Utilizing Log-Logistic Curve for determining Biologically Effective Dose and Critical Period of Weed Control

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DOSE !?

- Importance of DOSE was recognized 500 years ago.

- In the 15th century, Paracelsus (1494-1541), who practiced alchemy, suggested that ***the poison is in the dose***

- [“*Alle Ding sind Gifft und nichts ohn Gifft .Allein die Dosis macht das ein Ding kein Gifft ist.*”
- **“All things are poison and are not poison; only the dose makes a thing not a poison”.**

Biologically Effective Dose

Definition:

The herbicide dose that provides 90% control of an individual weed species (specific weed rate).

It is based on **dry matter** reduction or **visual** ratings and determined from a dose response curve.

Importance of Biol. Effective Dose

- For decision making (to spray or not ?!)
- Part of Integrated Weed Management Program:
  - ‘WHEN’ ‘WHAT’ & ‘HOW’ to control weeds

- WHEN TO CONTROL - Critical period of weed control
- WHAT LEVEL - Weed thresholds
- <u>HOW MUCH - Biologically effective dose</u>

How to determine Biolog. Effective Dose ?

- Determined from Dose Response curve
  - Please: DO NOT USE Polynomial curves (1^{st}, 2^{nd} orders.. Poly)
    - Parameters of Polynomials have no Biological meanings !!

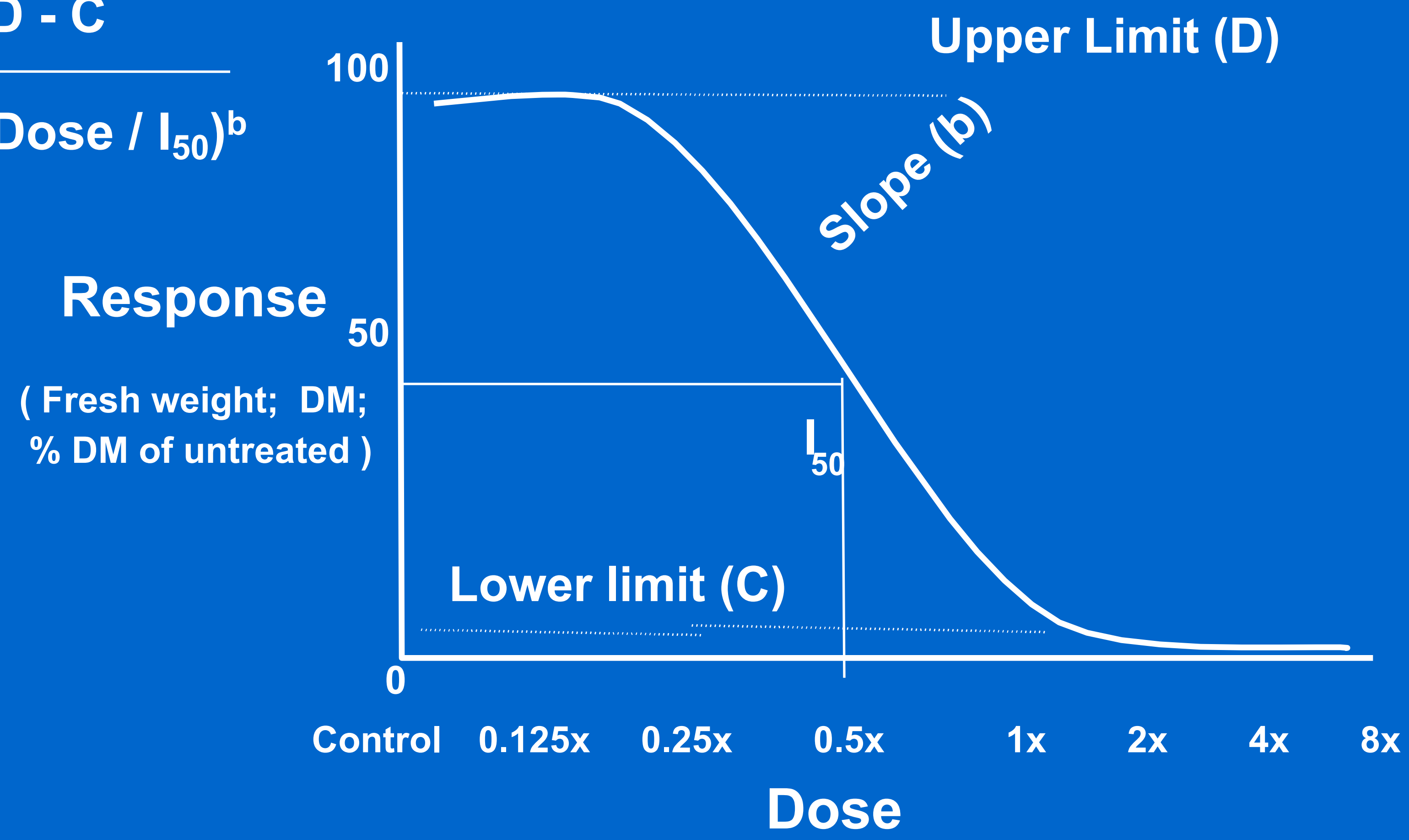
- Use the Log-Logistic Curve, which is sigmoidal in shape
- Appropriate dose selection is essential for curve analysis
  - Select about 7-10 doses
  - 3 doses for the ‘upper’ and 3 for the ‘lower’ limits of the curve and 1-3 for the ‘middle’ part.

How to determine Biologically Effective Dose ?

- Based on Dry Matter Reduction and/or Visual Ratings
- Some believe that Dry Matter better ‘biological indicator’ than simple Visuals
- Select the dose from a curve to:
  - control the weeds
  - offset its competitive ability against weeds

Log-Logistic Dose Response Curve

$$\text{Response} = C + \frac{D - C}{1 + (\text{Dose} / I_{50})^b}$$



Log-Logistic Dose Response Curve:

- Used in Herbicide Bioassays (field, greenhouse, lab):

- Crop tolerance: ED2.5; ED5; ED10
- Weed Control (ED80, ED90, ED95):
  - Chemical: Selectivity, Antagonism, Synergism, Residues.
  - Herbicide activity: Effects of Safeners, Adjuvants, Environment.
  - Non-chemical: Effects of flame weeding on plant size and density.

Weed Resistance: Compare curves susceptible vs resistant biotypes

Statistics (Knezevic et al. 2007; Knezevic & Datta, 2015):

- The 3 or 4 parameter Log-Logistic curve (my preference)
  - Weibull (3-4) can be also used
  - Based on Goodness of the fit, or use curve with the lowest RMS

Software for curve fitting: R & drc (Knezevic & Data, 2007 and 2015, my preference)

Important statistical steps: (output from ***summary*** command)

1. Lack-of-fit to Test Model Significance (p-value >0.05)

2. Curve parameters: **b** (slope), **c** (lower limit), **d** (upper limit), **e** (ed50) and their SE
Compare multiple curves: Compare all 4 parameters +/- Standard Errors

3. ED values:
ED2.5, ED5, ED10, ED15 for Crop Tolerance ;
ED50, ED80, ED90, ED95 for Weed Control, Resistance, ..etc

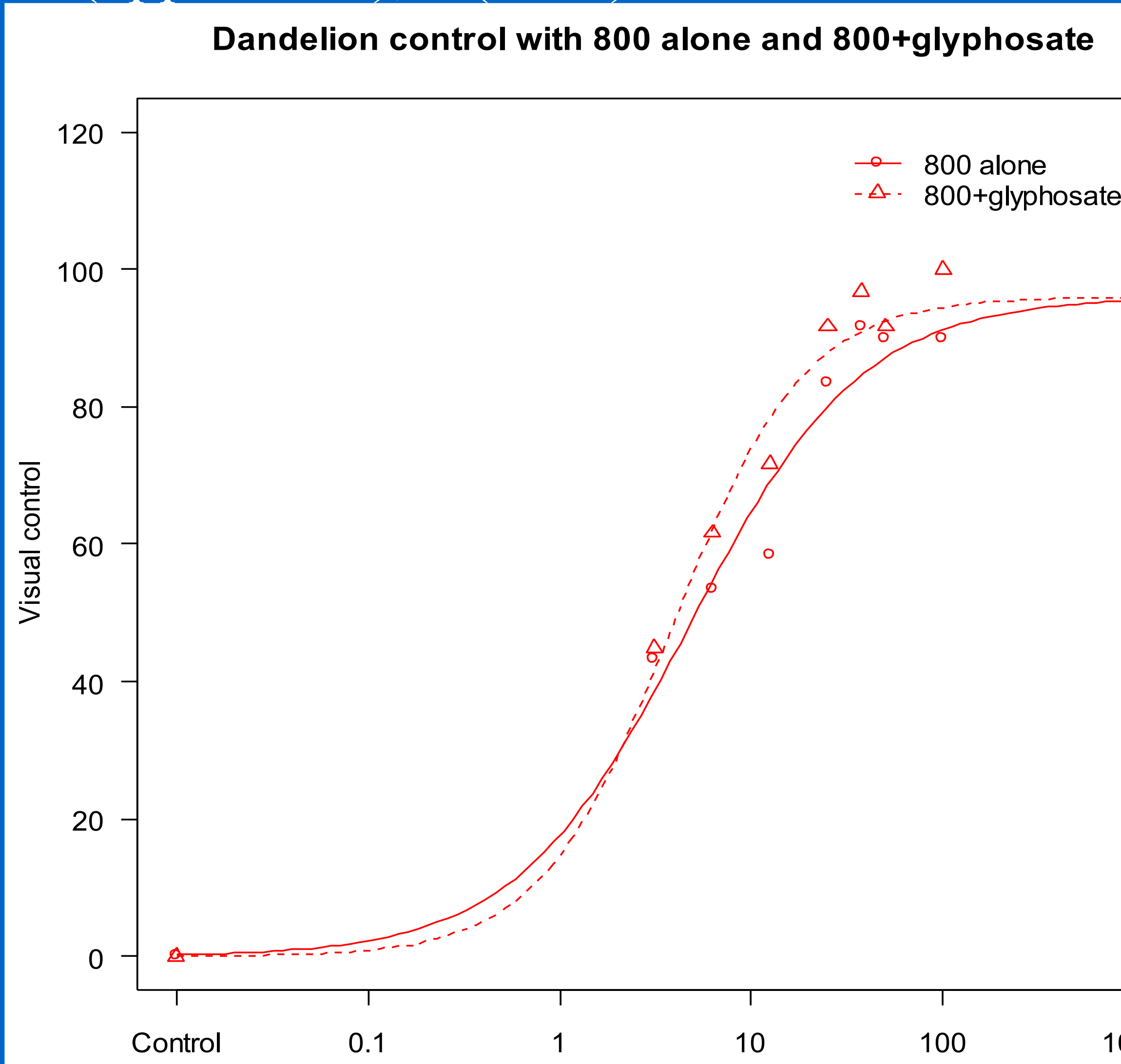
Statistics (Knezevic et al. 2007; Knezevic & Datta, 2015):

Compare 2 (or more) curves: compare their 4 parameters +/- Standard Errors

- Parameters: **b** (slope), **c** (lower limit), **d** (upper limit), **e** (ed50) and their SE

Curve 1:	Curve 2:	Significance
b1=8 (2)	b2=7 (2)	NS
c1=7 (1)	c2=8 (1)	NS
d1=98 (2)	d2=86 (4)	SIG
e1= 48 (3)	e2=52 (3)	NS

Curve 1 vs. Curve 2 = SIG different



Comparing ED values of Interest

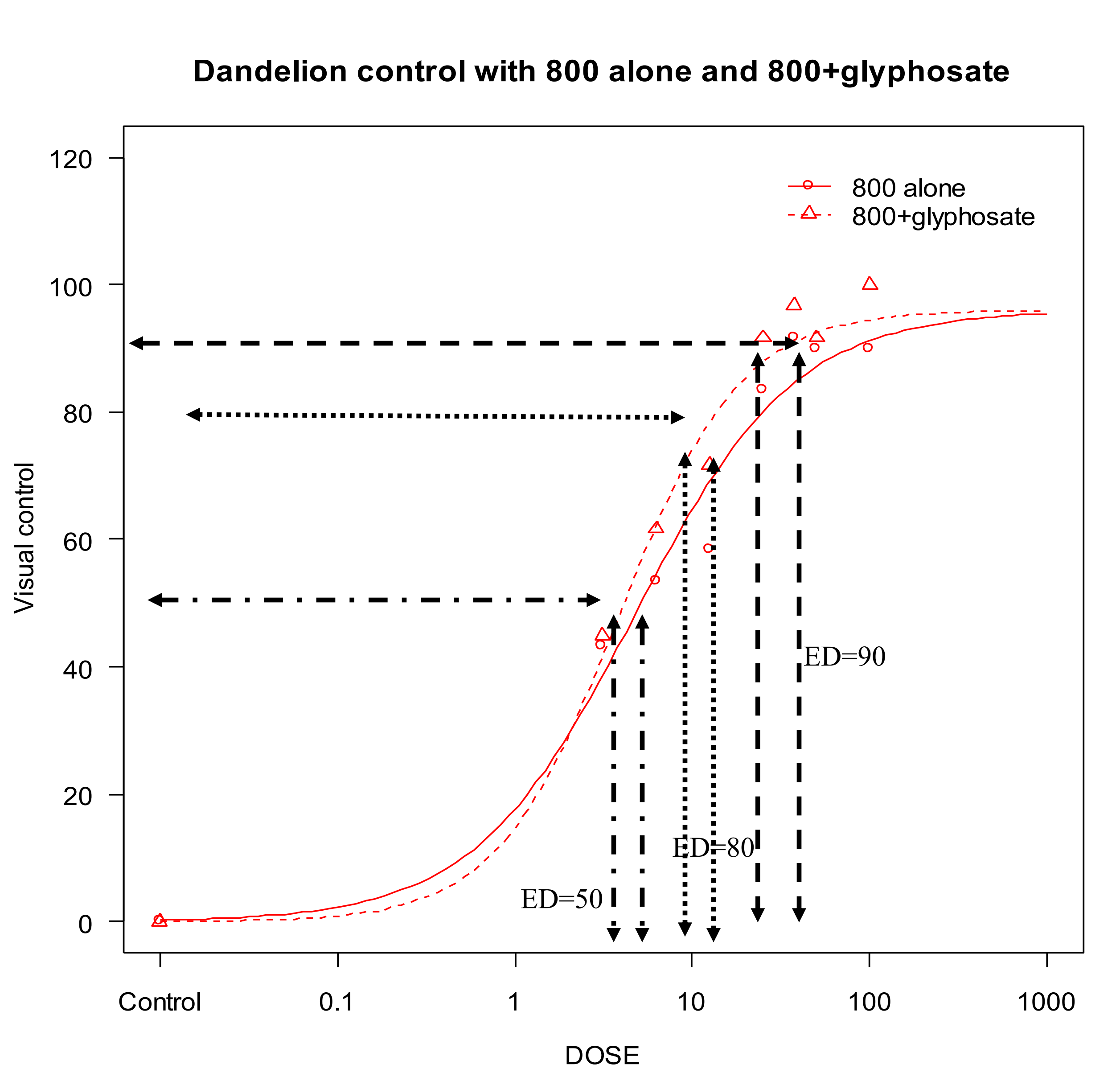
(Knezevic et al. 2007, Weed Tech. 21 (3) : 840-848)

- Calculate ED values of interest (eg. ED5……ED95)

- ED 5 – 5% control
- ED 50 – 50% control
- ED 80 – 80% control
- ED 90 – 90% control

- ED value ± standard error (SE)

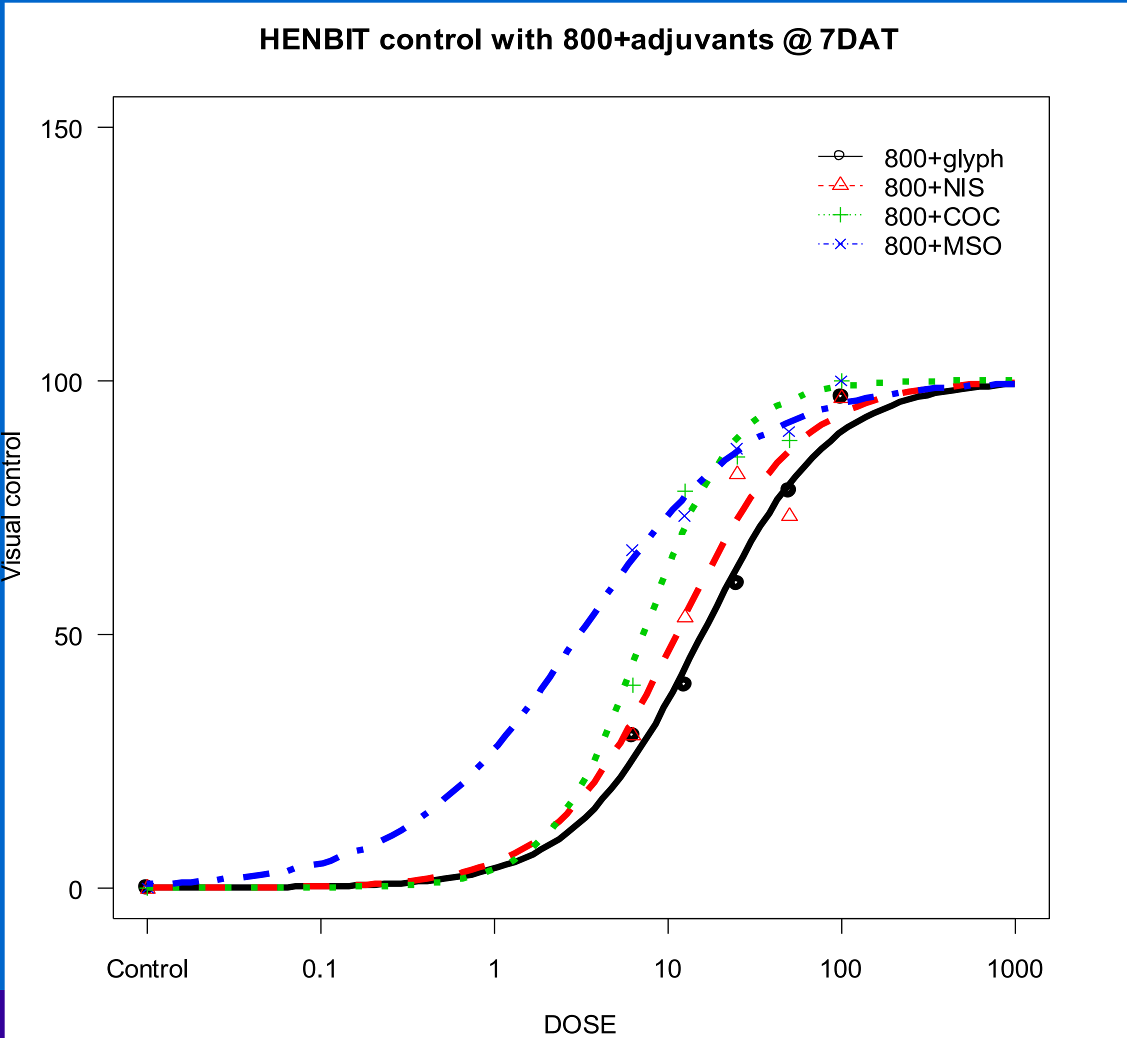
- Compare ED values between curves for significant difference based on:
  - "t-test" ("p-value"), or
  - use their SE



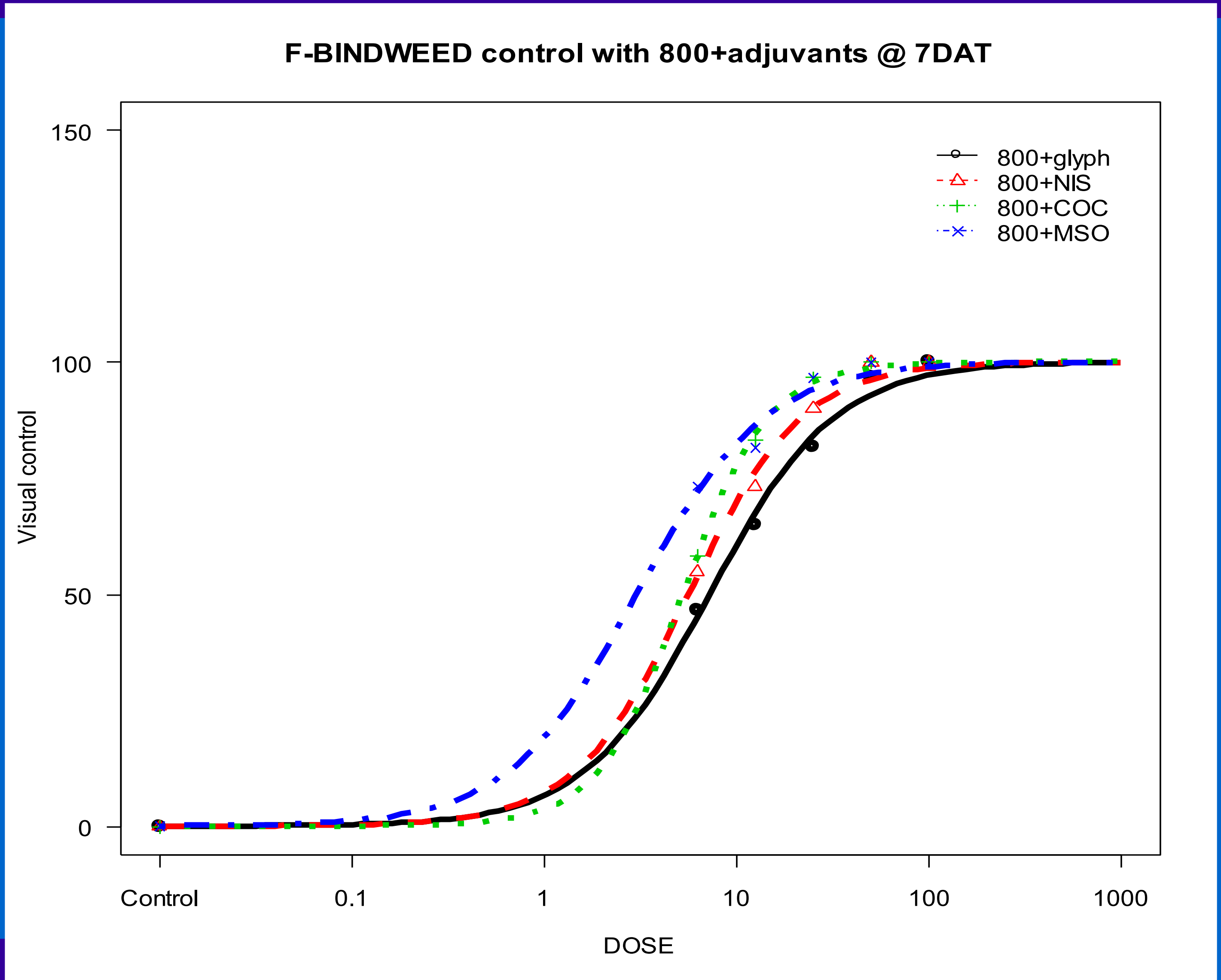
- Compare ED values between curves for significant difference using their SE

(Knezevic et al 2007)

Weed	Tankmix	Rating Date	ED80		ED90	
Henbit	800H + glyph	7DAT	51 (6)	SIG	103 (17)	SIG
	800H + NIS		35 (5)	SIG	68 (13)	SIG
	800H + COC		16 (2)	NS	39 (10)	NS
	800H + MSO		15 (2)	NS	27 (5)	NS

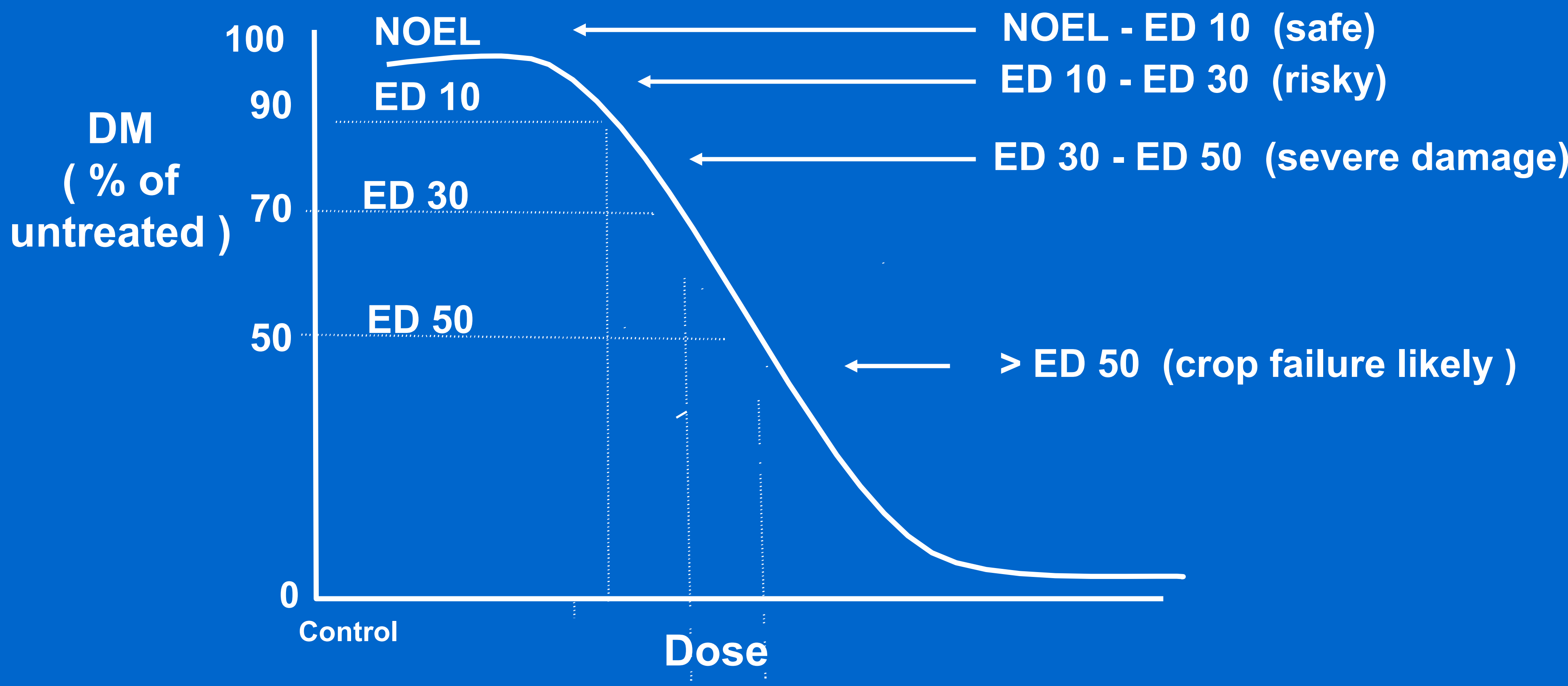


Weed	Tankmix	Rating Date	ED80		ED90 (Knezevic et al 2007)	
Bindweed	800H+glyph	7 DAT	30 (2)	SIG	48 (6)	SIG
	800H+NIS		18 (2)	SIG	35 (4)	SIG
	800H+COC		11 (1)	NS	16 (2)	NS
	800H+MSO		9 (1)	NS	16 (3)	NS



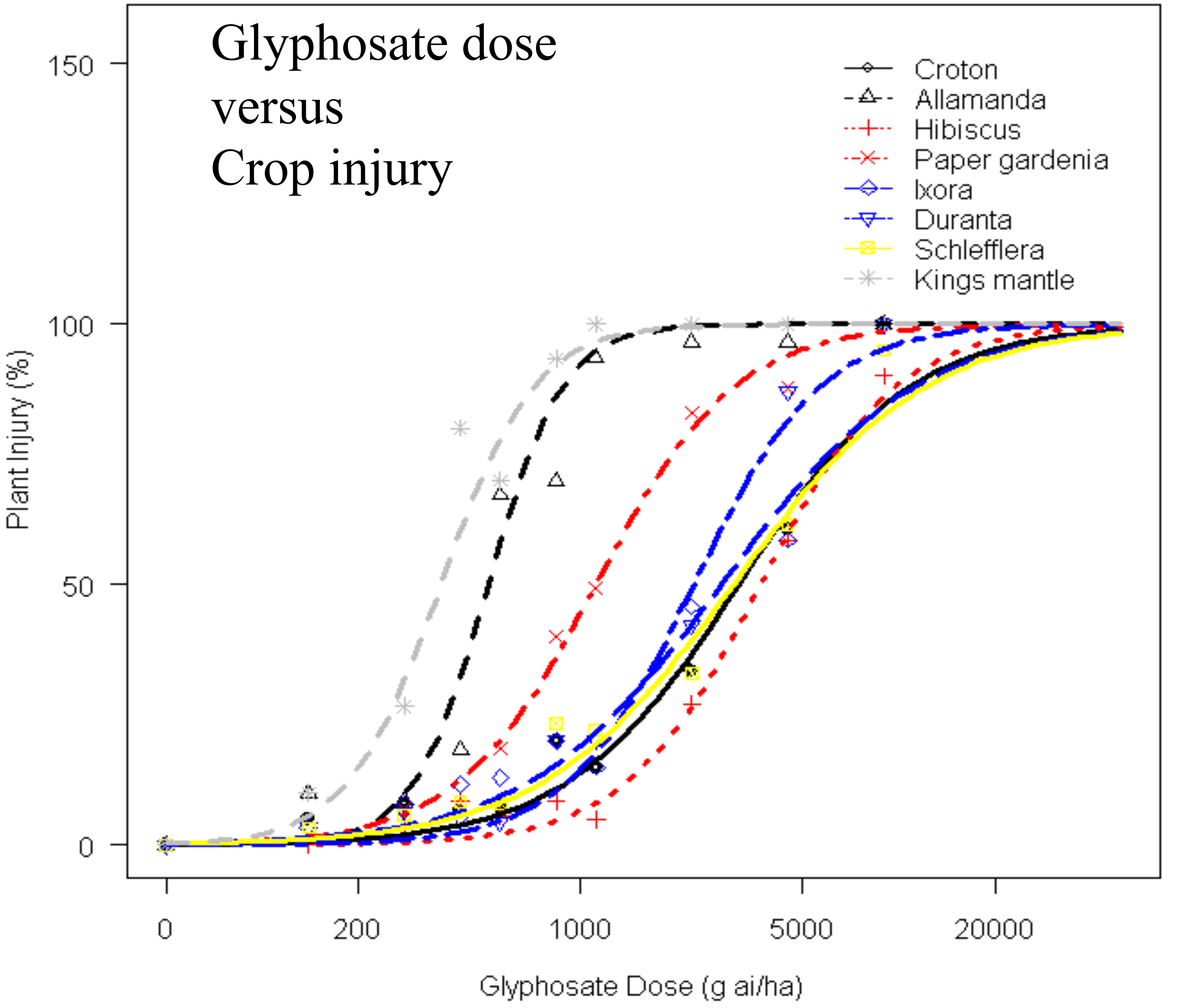
Log-Logistic Dose Response Curve

Testing crop tolerance



Hock et al. 2007

Dodder (*Cuscuta sp*) control in Tropical plants in Guam

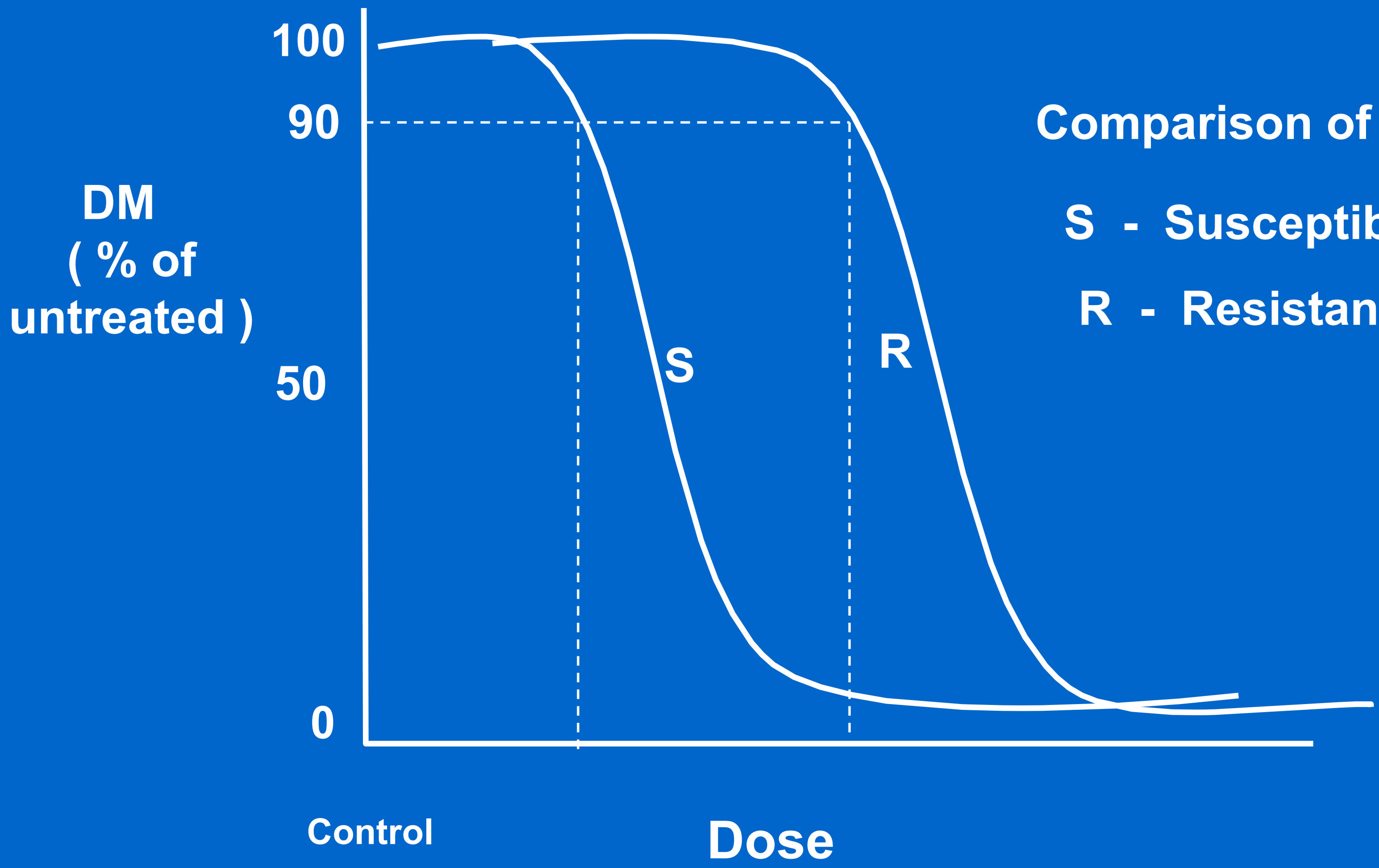


- Glyphosate doses (ED5, ED10, ED15 and ED20) that resulted in plant "visual quality reduction" of at least 5, 10, 15 and 20%, respectively (Hock et al. 2007)

Plant species	ED5 ± (SE)	ED10 ± (SE)	ED15 ± (SE)	ED20 ± (SE)
Croton	503 ± (114)	801 ± (140)	1068 ± (154)	1327± 162
Allamanda	231 ± (31)	283± (28)	321 ± (26)	353 ± (24)
Hibiscus	869± (168)	1254 ± (186)	1547± (191)	1867 ± (192)
Gardenia	255± (41)	372 ± (46)	459 ± (47)	558 ± (48)

Log-Logistic Dose Response Curve

Determine Weed Resistance



Comparison of two biotypes:

S - Susceptible biotype

R - Resistant biotype

Resistance levels of 5 marestail populations to glyphosate based on ED50 and ED90

- ***8 glyphosate doses:***
  - D1=0;
  - D2=0.25X (265 g ai/ha);
  - D3=0.5X (530 g ai/ha);
  - D4= 1X (1060g ai/ha);
  - D5= 2X (2120);
  - D6= 4X (4240);
  - D7= 8X (8480);
  - D8= 16X (16960 gai/ha)

2 application times: 4 plants/pot

1. 2-4” rosette (18-26 leaves)
2. 5-6” rosette (30-35 leaves)

Glyphosate Resistance Levels in 5 Marestail Populations @ 21 DAT, 1st applic. time
(Knezevic et al. 2006)

Rates (g ai/ha) for 50% control (ED50):

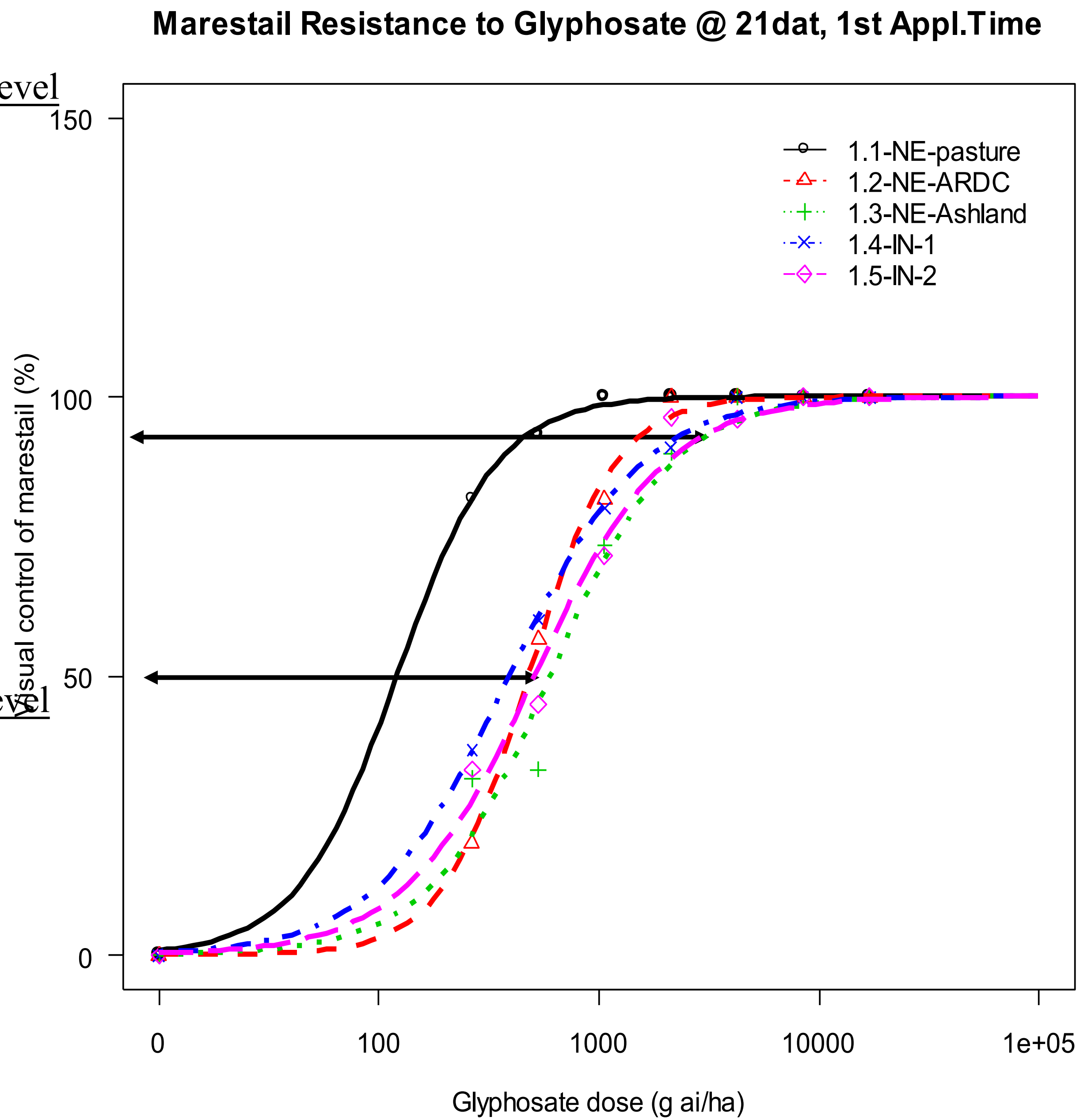
Population	Rate (S.E.)		Resistance level
1.1=NE-pasture	122	(40)	1x
1.2=NE-ARDC	484	(21)	3.9x
1.3=NE-Ashland	608	(32)	4.9x
1.4=IN 1	394	(24)	3.2x
1.5=IN 2	515	(29)	4.2x

Resistance level: 484/122=3.9x

Rates (g ai/ha) for 90% control (ED90):

Population	Rate (S.E.)		Resistance level
1.1=NE-pasture	384	(55)	1x
1.2=NE-ARDC	1308	(126)	3.4x
1.3=NE-Ashland	2452	(270)	6.3x
1.4=IN 1	1815	(237)	4.7x
1.5=IN 2	2311	(270)	5.9x

Resistance level: 1308/384 = 3.4x



Glyphosate Resistance Levels in 5 Marestail Populations (Knezevic et al. 2006)

Label rate (1x) = 22 oz/acre

Application time 1: 2-4" tall plants

Population	Resistance level	Rates of glyphosate to get 90% kill	
		Brand name	Generic
		(~ 4.5 lbs ae/gall)	(~3 lbs ae/gall)
1.1=NE-pasture	1x	22 oz/acre	32 oz/acre
1.2=NE-ARDC	3.4x	75 oz	109 oz
1.3=NE-Ashland	6.3x	138 oz	202 oz
1.4=IN 1	4.7x	103 oz	150 oz
1.5=IN 2	5.9x	130 oz	189 oz

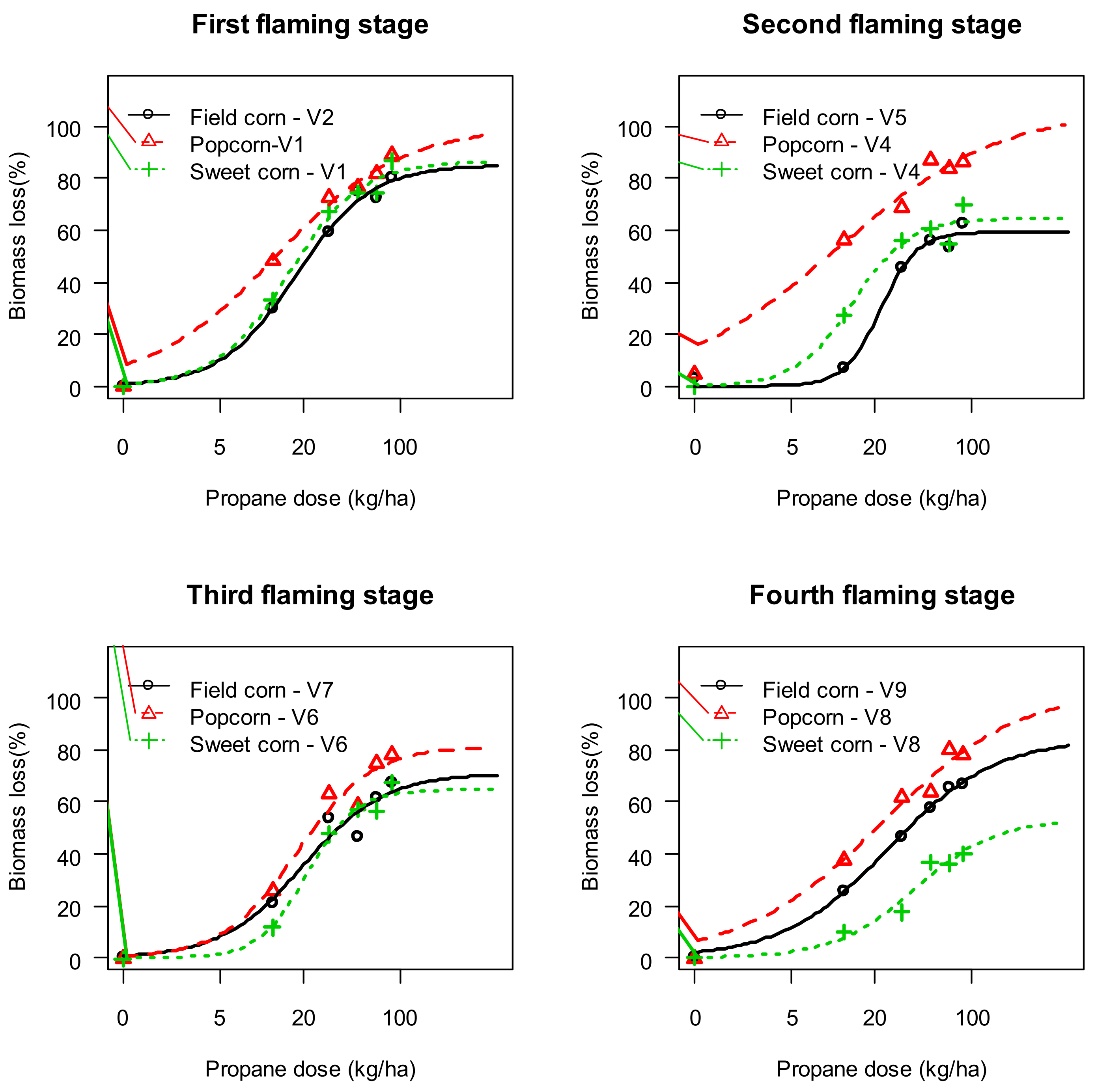
(4 plants/pot)

Application time 2: 5-6" tall plants

Population	Resistance level	Rates of glyphosate to get 90% kill	
		Brand name	Generic
		(~ 4.5lbs ae/gal)	(~3 lbs ae/gall)
1.1=NE-pasture	1x	22 oz/acre	32 oz/acre
1.2=NE-ARDC	4.4x	96 oz	140 oz
1.3=NE-Ashland	5.1x	110 oz	163 oz
1.4=IN 1	4.1x	112 oz	131 oz
1.5=IN 2	4.9x	107 oz	157 oz

Crop tolerance to flaming

Knezevic et al. 2008



Response of Glyphosate-Tolerant Soybean to Dicamba Based Herbicides

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University of Nebraska-Lincoln – Haskell Ag Lab – Concord, NE

Introduction

New dicamba-based herbicides such as Engenia® (N,N-Bis-(3-aminopropyl) methylamine salt) and XtendiMax® (diglycolamine salt) with Vapor Grip technology were developed to reduce dicamba volatility; however, there are claims that these products can still volatilize or drift and cause injuries to soybeans. Therefore, **the objective** of this study was to evaluate the response of glyphosate-tolerant soybean to micro-rates of dicamba herbicides with different formulations or technologies.

Materials and Methods

- Field experiments were conducted in 2017 and 2018 at Haskell Ag Lab, as a split-plot design with three dicamba herbicides, 6 dicamba rates, 3 application times in 4 replications.
- Dicamba micro-rates were: 0; 1/10; 1/50; 1/100; 1/500; 1/1000 of the label rate (560 g ae ha^{-1}).
- Plots had 4 rows of glyphosate-tolerant soybean, 10 m by 3 m.
- The 3 application times were: 2nd trifoliate (V2), 7th trifoliate/beginning of flowering (V7/R1), and full flowering (R2) growth stages.
- Visual evaluation of soybean injuries were at 7, 21 and 28 days after treatment (DAT).

Results

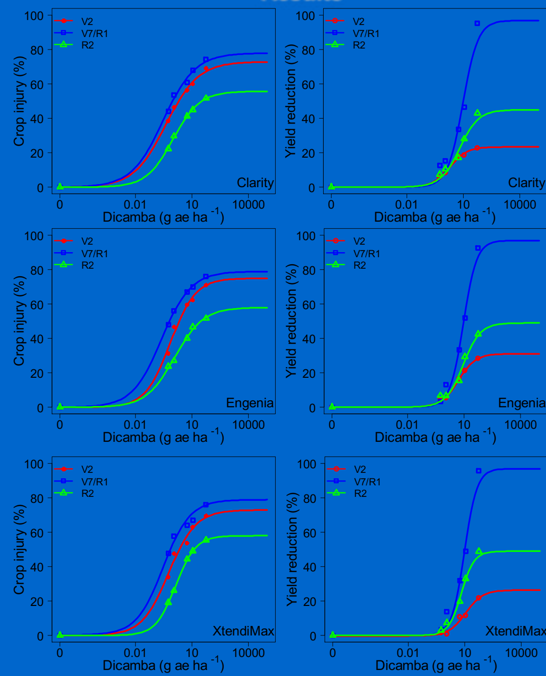

Figure 1. Response of GT-soybean to micro-rates of dicamba based herbicides

Table 1. Doses of dicamba products that resulted in plant injuries and yield losses of GT-soybean sprayed at three growth stages. Estimates were compared using standard errors (SE).

		Injury			Yield reduction		
Dicamba	Growth stage	ED_{10} (SE)	ED_{20} (SE)	ED_{50} (SE)	ED_{5} (SE)	ED_{10} (SE)	ED_{20} (SE)
		g ae ha^{-1}					
Clarity®	V2	0.09 (0.01)	0.14 (0.02)	0.72 (0.07)	1.91 (0.43)	2.14 (0.72)	5.39 (1.24)
	V7/R1	0.03 (0.01)	0.08 (0.02)	0.45 (0.09)	0.24 (0.12)	0.56 (0.21)	1.37 (0.37)
	R2	0.07 (0.00)	0.19 (0.01)	1.78 (0.81)	5.89 (2.32)	7.70 (2.67)	7.13 (2.43)
Engenia®	V2	0.11 (0.11)	0.16 (0.12)	0.99 (0.18)	0.41 (0.18)	1.85 (0.32)	1.92 (0.76)
	V7/R1	0.06 (0.00)	0.06 (0.01)	0.40 (0.08)	0.12 (0.06)	0.32 (0.13)	0.91 (0.26)
	R2	0.09 (0.00)	0.16 (0.01)	1.08 (0.14)	0.87 (0.21)	1.83 (0.15)	4.12 (1.02)
XtendiMax®	V2	0.09 (0.04)	0.19 (0.08)	0.71 (0.05)	0.45 (0.15)	1.95 (0.33)	2.14 (0.74)
	V7/R1	0.02 (0.00)	0.07 (0.01)	0.41 (0.04)	0.29 (0.15)	0.63 (0.26)	1.48 (0.44)
	R2	0.07 (0.01)	0.08 (0.01)	1.14 (0.15)	1.05 (0.21)	2.22 (0.53)	5.00 (1.19)

Curly pods of soybeans treated with dicamba at 1/10th rate for R2 timing, compared to normal pod shape in untreated control

Discussion and Conclusion

- The GT soybean was equally impacted by all three products (Clarity®, Engenia® and XtendiMax®) as suggested by visual injury and yield response (Figure 1)
- Increasing dicamba rate from 1/1000 to 1/10 of the label rate caused 20-80% injury with the greatest injury observed at V7/R1 stage. In fact, the stimated effective dose for 5%, 10% or 20% yield reduction suggested that V7/R1 was the most sensitive GT-soybean growth stage (Table 1).
- For example, 10% yield reduction occurred when 1.83-1.85 g ae ha^{-1} of Engenia® was applied at V2 or R2, whereas, a lower dose of 0.32 g ae ha^{-1} of Engenia caused the same level of yield reduction when applied at V7/R1.
- Similar doses were estimated for all three products, therefore dicamba drift on GT-soybean from these products should be avoided at all costs.

Effects of Dicamba Ultra Micro-rates on Soybean Yield – Hormesis or Not?

Stevan Z. Knezevic, Luka G. Milosevic, O. Adewale Osipitan and Jon Scott

University of Nebraska-Lincoln – Haskell Ag Lab – Concord, NE

Introduction

here are speculations that a drift of sub-lethal doses of dicamba erbicides to soybean can increase the yield through a phenomenon alled hormesis.

herefore, the **objective** of our preliminary study was to determine if he yield of glyphosate-tolerant soybeans could increase as a result of xposure to sub-lethal rates of dicamba.

Materials and Methods

- Field experiments were conducted in 2018 at Haskell Ag Lab, as a split-split-plot design with 10 dicamba rates, 3 application times and 4 replications.
- Plots had 4 rows with a dimension of 7.6 m by 3 m.
- Dicamba micro-rates used: 0; 1/10; 1/100; 1/1000; 1/5000; 1/10000; 1/20000; 1/30000; 1/40000 and 1/50000 of the label rate (560 g ae ha^{-1}).
- Application times: 2nd trifoliate (V2), beginning of flowering (R1), and full flowering (R2) growth stages.
- Soybean injury data were collected at 7, 14, 21 and 28 days after treatment (DAT). Yield and yield components data were also collected

Results

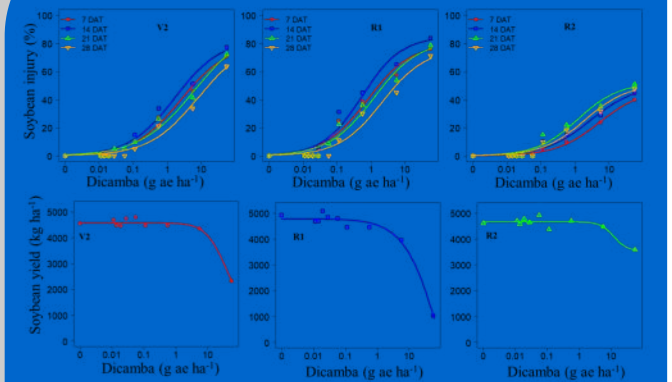

Figure 1. Soybean injury and yield response to low-rates of dicamba

Table 1. Doses of dicamba for 5, 10, and 20% yield loss

Stage	ED5 (SE)	ED10 (SE)	ED20 (SE)	Stage	ED5 (SE)	ED10 (SE)	ED20 (SE)
	g ae ha^{-1}				oz acre^{-1}		
V2	26.36 (10.2)	28.91 (9.04)	31.93 (0.32)	V2	1.03 (0.12)	1.14 (0.08)	1.26 (0.91)
R1	3.14 (1.08)	5.12 (1.02)	6.78(1.17)	R1	0.16 (0.08)	0.20 (0.03)	0.23 (0.06)
R2	22.11 (0.01)	6.10 (0.03)	11.11 (1.55)	R2	1.06 (0.09)	1.31 (0.08)	1.98 (0.16)

Cupping of leaves on dicamba treated soybeans for V2 timing

Apical meristem and stem damage caused by 1/10 of the dicamba label rate

Discussion and Conclusion

- There was no evidence that the ultra-low doses of dicamba increased soybean yield when applied at early vegetative (V2), early flowering (R1) or full flowering (R2) stage of growth (Figure 1).
- Application of 1/5000 to 1/10 of dicamba label rate caused 20 to 80% visual injury with the greatest injury at R1 (Figure 1).
- A 1/10 of the dicamba label rate caused 23 to 78% soybean yield loss depending on the growth stage of exposure; with the greatest yield loss (78%) at the R1 stage (Figure 1).
- Estimated dose of 28.9, 5.1 and 6.1 g ae ha^{-1} caused 10% yield loss at V2, R1 and R2 stages respectively.
- In general, our preliminary study suggested that there was no evidence that sub-lethal doses of dicamba could increase the yield of soybean irrespective of the growth stage of dicamba exposure, suggesting that there was no hormesis occurring. This study will be repeated in 2019.

Take home message

- Biologically Effective Dose is species specific
- Dose selection important for the curve analysis
- Practical significance:
  - Reduce production costs (dose lower than the label rate)
  - Reduce input of chemicals into environment
  - Select the dose from curve to:
    - control the weeds
    - or to offset its competitive ability against the crop

Statistics : Learn R …. Life will be GOOD ..

Critical Period of Weed Control (CPWC)

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Critical period of weed control (CPWC)

Definition:

Critical period of weed control is a period in the crop growth cycle during which weeds must be controlled to prevent yield losses.

Weeds that emerge before or after this period may not represent a threat to crop yields.

CPWC: “Window in growing season” (Knezevic et al. 2002).

Importance of CPWC

- For decision making (to spray or not ?!)
- Part of Integrated Weed Management Program:
  - 'WHEN' 'WHAT' & 'HOW' to control weeds

- <u>WHEN TO CONTROL - Critical period of weed control</u>
- WHAT LEVEL - Weed thresholds
- HOW MUCH - Biologically effective dose

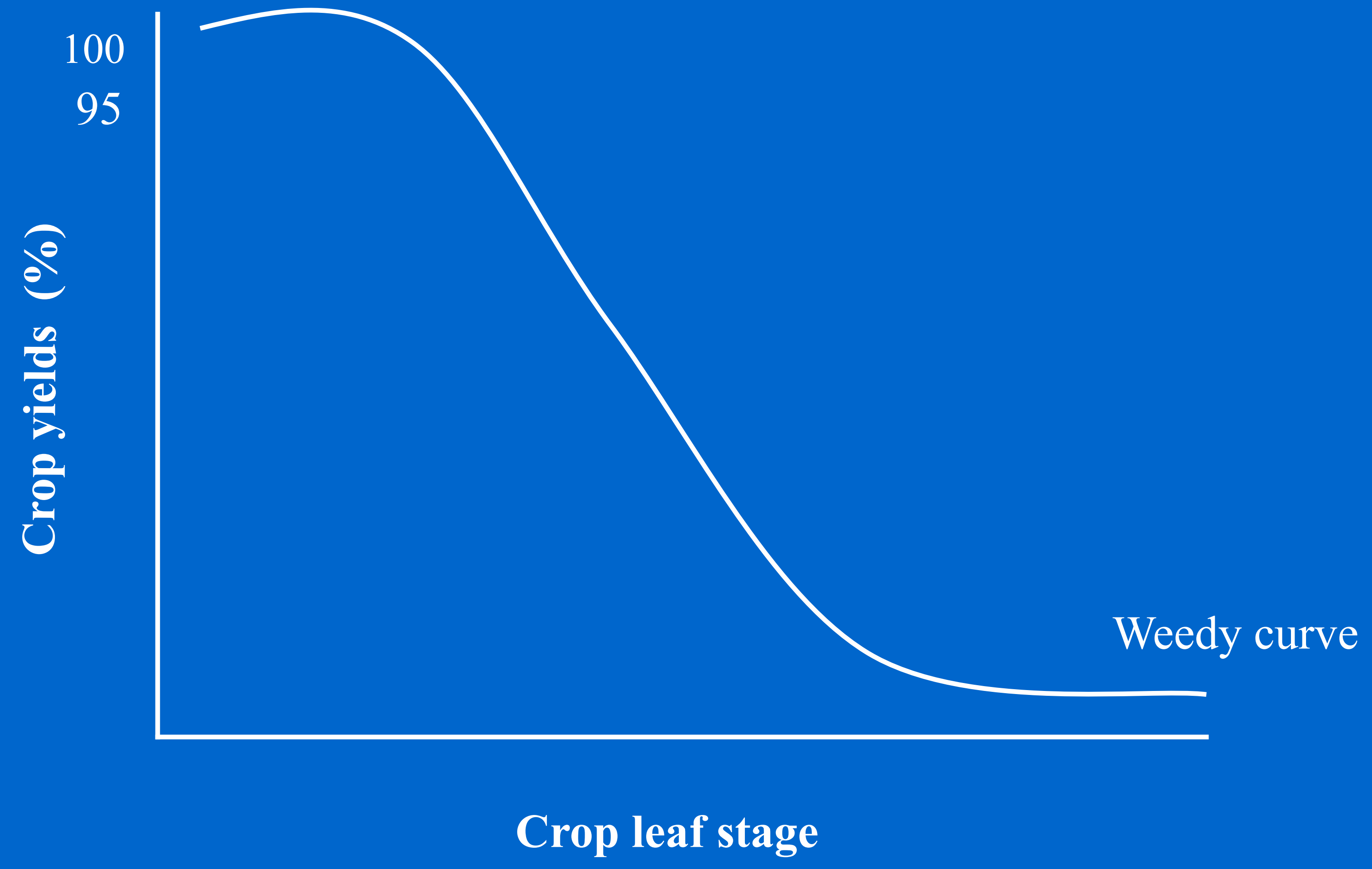
How to determine CPWC ?

- Have to grow crops and weeds together

- 2 sets of treatments for 2 curves
  - 1st set: Keep it weedy up to the specific leaf stage
  - 2nd set: Keep it weed free up to the specific leaf stage

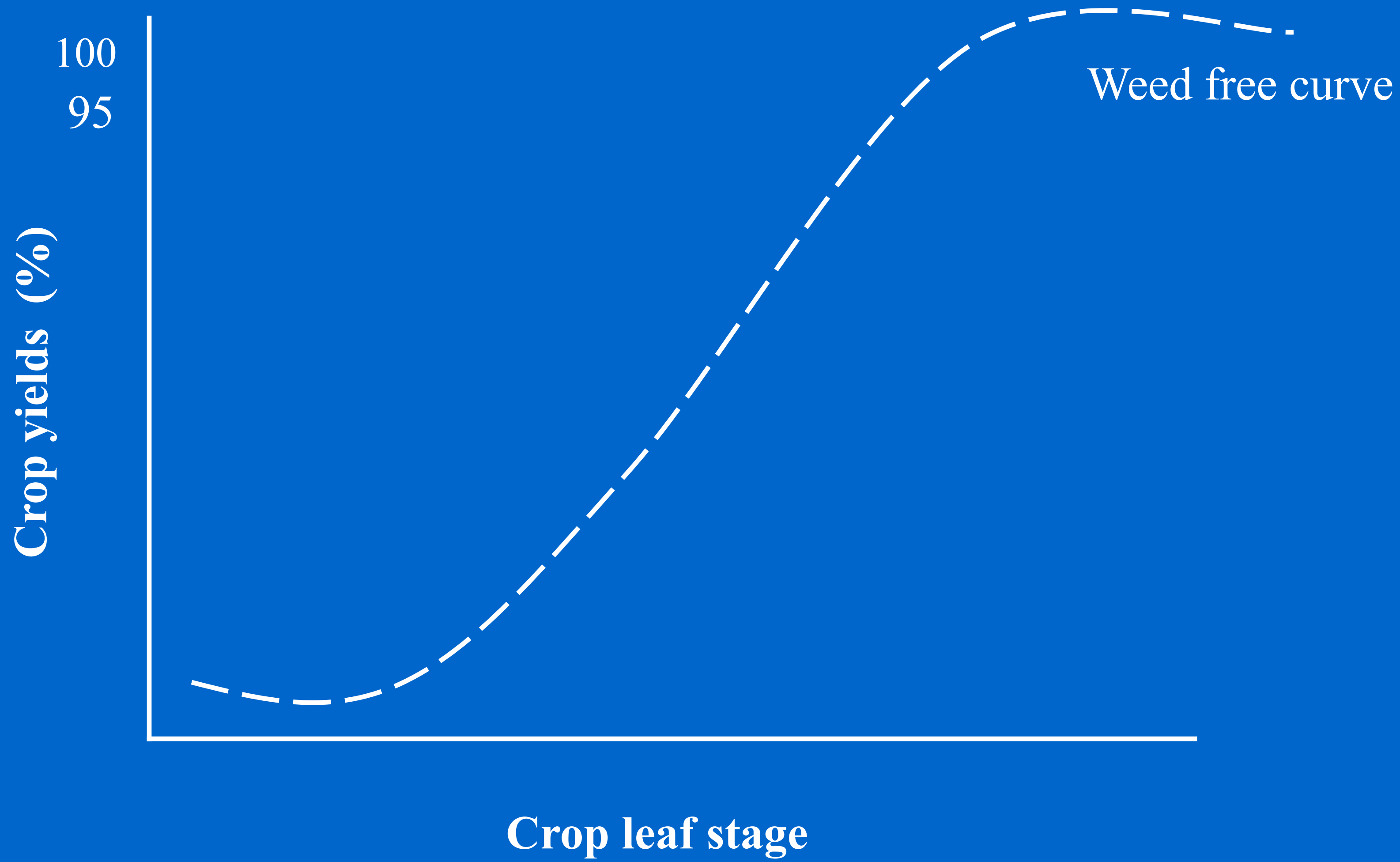
1st set: Keep it weedy = to get 'weedy curve'

Utilized to determine "starting point of CPWC" = "CTWR"

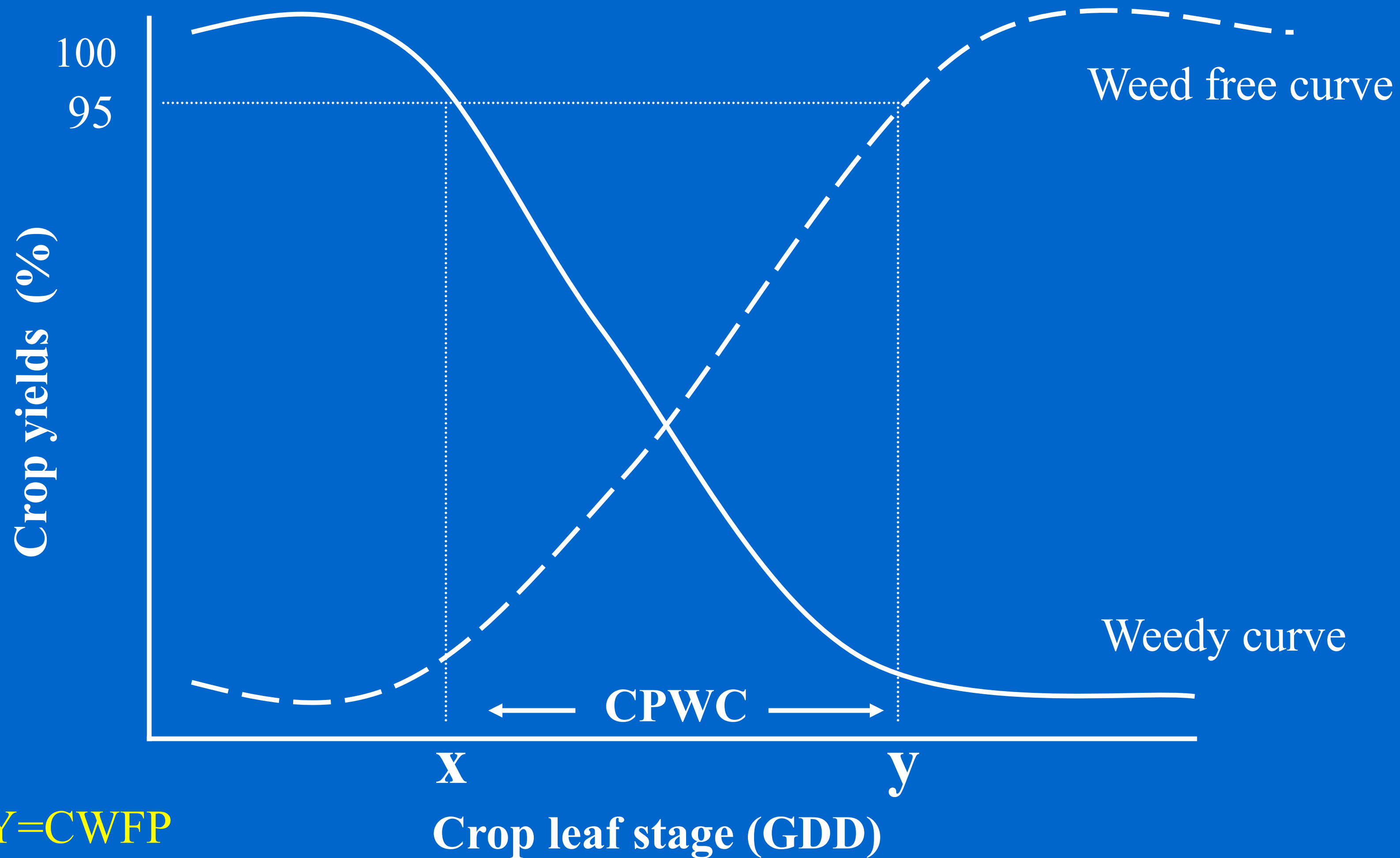


2nd set: Keep it weed free = ‘weed-free curve’

Utilized to determine the “ending point of CPWC” = “CWFP”



CPWC: from ‘x’ to ‘y’ leaf stage



X=CTWR … Y=CWFP

How to determine CPWC ?

- How many data points ? 6-10 ?
  - Must have Minimum of 5 (4+1) as 4 parameter curve was fit

- Min 6 -7 data points to fit each curve
  - 3 points around early part of season (vegetative stages)
    - Eg. in Corn (V1, V3, V5, V7); Eg. in Soybean (V1, V2, V3)
  - 3 points around later part of season (mostly reproductive stages)
    - Eg. in Corn (V12, V15, VT); Eg. in Soybean (R1, R2, R5)
  - 1 point around assumed crossing point of 2 curves
    - Eg. in Corn (V7, V9); Eg in Soybean (V5,V6)

Data to be collected (in every plot)

Basic data (which must be collected):

- Weather data
  - Daily Min & Max Temps, Rainfall, From crop emergence, for Calculating Thermal Time or GDD (X-Axis)
- Time of Weed and Crop Emergence
- Weed Species Composition at the time of weed removal
- Crop Yield and Yield Loss

Auxiliary Data, useful for data interpretation:

- Soil Moisture and Nutrient status
- Weed Species Density and Composition Few Times
- Weed and Crop Heights (1-2 weeks intervals)
- Weed Biomass @ time of removal
- Yield components

Statistics (Knezevic et al. 2002; 2015):

Anova in SAS or R (test treatment effects on variables (Yields, etc)

- Use PROC MIXED, not PROC GLM (not handle unbalanced or missing data)

Non-Linear Regressions: Treatment comparison of structured data in step-wise increments (eg. time intervals, dose, etc)

DO NOT USE Multiple-Comparison-Test: LSD, Duncan's test, etc

- can not separate treatment differences in structured data
- 10-20% difference can occur before detected by LSD

CPWC is determined according to "Acceptable Yield Loss" (AYL)

- AYL of 5% (most common) , but also 2.5% and 10% could shown

Statistics (Knezevic et al. 2002; Knezevic & Datta, 2015):

- The 4 parameter Log-Logistic curve (my preference)
  - Logistic (4), Gompert (3), Weibull (3-4) can be also used
  - Based on Goodness of the fit, or use one with the lowest RMS

Software for curve fitting: Does it really matter ?

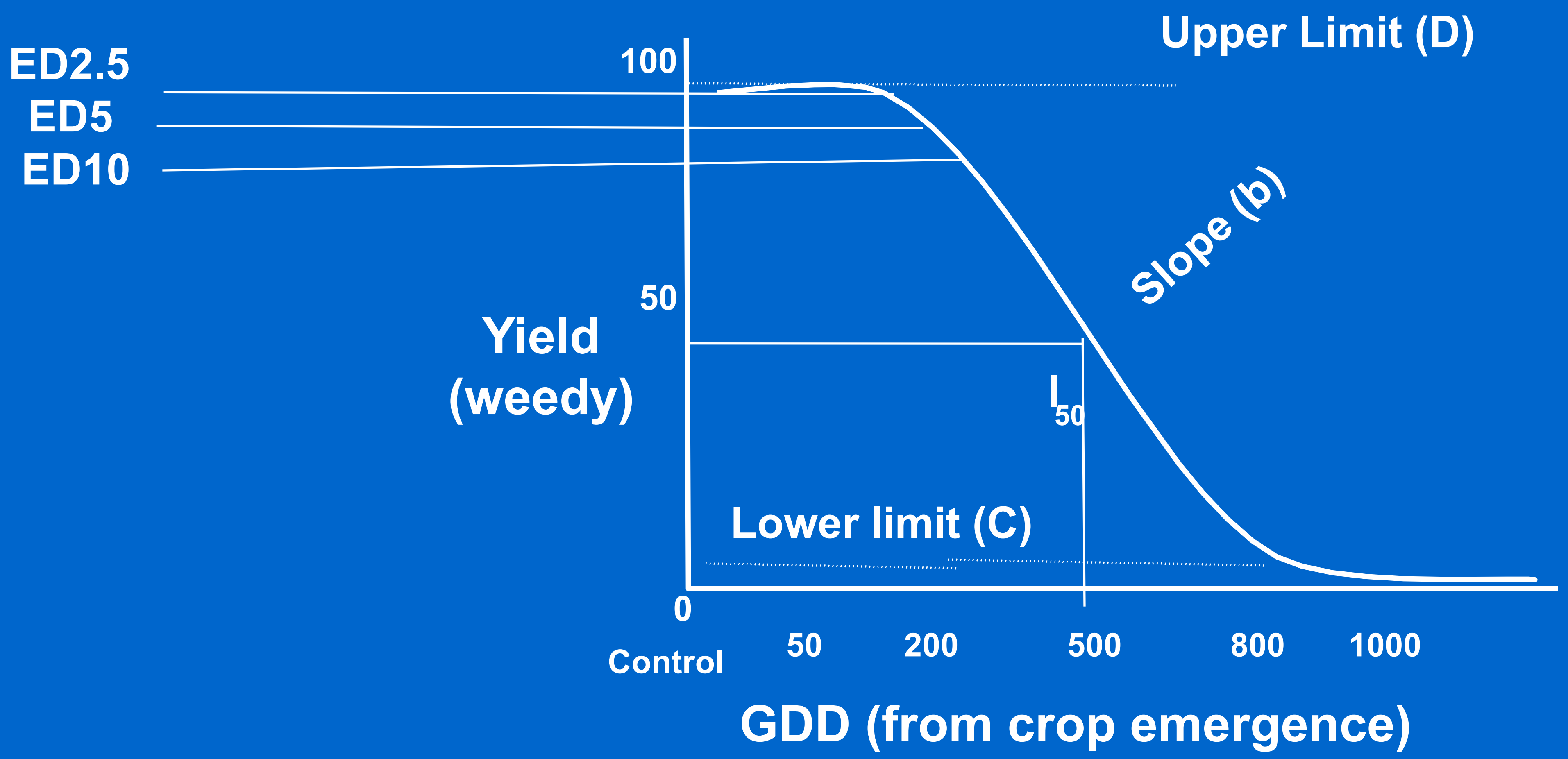
- SAS (Knezevic et al 2002;
- R & drc (Knezevic & Data, 2015, my preference)
- Others (Sigma-Plot, Excel, ?????_)

Important statistics: (output from ***summary*** command)

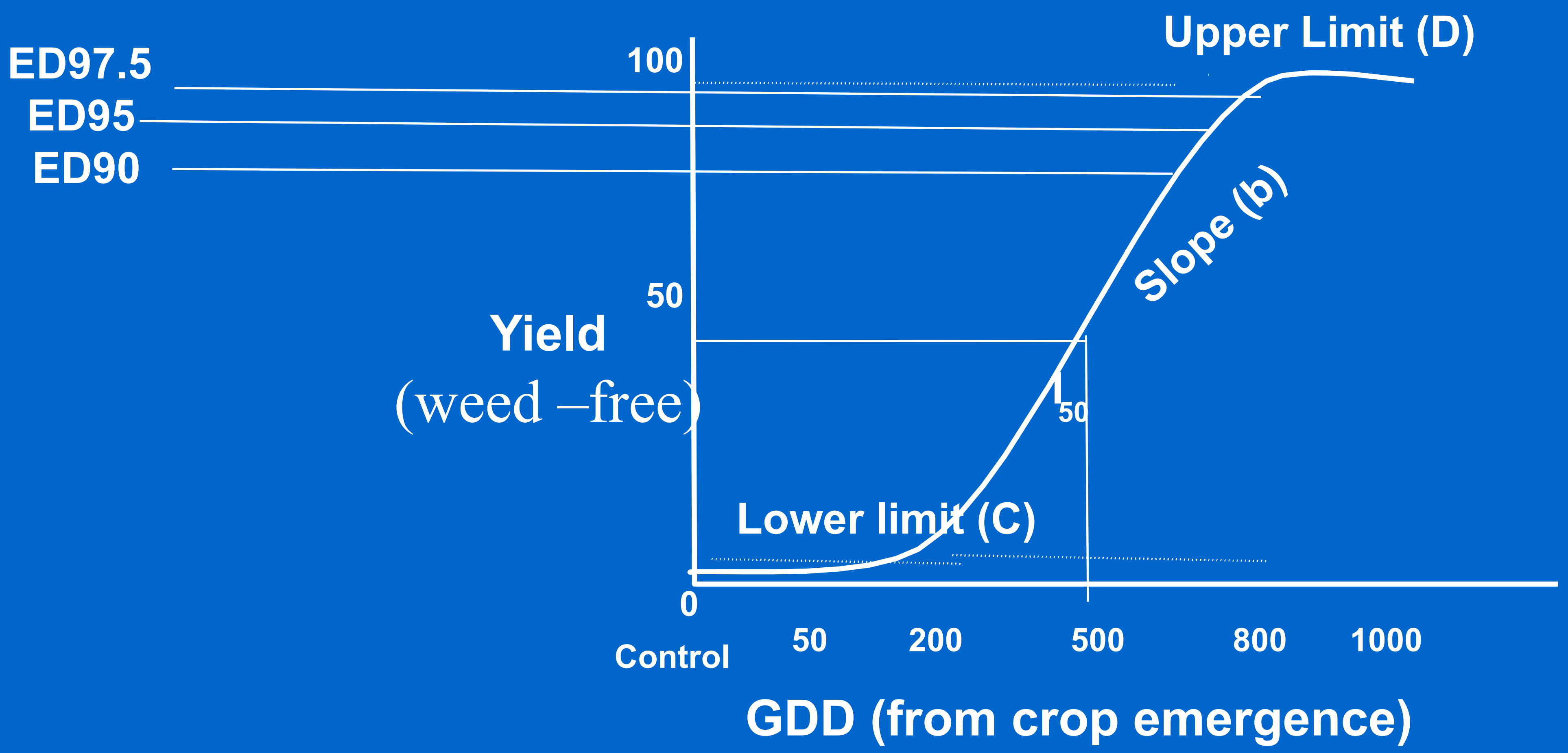
- Lack-of-fit Test for Model Significant (p-value >0.05)
- Curve parameters: **b** (slope), **c** (lower limit), **d** (upper limit), **e** (ed50) and their SE
  - Compare multiple curves: Compare all 4 parameters +/- Standard Errors

- ED values: ED2.5, ED5, ED10 for weedy curve; ED97.5, ED95, ED90 for weed-free curve

“Weedy Curve”: ED2.5, ED5, or ED10%

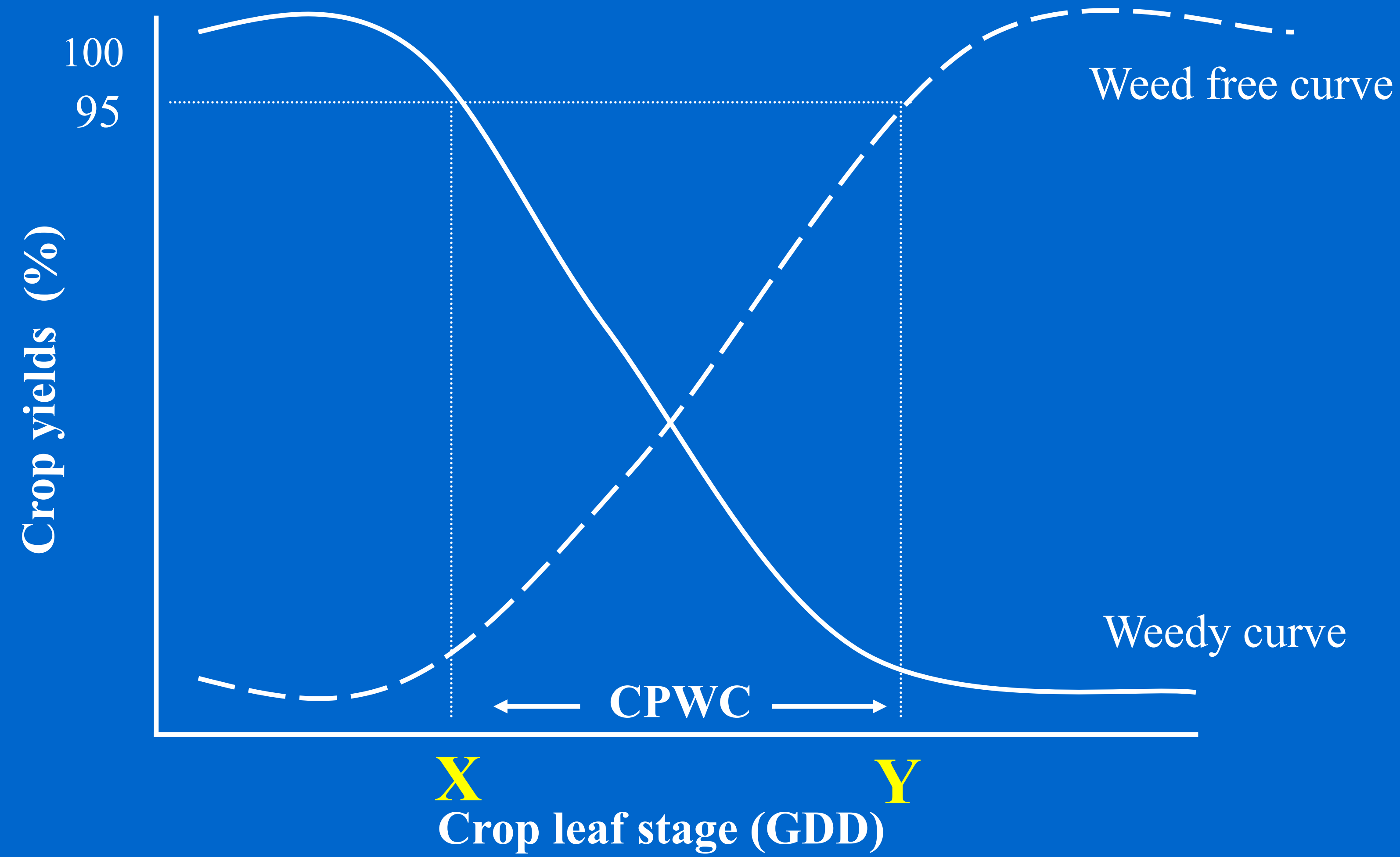


“Weed-free Curve”: ED97.5, ED95, or ED90%



CPWC: from ‘X’ to ‘Y’ leaf stage

ED5 = X = CTWR while ED95 = Y = CWFP



Examples of Manuscripts (see handouts)

Over 50 manuscripts were published in Weed Science, Weed Technology, Crop Protection ….. utilizing our recipe:

- Starting References:

- Knezevic & Datta, 2015: Critical Period of Weed Control; Revisiting Data Analysis. Weed Science, 63 (sp1):188-202

- Knezevic et al, 2002: Critical Period of Weed Control: The concept & data analysis. Weed Science, 50:773-786

Example study in corn: CPWC as influenced by N

CPWC in corn (Knezevic and Evans, 2000)

- Background information:
  - Years / Locations: 1999 & 2000 at Concord and Mead
  - Corn row spacing: 30 inches
  - Corn plant population: 24,000 / acre
  - N levels: 0, 55, 110 & 210 lbs / acre
  - Rainfall (April to September) :
    - Mead (25 inches in 1999, 16 inches in 2000)
    - Concord (16 inches in 1999, 11 inches in 2000)
  - Weed species composition:
    - At Concord: Waterhemp, Velvetleaf, Foxtails
    - At Mead: Smartweeds, Waterhemp, Velvetleaf, Foxtails

CPWC in corn as affected by N (Knezevic et al. 2002)

N level	**Corn growth stage**	
lbs / acre	**Leaf stage**	**Days after emerg.**
N=0	**V1 - V11**	**8 - 45**
N=55	**V3 - V10**	**10 - 42**
N=110	**V4 - V9**	**15 - 39**
N=210	**V6 - V9**	**20 - 39**

WEED-FREE
7.5” ROWS

WEED-FREE
15” ROWS

WEED-FREE
30” ROWS

CTWR in soybean (Knezevic et al. 2002)

Row spacing (inches)	Weeds must be removed by: soybean growth stage	DAE
7.5”	V3	19 days
15”	V2	15 days
30”	V1	9 days

V1 = 1st trifoliate
V2 = 2rd trifoliate
V3 = 3rd trifoliate
V4 = 4rd trifoliate

CTWR in Corn and Soybean:

Revisiting the Concept (Knezevic 2015-2020)

Why revisiting? …. Because of Weed Resistance

- "New": Glyphosate, PPO, HPPD, 2,4-D and "Old": Atrazine, ALS,
- Multiple resistance in weeds (4-5-6-way stacking)

- Need for IWM and diversification of weed control programs
  - PRE & POST-residual herbicides became critical

Can Herbicide Programs be compared based on CTWR?

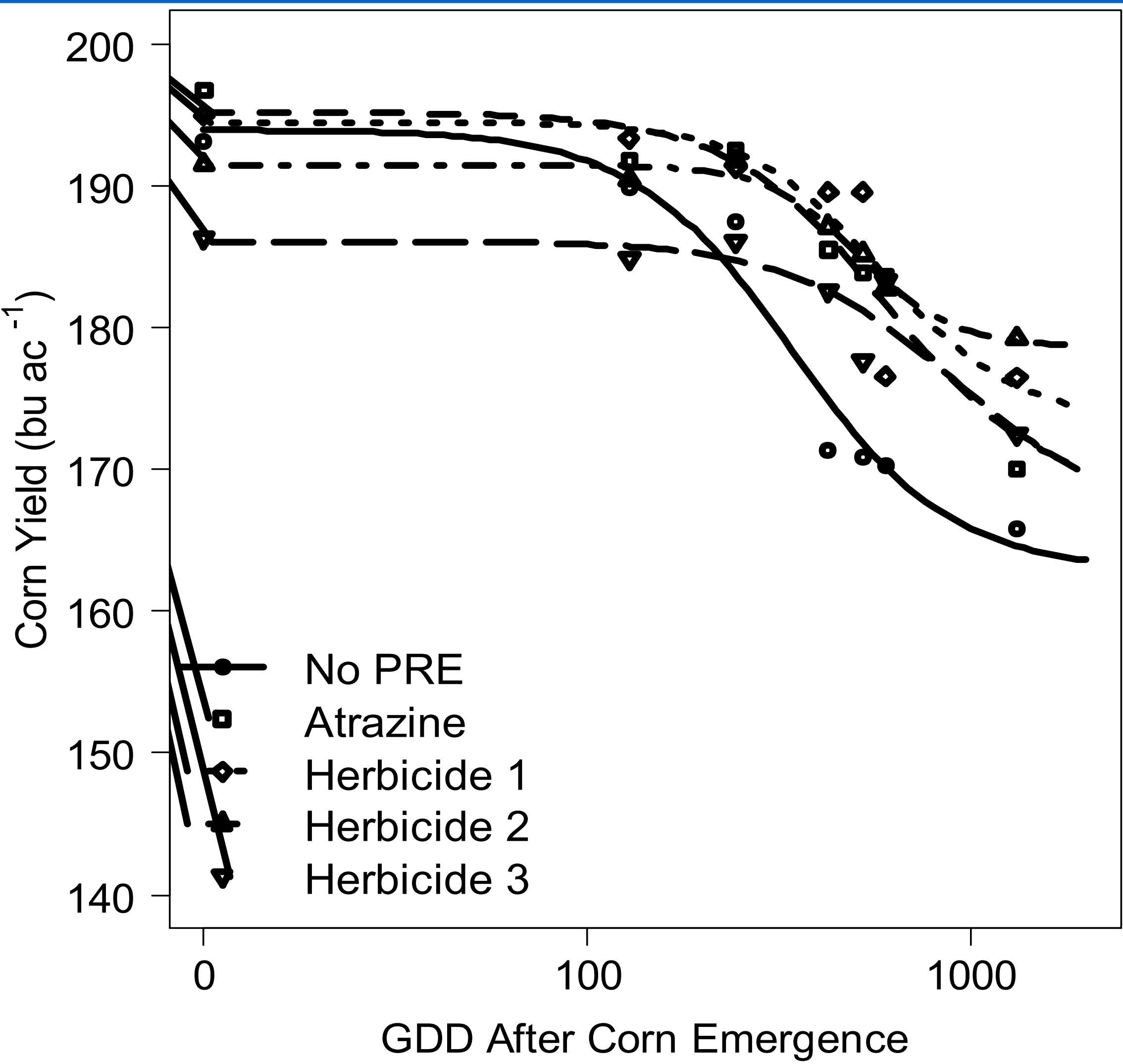
…Possibly …

Do PRE-Mixes of Multiple Actives = later CTWR ?

CTWR in Corn (Knezevic et al @ NCWSS-2017)

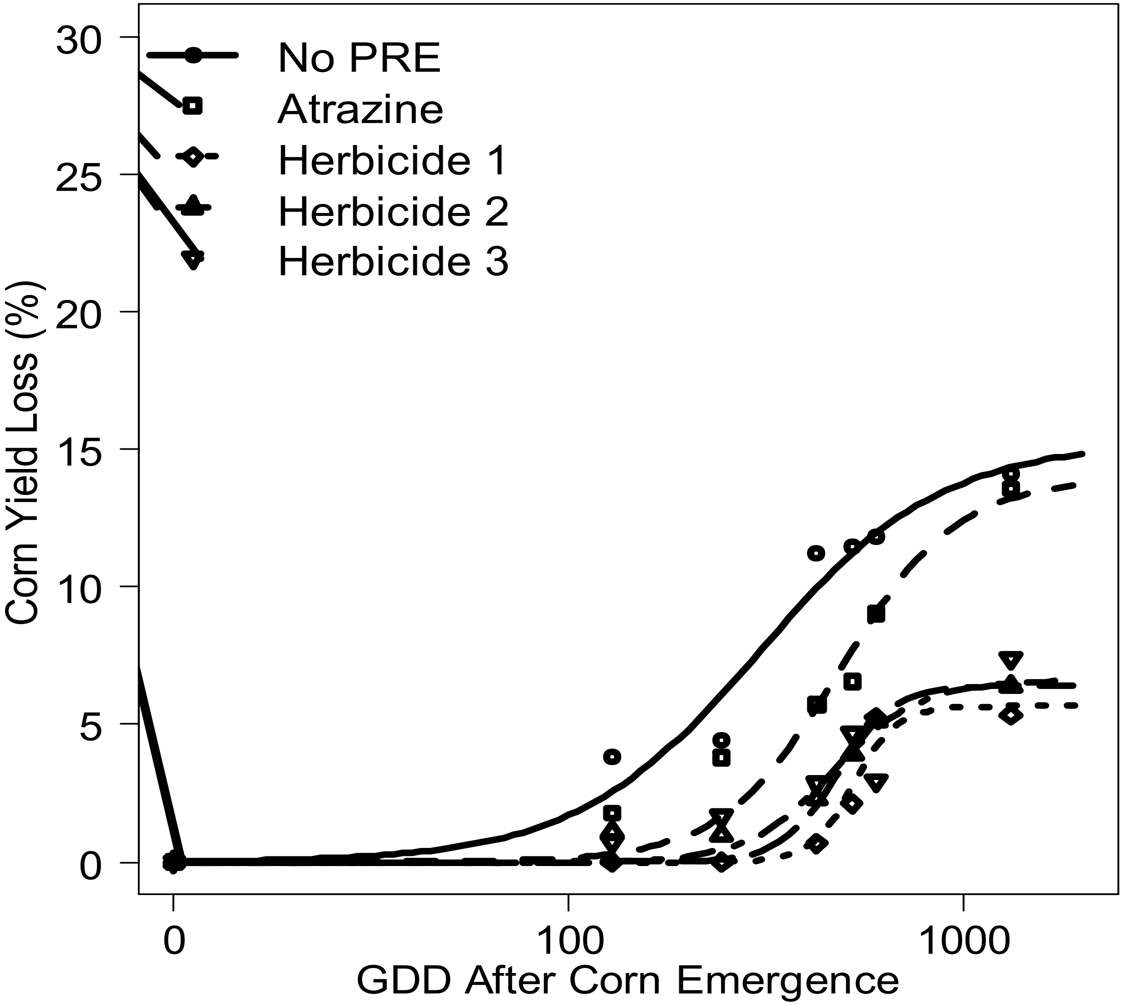
Treatment	GDD (SE)	DAE	Corn Growth Stage
NO PRE Herbicide	141 (5)	11	V3
Atrazine	205 (58)	16	V5
Verdict+Zidua	393 (25)	34	V10

CTWR in corn
as a tool to compare weed control programs



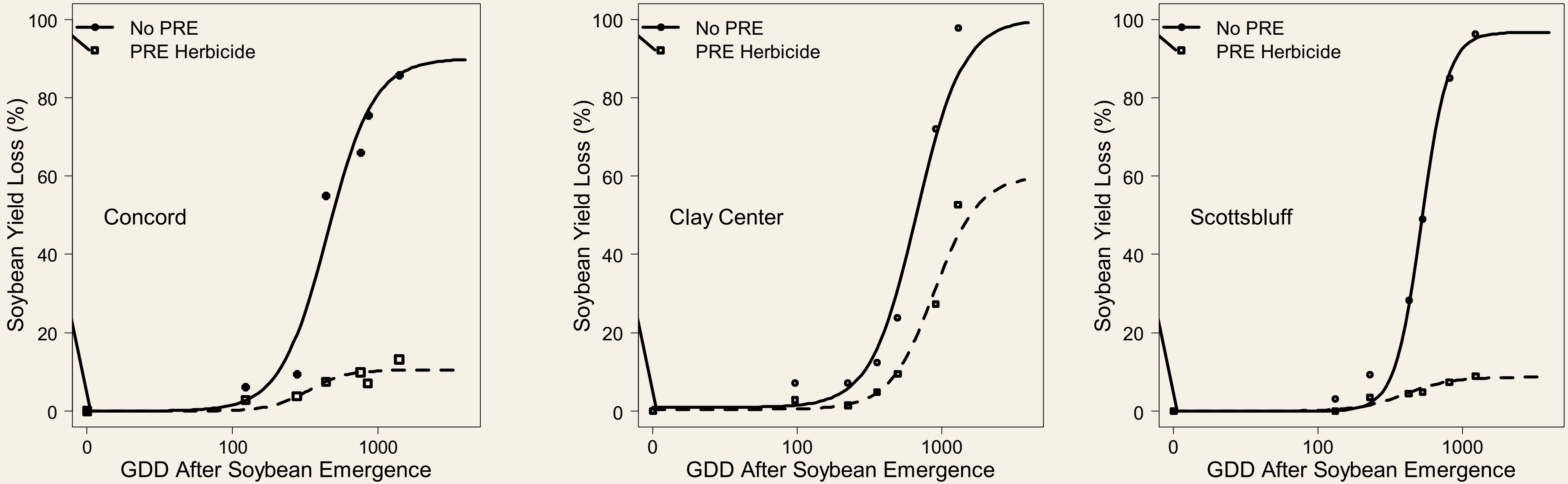
Treatment	GDD (SE)	Corn Stage
No PRE	113 (22.3)	V2
Atrazine	151 (13.4)	V4
Herbicide 1	416 (87.6)	V9
Herbicide 2	450 (27.4)	V10
Herbicide 3	435 (17.9)	V10

CTWR in corn
as a tool to compare various weed control programs



Treatment	GDD (SE)	Corn Stage
No PRE	113 (22.3)	V2
Atrazine	151 (13.4)	V4
Herbicide 1	416 (87.6)	V9
Herbicide 2	450 (27.4)	V10
Herbicide 3	435 (17.9)	V10

Critical time for weed removal as a potential tool for comparing herbicide programs in Soybean



Location		GDD (SE)	Stage
Concord	No PRE	156 (27)	V1
	Herbicide 1	504 (167)	V7
Clay Center	No PRE	228 (10)	V2
	Herbicide 2	533 (43)	R2
Scottsbluff	No PRE	213 (45.6)	V2
	Herbicide 3	481 (63.7)	R1

Critical Time for Weed Removal in Soybeans is Influenced by Soil-Applied Herbicides

N EXTENSION

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Introduction

❖From 2000-2010, the weed control in soybeans was based primarily on the POST applications of glyphosate based products, which caused the rapid increase in herbicide resistant weeds.

❖Therefore, there is a need to diversify weed control programs and use effective pre-emergent (PRE) herbicides with alternative modes of action (Stevan Knezevic-personal communications)

Objective

❑Evaluate the effects of soil-applied herbicides on critical time for weed removal (CTWR) in soybeans.

Material and Methods

Field experiments:

Concord, NE in 2015 and 2016.

➢**Planting day:** May 31, 2015 and June 14, 2016.

➢**Field operation:** No tillage.

➢**Treatment design:** Split-plot design with eight (2015) and four (2016) replications.

➢**Whole-plot:** No PRE herbicide and PRE herbicides:

▪*In 2015*: Authority assist® (sulfentrazone + imazethapyr, 280 g ai ha^{-1}).

▪*In 2016*: Authority assist® (sulfentrazone + imazethapyr, 210 and 420 g ai ha^{-1}).

➢**Split-plot:** POST application of labeled rate of glyphosate at 1st, 3rd, and 6th soybean trifoliate stage; 1142 g ae ha^{-1} at R2 and 867 g ae ha^{-1} at R5, and a weed free and a weedy treatment.

➢**Herbicide application:** CO_2-pressurized backpack sprayer.

Statistical analysis:

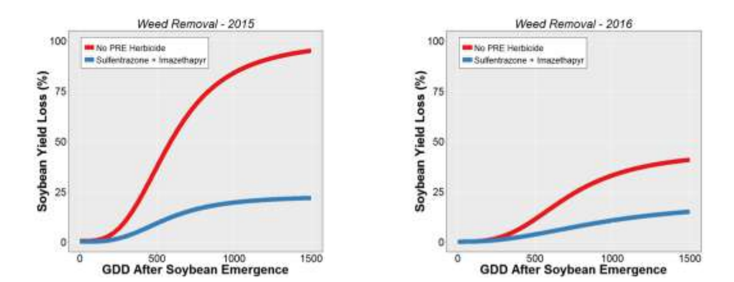
➢The F-test orvariance ratio model selection was performed to evaluate treatments between years using ANOVA function in R software.

➢Averaged weed species density was evaluated from 0.25 m^2 quadrats placed between the two soybean middle rows at each weed removal timing (Figure 2) .

➢Soybean yield loss (%) was regressed over growing degree days (GDD) with the three parameter log-logistic (l3) curve using drc package in R software.

▪*Regression parameters determined included* : slope, upper limit, and ED50.

Results



2016 (right) at Concord, NE.

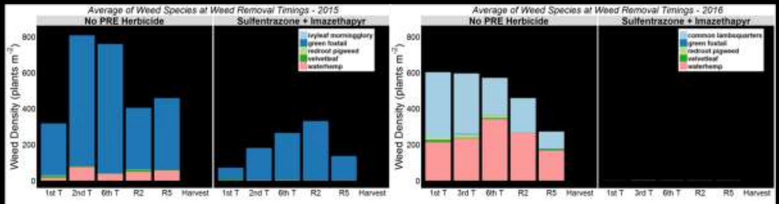


Figure 2. Averaged weed species density at each timing of weed removal with and without PRE herbicides in 2015 (left) and 2016 (right) at Concord, NE.

Table 2. CTWR based on 5% acceptable yield loss with or without PRE herbicide iat Concord, NE

2015	No PRE Herbicide	226 (6)	21	1st Trifoliate
	Sulfentrazone + imazethapyr	374 (59)	34	5th Trifoliate
2016	No PRE Herbicide	361 (73)	29	6th Trifoliate
	Sulfentrazone + imazethapyr	590 (139)	46	R1

yield losses were not as high as in 2015 (eg. 45% yield loss in plots without soil applied herbicides) due to late crop planting, which resulted in poor second weed flush and consequently lower competitive effect on soybean yield.

✓ Delayed CTWR in 2016 is the art-effect of the late crop planting, and the fact that early emerging weeds were controlled by cultivation during ield preparation for soybean planting (Williams II, 2006).

Conclusions

- The CTWR were clearly different between the two years, but they showed the benefit of using PRE herbicides.
- PRE herbcides controled early germinated weeds, which could also reduce the need for multiple applications of glyphosate;
- Use of soil applied herbicide will provide an additional mode of action for combating glyphosate resistant weeds.

Further studies: Include different PRE herbicides, locations, and crops.

Critical Time for Weed Removal in Corn as Influenced by PRE Herbicides

N EXTENSION

Ayse Nur Ulusoy, O. Adewale Osipitan, Jon E. Scott, Stevan Z. Knezevic, University of Nebraska-Lincoln, Concord, NE

Nebraska University of Lincoln

Introduction

❖There is need to diversify weed control program by using PRE herbicides in reducing multiple POST applications of glyphosate, and to provide additional mode of action for combating glyphosate resistant weeds in corn.

Objective

➢To evaluate the influence of PRE herbicides on critical time of weed removal (CTWR) in corn

Material and Methods

Field experiments:

▪**Location and year:** Experimental farm of Haskell Ag Lab, Concord, NE; 2017

▪**Field operation:** Conventional tillage

▪**Corn emergence day:** May 29, 2017

▪**Treatment design:** Split-plot design with 21 treatments in 4 replications

▪**Main-plot:** 3 herbicide regimes (No PRE and PRE application of two herbicides)
Acuron (atrazine + bicyclopyrone + mesotrione + s-metolachlor)
Atrazine

▪**Sub-plot:** 7 weed removal times (V3, V6, V9, V12, V15 corn growth stages, as well as weed free and weedy season long). Weeds were removed with glyphosate at label rate.

▪**Herbicide application:** CO2-pressurized backpack sprayer.

▪**Growth parameters:** Plant height, leaf area per plant, leaf area index and shoot dry weight were collected at corn tasseling (VT) growth stage

▪**Yield parameters:** These included number of ears per plant, number of kernels per ear, 100 kernel weight and grain yield.

Statistical analysis:

▪Corn yield loss (%) was regressed on growing degree days (GDD) using four parameter log-logistic (l4) curve in drc package of R software

Results

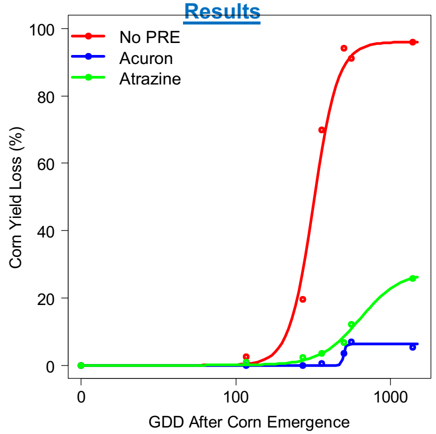


Table 1. CTWR based on 5% yield loss with and without PRE herbicide

Treatment	GDD (SE)[1]	DAE[2]	Corn Growth Stage
NO PRE Herbicide	185 (5)	12	V3
Atrazine	268 (157)	21	V6
Acuron	478 (112)	40	V12

➢ Based on 5% acceptable yield loss threshold, the CTWR ranged from 185 to 478 GDD which corresponds to V4 to V12 corn growth stages, depending on the herbicide regime.

➢ Without PRE herbicide, CTWR started at V4 growth stage.

➢ PRE application of Atrazine delayed the CTWR to V6 growth stage, while PRE application of Acuron provided the longest delay, up to V12 growth stage; coinciding with corn canopy cover.

Corn without PRE herbicides

Weed removal at V6

Weed removal at V15

Corn with PRE application of Atrazine

Weed removal at V15

Weedy season-long

Conclusions

❖PRE herbicides delayed the need for POST application of glyphosate, it also provided alternative mode of action for weed control in corn.

Extending Critical Time of Weed Removal in Dicamba-Tolerant Soybean with Residual Herbicides

Stevan Z. Knezevic, Pavle Pavlovic, O. Adewale Osipitan, Jon Scott and Ryan Rapp
University of Nebraska-Lincoln – Haskell Ag Lab – Concord, NE and Monsanto Company, Mitchell, SD

Introduction

➢Dicamba-tolerant soybeans were developed to provide an alternative herbicide mode of action with the use of dicamba for weed control in soybean and to manage herbicide-resistant broadleaf weed species.
➢Typically residual herbicides control early emerging weeds, thus they could potentially extend the critical time of weed removal (CTWR).

Objective

To evaluate how residual herbicides could extend the critical time of weed removal (CTWR) in dicamba-tolerant soybean

Material and Methods

Field experiments:

➢**Location and Year:** Concord, NE in 2018.
➢**Field operation:** Conventional tillage.
➢**Treatment design:** Split-plot design of 28 treatments with four replicates.
➢**Main-plot:** Four herbicide regimes
✓**NP**- No PRE with POST Roundup PowerMax® (glyphosate)
✓**WXR**- PRE Warrant® (acetochlor) and XtendiMax® (dicamba) with POST Roundup PowerMax®
✓**WXRX**- PRE Warrant® and XtendiMax® with POST Roundup PowerMax® and XtendiMax®
✓**WuWRX**- PRE Warrant Ultra® (acetochlor plus fomesafen) with POST Warrant®, Roundup PowerMax® and XtendiMax®

➢**Sub-plot:** Total of seven weed removal times (V1, V3, V6, R2 and R5 soybean growth stages, as well as weed-free and weedy treatments).
➢**Herbicide application:** CO_2-pressurized backpack sprayer.
➢**Yield Parameters:** Soybean yield collected at physiological maturity

Statistical analysis:

Soybean yields of each herbicide regimes were regressed against growing degree days (GDD) after soybean emergence using a four parameter log-logistic

Soybean at V6 Stage

Soybean at R2 stage

Results

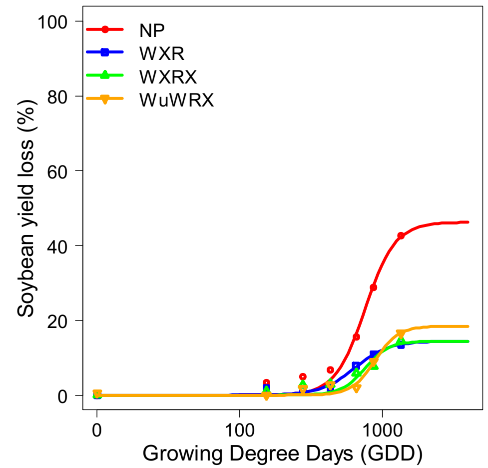


Figure 1. Soybean yield loss with and without residual herbicides

Table1. Critical time of weed removal (CTWR) based on 5% yield loss.

Herbicide Regimes	GDD (SE)[1]	DAE[2]	Soybean Stage
NP	214 (28.7)	17	V2
WXR	317 (51.8)	28	V4
WXRX	511 (53.7)	39	V6
WuWRX	619 (84.1)	48	R2

[1]GDD, growing degree days; SE, standard error. [2]Days after soybean emergence.

➢ The CTWR (based on 5% acceptable yield loss) started at V2 soybean stage in plots without residual herbicide application.
➢ The application of residual herbicides extended the CTWR to V4, V6 or R2 depending on the type of residual herbicide applied
➢ The greatest extension of CTWR (R2) was achieved with the PRE application of Warant Ultra® followed-by POST application of Roundup PowerMax® tank-mixed with XtendiMax®
➢ The least extension of CTWR (V4) was provided by PRE application of Warant® and XtendiMax® followed-by POST application of Roundup PowerMax®.

Conclusion

In general, it can be concluded that application of residual herbicides in dicamba-tolerant soybean clearly extended the CTWR.

Take home message

- Critical Period of Weed Control is useful tool
  - CPWC is applicable for both No-Till & Conventional-Till systems

- CTWR can be delayed 20-30 days by using PRE herbicides
- Practical significance:
  - Reduce production costs (spray when is needed)
  - Reduce input of chemicals into environment

Statistics : Learn R and drc package …. Life will be GOOD ..