The effects simulated herbivory on *Pseuderanthemum* grown in a greenhouse

Department of Biological Sciences, State University of New York Oswego, Oswego, NY 13126
Devin Narbone, HaMin Lee, and C. Eric Hellquist

ABSTRACT

Plants face numerous environmental pressures, including herbivory, which can impact their survival and fitness. This study simulated herbivory by mechanically damaging a common greenhouse weed species and assessed parameters such as photosynthetic efficiency and biomass recovery. Our results indicate that the plants that were noticeably healthier were more resilient to simulated herbivory.

INTRODUCTION

Herbivory: A central ecological interaction

- Herbivory, the consumption of living plants by animals, significantly impacts plant survival, fitness, and population dynamics (Lehndal & Ågren 2015).
- Plants have evolved various defense mechanisms against herbivores, including physical barriers, chemical defenses, and tolerance strategies (Waterman et al. 2019).
- The effects of herbivory on plant biodiversity vary widely within and among ecosystems, with herbivore-induced changes in dominance influencing biodiversity (Koerner et al., 2018).
- Simulated herbivory through mechanical damage provides a controlled method to study specific plant defense responses by isolating the physical component of herbivory from other factors (Waterman et al. 2019).
- Plant responses to simulated herbivory in controlled environments help explain defense mechanisms that may be obscured in complex field conditions (Estarague et al. 2023).

Species and Regional Context:

- *Pseuderanthemum variabile*, commonly known as "Pastel flower" or "Love flower," is a small perennial herb in the family *Acanthaceae* native to Australia, Papua New Guinea, and New Caledonia (Sharma & Vyas 2024).
- This species serves as a food plant for caterpillars of several butterfly species in the *Nymphalidae* family, making it subject to herbivory (Cook & Vargo 2000).
- As a common greenhouse weed that thrives in wet tropical climates and understory habitats (Howes, 2020).
- *P. variabile* provides an accessible model system for studying plant-herbivore interactions.

Research Objectives and Hypotheses:

- We examined the effects of varying levels of simulated herbivory on the growth and photosynthetic efficiency of *P. variabile* in greenhouse conditions.
- We compared responses between healthy and unhealthy plants to assess how initial condition affects tolerance and recovery following herbivory damage.
- We hypothesized that higher degrees of simulated herbivory will demonstrate reduced leaf production compared to those experiencing minimal or no damage.
- We predicted that healthy plants will exhibit enhanced recovery capacity following herbivory simulation, as shown by higher photosynthetic efficiency.
- Finally, we expected to find a positive correlation between plant biomass and leaf production, with higher biomass individuals generating more leaves regardless of herbivory treatment.

METHODS

We used 24 individual *P. variabile* plants, which were tagged for identification and categorized into three groups (A, B, and C) of 8 individuals each. Within each group, plants were further divided into two subsets: 4 healthy and 4 unhealthy replicates, based on their initial condition. To simulate levels of herbivory, mechanical damage was created using a hole puncher. The control group had no holes punched in either healthy or unhealthy plants. Moderate herbivory was simulated by punching 5 holes in healthy plants and 3 holes in unhealthy plants. High levels of herbivory had 10 holes punched in healthy plants and 6 holes in unhealthy plants. Photosynthetic efficiency was assessed weekly using a fluorometer to measure chlorophyll fluorescence. On the final day of the experiment biomass (mg) data was collected and the number of leaves produced were counted.

RESULTS and DISCUSSION

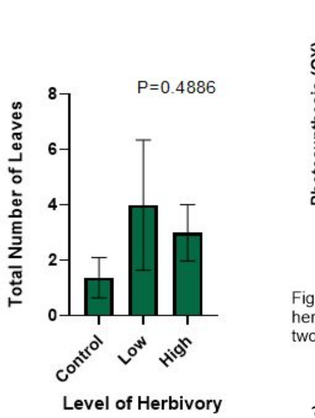

Figure 1. The effect of simulated herbivory on the number of leaves grown across the three varying levels of simulated herbivory. P-value is for one-way ANOVA. Error bars are for standard error of the mean.

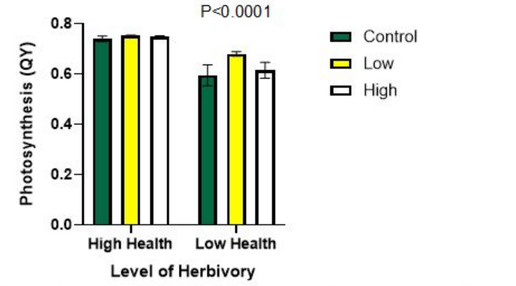

Figure 2. Photosynthetic levels (quantum yield) of varying levels of herbivory across differing levels of initial plant health. P-value is for two-way ANOVA. Error bars from standard error of the mean.

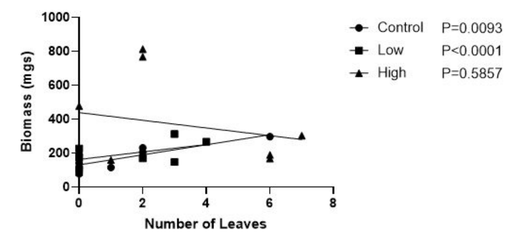

Figure 3. The correlation of biomass in milligrams to the number of leaves produced when placed under the effect of varying levels of simulated herbivory. P-values for simple linear correlation.

Results

- There were no differences in leaves produced (Figure 1, one-way ANOVA; p=0.49). The average number of leaves produced varied among herbivory treatments, with moderate herbivory yielding the highest mean (3.9), followed by high herbivory (3.0) and the control (1.4).
- Photosynthetic efficiency was significantly affected negatively by herbivory level and positively initial plant health status (Figure 2, two-way ANOVA; p<0.0001). Plants with high initial health maintained similar photosynthetic levels (~0.75 QY) regardless of herbivory treatment, while plants with low initial health showed greater variation in photosynthetic response across herbivory levels.
- Biomass production was positively correlated with leaf number in both the control (p=0.009) and low herbivory (p<0.0001) treatments. This relationship was negative, but not significant, in the high herbivory treatment (p=0.59). The strongest correlation was observed in the low herbivory treatment (Figure 3).

Discussion

Leaf Production Response:

- While not statistically significant (p=0.49), the trend of increased leaf production under moderate herbivory suggests potential compensatory growth mechanisms in *P. variabile*, aligning with the herbivory optimization hypothesis (McNaughton 1983).
- The reduced leaf production in high herbivory conditions relative to moderate herbivory indicates that excessive damage may force resource allocation toward defense rather than growth (Orians et al. 2011).

Photosynthetic Efficiency:

- Plant response to herbivory is context-dependent (interaction p<0.0001), supporting the hypothesis that more vigorous plants better tolerate herbivory (Price 1991).
- The increased photosynthetic efficiency in low-health plants under moderate herbivory suggests that damage-induced responses can improve plant performance, possibly through upregulation of stress response pathways (Nabity et al. 2009).

Biomass-Leaf Growth Relationship:

- The positive correlation between biomass and leaf growth in plants experiencing low herbivory (p<0.0001) indicates that this level of damage may optimize resource allocation to leaf growth, supporting the hypothesis that low herbivory can enhance plant fitness under certain conditions (Agrawal 2000).
- The lack of significant correlation between biomass and leaf production in high-herbivory plants (p=0.59) suggests severe damage disrupts the typical relationship between biomass accumulation and leaf growth reflecting stress-induced allocation shifts where resources prioritize survival over biomass production (Herms & Mattson, 1992).

Conclusions

Our findings contribute to evidence that plant responses to herbivory are highly context-dependent. Future research should examine molecular mechanisms underlying enhanced photosynthetic efficiency in moderately damaged plants with low initial health, as this may reveal novel stress adaptation pathways with potential applications in agriculture and conservation.

LITERATURE CITED

Agrawal, A. A. (2000). Trends in Plant Science 5(7): 309-313. https://doi.org/10.1016/s1360-1385(00)01679-4
Cook, R. P., & Vargo, D. (2000). Range extension of Doleschallia tongana (Nymphalidae) to the Samoan Archipelago, with notes on its life history and ecology. Journal of the Lepidopterists' Society 54(1): 33-35.
Estarague, A., Violle, C., Vile, D., Hany, A., Martino, T., Moulin, P., & Vasseur, F. (2023). Plant-herbivore interactions: Experimental demonstration of genetic variability in plant-plant signalling. Evolutionary applications 16(4): 772–780. https://doi.org/10.1111/eva.13531
Herms, D. A., & Mattson, W. J. (1992). The dilemma of plants: to grow or defend. The Quarterly Review of Biology 67(3): 283-335. https://doi.org/10.1086/417659
Howes, J. (2020). Australian Plants Society. https://resources.austplants.com.au/plant/pseuderanthemum-variabile/. Accessed: April 6th, 2024.
Koerner, S.E., Smith, M.D., Burkepile, D.E. et al. (2018). Change in dominance determines herbivore effects on plant biodiversity. Nat Ecol Evol 2: 1925–1932. https://doi.org/10.1038/s41559-018-0696-y
Lehndal, L., & Ågren, J. (2015). Herbivory Differentially Affects Plant Fitness in Three Populations of the Perennial Herb Lythrum salicaria along a Latitudinal Gradient. PloS one 10(9): e0135939. https://doi.org/10.1371/journal.pone.0135939
McNaughton, S. J. (1983). Compensatory plant growth as a response to herbivory. Oikos 40: 329-336. https://doi.org/10.2307/3544305
Nabity, P. D., Zavala, J. A., & DeLucia, E. H. (2009). Indirect suppression of photosynthesis on individual leaves by arthropod herbivory. Annals of Botany 103(4): 655-663. https://doi.org/10.1093/aob/mcn127
Orians, C. M., Thorn, A., & Gómez, S. (2011). Herbivore-induced resource sequestration in plants: why bother? Oecologia 167(1): 1-9. https://doi.org/10.1007/s00442-011-1968-2
Price, P. W. (1991). The plant vigor hypothesis and herbivore attack. Oikos 62: 244-251. https://doi.org/10.2307/3545270
Sharma S. & B. N. Vyas. 2024. Defense mechanisms in Pseuderanthemum species: Responses to simulated and natural herbivory stress. Plant Science 318: 111674. https://doi.org/10.1016/j.plantsci.2023.111674
Waterman, J. M., Cazzonelli, C. I., Hartley, S. E., & Johnson, S. N. (2019). Simulated Herbivory: The Key to Disentangling Plant Defence Responses. Trends in ecology & evolution 34(5): 447–458. https://doi.org/10.1016/j.tree.2019.01.008