Palmer amaranth: Biology, ecology, management and lessons learned from Georgia, California and New York

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Trouble with a Capital "T" and that Rhymes with "P" and that Stands for Pigweed

PIGWEED SPECIES LISTED AS SOME OF THE MOST COMMON AND TROUBLESOME WEEDS IN NORTH AMERICA BY CROP

	Most Common (Rank)	Most Troublesome (Rank)
2020 Corn	Pigweed spp. (4) Palmer amaranth (5)	Palmer amaranth (1) Waterhemp (2)
2019 Alfalfa	Pigweed spp. (1)	Pigweed spp. (1)
2019 Soybean	Waterhemp (1) Palmer amaranth (5)	Waterhemp (1) Palmer amaranth (3)

Surveys | Weed Science Society of America (wssa.net)

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Yield loss due to Palmer amaranth

CORN: 11 - 91% yield loss

Weed Sci. (2001) 49:202-208

SOYBEAN: 38 - 79% yield loss

Weed Sci. (20023) 51:37-43

COTTON: 60% yield loss

Cotton Sci. (2013) 17: 222-232

PEANUT: 28% yield loss

Weed Tech. (2010) 21:367-371

Harvest interference in response to palmer amaranth

Smith et al. (2000) Weed Tech. 14:122-126

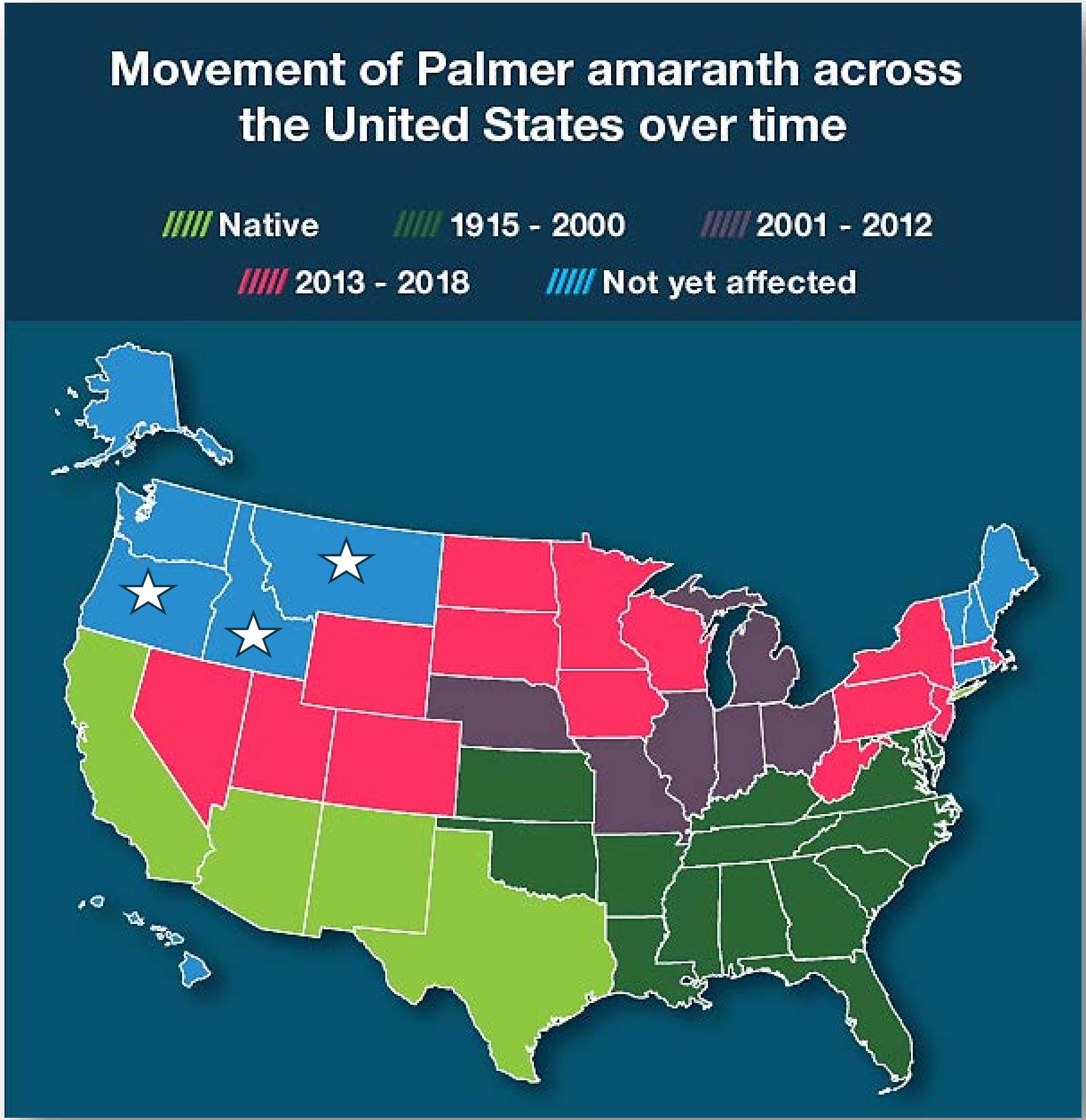
Palmer amaranth infestations reduced ground speeds and increased work stoppages

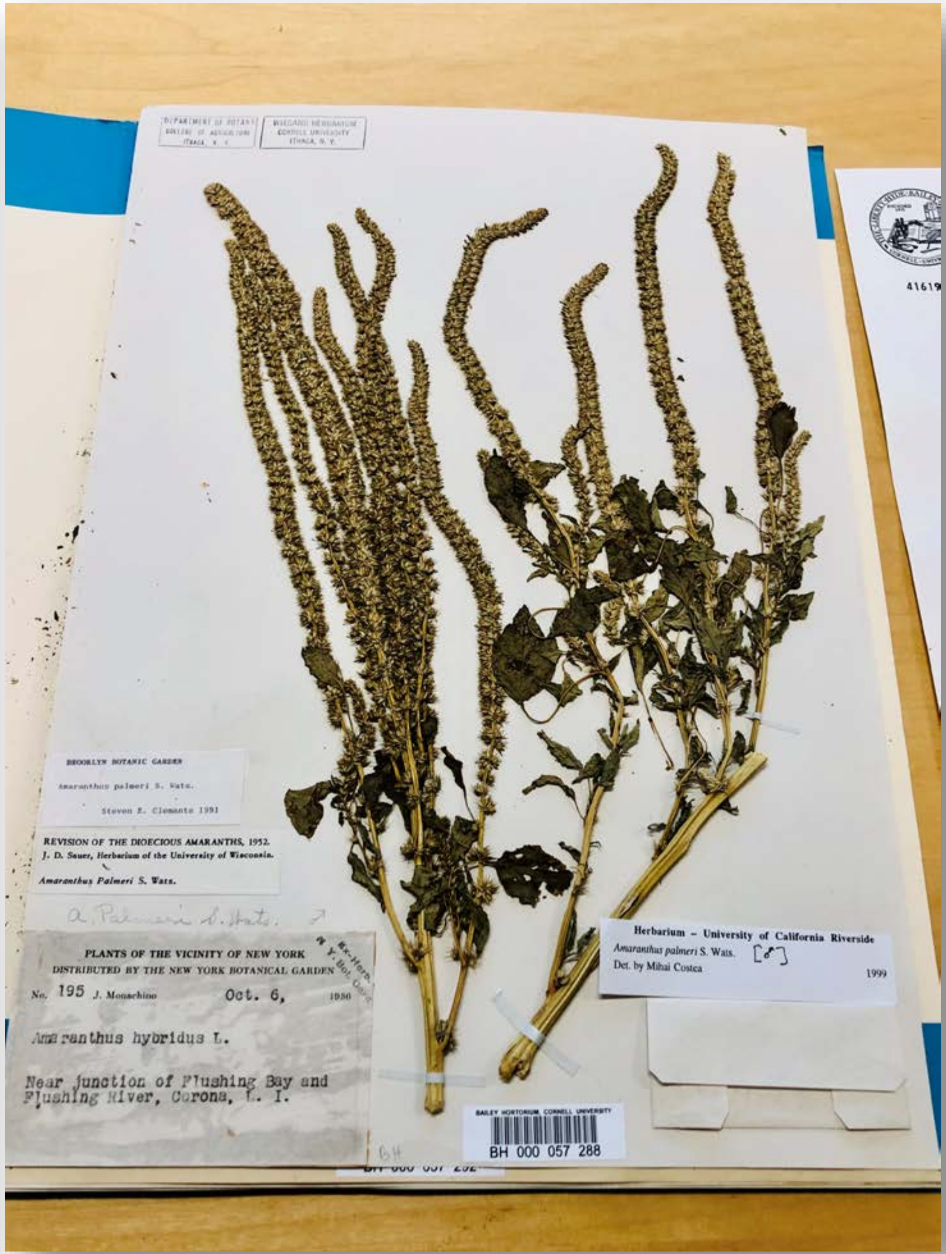
Palmer amaranth interference in-crop increased harvest time 2-4 fold

Morgan et al. (2001) Weed Tech 15:408-412

>0.7 plants m^{-1} row of cotton increased potential for damage to harvest equipment

Amount of trash in lint increased as did the cost of cleaning the fibers


Movement of Palmer amaranth across the United States over time
Native
1915 - 2000
2001 - 2012
2013 - 2018
Not yet affected


BROOKLYN BOTANIC GARDEN
Amaranthus palmeri S. Wats.
Steven E. Clemants 1991
REVISION OF THE DIOECIOUS AMARANTHS, 1952.
J. D. Sauer, Herbarium of the University of Wisconsin.
Amaranthus Palmeri S. Wats.
PLANTS OF THE VICINITY OF NEW YORK
DISTRIBUTED BY THE NEW YORK BOTANICAL GARDEN
No. 195 J. Monachino Oct. 6, 1930
Amaranthus hybridus L.
Near junction of Flushing Bay and Flushing River, Corona, L. I.
Herbarium – University of California Riverside
Amaranthus palmeri S. Wats.
Det. by Mihai Costea
1999
BAILEY HORTORIUM, CORNELL UNIVERSITY
BH 000 057 288

Palmer amaranth has been detected in one location in Manitoba and four locations in Ontario

Some of the Ontario detections were not recent

Not all were in fields (garden, railway)

No established populations to date

South Africa

New York

Palmer Amaranth Spread

Palmer Amaranth Spread

Agricultural & Environmental Letters

Research Letter

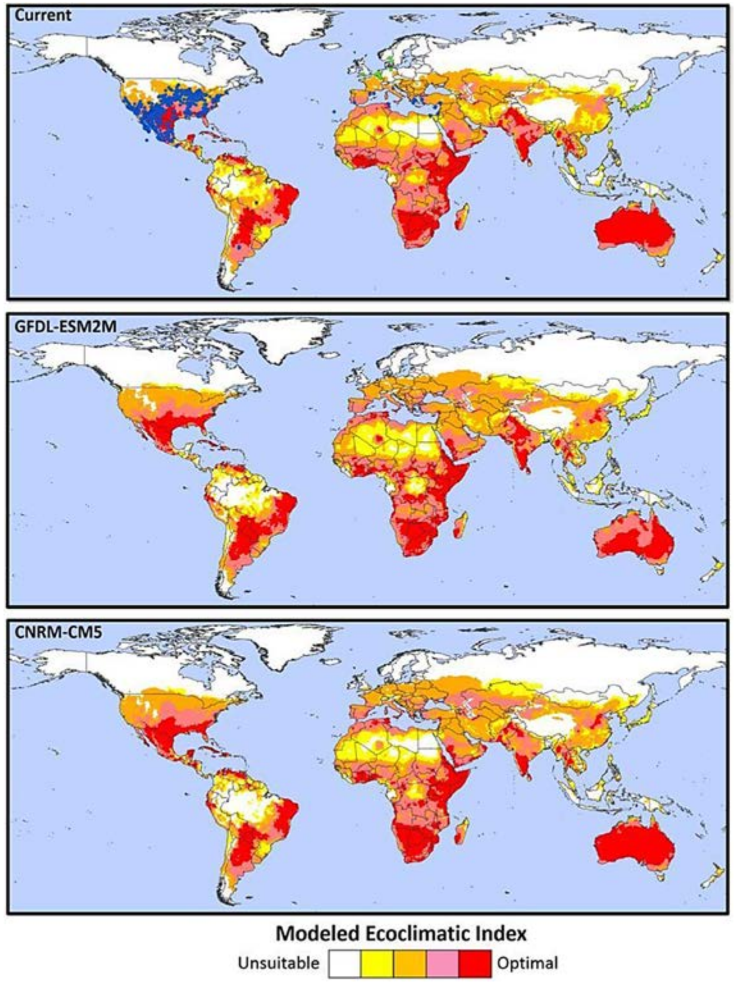
Potential Geographic Distribution of Palmer Amaranth under Current and Future Climates

Erica J. Kistner* and Jerry L. Hatfield

Core Ideas

- CLIMEX model projections match known Palmer amaranth distribution.
- Sub-Sahara Africa and Australia are at risk for Palmer amaranth establishment.
- Future climate scenarios indicate the potential for poleward range expansion.

Abstract: Herbicide-resistant weeds are increasingly becoming a major challenge for agricultural production worldwide. Palmer amaranth [*Amaranthus palmeri* (S.) Wats.] is an invasive annual forb that has recently emerged as one of the most widespread and severe agronomic weeds in the United States, due in part to its facility for evolving herbicide resistance. It has invaded several parts of the world, including key agricultural production regions in South America. Climate change will likely exacerbate the challenges of managing this species. To assess this, we developed a process-oriented bioclimatic niche model of Palmer amaranth to examine its potential global distribution under current conditions and future climate scenarios. The model agreed well with all credible current distribution data. Projected future increases in temperatures will expand potential Palmer amaranth range northward into portions of Canada and Europe. Model projections under current and future climates highlight several agricultural production regions of increasing and emerging risk from this weed.



Kistner and Hatfield (2018) Agric. Environ. Lett. 3:170044 doi:10.2134/ael2017.12.0044

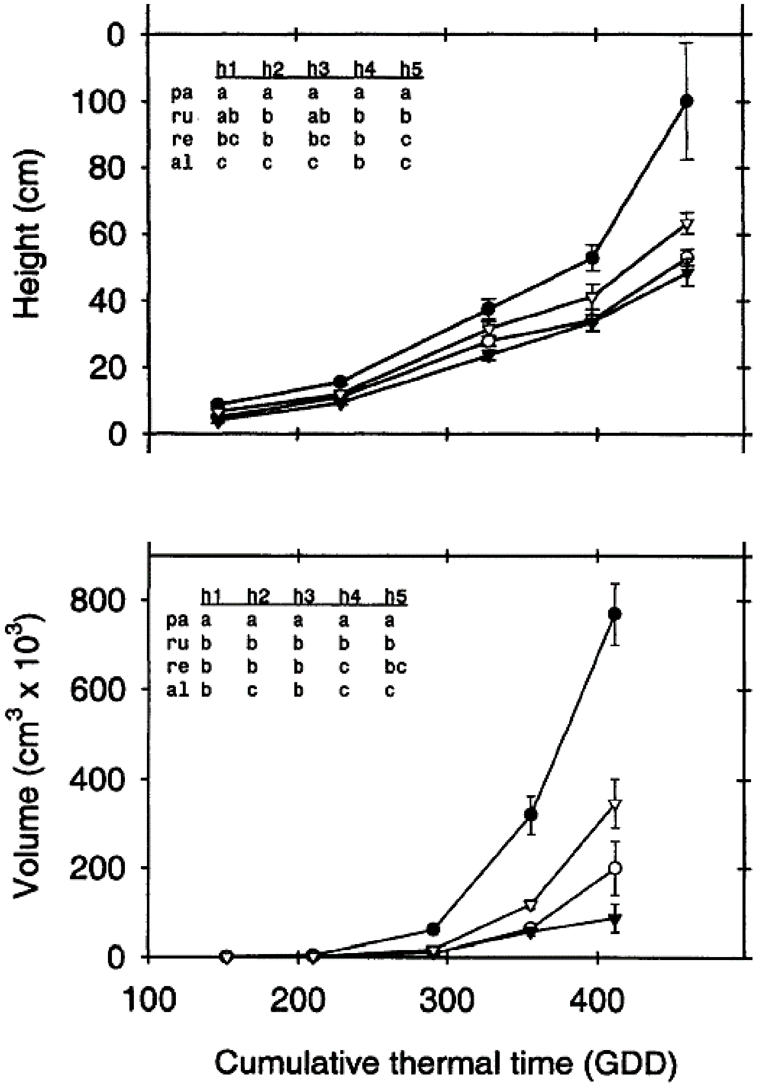
Why Worry?


It can grow tall




Palmer amaranth can occupy
a large volume of space


June Emergence (KS)



Palmer amaranth (2.1 - 2.4 m)

Waterhemp

Redroot

Palmer amaranth (2.8 - 4.8 m^3)

Waterhemp

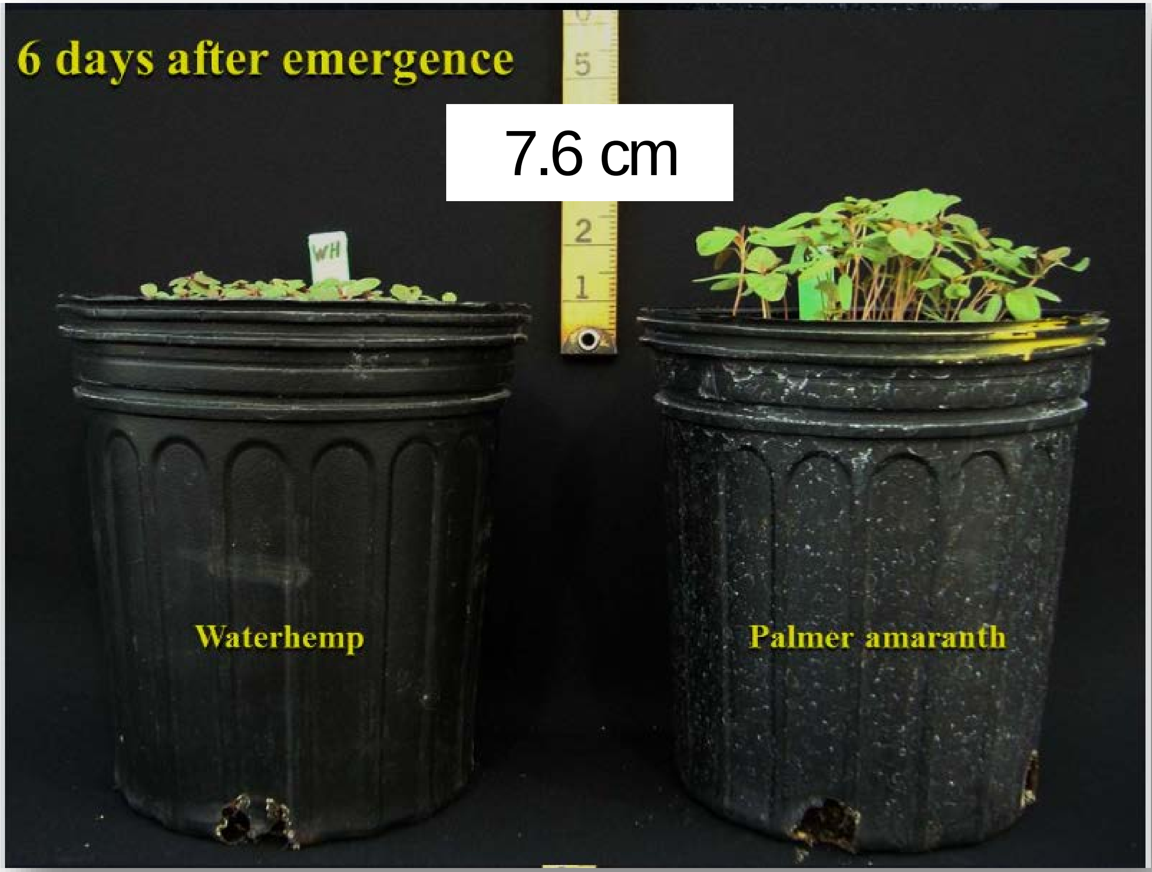
Redroot

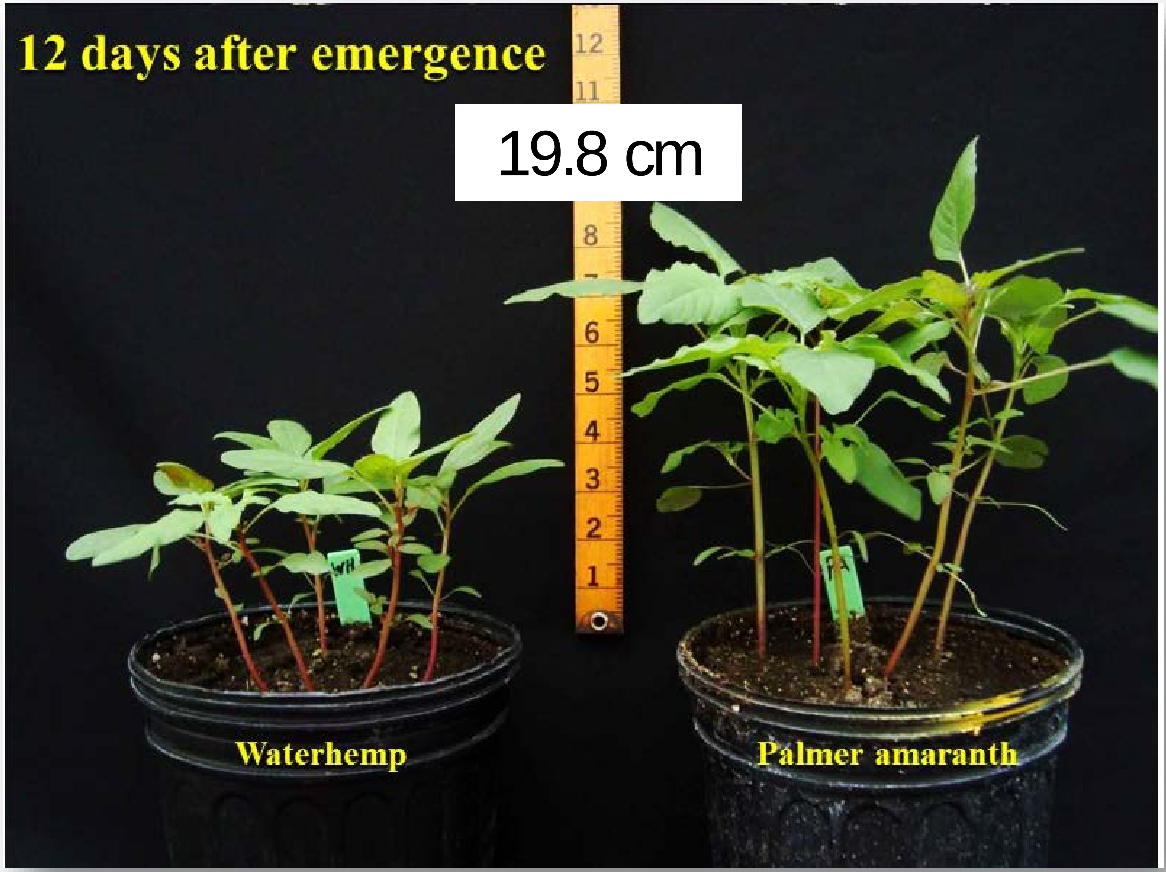
Palmer amaranth in Merced County (CA) 2018

Horak and Loughlin (2000) Weed Science 48:347-355

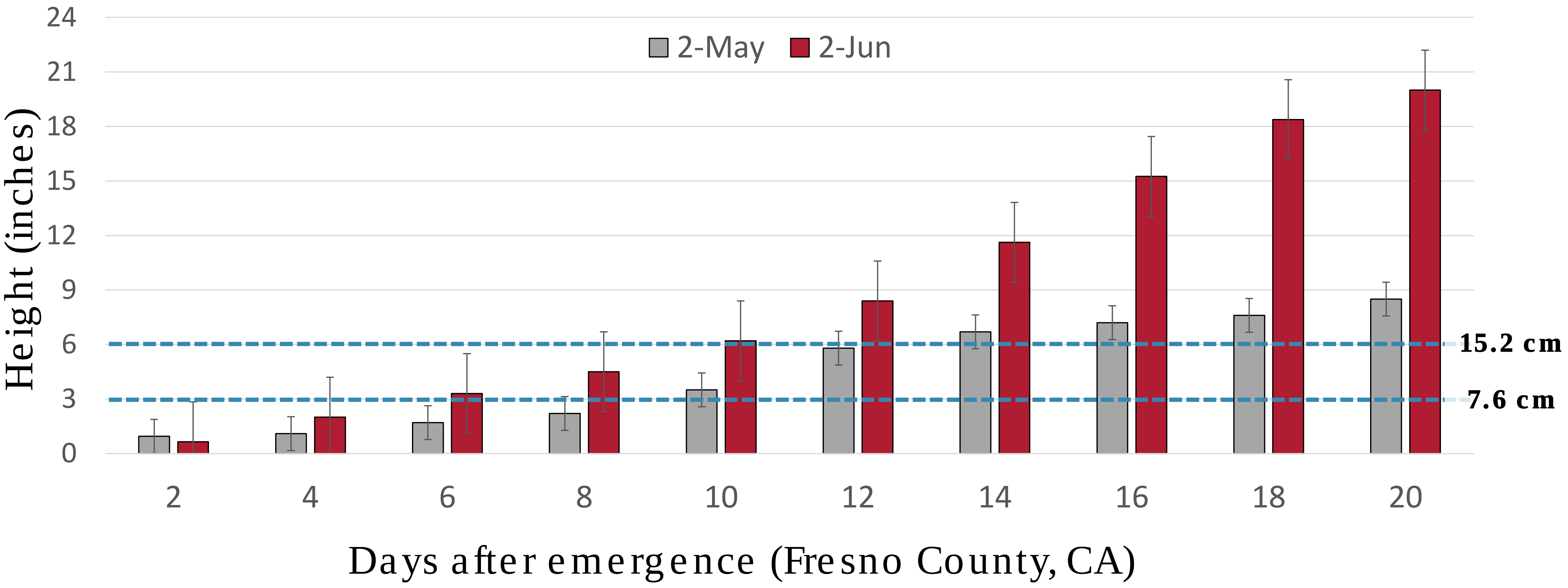
PALMER AMARANTH GROWS FAST

(*HTTP://BULLETIN.IPM.ILLINOIS.EDU/?P=2024*)

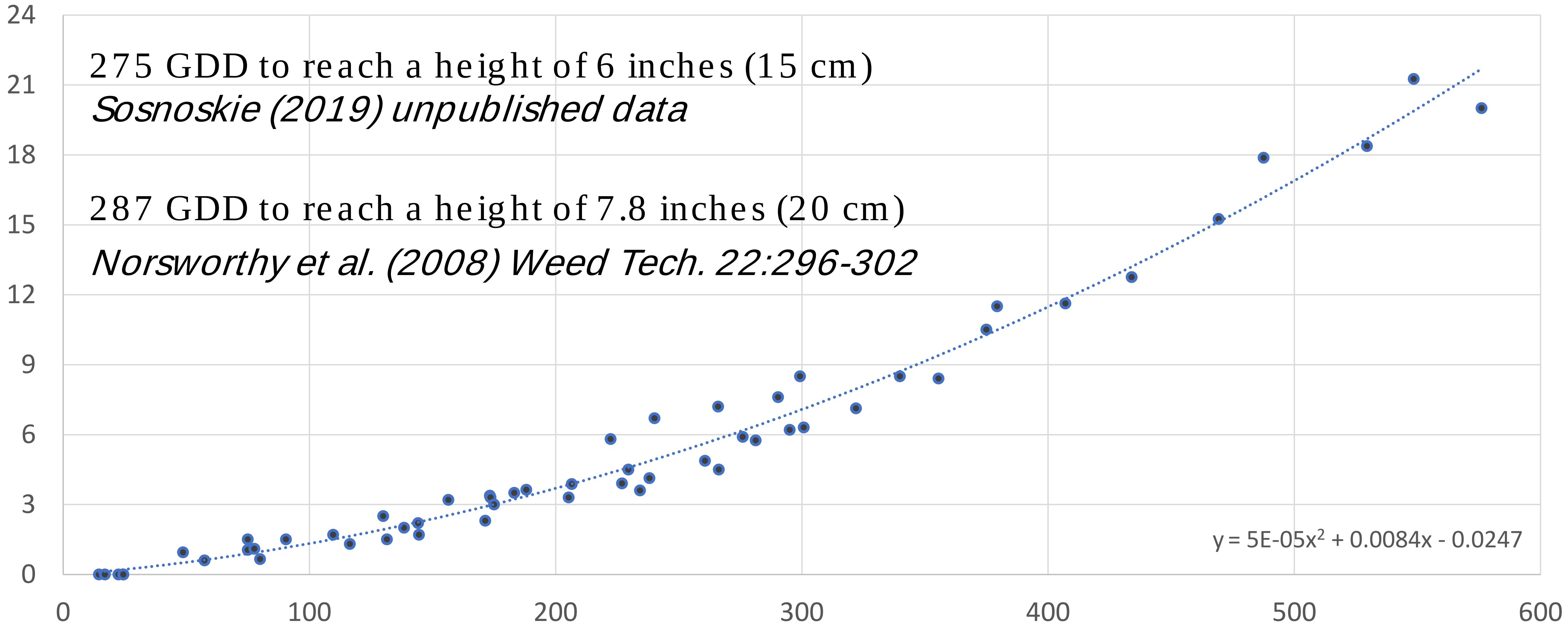




Palmer amaranth Grows Fast
But rate can be dependent on emergence date



PALMER AMARANTH HEIGHT (INCHES) VS GDD (BASE 50 F) CONDUCTED ON MERCED COUNTY POPULATION AT CSU FRESNO (2019)



PALMER AMARANTH GROWS FAST

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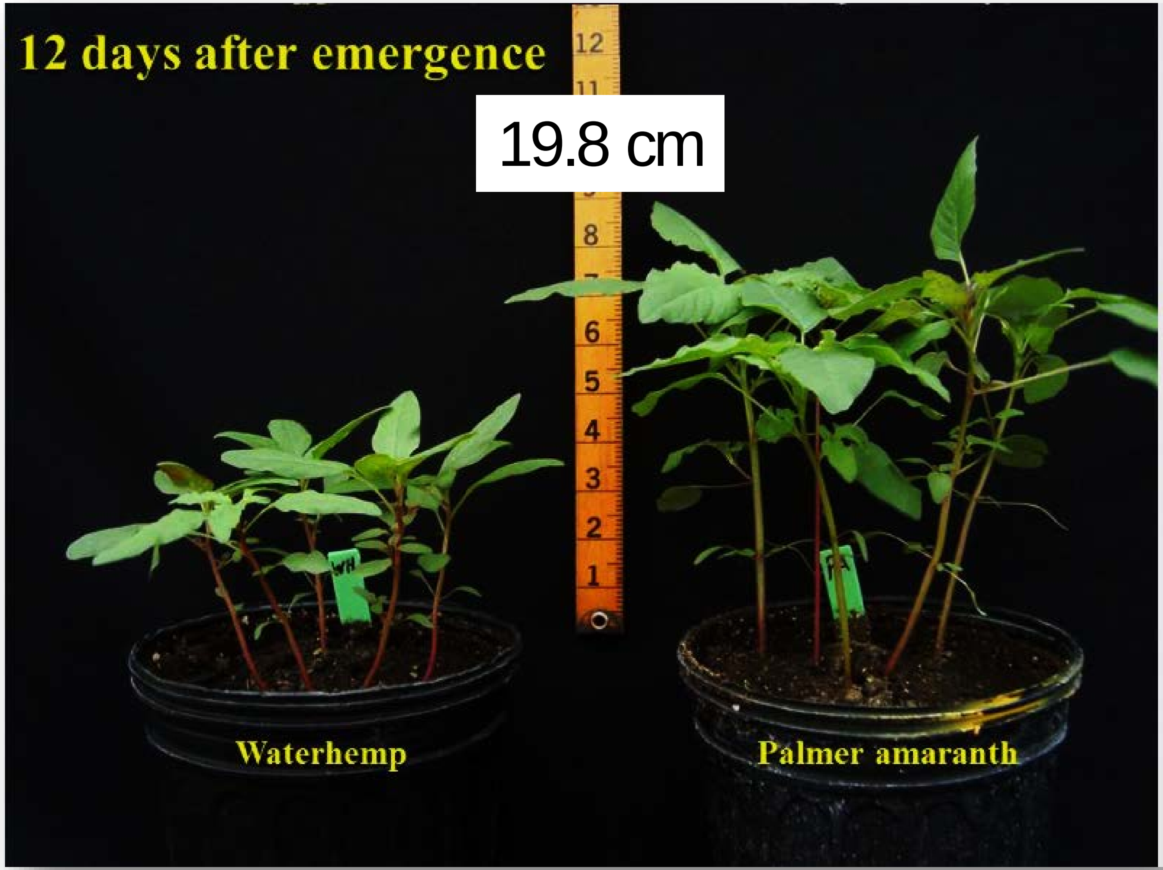

Palmer Amaranth Spread

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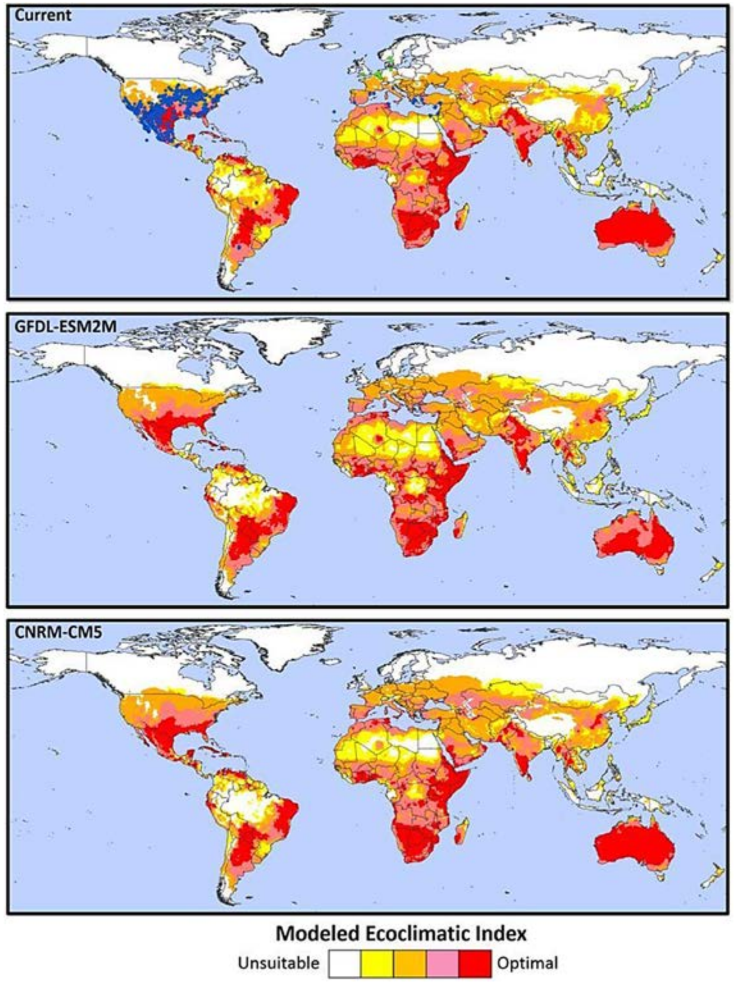

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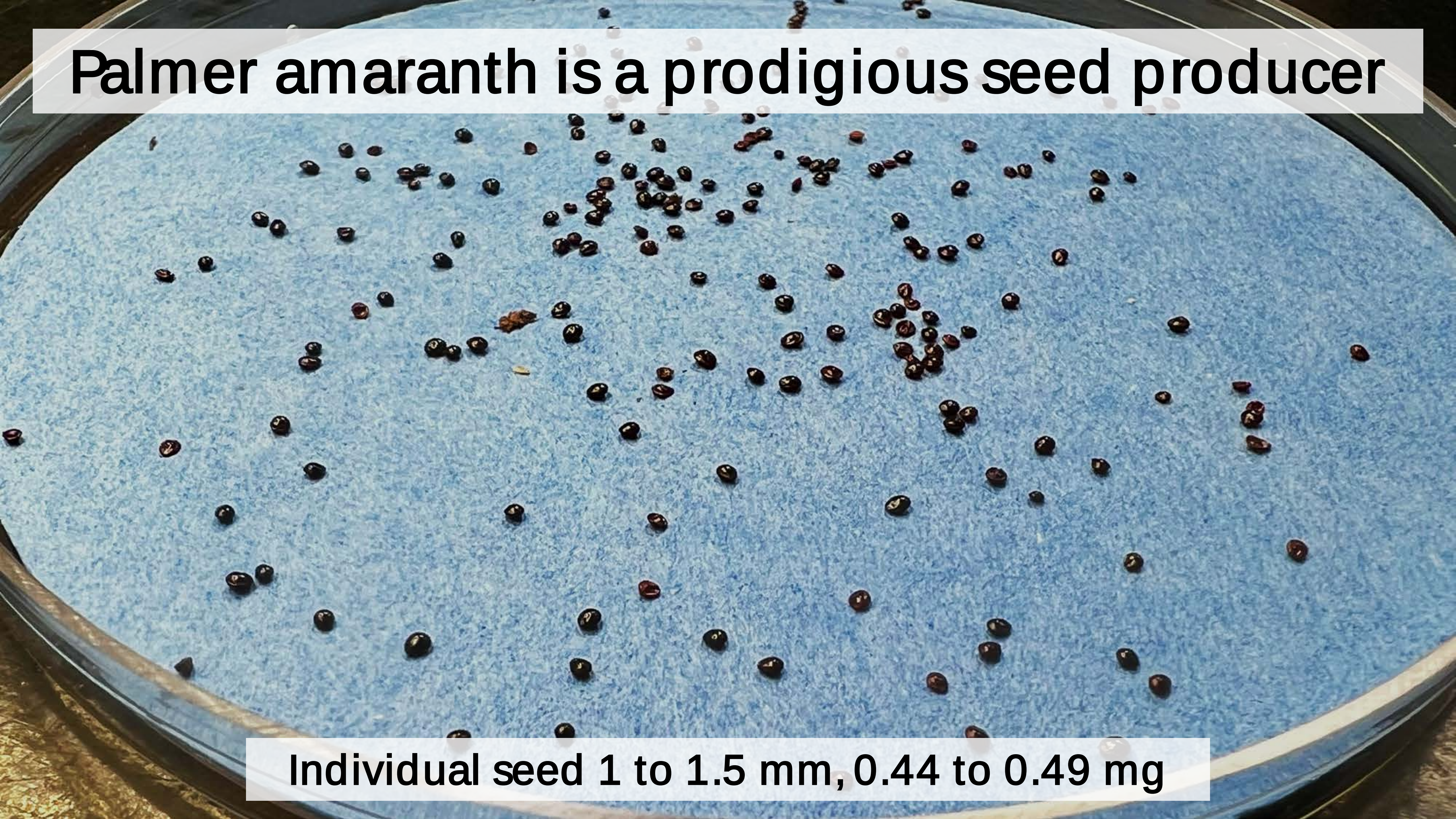
Effects of a Changing Environment on Palmer Growth

Response variables	CO_2 level (ppm)	Response	SE	p-value
Height (cm)	410	60.0	±3.12	0.0011
	750	69.3	±3.60	
Leaf area (cm^2)	410	2216	±532	0.0057
	750	2432	±584	
Stem dry matter (g)	410	13.9	±2.93	0.0014
	750	16.4	±3.45	
Plant volume (m^3)	410	0.1346	±0.0092	*<0.0001*
	750	0.1879	±0.0130	

Table 4. Marginal means and significant effects of CO_2 in height (cm), leaf area (cm^2), stem dry matter (g) and plant volume (m^3) in Palmer amaranth. Bonferroni-adjusted intervals statistically significant at a p-value of 0.0062 were used. SE: standard error.

Palmer amaranth is a prodigious seed producer



Individual seed 1 to 1.5 mm, 0.44 to 0.49 mg

Seed production in several amaranth species

Sellers et al. (2003) Weed Science 51:329-333

Species	Seed / plant
Palmer amaranth	250,700
Waterhemp	288,550
Red root pigweed	291,570
Tumble pigweed	50,090

This plant is producing more than 250,000 seed…

Maybe individual plants aren’t producing 250,000 seed, each, but what is the whole population producing?

- *Keeley et al. (1987) Weed Sci. 35: 199-204*
- No Competition, 200,000 – 600,000 seed plant^{-1}

- *MacRae et al. (2013) J Cotton Sci. 17:227-232*
- Cotton, 400,000 seed plant^{-1}

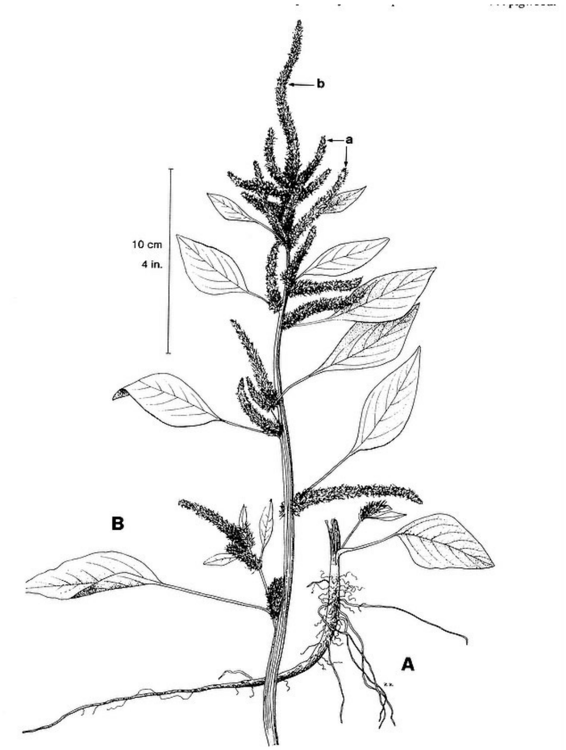
- *Jha et al. (2008) Weed Sci. 56:408-415*
- Soybean, 211,000 seed m^{-1} row

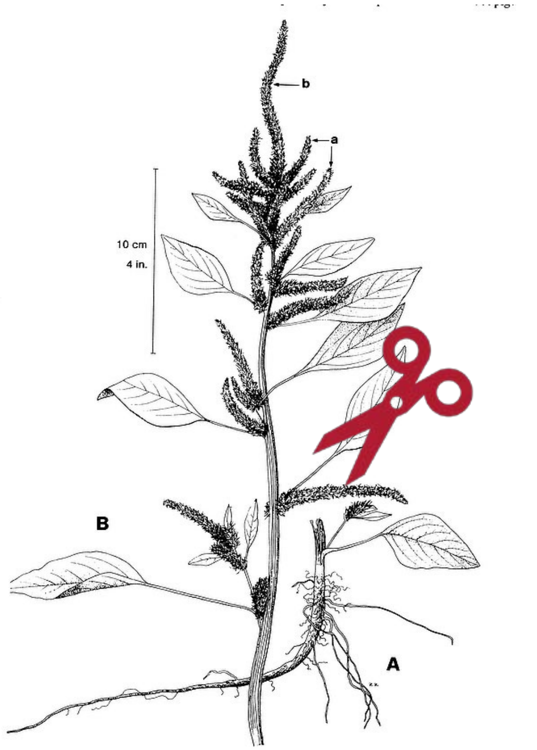
- *Burke et al. (2007) Weed Tech. 21: 367-371*
- Peanut, 124,000 seed m^{-1} row

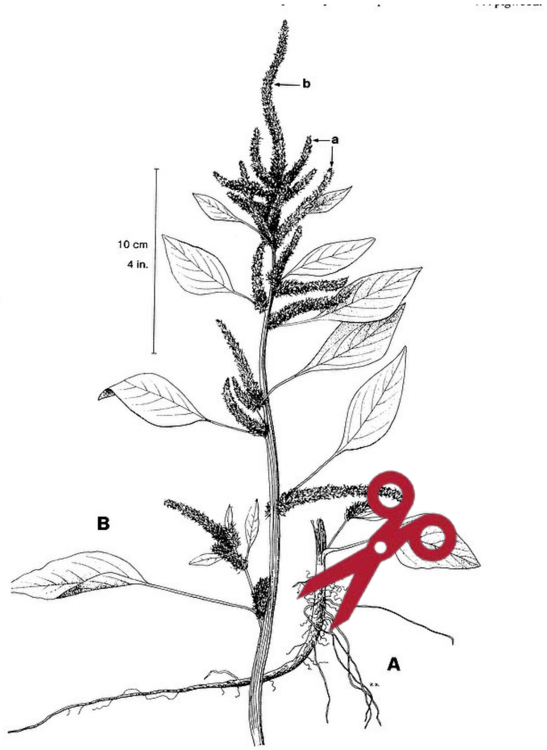
Compensatory Growth Palmer Amaranth

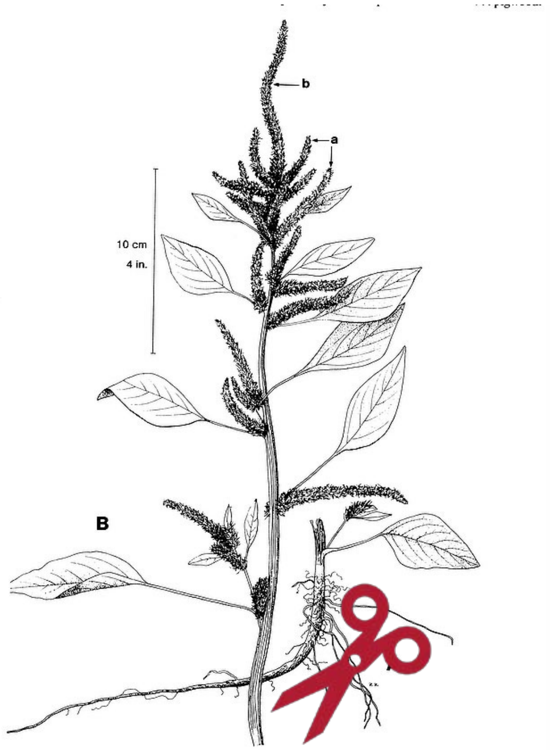
(Growing in competitive cotton variety, cut back at Palmer flowering/cotton canopy closure)

Intact Plants	15 cm	3 cm	0 cm (soil line)



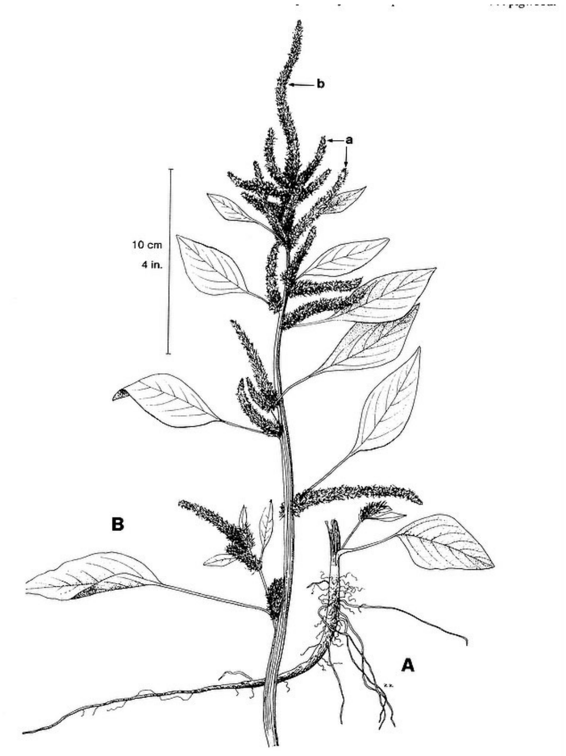






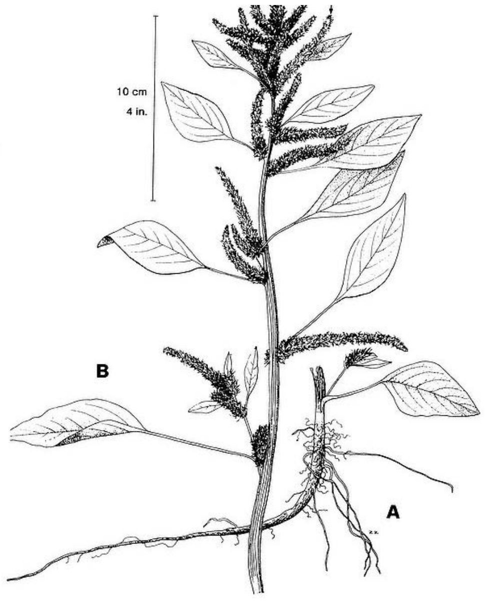
Intact Plants

100% survival
218 cm tall



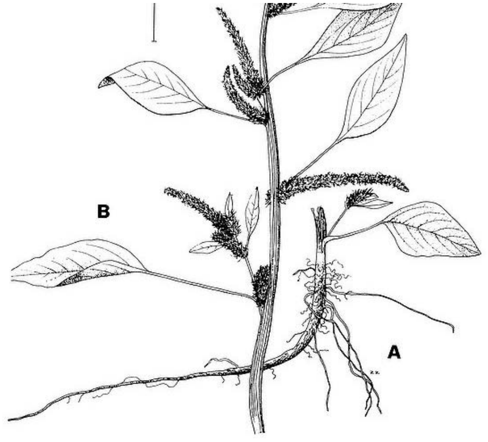
Cut to 15 cm

65% survival
102 cm tall



Cut to 3 cm

35% survival
38 cm tall



Cut to soil line

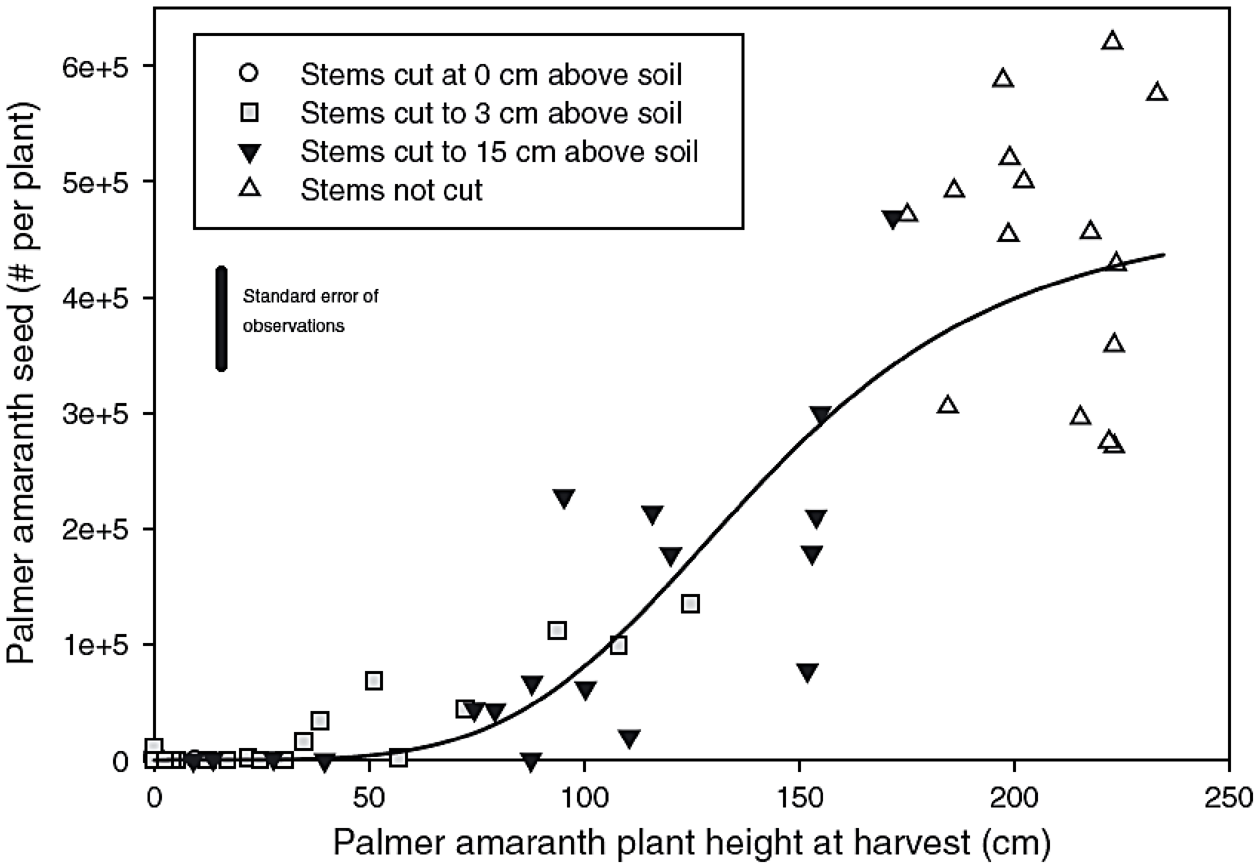
5% survival
2.5 cm tall

Cutting affected cotton yield

Treatment	Yield (t ha^{-1})
Intact	1.53
15 cm	3.04
3 cm	3.39
0 cm	3.41

Cutting affected Palmer seed production

Treatment	Seed plant^{-1}
Intact	435,000
15 cm	116,000
3 cm	28,000
0 cm	700

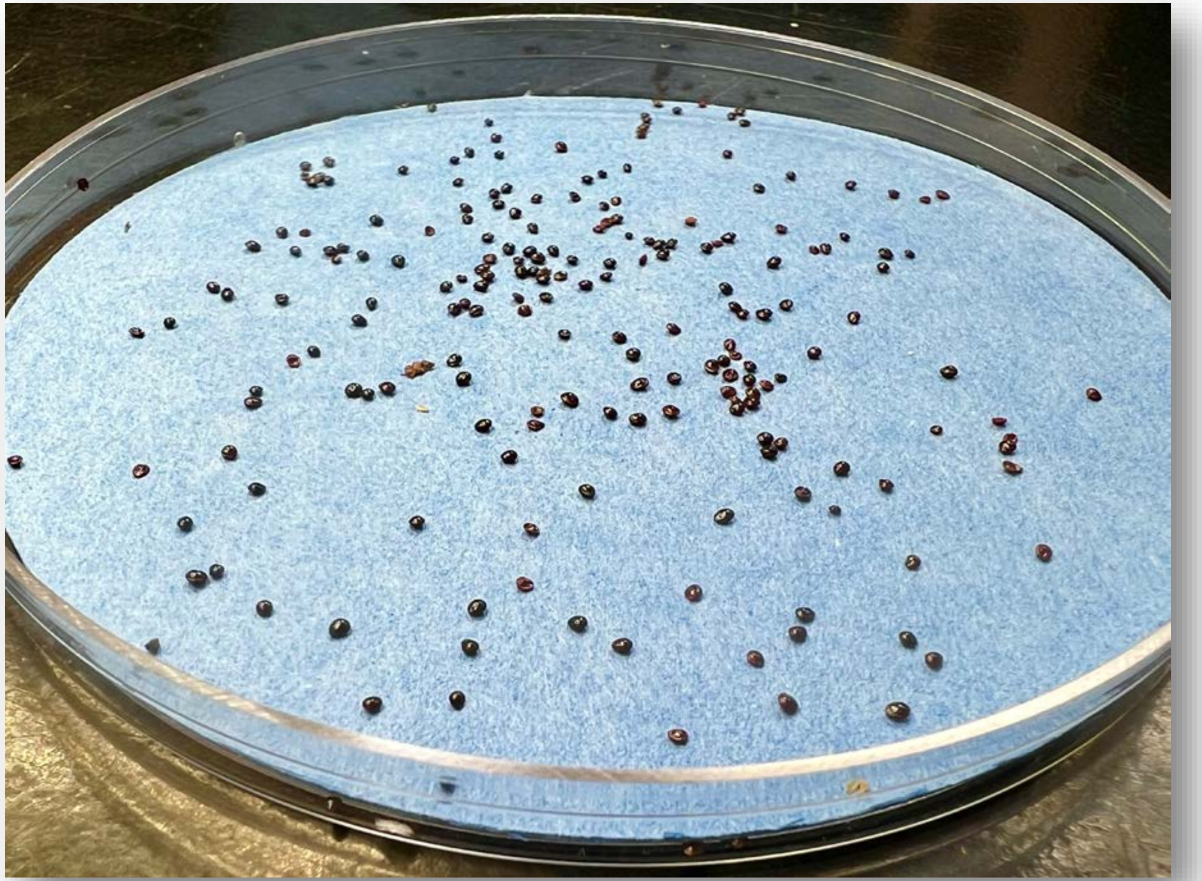


Seed Germination

Palmer amaranth has a minimum temperature threshold for germination of 17 C

Palmer amaranth germinates best at 30 to 37 C

Can germinate in day/night temperature regimens as hot as 45 C / 40 C



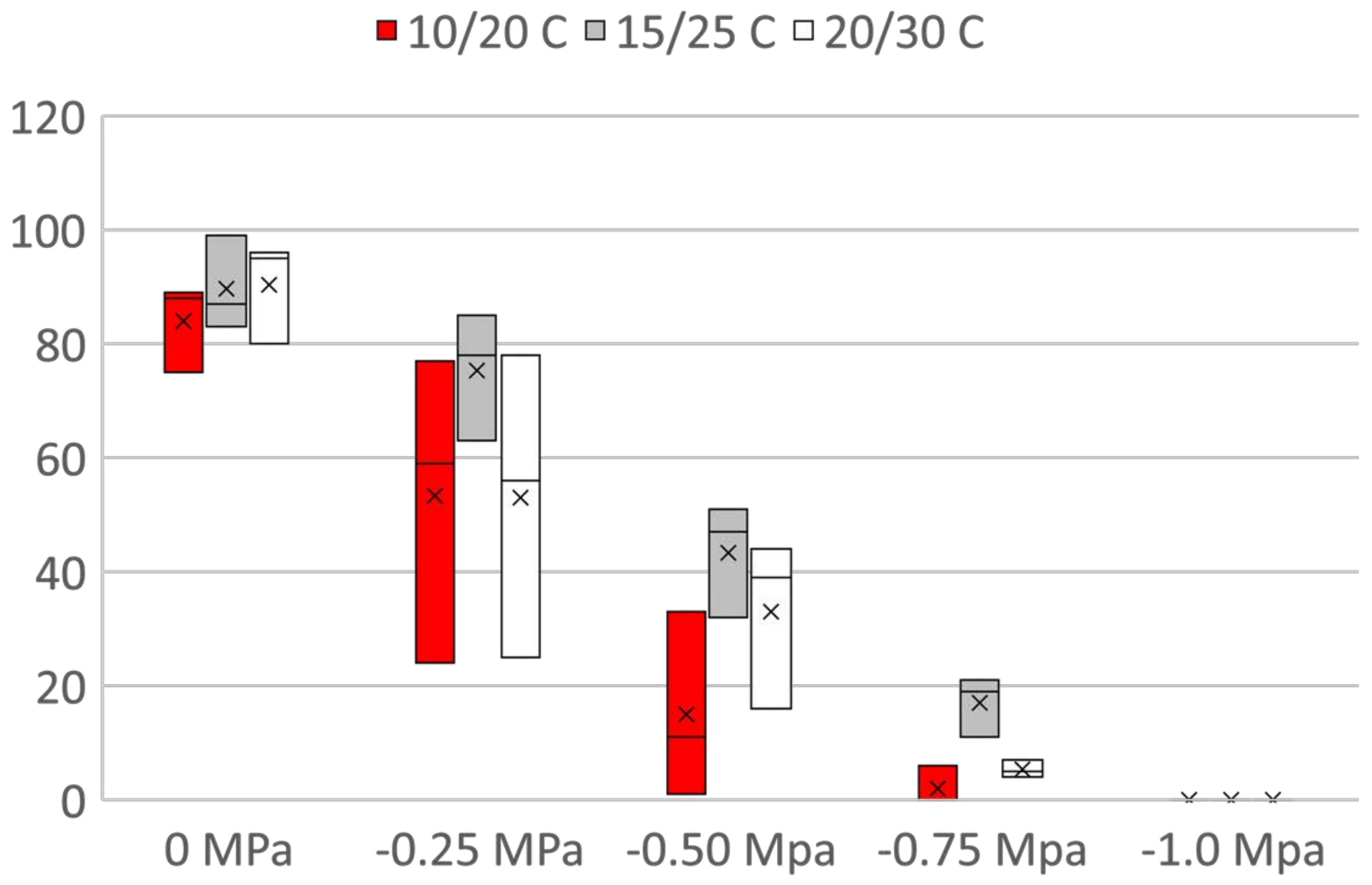
Seed Germination

Our germination studies suggest that base (lowest) water potential (Ψbase) for germination is between -0.75 and -1.0 MPa

Water potential (Ψ50) for 50% germination is between -0.28 and -0.44 MPa

Field capacity -0.01 to -0.03 MPa

Permanent wilting point -1.5 MPa

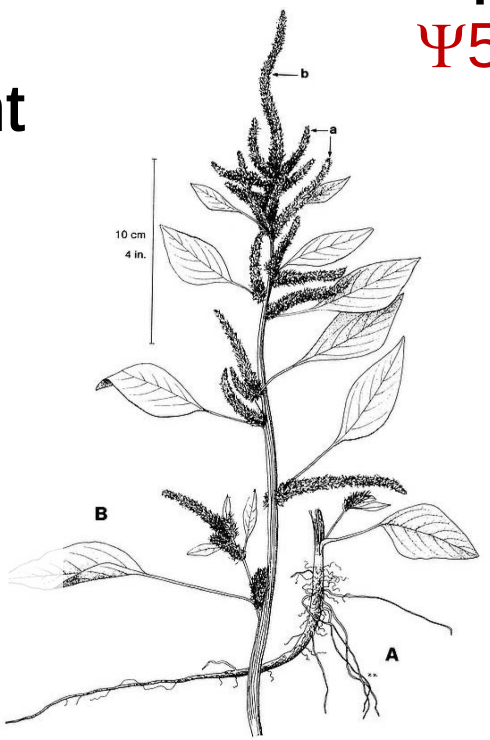


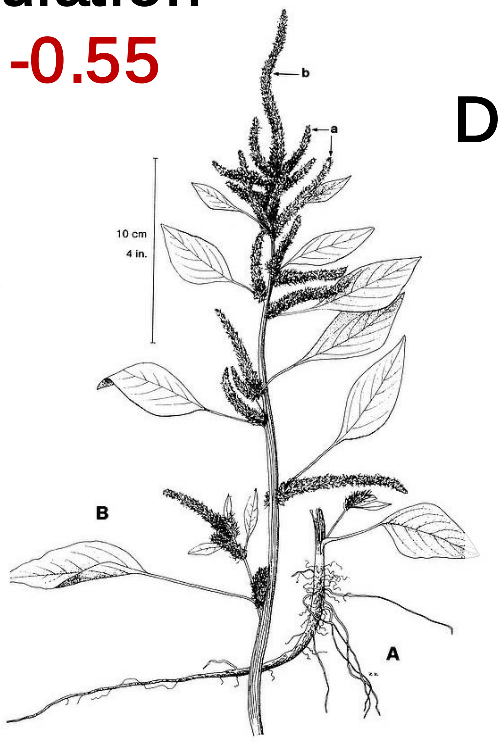
Maternal Water Stress and Impacts on Offspring germination

KS population
$\Psi50 = -0.55$

Well-Watered Parent
35 to 42% field capacity

Offspring
$\Psi50 = -0.21$ to -0.33





Drought-Stressed Parent
6 to 13% field capacity

Offspring
$\Psi50 = -0.63$ to -0.81

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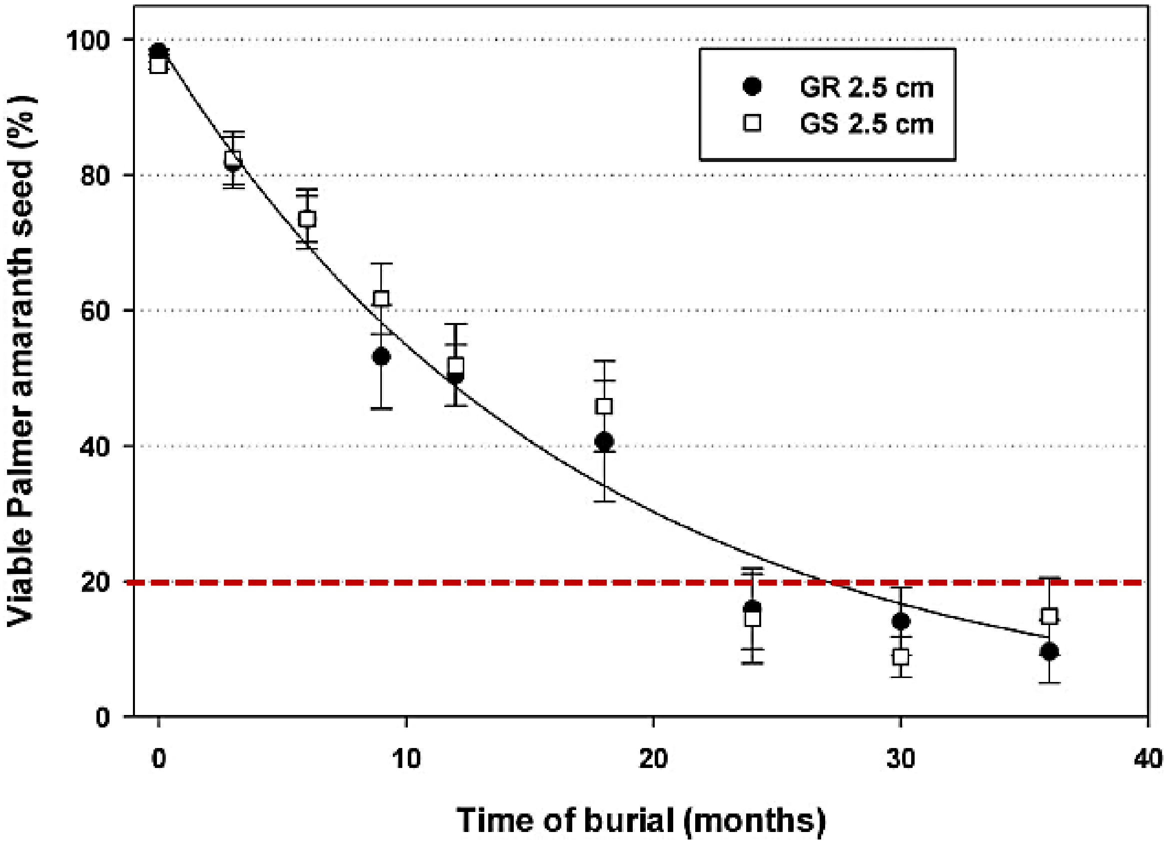
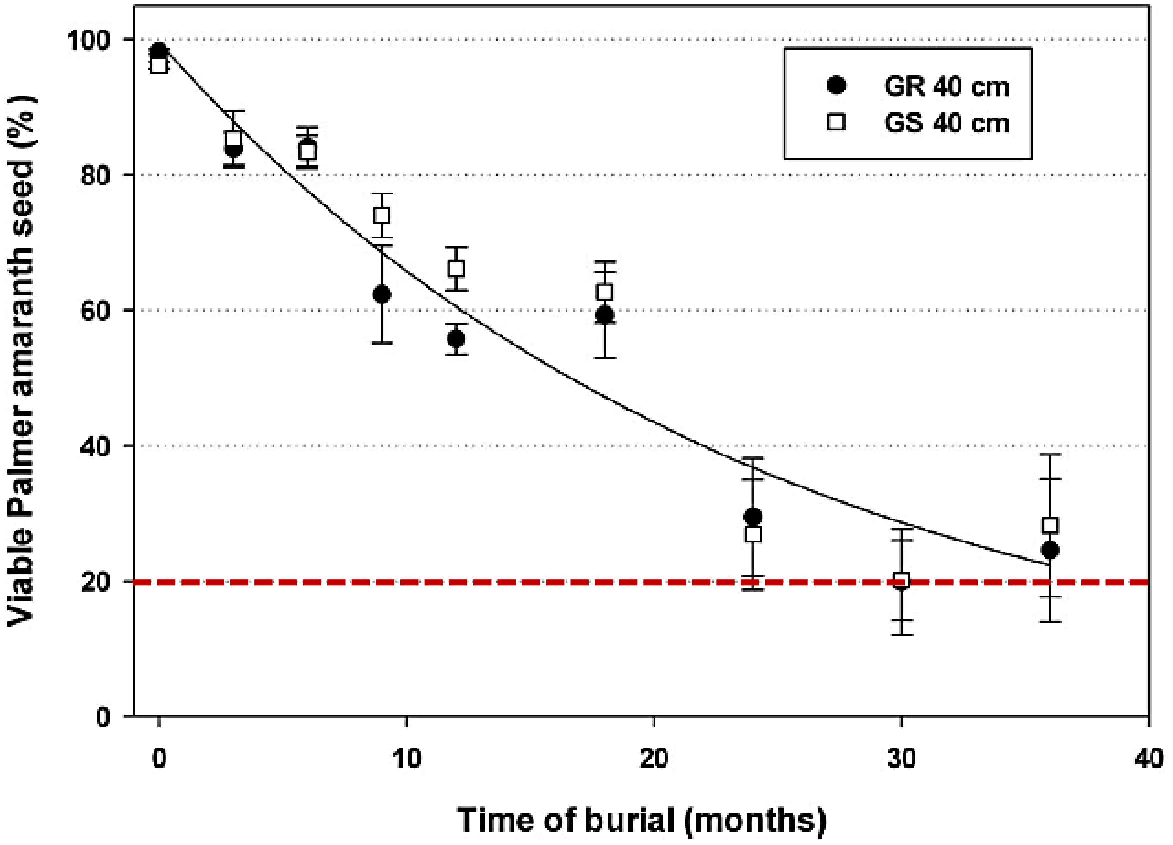
Matzrafi et al. (2021) Weed Science 69:31-38

Burial Depth and Duration Affect Seed Viability

Sosnoskie et al. (2013) Weed Sci. 61:283-288





Seed Survival

Composted manure

-90%

Ensiling

-40% to -60%

Passage thru digestive systems

-70% to -95%

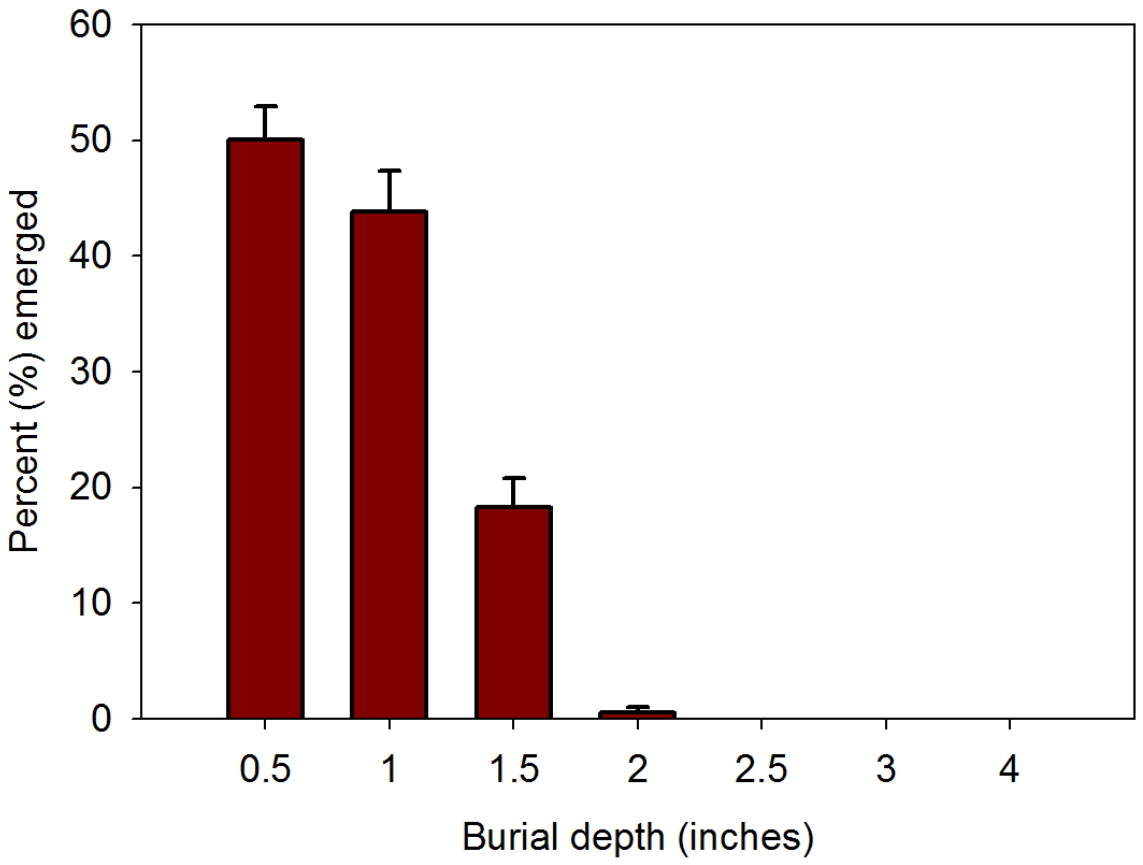
Seedling Emergence

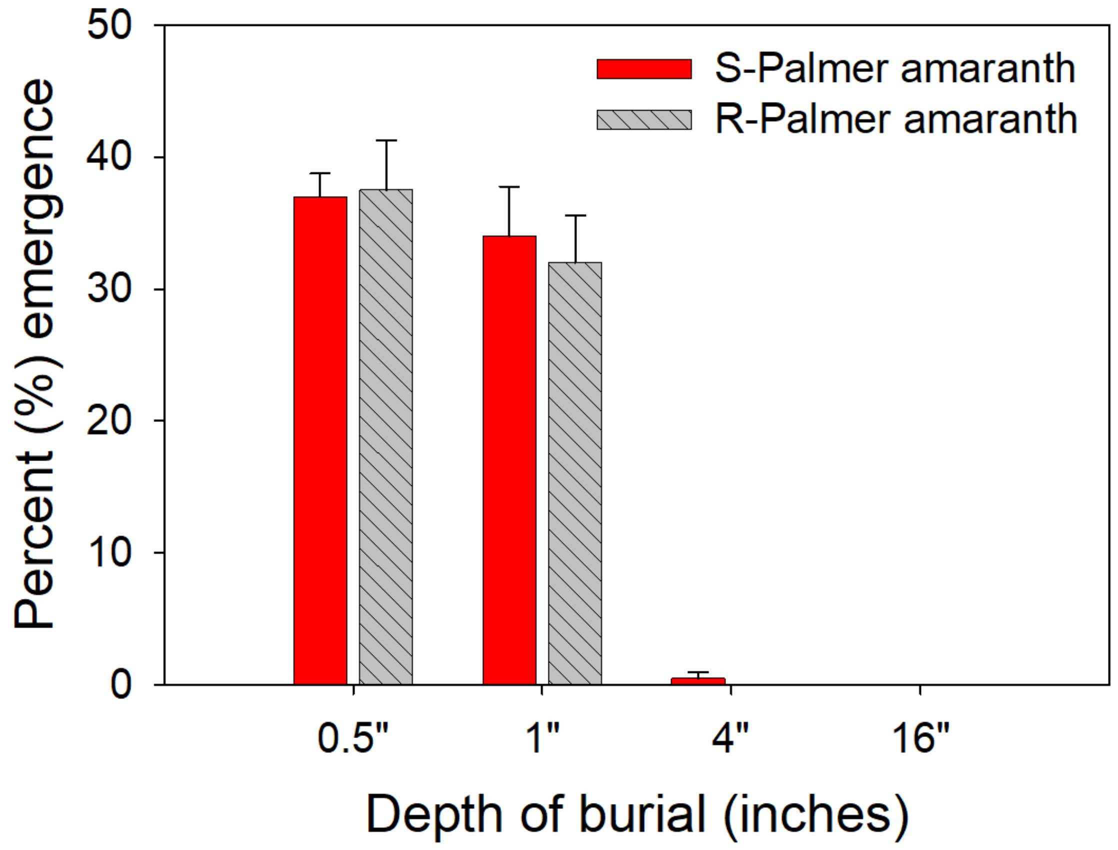
Seeds are small and contain limited nutrient resources to support seedling growth

Palmer amaranth emerges best from the top 0.75 cm to top 2.5 cm of the soil profile

Emergence practically never occurs in the field at depths greater than ~2 cm

Palmer amaranth seedling emergence as a function of burial depth






Herbicide Resistance

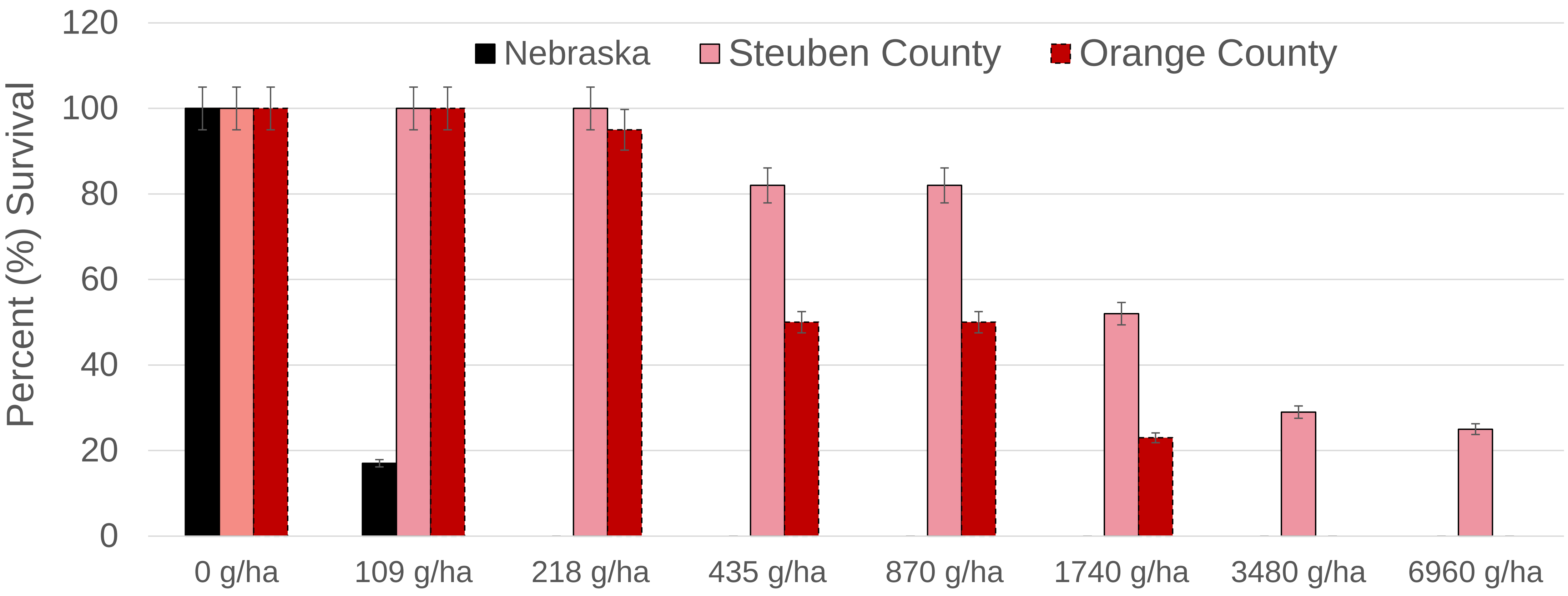
US populations resistant to glyphosate, ALS-, PSII-, PPO-, HPPD-, VLCFA-inhibiting herbicides as well as glufosinate, dicamba, 2,4-D

Waterhemp (*Amaranthus tuberculatus*)

Palmer amaranth (*Amaranthus palmeri*)

Response of 2 putative R populations (Steuben, Orange Counties) and 1 S population (Nebraska) to glyphosate

EPSPS copy number, ECC confirmed in Todd Gaines Lab at CSU



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A third population (Genesee County) is also resistant

Palmer Amaranth is in the Top Five Species for Developing Herbicide Resistance (9 SOA)

WSSA 2 – ALS-inhibitors – chlorimuron, chloransulam, others

WSSA 3 – DNAs – pendimethalin, trifluralin

WSSA 4 – Auxins – 2,4-D, dicamba

WSSA 5 – PS II-inhibitors – atrazine

WSSA 9 – EPSPS-inhibitors – glyphosate

WSSA 10 – Glutamine synthase-inhibitors – glufosinate

WSSA 14 – PPO-inhibitors – fomesafen, lactofen, others

WSSA 15 – VLCFA-inhibitors – S-metolachlor

WSSA 27 – HPPD-inhibitors – mesotrione, tembotrione, others

The Spread of Herbicide Resistance

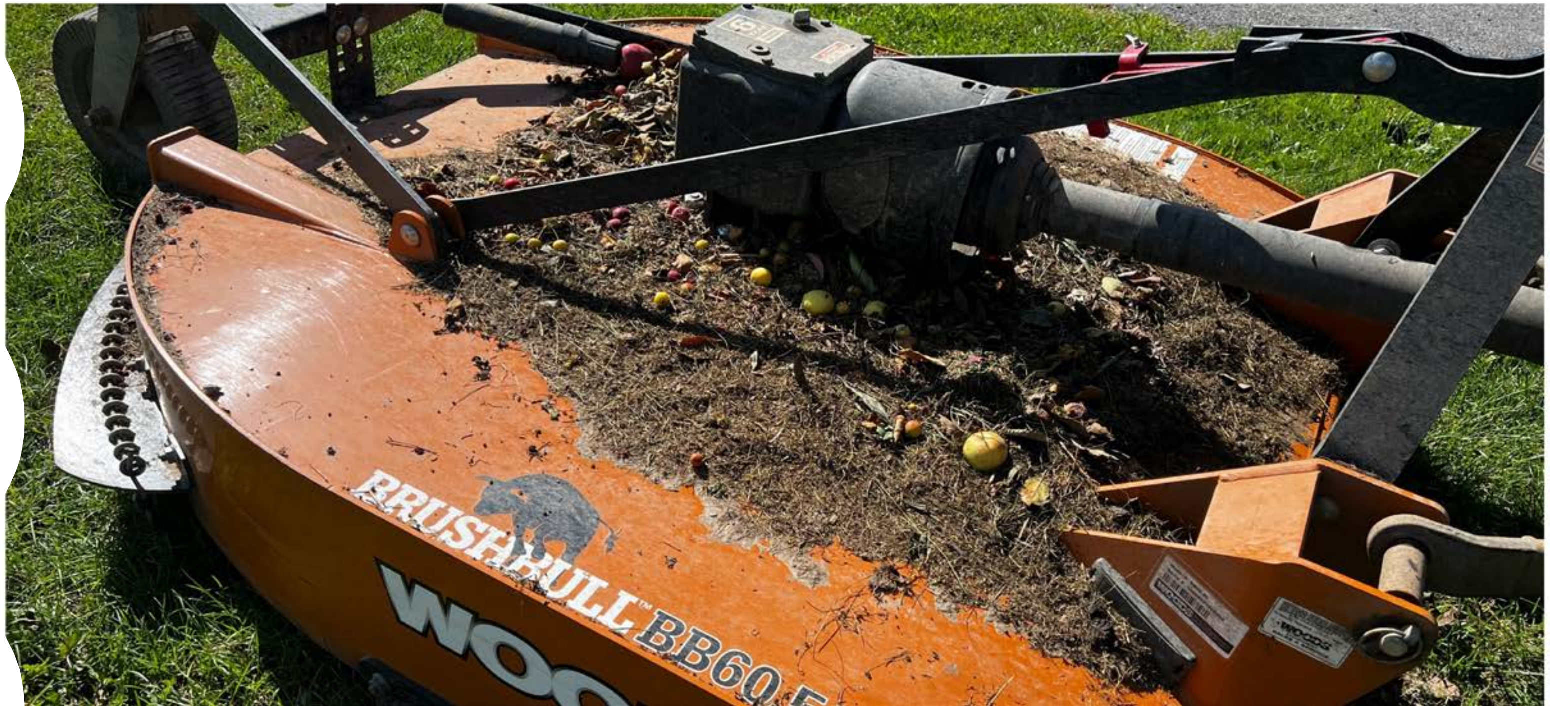
Evolution on site due to selective pressure

Movement via water or possibly animals

Dispersal via contaminated seed, animal feed

Dispersal via mulch, manure, and litter

Dispersal via equipment and human movement



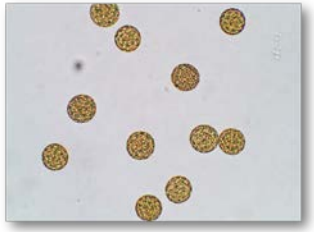
Palmer Amaranth is Dioecious

Male Plant - Flowers

Female Plant - Flowers



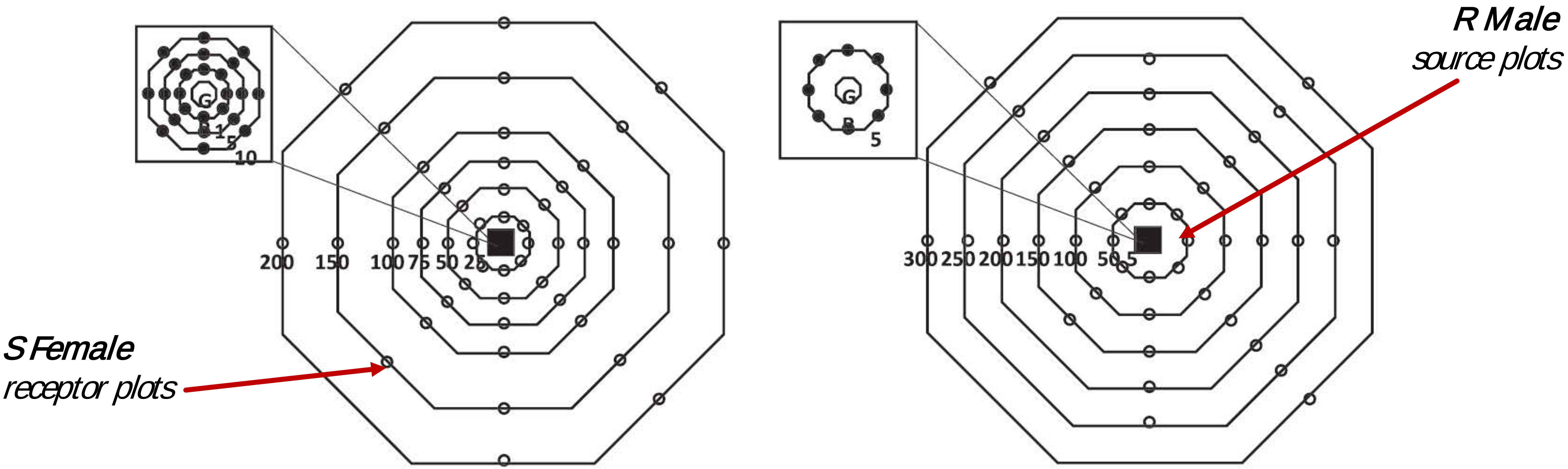

Pollen flow



Obligate out-crossing, moving of genetic material via pollen between plants

Includes genes conferring herbicide resistance

SOSNOSKIE ET AL. (2012) POLLEN-MEDIATED DISPERSAL OF GLYPHOSATE-RESISTANCE IN PALMER AMARANTH UNDER FIELD CONDITIONS. WEED SCI. 60:366-373



Glyphosate resistant (R) offspring were detected at every distance from the source population

EXAMPLE OF POLLEN – MEDIATED HERBICIDE RESISTANCE TRANSFER

- *Sosnoskie et al. (2012) Weed Science 60:366-373*
  - Glyphosate resistance in Palmer amaranth, pollen movement from resistant males to sensitive females
- *Liu et al. (2012) Weed Science 60:416-427*
  - ALS-inhibitor resistance in waterhemp, pollen movement from resistant males to sensitive females
- *Sarangi et a. (2017) Scientific Reports DOI:10.1038/srep44913*
  - Glyphosate resistance in waterhemp, pollen movement from resistant males to sensitive females
- *Ribeiro et al. (2014) Planta. 239:199-212*
  - Apomixis can occur in Palmer amaranth. How does it impact the observed results and affect the stability of the resistance trait?

HYBRIDIZATION?

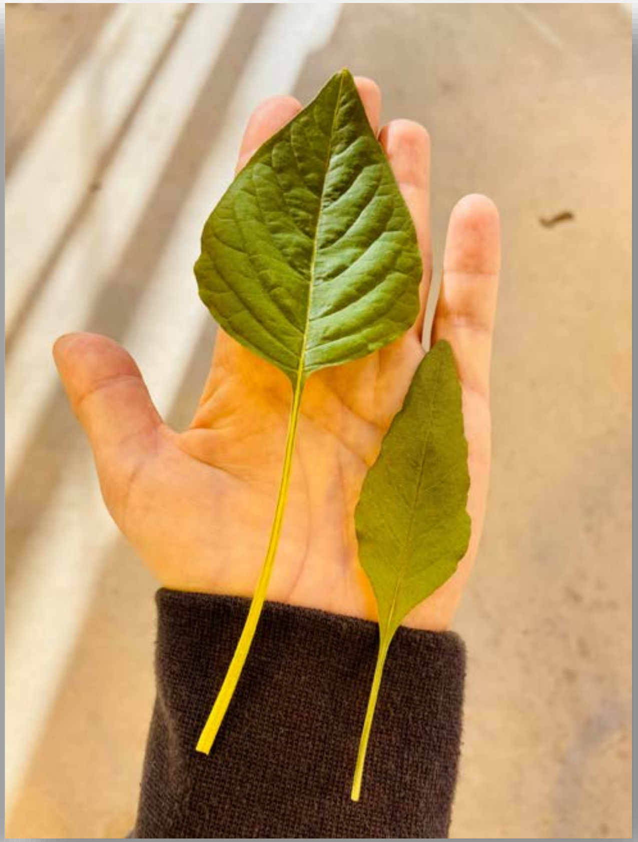
- *Nandula et al. (2014) Pest Management Science 70:1902-1909*
- Evidence suggests that part of the EPSPS amplicon from resistant *A palmeri* is present in glyphosate-resistant *A spinosus* and is likely due to a hybridization event between *A spinosus* and *A palmeri*

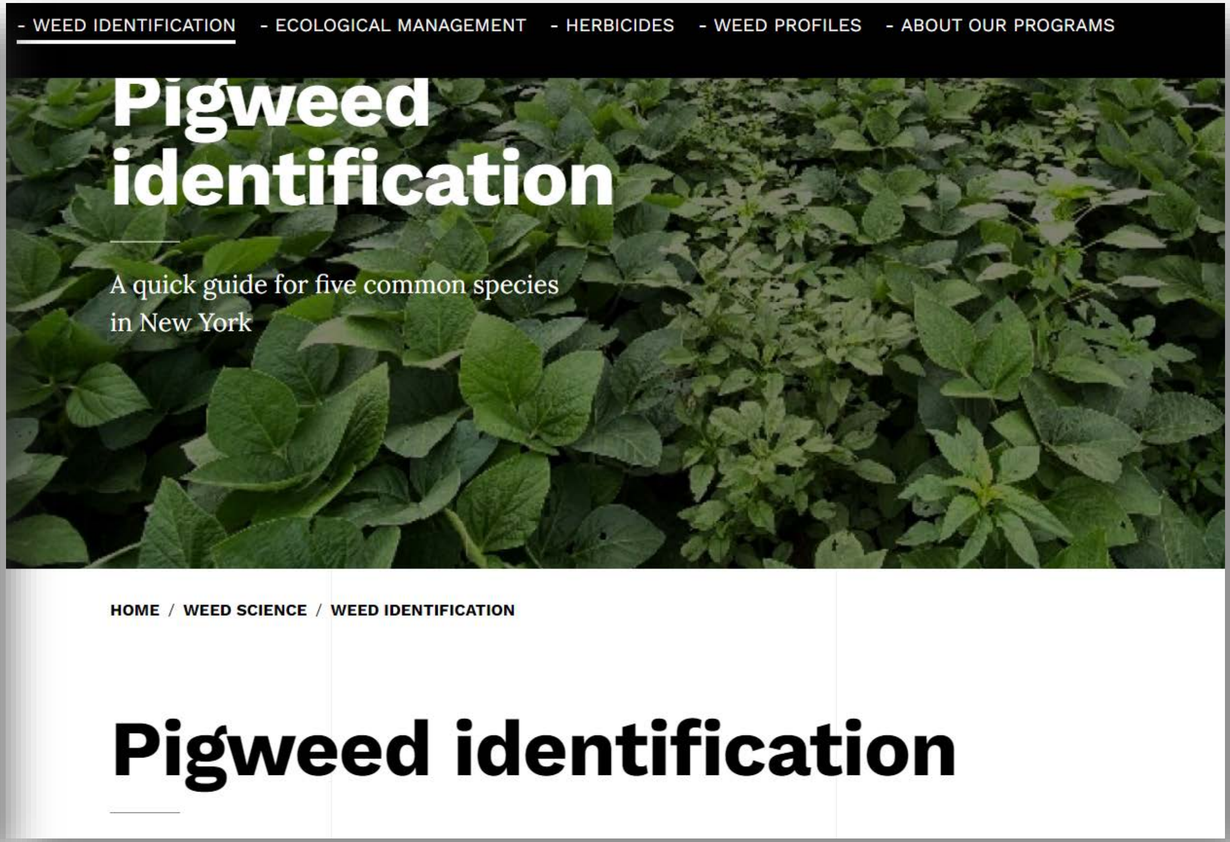
- *Oliveira et al. (2018) The Plant Journal 96:1051-1063*
- Results showed hybridization between *A tuberculatus* and *A palmeri* and the transfer of metabolism-based mesotrione resistance under field conditions.

So Now What?

SCOUT! SCOUT! SCOUT!

Scout fields, inspect off-farm inputs for presence of weed seed





Palmer amaranth - Getting Rid Of Weeds (growiwm.org)

Pigweed species Identification Guide

Dave Bilyea
University of Guelph – Weed Technician

Kristen Obeid (kristen.obeid@ontario.ca)
OMAFRA – Weed Specialist - Hort

Identify and Remove Survivors

Eliminate small infestations by hand

Identify control failures (chemical, physical, cultural)

Call university of government personnel if detected

Palmer amaranth - Getting Rid Of Weeds (growiwm.org)

Crop Rotation

Crop rotation diversifies the type and timing of disturbances

Taller growing crops may improve suppression of Palmer amaranth

Corn planting often occurs before temperatures rise, when Palmer amaranth's growth rate is slower

Including small grains in the rotation allows treatment at mid-summer when a larger percentage of Palmer amaranth plants have emerged and can be controlled with non-selective herbicides

Palmer amaranth - Getting Rid Of Weeds (growiwm.org)

Tillage and Cultivation

Primary tillage that buries Palmer amaranth seeds by inverting the soil (moldboard plowing) is an effective way of reducing seedling emergence

However, moldboard plowing a second time within a few years can return buried seeds back to the soil surface where they have a chance to germinate and emerge

Cultivation is very effective for small seedlings (less than 7.6 cm tall), but as plants increase in size, stems are capable of re-rooting and continuing growth

Palmer amaranth - Getting Rid Of Weeds (growiwm.org)

Consider Cover Crops

Cover crops can reduce the number of Palmer amaranth plants emerging over the course of the season

Cover crops may slow the growth of Palmer amaranth seedlings

Not all cover crops are created equal (e.g. cereals may be more suppressive than legumes)

Palmer amaranth - Getting Rid Of Weeds (growiwm.org)

Equipment Sanitation

Palmer amaranth - Getting Rid Of Weeds (growiwm.org)

Herbicides

Plant into a weed-free field using an effective non-selective herbicide prior to planting or using tillage just prior to planting to burn down emerged weeds

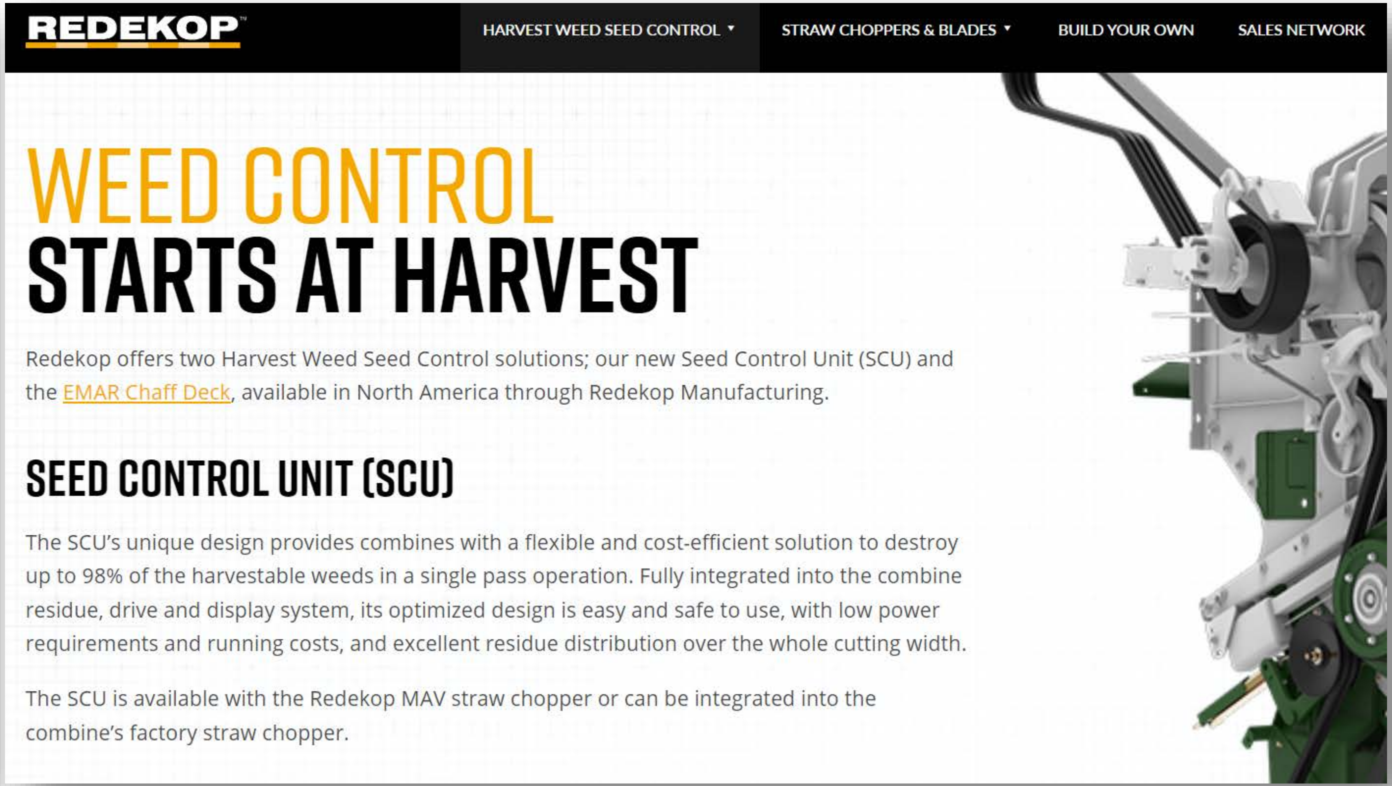
Preemergence or residual (or soil-applied) herbicides should be applied close to crop planting to provide the maximum amount of residual control

Postemergence applications need to be applied to Palmer amaranth at 7.6 to 10 cm in height and consider residuals as a tank mix partner for extended suppression

Use two or more effective modes of action with all herbicide applications to assist with herbicide resistance management as well as provide more consistent control

Palmer amaranth - Getting Rid Of Weeds (growiwm.org)

Novel Technology



Palmer amaranth - Getting Rid Of Weeds (growiwm.org)

Thank You!

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