Are seed collection zones needed for sourcing plant materials for longleaf pine ecosystem restoration?

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National Conference on Ecosystem Restoration

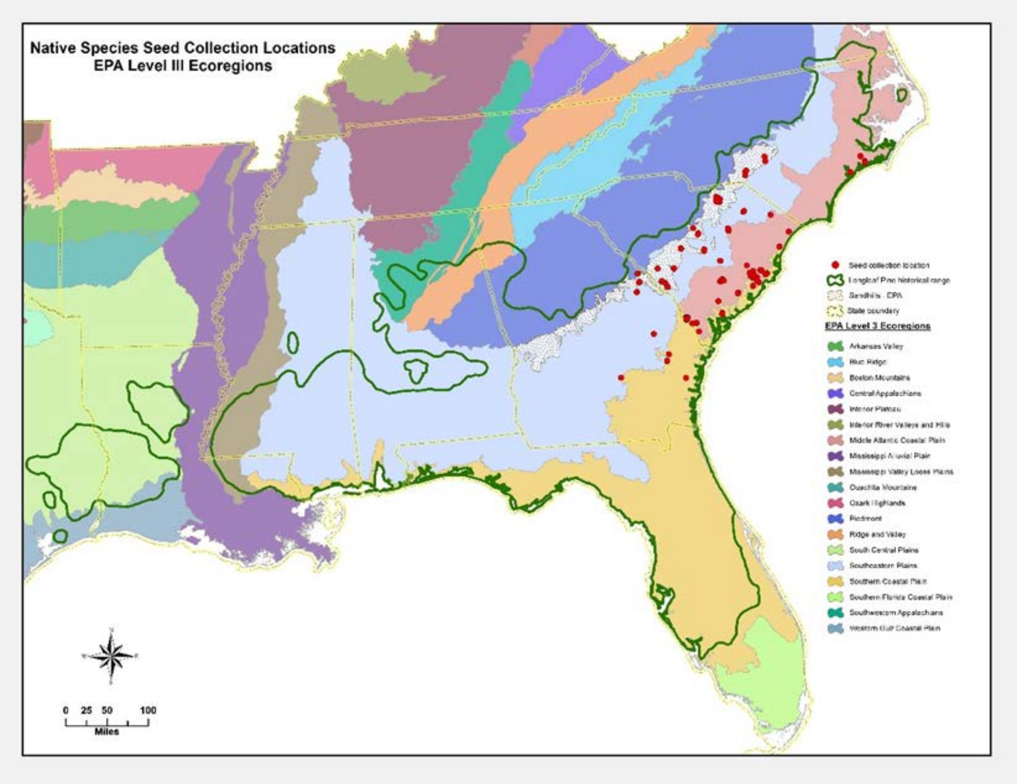
August 27, 2017

Presentation Objectives

- The LLP ecosystem and Need for seed, seed zones, strategies for addressing need
- Common garden studies in the LLP range – coordinated efforts
  - Gulf Coast study (Giencke et al 2018)
- Summarize results from Atlantic Coastal Plain study
- The need for seed collection zones?
- Genetic variation

Longleaf Pine Ecosystem Essentials

- Broad geographic extent
- Local variation is subtle, but controls diversity patterns (locally: soil texture, moisture availability, nutrient status)



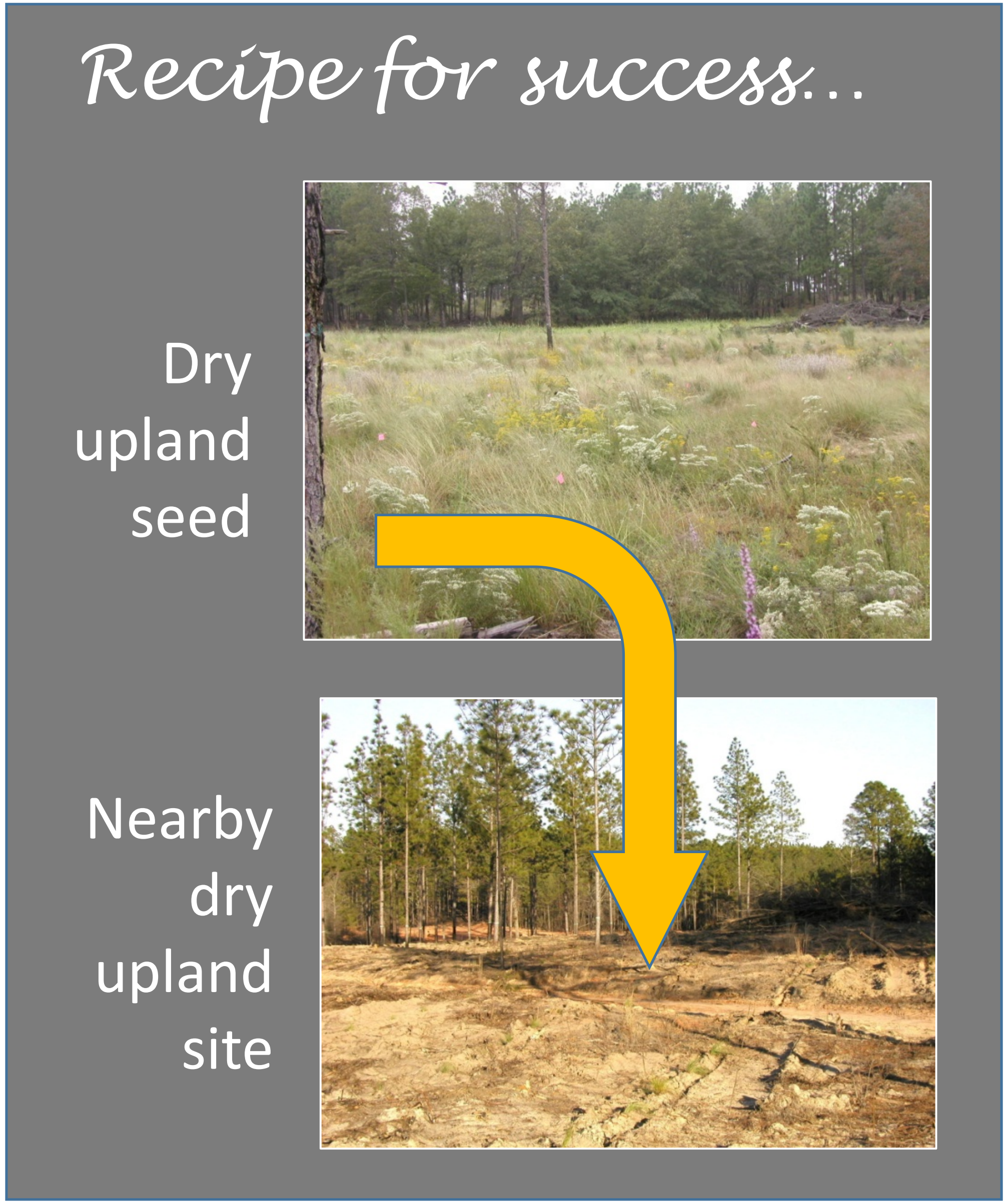
Open pine canopy
Diverse ground layer
Maintained by frequent, surface fire

Need for ecologically suitable seed for restoring longleaf pine communities

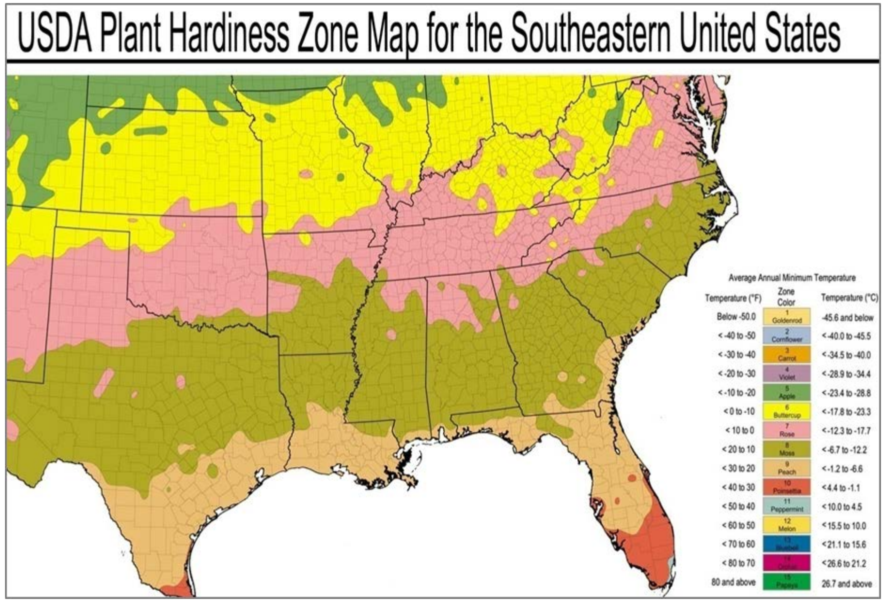
- Plant materials that will thrive in a restoration project
- Plant materials that do not threaten indigenous populations, conserve genetic resources
- Functional traits of interest are those that affect capacity to establish from seed in restoration projects

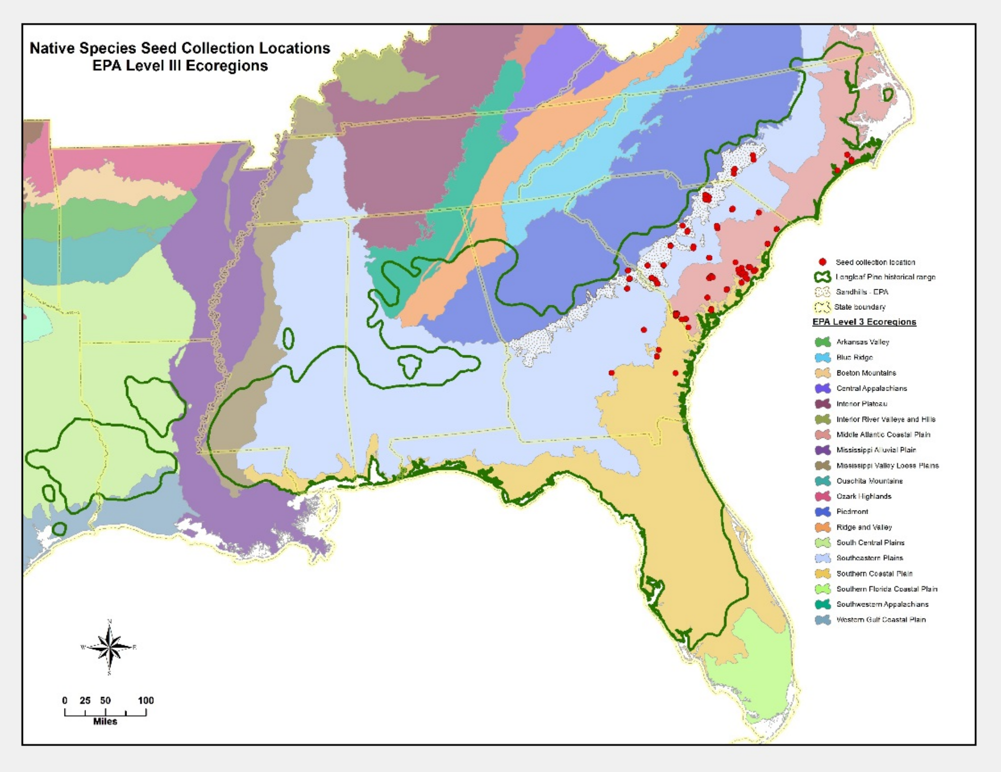
The safe solution

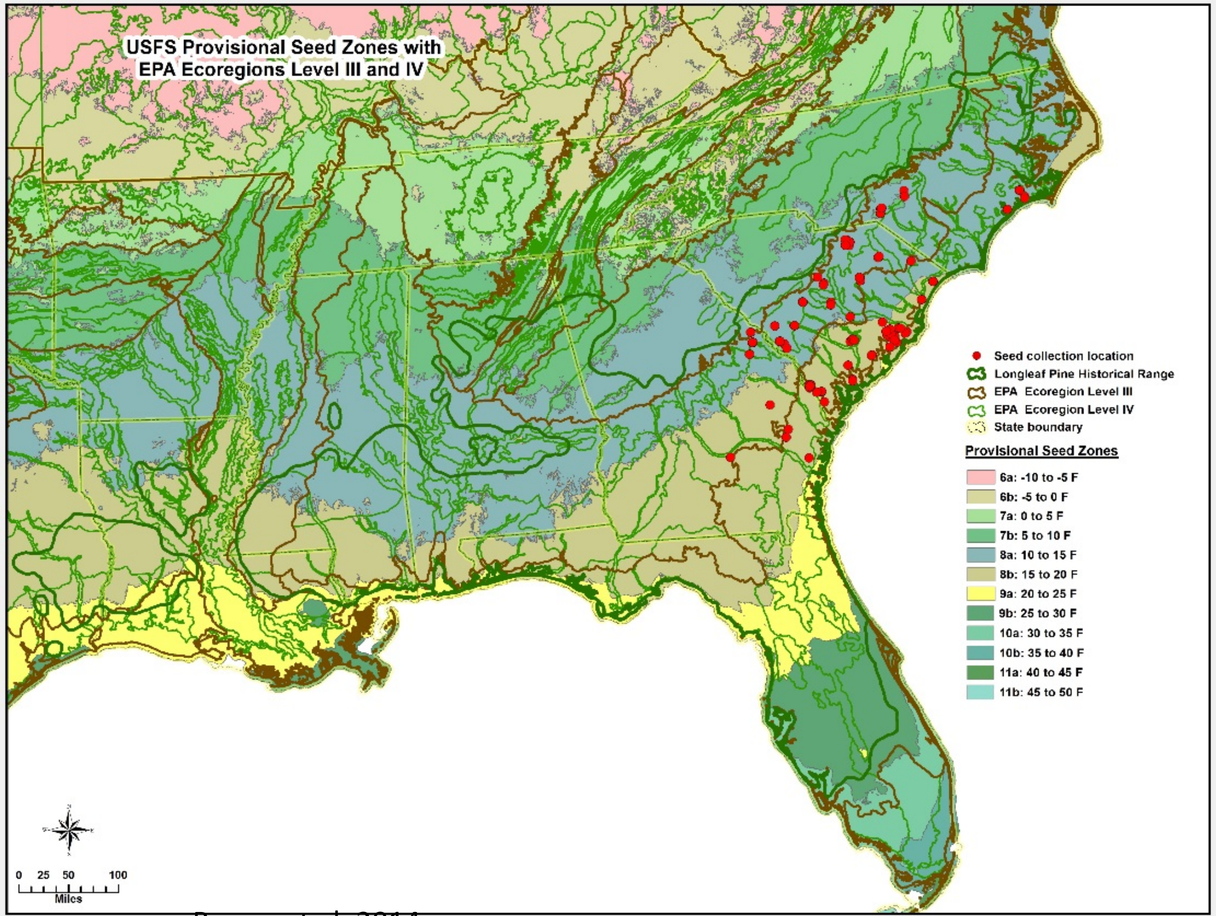
- Select seed sources from the closest possible location and collect from a site that physically matches the target site. (‘Local is Best’)
- May minimize risks of getting individuals maladapted to the restoration site, but provides no guidance for seed sources for wider distribution.



General Seed Zones







Bower et al. 2014

Applicability in SEUS to be determined with garden studies

Biogeographic considerations

- High levels of endemism throughout the ecosystem: opportunities, occurrences of speciation
  - Do patterns of endemism provide useful information related to intraspecific variation (fitness related) of widespread species, or genetic diversification related to geographic isolation?
- Species turnover across the range (legumes, mints, grasses)

Estill & Cruzan 2001

Patterns in Endemism may be telling us something important…

An ecoregion model for biodiversity conservation planning… The Nature Conservancy

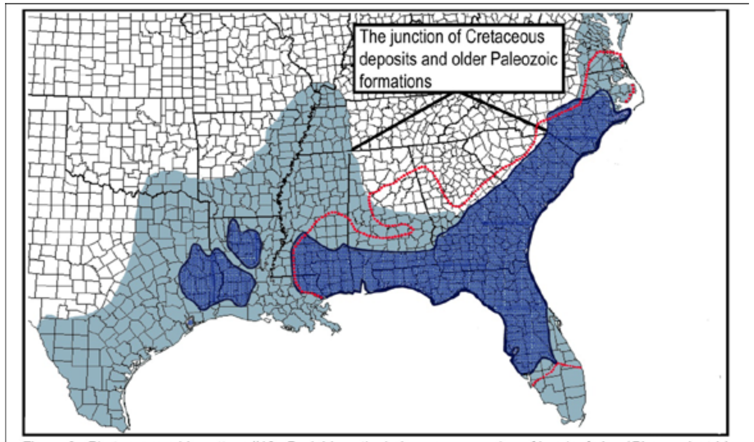


Figure 8. Phytogeographic pattern #18. Dark blue stippled area: core region of longleaf pine (*Pinus palustris*). Red dotted line: area of discontinuous or disjunct occurrences of longleaf pine. After Ware, Frost, and Doerr (1993). Light blue: Atlantic Coastal Plain, Gulf Coastal Plain, including the entire Mississippi Embayment. Adapted from Sorrie & Weakley (2001).

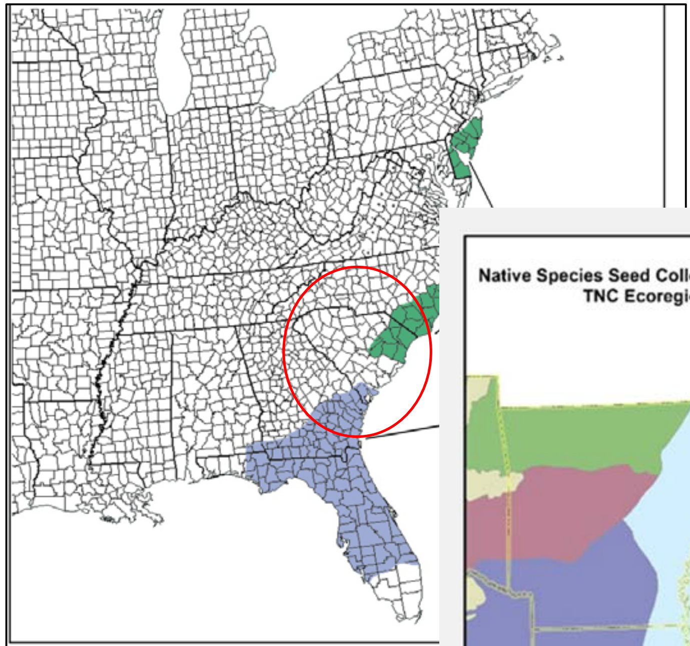


Figure 3. Phytogeographic pattern # 2 and # 6. #2 (green): b Delaware/eastern North and South Carolina. #6 (blue): south Florida westard to the central panhandle of Florida and south Sorrie & Weakley (2001).

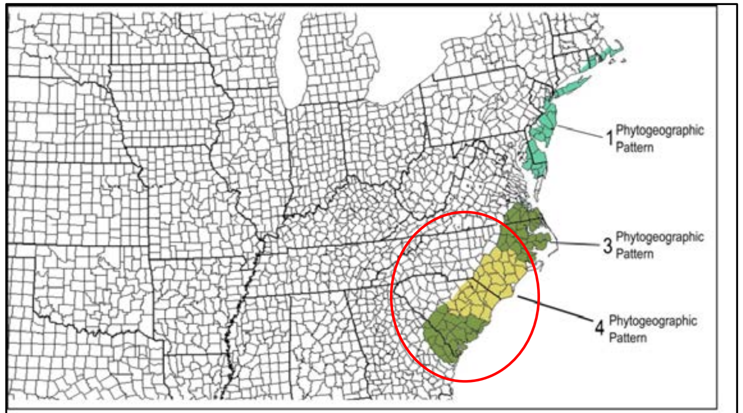
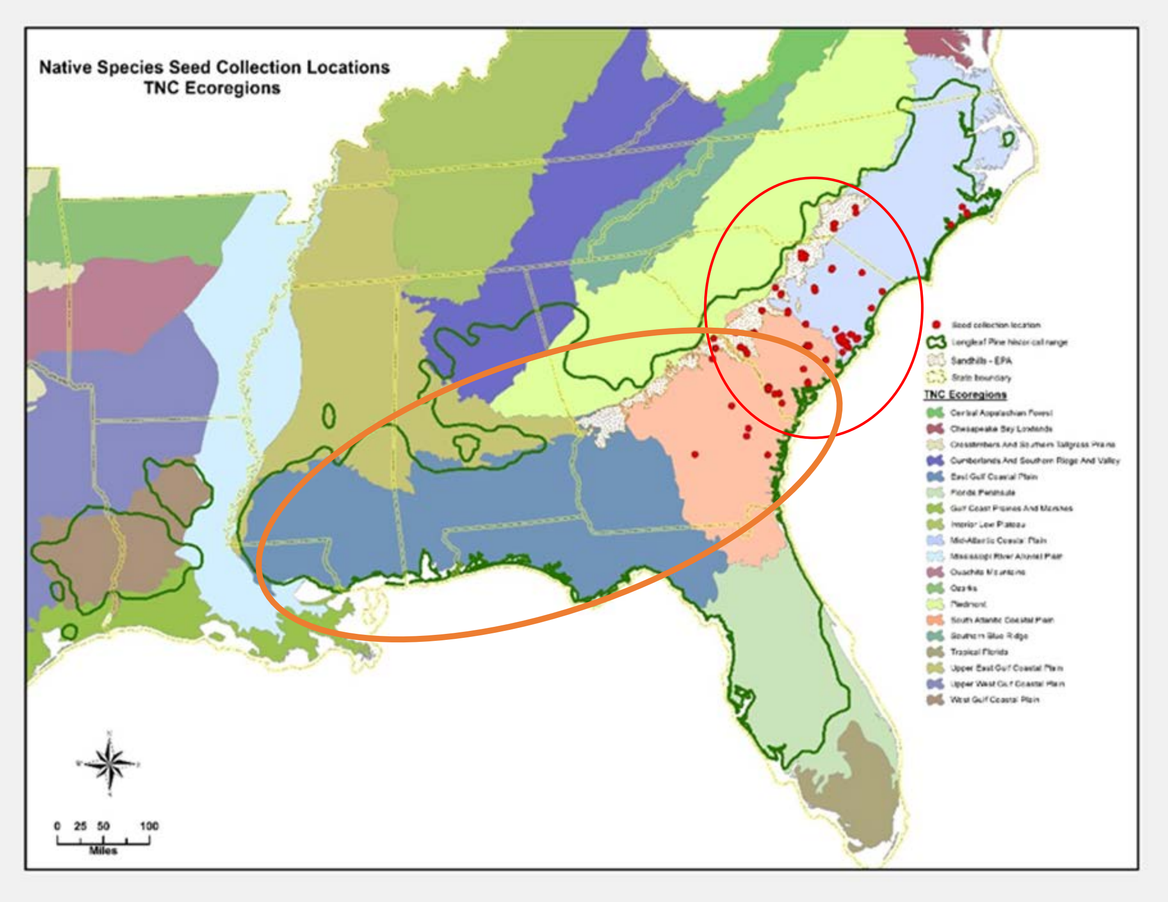


Figure 2. Phytogeographic patterns #1, #3, and #4. #1 (light blue): southeatern Massachuestts to southern New Jersey and adjacent Delmarva Peninsula. #3 (green): southeastern Virginia to southeastern Georgia. #4 (tan): southeastern North Carolina to northeastern South Carolina. Adapted from Sorrie & Weakley (2001).



More information, more of the LLP range

RESEARCH ARTICLE

Seed sourcing for longleaf pine ground cover restoration: using plant performance to assess seed transfer zones and home-site advantage

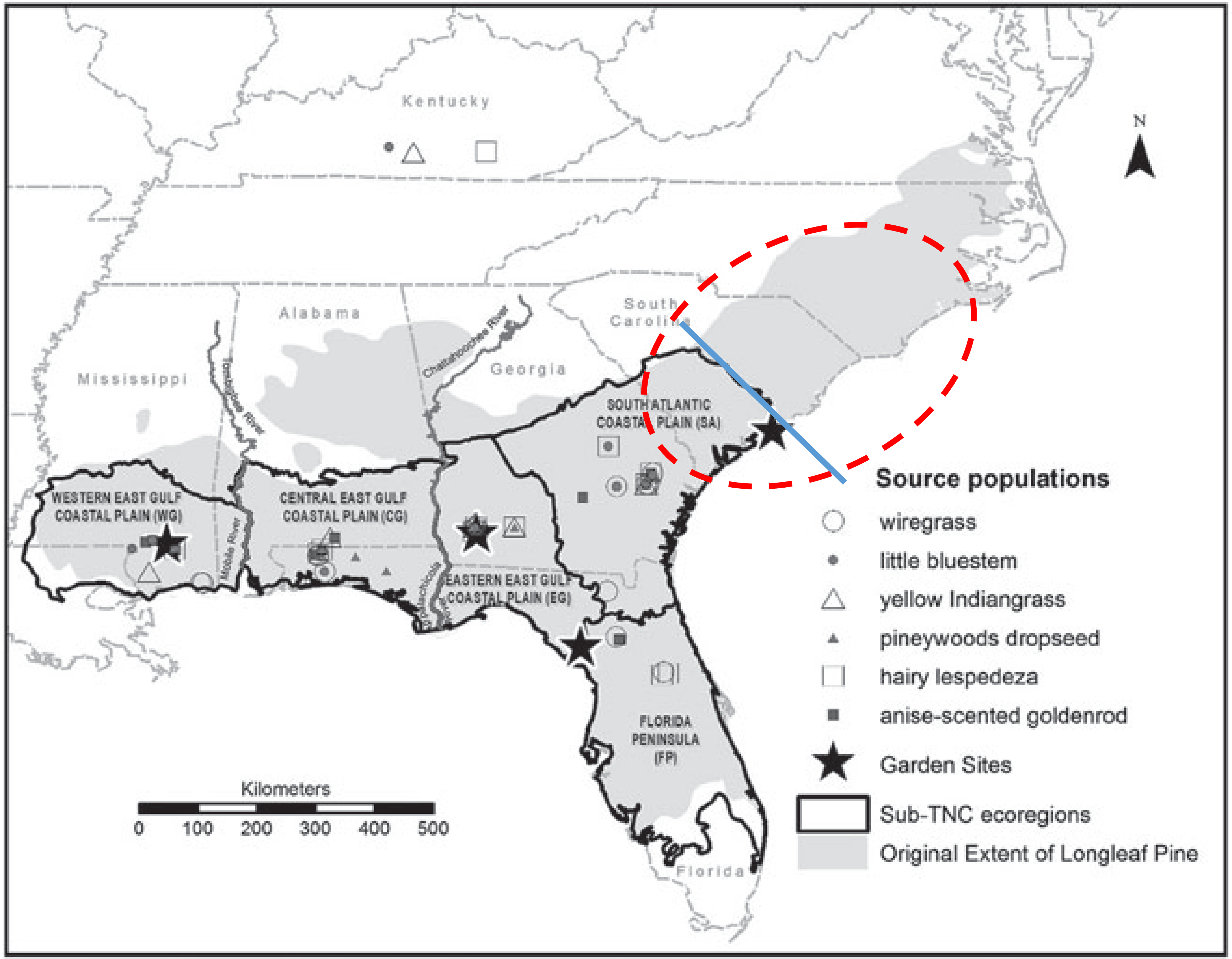
Lisa M. Giencke[1,2], R. Carol Denhof[3], L. Katherine Kirkman[1], O. Stribling Stuber[1], Steven T. Brantley[1]

Seed sourcing is a concern for restoration practitioners in all regions and habitats. The possibility that plants are most suited to their home environments due to genetic adaptations to local biotic and abiotic conditions prompts questions of how far plant material can be moved from home sites and remain ecologically appropriate in a restoration setting. We tested a suite of provisional seed transfer zones at multiple geographic scales to assess their ability to capture potentially adaptive genetic variability among populations in the southeastern United States. Furthermore, we examined the effects of seed source and phenotypic plasticity on plant performance and whether locally sourced individuals have adaptive advantages relative to more distantly sourced individuals. With a reciprocal transplant and a common garden study, we show that, although seed source is the best predictor of differentiation in plant performance, performance differences among populations across larger seed transfer zones within the longleaf pine ecosystem are relatively minor. These findings suggest that consideration of larger seed zones within the longleaf pine ecosystem that are also more logistically and economically viable is warranted. However, earlier flowering of individuals from seed sourced outside the longleaf pine ecosystem suggests that moving plant material greater distances is more likely to result in phenological mismatches between plants and pollinators. Species-specific differences, however, indicate there is insufficient evidence to support a recommendation for a single set of seed transfer zones within the southeastern United States for all species.

Key words: common garden, ecotype, genetic variation, longleaf pine ecosystem, reciprocal transplant experiment, seed transfer zones

- Similar species
  - 4 grasses (wiregrass, pineywoods dropseed, little bluestem, yellow Indiangrass)
  - 1 legume (Hairy lespedeza hirta)
  - 1 composite (anise-scented goldenrod)
- Similar traits measured
- Overlapping time frame
- East-West gradient, 4 ecoregions

Giencke, et al 2018. Rest. Ecol.



Some results

- Most variation occurred between populations
- “Northern” populations flowered much earlier
- Recommended a seed zone map

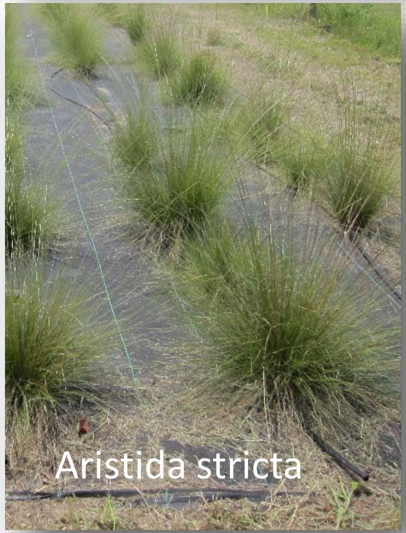
Methods- Species selection criteria

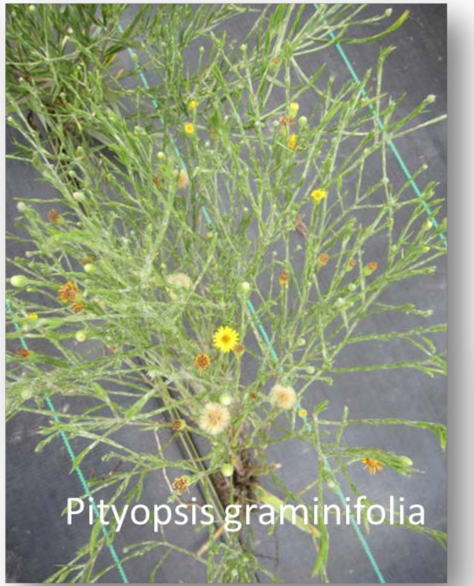
ECOLOGICAL VALUES	MARKET VALUES	PRODUCTION VALUES/COSTS
dominant groups/common	wildlife value	habitat breadth
continuous fine fuels	fuels/management cost	range
wildlife value	floral display	ease of growing in gardens/fields
generalized pollinator		ease of collection
representative of intact habitat (conservative)		availability
		ease of germination

Grasses, composites, legumes


Schizachyrium scoparium


Sorghastrum elliotii


Aristida stricta


Pityopsis graminifolia

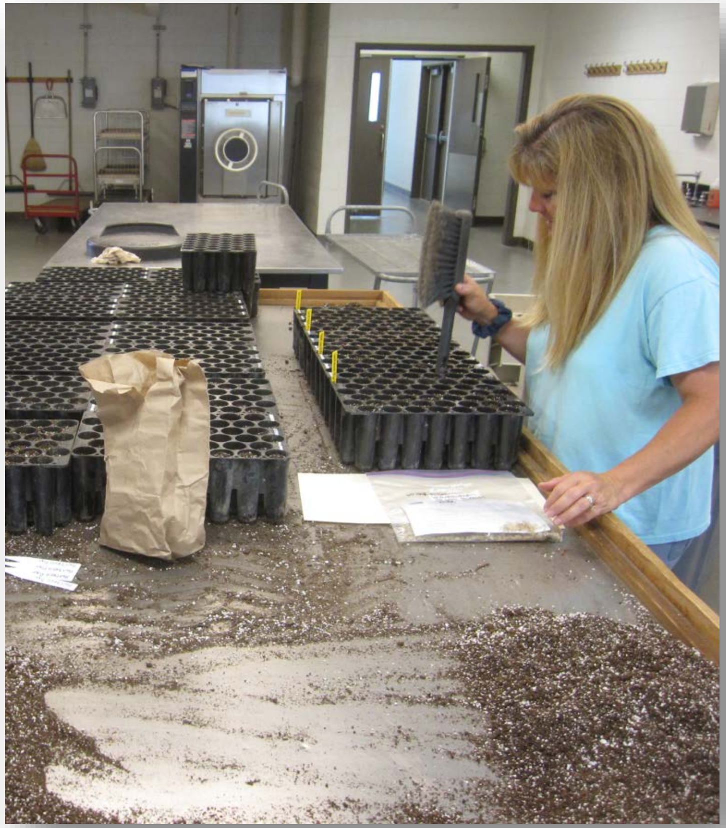

Solidago odora


Lespedeza capitata


Tephrosia virginiana

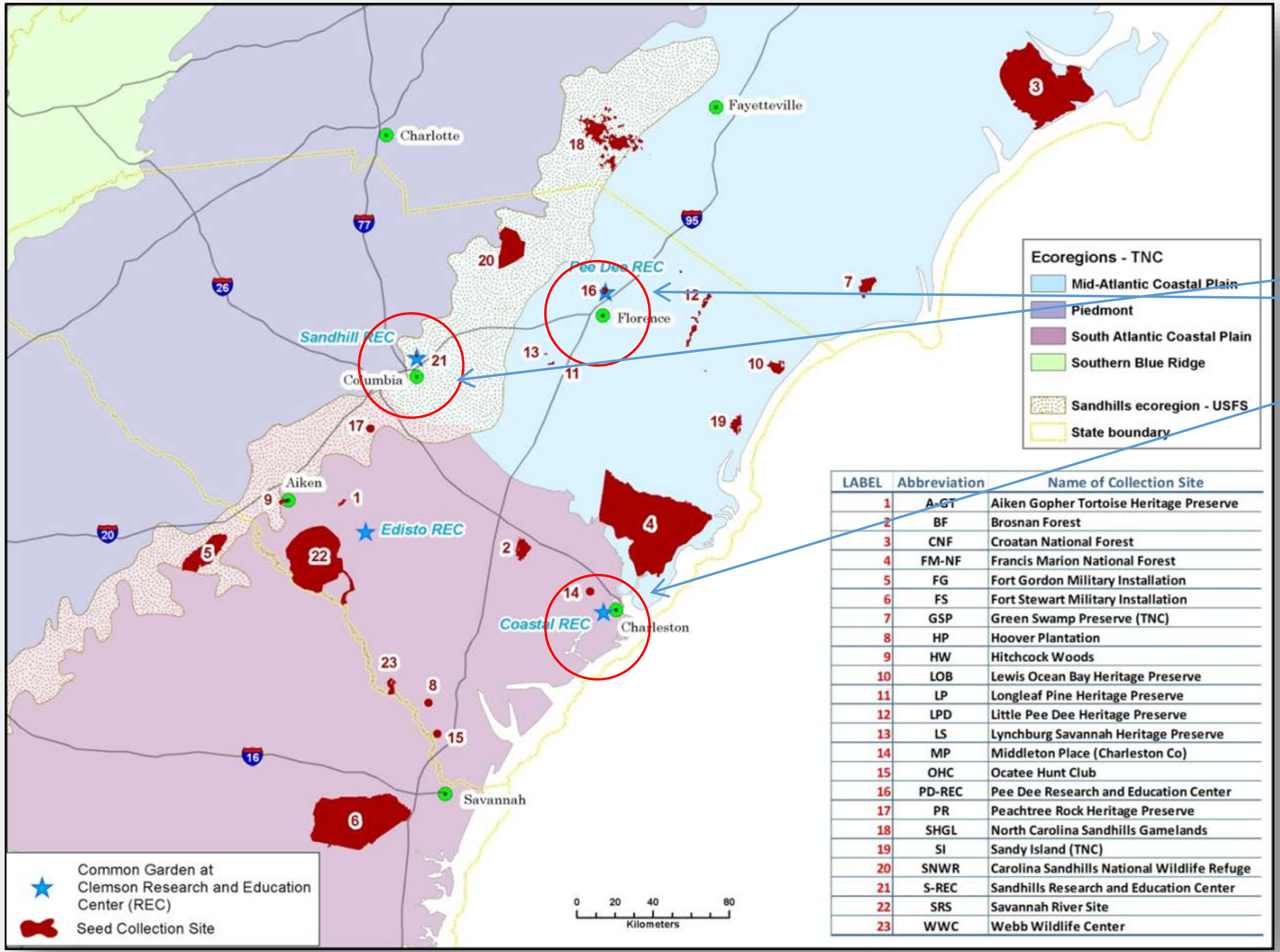
Germination, Greenhouse culture

- Sowed seed in Fafard 3B media in blocks of cells 2.5 cm diameter x 15 cm deep
- Germinated under mist & transferred to hand-watering regime
- Grown in a glass house x 8 weeks, under natural light supplemented on cloudy days
- Fertilized 1/10 strength commercial liquid NPK or slow release



How to synchronize legume seeds germination?
Experiment: hot water, scarify sand paper, nick with razor blade, control

3 Gardens



Locations

- Middle Atlantic Coastal Plain (MACP)
- Middle Atlantic Coastal Plain-Sand Hills (MACPSH)
- South Atlantic Coastal Plain (SACP)
- Clemson University Research and Education Centers (REC)

Garden Installation

- Sites were experimental fields
- Fallow at least 1 year prior to garden establishment
- Not tilled
- Landscape fabric laid down for weed control, moisture retention

Response variables

- Traits that may be related to performance in the target planting area

- Height, number of leaves
- Biomass
- Flowering phenology
- Reproduction (biomass; seed mass)
- Specific Leaf Area, Carbon Isotopes
- C, N content in leaves

Preliminary data analysis

- Considered the effects of garden location, ecoregion
  - Analysis of Variance Models

- Data Analysis Design:
  - 3 (2) Garden locations
  - 3 different Ecoregion Models (represent collection zone)
    - ECO2: SACP, MACP
    - ECO3: SACP, MSC, SH
    - ECO4: SACP, SACPSH, MACP, MACPSH

- Separate analysis of variance for each trait, species, ecoregion model

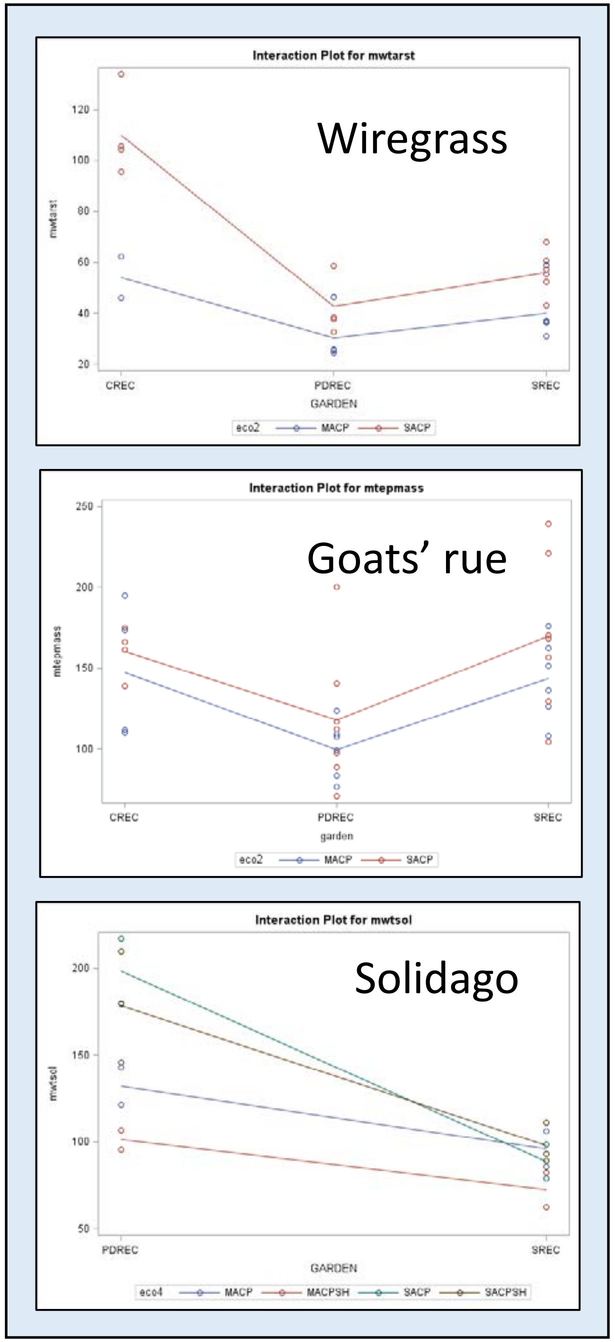
Response = GARDEN ECOREGION GARDEN*INTERACTION

Recently planted

Established Goats' Rue

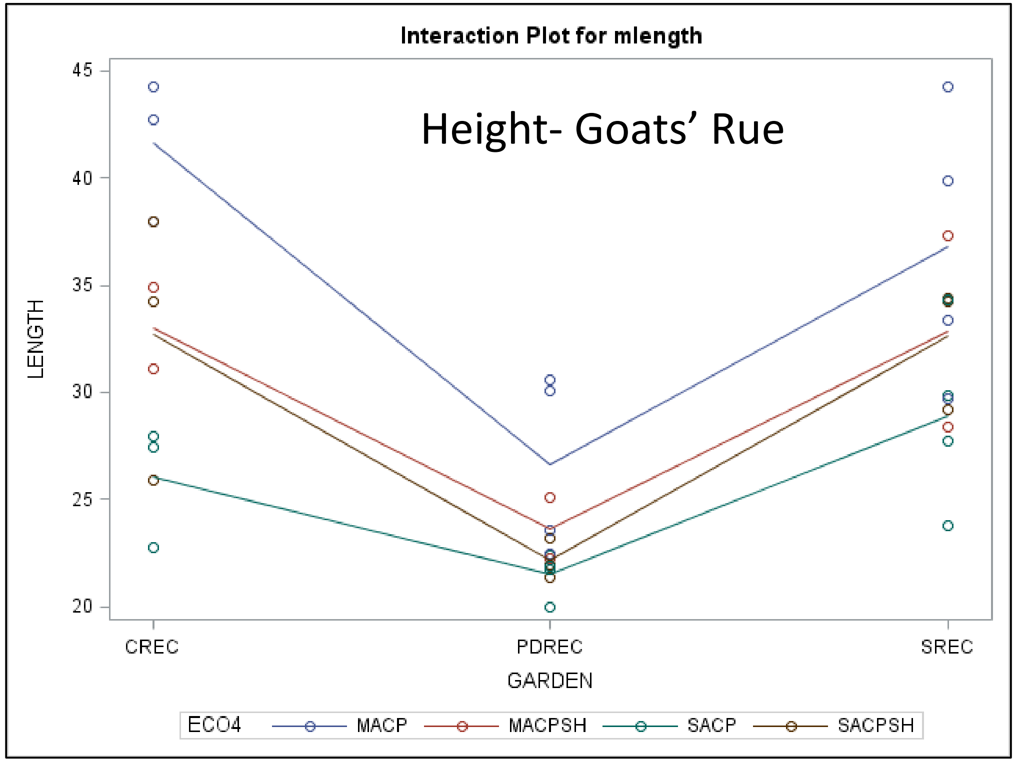
Biomass: model main effects

Species	Model	Garden	Ecoregion	Interaction
Wiregrass	**ECO2 <.0001**	<.0001	<.0001	.004
	ECO3 .0001	<.0001	.039	.168
	ECO4 <.0001	<.0001	.003	.089
Little bluestem	**ECO2 .044**	.009	.492	.469
	ECO3 .115	.012	.259	.875
	ECO4 .193	<.0001	.265	.907
Goats rue	**ECO2 .017**	.004	.136	.906
	ECO3 .138	.006	.744	.859
	ECO4 .192	.015	.350	.932
Round-headed Lespedeza	**ECO2 .001**	<.0001	.778	.798
	ECO3 .008	<.0001	.797	.975
	ECO4 --	--	--	--
Anise-scented Solidago	**ECO2 <.001**	<.0001	.001	.009
	ECO3 .011	.001	.350	.270
	ECO4 .000	<.0001	.007	.046



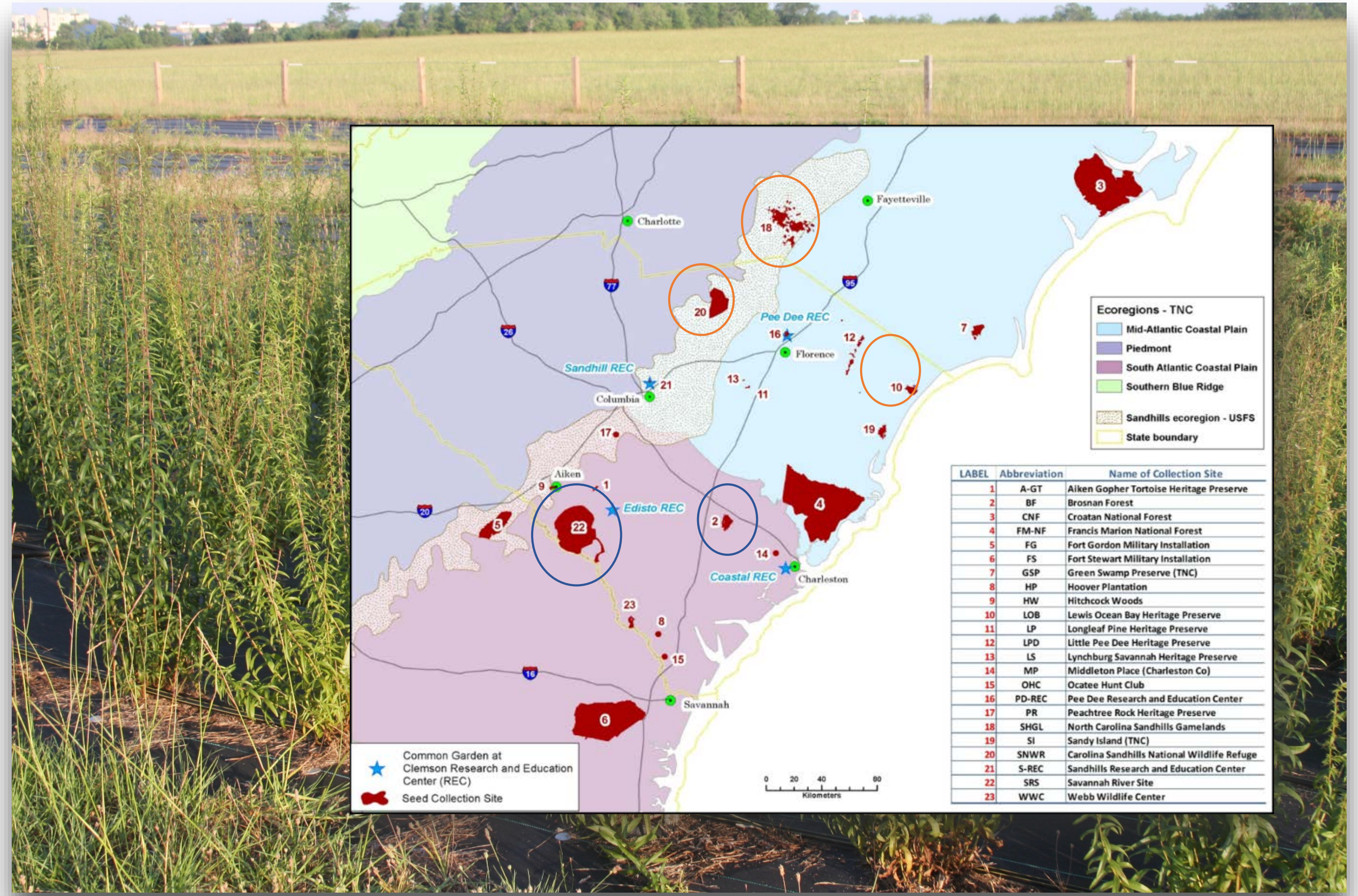
Height: model main effects

Species	Model	Garden	Ecoregion	Interaction
Goats rue	**ECO2 <.0001** **ECO3 <.0001** **ECO4 <.0001**	<.0001 <.0001 <.0001	.0006 <.0001 .0002	.399 .196 .457
Round-head Lespedeza	NS	--	--	--
Anise-scented Solidago	**ECO2 .0016** **ECO3 .019** ECO4 --	.0002 .0007	.196 .471	.963 .995



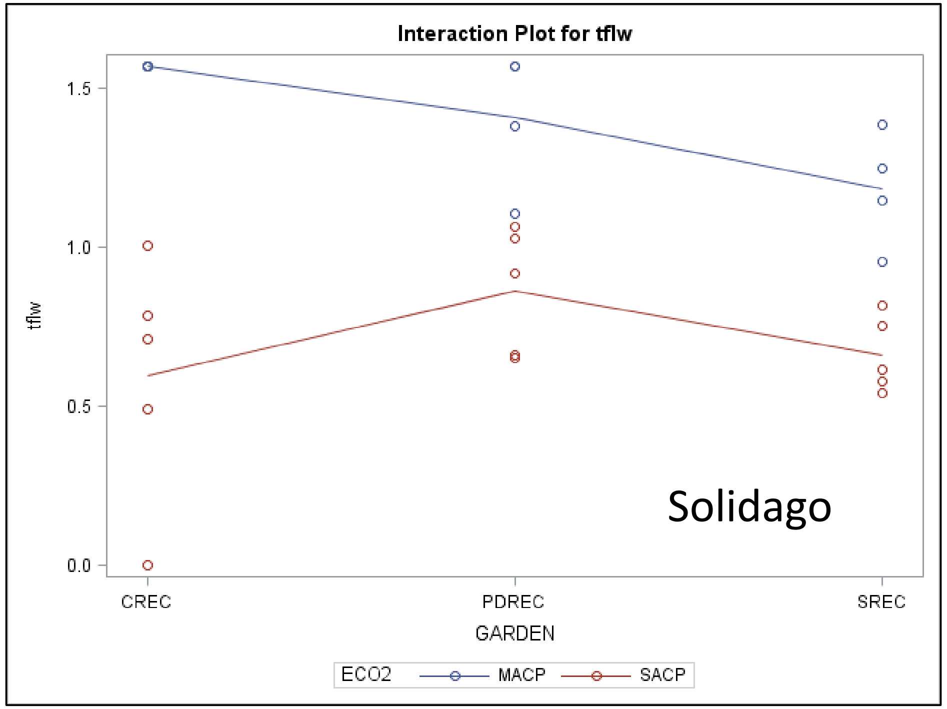
Results – Northern *Solidago* populations flower earlier

- 9 populations in the garden
  - 4 Middle Atlantic CP
  - 5 Southern Atlantic CP
- Flowering early
  - LOB, SHGL, SNWR
- Buds
  - PDREC, FG, WC, AGT
- Vegetative
  - SRS, BF

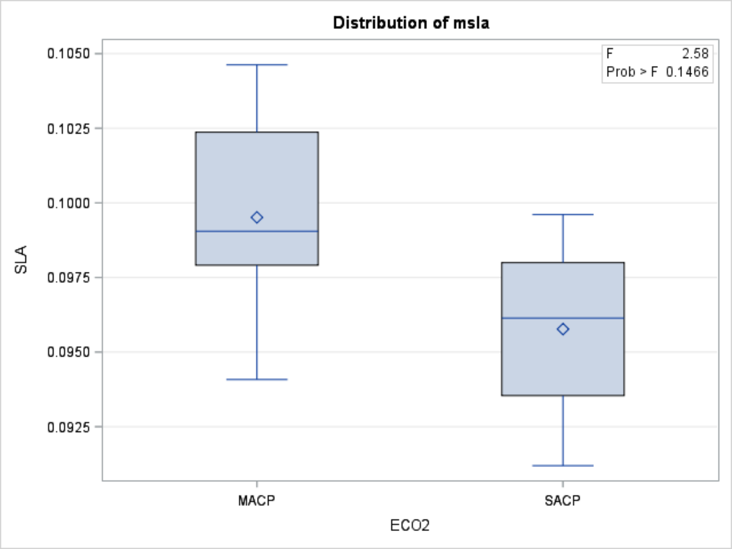


Percent flowering in September 2014 : main effects

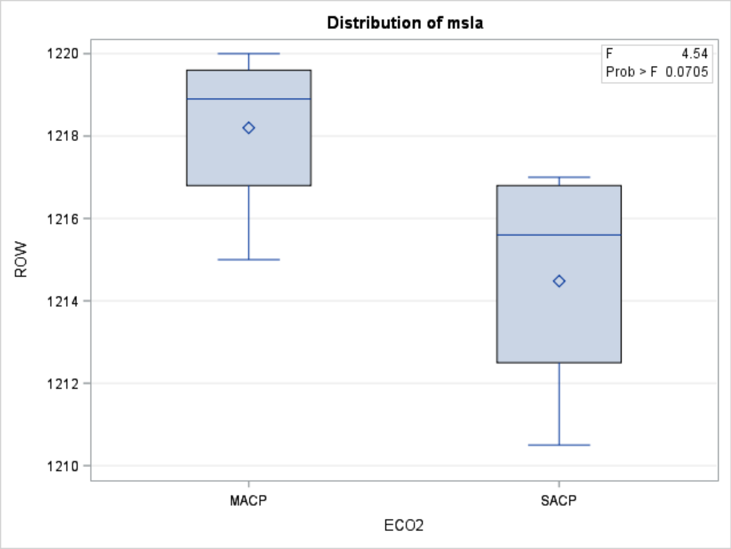
Species	Model	Garden	Ecoregion	Interaction
Round-headed Lespedeza	**ECO2 .0016** **ECO3 .019**	.0002 .0007	.196 .471	.963 .995
Anise-scented Solidago	**ECO2 <.0001** ECO3 .396 **ECO4 .0002**	.147 .456 .089	<.0001 .076 <.0001	.079 .772 .095



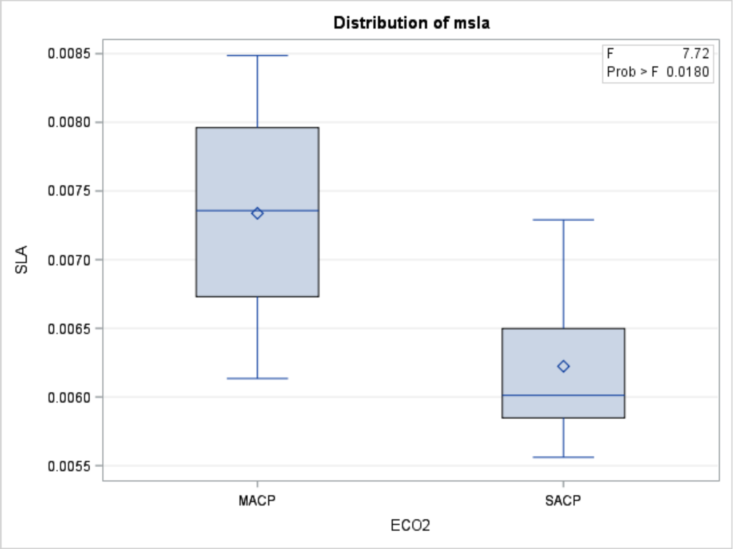
Specific Leaf Area, cm^2/mg



Lespedeza capitata



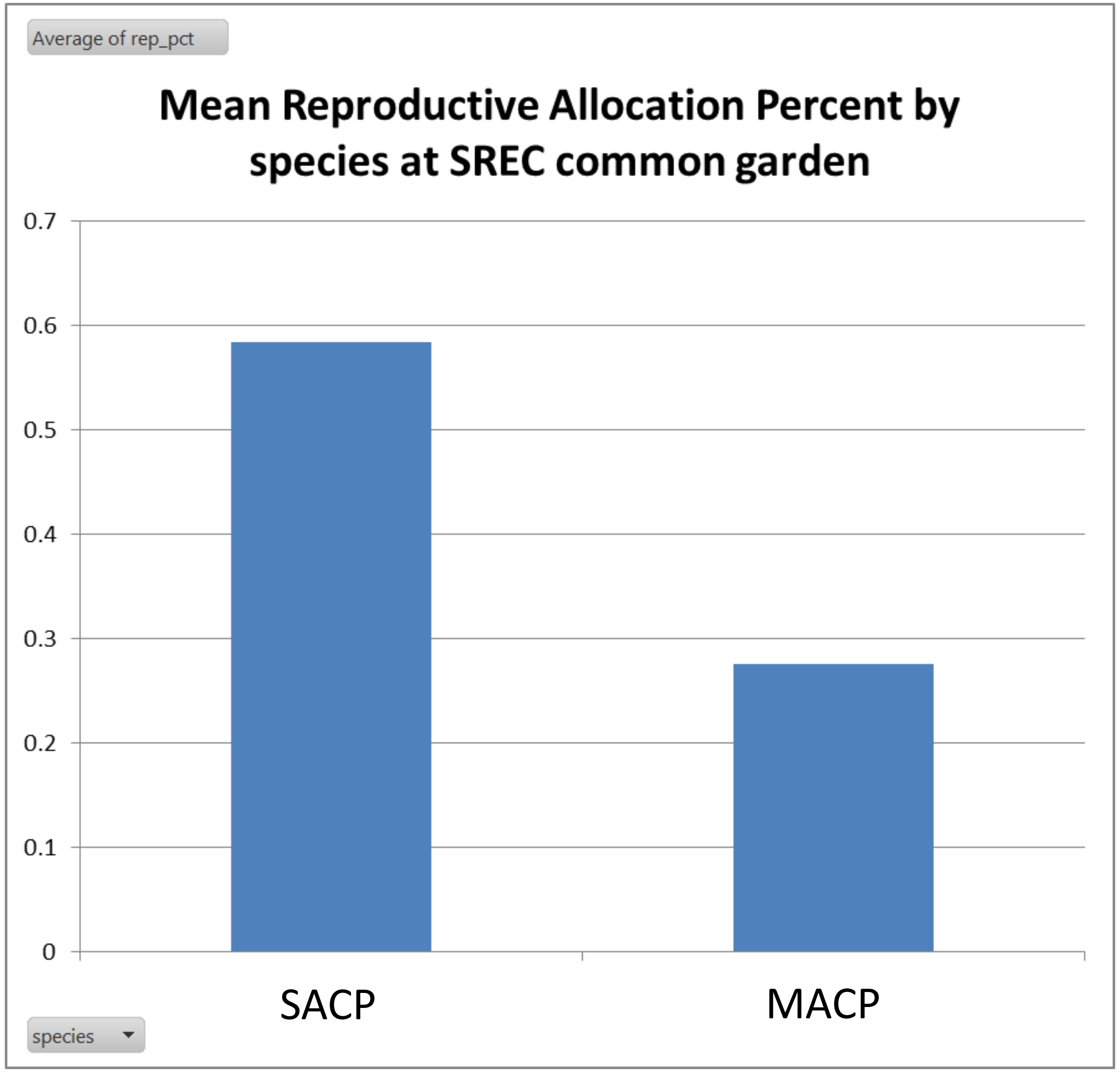
Solidago odora



Tephrosia virginiana

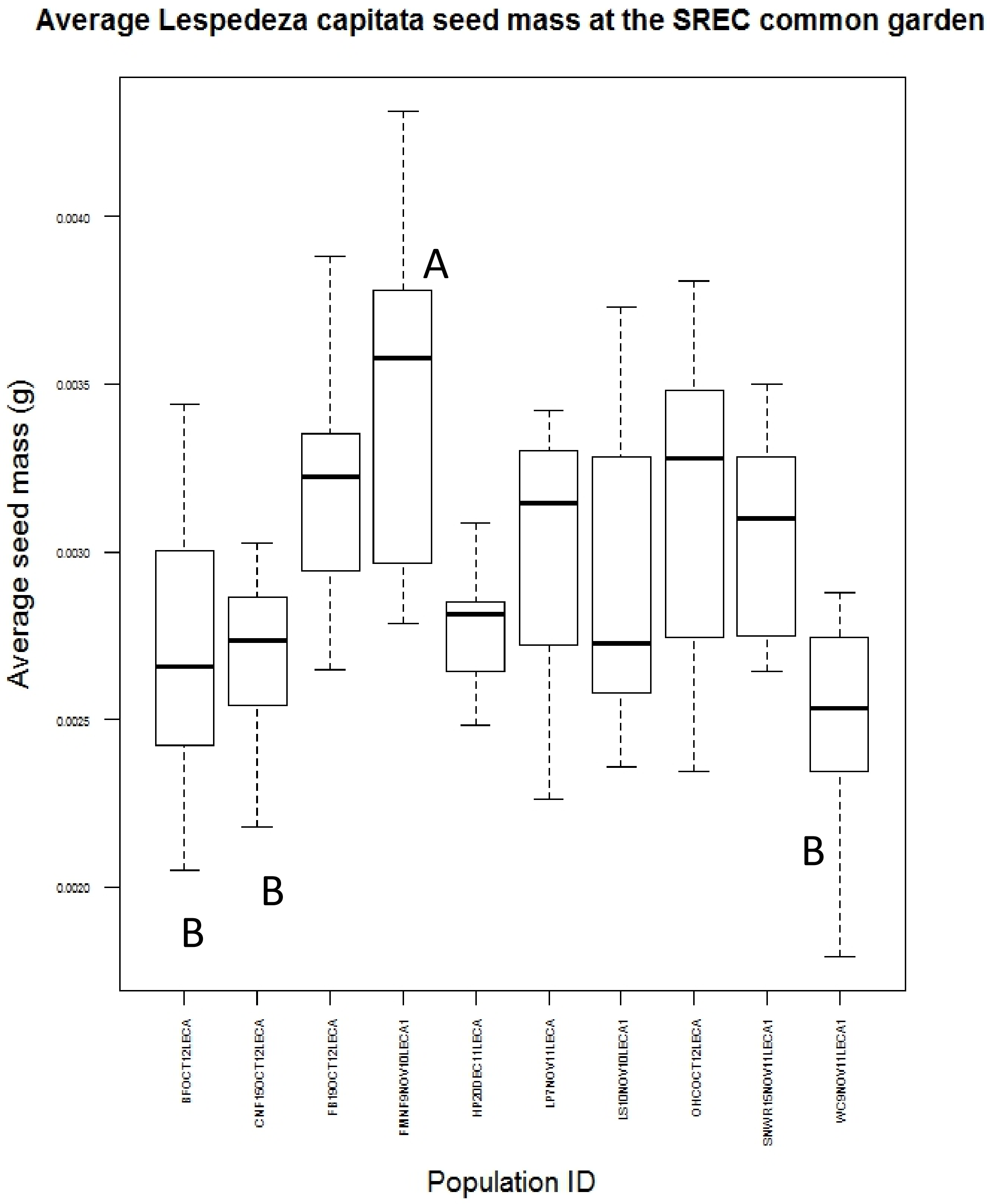
Results – *Aristida* spp reproductive effort

- Northern wiregrass (*A. stricta*) - MACP
- Southern wiregrass (*A. beyrichiana*) - SACP



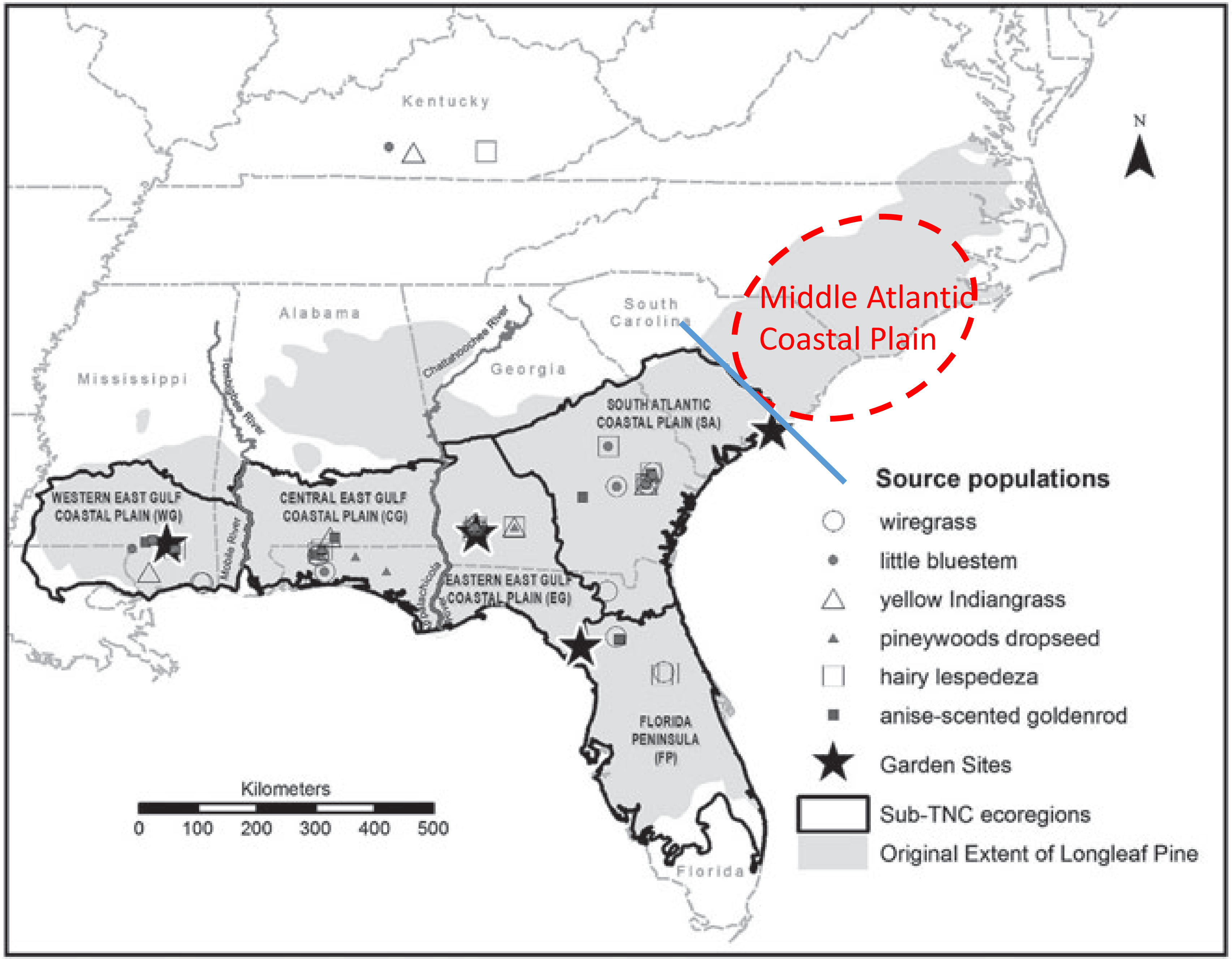
Results - Seed weight
Lespedeza

Populations vary, but not clearly related to geography



(Preliminary) Results Summary

- Always significant variation among populations of a species
- Evidence for geography related effect varied by species, trait
- Geographical models (ECO2,ECO3, ECO4) had significant effects for a subset
- Garden location had a significant effect on most traits
- Phenology differences may be strongest support for designating a separate Middle Atlantic Coastal Plain zone
- Interaction of Garden and Ecoregion effect were uncommon



Need for a seed zone collection model?

Need to know more…

- Performance in competitive situations
- More about germination and establishment
- Importance of within zone habitat variation
- Relationship to specific environmental factors that may change through time
- West Gulf Coast & Mountain Longleaf

Genetic diversity – relationship to geography

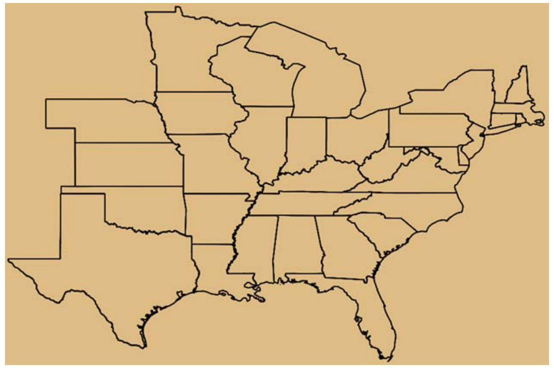
- Clemson University Graduate student, Jason Joines
- Expanded collections throughout the range of longleaf pine
- Preliminary study of genetic structure based on garden plants

- Understand gene structure, inform seed source selection without 3 years of work

Goat's rue (*Tephrosia virginiana*)

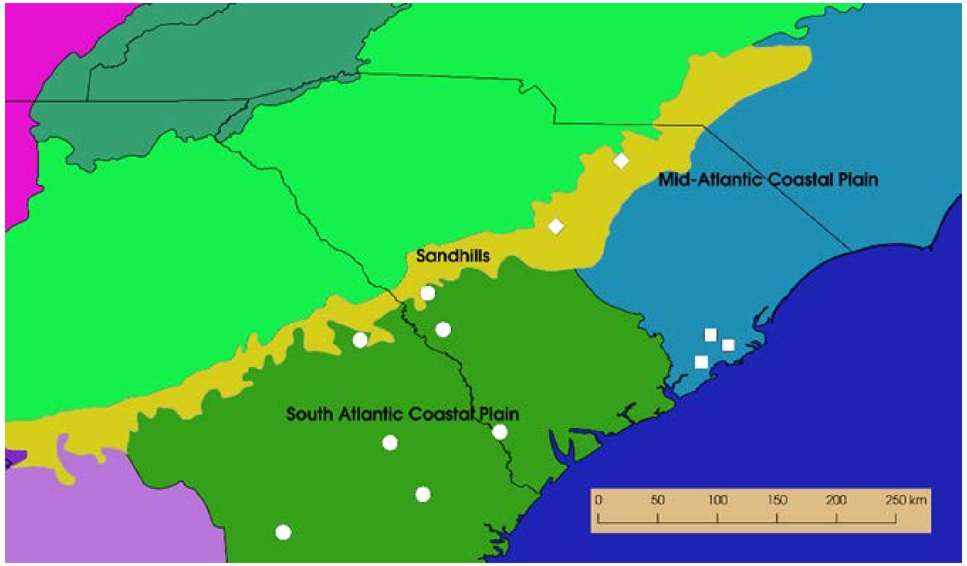
Genetic diversity related to geography

- 12 populations, 46 individuals
    - DNA extracted; GBS libraries created
- Libraries sequenced
- SNPs (single nucleotide polymorphisms) identified
- Mantel test of similarity between genetic & geographic distance
- AMOVA to examined the distribution of genetic variation among ecoregions, among collection sites within ecoregions, and among individuals within collection sites
- Principle Components Analysis to identify genetically similar groups

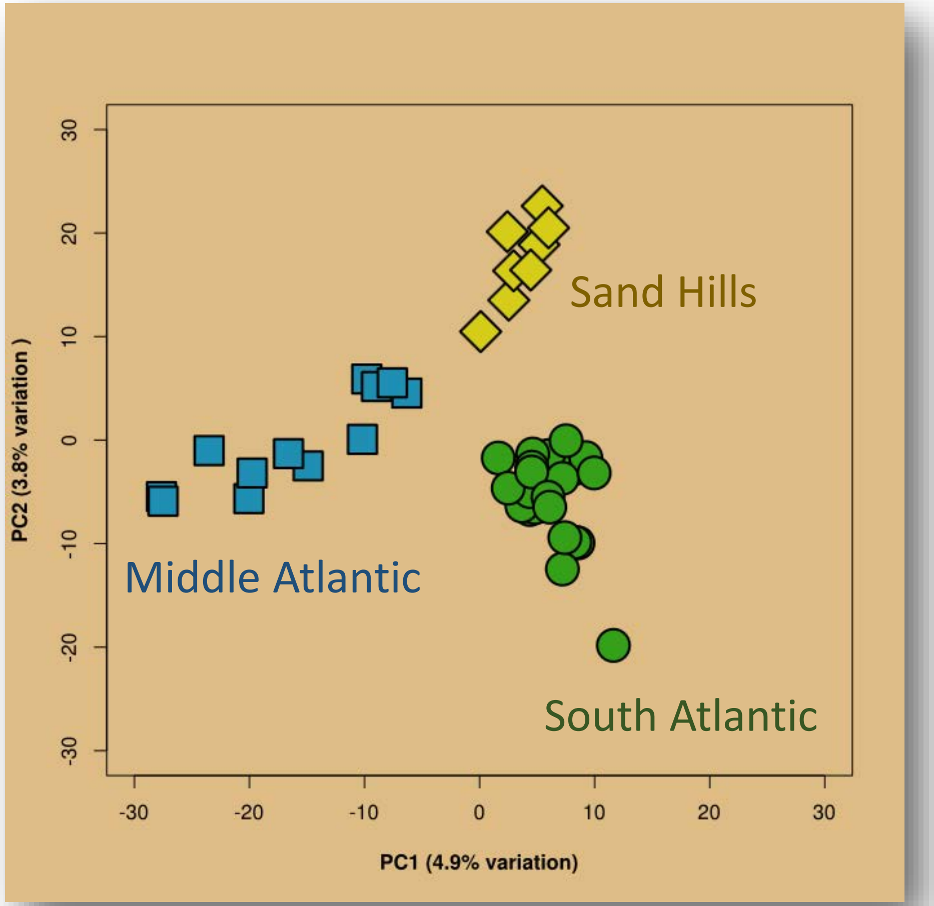


State level distribution of Tephrosia

Collection locations



Results



Variance component	% Variation	p-value
Among ecoregions	3.4	< 0.001
Among sites within ecoregions	12.3	< 0.001
Among Individuals within sites	84.3	

PCA of genetic dissimilarity: the first 2 principal components grouped individuals by ecoregion

So far, so good…

What's next?

Combine data into single analysis (LLA Meeting)

Complete genetic studies (2019)

Test results in field settings?

Thanks to our partners for collecting, testing, funding, providing garden space

- Jack Culpepper
- Nancy Jordan
- Bert Pittman
- Wayne Grooms
- Kathy Boyle
- Robin Mackie
- Bryan Mudder
- Gary Kaufman
- Jeff Glitzenstein
- Donna Streng
- Linda Lee
- Gary Burger
- Mike Walker

- Sudie Daves Thomas & family
- Lisa Lord
- Colette Degarady
- Allen Bridgmen
- Bob Franklin
- Michael Jenkins
- Carol Denhof
- Ocatee Hunt Club Manager
- Hoover Plantation Manager

- Forest Service National Seed Lab
- Francis Marion Sumter NF
- RNGR staff
- Clemson Research & Education Directors and Staff