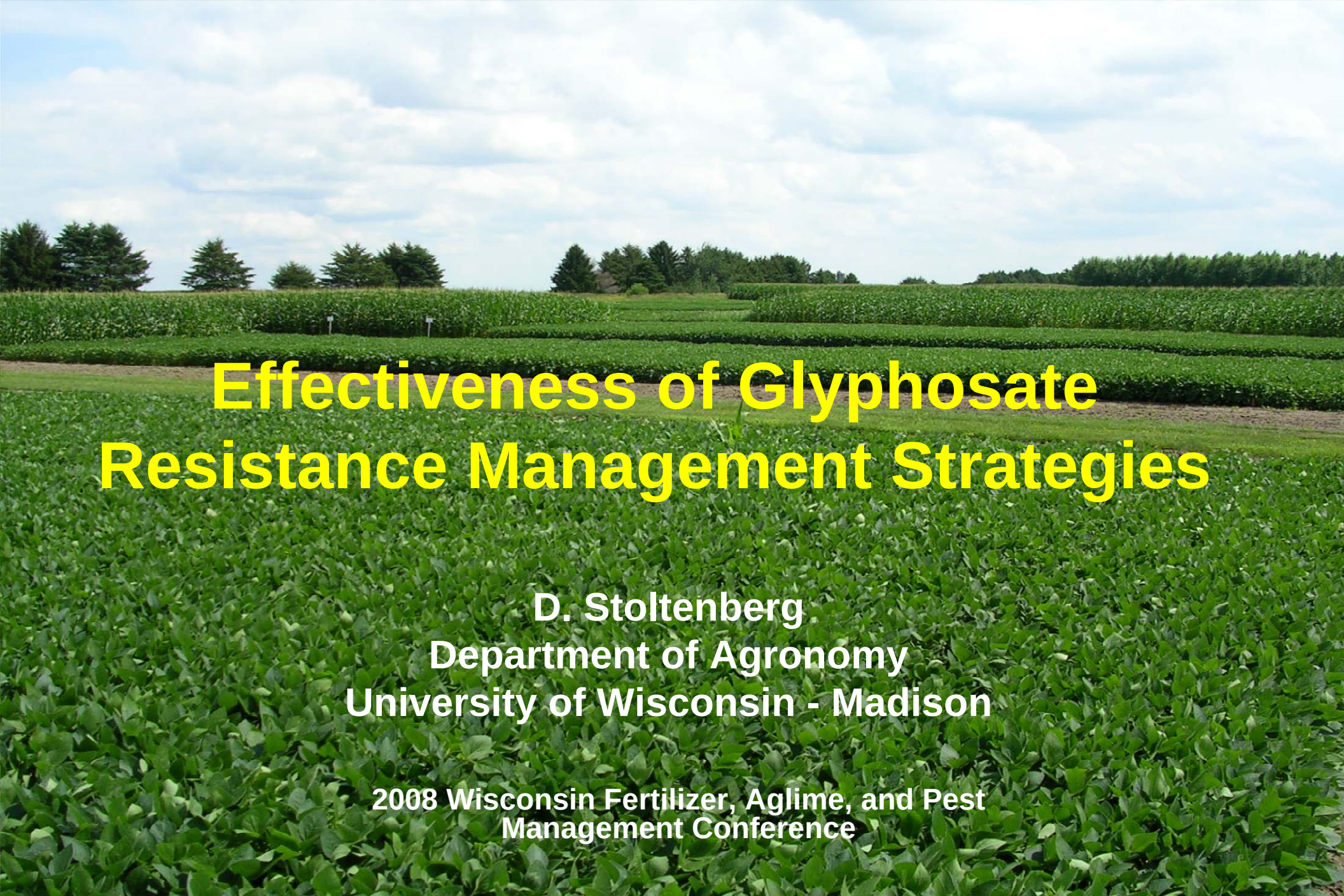

Effectiveness of Glyphosate Resistance Management Strategies

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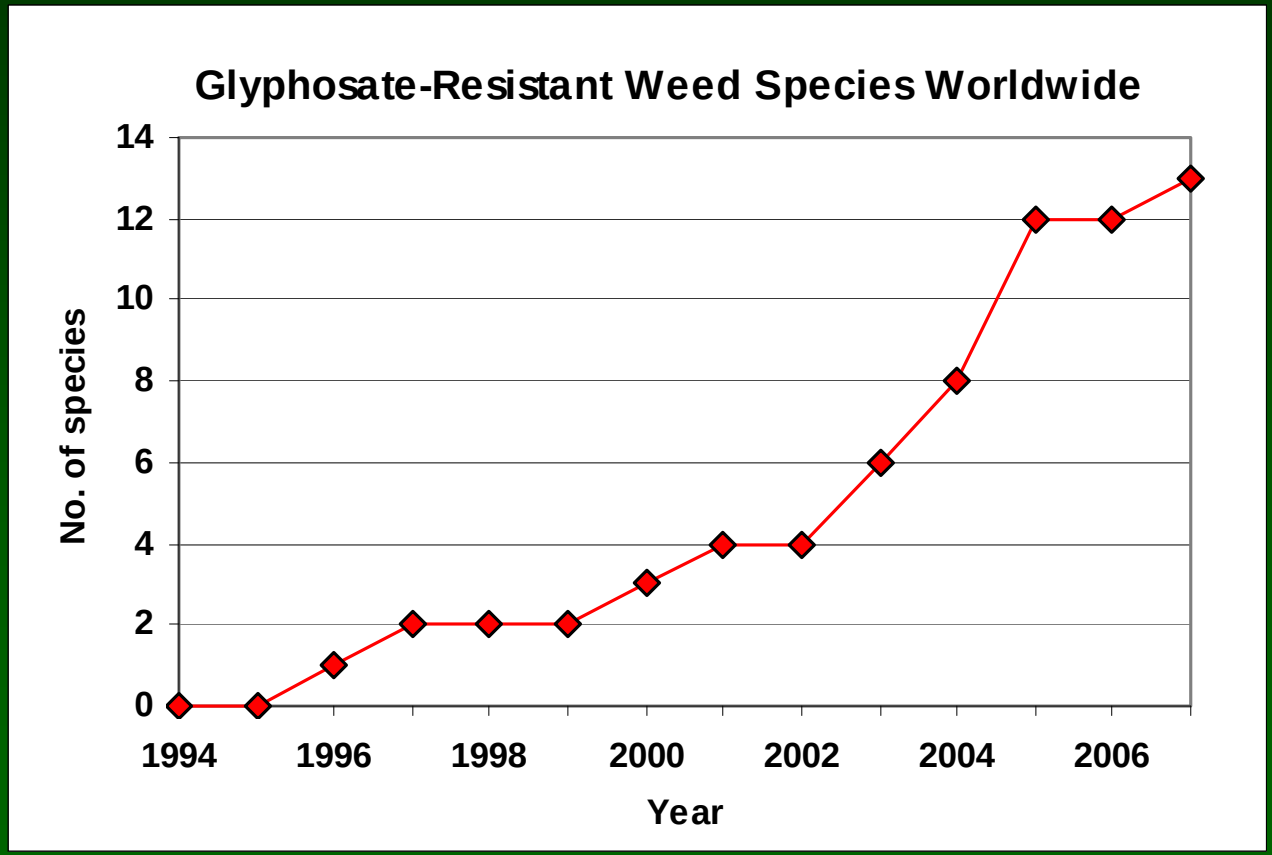
2008 Wisconsin Fertilizer, Aglime, and Pest Management Conference

Presentation Outline

- Background
  - Occurrence of glyphosate-resistant weeds
  - Glyphosate resistance management strategies
  - Factors affecting resistance development
- Do integrated weed management strategies reduce the probability of resistance to glyphosate?
  - Long-term assessment under field conditions

Confirmed Cases of Glyphosate-Resistant Weed Species

1996 – Rigid ryegrass
1997 – Goosegrass
2000 – Horseweed
2001 – Italian ryegrass
2003 – Buckhorn plantain
Hairy fleabane
2004 – Common ragweed
Giant ragweed
2005 – Common waterhemp
Johnsongrass
Palmer amaranth
Wild poinsettia
2007 – Junglerice



(Heap 2007, www.weedscience.org)

Glyphosate Resistance Management Strategies

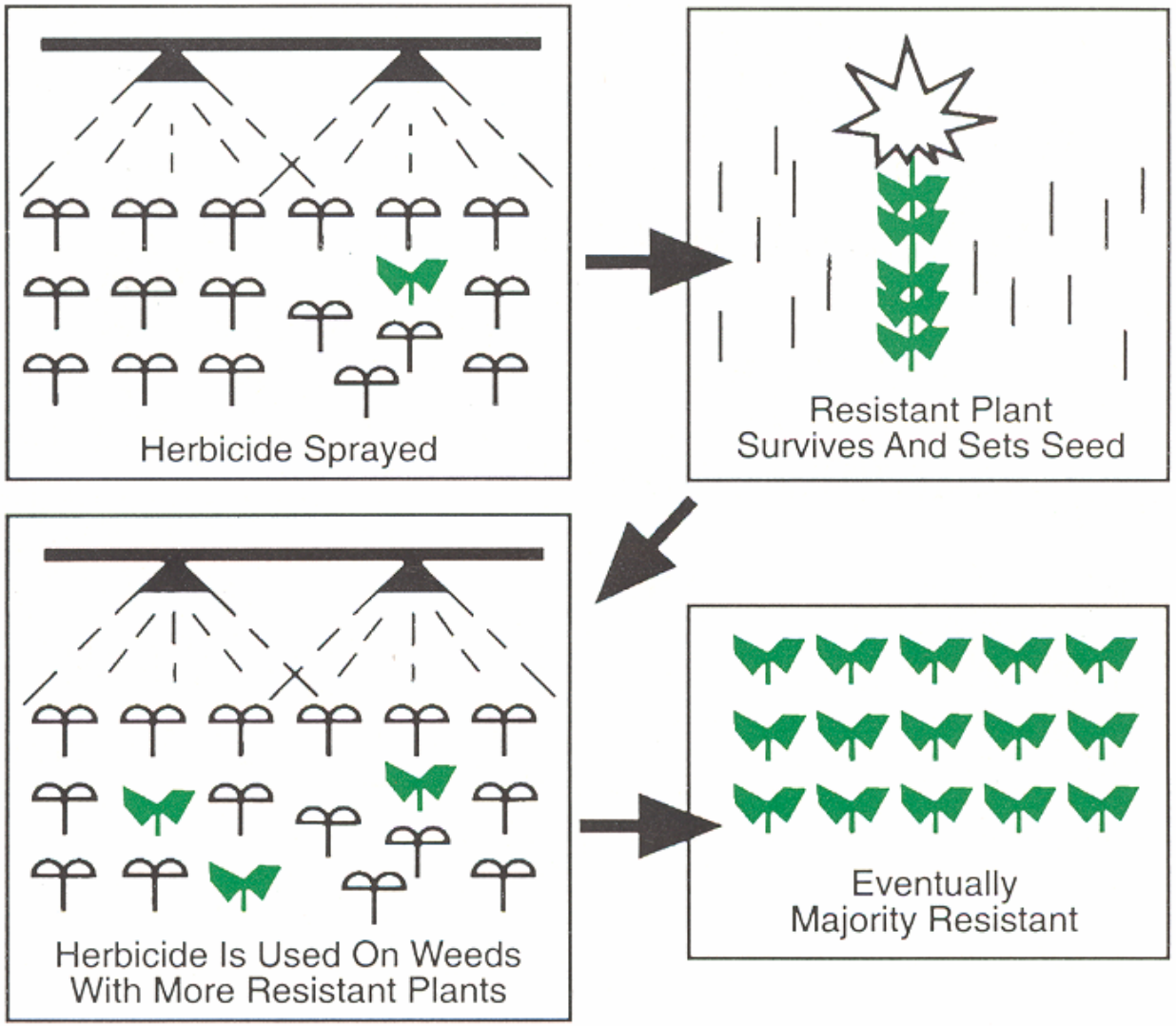
- **Rotate Roundup Ready and conventional crops**
- **Rotate glyphosate with different mode of action herbicides**
- **Apply a residual herbicide before glyphosate**
  - **or tank mix another herbicide with glyphosate**
- **Avoid more than two glyphosate applications to a field over a 2-year period**
- **Tank mix glyphosate applied burndown with a herbicide that has a different mode of action if glyphosate is also applied in-crop**
- **Use cultivation and other mechanical weed management practices**

(Boerboom and Owen 2006)

How Does Selection For Herbicide Resistance Occur?

Susceptible Weed

Resistant Weed



(Adapted from Gunsolus 1993)

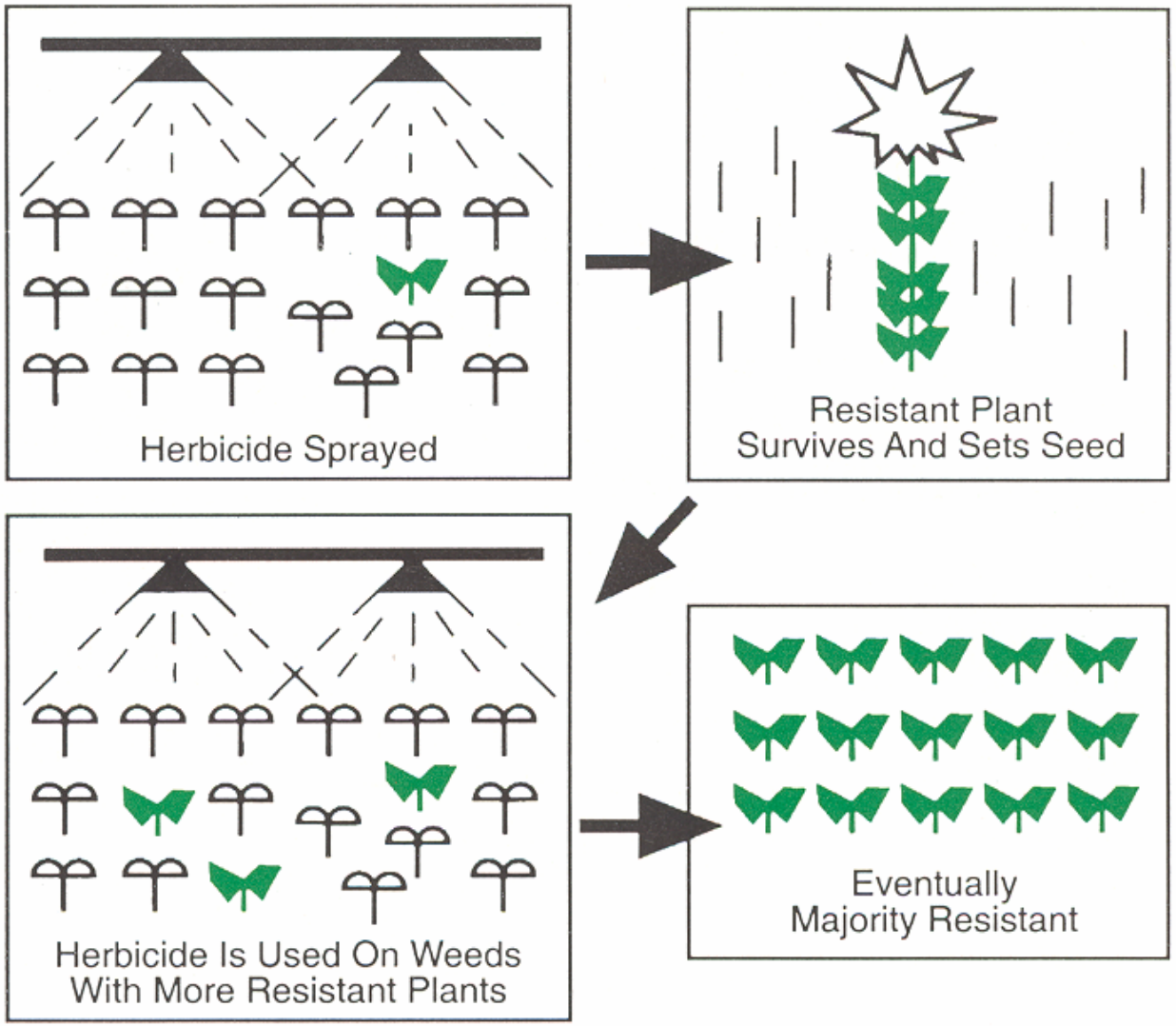
What is the likelihood of resistance occurring?

- How common are resistance traits?
  - Traits originate from natural genetic change
  - Are resistance traits relatively common or rare?
    - Common? 1 in 1,000,000 (10^{-6})
    - Rare? 1 in 1,000,000,000,000 (10^{-12})
- How many weeds are exposed to a herbicide mode of action over time?
  - What is the effectiveness and frequency of herbicide use?
- How are traits inherited and how do they move?
  - Do traits move to other plants by pollen?

How Does Selection For Herbicide Resistance Occur?

Susceptible Weed

Resistant Weed



(Adapted from Gunsolus 1993)

What is the likelihood of weed resistance occurring?

Frequency of resistance trait	Weed density		Probability of resistance	
	Weeds/10 ft^2	Weeds/75 acres		%
1 in 10^{10}	1	300,000	0.00006	0.006
	5	1.6 million	0.0003	0.03
	50	16 million	0.003	0.3
	500	160 million	0.03	3.0

1 in 10^{10} = 1 in 10,000,000,000

(Adapted from Jasieniuk et al. 1996)

Assessment of Glyphosate Resistance Management Strategies

UW-Arlington Ag Research Station
1998-2005

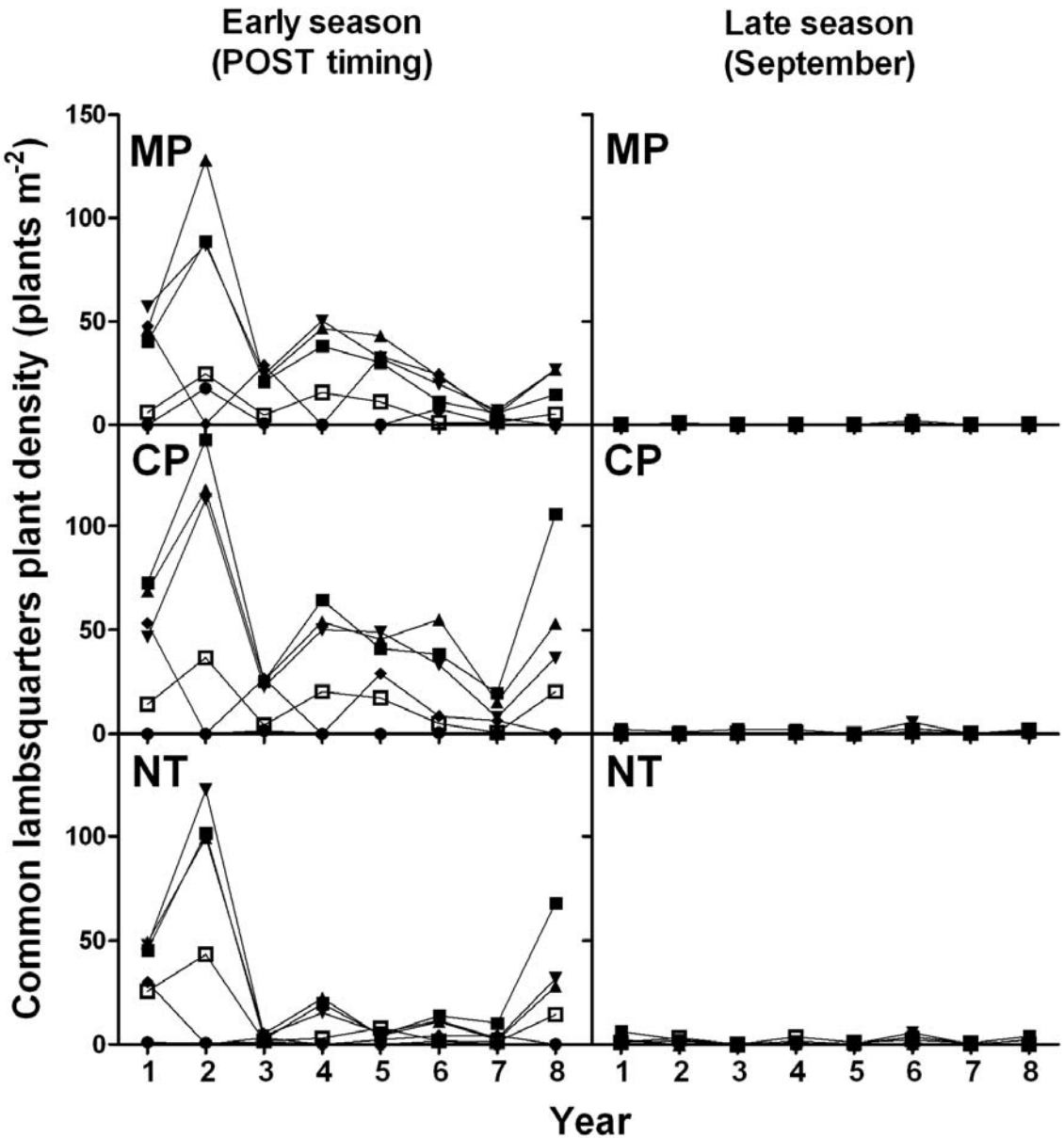
Estimating the Likelihood of Weed Resistance

- Resistance probability model (Jasieniuk et al. 1996)
  - Predicts the frequency of resistant plants (genotypes)
- Data inputs
  - Number of weeds exposed to glyphosate over time
    - Giant foxtail
    - Redroot pigweed
    - Common lambsquarters
    - Velvetleaf
    - Giant ragweed
  - Species-specific outcrossing rates
  - Frequency of resistance trait set at 1 in 10 billion (10^{-10})

Weed Management Treatments

	SOYBEAN Even years (1998-2006)	CORN Odd years (1999-2005)
1.	Glyphosate POST	Glyphosate POST
2.	Glyphosate POST	Glyphosate POST fb LPOST
3.	Glyphosate POST	Glyphosate POST fb cultivation
4.	Glyphosate POST	Non-glyphosate herbicides
5.	Metolachlor PRE fb Gly POST	Metolachlor PRE fb Gly POST

Common Lambsquarters Plant Density 1998-2005



- ■ Gly POST
- ▲ Gly POST (soybean)
  Gly POST fb LPOST (corn)
- ▼ Gly POST (soybean)
  Gly POST fb cultivation (corn)
- ♦ Gly POST (soybean)
  Non-glyphosate herbicides (corn)
- □ Metolachlor PRE fb Gly POST
- ● Non-glyphosate herbicides

Probability of Giant Foxtail Resistance 1998-2005

Across tillage systems

Weed management treatment	Number of plants treated 1998-2005	Probability of resistance	Relative probability of resistance[a]
	Millions / 75 acres	%	
Gly POST	388	3.8 c[b]	47 c
Gly POST fb LPOST[c]	303	3.0 c	37 c
Gly POST fb cultivation[c]	220	2.2 c	27 c
Gly POST // Non-Gly rotation	83	0.8 b	10 b
Metolachlor PRE fb Gly POST	8	<0.1 a	1 a

[a]Probability of resistance relative to the lowest probability among treatments.
[b]Means followed by the same letter within a column do not differ at the 5% level of significance.
[c]LPOST and cultivation in corn only.

Probability of Redroot Pigweed Resistance 1998-2005

Chisel Plow

Weed management treatment	Number of plants treated 1998-2005	Probability of resistance	Relative probability of resistance[a]
	Millions / 75 acres	%	
Gly POST	96	1.0 c[b]	21 c
Gly POST fb LPOST[c]	256	2.7 d	55 d
Gly POST fb cultivation[c]	102	1.1 c	22 c
Gly POST // Non-Gly rotation	22	0.2 b	5 b
Metolachlor PRE fb Gly POST	4	<0.1 a	1 a

[a]Probability of resistance relative to the lowest probability among treatments.
[b]Means followed by the same letter within a column do not differ at the 5% level of significance.
[c]LPOST and cultivation in corn only.

Probability of Lambsquarters Resistance 1998-2005

Chisel Plow

Weed management treatment	Number of plants treated 1998-2005	Probability of resistance	Relative probability of resistance[a]
	Millions / 75 acres	%	
Gly POST	280	2.8 b[b]	5 b
Gly POST fb LPOST[c]	186	1.9 ab	3 ab
Gly POST fb cultivation[c]	189	1.9 ab	3 ab
Gly POST // Non-Gly rotation	62	0.6 a	1 a
Metolachlor PRE fb Gly POST	86	0.9 a	1 a

[a]Probability of resistance relative to the lowest probability among treatments.
[b]Means followed by the same letter within a column do not differ at the 5% level of significance.
[c]LPOST and cultivation in corn only.

Probability of Velvetleaf Resistance 1998-2005

Across tillage systems

Weed management treatment	Number of plants treated 1998-2005	Probability of resistance	Relative probability of resistance[a]
	Millions / 75 acres	%	
Gly POST	29	0.3 b[b]	2 b
Gly POST fb LPOST[c]	34	0.4 b	2 b
Gly POST fb cultivation[c]	39	0.4 b	3 b
Gly POST // Non-Gly rotation	15	0.2 a	1 a
Metolachlor PRE fb Gly POST	24	0.3 b	2 b

[a]Probability of resistance relative to the lowest probability among treatments.
[b]Means followed by the same letter within a column do not differ at the 5% level of significance.
[c]LPOST and cultivation in corn only.

Summary

- The lowest probabilities of giant foxtail, redroot pigweed, and common lambsquarters resistance:
  - *S*-metolachlor PRE integrated with glyphosate POST
  - Glyphosate POST rotated annually with non-glyphosate herbicides
- The lowest probability of velvetleaf resistance:
  - Glyphosate POST rotated annually with non-glyphosate herbicides
- The probability of giant ragweed resistance did not differ among weed management treatments, but increased over time
- Integrated weed management strategies, particularly the use of effective non-glyphosate herbicides, are important for reducing the likelihood of weed resistance to glyphosate