

Effects of Herbivory on Growth and Sugar Content in Beet Cultivars

Nicholas A. Dinkel, Erika L. Weidner and Christopher R. Stieha

nadinkel@millersville.edu



Introduction

All plants experience biotic stress, such as herbivory, but respond to these stressors in various ways which can affect their fitness and therefore our health⁷. One plant response to herbivory is the reallocation of its resources, such as plants transporting resources away from herbivores by sending their resources above and below-ground depending on the location of herbivory. In the case of plant biomass, plants can reallocate resources to replace lost biomass⁵. In the case of nutrients and stored energy, reallocation can reduce the nutritional quality of the plant exposed to the herbivore, and therefore produce higher nutritional value and sweetness in agriculturally important components^{2,3}. To quantify these reallocation responses, various levels of above-ground herbivory were simulated on three different varieties of beets, *Beta vulgaris*, at two different stages: early and late^{1,6}. If plants reallocate resources to regrow lost biomass, then below-ground biomass will be lower in damaged plants rather than undamaged. If plants reallocate their resources in response to herbivory, then the below-ground biomass of damaged plants will have a higher sugar concentration than undamaged plants in both early and late stages of growth.

Objectives and Predictions

Quantify allocation of resources to formation of new biomass:

- Plants reallocate biomass in response to herbivory. We predict that plants with higher levels of above-ground damage will have more below-ground biomass than undamaged plants will.

Quantify beet sugar content responses to herbivory:

- Plants reallocate sugars in response to herbivory. We predict that damaged plants will have higher sugar content in their roots when compared to plants without damage. We also predict that sugar content within the leaves will be lower in plants with damage compared to plants without damage.

Methods

Two hundred ten plants (70 of each cultivar) were planted in tall 2.75-inch pots in the Millersville University Greenhouse on May 21st, 2021.

To simulate herbivory:

- Plants were subject to 0%, 25%, 50%, 75% simulated herbivory damage using a hole punch. This was roughly estimated based on surface area of the leaf being damaged. A hole punch was used to damage the plants as this imitates the chewing damage inflicted by the Beet Armyworm, *Spodoptera exigua*, a well-known agricultural pest⁴.
- Damage was inflicted at early (4-6 true leaves) and late (8-10 true leaves) stages of growth in order to determine any effects based on damage time⁶.

To quantify biomass and sugar concentration:

- To quantify biomass, plants were harvested, dead leaves were removed, roots were then rinsed, and plants were weighed.
- To quantify sugar concentration, we organized plants into grinding groups of three plants based on their variety, level of damage, and stage of damage. The above-ground vegetation for each grinding group was blended with 50mL of water, then filtered through a funnel to remove any large pieces. The solution was pipetted onto a refractometer to measure the above-ground Brix. This procedure was repeated on the below-ground biomass. Using this Brix measurement, we calculated the amount of sugar in the above-ground and below-ground biomass for each plant.
- We analyzed results using ANOVA in the R programming language.

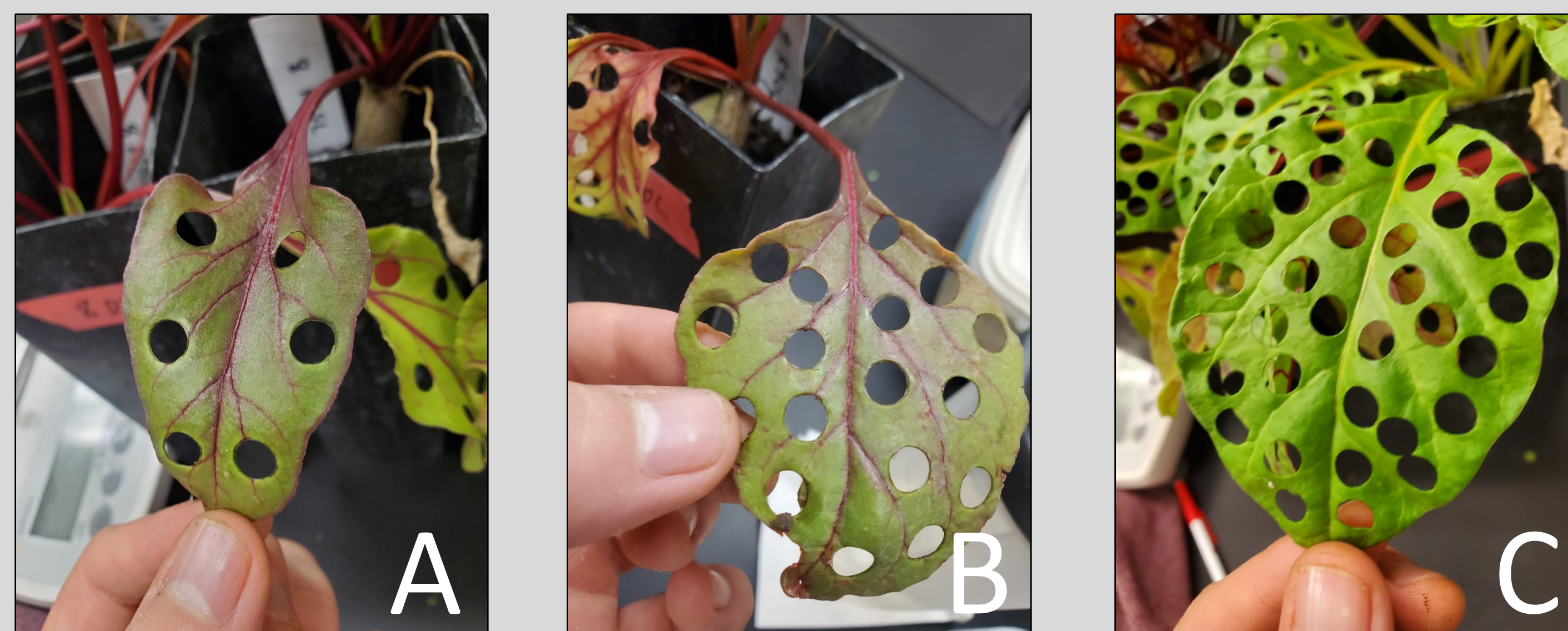


Figure 1. Representative images of leaf damage levels, 25% (A), 50% (B) and 75% (C).

Results and Discussion:

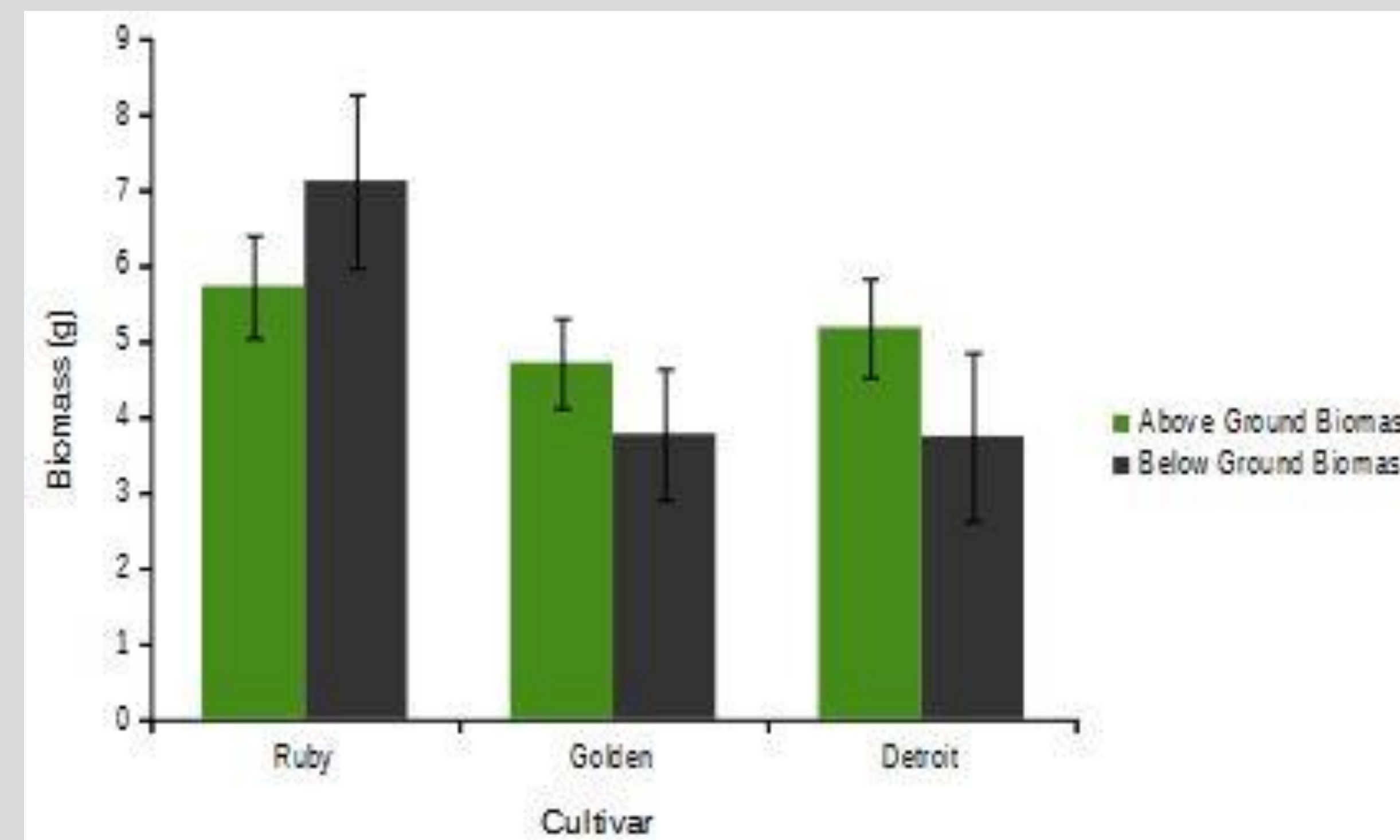


Figure 2. Mean above and below ground biomass of three beet cultivars subjected to early damage across all damage levels. Both early and late damage showed similar results. The cultivars differed with respect to above-ground biomass ($F_{2,99} = 4.3076$, $p = 0.017$) and below-ground biomass ($F_{2,99} = 11.3507$, $p < 0.001$), but damage levels did not differ with respect to biomass. Error bars indicate $\pm$ SEM.

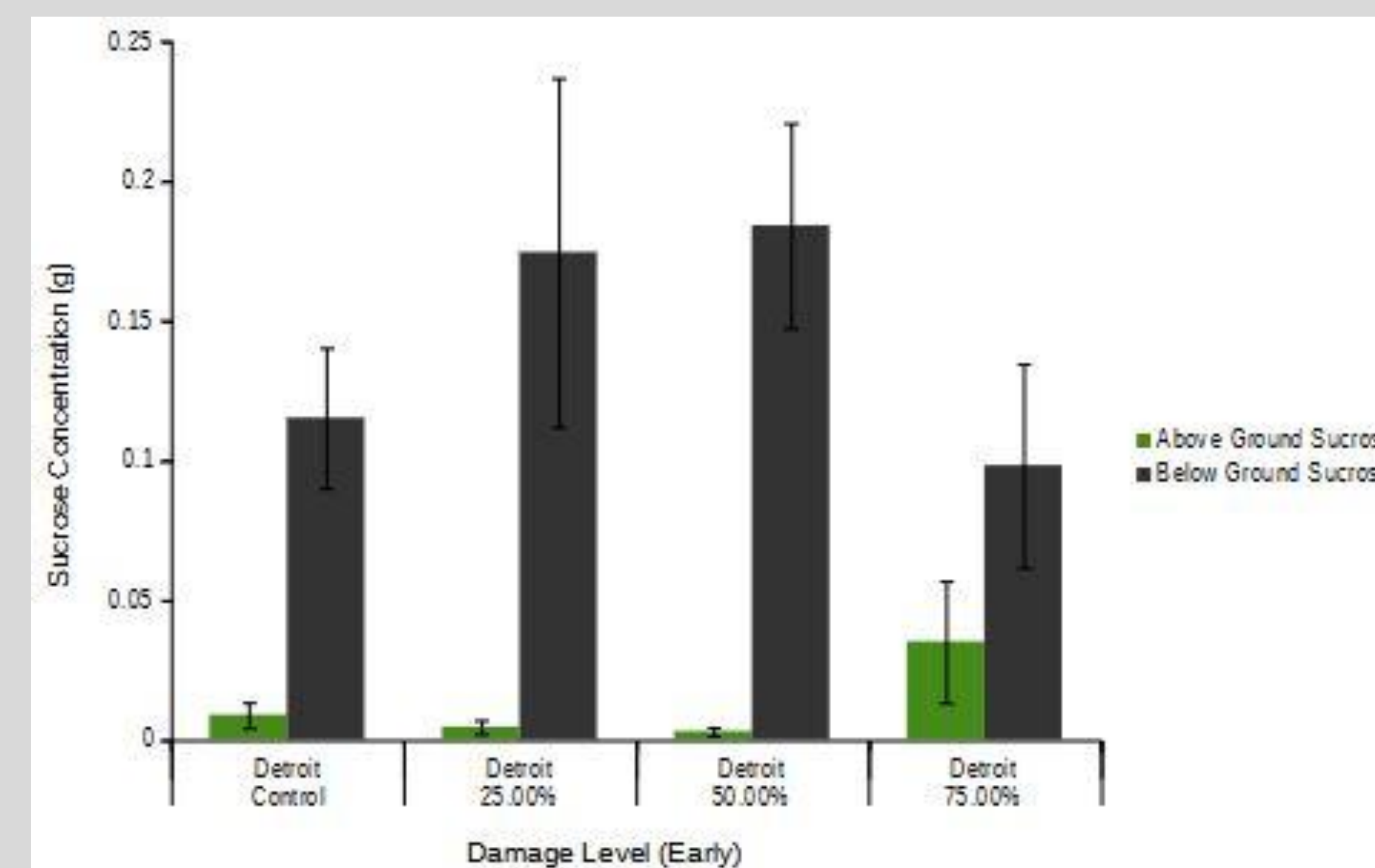


Figure 3. Mean sucrose content of Detroit Dark Red beet cultivar subjected to varying degrees of early leaf damage. Despite the appearance, there was no effect of damage on sucrose content in below-ground ($F_{3,24} = 0.8431$, $p = 0.4838$) or aboveground biomass ($F_{3,24} = 1.5245$, $p = 0.2337$), but late damage did have an effect. Error bars indicate $\pm$ SEM.

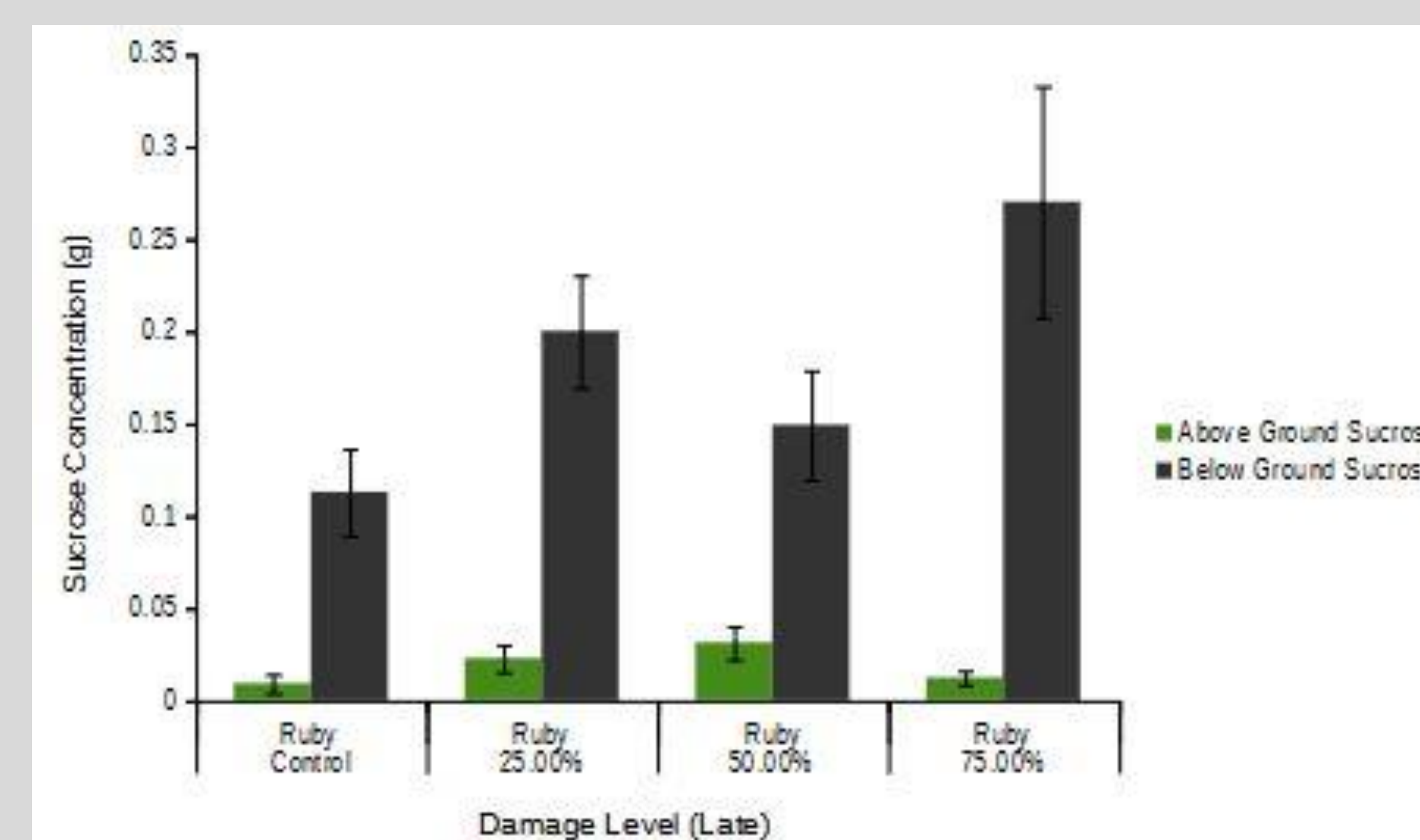


Figure 4. Mean sucrose content of Ruby Queen beet cultivar subjected to late leaf damage across damage levels. There was a trend where damage level impacted the sucrose content of the below-ground material ($F_{3,24} = 2.541$, $p = 0.0803$) and above-ground material ($F_{3,24} = 2.551$, $p = 0.0795$). Error bars indicate $\pm$ SEM.

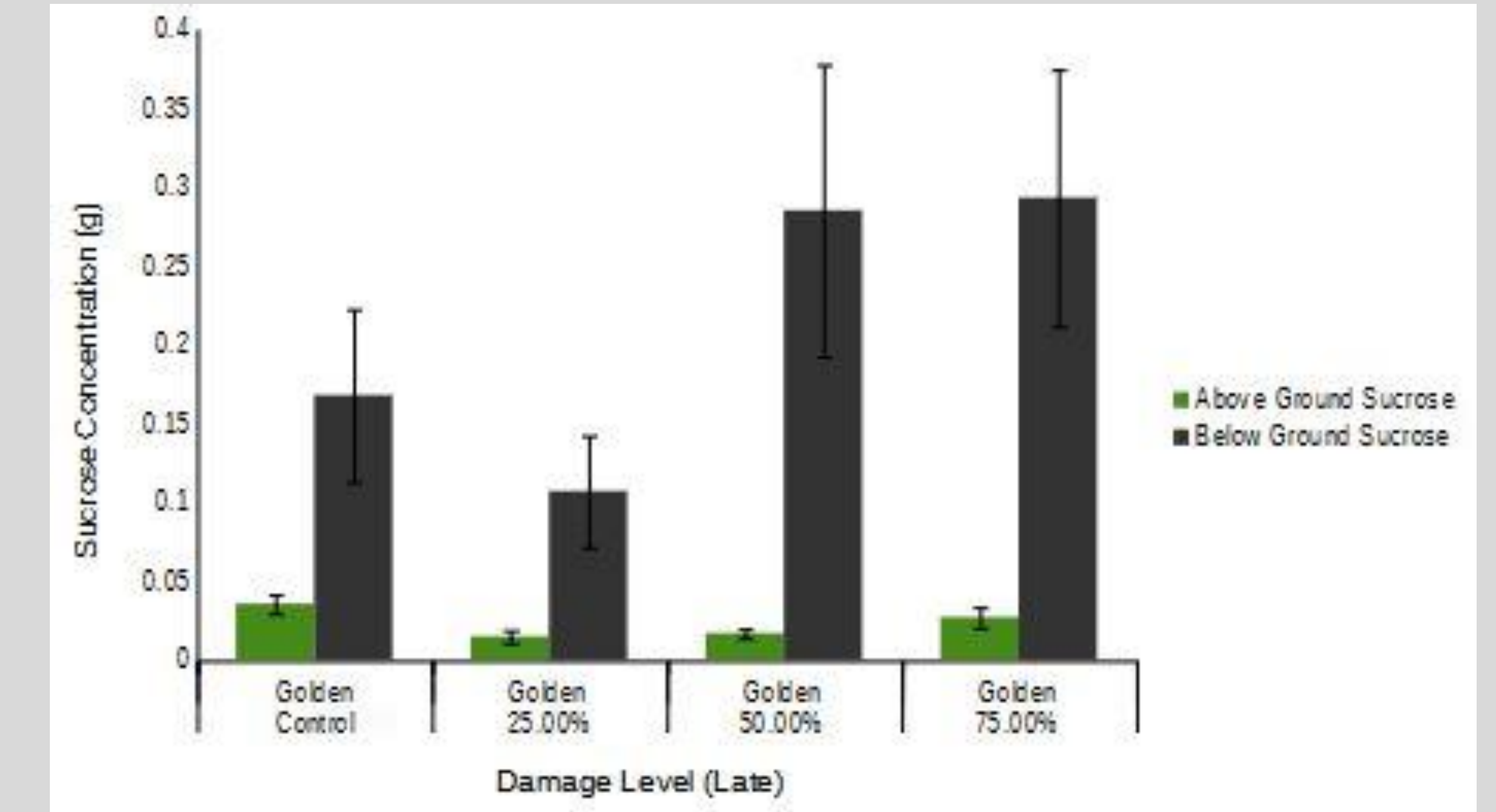


Figure 5. Mean sucrose concentration of Golden beet cultivar subjected to varying degrees of late leaf damage. There was an effect of damage on above-ground sugar amount ($F_{3,24} = 4.824$, $p = 0.009$), but no significant difference of damage on below-ground sucrose amount ($F_{3,24} = 1.6275$, $p = 0.2093$). Early damage did not affect sucrose amount. Error bars indicate $\pm$ SEM.

Conclusions

Plant Biomass Response:

- Contrary to our prediction, damage did not have a significant impact on above-ground and below-ground biomass production. The three cultivars did differ with respect to biomass, with Ruby Queen having the highest biomass above and below ground out of the three cultivars (Figure 2).

Plant Sugar Content Response:

- These results support our prediction that herbivory affected the sugar content in *Beta vulgaris*. As we continue our analysis, we do focus on biological significance.
- When subjected to low and intermediate levels of early damage, the Detroit Dark Red beet cultivar showed a noticeable increase in below-ground sucrose amount (Figure 3).
- Ruby Queen beet cultivar subjected to 25% and 75% damage late in growth tended to have the greatest increase in below-ground sucrose amount, whereas 50% damaged tended to have the greatest increase in above-ground sucrose content (Figure 4).
- Golden beets subject to late leaf damage of 50% and 75% appears to have the highest increase in below-ground sucrose amount (Figure 5).

Agricultural Significance:

- Some herbivore damage may lead to better tasting food.
- Plants subject to low to intermediate levels of damage early in growth may promote the growth of better tasting and more nutritious produce.
- Plants subject to high levels of damage late in growth may promote the growth of better tasting and more nutritious produce.

Acknowledgements:

Thank you to Heather Fogell and the Millersville University greenhouse crew for watering the plants.

References:

- Adhikari, S., & Kandel, T. P. (n.d.). Effect of Time and Level of Pruning on Vegetative Growth, Flowering, Yield, and Quality of Guava. *International Journal of Fruit Science*, 15, 290-301.
- Hailu, S., Seyoum, T., & Dechassa, N. (2008, January). Effect of combined application of organic-P and inorganic-N fertilizers on yield of carrot. *African Journal of Biotechnology*, 7, 27-34.
- Hassani, M., Heidari, B., & Stevanato, P. (2019, September 2). Combining abilities of sugar beet genotypes of root- and sugar- related traits under multi-environmental traits. *Plant Breeding*.
- Kaya, E., & Unlu, L. (2019, July 31). Determination of Population Development and Infestation Rate of The Beet Armyworm [*Spodoptera exigua* (Lepidoptera: Noctuidae)] in Sugarbeet Fields in Ilgin (Konya) District. *Selcuk Journal of Agriculture and Food Sciences*, 193-203.
- Molla, M. S. H., Robiul Alam, M., Islam, F., Akhtar Hossain, M., & Ahmed, M. (2002). Effect of Leaf Clipping on Plant Growth and Green Fodder Yield of Different Cultivars of Transplant Aman Rice. *Online Journal of Biological Sciences*, 748-751.
- Sugarbeet growth stage - american crystal sugar. (n.d.).
- Whitehead, S. R., Turcotte, M. M., & Poveda, K. (2016, August). Domestication impacts on plant-herbivore interactions: a meta-analysis. *Philosophical Transactions B*.