Wild Oat Resistance Management

K. Neil Harker
AAFC, Lacombe, AB

Kalispell, MT
Feb 4, 2016


KOCHIA SCOPARIA
NUISANCE OF GROWERS
Put to rest by a Group 14 mode of action and up to eight weeks of residual control. Lambs-quarters, redroot pigweed, wild buckwheat and others met the same fate.

Overview

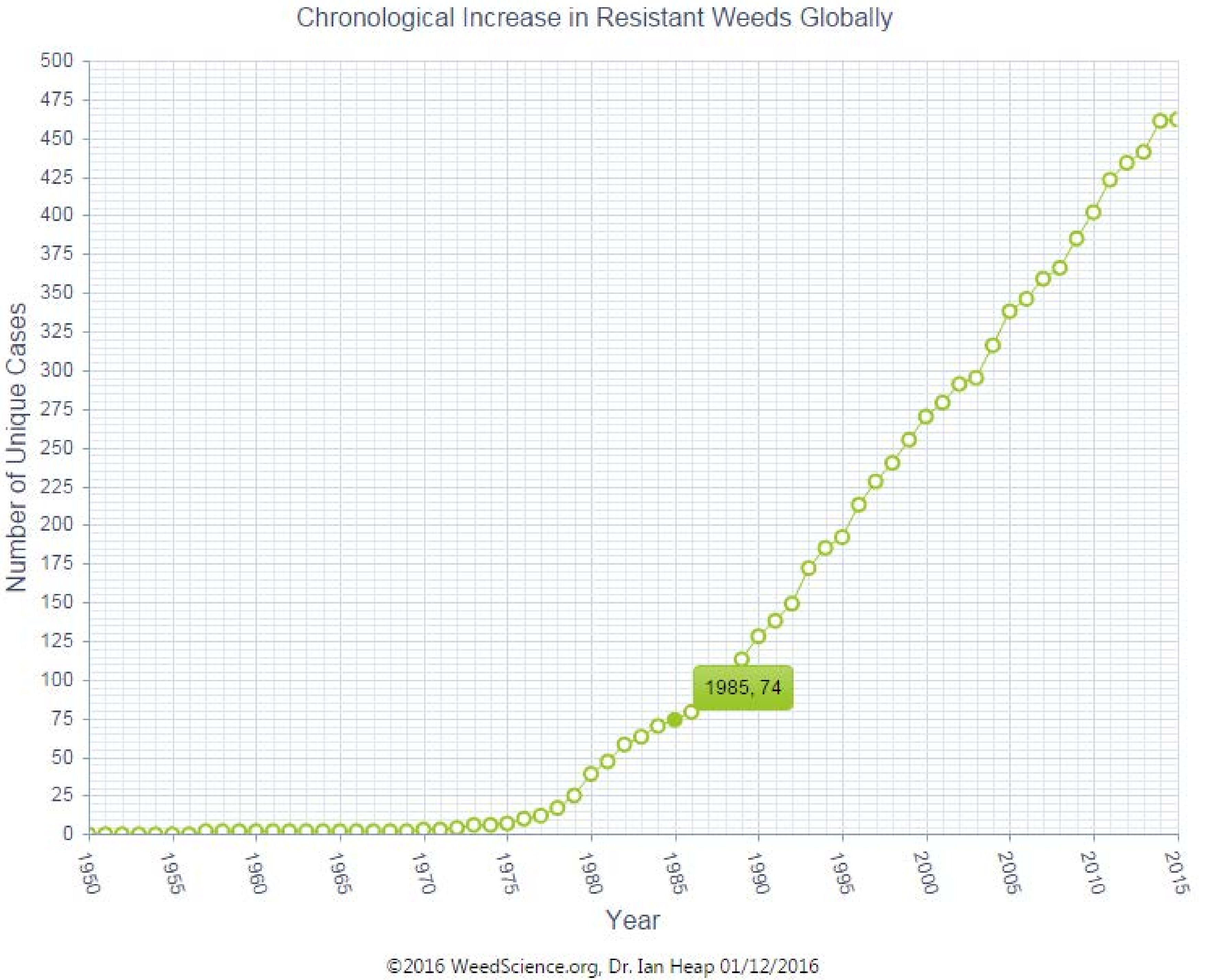
- Herbicide Resistance Situation
- Differential Resistance Risks:
  - Weeds & Herbicides (some are higher risks than others)
- Wild Oat Resistance Management Keys
  - Crop and Crop Stand Health
  - Diverse Cropping Systems
  - IWM
- Alternative Weed Control Methods
  - Will they work?

Photo : Robert Blackshaw

First, let's not be surprised when resistance happens.

Any repeated and consistent weed control practice will lead to resistance.

Photo: Barrett, S.C.H. 1983.
Crop mimicry in weeds. Econ. Bot. 37:255-282


Chronological Increase in Resistant Weeds Globally
Number of Unique Cases
0
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
425
450
475
500
1985, 74
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
Year
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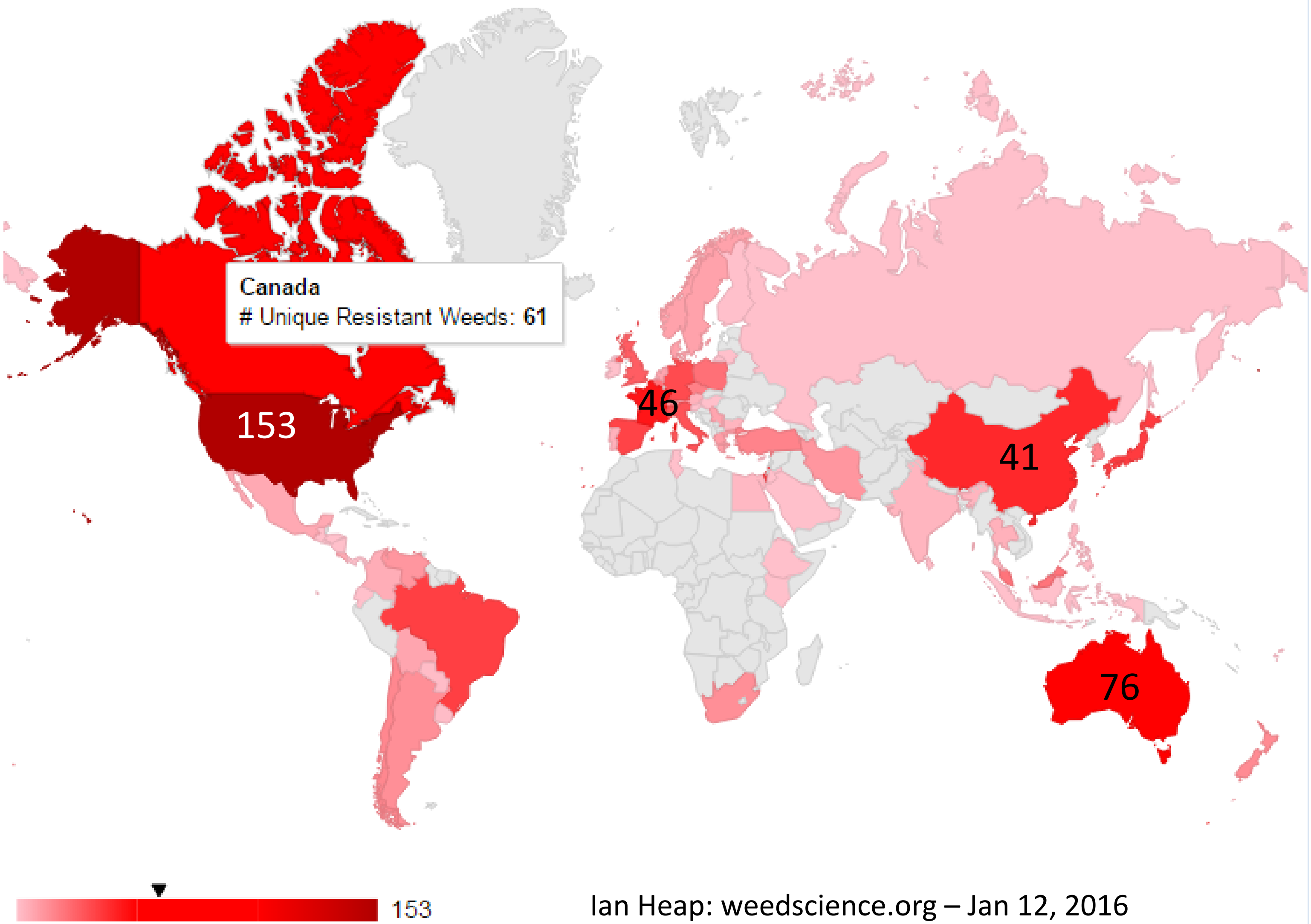
Unique Herbicide Resistance Cases

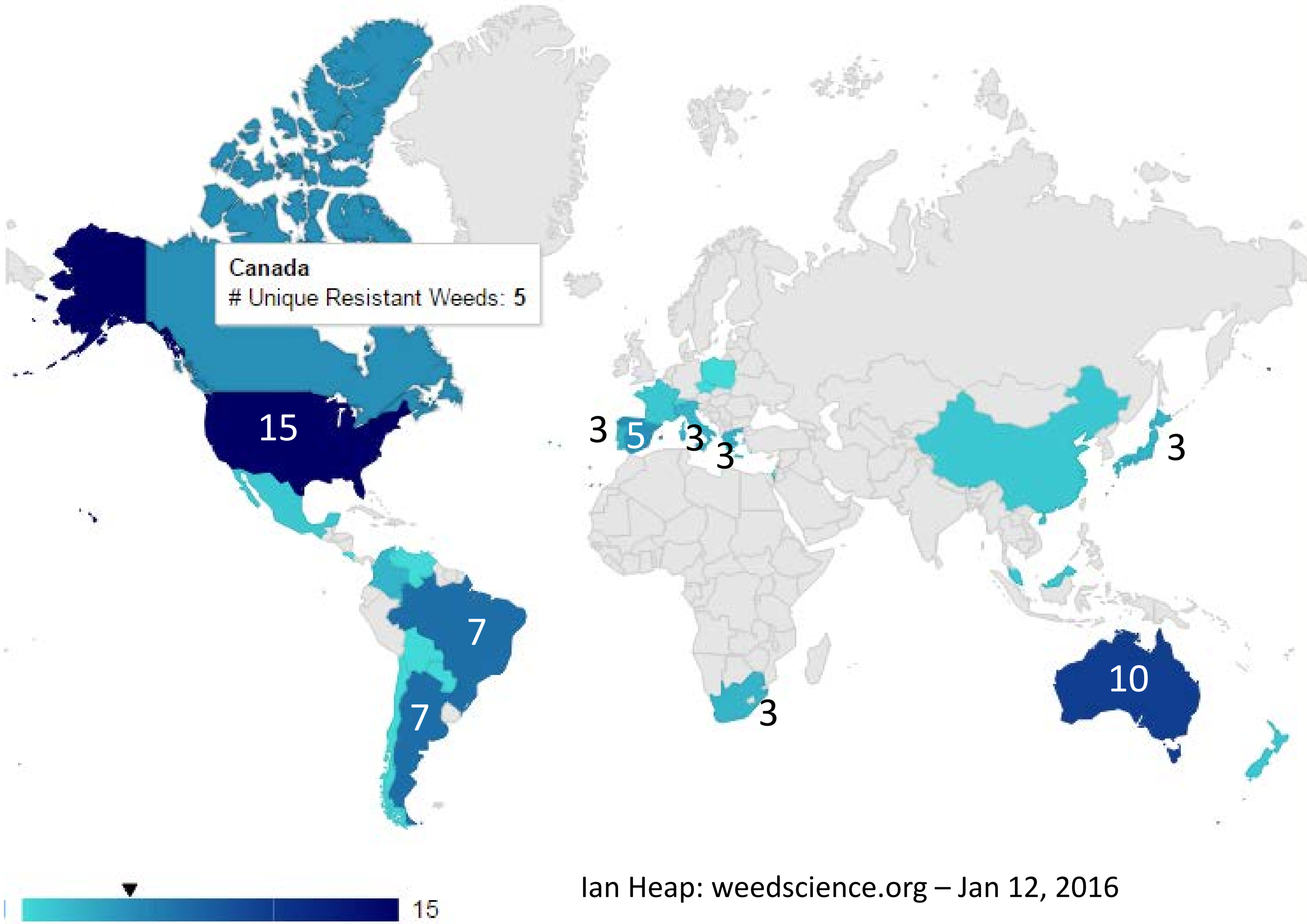
- Top 5 Countries



Ian Heap: weedscience.org – Jan 12, 2016

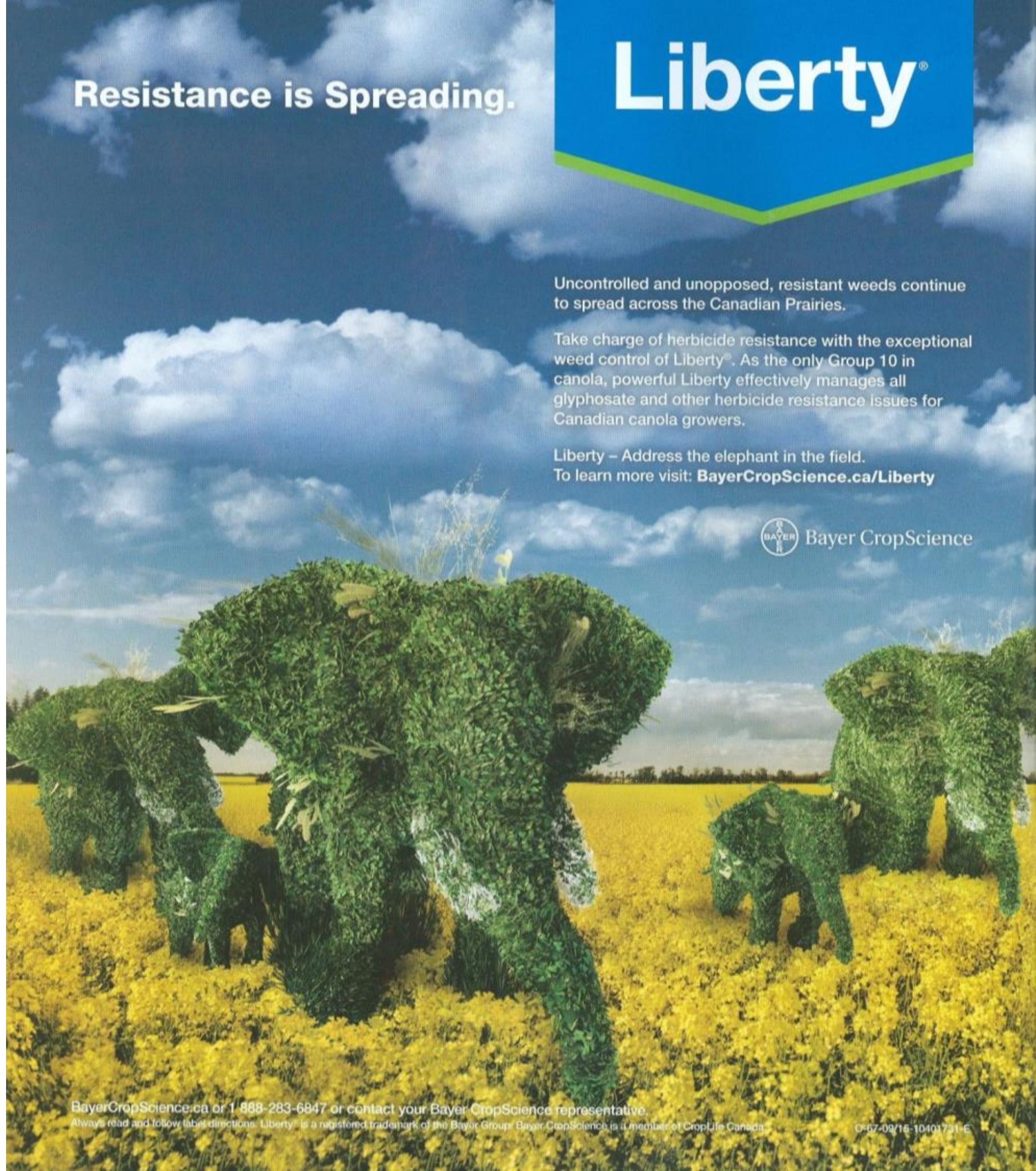
Glyphosate Resistance Cases

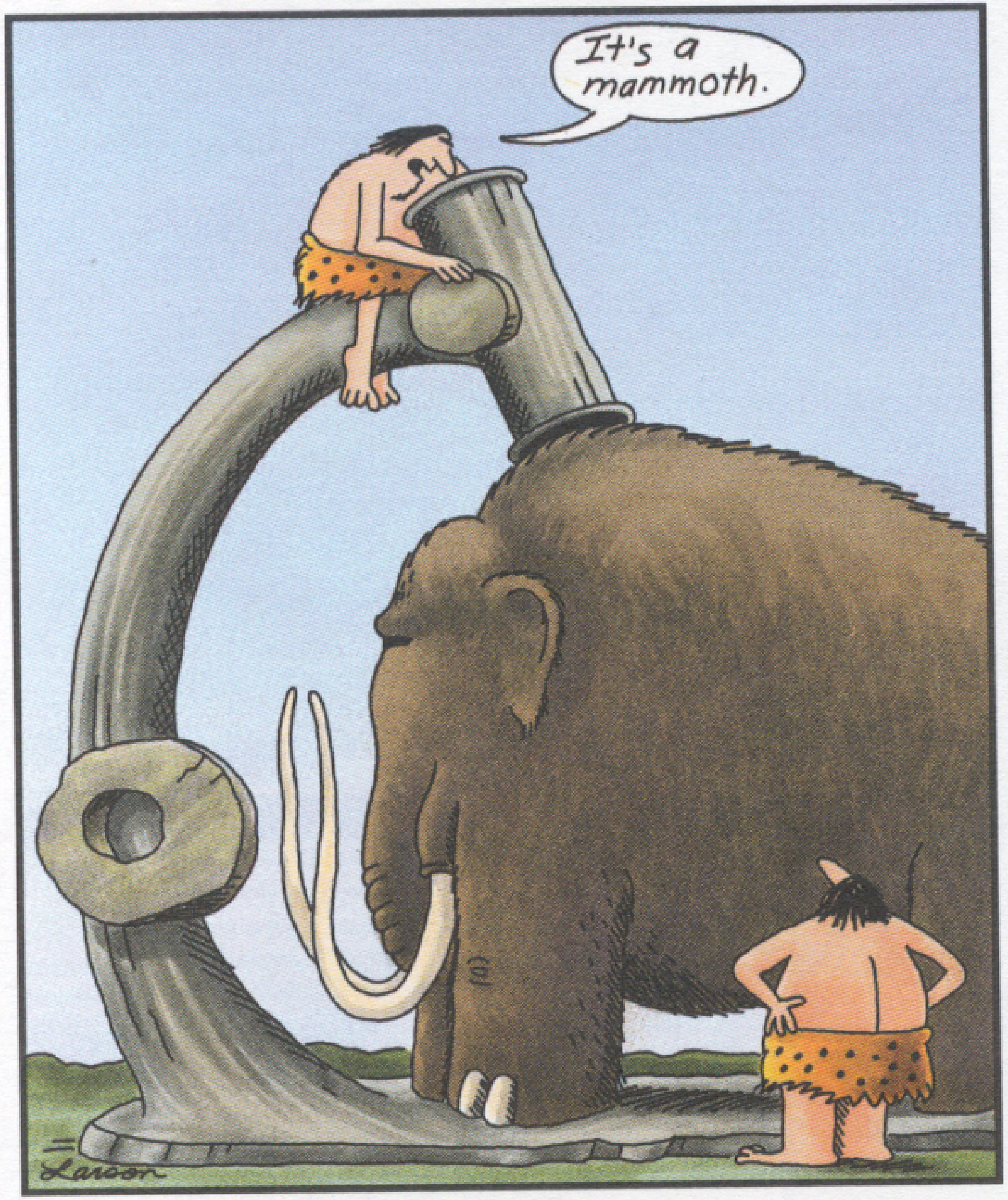
- Top 5 Countries (32 Unique GR Weed Species Globally)



Ian Heap: weedscience.org – Jan 12, 2016

And, "Resistance is Spreading"





Early microscopes

Why ?

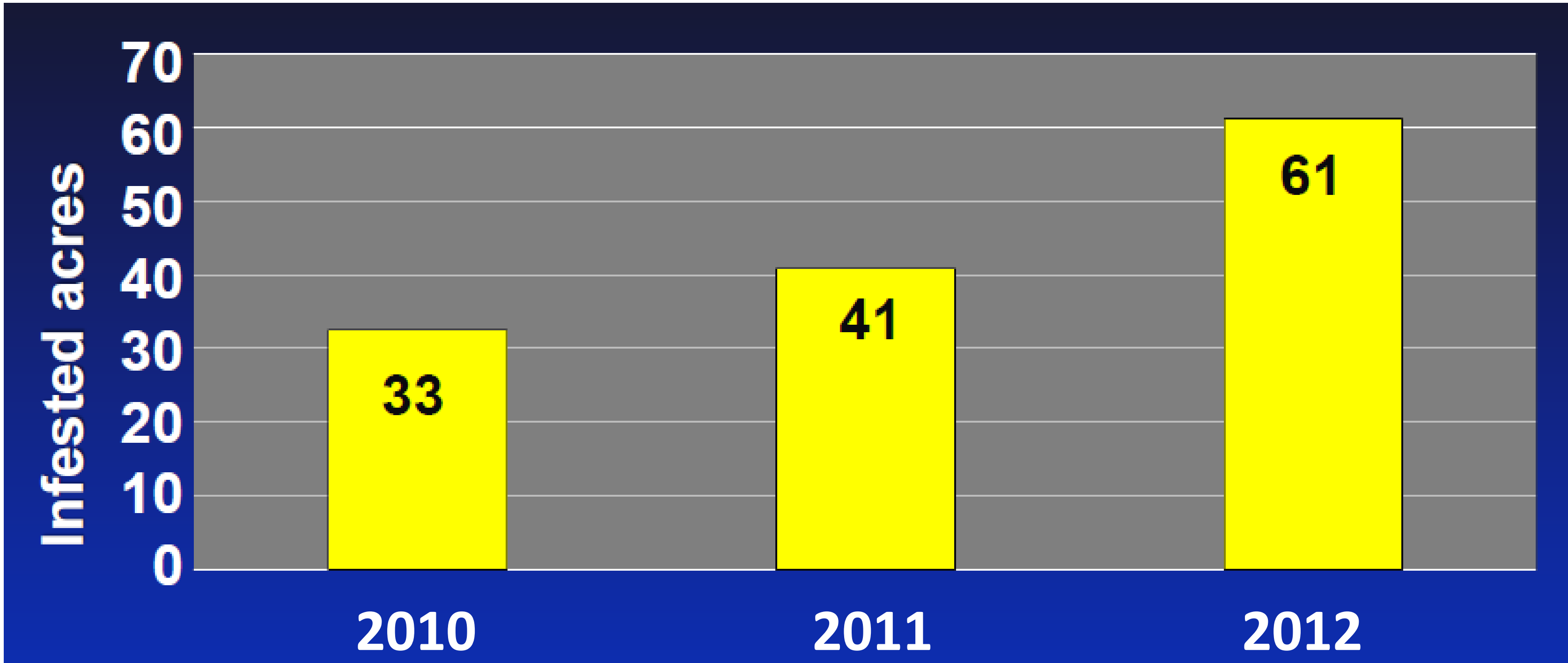
GR Palmer Amaranth Southern USA
- Let's talk "Selection Pressure"

- 4 fields of continuous cotton for ≥ 6 yr
- Herbicide regime
  - Preseed Burn-off: Gly (0.84 kg/ha) + dicamba
  - 1st In-crop herbicide: Gly (0.84 kg/ha) – early POST
  - 2nd In-crop herbicide: Gly (0.84 kg/ha) – prior to 5 leaves
  - 3rd In-crop herbicide: Gly (0.84 kg/ha) + diuron – POST-direct
  - Some years – 4th In-crop: Gly (0.84 kg/ha) + diuron – POST-direct

RESULT:

- By 2004, 4 Tennessee fields with GR Palmer amaranth - 2x to 4x rates
  - Steckel et al. 2008. Weed Technol. 22:119-123
- GR Palmer amaranth in Georgia resistant to 12x rates of glyphosate
  - Culpepper et al. 2006. Weed Sci. 54:620-626

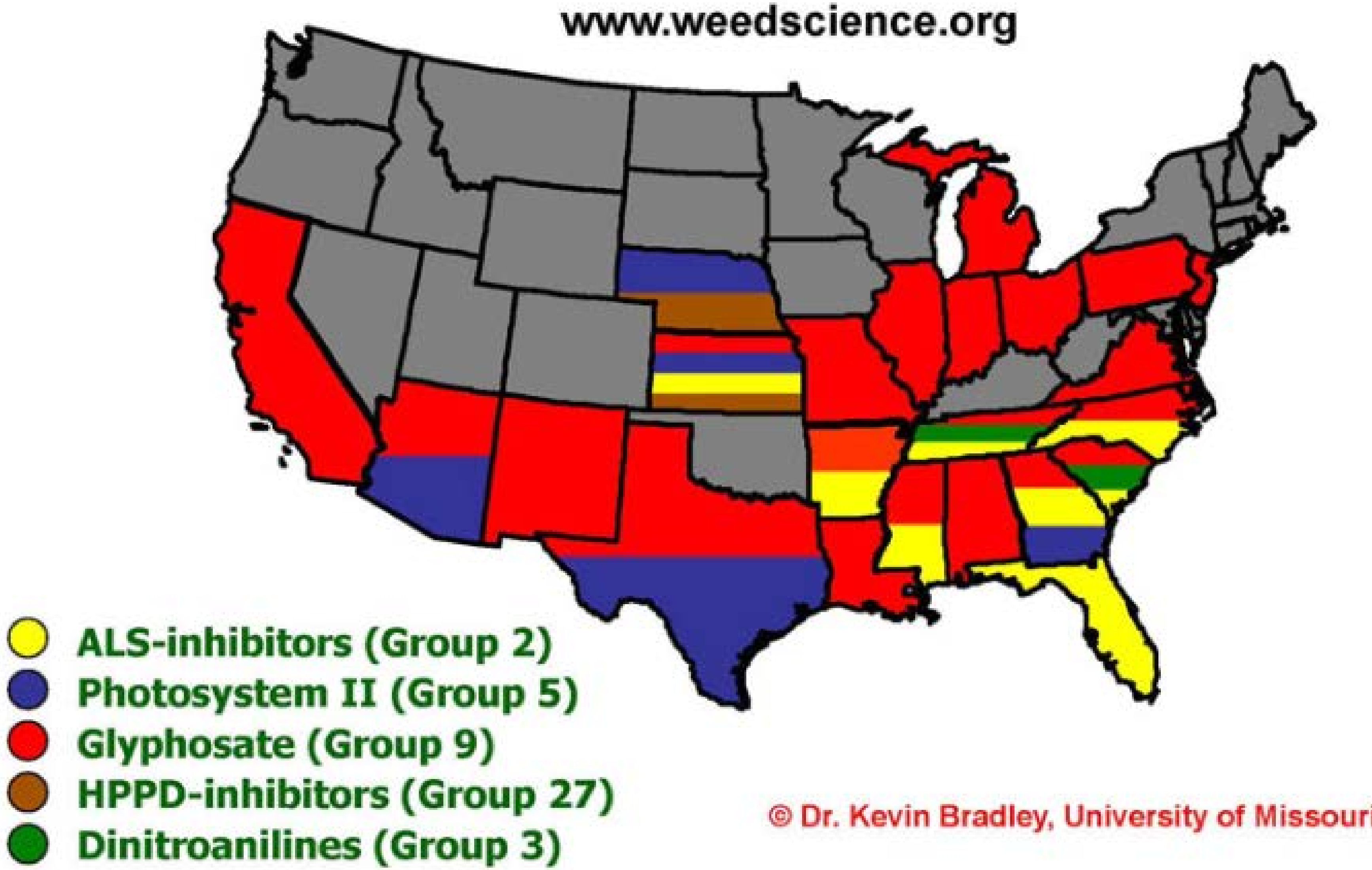
US Acres with GR Weeds (x 1,000,000)



- **Nearly half (49%) of surveyed U.S. farmers had glyphosate-resistant weeds in 2012.**

Dr. Jason Norsworthy, Univ. Arkansas

HR Palmer Amaranth - 2014



Many Years Ago?

“New” Weed Tool in Arkansas (Hoe)

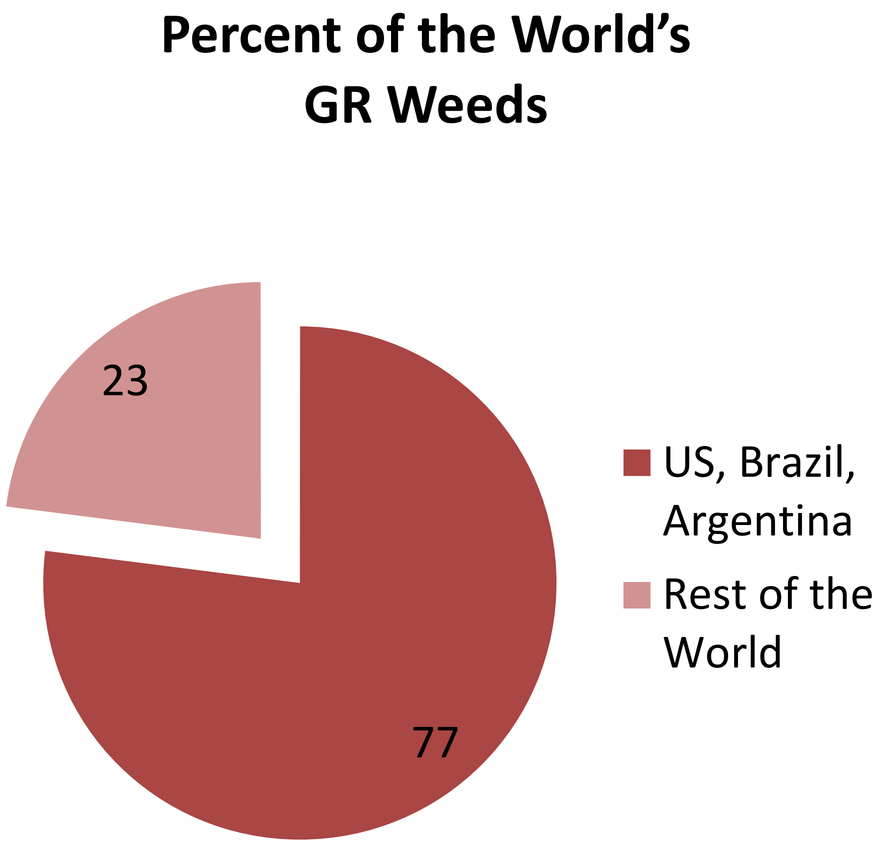
2011 Photo: Jason Norsworthy
University of Arkansas

Tillage is now a common scene

Photo Courtesy Stanley Culpepper

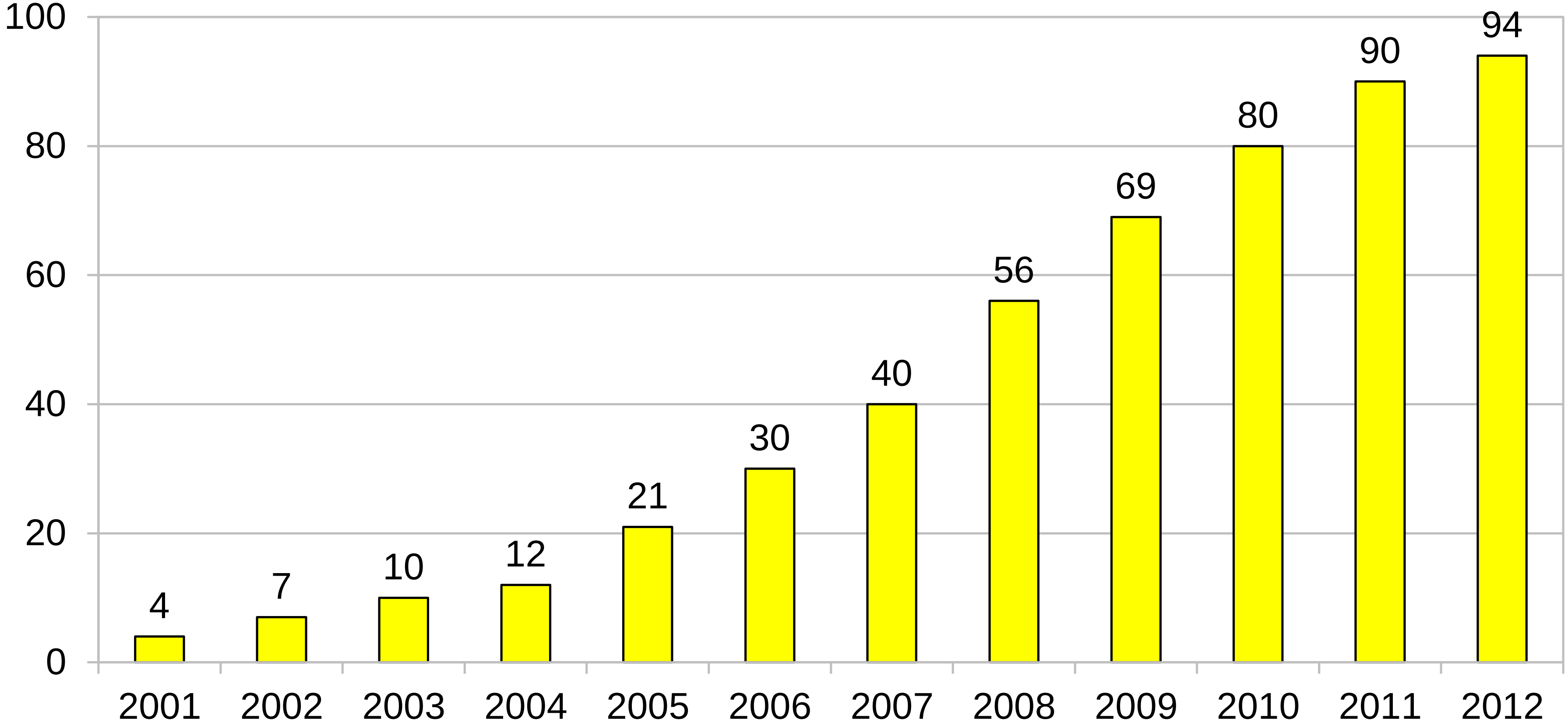
Where are the most GR Weeds?

- Where are the most GR Crops?
  - US, Brazil & Argentina have > 80% of world GR crop acres
  - 330 million acres in 2009
  - Worldwide, there are 112 known instances of GR Weeds



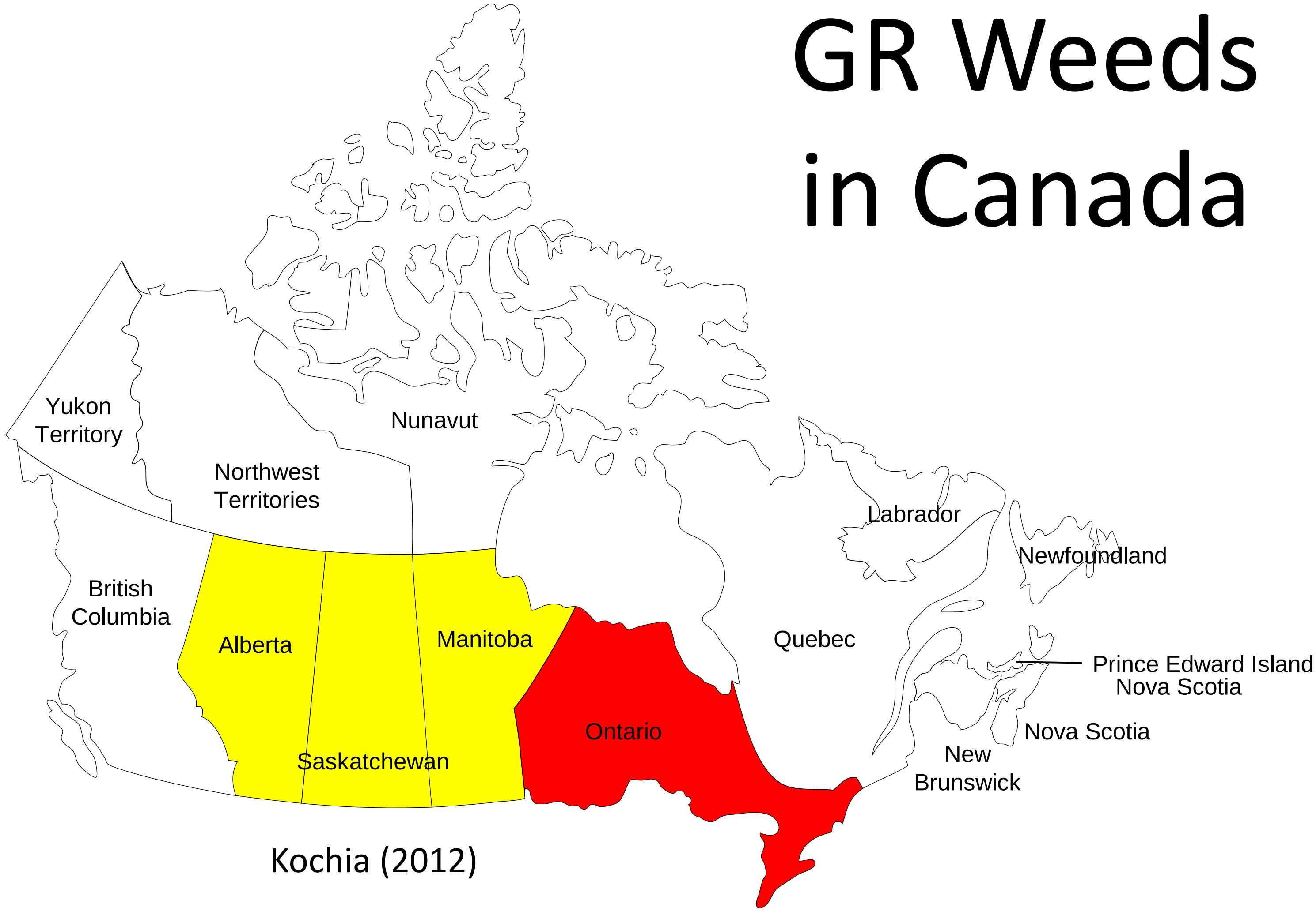
Holt et al. 2013. Plos One 9:1-7
www.plosone.org

Ontario Roundup Ready Corn
- Market Share (%)



Stratus

GR Weeds in Canada



Kochia (2012)

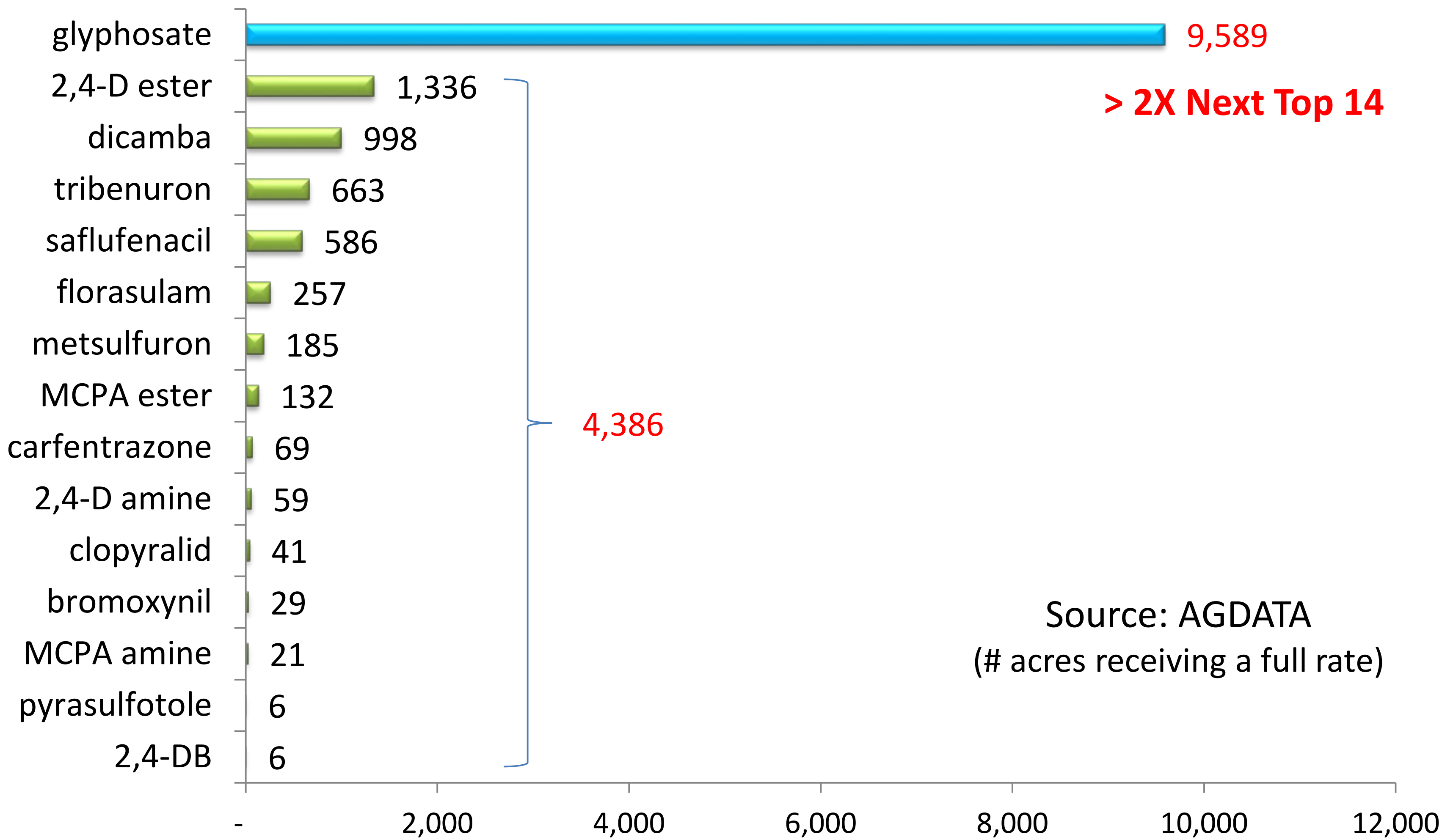
Giant ragweed (2008)

Canada fleabane (2011)

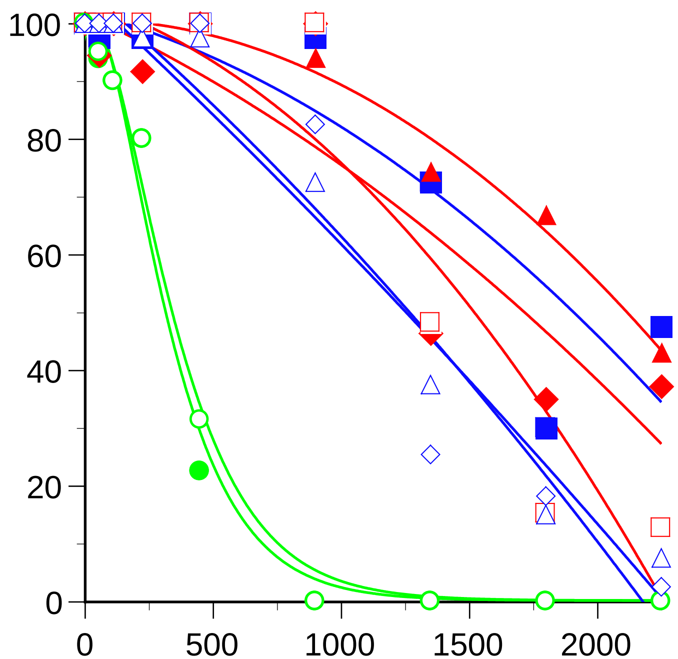
Common ragweed (2012)

Waterhemp (2014)

Acres of Active Ingredient Applied (x1,000)
- Western Canada (2012 - Summer & Chem Fallow only)



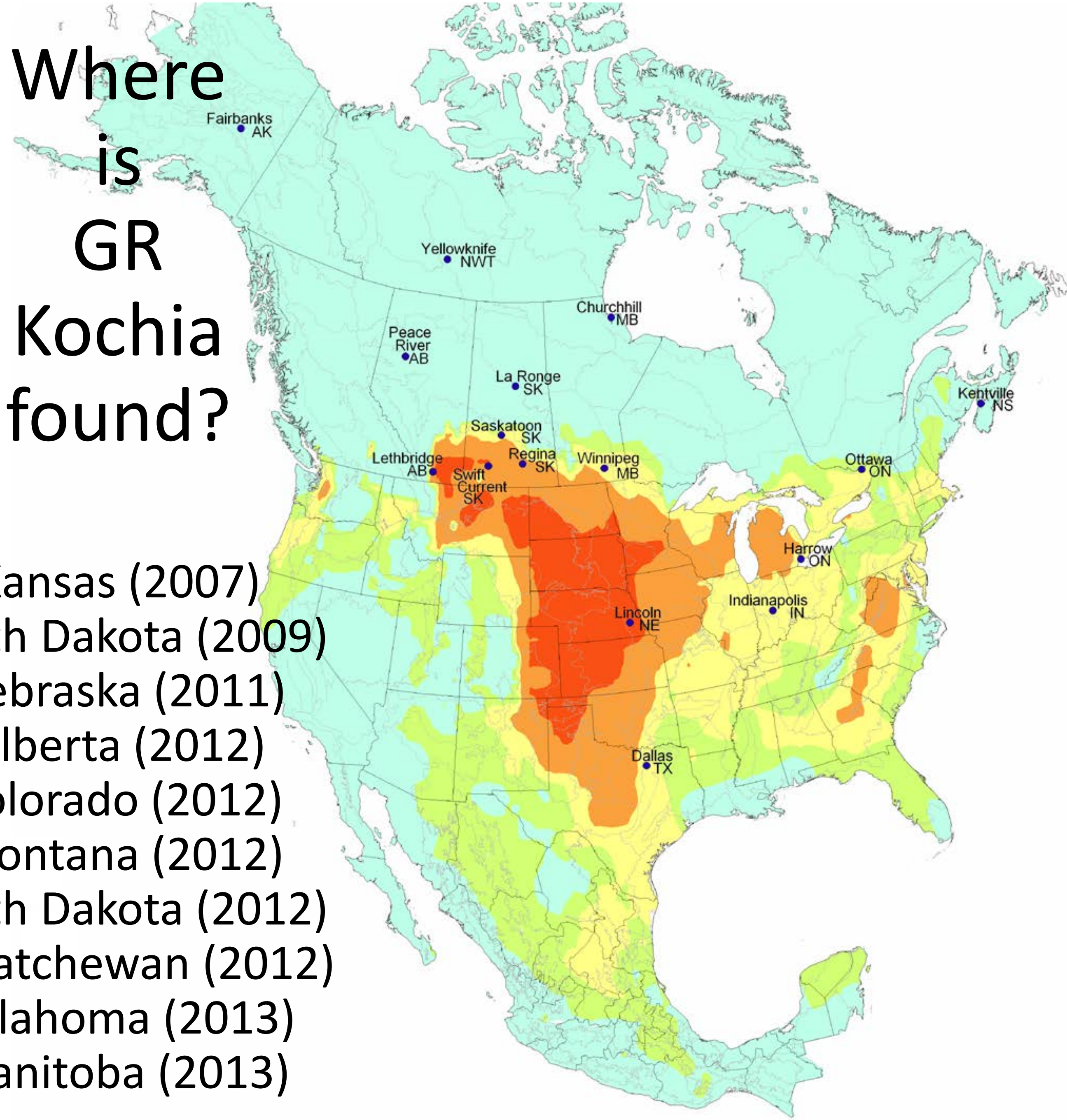
GR Kochia



	LD_{50}	RF
Phillip	1900	5.8
Hays	310	-
AB-F1	2250	6.9
AB-F2	1720	5.3
AB-F3	1740	5.4
Hanley	340	-
Scott	1260	3.9
Russel	1280	3.9

Where is GR Kochia found?

Kansas (2007)
South Dakota (2009)
Nebraska (2011)
Alberta (2012)
Colorado (2012)
Montana (2012)
North Dakota (2012)
Saskatchewan (2012)
Oklahoma (2013)
Manitoba (2013)



Where is the Most Kochia?

Elsewhere, in Malaysia…

WEED RESEARCH An International Journal of Weed Biology, Ecology and Vegetation Management

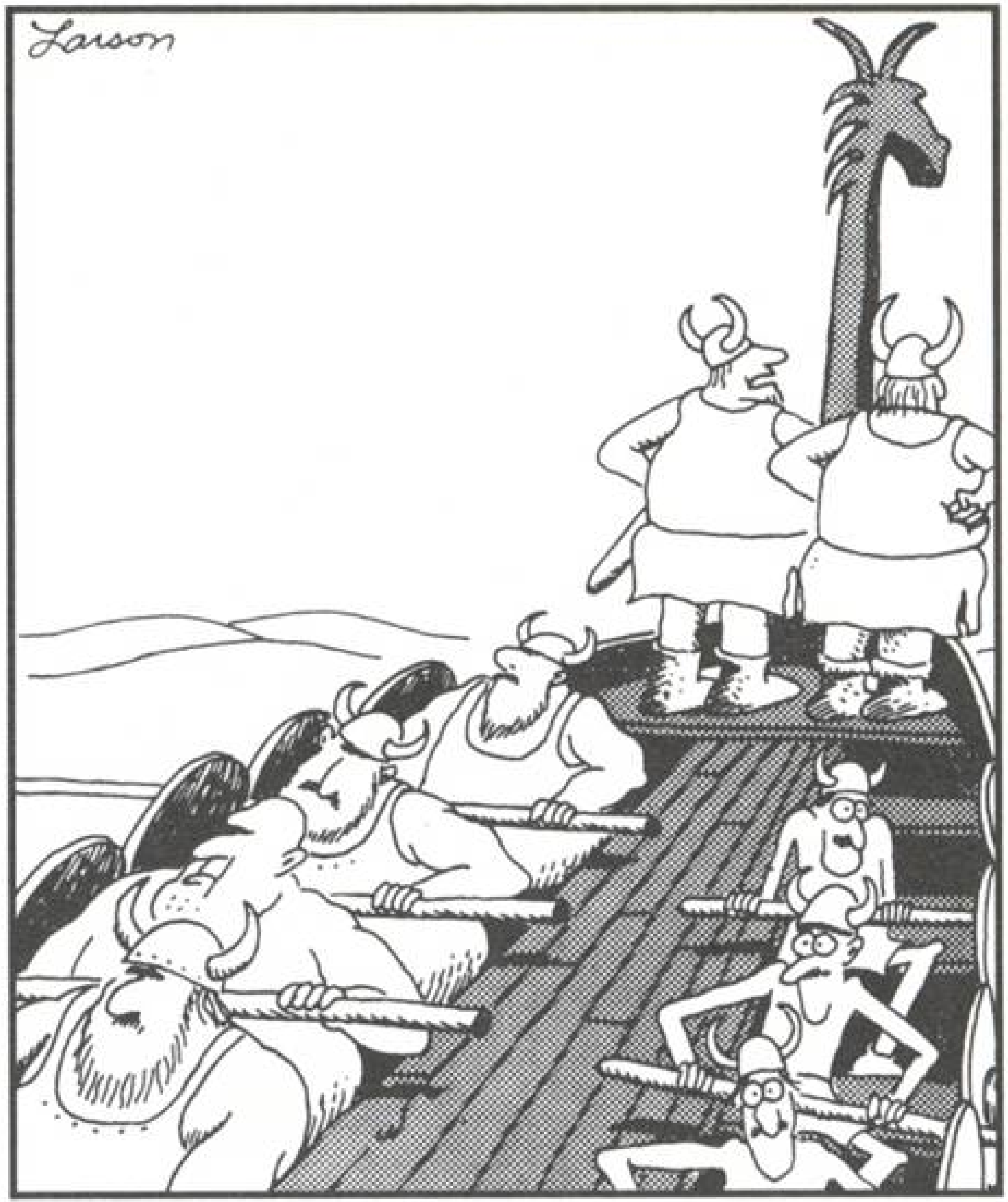
DOI: 10.1111/wre.12118

Multiple resistance across glufosinate, glyphosate, paraquat and ACCase-inhibiting herbicides in an *Eleusine indica* population

A JALALUDIN, Q YU & S B POWLES
Australian Herbicide Resistance Initiative, School of Plant Biology, University of Western Australia, Crawley, WA, Australia

Received 7 January 2014
Revised version accepted 16 July 2014

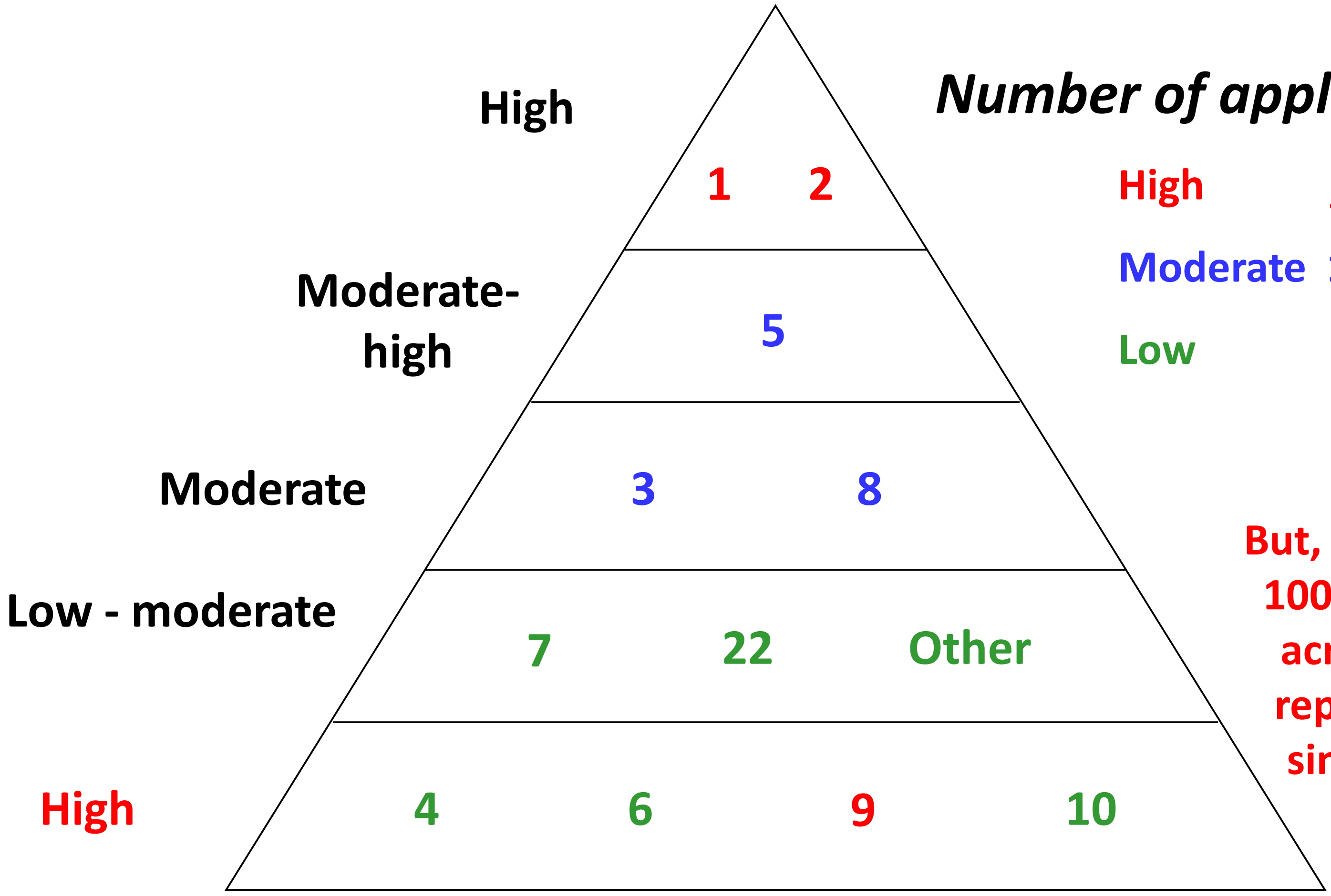
Weed Res. (2015) 55:82-89



"I've got it, too, Omar … a strange feeling like we've just been going in circles."

The
Herbicide Sales
Team
…
the
IWM
Team
…

Risk of Selection for Resistance - Herbicide Groups



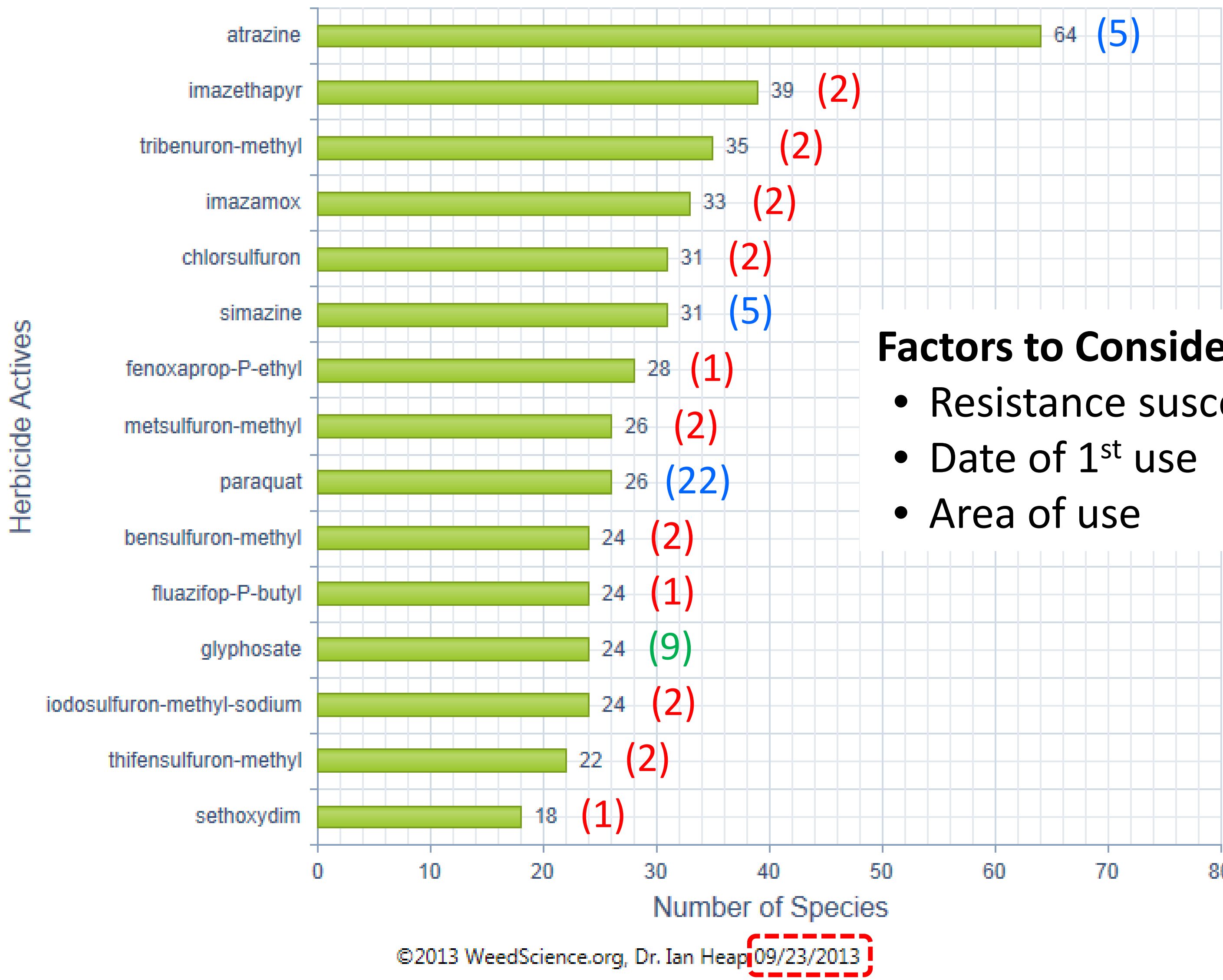
Number of applications:

High	**≤ 10**
Moderate	**11 - 20**
Low	**> 20**

But, what happens if 100's of millions of acres are treated repeatedly with a single "low risk" herbicide?

Beckie (2006) Weed Technol. 20:793-814

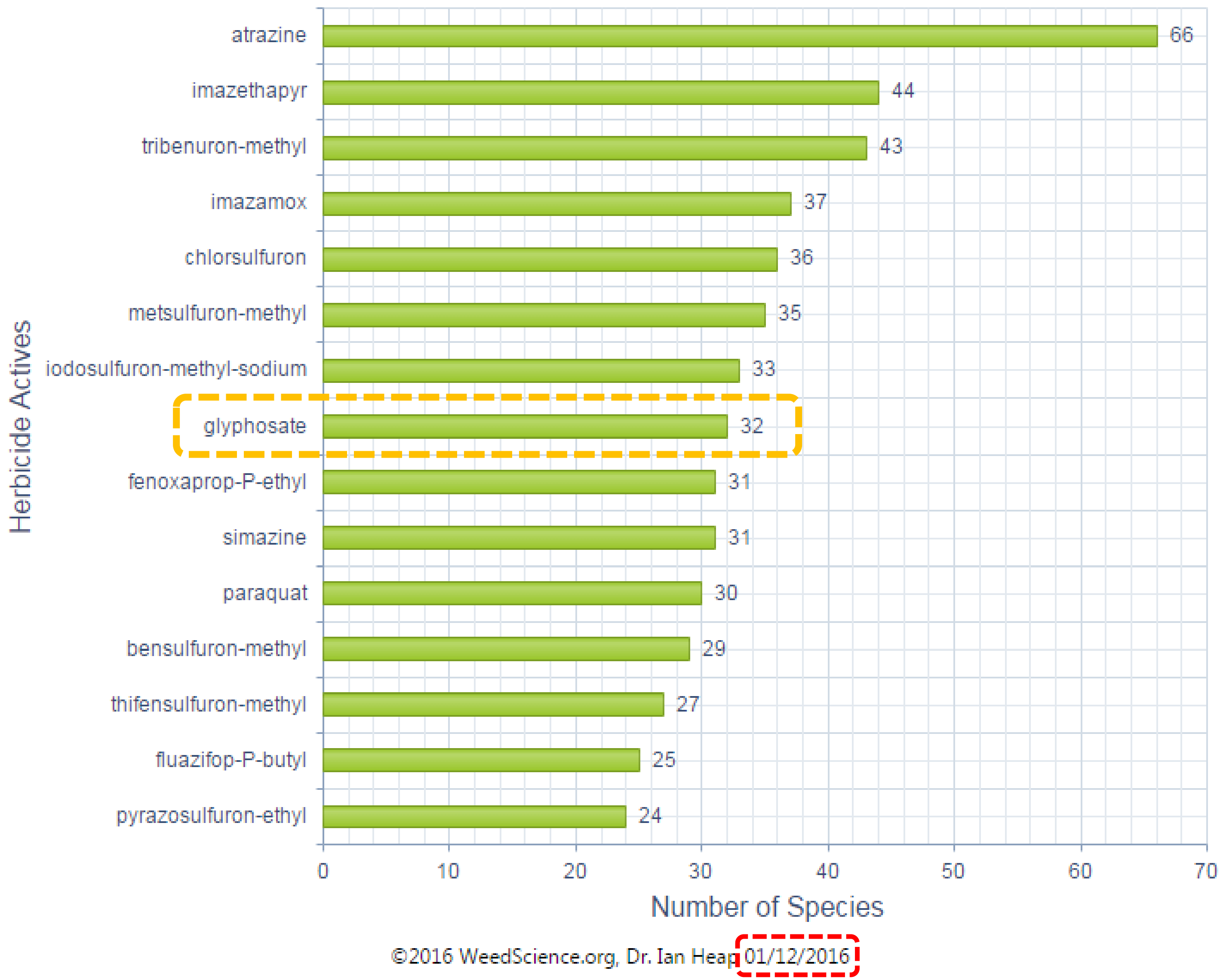
Weed Species Resistant to Individual Herbicides (Top 15)



Factors to Consider

- Resistance susceptibility
- Date of 1st use
- Area of use

Weed Species Resistant to Individual Herbicides (Top 15)



Risk of Resistance

- Weed Species Traits

Weed Resistance is a NUMBERS "game"

High Weed numbers:

- High density
- Broad distribution

High Genetic diversity:

- High frequency of resistance mutations

High Seed production:

- rapid increase in resistant biotype relative to susceptible population after herbicide application

High Out-crossing (gene spread):

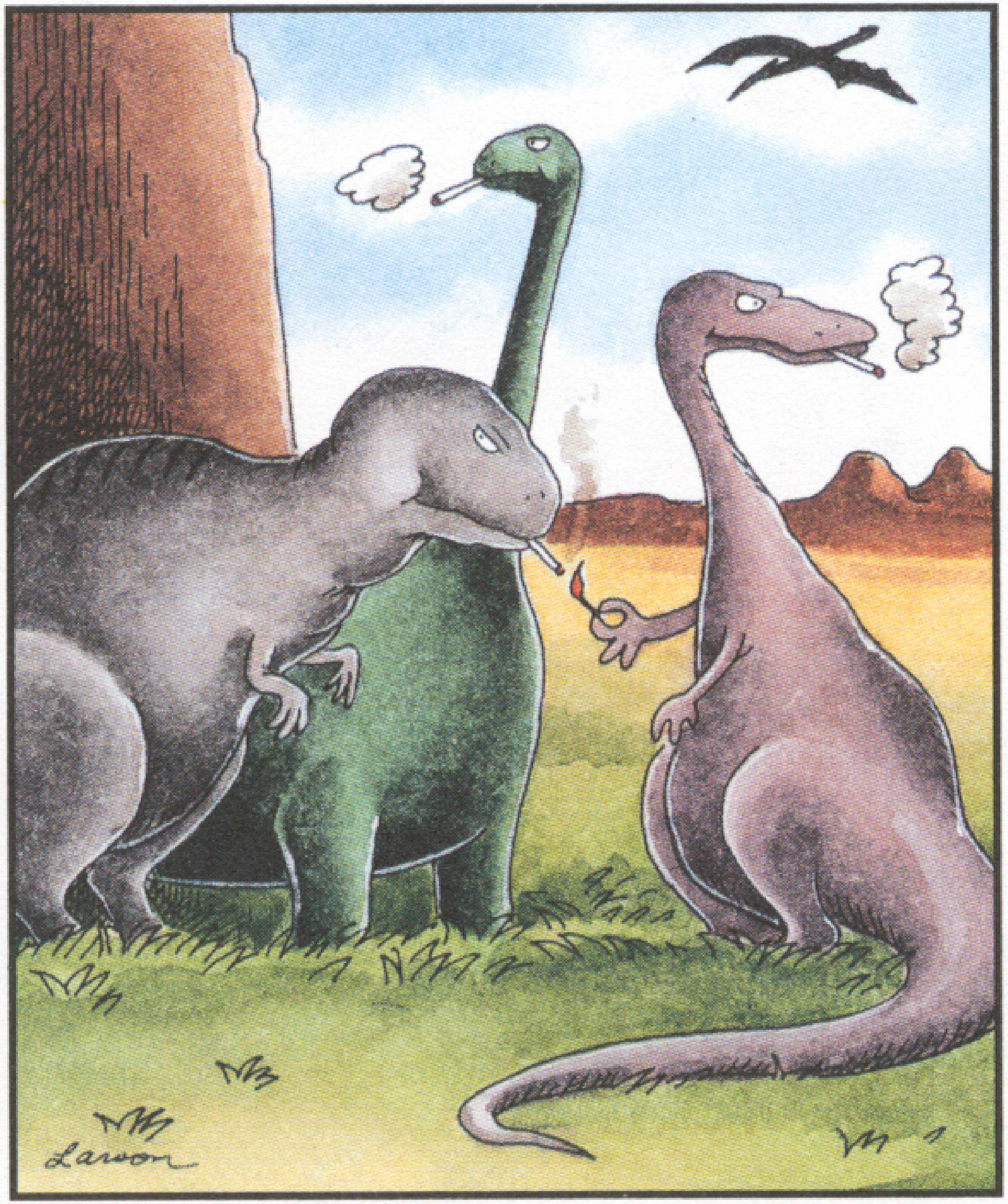
- rigid ryegrass, kochia, …

High Seed Bank Turnover (low seed dormancy)

- rigid ryegrass, kochia, …

High proportion of Herbicide Escapes:

- wild oat, cleavers, kochia,



The real reason dinosaurs became extinct

Other Reasons for Resistance …

Most Popular Western Canada Crop Rotations

#	Year 1	Year 2	Year 3	Year 4
1	Canola	Wheat	Canola	Wheat
2	Canola	Wheat	Wheat or Barley or Peas	Canola
3	Canola	Canola	Canola	Canola

In-crop herbicides in field crops (2006-2010)

Site of Action	Wheat	Barley	Canola	Flax	Field Pea	Lentil
	———————— % of fields ————————					
1	76	86		100	24	44
2	23	12		0	76	48
3	0	0		0	0	8
8	1	2		0	0	0
9	0	0		0	0	0
10	0	0		0	0	0
(n)	*775*	*280*		*49*	*129*	*49*

Adapted from: Beckie et al. 2013 Weed Technol. 27:171-183

In-crop herbicides in field crops (2006-2010)

Site of Action	Wheat	Barley	Canola	Flax	Field Pea	Lentil
	——— % of fields ———					
1	76	86	6	100	24	44
2	23	12	15	0	76	48
3	0	0	0	0	0	8
8	1	2	0	0	0	0
9	0	0	42	0	0	0
10	0	0	37	0	0	0
(n)	*775*	*280*	*345*	*49*	*129*	*49*

Adapted from: Beckie et al. 2013 Weed Technol. 27:171-183

New Herbicide Modes of Action

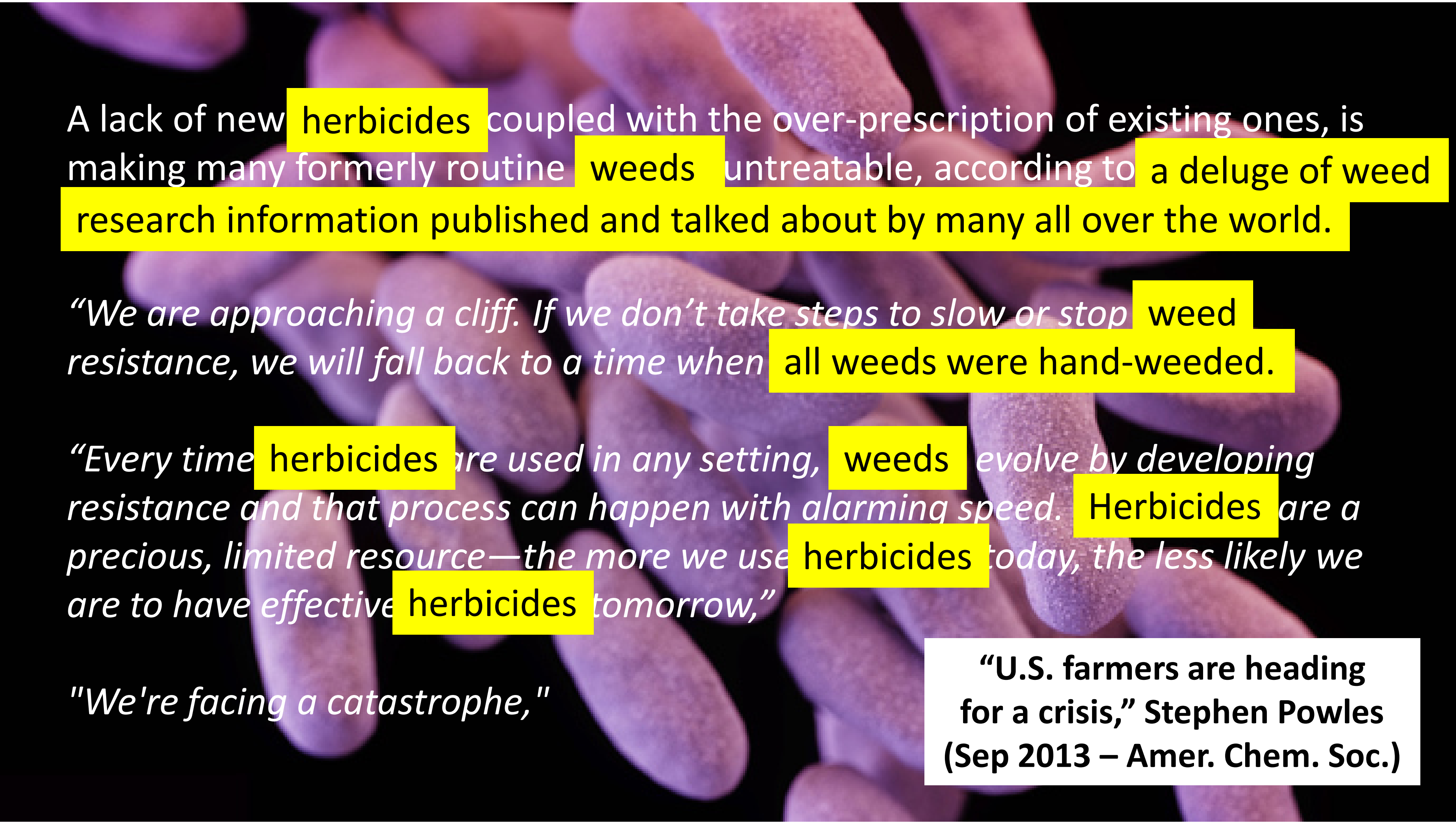
“No new major herbicide mode of action has been introduced in a commercial herbicide active ingredient in the last 20 years.

Duke. 2012. Pest Manag. Sci. 68:505-512

There goes another herbicide …

"This is a minor setback. The hunter-gatherer economy is still good."

Drug-Resistant Bacteria



A lack of new herbicides coupled with the over-prescription of existing ones, is making many formerly routine weeds untreatable, according to a deluge of weed research information published and talked about by many all over the world.

"We are approaching a cliff. If we don't take steps to slow or stop weed *resistance, we will fall back to a time when* all weeds were hand-weeded.

"Every time herbicides *are used in any setting,* weeds *evolve by developing resistance and that process can happen with alarming speed.* Herbicides *are a precious, limited resource—the more we use* herbicides *today, the less likely we are to have effective* herbicides *tomorrow,"*

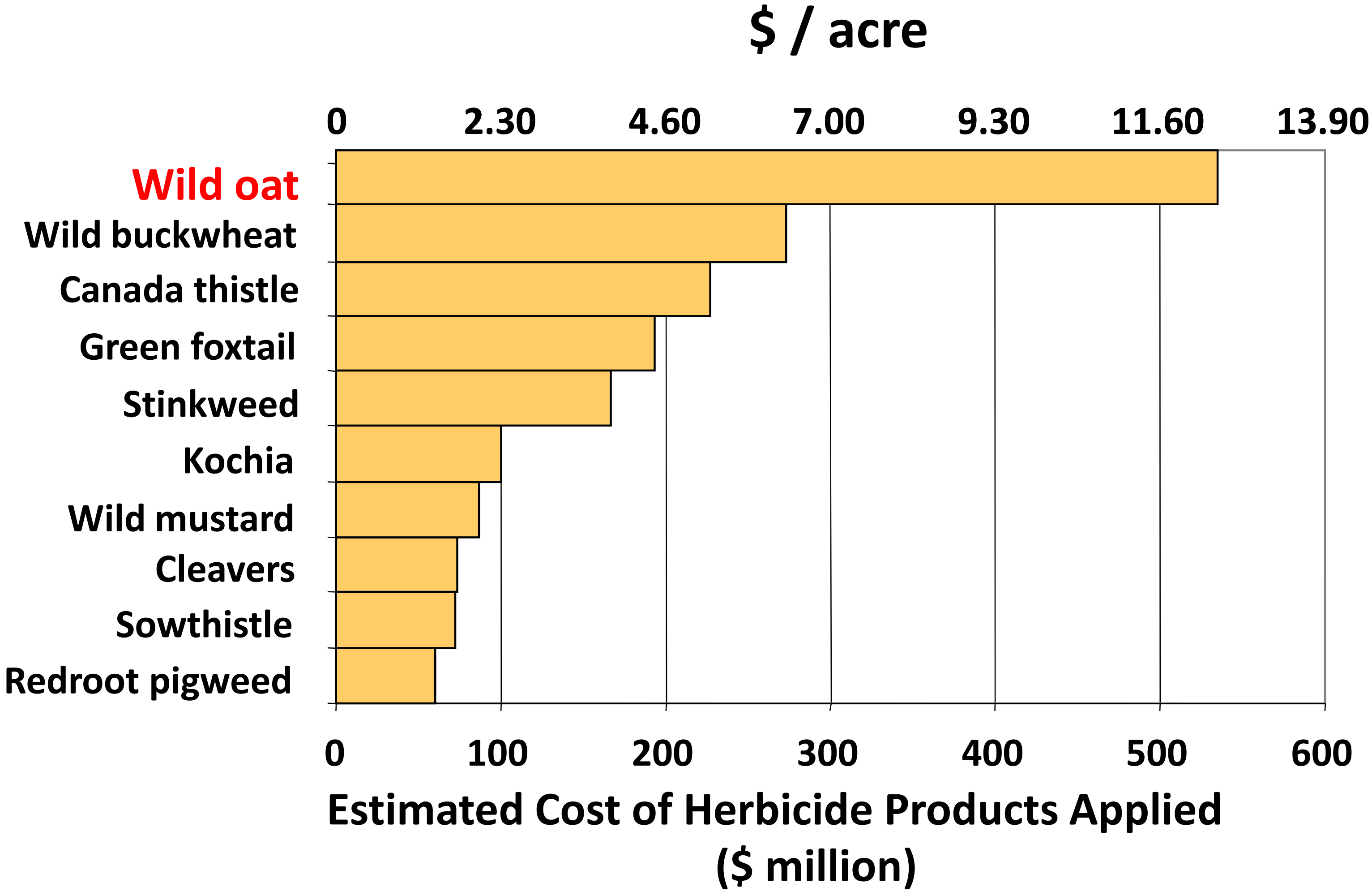
"We're facing a catastrophe,"

"U.S. farmers are heading for a crisis," Stephen Powles (Sep 2013 – Amer. Chem. Soc.)

Sep 17, 2013 http://rt.com/usa/drug-resistant-bacteria-us-979/

Back
to
Wild
Oat
…

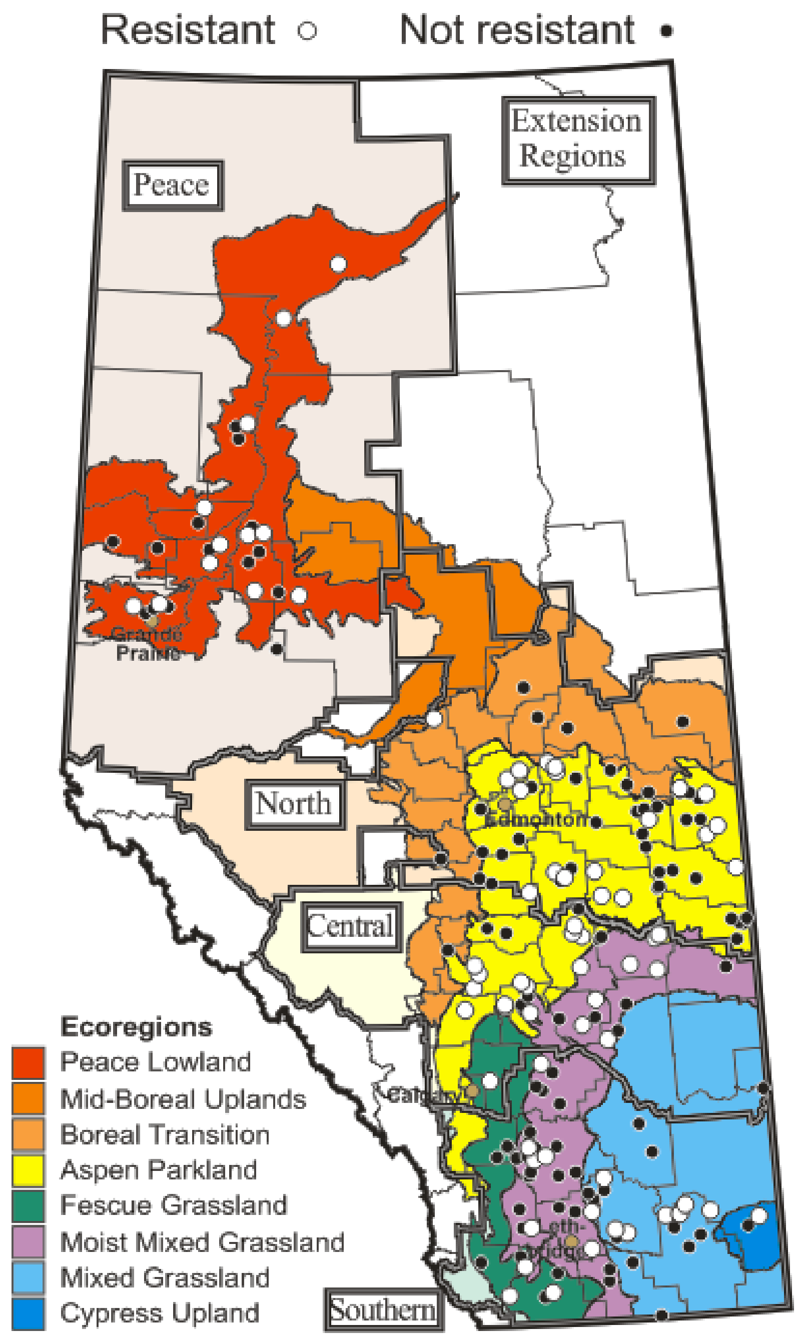
Top 10 Herbicide Targets
- Western Canada



Leeson et al. 2006. Ann. Mtg. Canadian Weed Sci. Soc.
Available: http://weedscience.ca/resources/annual-meeting-archived-files/

Group 1 (ACCase) Resistant *Wild Oat*

Alberta



2001: 11% of fields

2007: 39% of fields

2014: > 50%

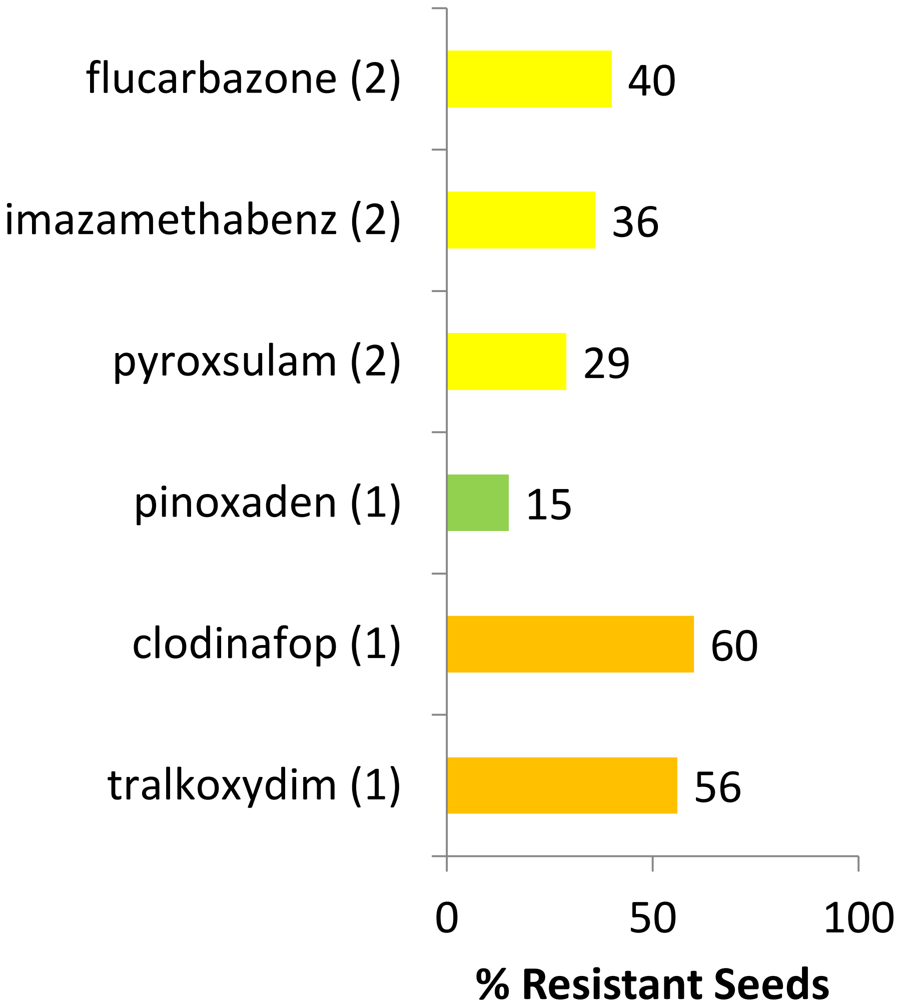
Provincial Resistance Maps
By Hugh Beckie

Post Management Patches – 3 Fields
- Central AB, Black Soil Zone

Dale Fedoruk, B.Sc. Ag., P.Ag., C.C.A.
Elite Environmental Ltd.
Red Deer, Alberta
elite.enviro@shaw.ca

Patches from Field 1 (Fall 2014)

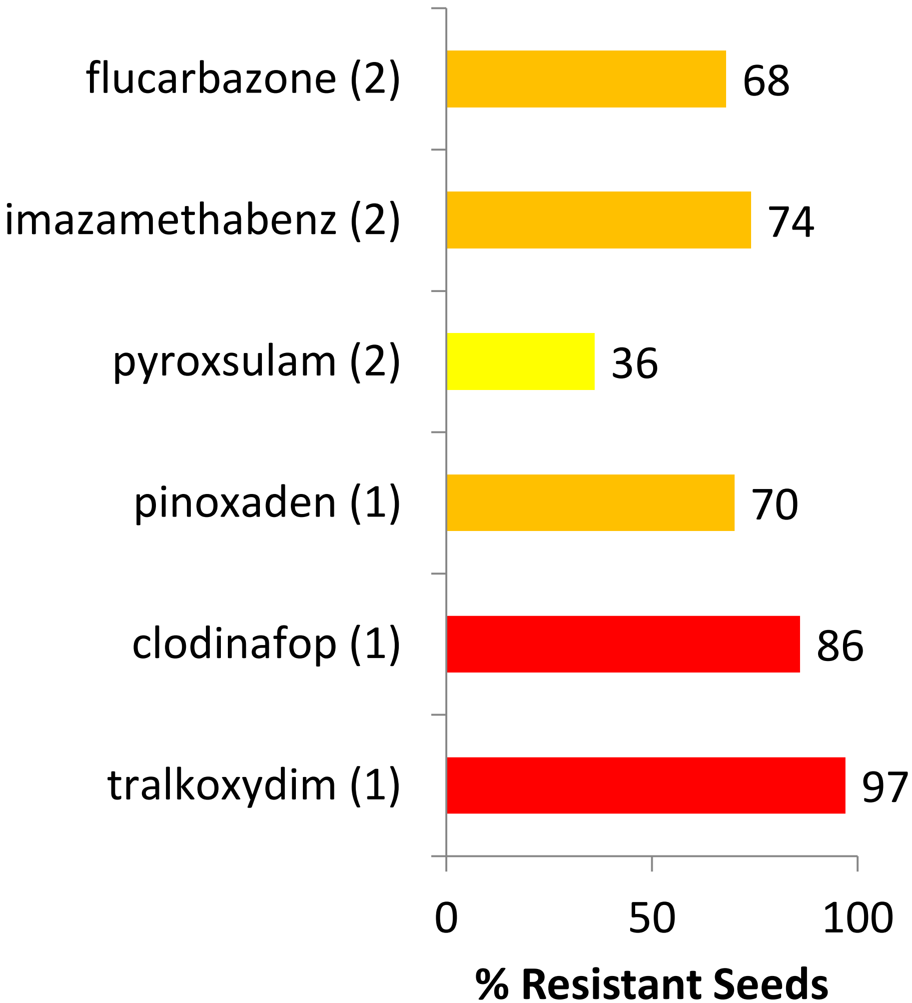
Year	Crop	WO Herbicides
2010	RR Canola	glyphosate
2011	Barley	pinoxaden
2012	Peas	imazamox/imazethapyr
2013	Barley	pinoxaden
2014	Barley	triallate + fenoxaprop



Cropping history & data: D. Fedoruk

Patches from Field 2 (Fall 2014)

Year	Crop	WO Herbicides
2010	RR Canola	glyphosate
2011	Barley	pinoxaden
2012	Barley	pinoxaden
2013	LL Canola	quizalofop/glufosinate + glufosinate
2014	Barley	pinoxaden + pinoxaden

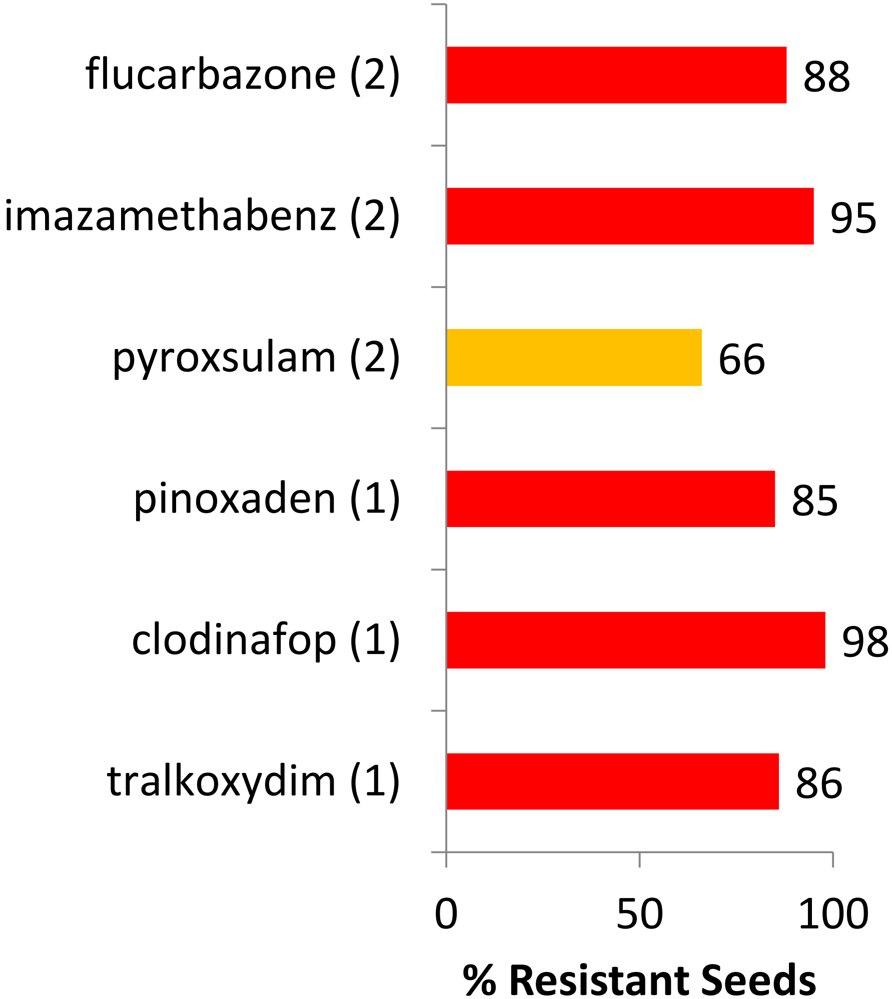


Cropping history & data: D. Fedoruk

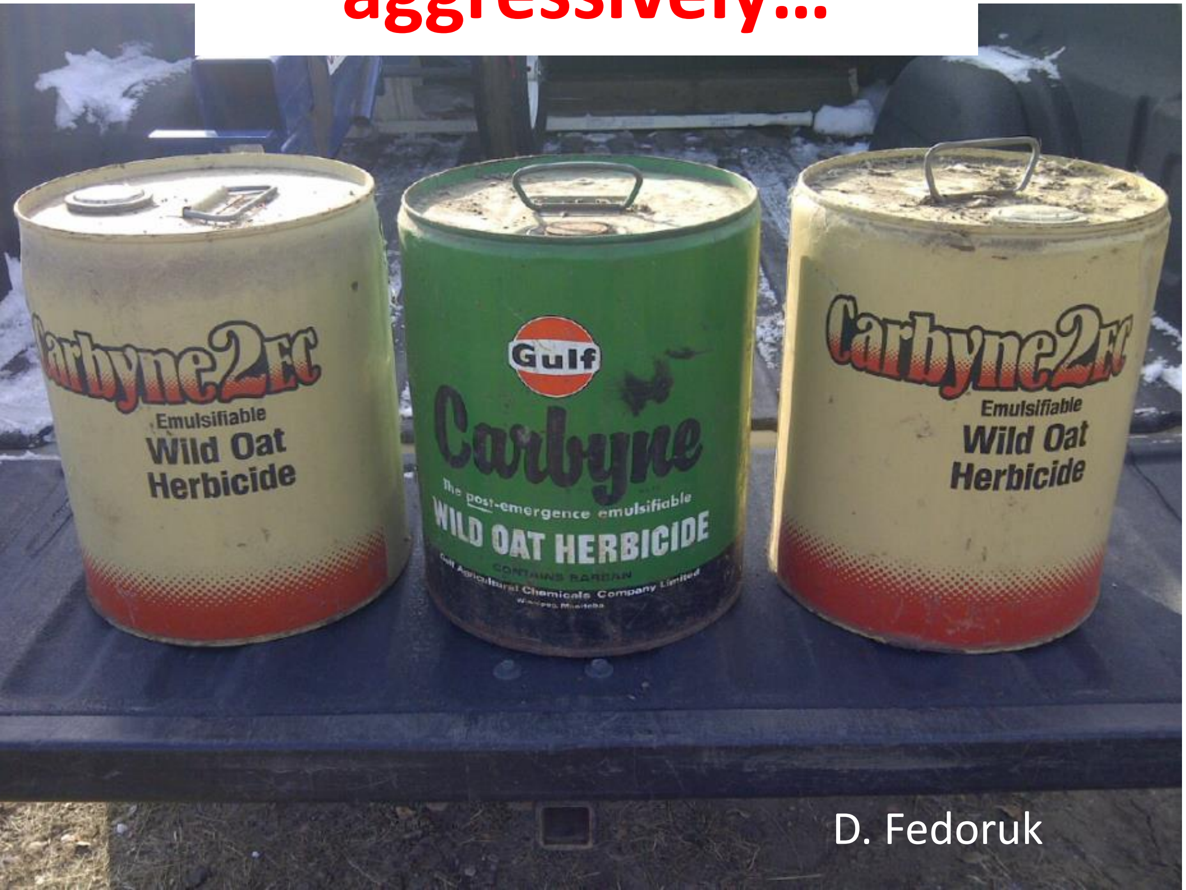
Patches from Field 3 (Fall 2014)

Year	Crop	WO Herbicides
2004	Wheat	clodinafop
2005	Wheat	fenoxaprop
2006	LL Canola	glufosinate/clethodim + clethodim
2007	Barley	pinoxaden + tralkoxydim
2008	Barley	imazamethabenz
2009	RR Canola	glyphosate + glyphosate
2010	Wheat	triallate/trifluralin + clodinafop
2011	Peas	quizalofop
2012	Wheat	pyroxsulam
2013	LL Canola	Glufosinate/clethodim
2014	Wheat	pyroxsulam + pinoxaden

Cropping history & data: D. Fedoruk



Perhaps we should not push 100% herbicide efficacy so aggressively…



Has anyone heard of resistance to barban (Carbyne) ?

Crop & Crop Canopy Health

Seeding Depth & Weeds?

Hybrid
4 mph
1 cm

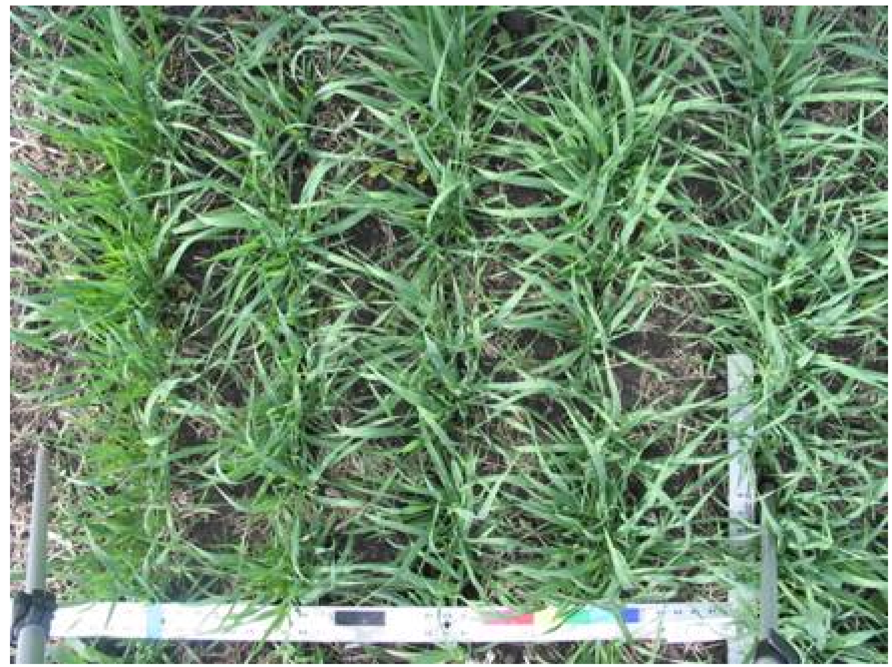
June 7 Photo
(April seeded)

Hybrid
4 mph
4 cm

Harker et al. 2012. Can. J. Plant Sci. 92:795-802

Fertilizer Placement & Weeds?

Barley Cover - June 20 , 2002



22%

90 kg/ha N in seed row

78%

90 kg/ha N pre plant band

Less Crop Canopy → More Weeds

22% vs. 78% Cover → WO Bio: 967 vs. 192 kg/ha

See Figure 1 - O'Donovan et al. 2008. Crop Sci. 48:1569–1574

Crop Health
- Rotating Varieties & Species
- continuous silage cropping

PRINCIPLE

Rotating Varieties & Species →

- ↑ Crop Health
- ↑ Productivity
- ↓ Diseases
- ↑ Crop Competition
- ↓ Weeds

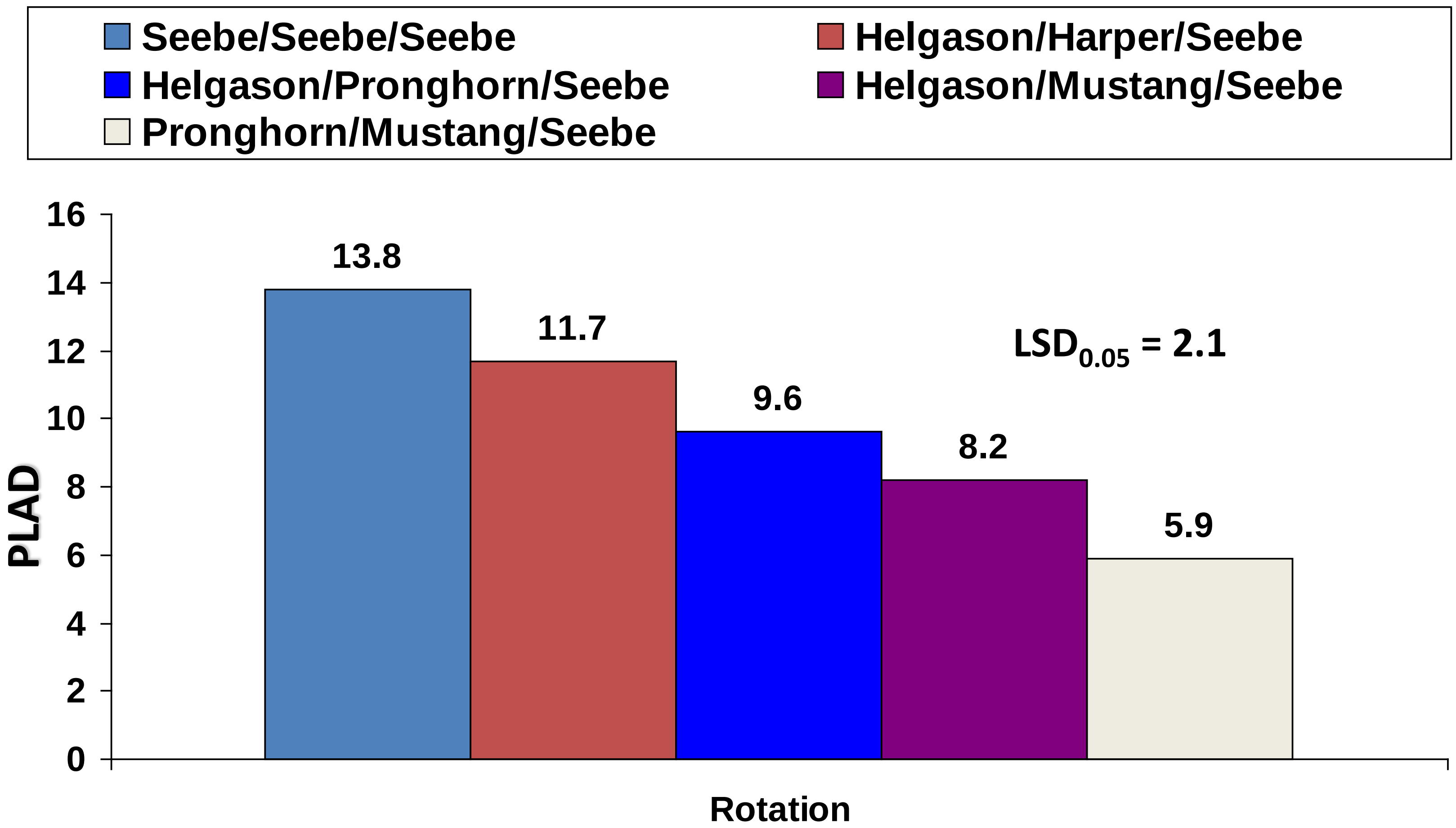
Materials and Methods

Cropping sequences: 2002-2004 & 2005-2007

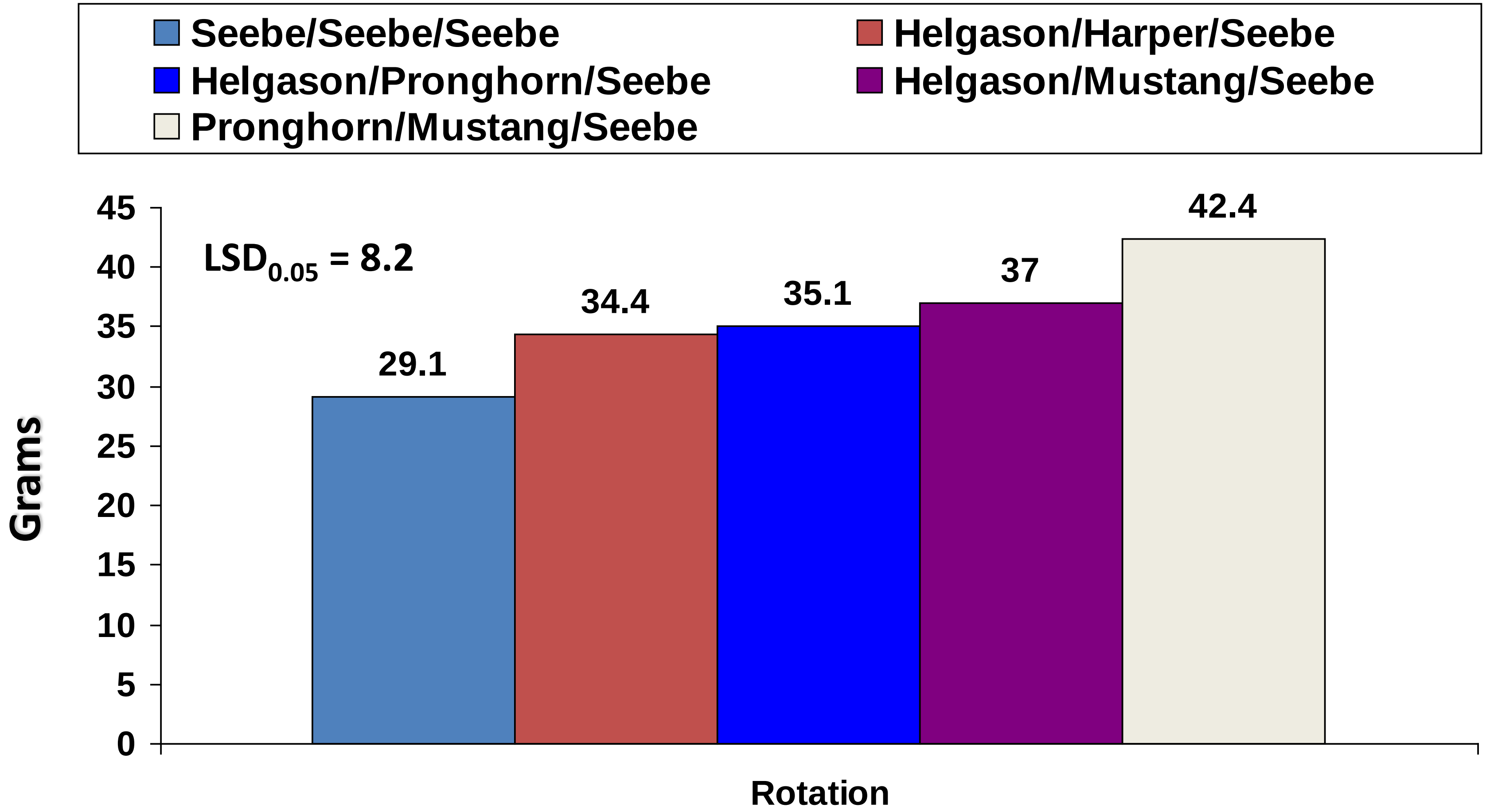
– Barley cv. 'Seebe' / 'Seebe' / 'Seebe'
– Barley cv. 'CDC Helgason' / 'AC Harper' / 'Seebe'
– 'CDC Helgason' / Triticale 'Pronghorn' / 'Seebe'
– 'CDC Helgason' /Oat 'AC Mustang' / 'Seebe'
– 'Pronghorn' / 'AC Mustang' / 'Seebe'

% Leaf Area Diseased (PLAD)

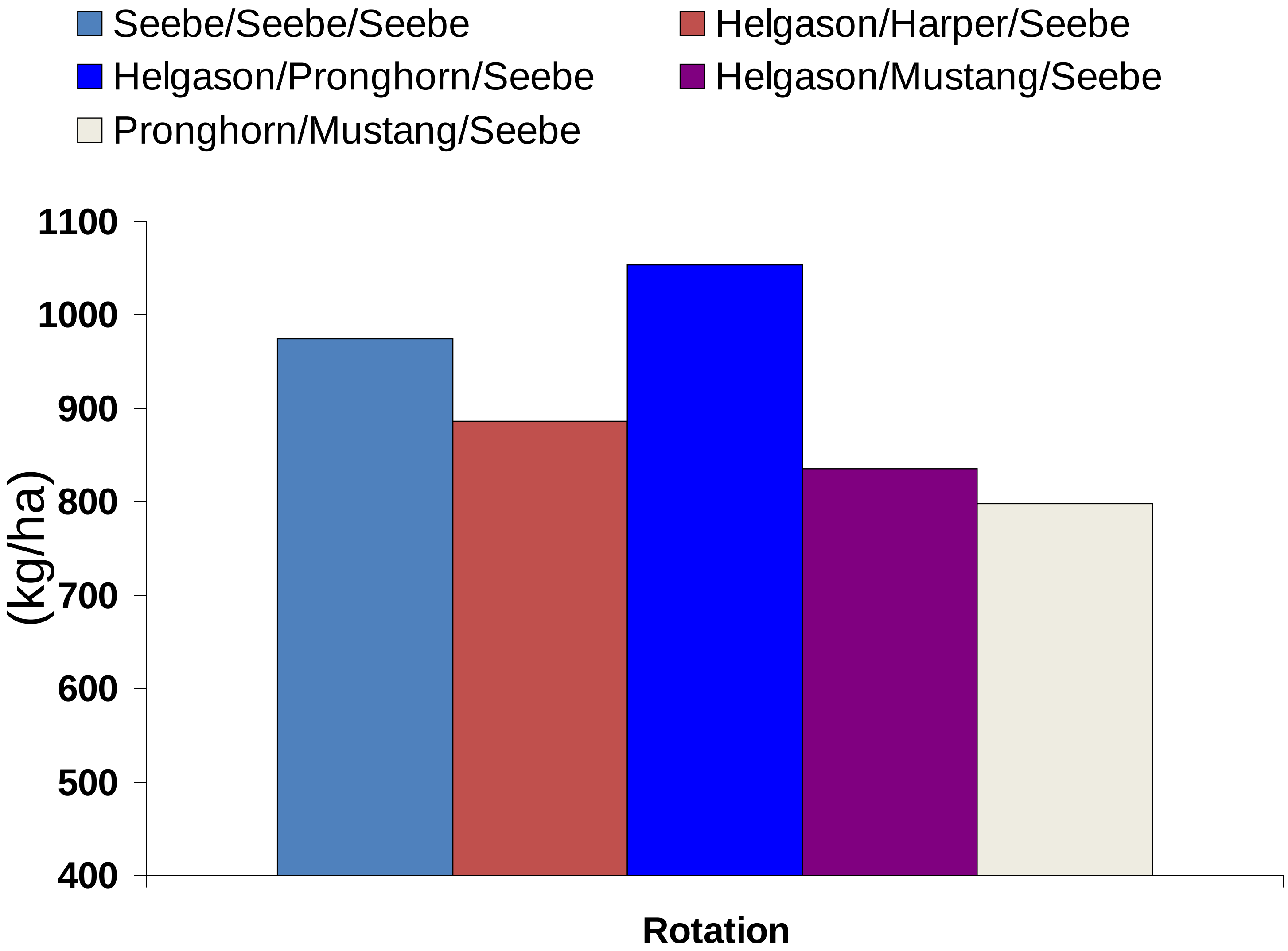
flag leaf – 2 (2004)



Root biomass (2004)



Wild Oat Biomass (2004)



Crop Health - Rotating Species

- Wheat – Canola
- Wheat – Canola – Peas
- Canola – Canola
- Wheat - Wheat
- Wheat – Lentils/Chickpeas – Wheat – Canola
- Wheat – Fallow
- Barley silage
- Barley silage - Winter Wheat – Canola
- Wheat – Alfalfa – Alfalfa – Alfalfa – Canola

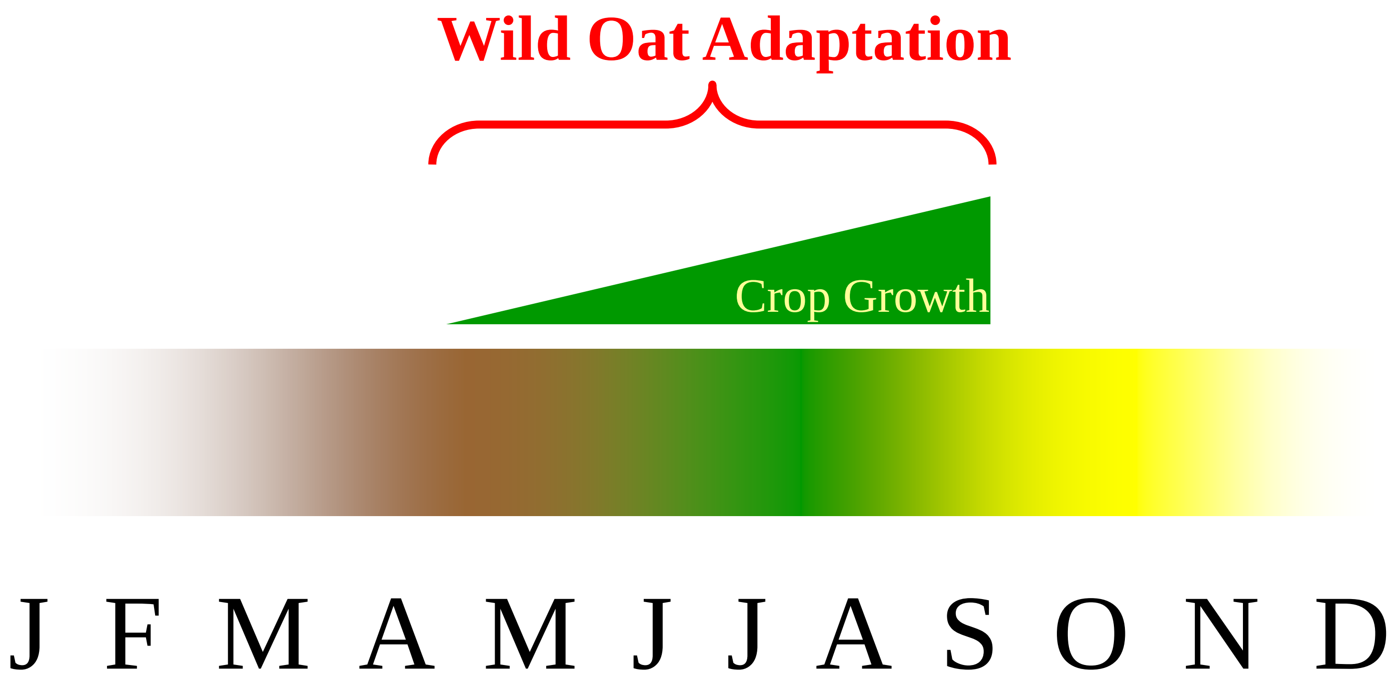
Weeds fortunate enough to grow in simple, repeated cropping systems will continue to have little difficulty adapting and thriving.

Cropping - Rotations & Cycles

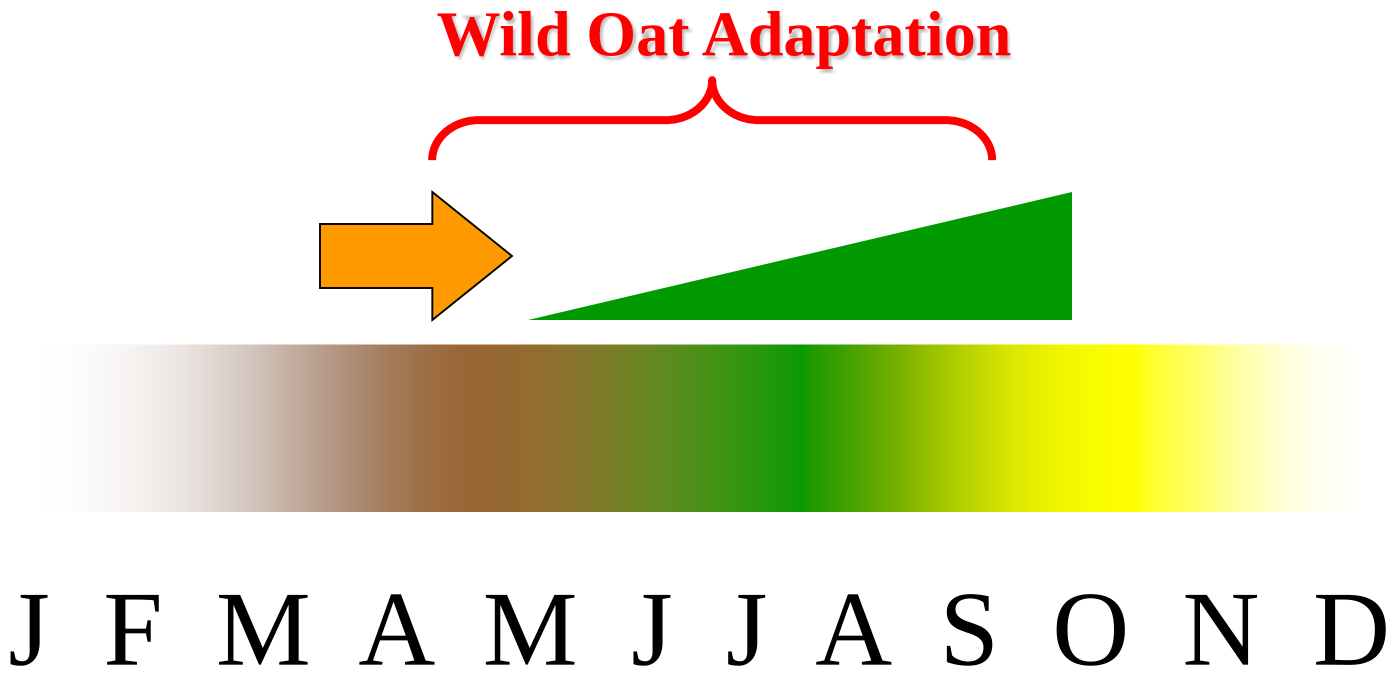
Winter - Spring - Summer - Fall - Winter

J F M A M J J A S O N D

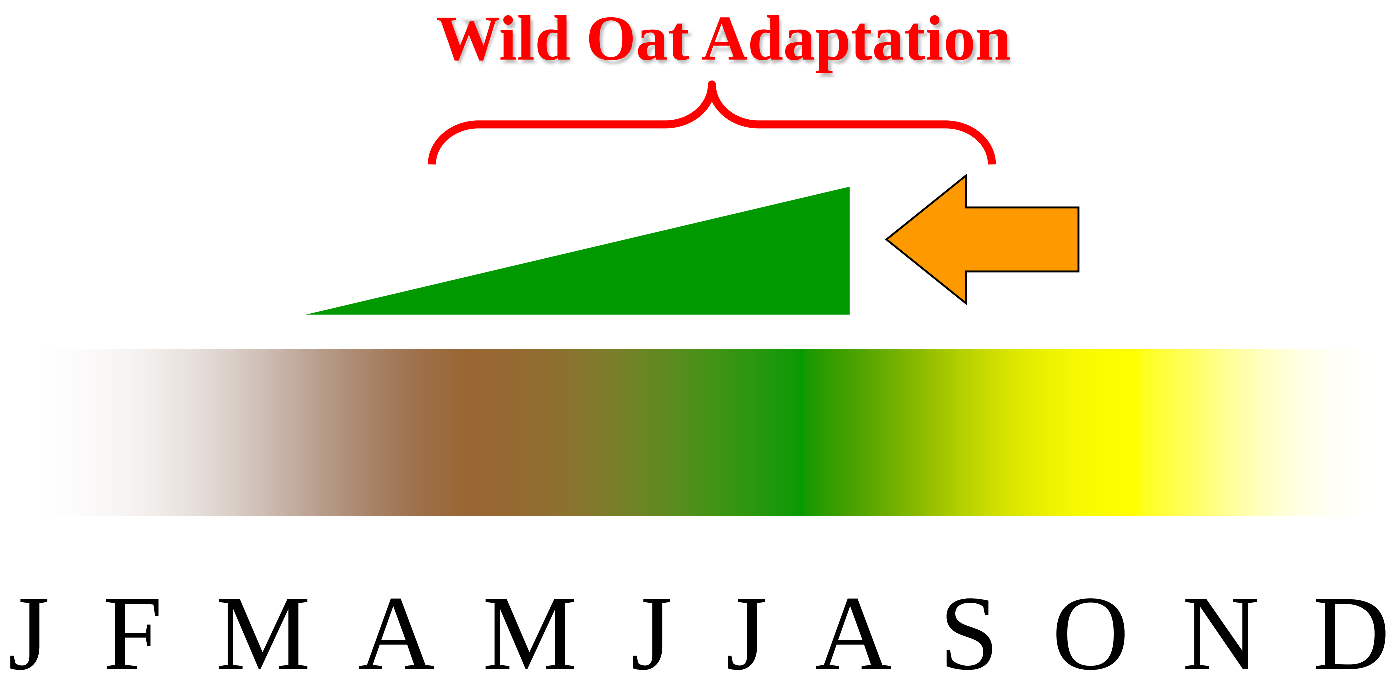
Cropping - Rotations & Cycles
- Summer Annual Crops



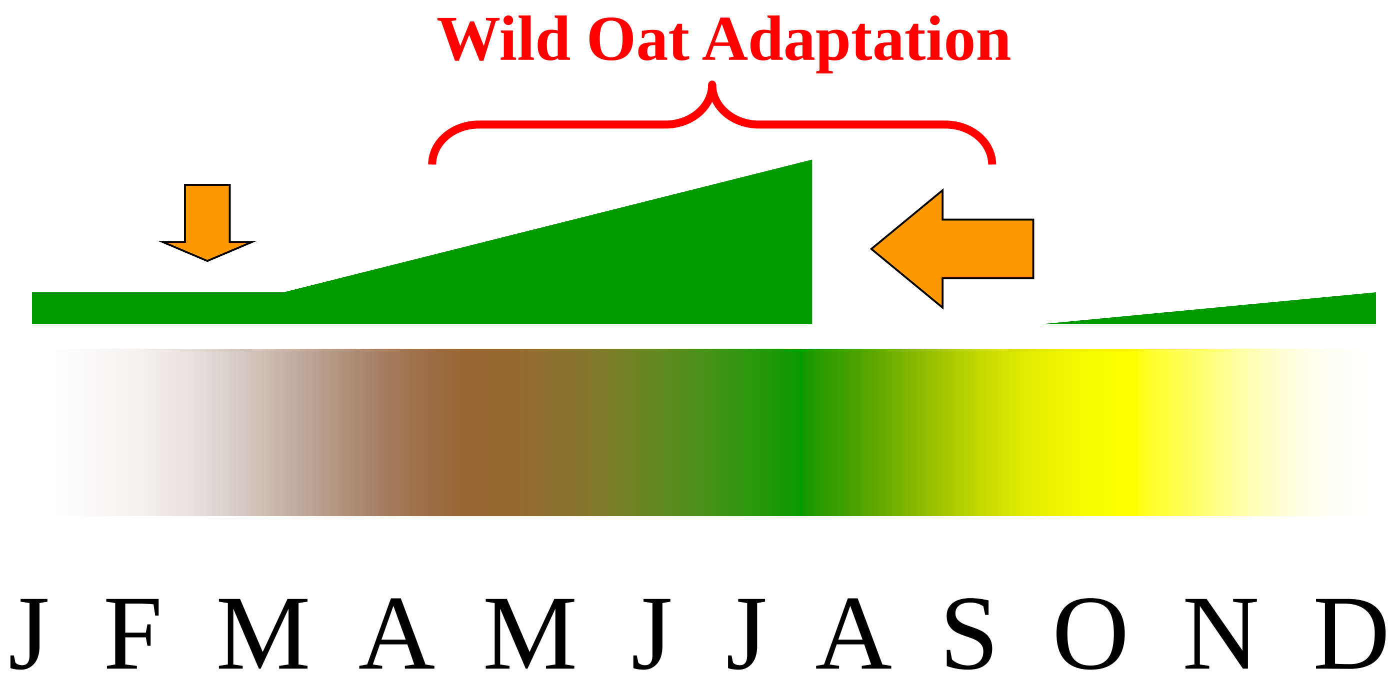
Cropping - Rotations & Cycles - Later Seeding



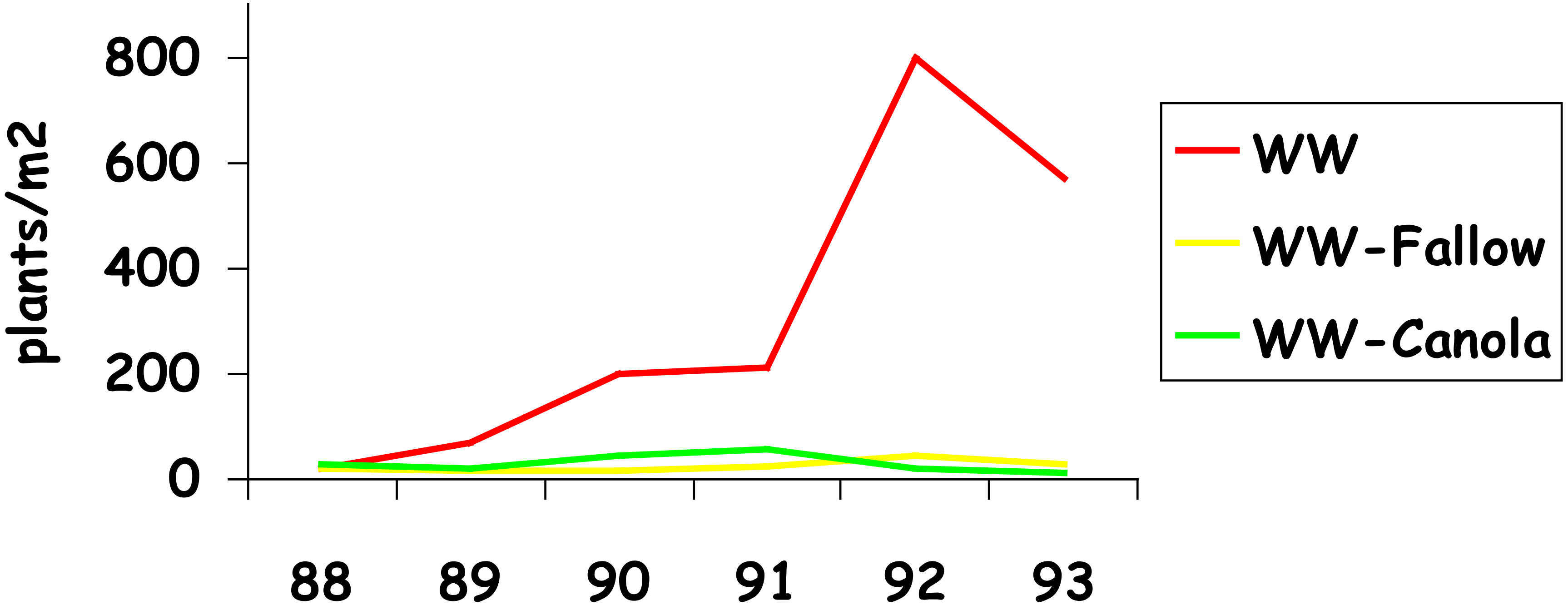
Cropping - Rotations & Cycles
- Earlier Seeding



Cropping - Rotations & Cycles
- Winter Annual Crops

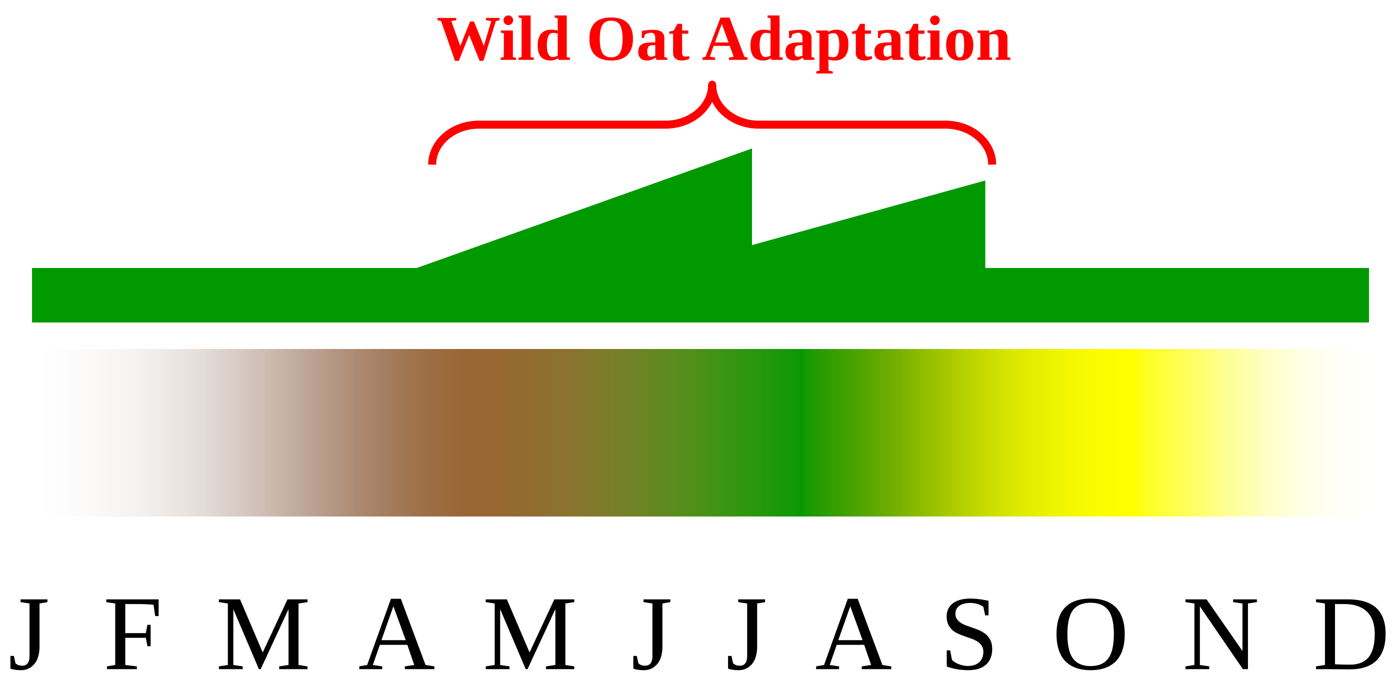


Downy Brome & Winter Wheat – Weed Density



Adapted from Blackshaw, Weed Technol. 1994. 8:728-732

Cropping - Rotations & Cycles
- Perennial Forages

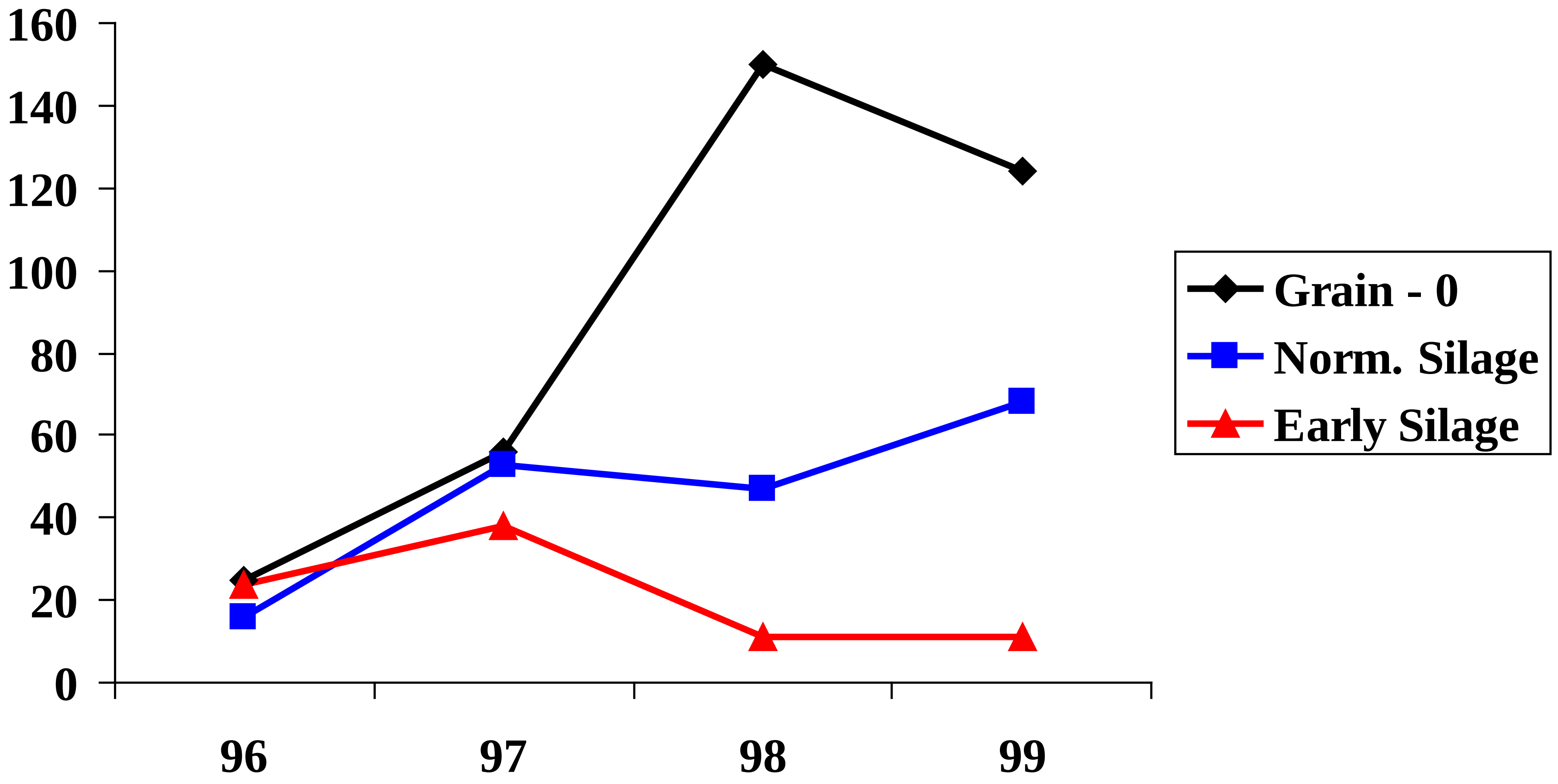


Silage Harvest Timing & Wild Oats?

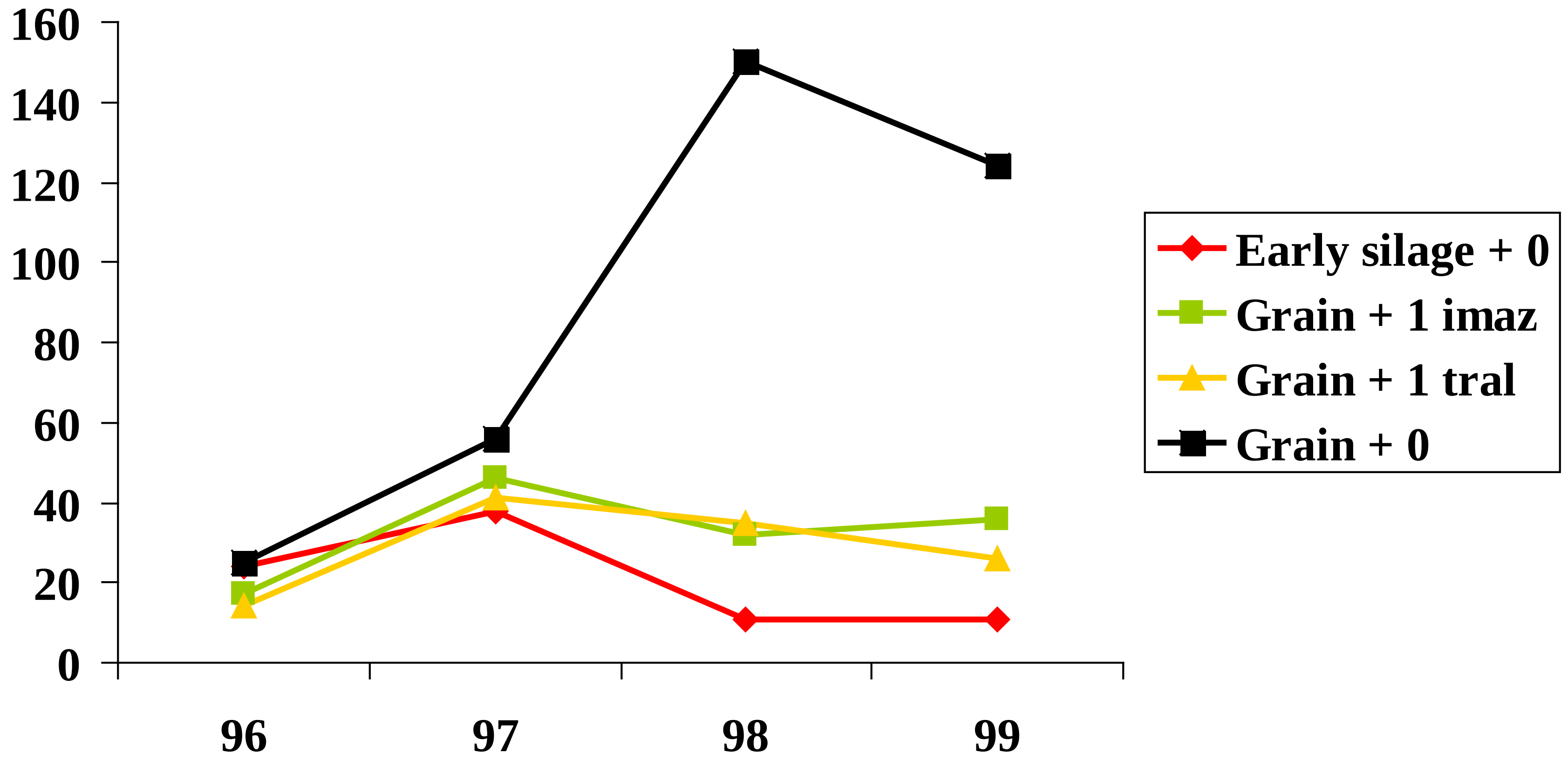
Treatments

1. Barley grain - no herbicide
2. Early-cut barley silage - no herbicide
3. Normal-cut barley silage - no herbicide
4. Barley grain - Assert (1/2)
5. Barley grain - Assert (1)
6. Barley grain - Achieve (1/2)
7. Barley grain - Achieve (1)
8. Early-cut barley silage - Assert (1/2)
9. Early-cut barley silage - Achieve (1/2)
10. Normal-cut barley silage - Assert (1/2)
11. Normal-cut barley silage - Achieve (1/2)

Treatments w/o Herbicides: - wild oat/m^2



Early Silage vs. Grain + Herb.: - wild oat/m^2



Harker et al. 2003. Weed Technol. 17:102-110

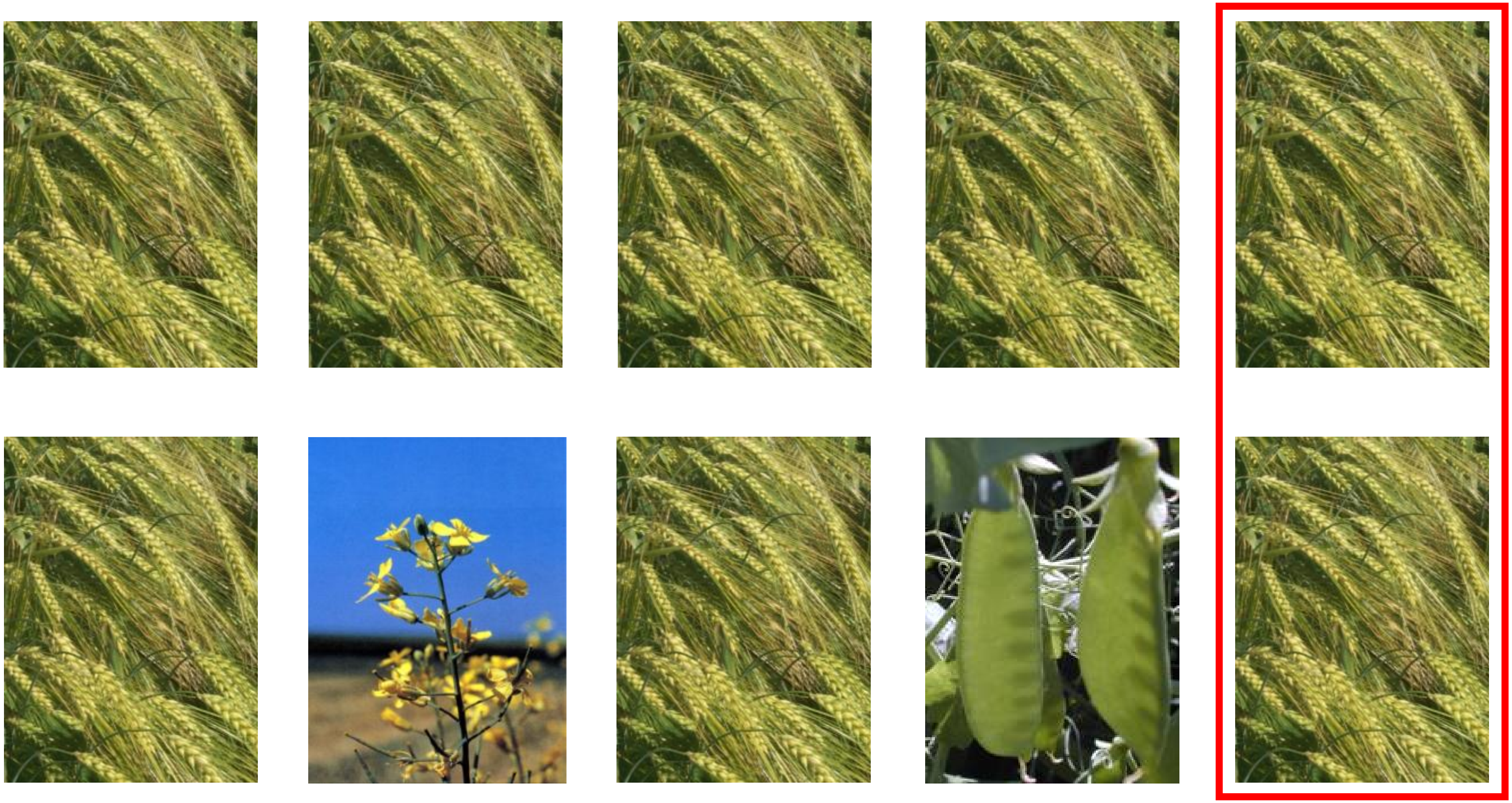
Integrated Weed Management

Treatments

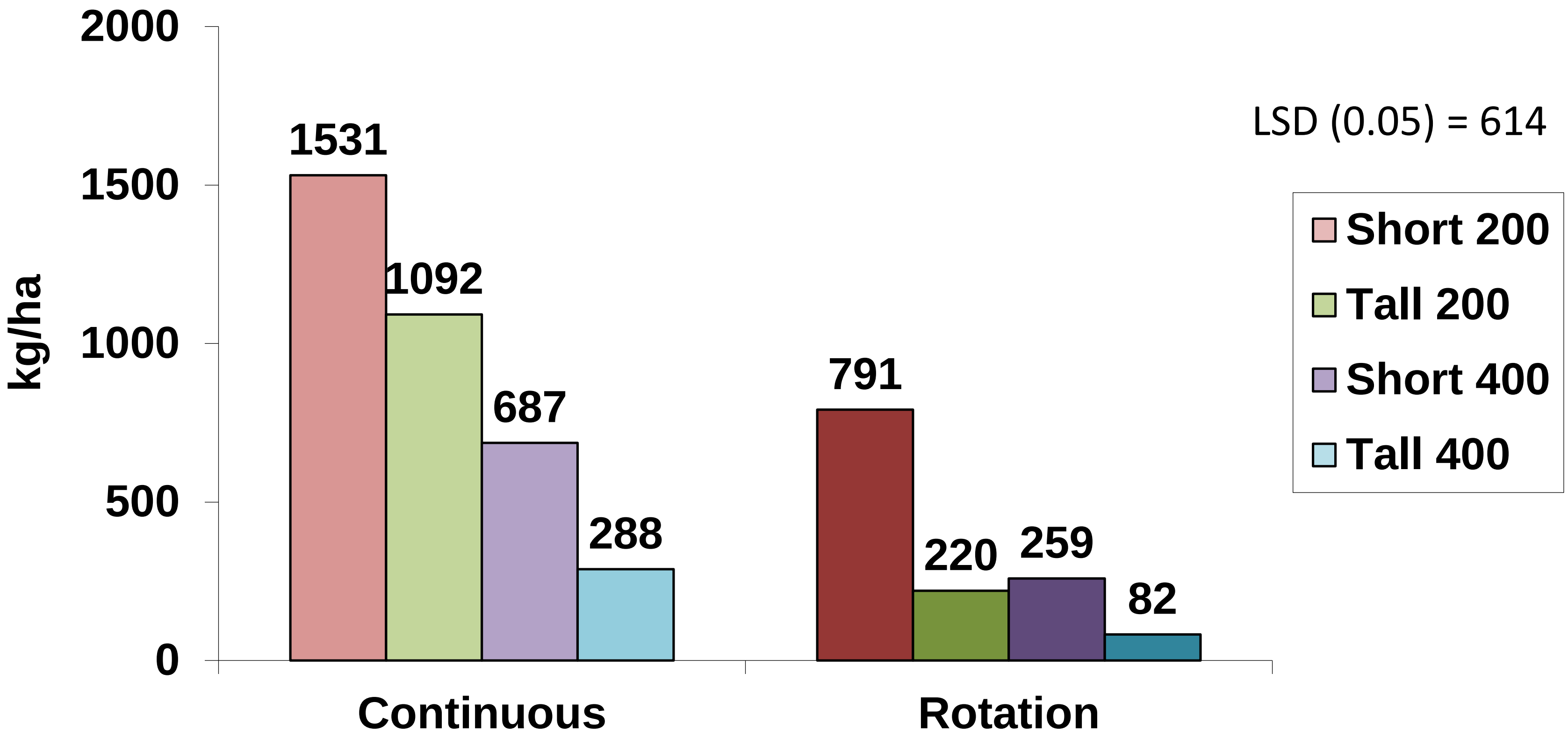
- Rotation – Continuous Barley vs. Bar-Can-Bar-Pea
- Varieties/Cultivars – Short versus Tall
- Seeding Rate – 1X or 2X (200 or 400 seeds/m^2)
- Herbicide Rate – ¼, ½, or 1X (ACCase or ALS)

- Treatments applied to same plots year after year – cumulative treatment effects

Year 5



Wild Oat BM – Maturity – ¼ X Rate – 2005 (3-site means after 5 years)



Combining Optimal Factor Synergy - Wild oat biomass Reduction

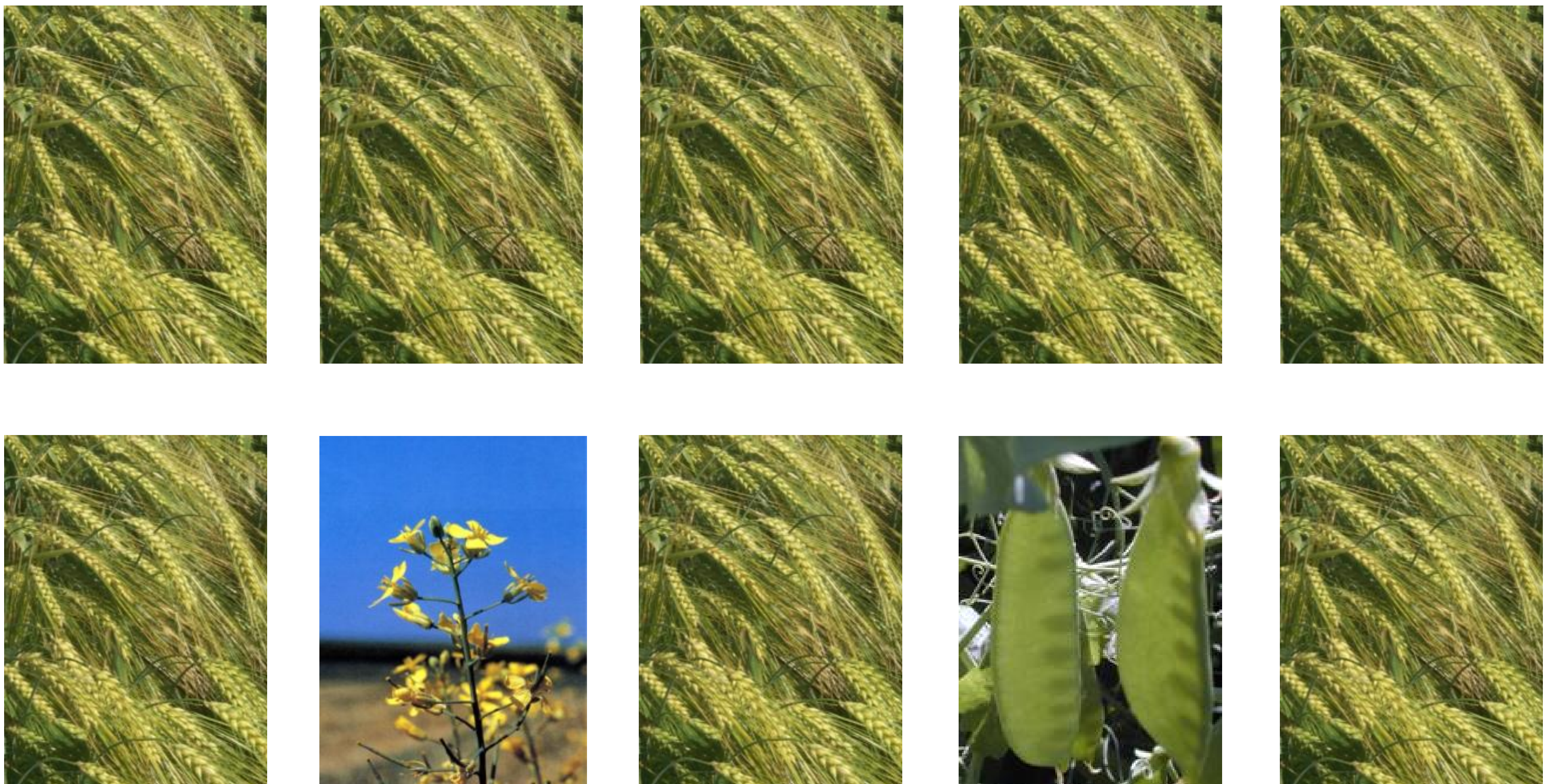
# Factors	Description	(x)	Range
1	1x to 2x	2.9	
	Short to Tall	1.9	
	Cont to Rot	2.7	2-3
2	1x-Short to 2x-Tall	6.3	
	1x-Cont to 2x-Rot	7.7	
	Short-Cont to Tall-Rot	7.3	6-8
3	1x-Short-Cont to 2x-Tall-Rot	18.7	19

Harker et al. 2009. Weed Sci. 57:326-337

August 23, 2005

Is a B-C-B-P-B rotation really diverse?

What would be better?



Materials and Methods

- Supplement natural wild oat infestation in fall and spring of the 1st year
- Combine optimal cultural wild oat management tactics with truly diverse rotations (not just summer-annuals) under no-till regime
- 14 Treatments
  - 100% herbicide, Chem Fallow and Alfalfa checks
- All plots receive a full rate of dicot herbicides
- 4 x 15 m plots in RCBD with 4 replications
- 8 locations

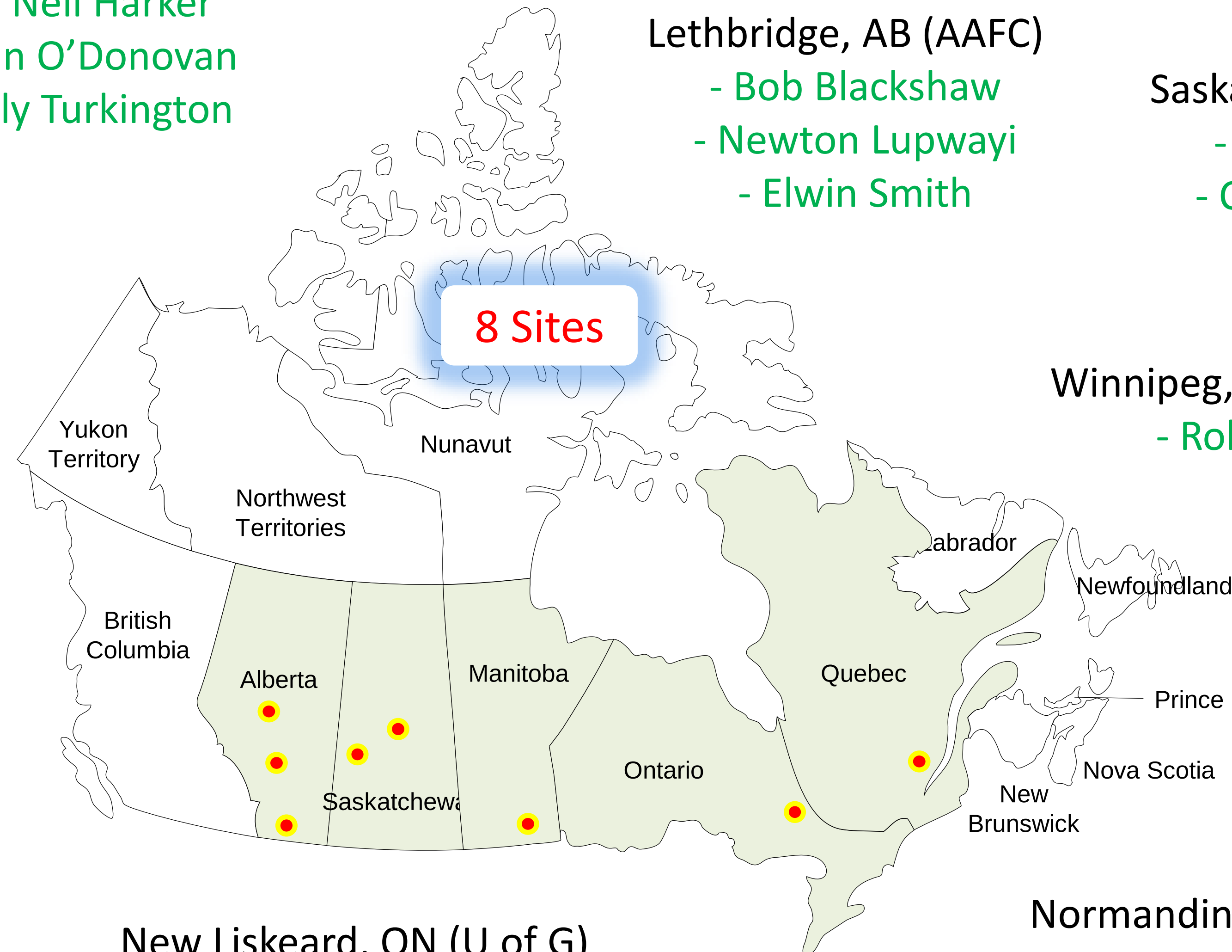
Edmonton, AB (U of A)
- Linda Hall

Scott, SK (AAFC)
- Eric Johnson

Lacombe, AB (AAFC)
- K. Neil Harker
- John O'Donovan
- Kelly Turkington

Lethbridge, AB (AAFC)
- Bob Blackshaw
- Newton Lupwayi
- Elwin Smith

Saskatoon, SK (U of S)
- Steve Shirtliffe
- Chris Willenborg



Winnipeg, MB (U of M)
- Rob Gulden

New Liskeard, ON (U of G)
- John Rowsell

Normandin, QC (AAFC)
- Denis Pageau

Data Collection

- Crop stand density - Spring
- Crop biomass - Summer
- Crop yield
- Wild oat density counts - Spring
- Wild oat biomass - Summer
- Wild oat seed bank determination

Treatments – I

Treatment	2010	2011	2012	2013
	Checks			
Canola-Wheat	C 100H	W 100H	C 100H	W 100H
Chem Fallow	C 50H	CF 100H	2xFR 0H	CF 100H
Alfalfa	C 50H	Alf 0H	Alf 0H	Alf 0H

Treatment	2010	2011	2012	2013
	Summer Annuals			
Canola-Barley	C 50H	2xB 0H	C 100H	2xB 0H
Canola-Barley	C 50H	2xB 50H	C 100H	2xB 50H
Can-Bar-Pea-Wht	C 50H	2xB 0H	P 100H	2xW 0H
Can-Bar-Pea-Wht	C 50H	2xB 50H	P 100H	2xW 50H

0, 50, & 100% Herbicide rates are for wild oat herbicides only, dicot herbicide rates were 100%

Treatments – II

Treatment	2010	2011	2012	2013
	Early-Cut Silage & Winter Annuals			
Can-ES-Pea-WT	C 50H	2xES 0H	P 100H	2xWT 0H
Can-FR-Pea-WT	C 50H	2xFR 0H	P 100H	2xWT 0H
Can-ES-ES-WW	C 50H	2xES 0H	2xES 0H	2xWW 0H
Can-ES-ES-Wht	C 50H	2xES 0H	2xES 0H	2xW 0H
Can-ES-WW-WT	C 50H	2xES 0H	2xWW 0H	2xWT 0H
Can-ES-WW-ES	C 50H	2xES 0H	2xWW 0H	2xES 0H
Can-ES-WT-ES	C 50H	2xES 0H	2xWT 0H	2xES 0H

0, 50, & 100% Herbicide rates are for wild oat herbicides only, dicot herbicide rates were 100%


Wild Oats Cut with Silage

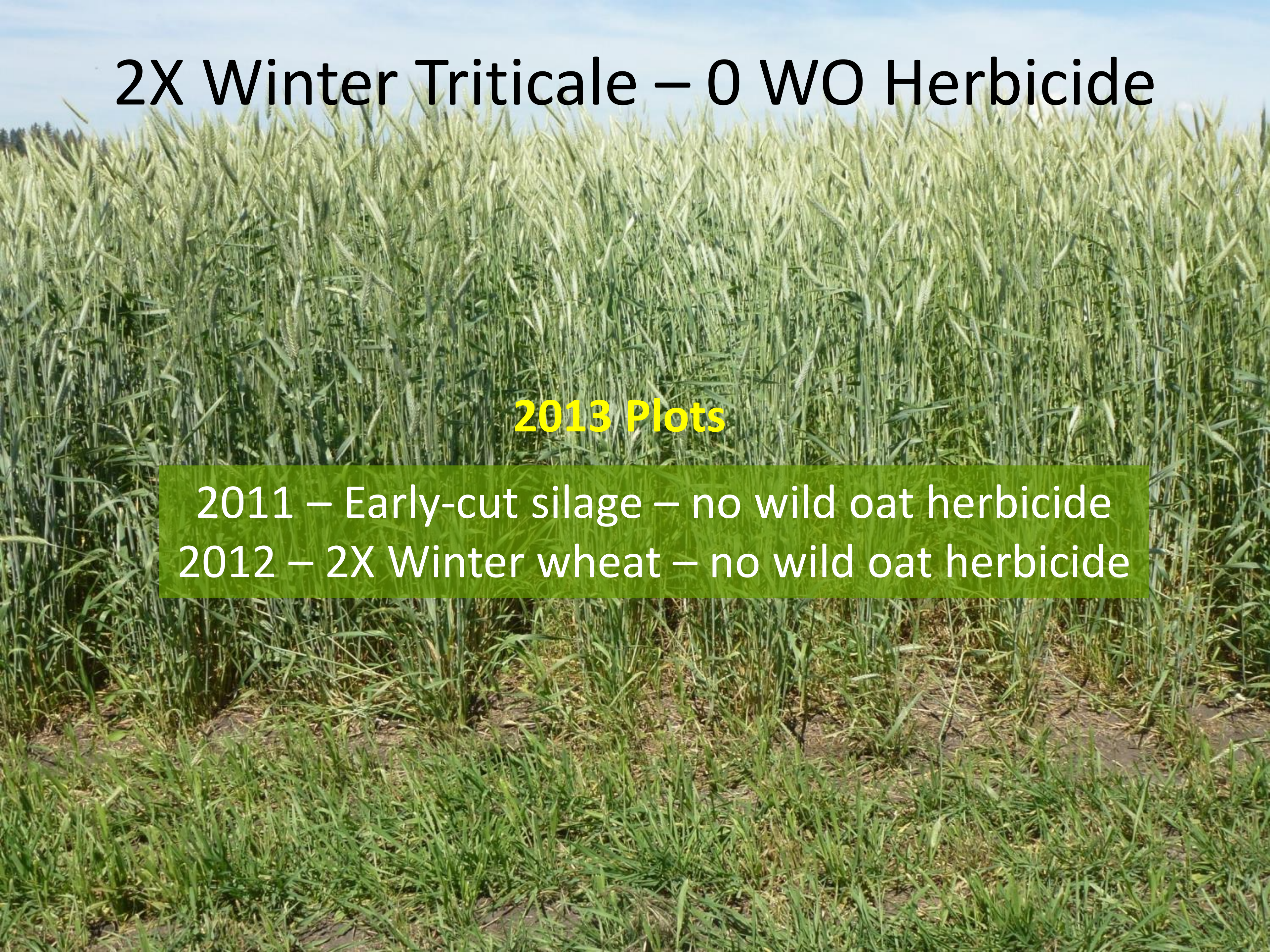

Cutting Alfalfa

2X Spring Wheat – 0 WO Herbicide

2013 Plots

2011 – Early-cut silage – no wild oat herbicide
2012 – Early-cut silage – no wild oat herbicide

2X Winter Triticale – 0 WO Herbicide

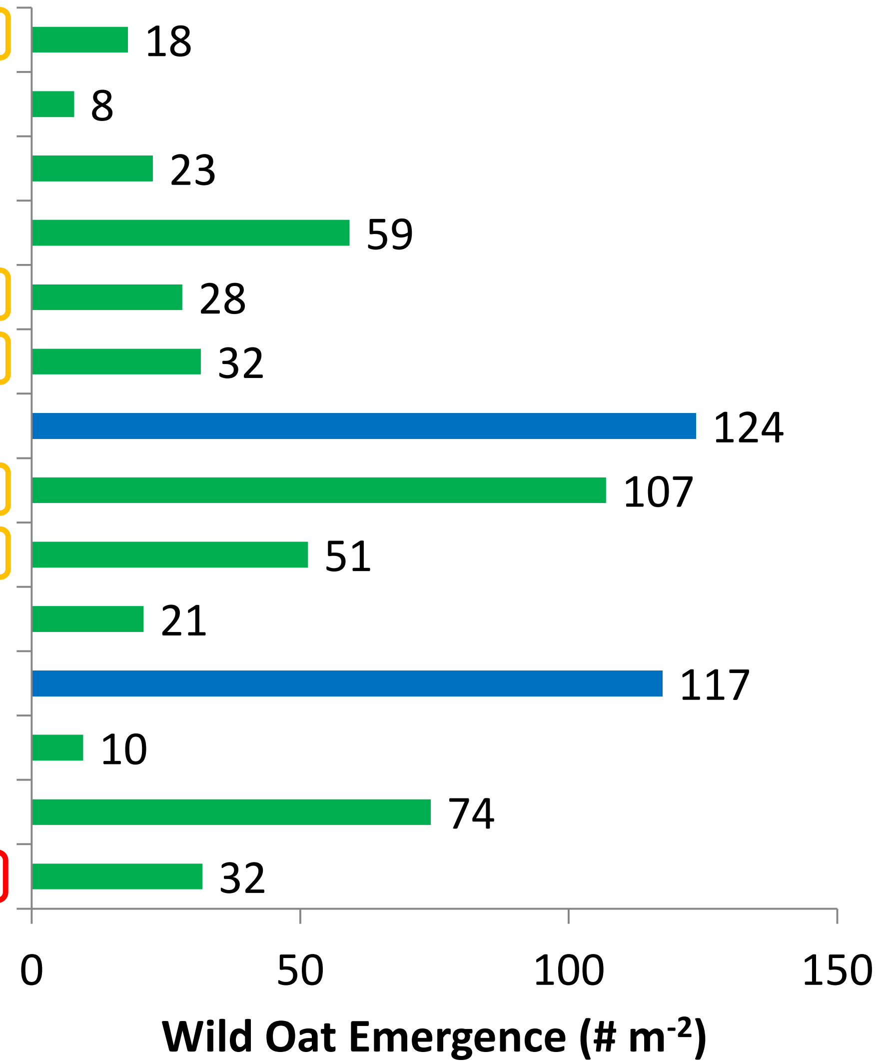


2013 Plots

2011 – Early-cut silage – no wild oat herbicide
2012 – 2X Winter wheat – no wild oat herbicide

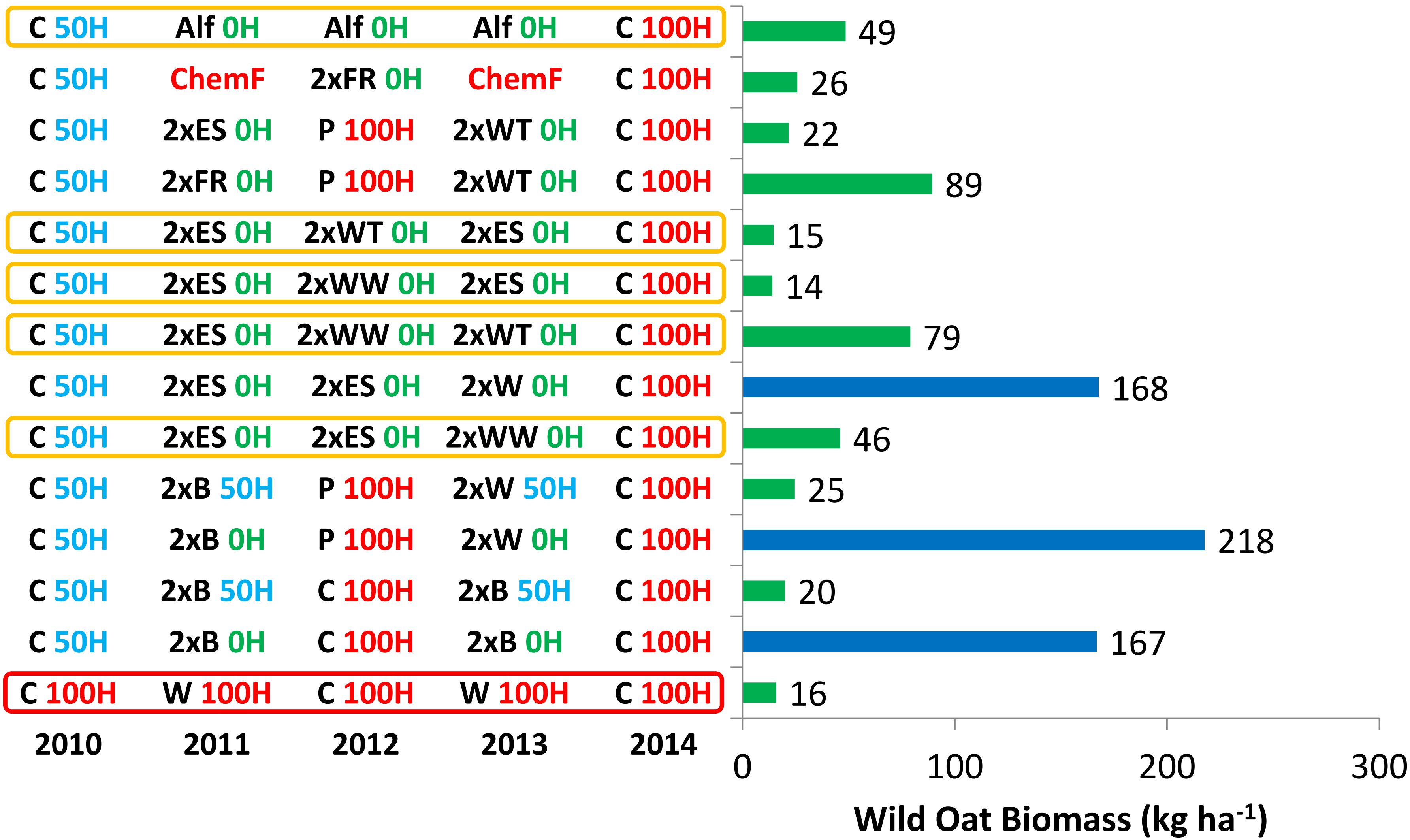
Wild Oat Emergence (2014) – 8 Sites

2010	2011	2012	2013	2014
C 50H	Alf 0H	Alf 0H	Alf 0H	C 100H
C 50H	ChemF	2xFR 0H	ChemF	C 100H
C 50H	2xES 0H	P 100H	2xWT 0H	C 100H
C 50H	2xFR 0H	P 100H	2xWT 0H	C 100H
C 50H	2xES 0H	2xWT 0H	2xES 0H	C 100H
C 50H	2xES 0H	2xWW 0H	2xES 0H	C 100H
C 50H	2xES 0H	2xWW 0H	2xWT 0H	C 100H
C 50H	2xES 0H	2xES 0H	2xW 0H	C 100H
C 50H	2xES 0H	2xES 0H	2xWW 0H	C 100H
C 50H	2xB 50H	P 100H	2xW 50H	C 100H
C 50H	2xB 0H	P 100H	2xW 0H	C 100H
C 50H	2xB 50H	C 100H	2xB 50H	C 100H
C 50H	2xB 0H	C 100H	2xB 0H	C 100H
C 100H	W 100H	C 100H	W 100H	C 100H



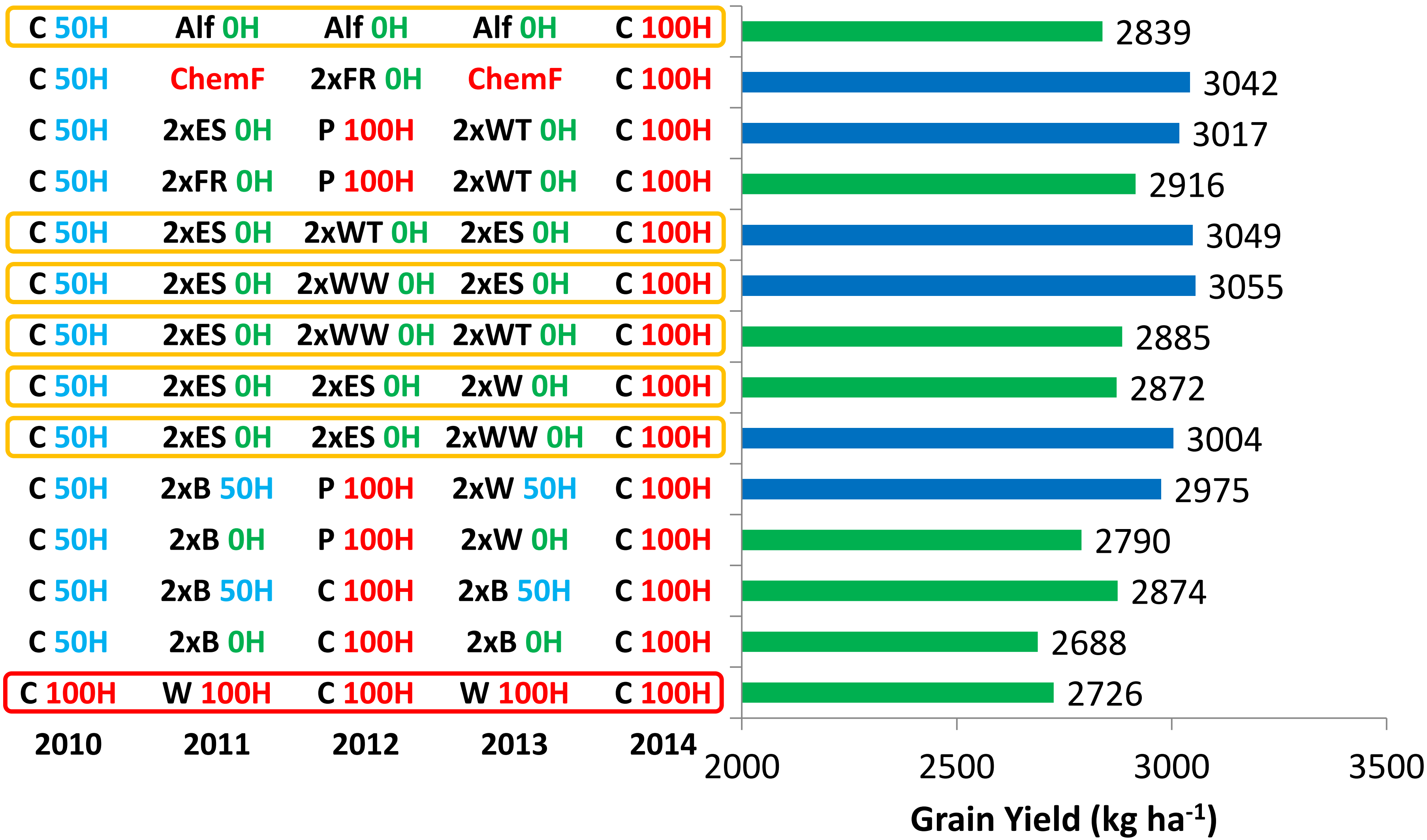
Blue bars are significantly greater than the bottom 100% herbicide treatment ($P < 0.05$)

Wild Oat Biomass (2014) – 4 Sites



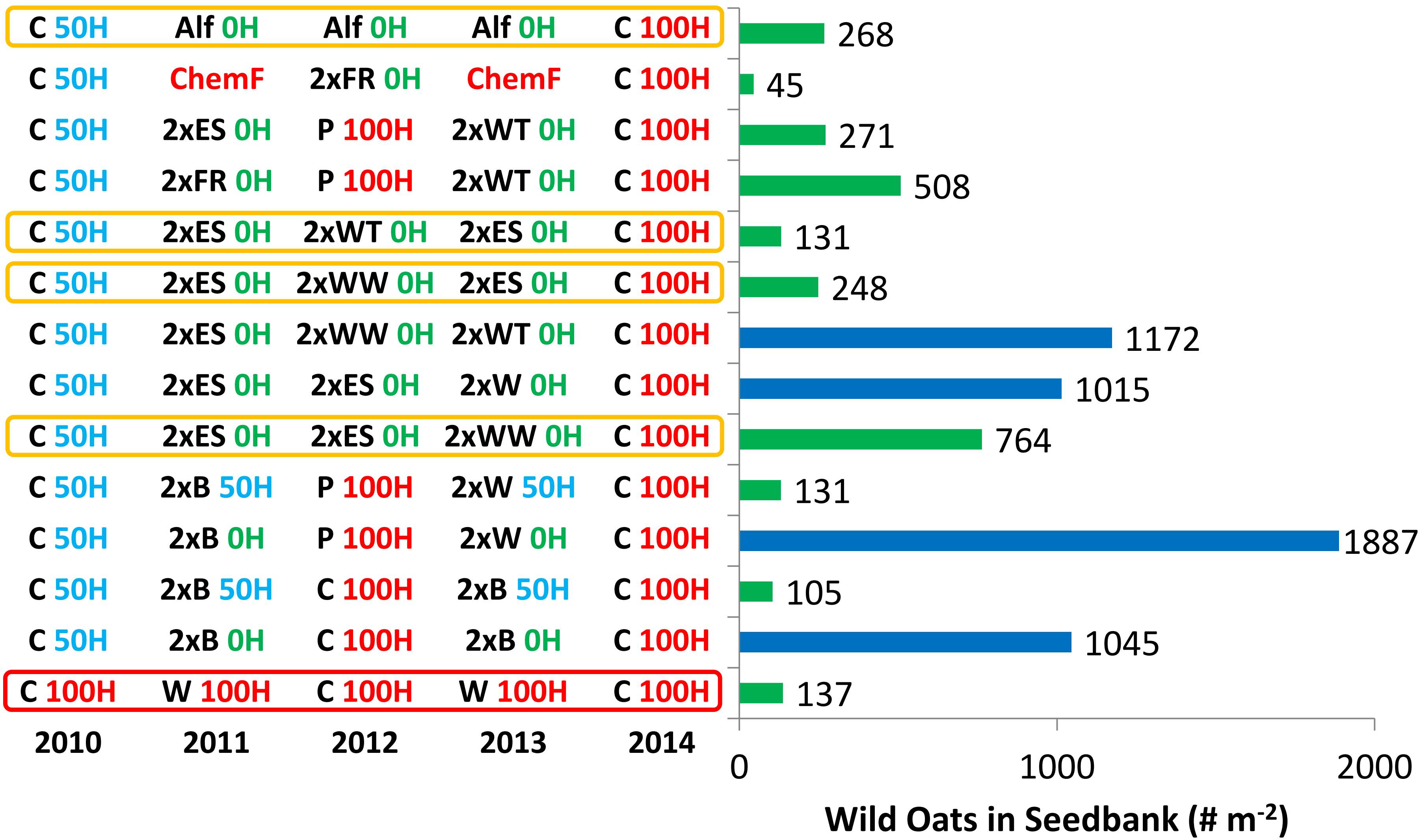
Blue bars are significantly greater than the bottom 100% herbicide treatment ($P < 0.05$)

Canola Yield (2014) – 7 Sites



Blue bars are significantly greater than the bottom 100% herbicide treatment ($P < 0.05$)

Wild Oat Seedbank (2014) – 7 Sites



Blue bars are significantly greater than the bottom 100% herbicide treatment ($P < 0.05$)

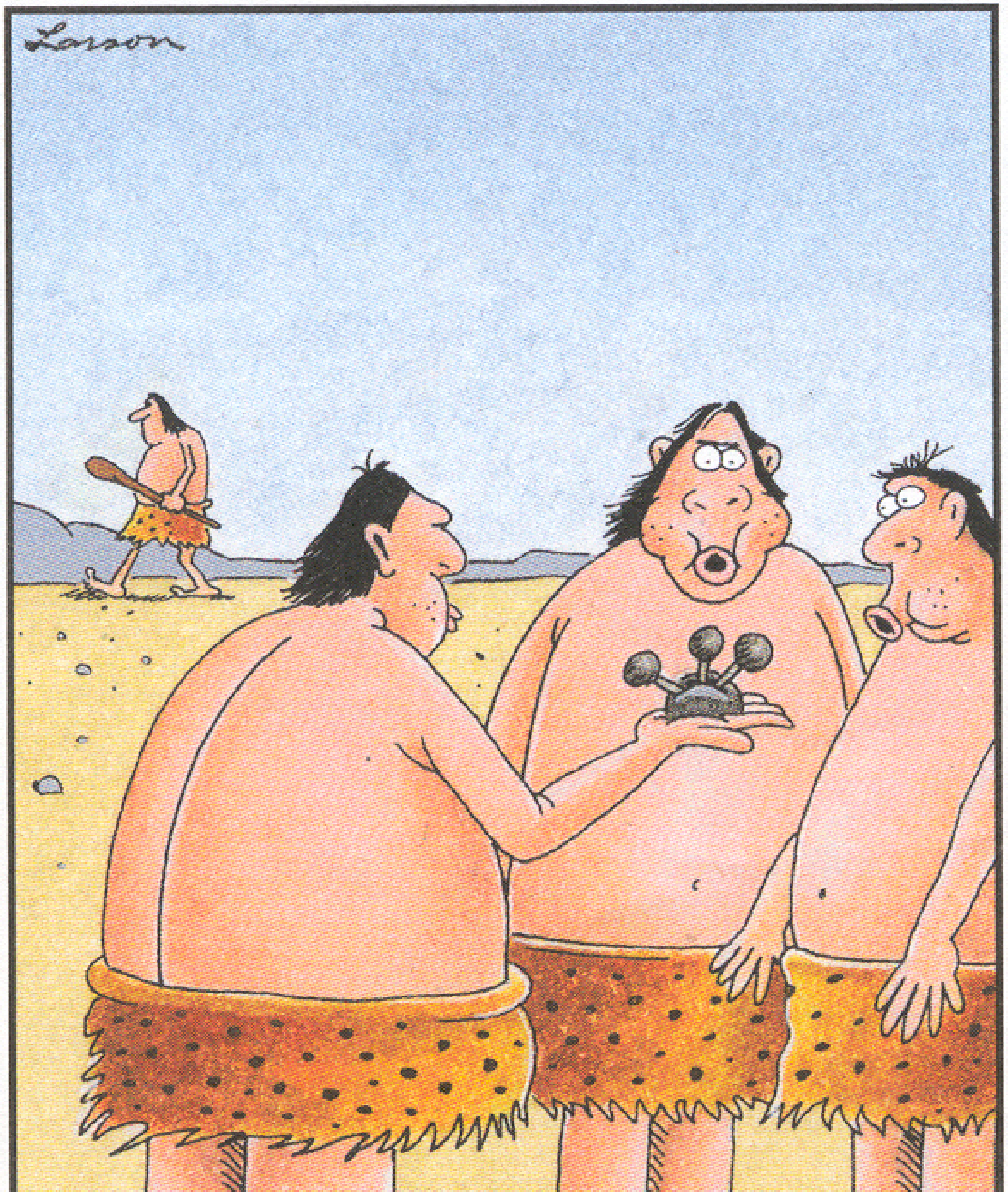
Conclusions - I

- Combining 2x seeding rates of early-cut barley silage with 2x seeding rates of winter cereals and excluding wild oat herbicides for 3 of 5 yr often led to similar wild oat density, above-ground wild oat biomass, wild oat seed density in the soil and canola yield as a repeated canola-wheat rotation under a full wild oat herbicide rate regime.
- Wild oat was similarly well-managed after three years of perennial alfalfa without wild oat herbicides.

Conclusions - II

- Forgoing wild oat herbicides in only two of five years from exclusively summer annual crop rotations resulted in higher wild oat density, biomass and seed banks.
- Management systems that effectively combine diverse and optimal cultural practices against weeds, and limit herbicide use, reduce selection pressure for weed resistance to herbicides and prolong the utility of threatened herbicide tools.

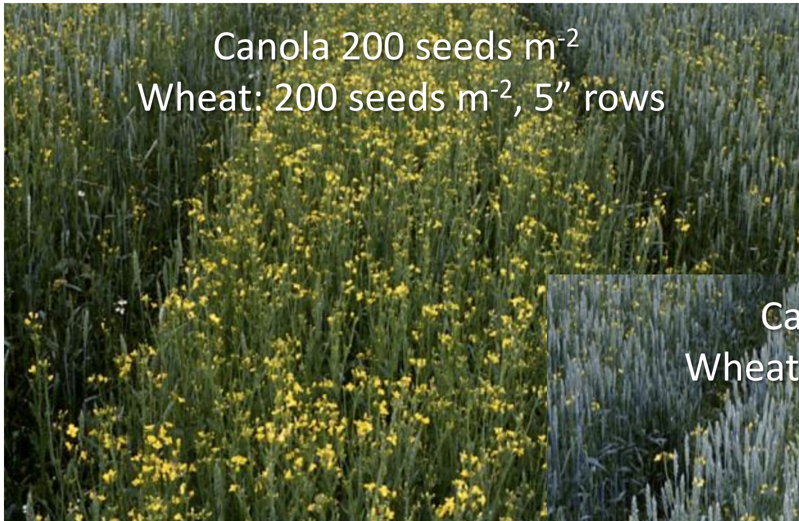
Harker et al. 2016. Weed Sci. 64:170-180



Danook shows off his Swiss Army Rock.

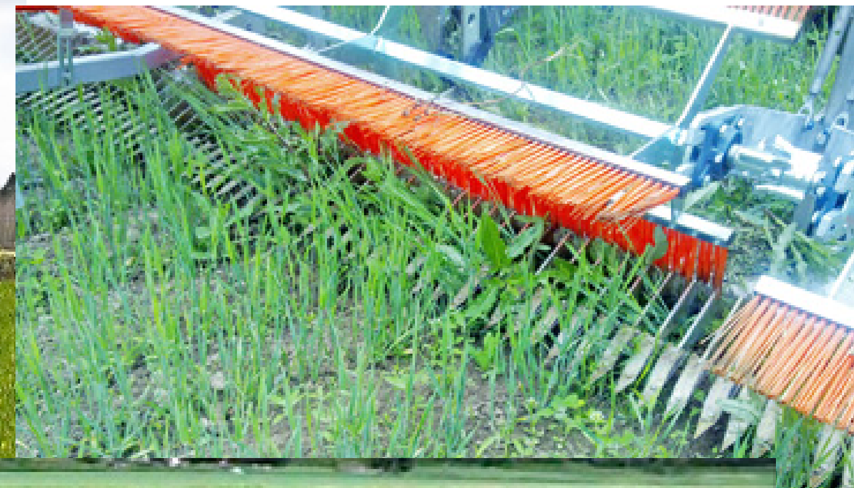
New
Weed
Mgmt.
Tools
…

Crop Density & Spatial Distribution



Weiner et al. 2001. J. App. Ecol. 38:784-790
Weiner et al. 2010. Evol. Appl. 3:473-479.
Photo credits: J. Weiner - Denmark

CombCut™



Weed Seed Removal / Destruction

Harrington Weed Seed Destructor

Walsh et al. 2012. Crop Sci. 52:1343-1347

Chaff Cart

Chaff in Narrow Windrows

Photos: Michael Walsh

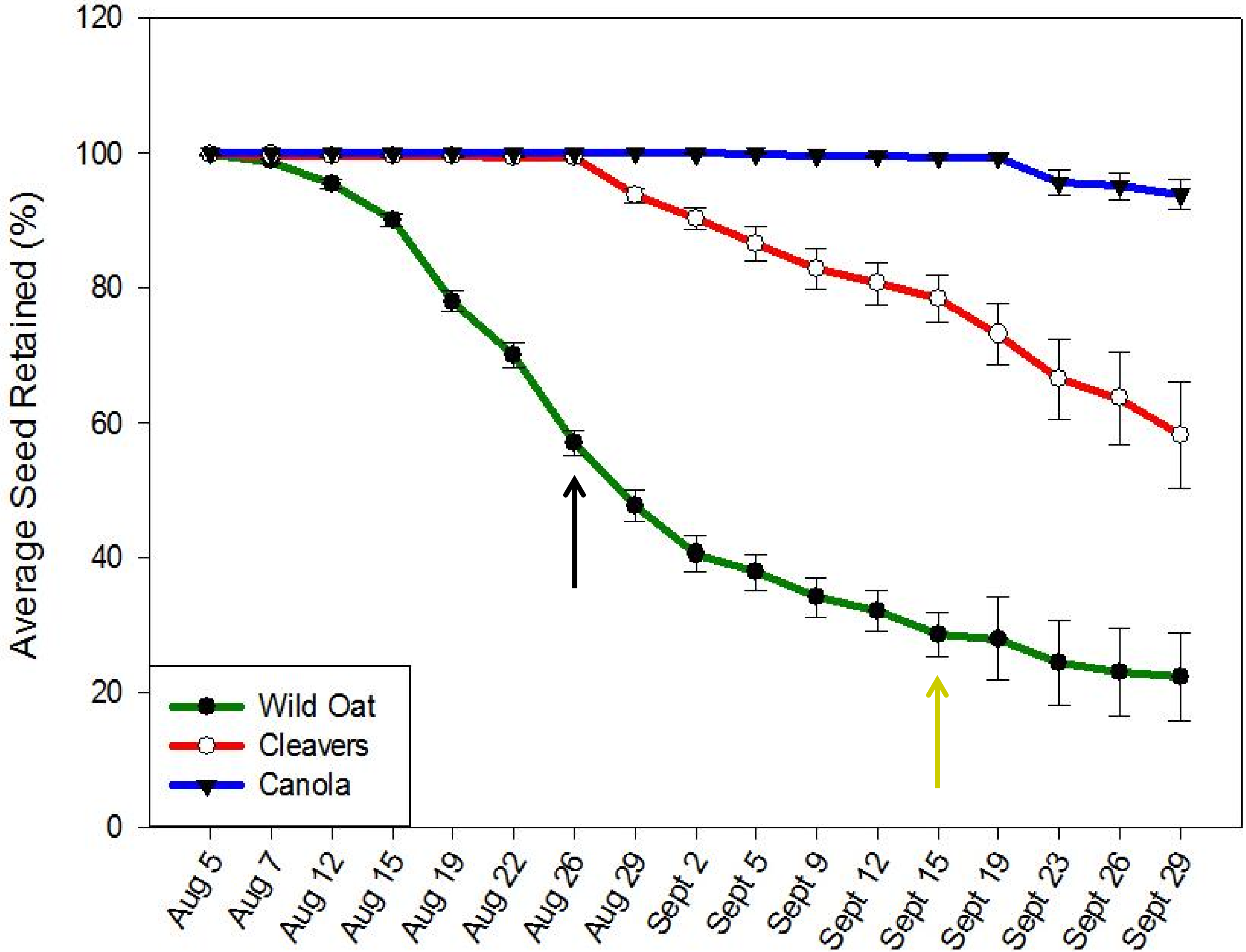
Burn Chaff & Weed Seed

- > 90% control of Ryegrass and Wild Radish
- Most Western AU growers use this technique

Photo: Michael Walsh

Chaff Diversion

Weed Seed Retention over Time – 1 site, 1 year



Weed Target Suitability

Excellent targets

- Canola, green foxtail

Good targets

- Cleavers, wild mustard

Poor target

- Wild oat

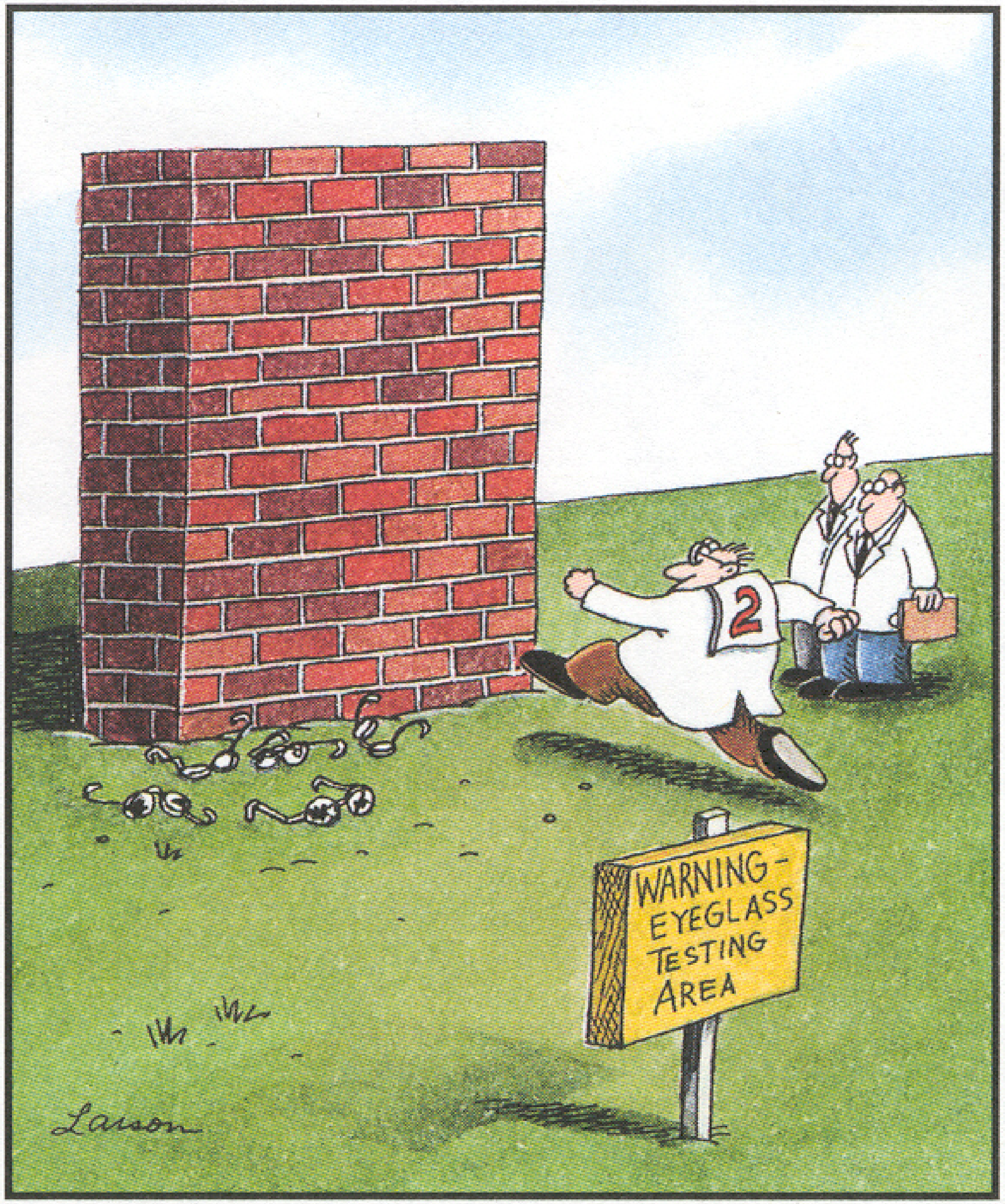
B. Tidemann

Summary - I

- Some herbicides are being over-used
- Weed Resistance to herbicides continues to increase at a rapid pace
- Many popular wild oat herbicides are already less useful than a few years ago
- Few or no new herbicide mode of actions are being registered
- Low Diversity Rotations are Dominant

Summary - II

- HR Canola → a Resistance Reprieve, but less cropping system diversity → more problems…
- The most-profitable crops drive a lack of rotational diversity
- Harvest Weed Seed Control should be taken seriously
- So far, Weed Resistance has not driven much greater IWM adoption – <u>that could change!</u>



Do We Have To Observe Resistance to Every Last Herbicide and Weed Before We Act Decisively?

Reducing Herbicide Resistance

"The only sustainable solution is for government or end-users of commodities to set herbicide-use reduction targets in our major field crops similar to European Union member states, and include financial incentives or penalties in agricultural programs to support this policy."

Beckie & Hall. 2014. Crop Protect. 66:40-45

"Say ... what's a mountain goat doing way up here in a cloud bank?"

There
Are
Signs
That
Serious
Trouble
is
Ahead
...

CANOLA CANADA
CANOLA COUNCIL OF CANADA

ALBERTA Canola PRODUCERS COMMISSION

SaskCanola™
Saskatchewan Canola Development Commission

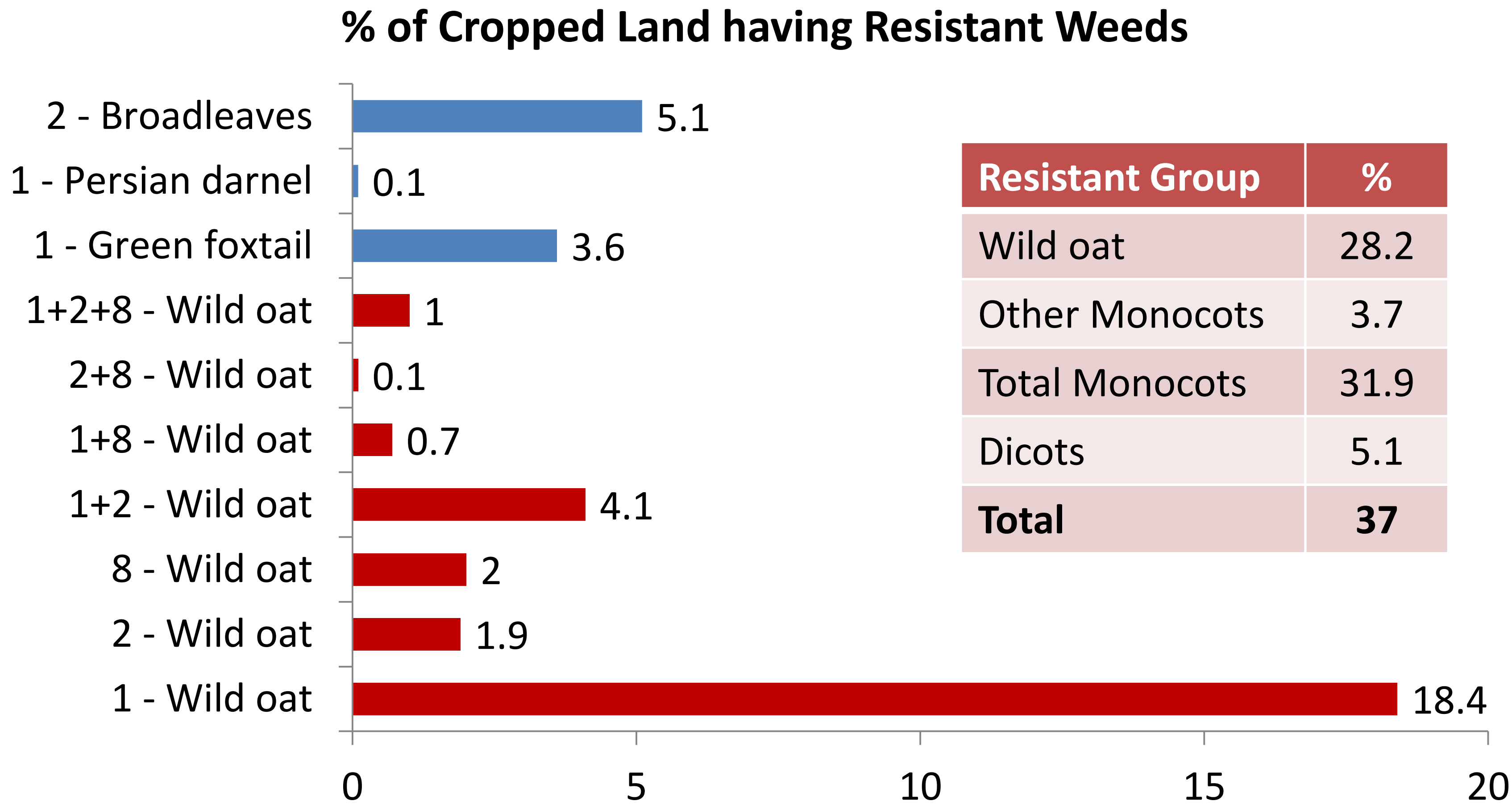
Manitoba Canola Growers

Alberta Barley

Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada

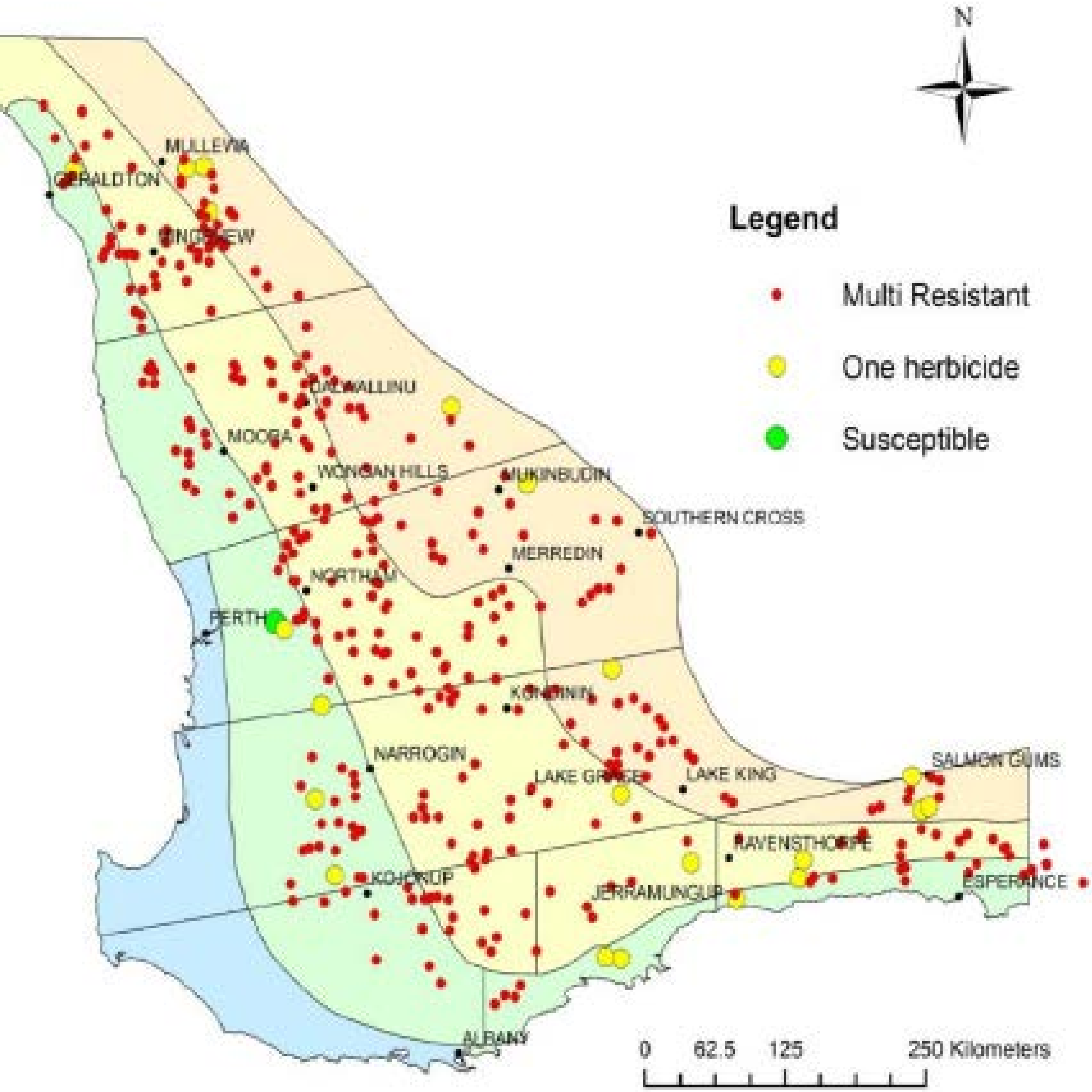
Western Grains Research Foundation

Western Canada Resistant Weeds
- Weed Resistance Spectrum (2007-2009)



Resistant Group	%
Wild oat	28.2
Other Monocots	3.7
Total Monocots	31.9
Dicots	5.1
Total	**37**

Adapted from: Beckie et al. 2013 Weed Technol. 27:171-183



15 million acre rigid ryegrass random resistance survey (West Aus.)

Owen et al. 2014
Weed Research