INNOVATING FOR BIODIVERSITY CONSERVATION

The urgency of safeguarding our native flora has driven my passion to enhance the efficacy of conservation efforts and contribute to the broader understanding of plant biodiversity. By employing a pluralistic approach that integrates various data types and sources, I will explore how to maximize the effects of taxonomic research by combining classical and cutting-edge methods.

HOW CAN PHENOMICS INFORM TAXONOMY AND PLANT CONSERVATION?

While much of my research is plant system agnostic, my previous focus has predominantly been on horticultural selections in *Cercis spp.* and native floral systems including *Sarracenia* and *Passiflora*. Across these systems, I aim to answer the questions:

1) How can modern phylogenomic approaches be integrated into taxonomic circumscription?
2) How can impacts on natural plant populations be minimized during research?
3) How can researchers efficiently leverage limited resources for plant conservation?

Through my work, I seek to develop rigorous pipelines for taxonomic delimitation that are applicable to a wide range of plant systems. Put simply**, my lab will focus on investigating plant system taxonomy while minimizing impacts on natural resources and maximizing conservation, education, and outreach.**

INTEGRATING MODERN AND HISTORICAL TAXONOMIC APPROACHES

My approach is characterized by its pluralistic nature, as I seek to bridge the gaps between taxonomy, breeding, and phenomics. Species concepts provide clearly defined sets of rules for taxonomic delimitation. However, because of their rigidity, they often lack utility in real-world applications. My unique approach leverages the Pluralistic Species Concept, which contends that a single optimal classification system exists for each taxon but the data types used to circumscribe species or subspecies may vary.

My lab will identify the genetic basis for the phenotypes historically used in taxonomic delineation. By unraveling the genes behind these relevant traits, I aim to combine traditional morphometric analysis with modern genetic techniques to advance understanding of plant taxonomy and conservation. In my dissertation, I used high throughput imaging of an F_2 ornamental breeding population of redbud (*Cercis canadensis*) to gather traits like leaf apex shape, leaf area, and tree height and used association mapping (GWAS) to identify regions of the genome associated with those phenotypes. This approach emphasizes the relevance of multiple genes used for phylogenetic analysis in downstream taxonomic interpretation and can be thoroughly extended using inexpensive *de novo* genome assemblies.

Phenotypes result from the intersection of genetics with the environment. While environment and ecology traditionally aid species delimitation, their integration with genomic and phenotypic data is rare. Comparing morphometric data from environmentally distant individuals allows measurement of the interaction of different genotypes and environments on phenotype. This multidimensional approach enhances taxonomic understanding and fosters opportunities for the development of high-throughput, low-cost methods. By comparing morphometrics of pressings from known provenance trees at JC Raulston Arboretum to wild specimens, I assessed environment's effect on *Cercis* subspecies traits while also identifying the genetic basis of these traits (Figure 1, publication in prep). Analyzing phenotypic responses in varied conditions enhances our insight into taxonomy's role in plant adaptability and resilience.

MINIMIZING IMPACTS ON NATURAL POPULATIONS

Taxonomy is crucial for conservation and breeding, forming the basis for effective management. In plant breeding, taxonomy guides parent plant selection for hybridization, enhancing cultivar development. In *Cercis canadensis*, the southwestern subspecies has a more compact growth form and

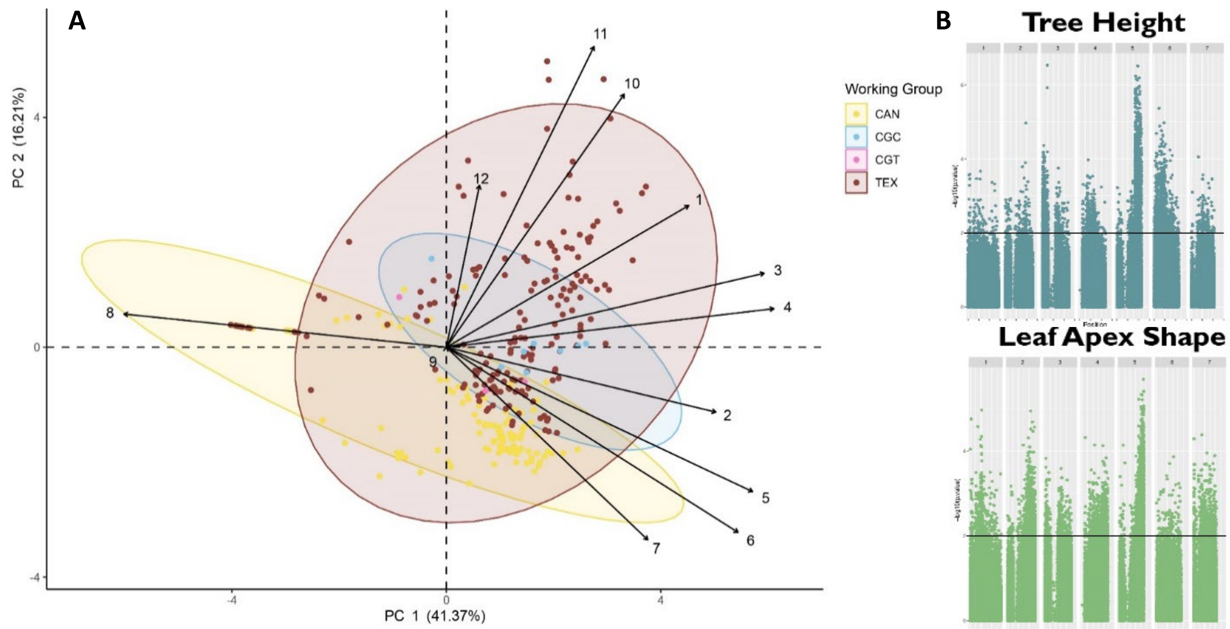

Figure 1 A) PCA of plants grown at the JC Raulston Arboretum (common garden) and those from the Fritsch et al., 2018 dataset (herbarium specimens for wild collected *Cercis*). The CAN (subsp. *canadensis;* yellow) and TEX (subsp. *texensis;* maroon) working groups are from Fritsch et al., 2018. The CGC (subsp. *canadensis;* blue) and CGT (subsp. *texensis;* pink) working groups are from the common garden. Ellipses are based on individuals within working groups. CGT does not have an ellipse because there are only three individuals from that group. Component loadings shown as black arrows: 1 – Leaf Apex Shape, 2 – Leaf Sinus Shape, 3 – Leaf Length, 4 – Leaf Width, 5 – Fruit Length, 6 – Fruit Width, 7 – Fruit Wing Width, 8 – Flower Length, 9 – Branchlet Pubescence, 10 – Leaf Pubescence, 11 – Leaf Trichome Number, 12 – Fruit Pubescence. **B)** Manhattan plots where X-axis displays chromosomes one through seven. Y-axis displays -log10 of raw p-values for each SNP. Each point represents an individual SNP with the black horizontal bar being placed at -log10=2 which roughly correlates to an adjusted p-value of ~0.1.

drought tolerance while the Mexican subspecies cannot survive extended cold. Even though the range of these subspecies overlaps, having a clear understanding of the taxonomy necessary to delimit these subspecies helps when selecting parents for hybridization. Unfortunately, the cumulative effects of repeated visitation and sampling for research and breeding have contributed to the decline of natural plant populations. **I minimize research impact on natural populations by collaborating with horticultural programs, botanical gardens, ex-situ collections, land trusts, government natural resources departments, landowners, and herbaria.** For instance, partnering with Atlanta Botanical Garden's ex-situ populations and ornamental breeding populations at Meadowview Biological Research Station for pitcher plants (*Sarracenia)* minimizes in-situ field work. Engaging diverse stakeholders removes reliance on destructive native sampling. Non-destructive methods like climatic data, plant-insect interactions, and remote sensing via low-cost data loggers and drones provide extensive ecological insights. By collaborating with diverse groups that share a common interest, I will continue to tap into cultivated populations for conservation and breeding, relieving pressure on wild plants.

MAXIMIZING RESOURCES, EDUCATION, AND OUTREACH

I am exploring new frontiers in established methodologies for plant science by utilizing 3D printing and rapid prototyping for the development of hardware. These custom tools facilitate adaptable data collection pipelines for rapid phenotyping and modeling of phenotypic variation. This approach helps alleviate resource constraints that can often hinder effective conservation work. I currently focus on the development of high-throughput, low-cost methods that leverage 3D printing technology (Figure 2). By creating innovative tools and resources, I intend to empower researchers and conservationists with the means to tackle conservation challenges in a resource-efficient manner. By involving my students in projects that incorporate a wide range of data sources, collection methods, and bespoke solutions, I aim to nurture the next generation of scientists with a profound appreciation for collaboration, exploratory methods, and biodiversity in plant science.

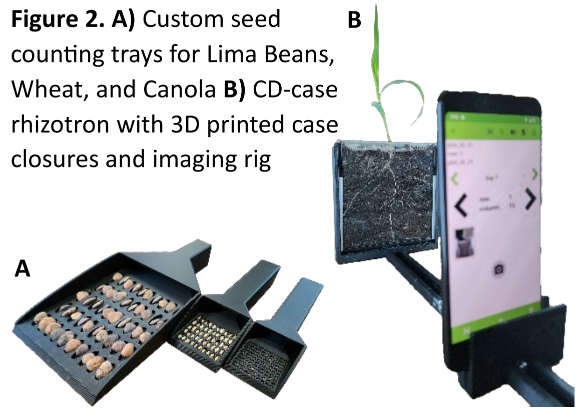

Figure 2. A) Custom seed counting trays for Lima Beans, Wheat, and Canola **B)** CD-case rhizotron with 3D printed case closures and imaging rig

TEACHING/MENTORING PHILOSOPHY

I believe my role is to facilitate learning and mastery by creating inclusive, accessible, and transparent lessons that foster critical thinking. Learning involves recalling and applying information, while mastery requires creative application of knowledge. I connect the "why" and "how" of what students learn, aiming for clarity and consistency. Recognizing educational disparities, I am dedicated to establishing equitable, student-centered, and inclusive environments. I view research, teaching, and outreach as interconnected components of my career, and I continually enrich my teaching and outreach practices with insights from my research.

I foster an inclusive and supportive environment for students of diverse backgrounds by prioritizing clarity and consistency and providing accessible resources for mentorship and teaching efforts. My goal is to create emotionally safe spaces where students can thrive and openly discuss their challenges. My enthusiasm for innovation and accessibility is evident in the resources I developed, especially in response to the challenges posed by the COVID-19 pandemic. These resources, including a 3D-printable board game and instructional videos, are available on my OSF repository (https://osf.io/n7yuw/).

I mentored numerous undergraduate and graduate students, actively engaging them in research-based experiences and peer-to-peer learning. I am passionate about nurturing young talent and providing a safe space to develop valuable skills for their professional and personal endeavors. During my graduate studies my undergraduate mentees were exposed to a diverse range of research subjects, from herbarium specimen collection, mounting, digitization, georeferencing, and cataloguing, to wet lab skills including DNA extraction, DNA quality control, library preparation, and gel electrophoresis. I was inspired by their enthusiasm and dedication and working with them remains a highlight of my academic journey.

During my postdoctoral fellowship, I mentored a recent high school graduate and a post-baccalaureate scholar. Together, the high school graduate and I explored horticulture, phenotyping, image analysis, 3D printing design, and the intricacies of maintaining 3D printing hardware during the summer of 2023. The post-baccalaureate scholar and I focused on building skills in processing, analyzing, and interpreting genetic and genomic data with a paper on onion (*Allium*) phylogenetics (in prep).

Looking ahead, my commitment to mentorship remains unwavering. I'm dedicated to promoting an emotionally safe environment and prioritizing students' well-being, both physically and mentally. In summary, my teaching and mentoring philosophy is built on inclusivity, support, and a devotion to nurturing students' potential. Through research, teaching, and service, I aspire to be a mentor who not only imparts knowledge but also inspires and empowers students to achieve their aspirations and make meaningful contributions to their fields and communities.

TEACHING ACTIVITIES

Throughout my career, I have developed multiple activities for teaching in the classroom and beyond. Including educational board games, modular workshops for incorporating novel technologies into research, and activities using 3D printed tools (Figure 3). I designed a hands-on workshop guiding participants through the process of designing and prototyping 3D printed designs. This workshop debuted at Botany 2023 and is set to expand to other conferences. For Plant Ecology courses, I created an educational board game to teach biological succession. In Plant Taxonomy I used 3D prints of real pollen grains to teach cladistics and dichotomous keys. My commitment to teaching and learning is a collaborative effort with my students, fostering their growth and curiosity while continuously improving my own abilities.

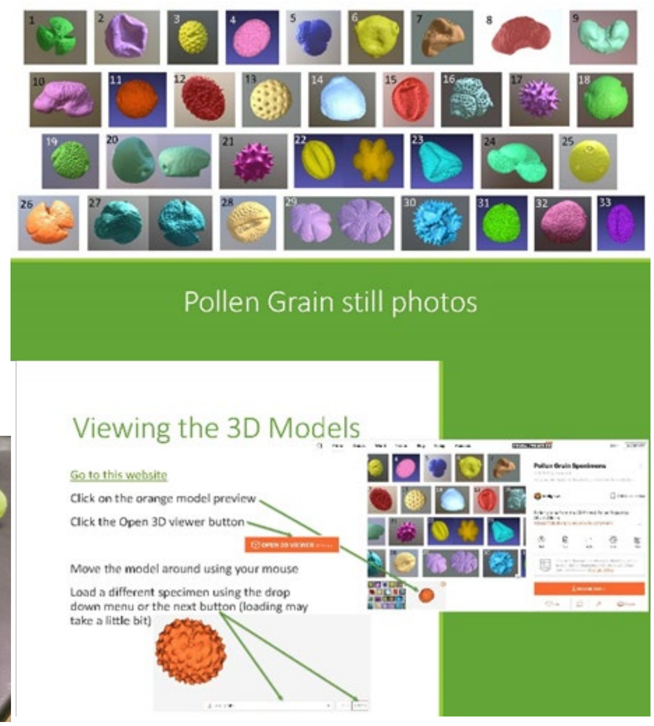

Figure 3. Activity teaching cladistics and dichotomous keys using 3D printed pollen

Part 1: Utilize provided materials (PowerPoint, images, or 3D models) to categorize pollen grains based on observed traits. Create a phylogram/dendrogram/tree to illustrate your hypothesis. Compare it with the genetic data-based phylogeny on the final slide and respond to the questions.

Part 2: Collaboratively generate a dichotomous key using the provided images and 3D models of pollen grains. Group size should not exceed 4 members, and each group should submit one key with all group members listed. Employ morphological terminology from previous labs to create an indented or bracketed key.

FUNDING AND COLLABORATION

At Michigan State University, my research program will be funded through a combination of internal, extramural, and industry sources. Proposals with a focus on taxonomic delineation can be drafted toward NSF (botany), USDA NIFA AFRI (breeding), and DOE (bioenergy). Professional society grants will support student projects and field work to gain insights into the role of taxonomy in conservation. Industry partnerships that I have cultivated during my postdoctoral fellowship (Prusa Research, LDO Motors, Fillamentum, Polymaker, Recreator 3D) will be maintained to develop technologies for further research. These collaborations provide resources, funding, and expertise that allow me to translate my research into practice. All these partnerships align with open-source principles, thereby benefiting researchers globally and maximizing outreach. My dedication to connecting taxonomy, phylogenetics, phenomics, plant breeding, and horticulture for conservation amplifies understanding, accessibility, and education. This position will allow me to delve into these questions via pluralistic strategies, collaboration, and the promotion of diversity.