Roundup Resistant Weeds

Changing Weedscapes of Minnesota

2014 MFVGA Cnf.

Roger Becker

University of Minnesota

University of Minnesota
EXTENSION
Driven to Discover℠

Historically, Species Shift

- Burning
  - Tall grass prairies
    - Non-woody, warm season species
- Tilling the prairies
  - Field bindweed
  - Annual Bdlfs.

Historically, Species Shift

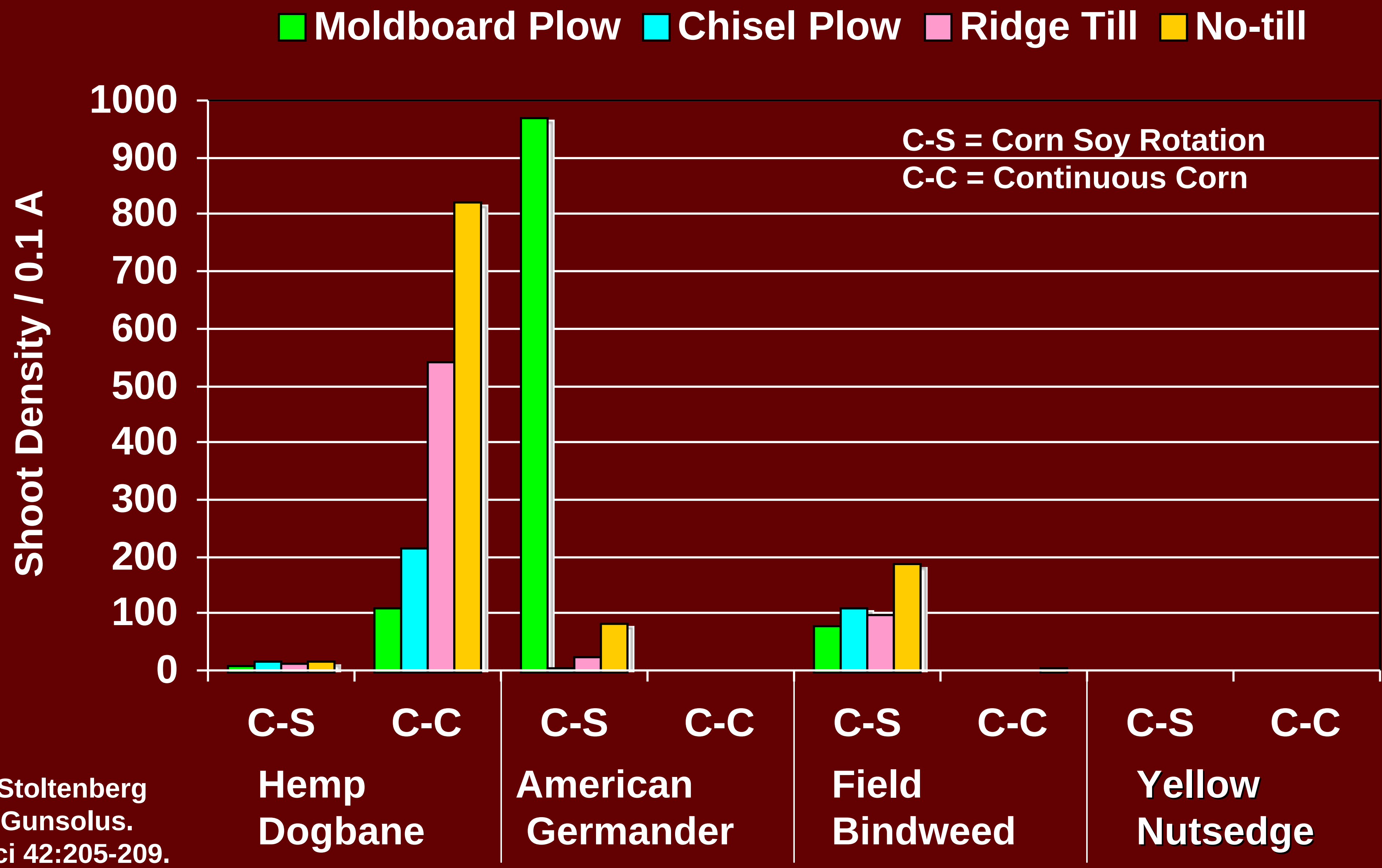
- Herb. and fertilizer
  - 2,4-D / N Bdlfs, -> grasses 50's 60's
  - Triazine, acetanilides, DNAs - grasses
    - Simazine, Atrazine, Randox
- Periodicity
  - Phenology, Seed Maturation
    - Wild Proso Millet matures before sweet corn
  - Earlier planting dates -> cool species
    - e.g. Giant foxtail, mustards, kochia
  - Non-residual herbicides -> warm species
    - e.g. Crabgrass, Eragrostis, purslane, carpetweed

Photo: Wolf, KState

Historically, Species Shift

- Rainy or droughty periods
- Reduced or no tillage
  - small seeded species and increased perennials
- Treflan + Sencor t.m. 70's and 80's
  - Eastern Black Nightshade
- Imidazolinones 90's
  - Waterhemp
- Glyphosate 2000's
  - Mare's Tail (not MN)
  - Waterhemp
  - Ragweeds

Perennial Weeds, 14 Year Study, Nashua IA



Buhler, Stoltenberg Becker, Gunsolus. Weed Sci 42:205-209. 1994.

It Takes a Village for Weeds Too!

What your neighbors do
DOES impact you

- **Roundup Ready world will shift the species you face in the non-GMO world**

Herbicide Resistant Weed-History

- **The first identified herbicide-resistant weed—spreading dayflower *(Commelina diffusa)* resistant to 2,4-D—was identified in 1957 in a sugarcane field in Hawaii.**
- **Since then, more than 200 weeds resistant to one or more herbicides have been identified worldwide.**

Glyphosate resistant marestail (3” rosette at treatment)

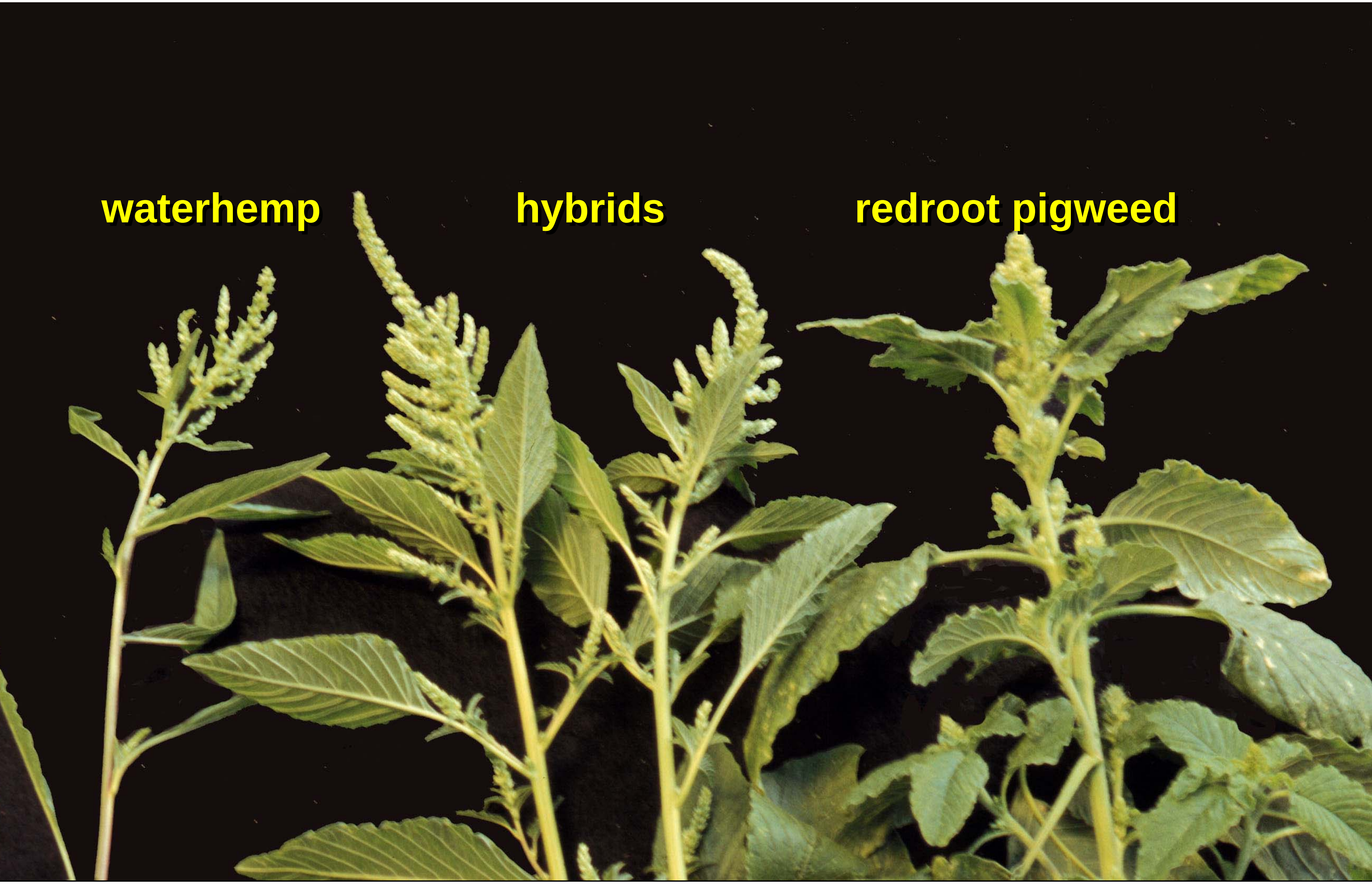
Resistant

Untreated

Resistant Susceptible

Susceptible

*Glyphosate rates in lbs. acid equivalent per acre. 24 DAT.Source: Univ. of Tennessee



Tranel 2001 University of Illinois

Waterhemp 2007
Rochester, MN

- Two applications of Roundup Ultra: 34 oz/A and 40 oz/A
- Numerous survivors
- Initial burndown
- Loss of tap root
- Prolific re-growth just above and below soil level

Gunsolus, U Mn Weed Sci.

Photo: Duane Rathmann

Waterhemp 2007 Swift County, MN

“Many waterhemp were killed but a few still survived”

One application of Roundup WeatherMax at 22 oz/A

Gunsolus, U Mn Weed Sci.

Photo: Jim Boersma

Quackgrass Resistance or Tolerance?

Phil Westra's Ph.D. work at MN 70's

- **2 of 10 biotypes of quackgrass naturally tolerant to glyphosate**
- **Evolution of glyphosate tolerant lines over the past 30 years**

Variation of Phenotype in Untreated Biotypes

104 oz, 2X,
Morrow Co.

Sandusky Co.

Madison Co.

Sensitive

J. Stachler, 2004 – Ohio State University

Common lambsquarters and glyphosate

Two applications of glyphosate

Is it resistance or environment?

Chris Boerboom, Univ. of WI

Inconsistent Performance of Glyphosate on Common Lambsquarters

What factors significantly influenced glyphosate and glufosinate activity across several weed species in the U of M Time of Day Study by *K. B. Martinson et al.?*

<u>Glyphosate</u>

Rate > Temp > Weed Height > Adjuvant> Relative Humidity > Time of Day > Dew

<u>Glufosinate</u>

Rate > Temp >Time of Day > Weed Height

Gunsolus, U Mn Weed Sci.

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Lambsquarters Population, Size, and Rate - Control with Glyphosate (Roundup Ultra Max)

19 DAT

J. Stachler, 2004 – Ohio State University

Evolution of Species Shift in Response to Continuous Practices

Adapted from Gunsolus, U Mn Weed Sci.

Weeds To Watch

Weed communities continually shift in response to management practices.

Failure to properly identify new weeds when they first enter a field may result in the plant becoming permanently established and increase weed management costs.

This poster was a six state effort funded by NC Region Pest Mgmt. Center

Gunsolus, U Mn Weed Sci.

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Seminis

Roundup Ready Technology for the fresh market

MONSANTO

Careers | Investors | Select a Country

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Sweet Corn

- **Sweet Corn Grown a Better Way**
- **Environmental Benefits of GM Sweet Corn**
- **Safety of Performance Series Sweet Corn**
- **Questions People Are Asking**
- **What Farmers Are Saying**

Home / Products / Sweet Corn Grown a Better Way

Sweet Corn Grown a Better Way

We all want to eat a balanced, healthful diet. We seek to serve our families high-quality fruits and vegetables that are nutritious, fresh and flavorful.

High-quality produce starts in the fields where our food is grown. America's farmers are proud to provide families with sweet corn that is delicious and wholesome.

Biotech sweet corn hybrids for the fresh market help farmers produce safe, nutritious and flavorful food, while reducing the number of insecticide applications.

Product Information for Farmers

Performance Series

(Bt/Roundup Ready Sweet Corn)

Performance Series™ Sweet Corn

Bacillus thuringiensis (B.t.)

- Cry1A.105, Cry2Ab2 and Cry3Bb1

Roundup Ready® Technology

- Roundup PowerMAX®
- Roundup WeatherMAX®

- Can not retain seed
- Crop destruct w/in 30 days after harvest
- Identity preserved production
  - Market only in U.S., Canada, Mexico

Minnesota's Herbicide Resistant Weeds-1.

- Lambsquarters
  (*Chenopodium album*)corn C1/5 - Photosystem II inhibitors (atrazine) 1982
- Velvetleaf
  (*Abutilon theophrasti*)corn C1/5 - Photosystem II inhibitors (atrazine)
- Redroot Pigweed
  (*Amaranthus retroflexus*)corn C1/5 - Photosystem II inhibitors (atrazine) 1991
- Wild Oat
  (*Avena fatua*)sugarbeet, wheat A/1 - ACCase inhibitors (diclofop-methyl) 1991
- Kochia
  (*Kochia scoparia*)cropland, wheat B/2 - ALS inhibitors (imazethapyr, thifensulfuron-methyl, tribenuronmethyl) 1994
- Common cocklebur
  (*Xanthium strumarium*)soybean B/2 - ALS inhibitors (imazethapyr) 1994

Minnesota's Herbicide Resistant Weeds-2.

- Giant Foxtail
  (*Setaria faberi*)corn, soybean B/2 - ALS inhibitors
  (imazethapyr, nicosulfuron, primisulfuron-methyl) 1996
- Robust White Foxtail
  (*Setaria viridis var. robusta-alba Schreiber*)soybean A/1 - ACCase inhibitors
  (fenoxaprop-p-ethyl, fluazifop-P-butyl) 1999
- Purple Robust Foxtail
  (*Setaria viridis var. robusta-purpurea*)soybean A/1 - ACCase inhibitors
  (fenoxaprop-p-ethyl, fluazifop-P-butyl, sethoxydim) 1999
- Giant Ragweed
  (*Ambrosia trifida*)soybean G/9 - Glycines
  (glyphosate) 2006
- Common Waterhemp
  (*Amaranthus rudis*)soybean G/9 - Glycines
  (glyphosate) 2007

HERBICIDE RESISTANT WEEDS - MINNESOTA

According to the International Survey of Herbicide Resistant Weeds, there 418 unique cases of herbicide resistant weeds globally with 228 species (131 dicots and 97 monocots). Weeds have evolved resistance to 21 of the 25 known herbicide sites of action and to 150 different herbicides. In Minnesota, 13 weed species have been recorded as having shown resistance to 6 herbicide sites of action and to 13 herbicides. Four species – Common and Giant ragweeds, Robust White Foxtail, and common waterhemp have shown multiple resistance for two sites of action. The most common resistance occurs in corn and soybean systems with two occurrences in wheat and one in sugar beets.

Common Name	Scientific Name	First Reported Occurrence	Cropping System	Herbicide
Common Lambsquarters	*Chenopodium album*	1982	Corn	atrazine
Velvetleaf	*Abutilon theophrasti*	1991	Corn	atrazine
Redroot Pigweed	*Amaranthus retroflexus*	1991	Corn	atrazine
Common Waterhemp	*Amaranthus tuberculatus (syn. Rudis)*	1994, 2007	Soybean	imazethyapyr, thifensulfuron-methyl, glyphosate
Wild Oat	*Avena fatua*	1991	Sugar beets and wheat	diclofop-methyl
Kochia	*Kochia scoparia*	1994	Cropland, wheat	imazethyapyr, thifensulfuron-methyl, tribenuron-methyl
Common Cocklebur	*Xanthium strumarium*	1994	Soybean	imazethyapyr
Giant Foxtail	*Setaria faberi*	1996	Corn and soybean	imazethapyr, nicosulfuron, primisulfuron-methyl
Robust White Foxtail	*Setaria viridis var. robusta-alba*	1996, 1999	Corn and soybean	imazethapyr; nicosulfuron; primisulfuron-methyl fenoxaprop-P-ethyl; fluazifop –P-butyl
Yellow Foxtail	*Setaria lutescens*	1997	Soybean	imazethyapyr
Purple Robust Foxtail	*Setaria viridis var. robusta-purpurea*	1999	Soybean	fenoxaprop-P-ethyl; fluazifop –P-butyl; sethoxydim
Common Ragweed	*Ambrosia artemisiifolia*	1998, 2008	Soybean	cloransulam-methyl, imazapyr, glyphosate
Giant Ragweed	*Ambrosia trifida*	2006, 2008	Soybean	cloransulam-methyl, glyphosate

Compiled by Tony Cortilet, MNA. Data obtained from the International Survey of Herbicide Resistant Weeds – Weed Science Society of America: http://www.weedscience.org/Summary/Country.aspx
01/07/2014

HERBICIDE RESISTANT WEEDS - MINNESOTA

Common Name	Scientific Name	Reported Occurrence	Site of Action	Actives	Trade Names (examples)
Common Lambsquarters	*Chenopodium album*	1982	Photosystem 2 inhibitors (C1/5)	atrazine	Aatrex, Fenatrol, Atranex; etc.
Velvetleaf	*Abutilon theophrasti*	1991	Photosystem 2 inhibitors (C1/5)	atrazine	Aatrex, Fenatrol, Atranex; etc.
Redroot Pigweed	*Amaranthus retroflexus*	1991	Photosystem 2 inhibitors (C1/5)	atrazine	Aatrex, Fenatrol, Atranex; etc.
Common Waterhemp	*Amaranthus tuberculatus (syn. Rudis)*	1994, 2007	ALS inhibitors (B/2) **AND** Glycines (G/9)	(ALS) imazethapyr; imazapyr; thifensulfuron-methyl **AND** (Glycine) glyphosate	(ALS) Pursuit, Arsenal, Harmony - (Glycine) RoundUp
Wild Oat	*Avena fatua*	1991	ACCase inhibitors (A/1)	diclofop-methyl	
Kochia	*Kochia scoparia*	1994	ALS inhibitors (B/2)	imazethapyr; thifensulfuron-methyl; tribenuron-methyl	Pursuit, Harmony, Express
Common Cocklebur	*Xanthium strumarium*	1994	ALS inhibitors (B/2)	imazethapyr	Pursuit
Giant Foxtail	*Setaria faberi*	1996	ALS inhibitors (B/2)	(ALS) imazethapyr; nicosulfuron; primisulfuron-methyl	Pursuit, Accent, Beacon
Robust White Foxtail	*Setaria viridis var. robusta-alba*	1996, 1999	ALS inhibitors (B/2) **AND** ACCase inhibitors (A/1)	(ALS) imazethapyr; nicosulfuron; primisulfuron-methyl **AND** (ACCase) fenoxaprop-P-ethyl; fluazifop –P-butyl	(ALS) Pursuit, Accent, Beacon (ACCase) Puma, Acclaim, Fusilade
Yellow Foxtail	*Setaria lutescens*	1997	ALS inhibitors (B/2)	imazethapyr	Pursuit
Purple Robust Foxtail	*Setaria viridis var. robusta-purpurea*	1999	ACCase inhibitors (A/1)	fenoxaprop-P-ethyl; fluazifop –P-butyl; sethoxydim	Puma, Acclaim, Fusilade, Poast
Common Ragweed	*Ambrosia artemisiifolia*	1998, 2008	ALS inhibitors (B/2) **AND** Glycines (G/9)	(ALS) imazethapyr; imazapyr; cloransulam-methyl; primisulfuron-methyl **AND** (Glycine) glyphosate	(ALS) Pursuit, Arsenal, Telar, Beacon (Glycine) RoundUp
Giant Ragweed	*Ambrosia trifida*	2006, 2008	ALS inhibitors (B/2) **AND** Glycines (G/9)	(ALS) cloransulam-methyl **AND** (Glycine) glyphosate	(ALS) Beacon (Glycine) RoundUp

Compiled by Tony Cortilet, MNA. Data obtained from the International Survey of Herbicide Resistant Weeds – Weed Science Society of America: http://www.weedscience.org/Summary/Country.aspx
01/07/2014

Development of Resistant Weeds in Minnesota

Herbicide Resistant Weeds in Minnesota, USA.

#	Year	Species	Site of Action	Actives	Contacts
1	1982	*Chenopodium album* Common Lambsquarters	Photosystem II inhibitors (C1/5)	atrazine	Jeffrey Gunsolus
2	1991	*Avena fatua* Wild Oat	ACCase inhibitors (A/1)	diclofop-methyl	Jeffrey Gunsolus
3	1991	*Abutilon theophrasti* Velvetleaf	Photosystem II inhibitors (C1/5)	atrazine	Jeffrey Gunsolus
4	1991	*Amaranthus retroflexus* Redroot Pigweed	Photosystem II inhibitors (C1/5)	atrazine	Jeffrey Gunsolus
5	1994	*Amaranthus tuberculatus (=A. rudis)* Tall Waterhemp	ALS inhibitors (B/2)	imazethapyr, thifensulfuron-methyl	Jeffrey Gunsolus
6	1994	*Kochia scoparia* Kochia	ALS inhibitors (B/2)	imazethapyr, thifensulfuron-methyl, tribenuron-methyl	Jeffrey Gunsolus
7	1994	*Xanthium strumarium* Common cocklebur	ALS inhibitors (B/2)	imazethapyr	Jeffrey Gunsolus
8	1996	*Setaria faberi* Giant Foxtail	ALS inhibitors (B/2)	imazethapyr, nicosulfuron, primisulfuron-methyl	Jeffrey Gunsolus
9	1996	*Setaria viridis var. major (=var. robusta-alba, var. robustapurpurea)* Giant Green Foxtail	ALS inhibitors (B/2)	imazethapyr, nicosulfuron, primisulfuron-methyl	Jeffrey Gunsolus
10	1997	*Setaria pumila (=S. glauca)* Yellow Foxtail	ALS inhibitors (B/2)	imazethapyr	Jeffrey Gunsolus
11	1998	*Ambrosia artemisiifolia* Common Ragweed	ALS inhibitors (B/2)	cloransulam-methyl, imazethapyr, primisulfuron-methyl	Terry Wright, Paul Schmitzer
12	1999	*Setaria viridis var. major (=var. robusta-alba, var. robustapurpurea)* Giant Green Foxtail	ACCase inhibitors (A/1)	fenoxaprop-P-ethyl, fluazifop-P-butyl	Jeffrey Gunsolus
13	1999	*Setaria viridis var. major (=var. robusta-alba, var. robustapurpurea)* Giant Green Foxtail	ACCase inhibitors (A/1)	fenoxaprop-P-ethyl, fluazifop-P-butyl, sethoxydim	Jeffrey Gunsolus
14	2006	*Ambrosia trifida* Giant Ragweed	Glycines (G/9)	glyphosate	Jeffrey Gunsolus, Jeff Stachler
15	2007	*Amaranthus tuberculatus (=A. rudis)* Tall Waterhemp	Glycines (G/9)	glyphosate	Jeffrey Gunsolus, Jeff Stachler
16	2007	*Amaranthus tuberculatus (=A. rudis)* Tall Waterhemp	**Multiple Resistance: 2 Sites of Action** ALS inhibitors (B/2) Glycines (G/9)	glyphosate, imazapyr, thifensulfuron-methyl	Jeffrey Gunsolus, Jeff Stachler
17	2008	*Ambrosia artemisiifolia* Common Ragweed	Glycines (G/9)	glyphosate	Jeffrey Gunsolus, Mike Christoffers, Jeff Stachler
18	2008	*Ambrosia trifida* Giant Ragweed	**Multiple Resistance: 2 Sites of Action** ALS inhibitors (B/2) Glycines (G/9)	cloransulam-methyl, glyphosate	Jeffrey Gunsolus, Jeff Stachler
19	2010	*Ambrosia artemisiifolia* Common Ragweed	**Multiple Resistance: 2 Sites of Action** ALS inhibitors (B/2) Glycines (G/9)	cloransulam-methyl, glyphosate, imazapyr	Jeffrey Gunsolus, Mike Christoffers, Jeff Stachler

Contributing Weed Scientists

Jeffrey Gunsolus
University Of Minnesota
Professor and Extension Weed Scientist
Department of Agronomy and Plant Genetics
411 Borlaug Hall, 1991 Upper Buford Circle
St. Paul Minnesota 55108
United States
Email: gunso001@umn.edu
URL: Website

Kevin Staska
Agrevo Usa Co.
Ridgetown Campus, 120 Main St. E.,
Bloomington Minnesota 55425
United States

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Recent Developments of Resistant Weeds Globally

Most Recent Cases of Herbicide Resistant Weeds Entered into the Database

(click on a column header to sort or click on a country for details)

#	Date Last Updated	Species	Country	First Year	Site of Action
1	January 8, 2014	*Conyza canadensis*	United States (Wisconsin)	2013	Glycines (G/9)
2	January 8, 2014	*Ambrosia trifida*	United States (Wisconsin)	2013	ALS inhibitors (B/2)
3	January 8, 2014	*Apera spica-venti*	Lithuania	2013	ALS inhibitors (B/2)
4	January 8, 2014	*Echinochloa crusgalli var. zelayensis*	China	2013	Synthetic Auxins (O/4)
5	January 7, 2014	*Phalaris minor*	India	2013	ALS inhibitors (B/2)
6	January 7, 2014	*Echinochloa crus-galli var. crus-galli*	Uruguay	2013	ALS inhibitors (B/2)
7	January 3, 2014	*Echinochloa crus-galli var. crus-galli*	Uruguay	2013	Synthetic Auxins (O/4)
8	January 2, 2014	*Kochia scoparia*	United States (Montana)	2013	**Multiple Resistance: 2 Sites of Action** ALS inhibitors (B/2) Glycines (G/9)
9	January 2, 2014	*Lolium perenne ssp. multiflorum*	United States (Missouri)	2013	**Multiple Resistance: 2 Sites of Action** ACCase inhibitors (A/1) ALS inhibitors (B/2)
10	January 3, 2014	*Poa annua*	United States (California)	2013	Glycines (G/9)
11	January 3, 2014	*Lolium perenne ssp. multiflorum*	United States (North Carolina)	2012	Glycines (G/9)
12	January 2, 2014	*Ambrosia trifida*	United States (Missouri)	2011	**Multiple Resistance: 2 Sites of Action** ALS inhibitors (B/2) Glycines (G/9)
13	January 2, 2014	*Conyza canadensis*	United States (Kansas)	2011	ALS inhibitors (B/2)
14	December 29, 2013	*Ambrosia artemisiifolia*	United States (Minnesota)	2010	**Multiple Resistance: 2 Sites of Action** ALS inhibitors (B/2) Glycines (G/9)
15	January 2, 2014	*Amaranthus tuberculatus (=A. rudis)*	United States (Missouri)	2009	**Multiple Resistance: 2 Sites of Action** ALS inhibitors (B/2) Glycines (G/9)
16	January 5, 2014	*Galium aparine*	Turkey	2008	ALS inhibitors (B/2)
17	December 29, 2013	*Amaranthus tuberculatus (=A. rudis)*	United States (Minnesota)	2007	**Multiple Resistance: 2 Sites of Action** ALS inhibitors (B/2) Glycines (G/9)
18	December 30, 2013	*Setaria viridis*	United States (Montana)	2005	ACCase inhibitors (A/1)
19	January 7, 2014	*Phalaris minor*	India	1994	ACCase inhibitors (A/1)
20	December 29, 2013	*Amaranthus tuberculatus (=A. rudis)*	United States (Minnesota)	1994	ALS inhibitors (B/2)

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LIFECYCLE DURATION OF HERBICIDE RESISTANT WEEDS VS WEED SPECIES IN GENERAL

The following two pie charts show the lifecycle duration for all of the herbicide-resistant weeds in the database in comparison to the lifecycle duration of 3,272 known weeds. It is clear that herbicide-resistant weeds are more likely to be annuals or biennials than perennials in comparison to weeds in general.

Fig 1. Lifecycle Duration for All Resistant Weed Species in the Database

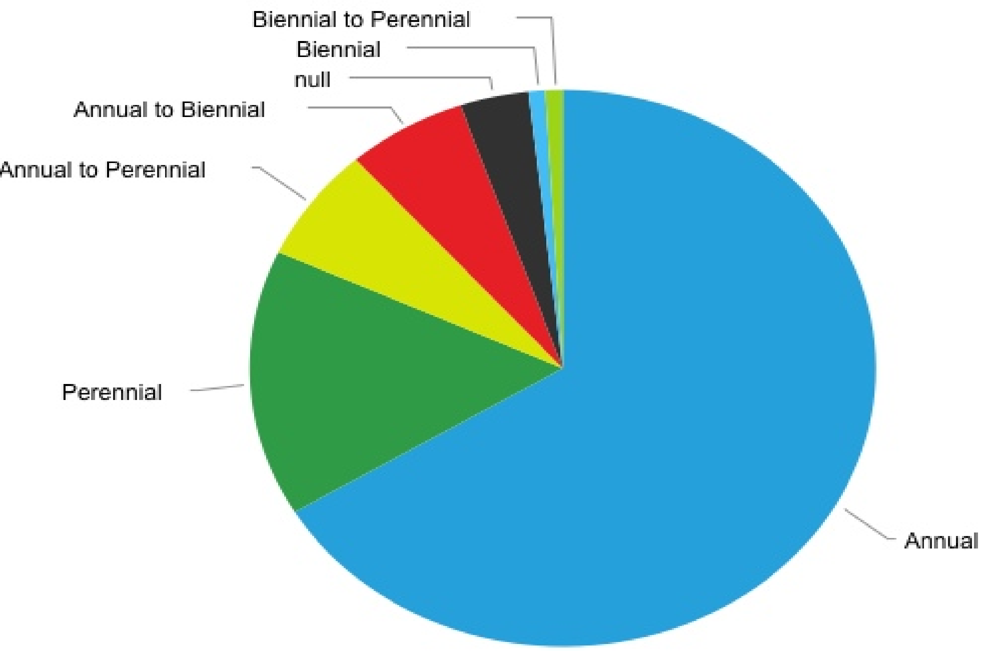
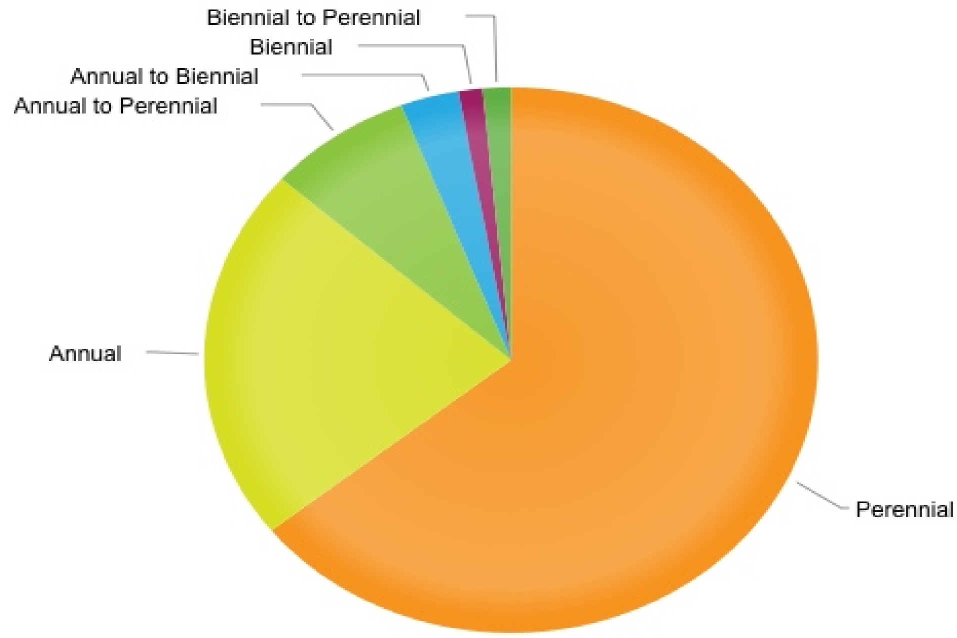


Fig 2. Lifecycle Duration for 3,372 Known Weed Species



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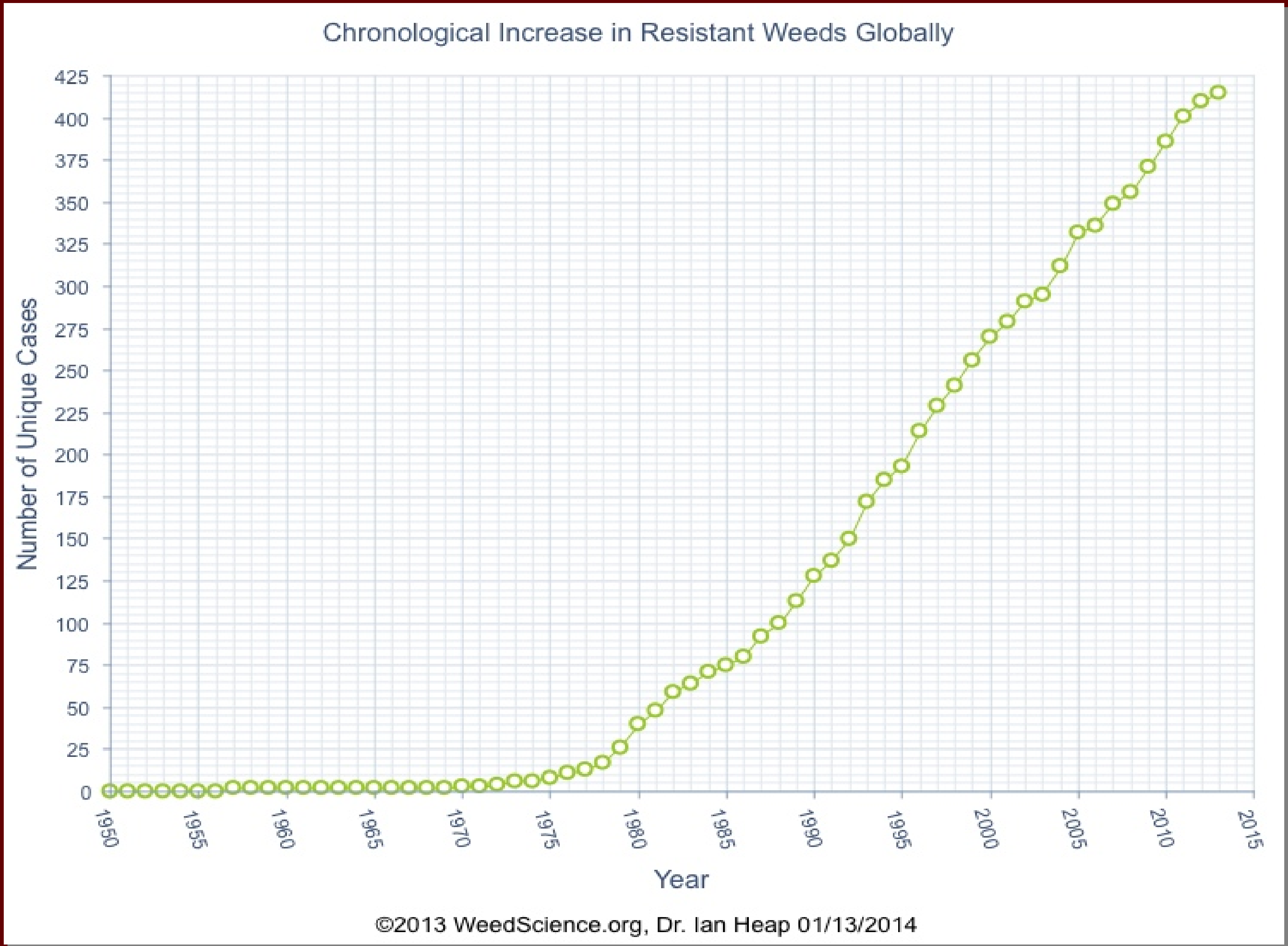

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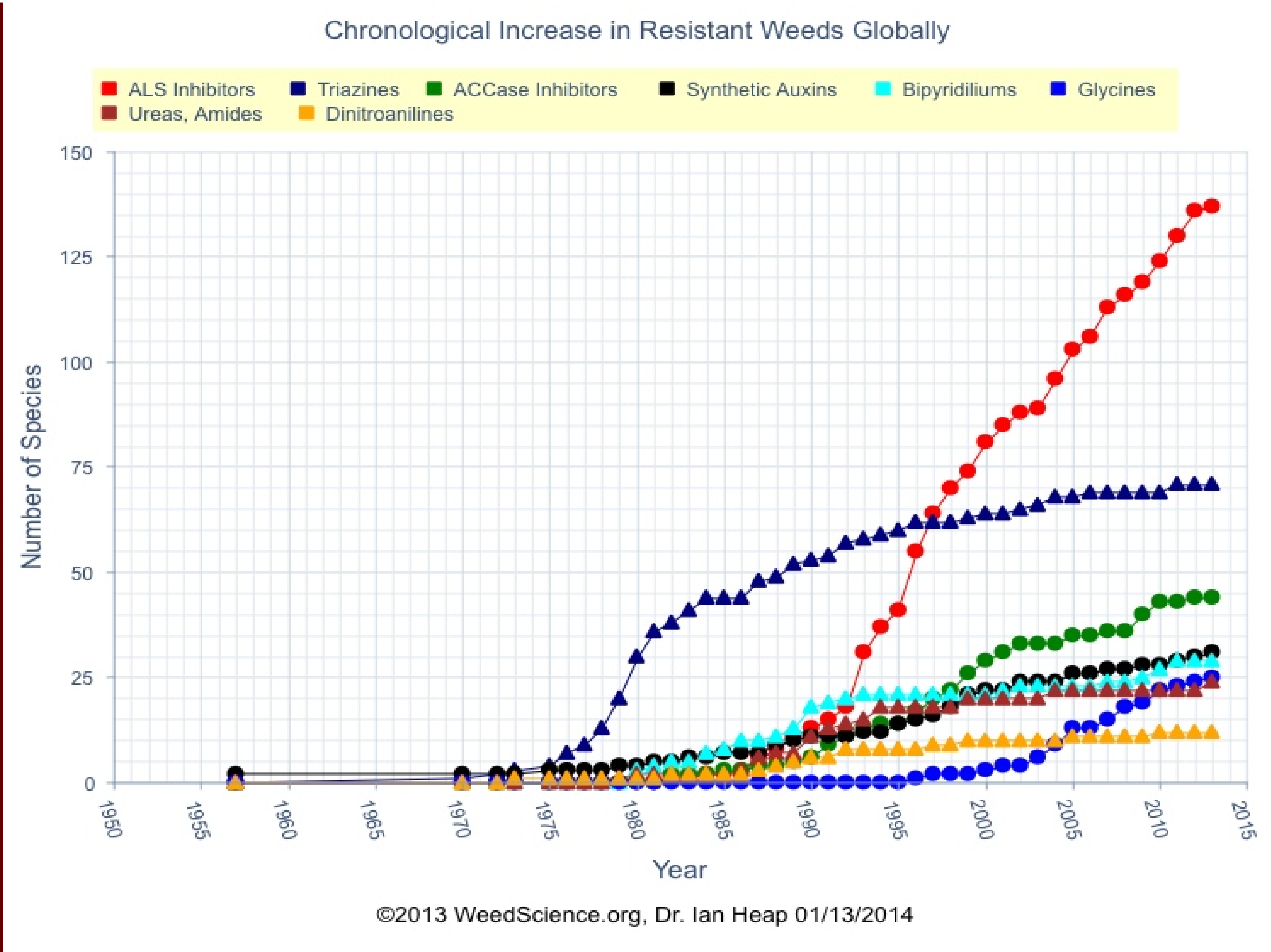

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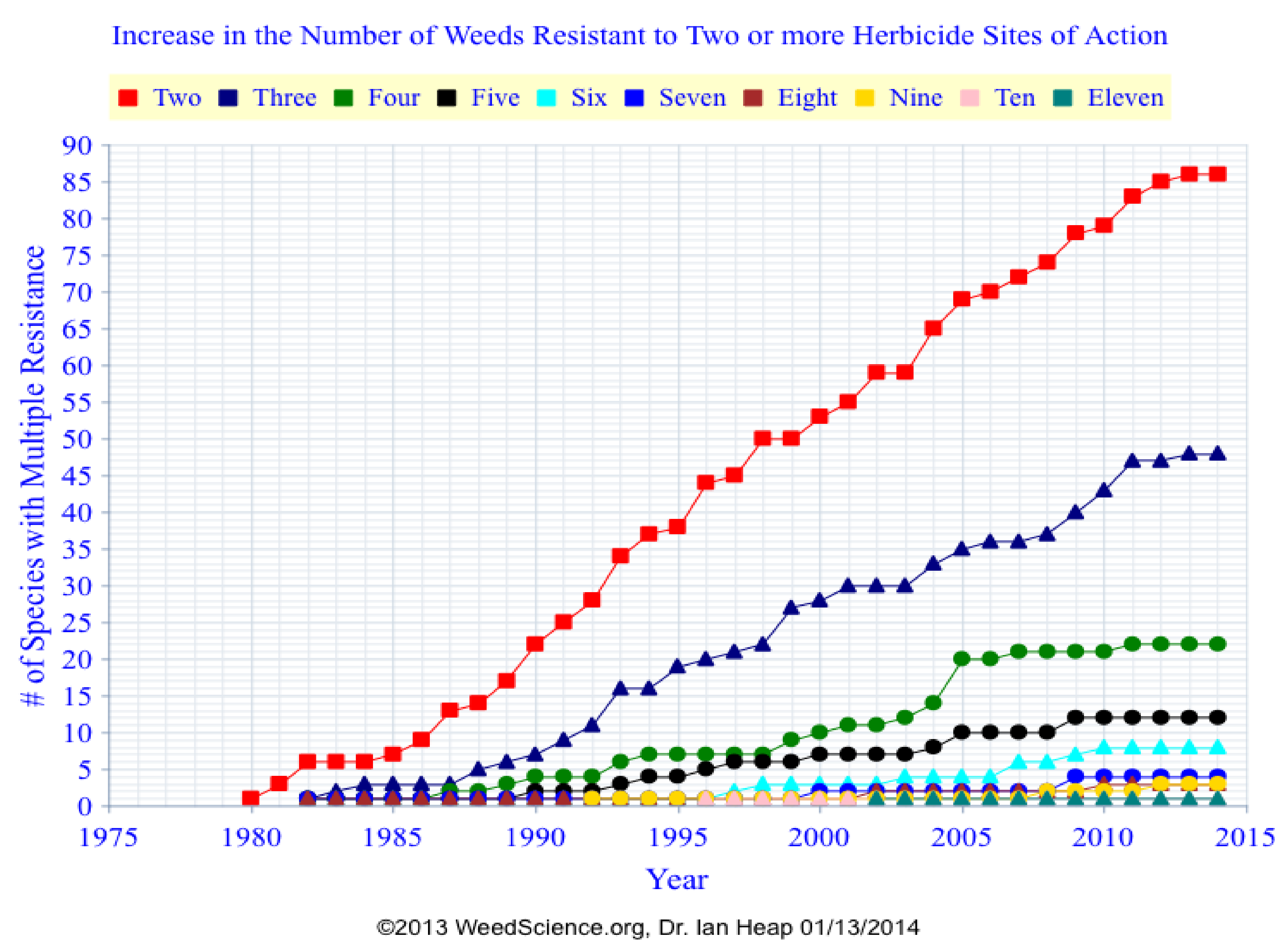
PLEASE NOTE: The graph does not necessarily plot multiple resistance in the same individual plant. Resistance to different SOA's may be found in separate populations, even in separate countries, this chart presents the cumulative number of SOA's recorded globally for a species. No Species Graph



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Palmer and Waterhemp

Palmer

- **Dioecious**
- **Tremendous seed producer**
- **Herbicide resistant**
- **ALS (#2), PSII (#5), glycines (#9), DNA (#3)**

Waterhemp

- **Dioecious**
- **Tremendous seed producer**
- **Herbicide resistant**
- **ALS (#2), PSII (#5), glycines (#9),**
- **HPPD (#27),**
- **PPO (#14), 2,4-D (#4)**

Palmer and Waterhemp

Palmer

Native to the desert Southwest

Most competitive of the Amaranth sp.

Growth rate as fast as ~2.5"/day

http://www.extension.iastate.edu/CropNews/2013/0820hartzlerpope.htm

Waterhemp

Native to the Midwest

2nd most competitive of the Amaranth sp.

Growth rate as fast as ~1.75"/day

http://southeastfarmpress.com/management/waterhemp-showing-greater-resistance-glyphosate

Hand Weeding

Hand Weeding

UT Extension

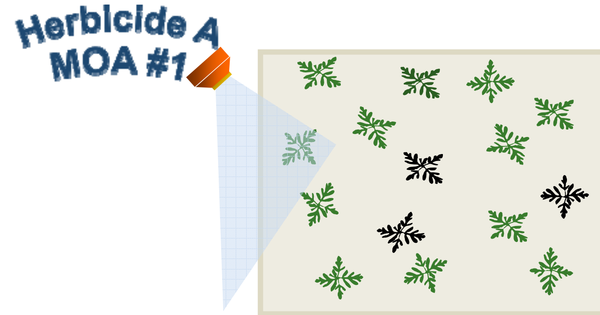
Herbicide Resistance (wssa.net/weeds/resistance)

How Herbicides Work

Herbicide Resistance Types

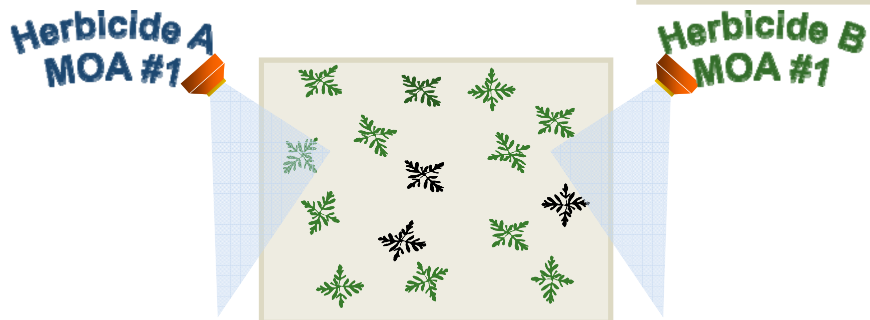
Single Herbicide Resistance

- **Resistant to only *one* herbicide**



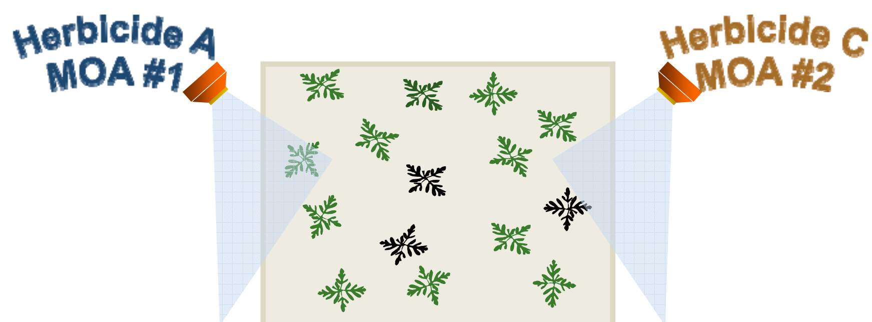
Cross Herbicide Resistance

- **Resistant to *two or more* herbicide families with *same mechanism of action***
  - **Single resistance mechanism**



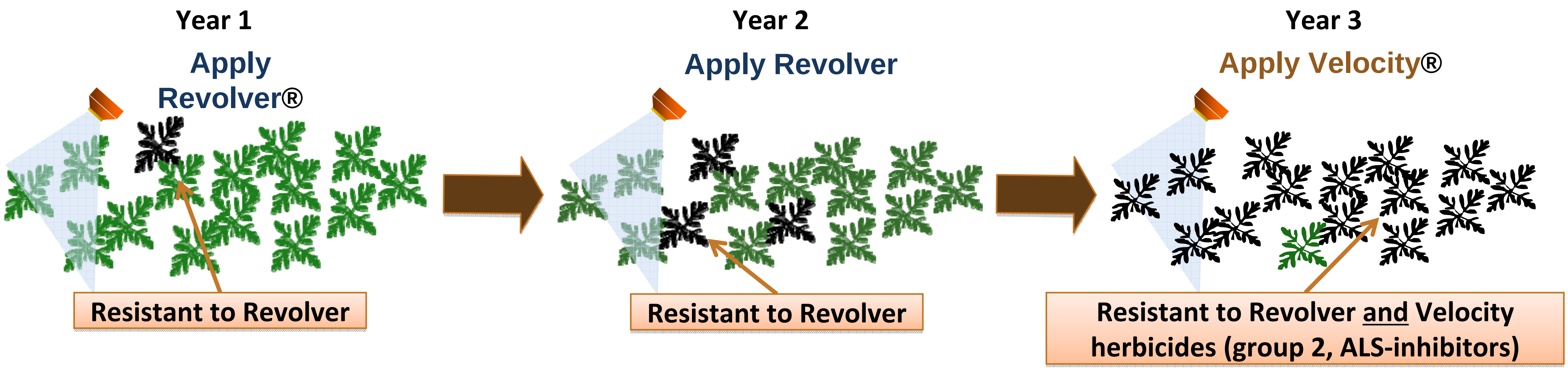
Multiple Herbicide Resistance

- **Resistant to *two or more* herbicides with *different mechanisms of action***
  - **May be the result of two or more different resistance mechanisms**



Herbicide Resistance Types: Cross Resistance

Example:

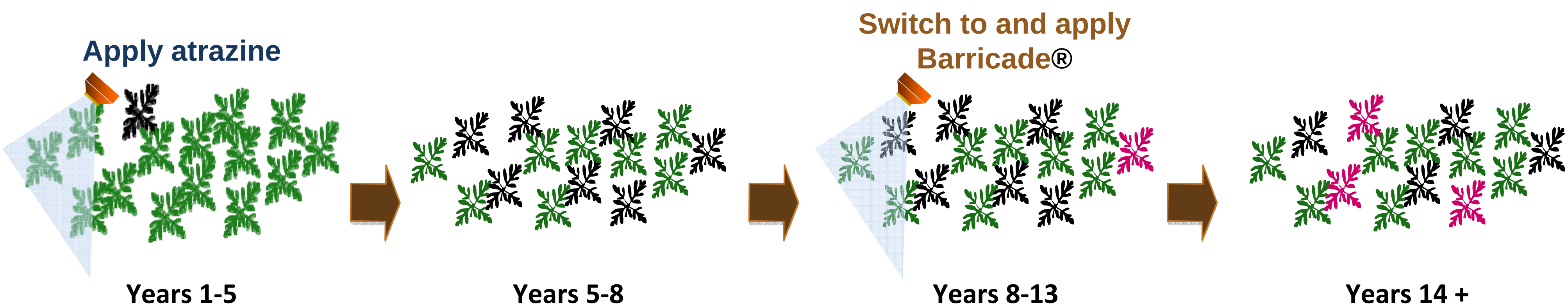


Revolver, a sulfonylurea, and Velocity, a pyrimidinyloxybenzoic acid, both belong to the ALS-inhibitors, or group 2 herbicides. Both herbicide products have the same mechanism of action.

CAUTION: Weeds that are herbicide-resistant to one member of a herbicide mechanism of action group may or may not be cross-resistant to all herbicides within that group. Consult your local extension specialist for more information.

Herbicide Resistance Types: Multiple Resistance

Example



Years 1-5	Years 5-8	Years 8-13	Years 14 +
Select for weeds resistant to group 5 herbicides (shown in black)	The population with resistance to group 5 herbicides increases	Select for weeds resistant to group 3 herbicides (shown in pink) from a population that is resistant to group 5	The population with multiple resistance to group 3 and 5 increases

Multiple resistance can occur following repeated applications of a single herbicide and selection for herbicide-resistant biotypes followed by repeated applications of another herbicide and selection for herbicide-resistant biotypes.

Conclusions

Repeated use of a herbicide selects for herbicide-resistant biotypes. Over time, the number of resistant individuals in the weed population increases until the majority of the population is herbicide-resistant.

Several factors in the field can affect the selection of herbicide-resistant weeds.

Once a weed is resistant to a single herbicide, it is possible for it to be resistant to another herbicide, with either the same or a different mechanism of action.

Herbicide Resistance Characteristics

Low-Level Resistance

- A continuum of plant responses from slightly injured to nearly dead
- The majority of plants display an intermediate response
- Susceptible plants will be present in the population, especially when herbicide resistance is determined early

Examples

Examples	
Roundup, etc.	GROUP 9 HERBICIDE
Ronstar, Dismiss, etc.	GROUP 14 HERBICIDE
Banvel, 2,4 D, etc.	GROUP 4 HERBICIDE
Gramoxone, etc.	GROUP 22 HERBICIDE

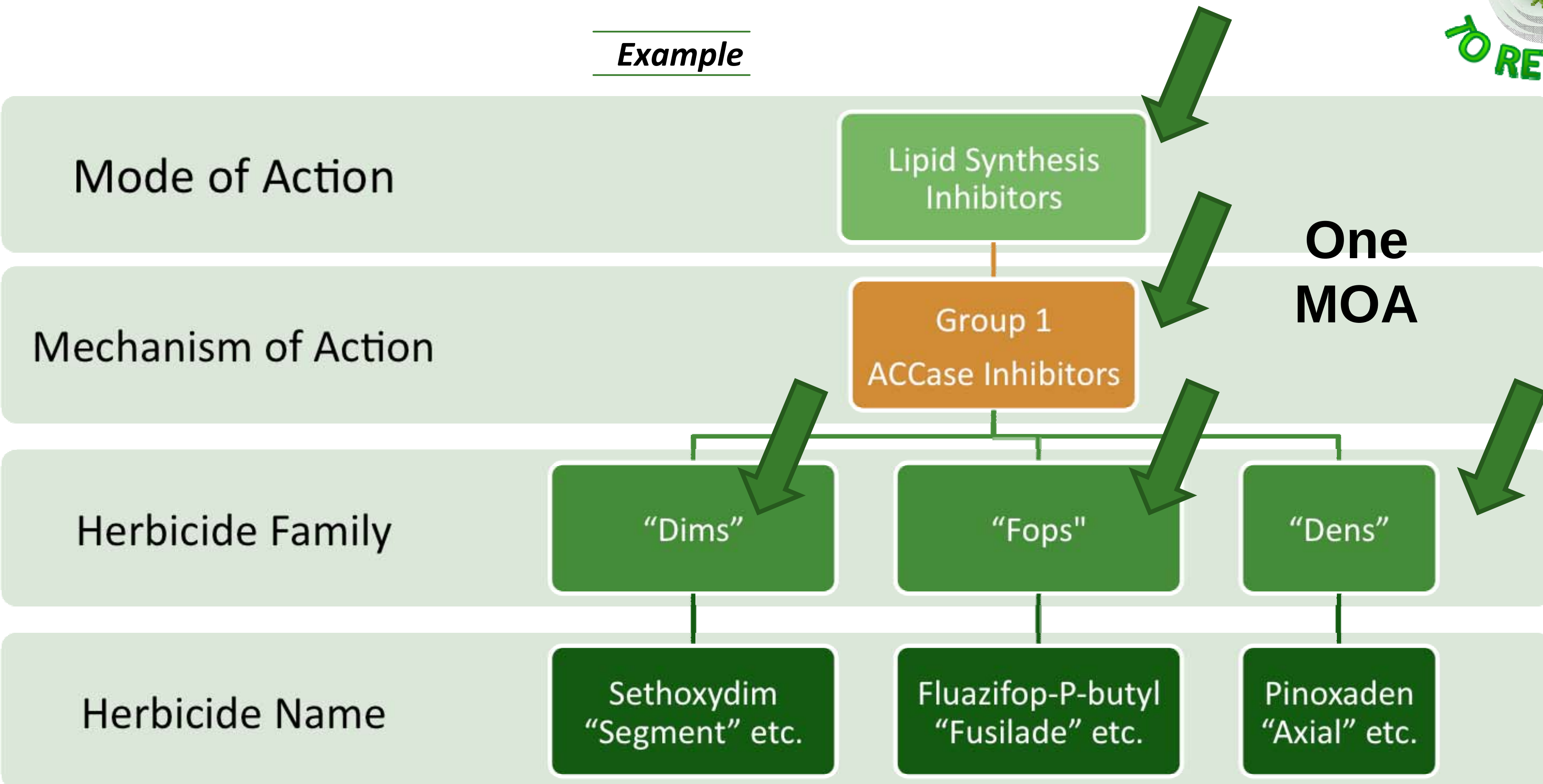
High-Level Resistance

- Plants are slightly injured to uninjured
- Few plants have an intermediate response
- Susceptible plants can be present in the population

Examples

Examples	
atrazine, Princep, Sencor, etc.	GROUP 5 HERBICIDE
Revolver, Monument, Velocity, etc.	GROUP 2 HERBICIDE
Acclaim, Fusilade, Segment, etc.	GROUP 1 HERBICIDE

Classification Hierarchy



Integrated Management

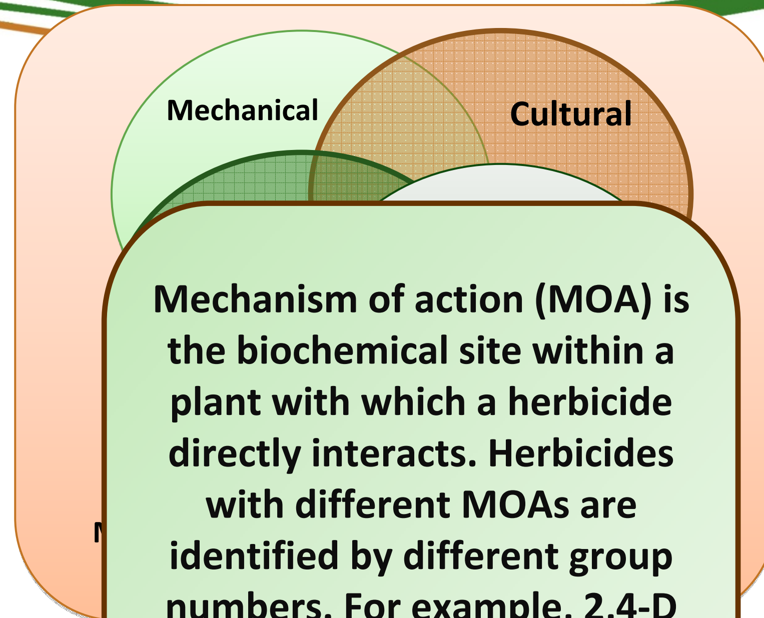
The best strategies to manage herbicide resistance in weeds are established on the concept of diversity of management practices.

Diversity can be achieved by:

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

and

Applyi[...] different[...] overlapp[...] is active o[...] target weed or weeds)



Mechanism of action (MOA) is the biochemical site within a plant with which a herbicide directly interacts. Herbicides with different MOAs are identified by different group numbers. For example, 2,4-D is a group 4 herbicide, and glyphosate is a group 9 herbicide.

[Click to close.]

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

FOR MORE INFORMATION

Proactive Management Tactics

Strategies to proactively delay herbicide resistance can include one or more of the following tactics:

Herbicide

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

Photo credits : Jim Brosnan, University of Tennessee.

Mechanical

- Cultivation
  - Timing (pre-plant, in-crop, post-harvest)
  - Frequency

Photo credits :http://masonkings.jd-dealer.co.uk/Services/Heath-Safety/Cultivator-Safety
.

Cultural

- Species and cultivar selection
- Plant population
- Fertilization
- Row spacing
- Crop Rotations
- Crop Phenology/planting harvest dates
- Fallow periods / hay or cover crops

Photo credits
:http://seasonsinthevalley.blogspot.com/2013/06/grey-county-farming-hay-harvest.html

Herbicide

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

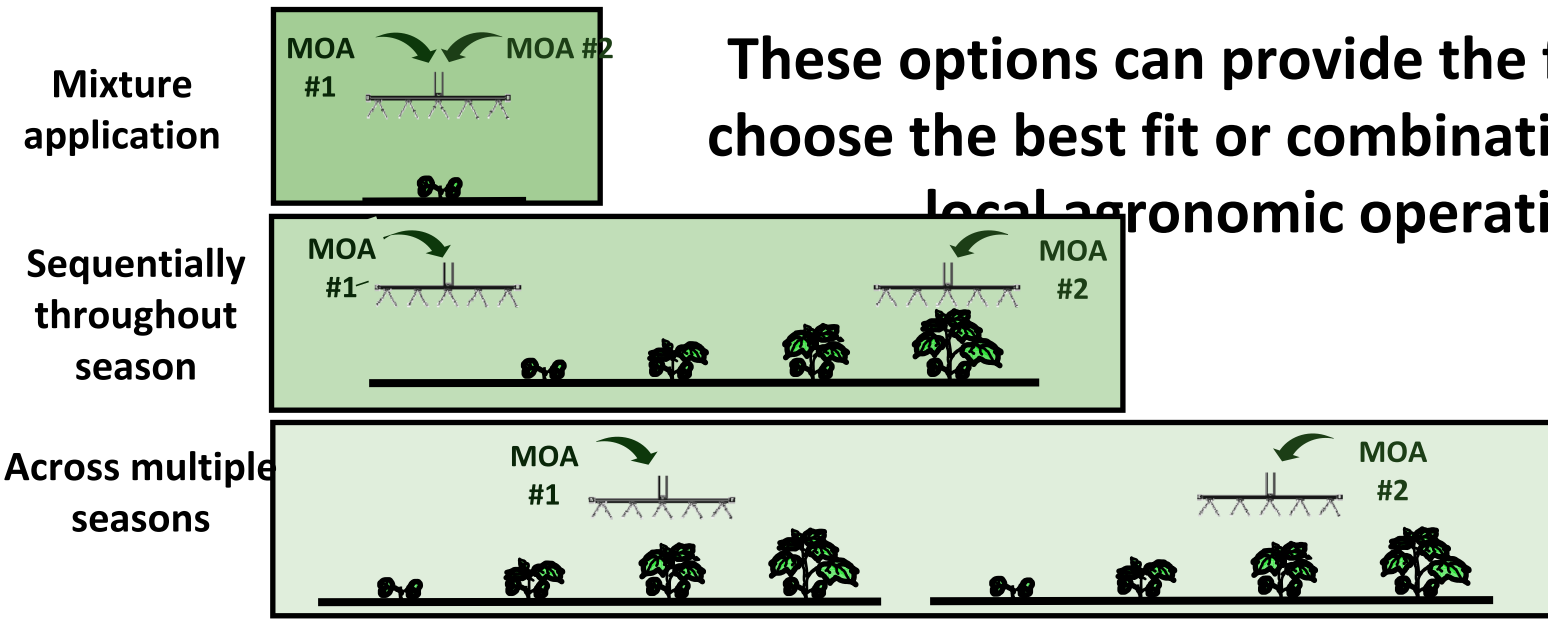
Repeated annual use of a herbicide with the same MOA in the absence of other MOAs or different management strategies can lead to resistance.

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 mechanisms of action (MOA) to manage herbicide resistance are:



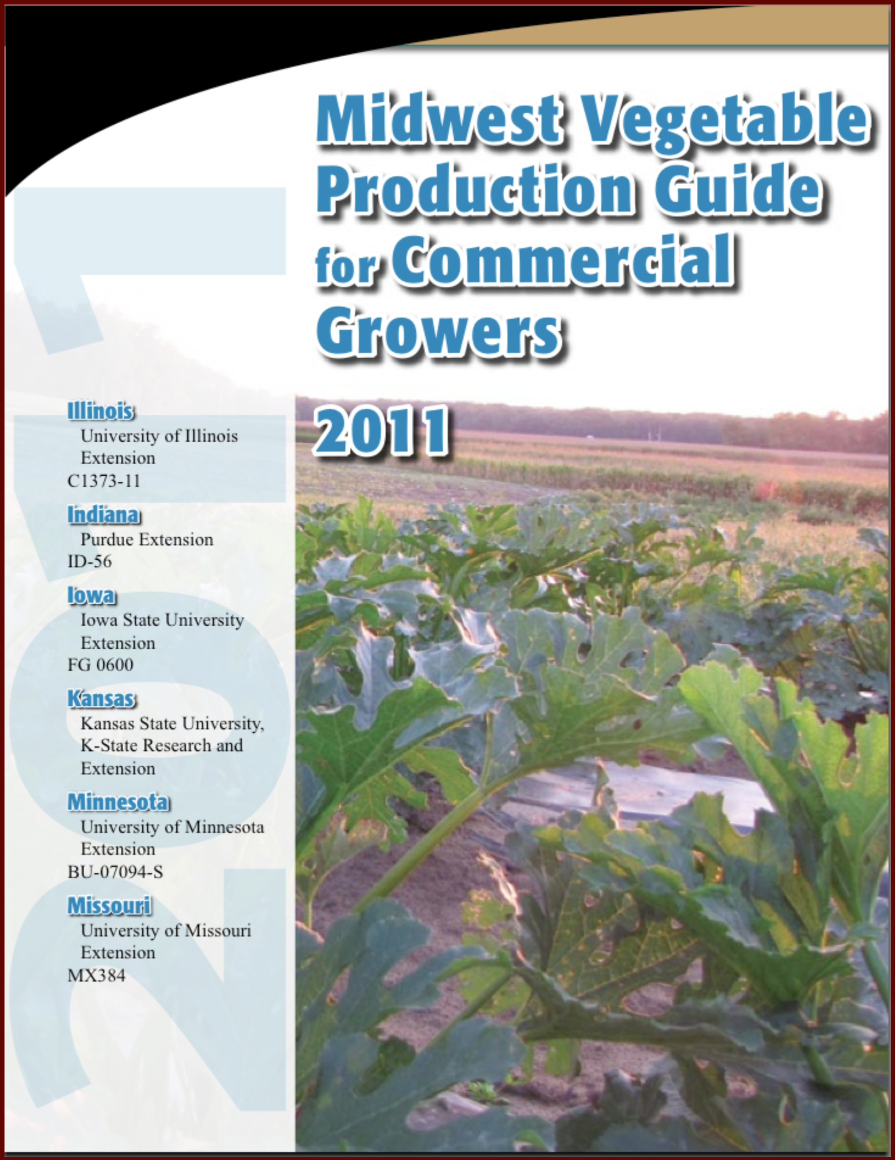
These options can provide the flexibility to choose the best fit or combinations of fit for local agronomic operations.

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.

Midwest Vegetable Production Guide for Commercial Growers

U of M contributions

Roger Becker, Vince Fritz
Bill Hutchison, Eric Burkness
Carl Rosen, Jerry Wright



http://btny.purdue.edu/Pubs/ID/ID-56/

New Herbicides In Sweet Corn

- **Future ?**
  - **Distinct (diflufenzopyr & dicamba)**
  - **Liberty (glufosinate)**
  - **Capreno?**

New Herbicides In Sweet Corn

Zidua soil applied (pyroxasulfone, BASF)

•Many grass and broadleaf weeds

•PPI, PRE

•E. POST at spiking up to V4 (4 leaf collars visible)

- Will not control emerged weeds
- Do not use adjuvants

•Seed at least 1 inch deep

•Do not exceed 2.75 oz. per acre per season on coarse soils, 5 oz. per acre per season on other soils

•37-day PHI.

New Herbicides In Sweet Corn

Zidua (pyroxasulfone, BASF)

Application Timing	Use Rate by Soil Texture[1] (ozs/A)		
	Coarse	Medium	Fine
Preplant surface	1.5 to 2.75	2.0 to 3.0	2.5 to 4.0
Preplant incorporated	1.5 to 2.75	2.0 to 3.0	2.5 to 4.0
Preemergence	1.5 to 2.75	2.0 to 3.0	2.5 to 4.0
Early postemergence	1.0 to 2.75	1.5 to 3.0	2.0 to 4.0

New Herbicides In Sweet Corn

Cadet POST (processing only?) (fluthiacet-methyl, FMC)

- **0.6-0.9 fl. oz. per acre**
- **from 2 collars to tasseling**
- **Broadleaf weeds**
  - **e.g. pigweed/waterehemp, vele, pesw, wibw, ebns, Kochia**
  - **Improves many others in T. M.**
- **Add COC or NIS**
- **Do not exceed 1.25 fl. oz. per acre per year**
- **40-day PHI**

New Herbicides In Sweet Corn

Anthem soil applied (pyroxasulfone + fluthiacet-methyl, FMC)

- Rates vary with texture, O.M.

ANTHEM fl oz/A (lb a.i./A)			
Organic Matter	**Coarse**	**Medium**	**Fine**
Less than 3%	7 - 8 (0.118-0.135)	8 - 10 (0.135-0.168)	9 - 11 (0.152-0.186)
Greater than 3%	7 - 8 (0.118-0.135)	8 - 11 (0.135-0.186)	10 - 13 (0.168-0.219)

- Controls many broadleaf and grass weeds
- 1 application per season to sweet corn
- 18-month replant restriction for all crops except corn
- 40-day PHI

New Herbicides In Sweet Corn

Anthem POST (pyroxasulfone + fluthiacet-methyl, FMC)

POST is also soil texture O.M. dependent

ANTHEM fl oz/A (lb a.i./A)		
COARSE	**MEDIUM**	**FINE**
5 - 8 (0.084-0.135)	6 - 9 (0.101-0.152)	7 - 12 (0.118-0.202)

- NIS or a silicone-based SU @ 8 fl. oz. / 25 gals. solution
- COC or MSO at 1-2 pts. /A
- may add UAN at 1-2 qts. /A or AMS

•Controls some broadleaf weeds < 2in. in height

New Herbicides In Sweet Corn

Anthem POST

- May temporarily injure sweet corn
  - If foliage is wet at application
  - Do not irrigate w/in 4 hr. of application
  - Some varieties sensitive
- 1 application per season
- 18-month replant restriction all crops except corn
- 40-day PHI

Soil Applied Herbicide Options

Preemergence options

- Annual grasses:
  - Metolachlor products, Outlook, Micro-Tech, Prowl, Define, Acetochlor products (Harness, Surpass), Eradicane, Zidua, Anthem
- Annual broadleaves:
  - Atrazine, Princep, Callisto, Zidua, Anthem

Premixes

- G-Max Lite (Outlook + atrazine)
- Bicep Lite II Magnum (Dual II Magnum + atrazine)
- Bullet or Lariat (Micro-Tech + atrazine)
- Camix, Lumax, Lexar
- Anthem ATZ

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Postemergence Herbicide Options

Annual grasses

- **Accent*, Accent Q***
- **Poast, Poast Plus (Poast Protected varieties)**
- **Option***

Annual broadleaves

- **Aim**
- **Anthem, (early, ATZ)**
- **Atrazine***
- **Basagran**
- **Cadet**
- **Callisto**
- **Impact***
- **Laudis***
- **Permit/Sandea**
- **Starane**
- **Stinger**
- **2,4-D**

*** Activity on grasses and broadleaves**

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Postemergence Herbicide Options (Cont.)

POST Package Mixtures

- Laddok (atrazine + Basagran)
- Priority (Aim + Permit / Sandea)

Roundup Tolerant Lines

- Roundup   New as of 2012

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The Underlying Cause of Weed Species Shifts

- A lack of diversification of weed management and other primary agronomic practices such as tillage and crop rotation

- Economics and time / labor management are often the primary reasons behind this lack of diversification

Recommendations Specific to glyphosate

- *Consider sequential herbicide programs using a soil-applied herbicide with a different site of action.*
- *Spray weeds at the proper time and with the proper rate.*
- *Avoid continuous glyphosate-resistant crops.*
- *Consider the advantages and disadvantages of the continued use of one herbicide versus rotation of herbicides.*

Weed Management in a Glyphosate Dominated World

Weed species shift potential

- The potential exists but which species?

Durable weed management strategies

- Diversification increases durability

Economics of corn and soybean weed management strategies

- You can pay now ($) or pay later (weed shifts)
- Factor time and labor management into your economic equation

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Species Shifts

Change in weed infestation

- **Species**
- **Biotypes**

Why?

- **No control tactic is equally effective against all weeds**

What Does Glyphosate Resistance Look Like?

Photo Credits to Dave Nicolai & Jeff Stachler

Weed Management in a Glyphosate Dominated World

Jeffrey L. Gunsolus

Extension Weed Science

gunso001@umn.edu

612-625-8130

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