In this paper we investigate two questions...

1) How do native plants adjust their functional traits for different environmental conditions?

&

2) Which of the five study species are well-suited for drought and competition?

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Art by Vicky Cheung
A plant could focus growth on roots during drought. A plant could focus growth on either on stems & leaves or roots, depending on the plant it competes with.

But it is not clear how a plant will focus growth when in competition and drought simultaneously...

Optimal partitioning theory? Plants allocate biomass to organs that acquire the most limiting resource.

Environmental filter theory? Drought & competition may filter out certain plants, depending on their traits...

Abiotic filter

Biotic filter

Drought tolerant plants grow slower and have smaller leaves...

Therefore, traits can be related to survival! As such, they can help guide plant selection for restoration projects.
WE PICKED FIVE NATIVE SPECIES COMMONLY USED FOR COASTAL CALIFORNIA RESTORATION AND TESTED HOW THEY RESPONDED TO DROUGHT AND INVASIVE COMPETITION.

FOR THE COMPETITION TREATMENT, WE USED FIVE INVASIVE SPECIES COMMONLY FOUND IN CALIFORNIA.
WE MEASURED KEY TRAITS TO UNDERSTAND HOW NATIVE SPECIES RESPONDED AND MANAGED STRESS FROM Drought AND INVASIVE COMPETITION. (4, 5)

1. **Lobedness**
   - Low: Leaf cooling via transpiration
   - High: Leaf cooling via nearby air

2. **Specific Leaf Area (SLA)**
   - $1g \rightarrow$ higher SLA related to low leaf life span
   - $3g \rightarrow$ lower SLA related to high leaf life span

3. **Major Vein length Per Area (VLA)**
   - Lower VLA: Related to higher water and sugar transport
   - Higher VLA

4. **Water Use Efficiency (WUE)**
   - The rate of carbon dioxide is taken up for photosynthesis
   - $\text{WUE} \propto \frac{\text{carbon assimilation}}{\text{stomatal conductance}}$
   - The rate of water leaving the leaf

5. **Growth rate & Biomass**
   - Aboveground biomass (AGB)
     - 7 months later: higher growth rate & biomass
   - Belowground biomass (BGB)
     - 7 months later: lower growth rate & biomass
We simulated four different environmental treatments with a combination of drought and invasive competition and compared the growth patterns of native species.

P.S.: The “well-watered” pot is also known as the control group, which does not receive any experimental treatment. Invasive species were shown at densities equivalent to those observed in the field.

**Experimental Designs:**

- **Drought**
- **Well-watered**
- **Drought + Competition**
- **Well-watered + Competition**
As a result, we found that some species are more tolerant to drought and competition, while other species are more sensitive...

These 2 species may be more sensitive to drought, because they were not able to adjust their biomass allocation and functional traits during drought (red and orange columns).

Bromus carinatus grew faster and had higher SLA in competition, indicating it may be suitable for restoring in areas with invasive species.

These 2 species were able to adjust allocation to roots in response to drought & competition. They also had no reductions in carbon assimilation or stomatal to drought.

Increased root growth could help improve acquisition of resources limited by drought or competition.
Bromus carinatus showed weak signs of competitive release, because it recovered faster when in drought + competition than in drought only...

Diplacus aurantiacus showed stronger signs of competitive release, because it had lower loss of photosynthesis and WUE (see supp) during drought and competition compared to just drought.
CONCLUSION

1) Native species have diverse responses to drought and invasive species & results are consistent with optimal partitioning theory and environmental filter theory.

2) The results imply that grass species may be effective species for coastal California grass restoration in invaded areas;

3) Grass may be more useful during dry years when there's less competition whereas introducing herbivores may be more effective during wetter years.
SUPPLEMENTAL
Trade-offs in growth responses

Plants have to balance growth patterns in order to survive, contrasting environmental filters. For example, it is uncommon to have focused growth in both roots and leaves during different stressors.

Diagram:
- **Resource Conservative**
  - High leaf C:N
  - High VLA
  - High lobedness
  - Low growth rate
- **Resource Acquisitive**
  - High SLA
  - High %N in leaf
  - High growth rate

**Snooth Allocation**

**Root Allocation**
STIPA PULCHRA AND SidalceA MALUFLORA GAS EXCHANGE WERE NOT AFFECTED BY DROUGHT OR COMPETITION.

DIPLOACUS AURANTIACUS HAD DECREASED CARBON ASSIMILATION AND STOMATAL CONDUCTANCE DURING DROUGHT, BUT HIGHER WUE WHEN IN BOTH COMPETITION AND DROUGHT.

DROUGHT DECREASED LUPINUS NANUS STOMATAL CONDUCTANCE, CARBON ASSIMILATION, CARBON ASSIMILATION AND WUE FURTHER DECREASED DURING DROUGHT AND COMPETITION.
Nighttime WUE

DURING NIGHTTIME, PLANTS EXPERIENCE RESPIRATION INSTEAD OF PHOTOSYNTHESIS. RESPIRATION IS THE RELEASE OF CO₂ FROM THE LEAVES AS A RESULT OF THE DARK CIRCLE.

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<tr>
<th>Well-watered</th>
<th>Drought</th>
<th>Well-watered + Competition</th>
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<td><img src="well-watered-competition.png" alt="Plant Image" /></td>
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**We used green light so we did not trigger photosynthesis during dark hours, because plants don't absorb green light.**

**COMPARISON INCREASED RESPIRATION AND DROUGHT DECREASED STOMATAL CONDUCTANCE FOR DIPLOCAUS AURANTIACUS.**

**COMPARISON INCREASED RESPIRATION ONLY DURING DROUGHT AND DROUGHT DECREASED STOMATAL CONDUCTANCE FOR STIPA PULCHRA.**

**DROUGHT DECREASED STOMATAL CONDUCTANCE, WHICH WAS FURTHER REDUCED WHEN IN COMPETITION FOR LUPINUS NANUS.**

**References**