The Effects of Biochar on Pollinator Visitation on Green Roof Infrastructure

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Introduction

Green roofs have received recent attention as a means of mitigating climate change impacts in urban environments (Berardi et al. 2014); green roofs are also known to promote biodiversity as compared to conventional roofs, making them ecological refuges for avian and arthropod species that are accustomed to urban environments (Wooster et al., 2022). Pollinator species richness in particular has declined, making green roofs important tools in maintaining urban biodiversity in the face of habitat loss as the development of urban areas puts pressure on green spaces (Goulson et al., 2015; Braaker et al., 2017). However, green roofs also tend to have harsh environmental conditions such as high winds, extreme temperature fluctuations, and soil erosion (Rowe et al., 2012; Cascone, 2019). As a result, biochar has been proposed as an additive to green roof substrate due to its ability to regulate soil moisture, soil temperature, and enhance microbial growth (Chen et al., 2018), with granulated biochar in particular being effective in improving water discharge quality and mitigating erosion (Liao et al., 2022ab). Despite claims about the impact of green roofs on pollinators and the impact of biochar amendments on green roof infrastructure, there have not yet been studies examining how biochar amendments affect pollinator visitation on green roofs. This project investigates bee visitation on green roof infrastructure, comparing results between native and *Sedum* plots as well as biochar-amended and control plots.

Methods

This project was conducted on the GRITlab2 facility on the roof of the John H. Daniels building at the University of Toronto. The site has 48 plots (1.8 m x 1.8 m), of which half are amended with 5% biochar by volume. Additionally, half of each type of substrate were seeded with a native seed mix (with supplementary planting) and the other half were planted with commercial (non-native) sedum mats dominated by *Phedimus kamtschaticus* with small amounts of *Sedum sexangulare* and *Sedum album*. The bee surveys were conducted from May to August 2023. Visual survey data was collected twice a week between the hours of 11:00 AM and 6:00 PM. At each plot, the number of bees, type of bee identified to the species or genus level, and species of flowers being visited were noted. Additionally, diurnal survey data was collected twice, where visual surveys were conducted once an hour from sunrise until sunset. Bee visitation data were analyzed using a generalized linear mixed effect model that included fixed effects of vegetation type and biochar treatment and random effects of plot and date, with a negative binomial residual distribution. Pairwise comparisons used a similar model with p-values adjusted using the false discovery rate method.

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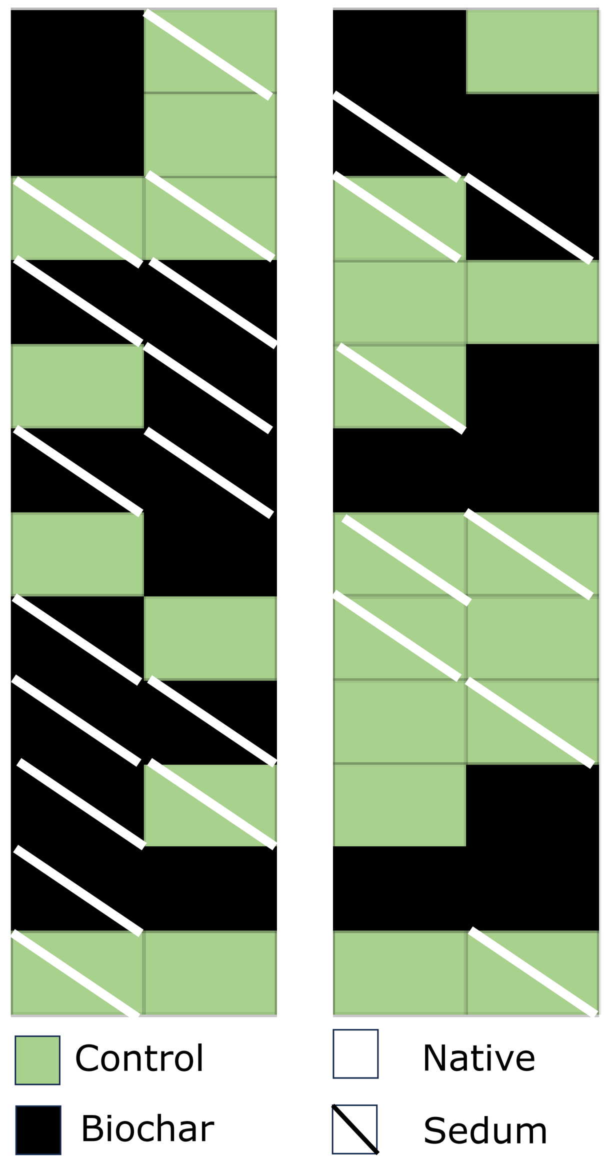
a)

b)

Figure 1 (above): GRITlab2 facility

Figure 2 (below): Experimental design



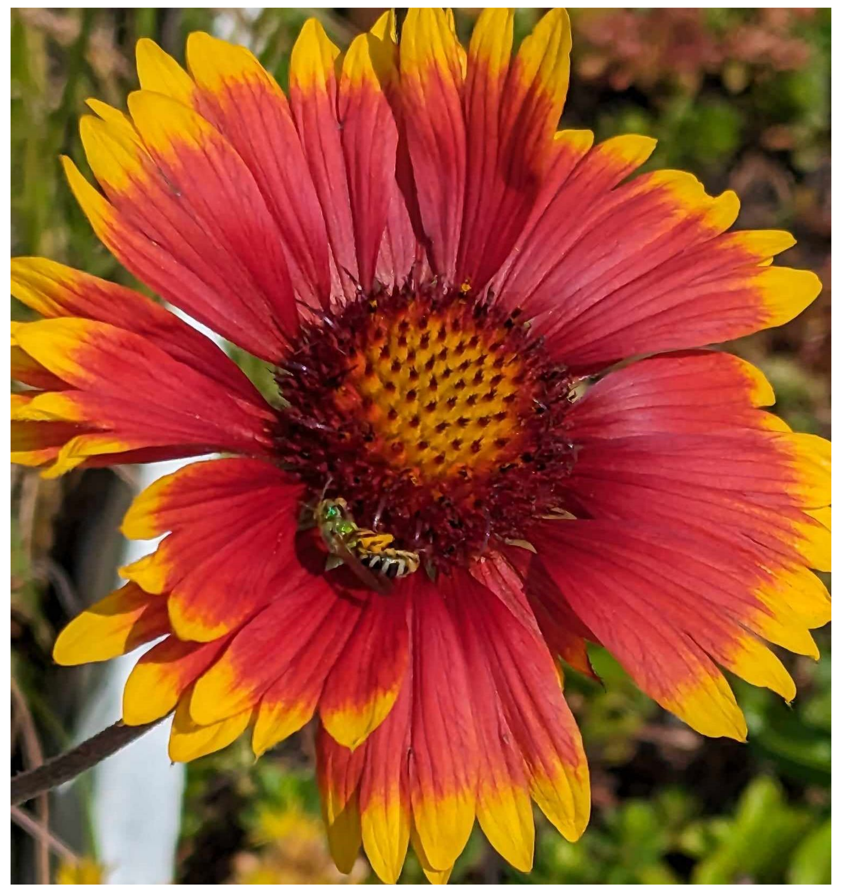


Figure 3: *Agapostemon virescens*, the Toronto city bee, on *Gaillardia aristata* (Great Blanket Flower)

Results

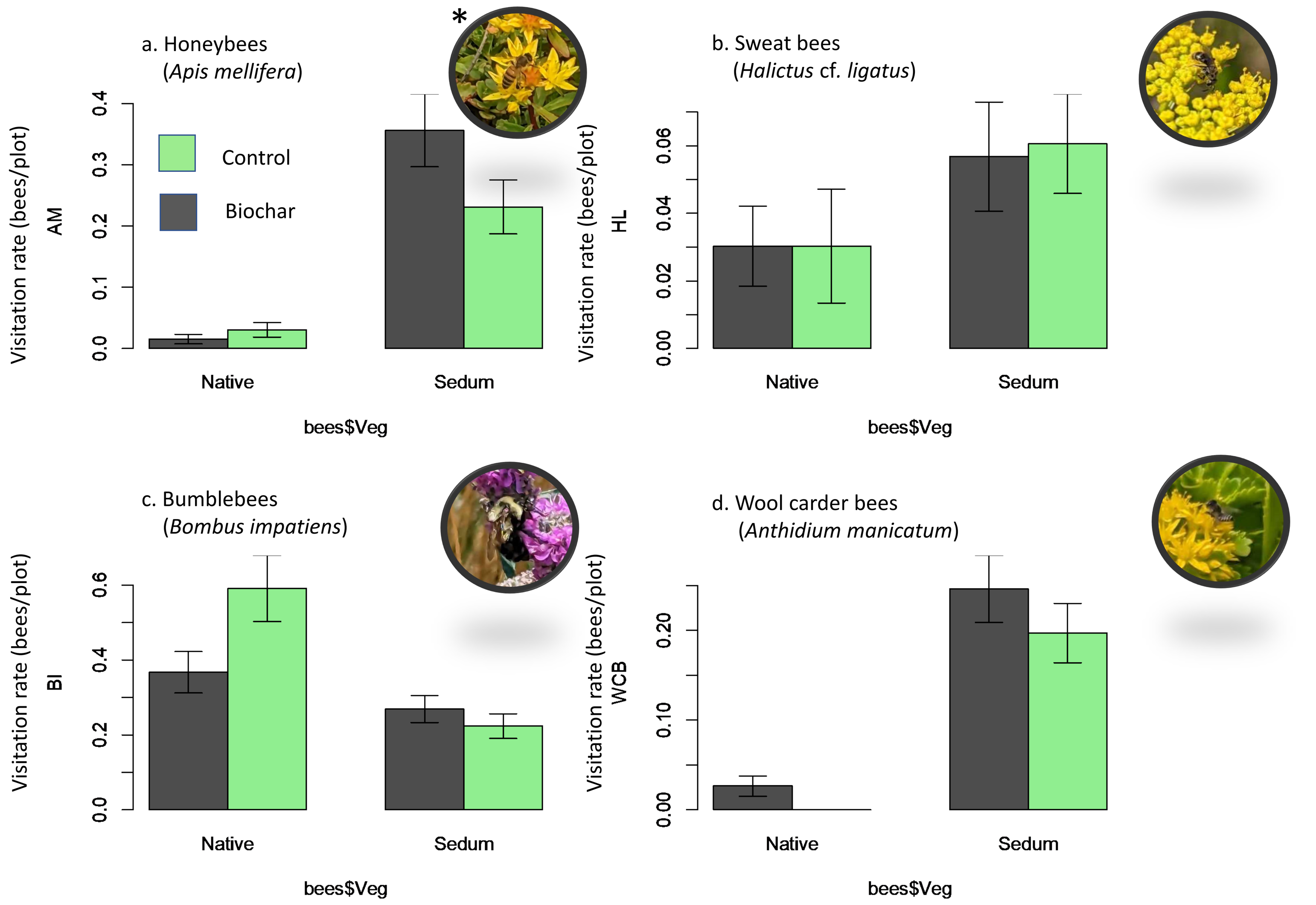


Figure 4: Results of semi-weekly observations of bee visitation for (a) honeybees (*Apis mellifera)* (b) sweat bees (*Halictus* cf. *ligatus)* (c) bumblebees (*Bombus impatiens*) and (d) wool carder bees (*Anthidium manicatum*). * Pairwise comparison significant at $p < 0.05$.

There were 22 surveys collected semiweekly and 31 collected during the two diurnal survey data collection periods. In the regular surveys honeybees (*Apis mellifera*) were more frequently observed on the *Sedum* plots ($p<0.001$), with biochar-amended plots being favoured ($p<0.05$; Fig. 1a). The common eastern bumble bee, *Bombus impatiens*, favoured native vegetation ($p=0.047$) with a trend to favoring the control plots (Fig. 1c). Members of genus *Halictus* were identified at the genus level only, and favoured *Sedum* ($p=0.037$). *Anthidium manicatum*, the European wool carder bee, also favoured *Sedum* ($p<0.001$). The bicolored striped sweat bee, *Agapostemon virescens*, did not have a significant difference between the plots visited ($p=0.999$). *Lasioglossum* (grouped by genus) also did not show a significant difference among treatments ($p=0.079$).

Discussion

Green roof infrastructure may function as an urban wildlife refuge, helping connect habitats that have been fragmented by development (Braaket et al., 2017). As shown above, honeybees and wool carder bees tended to prefer biochar-amended non-native sedum plots. *Bombus* and *Halictus* had a slight preference for control plots, with *Bombus* favouring native vegetation and *Halictus* favouring sedum. Honeybees and wool-carder bees are native to Europe (MavIvor et al., 2014; Gibbs and Sheffield, 2009). Their strong preference for the Eurasian *Phedimus* and *Sedum* species on the roof is consistent with recent research on pollinator visitation patterns on green roof infrastructure (MacIvor et al., 2014). Previous studies have also shown a correlation between increases in honeybee abundance and decreases in the species richness of native bees and other insects (MacKell et al., 2023; Lindström et al., 2016). The results thus suggest the importance of native plants on green roof infrastructure for maintaining native urban bee communities, though some native bees also commonly utilize the non-naitve *Phedimus* and *Sedum* species.

Biochar treatments had detectable effects on bee visitation patterns but effects were not always positive. Floral resource availability has an impact on pollinator communities (Goulson et al., 2015), and flower and fruit production have both been shown to increase in biochar-amended plants (e.g., Seehausen et al., 2016). Examining the relationship between floral resources, biochar-amended plots, and pollinator visitation may be an appropriate next step in this project. Green roof infrastructure remains an important object of study in urban ecology, due to both challenges posed by harsh green roof environments and the range of potential benefits provided.

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