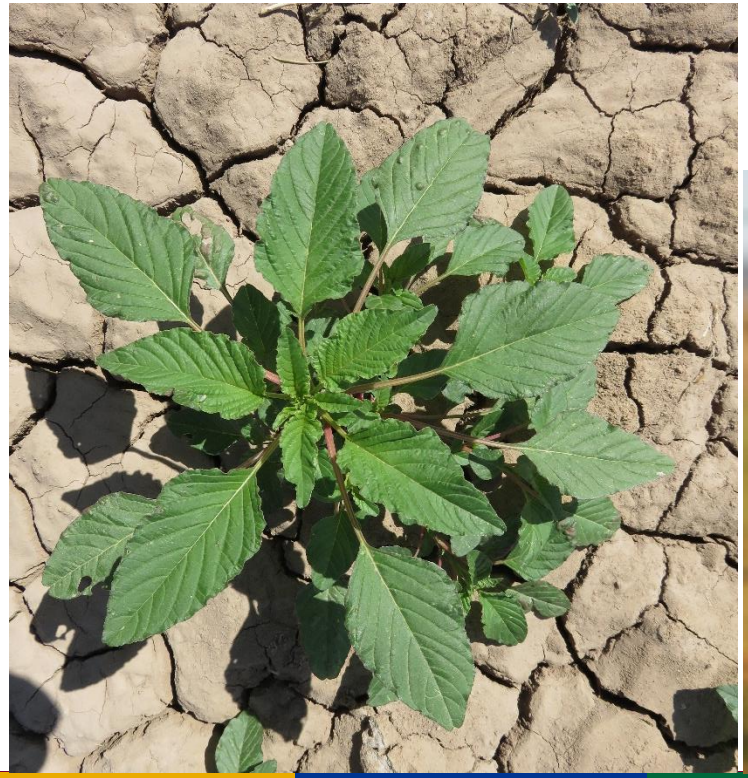
Mechanisms of Development of Herbicide Resistance in Weeds



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All About Discovery!
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Weed management in crops

- Weed management success directly related to weed management strategy
  - Integrated Weed Management (IWM)
- Difficult in cropping systems
  - Scouting, early detection-rapid response
  - Tillage, hand removal (hoeing)
  - Spot spraying
  - Problems with herbicide selectivity in some crops
- Usually takes time and money at a point when crop nets little/no profits

Herbicides

- Primary method of weed control in conventional agriculture
  - Inexpensive (can help reduce production costs)
  - Greater flexibility in timing of weed control
    - PRE and POST options
  - Results are often quick and may offer extended control
- Development of herbicide resistant crops improve chemical weed control
  - Herbicide resistant (HR) crops
    - Alfalfa, cotton, canola, corn, etc.

Herbicides

- Glyphosate – Round-up
  - Deemed as a ‘once-in-a-century herbicide’
  - Most widely used herbicide nationwide
    - Readily available
    - Inexpensive (can help reduce production cost in crops)
    - Broad-spectrum control
    - Results are often very quick
    - Rapid translocation within the plant
    - Very low mammalian and aquatic organism toxicity
    - Very low leaching potential
    - Breaks down quickly in the environment

Glyphosate

- Multiple crops developed to be resistant to glyphosate (GR)
  - Alfalfa, cotton, canola, corn, etc.
- Many growers overused the technology and planted ONLY GR crops
- Developed heavy reliance on glyphosate for weed control…
  - Often the only utilized means of control
  - Applied multiple times during growing season
- Lead to increase in weeds resistant to glyphosate

Herbicide resistance

- Tolerance – Ability of a species to survive and reproduce after herbicide treatment (natural tolerance)
  - Morningglory vs. glyphosate
- Resistance - **inherited** ability of a plant to survive and reproduce following a herbicide dose that is normally lethal to that specific plant
  - Must pass resistance trait to offspring

Herbicide resistance

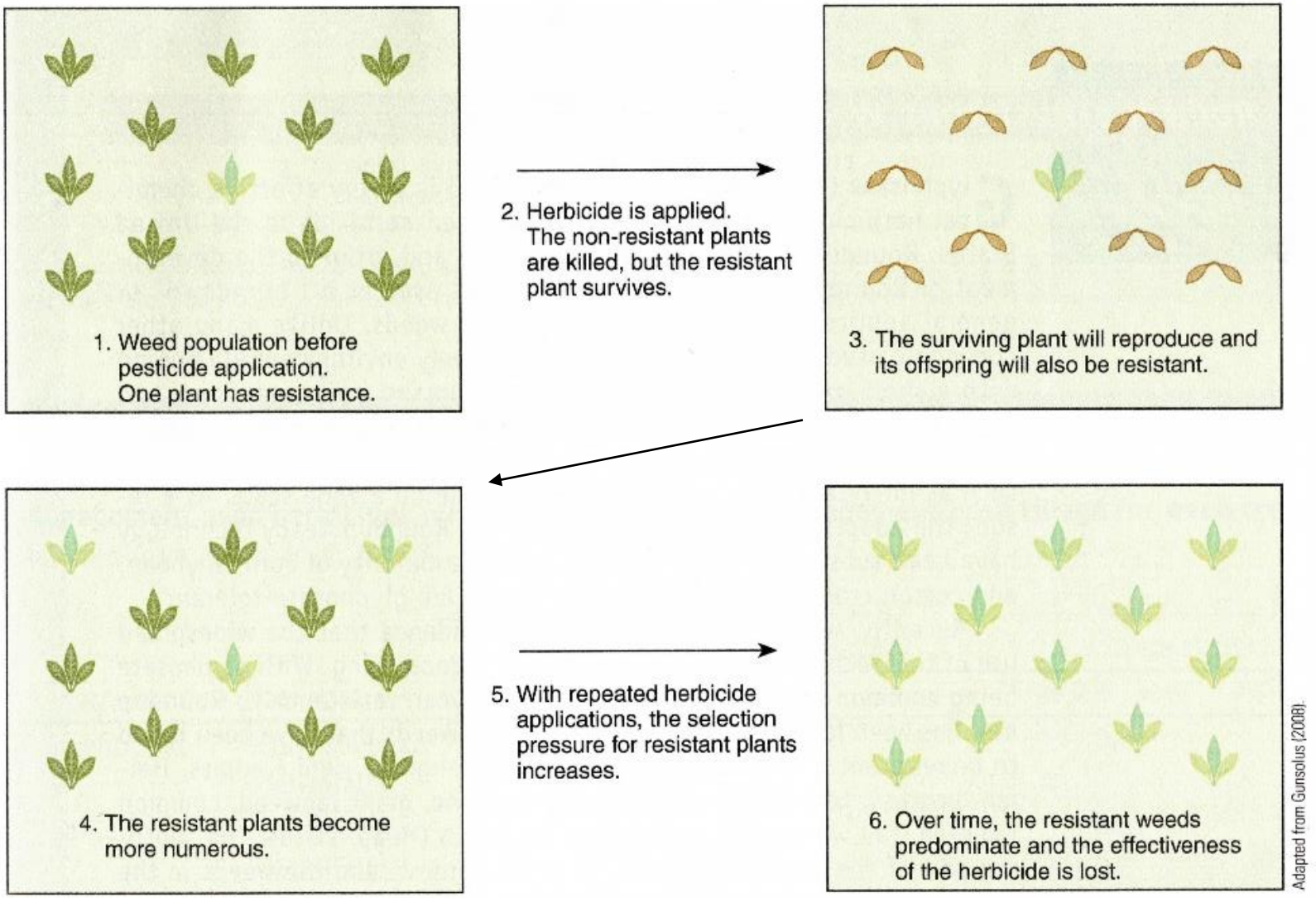
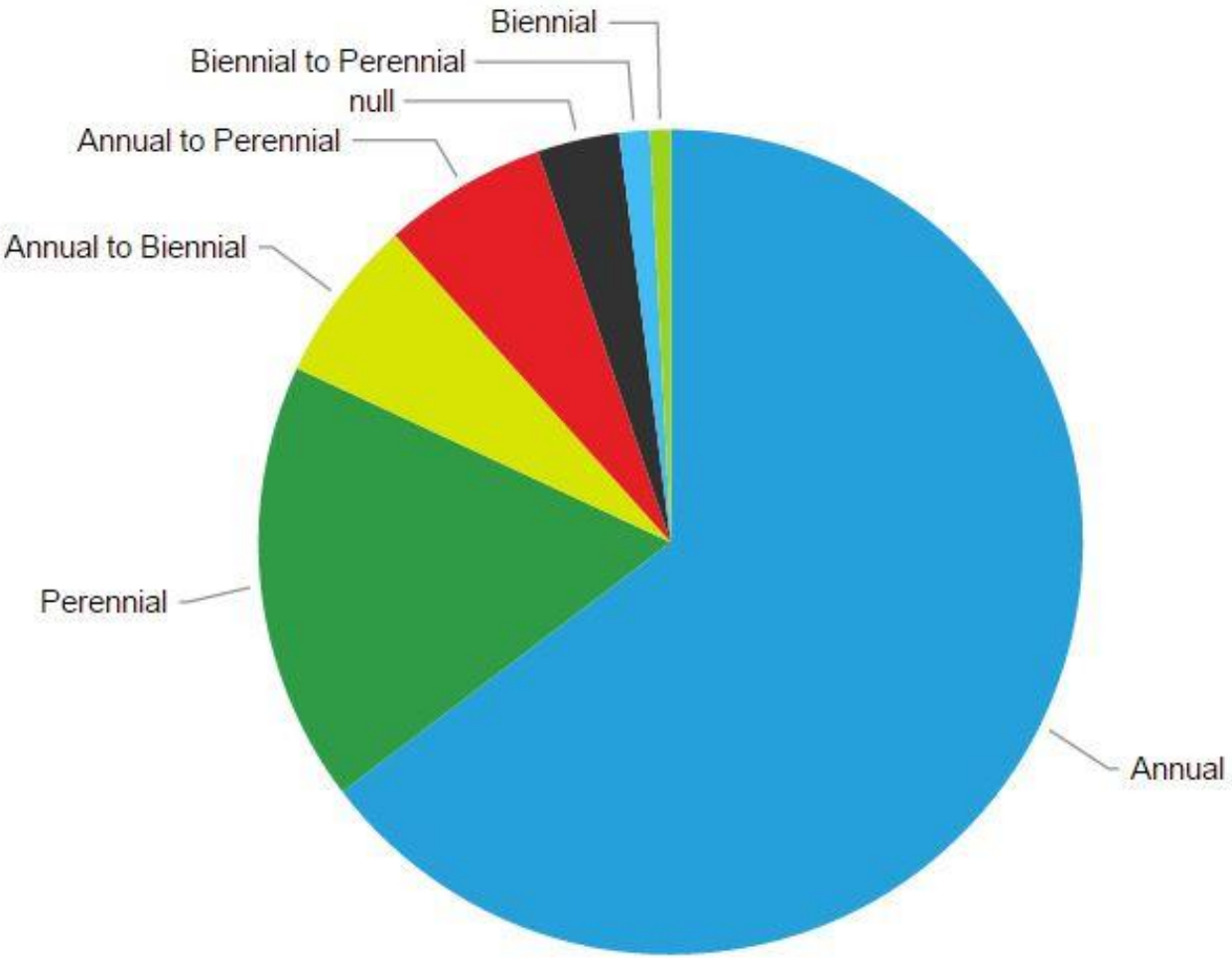
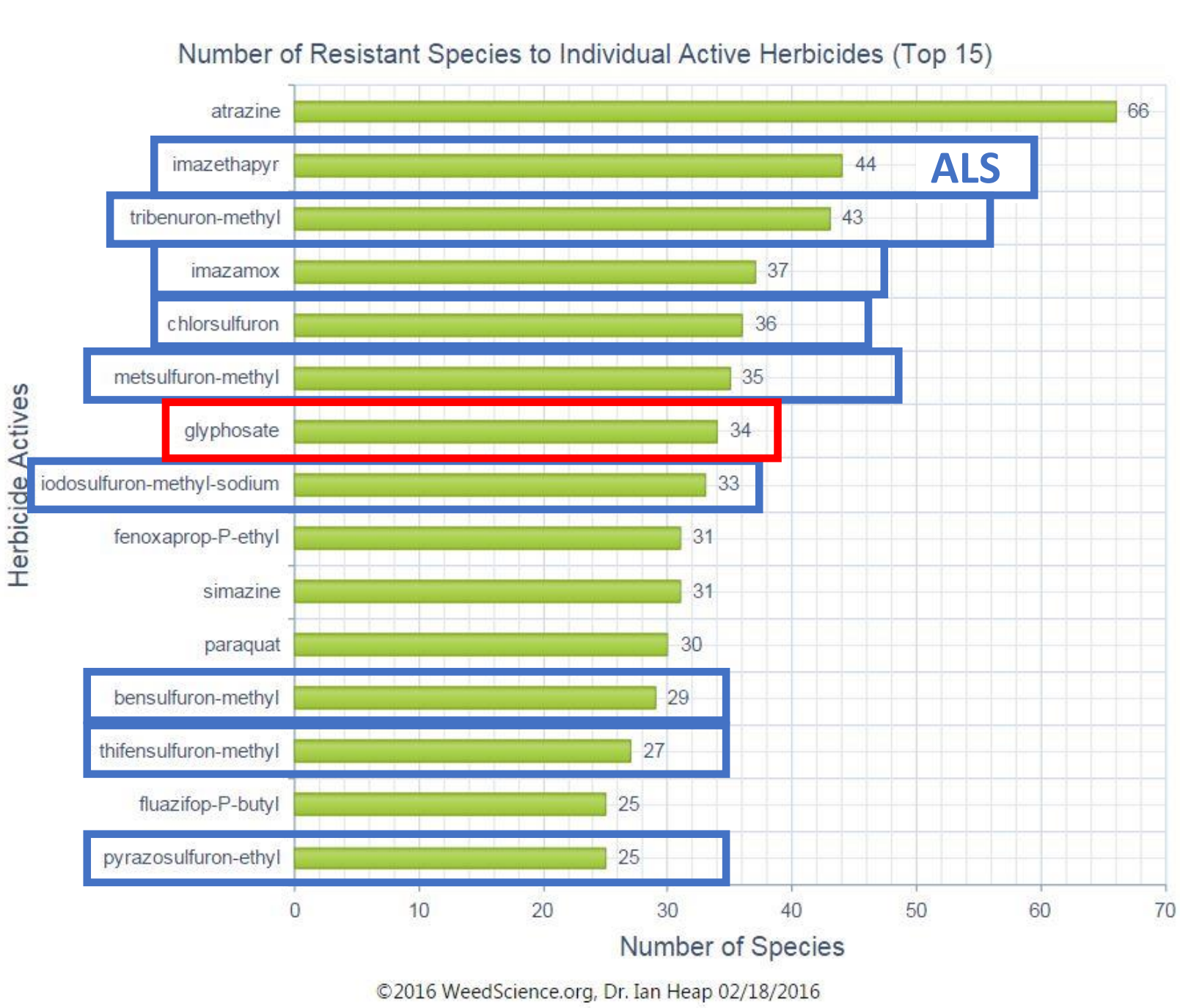


FIGURE 15-23 Steps in the development of herbicide resistance.

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




Number of Resistant Species to Individual Active Herbicides (Top 15)
Herbicide Actives
atrazine
imazethapyr
tribenuron-methyl
imazamox
chlorsulfuron
metsulfuron-methyl
glyphosate
iodosulfuron-methyl-sodium
fenoxaprop-P-ethyl
simazine
paraquat
bensulfuron-methyl
thifensulfuron-methyl
fluazifop-P-butyl
pyrazosulfuron-ethyl
66
44
43
37
36
35
34
33
31
31
30
29
27
25
25
ALS
0
10
20
30
40
50
60
70
Number of Species
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Herbicide resistance

- Causes of Resistance?
  - Lack of new herbicides with different modes of action (MOA) to help diversify
    - No new MOAs for over 30 years
      - Newer chemical families have been introduced but many have the same MOA
        - » Ex: Imidazolinone (imazapic), sulfonylurea (halosulfuron); both are ALS inhibitors
    - Once a weed becomes resistant to a specific chemical it often becomes resistant to other chemicals with same MOA
- Glyphosate is the ONLY chemical that inhibits EPSP synthase

Herbicide resistance

- Causes of Resistance?
  - Herbicides applied repeatedly (HR crops)
  - Herbicide mistakes
    - High/low rate, environmental conditions, wrong weed
    - WRONG TIMING – very common with glyphosate

How do plants become resistant?

- Resistance can lead to…
  - Cross resistance – multiple herbicides within same MOA
    - Often result of 1 resistance mechanism
  - Multiple resistance – multiple herbicides within same and multiple MOAs
    - Could include 1 or more resistance mechanisms

Five mechanisms of resistance

1. Altered site of action – prevents the herbicide from binding and working
2. Enhanced metabolism – ability of plant to convert herbicide molecule into form that is no longer toxic
3. Reduced absorption/translocation – restricted movement of herbicide to site of action
4. Sequestration – herbicide is immobilized in locales such as vacuoles or cell walls
5. Gene amplification – dilution of herbicide in relation to site of action

Herbicide resistance

- Scope of the problem - 2015
  - WSSA (weedscience.org) confirmed resistance
    - 22 of the 25 classes of herbicides
      - Some weeds resistant to multiple classes (MOAs)
    - 527 species of weeds in 50 states
      - California & Kansas tied for highest number of resistant weeds…25!

- State of New Mexico
  - 2 confirmed cases of herbicide resistant weeds
    - Kochia (1988) – ALS inhibitors
    - Palmer amaranth (2007) – Glyphosate
      - First confirmed in a pecan orchard in Las Cruces

Diagnosing herbicide resistant weeds

- Most often, other factors besides resistance lead to herbicide failure…
  - Improper calibration of spreader/sprayer
  - Wrong herbicide
  - Wrong rate
  - Environmental conditions
    - Too dry, too hot, too windy, etc.
  - Wrong application timing
    - Weed growth stage
      - PRE vs. POST
      - Too big/too small
  - Wrong weed

Diagnosing herbicide resistant weeds

- Resistance checklist
  - Are other weeds listed on product label controlled satisfactorily?
    - Most often only one weed species will show resistance in field
  - Do number of weeds seem unharmed when similar nearby weeds exhibit control/injury?
  - Did the same herbicide (or same MOA) fail in same area/same weed type of the field the previous year?
  - Do application records indicate excessive and/or repetitive use of herbicide MOA from year to year?

Diagnosing herbicide resistant weeds

- If you answered yes to any of the questions on the previous slide, there may be a problem…
- Resistance must be confirmed before problem gets out of control
  - Collaboration research between client, agent, and specialist

Prevention and Management of Resistance (IWM)

- Identification of resistance problems!
  - Resistant problems usually go undetected until 30% of weed population is resistant
  - Early detection and rapid response is key to prevent spread
- When resistance is detected, farmer must depend on IWM practices for weed management

Prevention and Management of Resistance (IWM)

- Monitoring
  - Use knowledge of weed lifecycle and environmental conditions to schedule scouting
    - The smaller the weed, the easier the control especially with herbicides
  - Weed map
    - Keep records of which weeds are germinating and where
    - Helpful in planning and implementing weed control programs

Prevention and Management of Resistance (IWM)

- Preventative weed management
  - The most important part of IWM
    - “an ounce of prevention is cheaper than the ‘cure’”
  - Managing weeds in surrounding areas
    - Fencerows, ditches, roadsides, neighboring fields
  - Plant certified seed (HR crops should be)
  - Controlling weeds before they set to seed
  - Cleaning and removing weeds from any equipment within and surrounding the field
    - Planting and harvesting equipment

Prevention and Management of Resistance (IWM)

- Cultural control
  - Management practices to give competitive edge to desired crop
    - Seedbed preparation (control of perennial weeds)
    - Proper fertilization if needed
    - Proper irrigation
    - Dense and vigorous crop stand can outcompete and shade out germinating weeds
      - May not be possible in some HR crops
        - » Cotton, etc.


See any weeds?

What can a management-free month do to weed pressure?

Prevention and Management of Resistance (IWM)

- Cultural control
  - Harvest management in perennial crops
    - Ex: timely harvests during peak growth points in HR alfalfa
      - First harvest after flowers appear = greater energy reserves in roots
  - Crop rotation
    - Rotations to other plants may help manage weed populations and improve soil conditions for future crops
      - Especially plants with different lifecycles (ex: alfalfa to winter wheat)

Prevention and Management of Resistance (IWM)

- Mechanical control
  - Effective in HR crop production (cotton)
  - Useful in HR forage?
    - Alfalfa
      - Mustard infested fields may be cut prematurely to get rid of mustards
        - » Forms lateral branches below cut point
        - » Produces flowers and seed anyway…

Prevention and Management of Resistance (IWM)

- Chemical
  - Use herbicides only when necessary (last resort)
  - Utilize multiple herbicide management strategies Conventional program
    - PREs and POSTs when available
  - Just because crop is HR, not strictly limited to the use of that herbicide!
    - Cost effective to do occasional rotation to old chemistry than having to rely on more expensive products because they don't work anymore

Prevention and Management of Resistance (IWM)

- Chemical
  - Rotate herbicides with DIFFERENT MOA
    - Keep weeds confused
  - Tank-mix to create more broad-spectrum control with differing MOAs
  - Additives that can improve herbicide efficacy
    - Surfactants, water conditioners, etc.
  - Always make applications in accordance with the label
    - Rates, timings, environmental conditions, etc.
    - Label is law

Take home message

- HR crops offer multiple benefits within a weed management system
  - Easily accessible, inexpensive (reduce production costs)
  - Greater flexibility with application timings
    - Broad spectrum control
  - Results are often quick
- Both HR weeds in NM (kochia, Palmer amaranth) are still relatively limited in distribution
  - Could that change very quickly?


Number of Herbicide-Resistant Species for the top 10 Weed Families
Number of Species
90
80
70
60
50
40
30
20
10
0
80
39
22
12
11
9
8
7
7
6
Poaceae
Asteraceae
Brassicaceae
Cyperaceae
Amaranthaceae
Scrophulariaceae
Chenopodiaceae
Alismataceae
Polygonaceae
Caryophyllaceae
Weed Family
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Take home message

- Many of the most problematic weeds in NM have an annual lifecycle and have displayed resistance in other states
  - Winter annuals
    - London rocket, shepherd's purse, annual bluegrass, prickly lettuce, etc.
  - Summer annuals
    - Marestail, junglerice, common lambsquarters, barnyardgrass, jimson weed, etc.
  - Perennials
    - Johnsongrass, yellow nutsedge, etc.

Weed issues in the future

- Resistance is one of the leading concerns
  - High demand for crop quantity and quality
    - HR crops

- Essential to incorporate an IPM management strategy even within a HR cropping system
  - Best way to combat resistant weeds
  - Only way to prevent development of additional resistance issues in NM


Questions?