Weed Adaptations to Chemical and Non-Chemical Control Practices

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Today's presentation

- Why weeds are problematic
- Herbicides and herbicide resistance
- Other causes of herbicide failure
- Non-chemical selective pressures
- Best Management practices for weed control

The problems with weeds…

Weeds are problems in more than just ag and hort systems…

- Beyond competition for water and nutrients…
- Reduced biodiversity
- Adverse effects on ecosystem functions
- Hazards to human and animal health
- Reduced safety through obstructions
- Loss of aesthetic value

Puncturevine seed head

An example of effects on ecosystem functions

Non-native species can impact fire cycles

Five things you probably never knew about California's wildfires

Patrick May
PUBLISHED: July 3, 2018 at 10:49 am | UPDATED: July 3, 2018 at 10:56 am
California News, Latest Headlines, News

A firefighter scrambles to stop the Pawnee fire as it spots across Highway 20 near Clearlake Oaks, Calif., on Sunday, July 1, 2018. (AP Photo/Noah Berger)

Non-native plants are helping California to burn, baby, burn

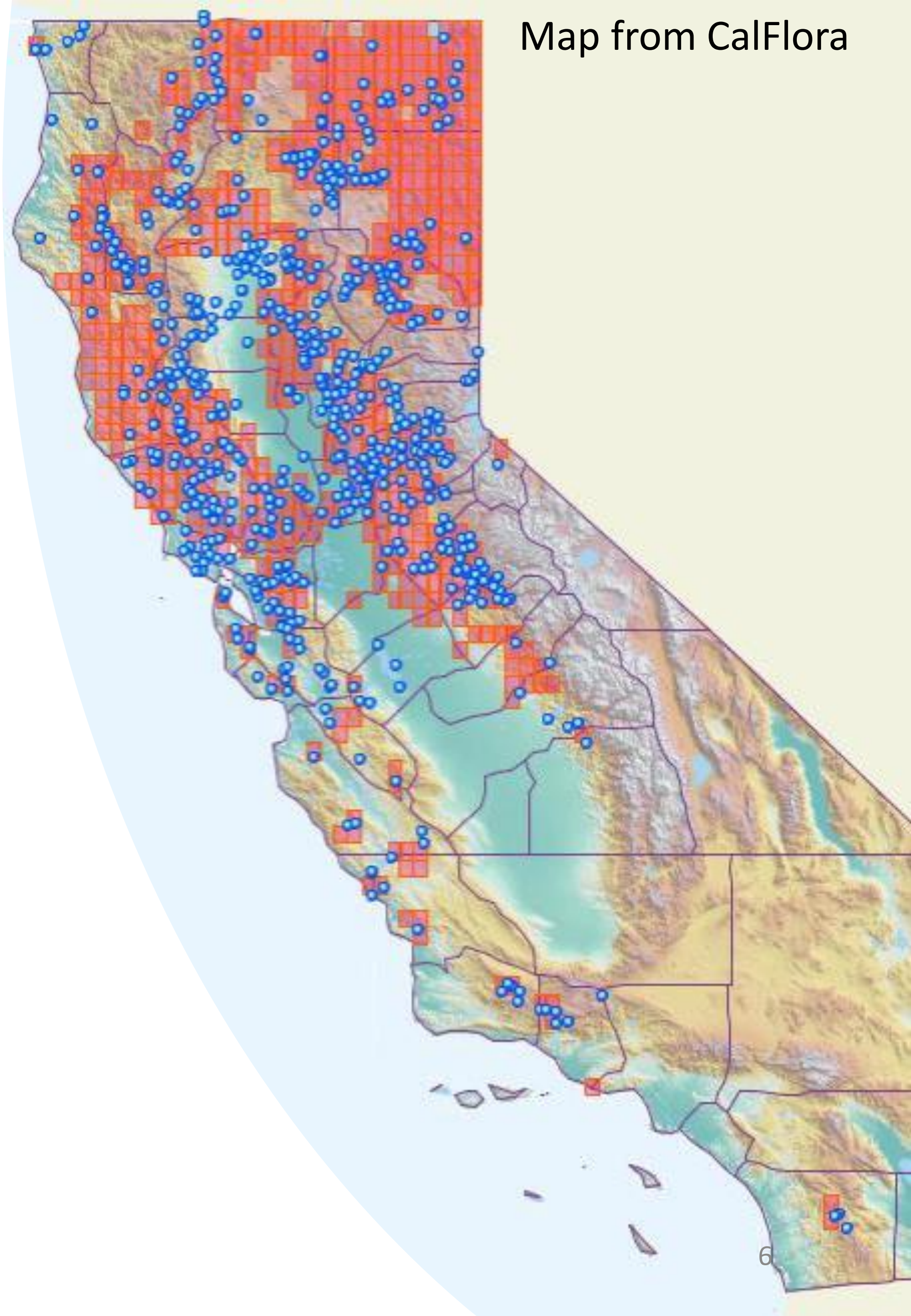
Travis Bean writes in UC Weed Science blog that despite all the news coverage of last year's wildfires, "almost no source has identified the actual fuels involved for this most recent fire season or any other. As a weed scientist, this is a particularly alarming omission, especially when it's highly likely that invasive plants may have been partially responsible for exacerbating the intensity and spatial scale of many, if not most, of 2017's fires." Bean writes that there's an apparent "tendency to lump fires into very broad categories (e.g., "forest" fire, "brush" fire, "wildfire") that tell managers, the public, and policy makers little about the actual fuel. Without letting the public and policy makers know that our wildfires are being dramatically worsened by fuels from invasive plants, it's difficult to build the political will and support for efforts to do a better job managing these fuels. As scientists and managers, simple data on the fuels involved and the antecedent weather would allow us to provide timely predictions on not just when and where these fires will strike, but also where and when we should be investing in fuel breaks, restoration, or other management actions that can save money, resources, and lives."

Medusahead

From: Medusahead Management Guide for the Western US

- Winter annual grass
- Native to Mediterranean
- First reported in OR in 1887
- Mainly infests rangelands
- Displaces native species
- Disrupts wildlife habitat
- Poor forage
    - Silica accumulator
    - Barbed seeds
- Alters fire regimes

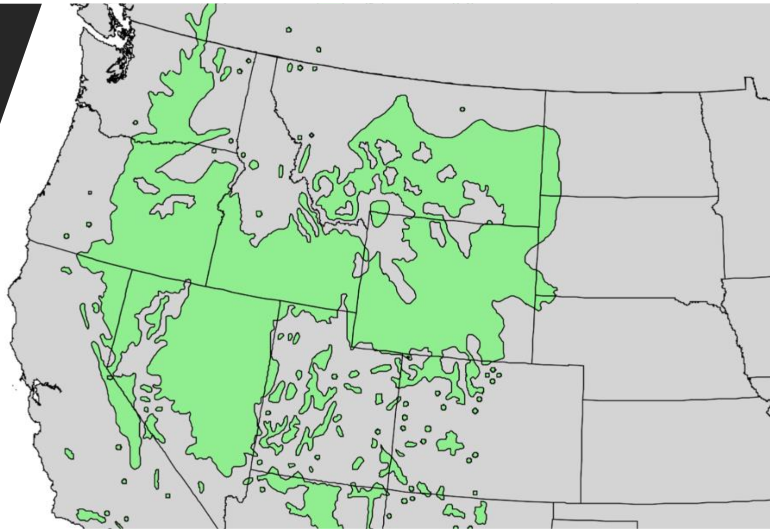
Map from CalFlora



Medusahead

From: Medusahead Management Guide for the Western US

- Acts as a fire promoter in the big sagebrush (*Artemesia tridentata*) steppe
- Fills in between sagebrush to create a continuous fuel corridor
- Many species of sagebrush are unable to regenerate from frequent fires




Herbicides for weed control

Herbicides are, for many, a critical component of weed control programs

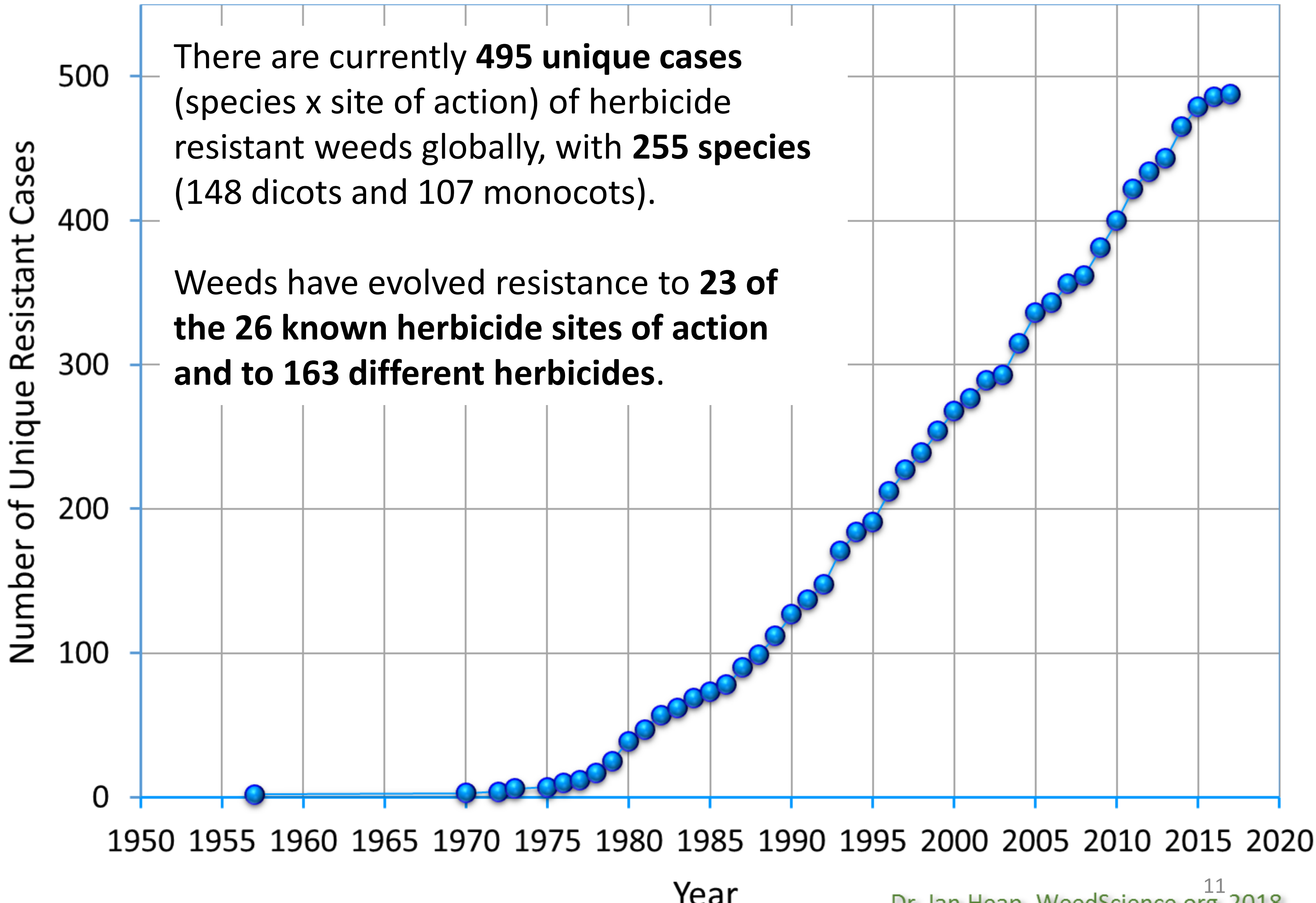
Photo from: A.S. Culpepper

Herbicides are not always 100% effective…
…and that is sometimes due to herbicide resistance

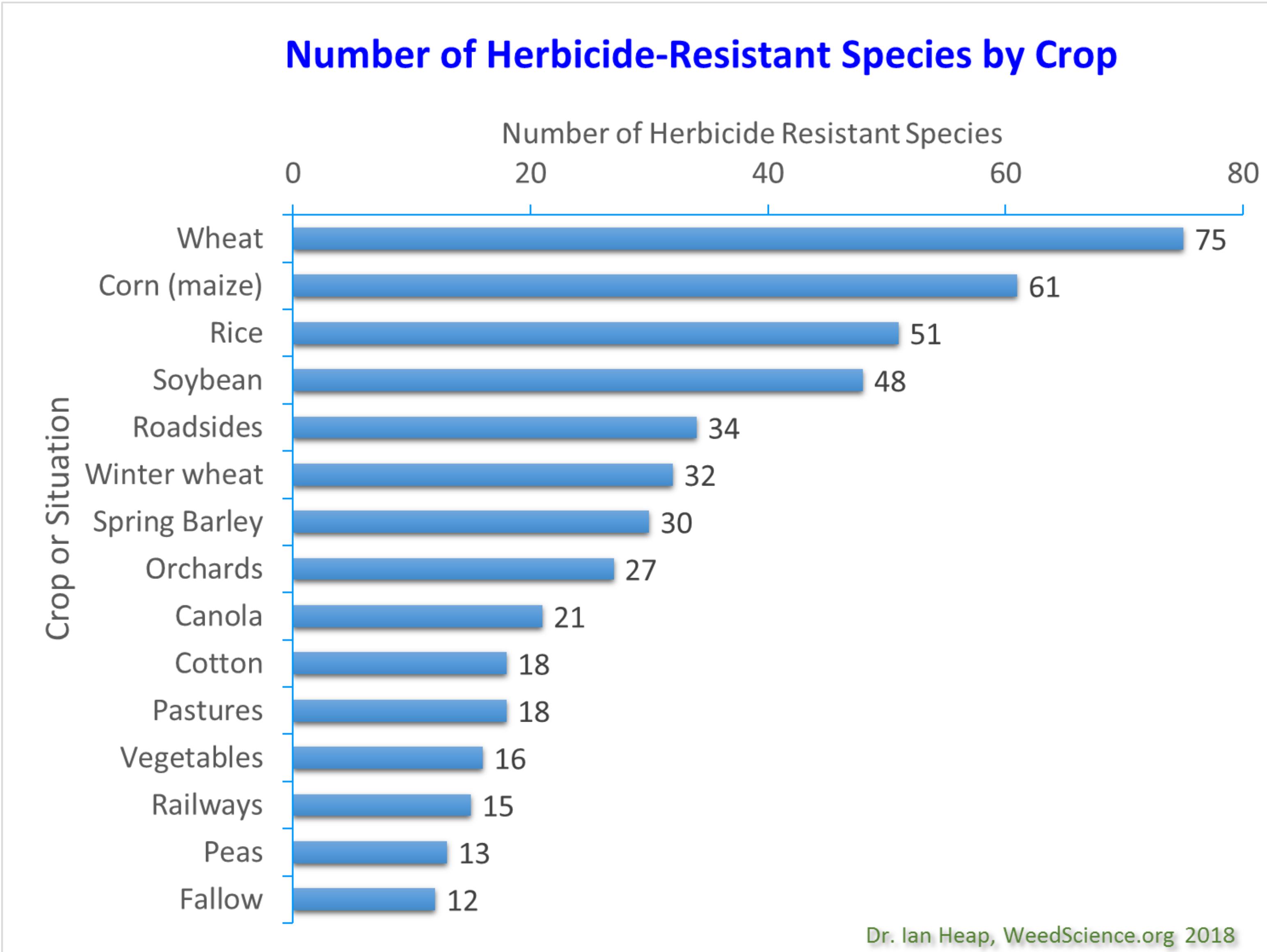
Global Increase in Unique Resistant Cases

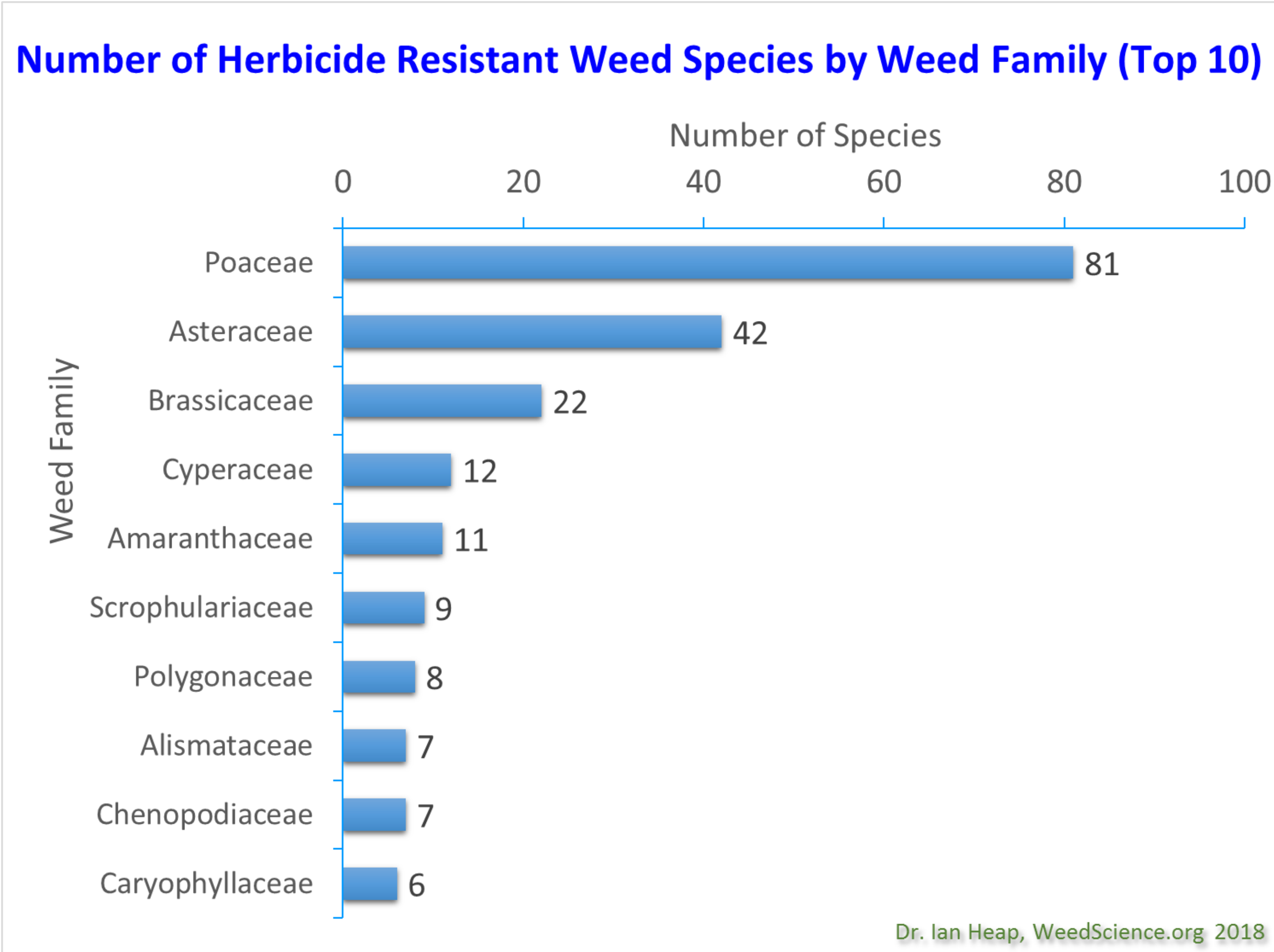
There are currently **495 unique cases** (species x site of action) of herbicide resistant weeds globally, with **255 species** (148 dicots and 107 monocots).

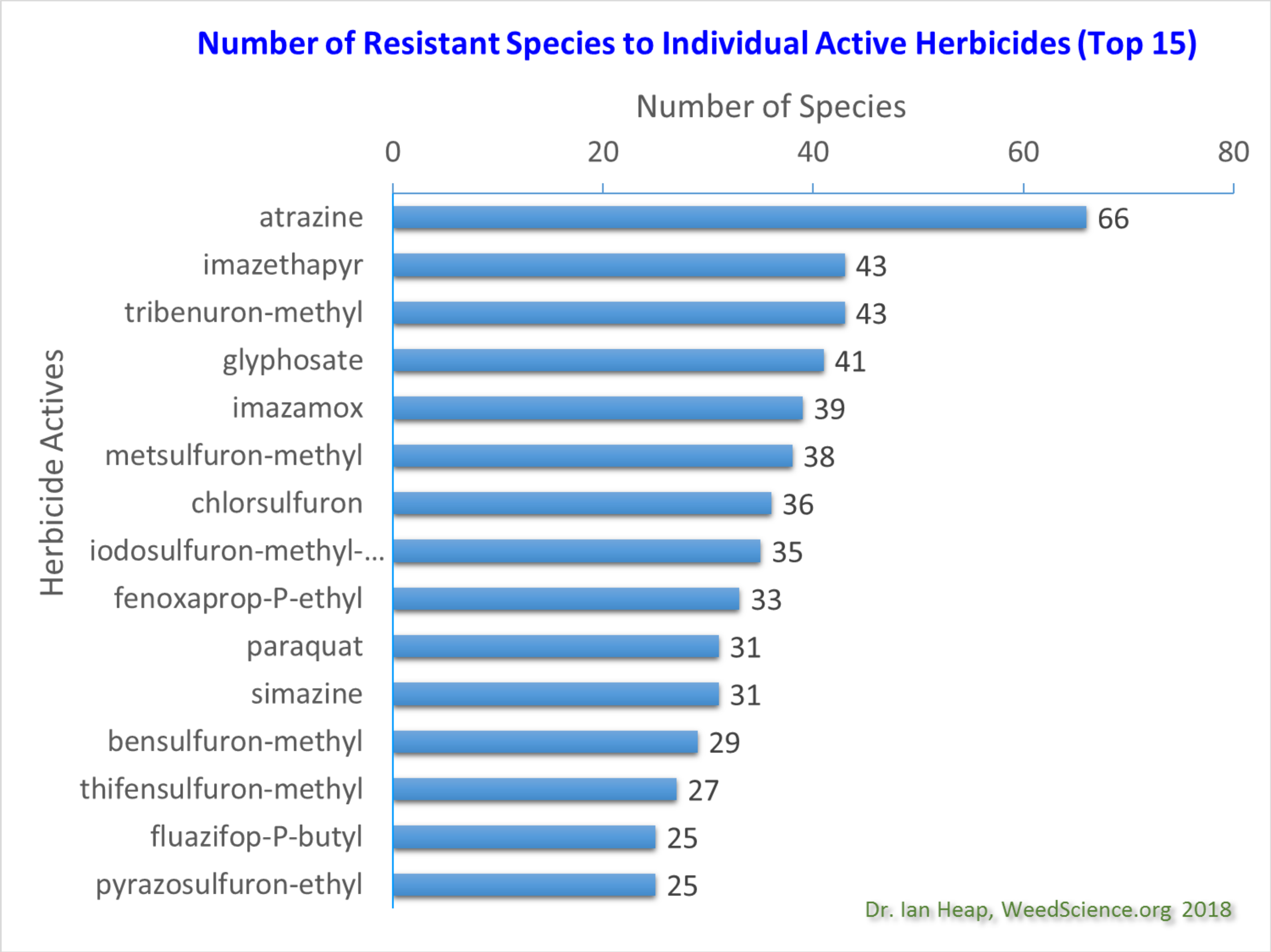
Weeds have evolved resistance to **23 of the 26 known herbicide sites of action and to 163 different herbicides**.



Dr. Ian Heap, WeedScience.org 2018


Number of Herbicide-Resistant Species by Crop
Number of Herbicide Resistant Species
0
20
40
60
80
Crop or Situation
Wheat
Corn (maize)
Rice
Soybean
Roadsides
Winter wheat
Spring Barley
Orchards
Canola
Cotton
Pastures
Vegetables
Railways
Peas
Fallow
75
61
51
48
34
32
30
27
21
18
18
16
15
13
12
Dr. Ian Heap, WeedScience.org 2018


Number of Herbicide Resistant Weed Species by Weed Family (Top 10)
Number of Species
0
20
40
60
80
100
Weed Family
Poaceae
81
Asteraceae
42
Brassicaceae
22
Cyperaceae
12
Amaranthaceae
11
Scrophulariaceae
9
Polygonaceae
8
Alismataceae
7
Chenopodiaceae
7
Caryophyllaceae
6
Dr. Ian Heap, WeedScience.org 2018


Number of Resistant Species to Individual Active Herbicides (Top 15)
Number of Species
0
20
40
60
80
Herbicide Actives
atrazine
66
imazethapyr
43
tribenuron-methyl
43
glyphosate
41
imazamox
39
metsulfuron-methyl
38
chlorsulfuron
36
iodosulfuron-methyl-...
35
fenoxaprop-P-ethyl
33
paraquat
31
simazine
31
bensulfuron-methyl
29
thifensulfuron-methyl
27
fluazifop-P-butyl
25
pyrazosulfuron-ethyl
25
Dr. Ian Heap, WeedScience.org 2018

Herbicide resistant weeds in CA

- 30 species by site of action combinations, dominated by two patterns of resistance.
- The first major category is multiple-resistance in a number of sedge and grass weeds of the **rice production** region of the Sacramento Valley.
  - ALS inhibiors
  - ACCase inhibitors
- The second broad category is glyphosate-resistant weeds in **orchards, vineyards, and associated non-crop areas** such as **roadsides, canal banks, and field margins and roundup-ready crops**.
  - Glyphosate

Herbicide Resistant Weeds in CA

Year	Species	Site of Action
1981	Senecio vulgaris Common Groundsel	Photosystem II inhibitors (C1/5)
1989	Lolium perenne Perennial Ryegrass	ALS inhibitors (B/2)
1993	Sagittaria montevidensis California Arrowhead	ALS inhibitors (B/2)
1993	Cyperus difformis Smallflower Umbrella Sedge	ALS inhibitors (B/2)
1994	Salsola tragus Russian-thistle	ALS inhibitors (B/2)
1996	Avena fatua Wild Oat	Cell elongation inhibitors (Z/8)
1997	Ammannia auriculata Eared Redstem	ALS inhibitors (B/2)
1997	Schoenoplectus mucronatus (=Scirpus mucronatus) Ricefield Bulrush	ALS inhibitors (B/2)
1998	Echinochloa phyllopogon (=E. oryzicola) Late Watergrass	ACCase inhibitors (A/1)
1998	Lolium rigidum Rigid Ryegrass	EPSP synthase inhibitors (G/9)
1998	Echinochloa phyllopogon (=E. oryzicola) Late Watergrass	Lipid Inhibitors (N/8)
2000	Echinochloa oryzoides Early Watergrass	Lipid Inhibitors (N/8)
2000	Ammannia coccinea Redstem	ALS inhibitors (B/2)
2000	Echinochloa crus-galli var. crus-galli Barnyardgrass	**Multiple Resistance: 2 Sites of Action** ACCase inhibitors (A/1) Lipid Inhibitors (N/8)
2000	Echinochloa phyllopogon (=E. oryzicola) Late Watergrass	**Multiple Resistance: 2 Sites of Action** ACCase inhibitors (A/1) Lipid Inhibitors (N/8)
2001	Phalaris minor Little seed Canary grass	ACCase inhibitors (A/1)
2002	Digitaria ischaemum Smooth Crabgrass	Synthetic Auxins (O/4)
2005	Conyza canadensis Horseweed	EPSP synthase inhibitors (G/9)
2007	Conyza bonariensis Hairy Fleabane	EPSP synthase inhibitors (G/9)
2008	Echinochloa colona Junglerice	EPSP synthase inhibitors (G/9)
2008	Lolium perenne ssp. multiflorum Italian Ryegrass	EPSP synthase inhibitors (G/9)
2009	Conyza bonariensis Hairy Fleabane	**Multiple Resistance: 2 Sites of Action** EPSP synthase inhibitors (G/9) PSI Electron Diverter (D/22)
2013	Cyperus difformis Smallflower Umbrella Sedge	PSII inhibitor (Ureas and amides) (C2/7)
2013	Poa annua Annual Bluegrass	EPSP synthase inhibitors (G/9)
2014	Schoenoplectus mucronatus (=Scirpus mucronatus) Ricefield Bulrush	PSII inhibitor (Ureas and amides) (C2/7)
2014	Conyza canadensis Horseweed	**Multiple Resistance: 2 Sites of Action** EPSP synthase inhibitors (G/9) PSI Electron Diverter (D/22)
2015	Amaranthus palmeri Palmer Amaranth	EPSP synthase inhibitors (G/9)
2015	Lolium perenne ssp. multiflorum Italian Ryegrass	Glutamine synthase inhibitors (H/10)
2015	Lolium perenne ssp. multiflorum Italian Ryegrass	**Multiple Resistance: 3 Sites of Action** ACCase inhibitors (A/1) EPSP synthase inhibitors (G/9) PSI Electron Diverter (D/22)
2016	Lolium perenne ssp. multiflorum Italian Ryegrass	**Multiple Resistance: 4 Sites of Action** ACCase inhibitors (A/1) ALS inhibitors (B/2) EPSP synthase inhibitors (G/9) PSI Electron Diverter (D/22)

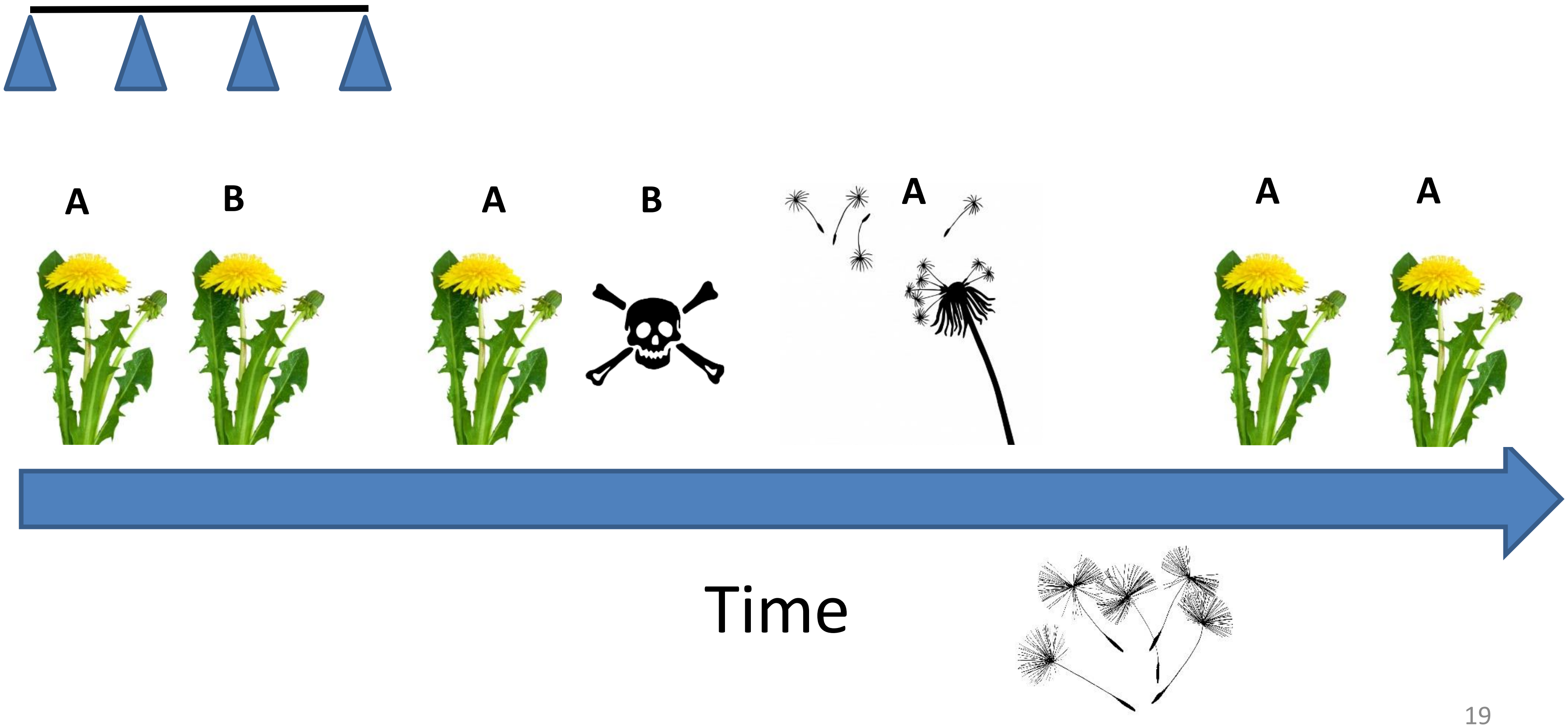
Species in CA with suspected glyphosate resistant populations

- Threespike goosegrass (spring emerging)
- Feather fingergrass (summer emerging)
- Windmillgrass (summer emerging)
- Sprangletop (summer emerging)
- Witchgrass (summer emerging)

Multiple HR weeds in CA

Year	Species	Herbicides	Systems
2000	Barnyardgrass	ACCase and lipid bionsynthesis inhibitors	Rice
2000	Late watergrass	ACCase and lipid bionsynthesis inhibitors	Rice
2009	Hairy fleabane	Glyphosate, paraquat	Orchards
2014	Horseweed	Glyphosate, paraquat	Orchards
2015	Italian ryegrass	ACCase inhibitors, glyphosate, paraquat	Orchards, alfalfa
2016	Italian ryegrass	ACCase and ALS inhibitors, glyphosate, paraquat	Orchards, alfalfa

Herbicide resistance is the result of evolution of weed populations in response to the selection pressure exerted by herbicides



Resistance before herbicides

OPEN ACCESS Freely available online PLOS ONE

DNA Analysis of Herbarium Specimens of the Grass Weed *Alopecurus myosuroides* Reveals Herbicide Resistance Pre-Dated Herbicides

Christophe Délye*, Chrystel Deulvot, Bruno Chauvel

INRA, UMR1347 Agroécologie, Dijon, France

734 dried plant specimens

Collected between 1788 – 1975

1 from 1888 with a mutation that can confer resistance to ACC-ase (WSSA 1) herbicides

Not every instance of weed control failure is due to herbicide resistance

Herbicides

Carrier Quality

Spray Solutions

- Water quality (spray solutions are >95% water)
- What goes in can affect what comes out
- Glyphosate is one of the best examples
  - *pH – high pH causes glyphosate to dissociate*
  - *Cations – Mg, Ca, Na can bind to glyphosate*
  - *Turbidity – glyphosate tightly bound to soil and OM*

Ammonium sulfate and glyphosate

- Glyphosate is antagonized by salts in hard water such as calcium, sodium, magnesium, and iron
  - These salts will preferentially bind to glyphosate
- Both ammonium (NH_3^{1+}) and sulfate (SO_4^{2-}) active
  - Free sulfate binds with Ca^{2+}, Na^{1+}, Mg^{2+}, or Fe^{2+} ions in the spray water
  - Glyphosate binds to the ammonium
  - Glyphosate is more readily absorbed into foliage when combined with ammonium than when combined with Ca^{2+}, Na^{1+}, Mg^{2+}, or Fe^{2+} ions

Best ‘plain language’ explanation of spray water effects on glyphosate efficacy

Google: glyphosate spray water quality Purdue

https://ag.purdue.edu/btny/weedscience/documents/water_quality.pdf

PURDUE UNIVERSITY

Created: 3/2/2012

PURDUE WEED SCIENCE

www.btny.purdue.edu/weedscience

The Influence of Spray Water Quality on Herbicide Efficacy

Gurinderbir Chahal
Postdoctoral Research Associate
Jared Roskamp
Weed Science Masters Candidate
Travis Legleiter
Weed Science Program Specialist
Bill Johnson
Professor of Weed Science
Purdue University
Extension Weed Science

What is Water Quality?

Water is a universal solvent, and it is used as a primary carrier for crop protection products applications, constituting more than 95% of the spray volume. The properties of water used for carrier in spray solutions can greatly influence the performance of herbicides including glyphosate, Ignite, Clarity, 2,4-D, Sharpen, Pursuit, Poast, Accent, and many other herbicides. Therefore, defining the role of water quality on herbicide efficacy is very important. Unlike pure water, water quality of groundwater is variable between sources. Water quality of groundwater is determined by several factors such as pH, hardness, alkalinity, turbidity, and temperature. Presence of dissolved cations like calcium, magnesium, iron, aluminum, zinc, manganese, sodium, potassium, cesium, and lithium can influence herbicide efficacy. The presence of calcium and magnesium carbonate makes water hard whereas carbonate and bicarbonate concentration determine the alkalinity of the water. The presence of soil and/or organic matter particulate leads to the turbidity in water.

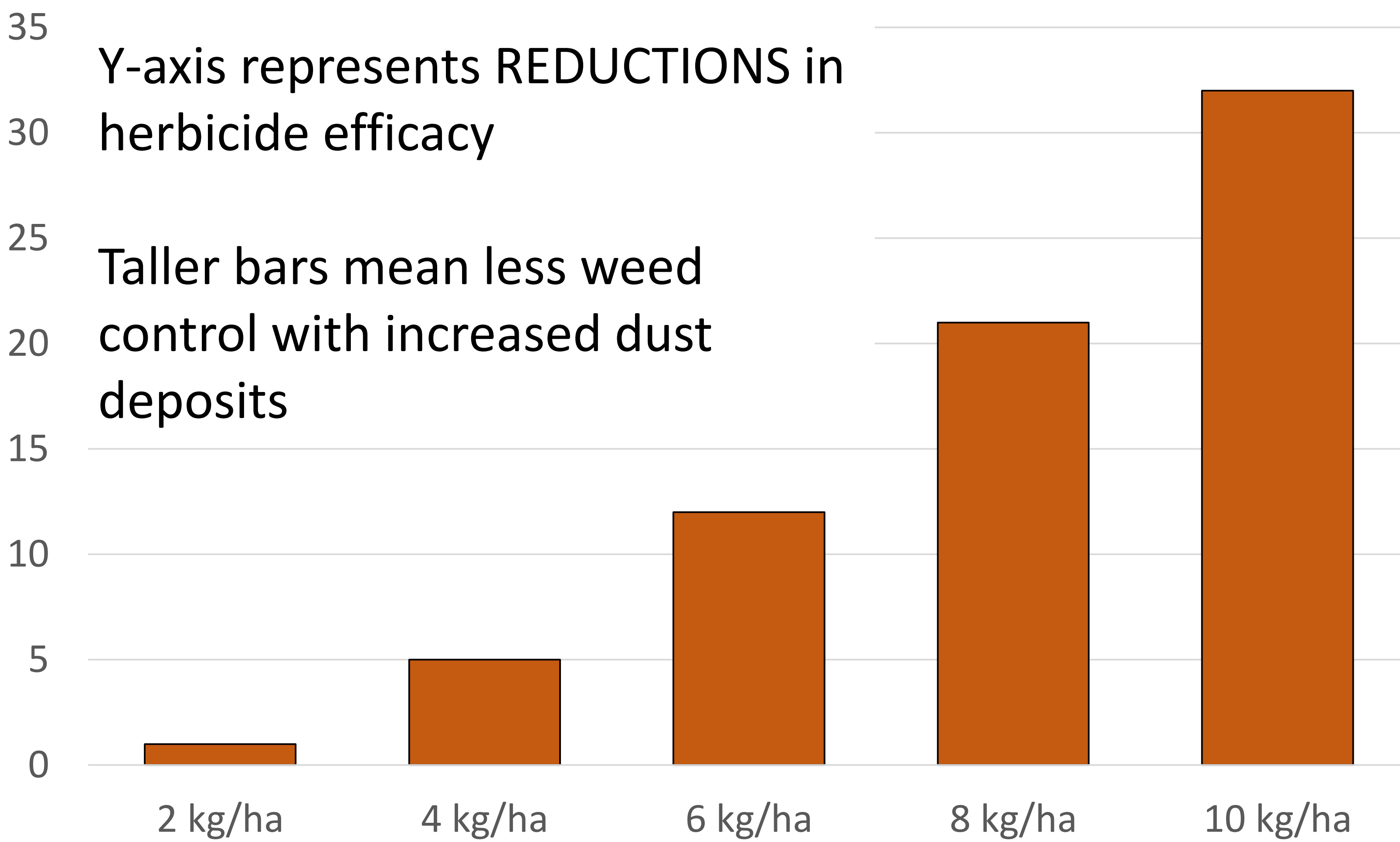
Environmental factors

Dust
Temperature

Dust that accumulates on leaves can bind to glyphosate and prevent uptake

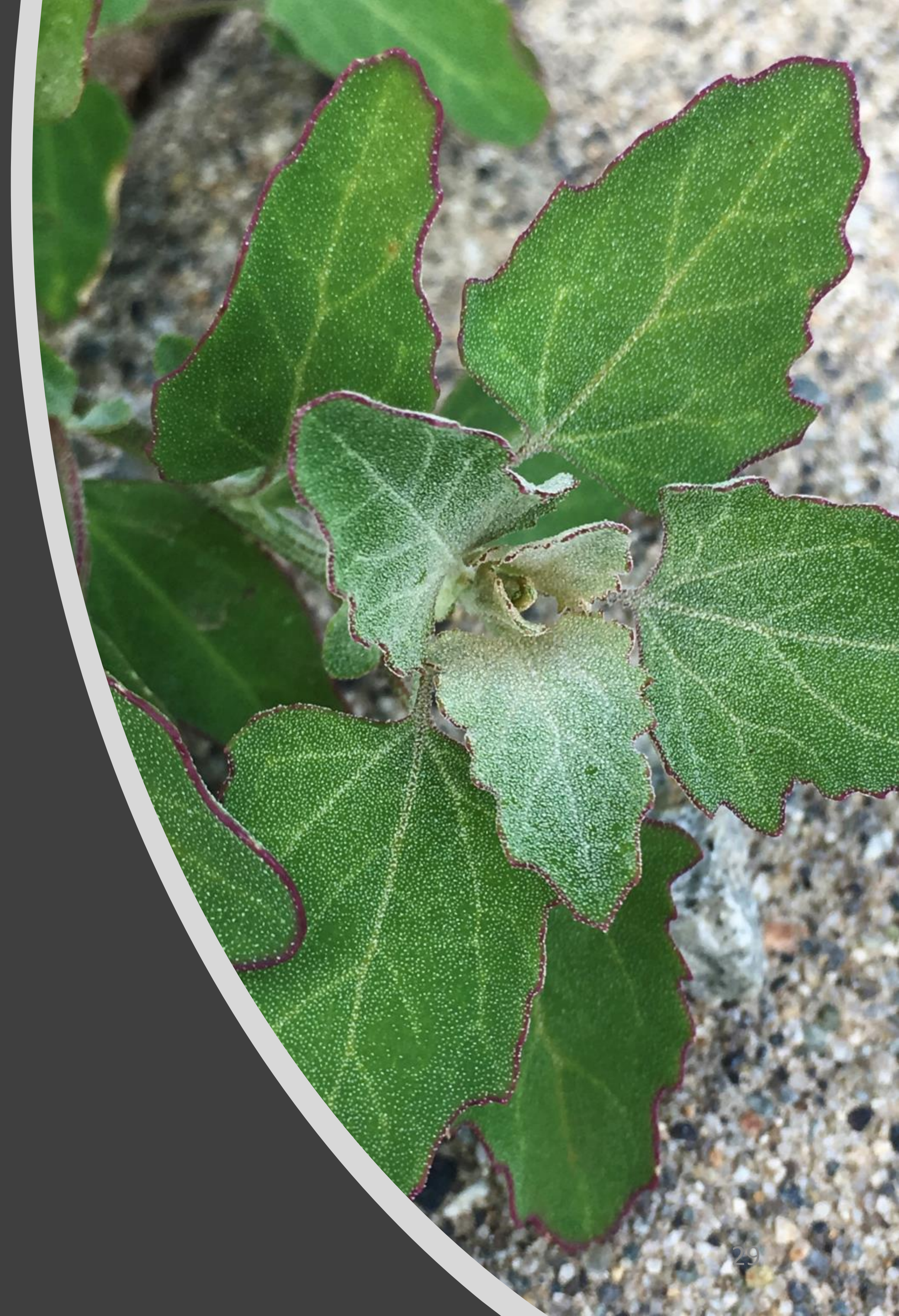
Photo by Andrew Kniss PhD

Zhou et al. (2006) Weed Science 54:1132-1136
Soil dust reduces glyphosate efficacy



Temperature effects on herbicide performance

- Herbicide efficacy can be adversely affected by very low and very high temperatures
- At temperature extremes, translocation and physiological activities may be reduced (which can primarily affect the efficacy of systemic herbicides)
- Plant growth, leaf area, leaf shape, and cuticle development can be impacted
- High temperatures can affect the deposition, volatility and breakdown of many products



Temperature and glyphosate

- Glyphosate translocation and distribution in plants can be inhibited at low temperatures

- Conversely, resistance to glyphosate is actually reduced in some species

- *Horseweed*
- *Marestail*
- *Perennial ryegrass*
- *Rigid ryegrass*
- *Johnsongrass*
- *Junglerice*
- *Barnyardgrass*

- *Mechanisms are still under investigation*

Weed Biology and Ecology

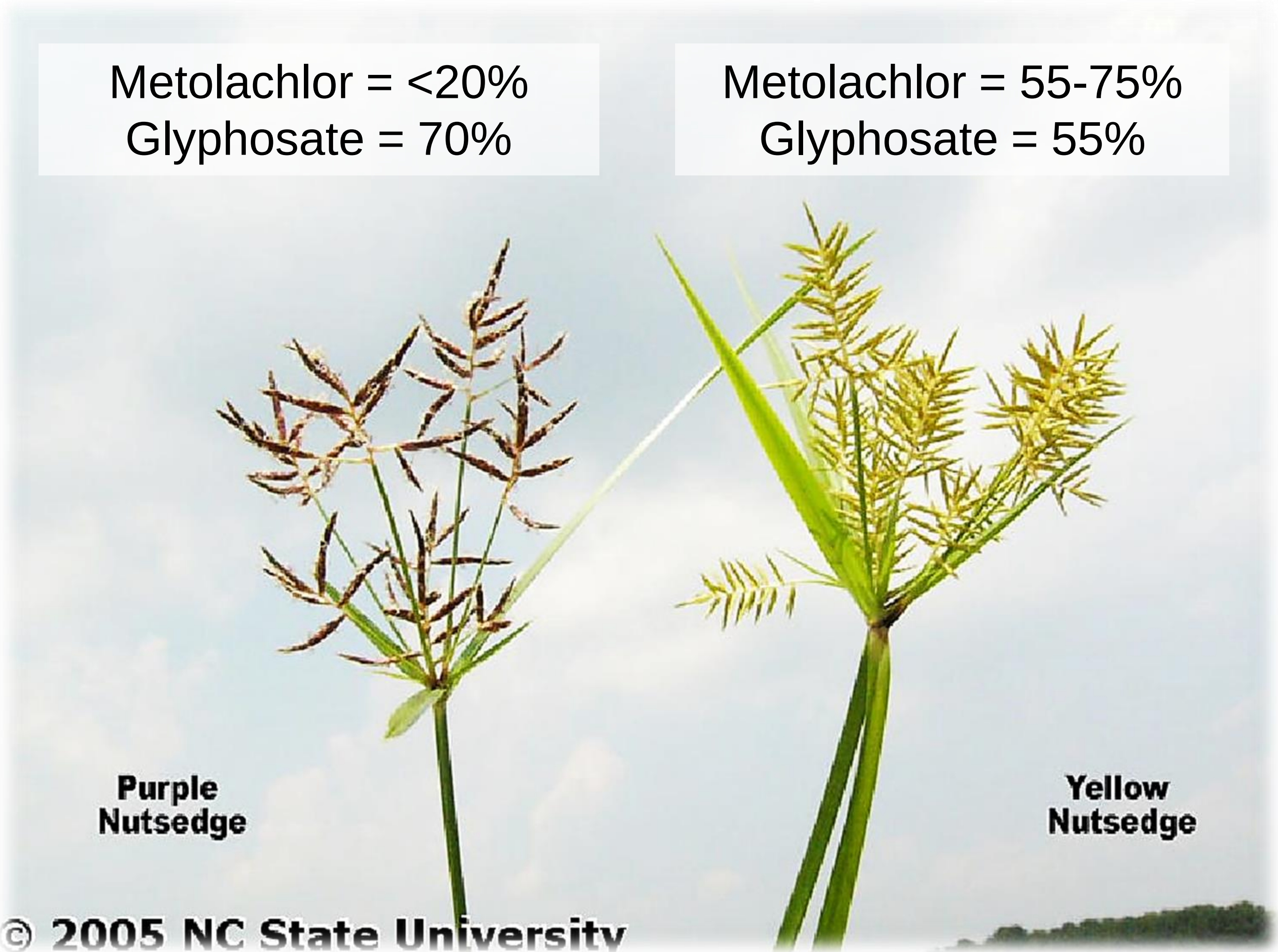
Identity

WHY IS WEED ID IMPORTANT?

- Because weed management strategies are not equally effective against all weeds

- Selectivity
  - Herbicides that target grasses vs broadleaf species
  - Mowing that can differentially affect erect vs prostrate plants
  - Cultivation that can control annuals but not perennials
  - Timing of operations to target summer vs winter annuals

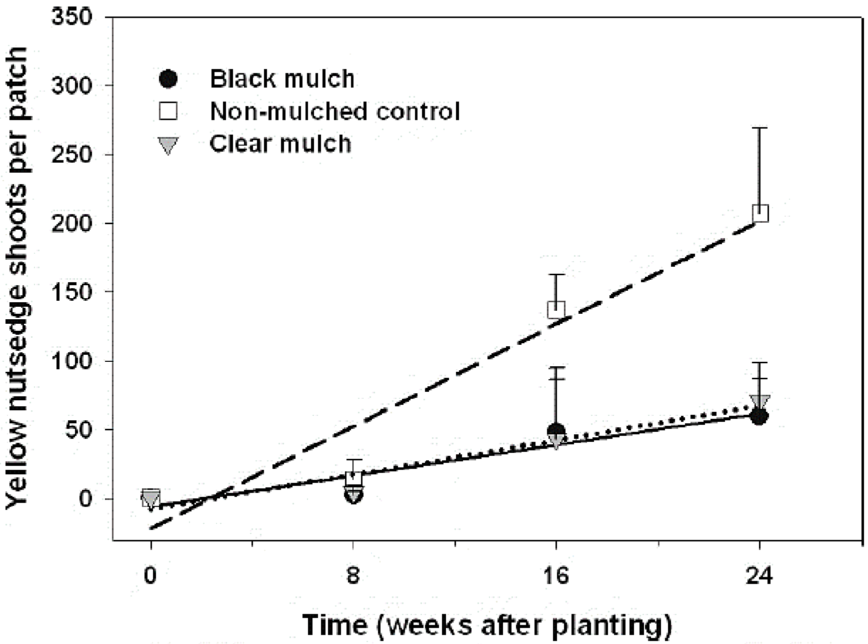
Herbicides and nutsedge control

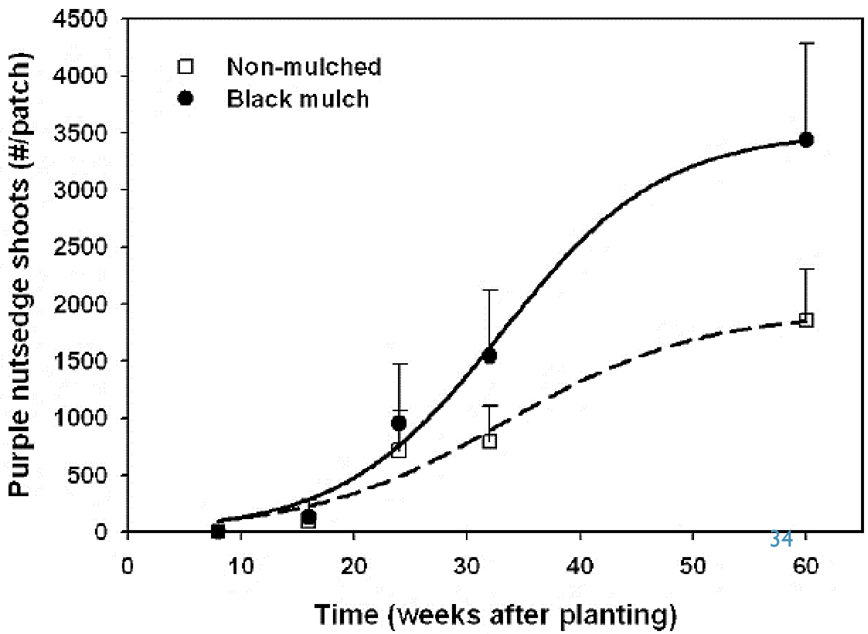


WEBSTER (2009)
WEED SCIENCE 53 : 839-845

Black polyethylene mulch is used as a weed barrier in many vegetable production systems.

YELLOW nutsedge shoot production was reduced in a mulched, as compared to bareground, system; PURPLE nutsedge shoot production increased under black plastic.





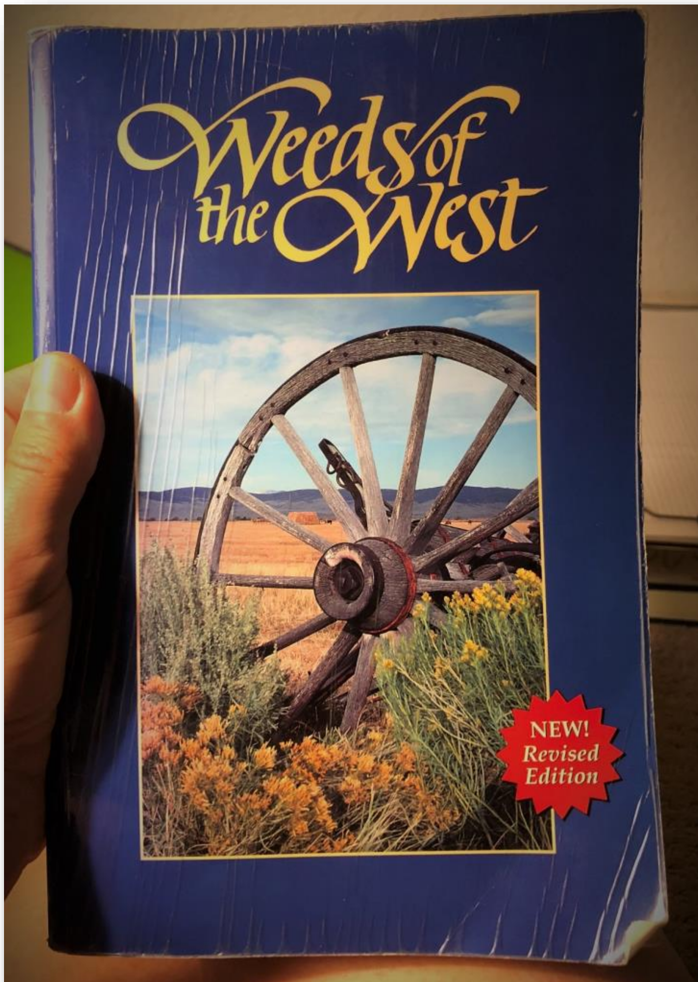
WEED ID GIVES YOU A STARTING POINT

- A successful identification provides you with the basic knowledge that you need to develop a successful management plan

- Ideally, control strategies will be adopted based on the sensitivity of a target species to control measures

TRADITIONAL TOOLS

WEEDS OF THE WEST



Tom D. Whitson, et al.

Western Society of Weed Science

ISBN-13: 0-941570-13-4

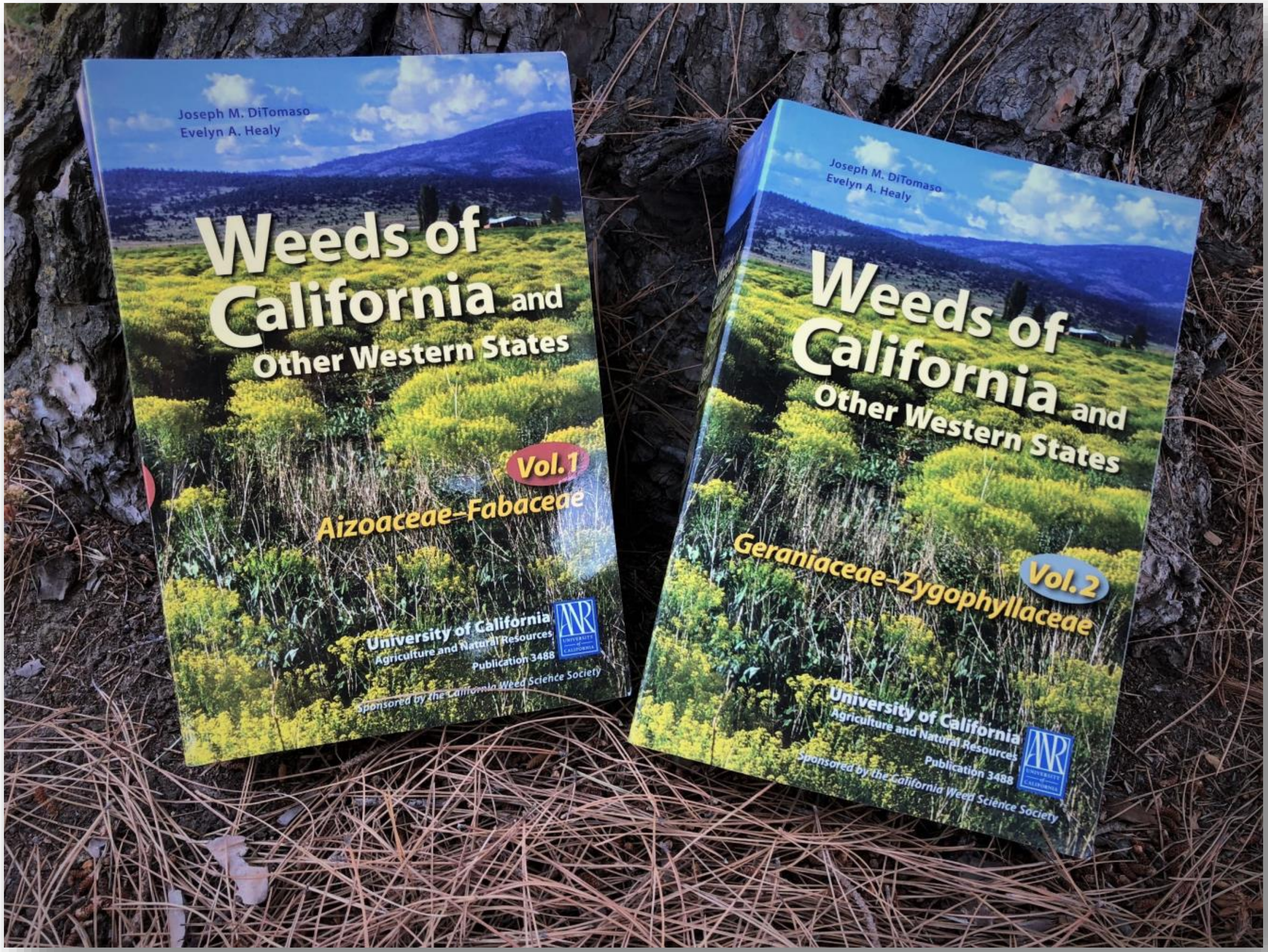
Descriptions of >350 species

Species comprise 51 plant families

"Truck Book"

NO LONGER IN PRINT
NO UPDATES
NO ADDITIONAL SPECIES ADDED
NO CHANGES IN TAXONOMY

WEEDS OF CALIFORNIA AND OTHER WESTERN STATES



WEEDS OF CALIFORNIA AND OTHER WESTERN STATES

- Joseph M. DiTomaso and Evelyn A. Healy
- UC ANR Publication 3488
- ISBN-13: 978-1-879906-69-3

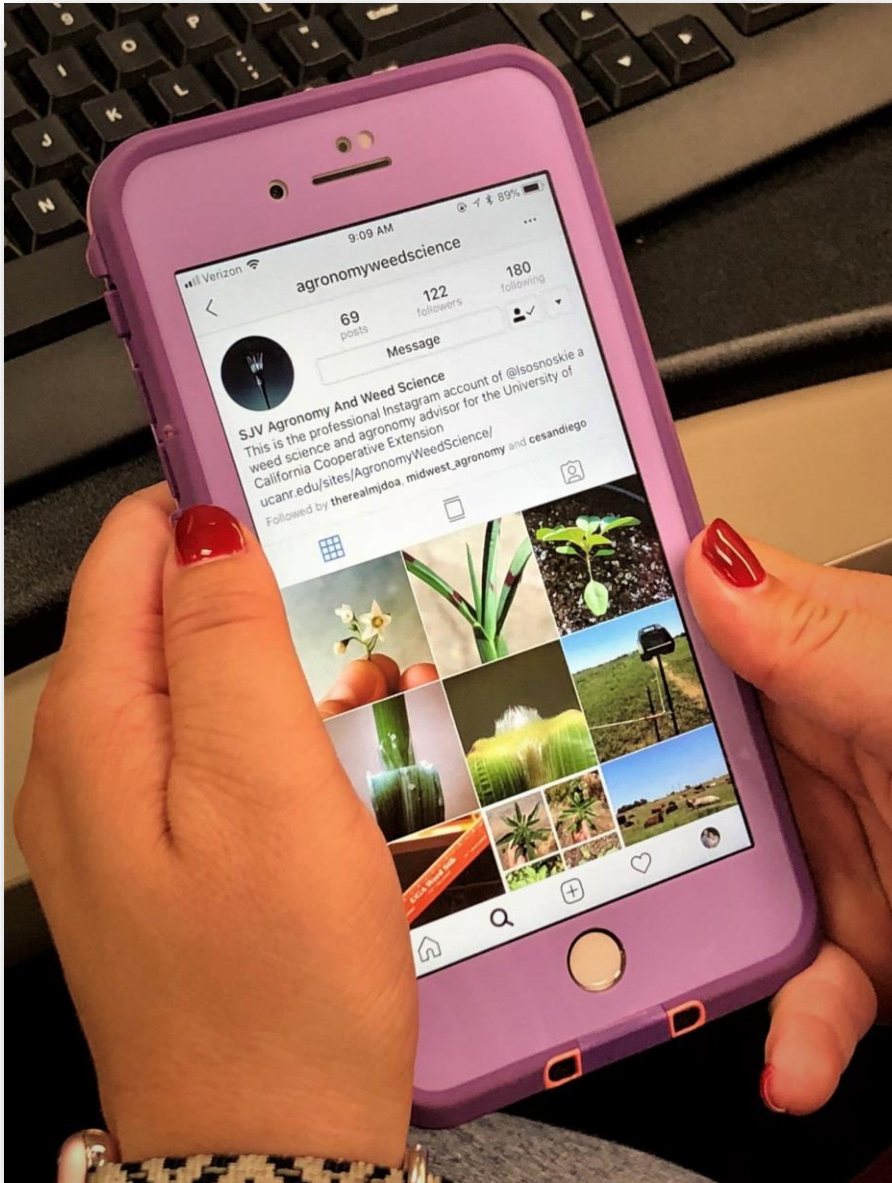
- Volume 1: Aizoaceae - Fabaceae
- Volume 2: Geraniaceae - Zygophyllaceae

WEEDS OF CALIFORNIA AND OTHER WESTERN STATES

- >700 species (>60 plant families) are described, photographed
- Specific subjects of interest or else as a comparative species
- ~60% non-native species, ~40% native species
- Photographs are provided on an included CD and are available use copyright free for educational purposes

WEEDS OF CALIFORNIA AND OTHER WESTERN STATES

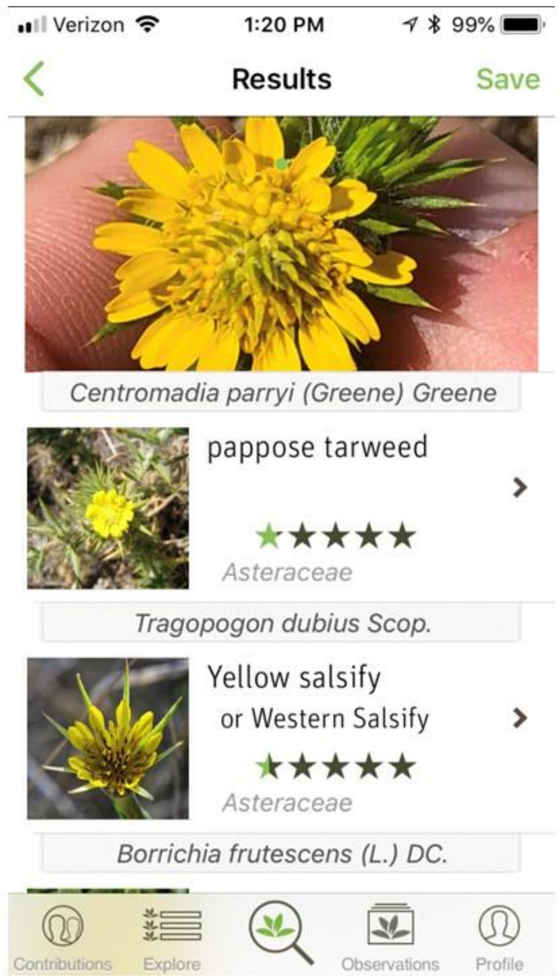
- 2 identification keys for the grass species
- 13 'shortcut' tables describing the differences between species that share unique or uncommon traits
  - Species with prickles, spines, or thorns
  - Parasitic plants
- 67 tables summarizing the differences between difficult-to-distinguish species
  - *Amaranthus* (pigweed) species
  - *Lepidium* (pepperweed) species
- "Office book"


Verizon
9:09 AM
89%
agronomyweedscience
69
posts
122
followers
180
following
Message
SJV Agronomy And Weed Science
This is the professional Instagram account of @lsosnoskie a
weed science and agronomy advisor for the University of
California Cooperative Extension
ucanr.edu/sites/AgronomyWeedScience/
Followed by therealmjdoa, midwest_agronomy and cesandiego

PHONE APPS

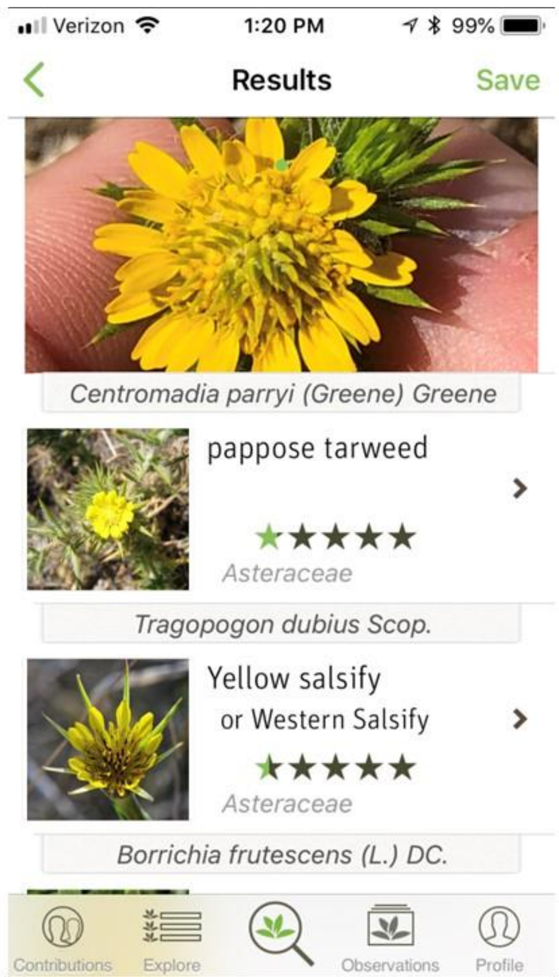
PL@NTNET


Verizon
1:20 PM
99%
Leaf
Flower
Fruit
Bark

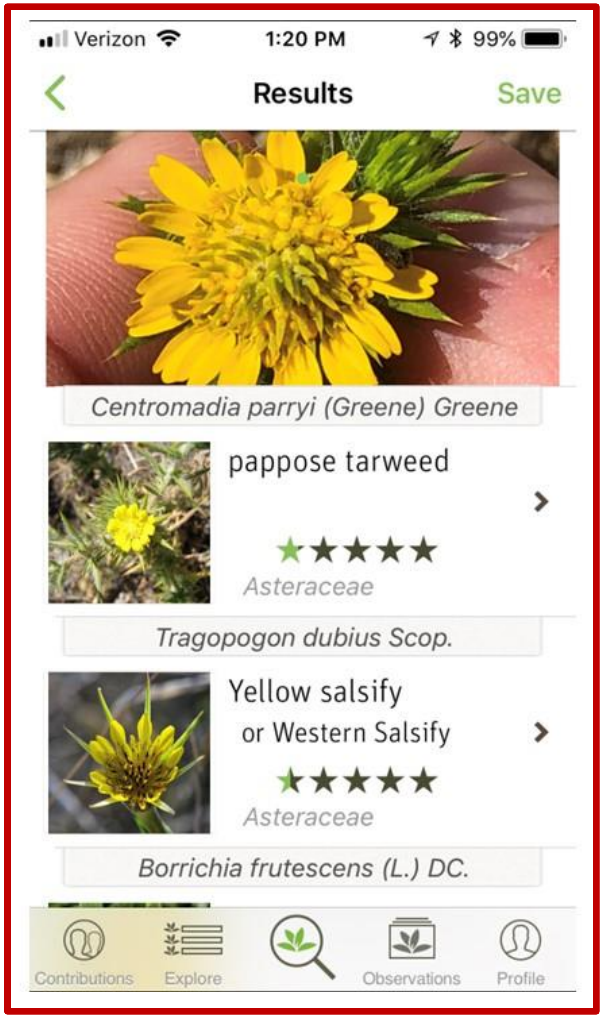

Verizon
1:20 PM
99%
Results
Save
Centromadia parryi (Greene) Greene
pappose tarweed
Asteraceae
Tragopogon dubius Scop.
Yellow salsify
or Western Salsify
Asteraceae
Borrichia frutescens (L.) DC.
Contributions
Explore
Observations
Profile


Verizon LTE
1:20 PM
99%
Wikipedia
WIKIPEDIA
Centromadia parryi
Centromadia parryi (pappose tarweed)[2] is a species of North American plants in the tarweed tribe within the sunflower family. It is native to California and, northern Baja California.[3][4]
Centromadia parryi
Scientific classification
Kingdom: Plantae
(unranked): Angiosperms

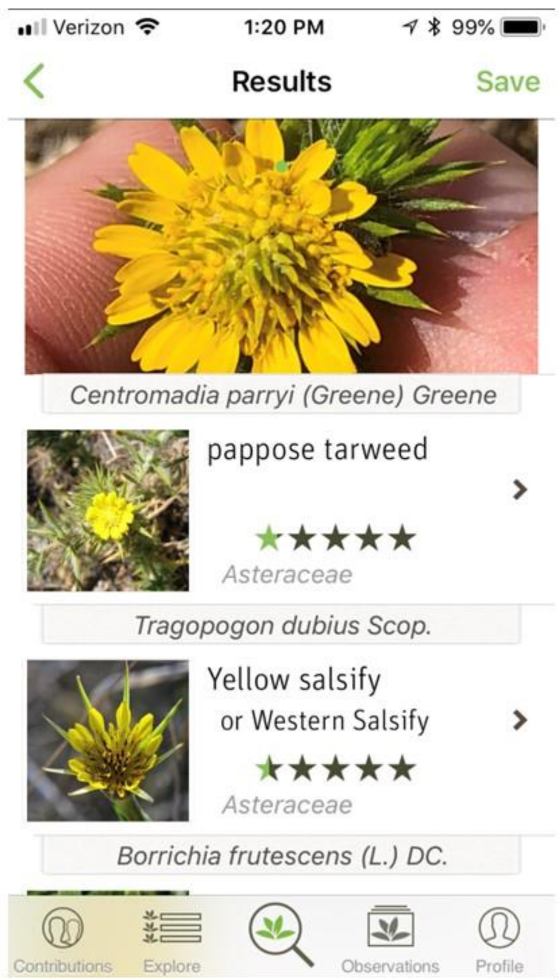
PL@NTNET USES VISUAL RECOGNITION SOFTWARE TO COMPARE YOUR UPLOADED PICTURE TO A DATABASE OF IMAGES



AFTER SCANNING AND COMPARING YOUR IMAGE, PL@NTNET RETURNS A LIST OF POTENTIAL SPECIES

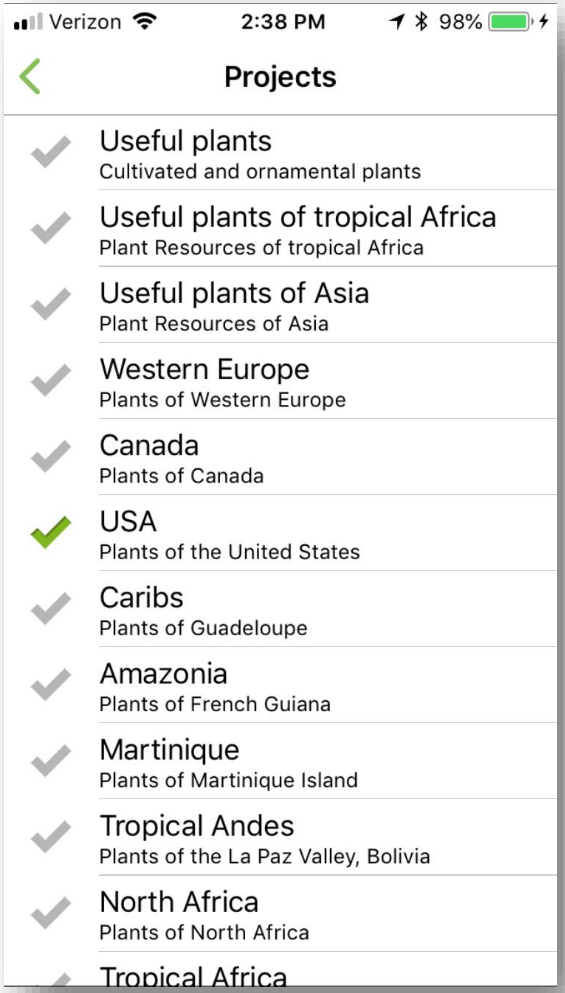


YOU CAN GET FURTHER INFORMATION ABOUT EACH SPECIES VIA A LINK THAT TAKES YOU TO ITS WIKIPEDIA PAGE



AVAILABLE DATABASES (PROJECTS)

The Pl@ntNet app has multiple databases (projects) that a user can draw upon to evaluate a specimen depending on where they are in the world



HOW DO YOU IMPROVE YOUR CHANCES?

Take clear and focused pictures

Minimize the background

Try submitting multiple images of different structures
- leaves
- flowers
- spines or bracts

Photos by Lynn M Sosnoskie

Selective pressure isn't limited to herbicide resistance

Lynn's first rule of weed science:

"For every weed control action there is an adaptive weed reaction."

Selective pressure isn't limited to herbicide resistance

- Mowing:
- Abu-Dieyeh and Watson (2005) J. Plant Interactions 1:239-252
- Impact of mowing and weed control on broadleaf weed population dynamics in turf
- Mowing to a height of 3-5 cm (1-2") over two seasons increased broadleaf plantain *(Plantago major*) and dandelion *(Taraxacum officianale*), mouseear chickweed (*cerastium* fontanum) and prostrate knotweed *(Polygonum arviculare*) densities in turfgrass

Selective pressure isn't limited to herbicide resistance

- Mowing:
- Abu-Dieyeh and Watson (2005) J. Plant Interactions 1:239-252
- Impact of mowing and weed control on broadleaf weed population dynamics in turf
- Why?
- Close mowing favors naturally prostrate habits, shorter ecotypes, and perennials that have root reserves to re-grow.

Prostrate habit, root reserves, plastic responses

Selective pressure isn't limited to herbicide resistance

- Mowing:

- Pirchio et al. (2018) Agronomy 8:15

- Autonomous mower vs. rotary mower: effects on turf quality and weed control in tall fescue lawn

- Use of a Husqvarna Automower 420 (turf mowing Roomba) resulted in lower turf height and higher densities of clovers (*Trifolium spp*.), a daisy (*Bellis perennis*), and a trefoil (*Lotus corniculatus*)

Selected for species that escaped mowing or expanded sideways in responses to the continuous and consistent short mowing heights

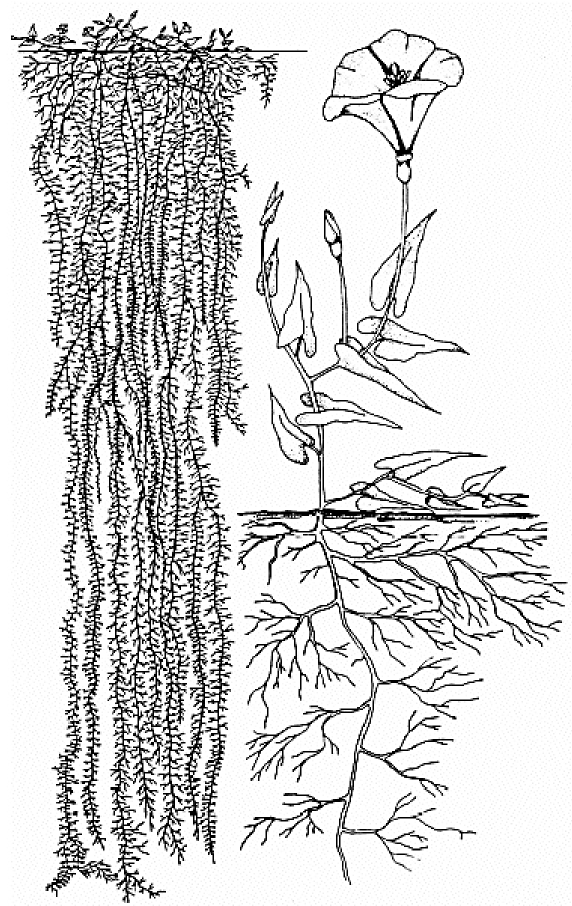
Selective pressure isn't limited to herbicide resistance

- Irrigation:
- Stoddard and Lanini (2015) Acta Horticulturae 1081:75-80
- Field Bindweed Management in Drip-Irrigated Processing Tomatoes
- The adoption of drip-irrigation in processing tomatoes resulted in reduced numbers of annual weed species (due to reduced surface wetting that stimulated germination)
- However, the adoption facilitated the spread of field bindweed (*Convolvulus arvensis*).

Field bindweed is a perennial vine in the morningglory family

Field bindweed below-ground

- Extensive root system
  - Vertical roots
  - Lateral roots
- Nutrient reserves to facilitate regrowth
- The species can take advantage of moisture that is deeper in the soil profile (such as that produced by buried drip irrigation)



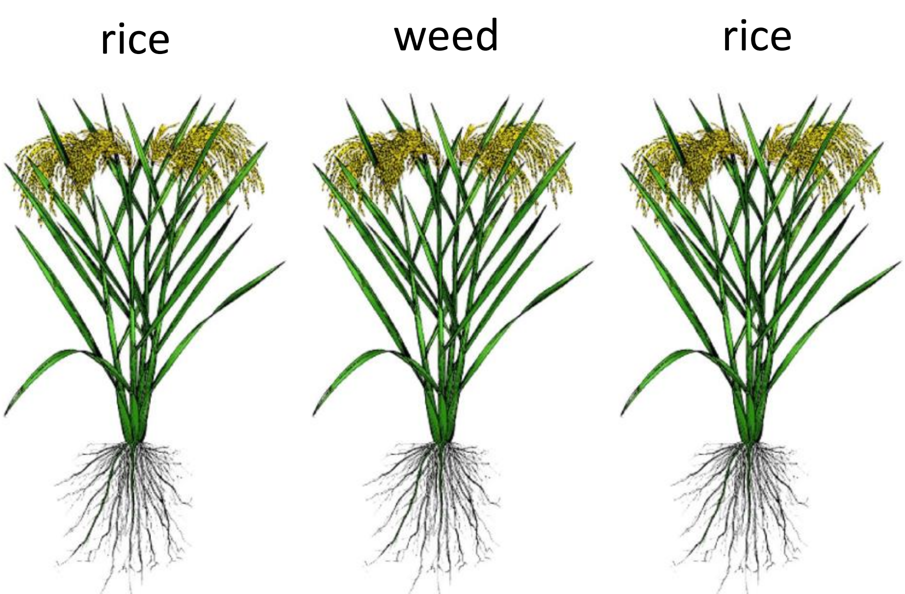
Root system of field bindweed, Convolvulus arvensis. Redrawn from B. F. Kiltz. 1930. J. Amer. Soc. Agron. 22:216-234

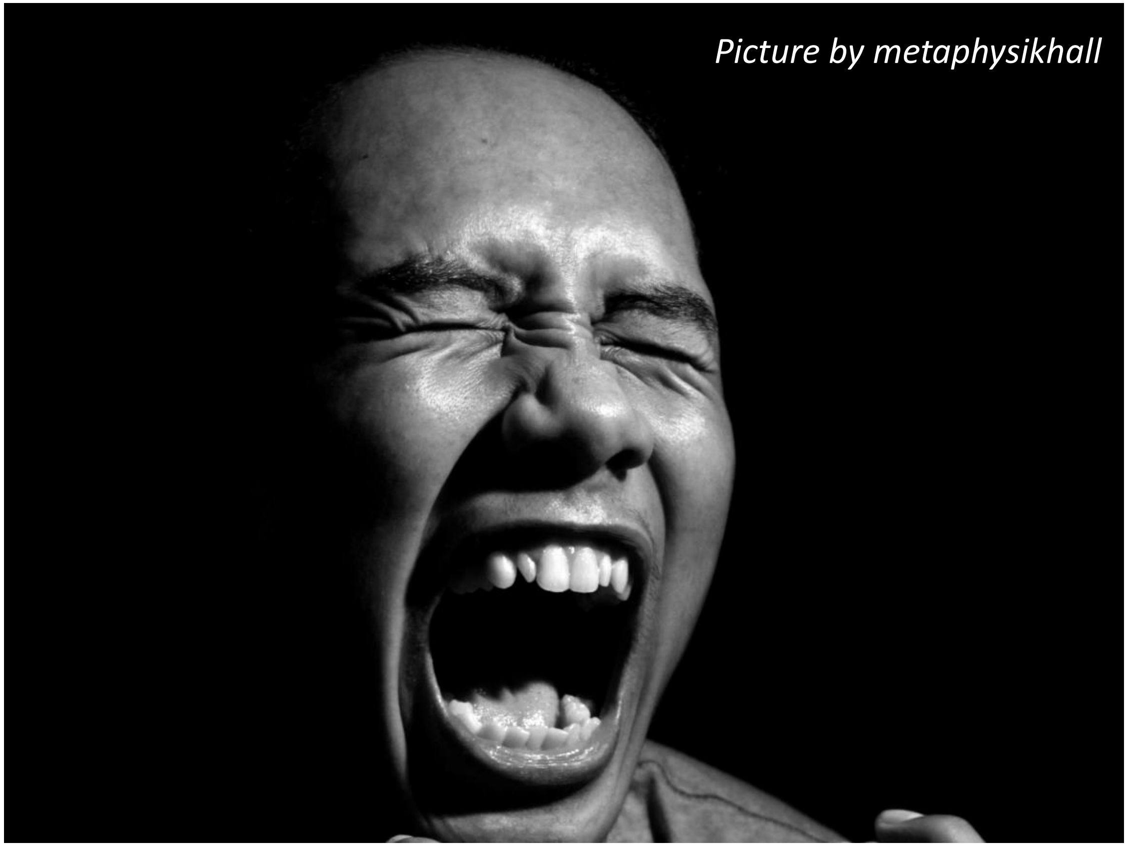
Selective pressure isn't limited to herbicide resistance

- Handweeding:
- McElroy (2014) Weed Science 62:207-216
- Vavilovian Mimicry: Nikolai Vavilov and his Little-Known Impact of Weed Science
- Barnyardgrass (*Echinochloa crus-galli*) is incredibly diverse in form and habit and is often referred to as a complex of subspecies
- *Echinochloa crus-galli* subsp. *oryzicola* is a form that physically looks like rice and even flowers and sets seed at the same time as rice
- Consequently, it is often escapes hand-weeding attempts

Because of the similarity in appearance, barnyardgrass subsp *oryzicola* can be difficult to distinguish from actual rice in a field

In this situation, barnyardgrass is left to grow and reproduce and further infest a field





Why is this so complicated!

The ultimate point…

Understand how disturbance can select for deleterious species

Weeds possess characteristics that allow them to become established and persist in many different environments

Disruptive forces (chemical, physical, environmental) select for species with traits that can survive those conditions

Sometimes the forces are controlled by us (i.e. herbicides) and sometimes the forces are out of our control (i.e. drought)

Be aware of shifts towards difficult to control species in the wake of control events and diversify tools as much as possible

THANK YOU

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