

Utilization of Native Annuals for Restoration

Ryan Busby

US Army Engineer R&D Center/Colorado State University

Mark Paschke

Colorado State University

Chris Herron

Colorado State University

Julie Rieder

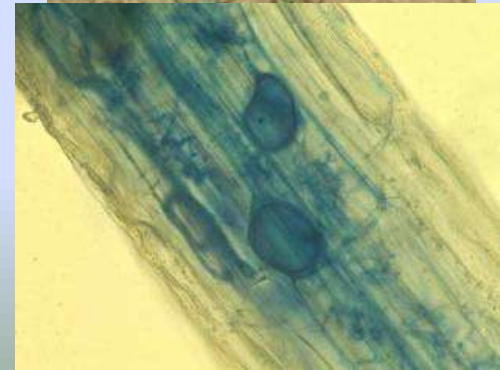
Colorado State University

**Colorado
State
University**



Overview

- Introduction on the Importance of Native Annuals
- Rapid Revegetation Following Fire
- Combating Specific Invasive Plants
- Role of Arbuscular Mycorrhizal Fungi in Succession
- Annual and Early-Seral Perennial Interactions with AMF



Introduction

Why Native Annuals?

- Fast establishment and growth
- Competition with non-native species
- Naturally replaced by native perennials



Introduction



Native Annuals



+

-



Native Perennials

Non-Native Invaders



Where do you get seed?

Native Seed Suppliers

- Granite Seed UT
- Pawnee Buttes Seed CO
- Western Native CO
- Ion Exchange IA
- Prairies Diversified ND

Specialty Weed Seed Suppliers

- Azlin Seed Service MS
- Paul Allen Farm Supply NE

Specialty Medicinal and Miscellaneous Seed Suppliers

- Darcy from the Forest UT
- CompanionPlants.com



Post-Fire Revegetation

Dinosaur, CO

- Steuwe fire - small ground fire, lightning ignition
- NW Colorado, south of Dinosaur
- Pinyon-juniper vegetative community
- Average annual precip. approx. 11 inches (279 mm)



DeBeque, CO

- Pyramid fire - small ground fire, lightning ignition
- NW Colorado, along I-70
- Pinyon-juniper vegetative community
- Average annual precip. approx. 11-12 inches (279-308 mm)

Areas burned in summer/fall 2007

High risk of post-fire cheatgrass invasion

4 treatments: control, annual, perennial, annual + perennial

7 Blocks per site 2 x 2 m plots

Post-Fire Revegetation

Annual Mix

- *Amaranthus retroflexus* (redroot pigweed)
- *Aristida purpurea* (purple threeawn)
- *Cleome serrulata* (Rocky Mountain beeplant)
- *Coreopsis tinctoria* (golden tickseed)
- *Digitaria sanguinalis* (hairy crabgrass)
- *Helianthus annuus* (annual sunflower)
- *Verbena bracteata* (bigbract verbena)
- *Vulpia microstachys* (small fescue)
- *Vulpia octoflora* (sixweeks fescue)

Perennial Mix

- *Achnatherum hymenoides* (Indian ricegrass)
- *Balsamorhiza sagittata* (arrowleaf balsamroot)
- *Elymus elymoides* (bottlebrush squirrel tail)
- *Elymus lanceolatus* (thickspike wheatgrass)
- *Eriogonum umbellatum* (sulphur-flower buckwheat)
- *Oenothera pallida* (pale evening primrose)
- *Pascopyrum smithii* (western wheatgrass)
- *Pseudoroegneria spicata* (bluebunch wheatgrass)
- *Sphaeralcea munroana* (munro's globemallow)

Post-Fire Revegetation

	Treatment	Dinosaur		DeBeque	
		2008	2009	2008	2009
Total Plant Cover	Annual	71.90 (2.04)	71.37 (3.62) a	44.61 (4.92) a	58.09 (4.99) a
	Perennial	72.48 (3.10)	85.51 (4.15) b	32.96 (3.54) b	81.72 (2.37) b
	Mixed	72.69 (3.21)	77.87 (2.63) ab	42.60 (4.45) ab	64.94 (3.93) a
	Control	68.07 (3.51)	83.16 (3.12) b	45.16 (4.88) a	81.56 (4.24) b
Exotic Annuals	Annual	63.36 (2.47)	59.32 (3.57) a	30.89 (6.01) a	59.32 (4.81) a
	Perennial	66.18 (2.91)	78.02 (1.67) b	28.94 (3.36) a	78.02 (2.49) b
	Mixed	64.87 (4.31)	70.58 (3.18) b	31.82 (3.71) ab	70.58 (4.57) ab
	Control	59.64 (5.52)	70.20 (3.82) b	42.86 (5.33) b	70.20 (4.10) b
Native Perennials	Annual	5.27 (1.36)	10.87 (2.85)	0.00 (0.00)	0.07 (0.07)
	Perennial	3.52 (0.83)	6.22 (1.73)	2.38 (0.61) a	0.30 (0.15)
	Mixed	3.05 (1.19)	6.77 (2.36)	0.75 (0.22) b	0.67 (0.05)
	Control	5.22 (1.59)	11.53 (0.30)	0.00 (0.00)	0.00 (0.00)
Seeded Annuals	Annual	0.96 (0.40)a	0.22 (0.10)	11.86 (1.49) a	0.52 (0.20)
	Perennial	0.00 (0.00)b	0.00 (0.00)	0.37 (0.25) b	0.89 (0.48)
	Mixed	0.82 (0.85)a	0.00 (0.00)	9.29 (1.92) a	0.37 (0.15)
	Control	0.07 (0.07)b	0.00 (0.00)	0.22 (0.15) b	0.29 (0.29)
Seeded Perennials	Annual	0.74 (0.49)	1.41 (1.17)	0.00 (0.00) a	0.07 (0.07) ab
	Perennial	1.05 (0.51)	2.47 (1.65)	2.38 (0.61) c	0.30 (0.15) ab
	Mixed	1.12 (0.80)	2.45 (1.29)	0.75 (0.22) b	0.67 (0.50) b
	Control	0.97 (0.50)	4.18 (3.19)	0.00 (0.00) a	0.00 (0.00) a

Greenhouse Native-Exotic Competition

Native Cover Crops + Exotic Species + Native Perennials

Native Cover Crops

Ambrosia artemisiifolia (common ragweed)

Helianthus annuus (annual sunflower)

Solidago canadensis (Canada goldenrod)

Antennaria microphylla (littleleaf pussytoes)

Exotic Plant Species

Bromus tectorum (cheatgrass)

Bromus arvensis (aka japonicum) (Japanese brome)

Cirsium arvense (Canada thistle)

Cardaria draba (whitetop)

Desired Native Perennials

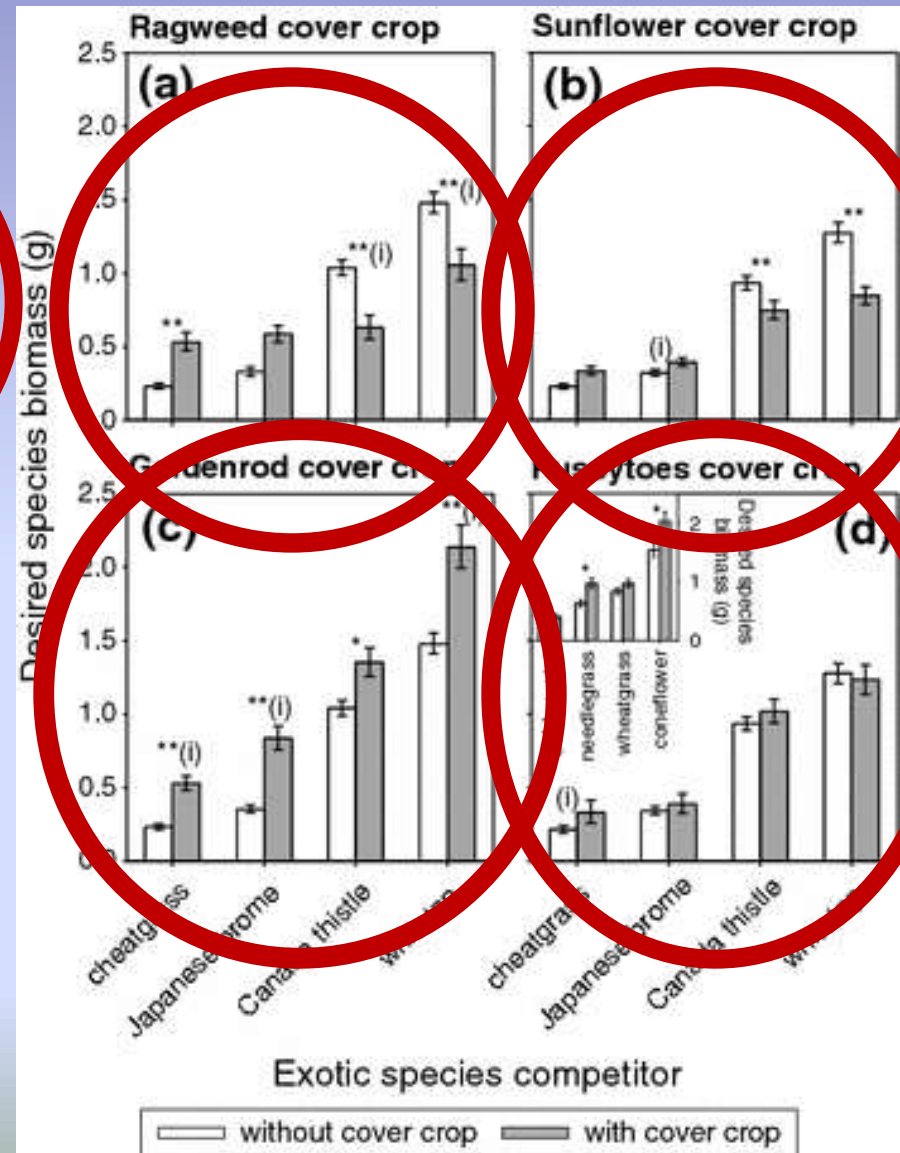
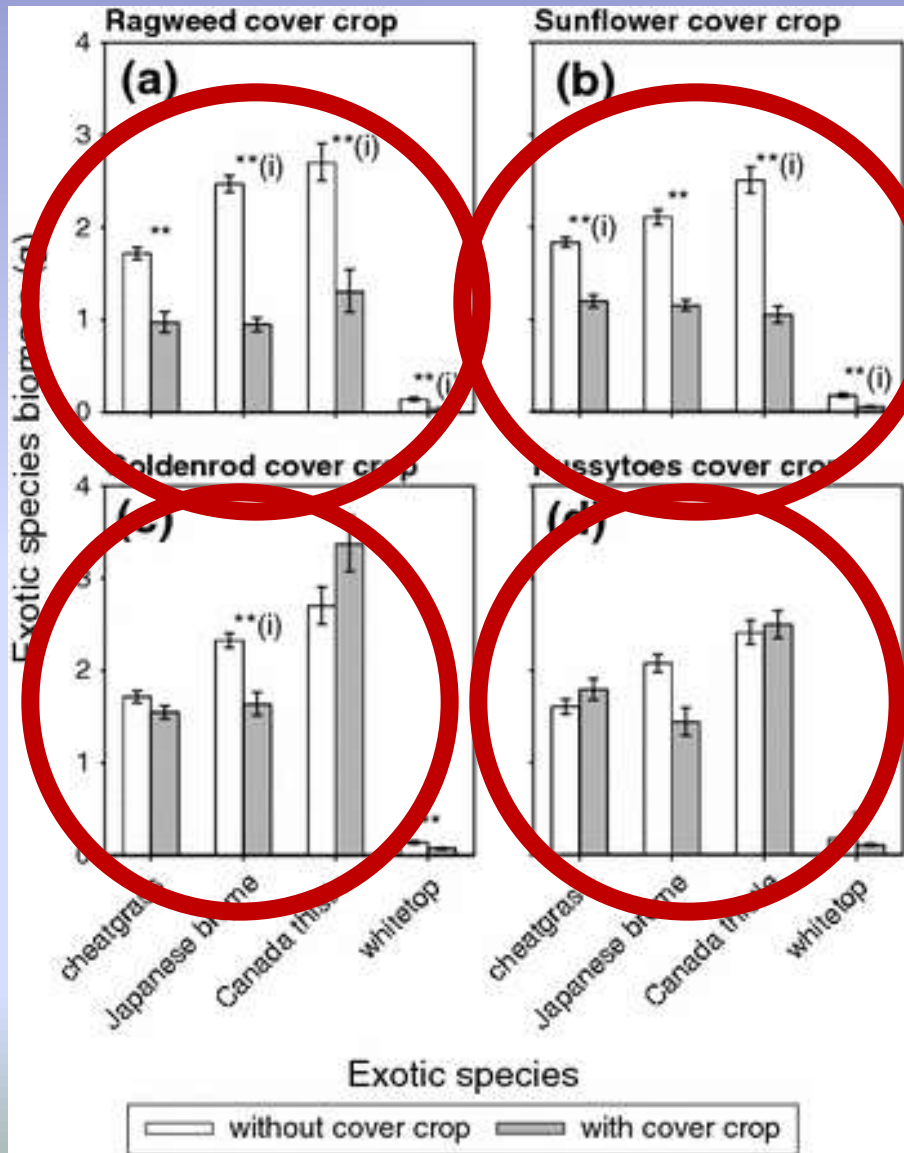
Heterotheca villosa (hairy false goldenaster)

Nassella viridula (green needlegrass)

Pascopyrum smithii (western wheatgrass)

Ratibida columnifera (prairie coneflower)

Greenhouse Native-Exotic Competition



Spotted Knapweed and Leafy Spurge in WI

5 blocks dominated by spotted knapweed and leafy spurge

5 replications of each treatment in each block

2 x 2 m plots

Standard Mix

Bouteloua curtipendula (sideoats grama)

Schizachyrium scoparium (little bluestem)

Symphotrichum oolentangiense (sky blue aster)

Rudbeckia hirta (blackeyed Susan)

Verbena stricta (hoary verbena)

Resistant Mix

Andropogon gerardii (big bluestem)

Panicum virgatum (switchgrass)

Grindelia squarrosa (curlycup gumweed)

Lupinus perennis (sundial lupine)

Symphotrichum laeve (smooth blue aster)

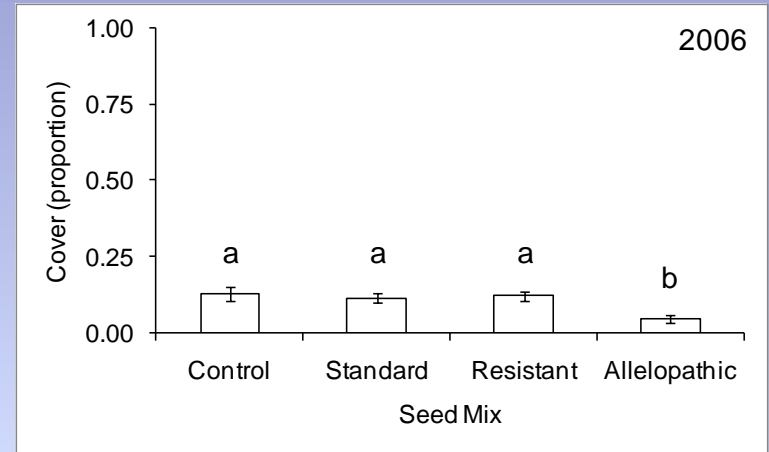
Allelopathic Mix

Ambrosia artemisiifolia (common ragweed)

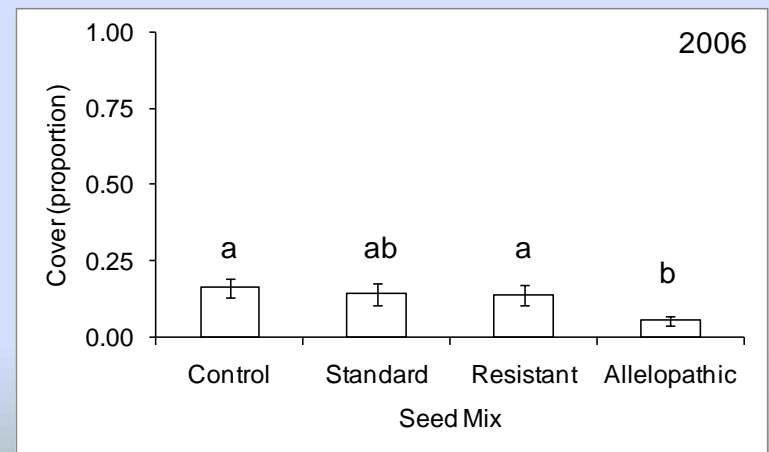
Asclepias syriaca (common milkweed)

Solidago canadensis (Canada goldenrod)

Solidago gigantea (giant goldenrod)



Cover of spotted knapweed at Fort McCoy, WI in 2006 among seed mix treatments.



Cover of leafy spurge at Fort McCoy, WI in 2006 among seed mix treatments.

Introduction

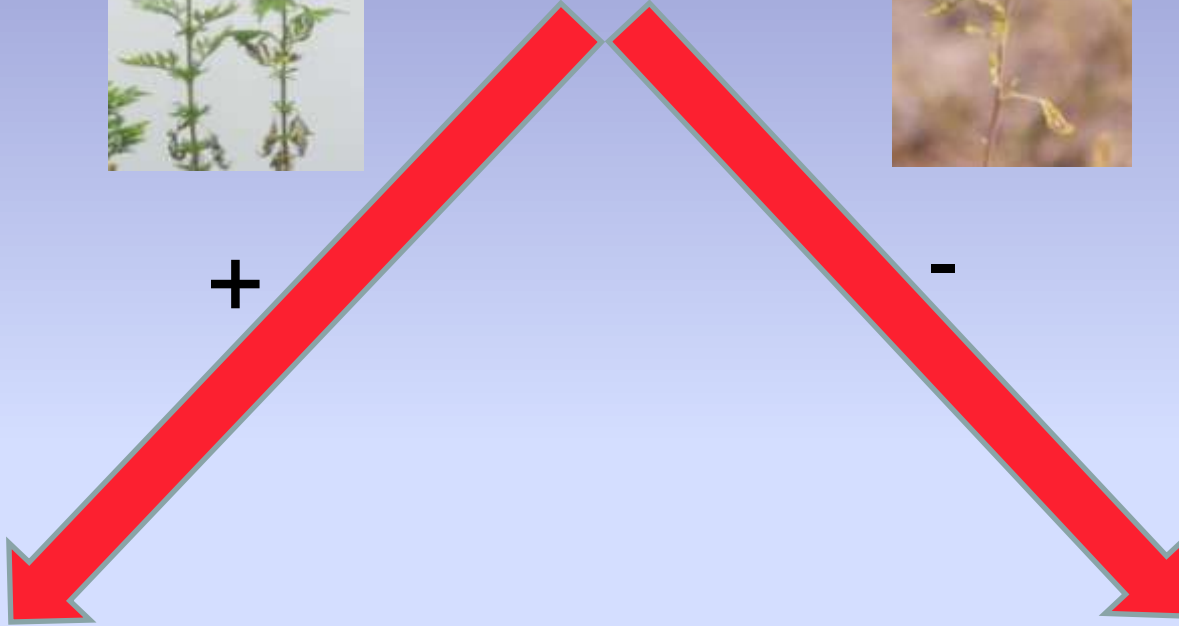


Native Annuals



+

-



Native Perennials

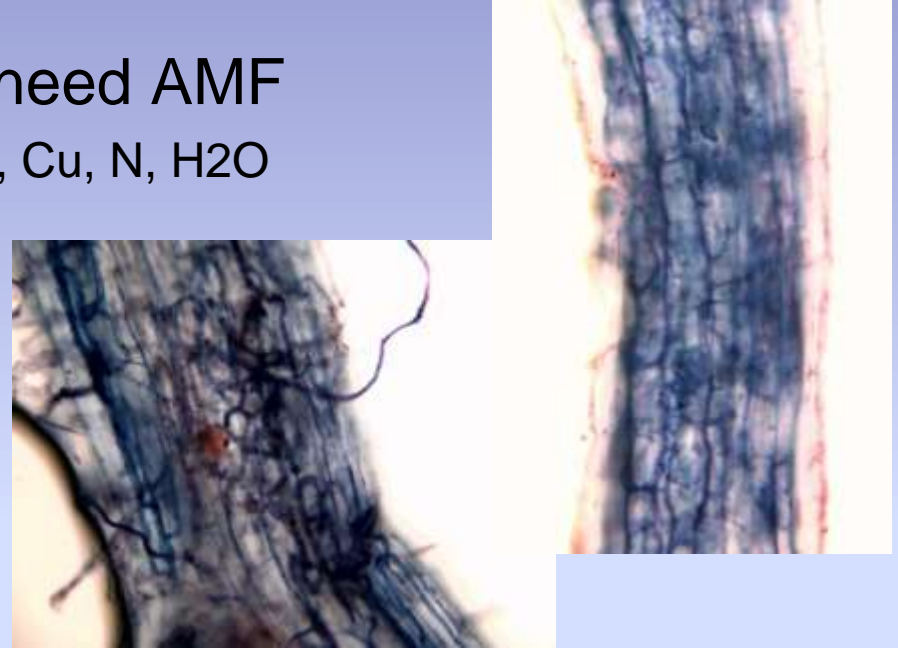
Non-Native Invaders



Importance of AMF in Restoration

- Most native perennial plants need AMF

- Primarily P acquisition, but also Zn, Cu, N, H₂O
- Resistance to Soil Pathogens
- Salinity Tolerance
- Exclusion of Soil Contaminants



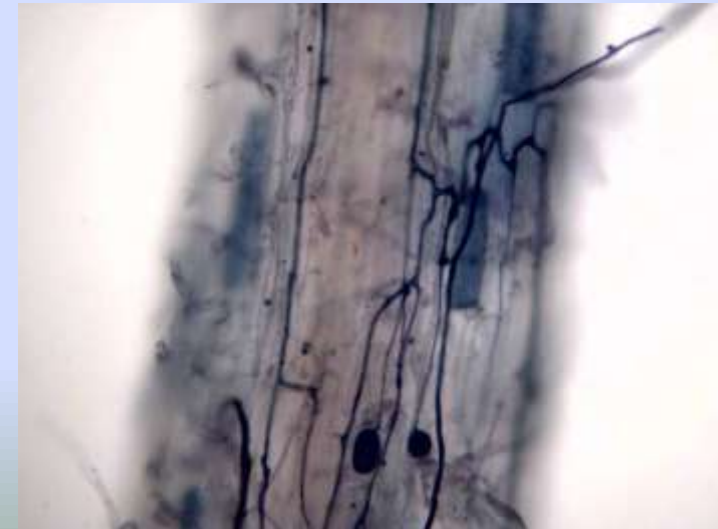
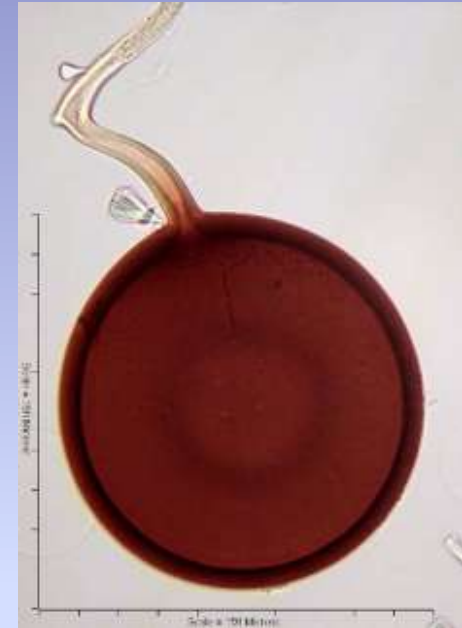
- Invasive plants alter AMF

- Spotted knapweed uses shared AMF networks to steal resources from native grasses
- Cheatgrass reduces AMF density in soils
- Garlic mustard inhibits spore germination through root exudates
- Russian thistle purges roots that become infected by AMF



Plant-AMF Interactions

- No Specificity
- DOES NOT MEAN Redundant Interactions
- Differential Benefits
 - Plant Response Specificity
 - Preferential Associations
 - Higher prevalence of certain associations
 - Variable sporulation of AMF species
- Multiple AMF infect single roots
- Individual AMF infect multiple hosts
- Competition Between AMF for Hosts
- Competition Between Plants for Benefits
- Parasitism to Mutualism



Diversity

- Greater AMF Diversity Supports Greater Plant Diversity

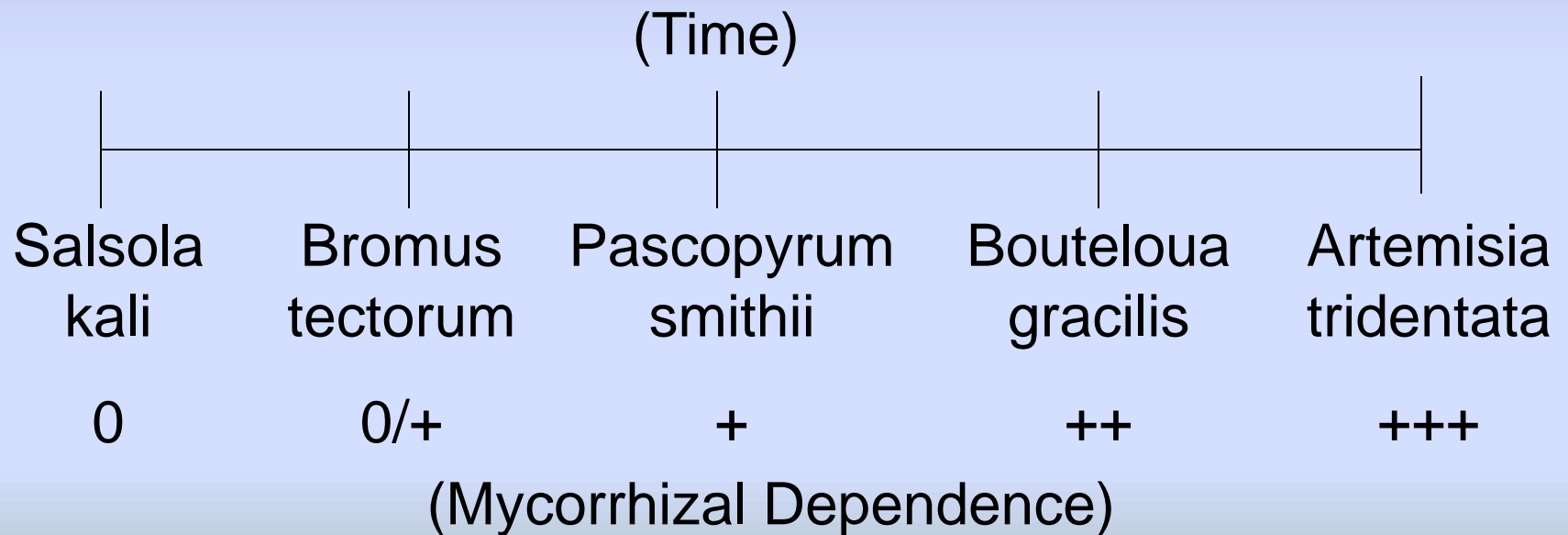


J. Morton, WVU

- Greater Plant Diversity Supports Greater AMF Diversity

AMF and Secondary Succession

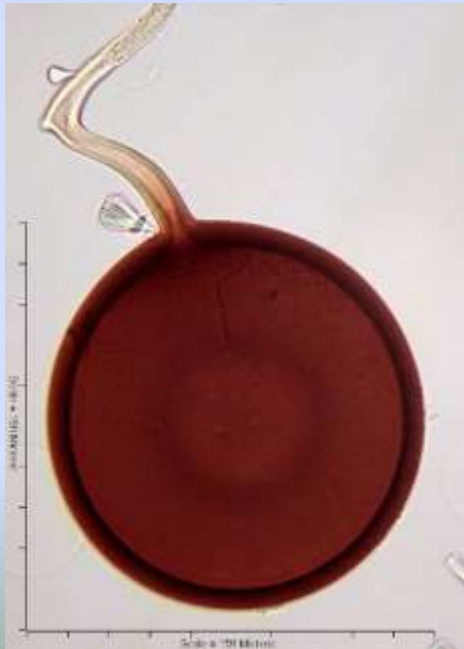
- AMF Density tied to Seral Status
- Removal of AMF Results in Annuals



Allen 1984

Unresolved AMF Questions

- Host-AMF Interactions with Most Species Unstudied
- Interactions Studied usually 1 Host- 1 AMF
- Generally AMF Response not Measured
 - Plant Response Assumes AMF Response



AMF Interactions with Early-Seral Plants

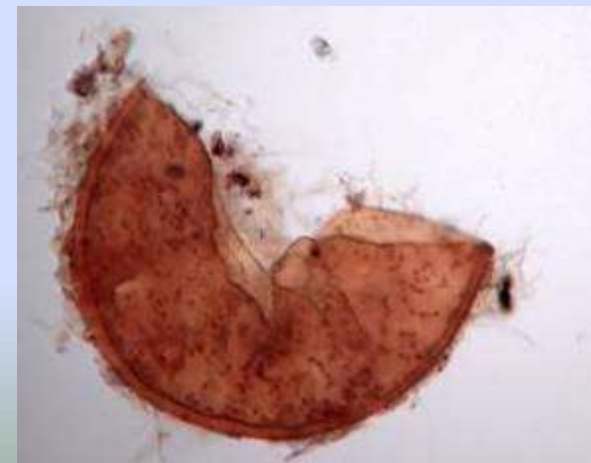
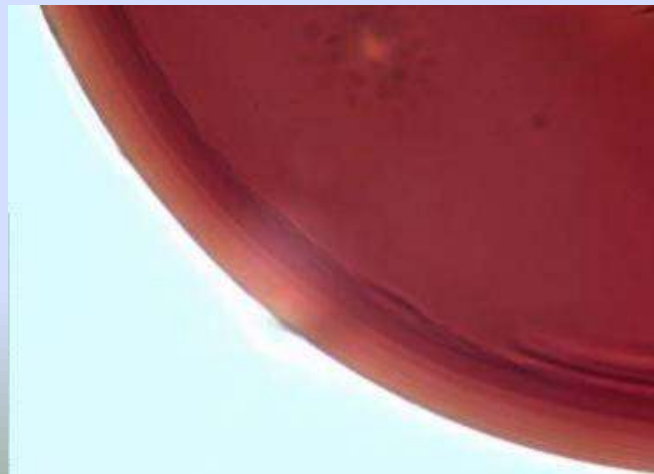
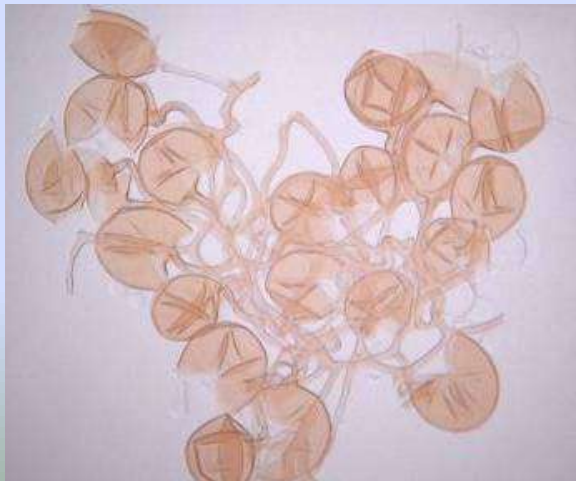
Methods

- 0.4 ha site selected at Camp Guernsey, WY
- Crested wheatgrass pasture invaded by cheatgrass and Japanese brome
- 8 random 18 L soil samples collected to a depth of 15 cm in May 2008
- Soils composited and thoroughly mixed



AMF Community

<u>Species</u>	<u>Frequency</u>
• <i>Glomus geosporum</i>	1.00
• <i>Glomus mosseae</i>	0.75
• <i>Glomus deserticola</i>	0.75
• <i>Paraglomus occultum</i>	0.50
• <i>Archaeospora trappei</i>	0.25
• <i>Entrophospora infrequens</i>	0.13
• <i>Acaulospora</i> sp.	0.13



Methods

- Soil divided into 2 treatments: AMF+, AMF-
- AMF- soils autoclaved on consecutive days and reinoculated with AMF+ Whatman #1 filtrate
- Seventeen host plant species treatments x 2 soil treatments x 5 reps



Host Plant Species

Perennial Forbs

Asclepias speciosa

Grindelia squarrosa

Linum lewisii

Monarda fistulosa

Oenothera caespitosa

Ratibida columnifera

Sphaeralcea coccinea

Annual/ Biennial Forbs

Ambrosia psilostachya

Cleome serrulata

Coreopsis tinctoria

Machaeranthera tanacetifolia

Oenothera pallida

Shrub

Artemisia tridentata ssp. *Wyomingensis*

Annual C3 Grass

Bromus tectorum

Perennial C3 Grasses

Elymus elymoides

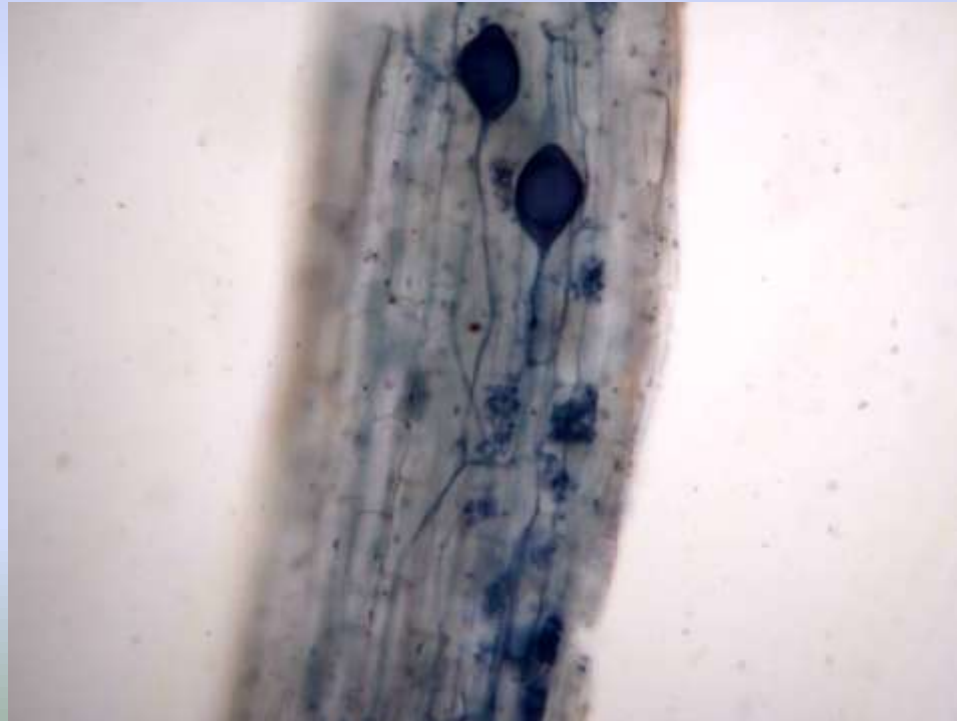
Poa secunda

Perennial C4 Grass

Aristida purpurea

Methods

- Shoot Biomass Collected after 4 Months
- Plant Relative Responsiveness =
$$\frac{\text{Mean Shoot Biomass (AMF+)} - \text{Mean Shoot Biomass (AMF-)}}{\text{Mean Shoot Biomass (AMF+)}} \times 100$$
- Trained Roots and Soils Mixed from each AMF+ Treatment
- Seeded with Sudangrass and Grown for 30 Days
- % Colonization of Sudangrass used for AMF Infection Density



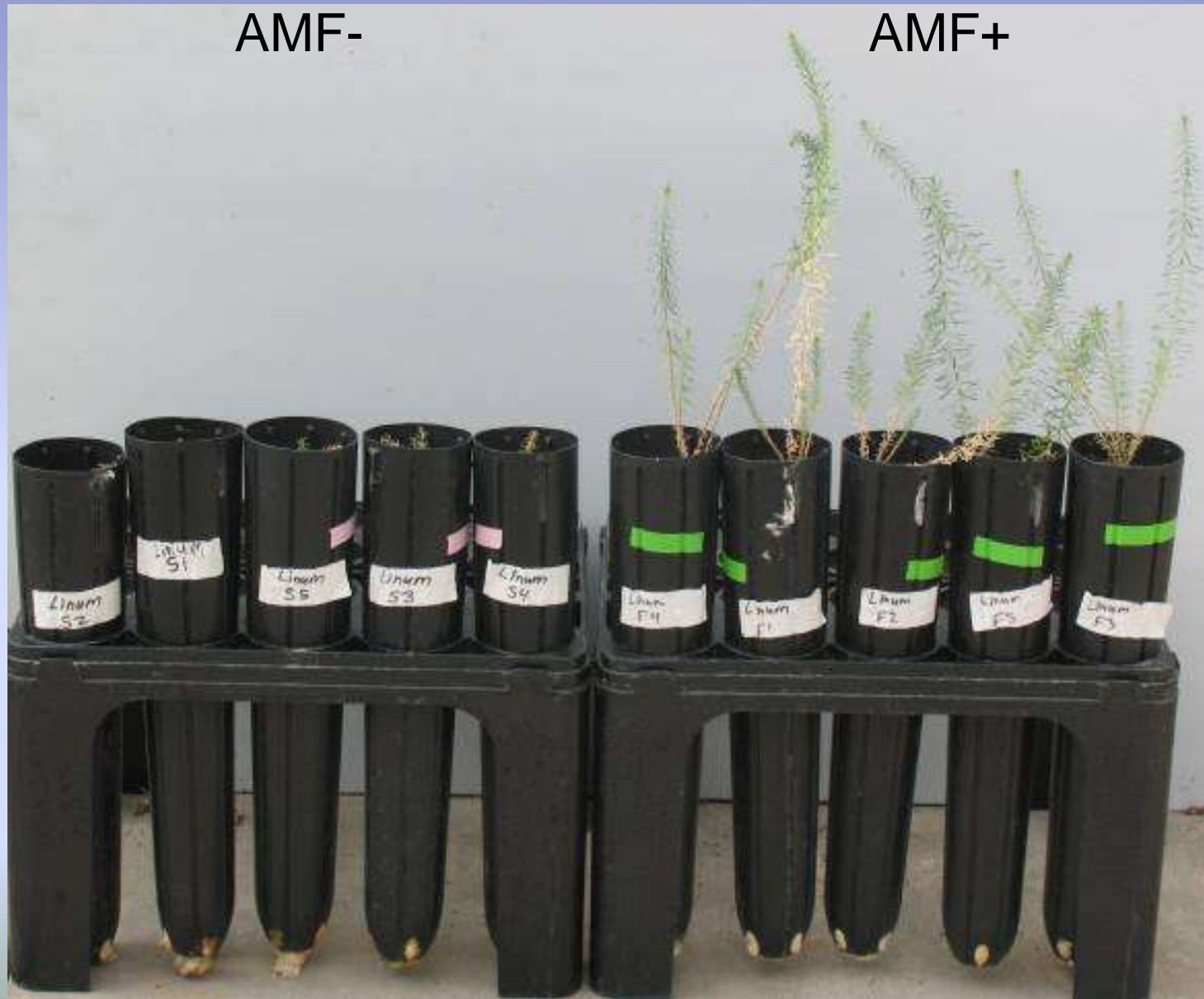
Statistical Analyses

- Relative Responsiveness by Species using t-tests (AMF+ vs. AMF- at $\alpha = 0.05$)
- AMF Infection Density Using ANOVA ($\alpha = 0.05$)
 - Mean separation using Dunnett's Test
 - All Host Treatments vs. Initial Soil

Linum lewisii

AMF-

AMF+



Bromus tectorum

AMF-

AMF+

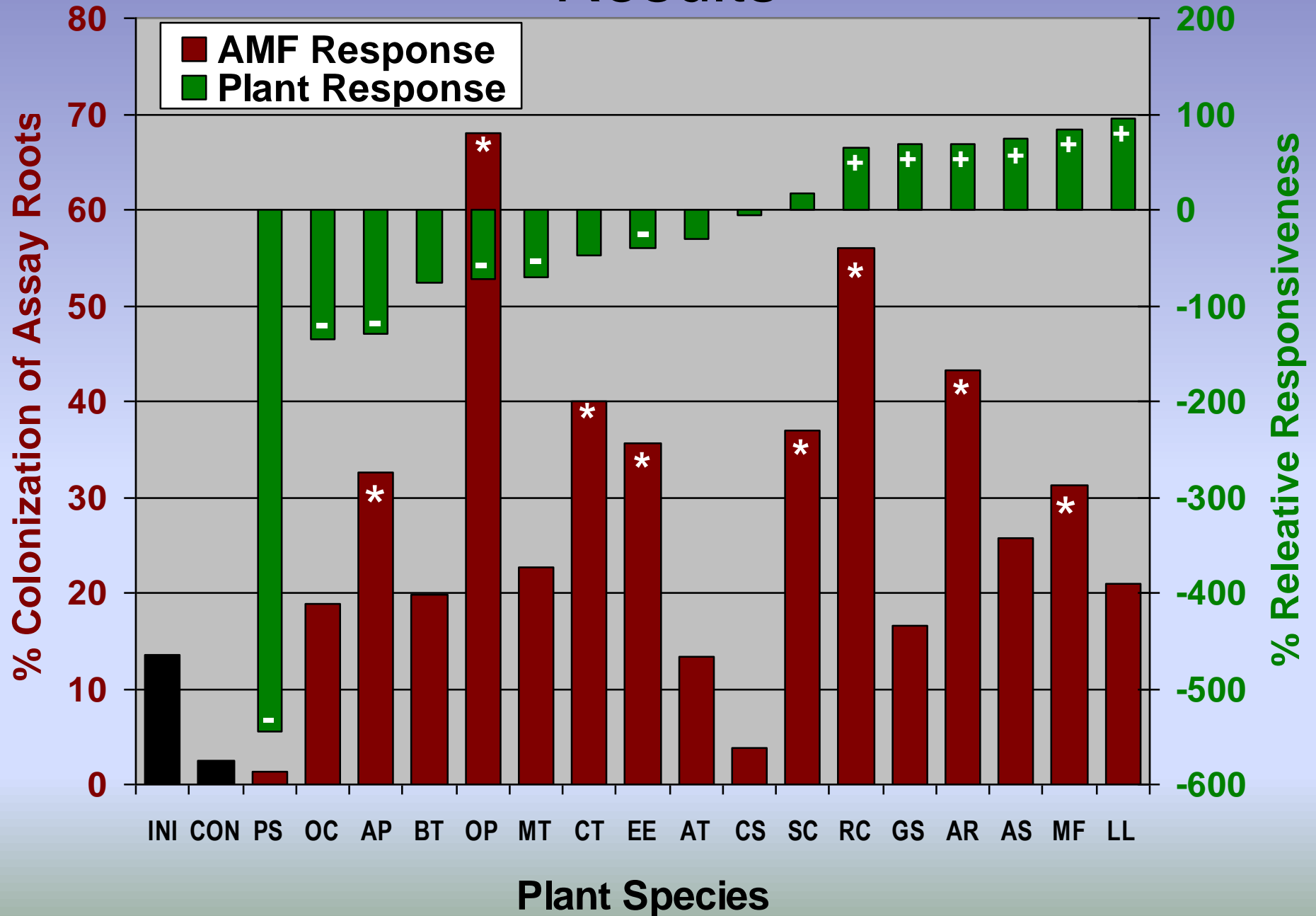


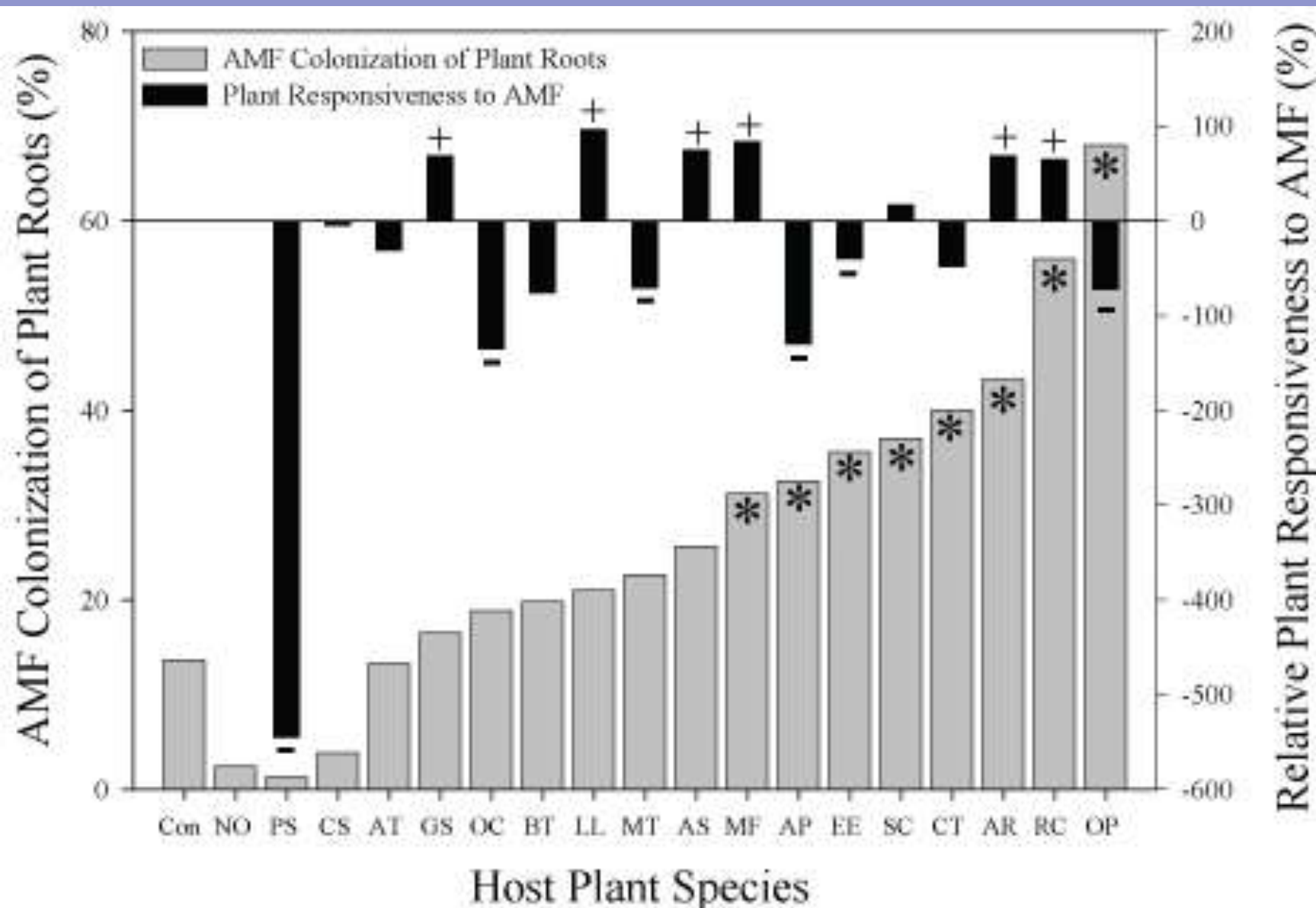
Ambrosia psilostachya



<u>Plant Host Species</u>	<u>Host Response</u>	<u>AMF Response</u>	<u>Interaction</u>
<i>Aristida purpurea</i>	+	+	Mutualism
<i>Monarda fistulosa</i>	+	+	Mutualism
<i>Ratibida columnifera</i>	+	+	Mutualism
<i>Coreopsis tinctoria</i>	0	+	Commensalism
<i>Sphaeralcea coccinea</i>	0	+	Commensalism
<i>Asclepias speciosa</i>	+	0	Commensalism
<i>Grindelia squarrosa</i>	+	0	Commensalism
<i>Linum lewisii</i>	+	0	Commensalism
<i>Artemisia tridentata</i>	0	0	Null
<i>Bromus tectorum</i>	0	0	Null
<i>Cleome serrulata</i>	0	0	Null
<i>Machaeranthera tanacetifolia</i>	-	0	Amensalism
<i>Oenothera caespitosa</i>	-	0	Amensalism
<i>Poa secunda</i>	-	0	Amensalism
<i>Ambrosia psilostachya</i>	-	+	Parasitism
<i>Elymus elymoides</i>	-	+	Parasitism
<i>Oenothera pallida</i>	-	+	Parasitism

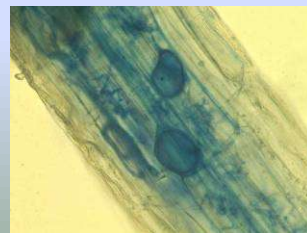
Results





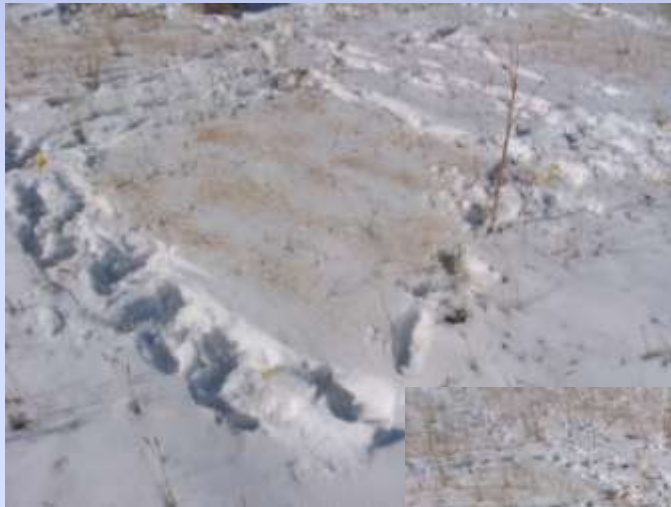
Conclusions

- Plant Response is NOT an Indicator of AMF Response
- Native Early- and Mid-Successional Species Interactions Highly Variable
- AMF Responses Need to be Considered
- Species such as *Oenothera pallida* and *Artemisia psilostachya* could function as nexus species



Ongoing Research

- Field study at same field location
 - Monocultures of study plant hosts with big sagebrush seeding and transplants



Acknowledgments

- Mark Paschke, Chris Herron, Julie Rieder, Laura Perry, Tom Grant, CSU
- Brett Wolk, CSU Restoration Ecology Lab
- REL Grad Students and Post-Docs
- REL Crew
- Hank Raizen, University of Illinois

Questions?

