**Introduction**

1. The world is heating
   1. Temps are increasing and it is not clear how plants will respond evolutionarily
   2. Three possible responses are adaptation, plasticity and range shifts
2. Heat can negatively affects many plant reproductive traits
   1. Examples

Climate change is rapidly altering environmental conditions at regional and local scales, leading to relatively rapid shifts in temperature regimes, precipitation regimes, and the severity of weather events (Seneviratne, Xuebin. et al. 2021). As a result, there is widespread interest in understanding how plants, a mostly sessile taxonomic group, will cope with these rapid changes (citations). Plants can respond in three ways while avoiding extinction; adapt relatively rapidly, tolerate changing conditions through plasticity in phenotype that allows acclimation to the new conditions, or shift ranges (Janzen 1967, Schlichting 1986, Molina-Montenegro and Naya 2012). Because the environmental conditions across a species’ range are often heterogeneous, in particular for species with ranges along a wide latitudinal gradient, selective pressures can differ among populations. Divergent selection in two regions can result in differing trait optima in the separate populations, leading to local adaptation (Kawecki and Ebert 2004). Alternatively, plants in populations with different environments may be phenotypically plastic in their response to environmental conditions but show little genetic divergence among those populations. Temperature, in particular, is a variable that can determine species distributions and can vary greatly in both severity and consistency with geographic region (Von Büren and Hiltbrunner 2022). In an effort to test for local adaptation of plants to regional thermal environments, we examined how temperature stress affected traits and specifically how heat and cold tolerance vary across a latitudinal gradient in a widespread weed, *Solanum carolinense* (Solanaceae).

Based on the IPCC Sixth Assessment Report (Seneviratne, Xuebin. et al. 2021), temperatures are changing at unprecedented rates throughout the world. According to the National Climate Assessment (USGCRP 2018), temperatures in the Midwestern and Southeastern United States have been steadily rising since the 1970’s. The changes to temperature regimes are expected to ultimately lead to temperatures that are above what is currently optimal for plant cellular processes, especially those affecting reproductive success (Sato, Kamiyama et al. 2006, Müller, Xu et al. 2016, Xu, Wolters-Arts et al. 2017, Jiang, Lahlali et al. 2019). Researchers have experimentally established that development in moderately high temperatures affects floral morphology (Charles and Harris 1972, Sato, Kamiyama et al. 2006, Müller, Xu et al. 2016), ovule viability (Xu, Wolters-Arts et al. 2017), pollen viability (Sato, Kamiyama et al. 2006, Din, Khan et al. 2015, Müller, Xu et al. 2016, Xu, Wolters-Arts et al. 2017, Poudyal, Rosenqvist et al. 2019), fruit set (Charles and Harris 1972, Sato, Kamiyama et al. 2006, Din, Khan et al. 2015), and seed set (Din, Khan et al. 2015) in crop species. For many of these studies, heat was detrimental to development and reproduction. Sato et al. (2006) found that elevated temperatures decreased fruit set and pollen viability as well as stamen height in tomato. Poudyal et al. (2019) found that pollen viability decreased in heat, but more tolerant tomato accessions had higher pollen germination than sensitive accessions. Xu et al. (2017) found that long-term mild heat decreased pollen viability, pollen number, female fertility, and fruit set. Charles and Harris (1972) found that flower production, fruit set, fruit size, pollen germination, and distance between the stigma and antheridial cone all decreased at high temperatures in tomatoes. Lastly, Muller et al. (2016) found that long-term mild heat resulted in floral deformations and low pollen viability in tomatoes. Thus, heat has been shown to have consistently negative effects on reproductive traits and correlates of male and female reproductive success in crop species.

While many in this field have established that heat or temperature stress in general is detrimental to vegetative and reproductive traits, the question remains: can plants evolve tolerance or other strategies to mitigate temperature stress quickly enough to track climate change? First, evolution might not be necessary, if the species can acclimate to novel temperatures through phenotypic plasticity. However, acclimation would require a species to have evolved acceptable levels of phenotypic plasticity and the responses to ques that improve or maintain fitness. In the case that a species can not acclimate or track the climate through evolution of tolerance to a set of temperatures, populations in areas with temperature stress may face local extinction unless they have the potential to migrate to more favorable conditions- range shifts. Lastly, local conditions introduce the possibility of divergent selection to act on the genetic diversity already within the population. Heritable trait means are likely to shift towards those that improve the chances of survival or reproduction for individuals in a population. For example, we would expect traits for plant populations in a colder region to differ from populations in a warmer region. Local adaptation to region specific climate conditions can be studied as a proxy for how populations in areas of warming could respond to changes in climate.

Here we present the results of two experimental studies on *Solanum carolinense*, where we sought to understand how environment affects reproductive phenotype and ultimately inform predictions of plant evolution in a warming environment. Our objectives were to (1) determine if local thermal conditions have divergently selected for temperature tolerance traits between northern and southern latitudes and (2) experimentally test the effects of moderate heat (32°C) versus control (25°C) temperatures during flower and fruit development on phenotypic expression of pre- and post-pollination reproductive traits. We leveraged the natural genetic variation of populations exposed to drastically different temperature conditions (Minnesota and Texas) and a common garden approach to examine ways evolutionary processes precondition tolerance to temperature stressors that are likely to occur with climate change. We hypothesized that southern populations of *Solanum carolinense* evolved greater tolerance to hot temperatures in reproductive and vegetative stages, due to exposure to consistently hotter conditions. We predicted that tolerance to moderate and extreme heat would be greater in southern plants because these plants have adapted to tolerate the extreme maximum temperatures and higher average temperatures. Conversely, we expected the opposite for plants from more northern populations – higher tolerance to extreme cold and lower tolerance to heat stress in general.