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Exploring Plant Interactions for Restoration: A Focus on Above and Belowground Traits

INTRODUCTION

1.

Image 1. Silphium Integrifolium cleaned Roots

Restoring land following damage and degradation through the implementation of native plant species is a vital part of keeping our ecosystems healthy (Egoh et al., 2021). Investigating the above and below-ground traits of plants can help meet restoration goals. We can improve restoration plant communities by considering plant traits. Evaluating root traits presents a challenge due to intensive labor and the time it can cost, yet it plays a crucial role in the restoration process (Garbowski et al., 2020). Investigating these traits can help us gain insight into plant performance. Plants tend to compete with each other for their resources and some even compete more with themselves than other species, so we need to further understand how they interact before introducing them together in restorations. We focused on evaluating and predicting root traits due to the difficulty associated with measuring them despite the importance of their influence on plant interactions. Understanding how these native species interact with one another might help us to understand how they interact with each other in restoration. This was our ultimate goal because every species and environment is unique. In order to meet these goals we conducted an interactive experiment on above-ground traits to better understand belowground traits.

2.

Image 2. Silphium Integrifolium polyculture Roots

HYPOTHESES

- Silphium and Dalea growth and trait responses are expected to vary across different little blue stem densities.
- Additionally, we hypothesize that root length can be predicted using easily obtainable shoot measurements.

METHODOLOGY

Plant Selection:
Three plant species-Little BlueStem Prairie grass(*Schizachyrium Scoparium/SIIN*), Rosinweed (*Silphium Integrefolium/ CSC*), and Purple Prairie Clover(*Dalea Purpurea/DAPU*).

Experimental Set Up:
- 202 plants across 80 pots with
- 8 different treatment groups were established.
  - Treatment 1 one SCSC in a pot.
  - Treatment 2 one DAPU in a pot
  - Treatment 3 one SIIN in a pot
  - Treatment 4 two SCSC in a pot
  - Treatment 5 two DAPU in a pot
  - Treatment 6 two SIIN in a pot
  - **Treatment 7 one SCSC, 2 DAPU, and 2 SIIN in a pot (Density One)**
  - **Treatment 8 two SCSC, 2 DAPU, and 2 SIIN in a pot (Density Two)**
- Pots filled with a 50/50 mix of soil and field conditioner for ease of root excavation.
- Inoculated with Mettewa soil and lab water to introduce site-specific microbes, enhancing root trait relevance and field site resemblance.
- Plants interacted for 6 weeks.

Tests Used:
- ANOVA and Mann-Whitney U test were used to compare means.
- To address hypothesis number 1 We used linear regression and Random forest algorithms to predict the traits.

Data Collection:
- Measured shoot growth and flowering patterns of the plants.
- Collected biomass of both shoots and roots for analysis.
- Root length and shoot height measurements were taken.

3.

IMAGE 3. GREENHOUSE PRAIRIE PLANT EXPERIMENT

Machine Learning:
Our analysis utilized a robust dataset of 1633 observations. Two predictive models were employed and compared for their performance. With the goal to predict root length. (See fig 6.)
- The training set has 1224 data points and the test set has 409
- We input plant height, shoot mass, leaves, and number of individuals in a pot to predict root length.
- Used Root Mean Square Error (RMSE)
- R-squared (RSQ)
- Mean Absolute Error (MAE)

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4.

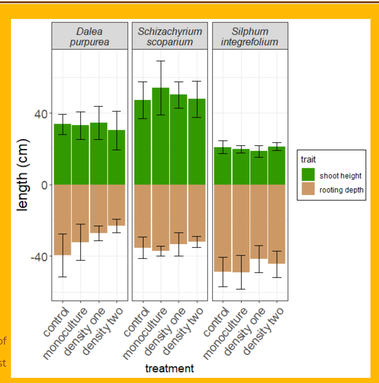


figure 4. Chart of shoot and root growth amongst *treatments.*

5.

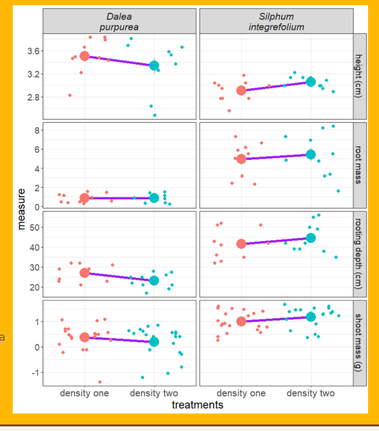


figure 5. Left-Dalea Purpurea. Right-Chart of *Dalea and Silphium treatments competition.*

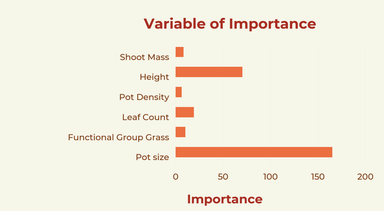
RESEARCH / FINDINGS

Outcomes:
- The Little Bluestem Prairie grass grew taller then the other species. (see fig 4.)

Silphium Integrefolium:
- **Silphium showed more growth under density two conditions than under density one conditions. (fig. 4)**
  - Shoot mass varied with treatments (R-squared = 0.2, p = 0.04).
  - Height differed by treatments (R-squared = 0.1, p = 0.03).
  - Showed greater root growth amongst all treatments.(see fig. 4, 5)
  - Root mass: W = 888, p = 0.4; not a significant difference.
  - Rooting depth: no significant difference across treatments.

Dalea Purpurea:
- **Dalea showed more growth under density one conditions than under density two conditions. (fig 5.)**
  - Shoot mass and height did not differ significantly across treatments.
  - Root mass: W = 752, p = 0.6; not a significant difference.
  - Root length varied with treatments (R-squared = 0.22, p = 0.04).
- These supports our hypothesis of variances across densities.

6.



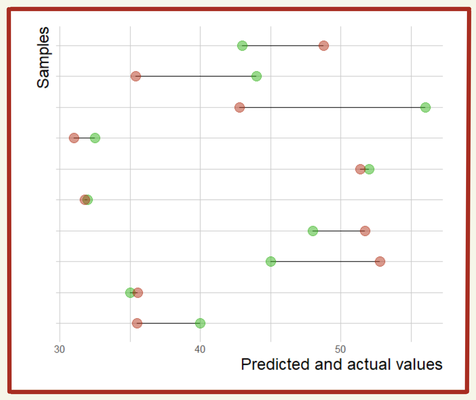


figure 6. Top- Chart of variable of importance. Bottom Chart-Predicted and actual values.

MACHINE LEARNING

- **We conducted an in-depth assessment of above-ground characteristics, including shoot height and leaf and shoot biomass, aiming to predict below-ground traits of root length.**
- observations. Two predictive models were employed and compared for their performance. (See fig 6.)

Model Performance Comparison:
1. Linear Regression:
   - RMSE: 3.74
   - RSQ: 0.88
   - MAE: 1.7
2. Random Forest:
   - RMSE: 2.56
   - RSQ: 0.94
   - MAE: 1.2

7.

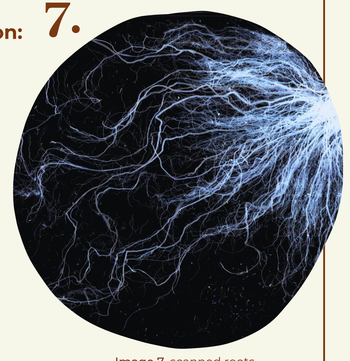


Image 7. scanned roots.

CONCLUSIONS

There is evidence that we can possibly predict root length from easy-to-measure aboveground traits, but more data is needed to improve this prediction.
- We found that the Dalea plants grown with a higher density of its species showed less growth amongst other plants. Dalea had reduced growth with more Little Bluestem density.
- We also discovered that overall Silphium will do better amongst Little Bluestem within a prairie environment. Silphium had increased growth with a higher Little Bluestem density.

These findings provide valuable insights for contemplation when considering land restoration strategies. Dalea might very well be a core competitor when considering little bluestem prairie plants.

RELATED LITERATURE
Wu, N. et al (2023). Comparing the performance of machine learning algorithms for estimating aboveground biomass in typical steppe of northern China using Sentinel imageries. Ecological Indicators, 154, 110723. https://doi.org/10.1016/j.ecolind.2023.110723

Siefert, A., Friesen et al (2021). An experimental test of stabilizing forces in the field niche. Ecology, 102(4). https://doi.org/10.1002/ecy.3290

Egoh, B. N., et al. (2021). Rewilding and restoring nature in a Changing World. PLOS ONE, 16(7). https://doi.org/10.1371/journal.pone.0254249

Garbowski, M. (2020). Getting to the root of restoration: Considering root traits for improved restoration outcomes under drought and competition. Restoration Ecology, 28(6), 1384–1395. https://doi.org/10.1111/rec.13291