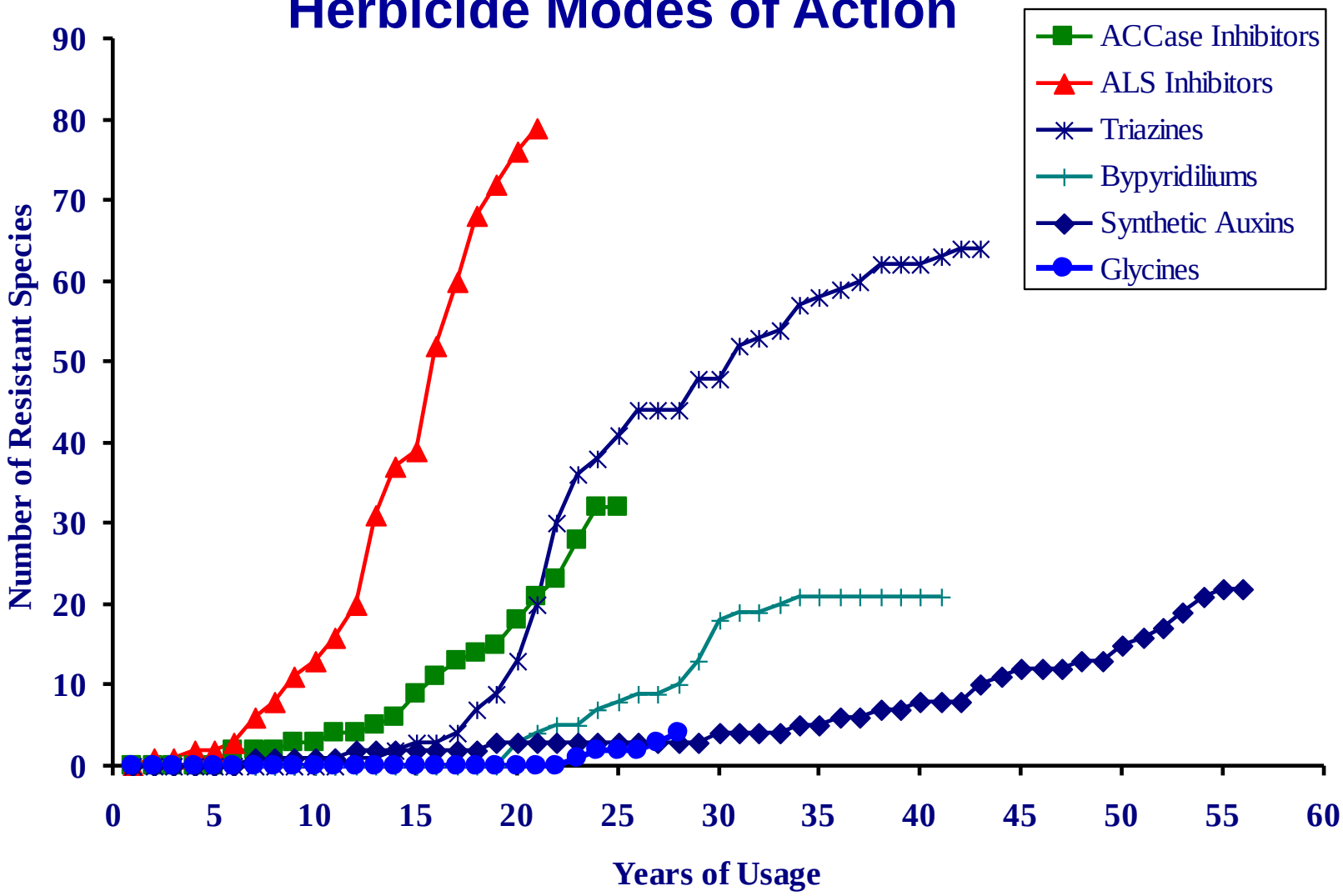
Avoiding Herbicide Resistance in the Developing World

- R. L. Nichols, Cotton Incorporated
- N. Burgos, Univ. of Arkansas
- A. Lawton-Rauh, Clemson Univ.
- J. Norsworthy, Univ. of Arkansas
- V. K. Vencill, Univ. of Georgia
- M. Bagavathianan, Texas A&M University

Cumulative Summary of Weed Species Resistant to Herbicide Modes of Action

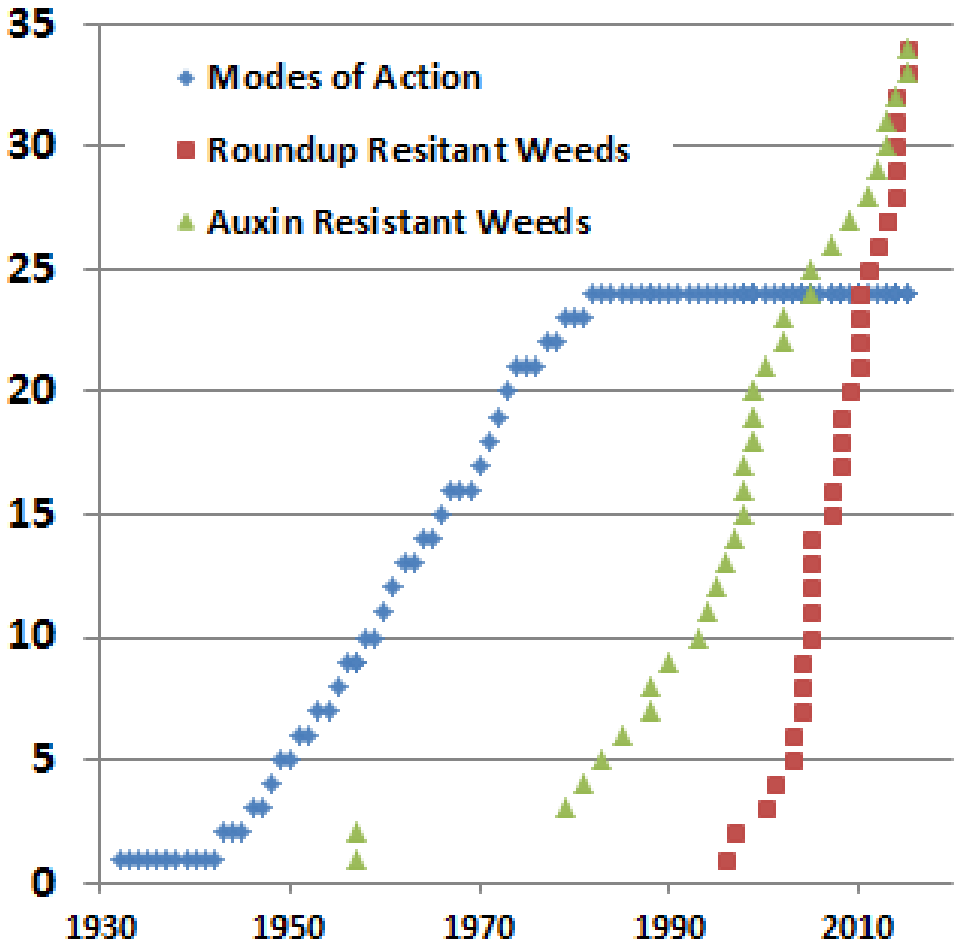


The Emerging Threat to Weed Management in U. S. Agriculture

70% of all U. S. Pesticide Costs are for Herbicides.

Discovery of New Herbicide Mechanisms of Action has Stalled.

Weeds Keep Gaining Resistance.



Developments in Economics and Agricultural Technology are Parallel

- Herbicides are widely used in the major grain producing areas of the world – Europe, North & South America, and Australia
- Moderately used in Asia
- Little use in Africa

Avoiding Herbicide Resistance

Evolution of Weed Resistance to Herbicides

Resistance is a function of

the size weed population, and

the intensity of selection

- **number of herbicide applications,**
- **frequency and management.**

A Specific Incidence of Weed Resistance in an Agronomic Crop

Palmer amaranth (*Amaranthus palmeri*) in Cotton (*Gossypium hirsutum*)

- **Cotton seedlings are weak competitors**
- **Palmer amaranth is very fast growing weed and a prolific seed producer**
- **Palmer amaranth populations are resistant to glyphosate, ALS, and PPO herbicides**

Two Dioecious amaranths in North America

- *Amaranthus tuberculatus* – Tall Waterhemp
  - Midwest; heavy soils - South Central
- *Amaranthus palmeri* – Palmer amaranth, Palmer pigweed
  - light soils - South & many soils Southwest

- The two dicots resistant to the most herbicide modes of action (6 each)
  - *A. palmeri* is invading the Midwest

Dioecious Amaranth *Species;* aka Pigweeds

Palmer Amaranth

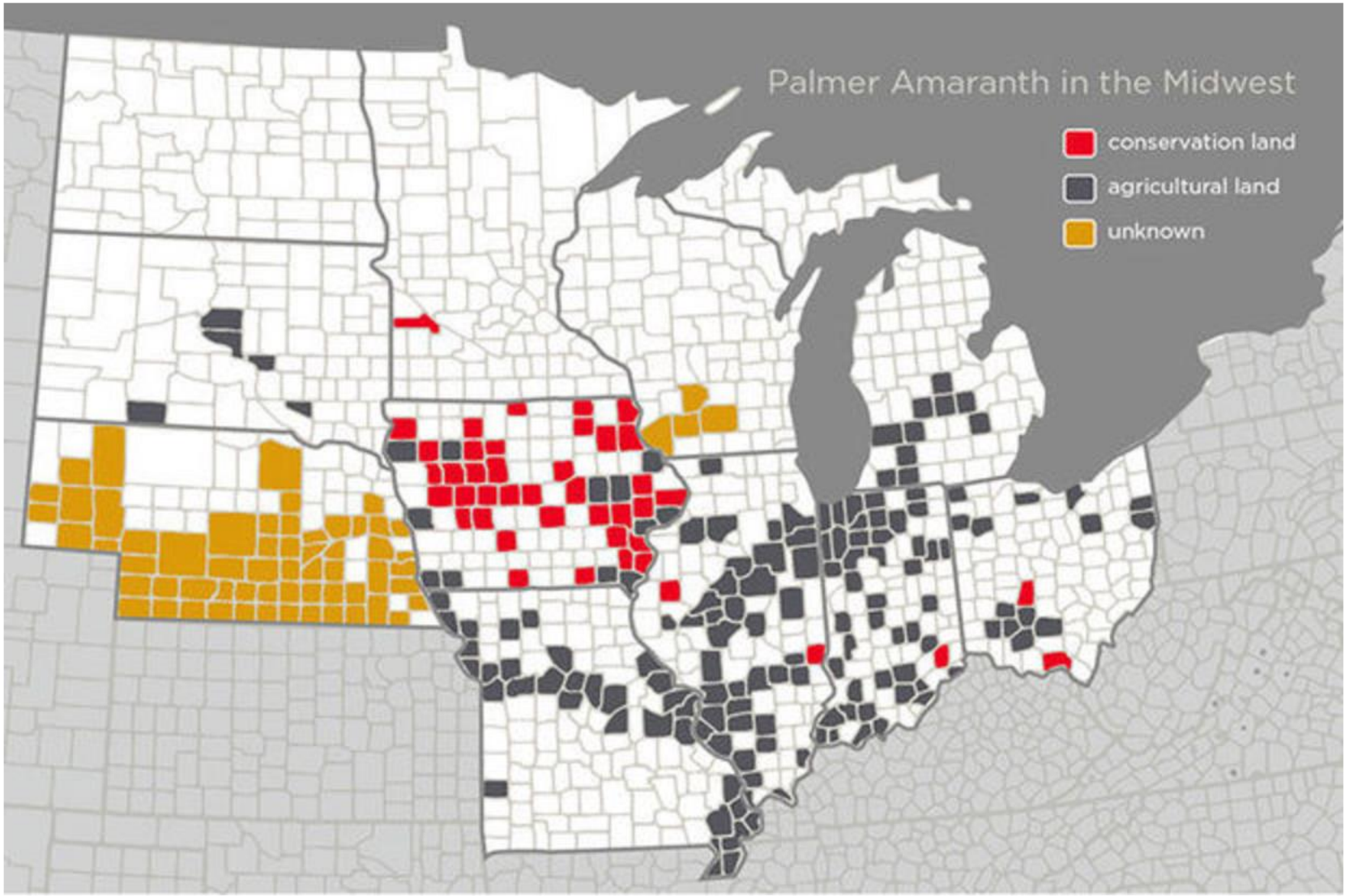
Waterhemp

Amaranthus palmeri

A dioecious annual herbaceous weed, growing to 1.5-3.0 m producing approx. 500,000 seed/year


Palmer amaranth
escapes
in cotton


Glyphosate-Resistant Palmer amaranth
impeding cotton harvest

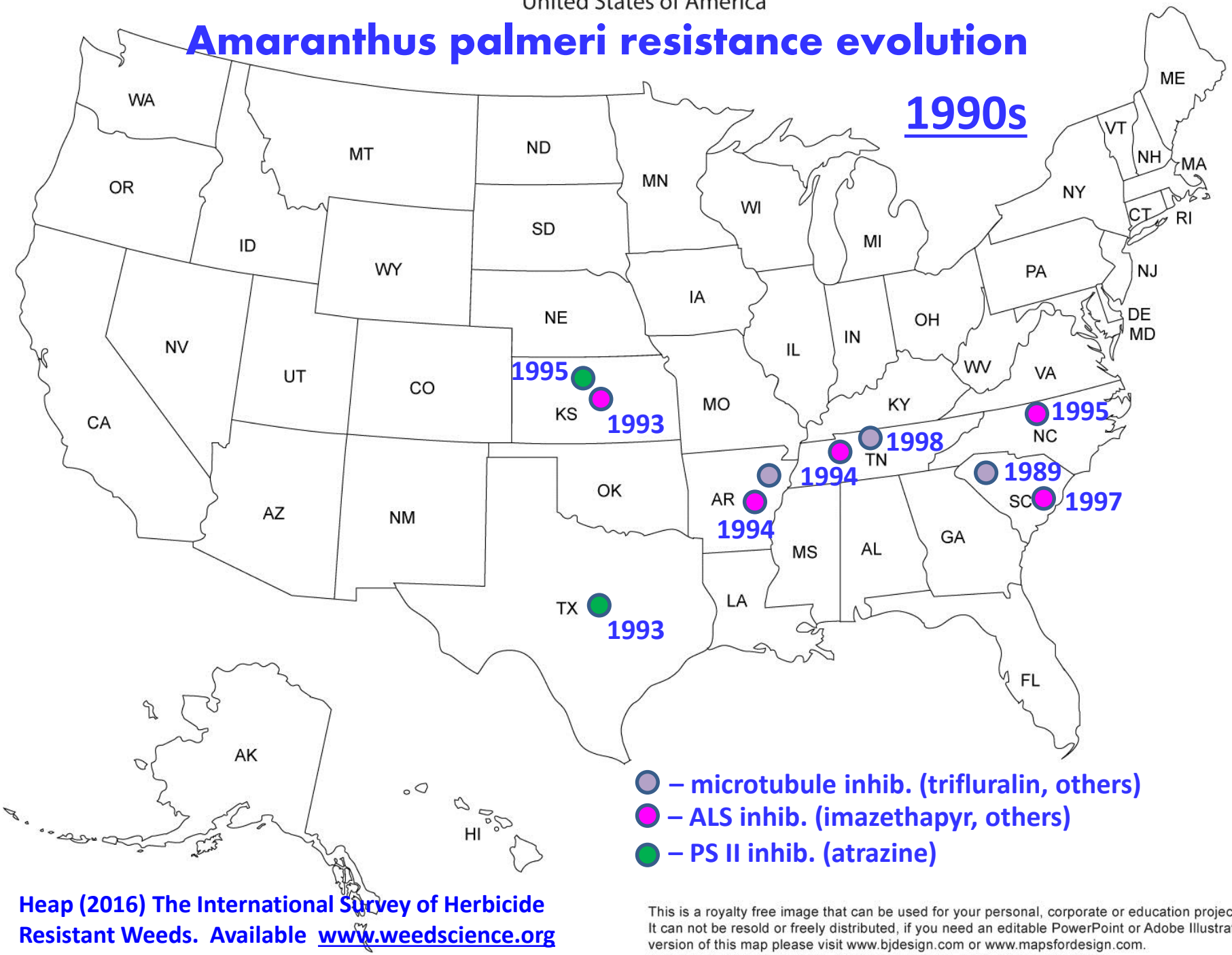


Weed scientists are finding Palmer amaranth across the Midwest. Counties in gray indicate Palmer amaranth was first found in an agricultural field, whereas red indicates it was first detected on conservation program land. Yellow signifies the source of introduction was not identified.

United States of America

Amaranthus palmeri resistance evolution

1990s



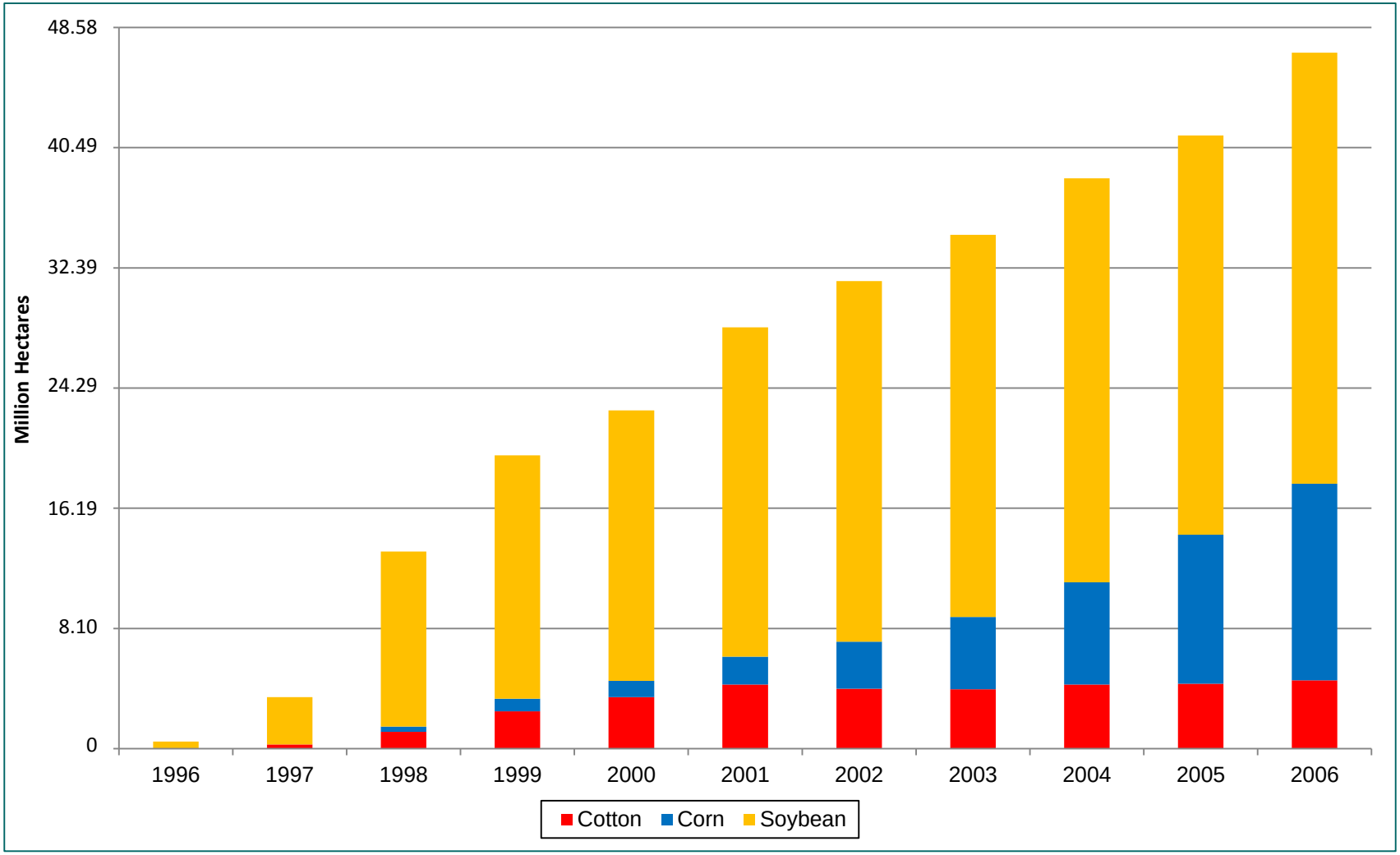
– microtubule inhib. (trifluralin, others)

– ALS inhib. (imazethapyr, others)

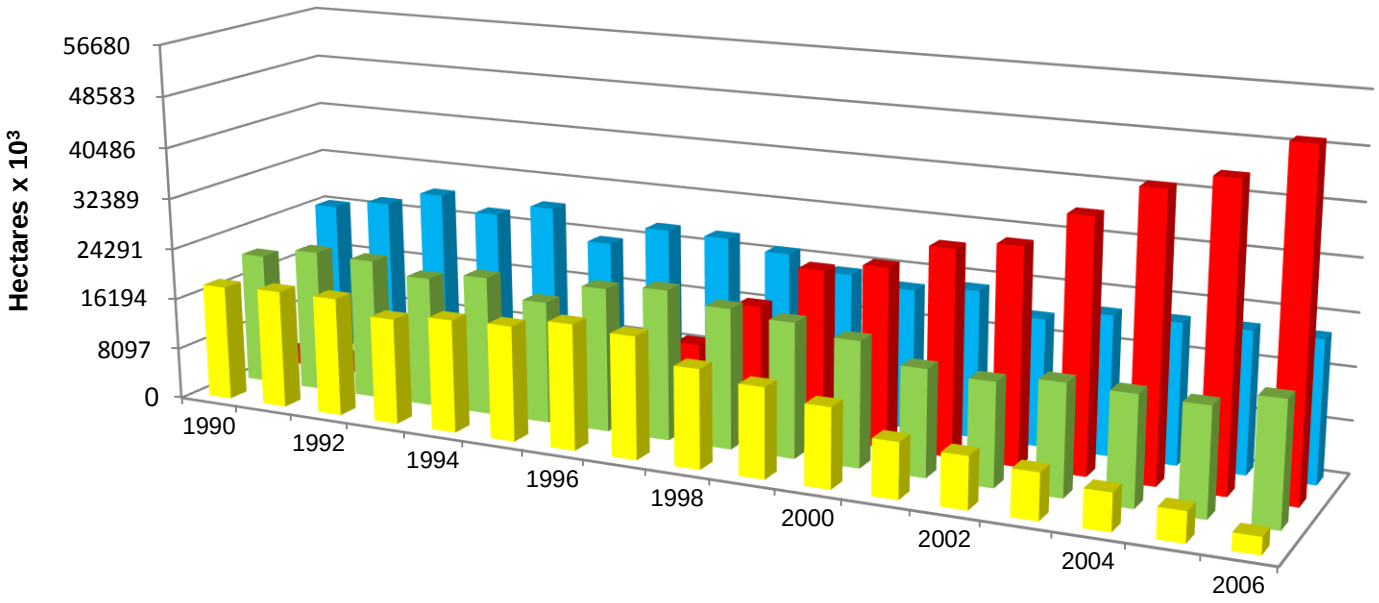
– PS II inhib. (atrazine)

Heap (2016) The International Survey of Herbicide Resistant Weeds. Available www.weedscience.org

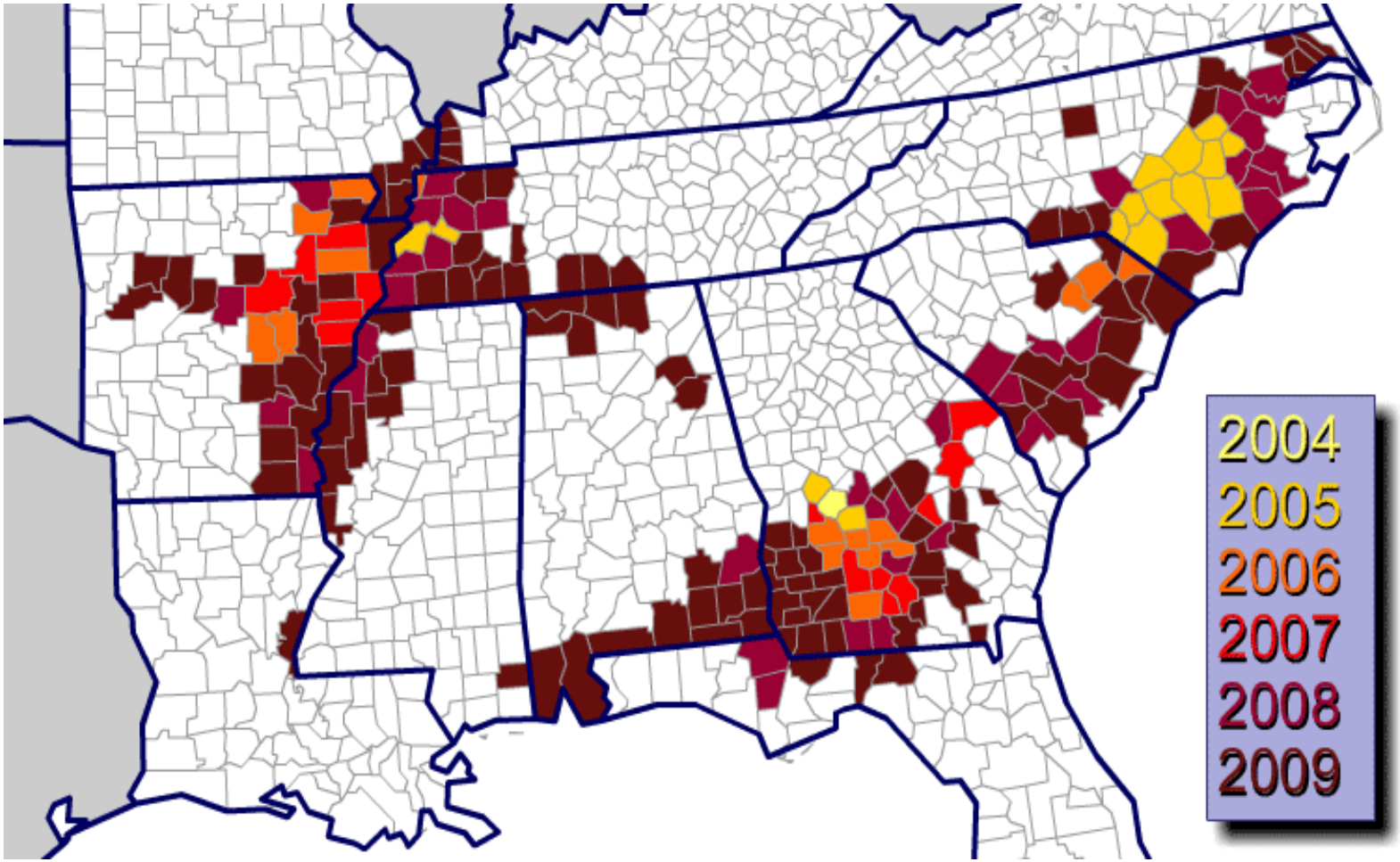
Hectares of Glyphosate-Resistant Crop Cultivars



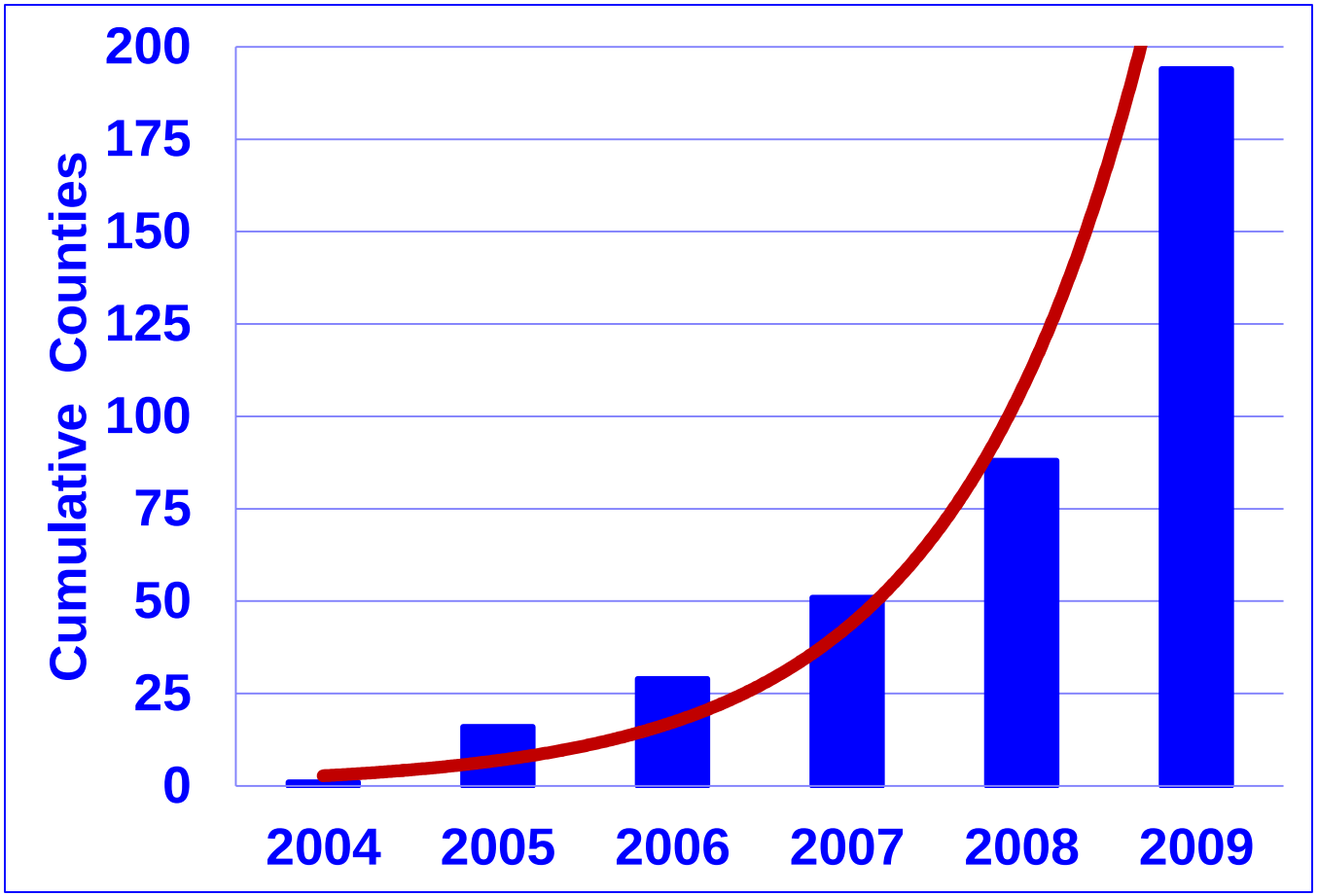
Total Hectares Exposed to Herbicide Modes of Action for Corn, Soybean, Cotton



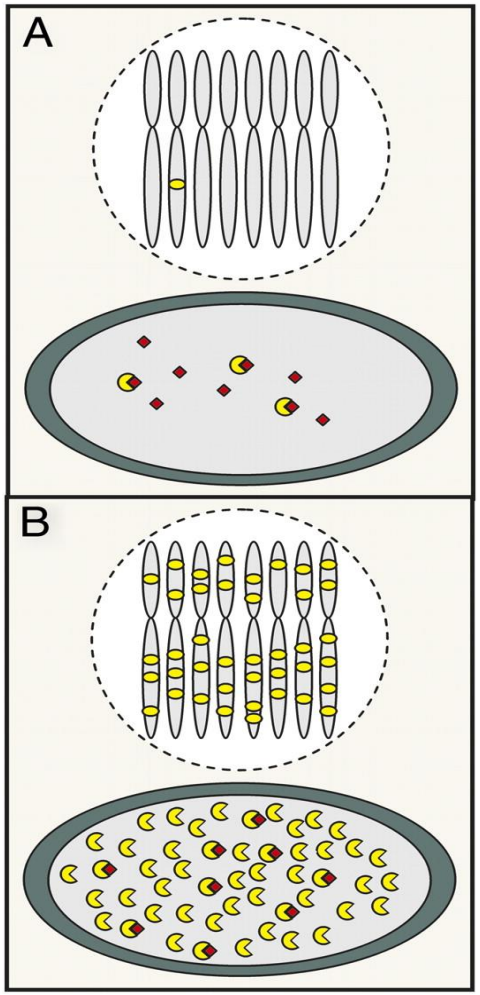
Expansion of Glyphosate-Resistant Palmer amaranth – counties infested



Counties with Glyphosate-Resistant Palmer Amaranth



EPSPS Gene Duplication: Glyphosate Resistance Mechanism



Susceptible

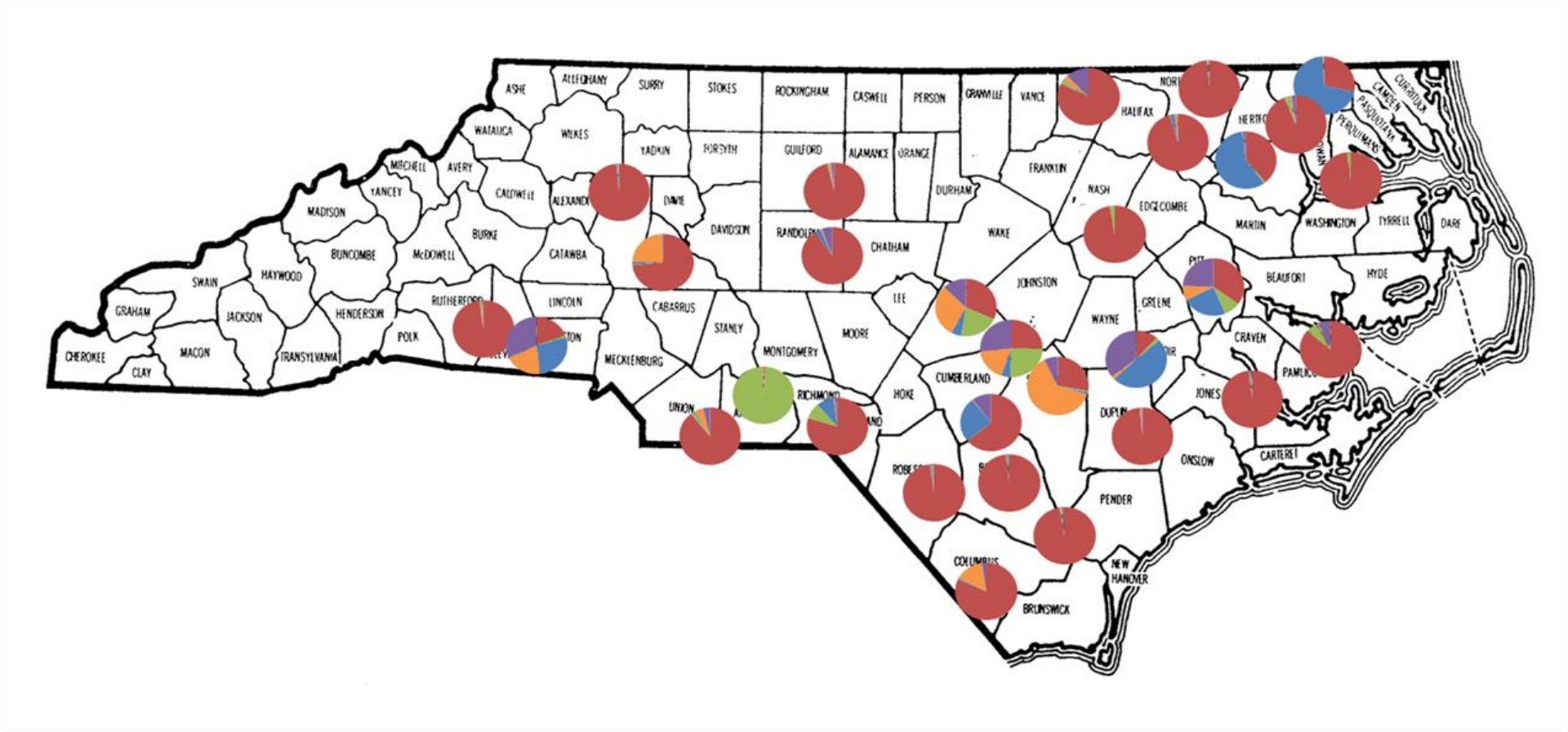
Resistant

Powles, PNAS 2010;107:955-956

- Resistant plants have many more *EPSPS* copies
- Extra gene copies are located on multiple chromosomes
- Gaines *et al.* 2010. Gene amplification confers glyphosate resistance in *Amaranthus palmeri.* Proc. Natl. Acad. Sci. USA 107:1029-1034.
- Molin *et al.* 2017. "*EPSPS* is part of a genome-region cassette/amplicon in *A. palmeri*" BMC Genomics 18:91

Population Genetics of Glyphosate Resistance in Palmer amaranth

- **Distribution of Genotypes in North Carolina - 2009**



Glyphosate Resistant Palmer amaranth

Economic Threat to Soybeans

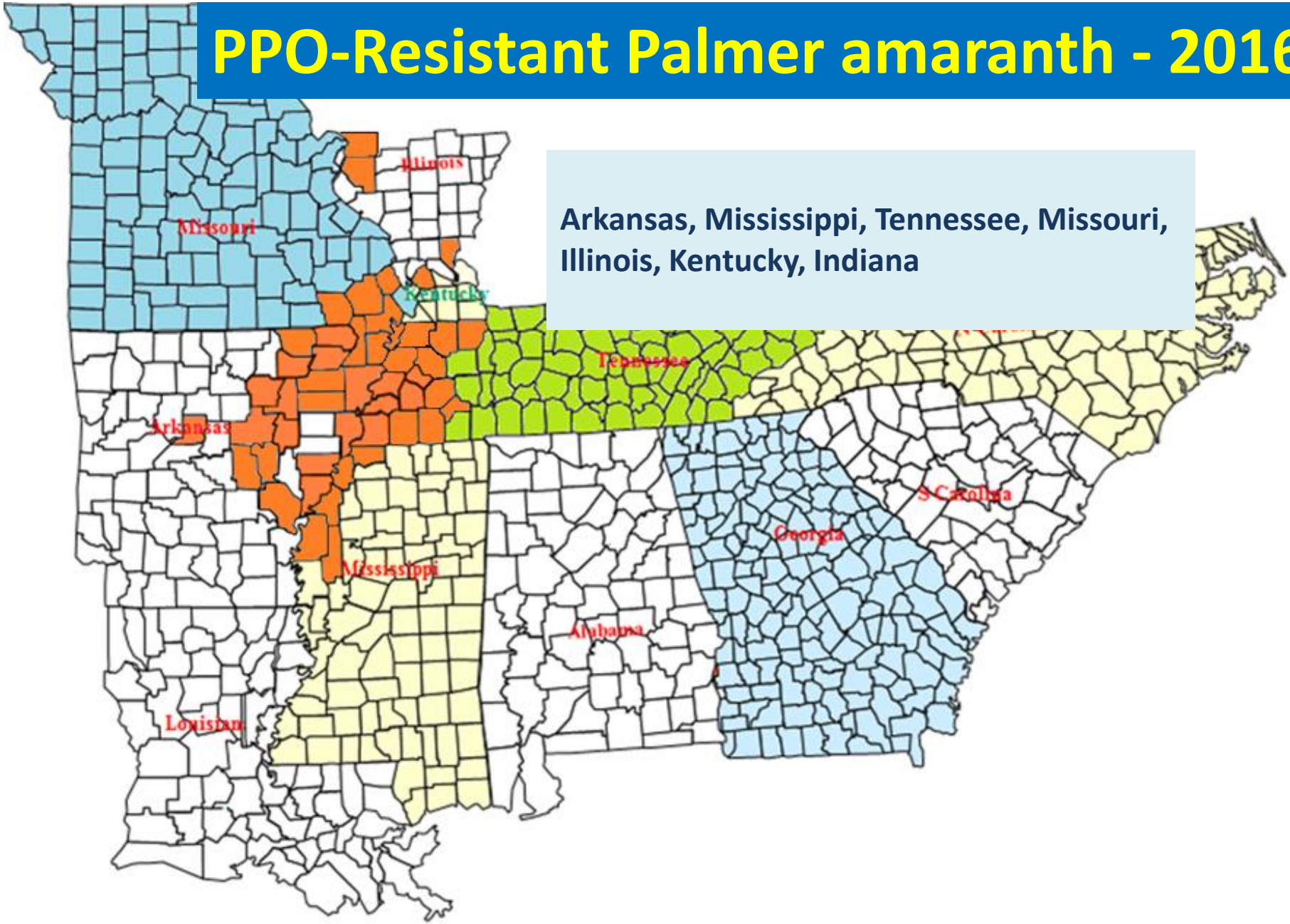
If ALS and glyphosate are compromised, PPO herbicides are the only post emergence option except glufosinate

Economic Threat to Cotton

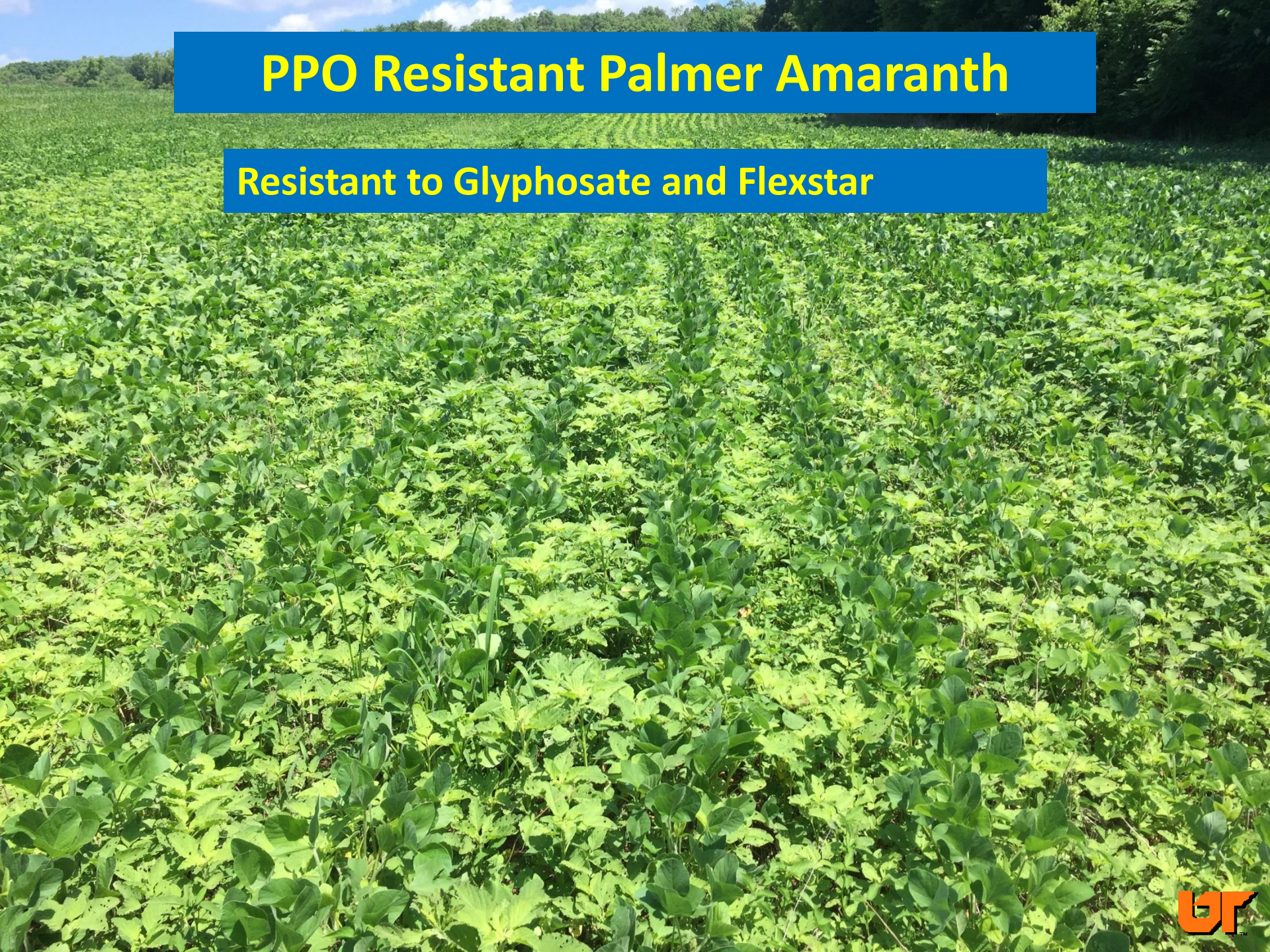
PPO herbicides are not an over-the-top option. If ALS herbicides and glyphosate are compromised, there are no selective post emergence options except glufosinate

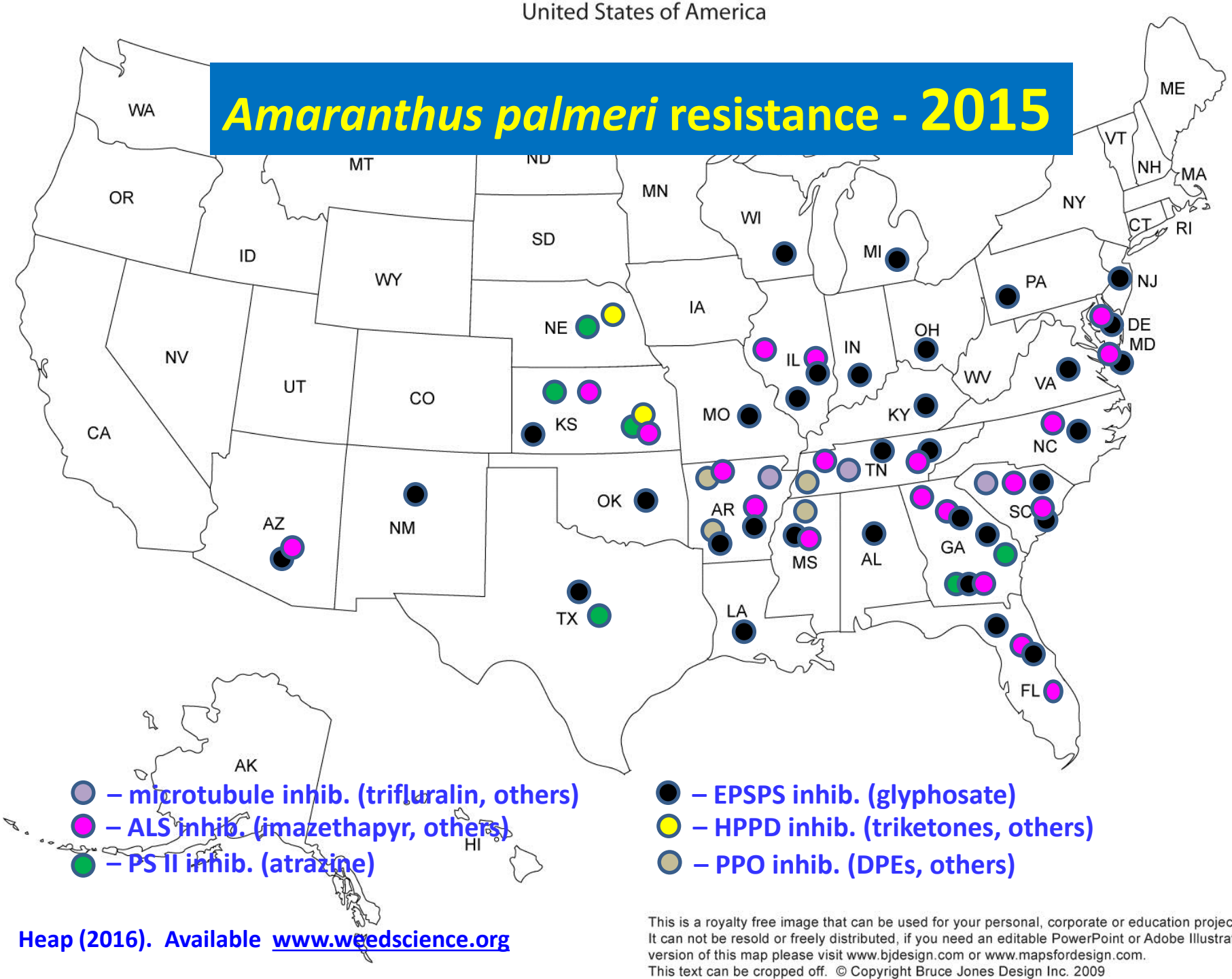
Nichols, R. L. 2010 – "Pigposium",
Forest City, Arkansas

PPO-Resistant Palmer amaranth - 2016



Arkansas, Mississippi, Tennessee, Missouri, Illinois, Kentucky, Indiana


PPO Resistant Palmer Amaranth
Resistant to Glyphosate and Flexstar



Heap (2016). Available www.weedscience.org

Impacts of Glyphosate-Resistant Palmer amaranth

- Increase complexity and costs of weed management in cotton and soybean
- Threat to compromise conservation tillage in the short-term
- May precipitate a cascade of resistance in post emergence broadleaf herbicides

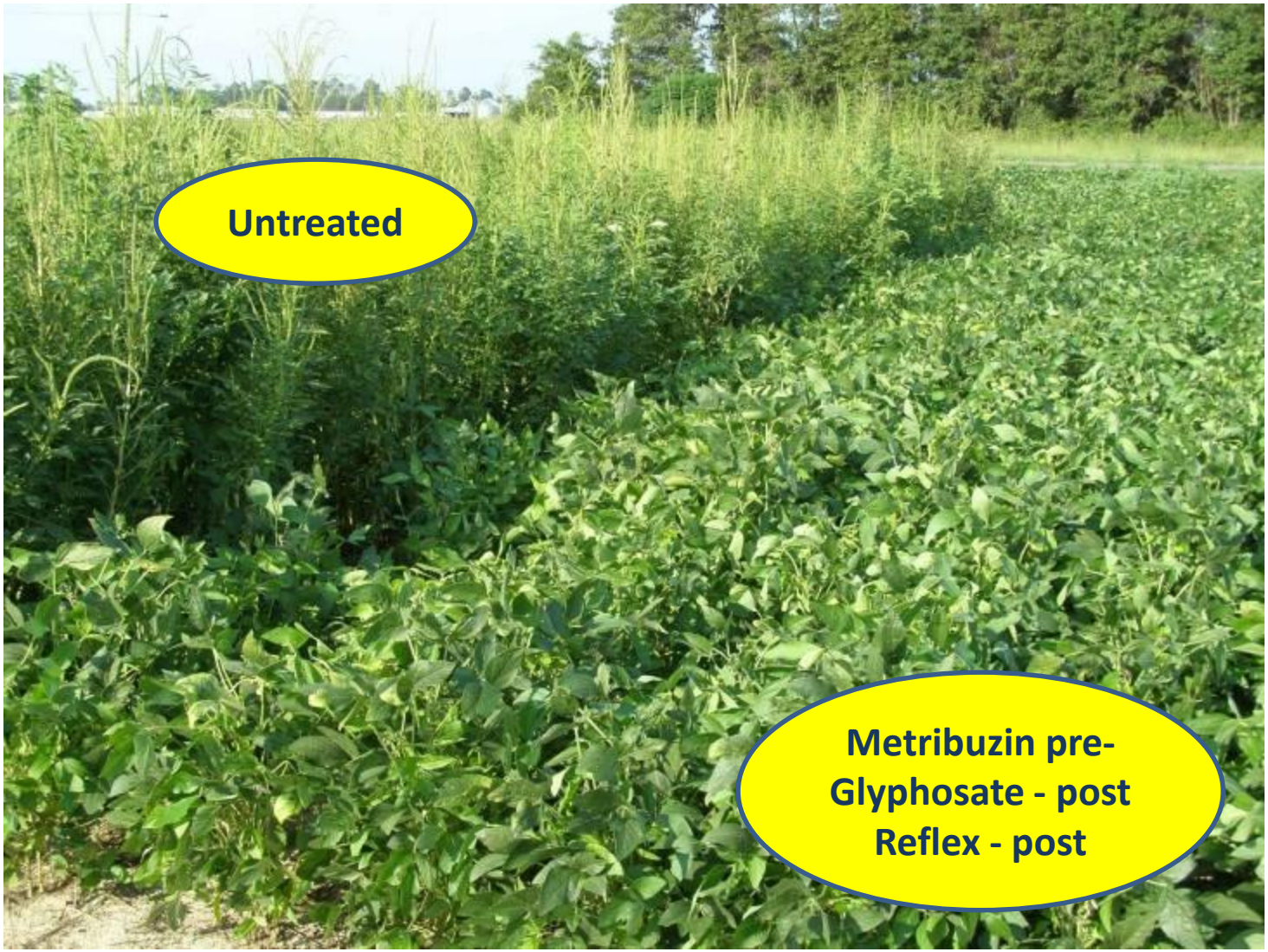
No One Knows How to Manage Herbicides for Infinite Sustainability.

We do know what causes their loss in the short term.

Detect Resistance Early

Managing Herbicide Resistant Weeds

- Know that Resistance is Present
- Change the Weed Management System
  - Rotate Crops
  - Rotate Herbicide Resistant Traits
  - Use Multiple Herbicide Mechanisms of Action
  - Scout and Be Prepared to Respond Quickly



Glyphosate-resistant Palmer amaranth, Wayne Co., NC

Pre-emergence followed by Post Emergence Herbicides

Weed Science Must Reinvent Itself

- **Past - The Post-emergence Herbicide Era is Ending. (ALS, glyphosate, and PPO resistance)**
- **Present** - Weed Management Systems Use Combined Pre-emergence Herbicides, Limited Post-emergence Options, and Some Cultural and Mechanical Control
- **Near Future – Probably Fewer Effective Herbicides, Greater Use of Cover Crops, Continuous Soil Coverage, and Zero Tolerance Systems.**
-
- **More Distant Future – Combination of Continuous Cover, Robotics, and Novel Weed Suppression Strategies**

Planting into 6 ton/acre Rye (Secale cereale) cover crops

(pendimethalin + flumeturon) pre-emergence followed by (glyphosate + pyrithiobac-Na+) post

ulpepper, UGA


No Herbicide
Herbicide

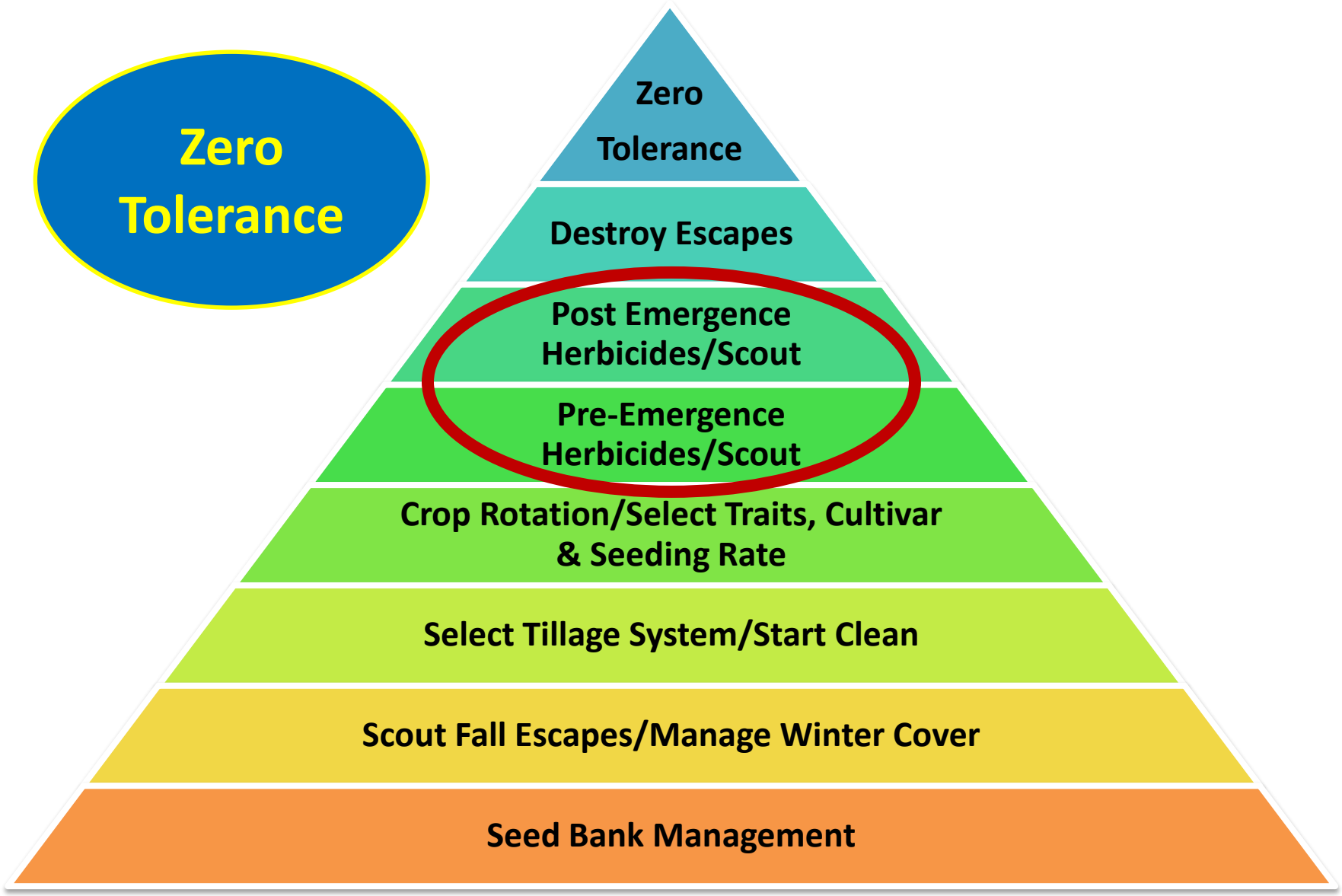
Weed Science Society of America UDSA- APHIS Collaboration

- Vencill, W. K., R. L. Nichols, T. M. Webster, J. Soteres, C. Mallory-Smith, N. Burgos, W. G. Johnson, and M. D. Owen. 2012. Herbicide Resistance: Toward an Understanding of Resistance Development and the Impact of Herbicide-Resistant Crops. Weed Science Special Issue: 60:2-30.

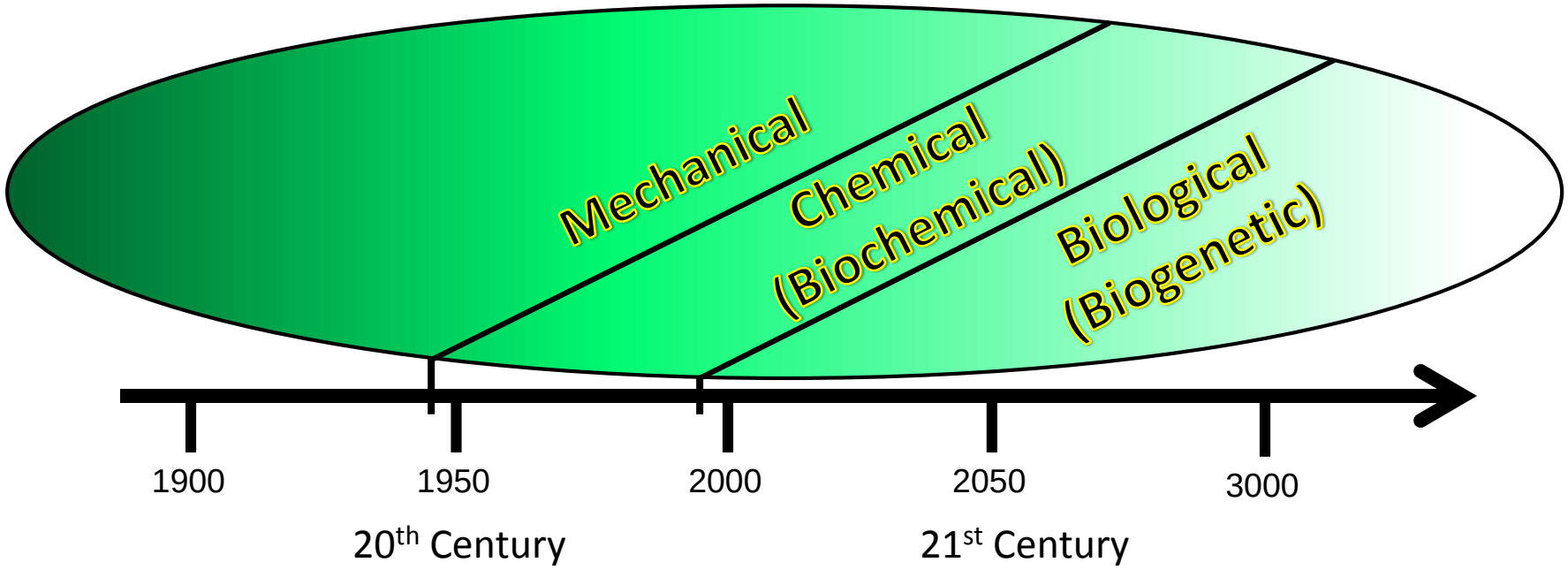
- Norsworthy, J. K., S. Ward, D. Shaw, R. Llewellyn, R. L. Nichols, T. M. Webster, K. Bradley, G. Frisvold, S. Powles, N. Burgos, W. Witt, and M. Barrett. 2012. Reducing the Risks of Herbicide Resistance: Best Management Practices and Recommendations. Weed Science Special Issue 60:31-62.

Delay Herbicide Resistance

- Rotate Crops
- Use Best Agronomic Practices to Promote Crop Growth
- Start Clean- Destroy Weeds Before Planting
- Use Multiple Techniques and Mechanisms of Herbicide Action
- Scout for Escapes
- Stay Clean – Eliminate Escapes


Zero Tolerance
Zero Tolerance
Destroy Escapes
Post Emergence Herbicides/Scout
Pre-Emergence Herbicides/Scout
Crop Rotation/Select Traits, Cultivar & Seeding Rate
Select Tillage System/Start Clean
Scout Fall Escapes/Manage Winter Cover
Seed Bank Management

Evolution of Weed Management Technologies



The Last Shall Be First

The Last Adopters May Know the Most about Extending the Longevity of Herbicide Mechanisms of Action.

“An Irony of Economic Opportunity”

Weed Management Theme

Herbicide Stewardship

Protecting

Crops

Environment

Technology