Breeding and trait mapping towards the domestication of *Silphium integrifolium*

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The domestication of wild plant species beginning approximately 11,000 years ago was one of the greatest innovations in human history (Diamond, 2002). All modern human societies have found themselves fundamentally molded by the choices, both conscious and unconscious, made by the first domesticators.

Today, we as a society find ourselves facing challenges both incredibly similar and wildly different from those faced by the first domesticators. Like them, we face new uncertainties in climate that may cause interruptions to traditional food supply systems, and the challenges posed by a growing population (Bellwood, 2005). Unlike them, we face threats from disease and regional interdependence only made possible by a combination of globalization and genetic realities of the pool of crops from which we draw (Tanksley & McCouch, 1997). Less than twelve plant species provide 80% of the world's calories (McCouch et al., 2013). This lack of diversity in cropping systems creates incredible vulnerabilities for modern agriculture.

Another issue facing modern agriculture is a reliance on annual grain production. These systems present a number of challenges, including inefficient nutrient and water use, and the risk of soil erosion (Foley et al., 2005). Annual agriculture is also a major contributor to annual carbon emissions, both because of inputs and reduced carbon sequestration (West & Marland, 2002). Perennial agricultural systems, conversely, have the potential to reduce erosion and nutrient loss through their extensive root systems and more permanent ground cover, increase the amount of atmospheric carbon sequestered in soil, and reduce the inputs and tillage necessary for crop production (Gantzer et. al., 1990 ; Glover et. al. , 2007; Zan et. al, 2001). This solution has seen limited adoption because there are currently few agronomically viable perennial grain species.

The need for perennial grain crops, and a need to increase crop diversity in general, means new crops need to be developed. One solution is to domesticate new crops from wild species (Smartt, 1990). *Silphium integrifolium* (Michx.), common name "rosinweed" or "silphium" is a wild member of the *Asteraceae* family native to the central United States (Kowalski, 2004).

Silphium was selected as a candidate for domestication due to its relatively large seed size, drought tolerance, and agronomically favorable morphology (De Haan et. al., 2015) Subsequent analysis has found seed oil content comparable to traditional sunflower varieties (Van Tassel et. al, 2017). Domestication is a complex process that historically took centuries, but leveraging modern knowledge of genetics and genomics will speed progress (Varshney et al., 2012).

Currently, research teams at a number of institutions are taking part in an interdisciplinary effort to domesticate this species, incorporating fields from agronomy to genomics to food science. My research is focused on the breeding and genetics of silphium, and encompasses four main objectives: 1) To describe phenotypic variation in current breeding germplasm, 2) to map traits of interest, 3) to carry out selection for traits of interest,4) and to quantify the effects of inbreeding in silphium.

The first two objectives will be addressed using the Silphium Domestication Panel, a population of 380 genotypes representing the diversity of the silphium breeding program at the Land Institute. These genotypes have been clonally propagated at six locations, ranging from northwest Minnesota to southeast Texas, and will be tracked over several years for a number of yield, architecture, and developmental timing traits. These traits will then be mapped in a genome wide association study, taking advantage of diverse material and historic recombination events to identify quantitative trait loci for as many traits of interest as possible (Zhu et. al., 2008).

Towards the objective of breeding for improved silphium, we have initiated two recurrent selection populations. The first population was started by intermating individuals that initiated floral transition, or bolted, in their first year of growth. Most silphium genotypes require a full year of growth prior to flowering, and decreasing this cycle time is an important trait for rapid improvement. The second population was initiated by intermating plants that were in the shortest 20% for height, and among the earliest plants to reach anthesis. Reduced height is desirable to decrease lodging and increase harvest index, and earlier flowering may help evade disease pressure in some environments. Families of half siblings will be evaluated for both of these populations, and selection continued.

Finally, the nature of inbreeding depression in silphium is being investigated using several half and full sibling families. Pollination treatments were applied randomly to individuals within families, with seed fill percentage and seed weight recorded. These treatments were designed to quantify the mechanical versus genetic barriers to self-pollination, to identify plants sharing S alleles, to quantify the general effect of crossing within a family, and the effect of hand pollination. Inbred and outcrossed offspring from several of these plants will be grown to measure the effects of inbreeding on seed germination, vigor, and yield.

Even with the benefits of modern science and technology domestication is a long process. However, progress towards the four stated objectives will help to lay the groundwork for successful silphium breeding, and contribute to the development of a well-informed and well-designed plan for domestication.

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