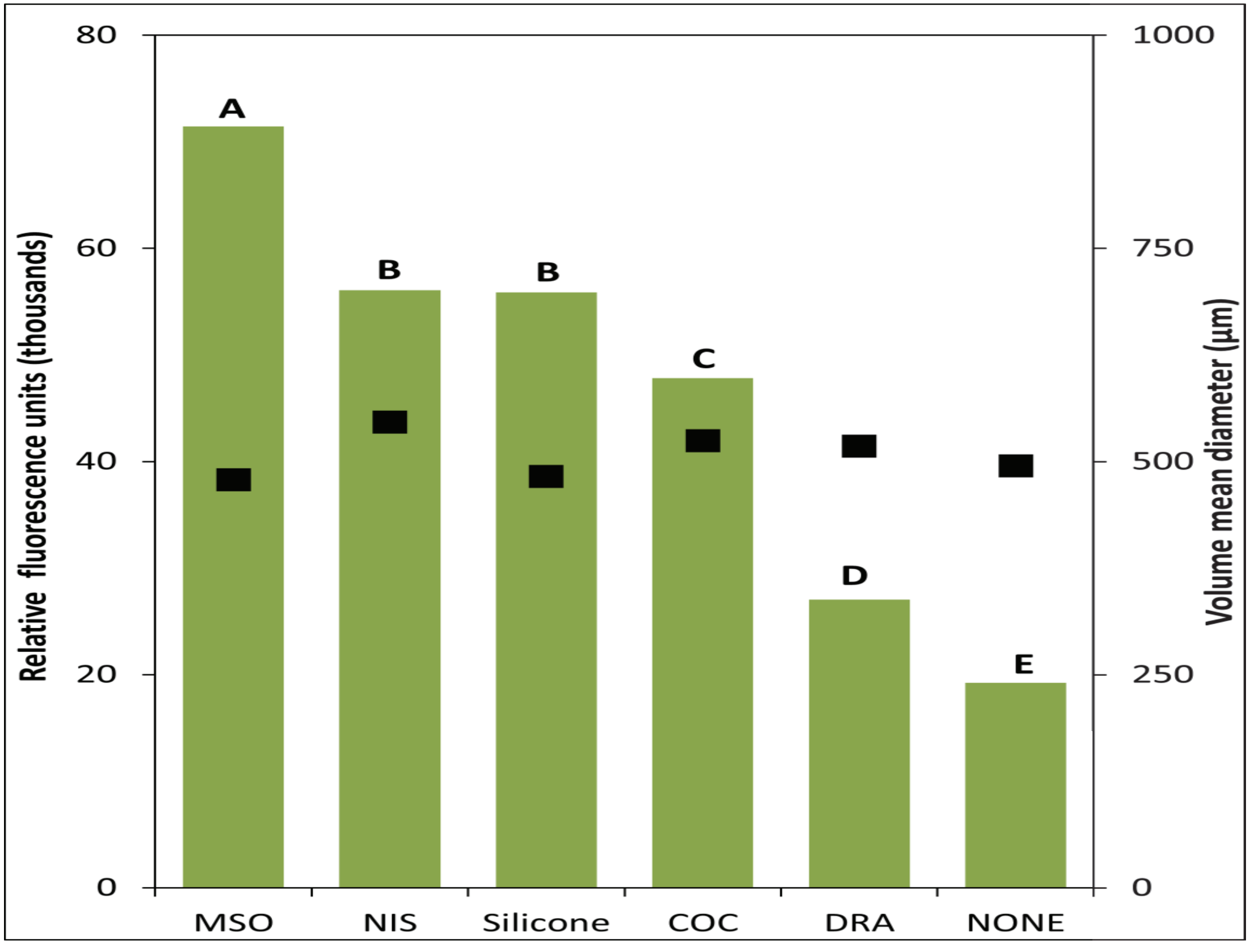


Feng et al., Weed Science 2003

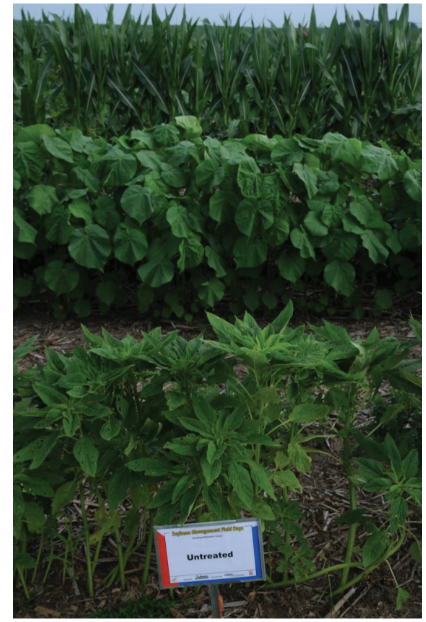
Impact of Nozzle Type on Droplet Retention



Impact of Adjuvant on Droplet Retention

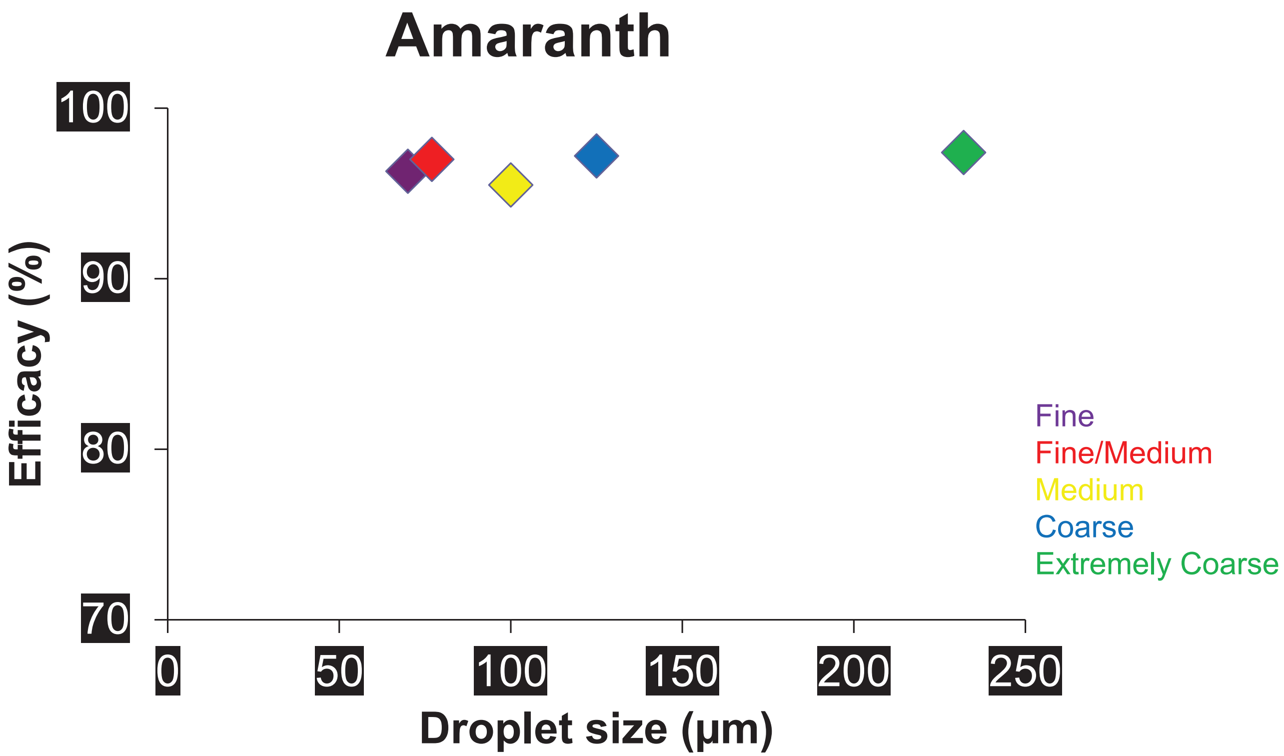


Field Studies



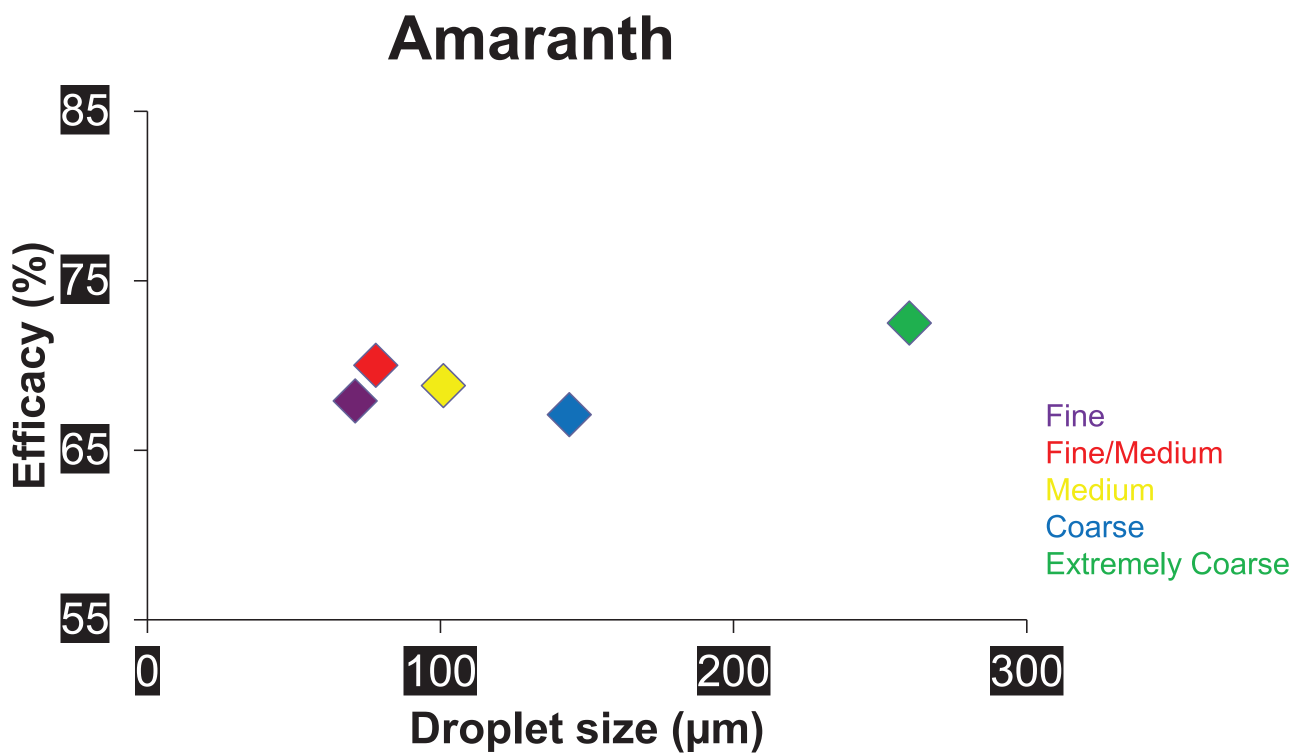
- Four locations in Nebraska
  - Bancroft, Clay Center, Courtland, Elba
- Four replications per location
- Five planted species
  - Amaranth, Flax, Velvetleaf, Soybean, Corn
- Five Nozzles plus an Untreated
  - XR11002 (Fine), XR11003 (Fine/Medium), TT11002 (Medium), AIXR11002 (Coarse), AI11002 (Extremely Coarse)

Glyphosate



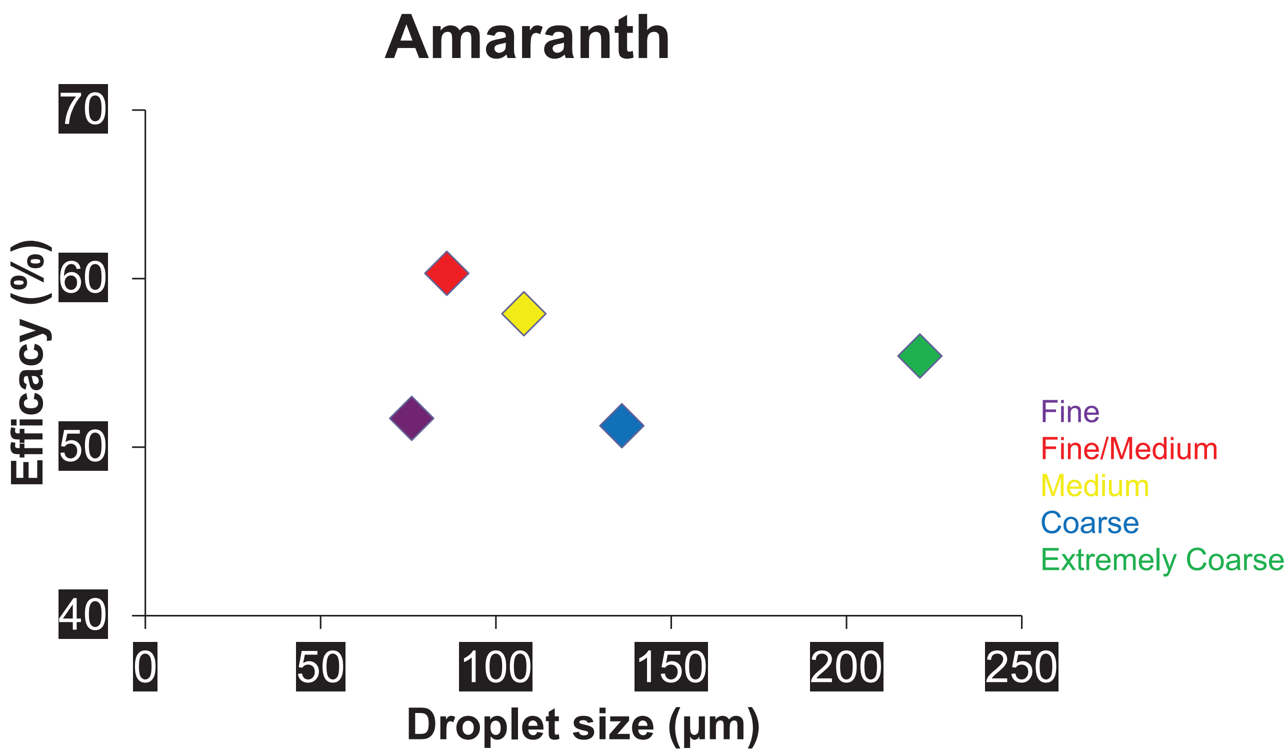
Creech et al. 2016

Dicamba



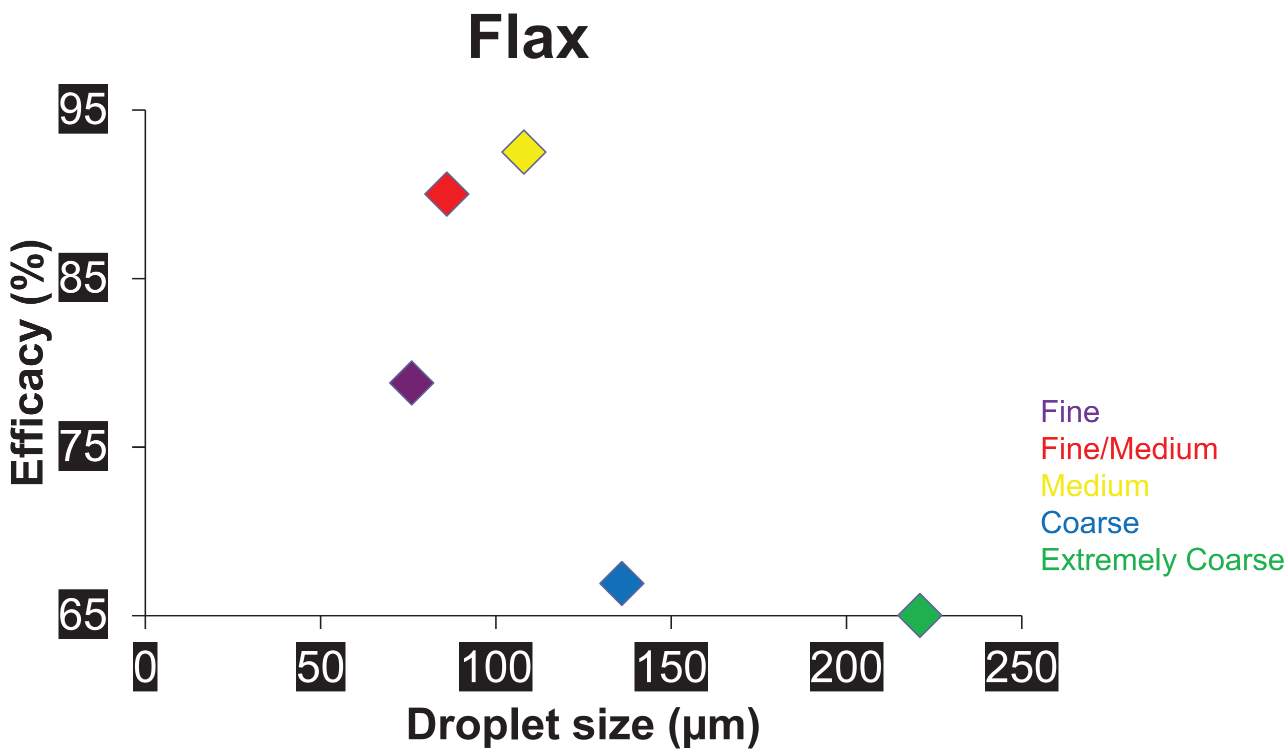
Creech et al. 2016

Fomesafen



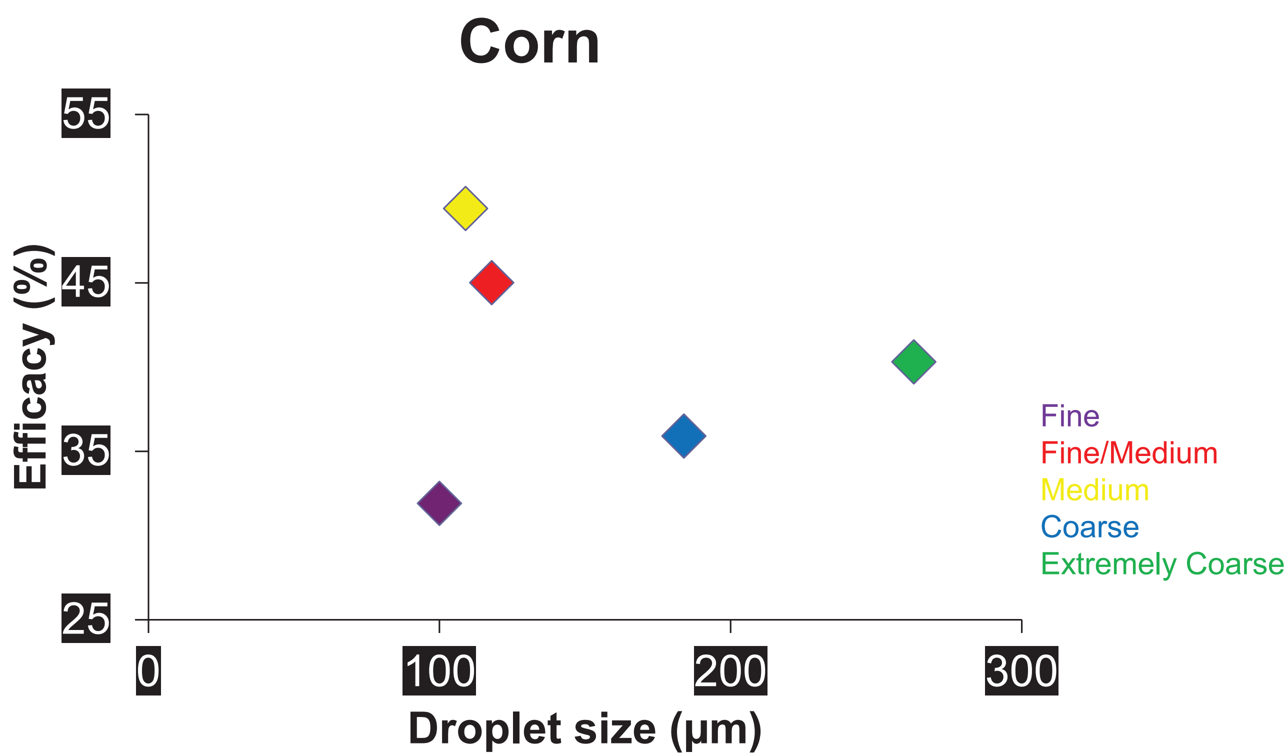
Creech et al. 2016

Fomesafen



Creech et al. 2016

Clethodim

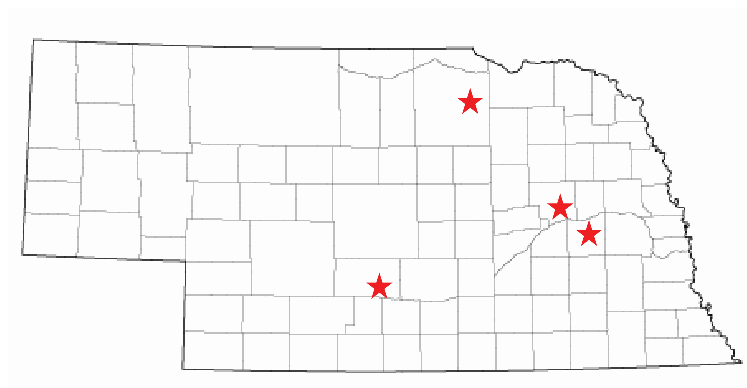


Creech et al. 2016

Carrier Rate

- Herbicides
  - Glyphosate (RoundUp PowerMax) – 3 GPA
  - Glufosinate (Liberty) – 15 GPA
  - Lactofen (Cobra) – 20 GPA
  - 2,4-D (Weedone) – 10 GPA
- Plots
  - 10’ x 30’
- Weed Control Ratings taken 14 and 28 DAT

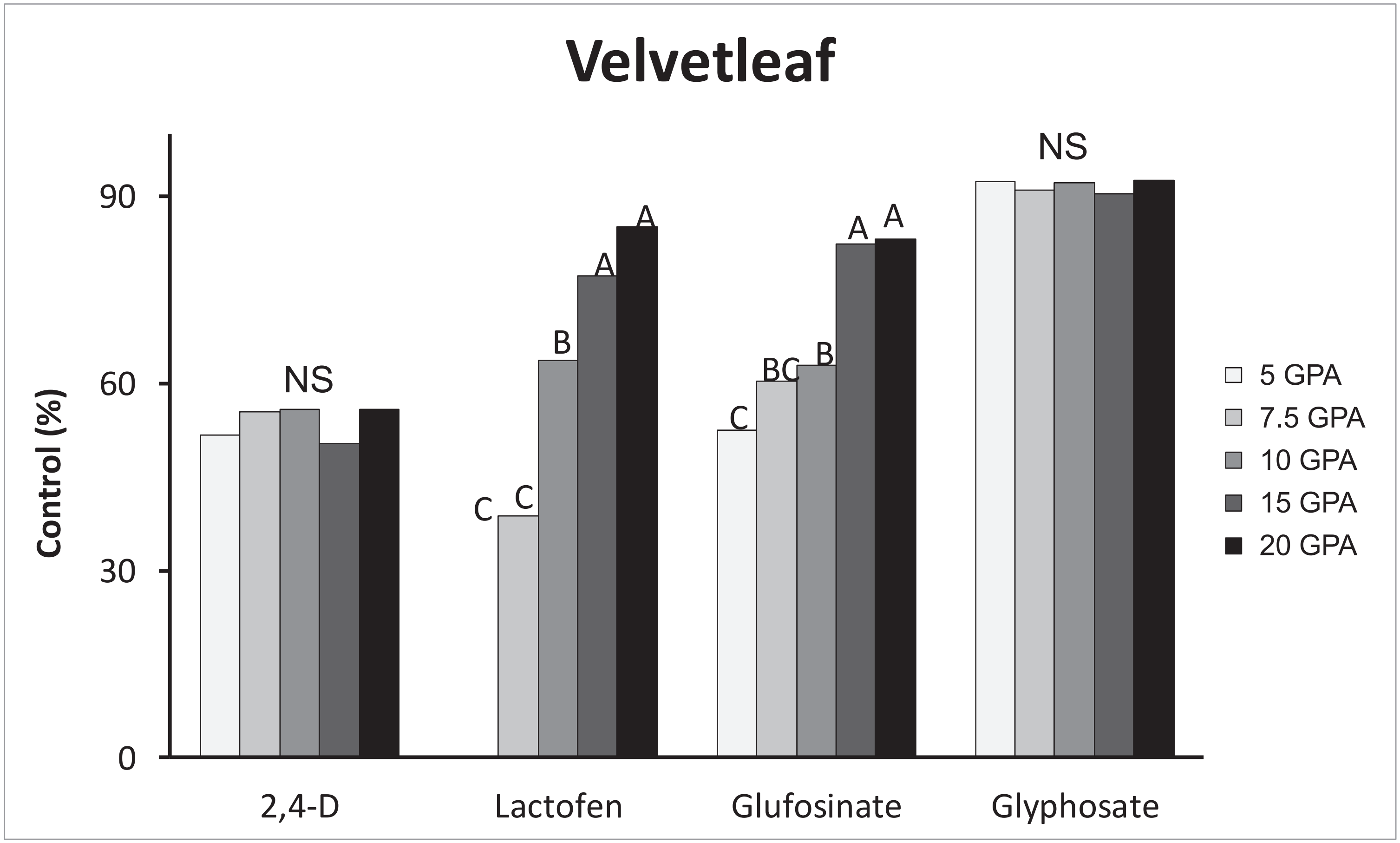
- Soybean Management Field Day Locations
  - Lexington, NE
  - O’Neill, NE
  - Platte Center, NE
  - David City, NE



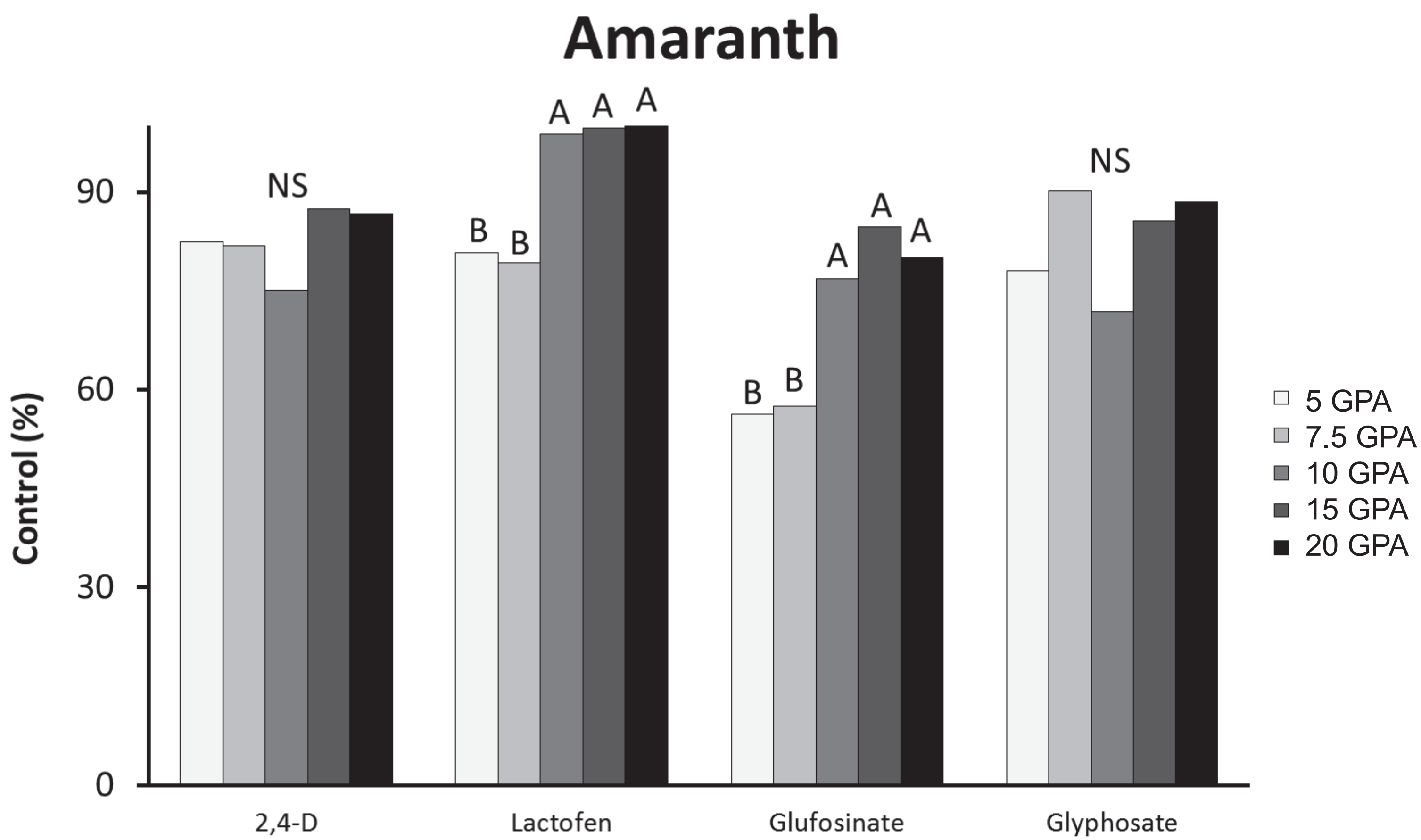
Materials and Methods

Carrier volume	Nozzle	Application speed
GPA		mph
5	XR11001	4
7.5	XR11001	4
10	XR11001	4
15	XR110015	4
20	XR11002	4.8

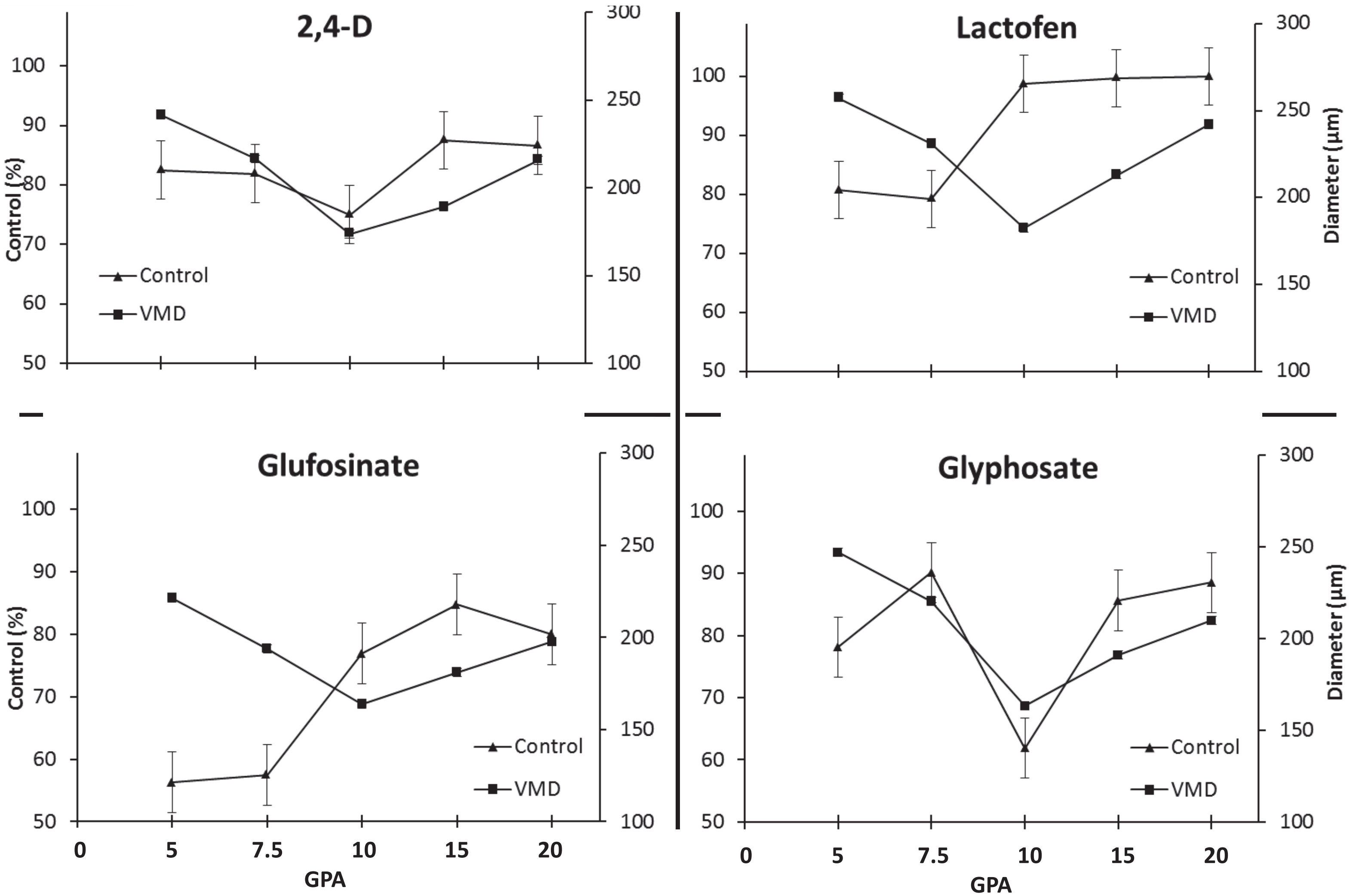
Results


Velvetleaf
Control (%)
90
60
30
0
NS
C
C
B
A
A
C
BC
B
A
A
NS
2,4-D
Lactofen
Glufosinate
Glyphosate
5 GPA
7.5 GPA
10 GPA
15 GPA
20 GPA

Results


Amaranth
Control (%)
0
30
60
90
NS
B
B
A
A
A
B
B
A
A
A
NS
2,4-D
Lactofen
Glufosinate
Glyphosate
5 GPA
7.5 GPA
10 GPA
15 GPA
20 GPA


5 GPA
12.5 oz/ac Cobra
8.5 lbs/100 Gal AMS
1% v/v COC
10 GP
12.5 oz/ac obra
8.5 lbs/100 G AMS
1% v/v CO


2,4-D
Lactofen
Glufosinate
Glyphosate
Control (%)
Diameter (µm)
Control
VMD
GPA
0
5
7.5
10
15
20
50
60
70
80
90
100
100
150
200
250
300

Amaranth

Experimental Design

- Randomized Complete Block Design with 4 Replications
- 10 inch tall Palmer amaranth
- 25 Total Treatments:
  - 2 Carrier Volumes (5 and 20 GPA)
  - 6 Droplet Sizes (150, 300, 450, 600, 750, and 900 µm)
  - 2 Herbicides [dicamba (Clarity®) and glufosinate (Liberty®)]
  - 1 Nontreated Control
- Applications were made using a Capstan PinPoint® Pulse-width Modulation (PWM) Sprayer
  - This allows for flow to be controlled by the relative proportion of time each electronically actuated solenoid valve is open (duty cycle)[1]
  - Duty cycle was demonstrated to have minimal impact on droplet size[2,3]

[1]Giles and Comino, 1989. J. of Commercial Vehicles. SAE Trans. 98:237-249
[2]Butts et al., 2015. Proc. North Cent. Weed Sci. 70:111. Indianapolis, IN
[3]Giles et al., 1996. Precision Agriculture. Proc. of the 3rd International Conference. 729-738. Minneapolis, MN

Nozzle type, orifice size, and application pressure combinations for each droplet size treatment.

Herbicide	Carrier volume	Droplet size	Nozzle	Application pressure
	gal ac^{-1}	µm		PSI
glufosinate	5	150	ER 110015	60
glufosinate	5	300	SR 11005	40
glufosinate	5	450	DR 11004	40
glufosinate	5	600	UR 11004	35
glufosinate	5	750	UR 11008	40
glufosinate	5	900	UR 11010	30
glufosinate	20	150	ER 110015	50
glufosinate	20	300	SR 11003	30
glufosinate	20	450	MR 11006	35
glufosinate	20	600	DR 11008	39
glufosinate	20	750	UR 11006	33
glufosinate	20	900	UR 11010	36

Butts et al. 2018

Nozzle type, orifice size, and application pressure combinations for each droplet size treatment.

Herbicide	Carrier volume	Droplet size	Nozzle	Application pressure
	gal ac^{-1}	µm		PSI
dicamba	5	150	ER 110015	60
dicamba	5	300	ER 11006	42
dicamba	5	450	SR 11006	35
dicamba	5	600	DR 11004	34
dicamba	5	750	DR 11008	35
dicamba	5	900	UR 11006	40
dicamba	20	150	ER 110015	60
dicamba	20	300	SR 11002	30
dicamba	20	450	MR 11004	39
dicamba	20	600	DR 11005	52
dicamba	20	750	DR 11006	38
dicamba	20	900	UR 11006	35

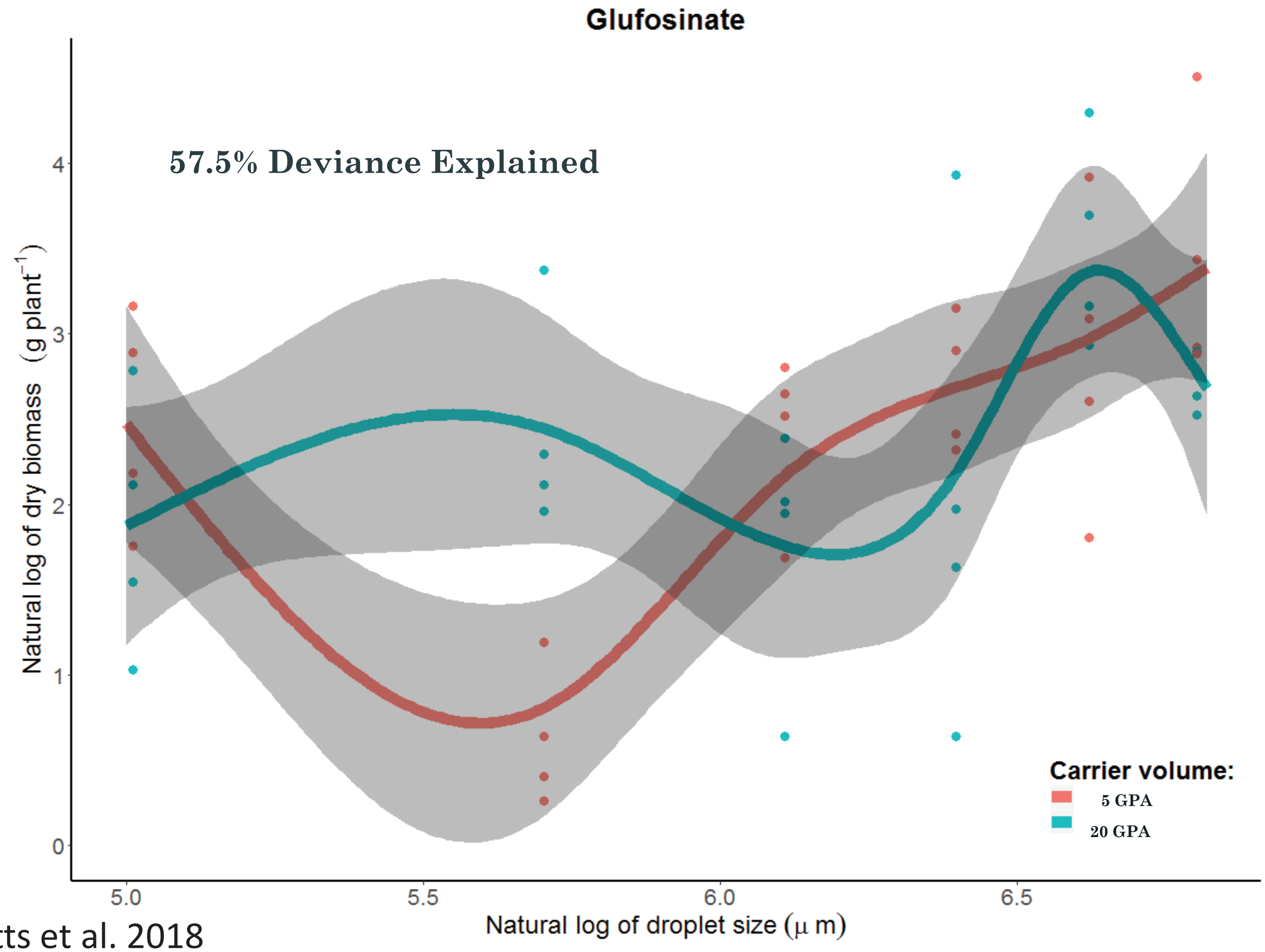
Butts et al. 2018

	Carrier Volume	Best Droplet Size for Biomass Reduction	% Reduction in Biomass from Control
Dicamba			
Glufosinate			

- Glufosinate:
  - For both carrier volumes, 750 and 900 µm droplets were not different from nontreated control for biomass reduction
- Dicamba:
  - For both carrier volumes, 900 µm droplets were not different from nontreated control for biomass reduction

Butts et al. 2018

GAM Model for droplet size and carrier volume effect on Palmer amaranth control



Butts et al. 2018

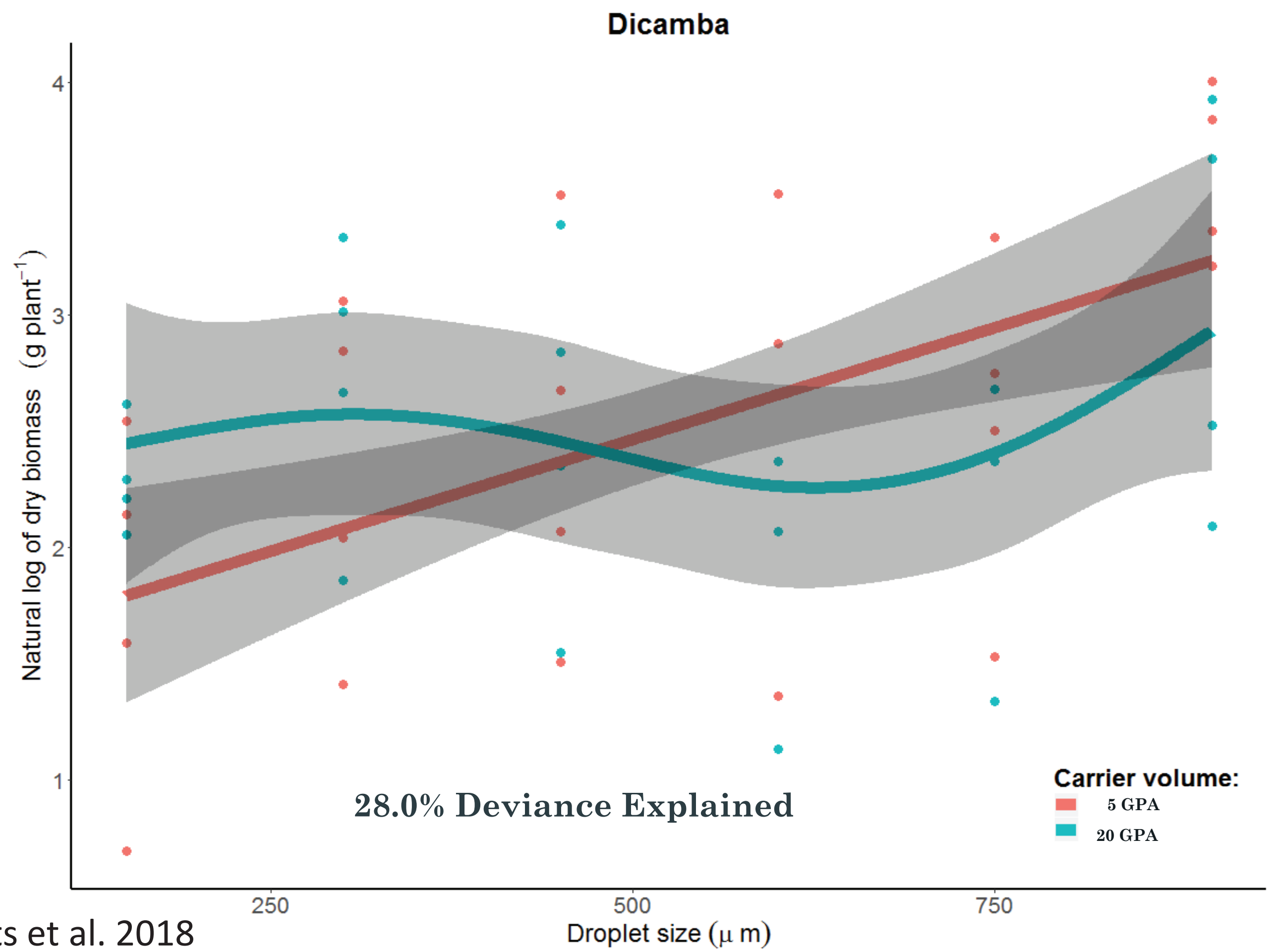
Glufosinate

5 GPA

14 DAA

Butts et al. 2018

GAM Model for droplet size and carrier volume effect on Palmer amaranth control



Butts et al. 2018

Dicamba

5 GPA

14 DAA

Butts et al. 2018

Optimum droplet sizes for maximum Palmer amaranth control

	Dicamba	Glufosinate
5 GPA		
20 GPA		

Butts et al. 2018

Tank Mixtures on Weed Control

- **horseweed[a]**, [*Conyza canadensis* (L.) Cronq]
- **kochia[a]**, [*Kochia scoparia* (L.) Schrad.]
- **common lambsquarters**, (*Chenopodium album* L.)
- **grain sorghum**, [*Sorghum bicolor* (L.) Moench subsp. bicolor.]

[a]Resistant to glyphosate

Treatments

Common name	Treatment rate
Glyphosate (Roundup PowerMax®)	600 g ae ha^{-1}
Lactofen (Cobra®)	110 g ai ha^{-1}
Fomesafen (Flexstar®)	65 g ai ha^{-1}
Ammonium Sulfate[a]	17 lb/100gal
80% Crop oil concentrate[b]	1% v v^{-1}

[a]Ammonium sulfate (AMS) was added to all treatments.

[b]Crop oil concentrate (COC) was added to all treatments except for glyphosate applied alone.

Nozzle Selection

Common Name	Nozzle Type[a]	DRT Feature[b]	
Extended Range	XR	None	
Air-Induction Extended Range	AIXR	Venturi, pre orifice	
Turbo Teejet Induction	TTI	Venturi, pre orifice, anvil shaped	
Guardian air	GA	Venturi, pre orifice, off-set angle	
Ultra Lo-Drift	ULD	Venturi, pre orifice	
TurboDrop® XL	TDXL	Dual cap, venture, pre-orifice	

[a]The listed nozzle types were all orifice size “04” with a manufacturer-rated spray plume angle of 110° except for ULD nozzles that were 120°.

[b]Drift reduction technology feature.

Herbicide Applications

Treatments were sprayed at:

- 187 l ha^{-1}
- 9.6 kph
- 276 kPa

Three-nozzle research track sprayer.

Nozzles spaced 50 cm apart and at 50 cm above the plants.

Results

ANOVA results based on biomass reduction at 28 DAT.

Type III Tests of Fixed Effects			
Effect	**Num DF**	**F Value**	**Pr-value[a]**
Herbicide solution	4	109.43	<.0001
Nozzle	5	1.08	0.3688
Herbicide solution*Nozzle	20	0.88	0.6164
Species	3	632.04	<.0001
Herbicide solution*Species	12	166.74	<.0001
Nozzle*Species	15	0.89	0.5708
Herbicide solution*Nozzle*Species	60	1.09	0.3900

[a]Significant value ($P \leq 0.05$).

Droplet spectra

	Spray-droplet distribution[a]								
	XR			GA			AIXR		
Herbicide solution	$Dv_{0.5}$[b] (µm)	≤ 150 µm[b] (%)	CC[c]	$Dv_{0.5}$[b] (µm)	≤ 150 µm[b] (%)	CC[c]	$Dv_{0.5}$[b] (µm)	≤ 150 µm[b] (%)	CC[c]
Glyphosate + AMS	240[t]	21.30[a]	F	397[r]	5.35[d]	C	487[l]	3.13[g]	VC
Lactofen + AMS + COC	268[s]	12.05[c]	M	443[o]	2.24[i]	VC	481[m]	1.68[j]	VC
Fomesafen + AMS + COC	265[s]	12.14[c]	M	432[p]	2.31[i]	VC	473[n]	1.70[j]	VC
Glyphosate + Lactofen + AMS + COC	269[s]	11.96[c]	M	393[r]	3.39[f]	C	471[n]	1.83[j]	VC
Glyphosate + Fomesafen + AMS + COC	266[s]	12.37[b]	M	409[q]	2.69[h]	C	444[o]	3.81[e]	VC

[a]$Dv_{0.5}$ represents the droplet size such that 50% of the spray volume is contained in droplets of equal or lesser values.

[b]Means within a column followed by the same letter are not statistically different ($P \leq 0.05$).

[c]The classification category for this study was made based on reference curves created from reference nozzle data at the PAT Lab as described by ASAE 572.1 where F = fine, M = medium, C = coarse, VC = very coarse, XC = extremely coarse, and UC = ultra coarse.

Droplet spectra

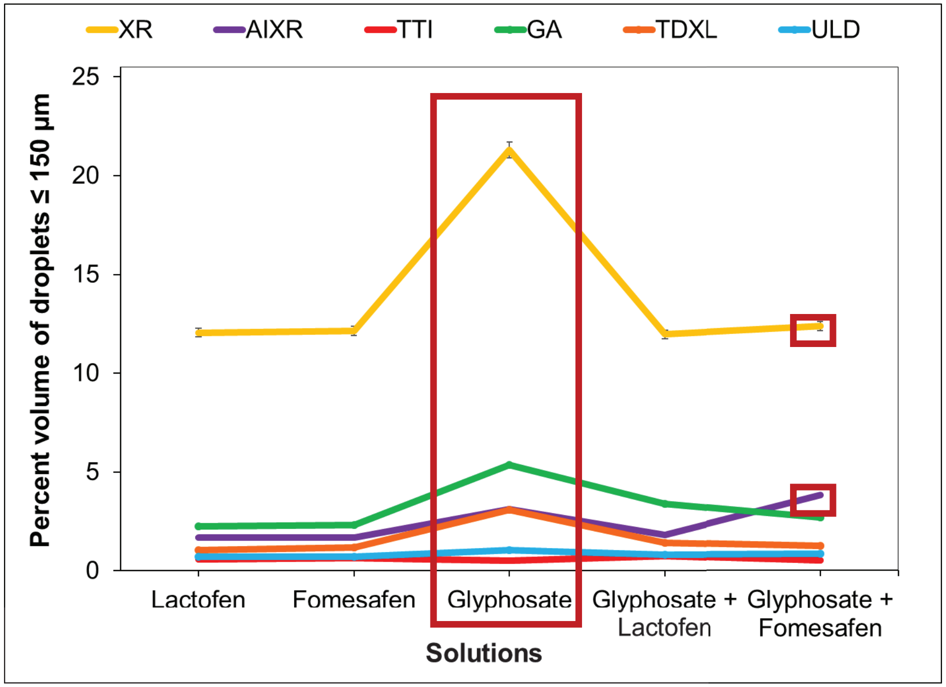
	Spray-droplet distribution[a]								
	TDXL			ULD			TTI		
Herbicide solution	$Dv_{0.5}$[b] (µm)	≤ 150 µm[b] (%)	CC[c]	$Dv_{0.5}$[b] (µm)	≤ 150 µm[b] (%)	CC[c]	$Dv_{0.5}$[b] (µm)	≤ 150 µm[b] (%)	CC[c]
Glyphosate + AMS	505[j]	3.08[g]	VC	610[f]	1.06[l,m]	XC	787[a]	0.52[q]	UC
Lactofen + AMS + COC	540[h]	1.04[l,m]	XC	624[e]	0.71[n,o,p,q]	XC	653[c]	0.58[p,q]	XC
Fomesafen + AMS + COC	527[i]	1.17[l]	VC	602[g]	0.70[n,o,p,q]	XC	640[d]	0.60[o,p,q]	XC
Glyphosate + Lactofen + AMS + COC	500[j]	1.41[k]	VC	609[f]	0.81[n,o]	XC	613[f]	0.76[n,o,p]	XC
Glyphosate + Fomesafen + AMS + COC	504[j]	1.24[l,k]	VC	610[f]	0.85[n,m]	XC	754[b]	0.50[q]	UC

[a]$Dv_{0.5}$ represents the droplet size such that 50% of the spray volume is contained in droplets of equal or lesser values.

[b]Means within a column followed by the same letter are not statistically different ($P \leq 0.05$).

[c]The classification category for this study was made based on reference curves created from reference nozzle data at the PAT Lab as described by ASAE 572.1 where F = fine, M = medium, C = coarse, VC = very coarse, XC = extremely coarse, and UC = ultra coarse.

Driftable fines



Colby’s Equation

- The responses of herbicides applied singly are used in calculating the “expected” response when they are applied in combination (Colby 1967)

Colby's Equation

$$E_1 = \frac{(X_1 Y_1)}{100}$$

- X_1 = 100 – X

  (X = observed response by herbicide A)

- Y_1 = 100 - Y

  (Y = observed response by herbicide B)

- E_1 = 100 – E

  (E = expected response by herbicides A + B)

Example

	Control (%)	
Herbicide	Observed	Expected
A	30	
B	50	
A + B	80	

$$E_1 = \frac{(X_1 Y_1)}{100} = \frac{(70*50)}{100} = 35$$

$$E = 100 - 35 = 65$$

Synergistic interaction

Example

	Control (%)	
Herbicide	Observed	Expected
A	30	
B	50	
A + B	65	

$$E_1 = \frac{(X_1 Y_1)}{100} = \frac{(70*50)}{100} = 35$$

$$E = 100 - 35 = 65$$

⇨ Additive interaction

Example

	Control (%)	
Herbicide	Observed	Expected
A	30	
B	50	
A + B	42	

$$E_1 = \frac{(X_1 Y_1)}{100} = \frac{(70*50)}{100} = 35$$

$$E = 100 - 35 = 65$$

⇨ Antagonistic interaction

Tank-mixture Interactions

	Horseweed			Kochia		
	Control[a] (%)			Control[a] (%)		
Herbicide Solution	**Observed[b]**	**Expected[c]**	**CI (%)**	**Observed[b]**	**Expected[c]**	**CI (%)**
Glyphosate + AMS	26.8 c			21.9 d		
Lactofen + AMS + COC	53.0 a			91.9 a		
Fomesafen + AMS + COC	39.5 b			84.7 b		
Glyphosate + Lactofen + AMS + COC	42.0 b		-	92.9 a		-
Glyphosate + Fomesafen + AMS + COC	38.1 b		-	77.0 c		-

[a] Percentage of control based on the biomass reduction at 28 DAT.
[b] Means within a column followed by the same letter are not statistically different P ≤ 0.05).
[c] Expected values were calculated as described by the Colby equation (1967); an asterisk adjacent to the expected control indicates antagonism.

Glyposate + Fomesafen
Tank-mixture

Fomesafen
Applied alone

At 14 DAT

Tank-mixture Interactions

	Common lambsquarters			Grain sorghum		
	Control[a] (%)			Control[a] (%)		
Herbicide Solution	Observed[b]	Expected[c]	CI (%)	Observed[b]	Expected[c]	CI (%)
Glyphosate + AMS	92.6 a			98.4 a		
Lactofen + AMS + COC	63.2 c			50.9 b		
Fomesafen + AMS + COC	72.9 b			49.7 b		
Glyphosate + Lactofen + AMS + COC	89.0 a		-	97.2 a		-
Glyphosate + Fomesafen + AMS + COC	90.4 a		-	96.9 a		-

[a] Percentage of control based on the biomass reduction at 28 DAT.
[b] Means within a column followed by the same letter are not statistically different $P \leq 0.05$).
[c] Expected values were calculated as described by the Colby equation (1967); an asterisk adjacent to the expected control indicates antagonism.

Tank-mixture Interactions

- Combination of glyphosate and fomesafen or sulfentrazone caused reduced efficacy of both herbicides (Starke and Oliver 1998)

- Flumiorac was antagonistic to glyphosate in Palmer amaranth (Nandula et al. 2012)

↓

- Reduction of glyphosate absorption and translocation

Take Home Messages!

- Particle drift can be influenced by formulation
- Nozzle selection has the greatest influence on particle size
- Adjuvants can reduce drift potential, but must be tested
- There is no substitute for common sense – if the wind is blowing droplets will move
- Pay attention to sensitive vegetation in surrounding areas
- Drift **WILL** happen! Mitigating drift is essential!

Questions?

- Greg Kruger
  - Cropping Systems Specialist
  - West Central Research and Extension Center
  - North Platte, NE
  - Website: pat.unl.edu
  - gkruger2@unl.edu
  - (308)696-6715

- Thank You!


why
?
where
when
who
?
?
QUESTIONS
why
who
?
how
where
who
what
?
how
why
?
when