Phylogenetic relationships of genus Amaranthus: A tool for evolutionary genetics studies

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emerging phylogeny & evolutionary genetics studies

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Genus Amaranthus

Locally adapted crop (?)

Weed: unintended during cultivation

http://pizzagoon.com/wp-content/uploads/2010/01/amaranth.jpg

http://permaculture.org.au/2010/03/17/gm-crops-are-melt-down-in-the-usa/

Amaranthus (ἀμάραντος), 苋菜：

~ 60-70 annual C4 species, five major 'types'

Grain crops

A. caudatus, A. hypochondriacus, A. hybridus, A. cruentus

Leaf-vegetable crops, potherbs (high lysine)

A. cruentus, A. tricolor, A. dubius, A. blitum, A. gangeticus, A. lividus, A. spinosus, (A. palmeri)

Showy ornamental varieties

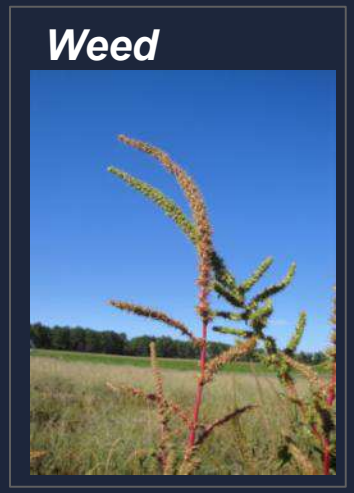
A. caudatus

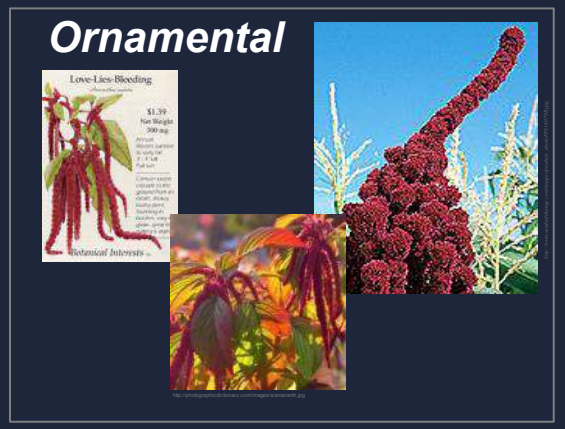
Herbaceous species with limited distribution

Several sp., A. retroflexus

Weedy species

A. palmeri, A. tuberculatus



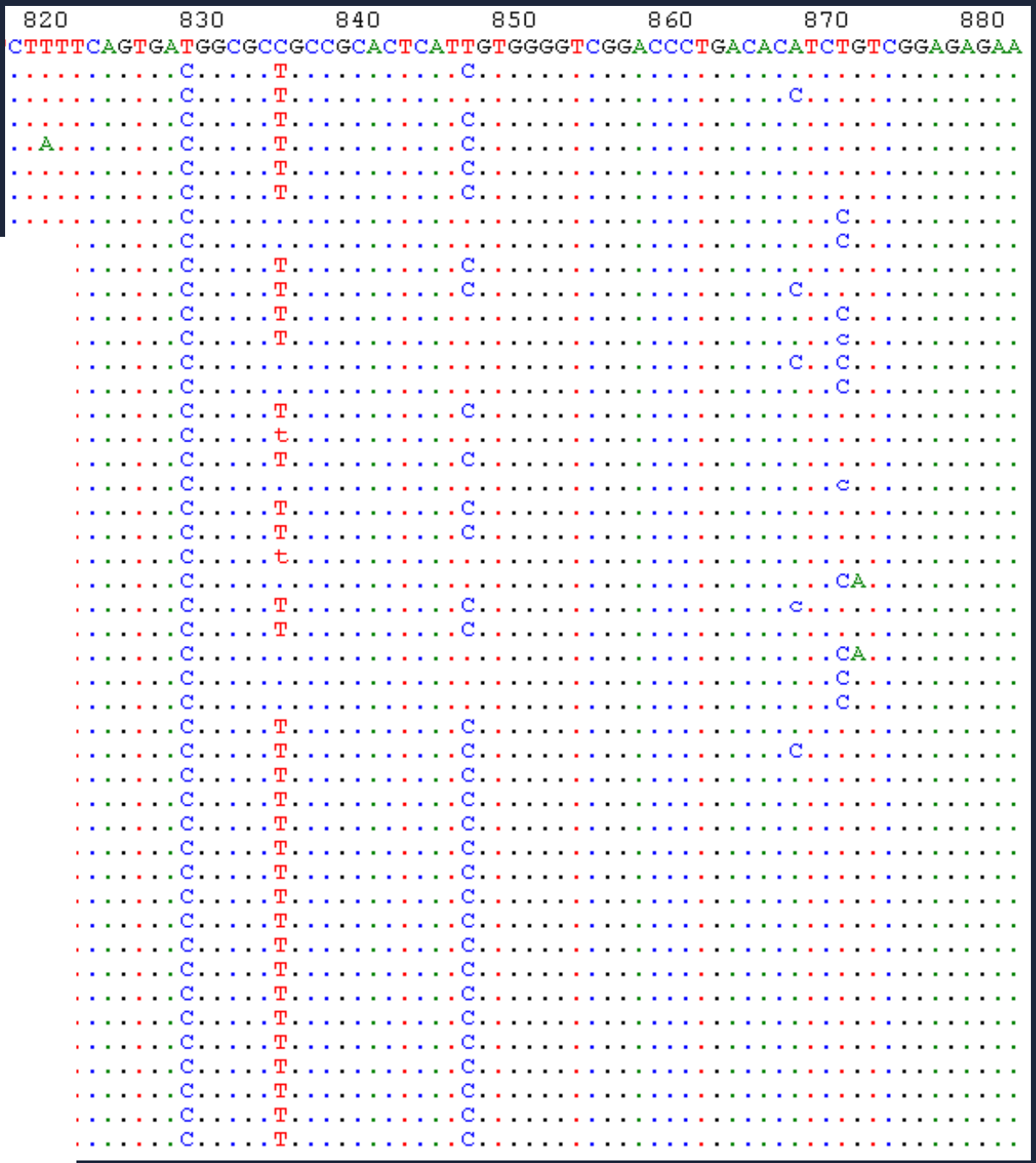


denine

hymine

ytosine

uanine

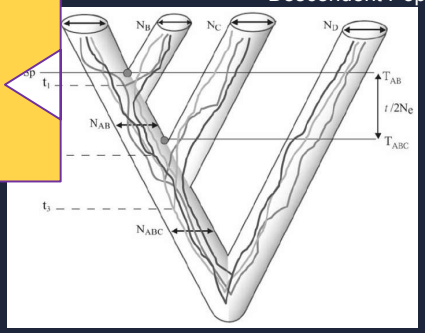


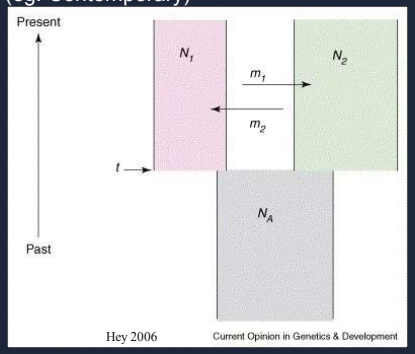
Workflow...

Explicit Models

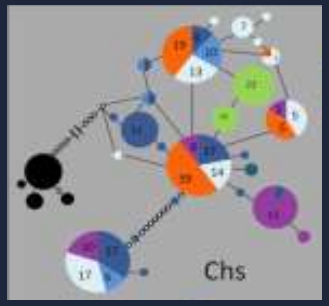
(eg. Isolation-Migration, Substitution Models, Phylogeny Estimation)

Descendent Pops (eg. Contemporary)

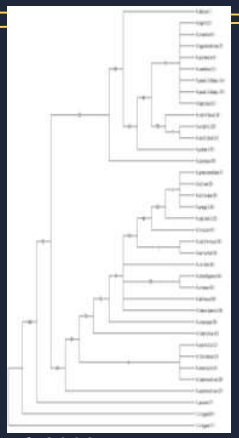




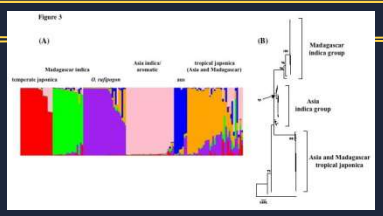
Ancestral Pops (Historical)

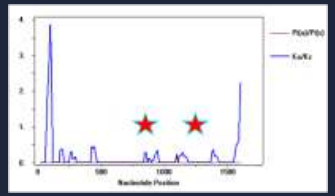


limer *et al.* 2010
nd submitted

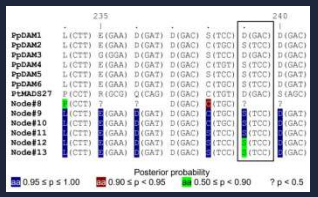


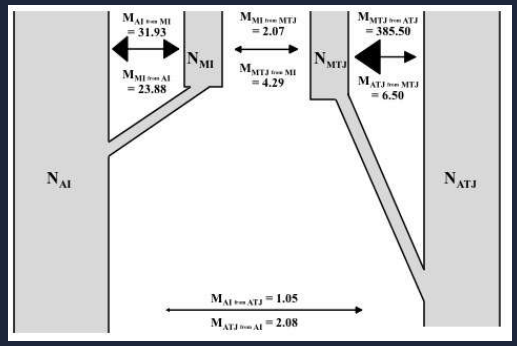
Jimenez *et al.* 2009





Jimenez *et al.* 2009





Mather *et al.* 2010

ences in genus Amaranthus:
tic history and adaptation

- **Contemporary Processes**
  A. palmeri (A. tuberculatus, A. spinosus)
  -- resistant vs. sensitive populations
  -- shared ancestral vs. independent variants
  (gene flow, or private)
  -- demography vs. selection

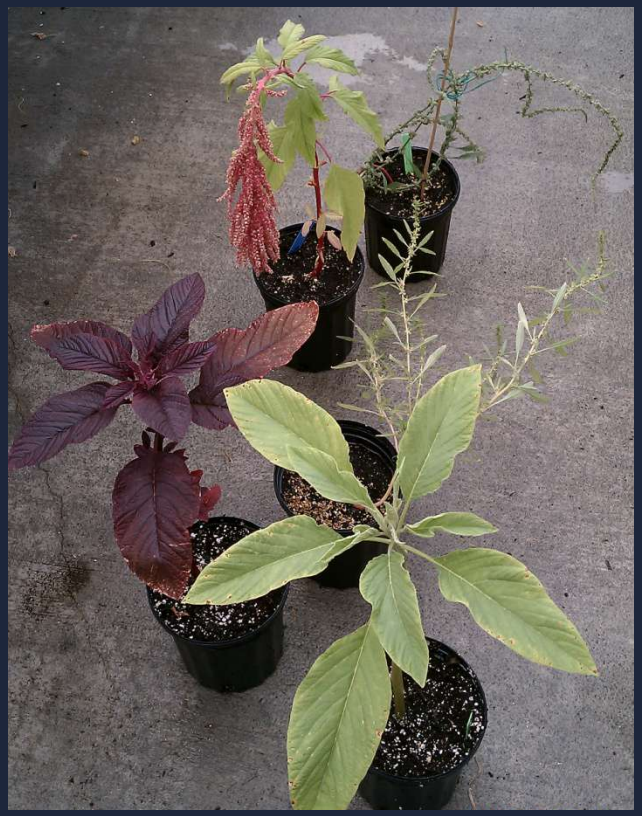
- **Molecular Evolution (candidate genes)**
  -- *Amaranthus palmeri*
  -- genus-wide 'weeds', 'types'
  -- phylogeny (ancestral vs. derived adaptations, crop origins)
  -- among species: crop history (support cultural records?)

- **Model Testing and Hypotheses**
  -- cultivation practices, management strategies,
  geography, expanded species distributions

Overview of sampling

Obtain seeds, grow in greenhouse

- Phylogenetic sampling
- Glyphosate-applied and non-applied localities
- Historical and contemporary populations
- Intensive sampling: *A. tuberculatus, A. palmeri, A. spinosus*



Non-candidate Genes: Phylogenetically informative

Normalized Roche 454 pyrosequencing data

***Amaranthus palmeri* (Burton Lab, NCSU)**

pooled resistant biotypes

pooled sensitive biotypes

***Amaranthus tuberculatus* (Tranel Lab, Uni. Illinois)**

pooled genome-wide representation

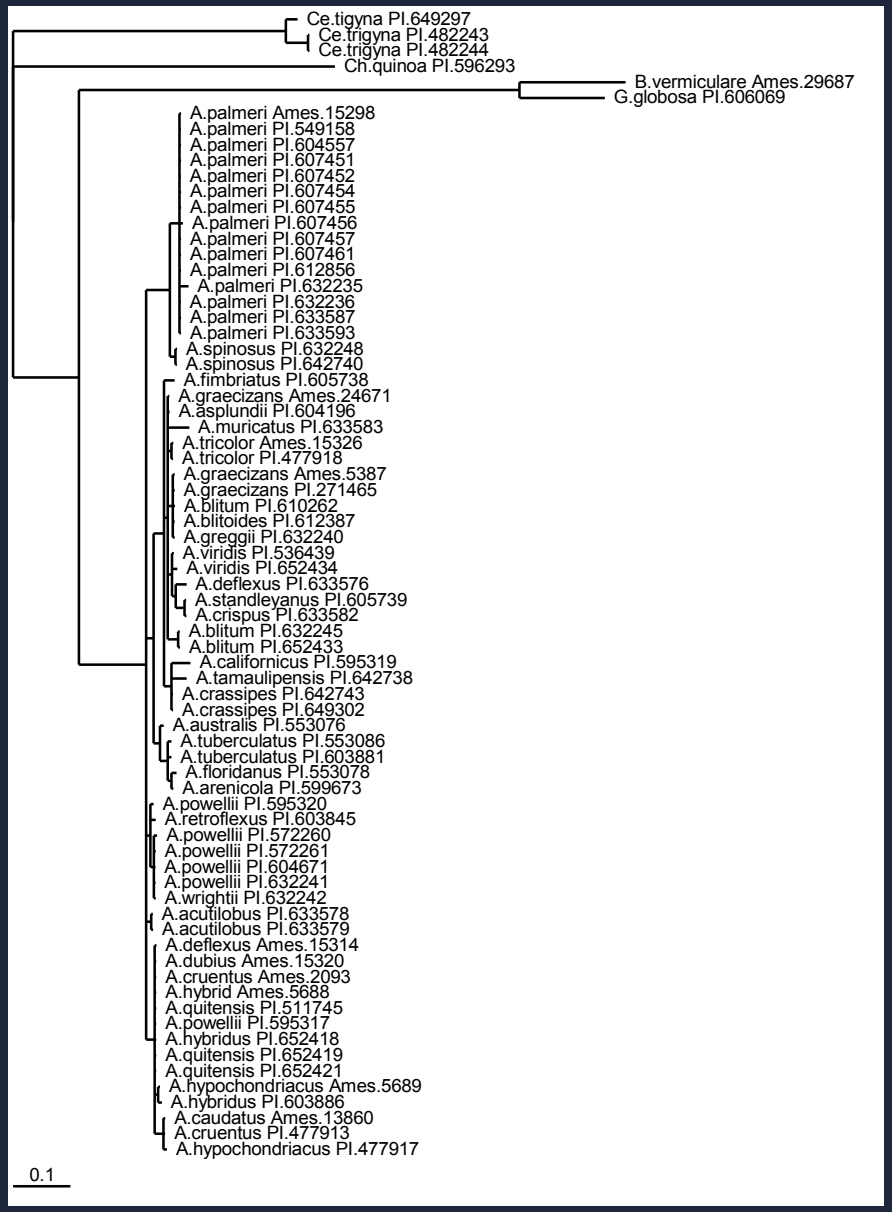
Local BLAST- compare assemblies

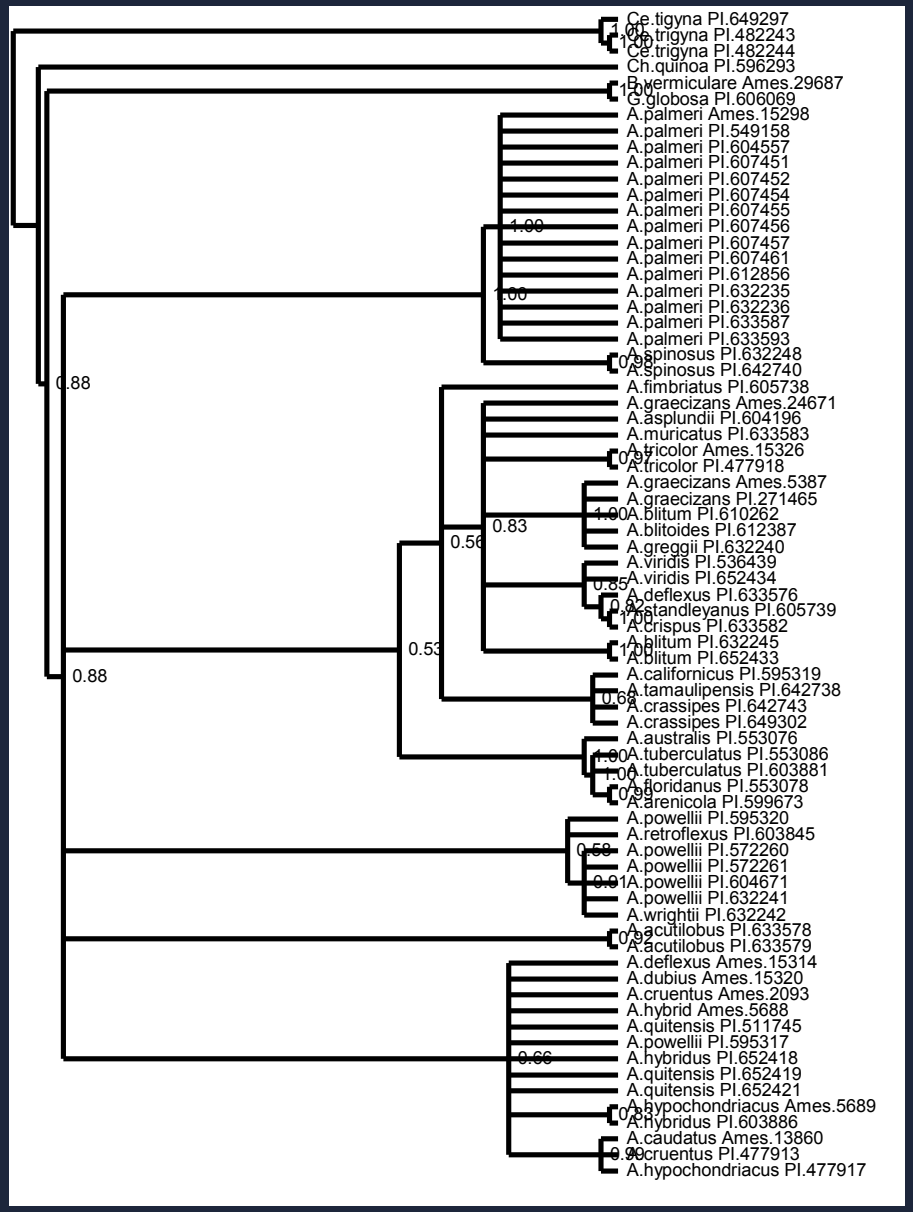
Sanger sequenced common 'non-candidate' genes

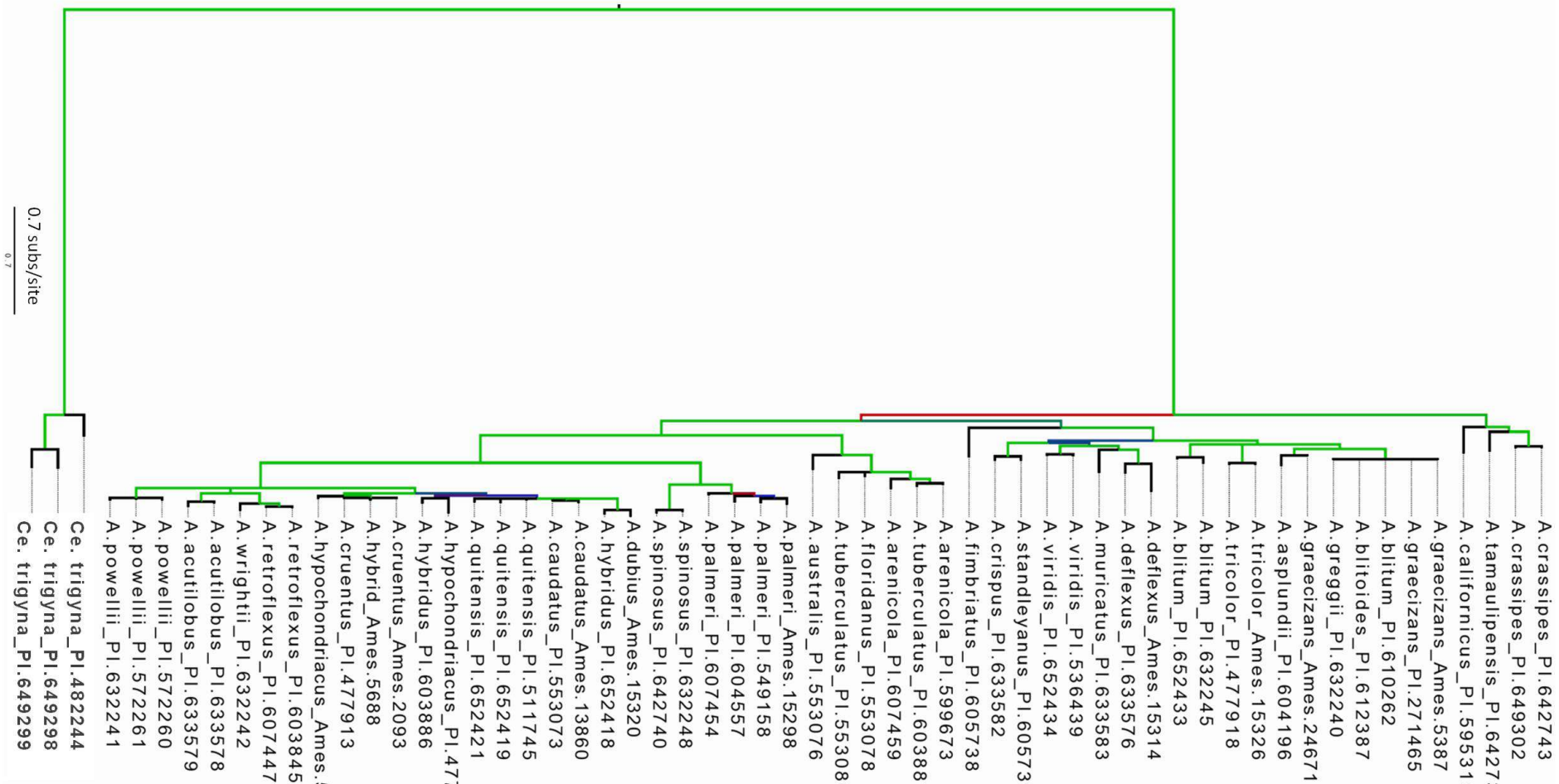
Gene		Putative function	# inf. sites / total # sites (# of indivs)	
MatK		maturase K	86 / 819 (75)	
ITS		5.8S rRNA gene and internal transcribed spacers 1 and 2	67 / 660 (69)	
Trn		tRNA-Leu (trnL) gene	35 / 830 (64)	
A7		Endosomal P24A protein precursor, putative	92 / 610 (64)	
		dead box ATP-		

Bayesian-based Phylogeny Estimation, Preliminary ITS Only

MrBayes, Generations = 2,000,000; final std dev split freq = 0.043512



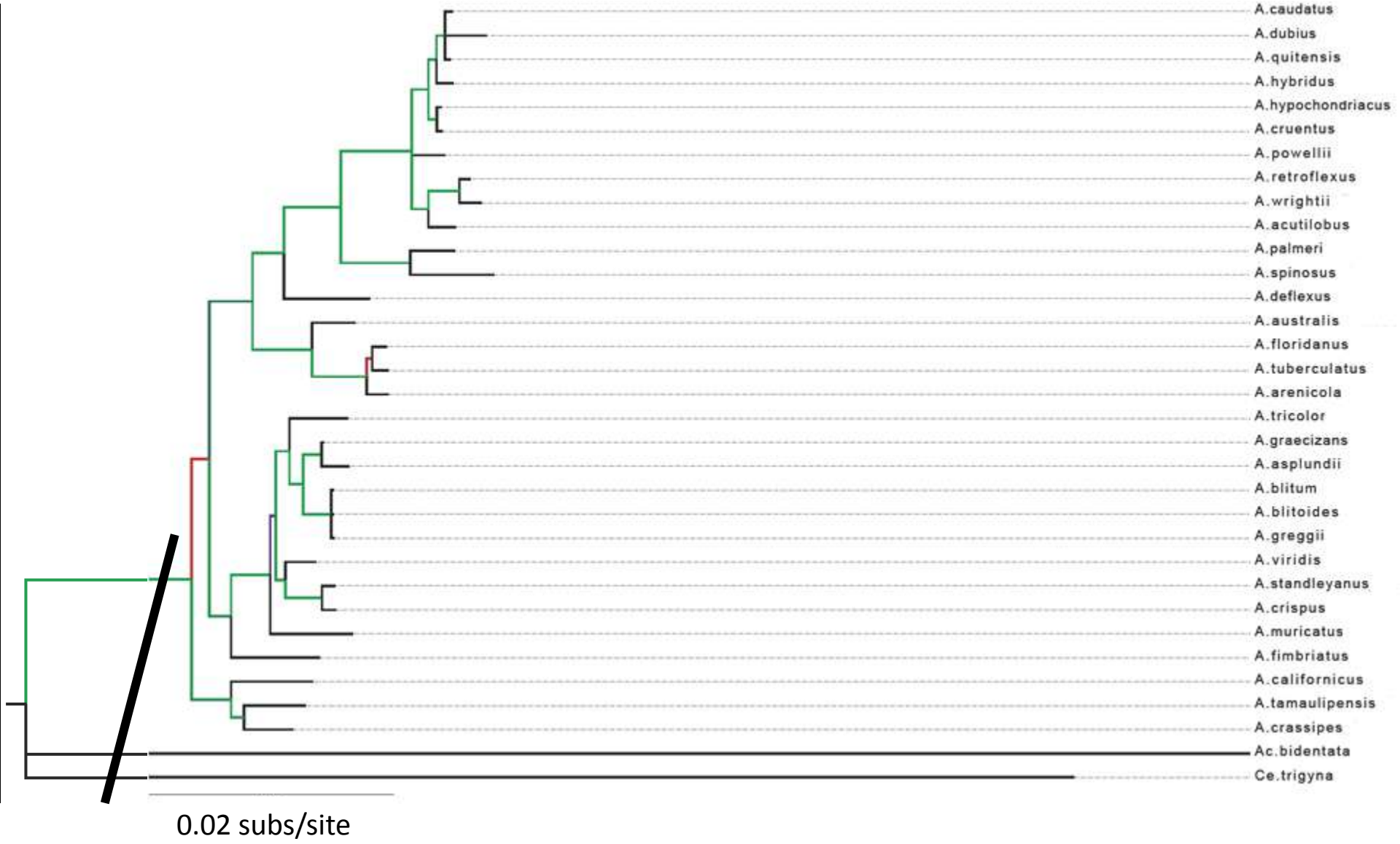




Posterior probabilities:

1.0 0.9 0.8 0.7 0.6

...in progress



Posterior pr

1.0 0.9

0.7 0.6

...in progress

Best fit phylogeny, 32 species

MrBayes

Mutation model: GTR with G

Generations = 2,000,000

6 Concatenated genes

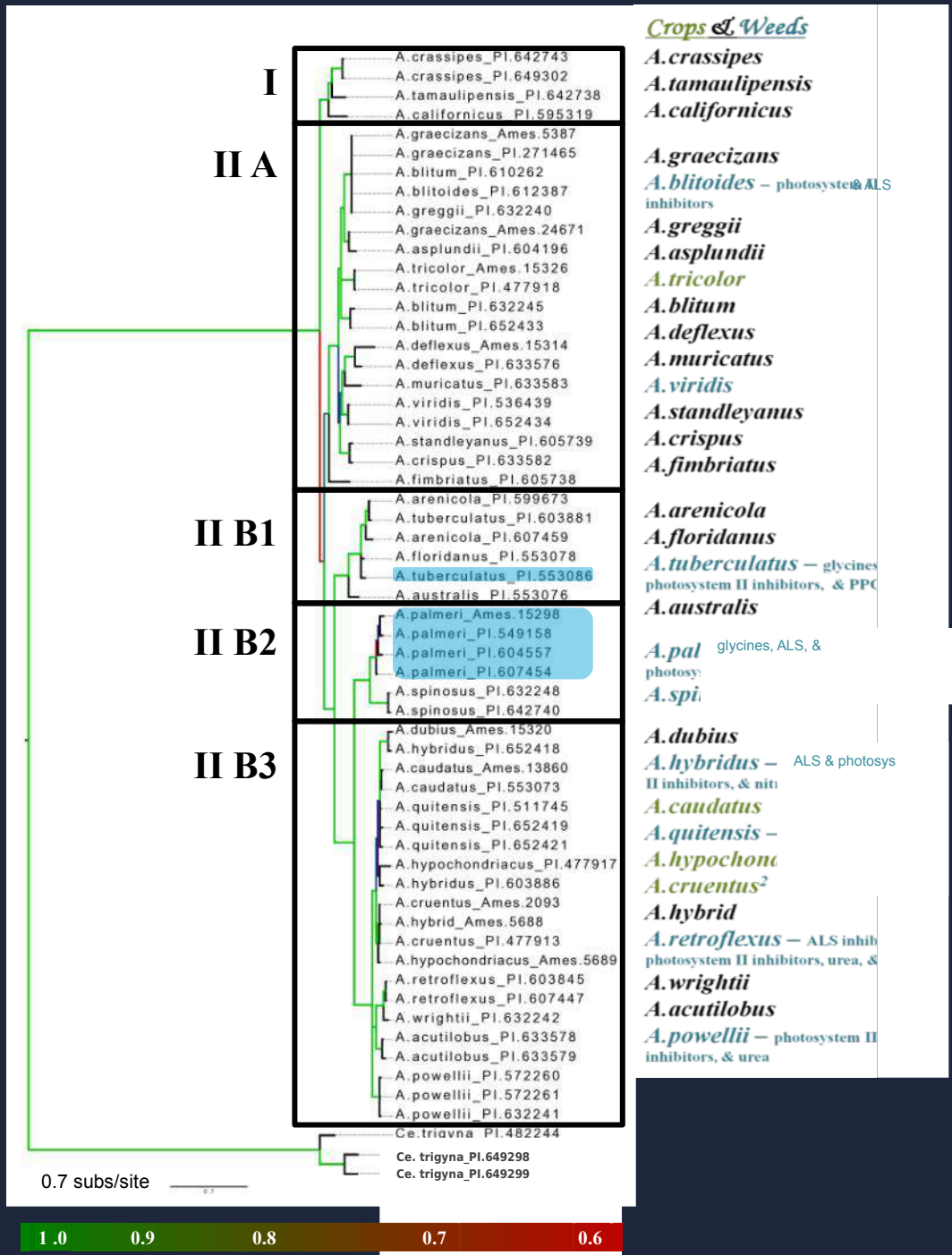
Scale bar = 0.7 substitutions/site

SNPs Phased or assigned ambiguity codes

InDel Variation resolved via sequenced clones

GTR with gamma distribution

…in progress



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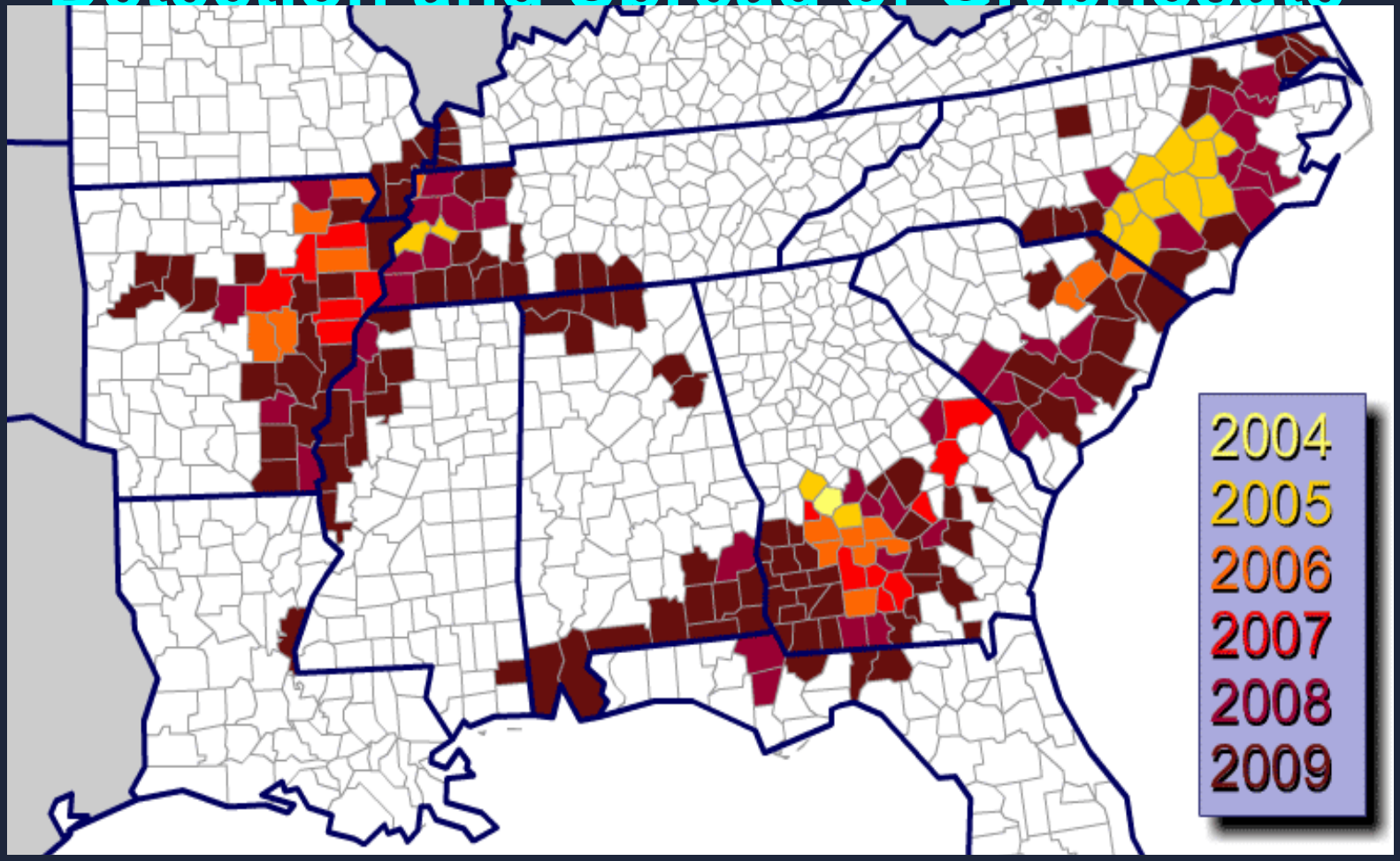
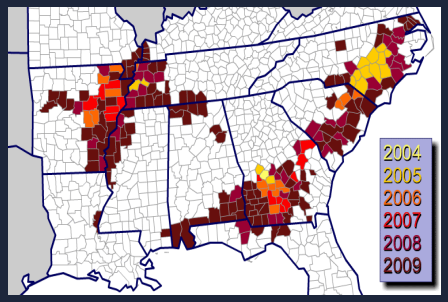
(Glyphosate) Herbicide SENSITIVE *Cottam*

http://vernon.tamu.edu/HOMEPAGE/TBAUGHMA/images/CottonField-01.jpg

Detection and Spread of Glyphosate




2004
2005
2006
2007
2008
2009

Strategies for weed control

preventative measures
(seed laws, equipment sanitation)

deplete the seedbank

reduce emergence by water management

targeted removal of individuals from the crop

crop rotation or fallowing

herbicide resistant crop systems
(eg. RoundUp-Ready, glyphosate)

Other glyphosate-insensitive species

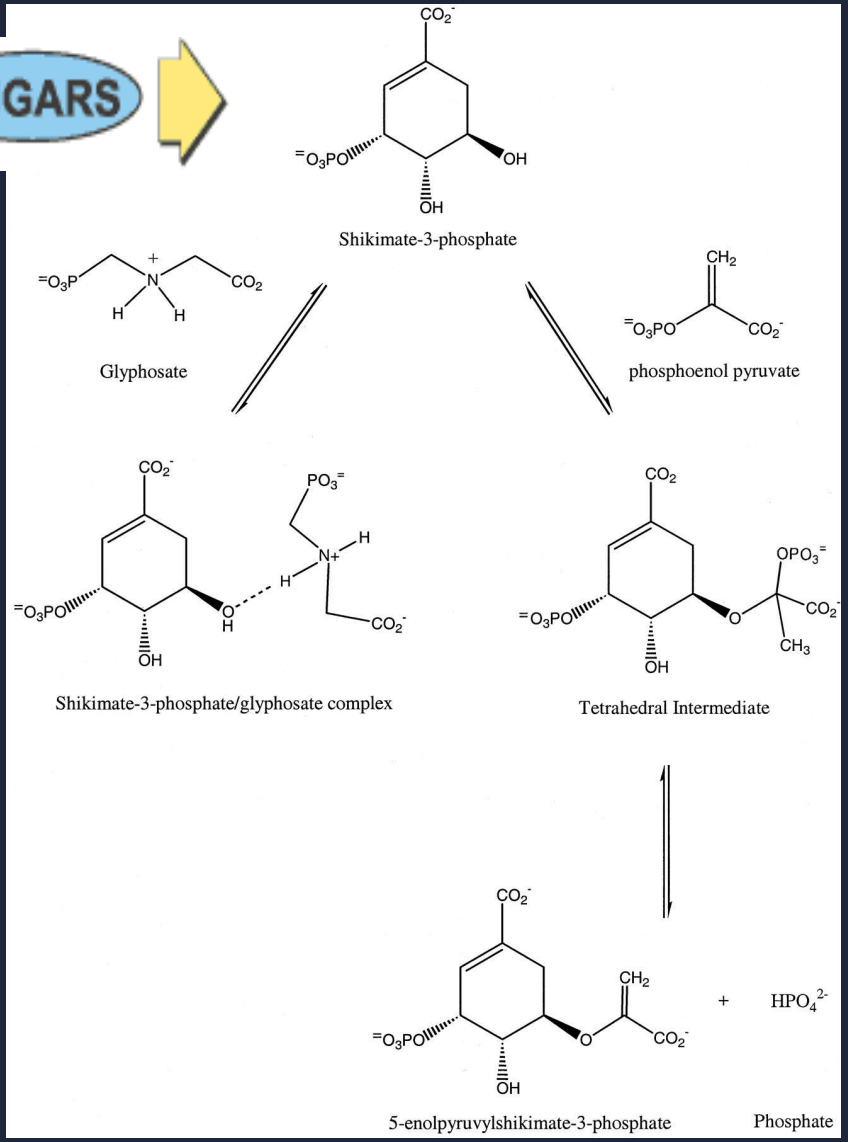
October 2010

Resistant = Insensitive

Ambrosia artemisiifolia **(USA)**
Ambrosia trifida **(USA)**
Conyza bonariensis **(South Africa, Spain, Brazil, Colombia, USA)**
Conyza canadensis **(Brazil, USA, China, Spain, Czech Repl.)**
Conyza sumatrensis **(Spain)**
Digitaria insularis **(Paraguay, Brazil)**
Echinochloa colona **(Australia)**
Eleusine indica **(Malaysia, Colombia, Philippines)**
Euphorbia heterophylla **(Brazil)**
Kochia scoparia **(USA)**
Lolium multiflorum **(Chile, Brazil, Spain, Argentina, USA)**
Lolium perenne **(Argentina)**
Lolium rigidum **(Australia, South Africa, France, Spain, Italy, USA)**
Parthenium hysterophorus **(Colombia)**
Plantago lanceolata **(South Africa)**
Sorghum halepense **(Argentina, USA)**
Urochloa panicoides **(Australia)**

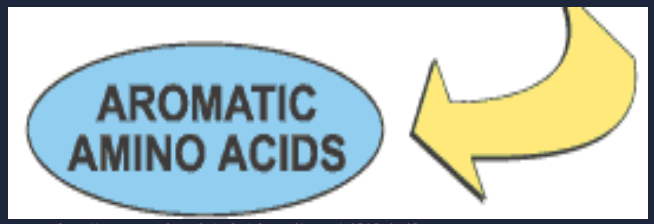
EPSPS:
5-enol pyruvylshikimate-3-phosphate **synthase**

Applied glyphosate competes with EPSPS



Alibhai M F , Stallings W C PNAS 2001;98:2944-2946

Phenylalanine
Tyrosine
Tryptophan



http://www.ag.ndsu.edu/pubs/plantsci/crops/a1219-4.gif

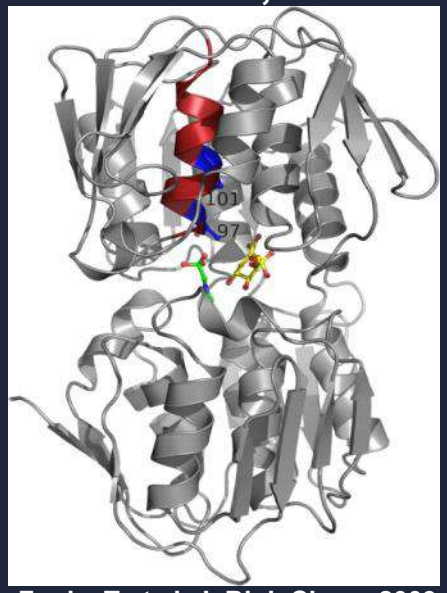
Glyphosate resistance, possible mechanisms

1). **EPSPS GM sites for 'RoundUp-Ready' (Thr97, Pro101)**
5-enol pyruvylshikimate-3-phosphate synthase

2.) **Proliferation of EPSPS gene copy number**
Gaines T A et al. PNAS 2010;107:1029-1034

3.) **Independent mechanism(s), other genes…?**

Thr97 and Pro101
WT EPSPS, E. coli



Funke T et al. J. Biol. Chem. 2009

Other herbicides commonly applied

Foliar herbicides
PS II inhibitors
Shoot growth inhibitors
Soil-applied herbicides
Root growth inhibitors

Resistant and Sensitive Pilot Populations: Genetic Variation, EPSPS

7 plants sampled from each population (*Amaranthus palmeri*)

Accession#	Location
PI549158	*Mali, Africa*
PI604557	Puebla, Mexico
PI633593	Colima, Mexico
(PI633587	*Senegal, Africa)*
Ames15298	Arizona, United States
PI607451	Kansas, United States
PI607452	Kansas, United States
PI607454	Kansas, United States
PI607455	Kansas, United States
PI607456	Kansas, United States
PI607457	Kansas, United States
PI607461	Kansas, United States
PI612856	Arizona, United States
PI632235	Arizona, United States
PI632236	Arizona, United States

Resistant (GR)
Susceptible (CL)

Resistant and Sensitive Pilot Populations: Genetic Variation, EPSPS

7 plants sampled from each population (*Amaranthus palmeri*)

ence diversity:
in susceptible popn

ing sites:
in susceptible popn

tive mutation rates:
0.20)

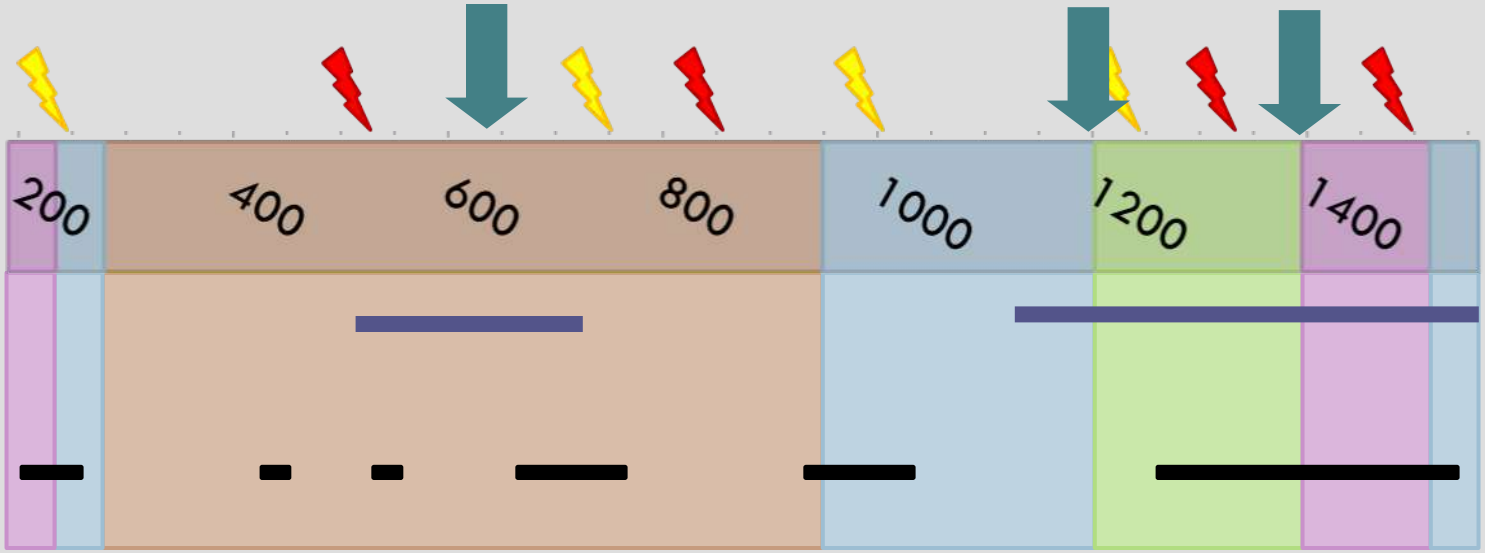
Resistant (GR)
Susceptible (CL)

EPSPS: Purifying Selection ‘Baseline’ with Recent Selective Sweep in GR?

GR πa/πs = 0

GR πa/πs = π

High Ka/Ks



nt sweep?

l
selection?:

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# of Amaranthus research in the lab

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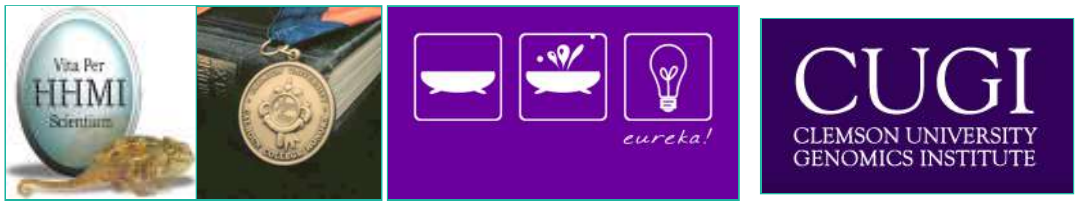

# of Amaranthus research in the lab

nternational
nship 2012..... Host?
lormancy