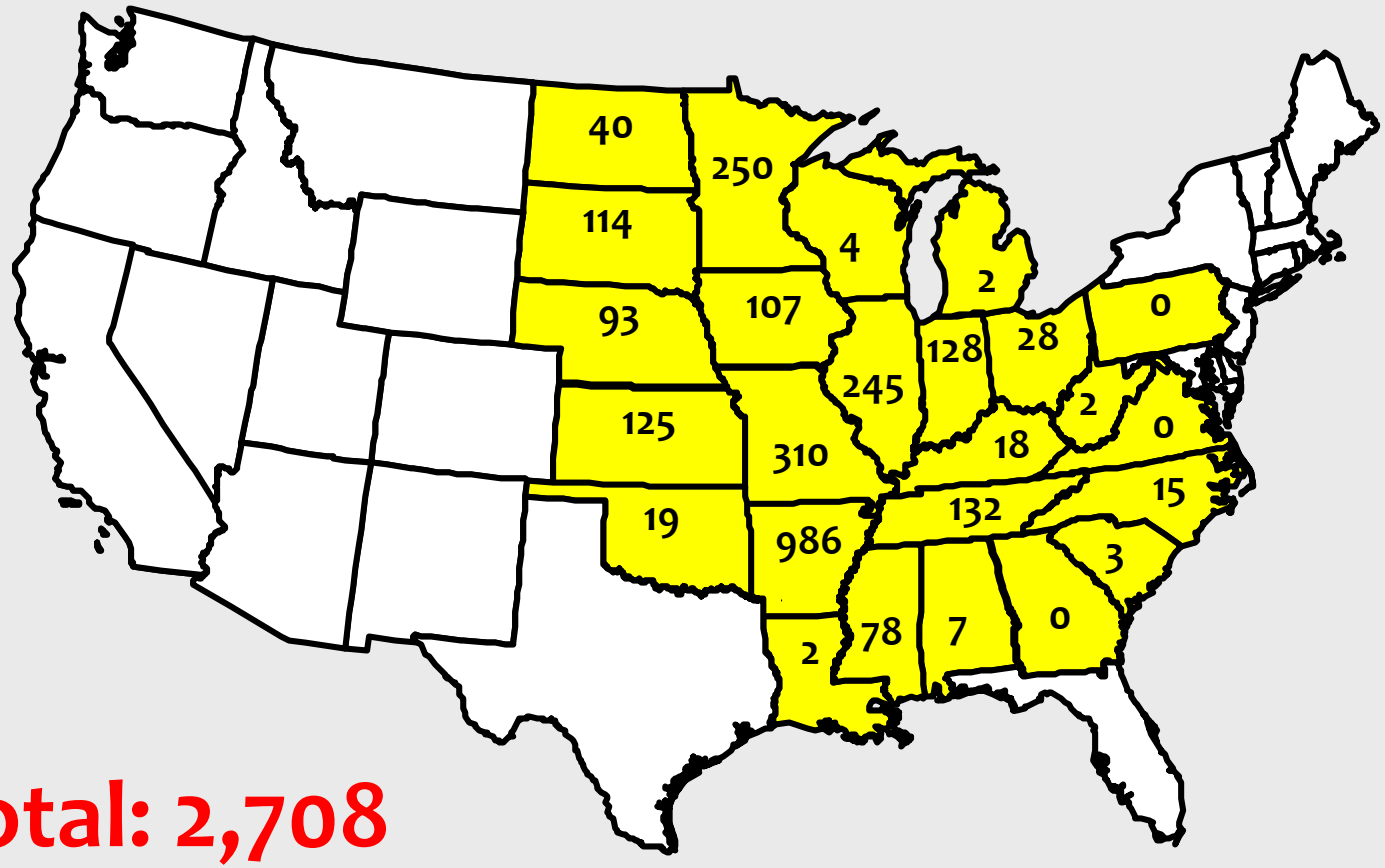
Dicamba:
Where it happened?
How it happened?
Why it happened?

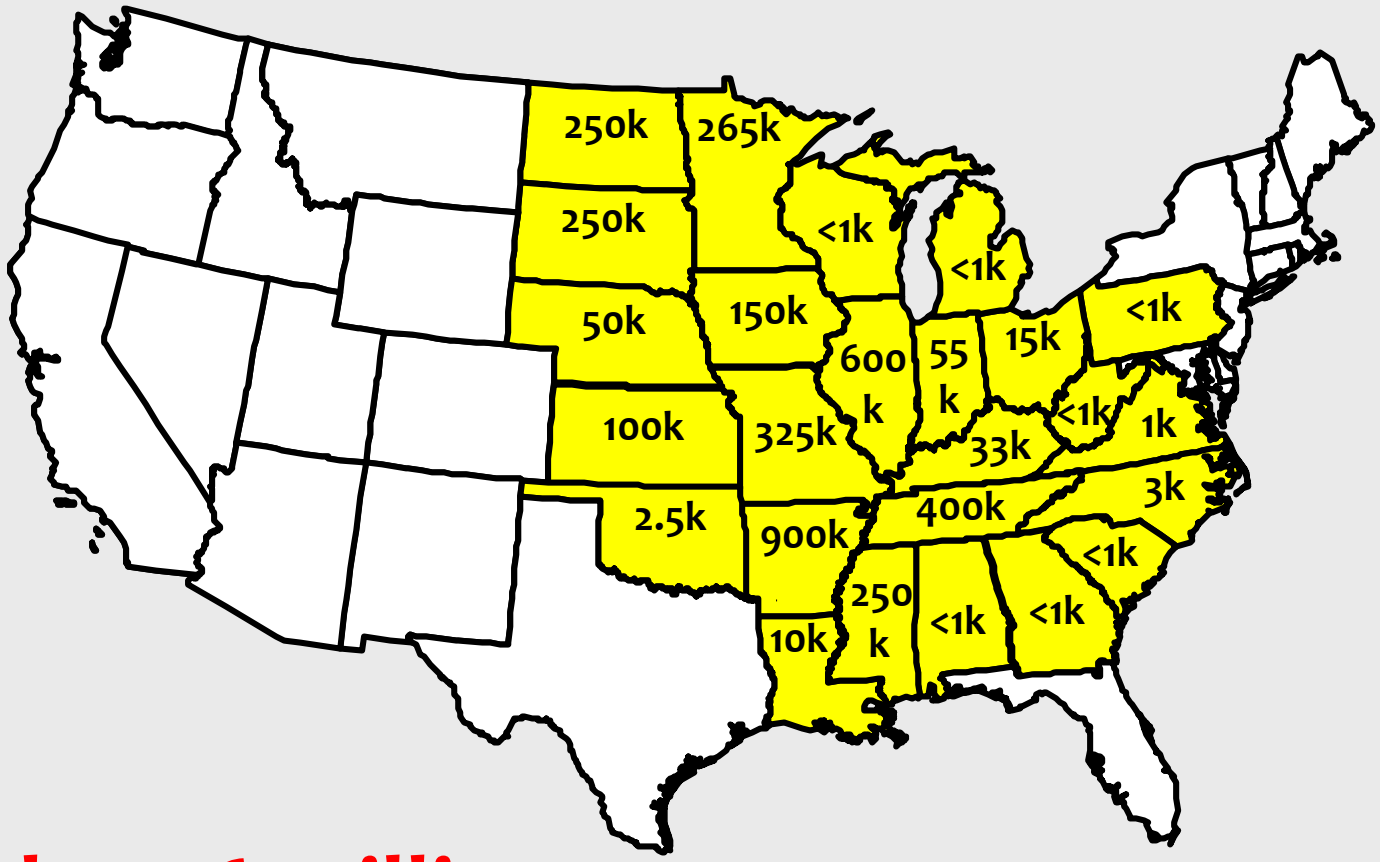
Rich Zollinger
NDSU Extension Weed Specialist

Official Dicamba-related Injury Investigations as Reported by State Departments of Agriculture (*as of October 15, 2017)



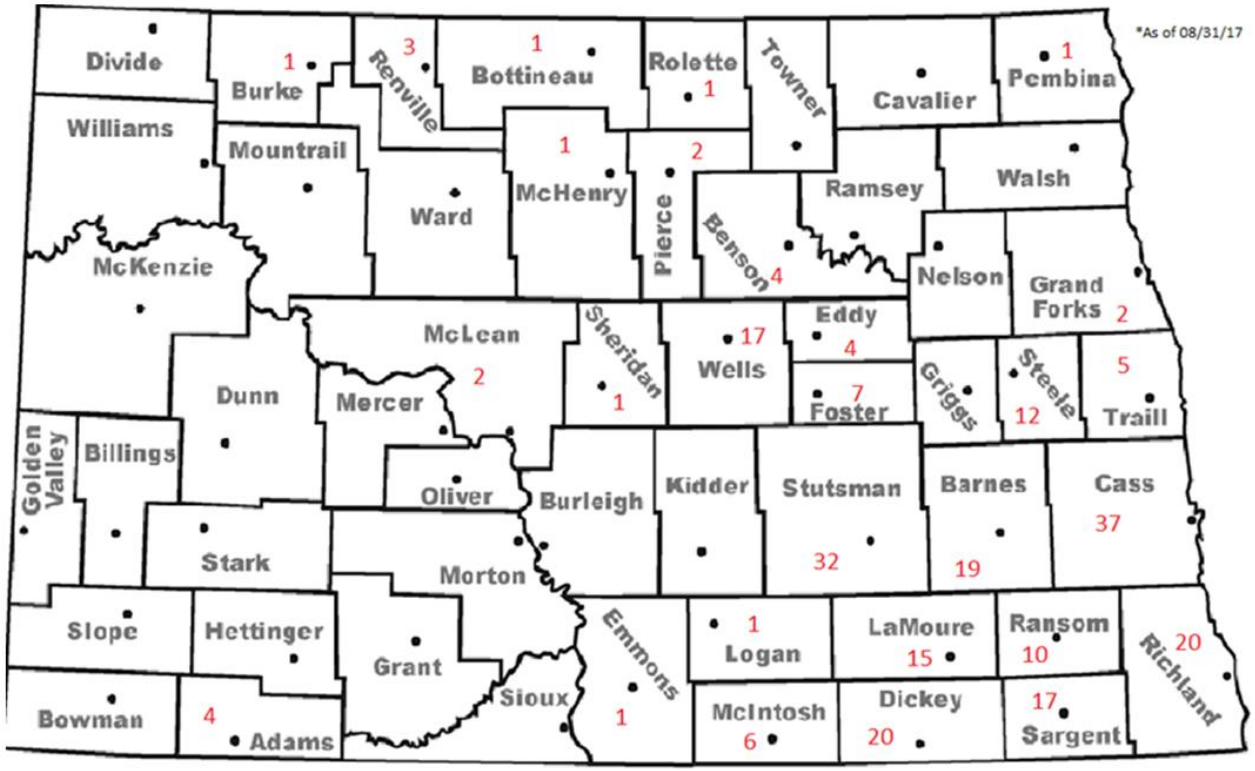
*Total: 2,708

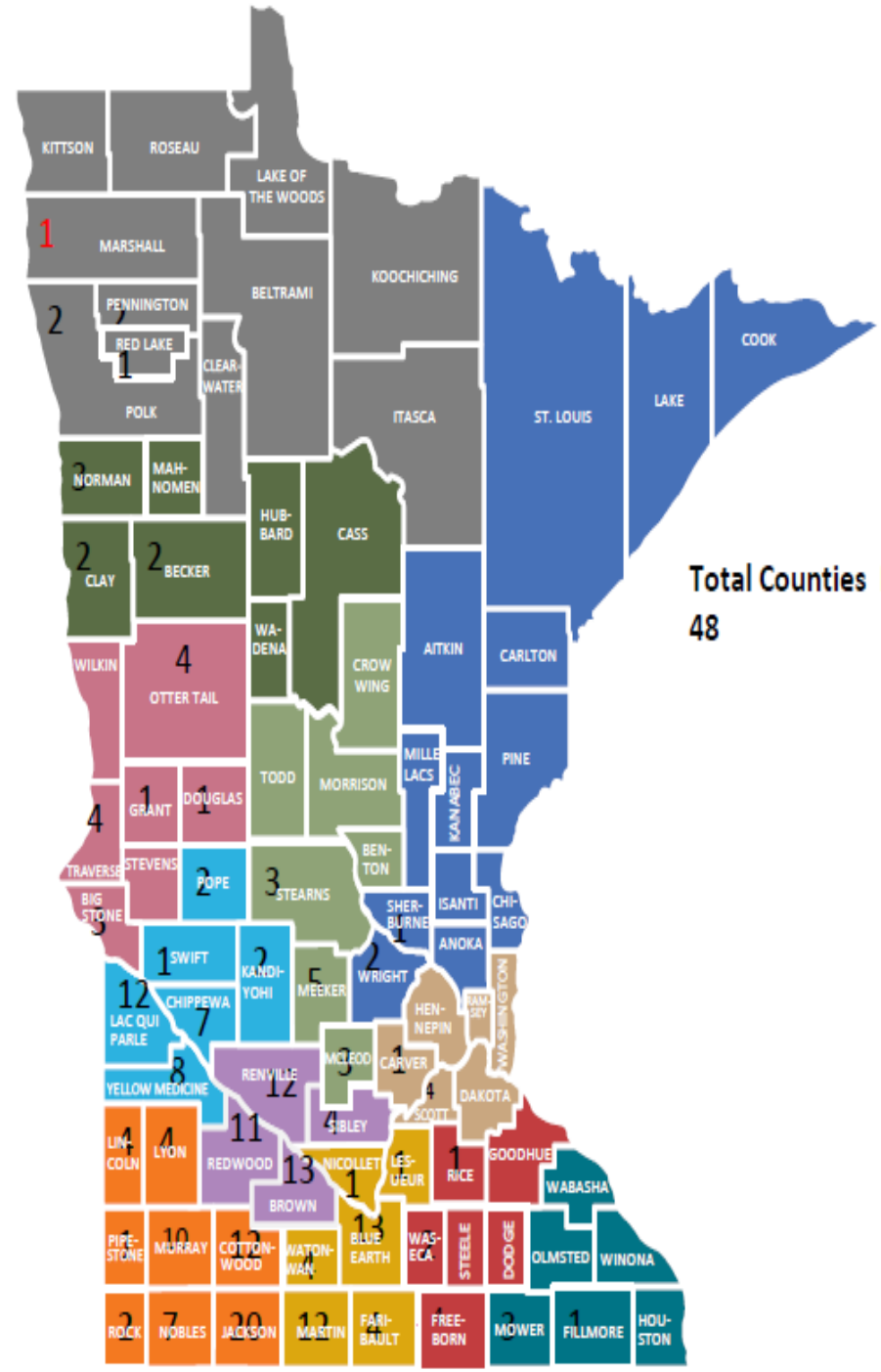
Estimates of Dicamba-injured Soybean Acreage in the U.S. as Reported by State Extension Weed Scientists (*as of October 15, 2017)



*Total: ~3.6 million

2017 Dicamba Survey Repo





7 Reasons WHY dicamba drifted in 2017?

Refer to page 29 in 2018 Weed Guide

Some reasons why off-site movement of dicamba drift occurred in 2017:

1. Soybean can show phytotoxic symptoms from dicamba at rates as low as 0.0004 oz ae/A (0.028 g/ha). Very small amounts of dicamba from contaminated sprayers, particle drift, and volatility can cause injury symptoms on soybean. Extremely high sensitivity of soybean to dicamba influences all other discussion points.
2. 2017 soybean acreage was approximately 8 m acres. The 25-30% adoption of dicamba tolerant (DT) soybean equals over 2 million soybean acres that dicamba was possibly applied.
3. Dicamba rate used in DT soybean is 8 oz ae/A compared to 0.5 to 2 oz ae/A used in wheat and corn. The higher rate of dicamba applied in DT soybean applied during a 3 week period in late June and early July resulted in very high release of dicamba into the environment, which could be a source for particle drift and volatility.
4. Higher temperatures occur in late June and early July. The vapor pressure of dicamba significantly increases as temperature increases.
5. Dicamba is normally applied in May and early June in wheat and corn. Dicamba in DT soybean allows application through R1 stage. Later applications are more prone to dicamba drift because temperatures are higher which allows greater dicamba volatility while soybeans are more advanced in growth to intercept dicamba, express injury symptoms, and possibly reduce yield.
6. Dicamba drift is more likely to cause yield loss the closer to and including reproductive stage. Summer solstice (June 21) is the reproductive trigger in soybean.
7. Precipitation normally decreases after late June. Dicamba is highly water soluble and rain events after application can "wash" the dicamba off plant leaves and on the soil surface into the soil to trap the dicamba and reduce off-target movement.

Why did dicamba drift?

1. Soybean acreage:

    ND Soybean: 600,000 to 8 million acres

2. Dicamba rate:

    0.5-1 oz ai in wheat and corn

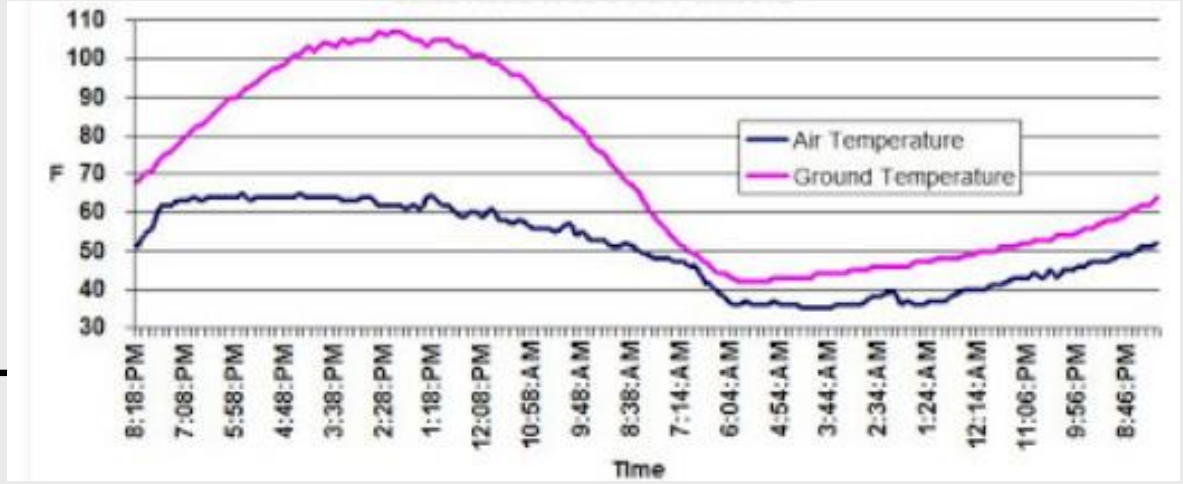
    8 oz ai in DT soybean

        “Atmospheric loading”

2017 = 25% adoption
2018 = 50% adoption – 2x more loading

Why did dicamba drift?

3. Application timing of dicamba on crops
   - EARLY timing on wheat or corn = 2 to 4-leaf
   - LATE timing on DT soybean = PRE through R1
     - June through mid-July
     - **“Atmospheric Loading”**

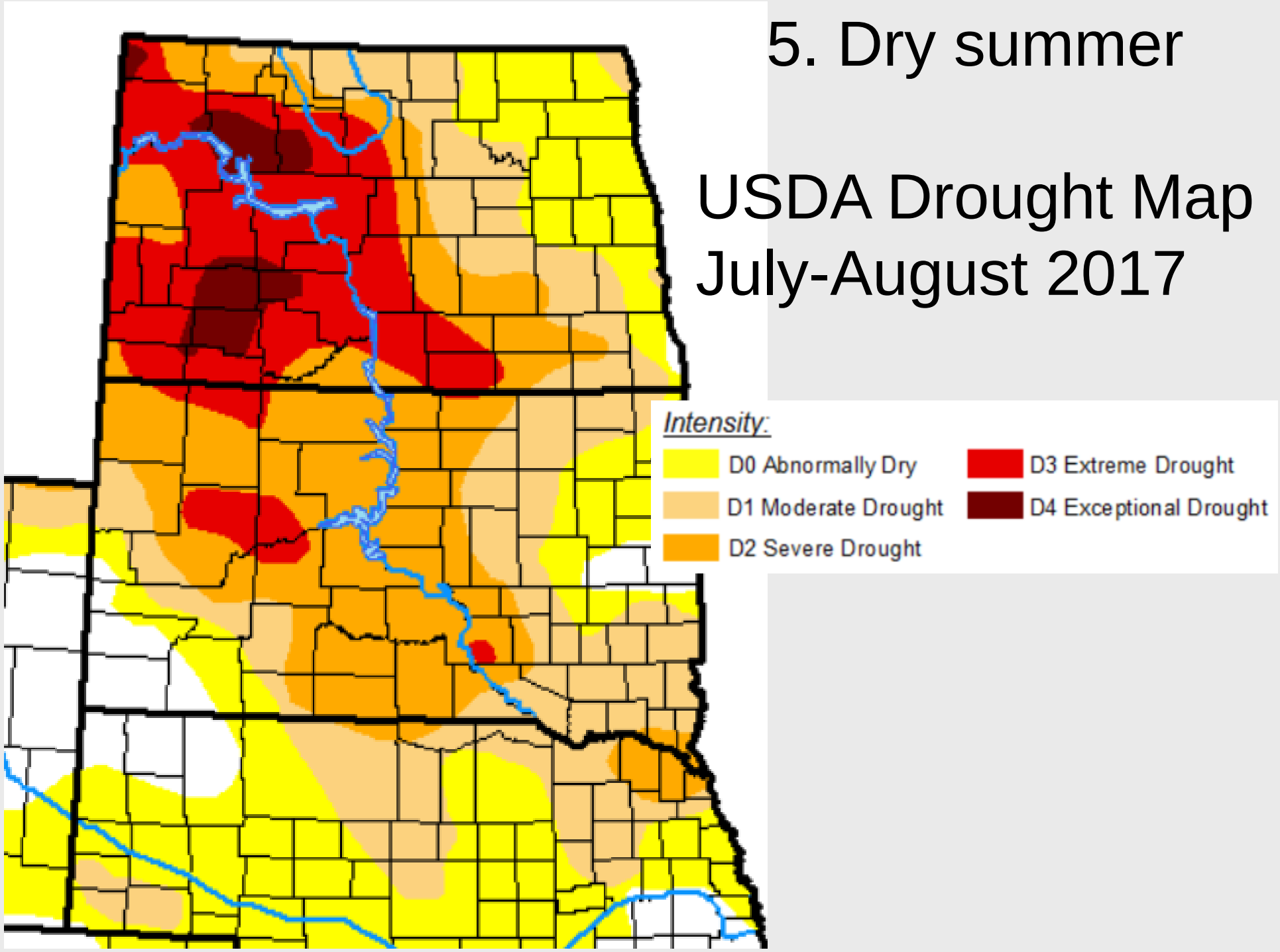


4. Hot temperatures:

	Vapor pressure	
Dicamba salt	0.000002	= ($x10^{-6}$)
Dicamba acid	0.00002	= ($x10^{-5}$) at 75F
Dicamba acid	0.004	= ($x10^{-3}$) at 100F
Water	24	

5. Dry summer

USDA Drought Map
July-August 2017



Why did dicamba drift?

5. Dry summer

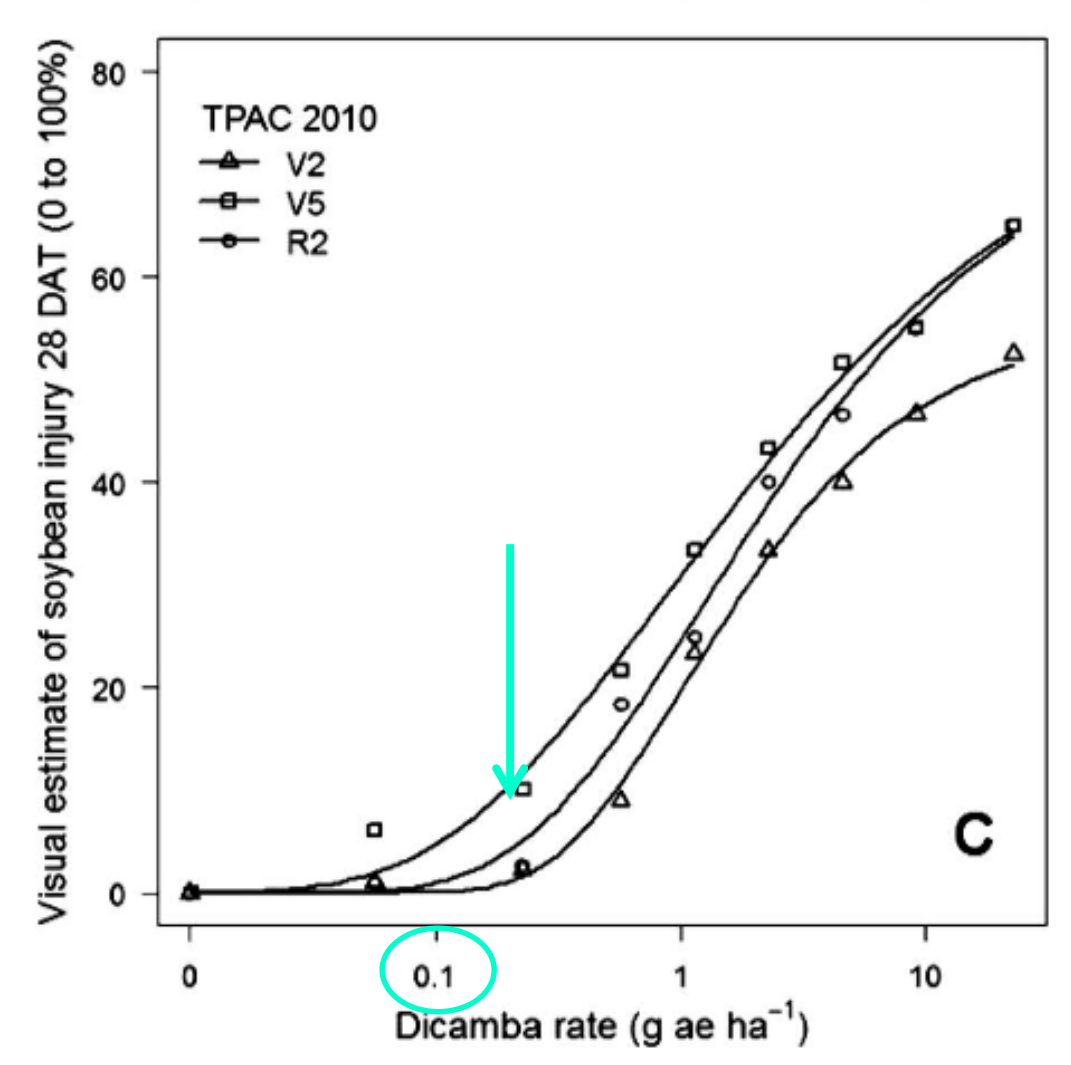
Soybean damage increases in drought stress conditions

Herbicide	H_2O solubility (ppm)
Prowl	0.33
Atrazine	35
Callisto	160
Harness/Surpass	282
Metolachlor	530
Glyphosate	10,500
Dicamba	250,000
Paraquat	620,000

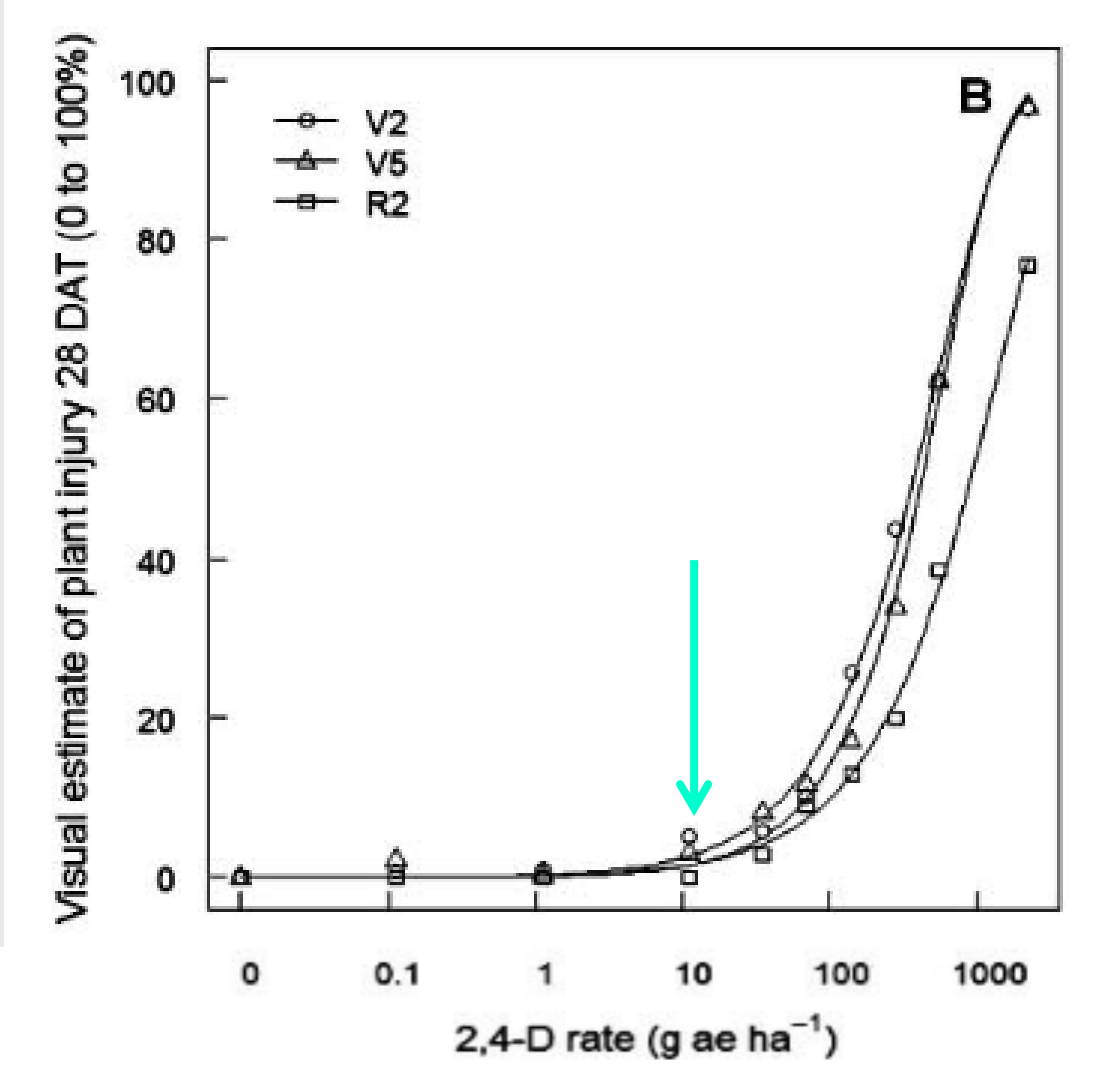
Why did dicamba drift?

6. The most underestimated factor…….

Soybean injury to dicamba and 2,4-D



Robinson et. al. 2013 Weed Sci 61:526-536



Robinson et. al. 2013 Weed Sci 61:68-76

Soybean is 100X more tolerant to 2,4-D

Platitude: A word or phrase used too often to be meaningful

Dicamba drift on sugarbeet and sunflower

Dr Brian Jenks, NDSU

Soybean response from dicamba and 2,4-D

Bradley, U of MO

Table 2.2. Soybean injury combined across 2011 and 2012.

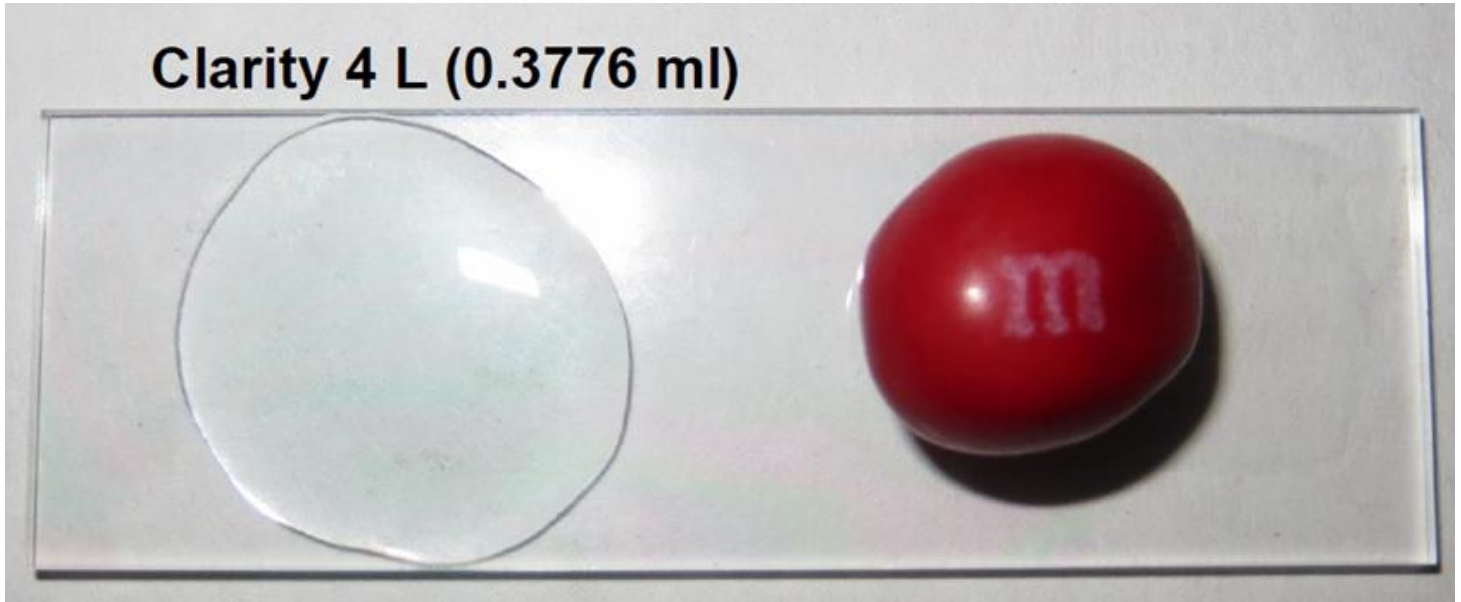
			Visible injury			
			2 WAT		4 WAT	
Herbicide	Rate		V3	R2	V3	R2
	oz ae/A		---------- % ----------			
2,4-D	0.0004		2	0	1	0
	0.004		1	0	1	1
	0.04		1	0	0	0
	0.4		3	0	0	0
Dicamba	0.0004	= 0.029 g/ha	21	15	10	17
	0.004	= 0.29 g/ha	28	17	9	16
	0.04		32	14	9	15
	0.4		44	18	12	14
LSD			18	9	5	3

Remember 0.1 g/ha

Soybean susceptibility to dicamba

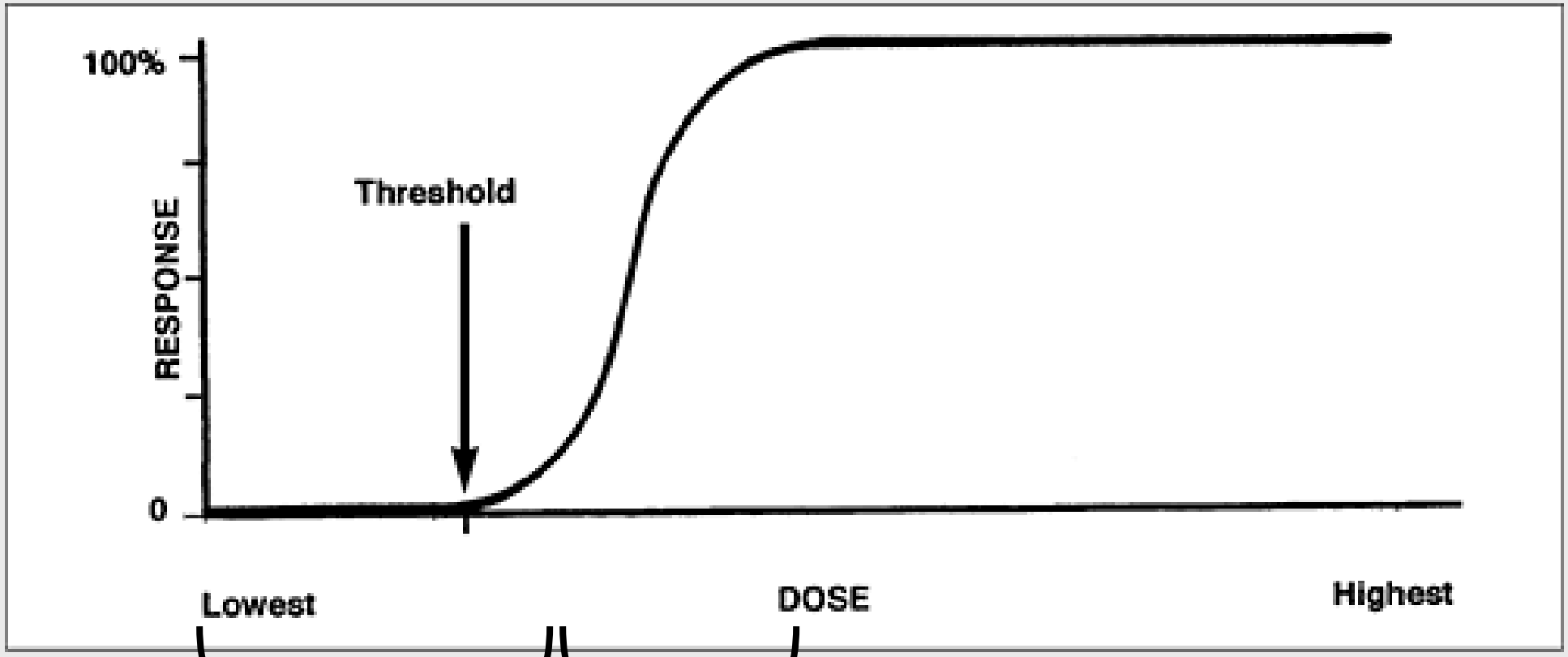
Lowest rate response:	Labeled rate	% of rate
Dicamba on soybean	0.5 lb ae/A	0.005%
Glyphosate on corn	0.75 lb ae/A	1%
Glyphosate on soybean	0.75 lb ae/A	10%

Soybean is 2,000X more susceptible to dicamba than glyphosate



Soybean flat dose response to dicamba

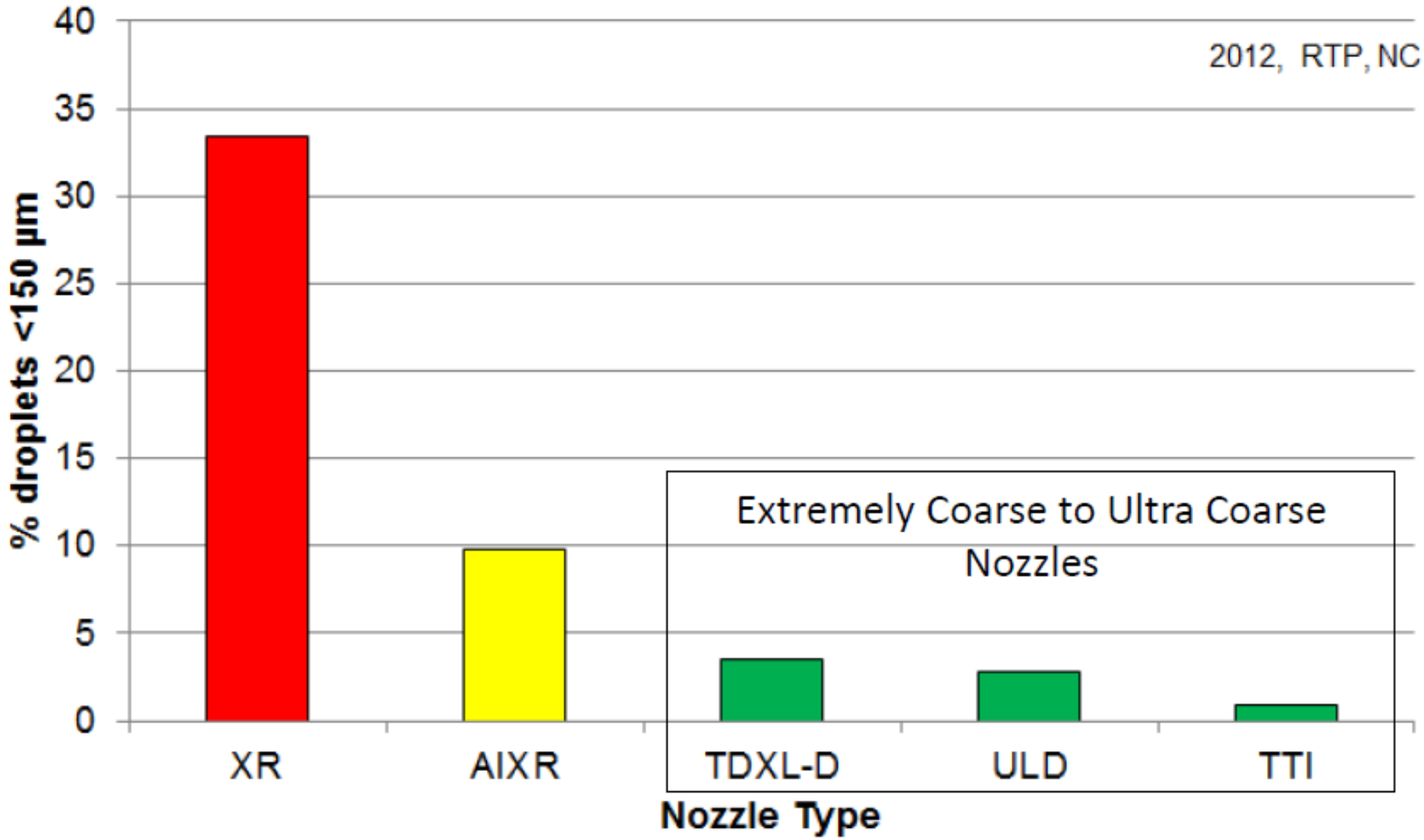
Soybean show leaf cupping at a wide dose rate



What does this mean regarding dicamba? Zero tolerance for soybean!

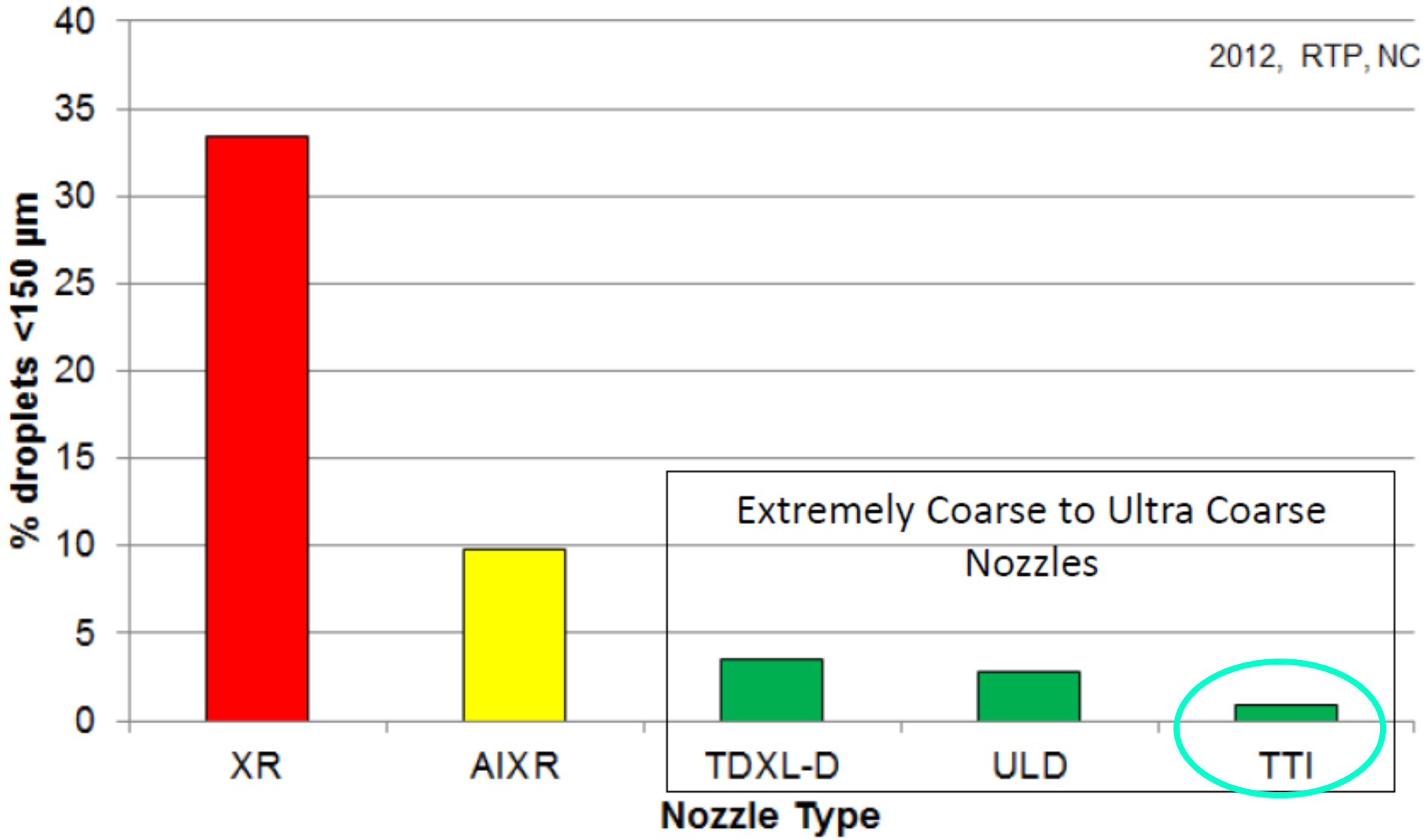
- Particle drift
- Contaminated sprayers
- Temperature inversions
- Run-off water
- Volatilization (vapor drift)

What is the point of this data?



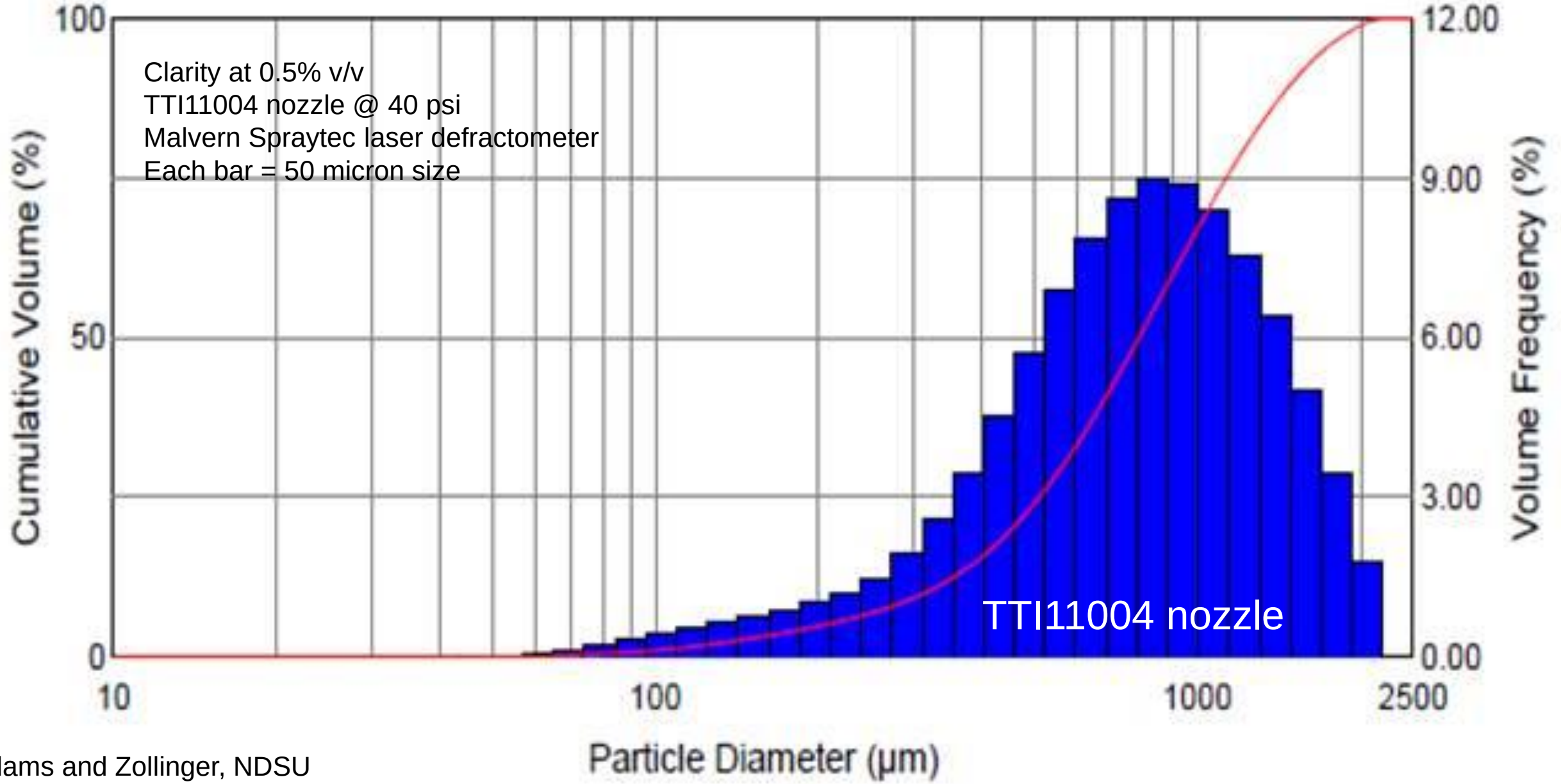
BASF data using Engenia Herbicide (0.5 lb ae/A) + Roundup WeatherMax (1 lb ae/A) and 04 orifice size at 40 PSI.

What is the point of this data?



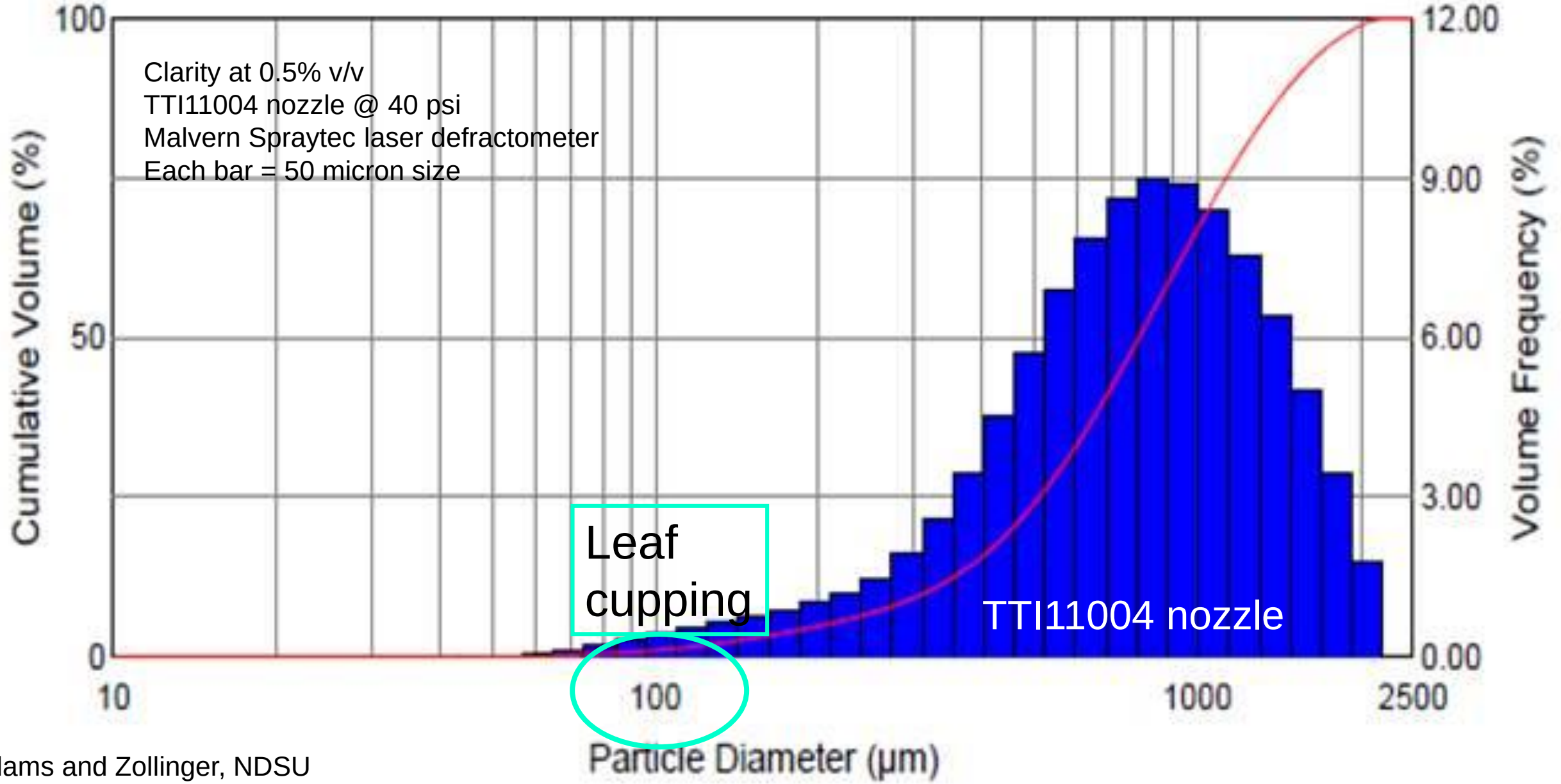
BASF data using Engenia Herbicide (0.5 lb ae/A) + Roundup WeatherMax (1 lb ae/A) and 04 orifice size at 40 PSI.

What is the point of this data?



Adams and Zollinger, NDSU

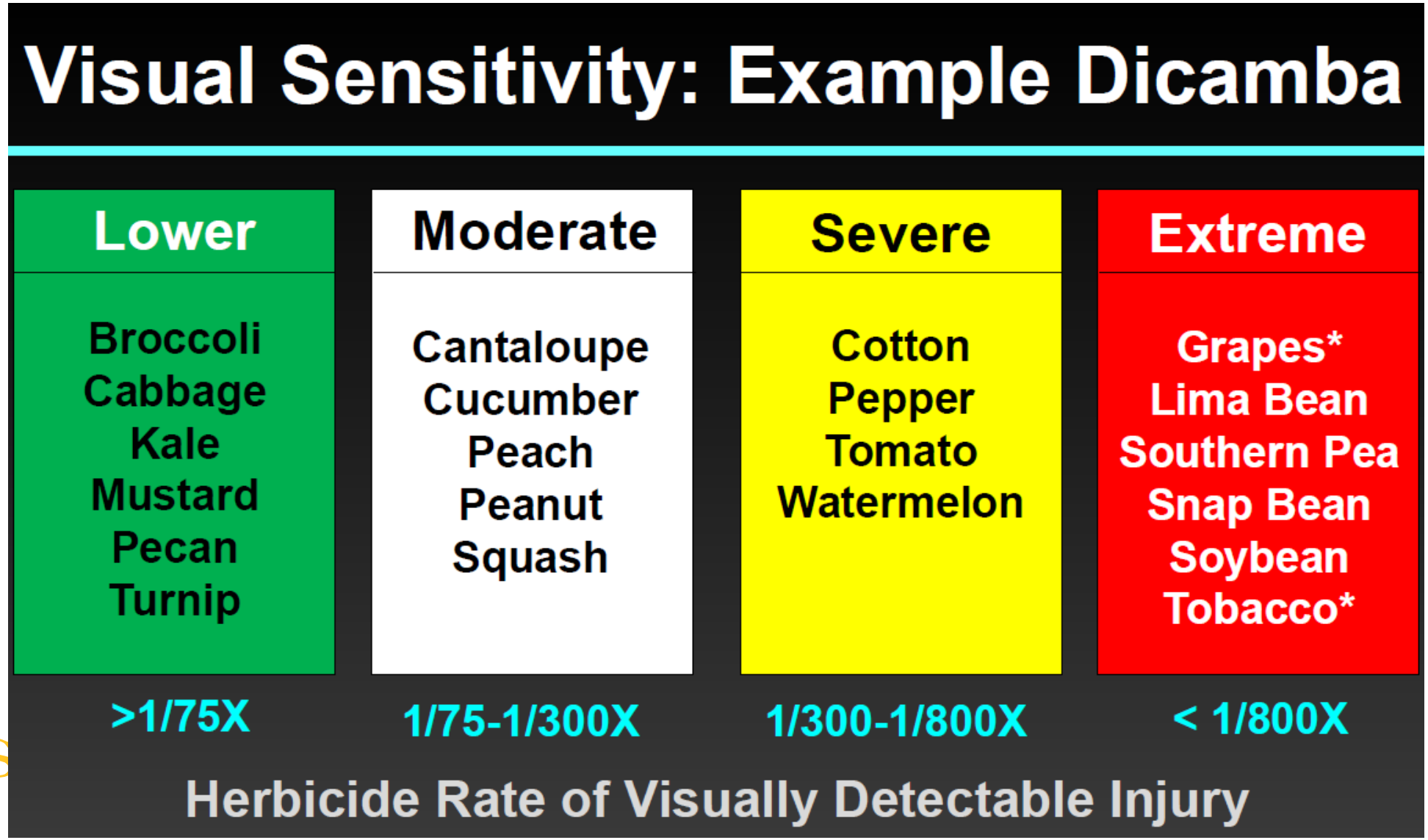
What is the point of this data?



Adams and Zollinger, NDSU

Crop susceptibility to dicamba

Southern states



NDS

Crop susceptibility to dicamba

NDSU

None/Low	Moderate/Severe	Severe
• Wheat	• Alfalfa	• Chickpea
• Barley	• Potato	• Dry bean
• Corn	• Safflower	• Field pea
• Canola	• Sunflower	• Lentil
• Flax	• Tomato	• Soybean
		• Sugarbeet

NDSU NORTH DAKOTA STATE UNIVERSITY

*Classification is visually detectable injury; North Dakota crops

Crop susceptibility to dicamba

NDSU

None/Low

- Wheat
- Barley
- Corn
- Canola
- Flax

Moderate

- Alfalfa
- Potato
- Safflower
- Sunflower
- Tomato

Severe

- Chickpea
- Dry bean
- Field pea
- Lentil
- Sugarbeet

Extreme/ Canary in the coal mine

- Soybean

NDSU NORTH DAKOTA STATE UNIVERSITY

*Classification is visually detectable injury; North Dakota crops

1 last point about DRIFT!

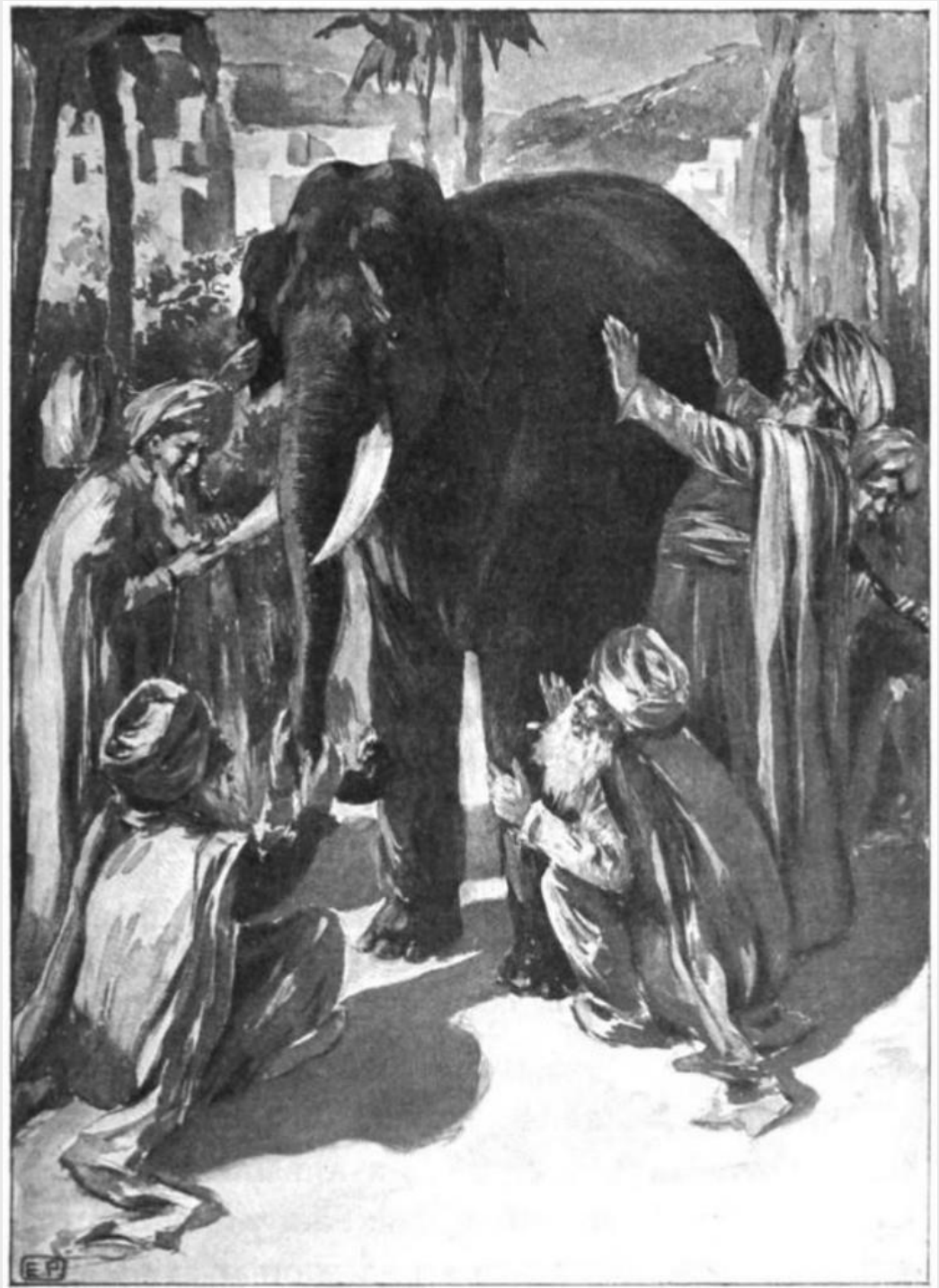
Just cause you didn't see injury…..
doesn't mean drift does not happen.

Example: dicamba
~30% (adoption) of 100 m soybean acres x 0.5 lb ai =
15 m lbs of dicamba applied in U.S.

Example: glyphosate
~200 m acres RR corn and soy x 0.75 lb ae =
150 m lbs glyphosate applied in U.S.

15 m lbs dicamba vs. 150 m lbs glyphosate

(Not include: preplant, higher rates, multiple applications, and other RR crops)



Parable of the 5 blind men and elephant

Trunk = snake

Leg = pillar/tree-trunk

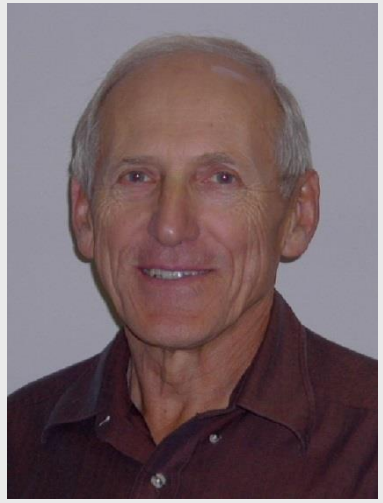
Side = wall

Tail = rope

Tusk = spear.

Dr. Don Penner
Michigan State University

“Most aspects of science and life can be explained through chemistry”



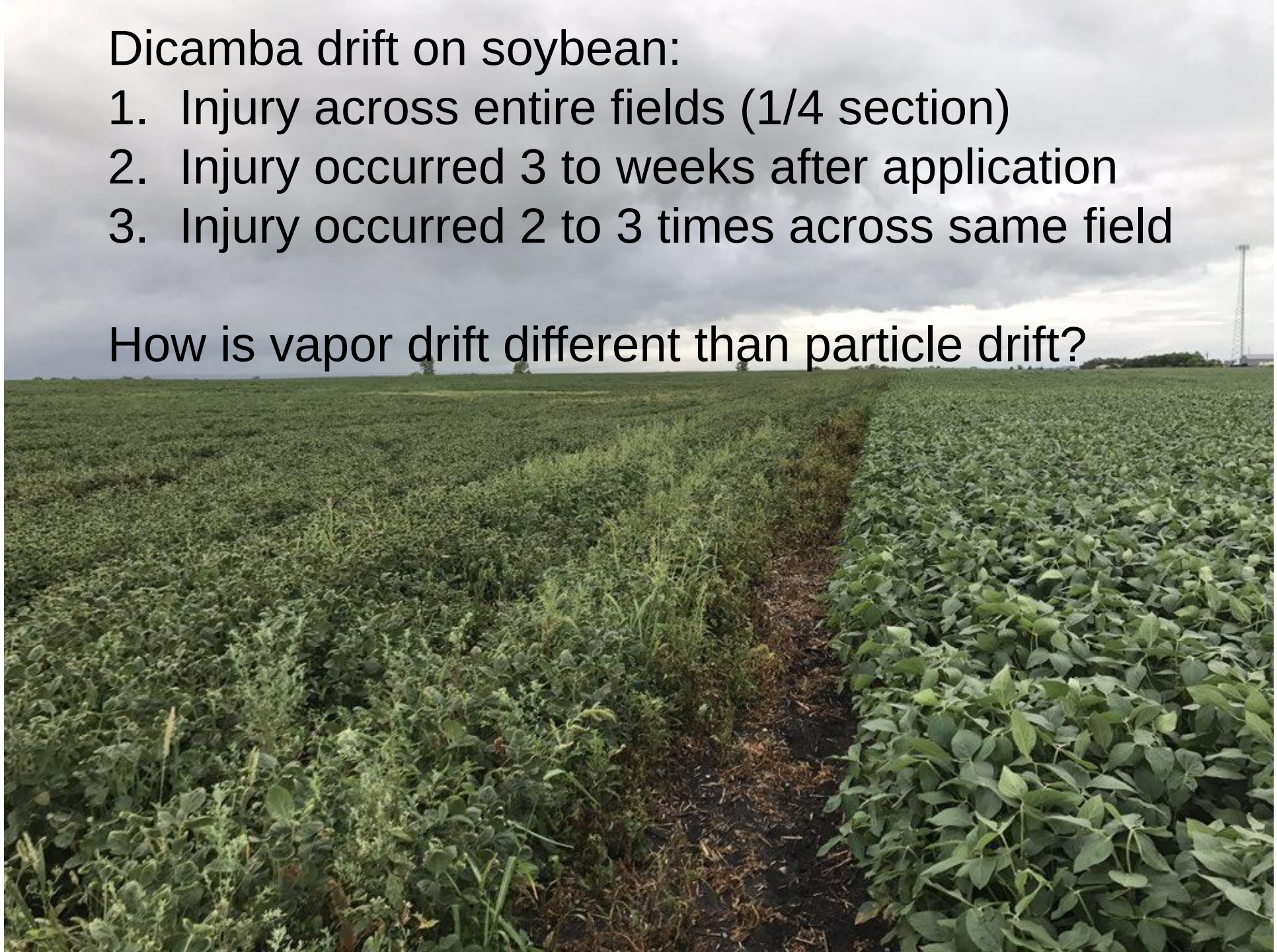
Dr. John Nalewaja
Michigan State University

“Tell science as a story”

Dicamba drift on soybean:

1. Injury across entire fields (1/4 section)
2. Injury occurred 3 to weeks after application
3. Injury occurred 2 to 3 times across same field

How is vapor drift different than particle drift?



Application Education Summary

Summary of Application Requirements

The XtendiMax™ herbicide with VaporGrip™ Technology application requirements are intended to help maximize weed control with on-target applications and minimize the potential of off-target movement.

THIS SUMMARY IS NOT A SUBSTITUTE FOR READING AND FOLLOWING ALL PRODUCT LABELING.

HERBICIDE
Low volatility XtendiMax™ herbicide with VaporGrip™ Technology

AMMONIUM SULFATE
Ammonium sulfate and ammonium-based additives are prohibited in applications that include XtendiMax™ with VaporGrip™ Technology

APPLICATION RATES
Apply 22 fluid ounces per acre for any single, in-crop application

SPRAY VOLUME
Apply in a minimum of 10 gallons of spray solution per acre

NOZZLES
To minimize drift, use nozzles approved on the herbicide product label and operating pressures to minimize driftable fines

SPRAY BOOM HEIGHT
Do not exceed a boom height of 24 inches above target pest or crop canopy. Excessive boom height will increase the potential for drift.

WEED HEIGHT
Spray weeds that are less than 4 inches tall

WIND SPEED
Apply when wind speed is between 3 and 10 mph

DOWNWIND BUFFER
Maintain the required label buffer to protect sensitive areas

SUSCEPTIBLE CROPS
Do not apply when wind is blowing toward adjacent susceptible crops

GROUND SPEED
Do not exceed 15 mph ground speed

TRIPLE RINSE
Use triple-rinse cleanout procedure

Some things a grower can control.
Once the droplet leaves the nozzle then no control

Very important question

1. What happens to bapma salt and Vapor Grip after droplet is released from nozzle?

1. Deposit formation after water evap.
2. Pool of H^+ on leaf surface and soil
3. Effect dew and small rain events

Very important question

As water evaporates in droplet:

- protons (H+) accumulate
- pH decreases = lower acidity
- acidity increase protonation (pKa)
- protonated dicamba = dicamba acid
- dicamba acid = volatile form

How does that affect the Vapor Grip?

Monsanto/BASF Academic Summit – Fall 2017

1. Under what conditions do dicamba anion and acid form?
2. Does the salt dissociate and bind again in an equilibrium?
3. Do other cations compete with binding sites of dicamba?
4. How does high surface temperatures influence dissociation?
5. What is the fate of dicamba under drought?
6. Does dew solubilize dicamba deposits and cause volatility?
7. How does dicamba cause symptoms 30 days after exposure?
8. How does dicamba injury soy multiple times on same field?
9. Explain effect of other ammonia sources?
10. Why was physical properties of dicamba not discussed?

Anonymous letter to AR Plant Board – Sept 2017

Dear Arkansas State Plant Board:

As a career agricultural formulation chemist, I have viewed the development of genetically modified crops to allow post emergent application of dicamba with skepticism regarding any formulation technology that could effectively keep dicamba from volatilizing after application.

The Facts about Dicamba

Acidity and Dissociation Constant
Dicamba is considered a strong acid having an acid dissociation constant (pKa) of 1.87. The pKa value indicates a compound's ability to dissociate from its salt when dissolved in water. The pKa value is also an indication of a compound's acidic strength.

Simply put, the lower the value the stronger the acid. When compared to 2,4-D, which has a pKa value of 2.8, dicamba is nearly 10 times more acidic than 2,4-D and is more

Due to the sensitive nature and the emotion this issue has generated, I am submitting these comments anonymously. Hope the plant board understands.

ability to associate with any stronger basic ion, a cation, that might also be present in

Questions:

1. How much dicamba is FREE?
2. What is the fate of dicamba?
3. In what form is free dicamba?

Herbicide Absorption

- How much glyphosate is absorption?

Herbicide Absorption

- How much glyphosate is absorption? = ~33%
- How much dicamba is absorbed?

Dicamba Absorption Data

- Wheat = 80% (Cessna Weed Sci 41:682-686)
- Leafy spurge = 60% (Lym et al. Weed Tech 19:329-341)
- Kochia = 35% (Cranston et al. Weed Sci 49:164-170)
- Apple leaf cuticles - No adjuvant = 15%

  6 adjuvants at 2 rates = 25 to 30%

  (Adams and Zollinger, 2016 – absorption studies conducted in Germany in collaboration with Clariant)

Dicamba Absorption Data

- Wheat = 80% (Cessna Weed Sci 41:682-686)
- Leafy spurge = 60% (Lym et al. Weed Tech 19:329-341)
- Kochia = 35% (Cranston et al. Weed Sci 49:164-170)
- Apple leaf cuticles - No adjuvant = 15%

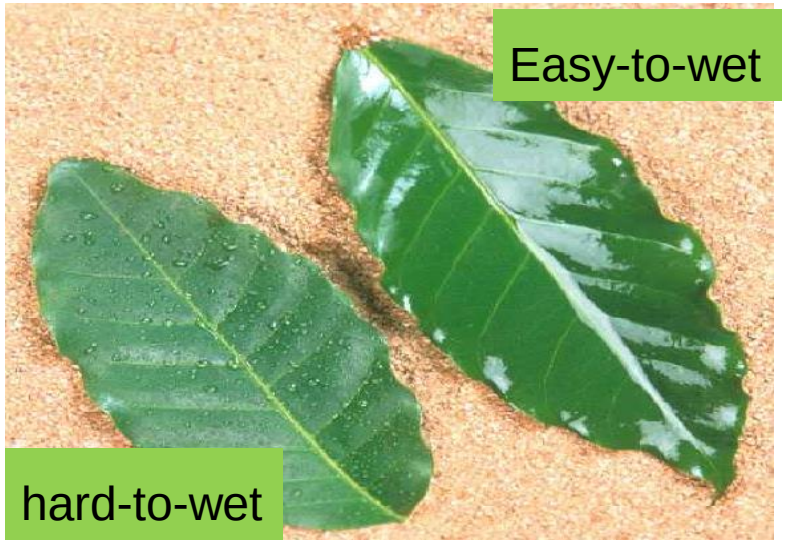
  6 adjuvants at 2 rates = 25 to 30%

  (Adams and Zollinger, 2016 – absorption studies conducted in Germany in collaboration with Clariant)
- Dicamba absorption in waterhemp = ?
- Dicamba absorption in soybean = ?

Dicamba Absorption Data

- Soybean = (-) surfactant = 38%

  (+) surfactant = ~75%



Dicamba Absorption Data

Soybean exude 66% of absorbed dicamba through roots!!!

* Implication on soybean toxicity
* Influence tissue residue tests

(Peterson, Haderlie, Hoefer, McAllister, Weed Sci 33:717-720)

Dicamba Absorption Data

- Average absorption

Soybean =	38-75%
Leafy spurge =	60%
Kochia =	35%
Apple cuticles -	15% -30%
	~50% absorbed
	~50 unabsorbed!

0.25 lb of dicamba on leaf + soil surface

7.5 m lbs of dicamba FREE!

Questions:

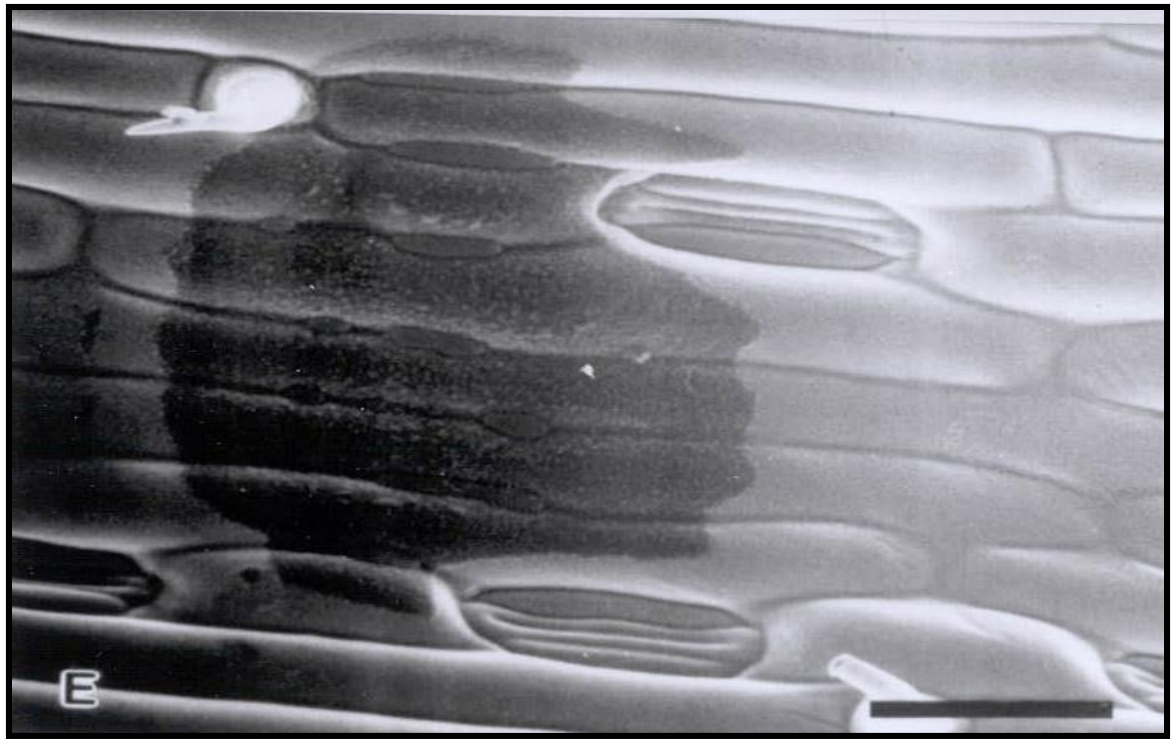
1. How much dicamba is FREE?
2. What is the fate of dicamba?
3. In what form is free dicamba?

What does dicamba look like after water is gone?

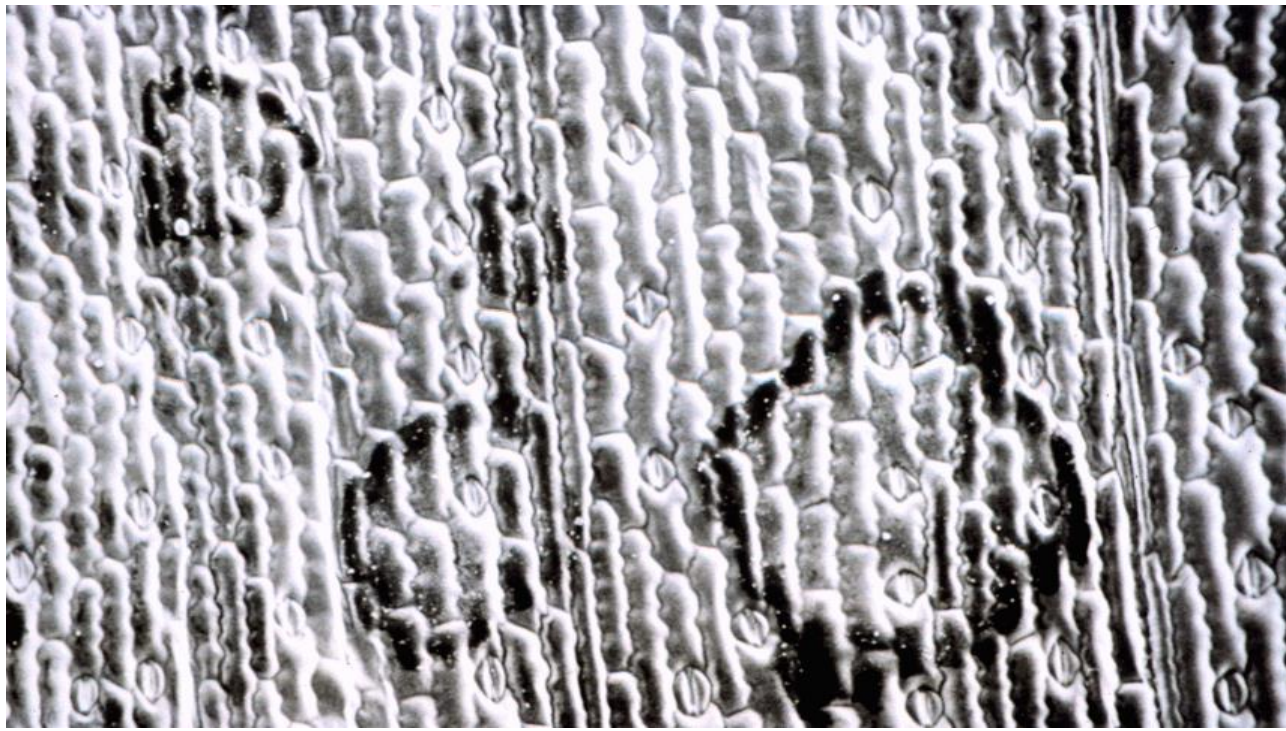
Herbicide deposit on leaf surface

What does dicamba look like after water is gone?

Herbicide deposit on leaf surface

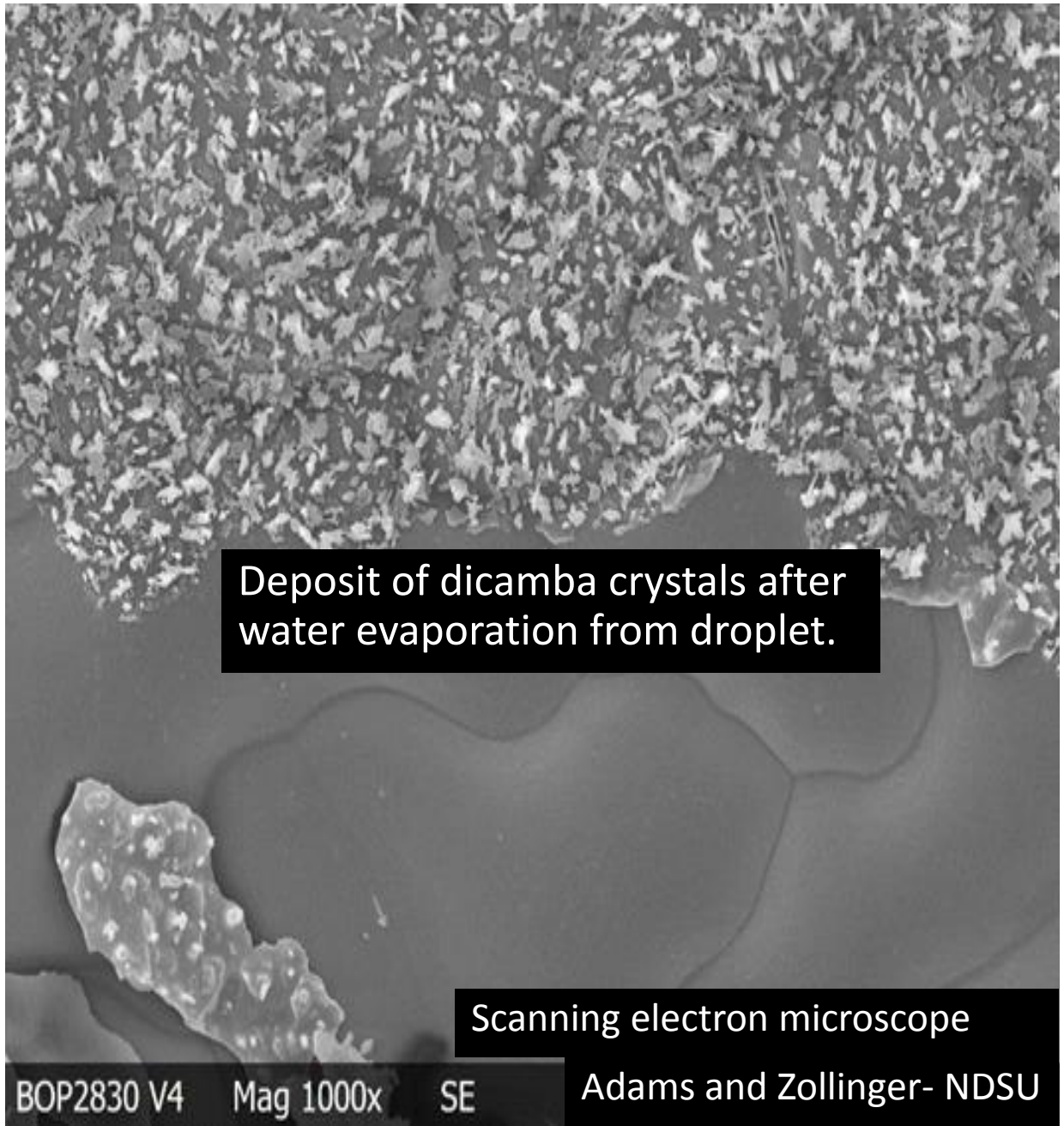


Glyphosate deposit



2,4-D ester

Dicamba crystallization on leaf surface

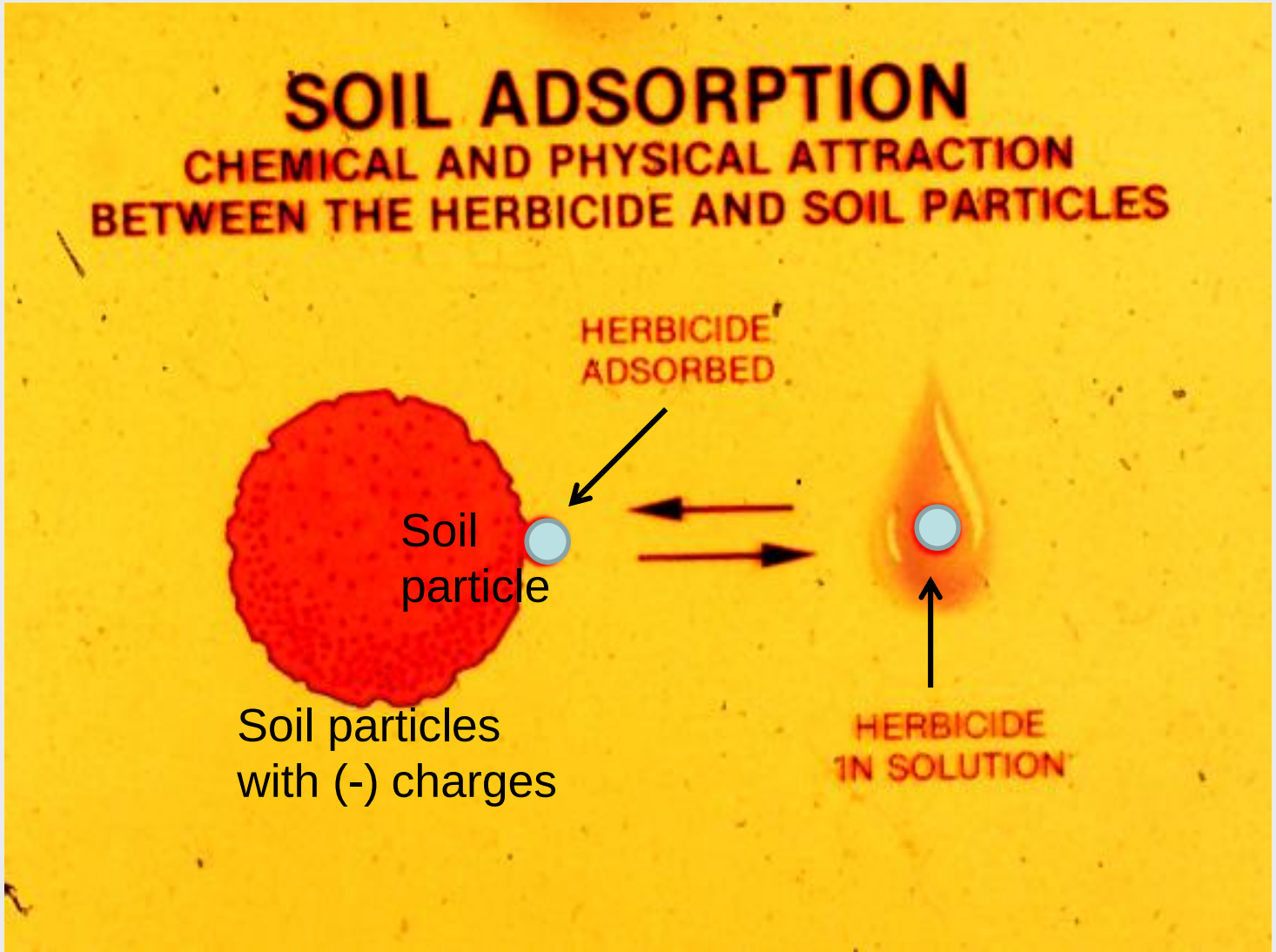


What is the fate of dicamba?

- Dissociated or acid?
- Wetting from dew?
- Wetting from light rain?
- Re-crystallized?

Universal principle of chemistry =

ADSORPTION



How much dicamba is adsorbed to soil?

Dicamba Absorption Data

Soil adsorption coefficient (Kd) = amount of chemical adsorbed to soil per amount of water.

- **Kd** = Concentration of chemical in soil/water

- **Koc** = (Kd * 100)/ % Organic carbon

  Concentration of chemical in OM/water

What are the values of dicamba?

Kd range = 0 to 600

Koc range = 0 to 10,000

Dicamba Physical Properties

	Koc (mg/L)	Kd (mg/L)
Acetamides	100-600	1.1-2.7
DNAs	3000-9000	-
EPTC	136-264	0.77-3
Sulfentrazone	43	1
Glyphosate	24,000	324-600
2,4-D	20-136	0.17-1.27
Clopyralid	~60	-
Fluroxypyr	40-71	0.78-1.34
Picloram	17-160	0.5
Dicamba	?	?

Dicamba Physical Properties

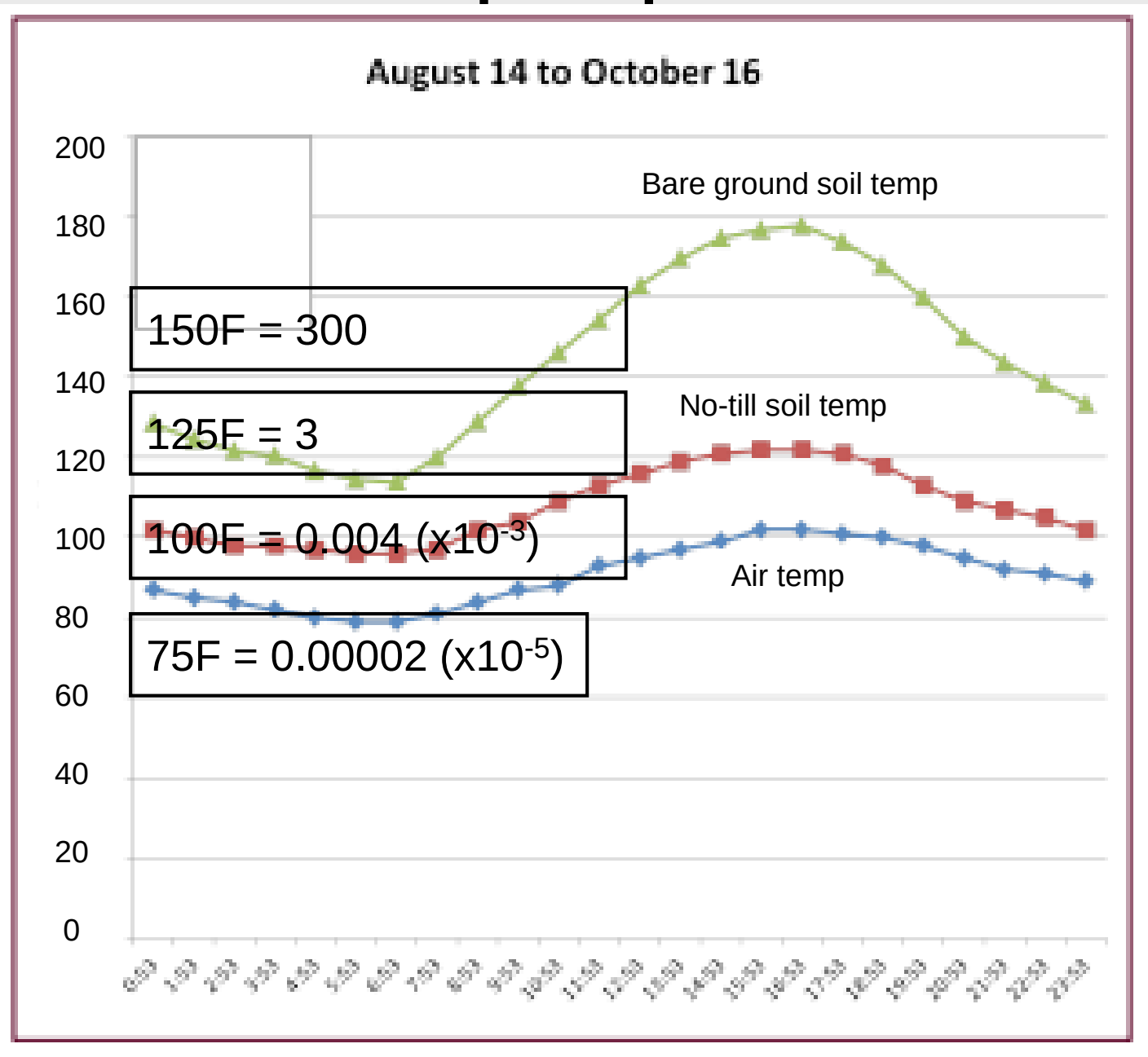
	Koc (mg/L)	Kd (mg/L)
Acetamides	100-600	1.1-2.7
DNAs	3000-9000	-
EPTC	136-264	0.77-3
Sulfentrazone	43	1
Glyphosate	24,000	324-600
2,4-D	20-136	0.17-1.27
Clopyralid	~60	-
Fluroxypyr	40-71	0.78-1.34
Picloram	17-160	0.5
Dicamba	2	0.05-0.13 – Not adsorbed!

What main environmental factor affects volatile herbicides on soil?

Herbicide vapor pressure

	mm Hg (mercury)		
Liberty	0.000000000009	($x10^{-12}$)	Non-volatile
Paraquat	0.000000001	($x10^{-9}$)	
Glyphosate	0.00000002	($x10^{-8}$)	
Treflan	0.0002	($x10^{-4}$)	Volatile
2,4-D salt	"Not volatile"	1.4×10^{-7}	
ester	0.0004	($x10^{-4}$)	
acid	0.4 (insoluble in water)		
Dicamba salt	0.000002	($x10^{-6}$)	
acid	0.00002	($x10^{-5}$) at 75F	
acid	0.004	($x10^{-3}$) at 100F	
Eptam	0.03	($x10^{-2}$)	
Water	24		

Temperature and vapor pressure of dicamba

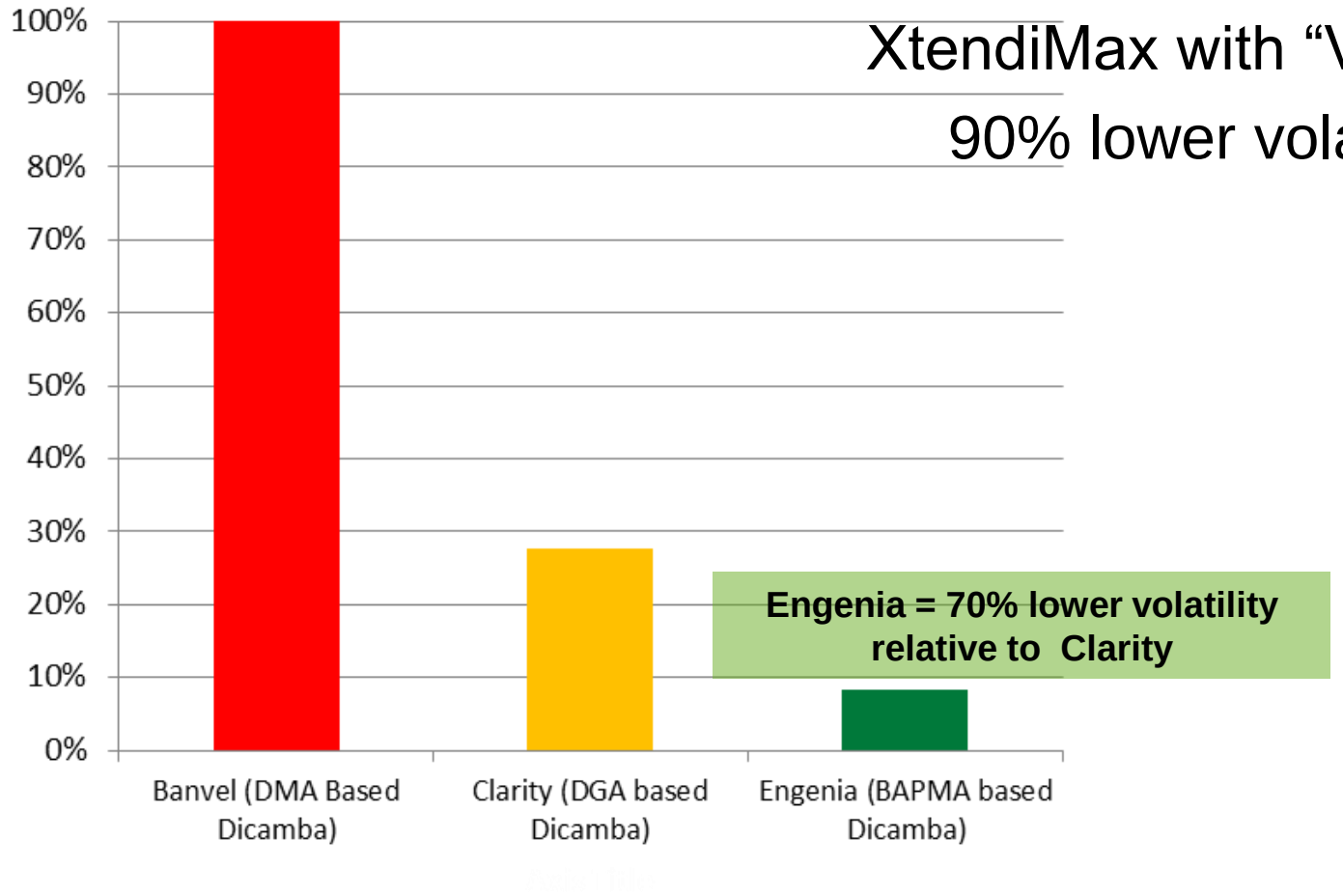


Questions:

1. How much dicamba is FREE?
2. What is the fate of dicamba?
3. In what form is free dicamba?

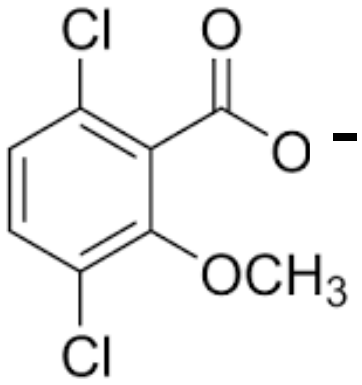
Why Engenia™ Herbicide?
A stepwise improvement on reduced volatility

Relative Volatility vs. Form of Dicamba[1]



XtendiMax with “Vapor Grip” =
90% lower volatility than Clarity

[1]Volatility ratings using five different measurement techniques: Field testing, Humidome, TGA, C^{14}, Incubator

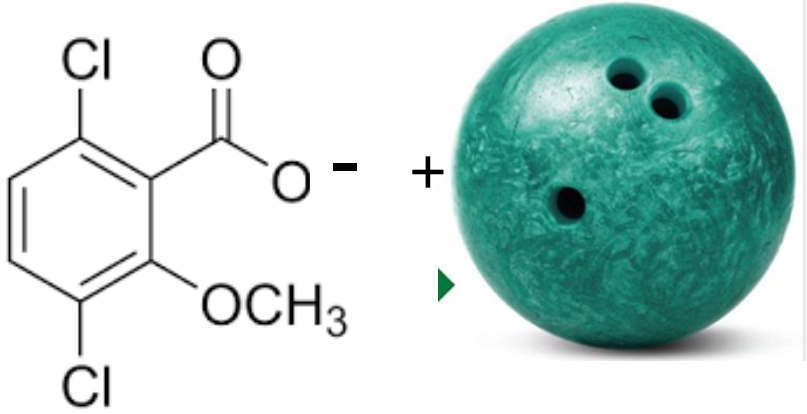


+ NH_3-CH_2-CH_2-O-CH_2-CH_2-OH + Vapor Grip??

Molecular weight = 105

Dicamba-dga = XtendiMax/FeXapan

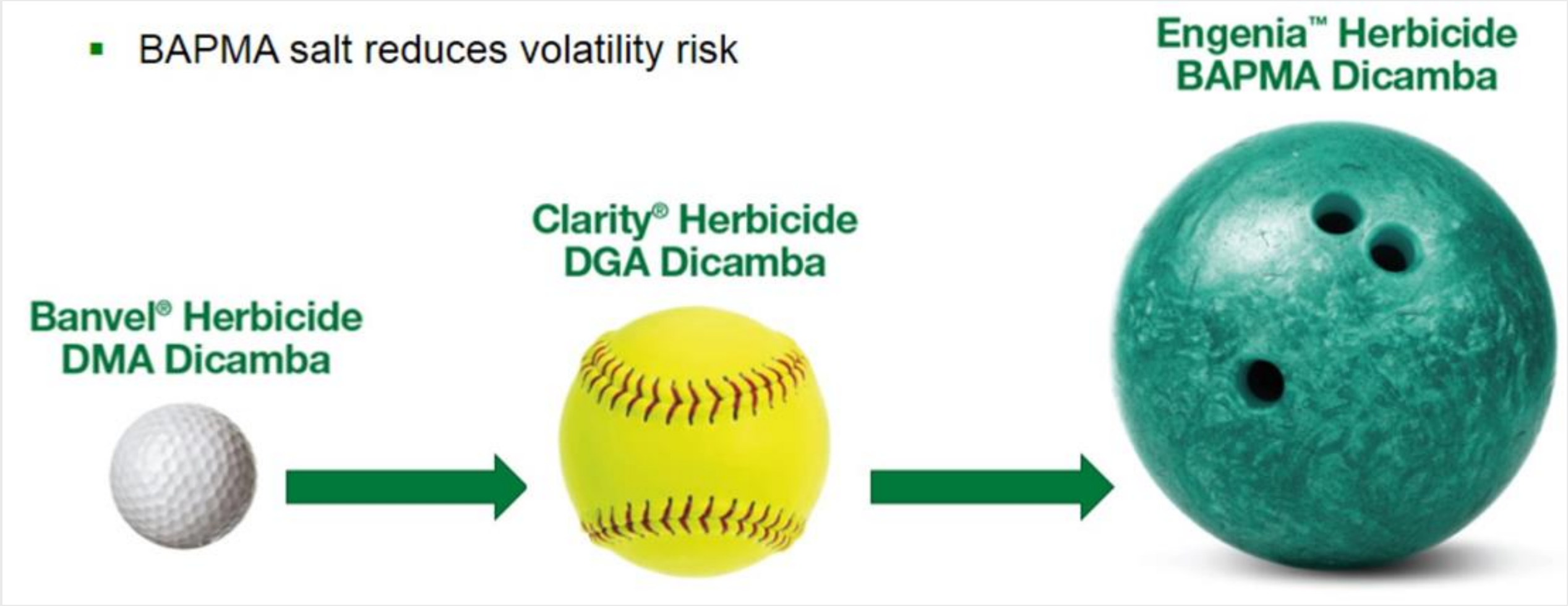
Molecular weight = 145



Dicamba-BAPMA = Engenia

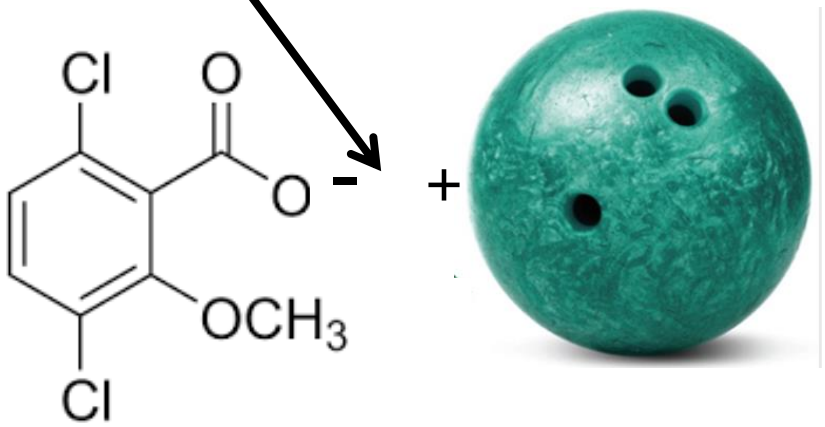
Engenia – Molecular Weight Theory

What is wrong with this picture?



Dissociation – fundamental principle of chemistry

Salt compounds dissociate in water!

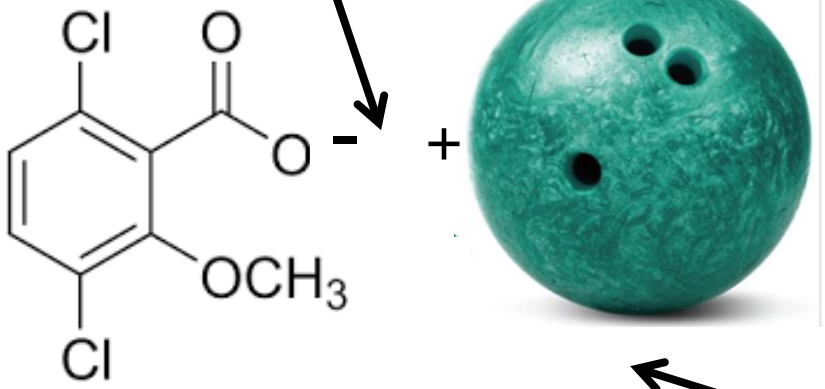


Dicamba-bapma or
-dga or
-dma

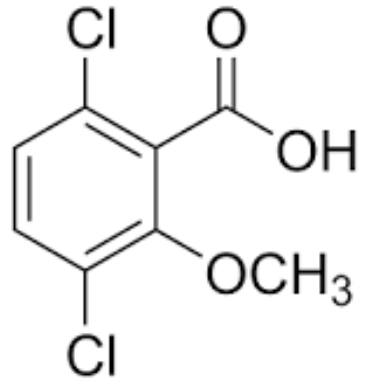
Glyphosate-K, IPA
2,4-D-dma
Basagran-Na
Express-methyl
Flexstar-Na
Liberty-NH_4
Raptor-NH_4
Status-Na
Stinger-mea
Dicamba-Na, dma, dga, bapma

Dicamba-acid = Volatile

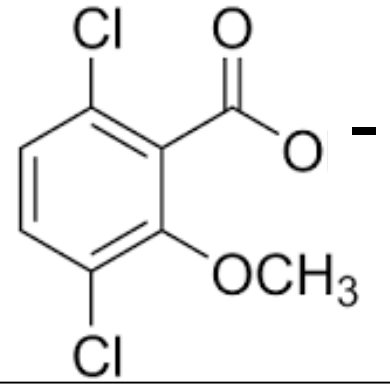
Dissociation



+



+H+



Dicamba-bapma or
-dga or
-dma

Dicamba-anion =
Not volatile

Anonymous letter to Arkansas Plant Board

Susie Nichols
Arkansas State Plant Board
P.O Box 1069
Little Rock, AR 72203

Dear Arkansas State Plant Board:

As a career agricultural formulation chemist, I have viewed the development of genetically modified crops to allow post emergent application of dicamba with skepticism regarding any formulation technology that could effectively keep dicamba from volatilizing after application.

The Facts about Dicamba

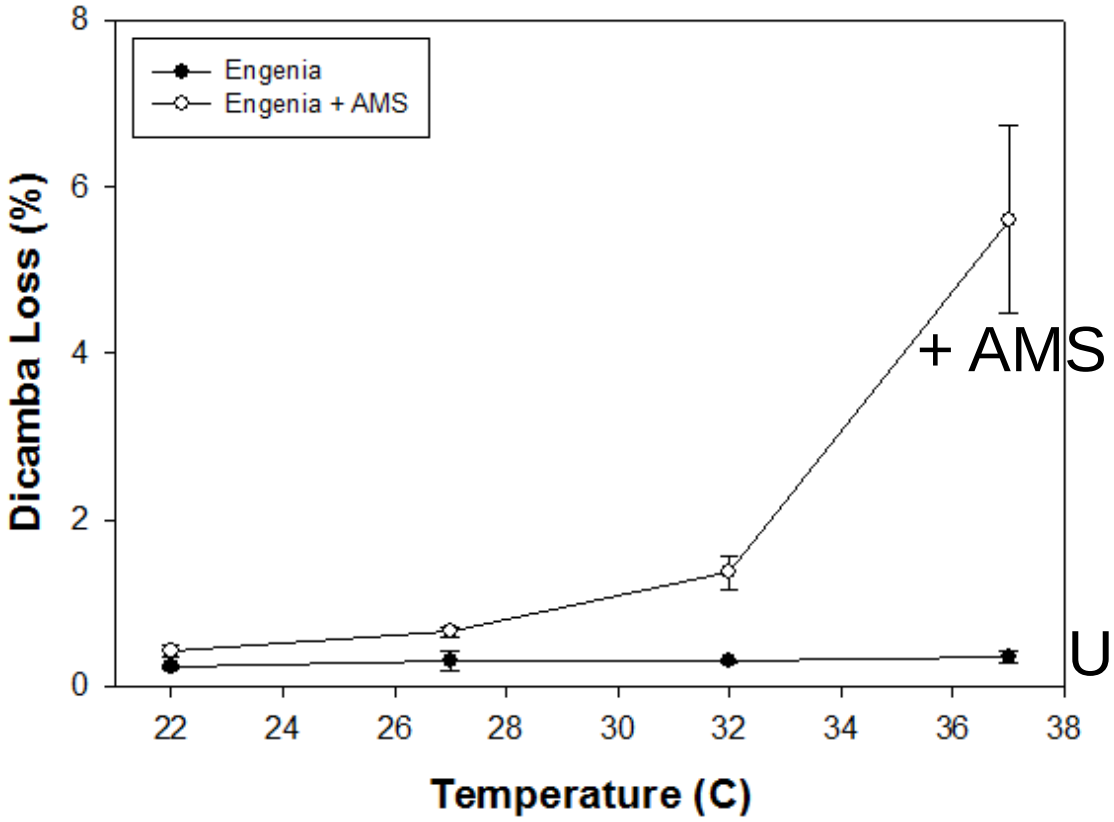
Acidity and Dissociation Constant

Dicamba is considered a strong acid having an acid dissociation constant (pKa) of 1.87. The pKa value indicates a compound's ability to dissociate from its salt when dissolved in water. The pKa value is also an indication of a compound's acidic strength.

Simply put, the lower the value the stronger the acid. When compared to 2,4-D, which has a pKa value of 2.8, dicamba is nearly 10 times more acidic than 2,4-D and is more acidic than glyphosate, which has 3 pKa values of 2.6, 5.6, and 10.3 due to glyphosate being a polyprotic acid.

Engenia™ Herbicide

Why will AMS be restricted?



+ AMS

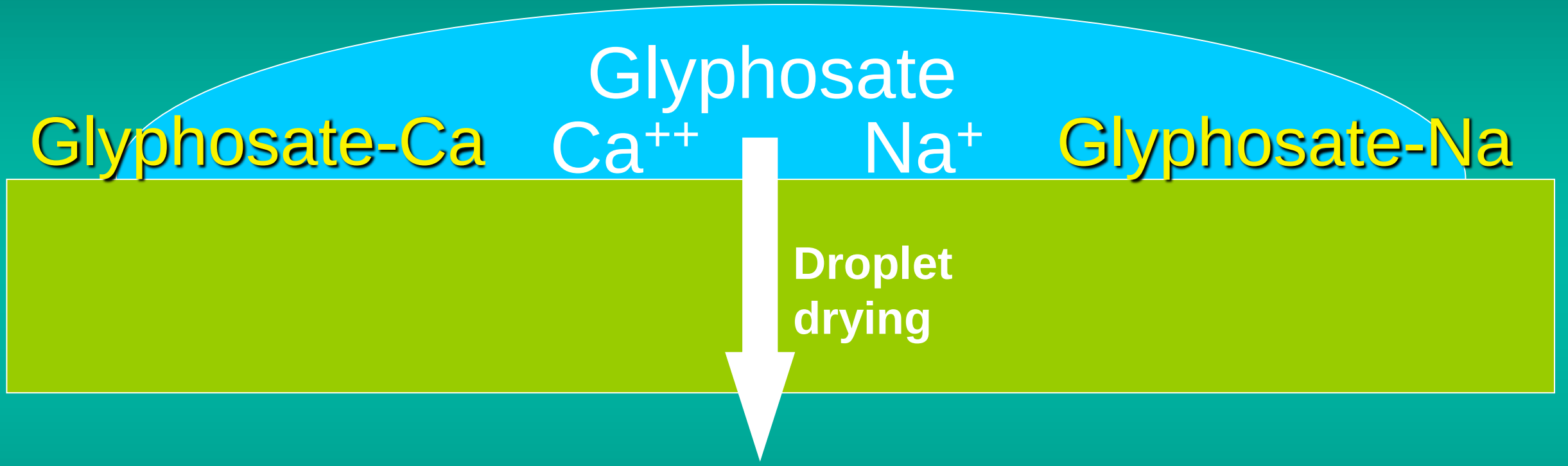
Un-dissociated Engenia

Application rates:
Engenia – 560 g/ha
AMS – 0.5% w/v

Test Conditions:

Time: 1 day (24 hr), Air flow: 0.5 l/min
using 2.5 l tank, Relative Humidity: 5%, Substrate: glass

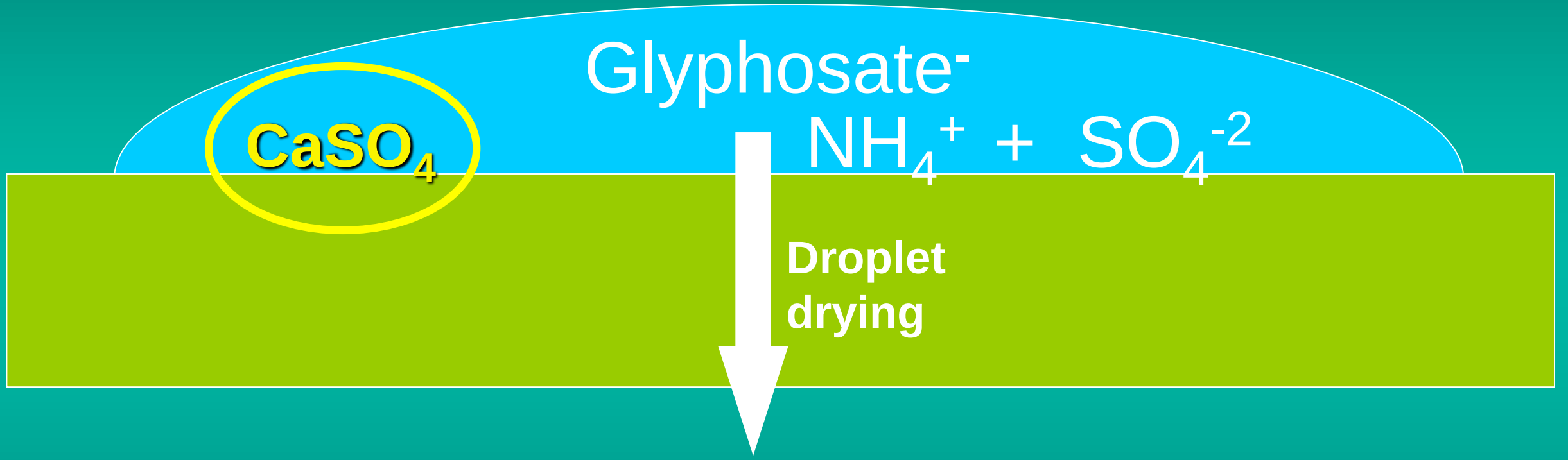
Spray Water Quality



very little absorption

Does the same thing happpen to dicamba?

Water Conditioner



Glyphosate-NH_4

Vapor Grip – The Great Inigma

XtendiMax with “Vapor Grip”?

90% lower volatility than Clarity

What is Vapor Grip?

Monsanto Academic Summit – Sept 27, 2018

“Polymerized carboxylic acids”???

What is the mode of action of Vapor Grip?

“Do not add acidifiers”

“Do not add AMS”

Dicamba Physical Properties

pKa = the pH value at which equal concentrations of the acid and conjugate base forms of a substance.

- At pKa:

  -1/2 molecules lose their protons = anion

  -1/2 molecules retain protons = neutral

Dicamba pKa =

50% molecules = anion = No volatility

50% molecules = acid = High volaitility

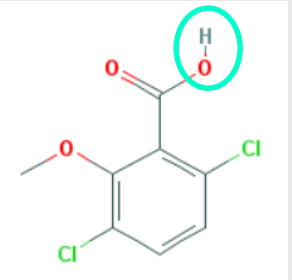
Dicamba Physical Properties

	pKa
Paraquat	--
Glyphosate	2.6, 5.6, 10.3
2,4-D	2.73
Aminopyralid	2.56 - dissociated and (-) charge
Clopyralid	2.3 - dissociated and (-) charge
Fluroxypyr	3
Picloram	2.3
Dicamba	1.87

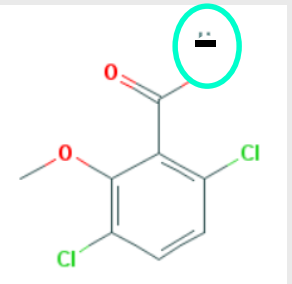
Dicamba Physical Properties

4. XtendiMax with “Vapor Grip”?

pH < 5.5 = dicamba-dga $\xrightarrow{H^+}$ dicamba-acid



pH > 5.5 = dicamba-dga $\longrightarrow$ dicamba-anion



Dicamba pKa = ~2 dissociation constant

Low H+

pH 6 = 99.99 : 0.01 ratio of anionic : acid molecules

pH 5 = 99.9 : 0.1 “

pH 4 = 99:1 “

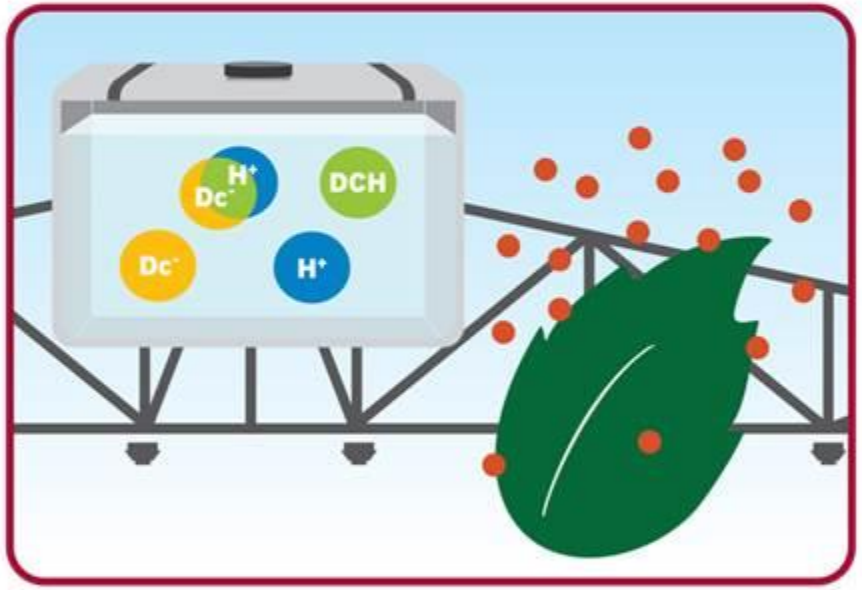
pH 3 = 90:10 “

High H+ pH 2 = 50:50 “

VaporGrip™ Technology

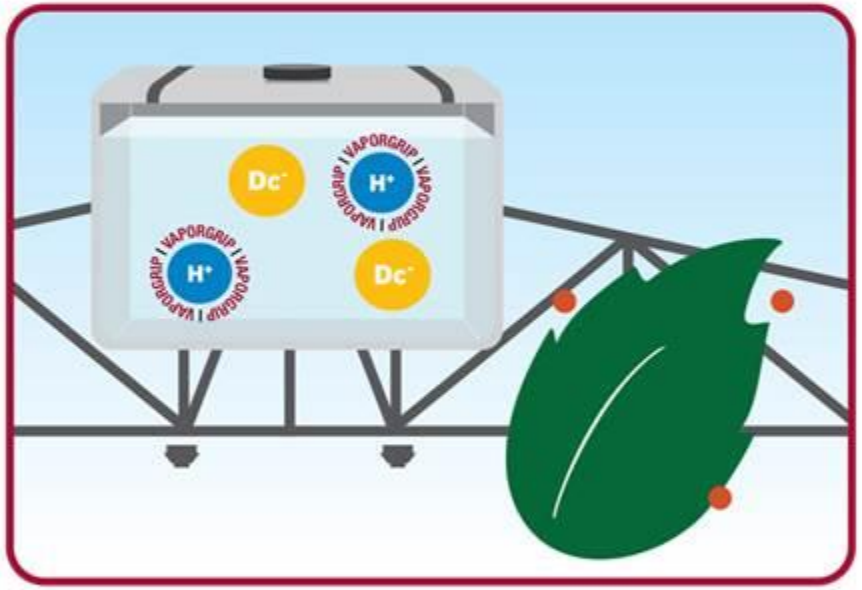
DMA Dicamba

(Not Approved for use in the Roundup Ready® Xtend Crop System)



In the tank there is the potential for dicamba acid (DCH) to form in solution and create off-target movement of dicamba through volatility after spraying

Low-Volatility Dicamba with VaporGrip™ Technology

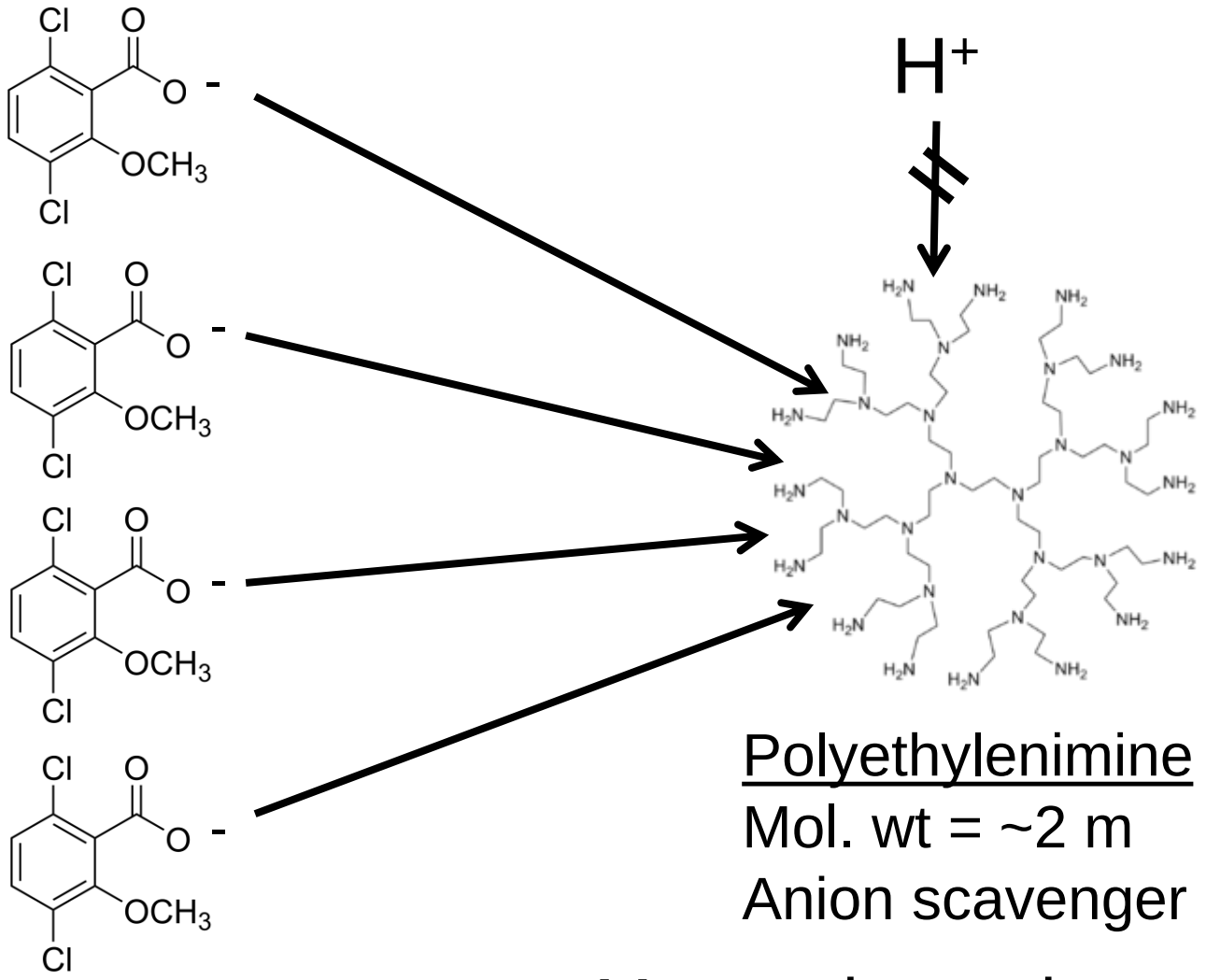


In the tank, VaporGrip™ Technology **prevents the formation of dicamba acid (DCH)** in solution, **minimizing potential off-target movement of dicamba** through volatility after spraying

THIS PRESENTATION ON APPLICATION REQUIREMENTS IS NOT A SUBSTITUTE FOR THE PRODUCT LABELING ALWAYS READ AND FOLLOW ALL PRODUCT LABELING.

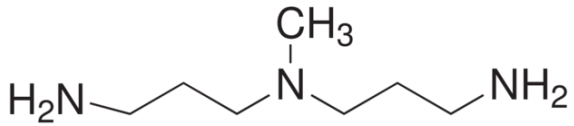
V1 – 11/2016

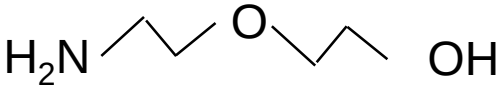
What is Vapor Grip?

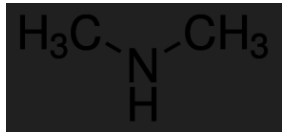


Dicamba-anion

Polyethylenimine
Mol. wt = ~2 m
Anion scavenger

BAPMA: 

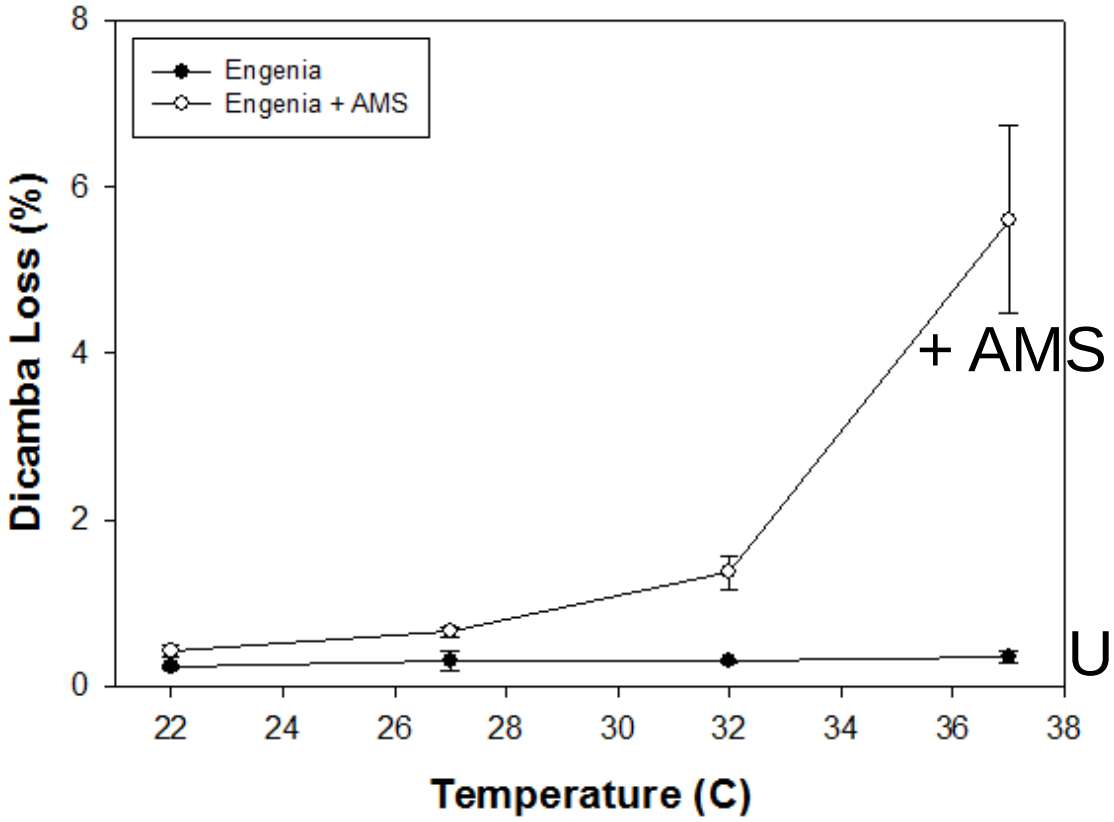
DGA: 

DMA: 

Many other anions can compete with binding sites.

Engenia™ Herbicide

Why will AMS be restricted?



+ AMS

Un-dissociated Engenia

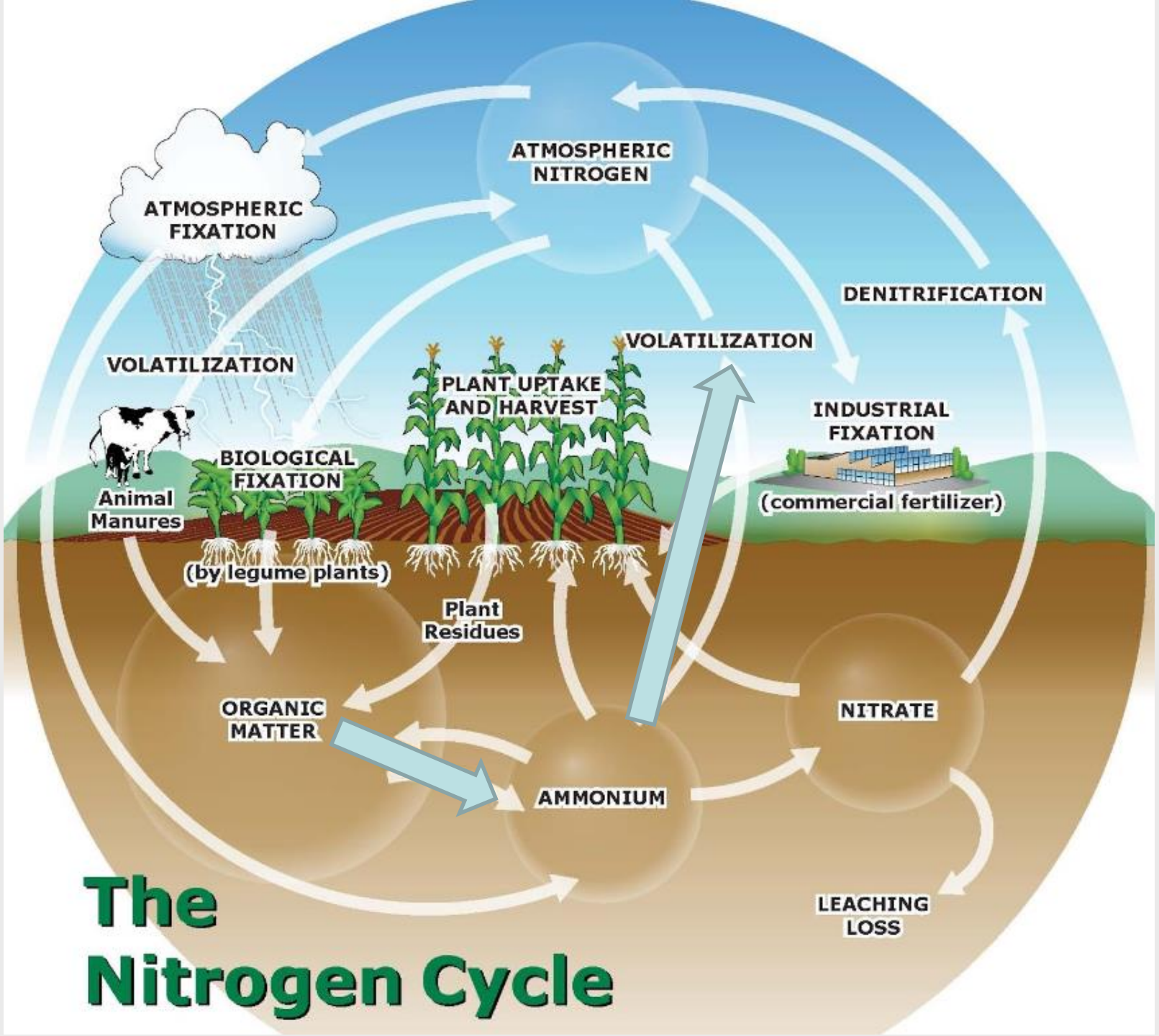
Mechanism of action:

1. NH3 volatilizes
2. Leaves behind H+
3. H+ lowers pH
4. > dicamba-acid

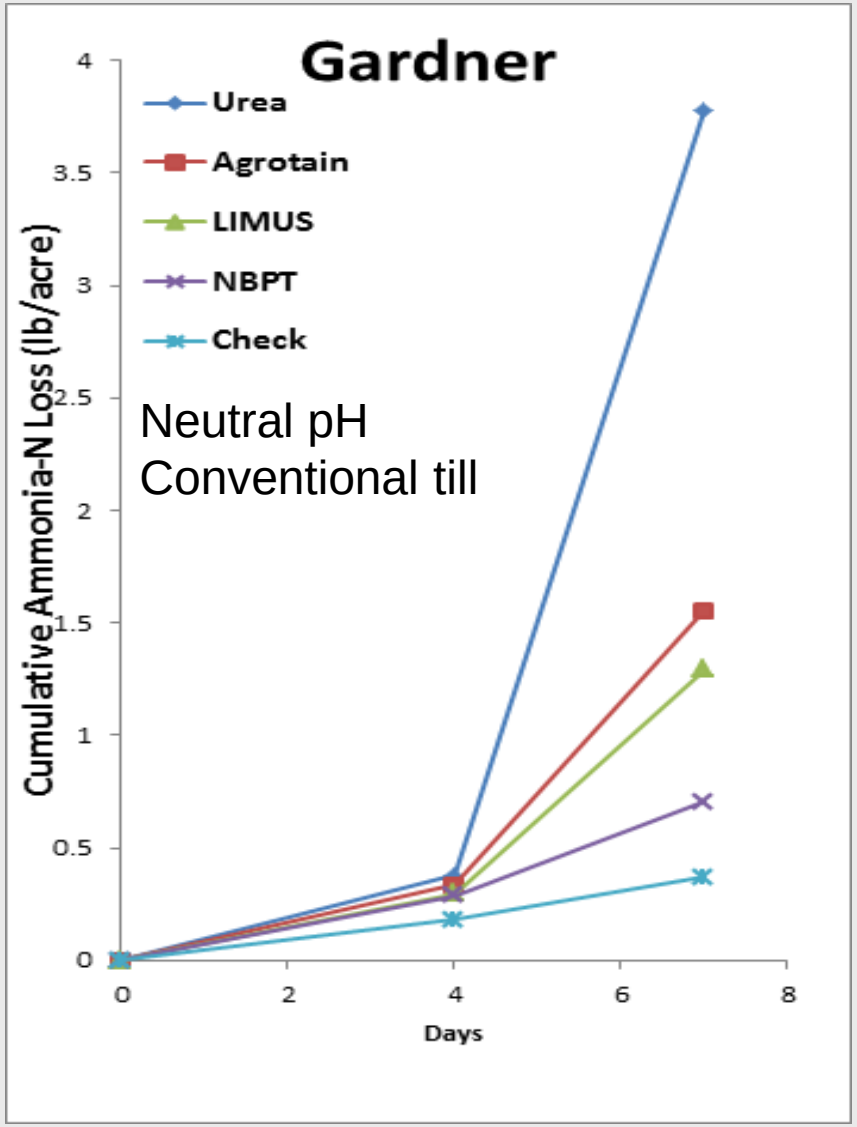
Application rates:
Engenia – 560 g/ha
AMS – 0.5% w/v

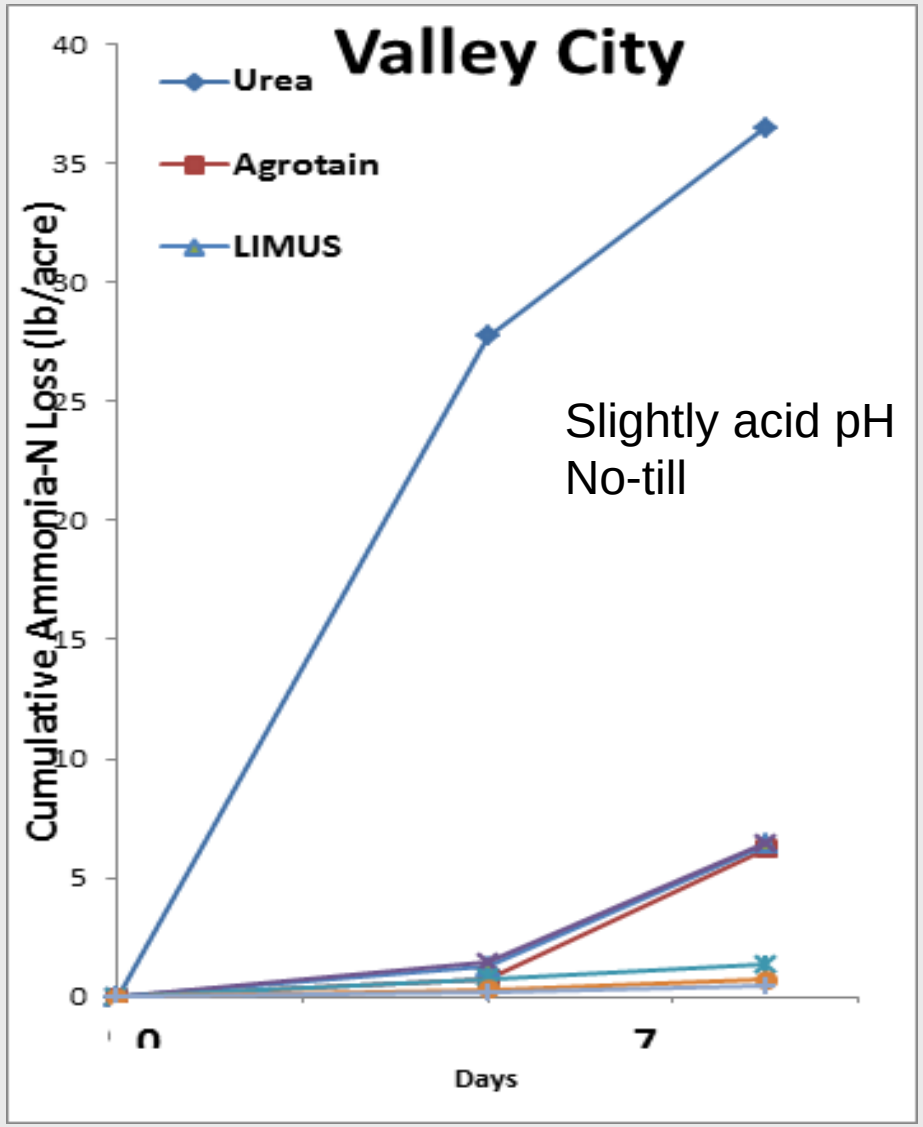
Test Conditions:

Time: 1 day (24 hr), Air flow: 0.5 l/min
using 2.5 l tank, Relative Humidity: 5%, Substrate: glass

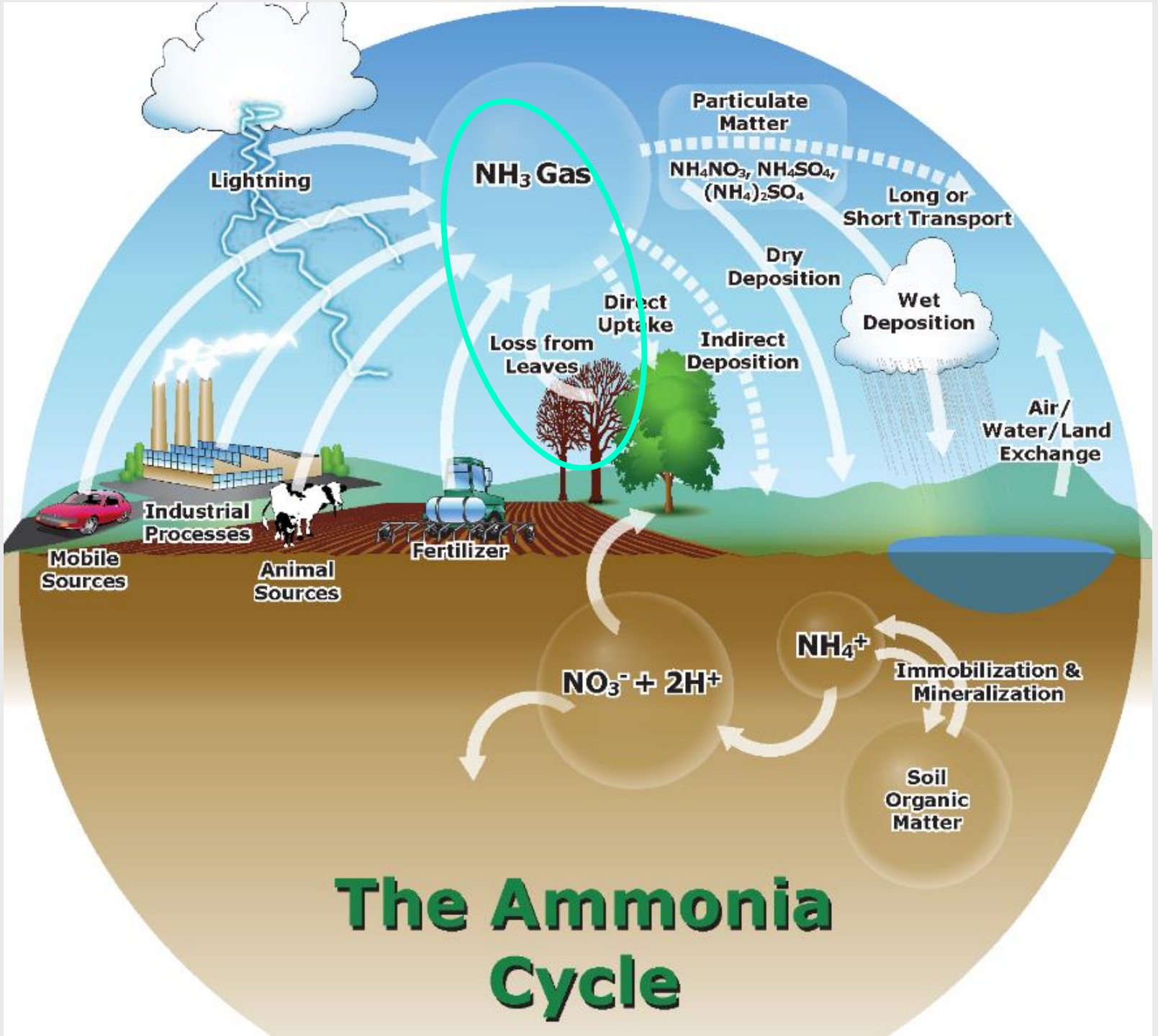

ATMOSPHERIC NITROGEN
ATMOSPHERIC FIXATION
DENITRIFICATION
VOLATILIZATION
VOLATILIZATION
PLANT UPTAKE AND HARVEST
INDUSTRIAL FIXATION
(commercial fertilizer)
BIOLOGICAL FIXATION
Animal Manures
(by legume plants)
Plant Residues
ORGANIC MATTER
NITRATE
AMMONIUM
LEACHING LOSS
The Nitrogen Cycle

Ammonia loss from soil, ND





2015, Franzen, NDSU


Lightning
NH_3 Gas
Particulate Matter
NH_4NO_3, NH_4SO_4, $(NH_4)_2SO_4$
Long or Short Transport
Dry Deposition
Wet Deposition
Direct Uptake
Loss from Leaves
Indirect Deposition
Air/ Water/Land Exchange
Industrial Processes
Mobile Sources
Animal Sources
Fertilizer
$NO_3^- + 2H^+$
NH_4^+
Immobilization & Mineralization
Soil Organic Matter
The Ammonia Cycle

Ammonia exchange from corn foliage during reproductive growth.

Francis, Schepers, and Sims

Agron J 89:941-94(1997)

Table 3. Concentration of NH_3–N and atom % ^{15}N in air drawn over various corn leaves at the R2–R3 growth stage in greenhouse and field.

Plant component	NH_3–N concentration	^{15}N concentration
	$\mu g\ N\ m^{-3}$	atom % ^{15}N
Field plots, 16 Aug.		
Ambient air	3.7 ± 0.1	0.3682 ± 0.0038
3rd leaf above ear	3.9 ± 0.3	0.4567 ± 0.0166
Ear leaf	5.1 ± 0.6	0.5890 ± 0.0465
3rd leaf below ear	4.2 ± 0.1	0.4395 ± 0.0204
LSD (0.05)	0.7	0.0502

Ammonia exchange from corn foliage during reproductive growth.

Francis, Schepers, and Sims

Agron J 89:941-94(1997)

- Nitrogen in plant foliage can be lost by volatilization (Farquhar et al., 1980)

- Loss of NH3 was found to occur during all sampling periods

- Highest volatilization rates occurred during reproductive growth (Harper et al., 1987; Holtan-Hartwig and Bockman, 1994)

- Agricultural crops (i.e. corn) grown under high N fertility levels will loose high levels of NH3 (Holtan-Hartwig and Bockman, 1994)

- Large number of plant communities dispersed across the land suggests that, in aggregate, vegetation is a significant source for atmospheric NH3.

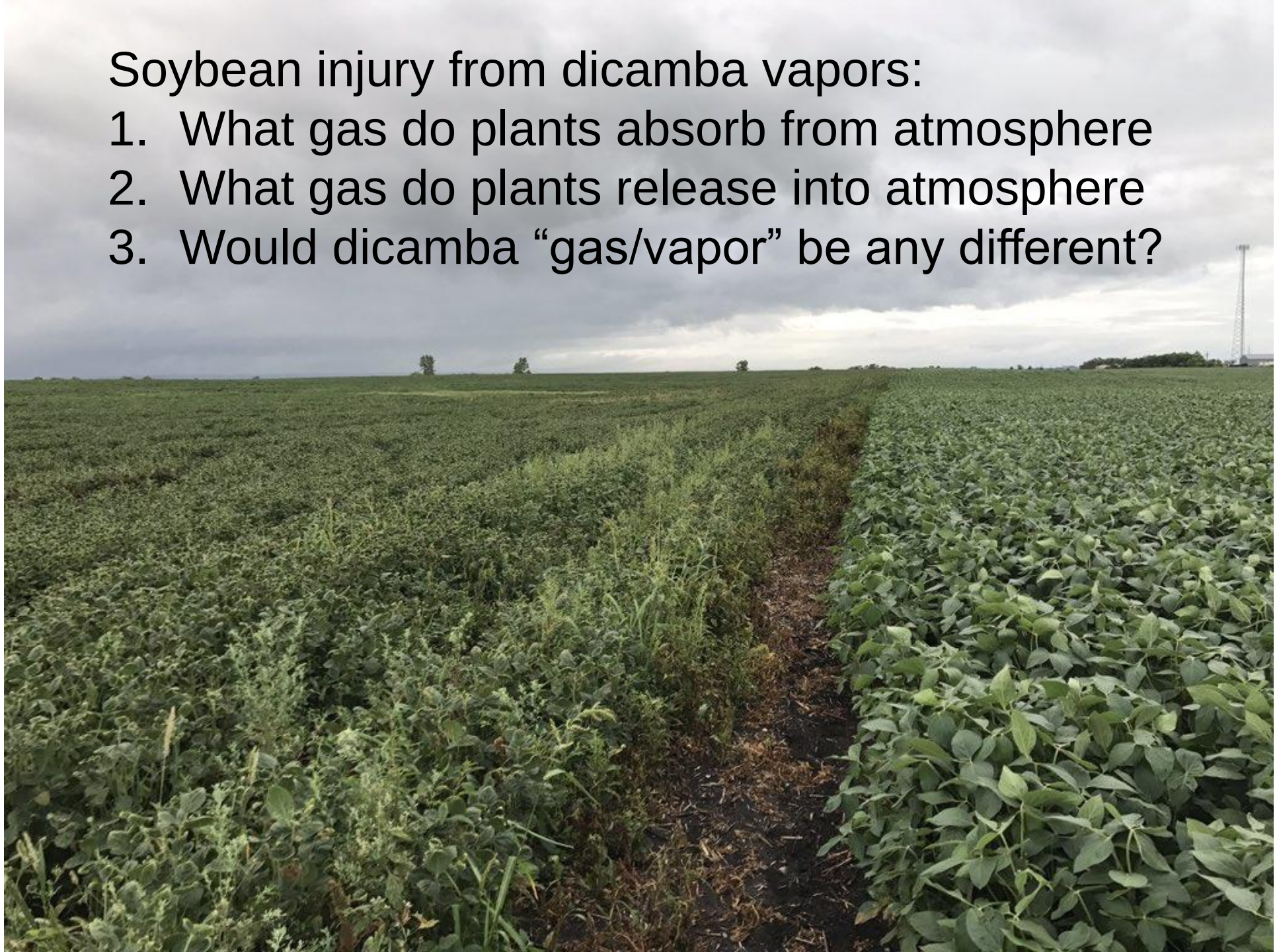
- ***The field study found that 15% of the applied N was lost as ammonia.***

Ammonia binding to anions

Ammonia/Ammonium is a:

- flirtatious ion moving from partner to partner
- binds with anions with the most attraction
- breaks up the marriage of dicamba and DGA salt
- DGA finds solace with calcium or sodium
- or disappears into the foliage and consumed for its N

- can on a whim then leave the anion alone as free acid
- when the ammonium cation has moved on, the lonely sulfates left behind acidify the soil.


Soybean injury from dicamba vapors:
1. What gas do plants absorb from atmosphere
2. What gas do plants release into atmosphere
3. Would dicamba “gas/vapor” be any different?

Dicamba Summary:

1. Unprecedented soybean susceptibility
2. Atmospheric loading
3. Low foliar absorption
4. No soil adsorption
5. High air and soil temperatures
6. Dissociation of salt
7. Fate as salt or acid
8. Pools of ammonia from soil and plants

Factors to reduce dicamba drift:

ND Weed Guide page 29

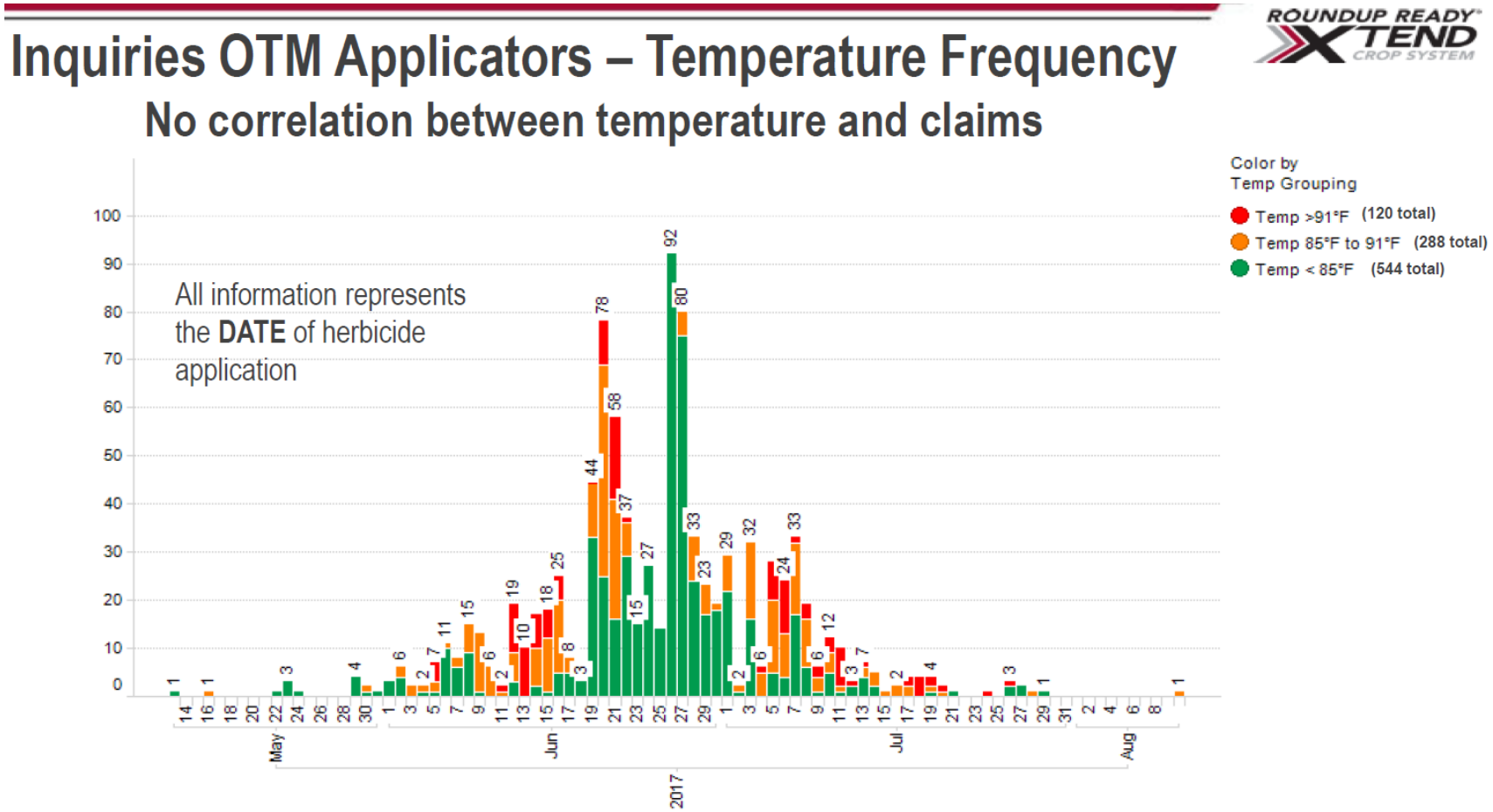
1. PRE only and maybe EPOST
2. Temperatures below 85
3. Sufficient rain to deposit dicamba in soil

Herbicide water solubility

Herbicide	H_2O solubility ppm)
Atrazine	35
Callisto	160
Harness/Surpass	282
Metolachlor	530
Prowl	0.33
Glyphosate	10,500
Dicamba	250,000
Paraquat	620,000

Factors to reduce dicamba drift:

1. PRE only and maybe EPOST
2. Temperatures below 85



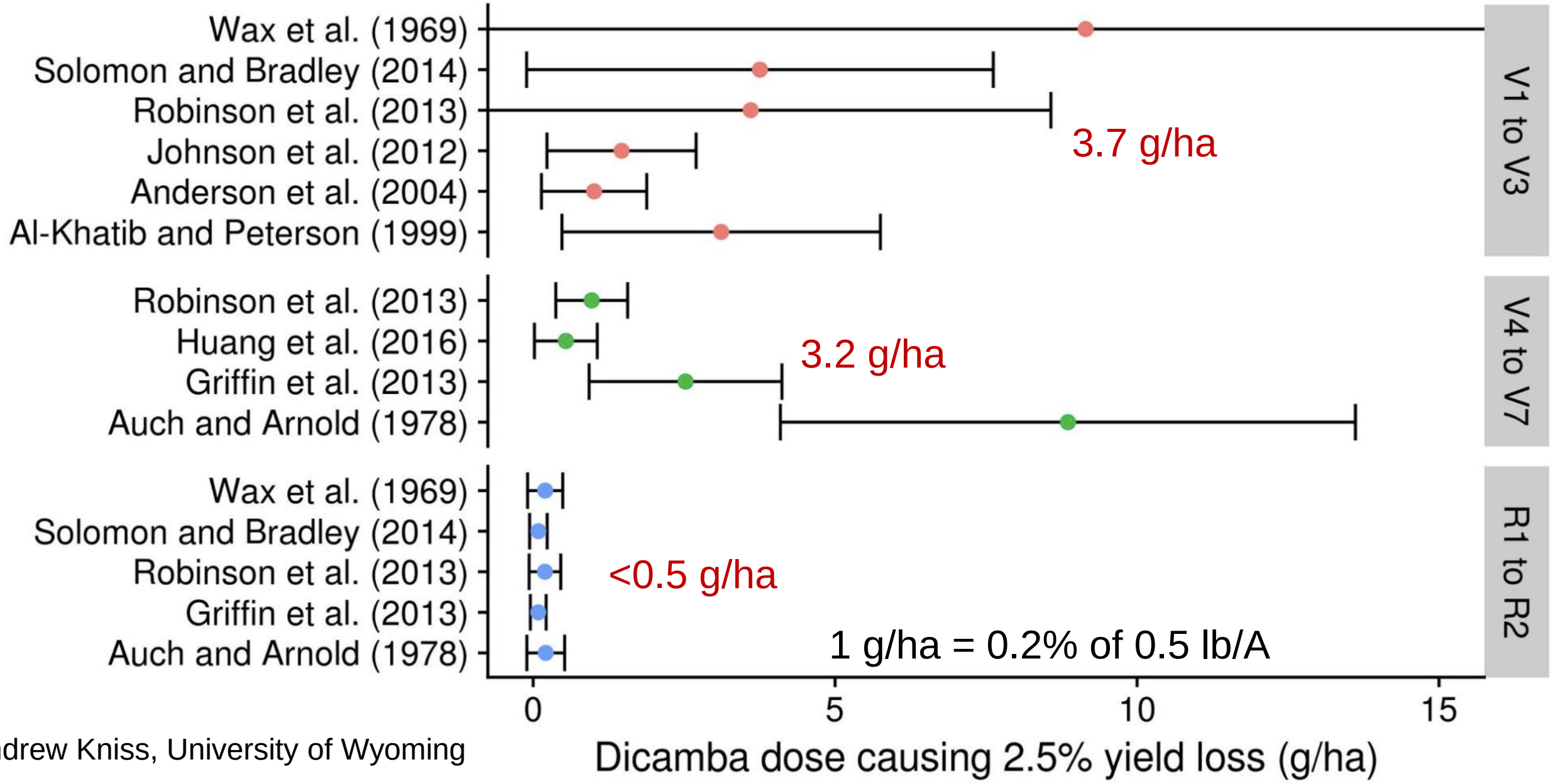
NDSU EXTENSION SERVICE

Table 1: Soybean Injury and subsequent yield
Columbia, MO 2016

Soybean stage	Herbicide Rate		% Injury	Yield
	dicamba rate*	Amount compared to labeled rate	14 Days After Treatment	Bushel/acre
V3	0.05 lb/a	1/10th	80	32
V3	0.005 lb/a	1/100th	70	54
V3	0.0005 lb/a	1/1000th	50	54
V3	0.00005 lb/a	1/10,000th	45	52
V3	Glyphosate only	----------	0	56
R1	0.05 lb/a	1/10th	80	6
R1	0.005 lb/a	1/100th	60	40
R1	0.0005 lb/a	1/1000th	50	49
R1	0.00005 lb/a	1/10,000th	20	55
R1	Glyphosate only	----------	0	59

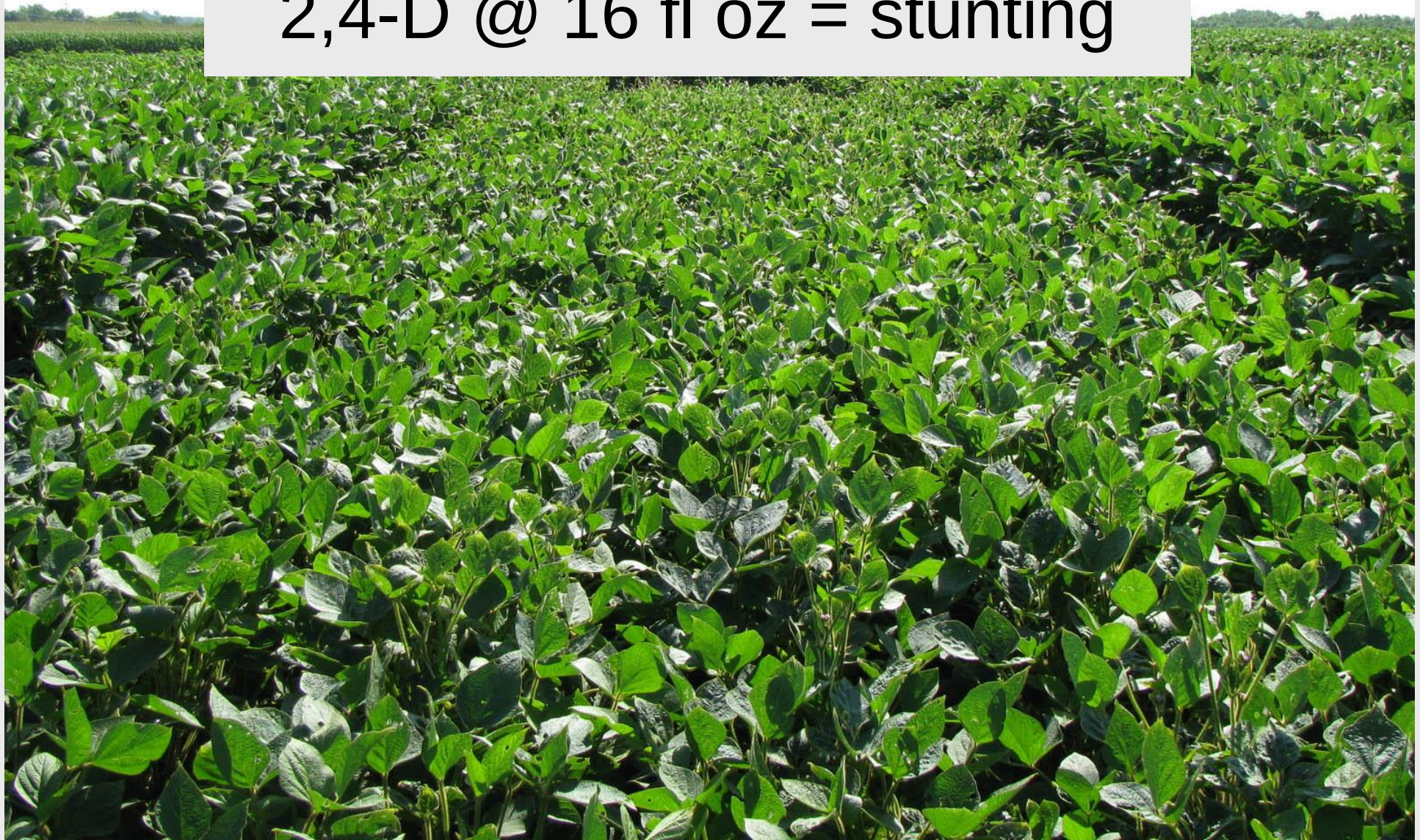
Soybean injury increases as plant age increase

Summary of dicamba yield studies



Andrew Kniss, University of Wyoming

2,4-D @ 16 fl oz = stunting



Xtend and Enlist Systems

	Dicamba	2,4-D
Soybean	Susceptible	~Tolerant
Acid	Volatile	Not volatile
AMS/NH_3	Volatile	Not volatile
Rate	0.5 lb ai	0.7-0.95 lb ai
Soil residue	2-3 weeks	None
Kochia	+	-

Waterhemp = size dependent


NDSU PLANT SCIENCES
NDSU
Agriculture is in our roots