A Step Back for New Problems: Tools for Resistant Weeds

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Dealing with herbicide resistance:

Where are we at? How did we get here?

And…..

It's not all about the herbicides!!

Current State of Resistance

- No new herbicide mechanism of action known to be released anytime soon!
- Last mode of action discovered was **~30** years ago – Group 27
- ⬆ Number of weeds with herbicide resistance
  - ⬆ weeds with multiple resistance
    - ⬆ acres infested

CWSS resources online:

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Additional resources available:

Canadian Weed Science Society - CWSS

https://**weedscience**.ca

CWSS resources online:

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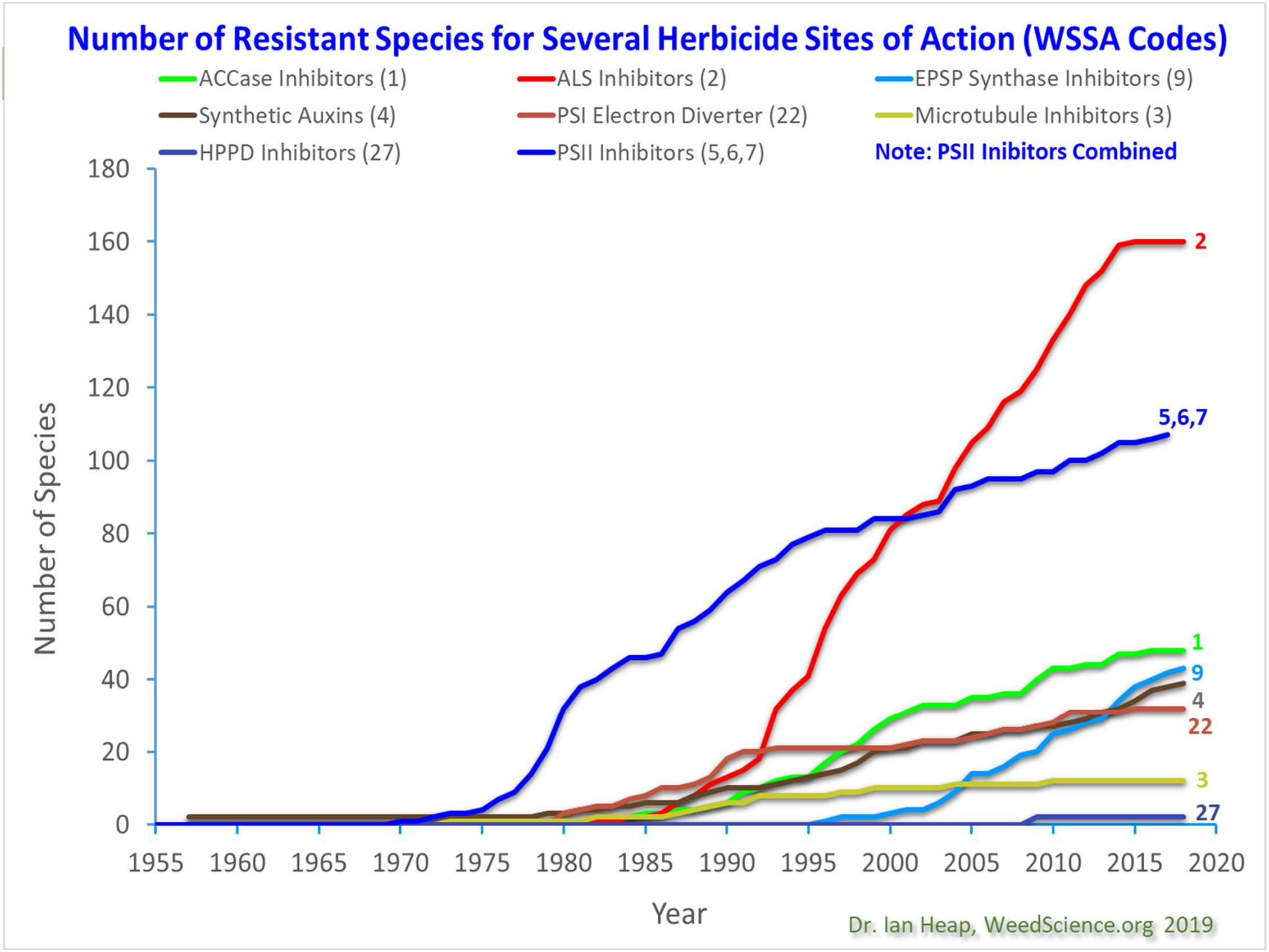
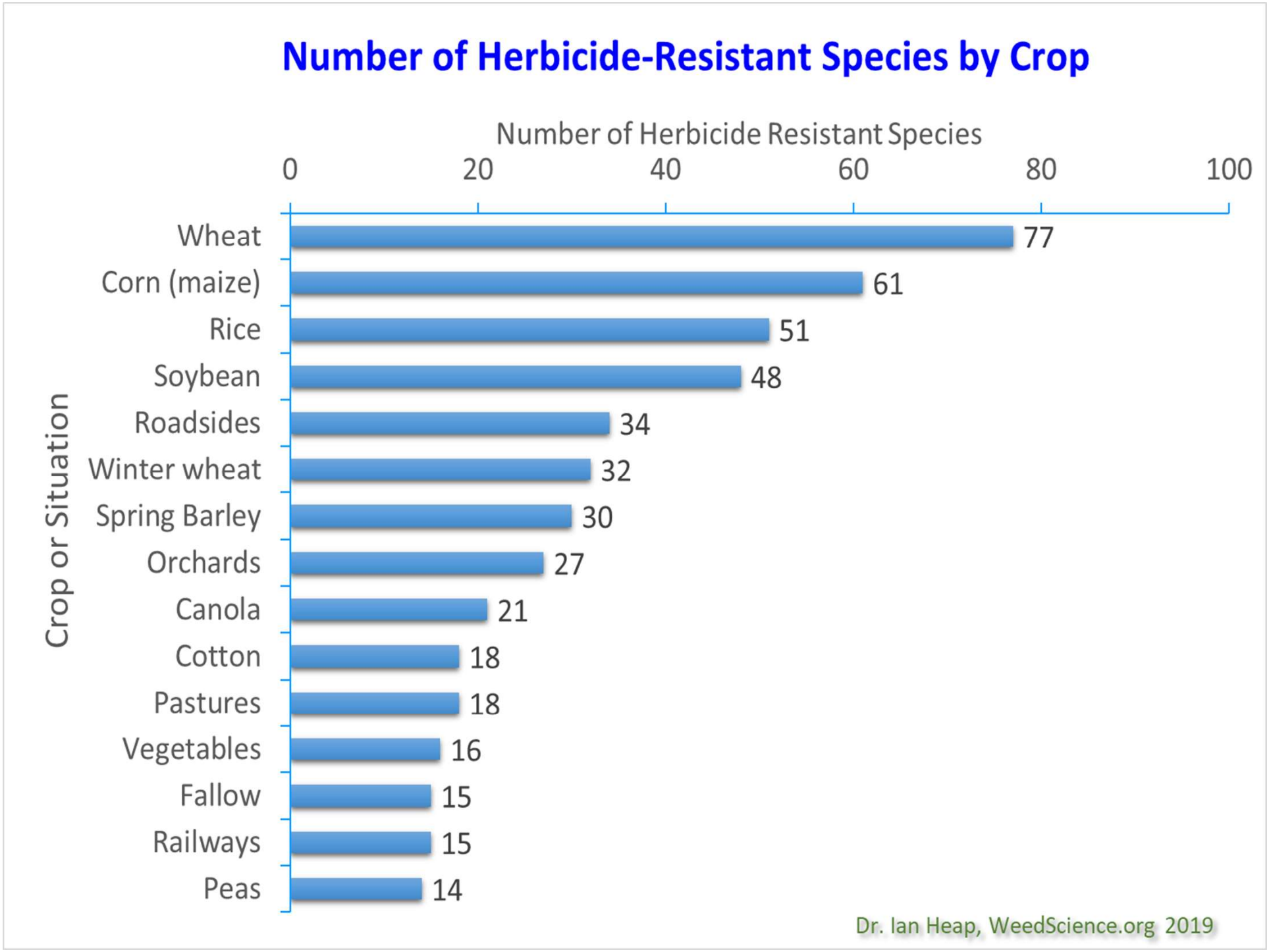
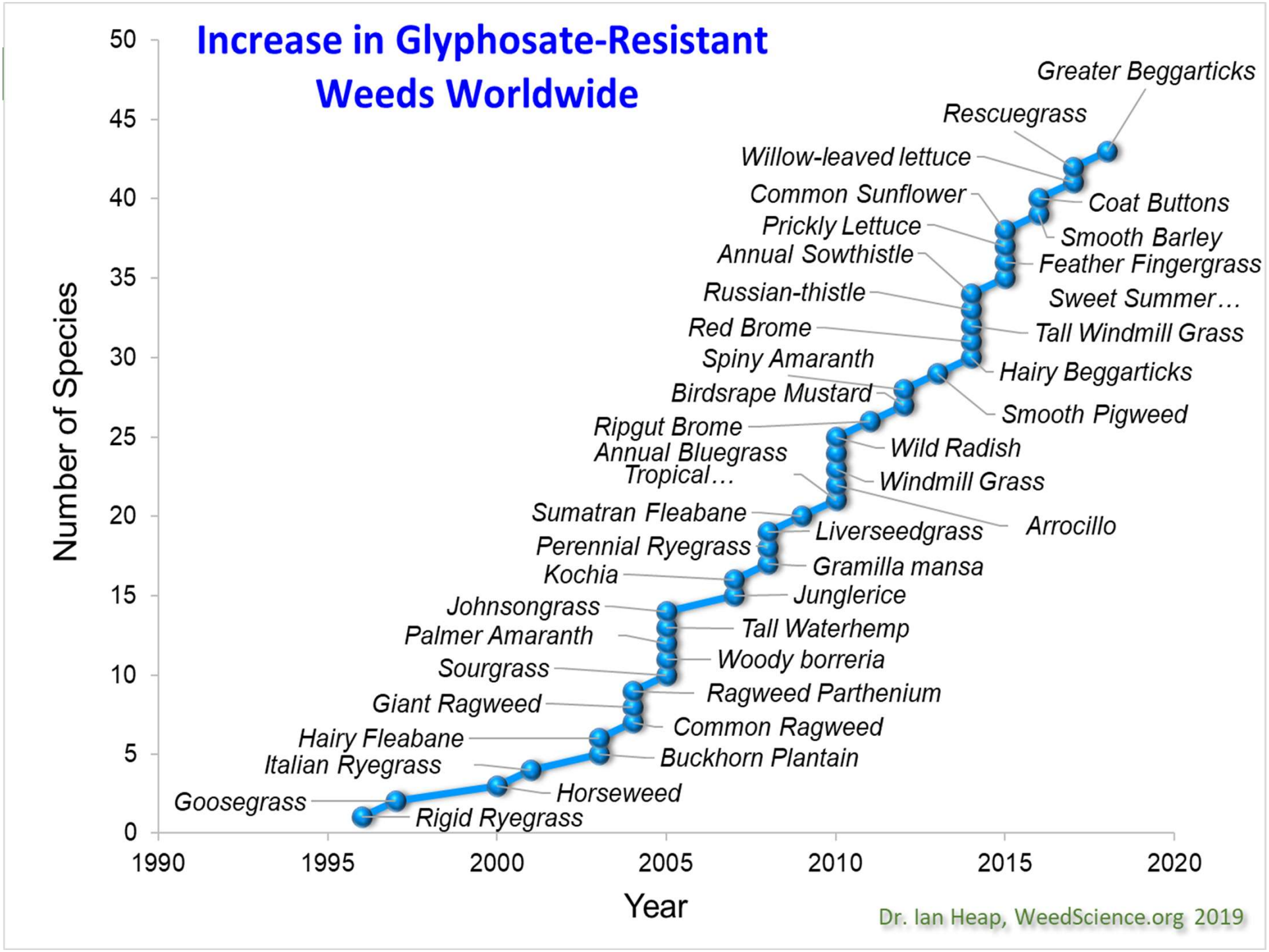
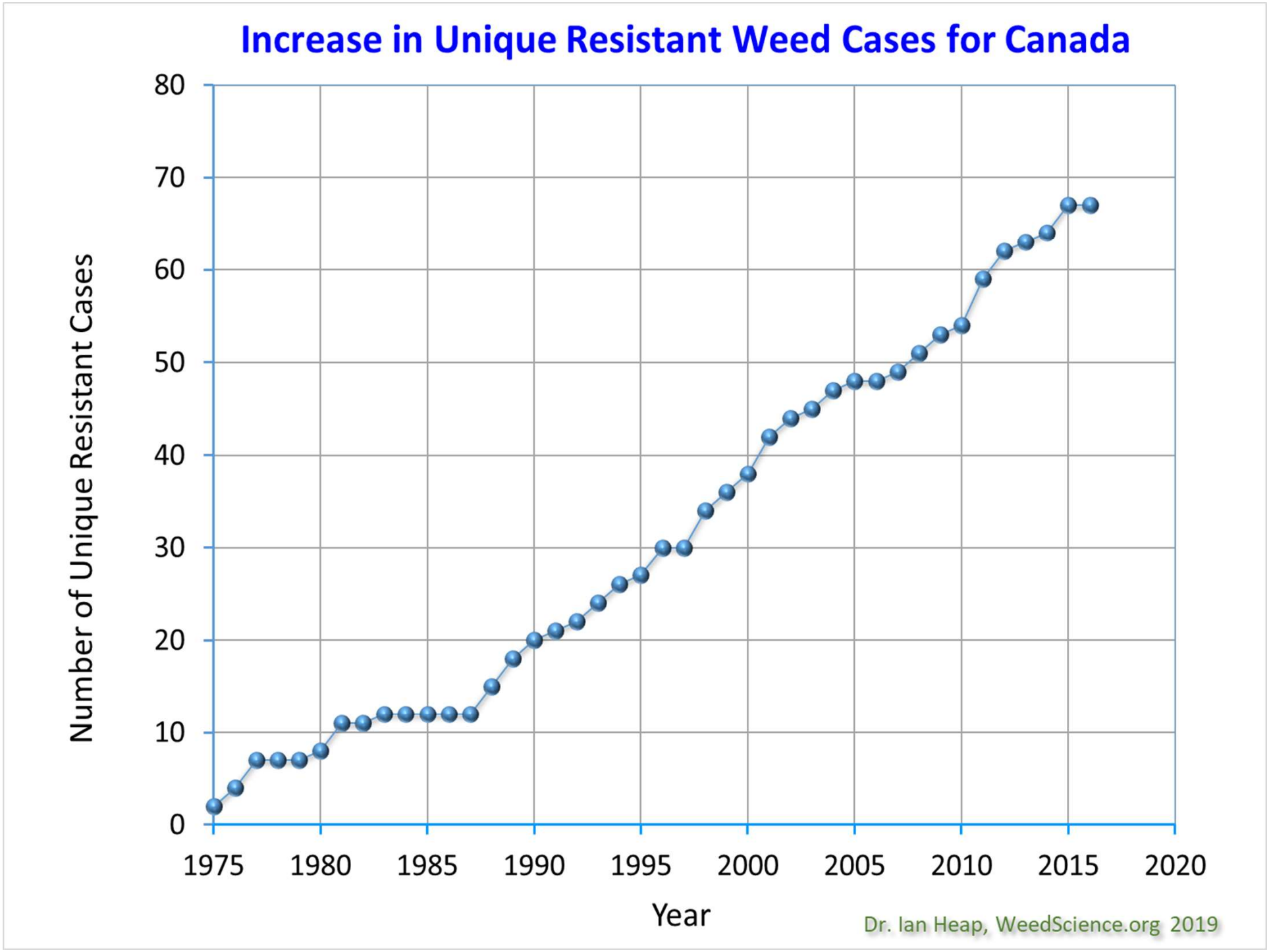

Number of Resistant Species for Several Herbicide Sites of Action (WSSA Codes)
ACCase Inhibitors (1)
ALS Inhibitors (2)
EPSP Synthase Inhibitors (9)
Synthetic Auxins (4)
PSI Electron Diverter (22)
Microtubule Inhibitors (3)
HPPD Inhibitors (27)
PSII Inhibitors (5,6,7)
Note: PSII Inibitors Combined
Number of Species
0
20
40
60
80
100
120
140
160
180
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year
2
5,6,7
1
9
4
22
3
27
Dr. Ian Heap, WeedScience.org 2019


Number of Herbicide-Resistant Species by Crop
Number of Herbicide Resistant Species
0
20
40
60
80
100
Crop or Situation
Wheat
77
Corn (maize)
61
Rice
51
Soybean
48
Roadsides
34
Winter wheat
32
Spring Barley
30
Orchards
27
Canola
21
Cotton
18
Pastures
18
Vegetables
16
Fallow
15
Railways
15
Peas
14
Dr. Ian Heap, WeedScience.org 2019


Increase in Glyphosate-Resistant Weeds Worldwide
Number of Species
Year
0
5
10
15
20
25
30
35
40
45
50
1990
1995
2000
2005
2010
2015
2020
Goosegrass
Rigid Ryegrass
Italian Ryegrass
Horseweed
Hairy Fleabane
Buckhorn Plantain
Giant Ragweed
Common Ragweed
Sourgrass
Ragweed Parthenium
Palmer Amaranth
Woody borreria
Johnsongrass
Tall Waterhemp
Kochia
Junglerice
Perennial Ryegrass
Gramilla mansa
Sumatran Fleabane
Liverseedgrass
Ripgut Brome
Annual Bluegrass
Tropical…
Wild Radish
Windmill Grass
Arrocillo
Birdsrape Mustard
Smooth Pigweed
Spiny Amaranth
Hairy Beggarticks
Red Brome
Tall Windmill Grass
Russian-thistle
Sweet Summer…
Annual Sowthistle
Feather Fingergrass
Prickly Lettuce
Smooth Barley
Common Sunflower
Coat Buttons
Willow-leaved lettuce
Rescuegrass
Greater Beggarticks
Dr. Ian Heap, WeedScience.org 2019


Increase in Unique Resistant Weed Cases for Canada
Number of Unique Resistant Cases
0
10
20
30
40
50
60
70
80
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year
Dr. Ian Heap, WeedScience.org 2019

State: Manitoba					
26	*Setaria viridis*	Green Foxtail	Manitoba	**1988**	Microtubule inhibitors (K1/3)
27	*Kochia scoparia*	Kochia	Manitoba	**1988**	ALS inhibitors (B/2)
28	*Avena fatua*	Wild Oat	Manitoba	**1990**	ACCase inhibitors (A/1)
29	*Sinapis arvensis*	Wild Mustard	Manitoba	**1990**	Synthetic Auxins (O/4)
30	*Setaria viridis*	Green Foxtail	Manitoba	**1991**	ACCase inhibitors (A/1)
31	*Sinapis arvensis*	Wild Mustard	Manitoba	**1992**	ALS inhibitors (B/2)
32	*Setaria viridis*	Green Foxtail	Manitoba	**1992**	**Multiple Resistance: 2 Sites of Action** ACCase inhibitors (A/1) Microtubule inhibitors (K1/3)
33	*Avena fatua*	Wild Oat	Manitoba	**1994**	**Multiple Resistance: 3 Sites of Action** ACCase inhibitors (A/1) ALS inhibitors (B/2) Antimicrotubule mitotic disrupter (Z/25)
34	*Sinapis arvensis*	Wild Mustard	Manitoba	**1994**	Photosystem II inhibitors (C1/5)
35	*Galeopsis tetrahit*	Common Hempnettle	Manitoba	**1995**	ALS inhibitors (B/2)
36	*Avena fatua*	Wild Oat	Manitoba	**1997**	ALS inhibitors (B/2)
37	*Avena fatua*	Wild Oat	Manitoba	**1997**	Lipid Inhibitors (N/8)
38	*Avena fatua*	Wild Oat	Manitoba	**1997**	**Multiple Resistance: 4 Sites of Action** ACCase inhibitors (A/1) ALS inhibitors (B/2) Lipid Inhibitors (N/8) Antimicrotubule mitotic disrupter (Z/25)
39	*Setaria viridis*	Green Foxtail	Manitoba	**2002**	ALS inhibitors (B/2)
40	*Amaranthus retroflexus*	Redroot Pigweed	Manitoba	**2002**	ALS inhibitors (B/2)
41	*Thlaspi arvense*	Field Pennycress	Manitoba	**2008**	ALS inhibitors (B/2)
42	*Galium spurium*	False Cleavers	Manitoba	**2008**	ALS inhibitors (B/2)
43	*Stellaria media*	Common Chickweed	Manitoba	**2008**	ALS inhibitors (B/2)
44	*Amaranthus powellii*	Powell Amaranth	Manitoba	**2008**	ALS inhibitors (B/2)
45	*Polygonum lapathifolium*	Pale Smartweed	Manitoba	**2009**	ALS inhibitors (B/2)
46	*Kochia scoparia*	Kochia	Manitoba	**2014**	**Multiple Resistance: 2 Sites of Action** ALS inhibitors (B/2) EPSP synthase inhibitors (G/9)
47	*Avena fatua*	Wild Oat	Manitoba	**2015**	**Multiple Resistance: 5 Sites of Action** ACCase inhibitors (A/1) ALS inhibitors (B/2) PPO inhibitors (E/14) Long chain fatty acid inhibitors (K3/15) Lipid Inhibitors (N/8)

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INTERNATIONAL SURVEY OF HERBICIDE RESISTANT WEEDS

November 2011

360 unique HR cases:

115 broadleaf species

85 grass species

51 in Canada

There are currently **510 unique cases** of herbicide resistant weeds globally, with **262 species** (**152 broadleafs** and **110 grasses**). Weeds have evolved resistance to **23 of the 26 known herbicide sites of action and to 167 different herbicides**. Herbicide resistant weeds have been reported in **93 crops in 70 countries**.

>75 in **Canada**

weedscience.org

Herbicide rotation risk pyramid

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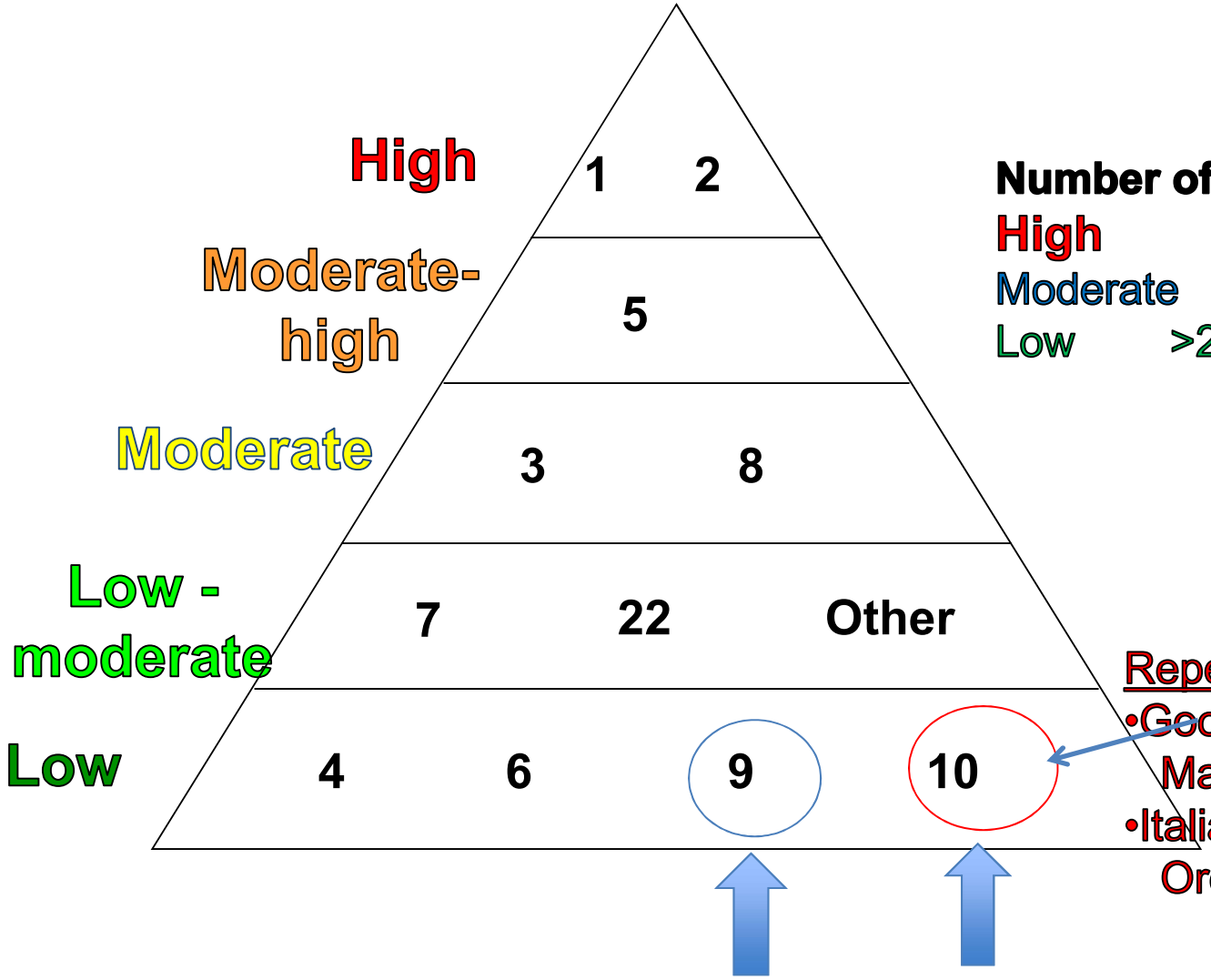

Number of applications

High	≤ 10
Moderate	11-20
Low	>20

Repeated applications

- Goose grass in Malaysia
- Italian ryegrass in Oregon

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Herbicide Resistance.....

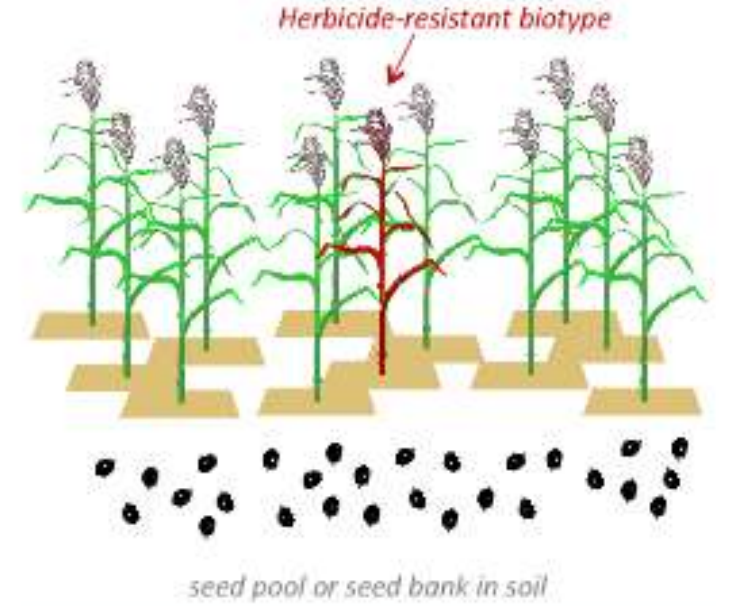
- HR issues have been around for years and we're still using herbicides?
- Have we taken 'the thinking' out of weed control?
- Are we heading to a train wreck?
  - Without changing weed control practices, YES!!

Progression of Weed Resistance

Weed resistance progresses logarithmically

Treatment	% Resistant Weeds in Population	Weed Control
0 Application	.0001	Excellent
1st Application	.00143	Excellent
2nd Application	.0095	Excellent
3rd Application	.294	Excellent
4th Application	4.22	Excellent
5th Application	69.5	Failure

Year 0 Credit: Mike DeFelice



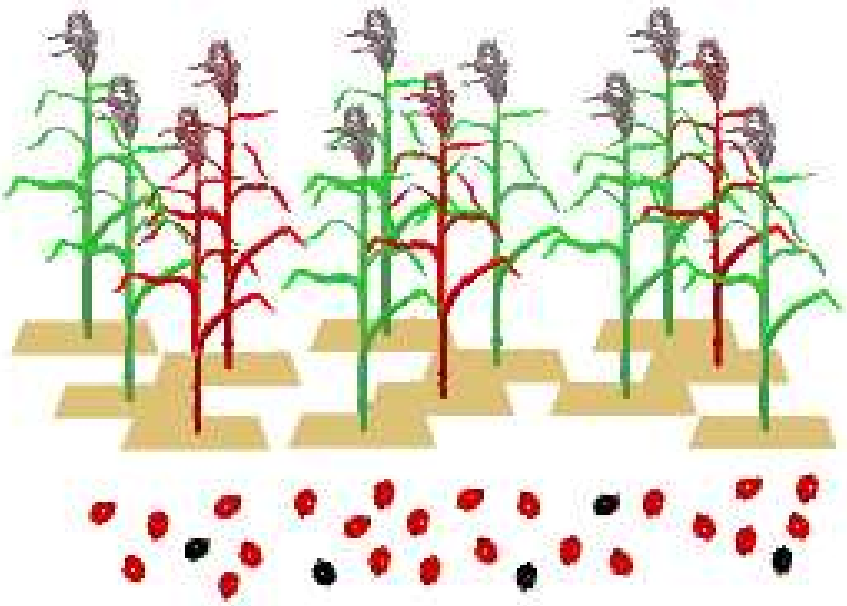
First application of herbicide to the initial population

Progression of Weed Resistance

Weed resistance progresses logarithmically

Treatment	% Resistant Weeds in Population	Weed Control
0 Application	.0001	Excellent
1st Application	.00143	Excellent
2nd Application	.0205	Excellent
3rd Application	.294	Excellent
4th Application	4.22	Excellent
5th Application	60.9	Failure

Year 4 Credit: Mike DeFelice



seed pool or seed bank in soil

Control may still appear acceptable, but the seed pool is almost completely composed of the resistant type

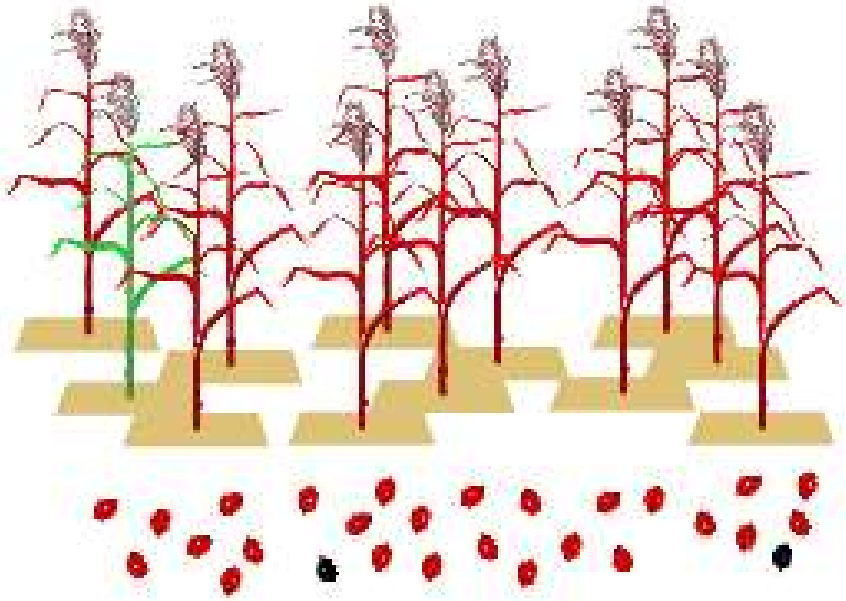
Progression of Weed Resistance

Weed resistance progresses logarithmically

Treatment	% Resistant Weeds in Population	Weed Control
0 Application	.0001	Excellent
1st Application	.00143	Excellent
2nd Application	.0205	Excellent
3rd Application	.294	Excellent
4th Application	4.22	Excellent
5th Application	**60.5**	**Failure**

Herbicide resistance cannot be reversed in a practical time frame. In many cases, the seed pool is unlikely to change back because there is no fitness penalty.

Year 5 Credit: Mike DeFelice



seed pool or seed bank in soil

Weed plants and seed pool are now mostly herbicide-resistant

Dealing with herbicide resistance:

- It's not all about the herbicides!!

  Integrated weed management practices include:

  cultural

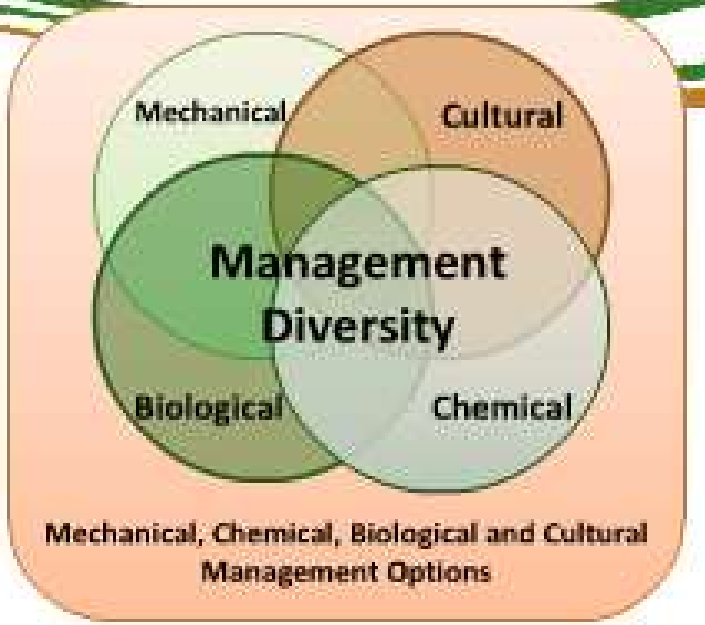
  mechanical

  herbicide

Diversity of Practices

The best strategies to manage herbicide resistance in weeds are established on the concept of diversity.

Diversity can be achieved by:



Using mechanical, cultural, and biological practices in addition to herbicides

and

Applying several herbicides with different mechanisms of action and overlapping control (each herbicide is active on the target weed or weeds)

A combination of tactics reduces the selection pressure imposed by any single practice.

FOR MORE INFORMATION

Proactive Management: Cultural Tactics

Crop Management. Agronomic practices, such as choice of hybrid or variety, differences in planting times, fertilizer management, row spacing, plant populations, seed bed preparation, and harvesting techniques can influence the growth cycle of weed species and therefore provide an advantage to the crop. For example, narrow crop row spacing can quickly shade sensitive weed species, while longer periods of weed control are generally required for wider row spacings.

Photo credits: Flickr Monsanto

Crop Rotation. Natural differences exist among the abilities of crops to compete with weeds. The greatest benefit in crop rotation comes as a result of the most diverse crop rotations, because they provide the greatest opportunities for exploiting differences in tillage practices, competitiveness, and herbicide choices.

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Cultural

- Crop Rotation
- Plant Populations
- Row Spacing
- Planting Date
- Fertilizer Placement
- Cover Crops

Managing herbicide resistance

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- Management methods:
  - Cultural control
    - Crop rotation
    - Crop type (including variety),

    Rye > oat > barley > wheat > canola > field pea > soybean > flax > lentil (Blackshaw et al., 2002)
    - Certified seed
    - Seeding date
    - Seeding rate
    - Row width – narrower for more rapid canopy closure
    - Fertilization – side-band & seed placed versus broadcast

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Crop Management

- Choice of hybrid/variety
- Different planting times
- Fertilizer management
- Row spacing
- Plant populations
- Seed bed preparation
- Harvest technique

All influence growth cycle of weed species

Solution–Understand impact of weed seed movement

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- Means of dispersal:
  - Water
  - Machinery
  - Wind
  - Humans
  - Animals / birds

MPR Photo/Ann Arbor Miller

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Crop Rotation

- **Diverse crop rotations**
  - Provide greatest opportunities to exploit **differences** in tillage practices, competitiveness and herbicide choices

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Mechanical

- Tillage
  - Pre-plant
  - In-crop
  - Post harvest

Proactive Management: Mechanical Tactics

Mechanical tactics include techniques such as:

- ✓ **Pre-plant tillage**
- ✓ **Strip or zone-tillage**
- ✓ **In-crop cultivation**
- ✓ **Post-harvest mowing and/or tillage**
- ✓ **Hand-rogueing before seed set**

Photo: Image number K5197-3 at the USDA-ARS image gallery.

Equipment sanitation is also important to slow the spread of herbicide-resistant weeds and weed seeds.

Harrington Seed Destructor

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Herbicide

- Multiple herbicides with different mechanisms of action
  - Mixes
  - Sequence
  - Across seasons

Proactive Management: Herbicide Tactics

Herbicide choice requires ***careful planning*** so that products with different mechanisms of action (MOA), or unique group numbers, and activity on the same target weeds, are intentionally combined with each other or other weed control practices.

SUSTAINABLE

Repeated annual use of a herbicide with the same MOA in the absence of other MOAs or different management strategies can lead to resistance.

NOT SUSTAINABLE

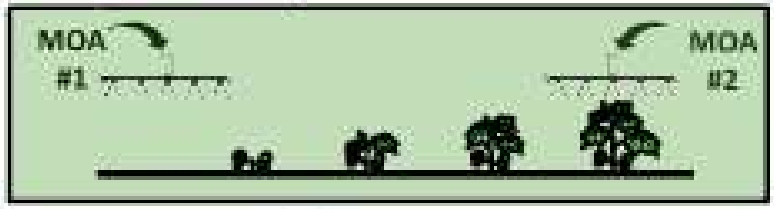
Note: For all herbicide applications, it is critical to apply the labeled rate at the correct time. Management strategies based only on a herbicide mechanism of action classification system, or herbicide group number, may not adequately address specific and local needs. Consult product labels and the assistance of your local extension specialist for more information.

Proactive Management: Herbicide Tactics

The main schemes for applying herbicides with different mechanism of action (MOA) to manage herbicide resistance are:

Mixture application

Sequentially throughout season

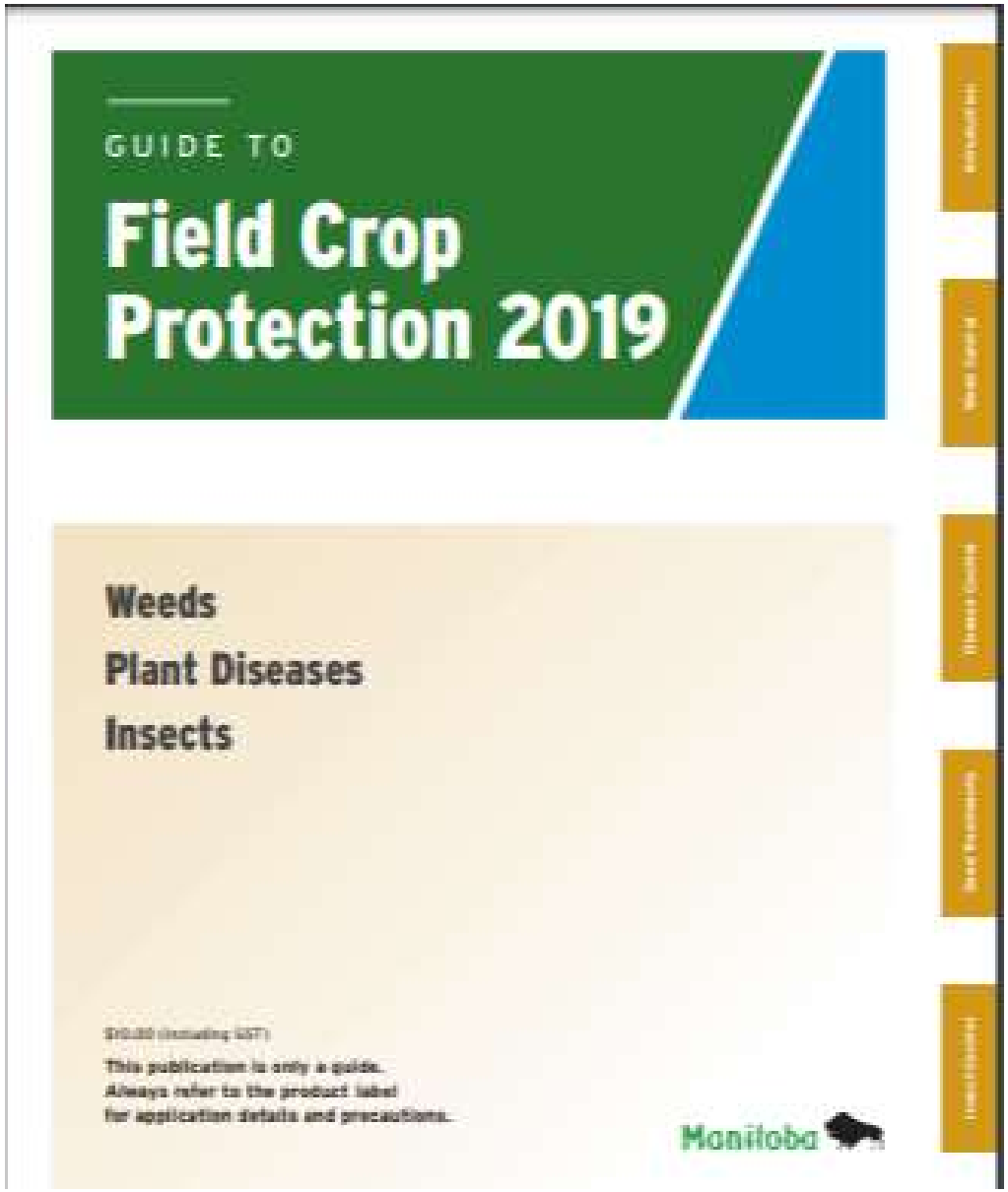


Across multiple seasons

Note: For all herbicide applications, it is critical to apply the labeled rate at the correct time. Management strategies based only on a herbicide mechanism of action classification system, or herbicide group number, may not adequately address specific and local needs. Consult product labels and the assistance of your local extension specialist for more information.

Benefits of Soil Residual Herbicides

- Time management
- Critical Weed Free Period
- Flushing weed control
- **Alternate modes of action**
  - multiple modes of effective action
  - herbicide layering



The next few slides are examples of the extensive information contained in the Guide. 2020 version available late winter/ early spring

Soil Residual Herbicides

When applied at recommended rates in a crop, most herbicide residues will disappear within a few weeks after application and impose no restriction on cropping options the next year. However, some herbicide residues do not degrade quickly, and can persist in the soil for months or years following application, thereby restricting the crops that can be grown in rotation. Herbicide residues in the soil are deactivated in various ways including:

- Break down by chemical reactions,
- Break down by soil microbes,
- Escape to the atmosphere as a gas (volatilization),
- Break down by light (photodegradation),
- Leaching,
- Binding to soil particles.

Herbicides often disappear from the environment by more than one of these mechanisms. Many herbicides considered to be non-residual are bound temporarily to soil particles while they are broken down gradually by either soil microbes or chemical reactions. The binding action insures that the herbicide is not available to the crop in quantities that will cause damage.

As a general rule, breakdown processes are favoured by warm, moist soil conditions. During the winter, when the ground is frozen, and in the summer when the soil is dry, herbicide degradation is reduced. The residual activity of certain herbicides is also affected by soil organic matter and soil pH. These soil factors are seldom uniform across a field.

Herbicide carryover is aggravated by low levels of organic matter and is more likely to occur on eroded hilltops than in other parts of a field. The risk of herbicide carryover will also be greater in sprayer overlaps which are most common around headlands and slough margins.

Growers should be aware of the residual properties before applying any herbicide if they are to avoid cropping restrictions in following years. Knowledge of the limitations associated with herbicides that leave a soil residue, along with an accurate record of application (i.e. rates, locations) will serve to minimize rotational problems. Each herbicide used in mixes should be considered separately.

Soil tests using chemical extraction cannot always give a good indication of the potential injury risk from herbicide residue because of the influence of organic matter, clay and pH. Because of this, a field bioassay or laboratory bioassay, where plants are grown directly in the treated soil are best for detecting the potential for injury. These tests are not intended to be used to shortcut restrictions on the label, but provide information on rotational crops where none is available.

Injury symptoms from other causes can resemble herbicide carryover injury (i.e. cold weather, flooding, drought, insects, diseases, etc.). Consult with your local agronomist on potential causes before spending money on testing.

Herbicides that leave a soil residue and are of particular concern in Western Canada are found in the following chart.

Re-cropping Restrictions -Residual Herbicides:

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PRODUCT	Alfalfa	Barley	Canaryseed	Clearfield canola	Non-Clearfield canola	Fababeans	Field corn	Dry beans	Field Peas	Flax	Forage grasses	Lentils	Mustard†	Oats	Potatoes	Rye	Soybeans	Sunflowers	Wheat (durum)	Wheat (spring)	Wheat (winter)
2,4-D*	1	1	1	1	1		1	1	1	1	1	1		1		1			1	1	1
Accent	10 mths	10 mths		10 mths	10 mths		10 mths										10 mths			1	4 mths
Altitude FX2		1		1	1				1	1		1	2	1				1		1	3 mths
Amitrol 240		1d	1	1d	1d		10d*	10d*	5d*	1		1	1	1			6d	1	1d	1d	1d
AAtrex, Primextra II Magnum						1*	1		1*	1*											
Ares		1	1	1	2		1		1	2		1		1				2	2	1	
Authority / Authority Charge	1	1		1	1	0	1		0	0		2	0				0	0	1	1	1
Authority Supreme							1		0								0	1	1	1	1
Avadex	0	0	0	0	0	1	1	1	0	0		1	0	2		1	1	1	0	0	0
Barricade II, Predicade, Retain, Signal FSU, TraxosTwo	2	1	2	1	1	2	2	2	1	1	1	1	1	1	2	1	2	2	1	1	1
Command 360 ME	2	2	2	1	1	2	1	1	2	2	2	2	2	2	1	2	1	2	2	1	16 mths
Curtail M, Prestige XC	2	1	2	1	1	2	1	2	1*	1	1	2	1	1		1	2	2	1	1	1
Dicamba*		1		1*	1*		1	1*						1			1		0*	0*	1
Dual II Magnum							1								1		1				4.5 mths
Eclipse III, Clopyralid		1		1	1				10 mths*	1	1		1	1		1			1	1	
Edge	0		2	0	0	0		0	0		2	0	0	2			0	0	1*	1*	
Fierce							7 days										0			7 days	

Topramezone

Herbicide Group
27 - topramezone
(Refer to page 45)

Company:

AmVac Corporation, distributed in Canada by UAP (*Impact* - PCP#28141)

BASF Canada (*Armezon* - PCP#30131)

Formulation:

336 g/L topramezone formulated as a suspension.

- Container size:
  - *Armezon:* 0.6 L
  - *Impact:* 8 L

Crops and Staging:

Corn (field†, seed, sweet††): From the 1 to 7 leaf stage

† Including both conventional and herbicide tolerant varieties.
†† NOTE: Tolerance of sweet corn varieties to topramezone and its mix partners may be variable. When tolerance is unknown, check with the supplier of seed and/or apply to a small area first to assess tolerance.

Weeds and Staging:

The following weeds are controlled with topramezone unless otherwise indicated:

Topramezone MUST BE applied in tank mix with one of the herbicide options indicated in "Tank Mixes:"

- ***Grass weeds below from the 1 to 4 leaf stage:***
  - Barnyard grass*
  - Foxtail (green and yellow)*
- ***Broadleaf weeds below from the 1 to 8 leaf stage:***
  - Chickweed (common)*
  - Kochia (up to 10 cm)**
  - Lamb's-quarters*
  - Lady's-thumb*
  - Nightshade (eastern black)
  - Pigweed (redroot, green)
  - Ragweed (common)
  - Velvetleaf*
  - Volunteer canola (up to 8 leaf) including glyphosate-tolerant varieties**
  - Wild mustard

*** Suppression only.**
**** *Armezon* only. All types including glyphosate-resistant varieties.**

Effects of Growing Conditions:

When weeds are stressed because of drought, flooding, hot or cool temperatures, weeds are not actively growing, control may be reduced.

Tank Mixes:

Herbicides:

Topramezone must be mixed with one of the following:

- ***Field and Sweet Corn:***
  - *AAtrex* (0.42 L per acre) (DO NOT use Merge with this mix in sweet corn)
- ***Field corn only:***
  - *Frontier Max* (0.3 L per acre) + *AAtrex* (rates above)
- ***Glyphosate tolerant corn only:***
  - Glyphosate (360 g ae per acre, no adjuvant required) (see glyphosate page for details)
  - Glyphosate + *AAtrex* (rates above)
  - Glyphosate + *AAtrex* (rates above) + *Frontier Max* (rates above)

Fungicides: None registered.

Fertilizers: None registered.

Insecticides: None registered.

Note: The above mixes are those listed on the topramezone label only.

Adding ingredients in the correct order is critical for optimum performance. Check labels of both products to be mixed for directions. General guidelines can be found on page 11.

Restrictions:

- **Rainfall:** DO NOT apply if heavy rain is forecast. Contact manufacturer for more information.
- **Re-entry Interval:** DO NOT enter treated fields for at least 12 hours.
- **Grazing Restrictions:** DO NOT graze treated fields or cut for feed within 45 days of application.
- **Pre-harvest Interval:** Leave 45 days between application and harvest.
- **Re-cropping Interval:** Field corn only may be seeded to treated areas after a crop failure. Winter wheat may be seeded a minimum four months after application. Spring wheat, canola, field corn, navy (white) bean, soybean, lentils, pea and alfalfa may be seeded the following crop year. Check tank mix options for additional reseeding restrictions. Conduct a field bioassay (a test strip grown to maturity) the year before growing any other crop.
- **Aerial Application:** DO NOT apply by air.
- **Storage:** Store in a cool (above 5°C), dry area. If product is frozen, bring to room temperature and agitate before use.
- **Buffer Zones:**

Application method	Buffer Zones (metres') Required for the Protection of:		
	Aquatic Habitats of Depths		Terrestrial habitat
	Less than 1 m	Greater than 1 m	
Ground *	1	1	5

See page 36 for an explanation of the different habitats.

*** Buffer zones can be reduced by 70% when using shrouds and by 30% when using cones mounted less than 12 inches from the crop canopy.**

Table 8. Herbicide Site of Action and Chemical Family for Resistant Weed Management, *continued*

Site of Action (Group)	Common Name	Herbicide Tradename	Premix or Co-pack† Tradenames*
Sulfonylurea "SU" *continued*	tribenuron	*Express SG=Spike=MPower Extra =Inferno WDG*	*Barricade II*†, Broadside*†=Refine M*†, Express FX*†, Express Pro, Enforcer MSU*†, Inferno Duo, Ko-Act*†=MPower X-Ko, Luxxur†, MPower X-Pro†, Predicade*†, Refine SG=Nimble=Deploy=MPower R =Boost=Draft, Retain SG*†, Signal FSU*†, Travallas, Triton C*, Triton K*†*
Triazolopyrimidine "TZP"	florasulam	*PrePass Flex=Priority=MPower Battlefront=Blitz=FirstPass*	*Broadband*, Cirpreme XC*†, MPower Battlefront M†*=Frontline XL*= Topline*†, MPower Battlefront+2,4-D†*=Frontline 2,4-D*†, HotShot*†, Korrex II*†, Paradigm†, MPower Kickoff*†=PrePass XC*†, MPower Battlefront CM†*=Spectrum*†, Stellar*†=Outshine*†, Stellar XL**
	pyroxulam	*Simplicity*	*Rexade*†, Tandem*†*
Sulfonylamino-carbonyltriazolinone "SACT"	flucarbazone	*Everest/Sierra 2.0, Everest/Sierra 3.0*	*Inferno Duo*
	propoxycarbazone-sodium	*Olympus*	-
	thiencarbazone	*Varro*	*Luxxur†, Predicade*, Velocity m3**
Mitotic Inhibitor (3) Dinitroaniline (DNA)	ethalfluralin	*Edge*	-
	trifluralin	*Treflan=Bonanza=Rival*	*Fortress MicroActiv**
Benzamide	propyzamide	*Kerb (SC, 50WP)*	-
Growth Regulators (4)	2,4-D amine	*2,4-D, others*	*Dyvel DSp, Restore II*
	2,4-D ester	*2,4-D Ester, Salvo*	*Approve*=Leader*=Thrasher*=Thumper*, Blackhawk*(† old form), Turboprop,*

Table 8. Herbicide Site of Action and Chemical Family for Resistant Weed Management

Site of Action (Group)	Common Name	Herbicide Tradename	Premix or Co-pack† Tradenames*
ACC-ase Inhibitor (1) Aryloxyphenoxy propionic acid "Fop"	clodinafop	*Horizon NG=Foothills NG=Nextstep NG, Cadillac One=Ladder All In, Aurora= Cadillac=Foax=Ladder=Signal=Slam'-R*	*Signal FSU*†, Traxos, TraxosTwo*†*
	fenoxaprop	*Puma Advance =Wildcat Enhanced, Bengal WB= Cordon=MPower HellCat= Vigil WB*	*Tundra*
	quizalofop	*Assure II=Yuma GL*	-
Cyclohexanedione "Dim"	clethodim	*Select=Centurion=Antler=Arrow= Clethodim 250=MPower Independence= Shadow RTM=Patron = Statue, Arrow-All-In*	-
	sethoxydim	*Poast Ultra*	*Odyssey Ultra/Odyssey Ultra NXT*†, Solo Ultra*†*
	tralkoxydim	*Achieve=Bison=Marengo=Nufarm Tralkoxydim*	-
Phenylpyrazolin "Den"	pinoxaden	*Axial*	*Axial iPak*†, Axial Xtreme*, BroadBand*, Rezuvant†*, Traxos, TraxosTwo*†*
ALS Enzyme Inhibitor (2) Imidazolinone "Imi"	imazamethabenz	*Assert=Avert*	-
	imazamox	*Solo/Solo ADV, Mizuna, Davai 80SL*	*Altitude FX2*, Ares, Odyssey=Duet=MPower Ninja, Odyssey NXT, Odyssey Ultra/Odyssey Ultra NXT*†, Salute*†, Solo Ultra*†, Tensile*†, Viper ADV*
	imazapyr	-	*Ares, Salute*†*
	imazethapyr	*Pursuit=Gladiator=MPower Kamikaze= MultiStar=Phantom*	*Odyssey=Duet, Odyssey NXT, Odyssey Ultra/Odyssey Ultra NXT*†*

Common Soil Residual Herbicides

WSSA Group	Timing	Site of Action	Example Products
2	**POST**	ALS Amino Acid synthesis Inhibitor	Davai, Solo, Odyssey, Option
3	**PPI** (soil active)	Mitosis Inhibitor/ cell division – bind to tubulin	Edge, Treflan, Fortress MicroActiv
5	**PPI** (soil active)	PSII Inhibitor/ Membrane disruptor	Aatrex, Primextra II Magnum
8	**PPI** (soil active)	Lipid Synthesis Inhibitor (Non-ACCase)	Avadex, Fortress MicroActiv
14	**POST** (foliar) with slight soil activity	PPG oxidase or Protox Inhibitor	Reflex, Flexstar GT, Authority, Valtera
15	**PPI, PRE** (surface) with residual soil activity	Very long chain fatty acid inhibitor	Focus, Zidua, Dual II Magnum
27	**POST** - Somewhat systemic (has soil residues)	HPPD Pigment Inhibitor	Shieldex 400 SC, Impact, Armezon

Factors Affecting Herbicide Persistence

- soil characteristics (texture, organic matter, pH)
- herbicide characteristics
- soil interception/plant residue
- rainfall (total amount and distribution over the year)
- rate of herbicide applied
- application date
- growing conditions following planting in the spring

Soil - Impact on Herbicide Persistence

- temperature
- moisture
  - microbial and chemical degradation
  - reduced moisture causes herbicides to bind more tightly to soil particles (adsorption) – unavailable for degradation or uptake
- OM/Soil Texture (clay content)
  - provides binding sites for herbicide adsorption
- pH (7.0 neutral)
  - determine characteristics of herbicide adsorption
  - can influence microorganism activity

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Maximizing Trifluralin Effectiveness

- ***High volatility*** – must be incorporated very soon after application
- Binds tightly to surface residue, will not wash off with rainfall
  - spray with the direction of the stubble
- trifluralin not highly water soluble, once it is incorporated, not much chance of impacting seed as long as seed is placed below the herbicide layer

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Maximizing Pyroxasulfone Effectiveness

- ***Non-volatile*** – incorporation may be a **detriment**
- Requires water for activation – delay in rainfall could result in poor weed control
- Will wash off surface residue but will not volatize so is not lost
- Heavy rainfall can leach pyroxasulfone below the weed seed zone and into the crop zone = increased crop injury and less weed control

Example – Not all soil applied herbicides the same:

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Primextra II Magnum (atrazine, S-metolachlor)

- **WARNING:**

  Do not plant any crop other than corn in the same year on land treated with PRIMEXTRA II MAGNUM Herbicide as injury may occur. The following year there is virtually no hazard to soybeans, white beans, corn, oats or barley (not underseeded to a legume) in Eastern Canada. Moldboard plough and till soil thoroughly before planting these rotational crops. In the Prairie Provinces, corn must be planted the year following application**. However, when the rotational crop is subjected to stress conditions, e.g. abnormally hot, dry weather, preceded by extended periods of dry weather the previous season, injury may occur.**

Post emergent products may also have concerns; but additional risk with soil-applied

Always check the label for warnings and other information!

Herbicide Resistance

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Rapid changes with development of herbicide resistance have resulted in a number of different guidelines, all with valuable points.

'10-point "minimum requirement" list for farmers to control the resistance problem in weeds':

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- **Maintain a weed-free zone** field borders, 100% of acres
- **Practice zero-tolerance (100% weed control)** when herbicides are main tool
- **Choose the most effective herbicide(s)**
- **Apply the most effective soil-applied herbicide(s)**
- **Rotate herbicide mechanisms of action**.
- **Plant a different type of herbicide-resistant crop every other year**
- **Apply post-emergence herbicides to small (1- to 3-inch) weeds**
- **Include the most effective adjuvant(s)** focus on weed control
- **Apply herbicides at the appropriate droplet size** herbicide type
- **Reduce sprayer travel speeds**.

Top 10 Herbicide Resistant Weed Management practices

- 10. **Keep Records**
- 9. Strategic tillage; if, where or when needed
- 8. Field+site-specific weed mgmt (1 size may not fit all)
- 7. Weed sanitation: border control+slowing HR dispersal
- 6. In-crop selective herbicide rotation
- 5. Herbicide grp rotation: **avoid back-to-back in-crop** Grp 1 or 2
- 4. Herbicide mixtures/sequences: better than rotations
- 3. **Scout: know your enemy**
- 2. **Competitive** crops/practices that promote competitiveness
- 1. **Crop diversity**

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A National Summit on Strategies to Manage Herbicide-Resistant Weeds May 2012

National Academy of Science

Herbicide Resistance – Best Management Practices

Herbicide Resistance – Best Management Practices

- Understand the biology of the weeds

- Use a diversified approach toward weed management
  prevent weed seed production
  reduce # weed seeds in soil seedbank.

- Plant into weed-free fields. Keep fields as weed free as possible.

Herbicide Resistance – Best Management Practices

- Plant weed-free crop seed
- Scout fields routinely.
- Use multiple herbicide mechanisms of action (MOAs) that are effective against the most troublesome weeds or those most prone to herbicide resistance.

Herbicide Resistance – Best Management Practices

- Crop competition to suppress weeds
- Use other practices – e.g. mechanical
- Prevent field-to-field and within-field movement of weed seed or vegetative propagules.

Herbicide Resistance – Best Management Practices

- Manage weed seed at harvest and after harvest to prevent a buildup of the weed seedbank.

- Manage field borders

Back in the 'old days'…..personal experience and observations:

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As a Red River Valley agronomist:

- Saw customer change in weed management from soil incorporated to post emergent herbicides–ease of application, improved weed control

- Move away from soil incorporated products like trifluralin, ethafluralin, triallate, to newer Group 1 products and others– ease of application, timing.

Reasons for this complete change in management included:

- no longer needed incorporation – reduced tillage, less risk of wind and water erosion;
- Flooding - which limited fall applications, and potentially efficacy;
- improved level of weed control/cleaner fields
- Ease of application; and with introduction of HT crops, ease of product choice

Fast forward to today – we're now paying for that 'ease' of choices.
Realities to we need to think about include **increased diversity** in all aspects of growing crops..

Back in the 'old days'…..personal experience and observations:

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To paraphrase a crop input colleague:

- We need to juggle up our herbicide choices – and get some soil incorporated herbicides back in to the rotation
- We need to ratchet down our expectations for degree of weed control with those products
- We have to be better about long term planning – making best use of the management tools we have
- Farming isn't easy! Complexity is increasing all the time.
- The choices we make now affect the future – what's the long term cost of a short term decision today?
- NO SILVER BULLETS!!

Herbicide Resistance

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- Make sure you ask ALL the questions!
  →Both producer and agronomist
  (increased importance with more complex cropping/HR weed/residual herbicide concerns – increased importance for record keeping)
- Importance of local agronomist
- Build relationships; 2nd and 3rd set (or more) of eyes will support the success of your farm

Herbicide Resistance

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Key points to include to any list for managing herbicide resistance:

Scout!!

- Importance of knowing your weeds and staging, and stage of crop. Pre-seed? preplant incorporated? pre-emergement? burn off? post emergent? tillage? mowing? patch control? hand roguing?
- Follow up scout – is your weed control working? What measures to take?

→keeping an eye on your crops throughout the growing season becomes more important with these increasing challenges. The need to deal with weed issues immediately and completely has never been more important!!

Keep Records!!

- Soil applied and soil incorporated herbicides increase the need for good records →for ongoing weed management decisions AND to prevent crop injury in future crop seasons.

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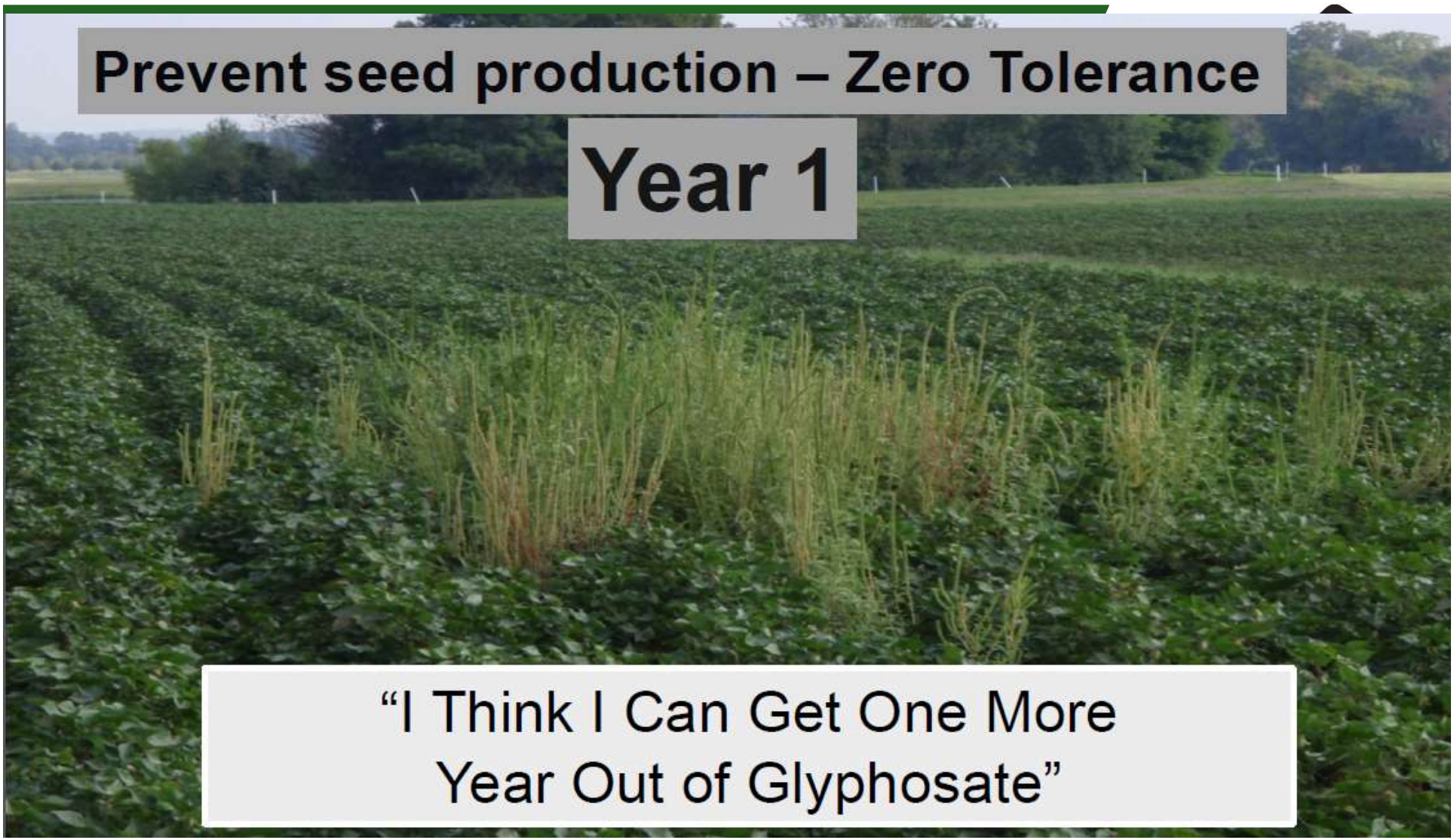
Take-home.....

- Will this happen to me? YES!!!
  → and it likely already has!!
- Is there a magic bullet? NO!!!
- Know what's coming, and continue with good crop management decisions


Prevent seed production – Zero Tolerance
Year 1
“I Think I Can Get One More
Year Out of Glyphosate”

Herbicide Resistance

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Sources:

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QUESTIONS?

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