**Introduction**

Temperatures in Minnesota will rise drastically in the next several decades (Fig. 1), and it is important to understand how plants will react to this climate change. Some researchers have studied these reactions with resurrection studies, in which modern and antecedent plant lines are grown in a common environment to monitor evolution thus far and possible adaption to new environments (Franks and Weis, 2007). However, few studies have investigated the hybrid progeny of these resurrected lines. The hybrids serve as a study system for understanding evolution and maternal effects (changes in phenotype based on the environment of the mother).

We are using the F2 generation hybrids of a resurrection experiment to study the effect of rising temperature on evolution and maternal effects in Helianthus annuus (Fig. 2). We expect that hybrids grown in either temperature environment will have some characteristics of plants grown in their maternal parent’s environment. Based on the previous generation, we also expect that individuals in elevated temperatures or from modern lines will be taller than those in ambient temperatures or from antecedent lines. We are also studying how H. annuus has changed genetically since the 1980s. To do this we will perform a population structure analysis. This may give clues about the reason for the phenotypic difference between modern and antecedent lineages.

**Methods**

**Structure Analysis**
- Transcriptome accessions downloaded from NCBI
  - 3 wild
  - 7 landrace
  - 10 modern
  - 3 H. annuus texanus
  - 16 new samples from Minneapolis
- Data was cleaned and filtered to only keep high quality sites
- After filtering, 122,022 sites remained
- The data was subset to 3427 sites
- Structure (v 2.3.4) was used to determine the most likely number of genetic clusters (K)

**Experimental Setup**
- Blocks (n=429)
  - Excess seedlings were grown to ensure enough plants (Fig. 3A, 3B)
  - 6 blocks total with 40 of each treatment in each block (Fig. 3C)
- Treatments
  - Offspring treatment
    - Ambient
    - Elevated
    - Warming chambers were constructed to raise the temperature (Fig. 3D)
- Maternal age
  - 9 modern lines (3 years old)
  - 12 antecedent lines (39 years old)
- Maternal environment
  - Ambient
  - Elevated

**Data Analysis**
- Measurements
  - Mortality
  - Height
  - Leaf Count
  - Collected Flowers
  - Seed Count
  - Flower Diameter
- LMM
  - Generalized linear fit model for binomial distribution
  - Mortality
  - Standard least squares fit model
    - Height
    - Leaf Count
    - Collected Flowers
    - Seed Count
    - Flower Diameter

**Results**

Maternal Age had significant effects on mortality, height, leaf count, and collected flowers. The Modern H. annuus plants were healthier overall as they had lower mortality rates, were taller, and had more leaves and flowers (Fig. 4) (p<0.05). There was no significant effect of the combination of maternal age and offspring treatment for any trait. The antecedent lineage plants did poorer than the modern plants in terms of height and flowering even in their ideal conditions. This suggests that the modern H. annuus may have evolved greater phenotypic plasticity. This could allow the species to endure the dramatic warming predicted, as plasticity may be a more important factor than genetic diversity for allowing species to persist in changing environments (Vitasse et al., 2010).

Plants in the ambient maternal environment had a more varied height response in the different treatments than the plants in an elevated maternal environment (Fig. 5). This could indicate that due to the stressed maternal environmental conditions, there was decreased transgenerational plasticity. This effect only appeared later in the study, while traditionally the maternal effect is more important in early growth.

Modern lineages seem to have introgression from cultivated varieties. In Figure 6, the Antecedent lineages do not show any introgression, except for one individual. In the modern lineages, all lines show introgression (Fig. 6). This explains why the modern lineages are phenotypically similar cultivated phenotype. This similarly explains why the modern phenotype is taller, as in the cultivated varieties there has been artificial selection for taller plants.

**Discussion**

**References**


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