# Climate Change and Ecological Impacts

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# Extreme Climatic Events (ECEs)

Organisms are more sensitive to abrupt, rather that gradual, changes

Current climate change models predict an increase in both likelihood and intensity of ECEs

Much more data on ecological responses to ECEs, compared to long-term climate change (funding, time, etc.)

# Climate and Insects

Increased temperatures can speed up metabolic processes -> increased plan damage

Reduced over-wintering mortality risks

Species distributions

Altered phenology

Indirect effects through changes to plant productivity, plant tissue nutrient content, and plant chemistry

# Climate and Birds

Changes to distributions

Altered precipitation regimes affecting breeding productivity

Phenological changes in migration; mismatch with available food sources

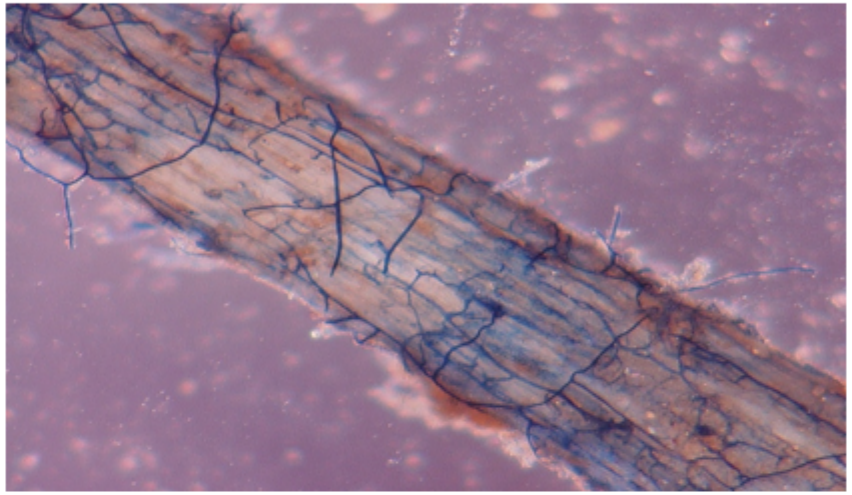
Changes in the onset of breeding

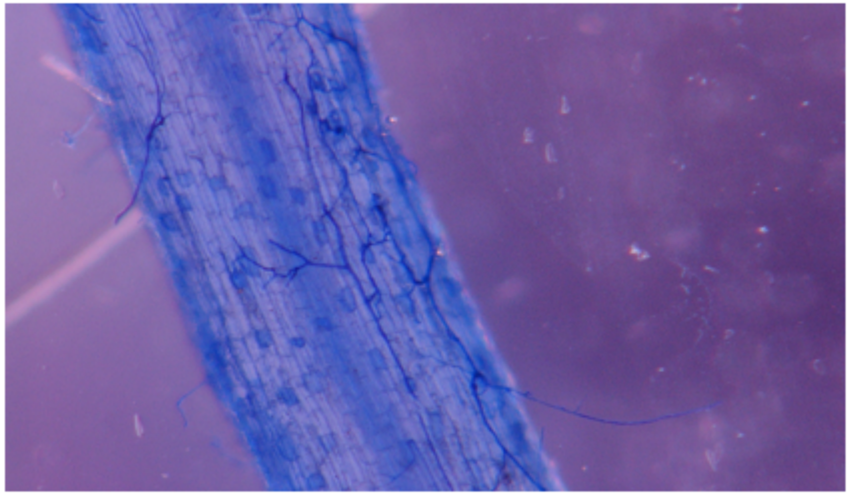
# Soil Microbial communities

Incredibly diverse and important for healthy, functioning plant communities

~80% of earth's terrestrial vascular plants form symbioses with mycorrhizal fungi

Severe, prolonged drought can desiccate soil fungi, indirectly affecting plant health





# Effects of Climate on Plant Communities

Decreases in soil moisture impact abundance and distribution of certain plant species

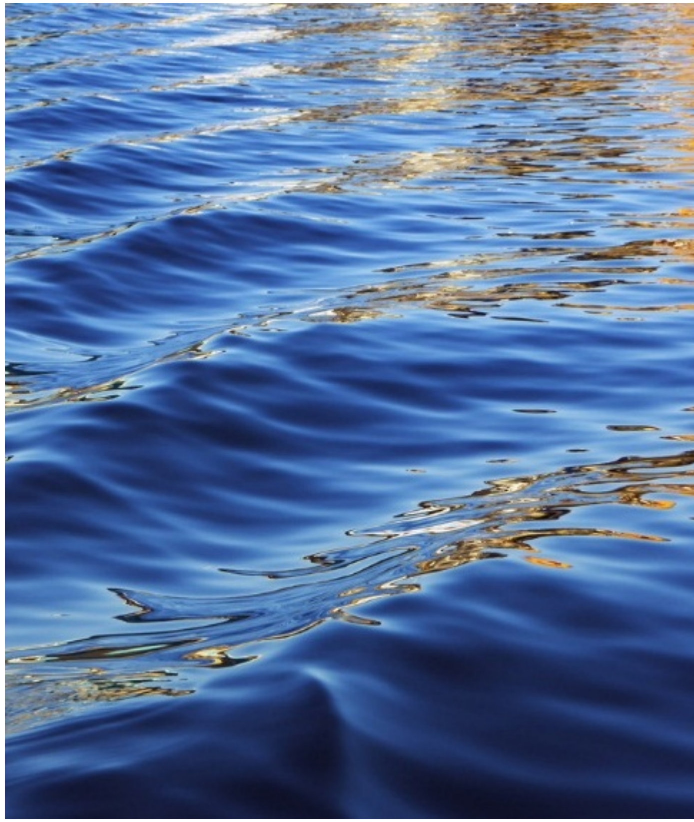
Resultant alterations to plant community assemblages

- persistence of deep-rooted perennials
- decrease in abundance of shirt-lived perennials and annuals

Shrub expansion into grasslands

Altered disturbance regimes (e.g. fire)

# Effects of Drought on Native and Invasive Prairie Grasses



# Grasslands of the World

Grassland ecosystems make up approximately 41% of Earth's terrestrial surface

Provide many goods and services, such as:

- Nutrient cycling
- Soil stabilization
- Aquifer recharge
- Wildlife habitat
- Ecotourism

# Diminishing Grasslands

Grasslands are widely considered the most threatened of all of Earth's biomes

Roughly 1% of North America's tallgrass prairie ecosystem remains (Sampson & Knopf 1994), due to:

- Agricultural conversion
- Fragmentation & Urbanization
- **Invasion by non-native species**
- **Climatic variability**

Impacts not only on the plant-level, but also key symbionts

# Drought in Grasslands

Many temperate plant species are resilient, rather than resistant, to drought -> short-term vulnerability

Reduction in productivity, lower reproductive success, and alterations to species composition

Impacts largely depend on antecedent effects, drought intensity, and diversity of plant community

# On the Colorado Plateau (Munson et al. 2011)

Temperature changes (MAT):

- Increased 0.18°C per year (1989-1995)
- Increased 0.06°C per year (1995-2003)
- Decreased 0.14°C per year (2003-2008)

Findings:

- In grasslands, decrease of $C_3$ and increase of $C_4$ cover
- Generally, no change in shrubland communities
- In high elevation woodlands, increase in *Juniperus* canopy cover with increasing temperatures

# Arbuscular Mycorrhizal (AM) Fungi

Symbiotic soil fungi; increase nutrient uptake plants

Important in shaping plant community structure of grasslands

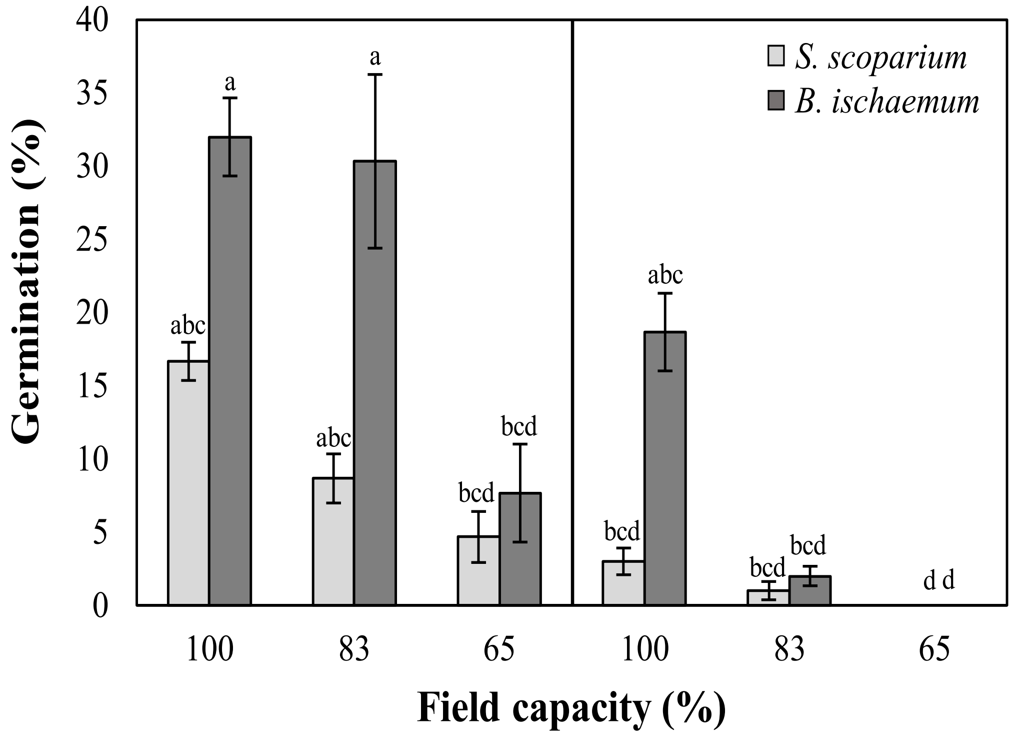
Many native, warm-season grasses depend on AM fungi for the completion of life cycles.

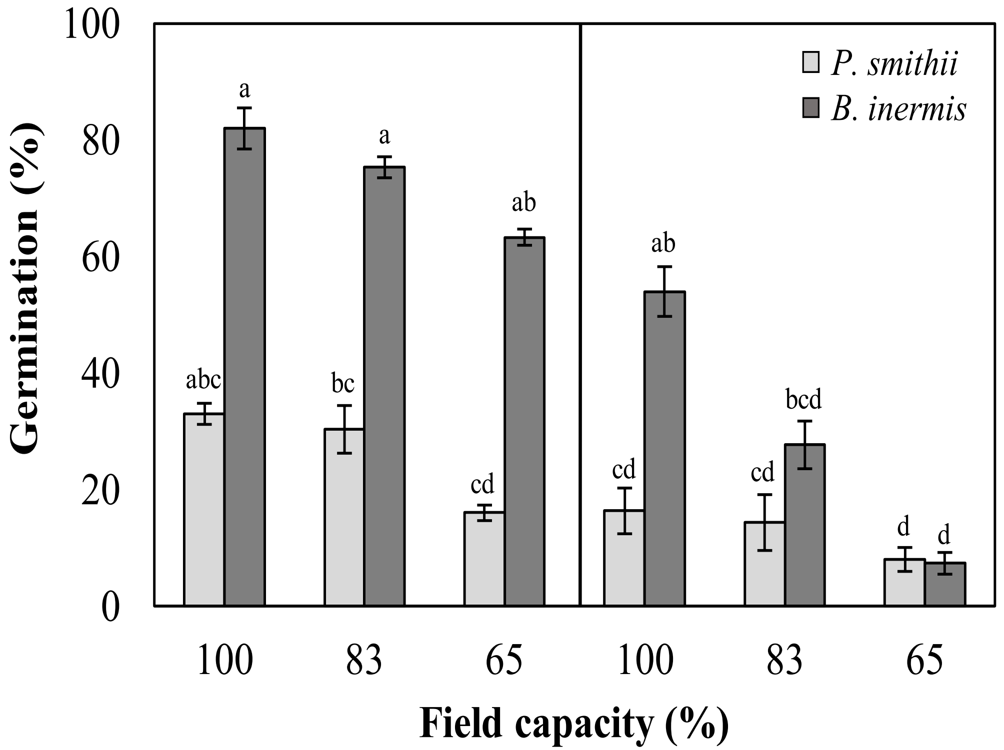
# Objectives of this Study

1) Assess the effects of reduced soil moistures and elevated temperatures on paired native and invasive $C_3$ and $C_4$ prairie grasses.

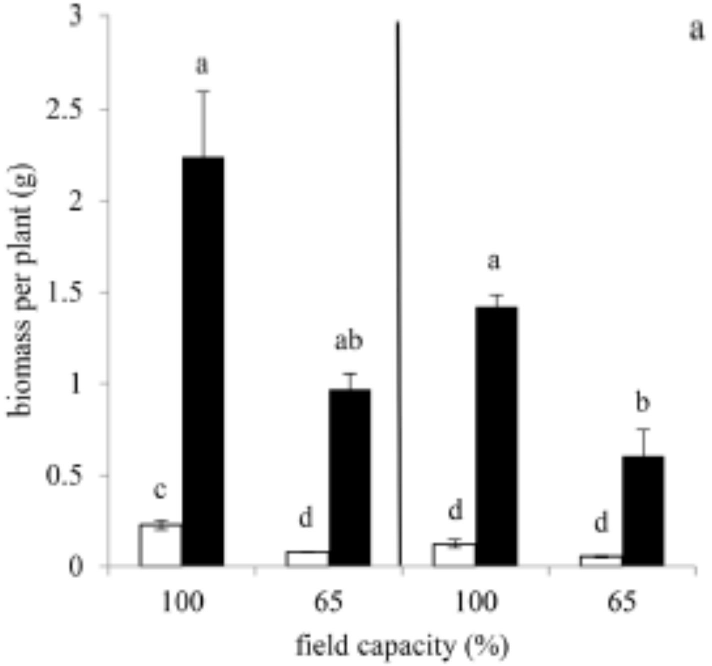
2) Assess the effects of reduced soil moistures and elevated temperatures on soil fungal communities associated with these plants.

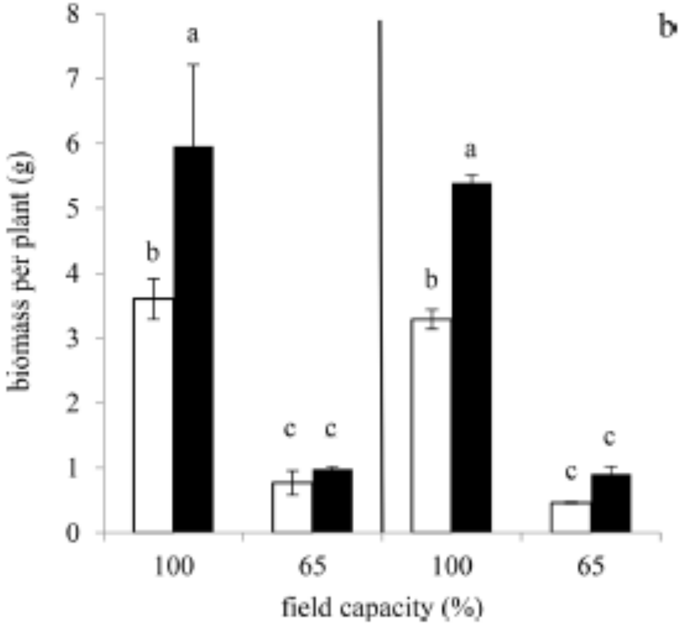
# Germination



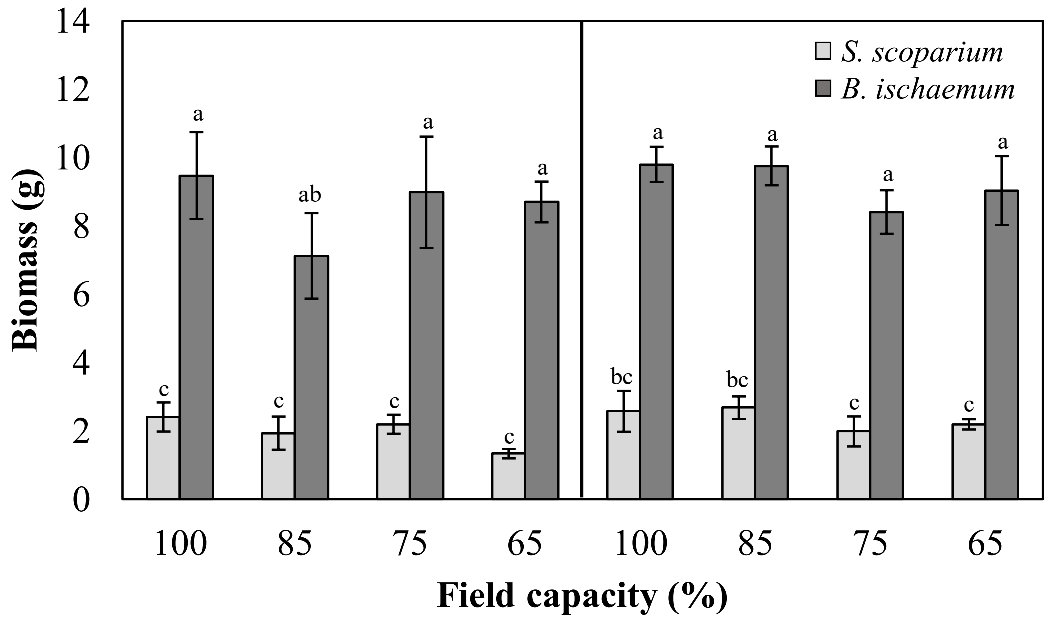



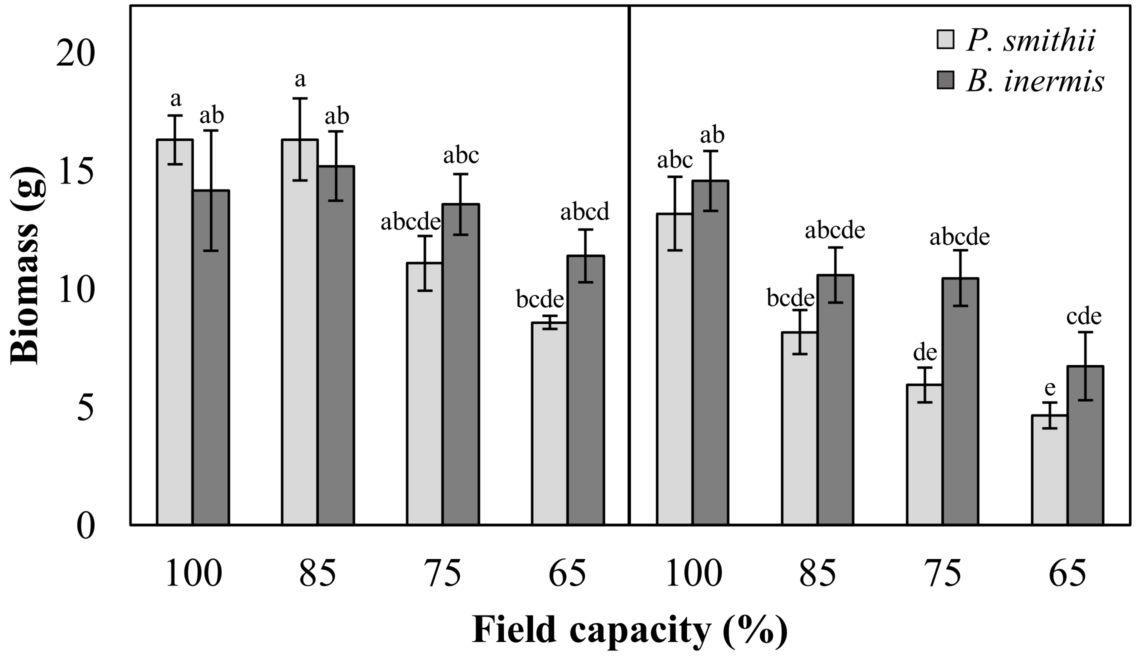
# Seedling Biomass



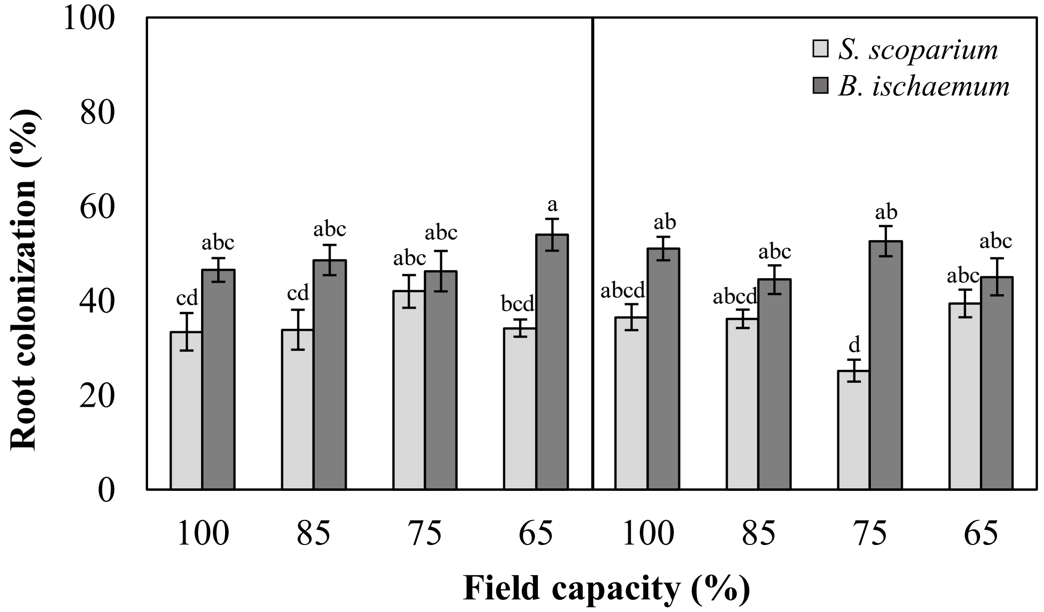



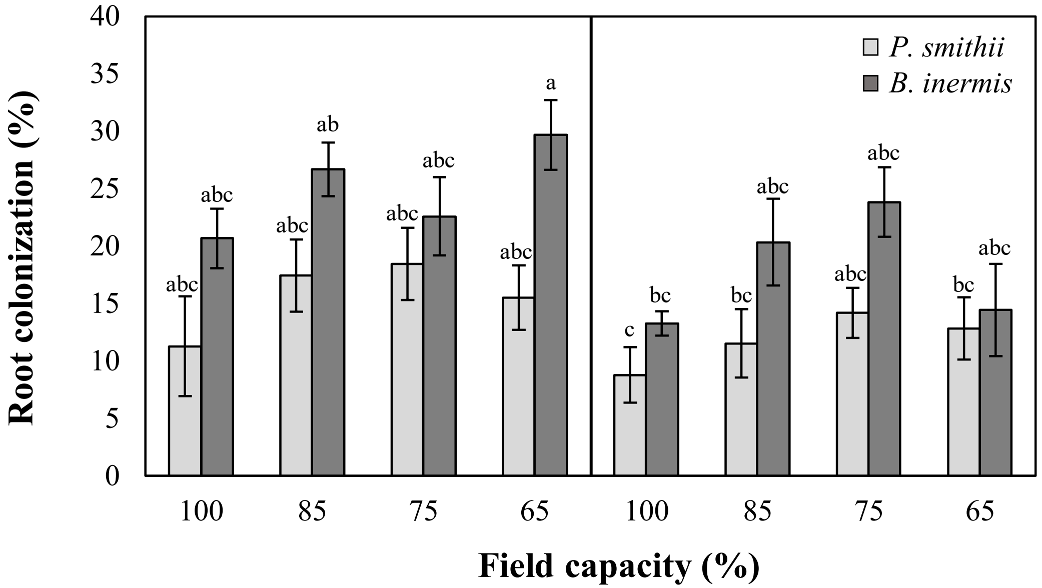
# Established Plant Biomass



# AM Fungal Community



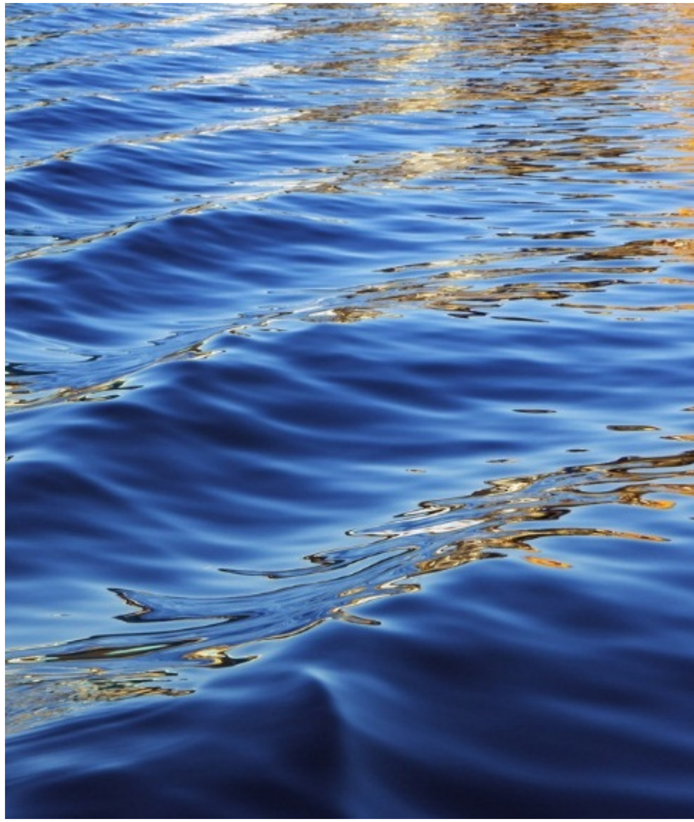
# Conclusion/Summary

Non-native invasive grasses appear to be much more tolerant of severe drought coupled with elevated temperatures, relative to native species

Non-native species continually displayed greater AM fungal associations, potentially a mechanism for drought tolerance

Under projected climate scenarios, non-native prairie grasses may continue to expand and out-compete neighboring native species

# Drought and Plant-Soil Feedbacks

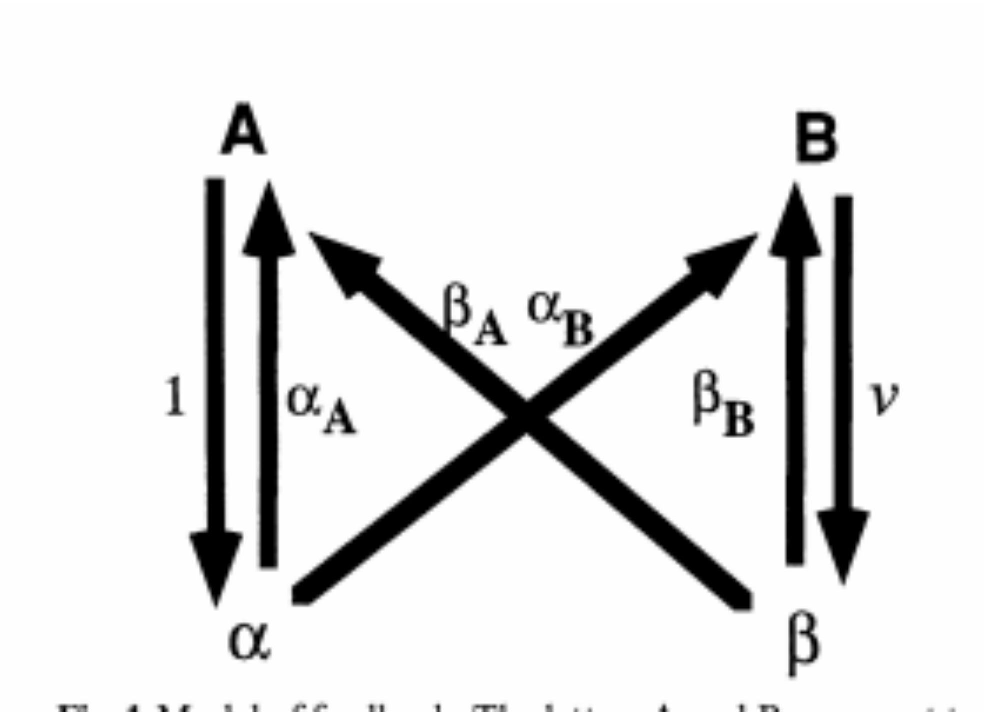


# What is a Plant-Soil Feedback (PSF)?

Plants don’t exist in a vacuum; they are always interacting with the soil around them

Root exudates in the form of phytohormones, allelopathic compounds, etc.

**Plants affect soil abiotic and biotic characteristics, and resultant soil conditions impact subsequent plant growth and performance**



# Role of PSF in Plant Community Structure

PSFs can dictate :

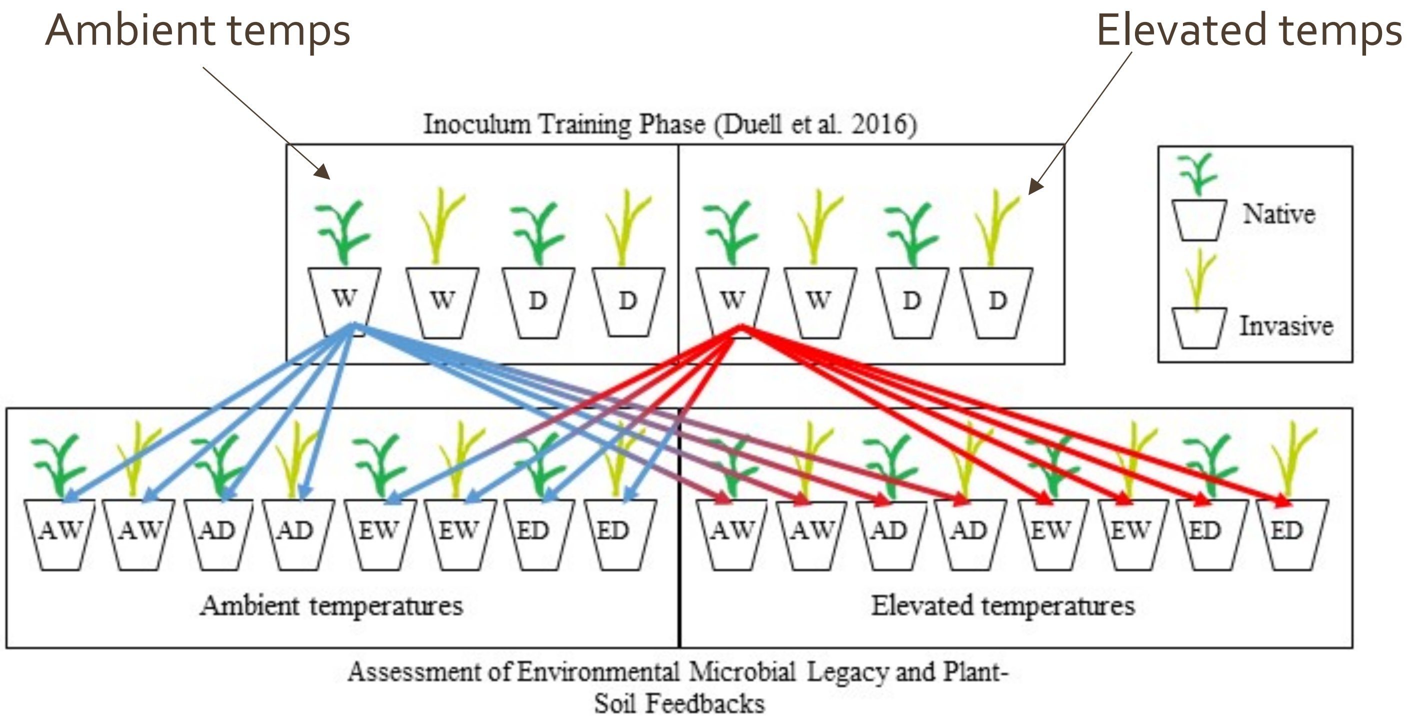
- Plant community structure and function
- Species arrangement on the landscape
- Dominance of some species, especially invasives

Many knowledge gaps surrounding effects of abiotic conditions on PSFs

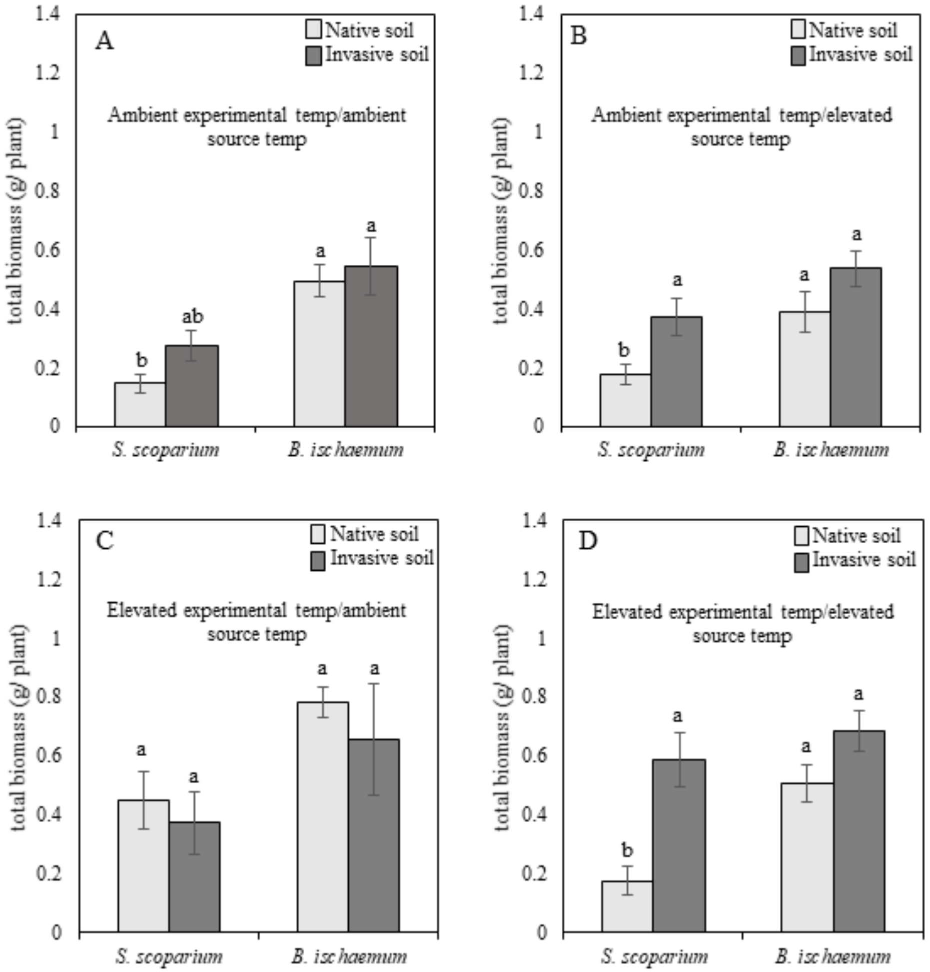
# Objectives of this Study

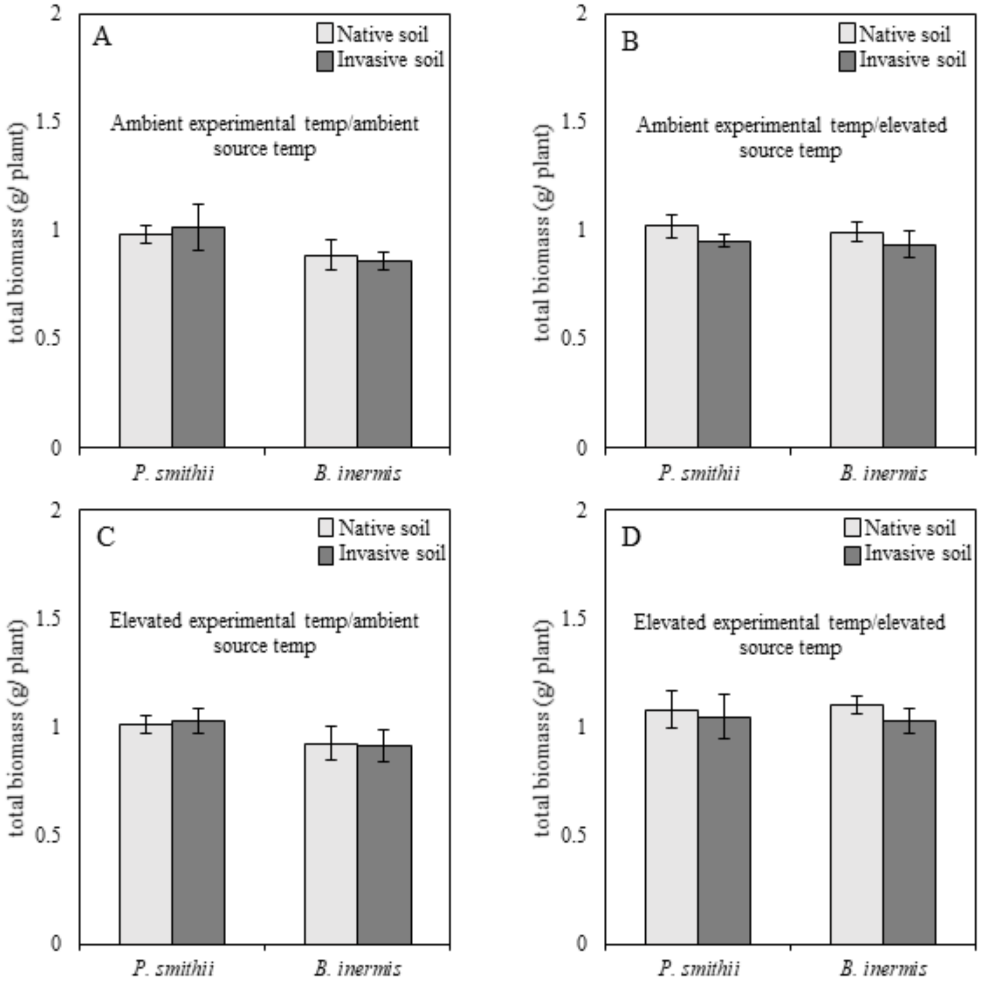
1) Assess the strength and direction of native and non-native grass PSFs under ambient conditions (well-watered and moderate temperatures)

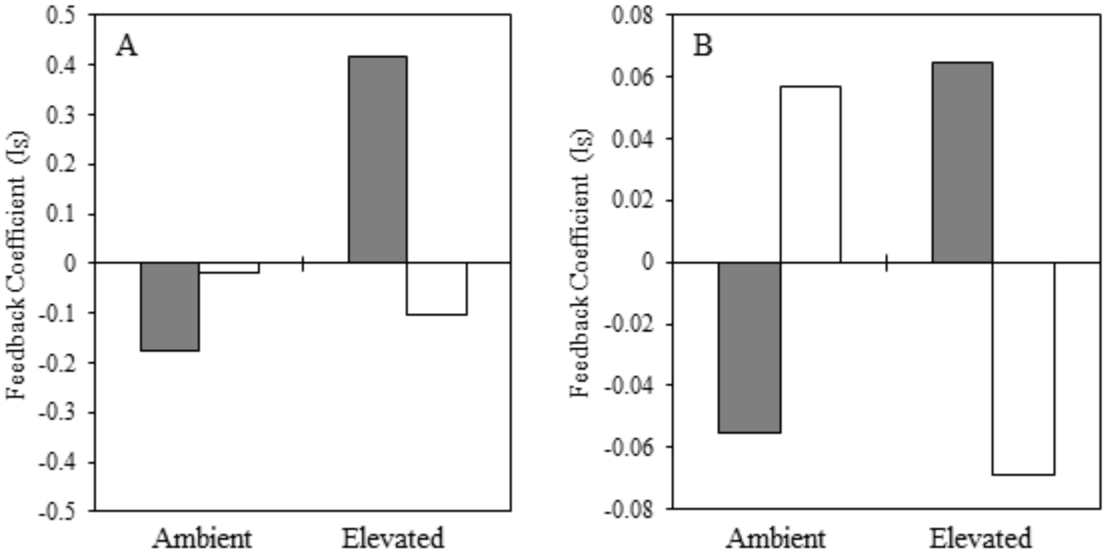
2) Examine the strength and direction of native and non-native grass PSFs under projected climate scenarios (drought conditions and elevated temperatures)


Ambient temps
Elevated temps
Inoculum Training Phase (Duell et al. 2016)
W
W
D
D
W
W
D
D
Native
Invasive
AW
AW
AD
AD
EW
EW
ED
ED
AW
AW
AD
AD
EW
EW
ED
ED
Ambient temperatures
Elevated temperatures
Assessment of Environmental Microbial Legacy and Plant-Soil Feedbacks

# Results


A
B
C
D
Native soil
Invasive soil
Ambient experimental temp/ambient source temp
Ambient experimental temp/elevated source temp
Elevated experimental temp/ambient source temp
Elevated experimental temp/elevated source temp
total biomass (g/ plant)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
b
ab
a
S. scoparium
B. ischaemum


A
B
C
D
Native soil
Invasive soil
Ambient experimental temp/ambient source temp
Ambient experimental temp/elevated source temp
Elevated experimental temp/ambient source temp
Elevated experimental temp/elevated source temp
total biomass (g/ plant)
0
0.5
1
1.5
2
P. smithii
B. inermis

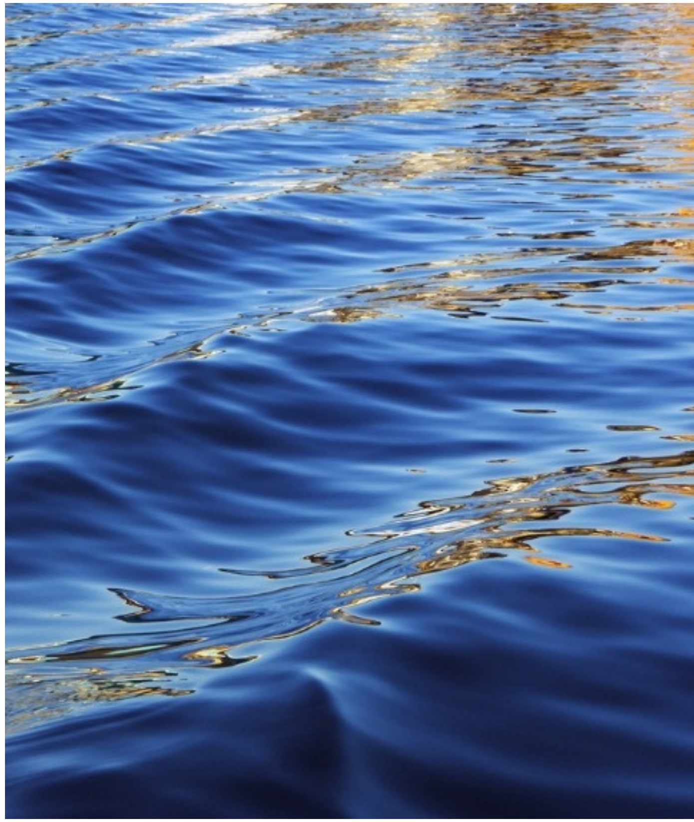



So…what does this mean??

When conditions are similar from $t_1$ to $t_2$, negative PSF between native and invasive species are generated, suggesting coexistence.

However, positive PSF are detected when conditions change from $t_1$ to $t_2$, suggesting dominance by invasive species

# Effects of Drought on Wildflowers: Implications for Pollinator Conservation



# Impacts of Climate Change on Flowering Plants

- Altered phenologies (i.e. germination, flowering, seed set, etc.)

- Reduced productivity and floral resources

- Altered anti-herbivore defenses

# Multi-trophic Consequences

- Delayed or accelerated phenologies can result in mismatch with pollinators
- Reduced floral resource production leads to disrupted pollinator interactions
- Altered defenses may disrupt tightly-linked symbioses

# Objectives of this Study

1) Assess productivity and reproductive responses of prairie forbs to reduced soil moistures

2) Examine the effects of drought on floral resources (nectar)

3) Assess the effects of reduced soil moistures on production of plant anti-herbivore defenses

4) Determine the effects of reduced soil moistures on AM fungal communities associated with these species

*Salvia azurea*
Pitcher sage

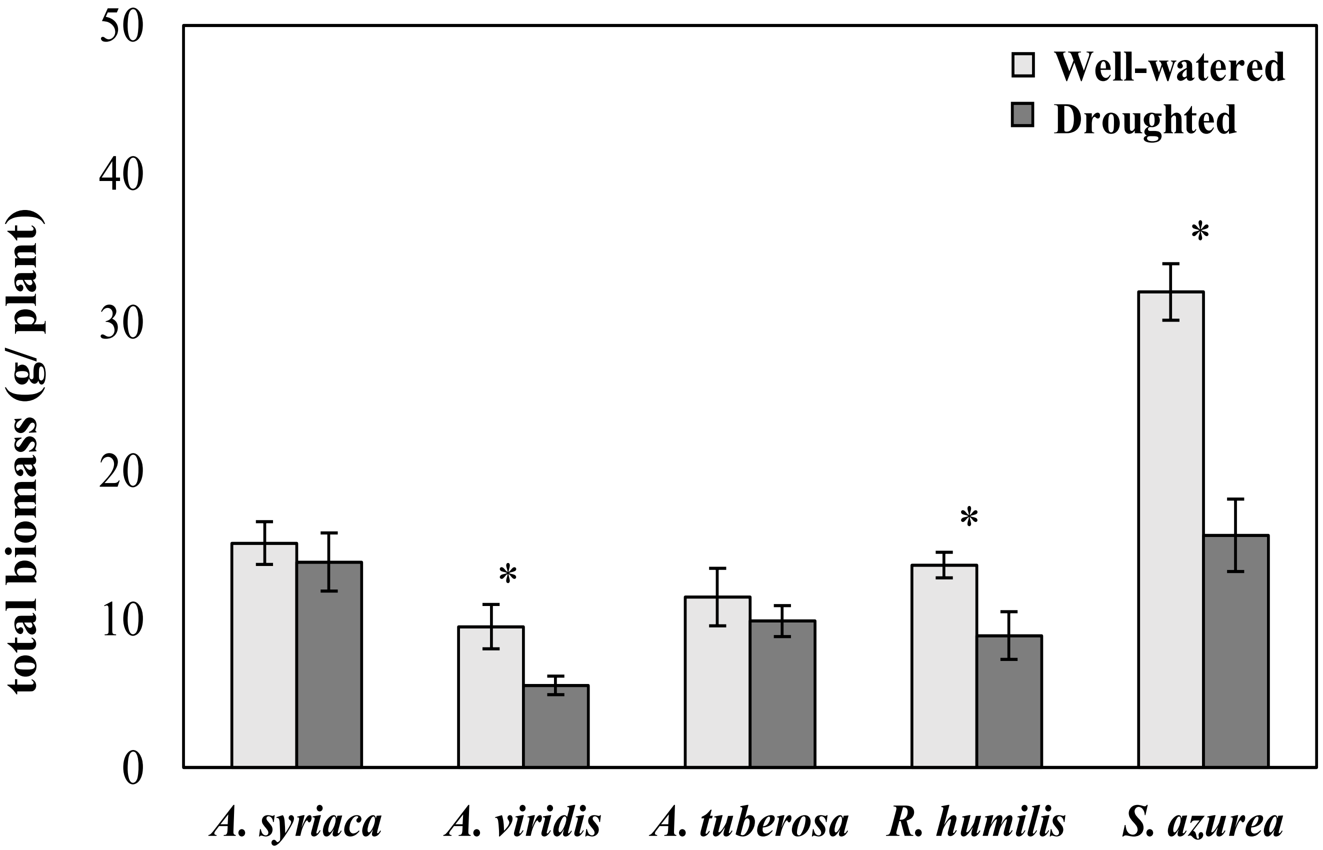
*Asclepias tuberosa*
Butterfly milkweed

*Ruellia humilis*
Hairy wild petunia

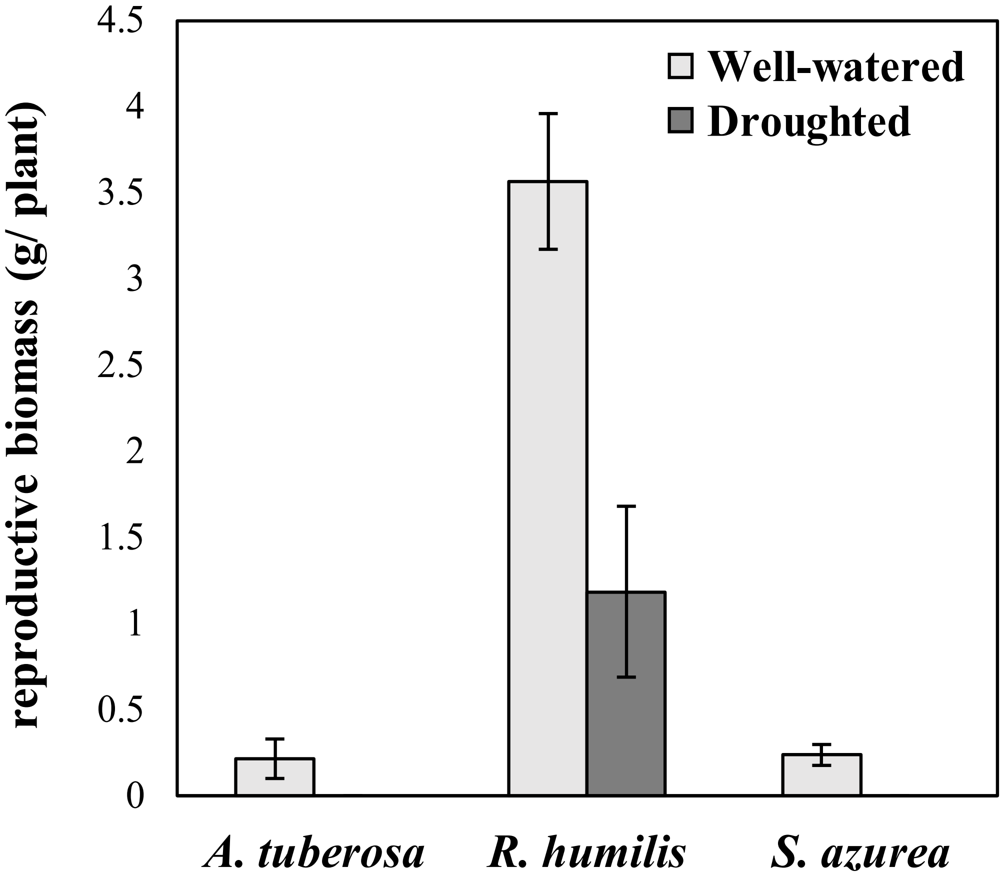
*Asclepias viridis*
Green antelopehorn

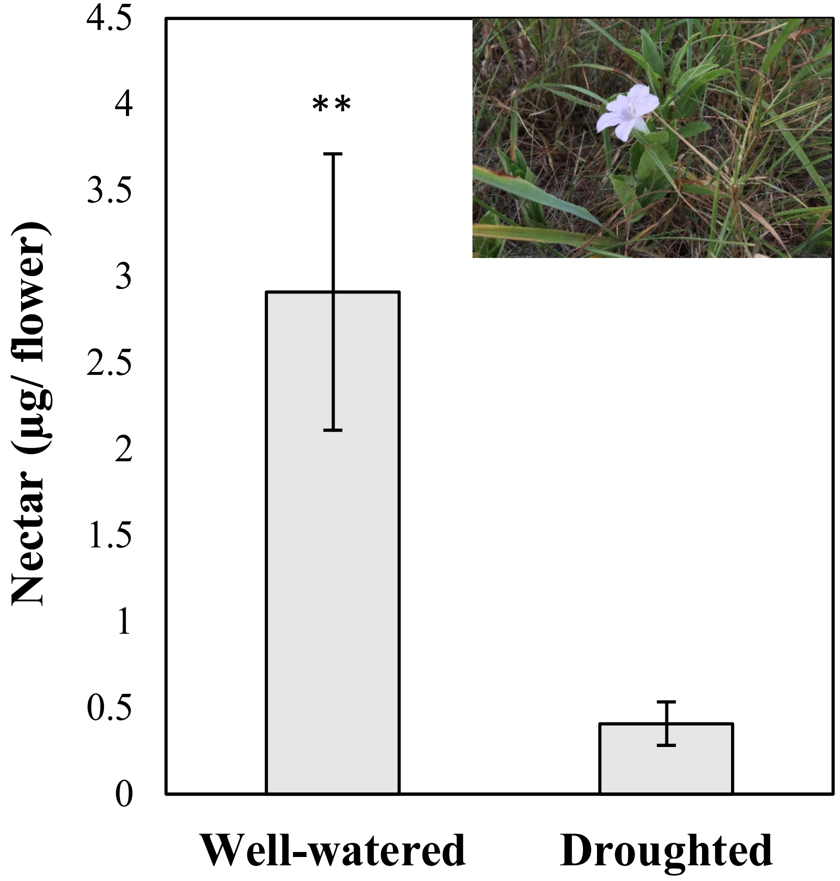
*Asclepias syriaca*
Common milkweed

# Total Biomass Production

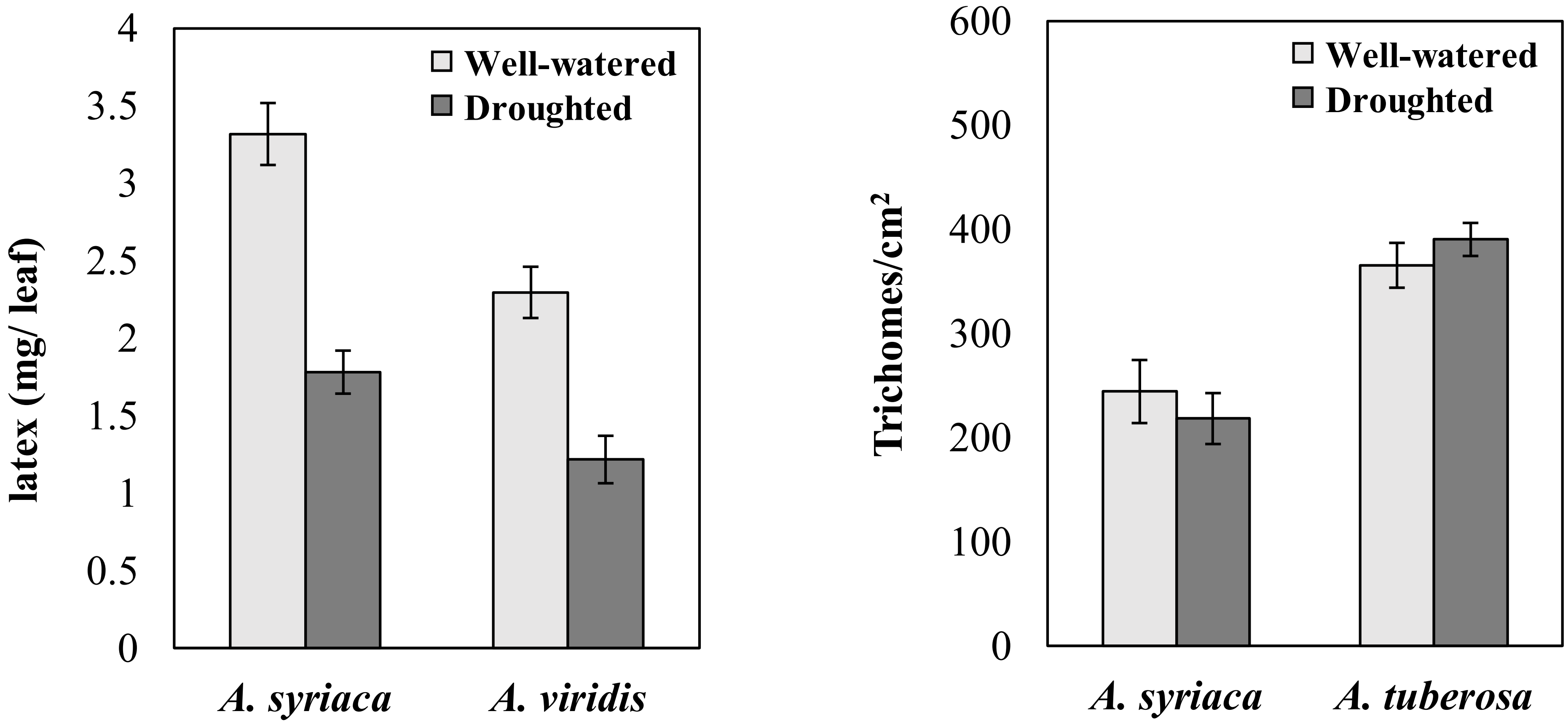



# Reproductive Biomass & Nectar Production

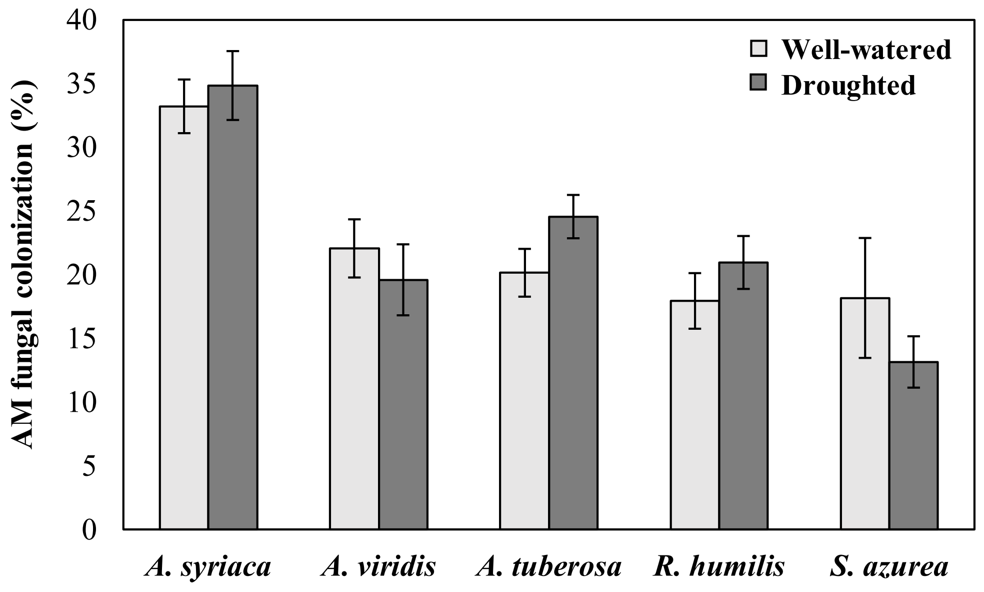


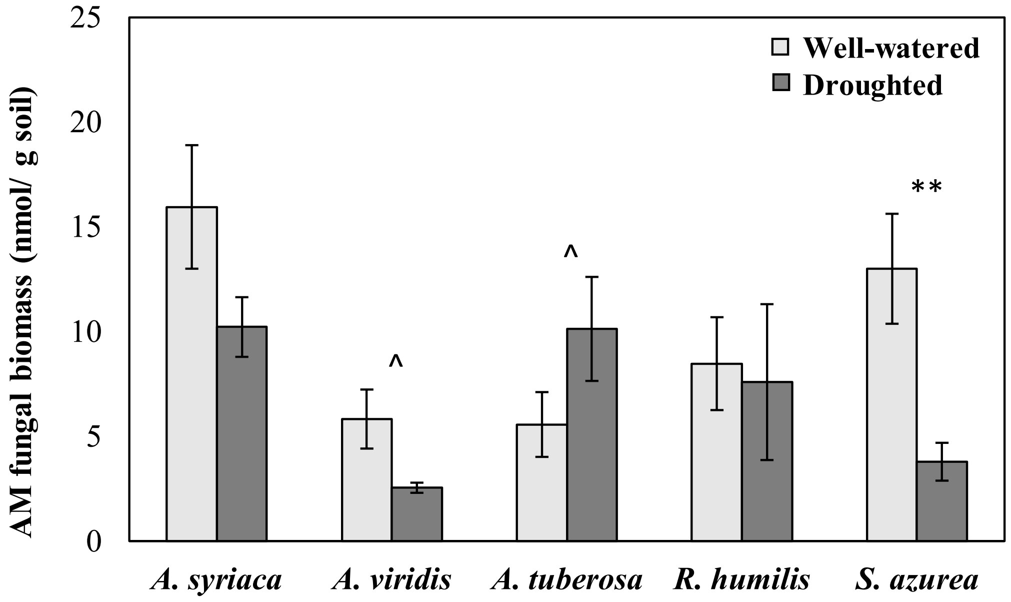



# Plant Defenses



# AM Fungal Communities



# Conclusion/Summary

Drought reduces productivity and reproductive capabilities of grassland forbs

Drought may reduce nectar production in these species

Drought can impact the production of anti-herbivore defenses, but the responses appear to be largely species-specific

Impacts on soil microbial communities may also depend on host plant identity

# Take-home Message

- Climate change typically affects organisms indirectly through ECE's
- Many trophic levels impacted, from soil fungi to plant communities, and arthropods to birds
- Because organisms do not exist inside a vacuum, there will be indirect consequences for organisms that depend on those that are directly affected
- Many of these relationships are incredibly complex, and we are just starting to tease apart the impact of climate and weather patterns on these interactions