

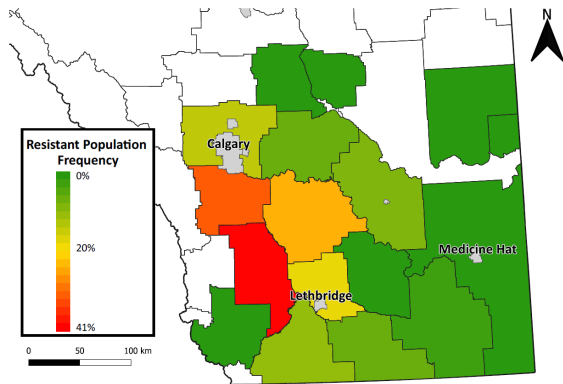


Charles.Geddes@agr.gc.ca
X @charlesmgeddes

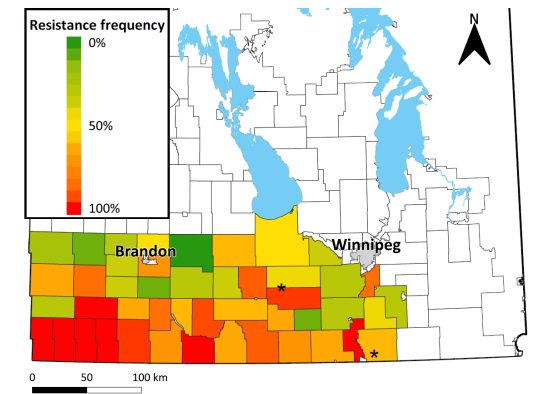
Wild World of Weeds Workshop
January 16, 2024

Keynote Address – part 2

Multiple herbicide-resistant kochia – a Canadian perspective, eh...



Charles Geddes
Research Scientist
Weed Ecology and Cropping Systems
Agriculture and Agri-Food Canada
Lethbridge Research and Development Centre



Outline

1. HR kochia monitoring
2. PPO inhibitor (Group 14)-
resistant kochia in Canada
3. Kochia integrated management



Kochia biology

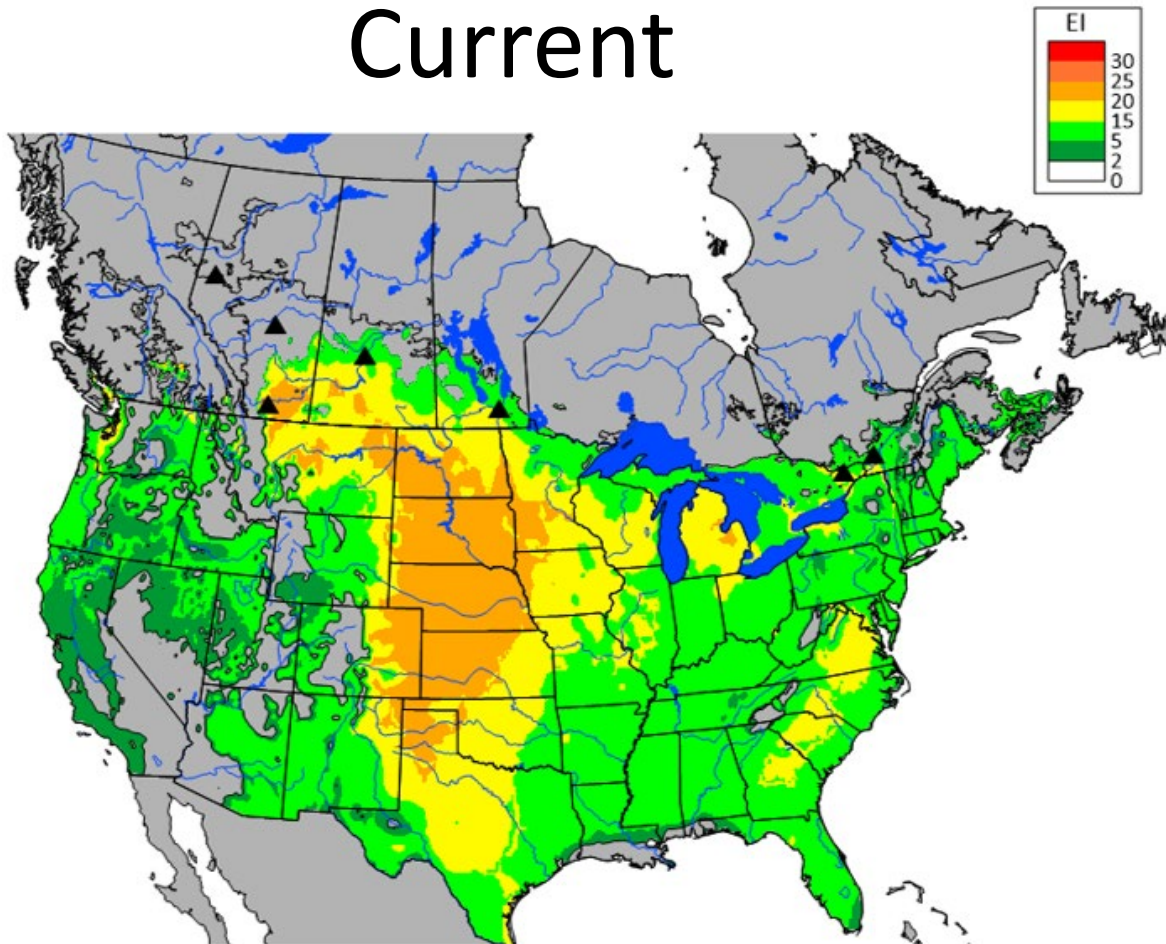
- First weed to emerge in spring
- Genetically diverse
- Phenotypic plasticity
- Up to 100,000 seeds plant⁻¹
- Tumbleweed
- Protogynous flowering
- High seedbank turnover
- Drought, saline & cold tolerant



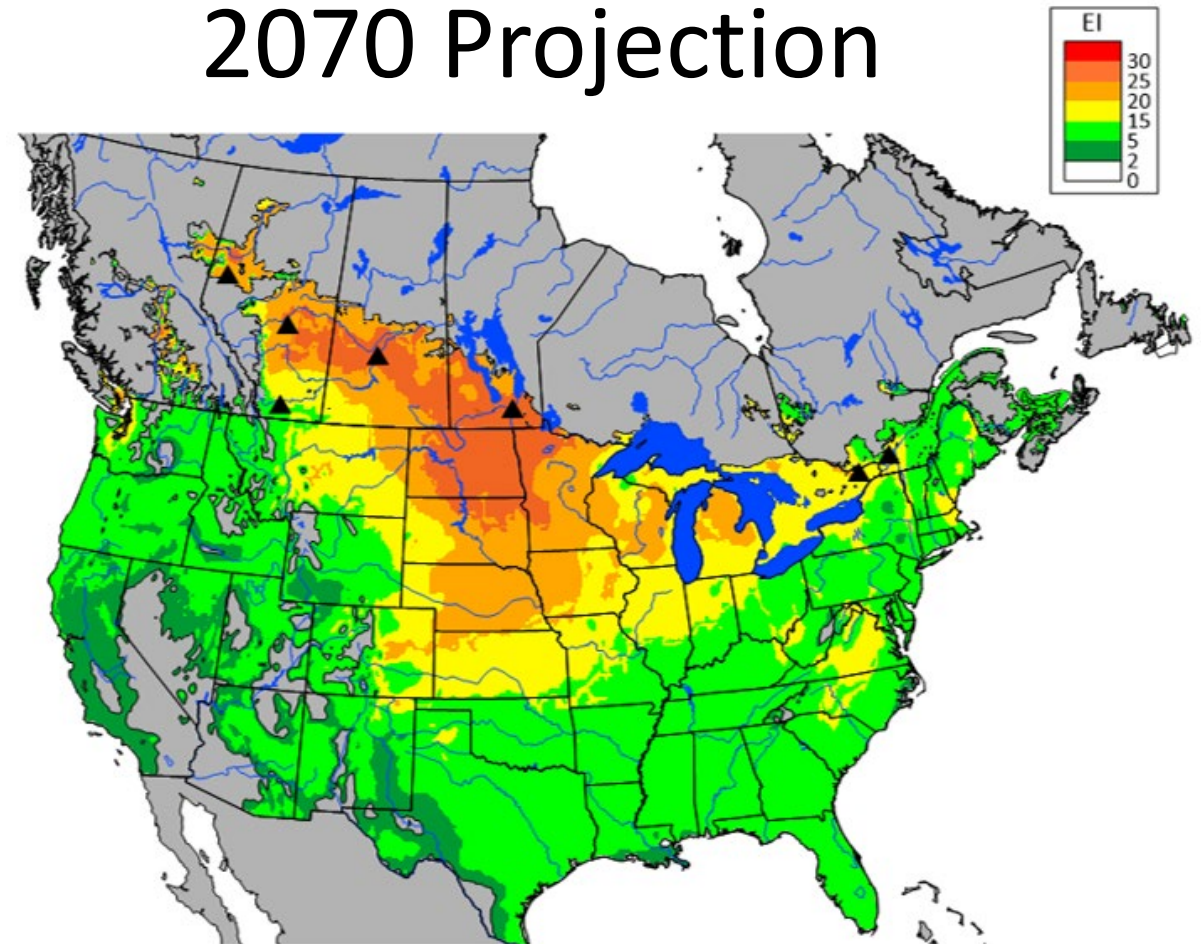
Kochia (*Bassia scoparia*)



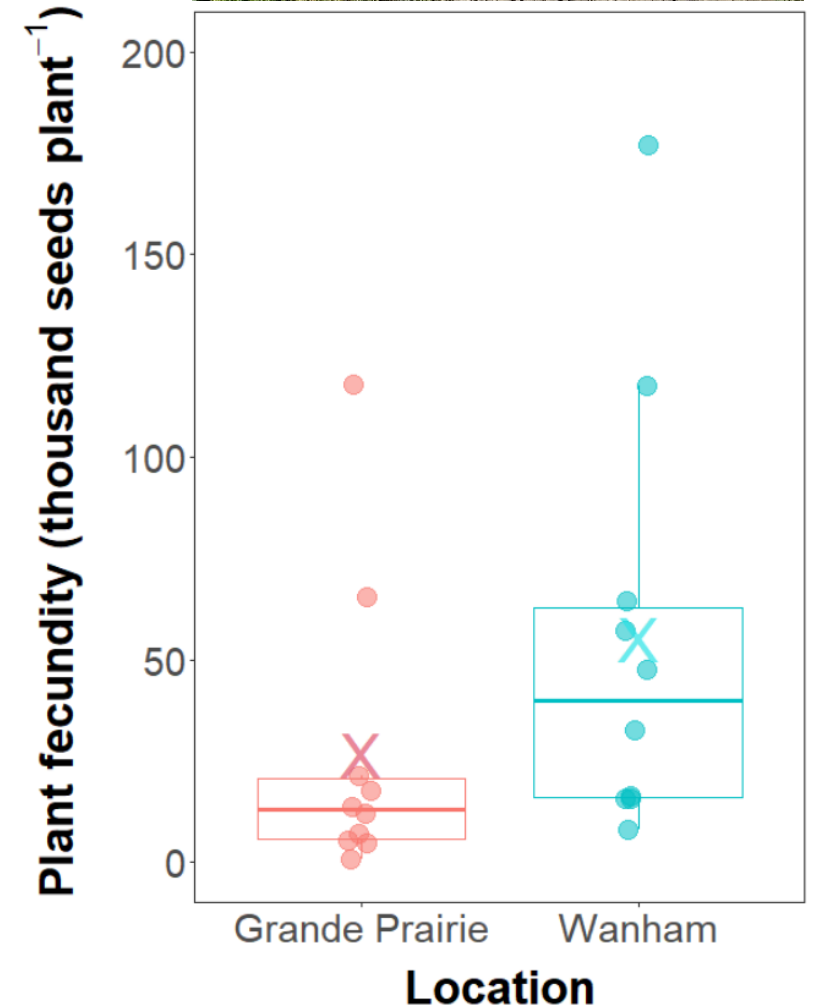
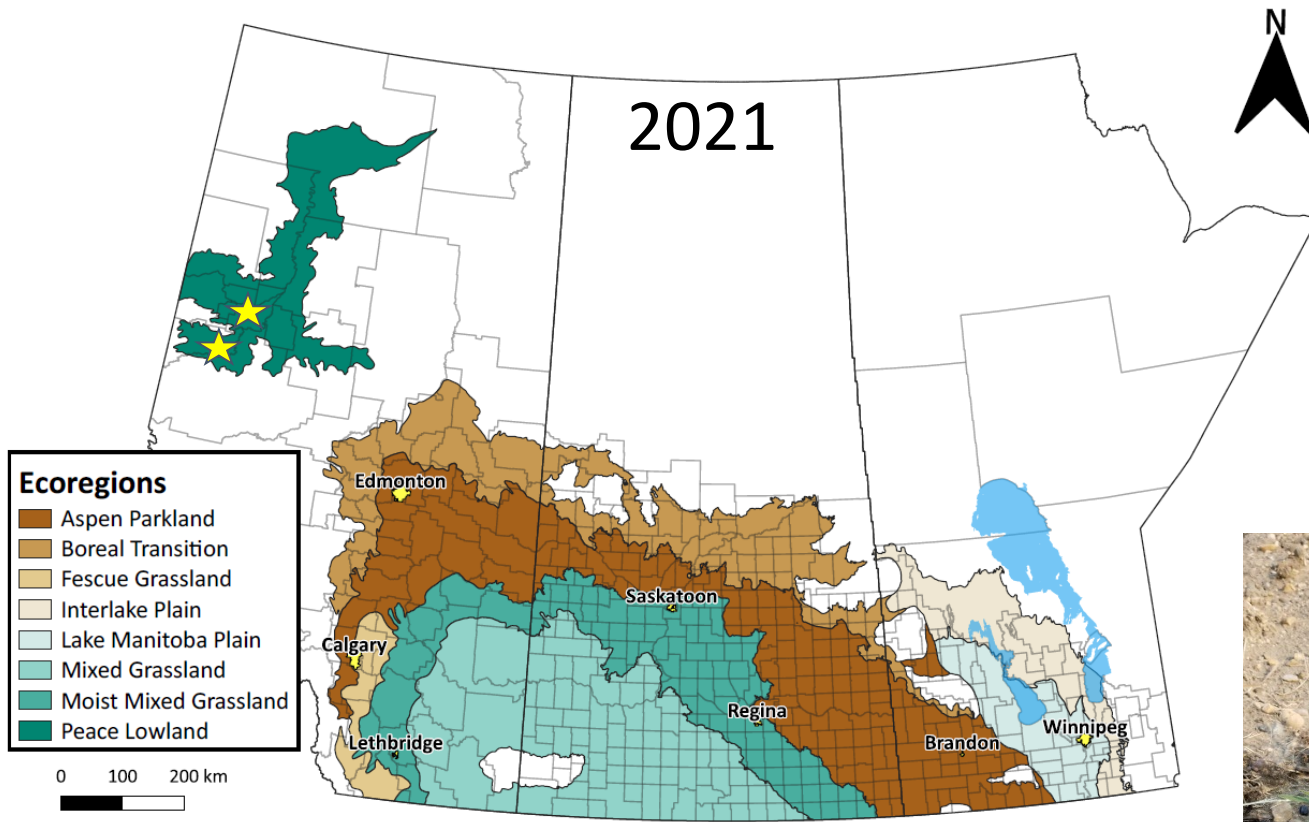
Current



2070 Projection



Kochia in Peace Country

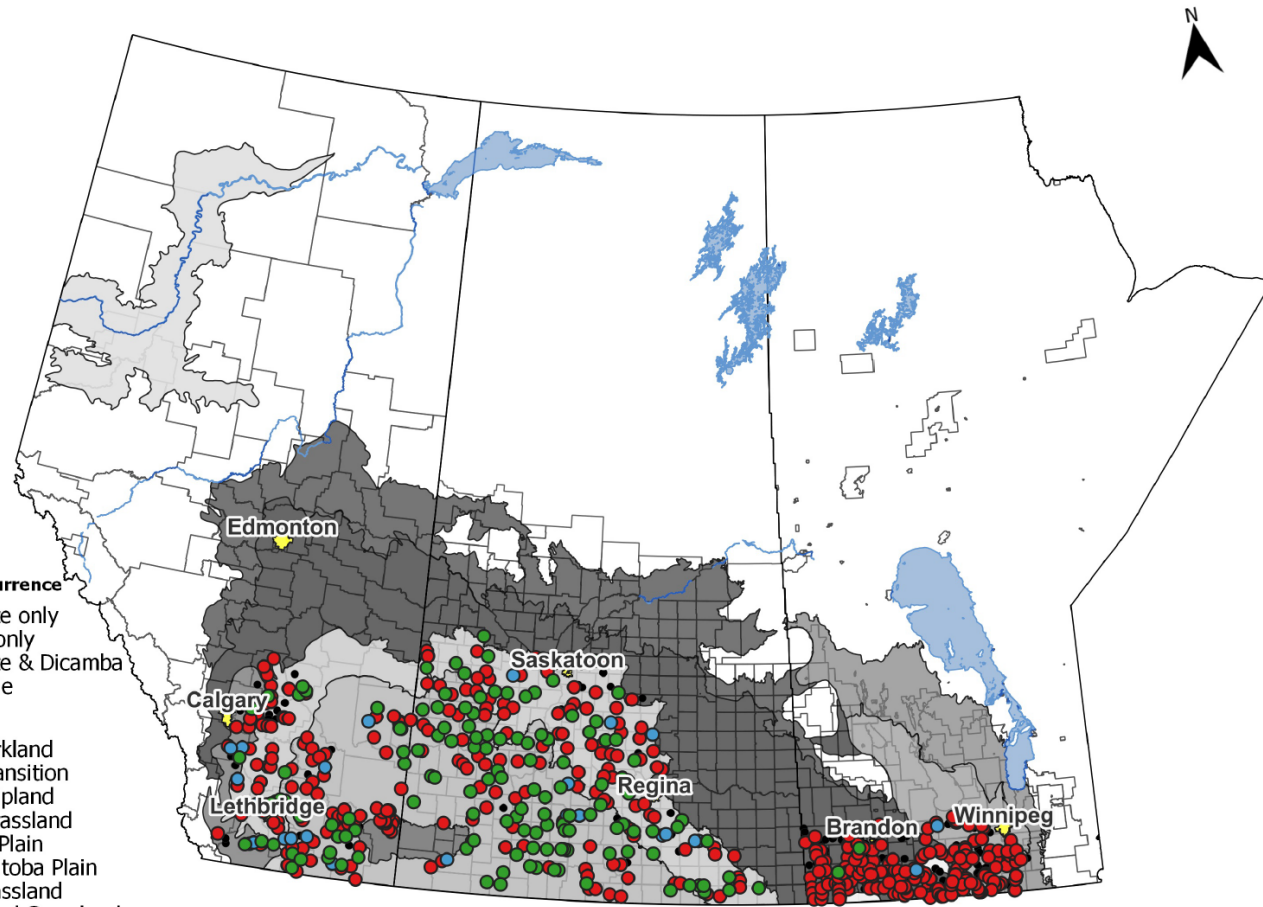


History of first confirmations for HR kochia

Table 1. Confirmation timeline of herbicide-resistant kochia in Canada and the United States.

SOA	Group	First confirmation	
		United States	Canada
PS II inhibitors	Group 5	1976 – KS	
ALS inhibitors	Group 2	1987 – ND & KS	1988 – MB & SK
Auxin mimics	Group 4	1994 – MT	2015 – SK
EPSPS inhibitor	Group 9	2007 – KS	2011 – AB
PPO inhibitors	Group 14	2022 – ND	2021 – SK

Glyphosate and dicamba resistance



Herbicide-resistant kochia (2018-2021)

Ecotype	No. samples	%
Susceptible	185	22
Glyphosate-resistant	468	54
Dicamba-resistant	38	4
Glyphosate + dicamba-resistant	169	20
Overall	860	78

- Resistance occurrence**
- Glyphosate only
 - Dicamba only
 - Glyphosate & Dicamba
 - Susceptible
- Ecoregions**
- Aspen Parkland
 - Boreal Transition
 - Cypress Upland
 - Fescue Grassland
 - Interlake Plain
 - Lake Manitoba Plain
 - Mixed Grassland
 - Moist Mixed Grassland
 - Peace Lowland
 - Southwest Manitoba Uplands

Herbicide-resistant kochia in MB – 2018

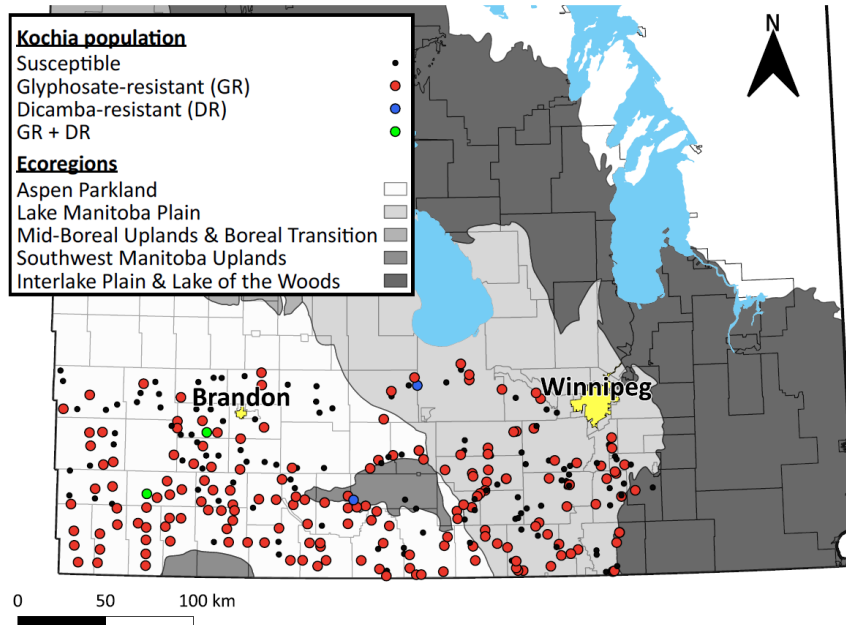
459



SHORT COMMUNICATION

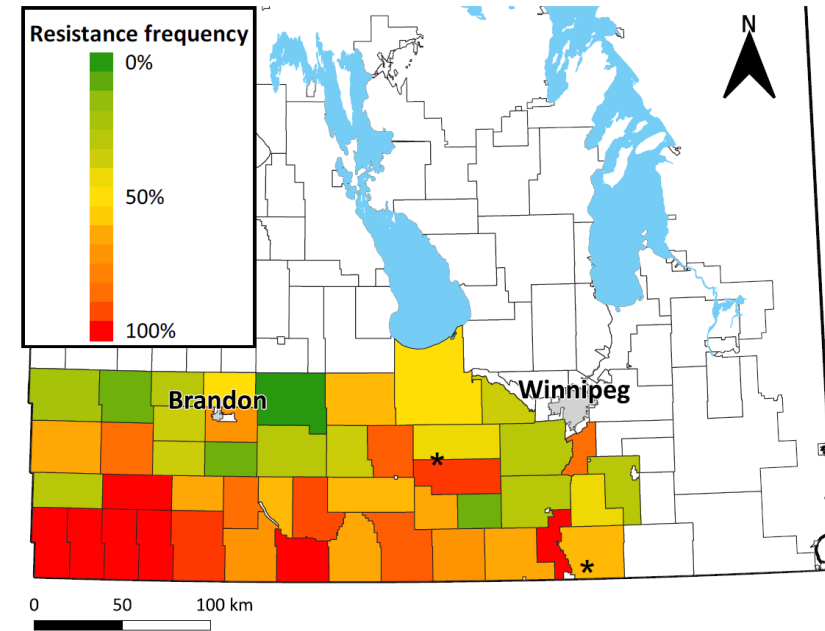
Rapid increase in glyphosate resistance and confirmation of dicamba-resistant kochia (*Bassia scoparia*) in Manitoba

Charles M. Geddes, Mattea M. Pittman, Robert H. Gulden, Tammy Jones, Julia Y. Leeson, Shaun M. Sharpe, Scott W. Shirriff, and Hugh J. Beckie



58% GR

1% DR



Herbicide-resistant kochia in SK – 2019

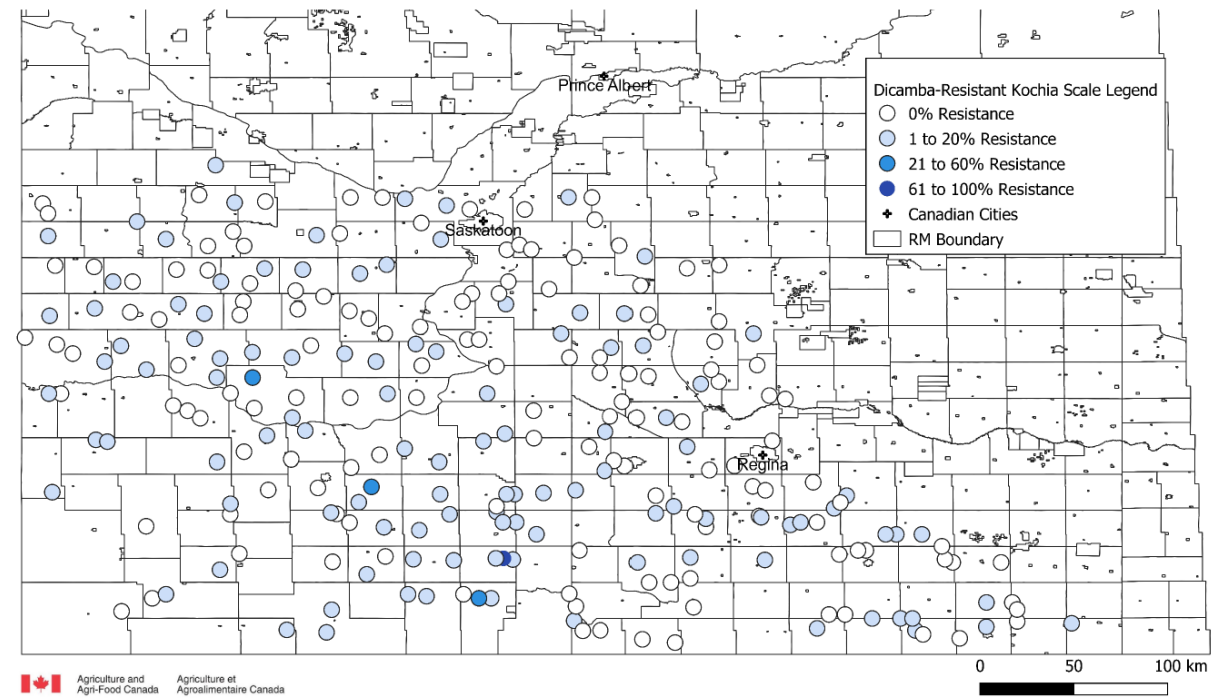
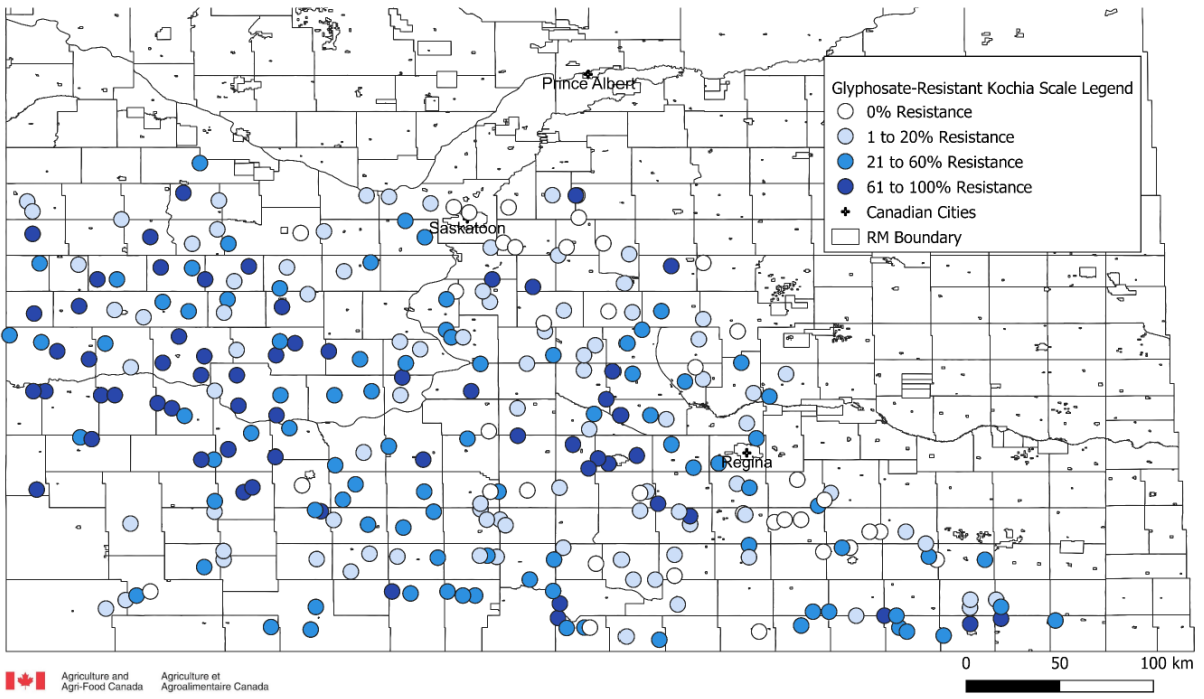
Survey of glyphosate- and dicamba-resistant kochia (*Bassia scoparia*) in Saskatchewan

Shaun M. Sharpe^a, Julia Y. Leeson^a, Charles M. Geddes^b, Christian J. Willenborg^c, and Hugh J. Beckie^a

^aSaskatoon Research and Development Centre, Agriculture and Agri-Food Canada, 107 Science Place, Saskatoon, SK S7N 0X2, Canada; ^bLethbridge Research and Development Centre, Agriculture and Agri-Food Canada, 5403 1st Avenue South, Lethbridge, AB T1J 4B1, Canada; ^cCollege of Agriculture and Bioresources, University of Saskatchewan, 51 Campus Drive, Saskatoon, SK S7N 5A8, Canada

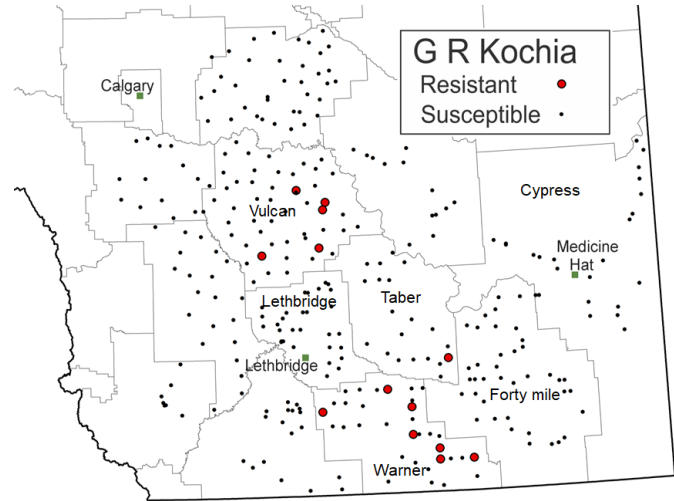
87% GR

45% DR



Herbicide-resistant kochia in AB

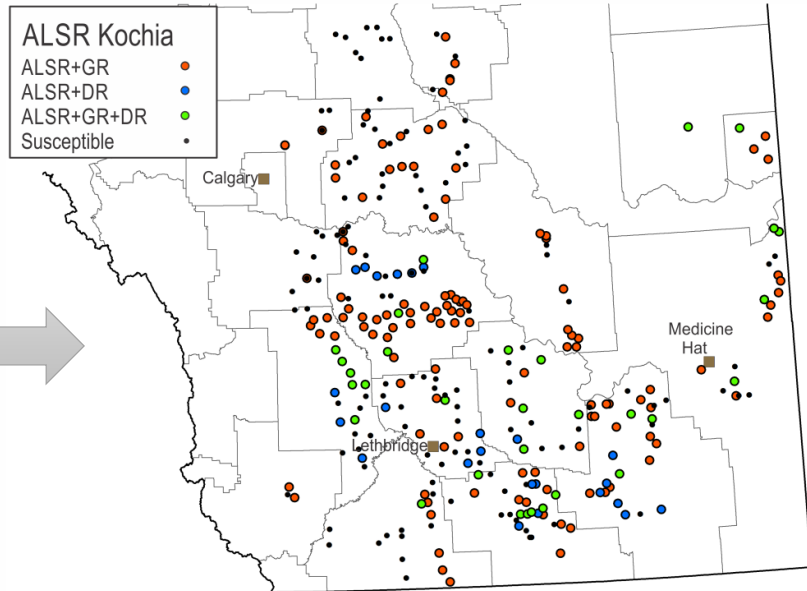
Hall *et al.*, 2014



2012 Survey

- 100% ALSR
- 4% GR
- 0% DR

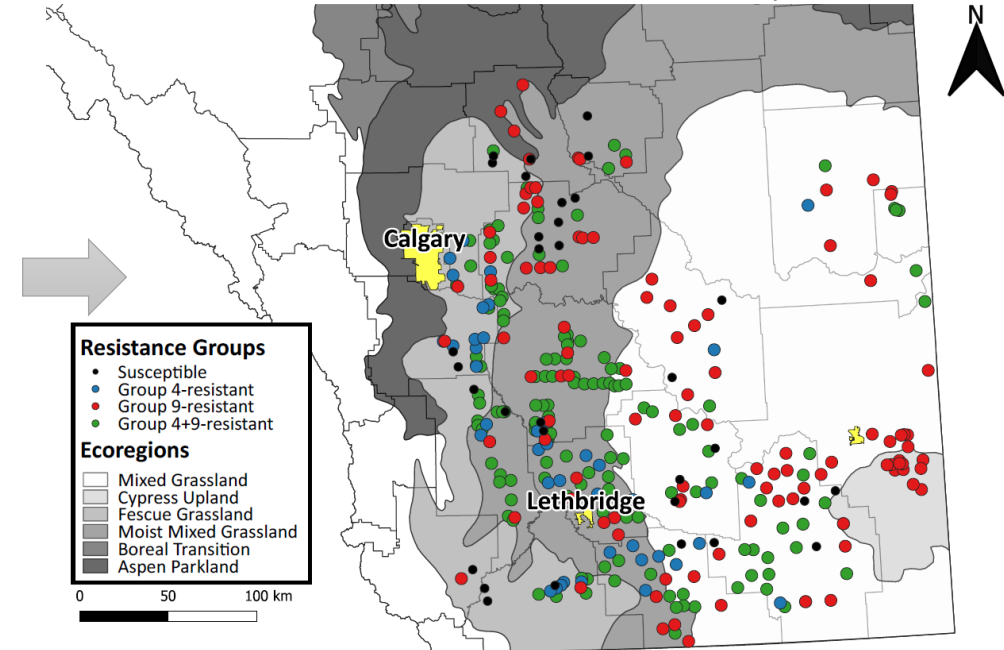
Beckie *et al.*, 2019; Geddes *et al.*, 2022a



2017 Survey

- 100% ALSR
- 50% GR
- 18% DR
- 13% FR

Geddes *et al.*, 2023

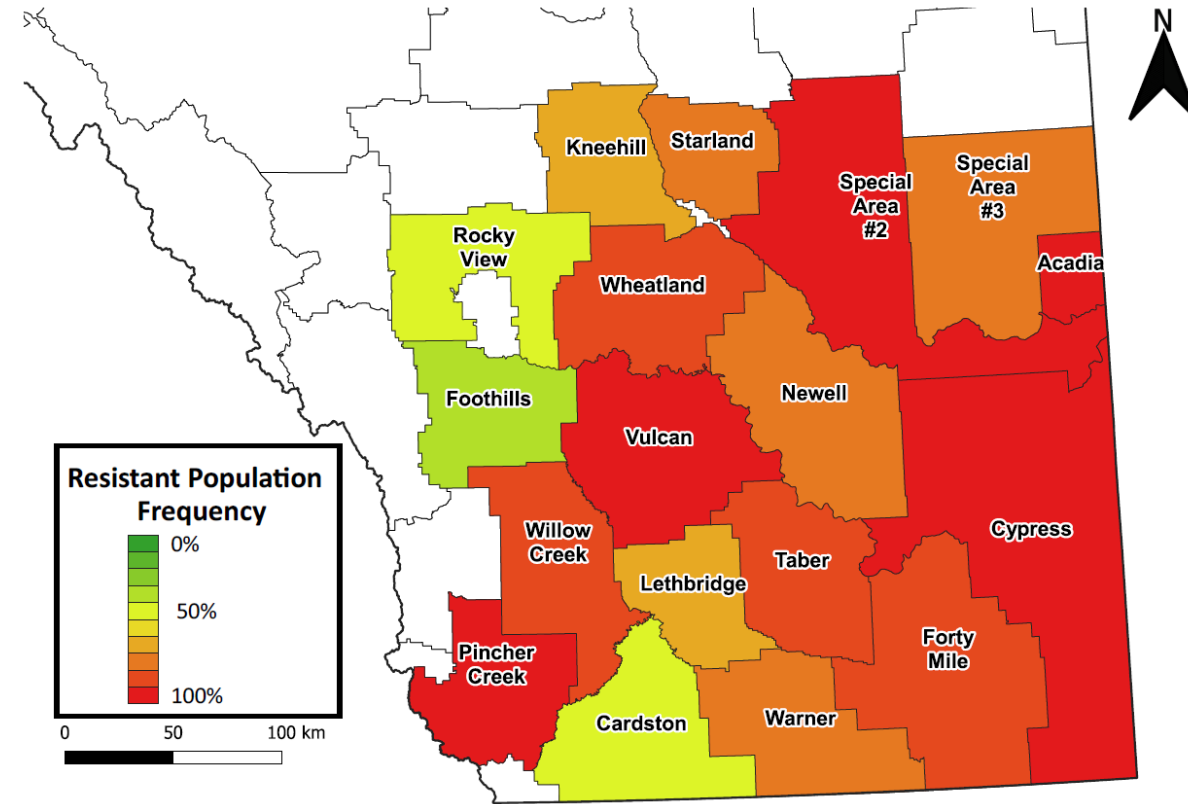
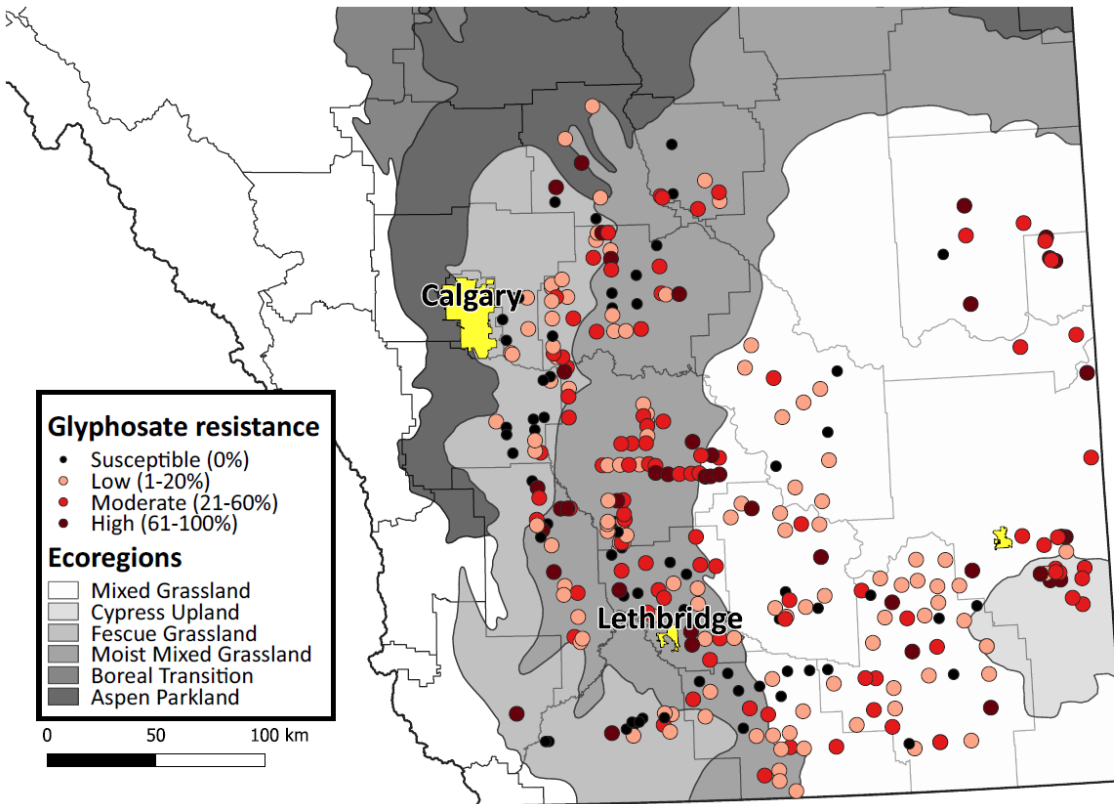


2021 Survey

- 100% ALSR (assumed)
- 78% GR
- 28% DR
- 44% FR

Glyphosate-resistant kochia in AB – 2021

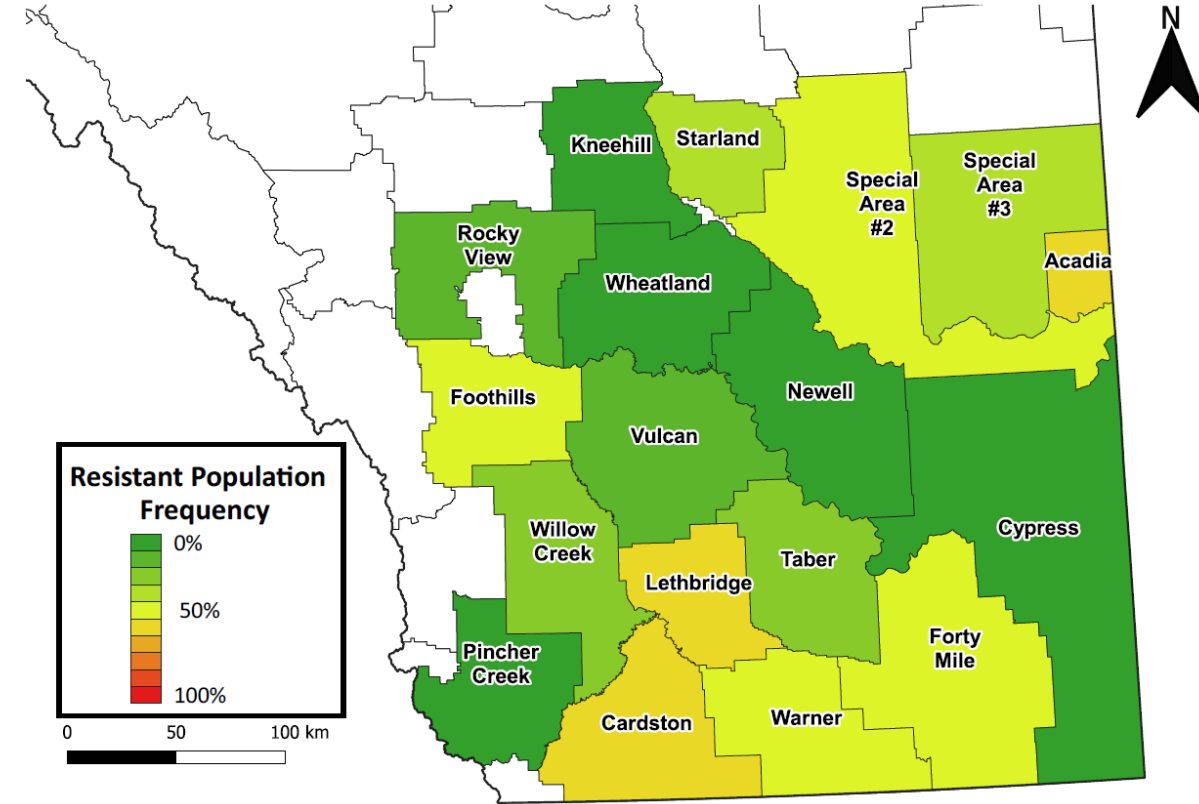
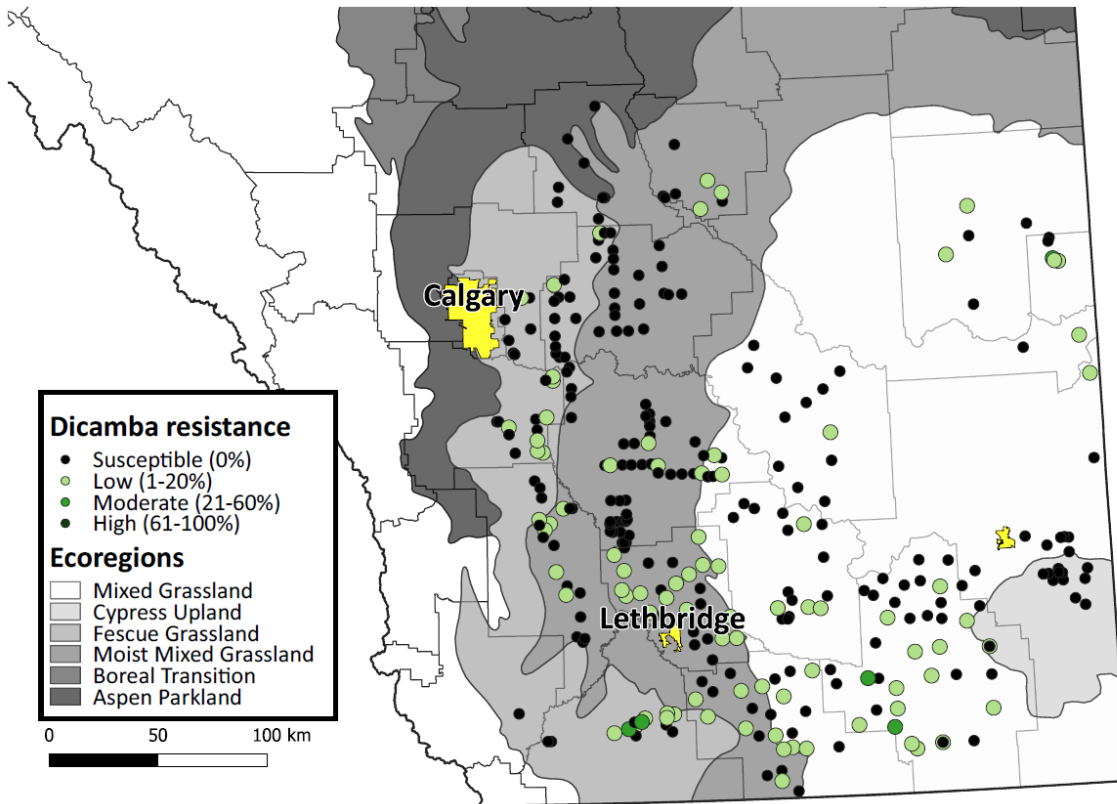
78% GR



Geddes *et al.*, 2023

Dicamba-resistant kochia in AB – 2021

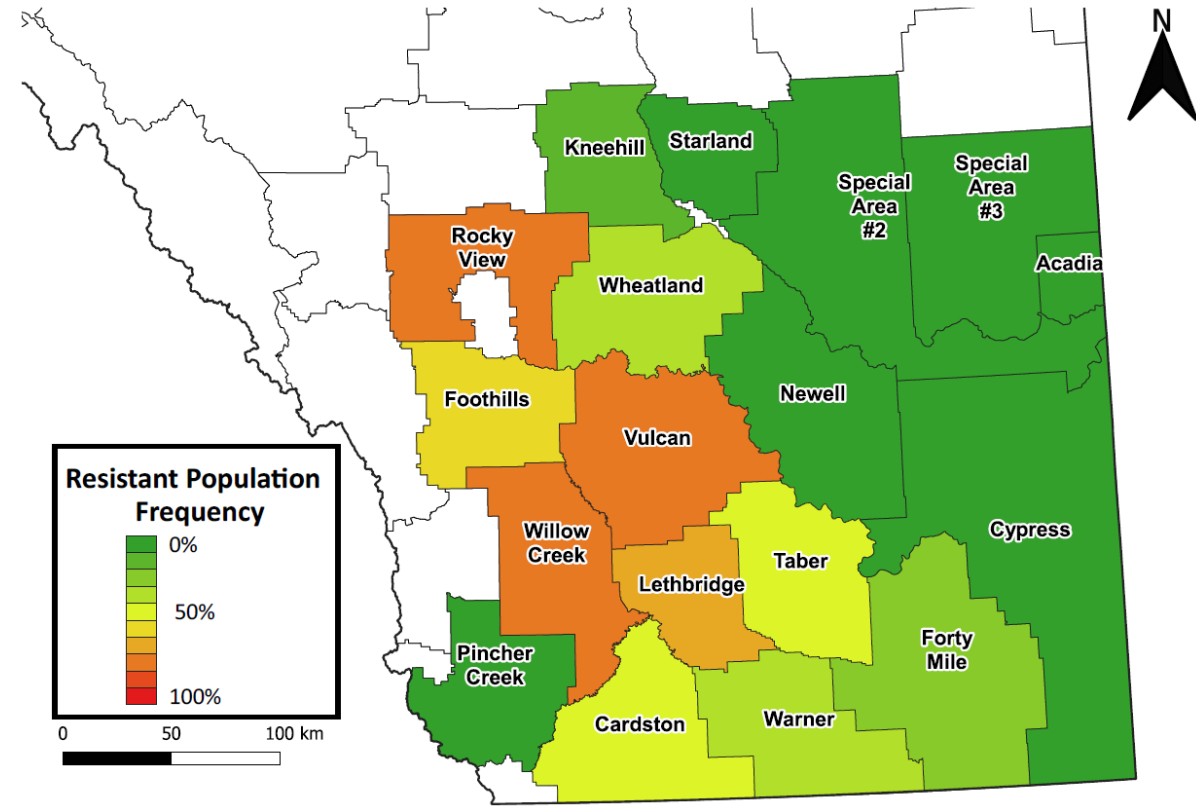
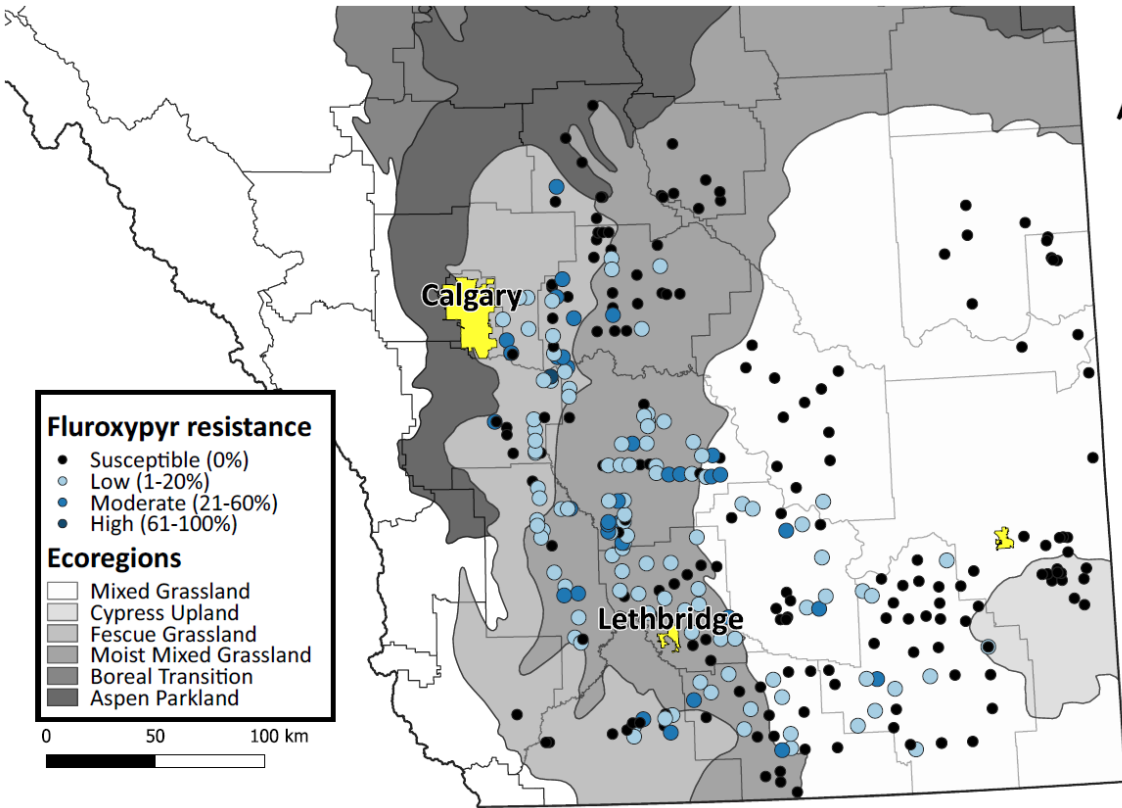
28% DR



Geddes *et al.*, 2023

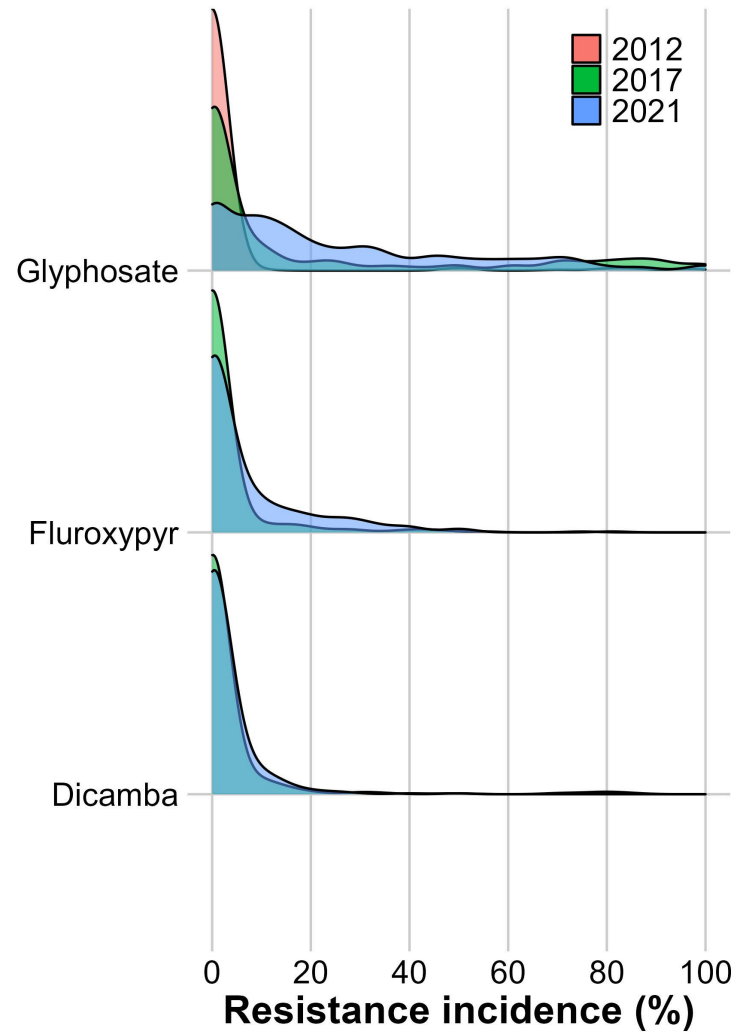
Fluroxypyr-resistant kochia in AB – 2021

44% FR



Geddes *et al.*, 2023

Alberta in 2021 ($n = 314$)

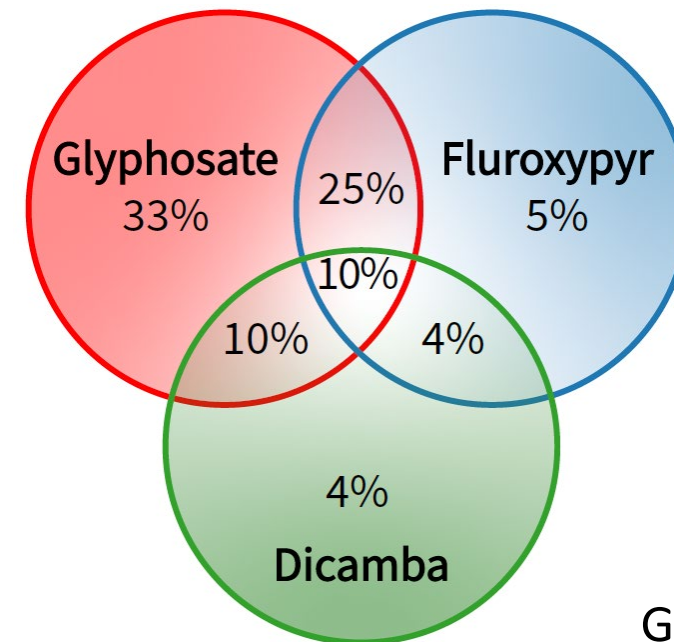


Increasing frequency of multiple herbicide-resistant kochia (*Bassia scoparia*) in Alberta

Charles M. Geddes^a, Mattea M. Pittman^a, Linda M. Hall^b, A. Keith Topinka^b, Shaun M. Sharpe^c, Julia Y. Leeson^c, and Hugh J. Beckie^c

^aLethbridge Research and Development Centre, Agriculture and Agri-Food Canada, Lethbridge, AB T1J 4B1, Canada; ^bDepartment of Agricultural Food & Nutritional Science, University of Alberta, Edmonton, AB T6G 2P5, Canada; ^cSaskatoon Research and Development Centre, Agriculture and Agri-Food Canada, Saskatoon, SK S7N 0X2, Canada

Corresponding author: Charles M. Geddes (email: Charles.Geddes@agr.gc.ca)



Geddes *et al.*, 2023

Mixing auxin mimics



Susceptible

FR

DR/FR

Dicamba:Fluroxypyr

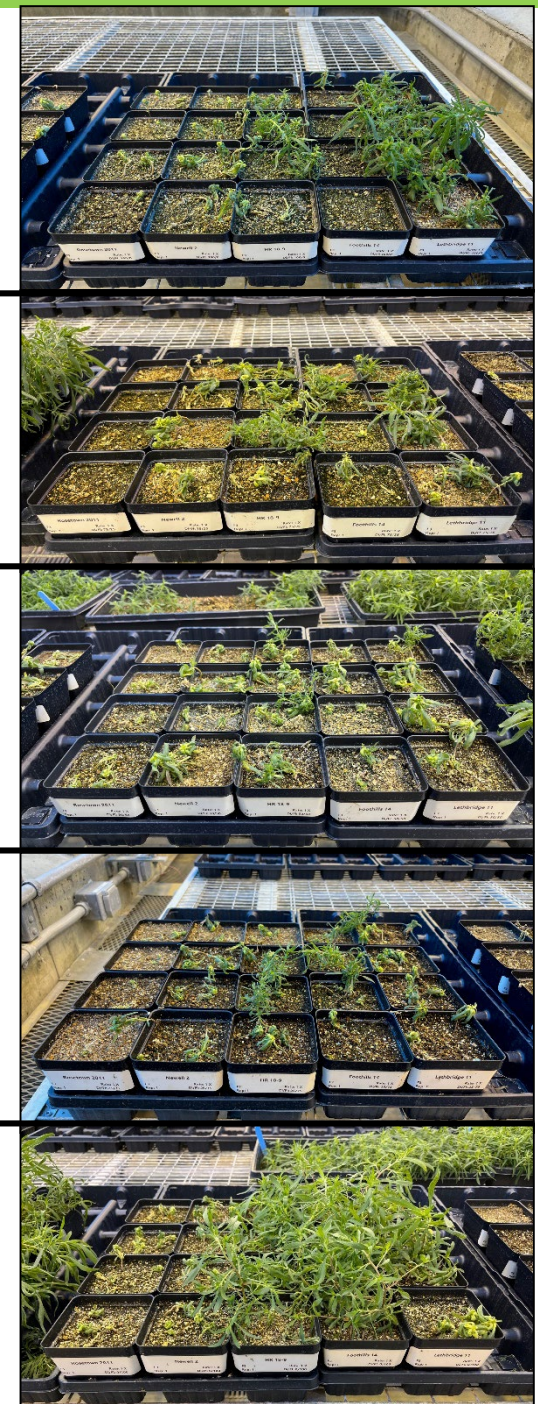
100:0

75:25

50:50

25:75

0:100



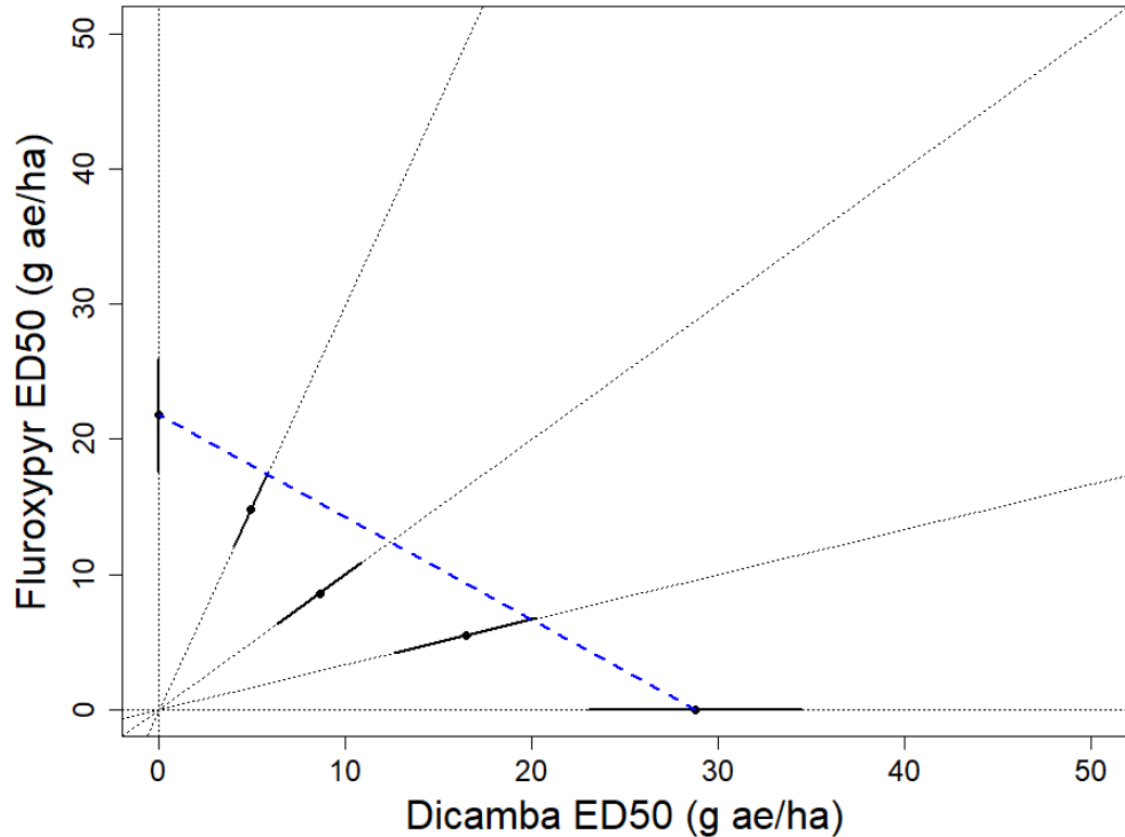
140 g ae ha⁻¹

Preliminary

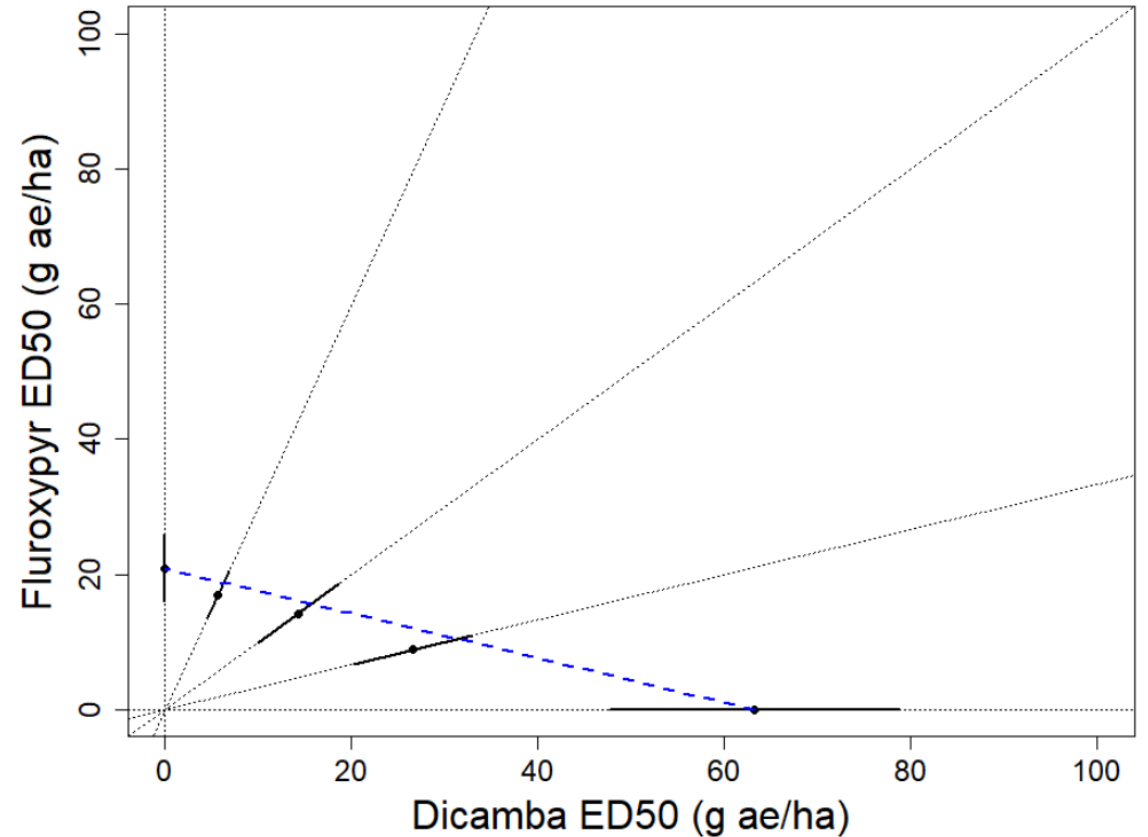
Interaction between auxin mimics

Preliminary

Auxinic herbicide-susceptible kochia



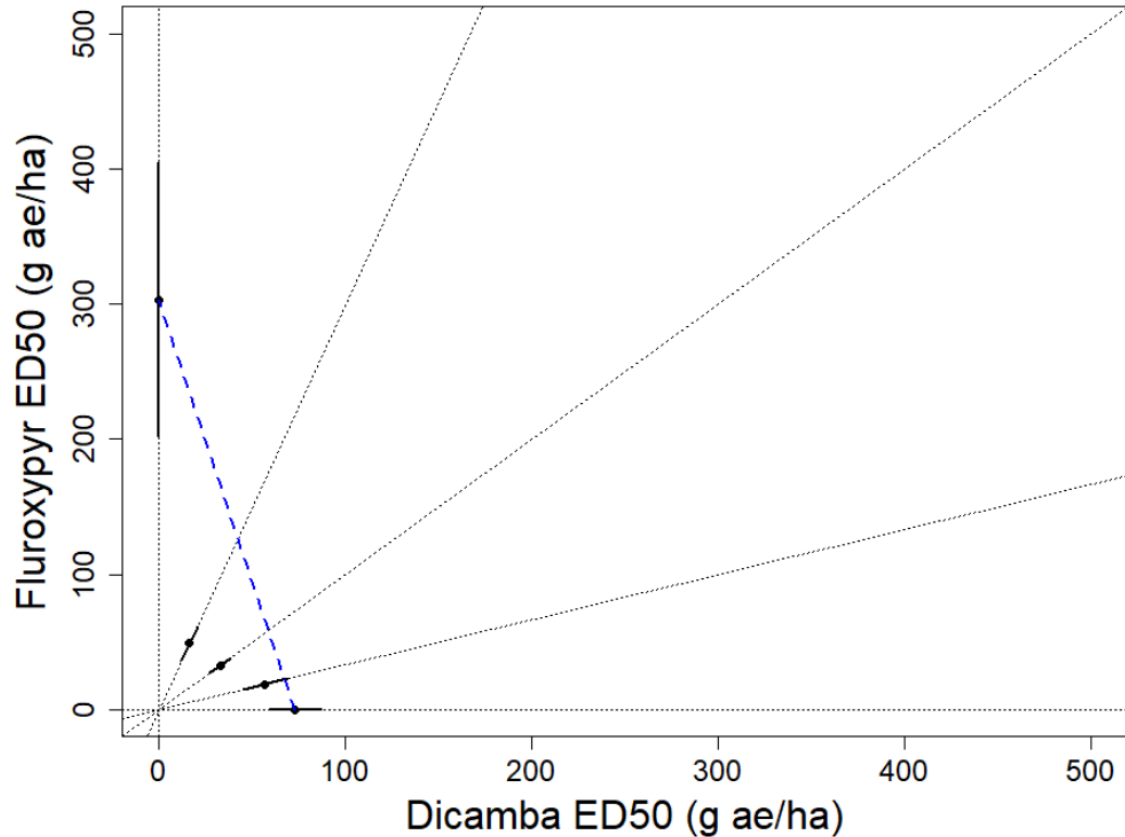
Auxinic herbicide-susceptible kochia



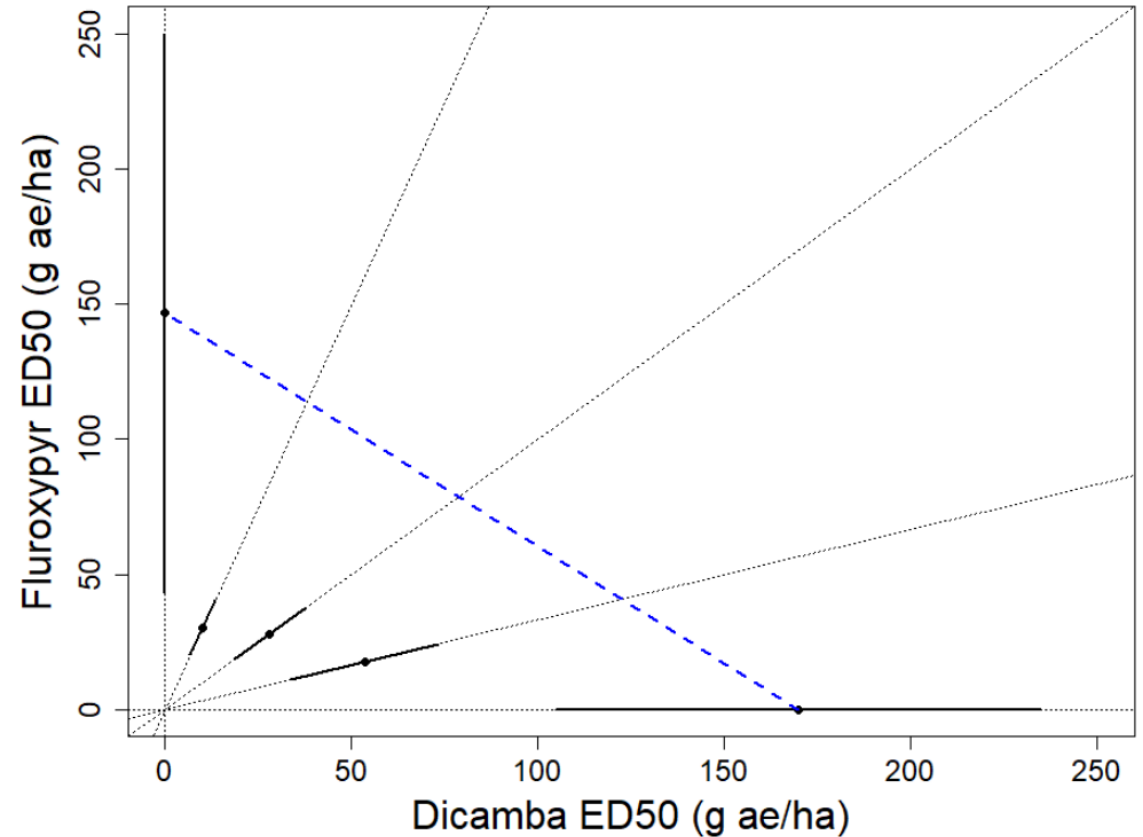
Interaction between auxin mimics

Preliminary

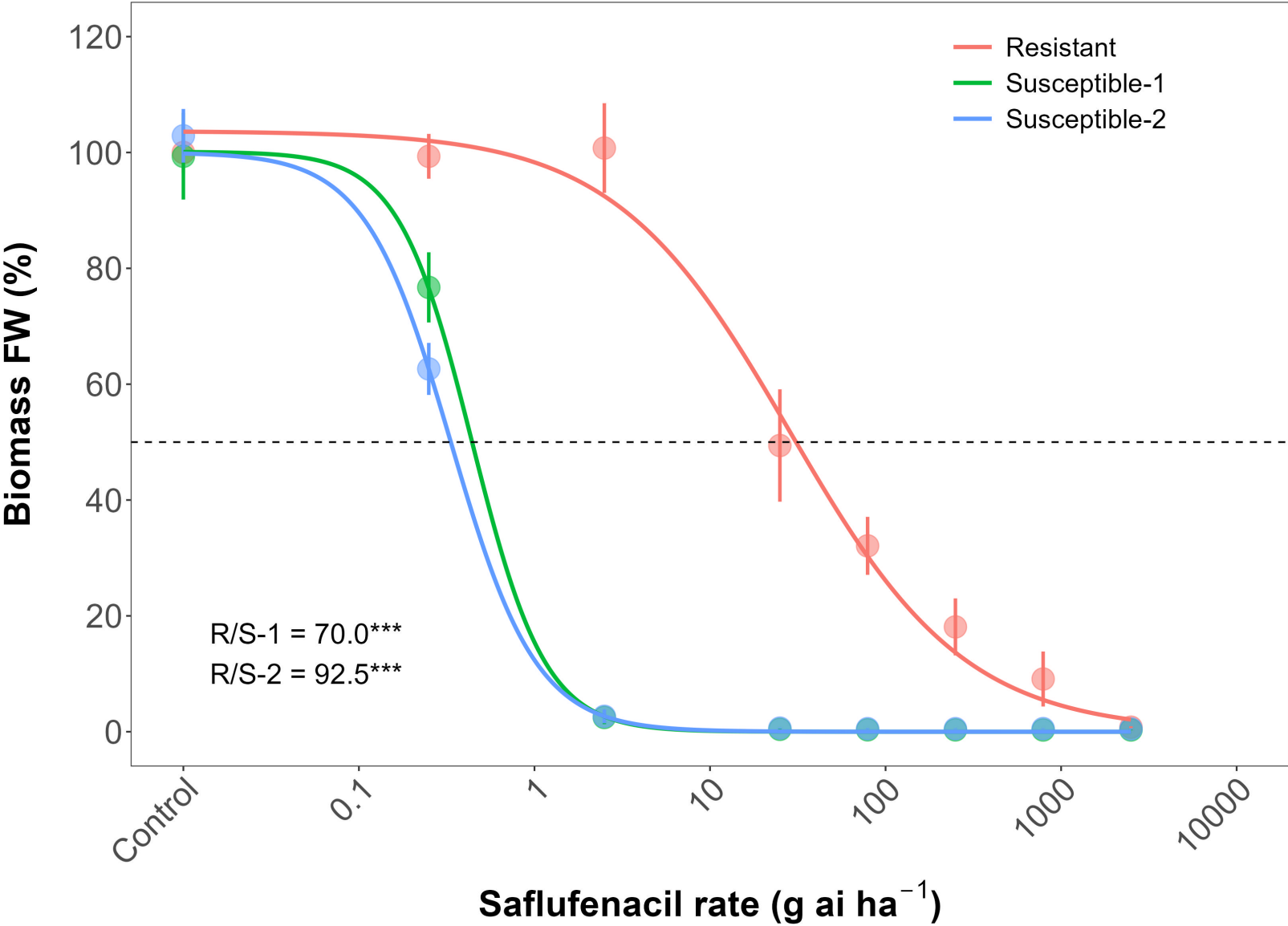
Fluroxypyr-resistant kochia



Dicamba + fluroxypyr-resistant kochia



PPO inhibitor (Group 14)-resistant kochia



Foliar-applied
21 days after treatment

1 plant per pot



0

0.25

2.5

25

79

250

790

2500

Saflufenacil rate (g ai ha⁻¹)

R

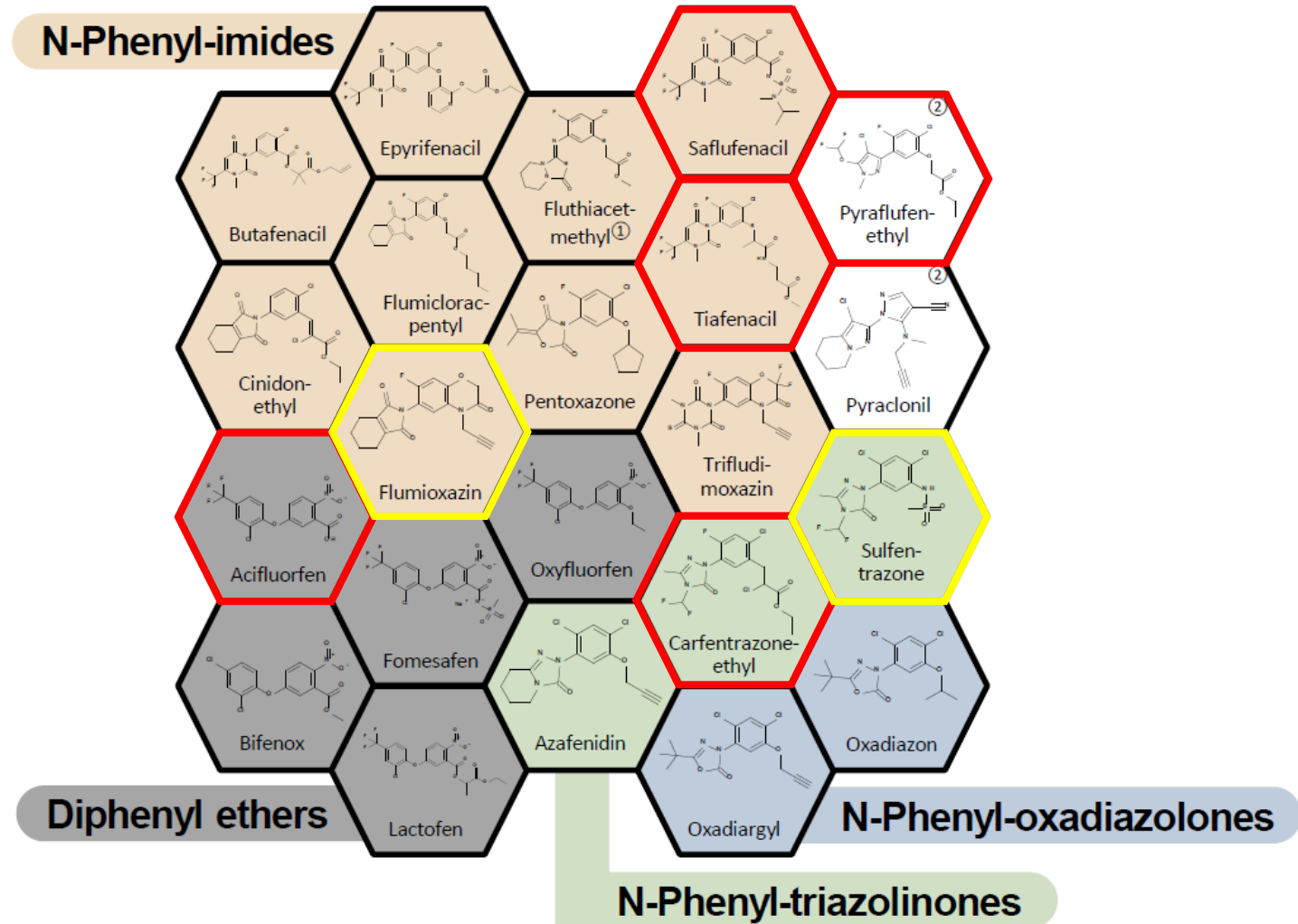
S2

S1

Cross-resistance to other PPO inhibitors?

Inhibition of Protoporphyrin Oxidase

14



Foliar-applied
21 days after treatment

1 plant per pot



0

0.175

1.75

17.5

55.3

175

553

1750

Carfentrazone rate (g ai ha^{-1})

R

S2

S1

Foliar-applied
21 days after treatment

1 plant per pot



0

3

30

300

948

3000

9480

30000

Acifluorfen rate (g ai ha⁻¹)

PPO inhibitor dose-response experiments

Foliar-applied dose

Active ingredient

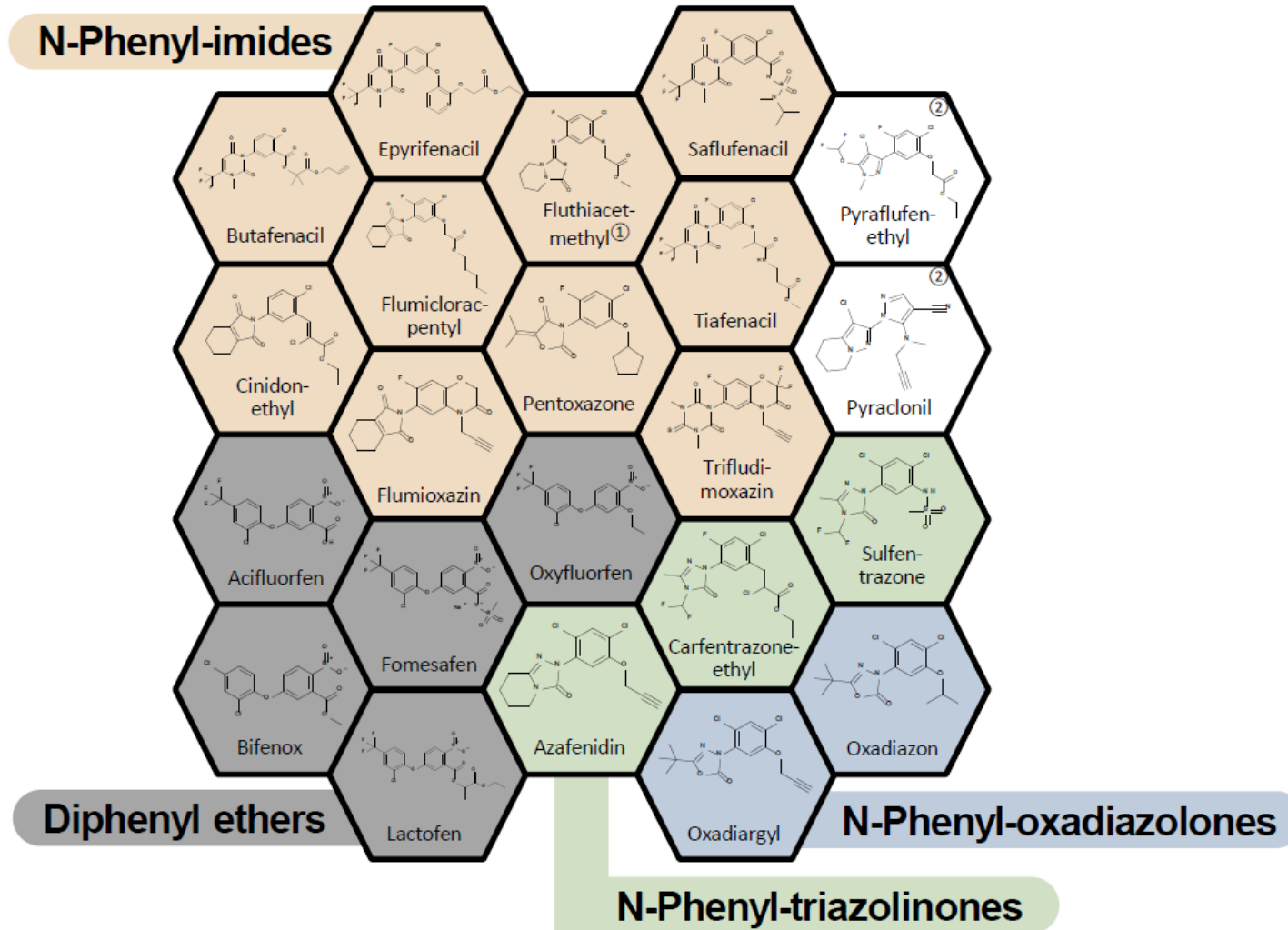
Saflufenacil

Carfentrazone

Tiafenacil

Pyraflufen-ethyl

Acifluorfen



experiments

	R/S1	R/S2
am	4.2	5.8
1	24.7	16.3
am	TBD	TBD
1	TBD	TBD

Soil-applied
42 days after treatment
Clay loam soil

20 viable seeds per pot



0

26

53

105

210

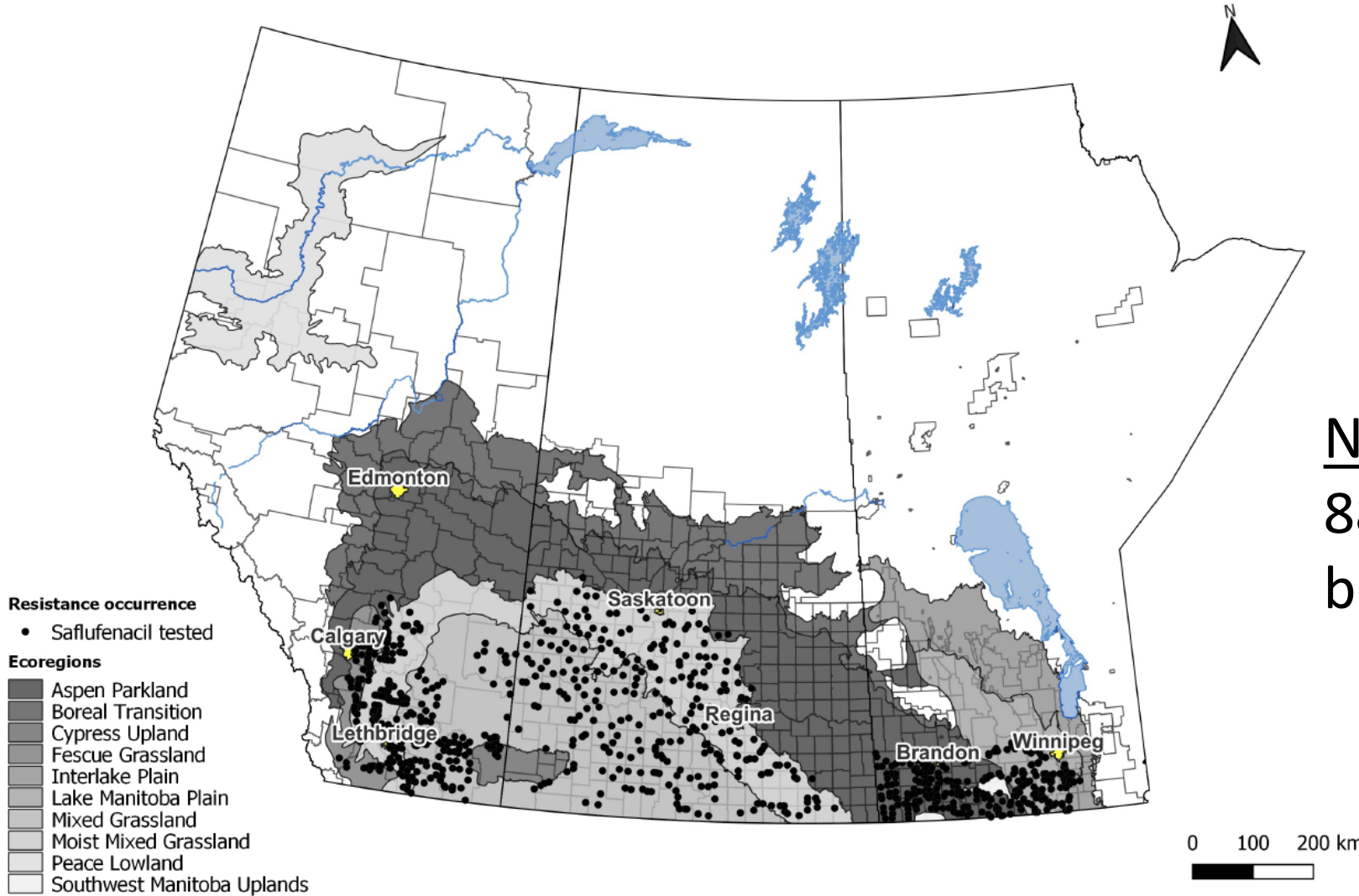
420

840

1680

Sulfentrazone rate (g ai ha⁻¹)

R
S2
S1



No saflufenacil resistance in 882 kochia samples collected between 2018 and 2021.

Table 1. Registered herbicide options to control Group 2, 4, 9 and 14-resistant kochia in the Canadian Prairies^a

Use window and herbicide	Wheat	Barley	Oat	Corn	Canola	Mustard	Flax	Soybean	Pea	Lentil
Soil-applied pre-plant										
Ethalfluralin ^b (3)					C	C		C	C	C
Trifluralin + metribuzin ^b (3 + 5)									C	
Pyroxasulfone (15)	S								S	S
Foliar-applied pre-plant										
Bromoxynil ^c (6)	C	C	C		C		C			
Bromoxynil + topramezone (6 + 27)					C					
In-crop										
Bromoxynil (6)	C	C	C	C			C			
Glufosinate ^d (10)				C	C			C		
Topramezone (27)				C						
Bromoxynil + tolpyralate (6 + 27)	C	C								
Bromoxynil + pyrasulfotole (6 + 27)	C	C								

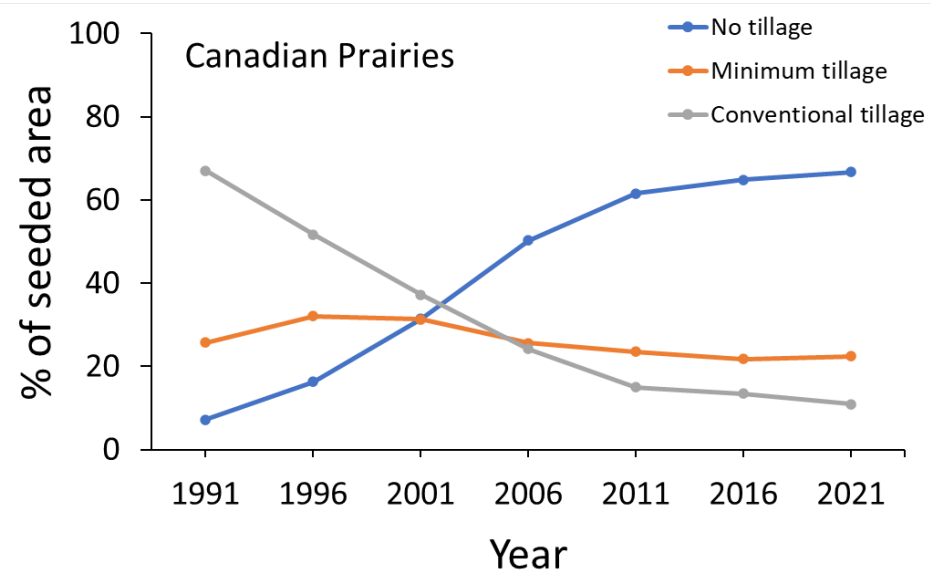
^aBased on the 2023 Alberta Crop Protection Guide (i.e., Blue Book); ^bPre-plant incorporated; ^cMixed with glyphosate only;

^dGlufosinate-resistant varieties only.

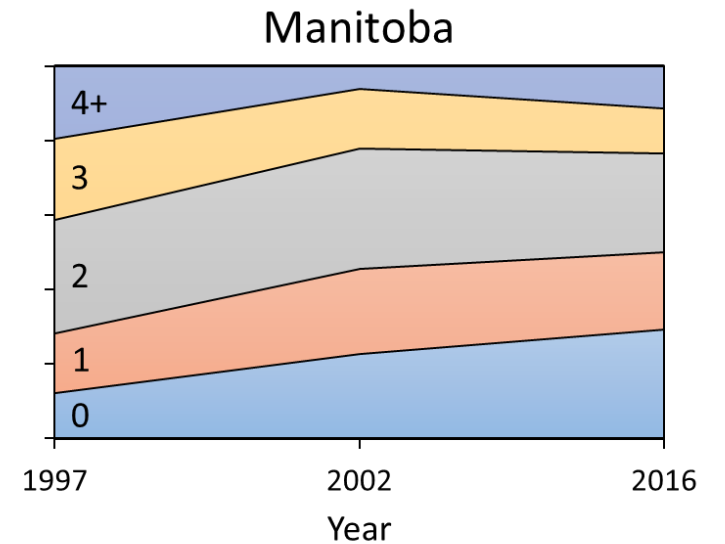
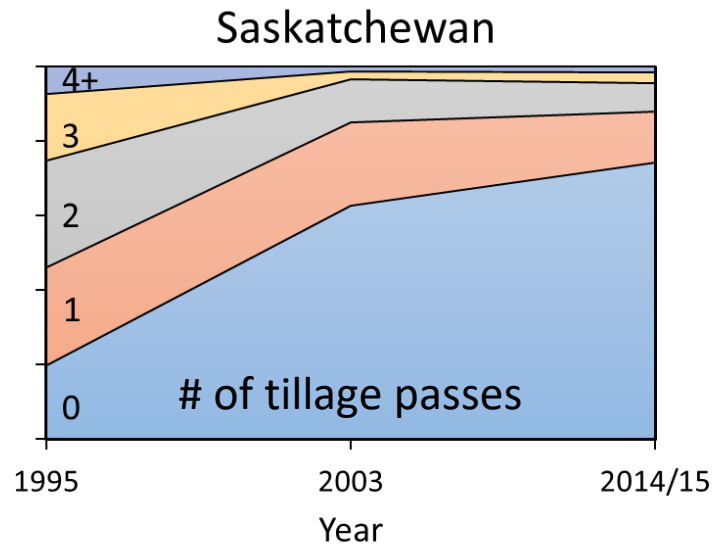
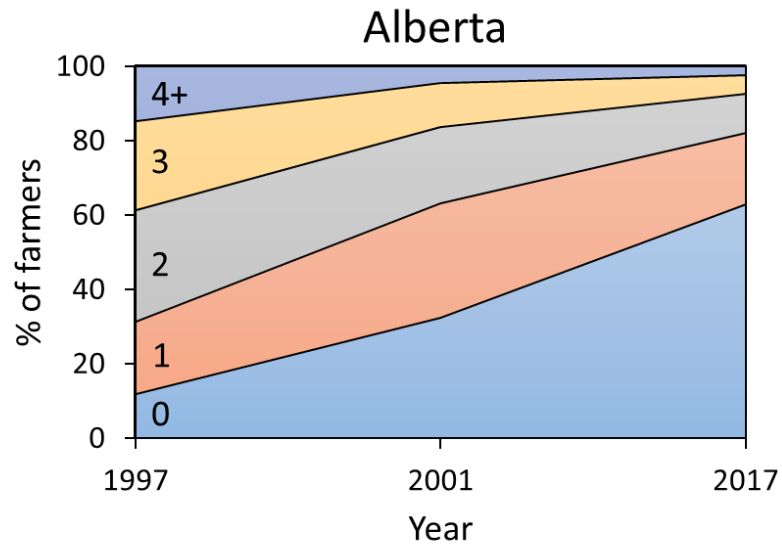
What does this mean for pre-plant
weed control moving forward???

Changes in tillage systems

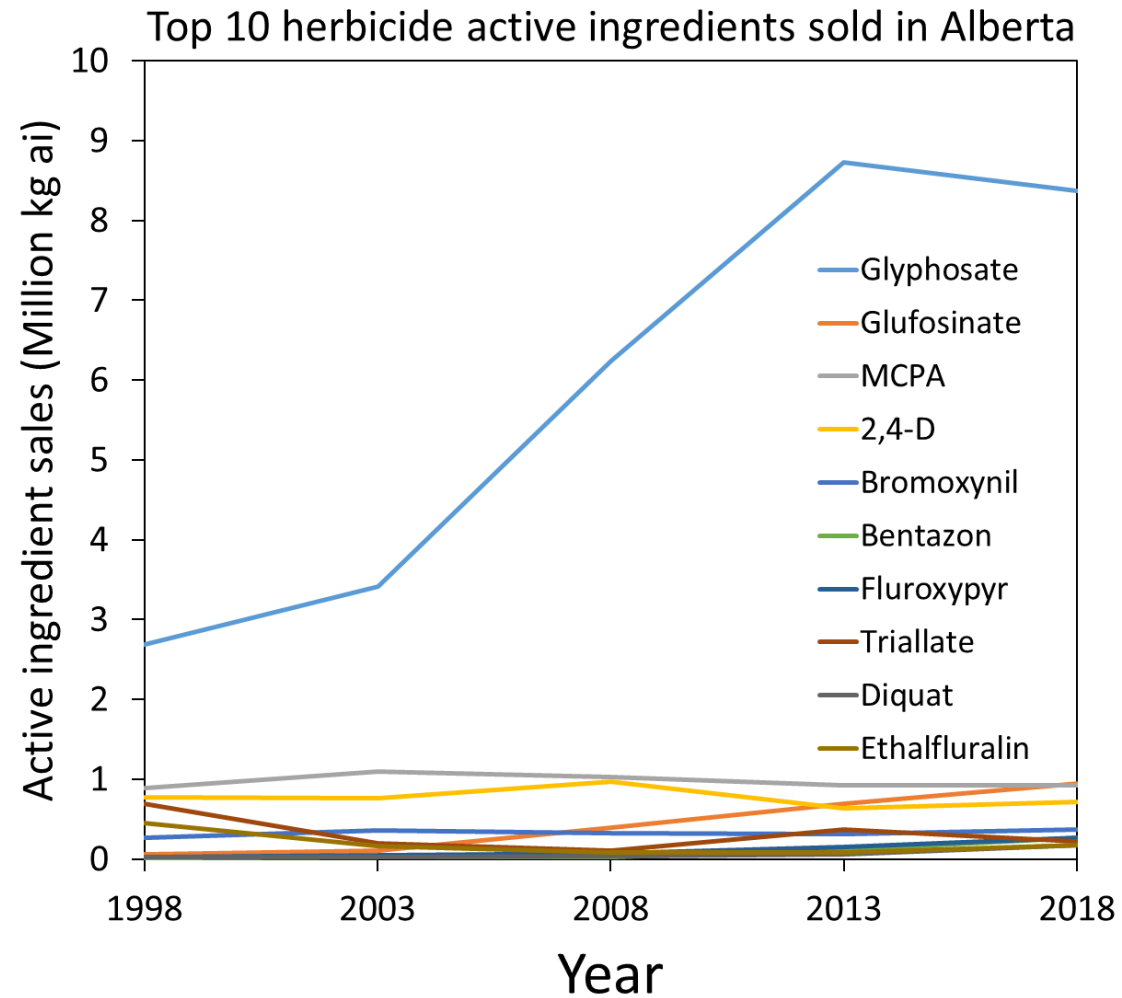
Statistics Canada 2022



Weed Survey Series Questionnaire Data (Julia Leeson)



Changes in herbicide use



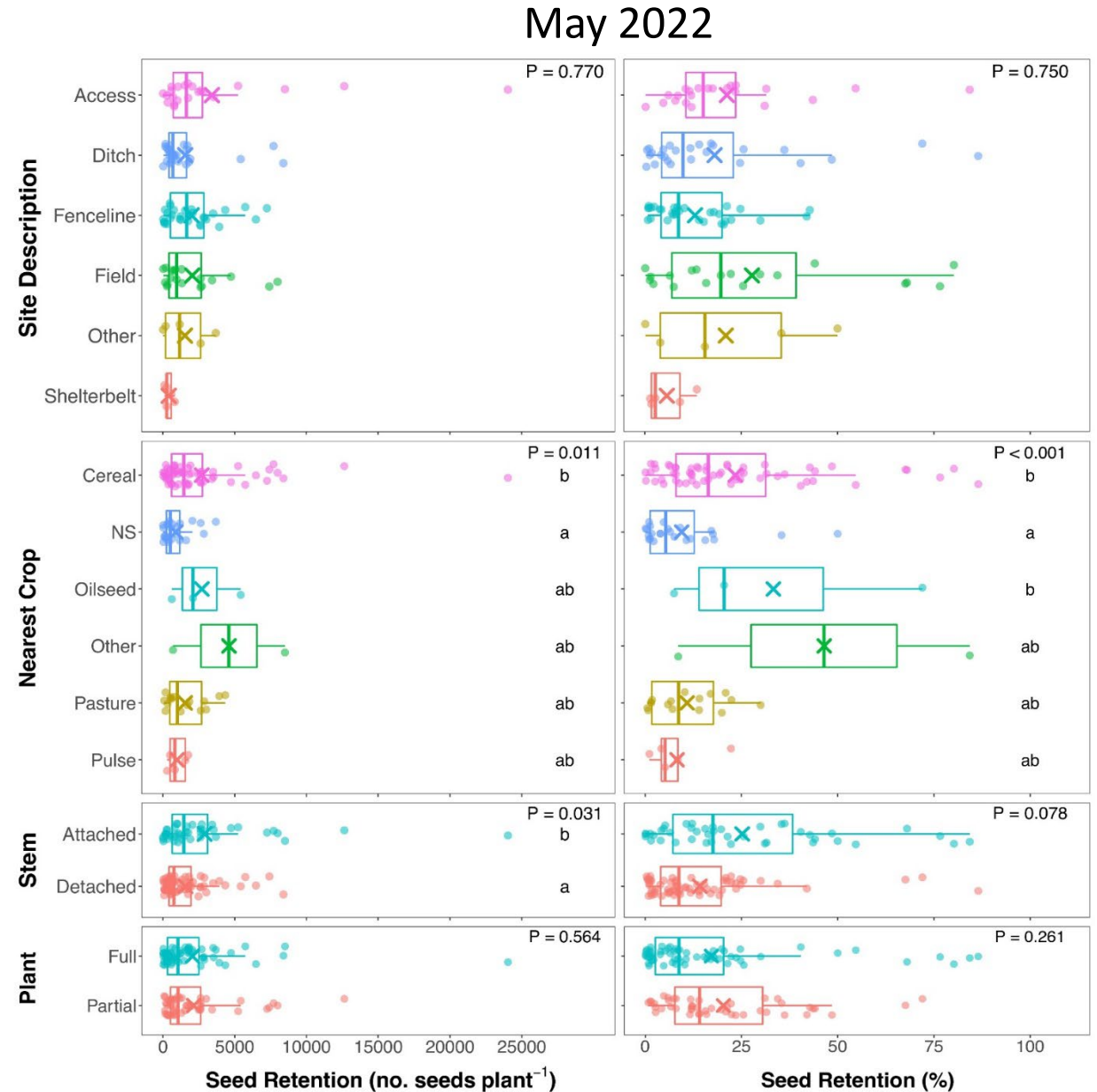
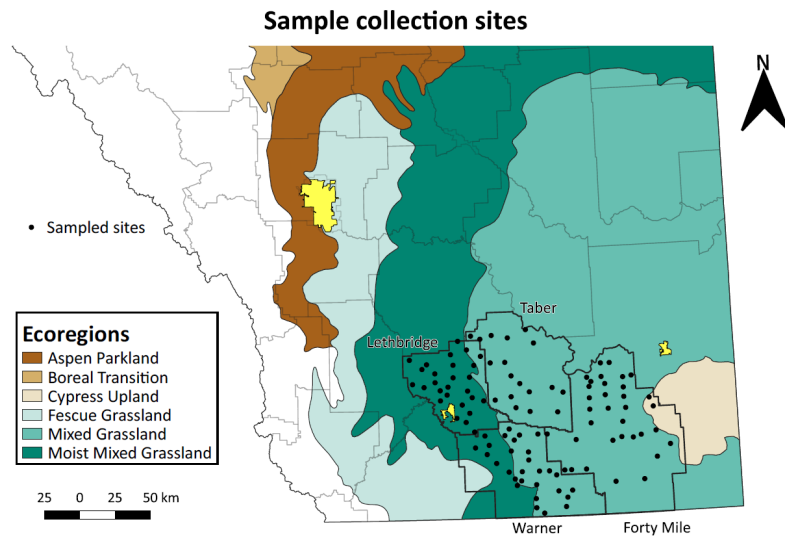
Serotiny facilitates kochia (*Bassia scoparia*) persistence via aerial seedbanks

Charles M. Geddes and Mattea M. Pittman

Agriculture and Agri-Food Canada, Lethbridge Research and Development Centre, Lethbridge, AB, Canada

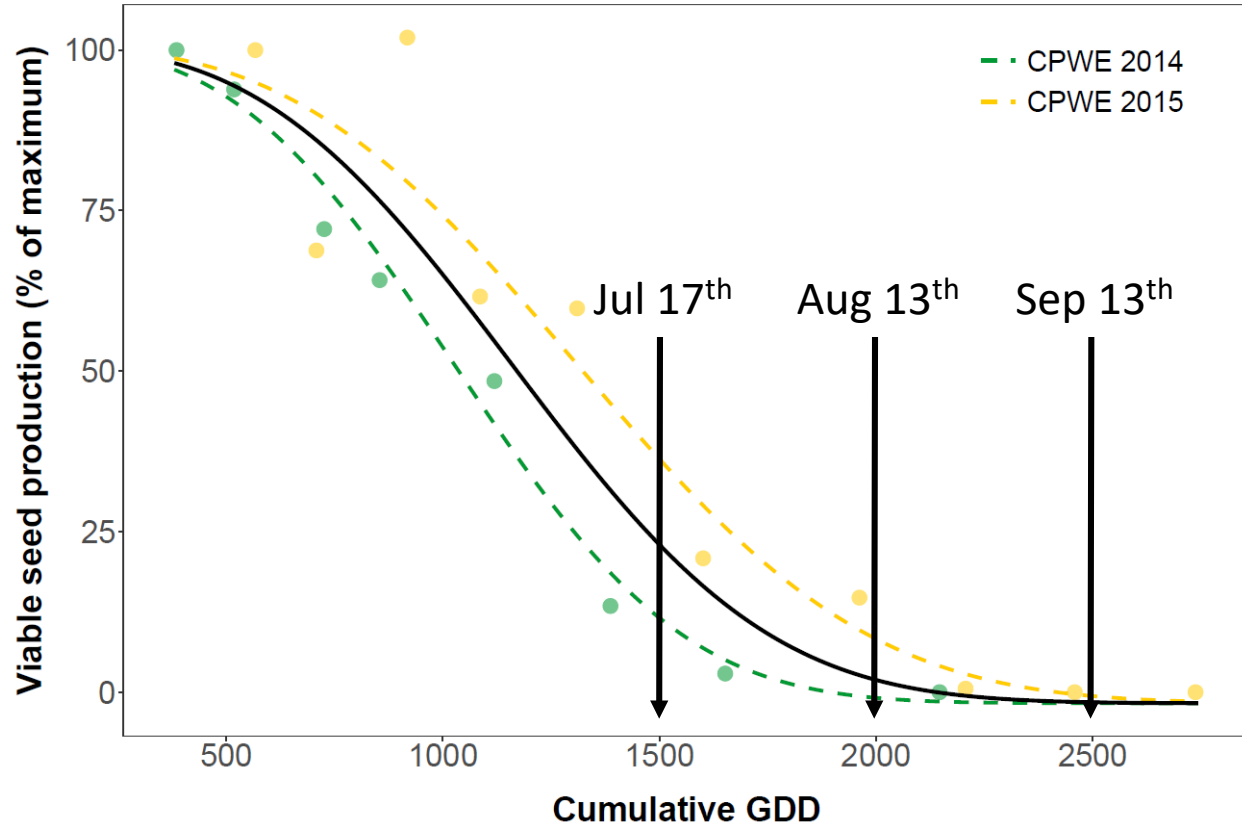
Corresponding author: Charles M. Geddes (email: Charles.Geddes@agr.gc.ca)

How many seeds remain on kochia plants in the spring?

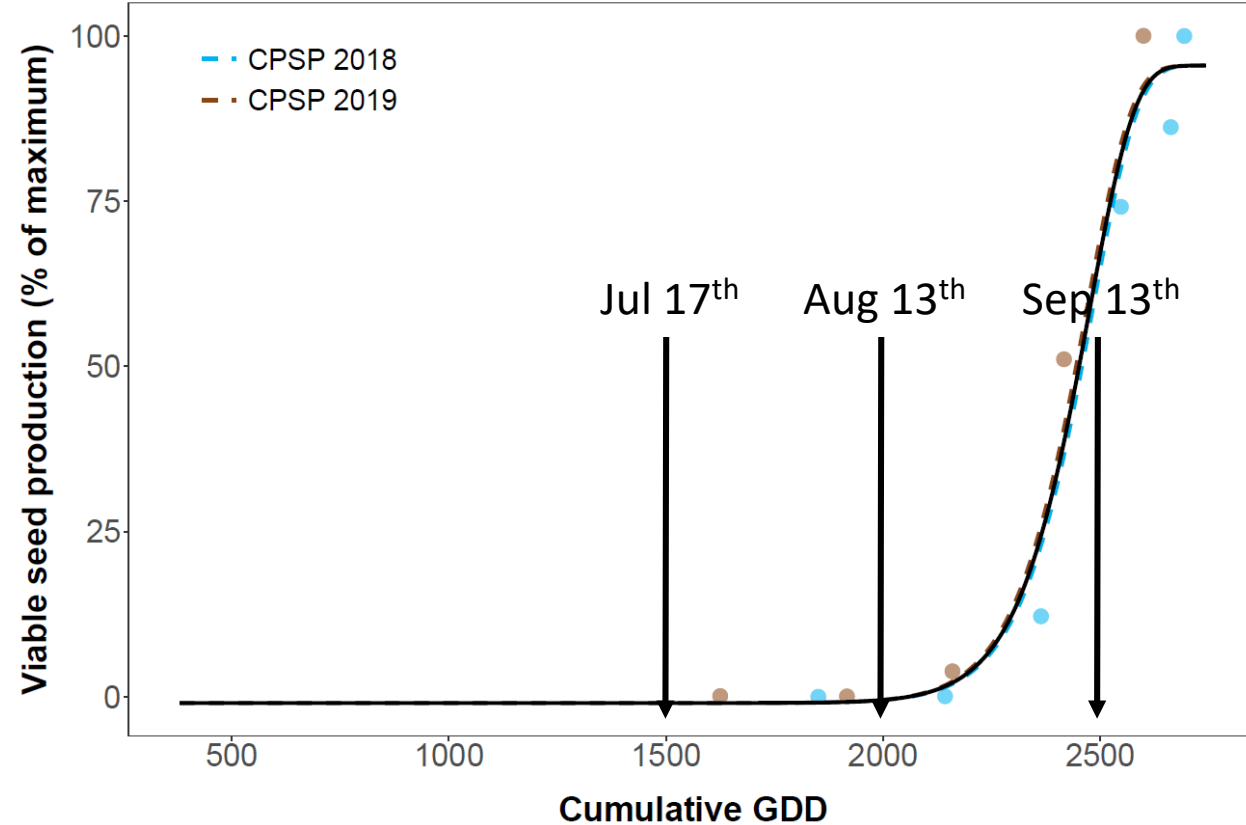




a Critical period for weed emergence (CPWE)

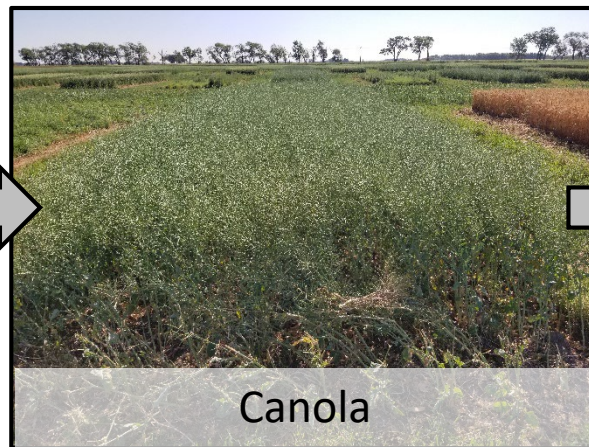
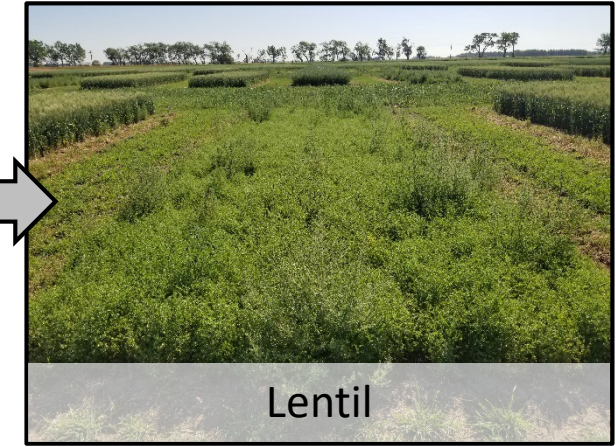


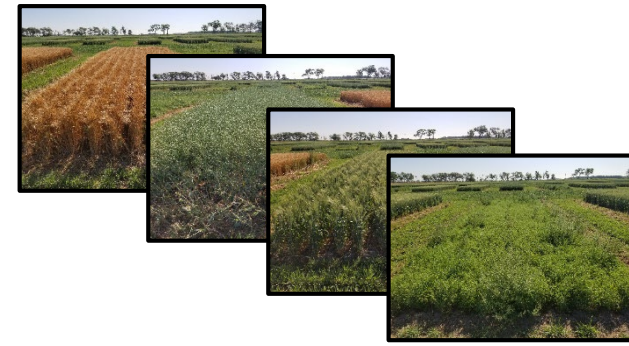
b Critical period for seed production (CPSP)



Crop rotation diversity

Aug 04, 2020

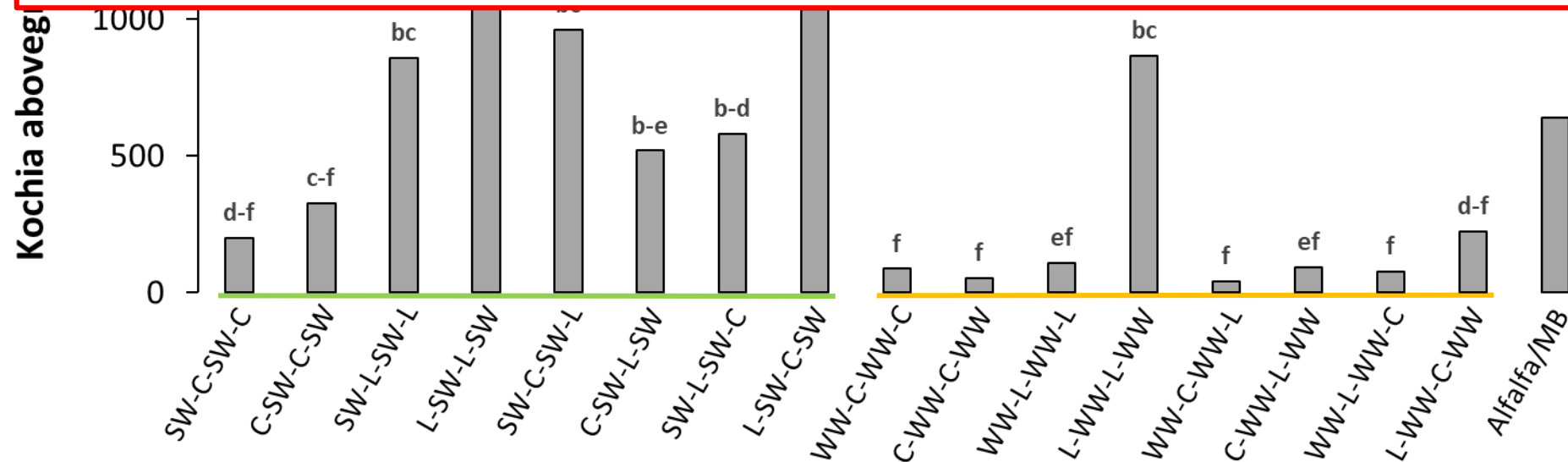




Crop rotation diversity



WW in rotation = ↓ kochia biomass by 72% ($P < 0.0001$)
 Alfalfa/MB = similar kochia biomass to SA rotations ($P = 1.0000$)



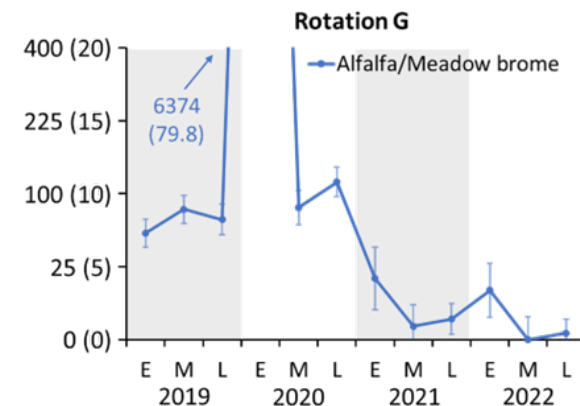
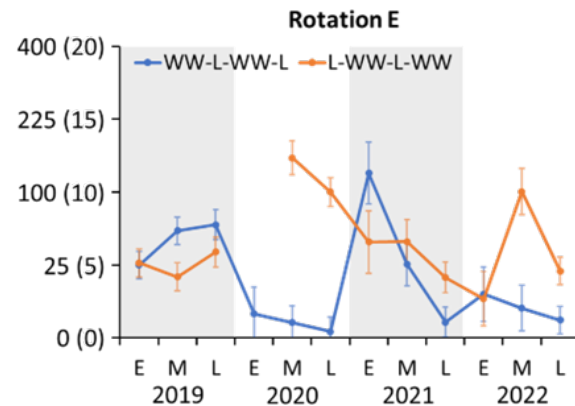
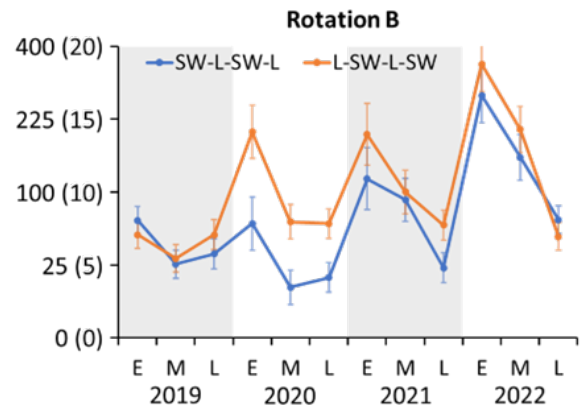
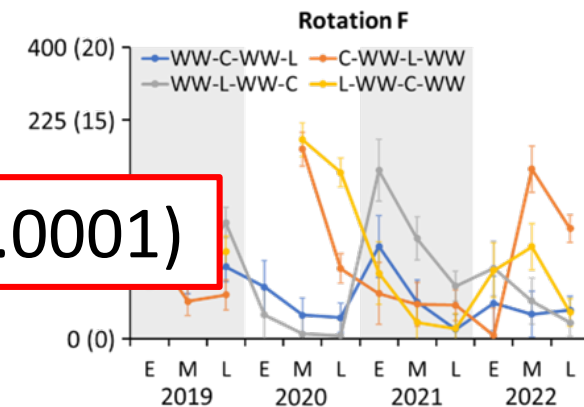
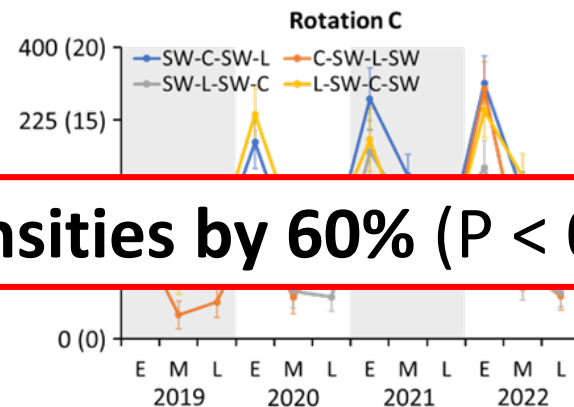
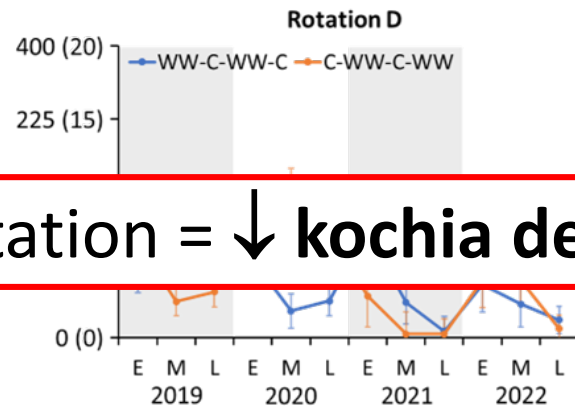
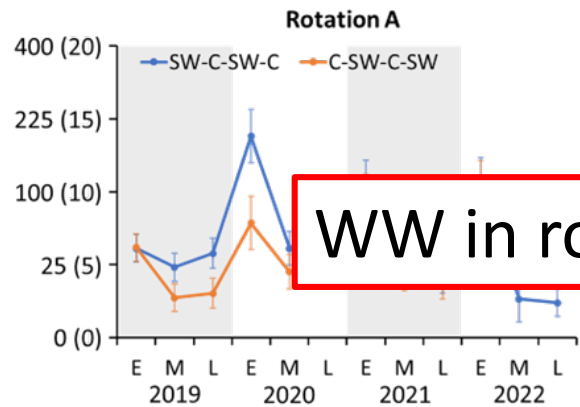


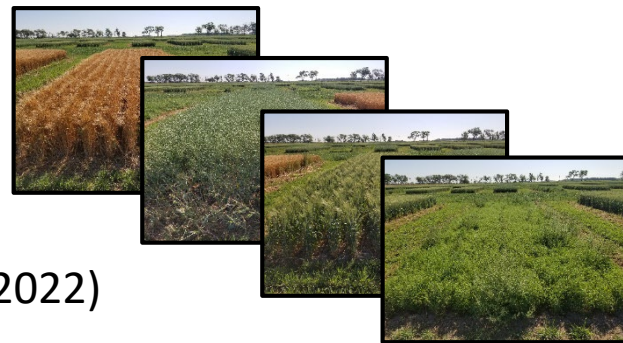
Crop rotation diversity

Lethbridge, AB (2019-2022)

Kochia plant density – plants m⁻² (sqrt plants m⁻²)

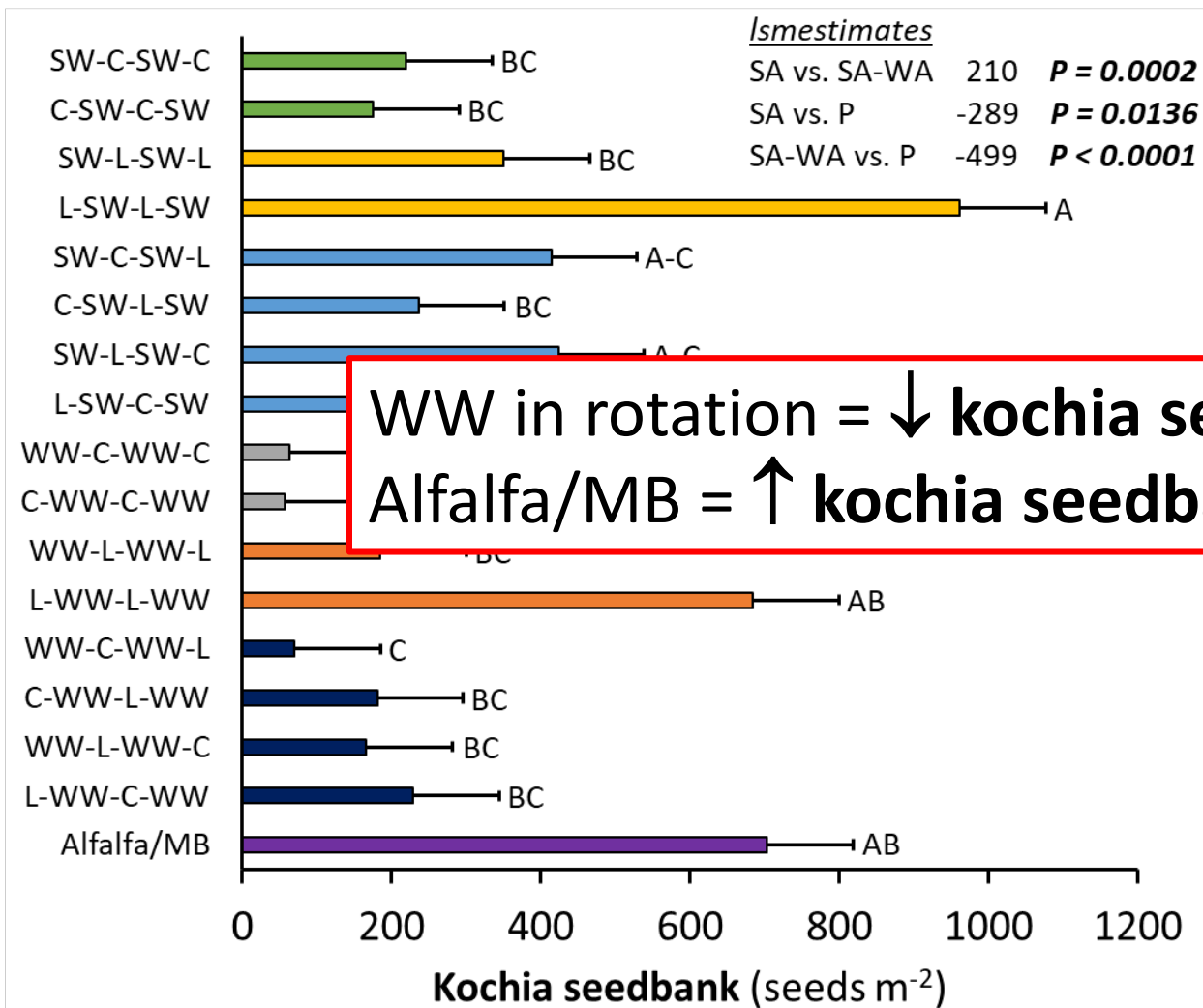
WW in rotation = ↓ kochia densities by 60% (P < 0.0001)





Crop rotation diversity

Lethbridge, AB (2019-2022)



WW in rotation = ↓ kochia seedbank by 51% ($P = 0.0002$)
Alfalfa/MB = ↑ kochia seedbank by 70% ($P = 0.0136$)

Layering cultural with chemical weed management

Aug 17, 2020

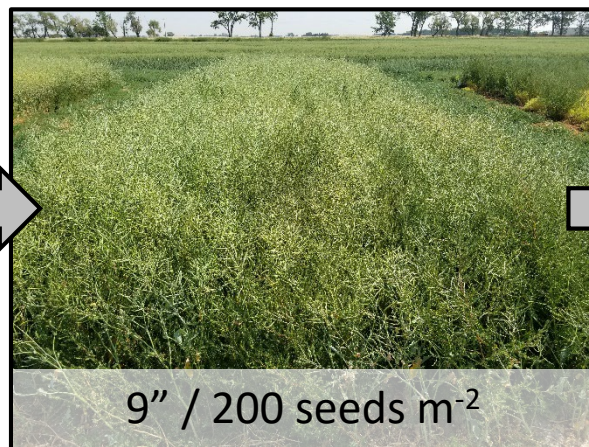


Table 1. Impact of crop rotation phase, row spacing, and seeding rate on kochia plant density, biomass, and seed dockage across the four-year (2018-2021) study and seedbank densities after the four years.

Main factor	Factor level	Plant density			Biomass	Seed dockage	Seedbank density
		Early	Mid	Late			
		----- no. plants m ⁻² -----			-- kg ha ⁻¹ --	----- no. seeds m ⁻² -----	
Rotation phase	Wheat	112 a	27 a	27 a	220 c	1,121 d	2,172 c
<p>↓ rows + ↑ seeding rates = ↓ kochia densities by 59%</p> <p>↓ rows + ↑ seeding rates = ↓ kochia biomass by 80%</p> <p>↓ rows + ↑ seeding rates = ↓ kochia seedbank by 63%</p>							
Row spacing	Wide	88 A	33 A	28 A	889 A	3,945 A	4,706 a
	Narrow	60 B	17 B	14 B	396 B	2,358 B	3,129 b
Seeding rate	100%	87 a	30 a	26 a	853 a	4,731 a	5,003 a
	200%	62 b	19 b	16 b	420 b	2,855 b	2,801 b

In Summary,



- Multiple herbicide-resistant kochia is a growing concern.
- Group 14-resistant kochia has been confirmed in SK and ND
- Could cause a shift in tillage systems absent of new alternatives for pre-plant weed control.
- While there is no silver bullet, effective tools for HR kochia management are available.

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