Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

HR crop management: a Canadian perspective

Hugh J. Beckie

Science & Technology Branch

Canada

Transgenic/GM crops: global area in 2014: 182 million ha

	M ha	***%***
1. United States	73.1	40.3
2. Brazil	42.2	23.2
3. Argentina	24.3	13.4
4. India	11.6	6.4
5. Canada	**11.6**	**6.4**

First generation traits:

HR : 58%

Bt : 14%

HR + *Bt* : 28% (stacked)

Herbicide Resistance Stewardship/Management Plan (required since 2004)

Canadian Food Inspection Agency
Agence canadienne d'inspection des aliments

Applicant needs to address:

- Control of volunteers; identify any potential changes in agronomic practices related to the HR trait which could impact sustainability, e.g., soil conservation
- **Selection of herbicide resistance in weeds resulting from the potential continued application of the same herbicide in subsequent rotations: guidelines for rotation of crops and herbicides**
- Introgression of HR trait into related species
- Management of the HR crop during the growing season, esp. where multiple resistance due to cross-pollination could arise in subsequent growing seasons
- Communication to growers; **efficient reporting mechanism**
- Monitoring effectiveness of the stewardship plan

Pest Management Regulatory Agency

PMRA ARLA

Resistance management labeling in Canada since 1999

Weed Technology. 1999. Volume 13:655–661

Symposium

The Effect of Labeling Herbicides with Their Site of Action: A Canadian Perspective[1]

HUGH J. BECKIE, FA-YAN CHANG, and F. CRAIG STEVENSON[2]

Resistance BMPs on labels
(PMRA Regulatory Directive DIR2013-04 – updated from 1999)

- Rotate the use of (name of product) or other Group (site of action group number) herbicides within a growing season (sequence) or among growing seasons with different herbicide groups that control the same weeds in a field

- Use tank mixtures with herbicides from a different group; the less resistance-prone partner should control the target weed(s) as effectively as the more resistance-prone partner

- Herbicide use should be based on an IWM program that includes scouting, historical information related to herbicide use and crop rotation, and considers tillage (or other mechanical control methods), cultural (e.g., higher crop seeding rates; precision fertilizer application method and timing to favour the crop and not the weeds), biological (weed-competitive crops or varieties), and other management practices

Resistance BMPs on labels

- Monitor weed populations after herbicide application for signs of resistance development. If resistance is suspected, prevent weed seed production in the affected area if possible by an alternative herbicide from a different group. Prevent movement of resistant weed seeds to other fields by cleaning harvesting and tillage equipment when moving between fields, and planting clean seed

- Have suspected resistant weed seeds tested by a qualified laboratory to confirm resistance and identify alternative herbicide options

- Contact your local extension specialist or certified crop advisors for additional pesticide resistance management recommendations for specific crops and weed biotypes

- For futher information or to report suspected resistance, contact (company) at (toll free number) or at (internet site)

A Framework for Postrelease Environmental Monitoring of Second-generation Crops with Novel Traits

Hugh J. Beckie,* Linda M. Hall, Marie-Josée Simard, Julia Y. Leeson, and Christian J. Willenborg

ABSTRACT

As first-generation genetically modified/transgenic crops with novel agronomic traits have been grown commercially in a number of countries since the mid-1990s, second-generation crops with novel traits (CNTs) are now being tested in confined field trials around the world. Postrelease monitoring (PRM) of abiotic stress–tolerant and other second-generation CNTs will strengthen prerelease environmental risk assessments, for which protocols are being developed. We outline a comprehensive framework and protocol for case-specific PRM of such CNTs in Canada, using drought-tolerant canola (*Brassica napus* L.) as a model CNT. The primary potential environmental risk associated with cultivation of drought-tolerant canola is increased invasiveness of volunteers or feral plants (self-perpetuating populations) and weedy relative–crop hybrids or backcrossed progeny in ruderal (noncropped disturbed) and natural areas adjacent to CNT cultivation, resulting in loss of abundance or biodiversity of native plant species. Accurately predicting CNT invasiveness a priori is problematic, especially for traits that may enhance plant fitness and invasiveness. Thus, PRM can effectively address the greater uncertainties in the environmental risk assessment of these second-generation vs. first-generation CNTs and thereby enhance environmental protection and security of the food supply.

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Abbreviations: CFIA, Canadian Food Inspection Agency; *Bt*, *Bacillus thuringiensis*; CNT, crop with novel trait; EMAN, Ecological Monitoring and Assessment Network; ERA, environmental risk assessment; EU, European Union; GM, genetically modified; NAHARP, National Agri-Environmental Health and Reporting Program; PRM, postrelease monitoring.

Monitoring has been defined as the detection of changes and effects related to specific causes (Hellawell, 1991), or the systematic measurement of selected variables and processes that may be affected by a given practice (EFSA, 2005; Ghosh and Jepson, 2006). For example, field and associated grower surveys to determine the nature and occurrence of weed resistance through herbicide selection have been regularly conducted across agroecoregions in western Canada (Fig. 1) during the past 15 yr (Beckie et al., 2008a); weed surveys in conjunction with field management questionnaires have been routinely conducted after in-crop herbicide treatments in arable fields in the region for >30 yr (Leeson et al., 2005). Monitoring can help discern temporal trends, quantify year-to-year stochasticity, and assess ecoregion influences on the subject of interest if periodically conducted using similar methodology. Associations between agronomic practices detailed in field

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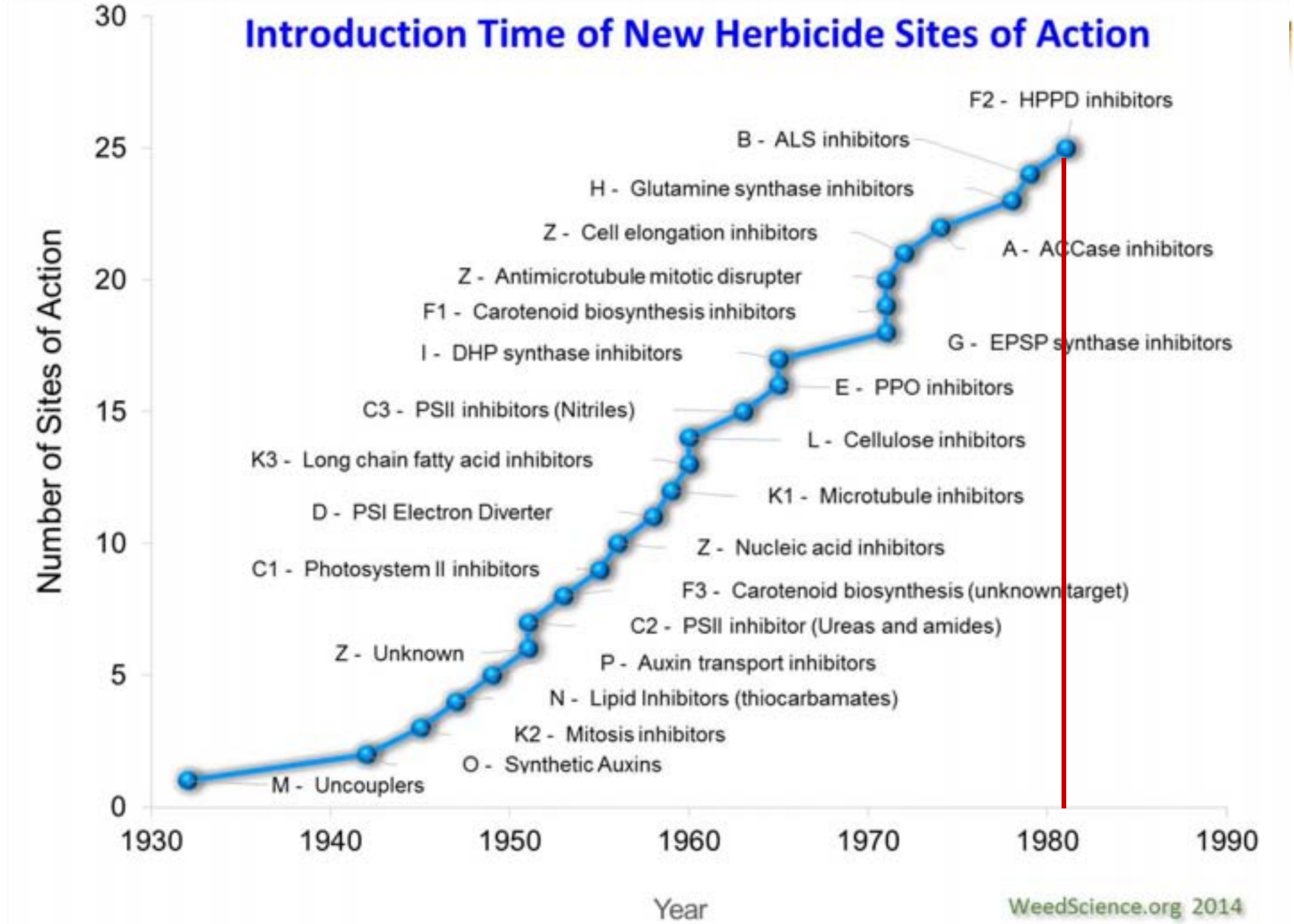
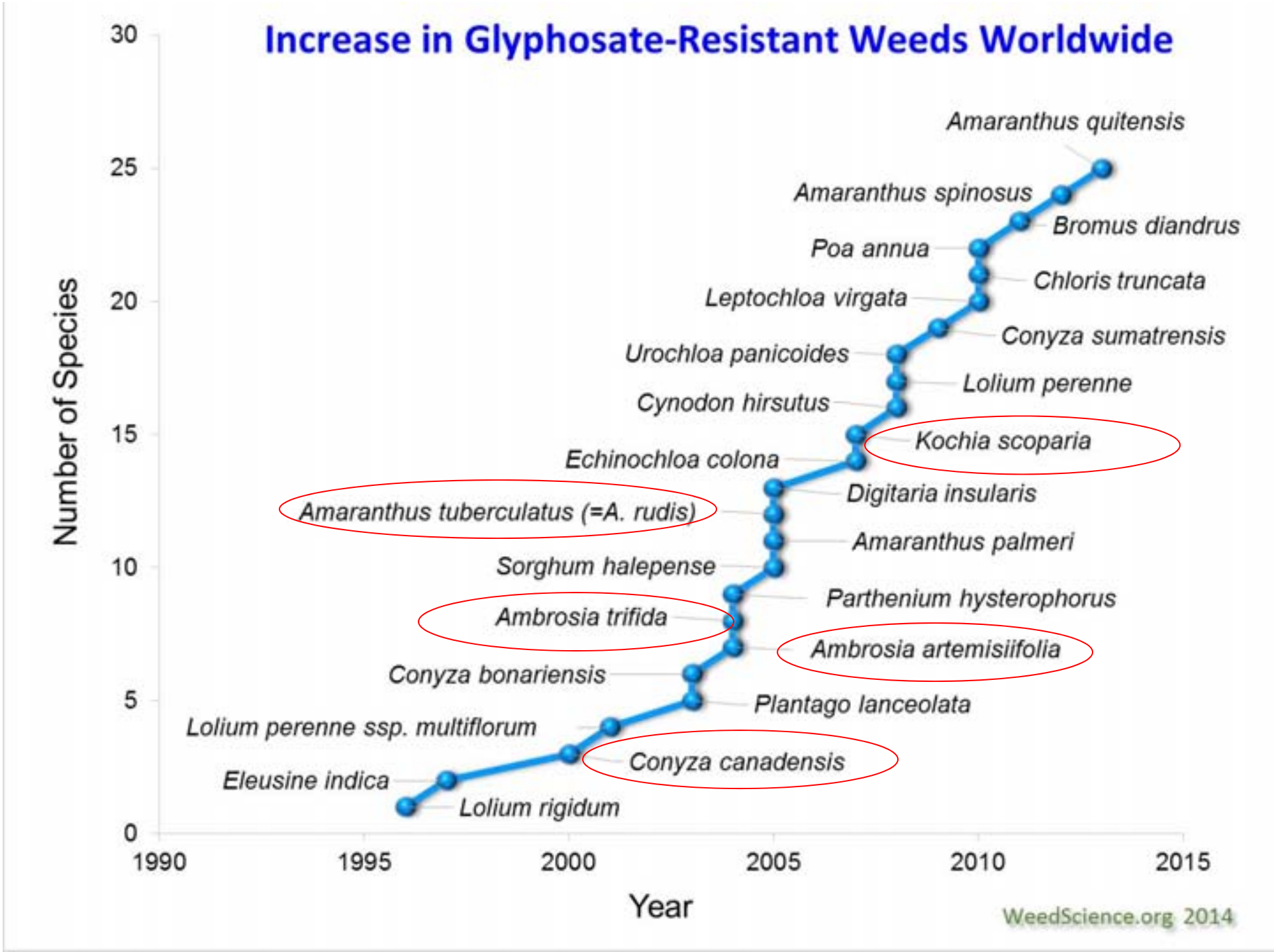
Monitoring / Surveillance

- Regular, periodic random field surveys of HR weeds led by a public institution (each usually conducted within provincial or state boundaries)
- Grower management questionnaires may accompany the field survey data collection; correlation analysis can identify reduced-risk practices
- Supplemented by testing samples of suspected HR weeds submitted by growers to a qualified lab, and mapping occurrence
- Combined activities will allow close tracking of HR weed occurrence in time and space, and facilitate early grower awareness and timely management

Education/Extension

Weed Resistance Monitoring in the Canadian Prairies


Introduction Time of New Herbicide Sites of Action
Number of Sites of Action
Year
0
5
10
15
20
25
30
1930
1940
1950
1960
1970
1980
1990
F2 - HPPD inhibitors
B - ALS inhibitors
H - Glutamine synthase inhibitors
Z - Cell elongation inhibitors
A - ACCase inhibitors
Z - Antimicrotubule mitotic disrupter
F1 - Carotenoid biosynthesis inhibitors
G - EPSP synthase inhibitors
I - DHP synthase inhibitors
E - PPO inhibitors
C3 - PSII inhibitors (Nitriles)
L - Cellulose inhibitors
K3 - Long chain fatty acid inhibitors
K1 - Microtubule inhibitors
D - PSI Electron Diverter
Z - Nucleic acid inhibitors
C1 - Photosystem II inhibitors
F3 - Carotenoid biosynthesis (unknown target)
C2 - PSII inhibitor (Ureas and amides)
Z - Unknown
P - Auxin transport inhibitors
N - Lipid Inhibitors (thiocarbamates)
K2 - Mitosis inhibitors
O - Synthetic Auxins
M - Uncouplers
WeedScience.org 2014


Increase in Glyphosate-Resistant Weeds Worldwide
Number of Species
Year
0
5
10
15
20
25
30
1990
1995
2000
2005
2010
2015
Amaranthus quitensis
Amaranthus spinosus
Bromus diandrus
Poa annua
Chloris truncata
Leptochloa virgata
Conyza sumatrensis
Urochloa panicoides
Lolium perenne
Cynodon hirsutus
Kochia scoparia
Echinochloa colona
Digitaria insularis
Amaranthus tuberculatus (=A. rudis)
Amaranthus palmeri
Sorghum halepense
Parthenium hysterophorus
Ambrosia trifida
Ambrosia artemisiifolia
Conyza bonariensis
Plantago lanceolata
Lolium perenne ssp. multiflorum
Conyza canadensis
Eleusine indica
Lolium rigidum
WeedScience.org 2014

GR kochia across the Canadian prairies

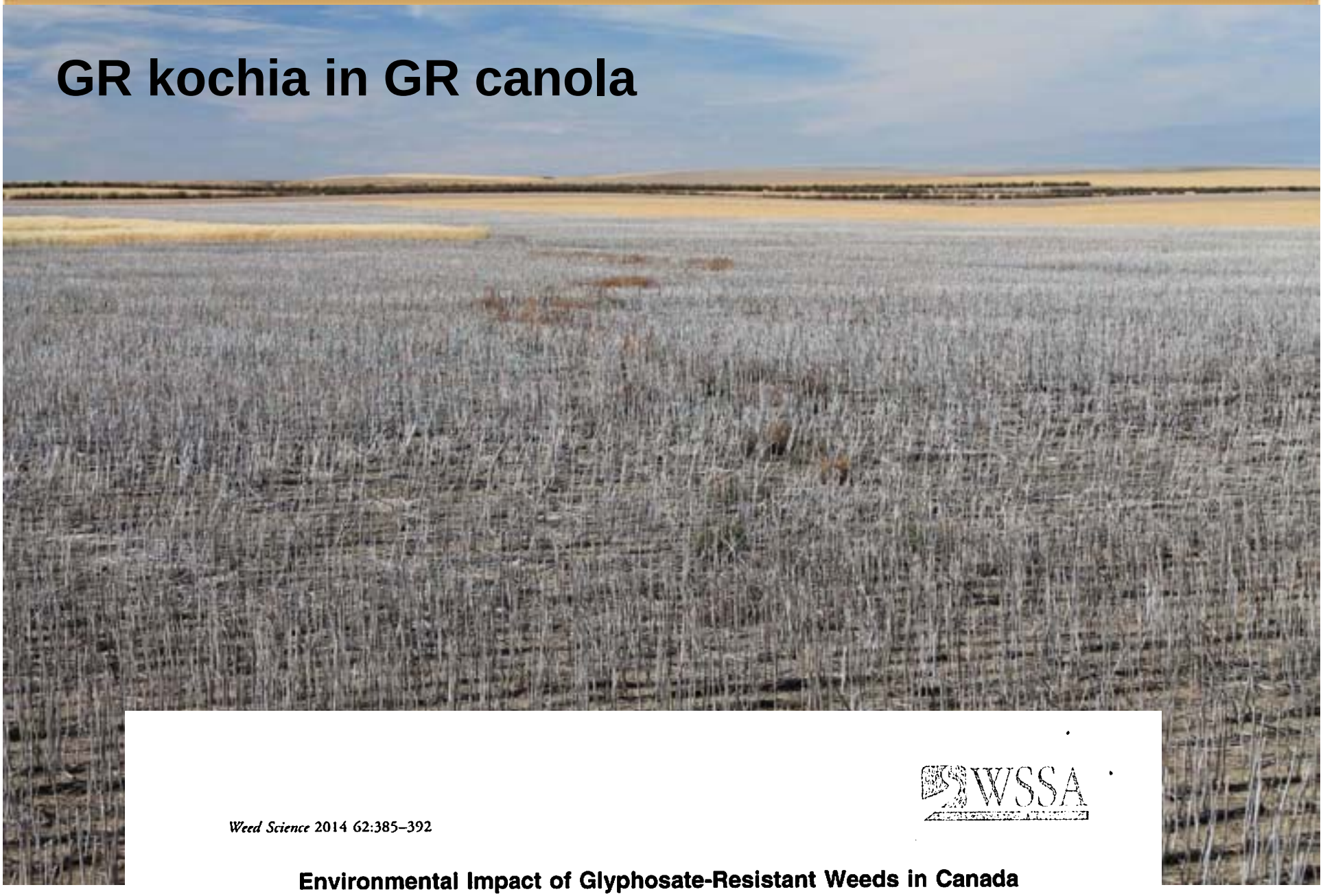
Y:/Agricultural Institute of Canada/CJPS/Articles/CJPS-2014-328/CJPS-2014-328.3d[x] Monday, 22nd December 2014 20:26:14

SHORT COMMUNICATION

Glyphosate-resistant kochia (*Kochia scoparia* L. Schrad.) in Saskatchewan and Manitoba

Hugh J. Beckie[1], Robert H. Gulden[2], Nasir Shaikh[3], Eric N. Johnson[4], Christian J.

GR kochia in GR canola

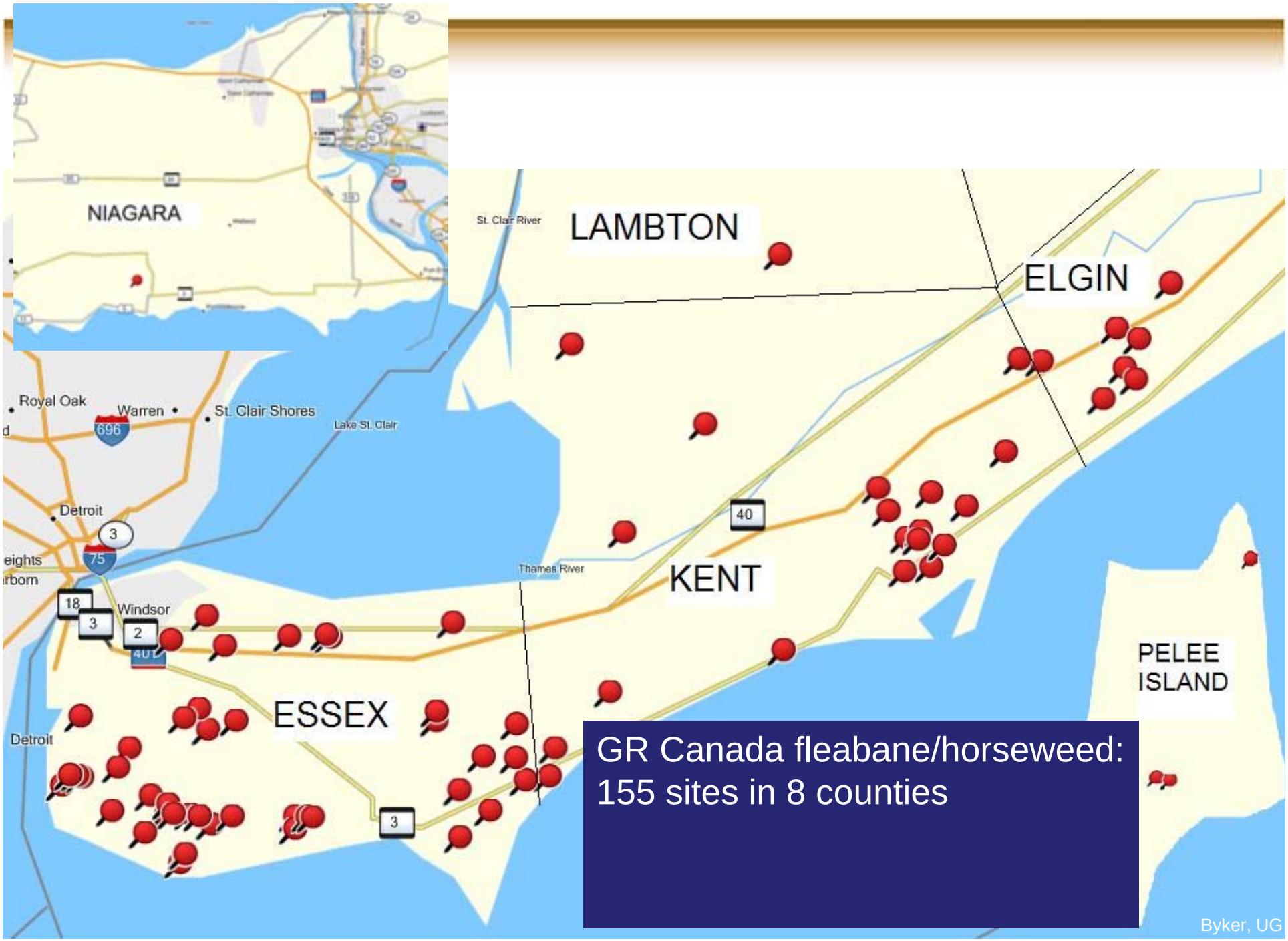


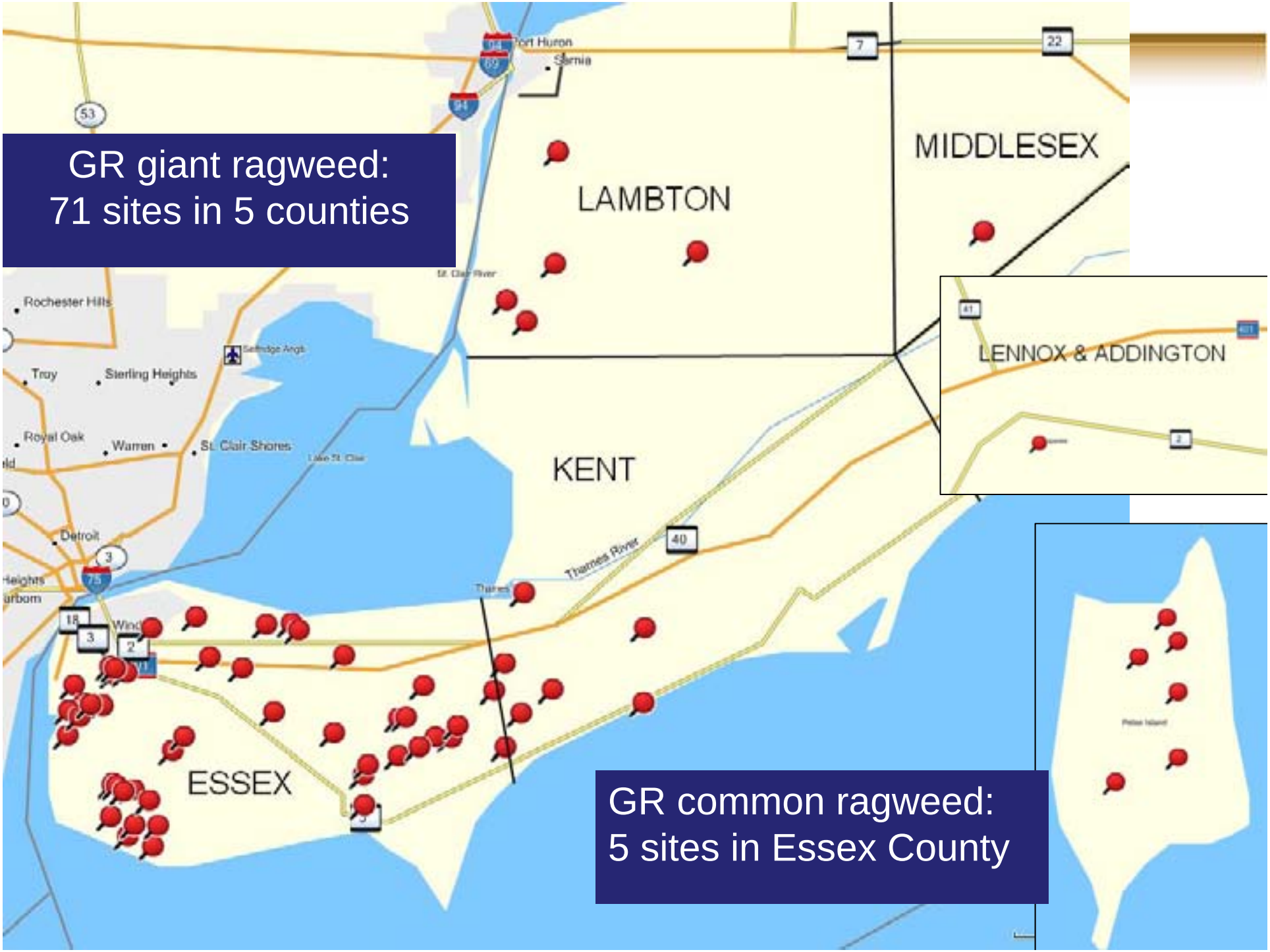
Weed Science 2014 62:385–392

WSSA

Environmental Impact of Glyphosate-Resistant Weeds in Canada

Hugh J. Beckie, Peter H. Sikkema, Nader Soltani, Robert E. Blackshaw, and Eric N. Johnson*


NIAGARA
St. Clair River
LAMBTON
ELGIN
Royal Oak
Warren
St. Clair Shores
Lake St. Clair
696
Detroit
3
75
Thames River
KENT
40
18
Windsor
2
ESSEX
PELEE
ISLAND
Detroit
3
GR Canada fleabane/horseweed:
155 sites in 8 counties
Byker, UG

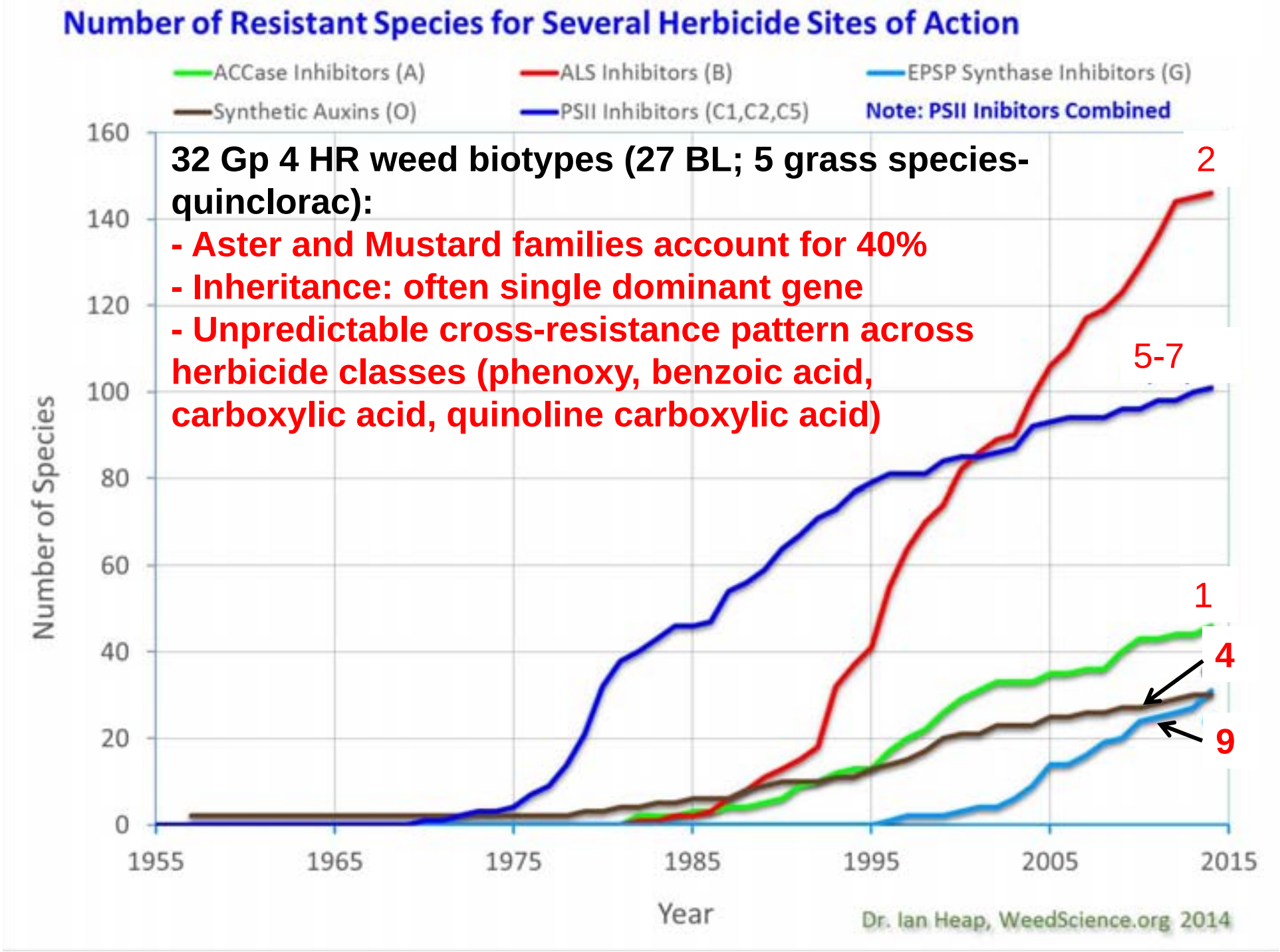

GR giant ragweed:
71 sites in 5 counties
LAMBTON
MIDDLESEX
KENT
ESSEX
LENNOX & ADDINGTON
Port Huron
Sarnia
Rochester Hills
Troy
Sterling Heights
Selfridge Angb
Royal Oak
Warren
St. Clair Shores
Detroit
Thames River
GR common ragweed:
5 sites in Essex County

Stacked-HR trait soybean

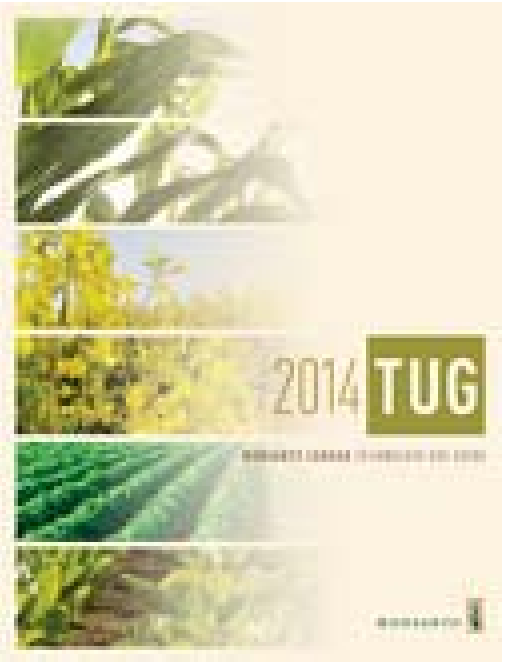
- Management of GR weeds, such as giant and common ragweed, horseweed, and/or kochia
- Roundup Ready 2 Xtend™: glyphosate + dicamba
- Approved in 2012 in Canada (available in 2016)
- Dicamba at 600 g ai/ha (or 300 *fb* 300); E.I. = 15.8 (**moderate**)
- Enlist™: glyphosate + 2,4-D
- Approved in 2013 in Canada (available in 2016)
- 2,4-D at 834 g ai/ha x 2 sequential applications max ; E.I. = 25.6 (**high**)

Stacked-HR trait (glyphosate + dicamba) canola (Roundup Ready 2 Xtend™)

- Dicamba-HR canola expected to be approved and released in the next decade (after corn)
- Cultivars with three-way stack (incl. glufosinate)
- Dicamba-HR canola susceptible to another auxinic herbicide, 2,4-D, commonly used to control volunteers
- What will be the management implications?
- dicamba currently applied to 10 - 15% of wheat and barley fields @ 140 g ai/ha (2 crops cover 50% of annually-cropped area)
- increasing acreage of soybean and corn (incl. cultivars with this stacked trait) across the Canadian prairies will increase the dicamba selection pressure for HR weeds (300 - 600 g ai/ha)
- growers will need to tank-mix another herbicide with dicamba or an alternative to dicamba to control canola volunteers in a cereal crop grown the following year


Number of Resistant Species for Several Herbicide Sites of Action
ACCase Inhibitors (A)
ALS Inhibitors (B)
EPSP Synthase Inhibitors (G)
Synthetic Auxins (O)
PSII Inhibitors (C1,C2,C5)
Note: PSII Inibitors Combined
32 Gp 4 HR weed biotypes (27 BL; 5 grass species- quinclorac):
- Aster and Mustard families account for 40%
- Inheritance: often single dominant gene
- Unpredictable cross-resistance pattern across herbicide classes (phenoxy, benzoic acid, carboxylic acid, quinoline carboxylic acid)
2
5-7
1
4
9
Number of Species
0
20
40
60
80
100
120
140
160
1955
1965
1975
1985
1995
2005
2015
Year
Dr. Ian Heap, WeedScience.org 2014

Technology Stewardship Agreement & Use Guide (TUG): improving stewardship



- Growers do not usually read the TUG; mandatory training sessions for growers to enhance adoption of BMPs
- Industry main objective: regulate planted and harvested seed
- Industry does not really monitor effectiveness of the stewardship plan
- Recommendations needed on herbicide-use intensity (e.g., multiple applications of glyphosate, dicamba, etc. in a field every year) and HR crop rotation frequency thresholds (e.g., back-to-back canola cultivation)
- Enhanced industry and federal & provincial/state government incentives (e.g., crop insurance) to increase adoption of BMPs
- Useful model to emulate?: GMHR canola (no glyphosate the following year) and cotton (post-herbicide surveys) in Australia

Which direction are we going?
The road less travelled……..

- Proactive HR weed management is rare; growers greatly discount potential future vs. present rewards
- Cultivars with stacked HR traits will provide a short-term respite from HR weeds, but will perpetuate the herbicide treadmill and accelerate the selection of multiple-HR weed populations in the longer term – industry stewardship plans need teeth
- Recommendations needed for maximum herbicide-use intensity (within and across growing seasons) and HR crop rotation frequency
- Concomitantly, industry and government incentives must expand to improve grower adoption of BMPs for HR crops and HR weeds
- The only long-term / sustainable solution is for government or end users of commodities to set herbicide-use reduction targets in our major field crops, and include financial incentives or penalties in agricultural programs to support this policy