

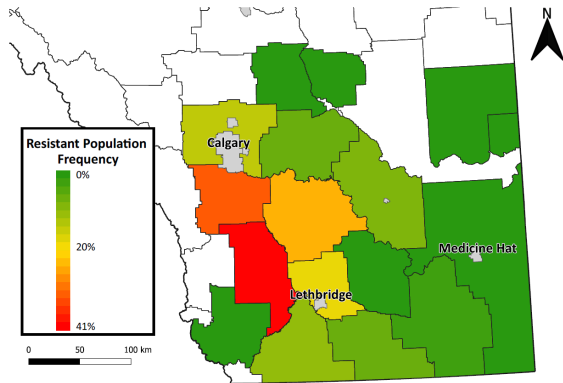


Charles.Geddes@agr.gc.ca
X @charlesmgeddes

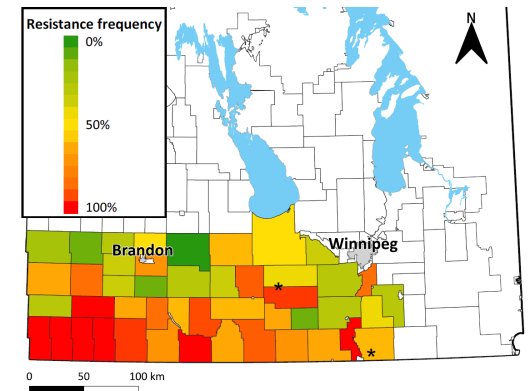
Wild World of Weeds Workshop
January 16, 2024

Keynote Address – part 1

Herbicide-resistant weeds on the Canadian Prairies



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



Agriculture and
Agri-Food Canada

Agriculture et
Agroalimentaire Canada

Canada

Charles.Geddes@agr.gc.ca

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Prairie Region of Canada

- ~67,454,206 ac. of annual crop production
 - 87% of annual-cropped area in Canada
 - Alberta: 20,660,243 ac.
 - Saskatchewan: 36,943,546 ac.
 - Manitoba: 9,850,426 ac.
- Dominant crop types
 - Wheat: 35%
 - Canola: 31%
 - Pulses: 13%



Lethbridge growing season (April – October)

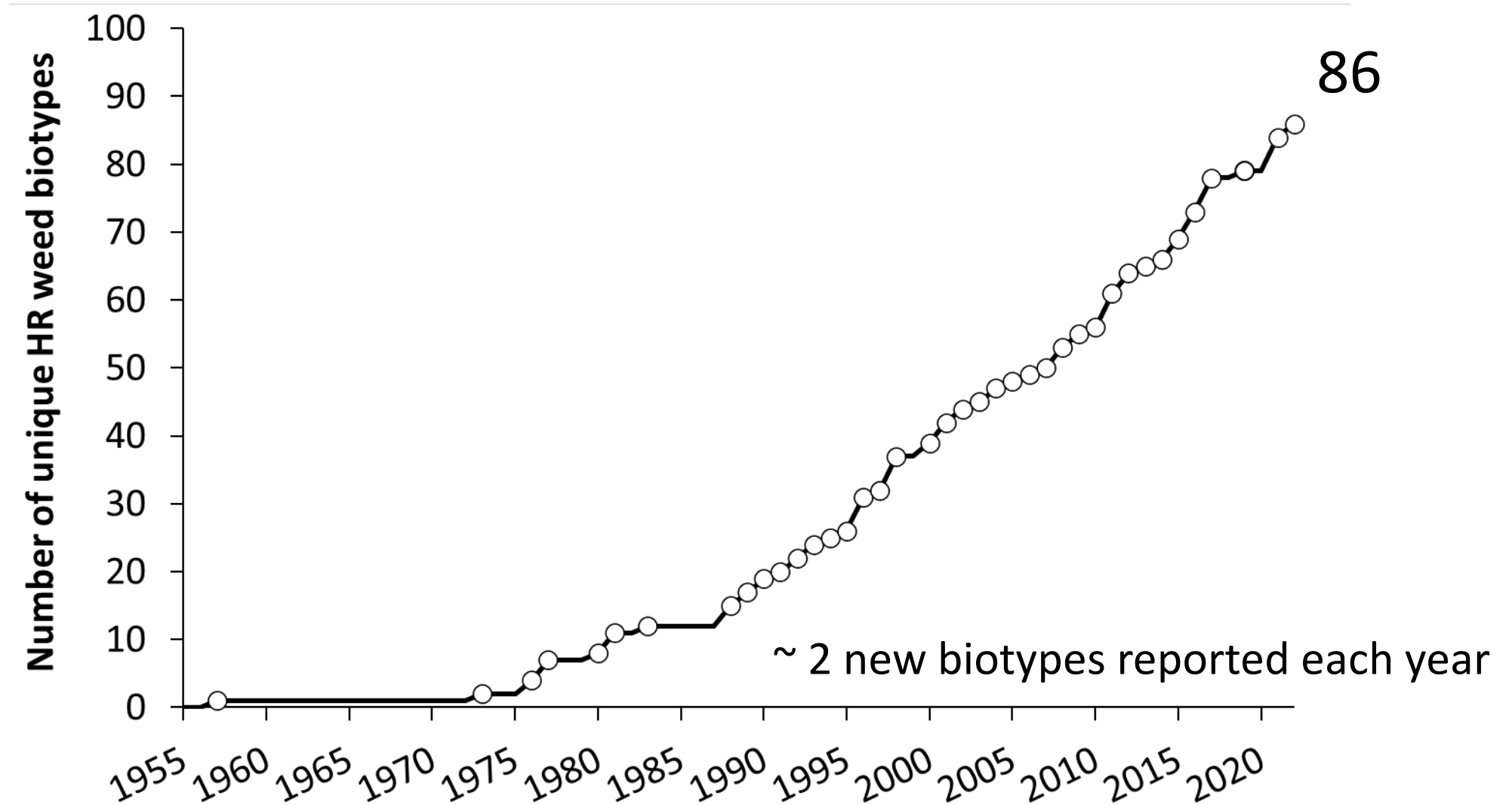
- Mean temp. = 12.8°C (55°F)
- Mean precip. = 12.6"

Outline

1. HR weeds in Canada
2. HR weed monitoring across the Canadian Prairies
3. New HR weeds



Unique herbicide-resistant weeds in Canada

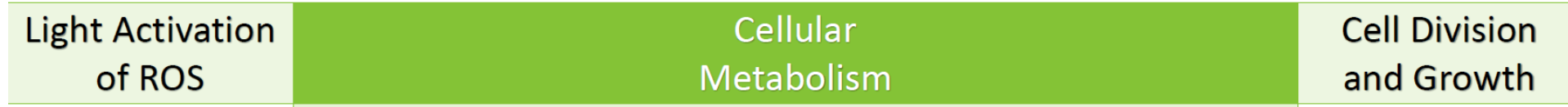


Herbicide-Resistant Weeds in the Prairie Region

Charles M. Geddes

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

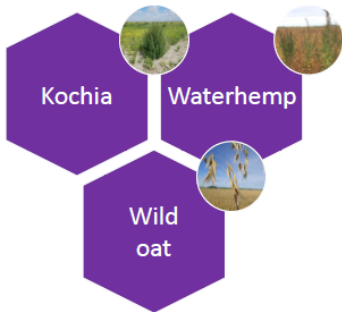
Charles.Geddes@agr.gc.ca
@charlesmgeddes



Group 5 PS II inhibitors – Serine 264 binders



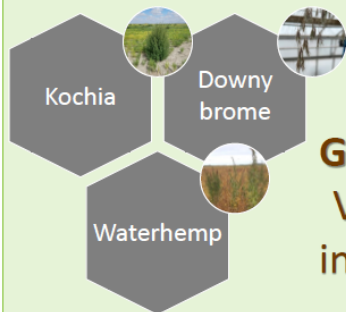
Group 14 PPO inhibitors



Group 1 ACCase inhibitors



Group 9 EPSPS inhibitor



Group 15 VLCFAE inhibitors



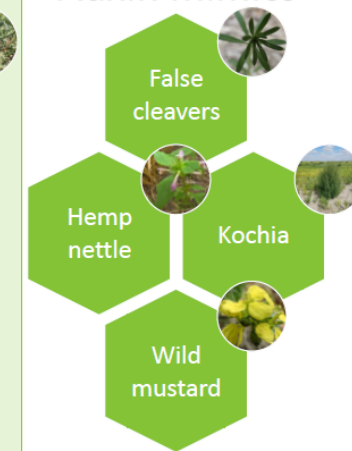
Group 2 ALS inhibitors



Group 3 Microtubule assembly inhibitors



Group 4 Auxin mimics

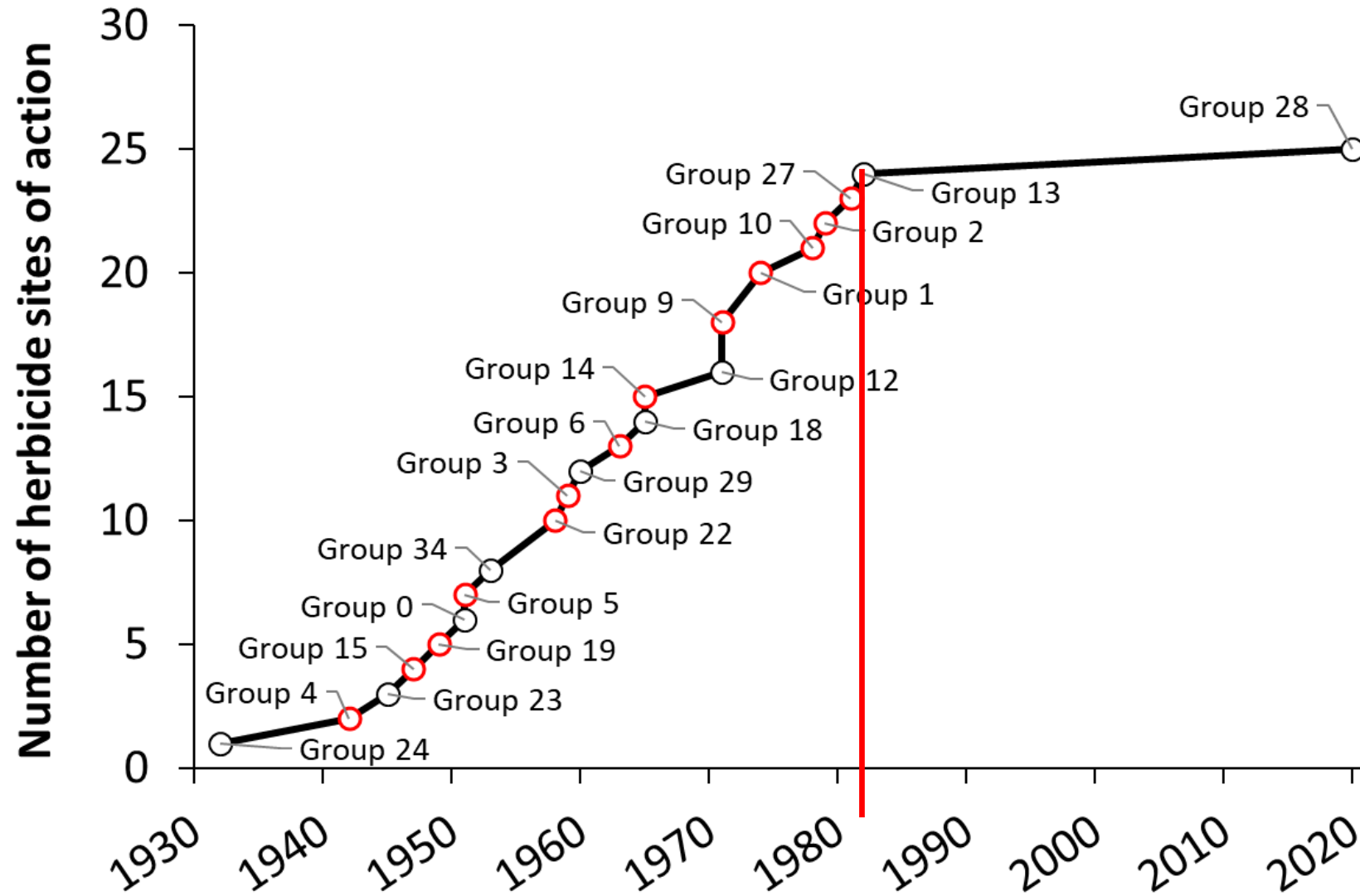


Agriculture and Agri-Food Canada

Agriculture et Agroalimentaire Canada



Introduction of new herbicide sites of action

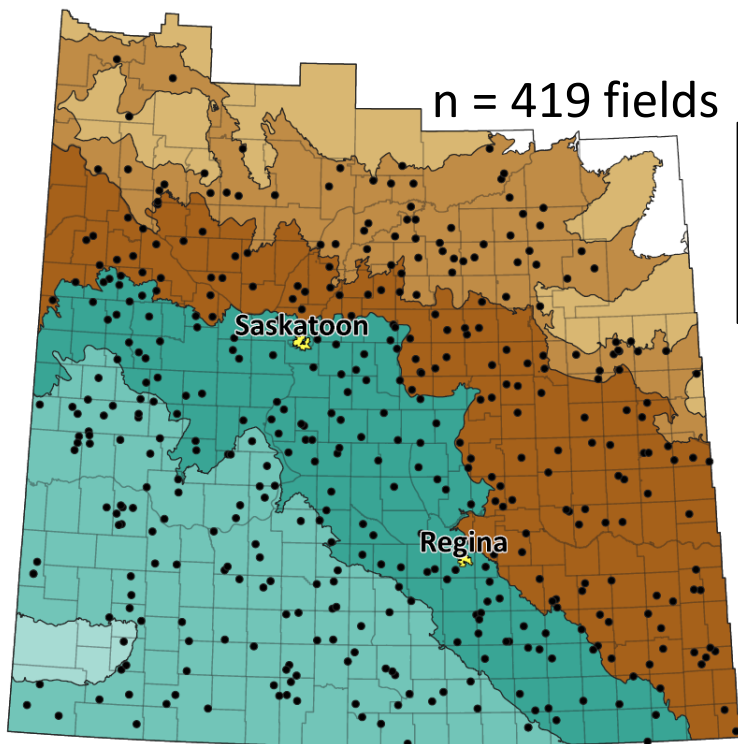


Top 5 resistance issues on the Canadian Prairies

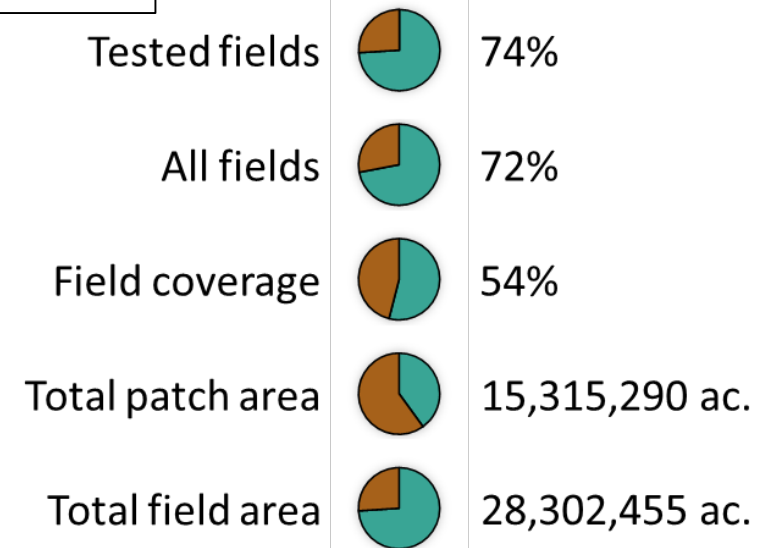
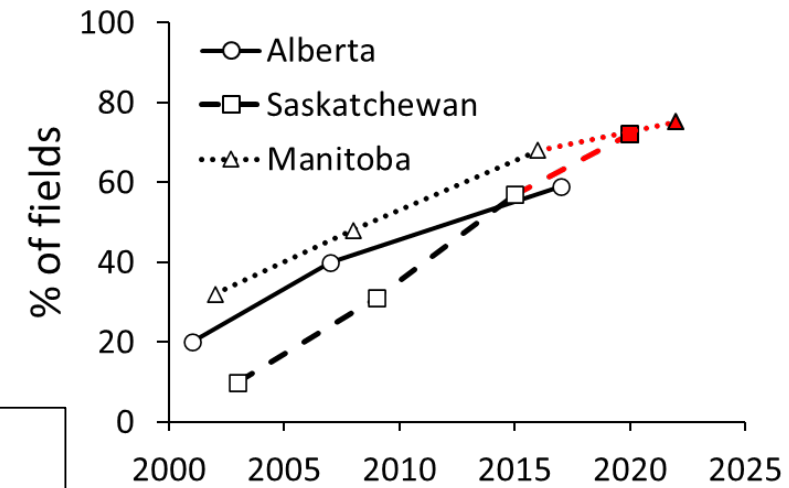
- Group 1 + 2-resistant grass weeds causing reliance on soil-applied herbicides
- Spread of multiple herbicide-resistant kochia (Groups 2, 4, 5, 9 & 14)
- Advancing range of invasive herbicide-resistant *Amaranthus* spp.
- Heavy reliance on glyphosate at multiple use windows
- Spread of several Group 2-resistant weeds

Saskatchewan survey 2019/2020

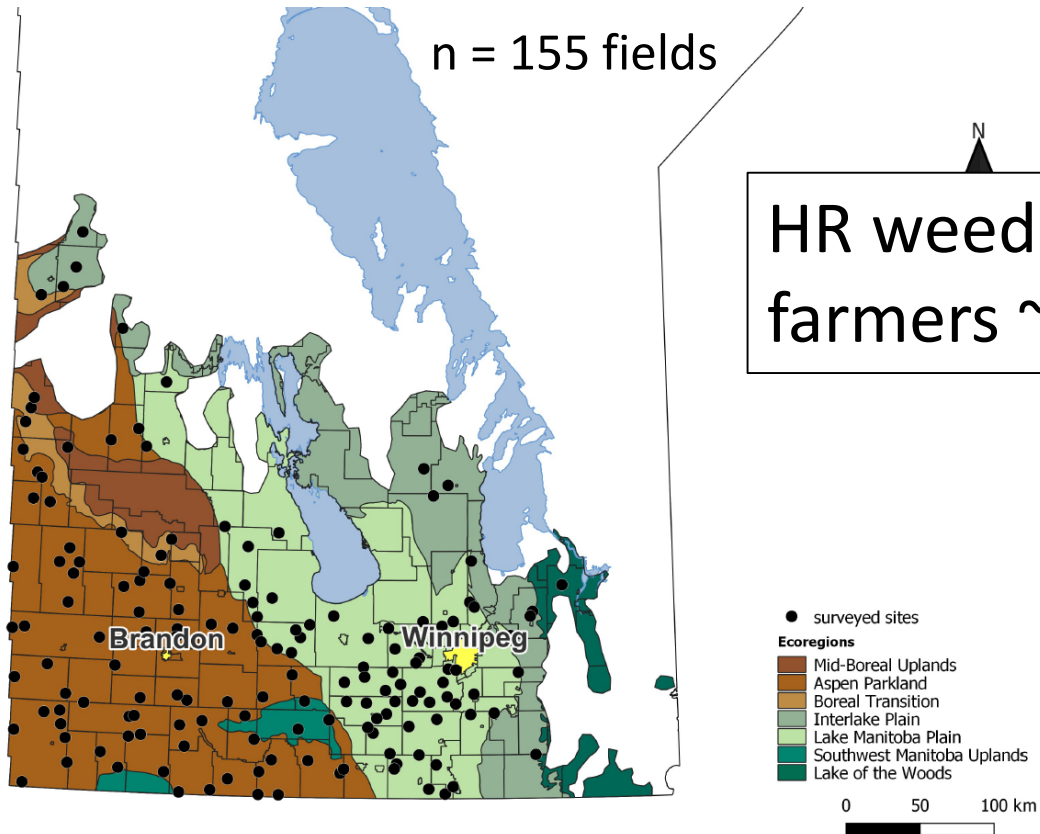
Saskatchewan Survey in 2019-2020



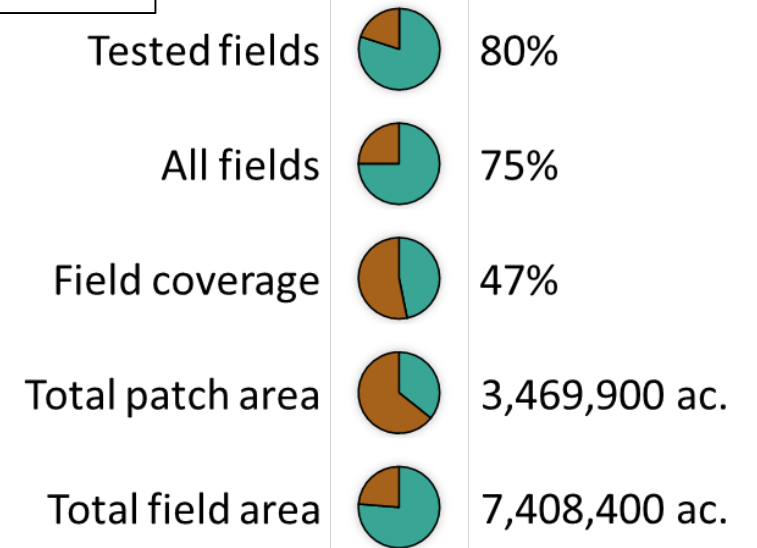
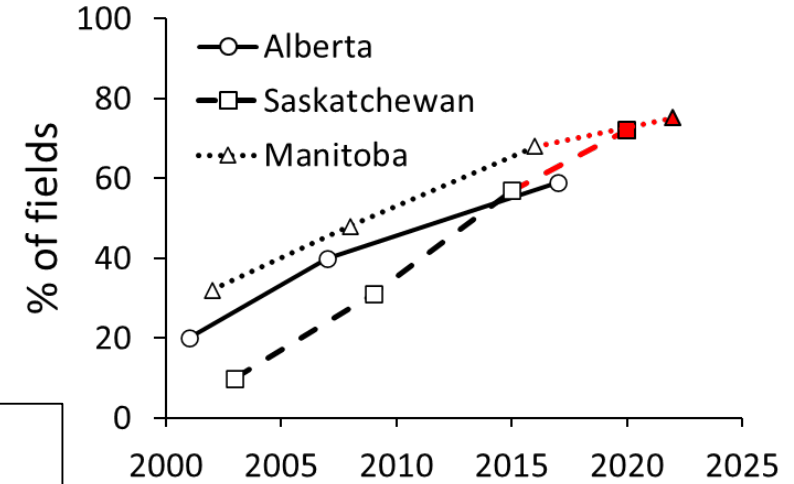
HR weeds cost Saskatchewan farmers ~\$340 million annually



Manitoba survey 2022



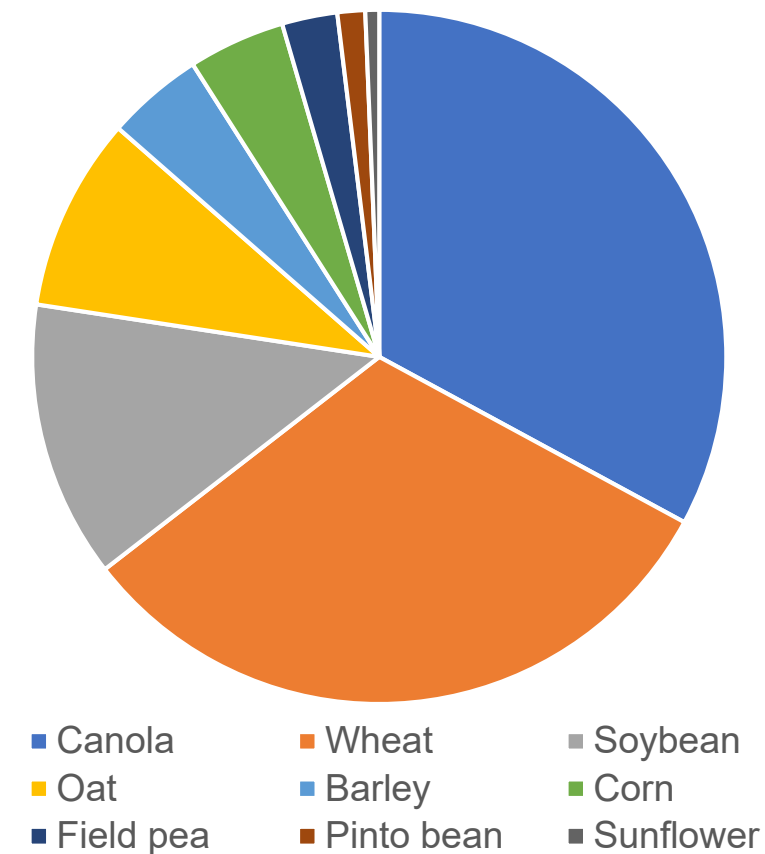
HR weeds cost Manitoba farmers ~\$81 million annually



Field stratification

Table 1. Field allocation by crop and ecoregion.

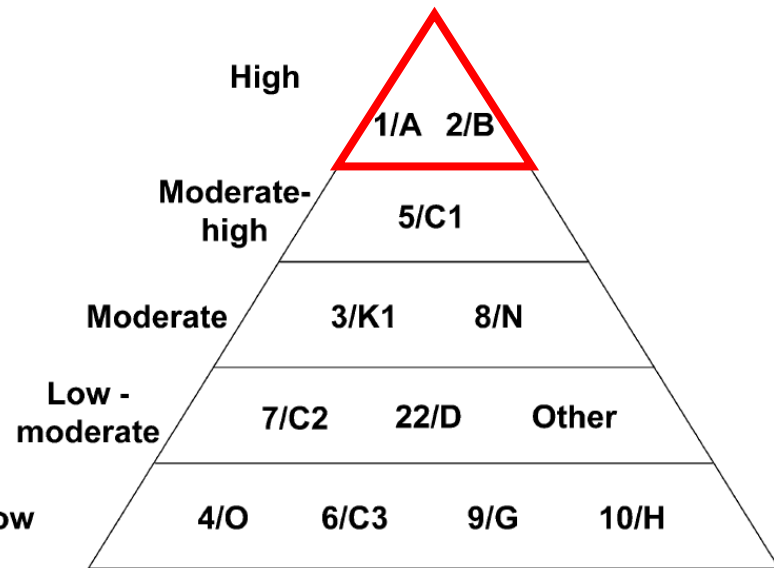
Crop	Aspen Parkland ^a	Boreal Transition ^b	Lake Manitoba Plain	Interlake Plain ^c	All areas	% of all areas
	----- no. of fields -----					%
Canola	22	7	18	4	51	33
Wheat	25	1	18	5	49	31
Soybean	7	0	13	0	20	13
Oat	10	0	4	0	14	9
Barley	5	0	1	1	7	5
Corn	1	0	4	2	7	5
Field pea	3	0	1	0	4	3
Pinto bean	0	0	2	0	2	1
Sunflower	0	0	1	0	1	<1
Sub-total	73	8	62	12	155	100
% of total	47	5	40	8	100	100



^aIncludes SW MB Uplands; ^bIncludes Mid-Boreal Uplands; ^cIncludes Lake of the Woods

Herbicides tested

Resistance selection



Beckie, 2006

Table 2. Herbicides used for resistance diagnostics.

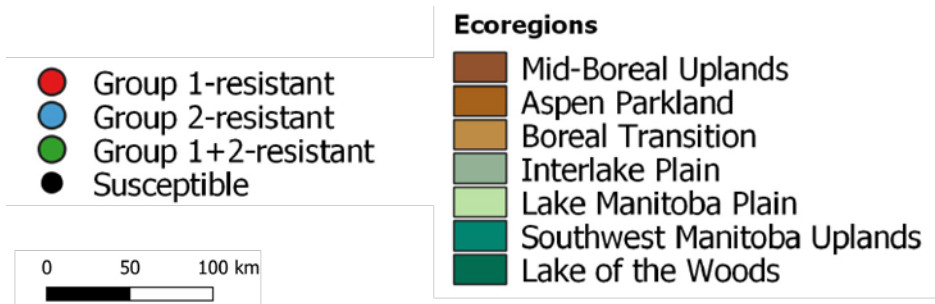
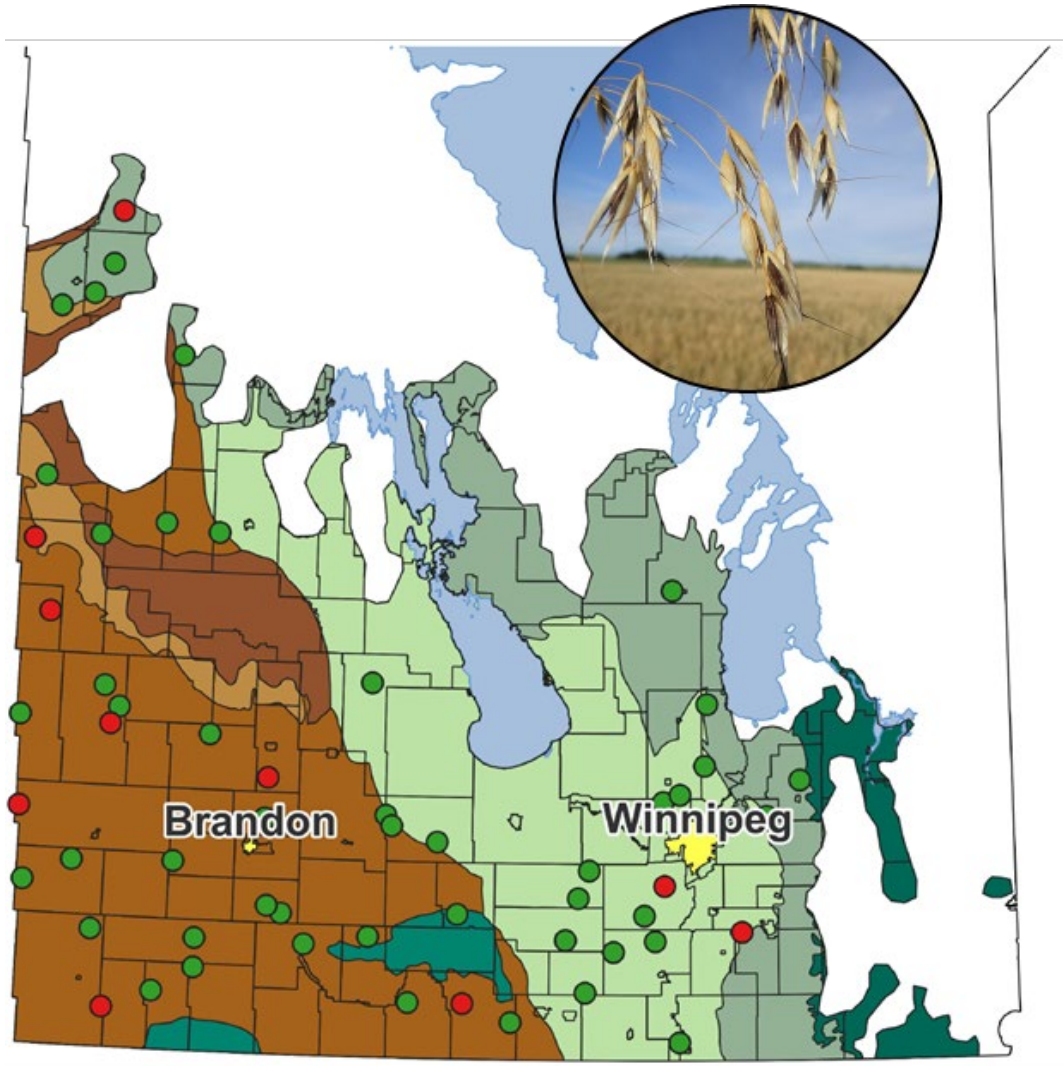
Herbicide common name	Herbicide trade name	Rate (g ai/ae ha ⁻¹)
Fenoxaprop	Puma [®] Advance ¹	60 & 150
Quizalofop	Assure [®] II ^{2,a}	48 & 70
Tralkoxydim	Liquid Achieve [™] SC ^{3,b}	200 & 400
Clethodim	Centurion ^{®4,c}	90
Imazamox	Solo [®] ADV ⁴	35
Imazethapyr	Pursuit [®] 240 ^{4,d}	75
Imazapyr	Arsenal [®] PowerLine ^{4,d}	72
Thifensulfuron + Tribenuron	Refine [®] SG ^{5,d}	15(10+5)
Chlorsulfuron	Telar [®] XP ^{1,d}	22 & 89
Glyphosate	Roundup WeatherMAX ^{®1}	900

Company name: ¹Bayer CropScience Inc.; ²AMVAC Chemical Corp.; ³Corteva Agriscience; ⁴BASF Canada Inc.; ⁵FMC of Canada Ltd.

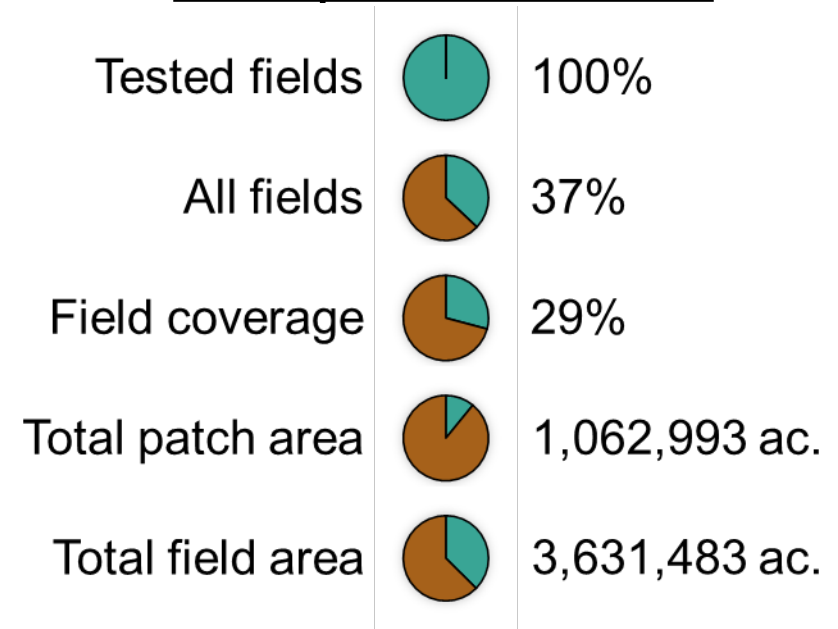
Adjuvants: ^aMerge[®] @ 0.5% v/v; ^bTurbocharge[®] @ 0.5% v/v; ^cAmigo[®] @ 0.5% v/v; ^dAgral[®] 90 @ 0.25% v/v



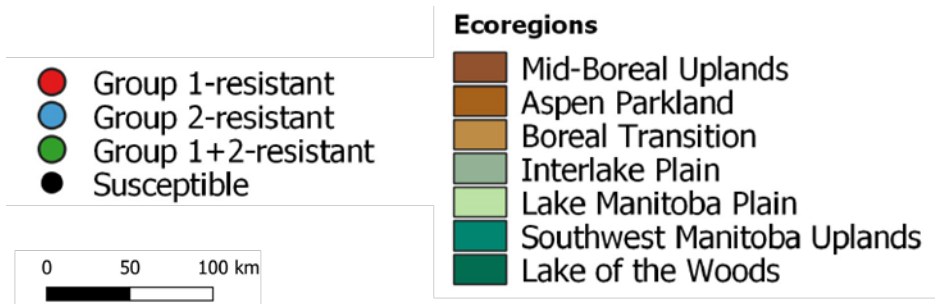
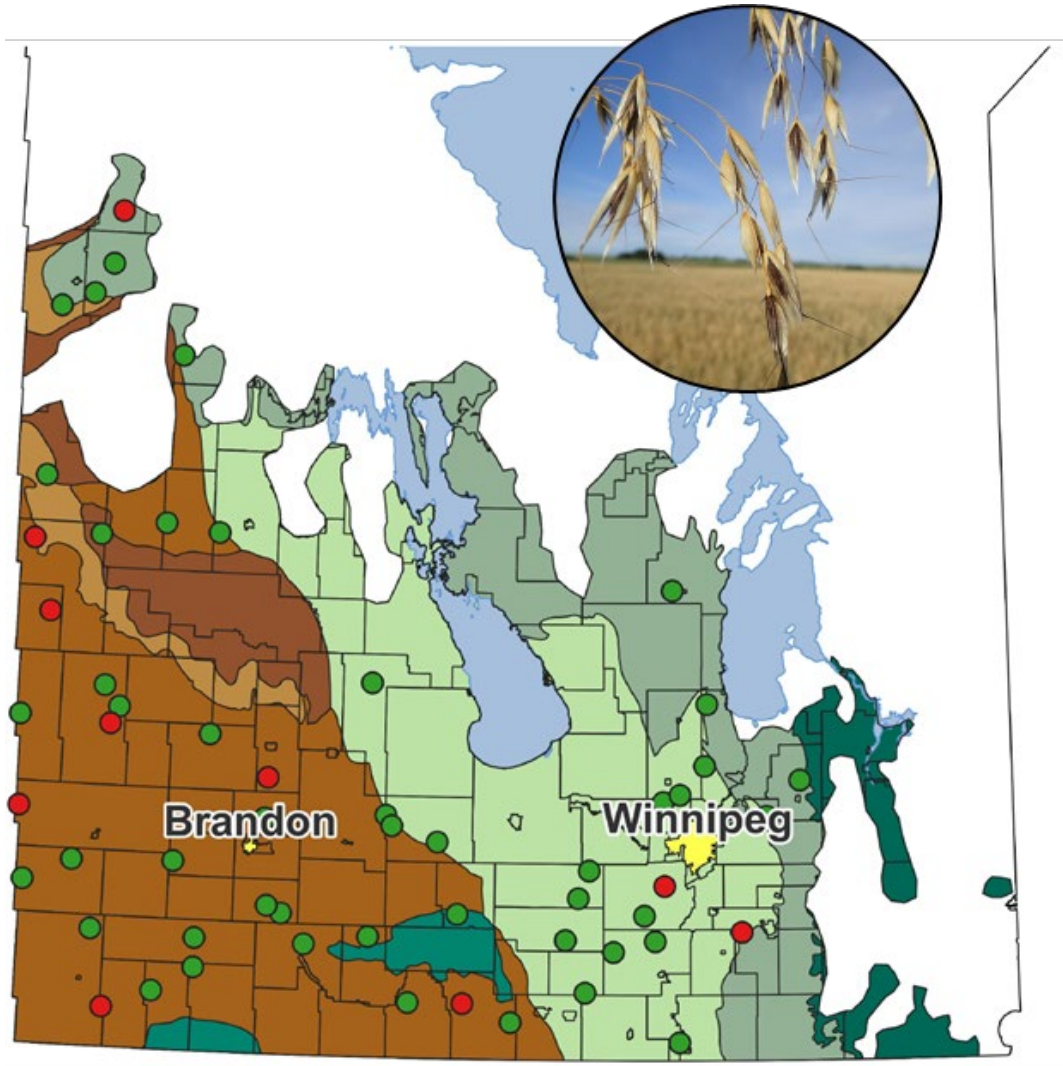
HR Grass Weeds



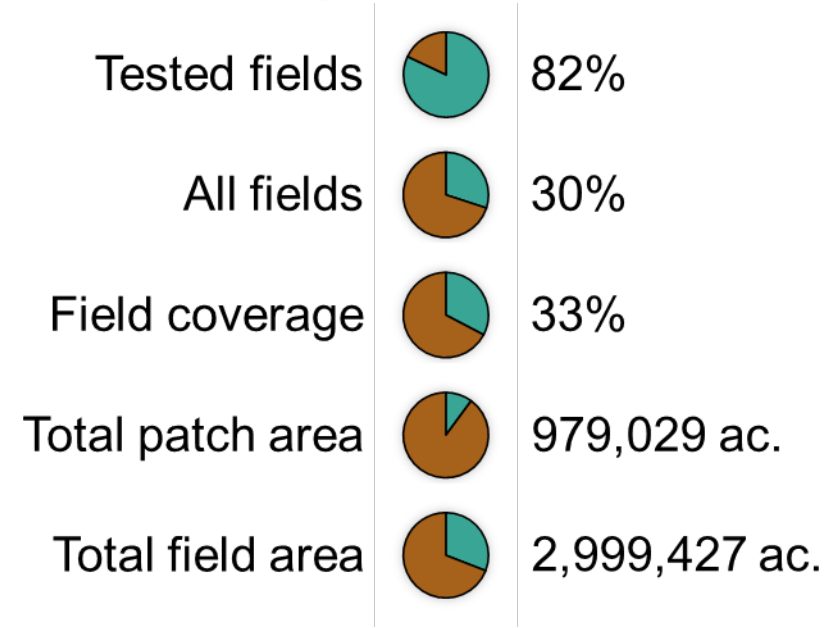
Group 1 resistance



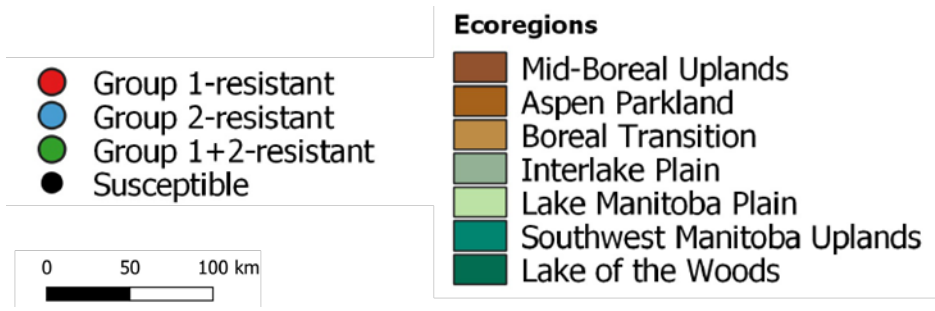
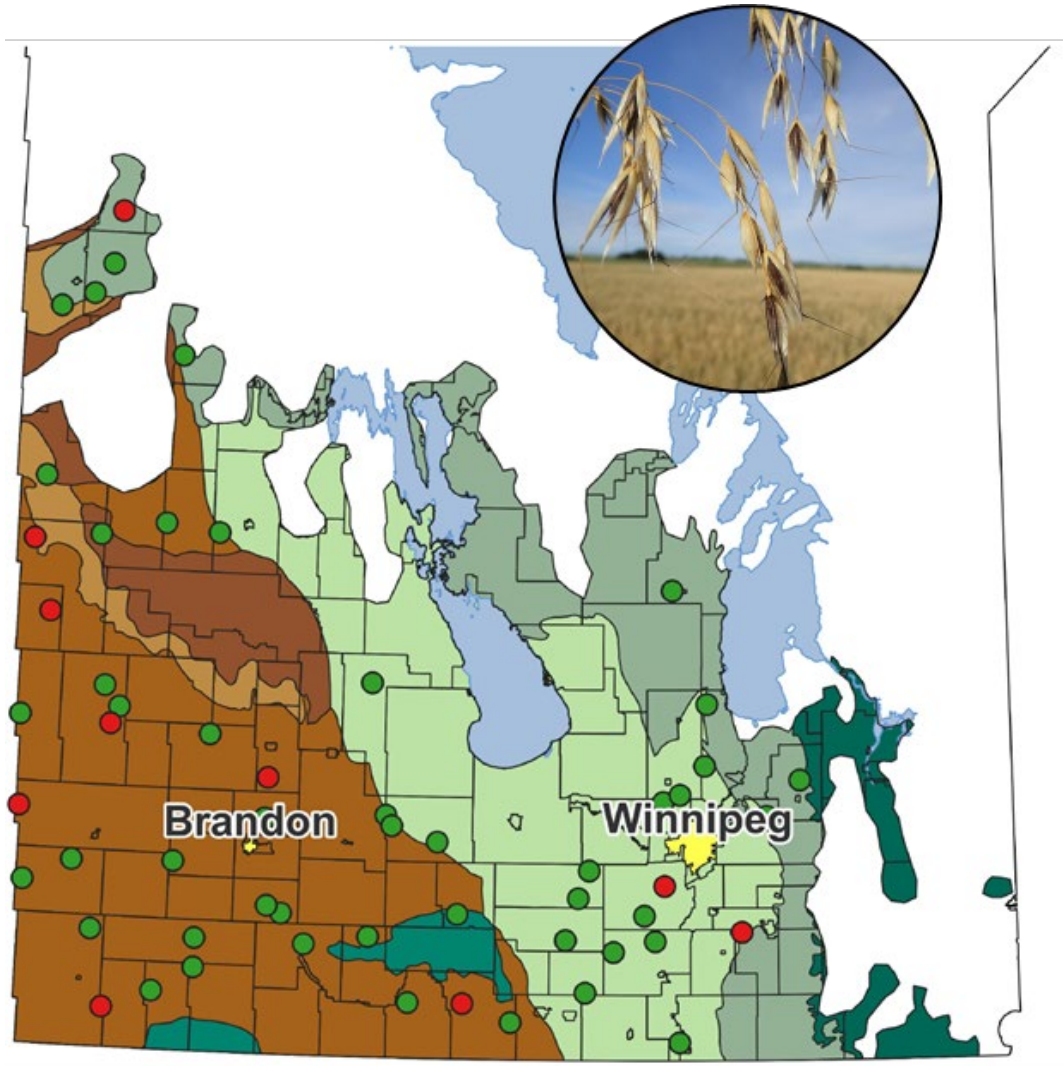
Wild oat



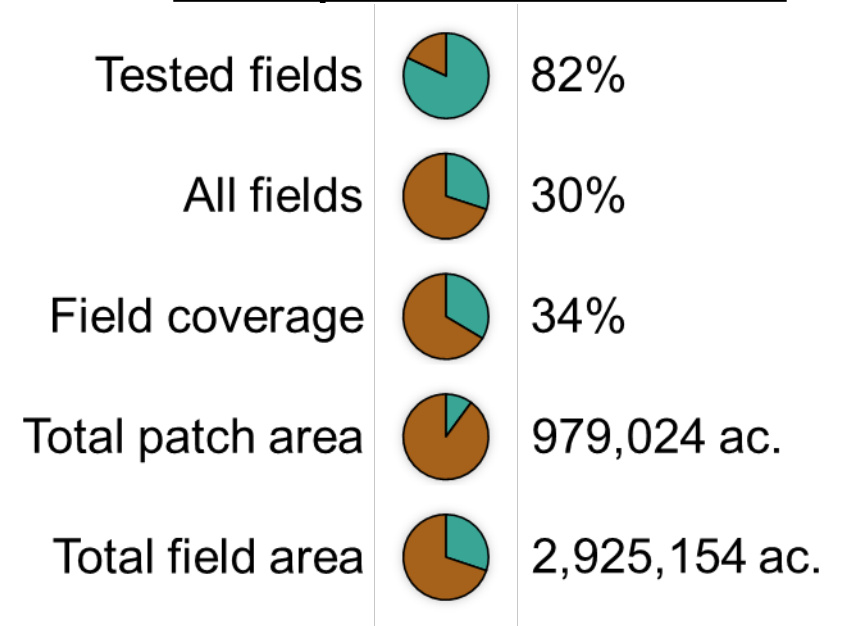
Group 2 resistance



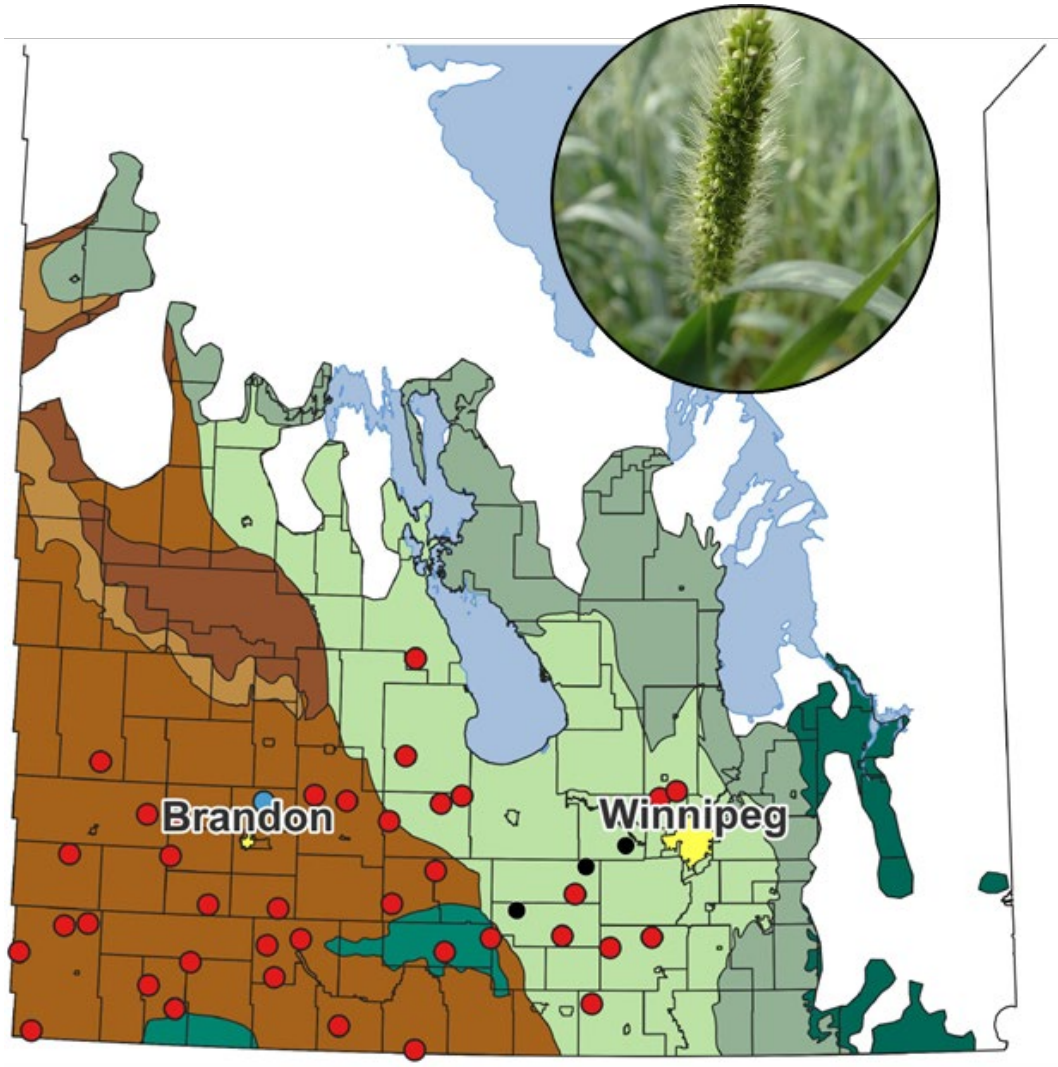
Wild oat



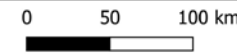
Group 1+2 resistance



Wild oat



- Group 1-resistant
- Group 2-resistant
- Group 1+2-resistant
- Susceptible



Ecoregions

- Mid-Boreal Uplands
- Aspen Parkland
- Boreal Transition
- Interlake Plain
- Lake Manitoba Plain
- Southwest Manitoba Uplands
- Lake of the Woods

Group 1 resistance

Tested fields		88%
All fields		27%
Field coverage		72%
Total patch area		2,096,351 ac.
Total field area		2,892,445 ac.

Green foxtail



Alberta Grains



Sask Wheat DEVELOPMENT COMMISSION

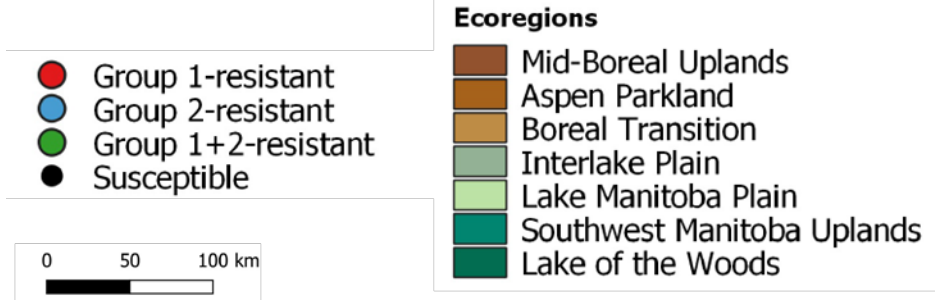
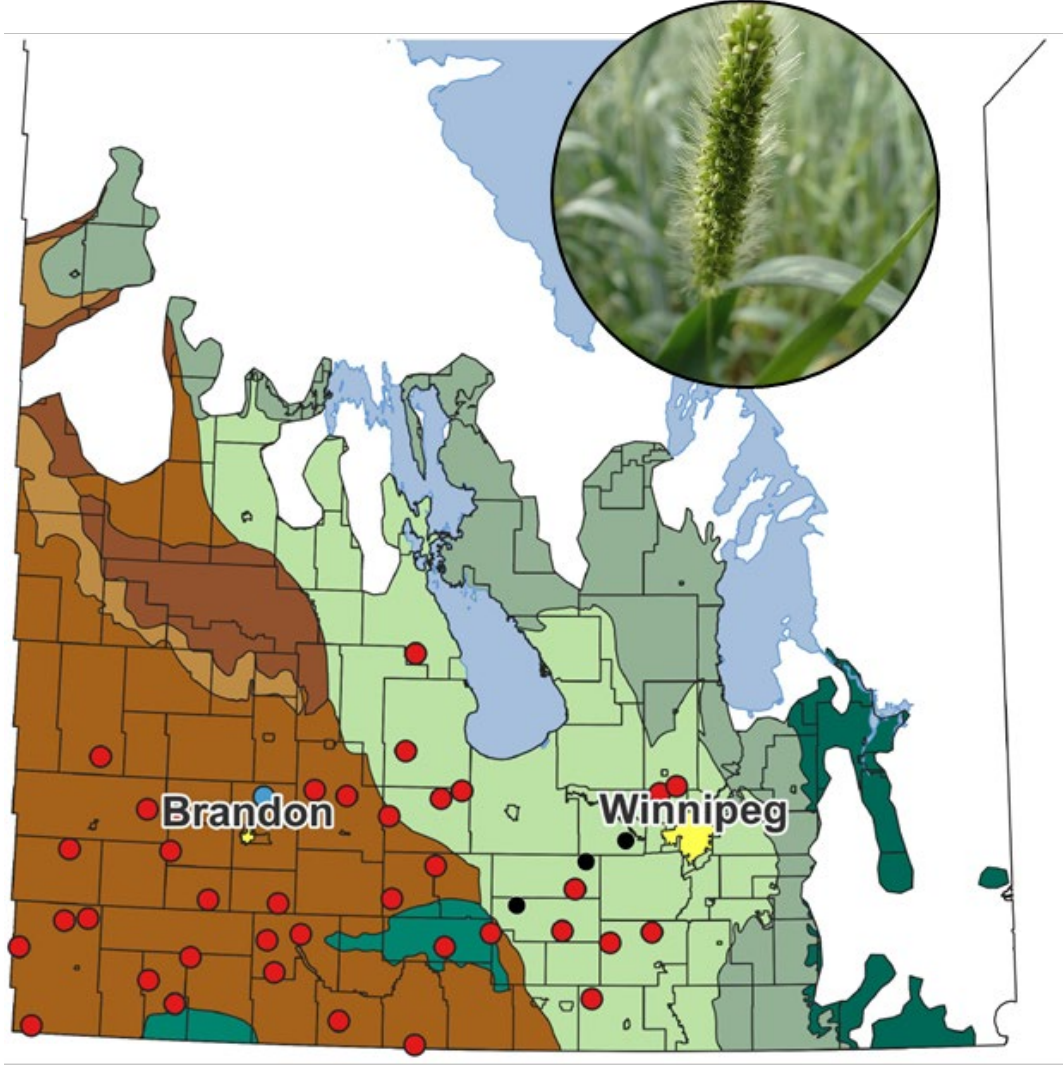
Manitoba 



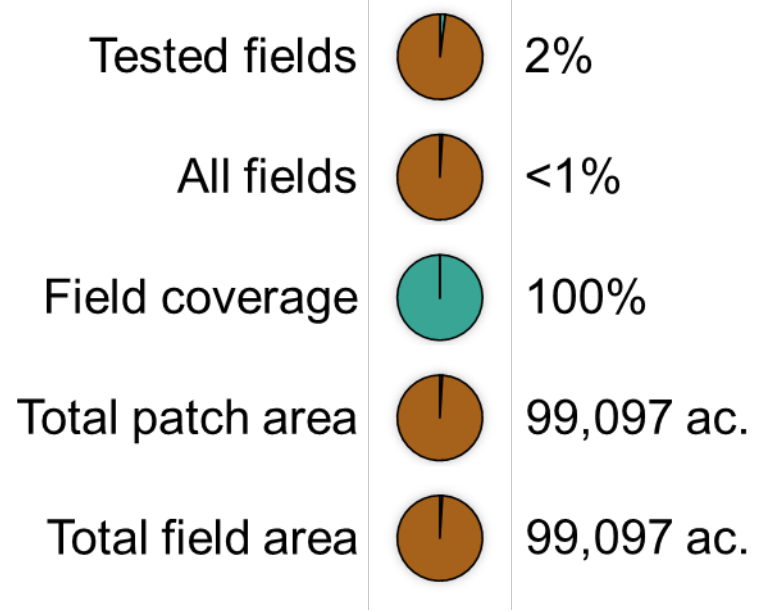
MANITOBA Pulse Soybean GROWERS



WGRF

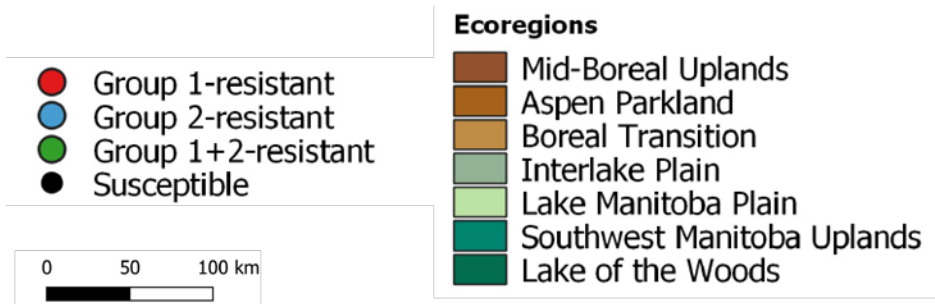


Group 2 resistance

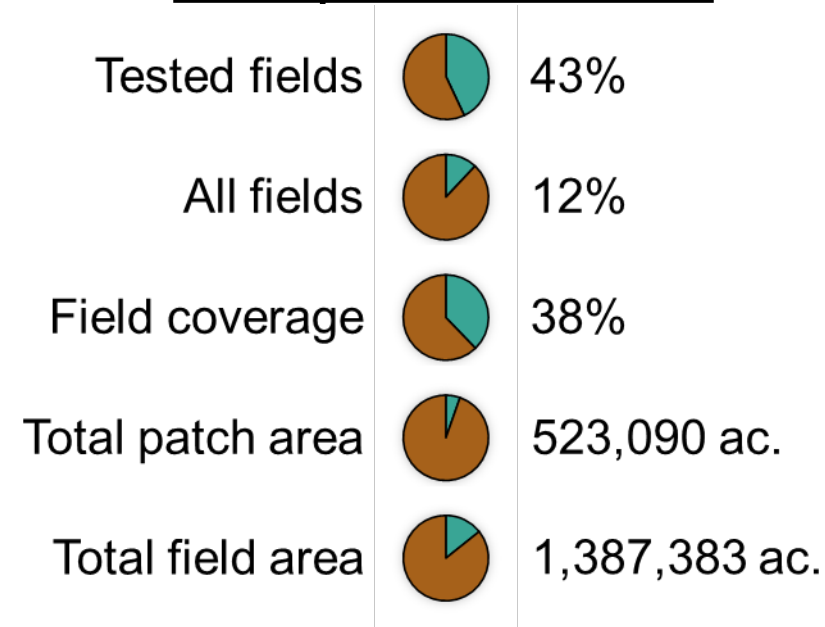


Green foxtail

Geddes *et al.*, Unpublished



Group 1 resistance



Yellow foxtail



Alberta Grains



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Manitoba 



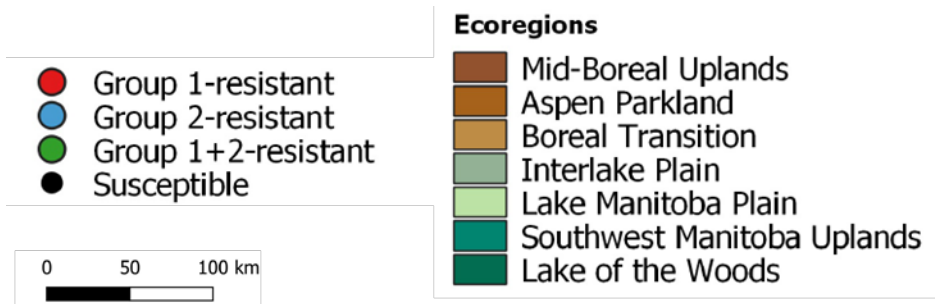
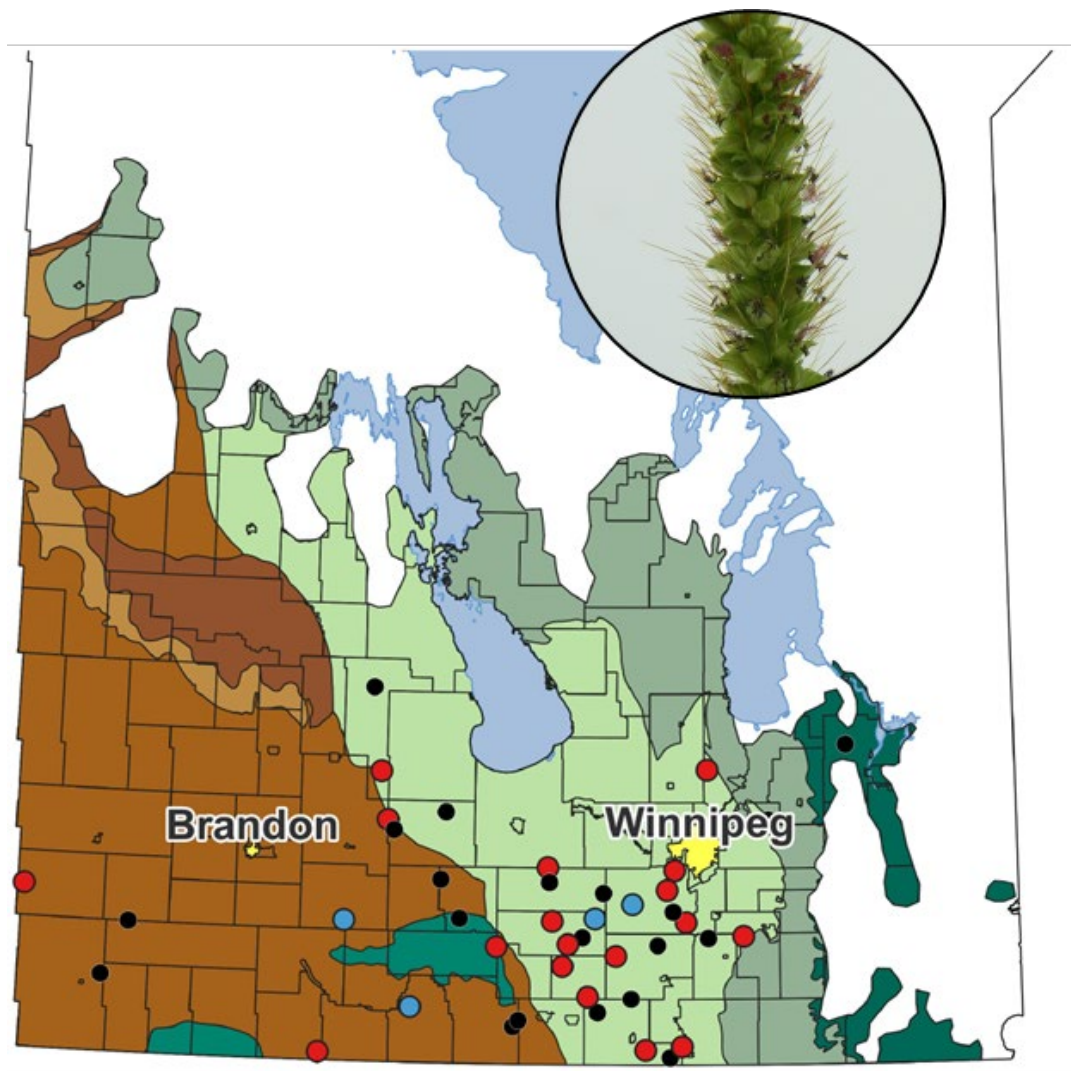
MANITOBA CROP ALLIANCE

MANITOBA Pulse Soybean GROWERS

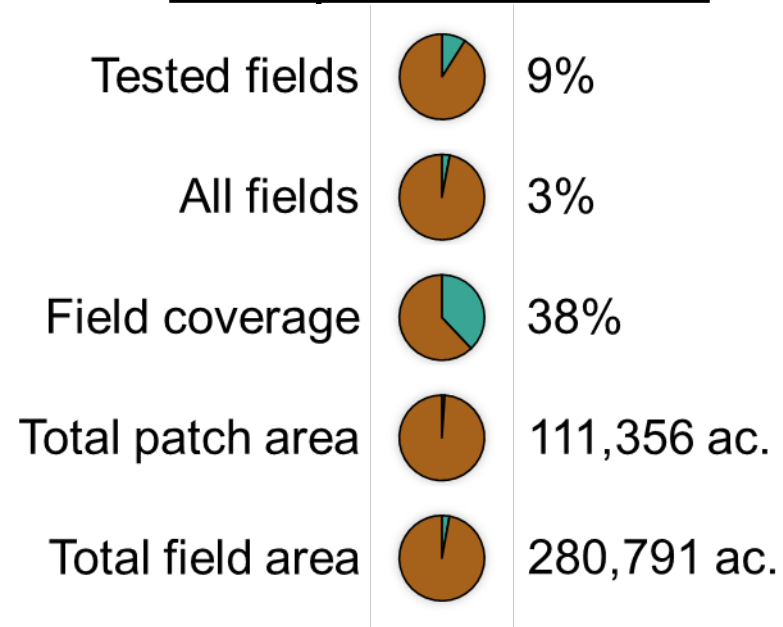


Manitoba Canola Growers Association

WGRF 

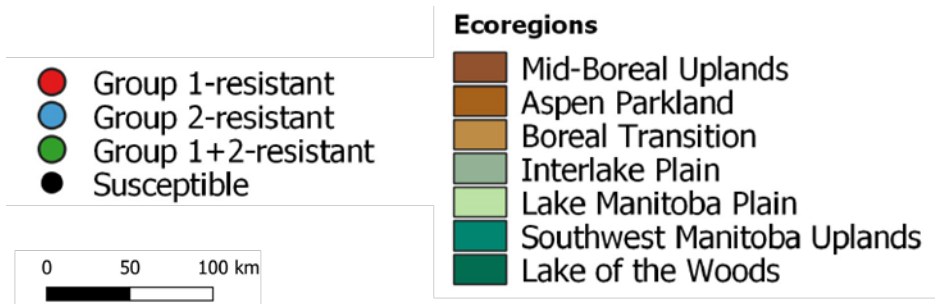
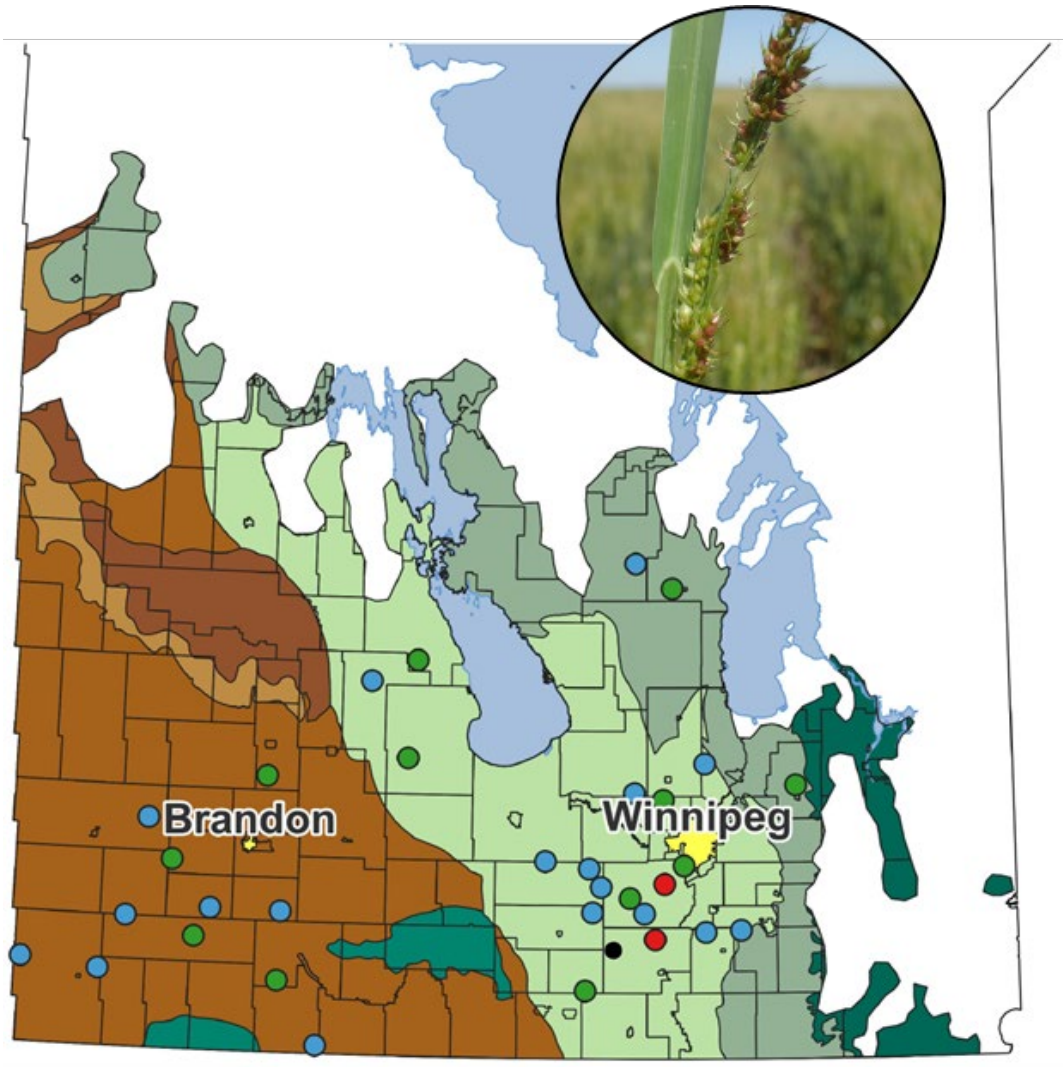


Group 2 resistance

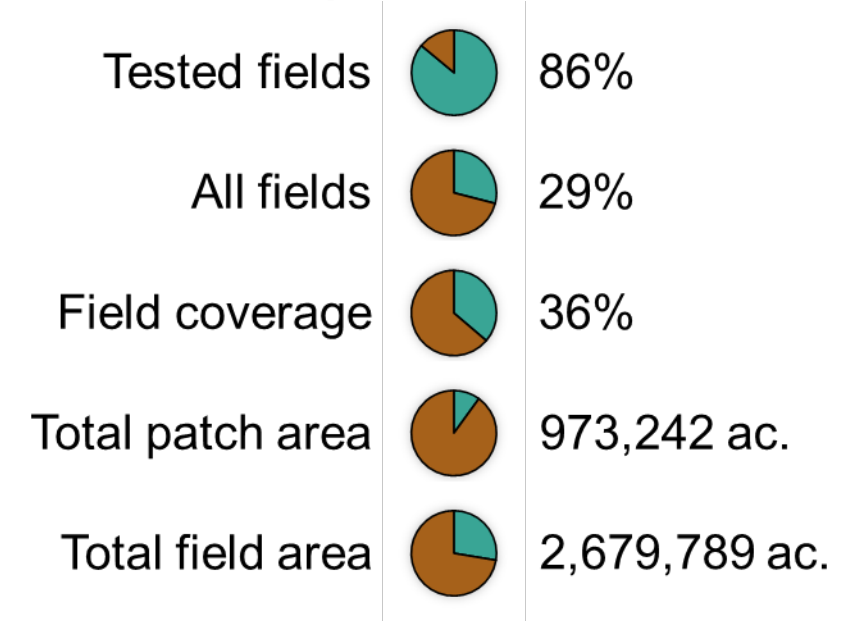


Yellow foxtail

Geddes *et al.*, Unpublished



Group 2 resistance



Barnyardgrass



Alberta
Grains



Government
of
Saskatchewan



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CROP
ALLIANCE



New Putative* HR Grass Weeds

*official first confirmation requires further dose-response experiments



Alberta Grains



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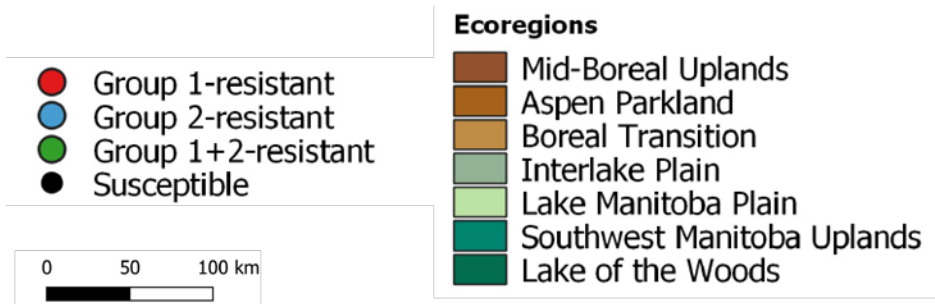
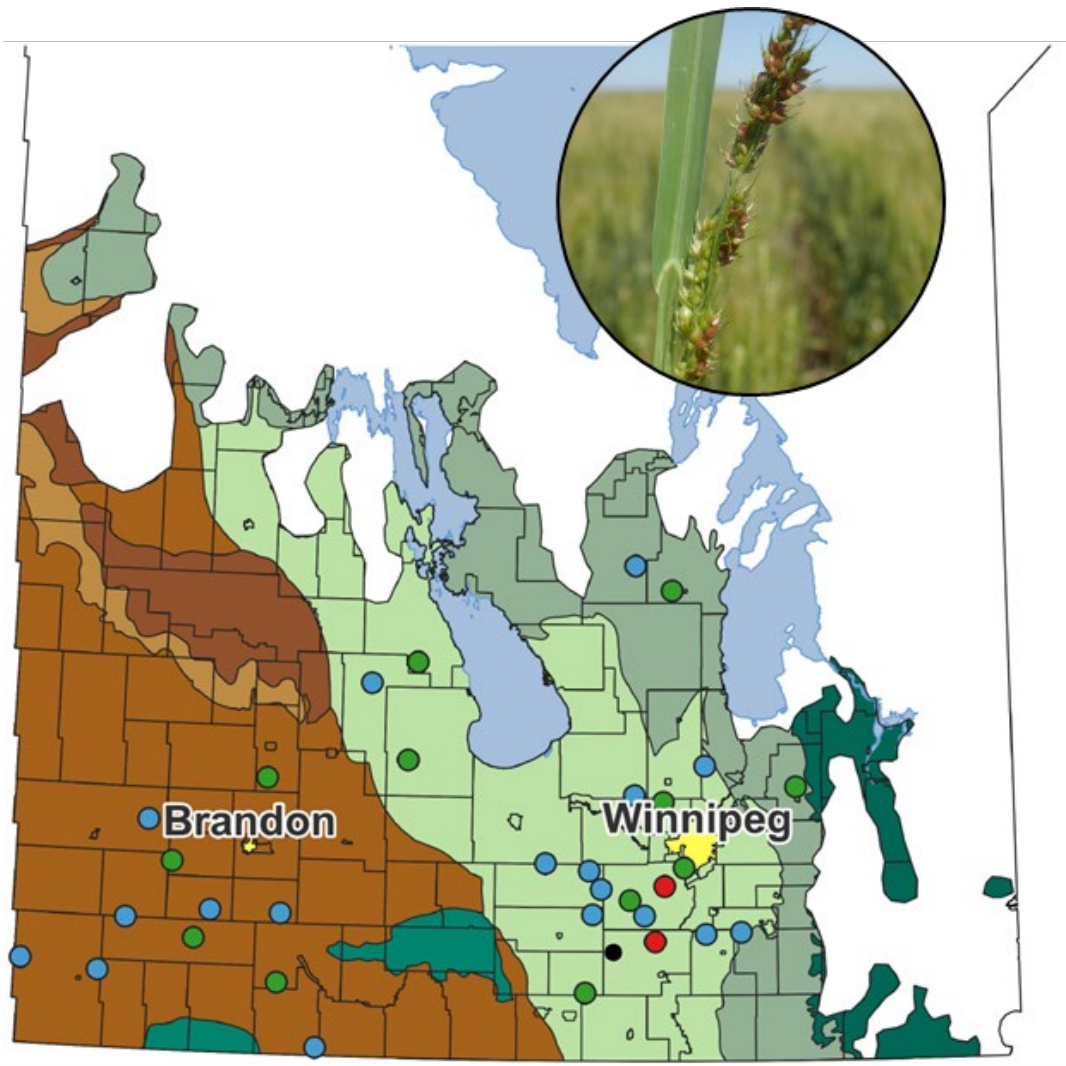


MANITOBA CROP ALLIANCE

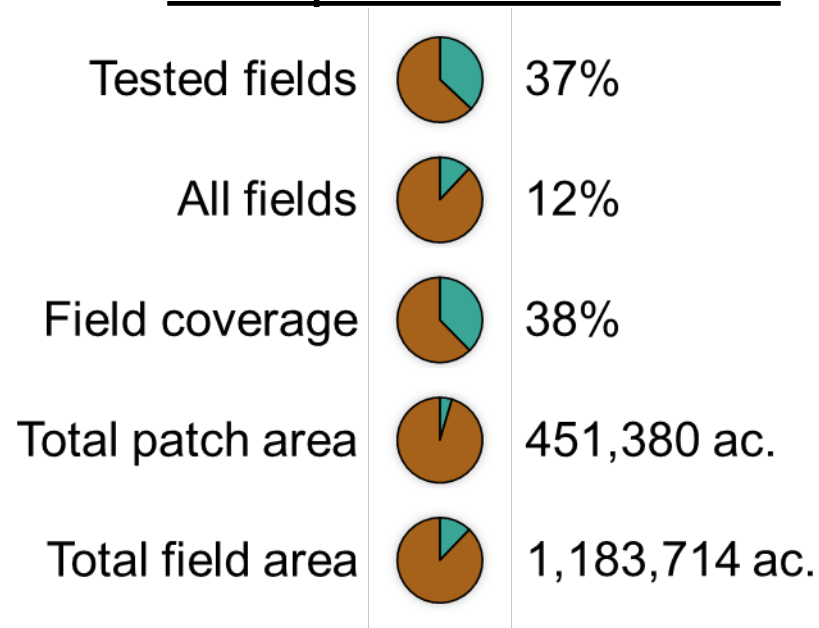
MANITOBA Pulse Soybean GROWERS



Manitoba Canola Growers Association

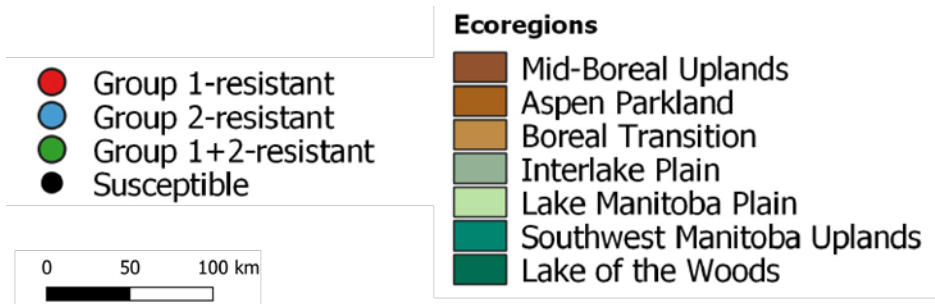
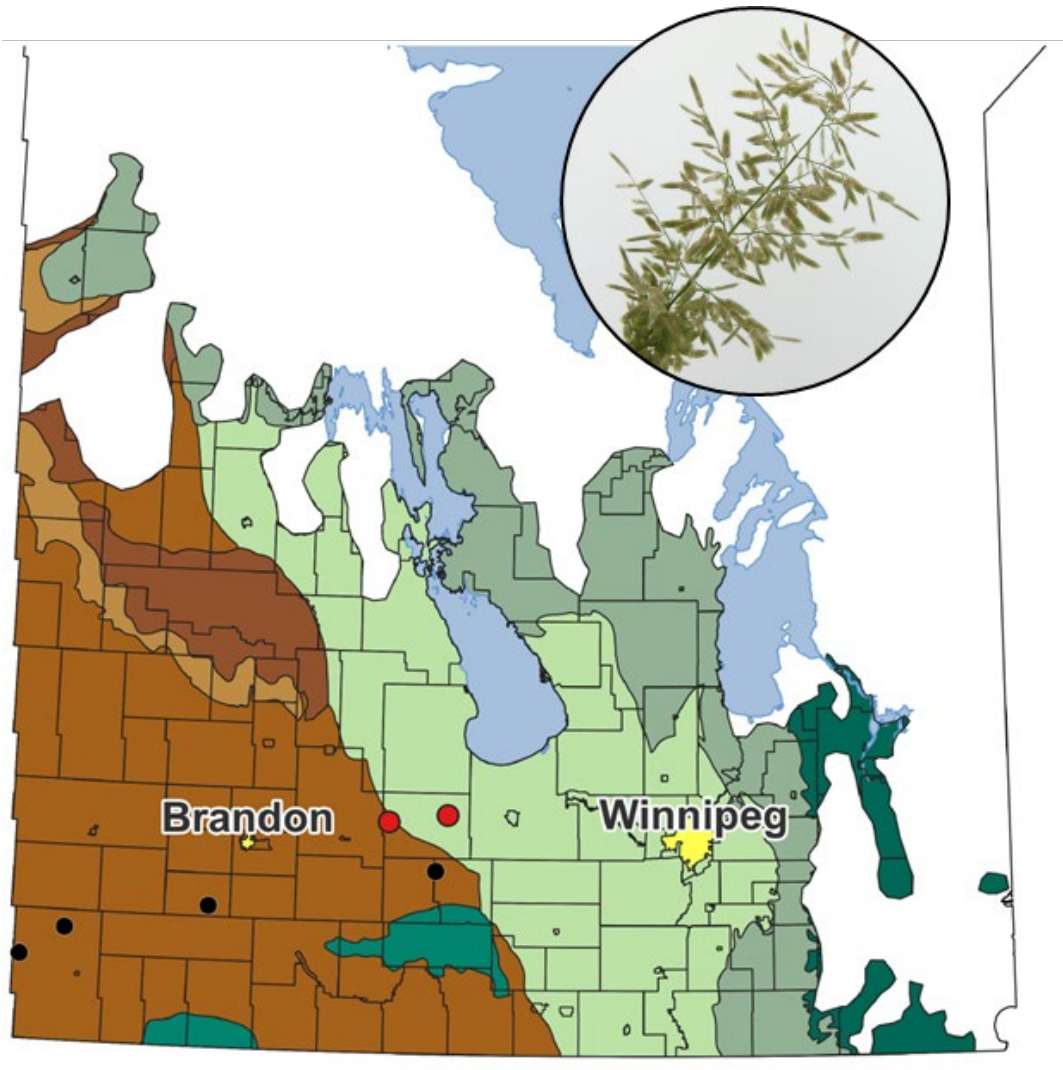


Group 1+2 resistance

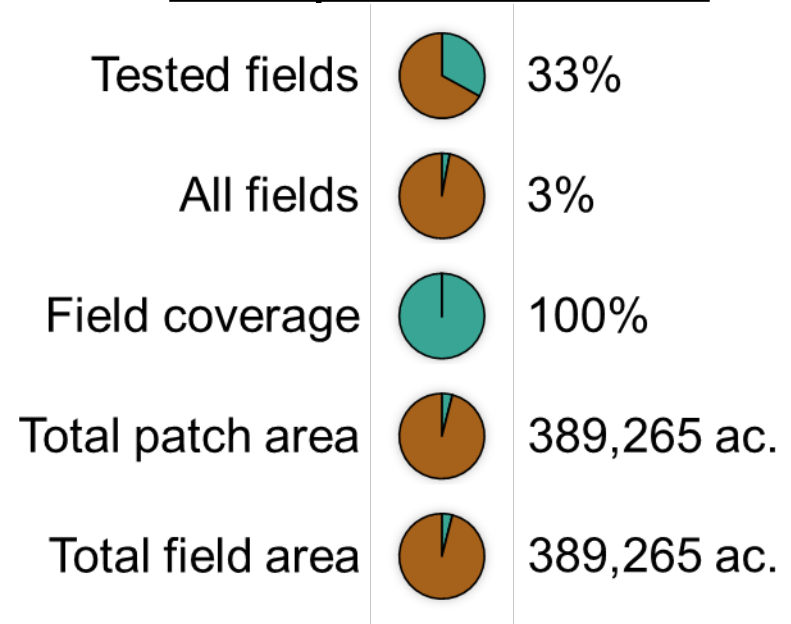


Barnyardgrass*

Geddes *et al.*, Unpublished



Group 1 resistance



Stinkgrass*



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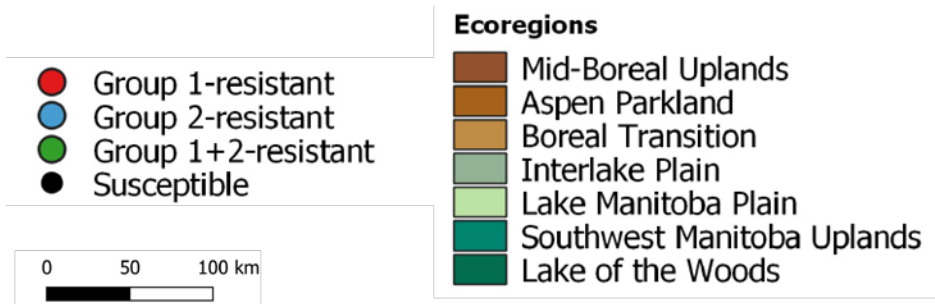
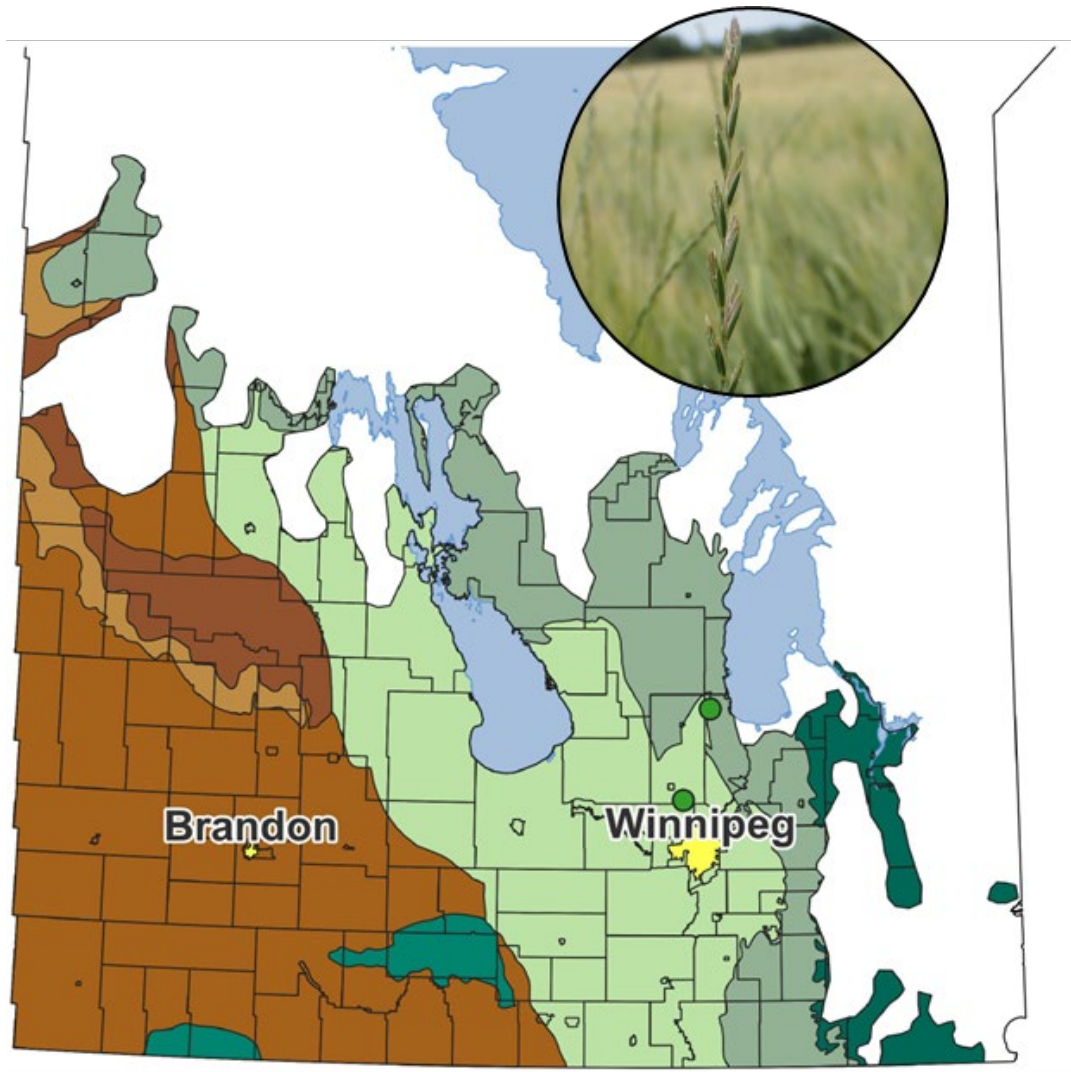


MANITOBA CROP ALLIANCE

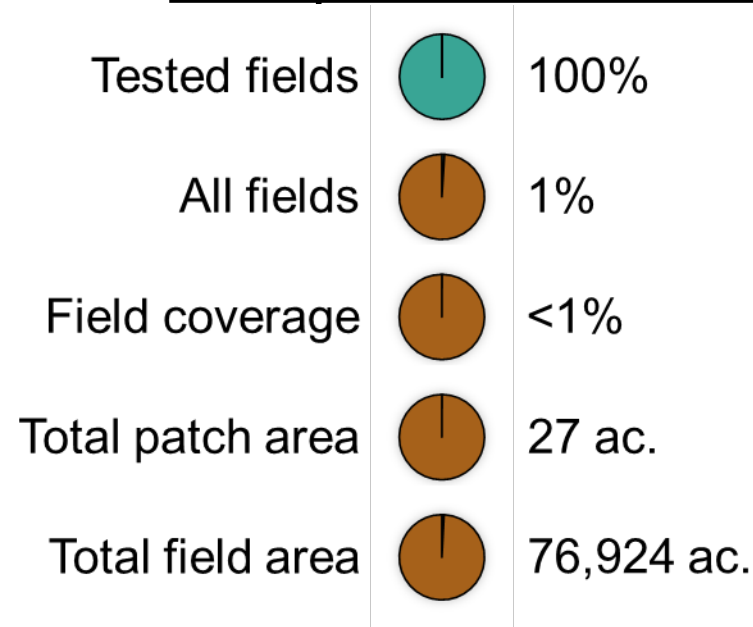
MANITOBA Pulse Soybean GROWERS



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Group 1+2 resistance



Quackgrass*

Geddes *et al.*, Unpublished



HR Broadleaf Weeds



Alberta Grains



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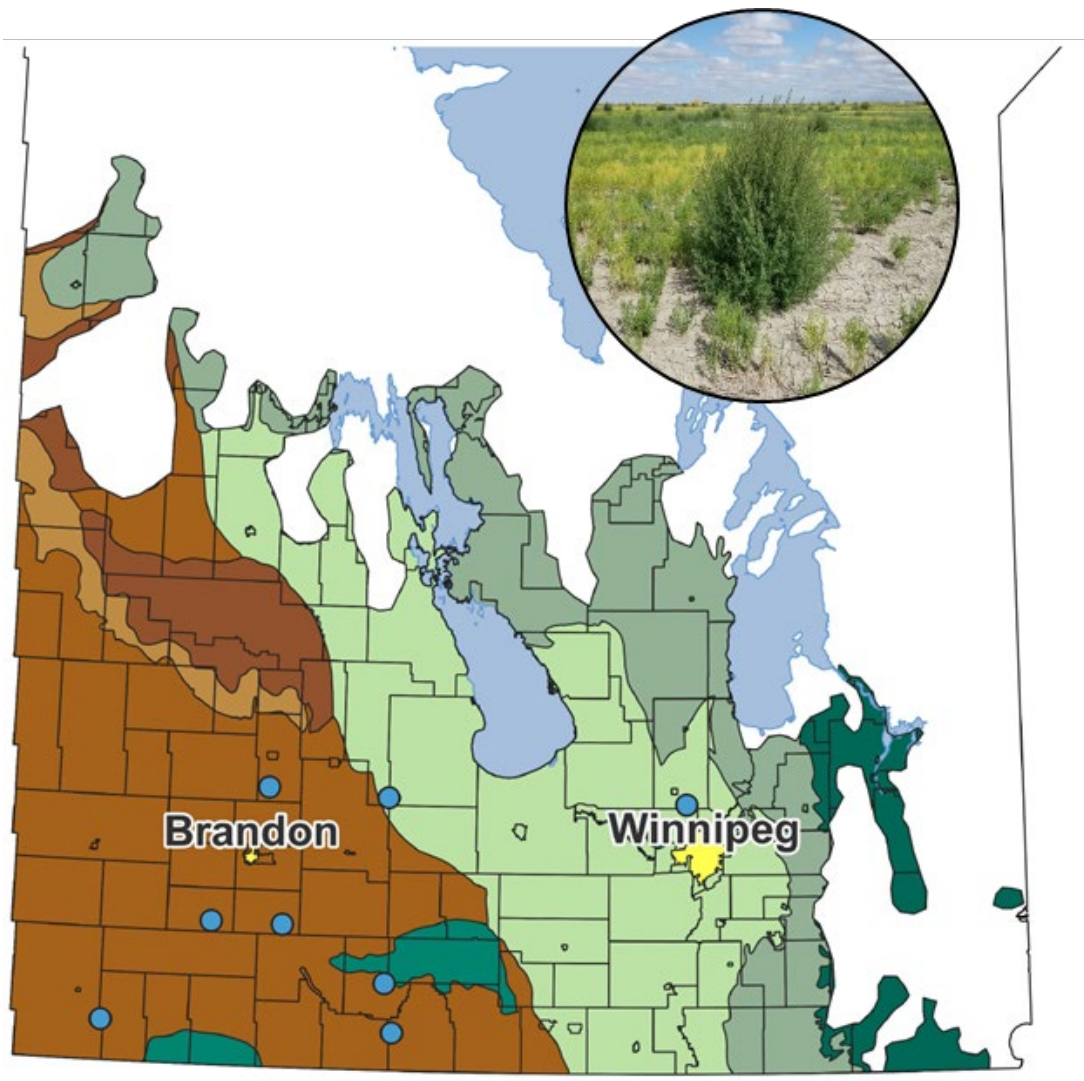
MANITOBA CROP ALLIANCE

MANITOBA Pulse Soybean GROWERS

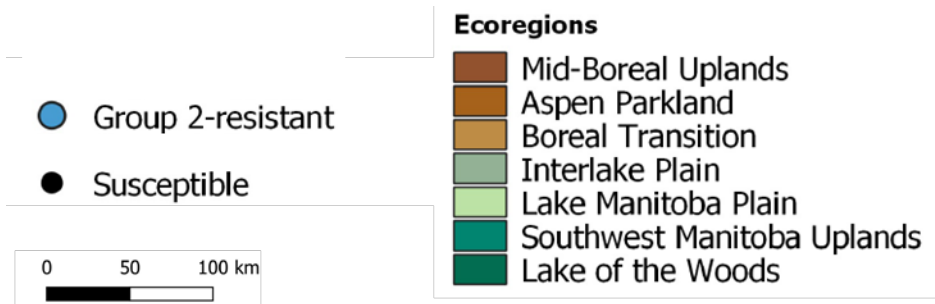


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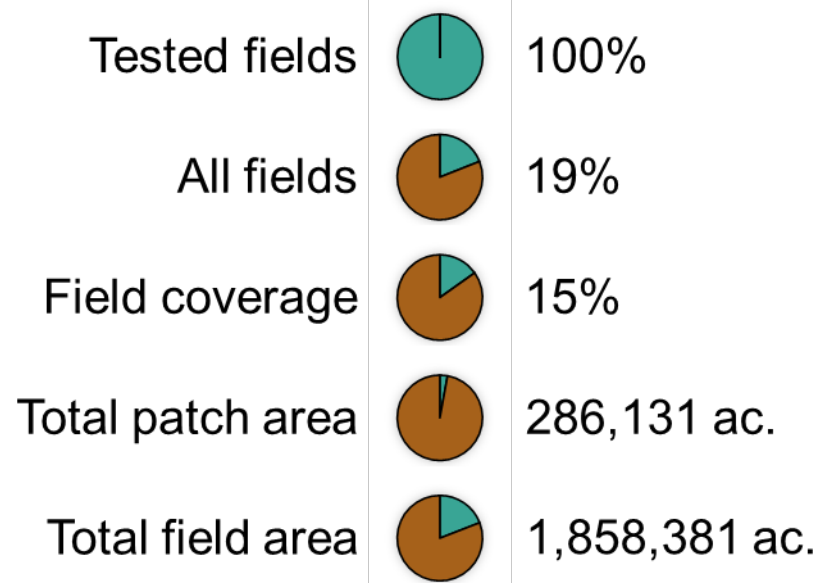
WGFRF



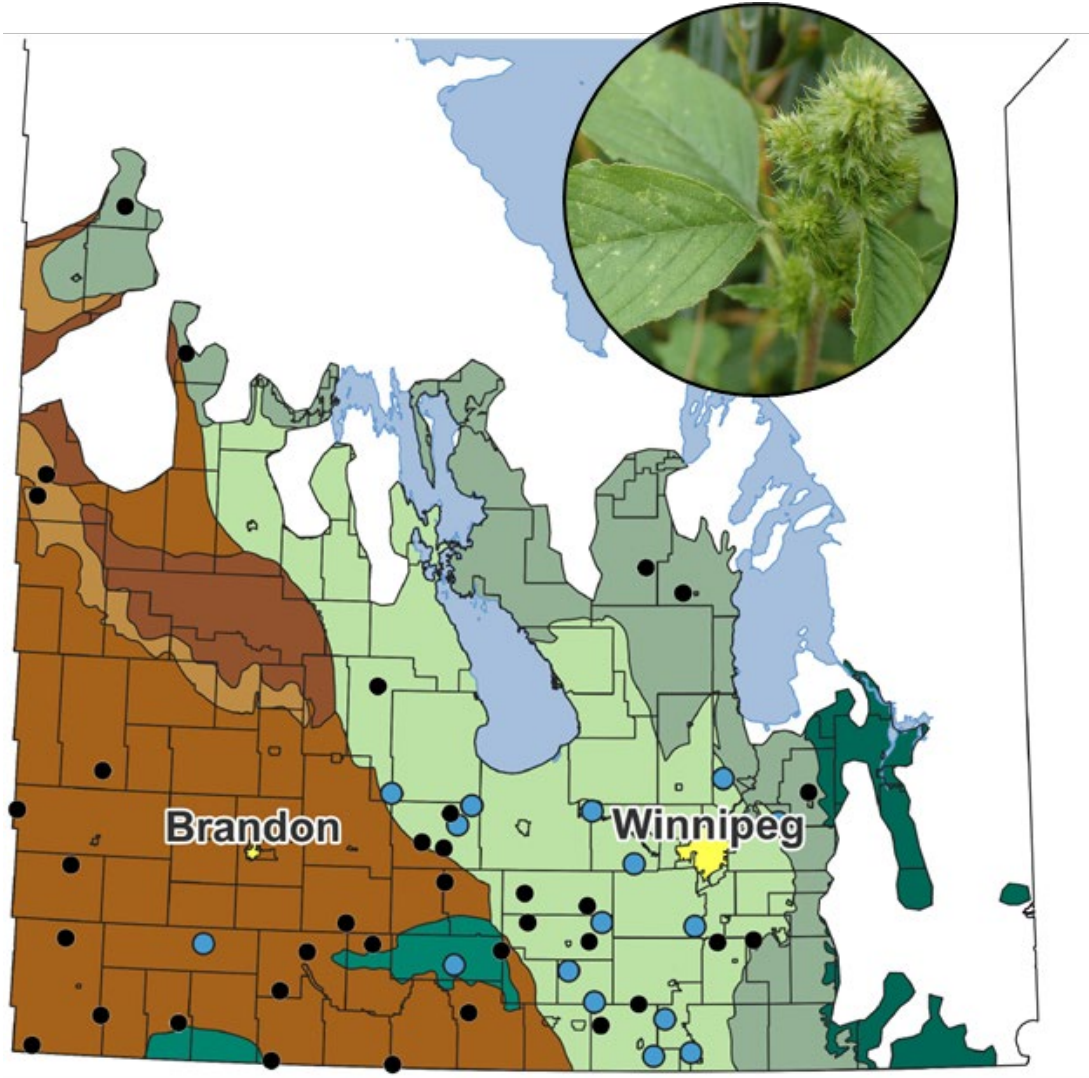
Kochia



Group 2 resistance

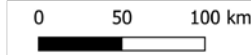


Geddes *et al.*, Unpublished



Pigweeds

- Group 2-resistant
- Susceptible



Ecoregions

- Mid-Boreal Uplands
- Aspen Parkland
- Boreal Transition
- Interlake Plain
- Lake Manitoba Plain
- Southwest Manitoba Uplands
- Lake of the Woods

Group 2 resistance

Tested fields		31%
All fields		13%
Field coverage		57%
Total patch area		868,197 ac.
Total field area		1,515,952 ac.



Alberta Grains



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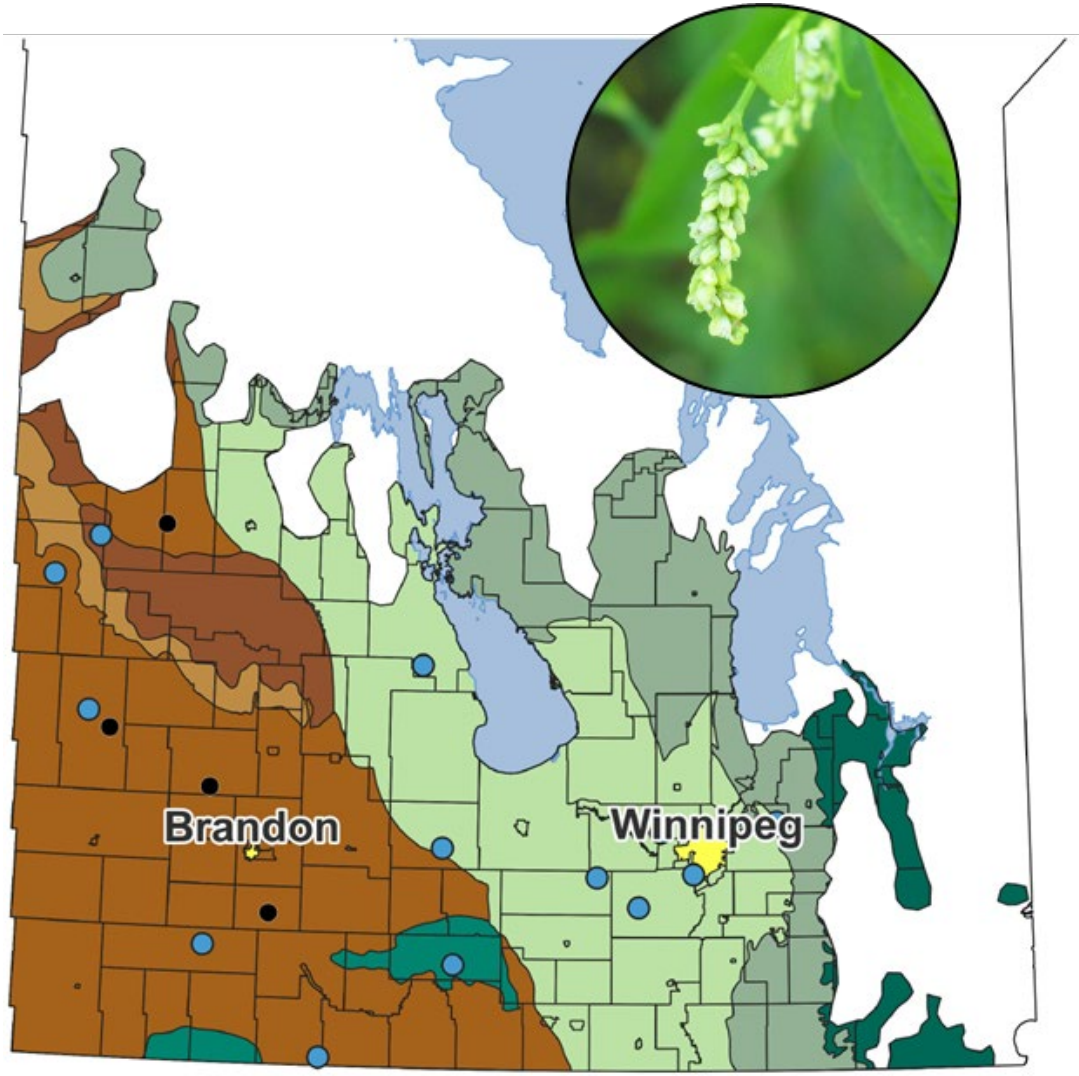
MANITOBA CROP ALLIANCE

MANITOBA Pulse Soybean GROWERS





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Pale smartweed

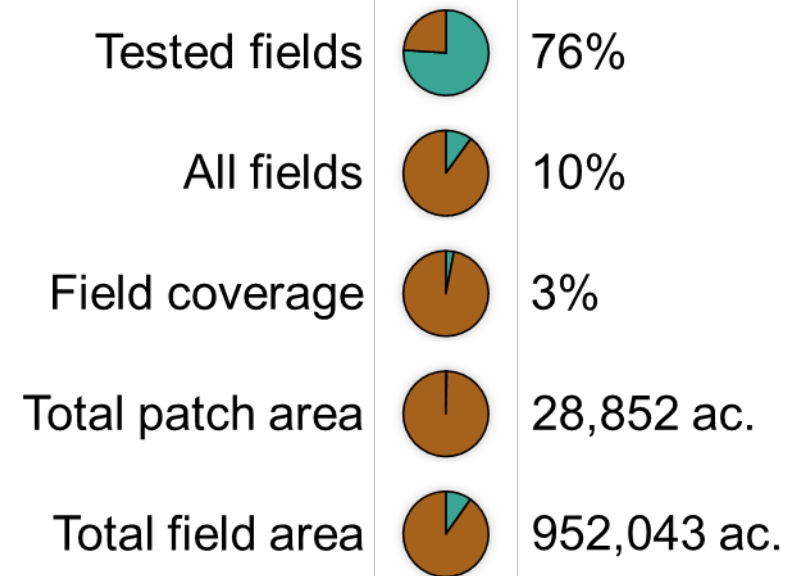
-  Group 2-resistant
-  Susceptible



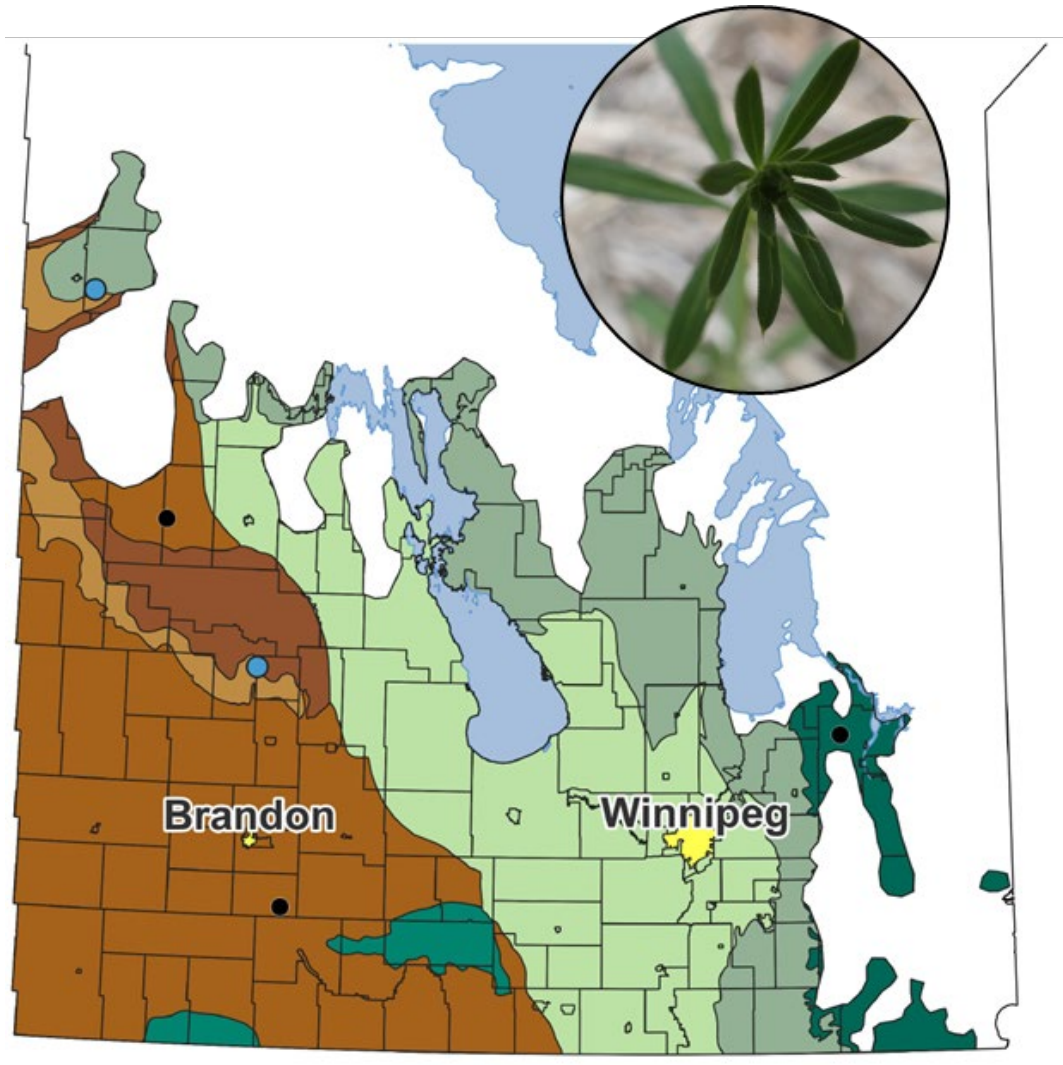
Ecoregions

-  Mid-Boreal Uplands
-  Aspen Parkland
-  Boreal Transition
-  Interlake Plain
-  Lake Manitoba Plain
-  Southwest Manitoba Uplands
-  Lake of the Woods

Group 2 resistance



Geddes *et al.*, Unpublished



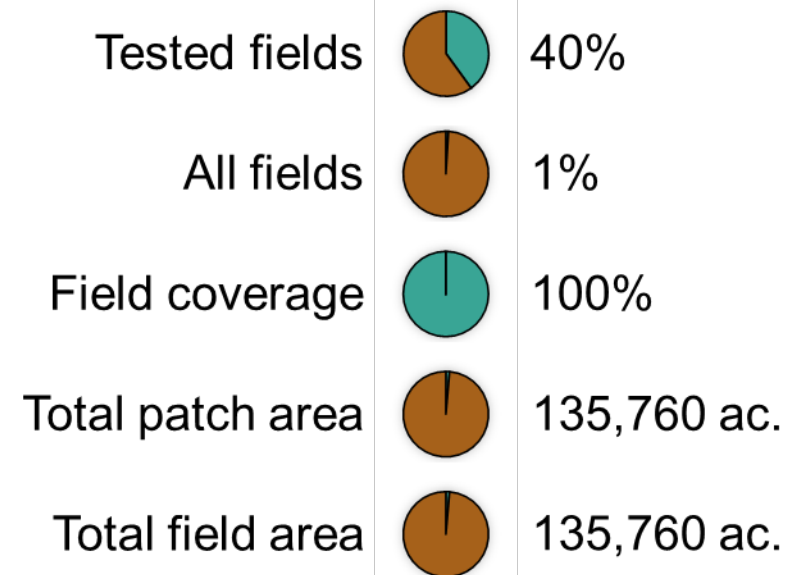
- Group 2-resistant
- Susceptible



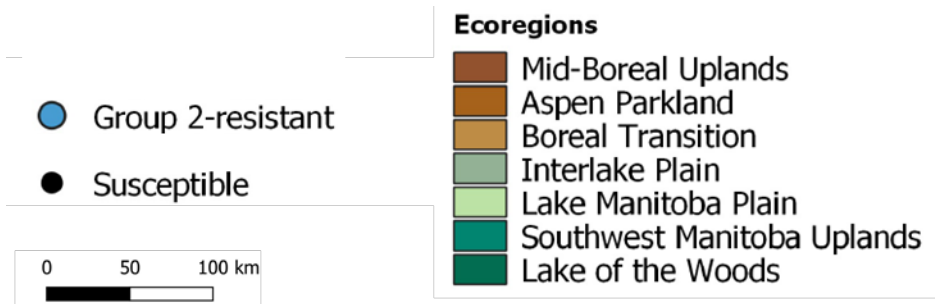
Ecoregions

- Mid-Boreal Uplands
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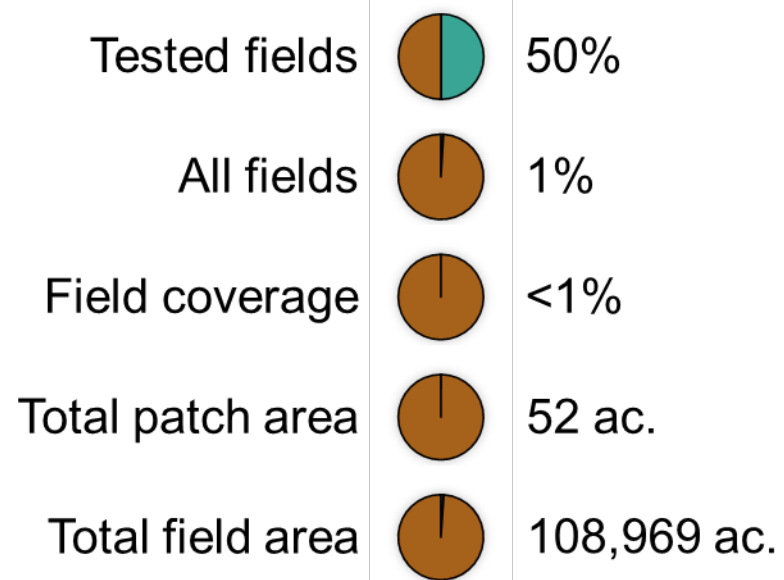
Group 2 resistance



False cleavers



Group 2 resistance



Shepherd's purse



Alberta Grains



Sask Wheat DEVELOPMENT COMMISSION

Manitoba



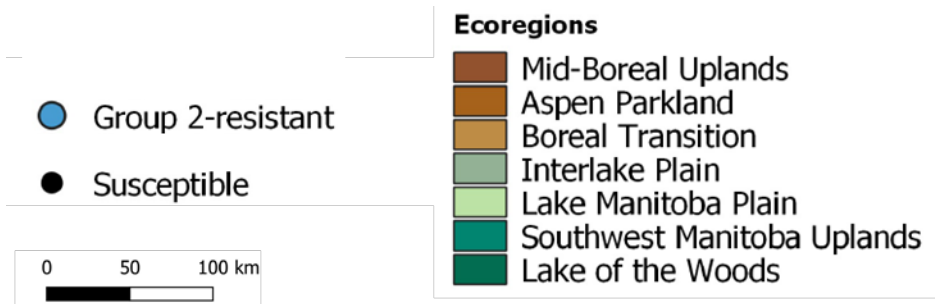
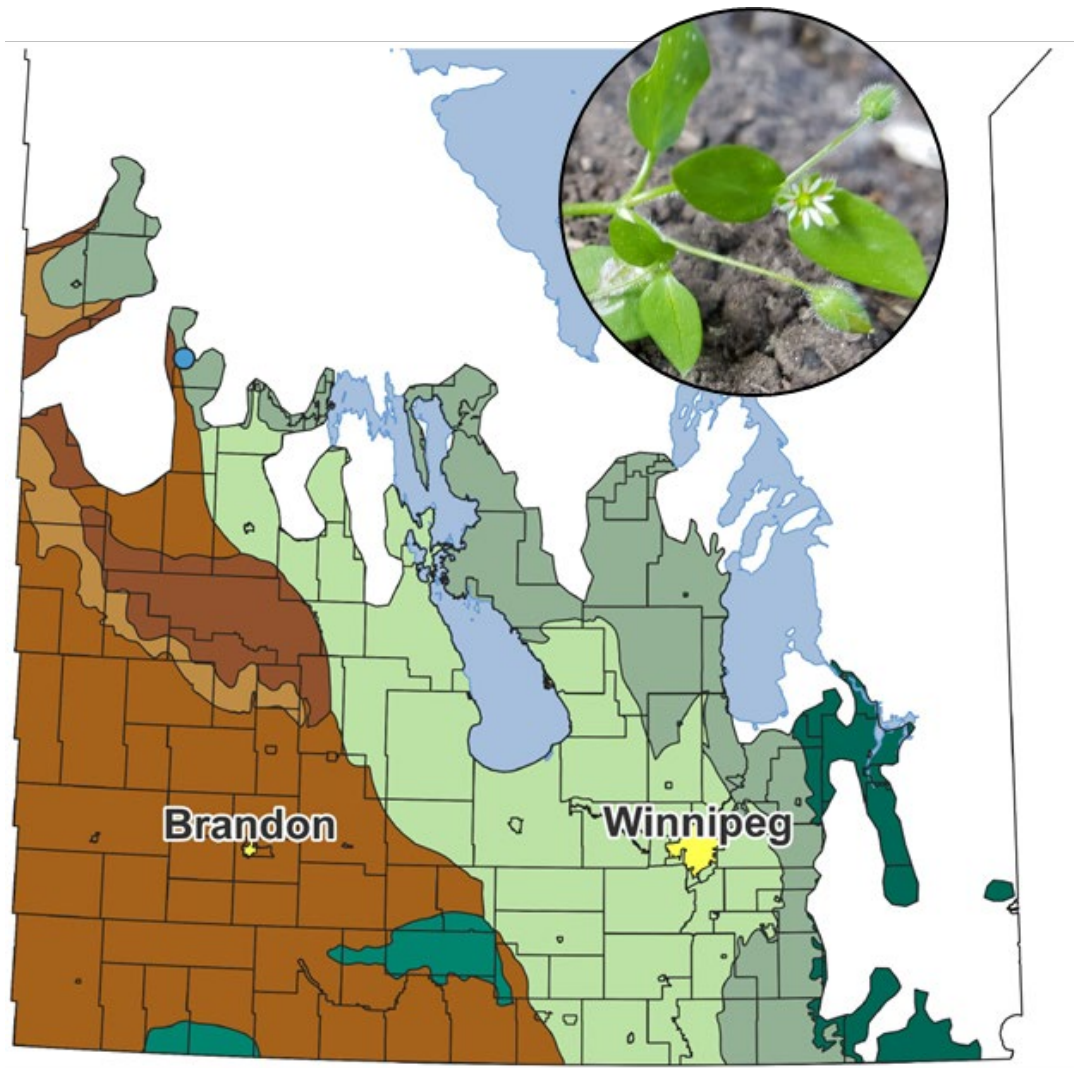
MANITOBA CROP ALLIANCE

MANITOBA Pulse Soybean GROWERS

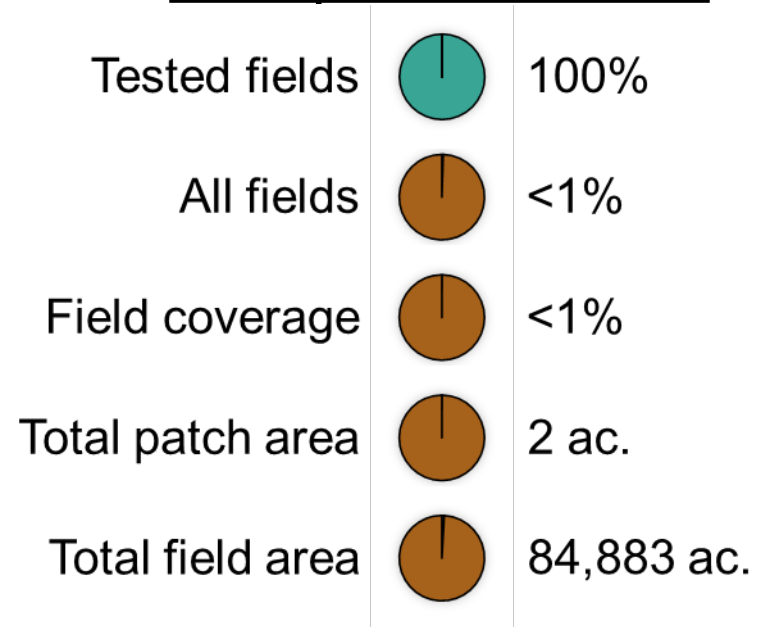


Manitoba Canola Growers Association

WGRF



Group 2 resistance



Chickweed

Geddes *et al.*, Unpublished



Alberta
Grains



Government
of
Saskatchewan



MANITOBA
CROP
ALLIANCE

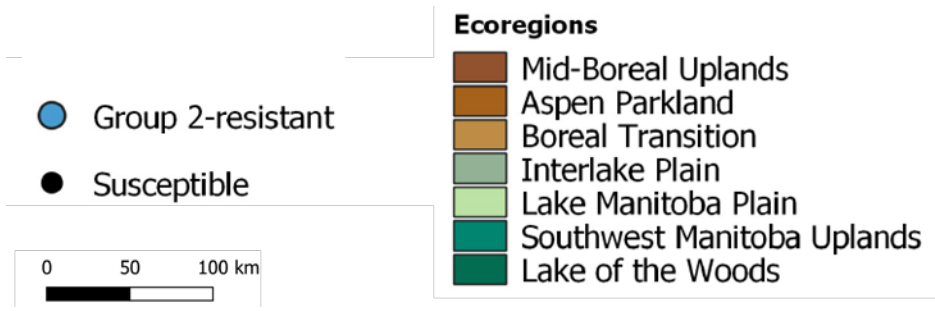


Manitoba
Canola Growers
Association

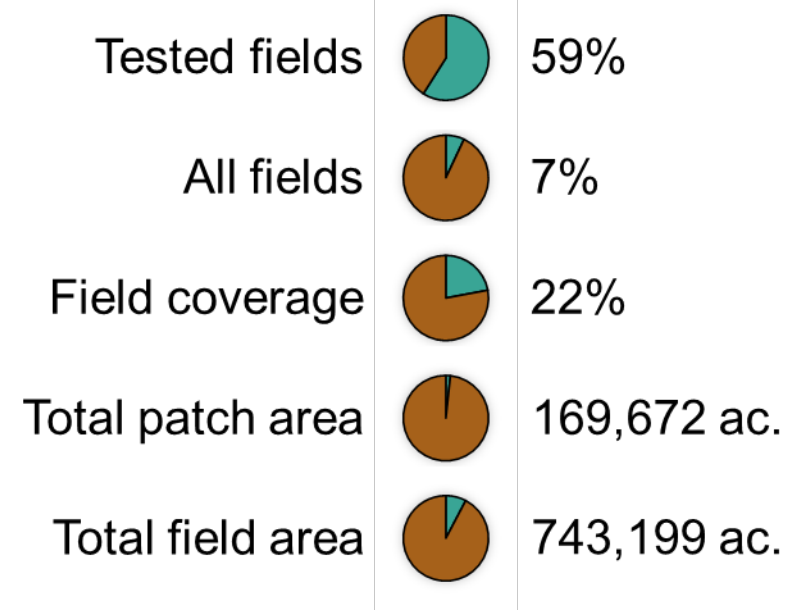


New Putative* HR Broadleaf Weeds

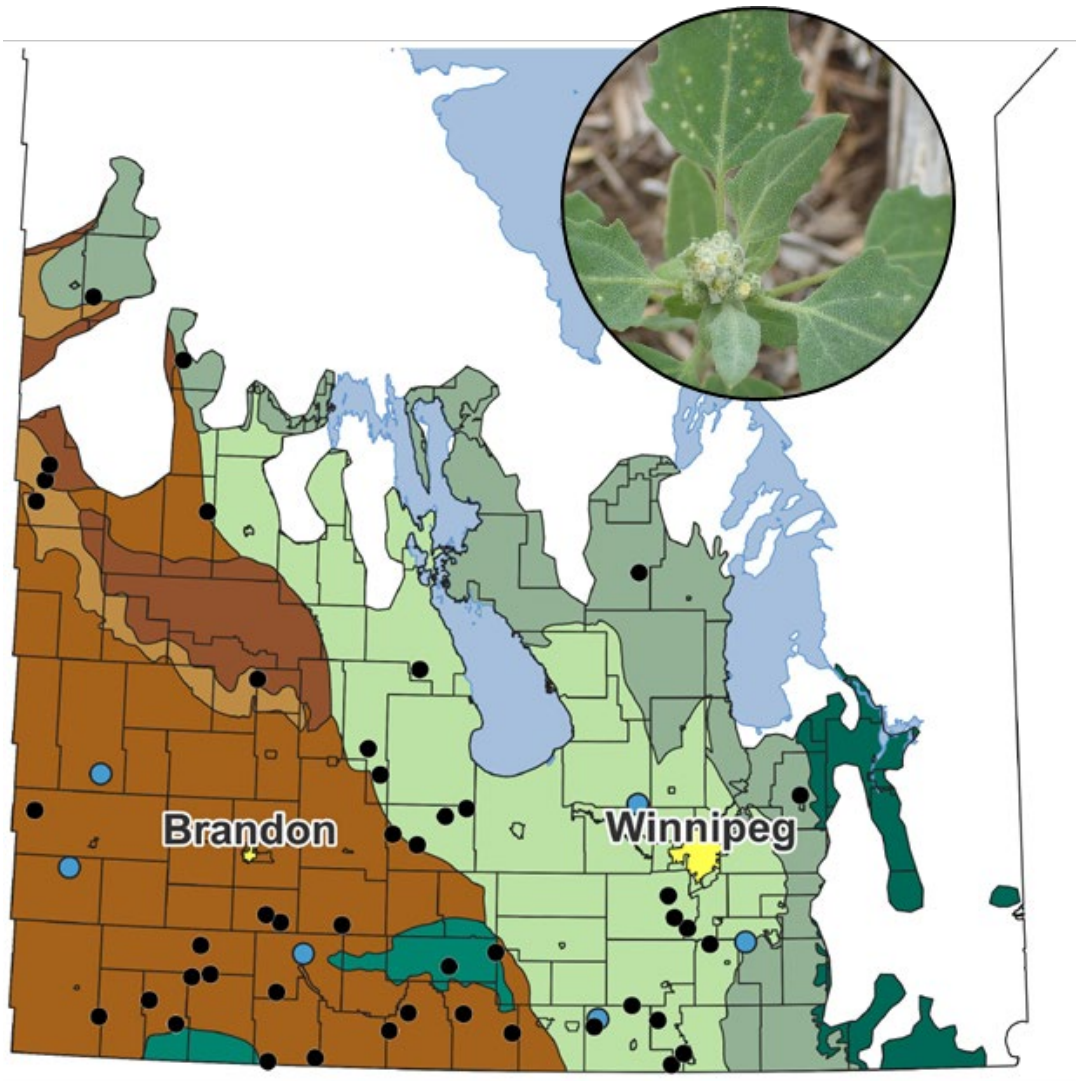
*official first confirmation requires further dose-response experiments



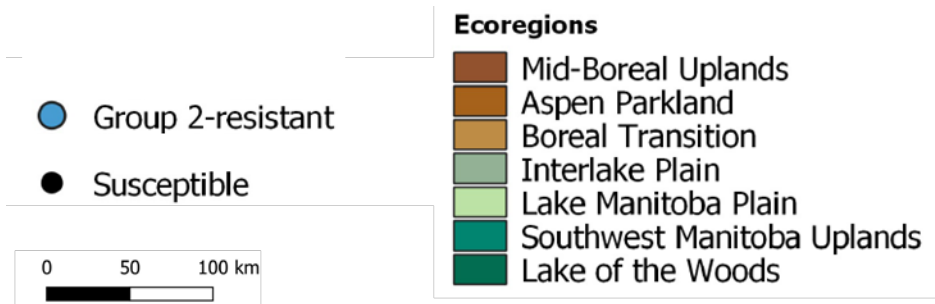
Group 2 resistance



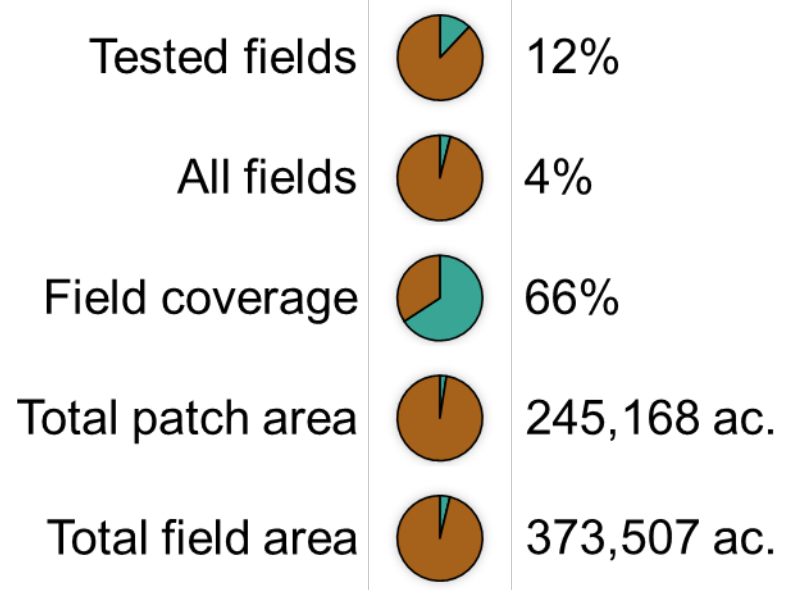
Spiny sowthistle*

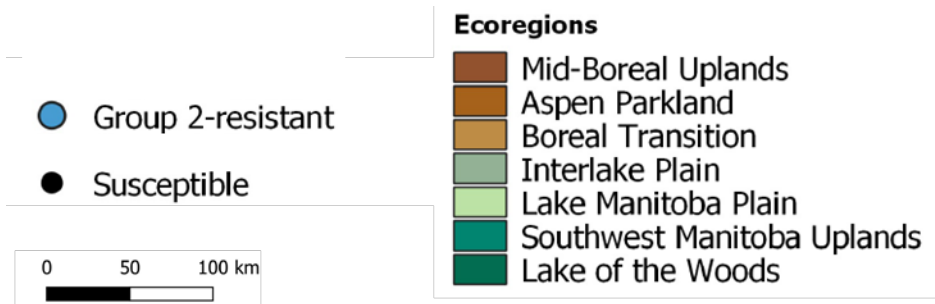


Lamb's quarters*

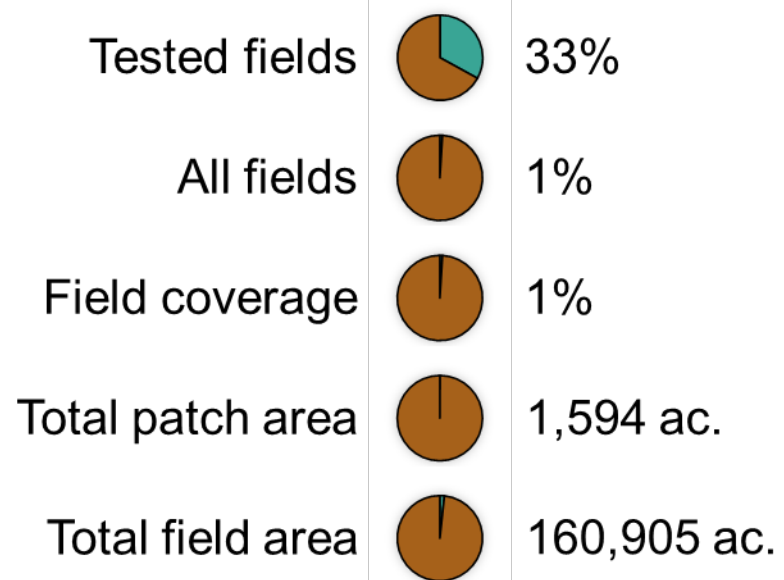


Group 2 resistance





Group 2 resistance



Horseweed*

Table 3. Frequency of confirmation of each weed biotype resistant to acetyl-CoA carboxylase (ACCCase)- or acetolactate synthase (ALS)-inhibiting herbicides among fields tested and among all fields sampled, and the land area and field area occupied.

Common name	Scientific name	Resistance	Tested fields	All fields	Area occupied	Field area
			%	%	ha	ha
Grass:						
Wild oat	<i>Avena fatua</i>	ACCCase	100	37	430,178	1,469,609
Green foxtail	<i>Setaria viridis</i>	ACCCase	88	27	848,363	1,170,531
Yellow foxtail	<i>Setaria pumila</i>	ACCCase	43	12	211,687	561,454
Barnyardgrass*	<i>Echinochloa crus-galli</i>	ACCCase	33	11	146,349	455,787
Stinkgrass*	<i>Eragrostis cilianensis</i>	ACCCase	33	3	157,530	157,530
Quackgrass*	<i>Elymus repens</i>	ACCCase	100	1	11	31,130
Wild oat	<i>Avena fatua</i>	ALS	82	30	396,199	1,213,825
Barnyardgrass	<i>Echinochloa crus-galli</i>	ALS	86	29	393,857	1,084,472
Yellow foxtail	<i>Setaria pumila</i>	ALS	9	3	45,064	113,632
Green foxtail	<i>Setaria viridis</i>	ALS	2	<1	40,103	40,103
Quackgrass*	<i>Elymus repens</i>	ALS	100	1	11	31,130
Wild oat	<i>Avena fatua</i>	ACCCase + ALS	82	30	396,197	1,183,768
Barnyardgrass*	<i>Echinochloa crus-galli</i>	ACCCase + ALS	37	12	182,667	479,032
Quackgrass*	<i>Elymus repens</i>	ACCCase + ALS	100	1	11	31,130
Broadleaf:						
Kochia	<i>Bassia scoparia</i>	ALS	100	19	115,793	752,060
Pigweeds.	<i>Amaranthus</i> spp. ^a	ALS	31	13	351,347	613,484
Pale smartweed	<i>Persicaria lapathifolia</i>	ALS	76	10	11,676	395,278
Spiny sowthistle*	<i>Sonchus asper</i>	ALS	59	7	68,664	300,762
Lambsquarters*	<i>Chenopodium album</i>	ALS	12	4	99,216	151,153
Horseweed*	<i>Erigeron canadensis</i>	ALS	33	1	645	65,116
False cleavers	<i>Galium spurium</i>	ALS	40	1	54,940	54,940
Shepherd's purse	<i>Capsella bursa-pastoris</i>	ALS	50	1	21	44,098
Chickweed	<i>Stellaria media</i>	ALS	100	<1	<1	34,351
All HR Weeds			80	75	1,404,228	2,998,079

^aIncludes *Amaranthus retroflexus* and *Amaranthus powellii*

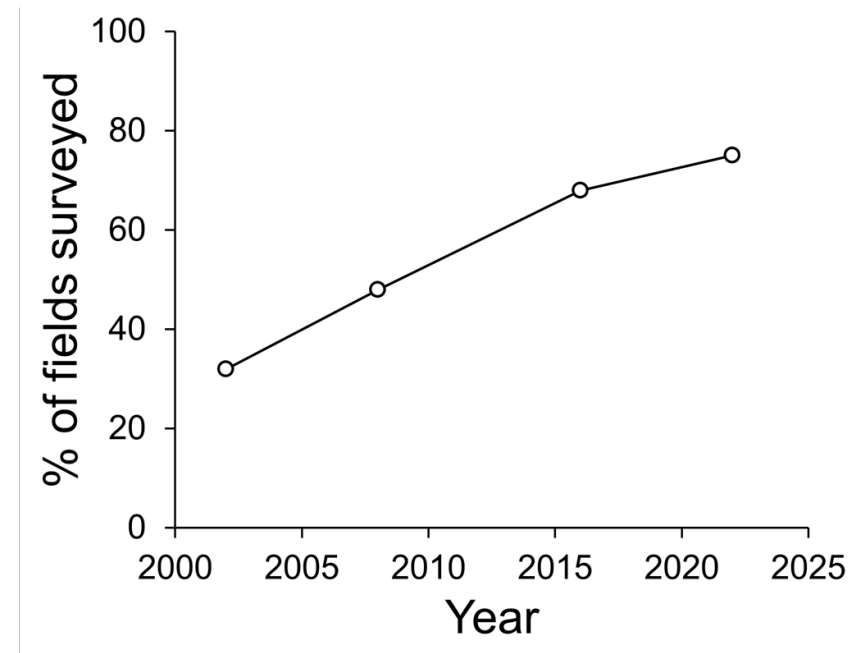
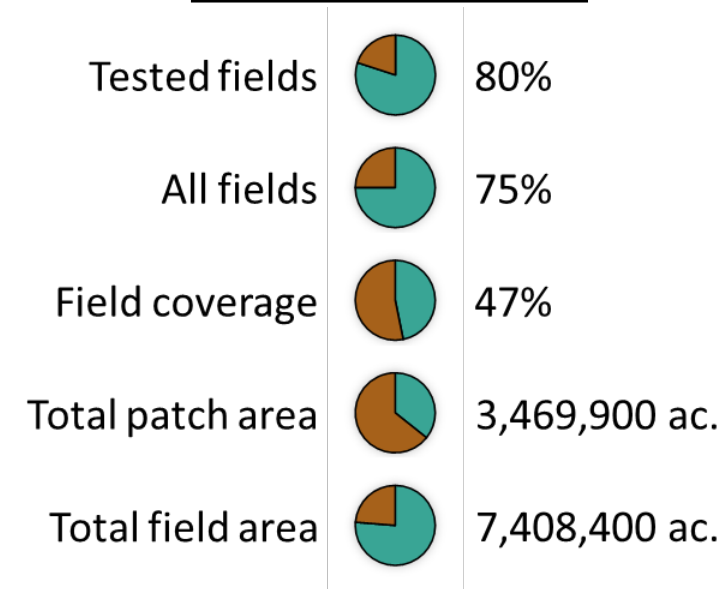


Figure 2. The percentage of surveyed fields occupied by herbicide-resistant weeds in the current (2022) and historical (2002, 2008 & 2016)²⁻⁴ surveys of Manitoba.

Conclusions from MB survey

- 80% of tested fields had at least one HR weed present
- 75% of all fields had at least one HR weed present
- Patch area (all HR weeds): ~3.5 million ac.
- Field area (all HR weeds): ~7.4 million ac
- HR weeds cost Manitoba farmers ~\$81 million annually
- New issues that warrant further investigation:
 - Putative ACCase inhibitor-resistant:
 - barnyardgrass, quackgrass, and stinkgrass
 - Putative ALS inhibitor-resistant:
 - quackgrass, spiny sowthistle, lambsquarters, and horseweed

All HR Weeds



Other new HR Weeds on the Canadian Prairies

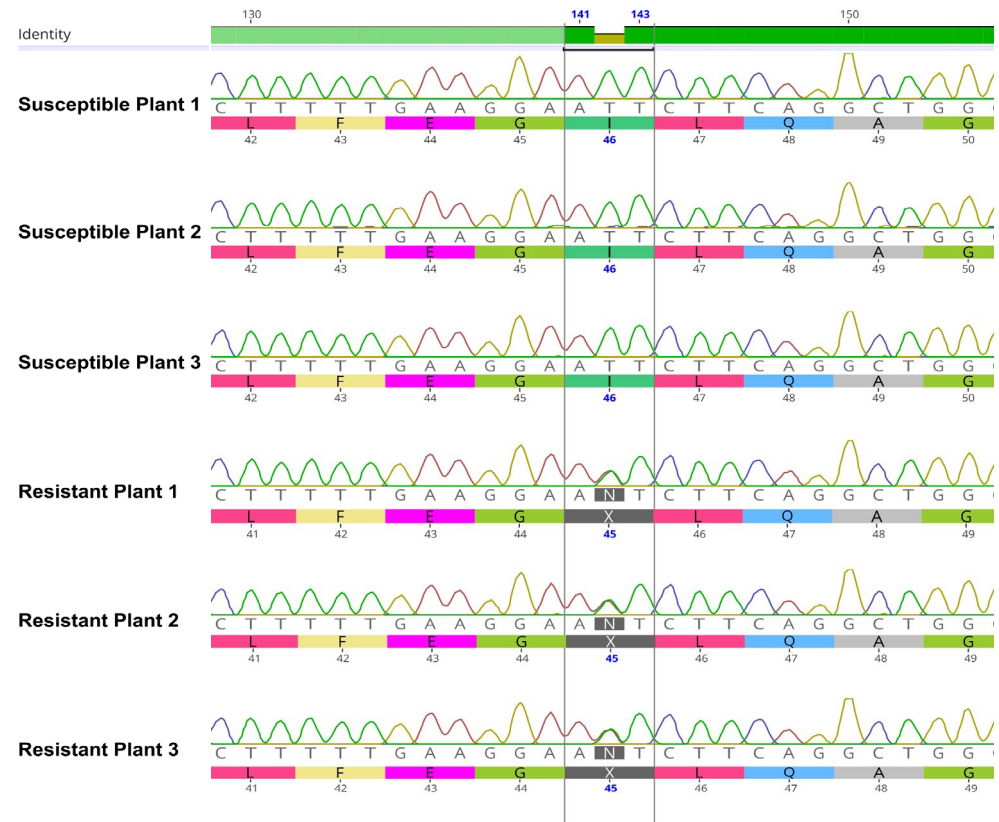
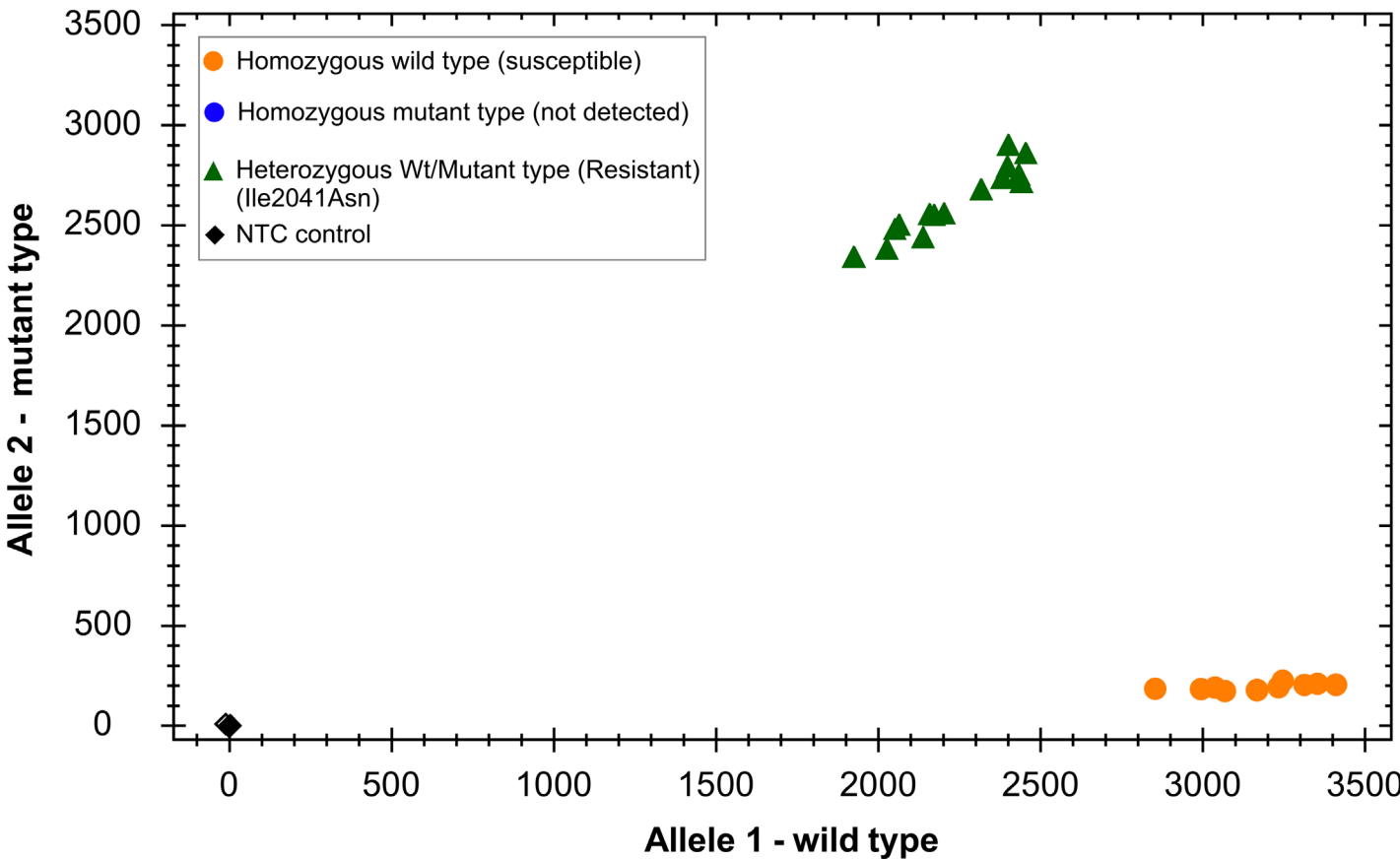
Quizalofop-resistant foxtail barley



Quizalofop-resistant foxtail barley




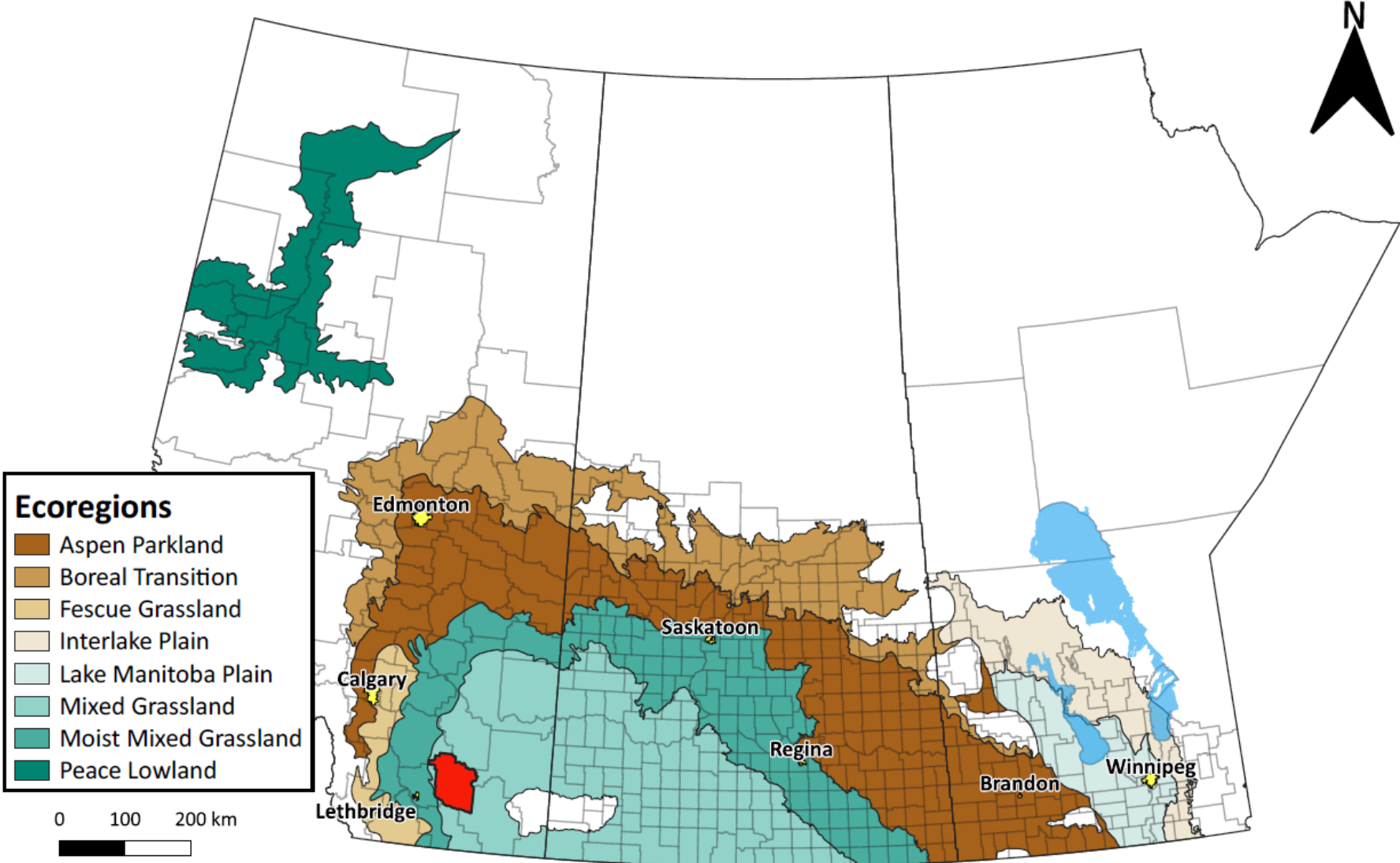
Allelic Discrimination Plot



Geddes *et al.*, unpublished

Glyphosate-resistant downy brome

 Glyphosate-resistant downy brome (*Bromus tectorum* L.)



Glyphosate-resistant downy brome

Application timing				Crop	Common name	Trade name	Rate g ae/ai ha ⁻¹	Company ^b
Year	Month	Day	Window ^a					
2020			PP	Spring wheat	Glyphosate	Stonewall® 540	667	WinField® United Canada
2020			POST	Spring wheat	Pyroxsulam	Simplicity™ GoDRI™	70	Corteva Agriscience Canada
2021	April	09	PP	Spring canola	Glyphosate	Stonewall® 540	1134	WinField® United Canada
2021	April	29	PP	Spring canola	Glyphosate	Stonewall® 540	1000	WinField® United Canada
2021	June	01	POST	Spring canola	Glyphosate	Roundup Transorb® HC	934	Bayer CropScience Inc.
2021	June	23	POST	Spring canola	Glyphosate	Roundup Transorb® HC	934	Bayer CropScience Inc.

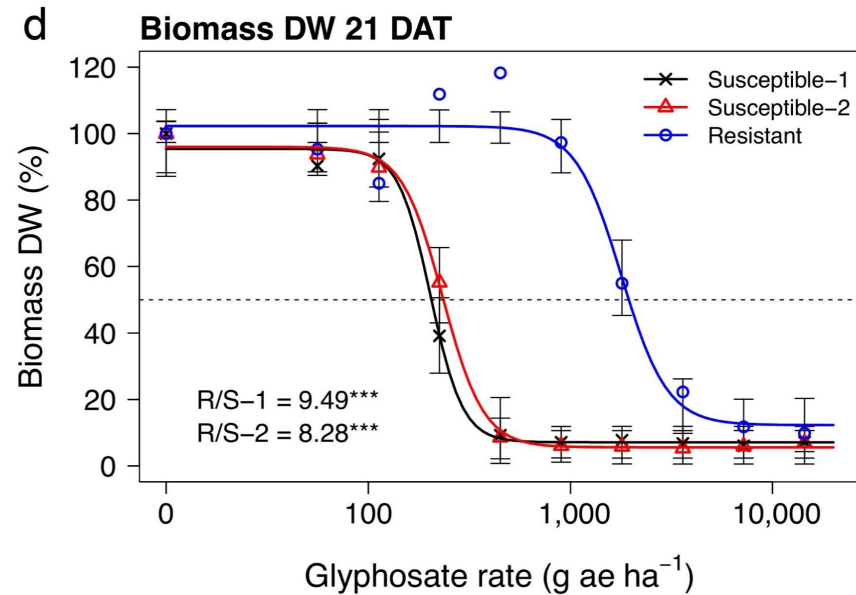
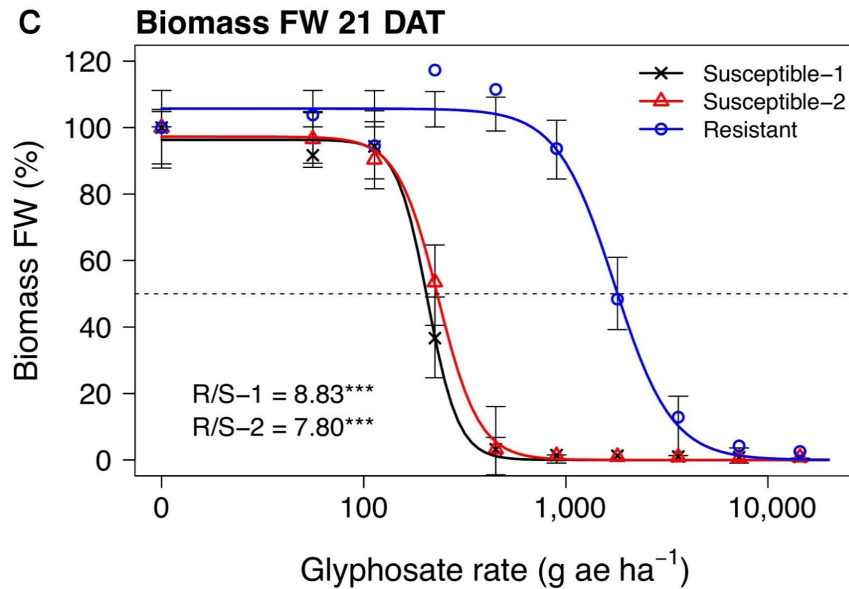
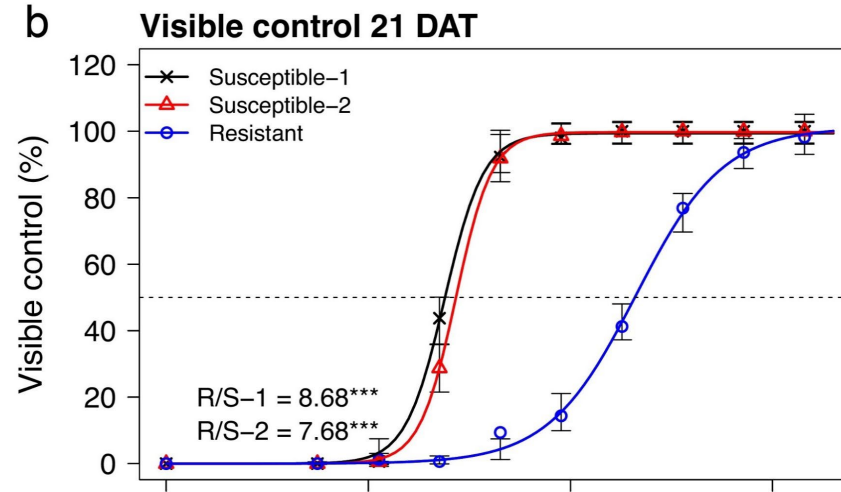
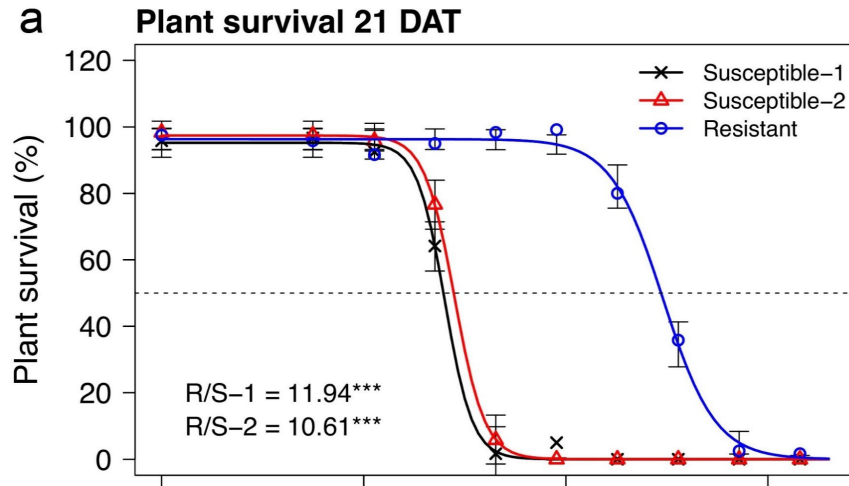
Table 1. Recent crop and herbicide use history in the field where glyphosate-resistant downy brome was initially confirmed. ^aApplication window abbreviations: PP, pre-plant; POST, post-emergence. ^bBayer CropScience Inc., Calgary, AB www.cropscience.bayer.ca; Corteva Agriscience Canada Company, Calgary, AB www.corteva.ca; WinField® United Canada, ULC, Saskatoon, SK www.winfieldunited.ca.



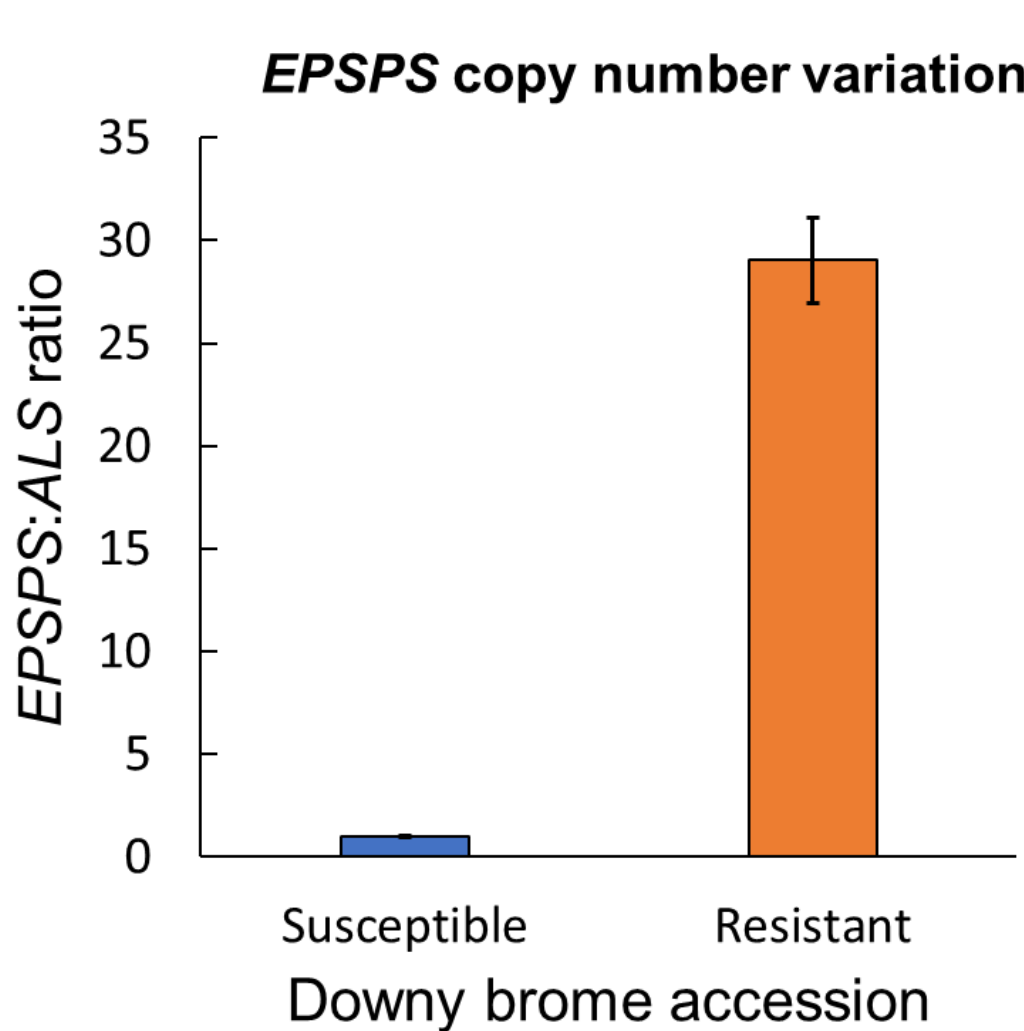
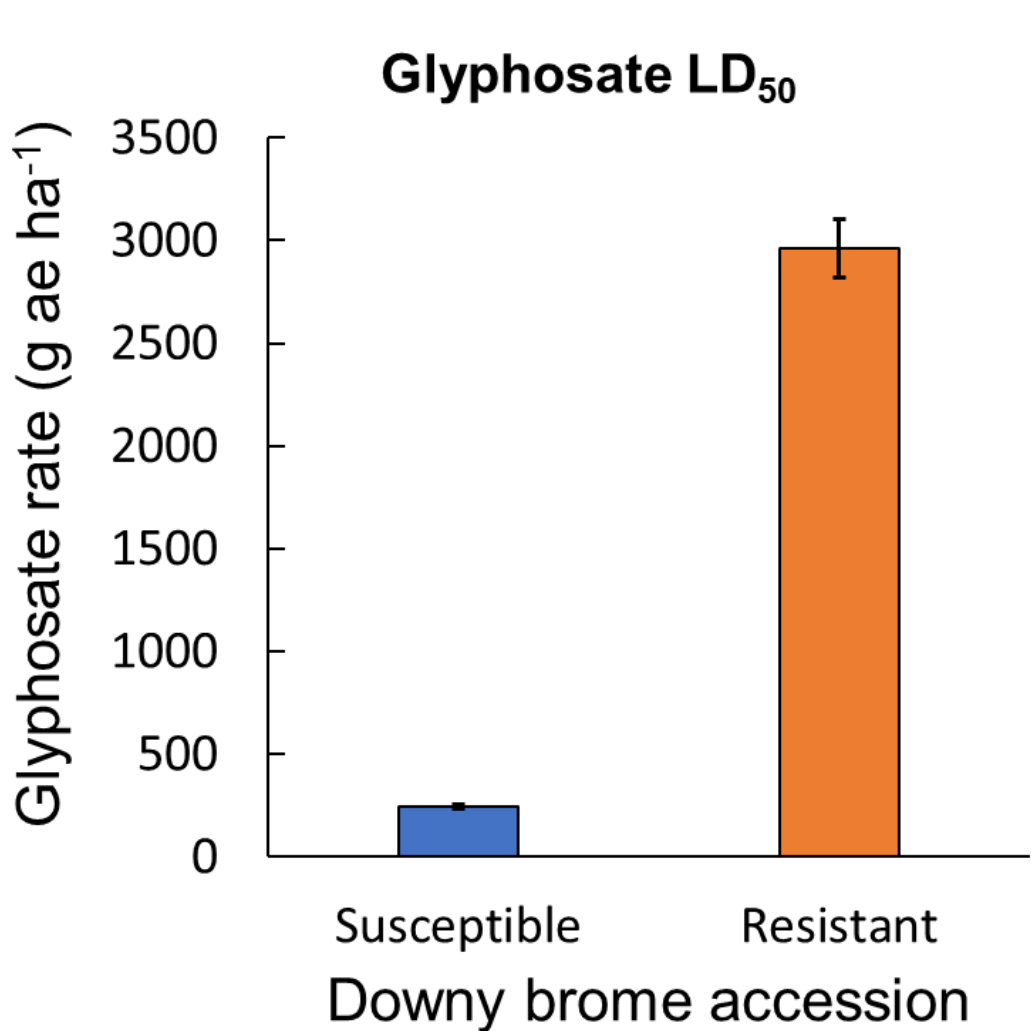
Glyphosate-resistant downy brome



Glyphosate-resistant downy brome



Glyphosate-resistant downy brome



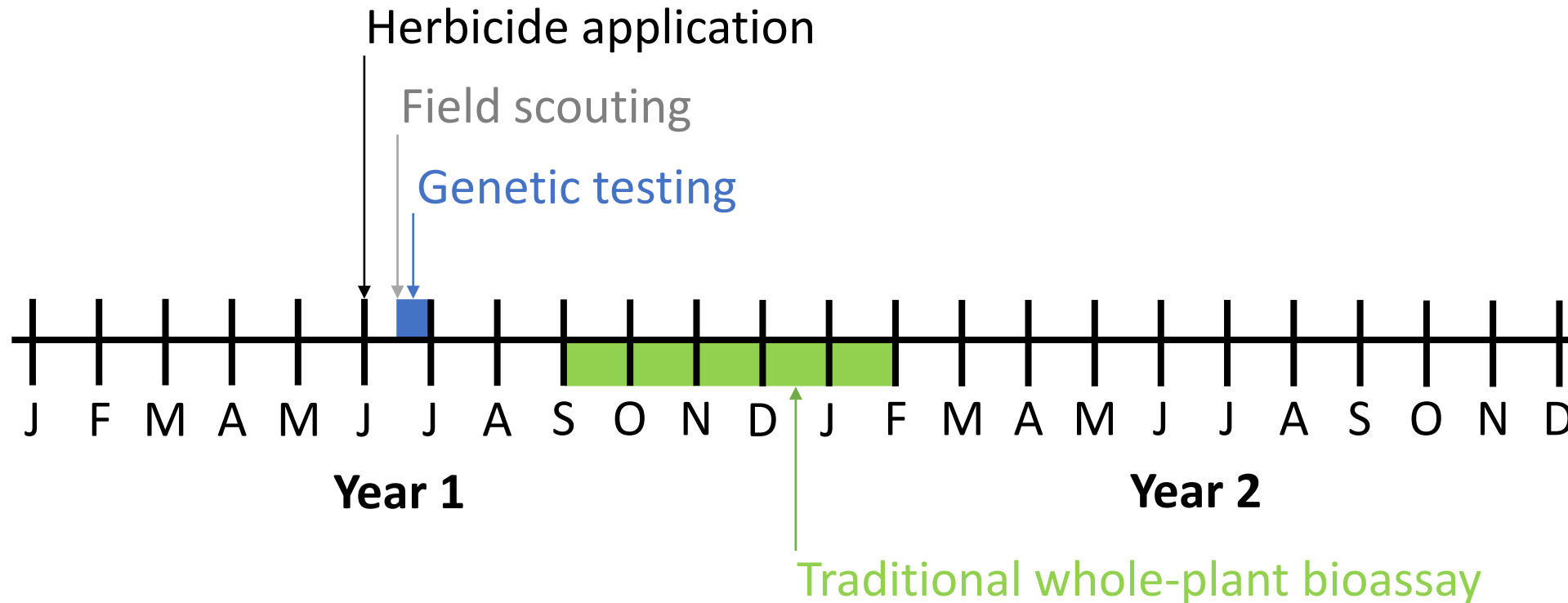
Developing rapid in-season diagnostic tests for herbicide resistance

#	Weed species	Scientific name	Resistance (herbicide group)	Resistance mechanism
1	Foxtail barley	<i>Hordeum jubatum</i>	1	Target site mutation*
2	Green foxtail	<i>Setaria viridis</i>	1	Target site mutations*
3	Yellow foxtail	<i>Stellaria pumila</i>	1	Target site mutation*
4	Common chickweed	<i>Stellaria media</i>	2	Target site mutation
5	False cleavers	<i>Galium spurium</i>	2	Target site mutations
6	Kochia[#]	<i>Bassia scoparia</i>	2	Target site mutation
7	Japanese brome	<i>Bromus japonicus</i>	2	Target site mutations*
8	Narrowleaf hawkbeard	<i>Crepis tectorum</i>	2	Target site mutations*
9	Pale smartweed	<i>Persicaria lapathifolia</i>	2	Target site mutations*
10	Redroot pigweed	<i>Amaranthus retroflexus</i>	2	Target site mutations*
11	Russian thistle[#]	<i>Salsola tragus</i>	2	Target site mutation
12	Stinkweed	<i>Thlaspi arvense</i>	2	Target site mutation*
13	Downy brome	<i>Bromus tectorum</i>	9	EPSPS gene duplication*
14	Kochia[#]	<i>Bassia scoparia</i>	9	EPSPS gene duplication

[#] Adapted from published literature

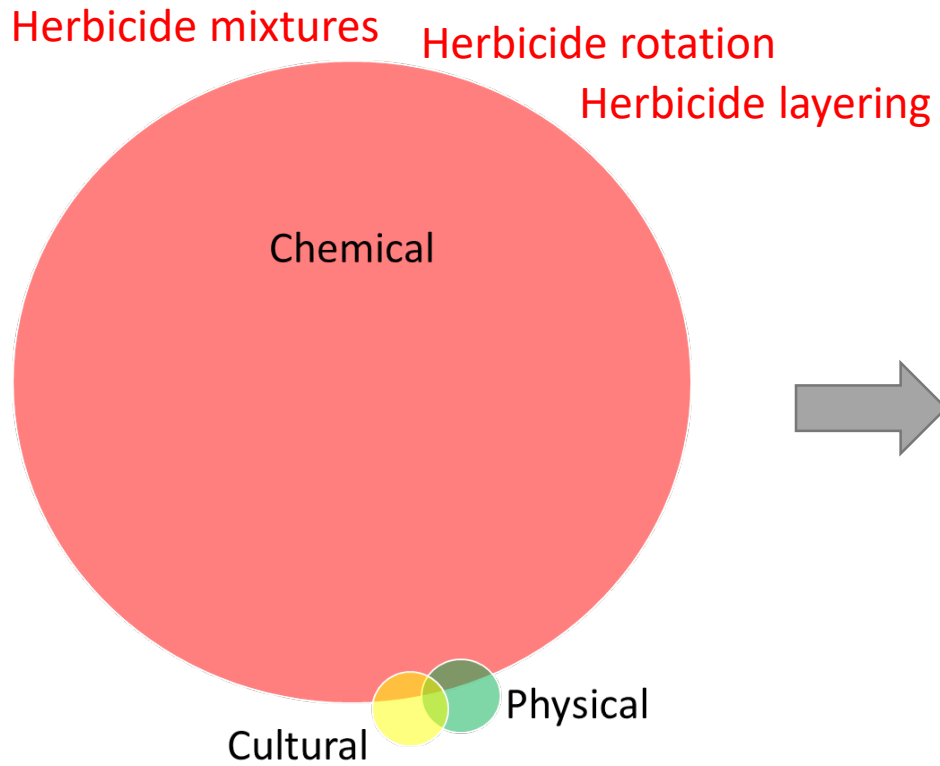
* Includes first report of at least one mechanism

Genetic testing vs. traditional bioassays

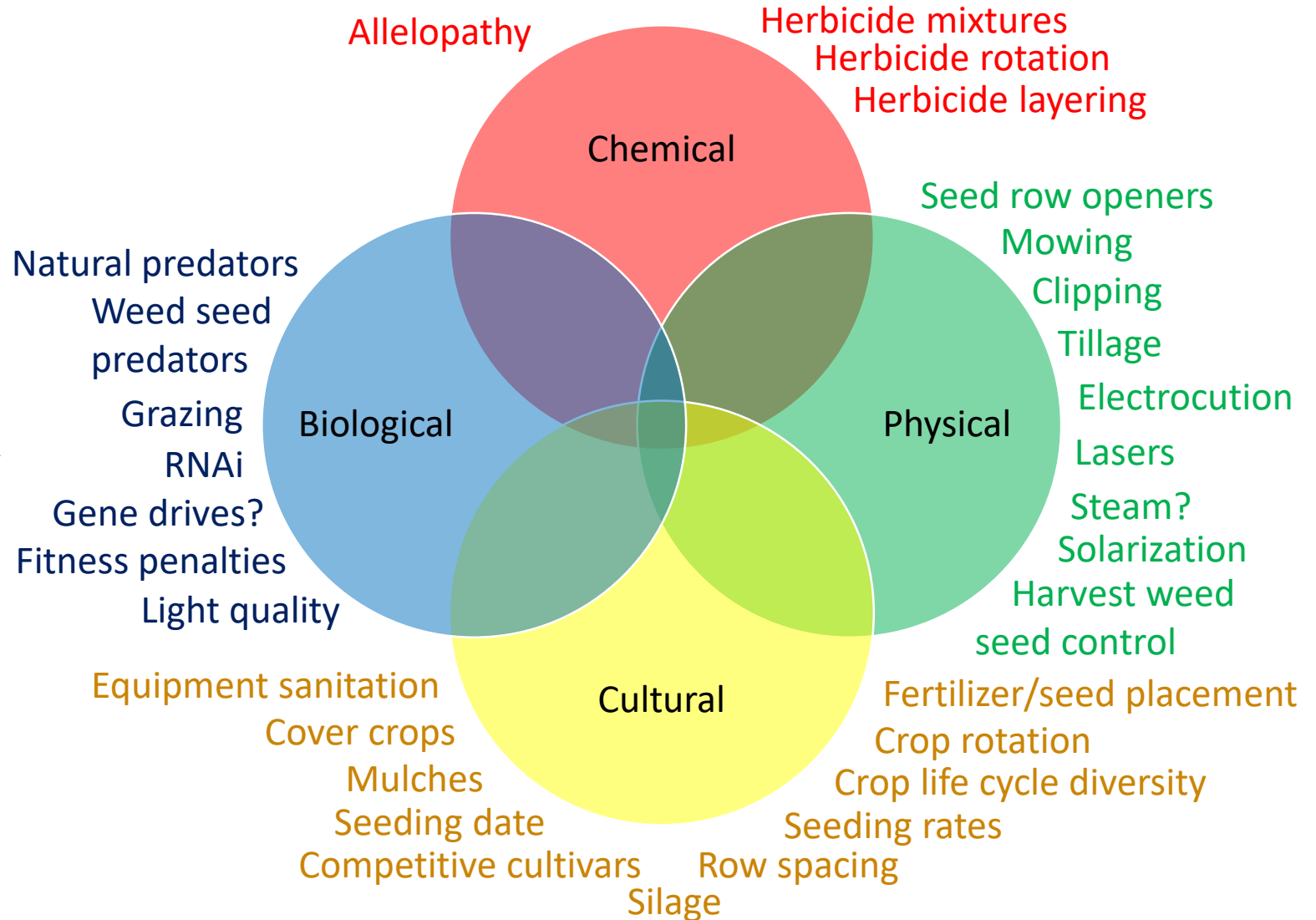


Need for IWM

Contemporary weed management

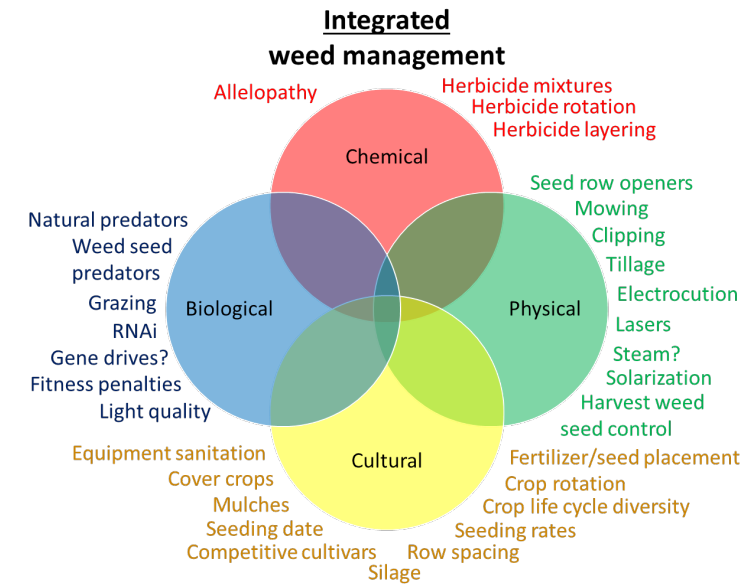


Integrated weed management



In Summary,

- HR weeds are a growing issue in western Canada and elsewhere.
- Understanding the resistance issues in your fields can help inform management strategies.
- Integrating non-chemical practices will be necessary to prolong the useful lifetime of remaining herbicides.



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