Transgenerational plasticity in the annual plant *Polygonum persicaria*: effects of the grandparent environment on plant development

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INTRODUCTION

- **Plasticity** is when a single genotype expresses multiple phenotypes in different environments.
- Plasticity is a mechanism by which organisms can acclimate to environmental changes without underlying genetic change and the longer process of evolution.
- Plasticity can occur within a single generation or can occur across multiple generations, the latter describing **transgenerational plasticity**, which is when the environment experienced by previous generations affects growth and development in the current generation.
- **For plants**, the light conditions experienced in the current and parent environments, specifically whether a plant was raised in full sun or shade, can impact plant growth and development.

- *Polygonum persicaria* is an annual generalist plant that grows throughout CT, which can transmit environmental information from previous generations via transgenerational plasticity.
- Previous work in the Sultan lab has shown that the *grandparent environment influences offspring development in different drought conditions*, and that the *parent light environment influences offspring development in different light conditions.*
- **Therefore, we were interested in exploring if the grandparent light environment influences grand-offspring growth and development.**

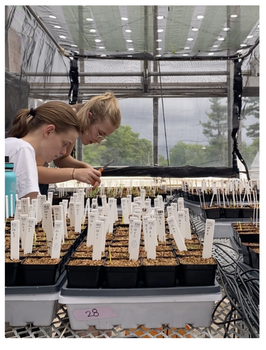
- We collected phenotypic data on emergence time, total leaf area (canopy), height, and aboveground biomass. Here, we focus on emergence time, height, and biomass as three key phenotypic traits that are telling about the plants' development.
  - ***Emergence:*** *P. persicaria* is an annual plant often emerging in communities with a mix of annual species, so successful early emergence is key to growing larger than neighbors and gaining access to aboveground resources.
  - ***Height:*** height measurements are important from the context of competition, in which plants might need to grow taller than their neighbors to gain access to more light.
  - ***Biomass:*** Biomass is a good proxy for a fitness measurement because it is highly correlated with reproductive output and a good measurement of plant performance.

RESEARCH QUESTIONS

1. Does the light environment experienced by grandparents (sun versus shade) affect the growth and development of their grandchildren, and how does this alter our picture of plant development?
2. How big are the effects of the grandparent environment on offspring compared to other variables (parental environment, offspring environment, genotype)?
3. Do we see interactions between genotype, offspring, parent, and grandparent environments that ultimately affect plant development?

METHODS

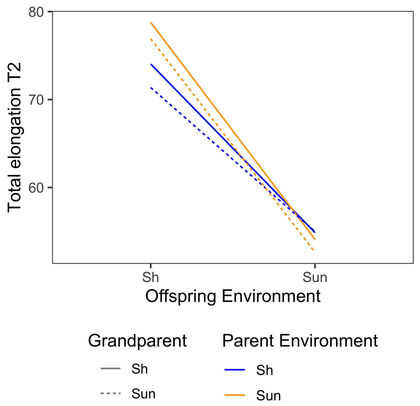
- We grew 10 isogenic lines each in
  * 2 grandparent environments (sun vs. shade, 2019)
  * 2 parent environments (sun vs. shade, 2020)
  * 2 offspring environments (sun vs. shade, 2021)
  for a total of 80 experimental contrasts
- Measured over 2500 plants (up to 24 replicates for most traits, 8-24 replicates for biomass collection)
- Plants were grown in a 1:1:1 mixture of vermiculite, topsoil, and turface with a 1 cm layer of vermiculite on top of the pots and were watered using bottom watering
- Emergence time was recorded daily for 2 weeks.
- Height, total leaf area (canopy), and biomass measurements were taken twice early in the life cycle, at 12-14 and 21-23 days post sowing.

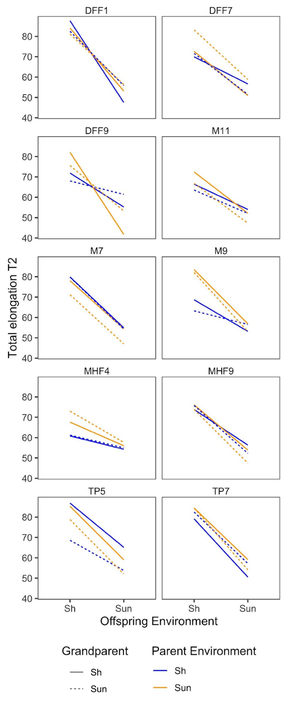


Undergraduates Annie and Chloe harvesting plants in the shade treatment in order to determine biomass

RESULTS

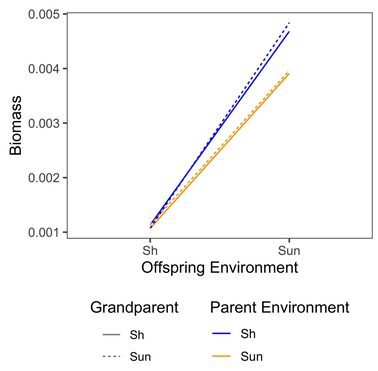
Height

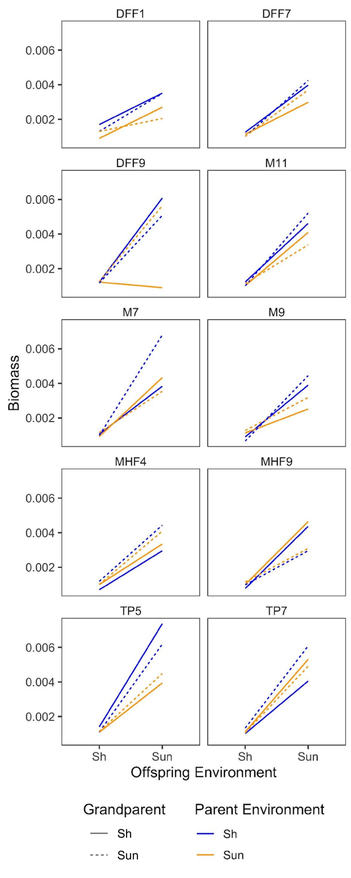




- Data from our second height measurement at 23 days from sowing--showed a strong average parental effect ($p<0.001$) on offspring height, with parent sun producing taller plants on average than parent shade.
- However, it seems that the parental effect depended on the offspring's environment in a parent by offspring interaction ($p<0.001$), as offspring in the sun were taller if they had shade parents, while offspring in the shade were taller if they had sun parents.
- The grandparent environment also had a significant effect ($p<0.001$) on offspring height, but to a lesser degree than the parent environment. Generally, offspring with shade grandparents grew taller than those with sun grandparents, independent of the offspring environment.
- What is most interesting is the strong genotype by parent by grandparent interaction ($p<0.001$), which showed that different genotypes are integrating information from the two previous generations differently during development.

Biomass

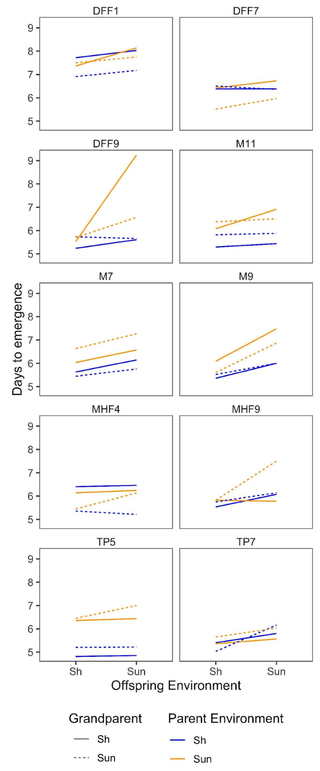


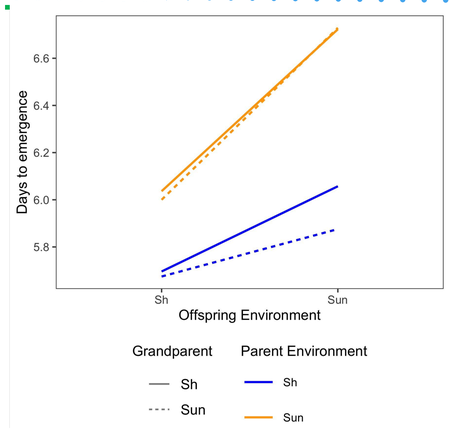


- Differences in biomass were most influenced by the date of emergence, with plants that emerged earlier having a significantly higher biomass at 12 days post sowing than those with later emergence ($p<0.001$).
- The parent effect on offspring biomass was significant but small ($p<0.05$), but there was not an average grandparent effect.
- However, there were large interactions of the grandparent environment with genotype, genotype by offspring, and genotype by parent, indicating that biomass depends on individual genotypes combining information from grandparent, parent, and offspring environments.
- There was also a very significant ($p<0.001$) and large effect of genotype on biomass, with 3 of the 10 genotypes represented in this study having biomasses that were quite higher than the remaining genotypes.

RESULTS CONT.

Emergence





- Most significant for offspring emergence time was the parental effect ($p<0.001$), as well as the grandparent interaction with genotype.
- In both offspring environments, plants with sun parents emerged later than plants with shade parents. They also emerged over a longer period of days.
- The grandparent effect was smaller than the parent effect and was not significant when observed on its own ($p=0.139$). However, it was significant when interacting with genotype ($p<0.001$). This genotype by grandparent interaction means that the plant is integrating grandparental information differently depending on its genotype.
- Overall, genotype had the highest significance in determining offspring emergence time.

DISCUSSION

- The finding that genotypes vary in how they integrate and respond to current and previous environments means that **the process of inheriting information from previous environments can itself evolve.**
  - Our research controlled for genotype (through the development of isogenic plant lines) and the grandparent, parent, and offspring environments.
  - Controlling for genotype has allowed us to see that different genotypes integrate parental and grandparental information differently during development.
  - Because transmission of information from previous environments has a genetic basis, the process by which information is transmitted and inherited can itself evolve.
- The finding that plants respond to the environments experienced by previous generations, in addition to their own environment, has important implications for thinking about how organisms can respond to environmental change, including rapid and intense anthropogenic changes (e.g. habitat fragmentation, climate change, invasive/weedy species, etc.).
  - Evolution may be acting on these plastic response systems, in addition to specific plant traits.
  - Inherited plasticity could allow some species to survive these anthropogenic changes by broadening responses to changing environmental conditions.