Comparative Analysis of Wild Annual and Herbaceous Perennial *Astragalus* (Fabaceae)

Summer D. Sherrod[1], Sterling Herron[2], E. Claudia Ciotir[2], Allison J. Miller[2]

[1] UNT UNIVERSITY OF NORTH TEXAS
[2] SAINT LOUIS UNIVERSITY

Acknowledgements
The authors would like to thank the Missouri Botanical Garden greenhouse staff, Emma Bergh, Monica Carlsen, Peter Hoch, Wendy Applequist, Matthew Albrecht, Claire Waldmen, Joseph Smith, and many other associates for their assistance with this project


A. canadensis
© Summer D. Sherrod


A. crassicarpus
© Prairie Moon Nursery


A. lindheimeri
© Terry Pringle


A. nuttallianus
© Marilyn M. Knight

Introduction

Many ecological crises are driven in part by agricultural activities.[4] Herbaceous perennial crops planted in polycultures that mimic natural ecosystems are proposed as an auspicious solution to modern agricultural challenges.[1, 3, 4, 6] There is just one problem: herbaceous perennial crops do not exist.[6] **Little is known about the domestication of herbaceous perennials**.[4, 6] How will selection for reproductive output affect vegetative traits and perenniality? This study seeks preliminary answers by examining physiological and morphological characteristics of wild annual and perennial *Astragalus* species through multiple experiments with both live plants and herbarium specimens.

We hypothesized that…

1. Perennials will exhibit lower germination rates than annuals, without either being significantly affected by cold stratification
2. Perennial seedlings will grow at a slower rate than annuals
3. Perennial seedlings will exhibit greater biomass allocation to root systems than annuals
4. Mature perennial plants will exhibit trade-offs in the allocation of resources to their reproductive and vegetative characteristics relative to annuals [2, 5]

Methods

Study System and Species Selection

Monophyletic *Astragalus* is the largest plant genus in existence (3000+ sp.)– most species are either annuals or herbaceous perennials, advantageous for studying relations between the two

- Perennials: *A. canadensis* and *A. crassicarpus*
- Annuals: *A. lindheimeri* and *A. nuttallianus*

Experiments

Hypothesis 1: Conducted comparative germination trials examining effect of cold stratification on the two life strategies; data was analyzed with a generalized linear mixed-effects model
Hypothesis 2: Successful germinants were transplanted and measured after 15 and 21 days of growth to examine growth rate; data was analyzed with a generalized linear mixed-effects model
Hypothesis 3: After 21 days, seedlings were harvested and dried, then mass of the root and shoot systems measured; ratios were analyzed with one-way analysis of variance (ANOVA)
Hypothesis 4: Vegetative and reproductive structures on herbarium specimens from Missouri Botanical Garden collections were measured to examine their relationship; data were analyzed using Spearman's correlation matrices and factorial ANOVAs

Results

Hypothesis 1: Cold stratification greatly improved germination percentages of both perennials and annuals but the two life strategies exhibited only minor differences overall. (Figure 1)
Hypothesis 2: Average seedling heights and early growth rates between life strategies were statistically nonsignificant. (Figure 2)
Hypothesis 3: There were only marginally significant differences in root:shoot biomass ratios between the life strategies. (Figure 3)
Hypothesis 4: In *Astragalus* overall, reproductive traits are generally positively correlated with vegetative traits – this trend is mirrored within annuals. In perennials, however, pod characteristics are negatively correlated with vegetative traits while flower characteristics are positive. Using data from the living accessions and herbarium specimens, we found only minor differences in seed mass between the life strategies. (Figure 4)

Conclusions

Our study found only marginally significant differences in the physiological characteristics of select perennial and annual *Astragalus* species. It is possible that small sample sizes affected this outcome since the patterns in our results largely followed our hypotheses (see figures). The demonstrated correlation between morphological traits in perennials was unexpected – it is possible that measurements of herbarium specimens for *A. canadensis* skewed the results since a full, mature plant cannot fit on one herbarium sheet. However, it is encouraging that floral traits are positively correlated with all vegetative traits in perennial plants, and nearly all traits are positively correlated across these species. These findings are encouraging since they generally indicate a lack of physiological differences and morphological trade-offs in perennial and annual *Astragalus*. The future of polyculture agriculture systems, which may include perennial *Astragalus* crops, is promising.

Figure 1: Germination Probability by Treatment

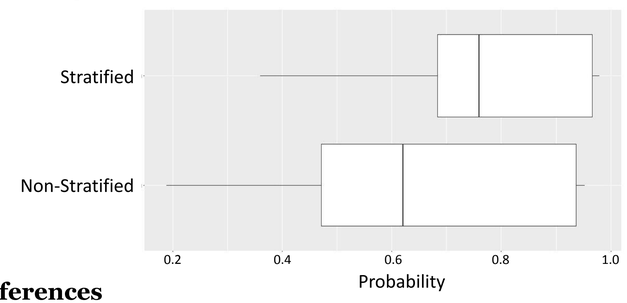


Figure 2: Growth Rate by Strategy

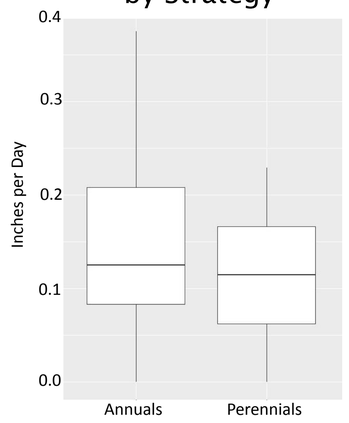


Figure 3: Biomass Ratio by Strategy

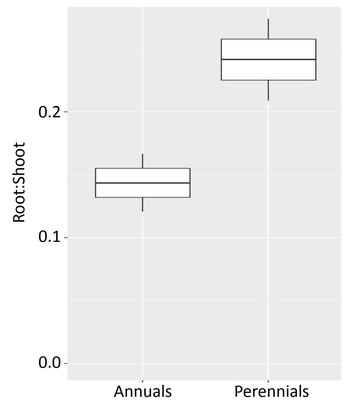
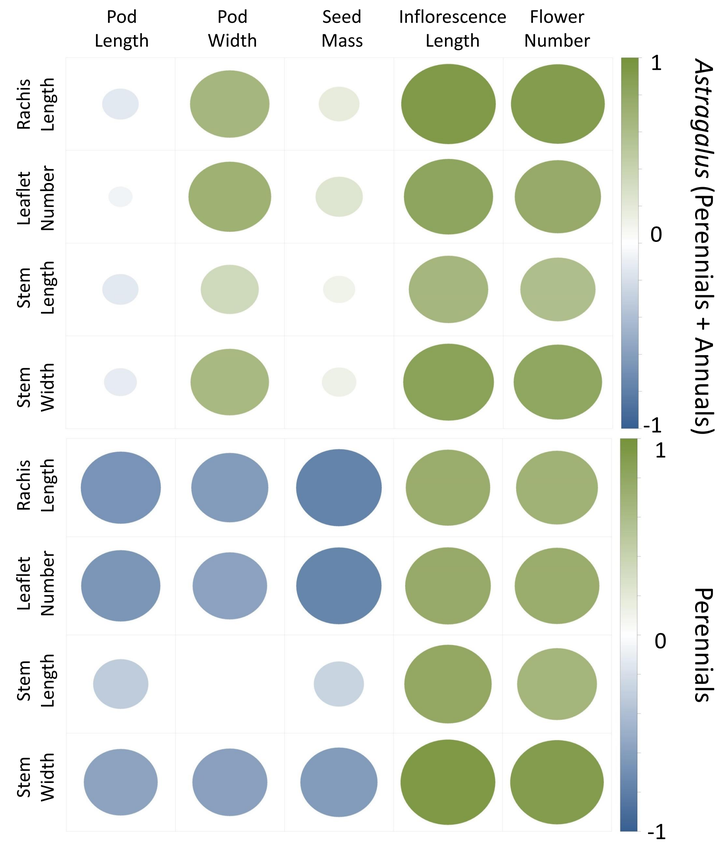


Figure 4: Correlation Matrices for Vegetative and Reproductive Characteristics of *Astragalus*



References

1. DeHaan, L. R., D. L. Van Tassel, and T. S. Cox. 2005. Perennial Grain Crops: A Synthesis of Ecology and Plant Breeding. *Renewable Agric. Food Syst.* 20:5-14.
2. Diaz, S., J. Kattge, L. D. Gorne et al. 2016. The Global Spectrum of Plant Form and Function. *Nature* 529:167-171.
3. Jackson, W. 1980. *New Roots for Agriculture.* Lincoln, NE: University of Nebraska Press.
4. Montgomery, D. R. 2007. Soil Erosion and Agricultural Sustainability. *Proc. Natl. Acad. Sci. USA* 104:13268-13272.
5. Roff, D. A., and D. J. Fairbairn. 2007. The Evolution of Trade-offs: Where are we? *J. Evol. Biol.* 20:433-447.
6. Van Tassel, D. L., L. R. DeHaan, and T. S. Cox. 2010. Missing Domesticated Plant Forms: Can Artificial Selection Fill the Gap? *Evol. Appl.* 3:434.