

The Increasing Prevalence of Palmer amaranth (*Amaranthus palmeri*) and Common waterhemp (*Amaranthus tuberculatus*) in the Central Valley

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Palmer amaranth and Common waterhemp

- Belong to the Amaranthaceae
- 38 species of *Amaranthus* in the U.S., 75 worldwide
- Summer annual dicot C4 plants
- Both species are classified among the top 5 worst weeds in US agriculture by the WSSA
- Rapid growth, up to 1-2 in./ day

Palmer amaranth



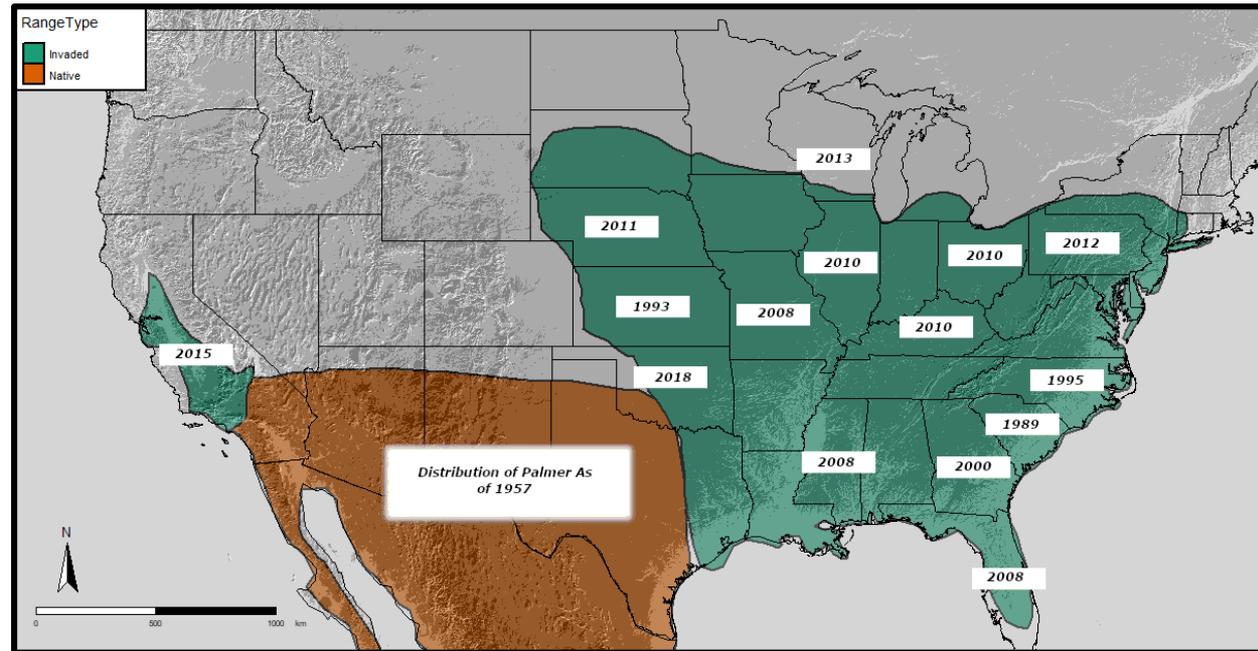
Photo: Lynn Sosnoskie (L)
IwillTakeAction.com (R)

Erect plants, can grow up to 6-8 feet tall, sometimes up to 10 ft
Leaves are wider and ovate, sometimes with silvery watermark
Stems are hairless.
Native to SW USA

Background

The plant has found recent success in agricultural fields in the Californian Central Valley, as chemical herbicides began to fail in the region in 2015 (Rios et al. 2016).

This ongoing range expansion gives us an opportunity to examine the genetic diversity and structure of emerging Central California demes of this weedy species.



Palmer amaranth started in the desert Southwest (orange shading) and expanded well into the northeastern and Midwestern U.S., and most recently into Central California. States in the invaded regions (green shading) are labeled with the year that the first herbicide resistant biotype was detected (Sauer 1957; Heap 2020).



Common waterhemp



Source: Lynn Sosnoskie



Source: Jose Carvalho

Erect plants, can grow up to 8 feet tall
Leaves are glossy, alternate, ovate to lanceolate.
Stems are hairless.
Cotyledons are egg shaped but can be difficult to distinguish from Palmer

Amaranthus tuberculatus (Waterhemp)

- Native to Mississippi Valley
 - Two varieties: *rudis* (west) and *tuberculatus* (east)
- Began invading agroecosystems in 1950's
 - Attributed to changing agricultural practices

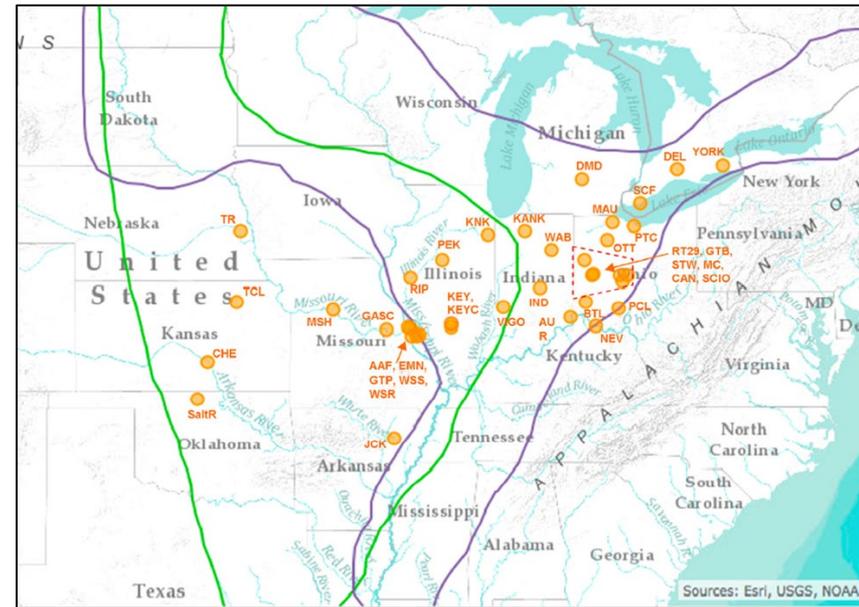


Figure 6. – Historical ranges of both waterhemp varieties (Waselkov & Olsen, 2014) adapted from Sauer (1957). Geographical range of western variety *A. tuberculatus* var. *rudis* indicated by region outlined in green. Geographical range of eastern variety *A. tuberculatus* var. *tuberculatus* indicated by region outlined in purple. Orange circles represent waterhemp populations sampled in the Waselkov & Olsen (2014) paper.

Palmer amaranth and Common waterhemp

- Dioecious plants
- Outcrossed and traits are passed through pollen
- Prolific seed producers - 200,000-600,000 seeds per female plant in Palmer; up to 2 million seeds per plant reported in waterhemp



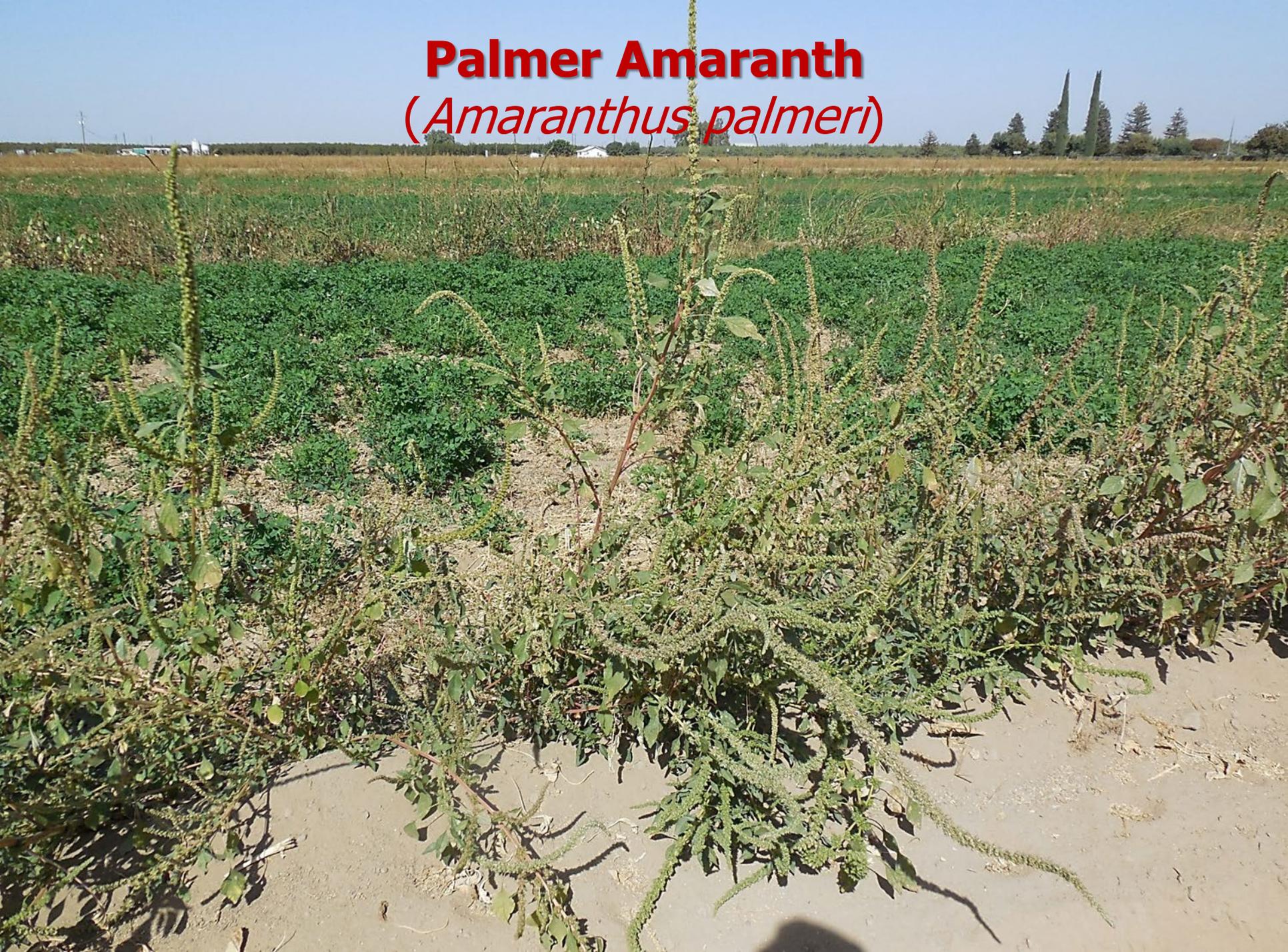
Inflorescences and flowers of female Palmer amaranth (L) and waterhemp (R).,
Source: Iowa State University

Palmer **Powell** **Redroot** **Smooth** **Waterhemp**



Source: University of Illinois

Palmer Amaranth
(*Amaranthus palmeri*)





Kings County



Tulare County



Fresno County



Tulare County

Glyphosate-resistant (GR) populations of Palmer amaranth have been confirmed in 29 states in the U.S. since 2005 including CA

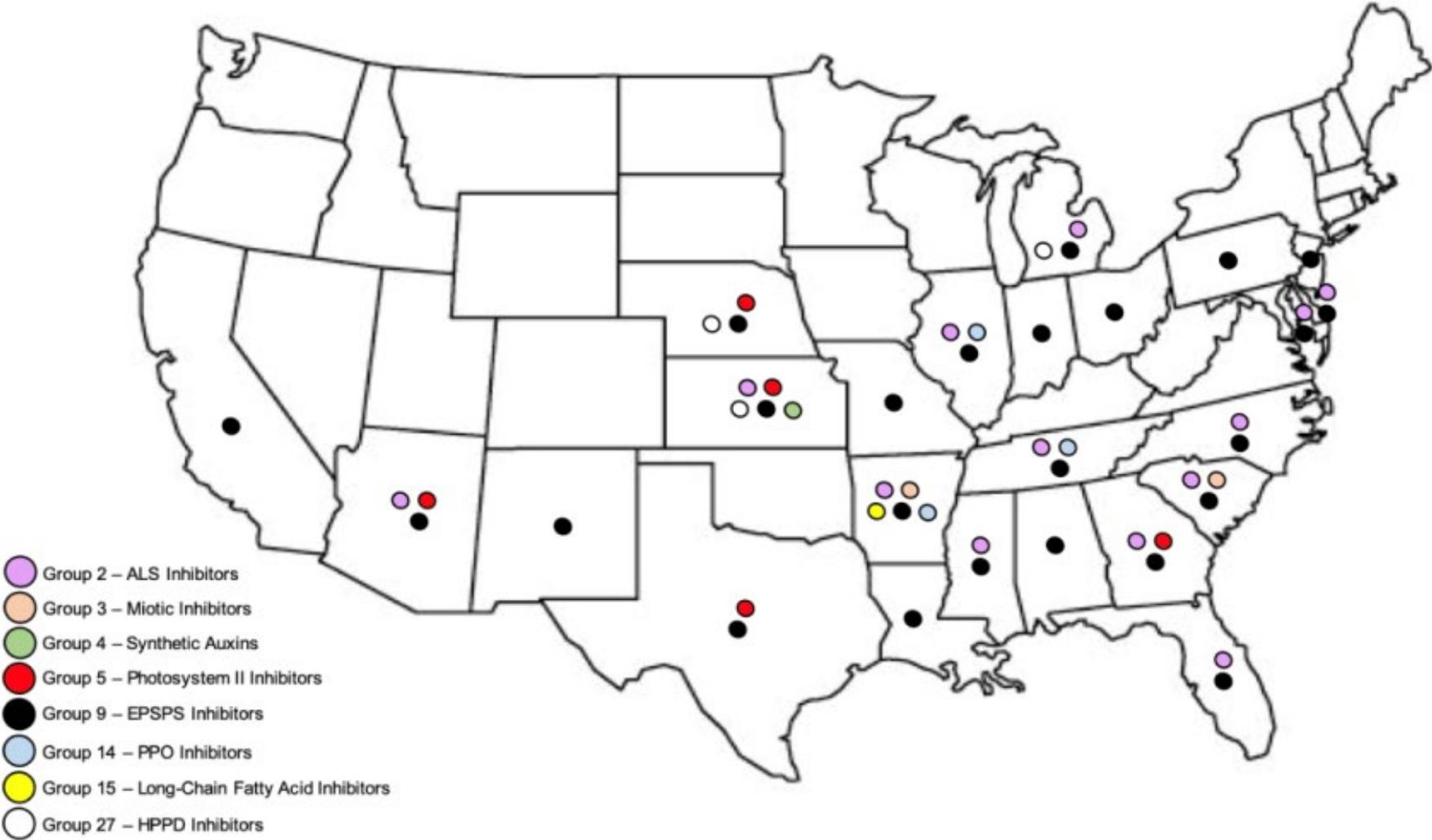


Glyphosate-resistant (GR) populations of common waterhemp have been confirmed in 19 states in the US but not yet in CA

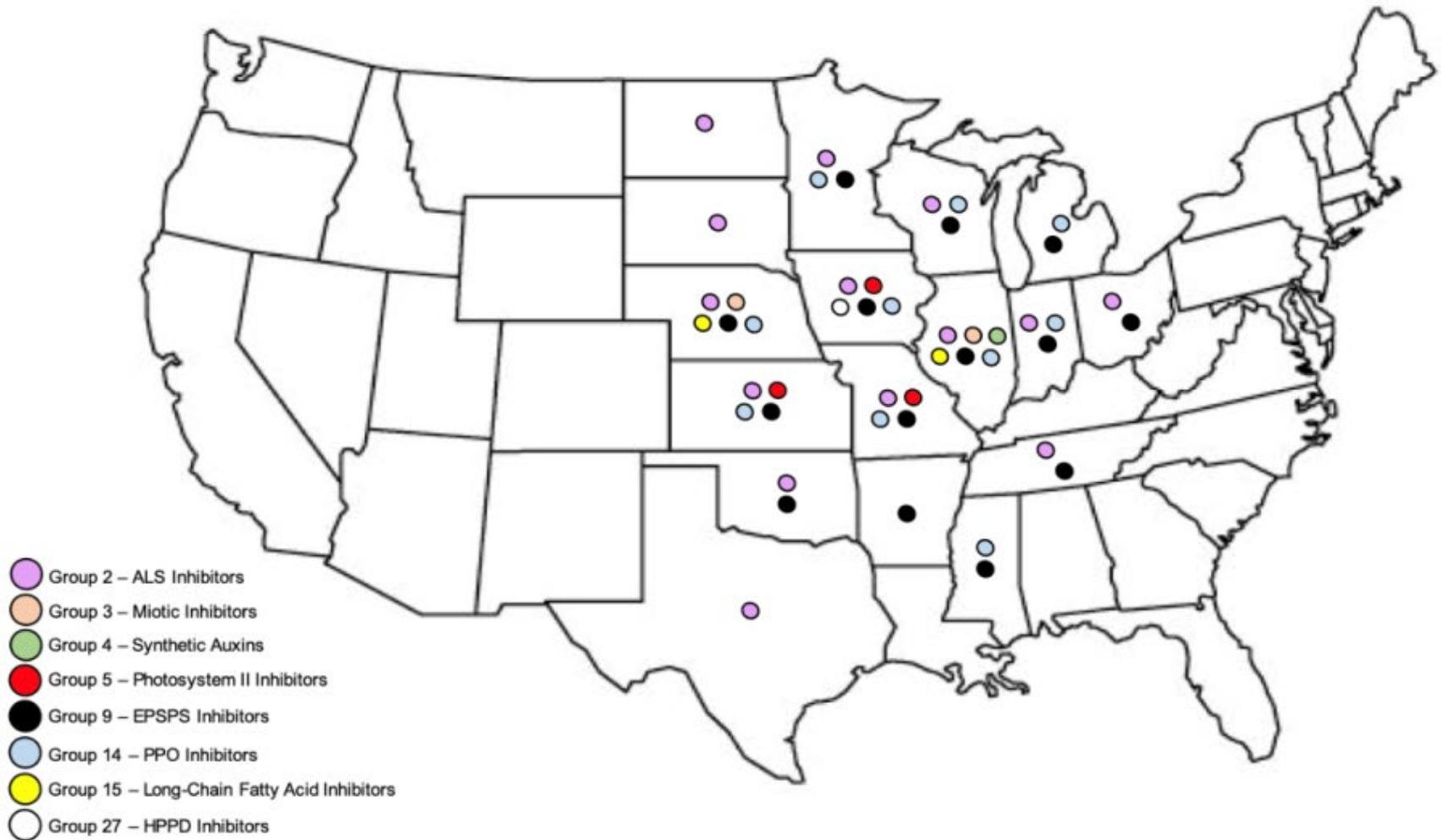
Multiple resistant populations of Palmer amaranth and Common Waterhemp

- ALS inhibitors
- Photosystem II inhibitors
- Glyphosate
- HPPD inhibitors
- PPO inhibitors
- Long chain fatty acid inhibitors
- Auxins
- Mitotic inhibitors

Distribution of Herbicide Resistant Populations of Palmer Amaranth



Distribution of Herbicide Resistant Populations of Waterhemp

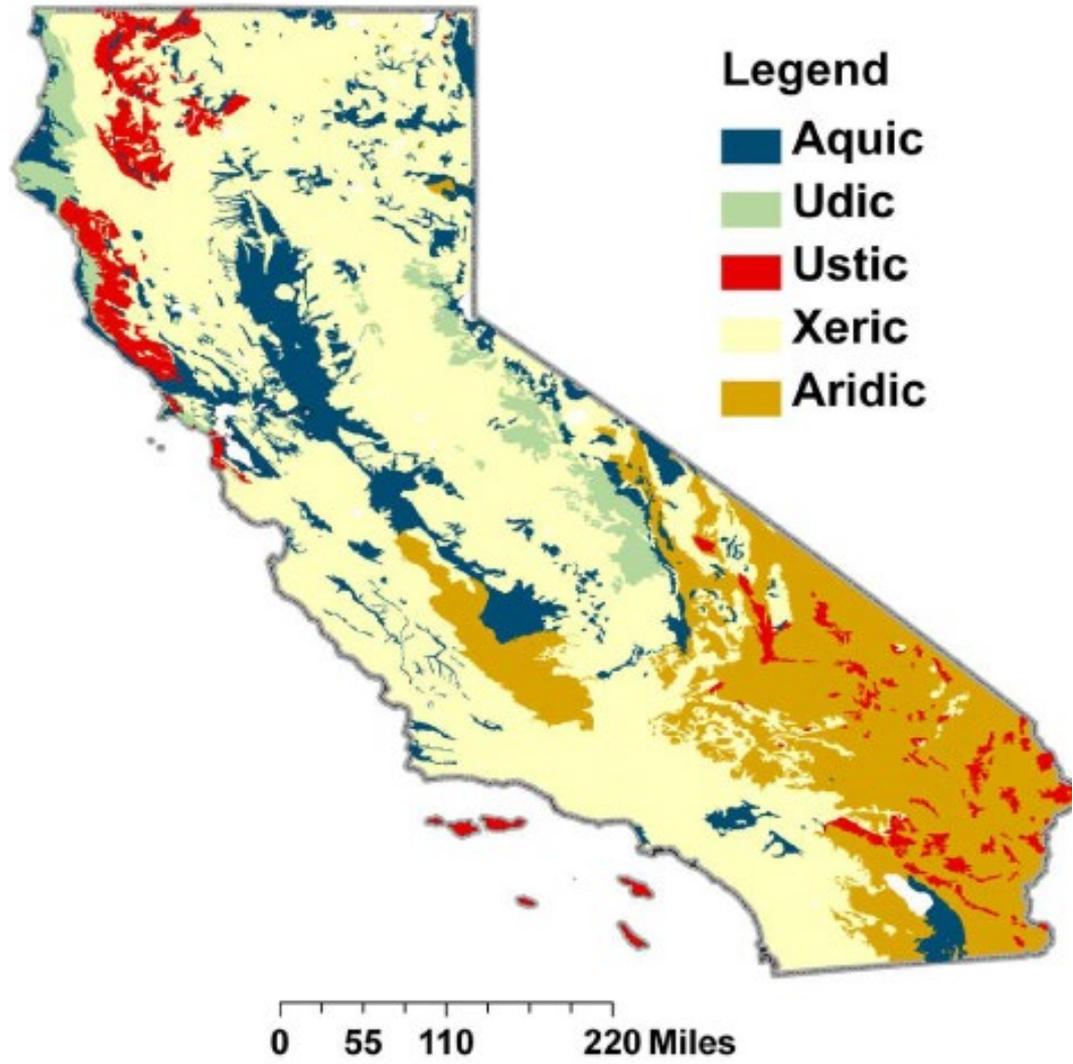
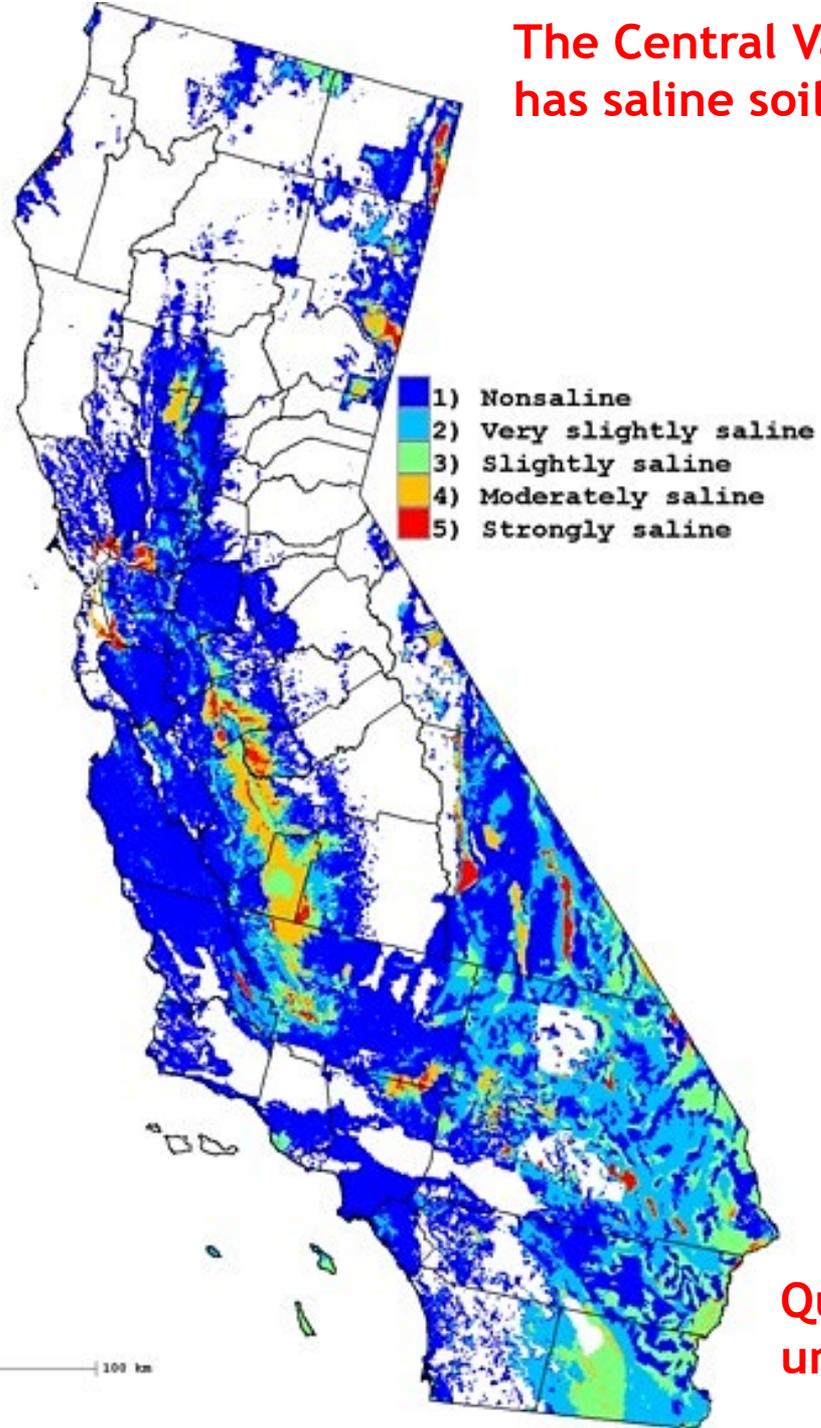




Questions to be addressed

- How well will these species adapt to our local conditions in the Central Valley?
- Do we have glyphosate-resistant populations?
- What alternative herbicide choices do we have?
- Where did these populations come from?

The Central Valley is arid and the western part of the Valley has saline soils



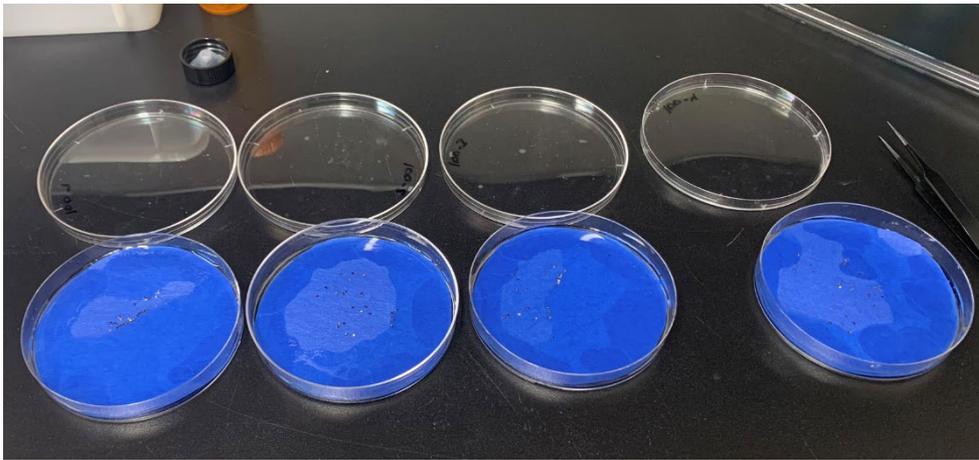
Question of interest ~ Can they germinate under drought and salinity stress conditions??

How well will these species adapt to our local conditions in the Central Valley?

- Studies to verify drought, salinity, and pH tolerance for seed germination
 - Simulated drought conditions by creating solutions of various water potentials using polyethylene glycol
 - Simulated salinity conditions by creating solutions of various electrical conductivity using NaCl
 - Simulated soil pH conditions by creating pH buffer solutions

Germination

Testing the germination of GR and GS palmer amaranth and GS common waterhemp seeds in petri dishes placed in a growth chamber programmed at a constant temperature of 22 C with a 12 hr day and night length



20 seeds of GR and GS palmer amaranth in each petri dish
Each treatment was replicated 5 times in a completely randomized design

Materials and Methods

I. Moisture requirement for germination

- Treatments: Different Water potential solutions were prepared using Polyethylene Glycol (PEG)
 1. 0 MPa [Control, 100 ml pure deionized (DI) water]
 2. -0.149 MPa (10 g PEG + 100 ml DI water)
 3. -0.51 MPa (20 g PEG + 100 ml DI water)
 4. -1.09 MPa (30 g PEG + 100 ml DI water)
 5. -1.88 MPa (40 g PEG + 100 ml DI water)
 6. -2.89 MPa (50 g PEG + 100 ml DI water)
 7. -4.12 MPa (60 g PEG + 100 ml DI water)
 8. -5.56 MPa (70 g PEG + 100 ml DI water)

Materials and Methods

II. Salinity tolerance during germination

- Treatments: Different millimolar (mM) solutions were prepared using lab grade NaCl
 1. 0 mM [Control, 100 ml pure deionized (DI) water]
 2. 25 mM (0.15 g NaCl + 100 ml DI water)
 3. 50 mM (0.24 g NaCl + 100 ml DI water)
 4. 100 mM (0.58 g NaCl + 100 ml DI water)
 5. 150 mM (0.88 g NaCl + 100 ml DI water)
 6. 200 mM (1.17 g NaCl + 100 ml DI water)
 7. 250 mM (1.46 g NaCl + 100 ml DI water)

Materials and Methods

II. Salinity tolerance during germination

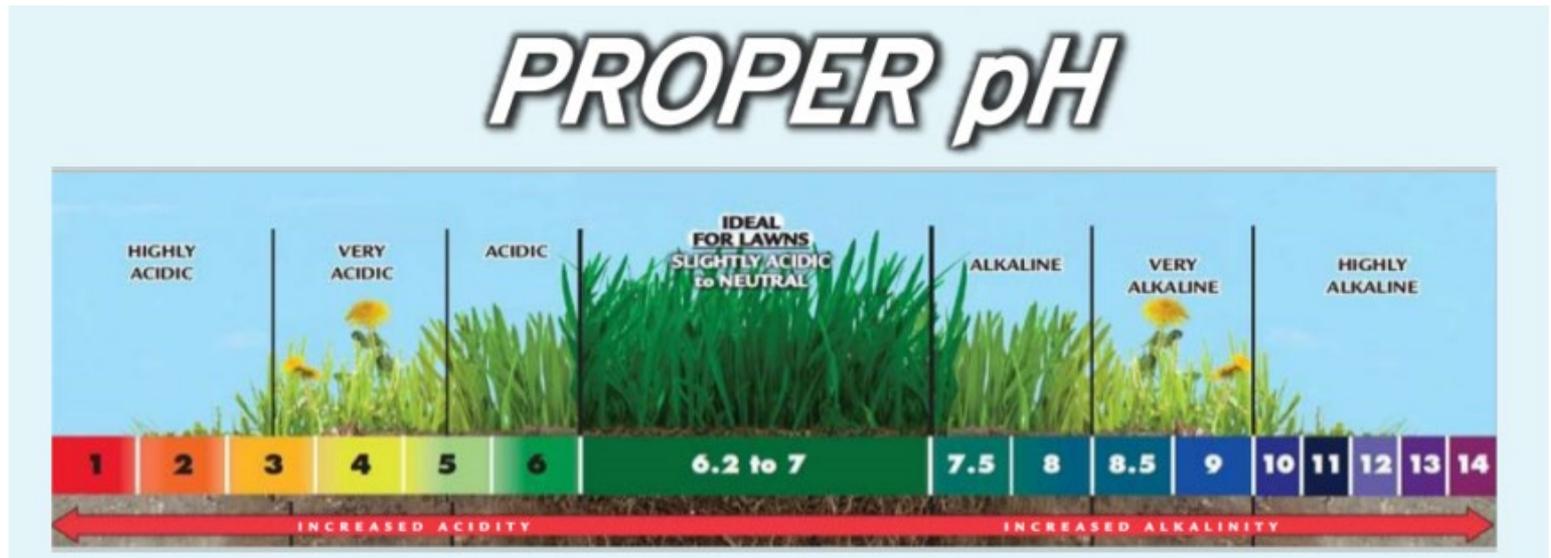
<u>Treatment</u>	<u>Corresponding electrical conductivity (EC)</u>
	decisiemens/m (dS/m)
• 0 mM	0
• 25 mM	2.5
• 50 mM	5
• 100 mM	10
• 150 mM	15
• 200 mM	20
• 250 mM	25



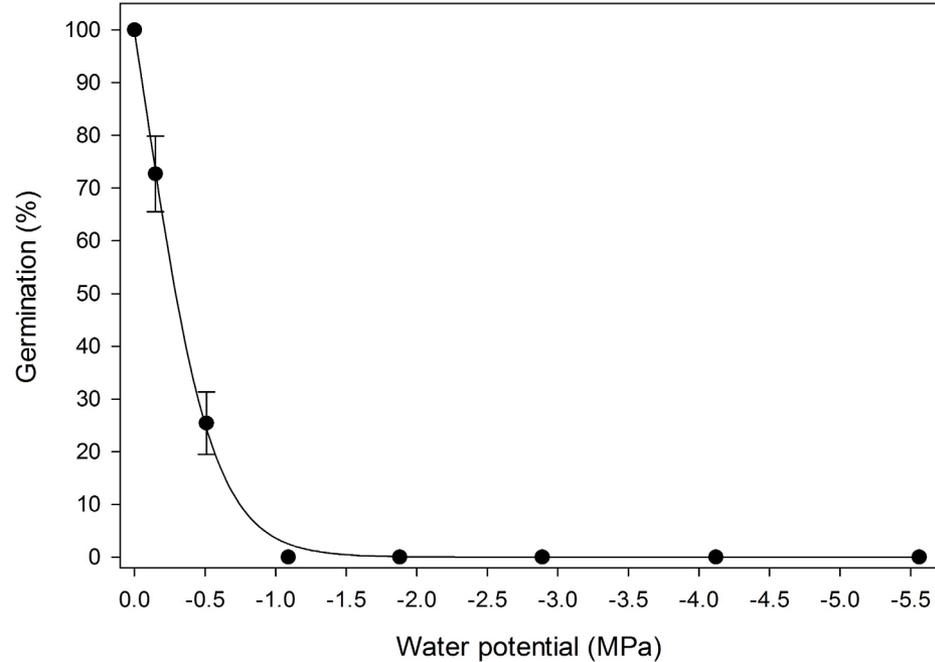
Solutions Calibrated with a
Spectrum Soil EC meter

Germination - Tolerance to pH levels

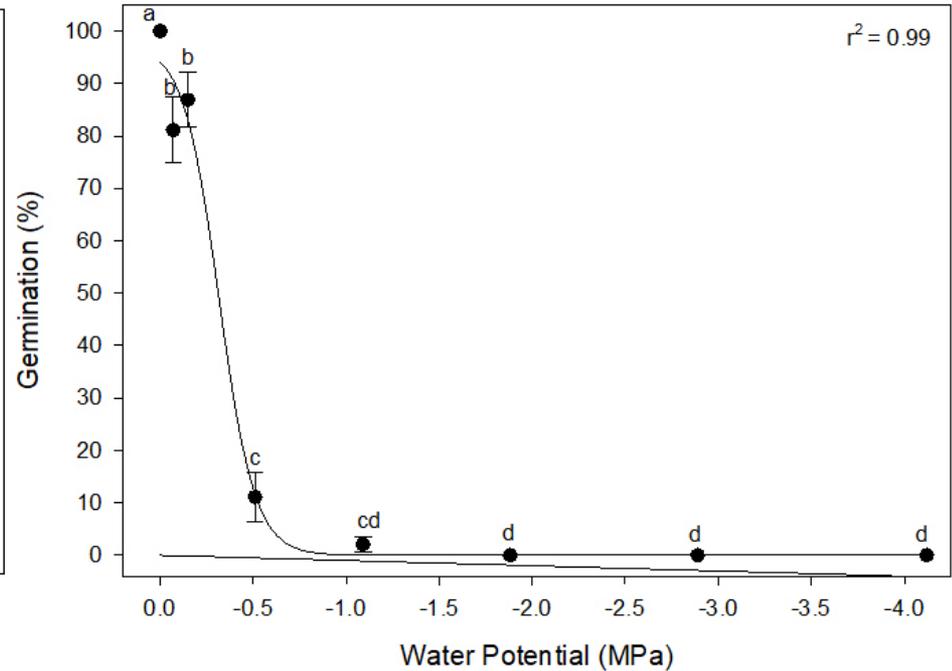
- Germination under a range (5, 6, 7, 8, 9) of pH levels with solutions prepared with:
 - Citrate buffer 5
 - Pbs 6-8
 - Tris-HCl 9



Drought Tolerance



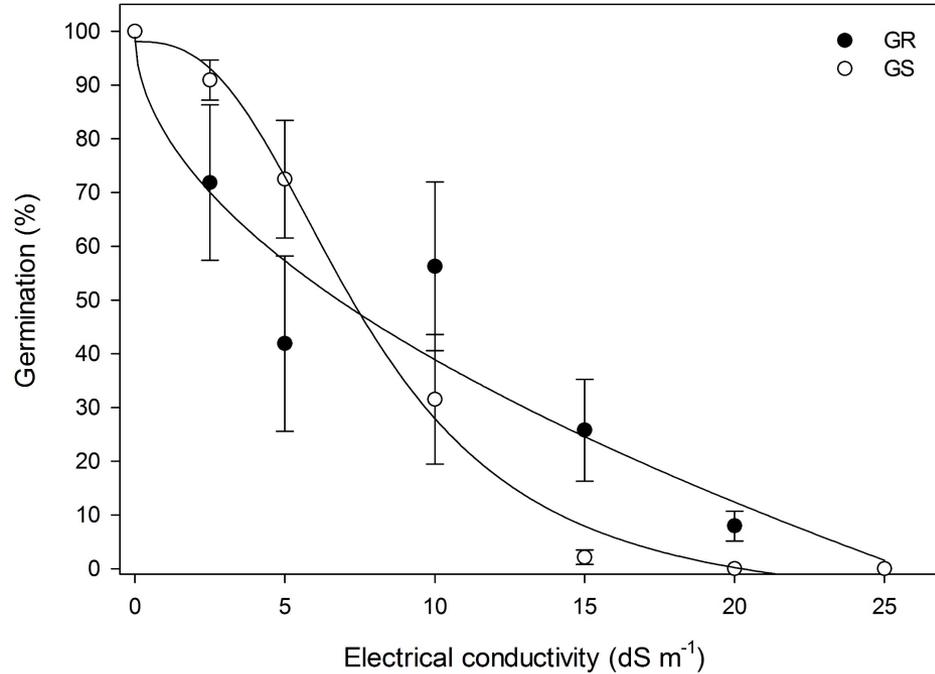
Palmer amaranth



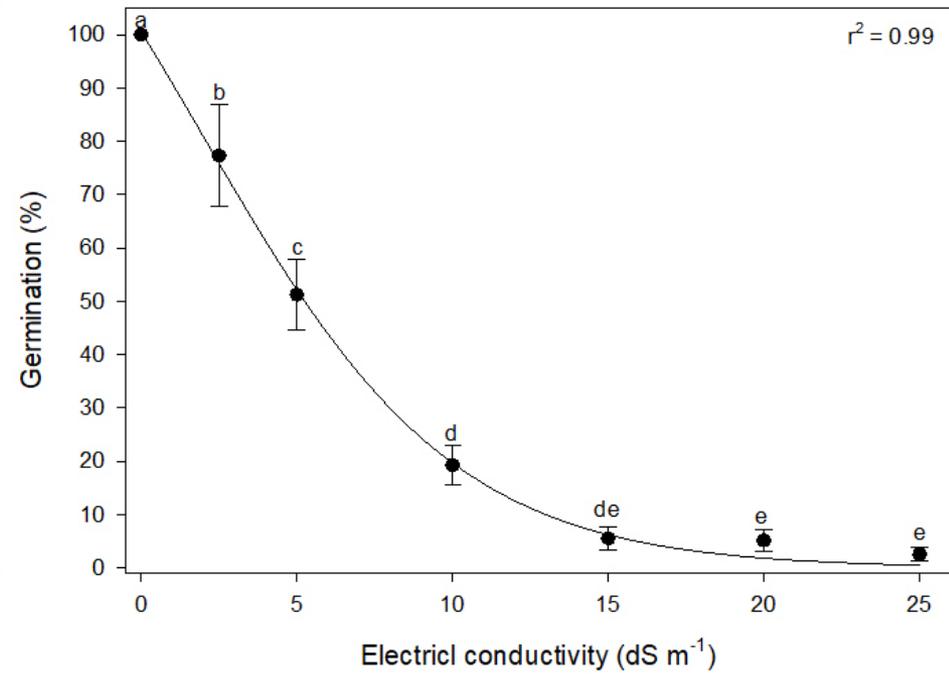
Common waterhemp

Not very drought tolerant - need adequate moisture for germination

Salinity Tolerance



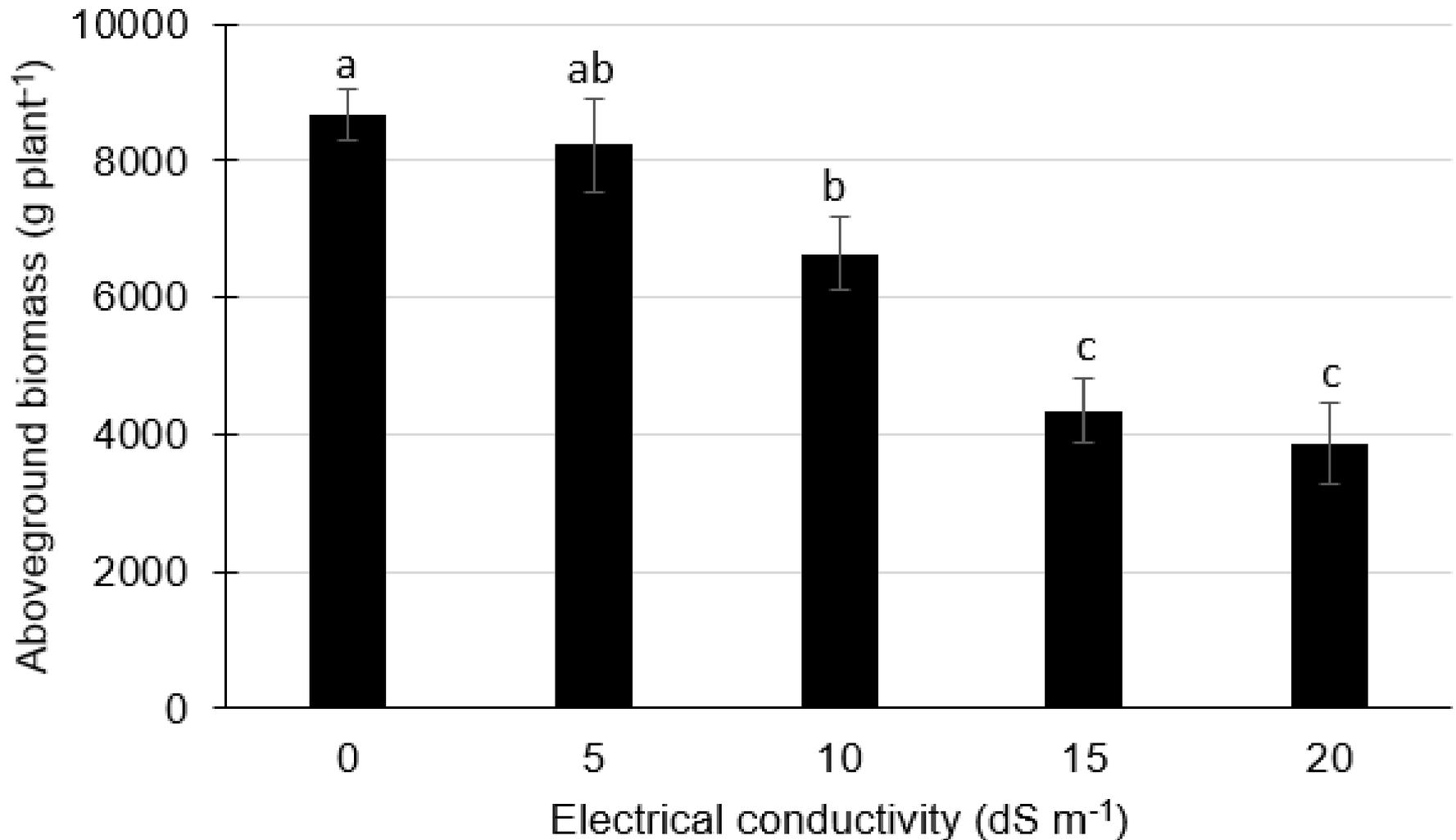
Palmer amaranth



Common waterhemp

Very tolerant to salt stress

Salinity Tolerance - Palmer amaranth



Very tolerant to salt stress - high potential of invading the west side



0 dS m⁻¹

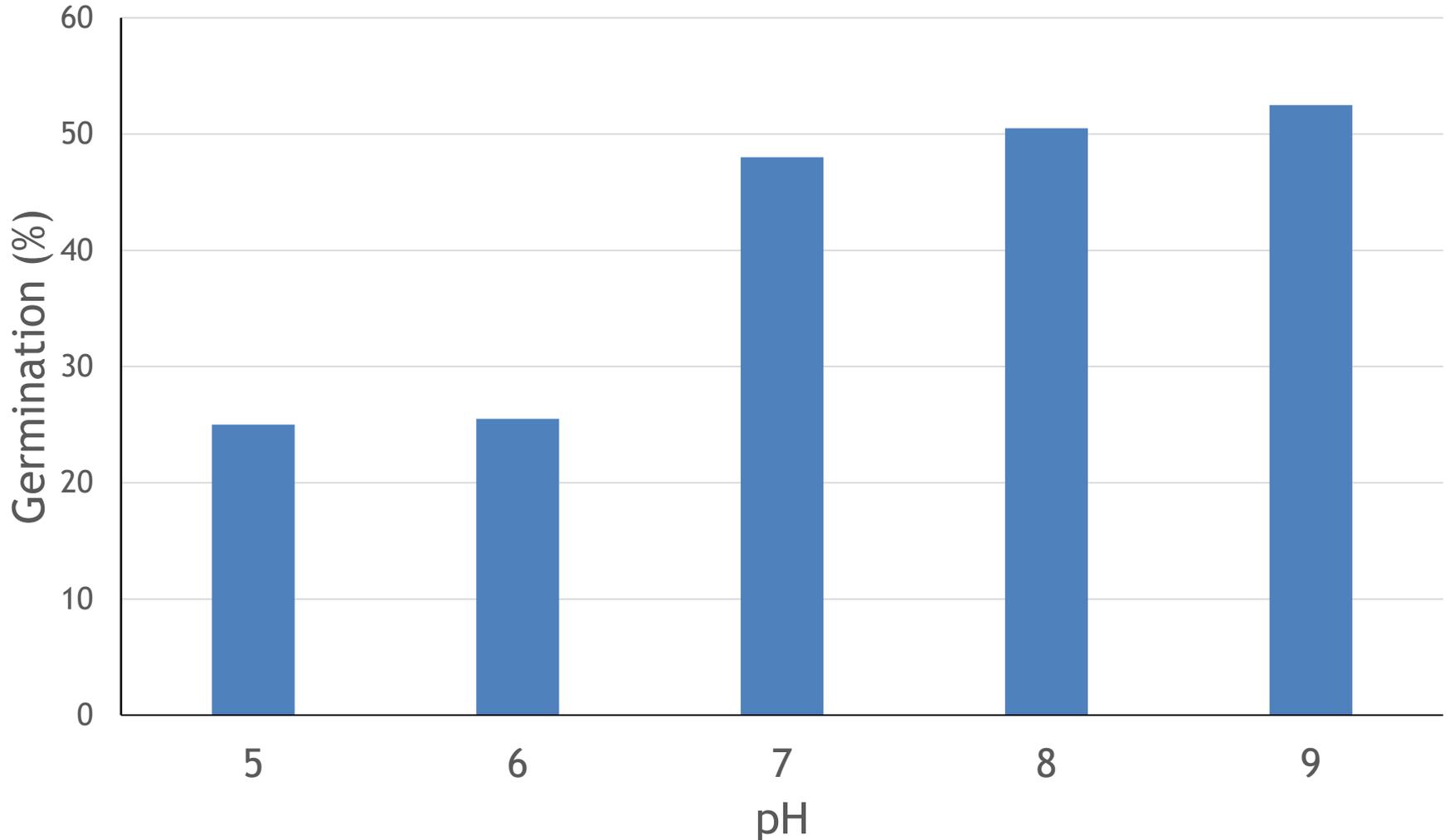
5 dS m⁻¹

10 dS m⁻¹

15 dS m⁻¹

20 dS m⁻¹

pH Tolerance



More adapted to pH 7 and higher

Do we have glyphosate-resistant populations in the Central Valley?

- Yes, in the case of Palmer amaranth

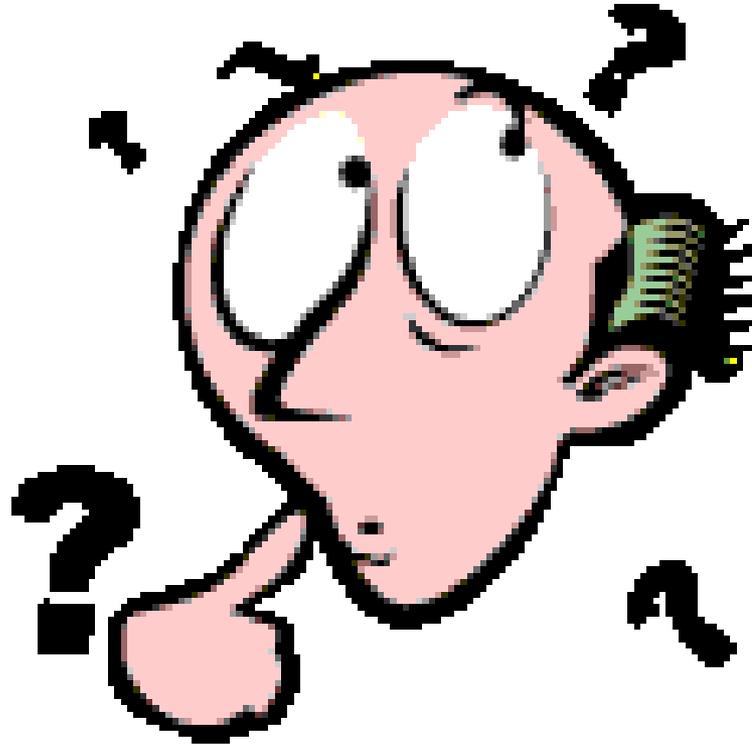


Do we have glyphosate-resistant populations in the Central Valley?

- Not confirmed yet, in the case of waterhemp
- We were able to control them with label rates of glyphosate, rimsulfuron, glufosinate, and Suppress when sprayed at the 3" stage but the story was different when sprayed at the 6" stage



**What alternatives do we have for their
post-emergence control?**



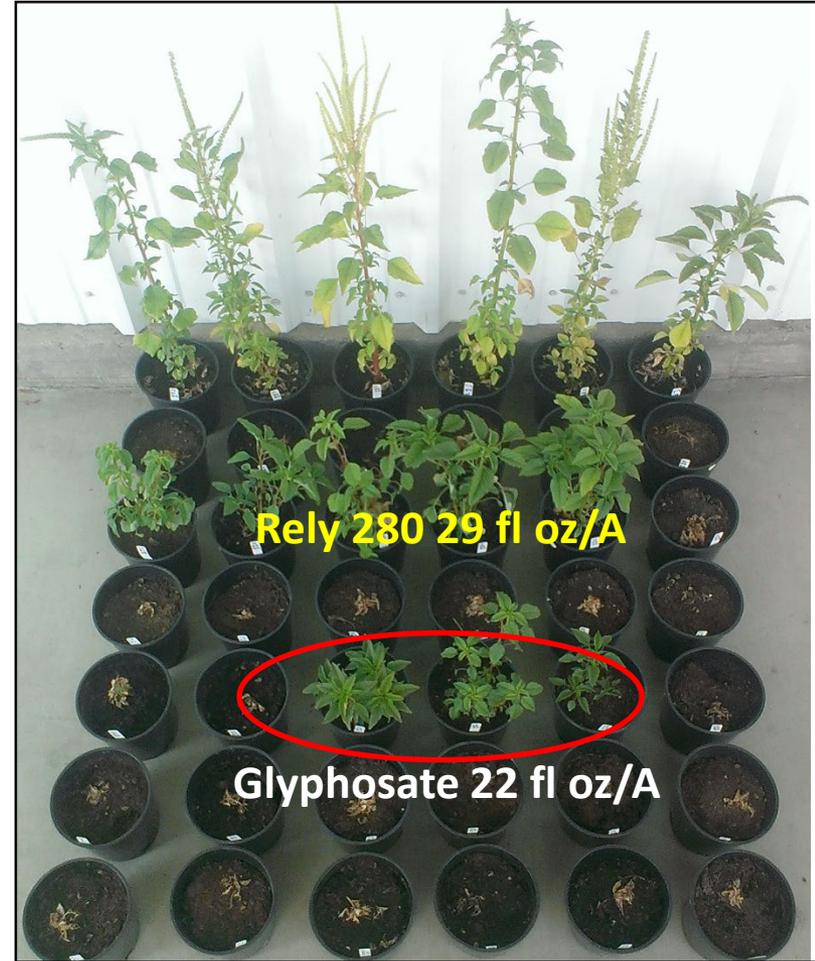
Mortality of Palmer amaranth plants at three different growth stages with different herbicides

Treatment	Rate	4- to 6-leaf stage	8- to 10-leaf stage	12- to 16-leaf stage
		% control		
Saflufenacil	1 oz/ac	100a	100a	100a
Glyphosate	22 fl oz/ac	96a	68b	43b
Paraquat	1 pt/ac	100a	100a	100a
Glufosinate	29 fl oz/ac	100a	39c	20c
Rimsulfuron	1 oz/ac	84a	86a	67b

2nd Growth Stage-



3rd Growth Stage



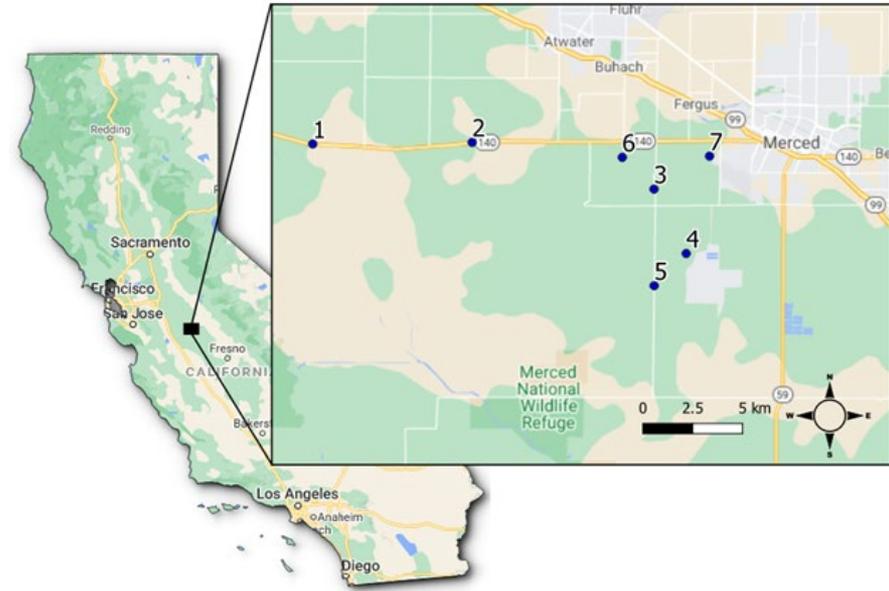
Mortality of Palmer amaranth plants treated with different herbicides at the 8- to 10-leaf stage in the greenhouse pot study 28 days after treatment.

Treatment	Rate	Plant Mortality (%)
Saflufenacil ^A + Glyphosate ^B	1 kg ai ha ⁻¹ + 840 g ae ha ⁻¹	100a
Saflufenacil ^A + Glufosinate ^C	1 kg ai ha ⁻¹ + 1.43 kg ai ha ⁻¹	100a
Saflufenacil ^A + Dicamba ^D	1 kg ai ha ⁻¹ + 1.43 kg ai ha ⁻¹	100a
Rimsulfuron ^E + Glyphosate ^B	12.5 g ai ha ⁻¹ + 840 g ae ha ⁻¹	100a
Tembotrione ^F + Glyphosate ^B	0.22 g ai ha ⁻¹ + 840 g ae ha ⁻¹	100a
Flumioxazin + Pyroxasulfone ^G + Glyphosate ^B	0.2 kg ai ha ⁻¹ + 840 g ae ha ⁻¹	100a
Flumioxazin + Pyroxasulfone ^G + Glufosinate ^C	0.2 kg ai ha ⁻¹ + 1.43 kg ai ha ⁻¹	100a
Flumioxazin + Pyroxasulfone ^G + Dicamba ^D	0.2 kg ai ha ⁻¹ + 1.43 kg ai ha ⁻¹	100a
Dicamba ^D + Paraquat ^H	1.43 kg ai ha ⁻¹ + 1.4 kg ai ha ⁻¹	100a
Glufosinate ^C + Glyphosate ^B	1.43 kg ai ha ⁻¹ + 840 g ae ha ⁻¹	100a
Glyphosate ^B	840 g ae ha ⁻¹	100a
Untreated Control		0b

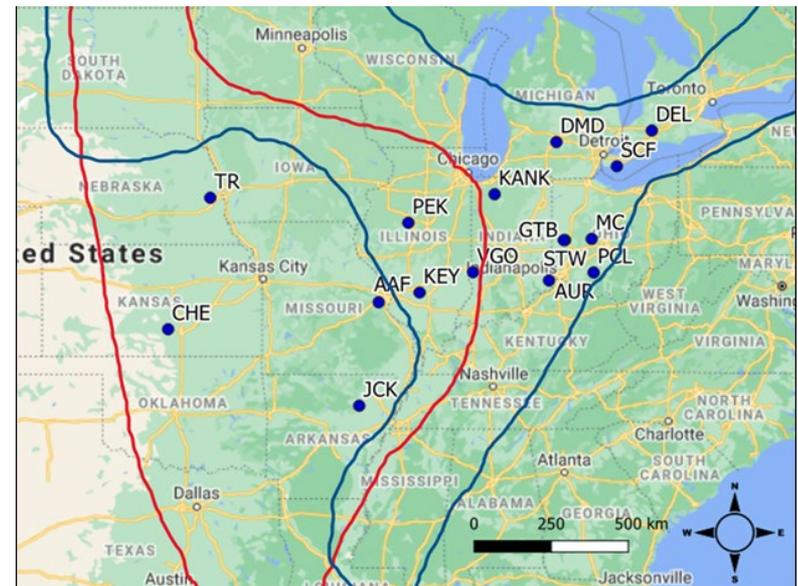
Trade names: ^ATreevix, ^BRoundup WeatherMax, ^CRely 280, ^DClarity, ^EMatrix, ^FLaudis, ^GFierce, ^HParaquat

Genetic Study of Waterhemp Origins

- Merced, CA - 7 populations
 - Almond, corn, hay, wheat, rice fields

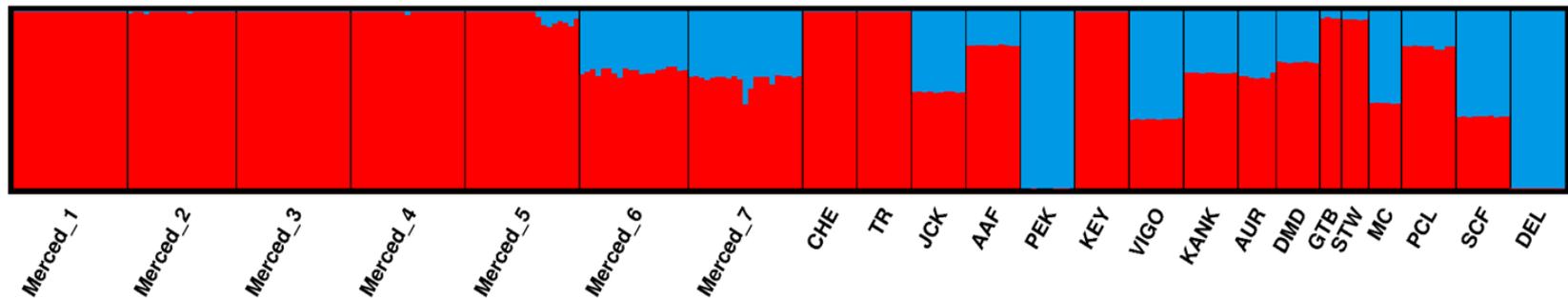


- Midwest - 16 populations
 - Collected 2009-2010 (K. Waselkov)
 - Previously extracted genetic material
 - 4 - 10 individuals



Genetic Clustering of Merced Waterhemp

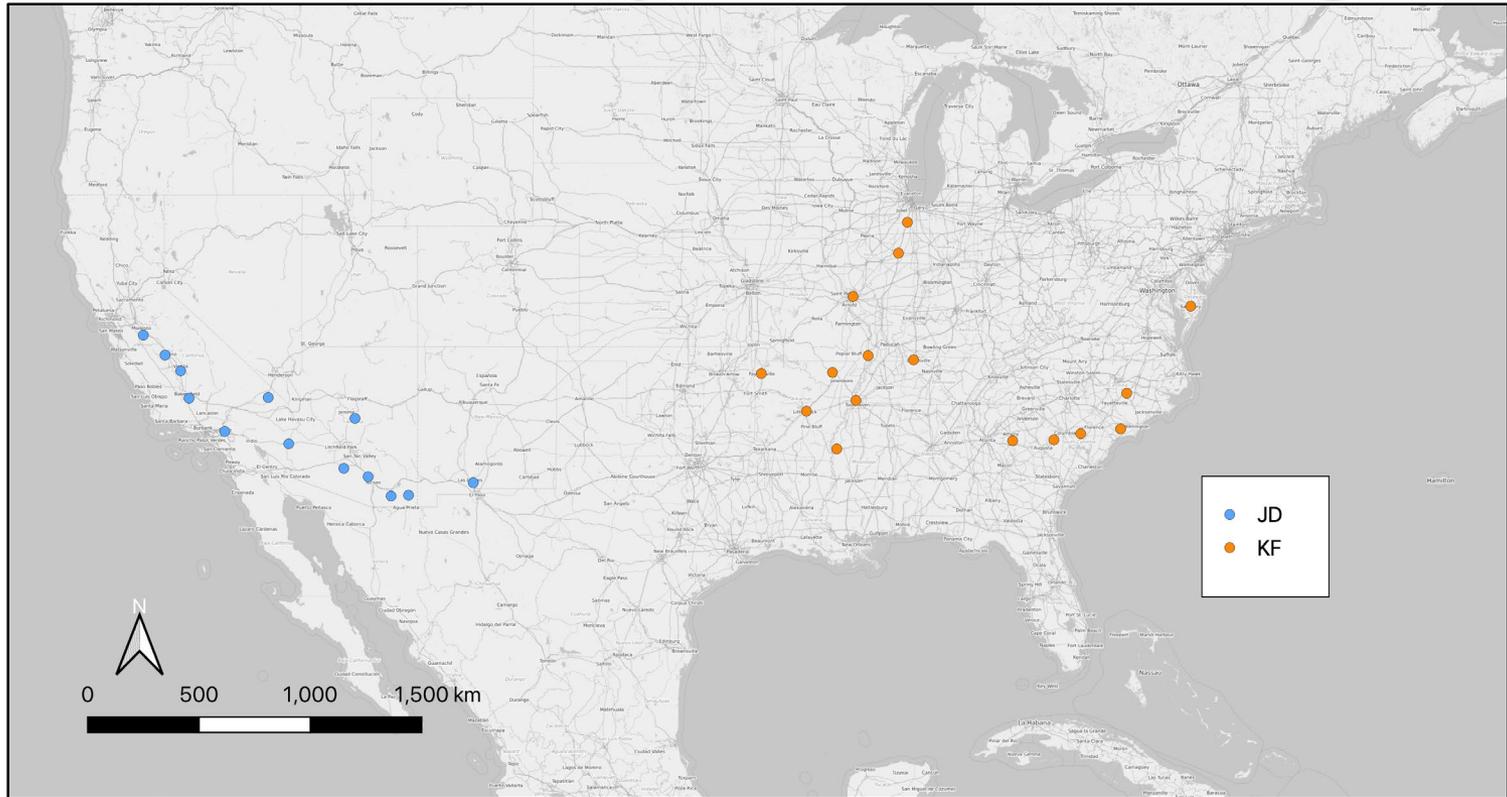
Genetic Clustering based on 2,323 SNPs, using software program
STRUCTURE



- Analysis of Midwestern and Merced County populations:
 - 2 genetic clusters identified
 - Red = western variety (“rudis”)
 - Blue = eastern variety (“tuberculatus”)
 - Correlates with geographic structure in Midwest
 - Merced derived largely from western cluster (red)
 - But populations 6 +7 have some genes from the eastern cluster



Genetic Study of Palmer Origins



- Very similar to waterhemp study!
- But more populations (29) sampled because of the larger total range of the species: native (Southwest) and invaded ranges

Genetic origins of our populations?

Preliminary results from analysis of genotyping-by-sequencing data for waterhemp show the presence of genes from both western (*A. tuberculatus* var. *rudis*) and eastern (*A. tuberculatus* var. *tuberculatus*) subspecies of waterhemp in Merced County.

Genomic data is still being collected and analyzed for Palmer amaranth populations in the native Southwestern range, the invaded Eastern U.S. range, and the invaded Central California range, to identify the source of the California populations.

Scientists explore genetic weed control

By **Margaret Evans**

Reading Time: 3 minutes

Published: September 19, 2019

News

[Sassy_Social_Share]



Dr. Patrick Tranel, left, works with University of Illinois graduate student Jacob Montgomery, who co-authored the research paper that compared male and female Palmer amaranth plants in the greenhouse. | University of Illinois photo

The goal is to modify male plants that would mate with wild females and produce nothing but male offspring

Conclusions

Glyphosate-resistant Palmer amaranth populations have been documented in the Central Valley but common waterhemp has not been confirmed yet

Both species do not seem to be very drought tolerant at germination but are very salt tolerant and have the potential to invade the saline soils in the westside with a pH range of 7 - 9

Best to control these with postemergence herbicides before they reach the 8-leaf stage; several POST herbicide options

Mixture of western and eastern subspecies of waterhemp present in Merced; GR Palmer may have come from elsewhere

Acknowledgments

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