

Variation of Pollen Mass Across Species, Habitat Types, and Time

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Abstract

Bumble bees are crucial pollinators in both agricultural and wild ecosystems, and as pollinators they rely almost exclusively on floral resources as a source of food. However, in many natural and agricultural areas there has been a decrease in floral diversity and abundance, which in turn has caused nutritional stress for wild pollinators. As a result, many wild bumble bee populations are declining. Therefore, scientists are beginning to research the nutritional requirements of wild bumble bees and the nutrients available in the pollen and nectar they collect. However, there has yet to be any research attempting to quantify the mass of pollen available at the landscape-scale. We addressed this knowledge gap by looking into the variation of pollen mass per flower across species, habitat types, and time. The study was done by collecting flower anthers that have not undergone dehiscence and weighing them out wet and dry to get an estimation of pollen mass. We found that there was significant variation in the pollen mass between species and across the different flowering seasons, but not between habitats. We also found a significant difference in weight between wet and dry anthers, indicating that a majority of anthers consist of mostly water. This research provides a critical but understudied component of pollinator nutritional ecology by quantifying anther mass as an estimate for pollen quantity in the landscape. This research will be used along with pollen macronutrient analyses in the future to build a nutrient landscape available to foraging bees.

Introduction

Approximately 87% of flowering plant species are pollinated by animals (Ollerton et al. 2011). Wild bumble bees rely on floral nectar and pollen as their food and nutrient resources and

consequently are some of the most abundant and effective pollinators in both natural and agricultural ecosystems (Goulson 2010). They specifically forage to acquire essential and beneficial nutrients, such as proteins, lipids, carbohydrates, and an array of micronutrients (Raubenheimer and Simpson 2018). These floral resources and foraging decisions are therefore important to bumble bee fitness, since meeting their optimal nutritional intake is essential to their growth, reproduction, and overall survival (Wagner et al. 2013, Simpson et al. 2010).

Many bumble bee populations have been experiencing serious population declines due to nutritional stress caused by the loss of floral resources (Goulson et al. 2015, Woodard and Jha 2017, Vaudo et al. 2020). While nectar is the main source of energy for adult foraging bees, pollen is the major source of protein, lipids, and micronutrients for bees as developing larvae (Vaudo et al. 2020). Although pollen nutritional quality is crucial for bee health, plant species that produce high quality pollen may not necessarily produce high quantities of the pollen. Therefore, understanding how the quantity of pollen interacts with the nutritional content of pollen will be critical for understanding the nutrients available to bees in the landscape (i.e., the nutrient landscape).

It's been shown that pollen abundance and size play an important role for bee health as well (Buchmann and O'rourke 1991). Knowing this, we expect pollen mass to have a similar effect. However, we do not yet know how much pollen is available to foraging bees in the landscape. Due to this, I carried out research that showcased the variation of pollen mass across the different flowers per plant species, different habitats, and across the seasons. This will allow us to understand which species have higher pollen mass per flower, know the amount of pollen available in each habitat, and better understand the phenology of pollen mass. By weighing anther mass for species across the growing season, this research will provide an estimate of the quantity of macronutrients available to wild bumble bees in the surrounding areas.

Methods

I carried out this project by visiting different field sites that were established by Dr. Jane Ogilvie in 2015. I collected flower anthers from 35 different species that haven't undergone dehiscence to achieve the maximum amount of pollen the plant can produce. These anthers were gathered into centrifuge tubes by using forceps to pluck them. Next, I weighed out approximately 1 mg of anthers and took the count of how many anthers were needed to reach this weight to standardize the weight for all flower species, as the flower anther mass will vary from plant to

plant. This allows us to compare the pollen masses between the different species. I then dried the anthers at 100°C for approximately 24 hours, and again weighed out at least approximately 1 mg of anthers and took the count of how many anthers were needed to reach this weight. I also found the set number of anthers for each species, or average if there was variation (e.g., Asteraceae species), and determined whether these anthers were collected from flowers found in a dry meadow or a wet meadow. I also determined the seasonal time these flower species occurred (i.e., early, middle, or late season).

Results

For analysing the data, we measured the average anther weight per flower (mg) between the different variables: species, wet or dry meadows, flowering seasons. We ran One-way Anova tests for all of the analyses and found significant variation amongst all variables except for habitat types.

Variation Across Species:

We found significance in the variation of pollen mass across all 35 plant species ($Df = 34$, $F = 60.18$, $P < 0.005$).

Variation of Wet and Dry Anther Weight Across Species:

We still found significance in the variation of anther weight across all species when separated between wet and dry anther weights ($Df = 34$, $F = 85$, $P < 0.005$).

Difference in Variation Between Wet and Dry Anther Weights for Each Species:

There was significant difference in the variation between wet and dry anther weights for each species ($Df = 1$, $F = 288.5$, $P < 0.005$).

Difference in Variation Between Wet and Dry Anther Weight of All Species:

When looking at the averages of all wet and dry anther weights we found significance in the difference in variation between the two groups ($Df = 1$, $F = 54.41$, $P < 0.005$).

Difference in Variation Between habitats:

Visualizing at a larger communal scale, we found no significance in the difference of pollen mass variation between wet and dry meadows ($Df = 1$, $F = 0.619$, $P = 0.432$).

Difference in Variation Between Seasons:

Although there wasn't any significance when separating the plant communities by habitat, we did find significance in the difference of pollen mass variation when they were separated by seasons ($Df = 2$, $F = 8.989$, $P < 0.005$).

Discussion

Understanding the nutritional availability of pollen is imperative to pollinator nutritional ecology. With our estimations of pollen mass and existing qualitative analyses of pollen nutritional content, we can now fully visualize the wild bee nutrient landscape.

When viewing the pollen mass at a species level (Figure 1), we find that it varies from species to species. Some notable species include: *Salix spp*, *Chamaenerion angustifolium*, *Frasera speciosa*, *Senecio integerrimus*, *Castilleja sulphurea*, *Erythronium grandiflorum*, and *Wyethia amplexicaulis*. These seven species offer the largest amount of pollen per flower to wild bees when foraging, so it would be beneficial to study their nutritional content to see whether these species also produce high quality pollen. It would also be beneficial to take into consideration their abundance. Although these species produce a substantial amount of pollen per flower, if their abundance in the community is lower proportionally than plant species that produce less pollen than these high producing species might be less dominant than previously thought.

These results are taking into consideration the average anther weight of both wet and dry anthers for each species. However, once the averages are separated into these two groups, we find that the average dry anther weight is considerably lower than the average wet anther weight (Figure 2). This tells us that the anthers mostly consisted of water, so the actual amount of pollen by weight in the anther is lower than expected. We see this especially with 6 of the 7 aforementioned species. Their average anther weight falls more in line with the rest of the plant species when water content is removed. Interestingly though, *W. amplexicaulis*, *Heliomeris multiflora*, *Erigeron speciosus*, and *Helianthella quinquenervis*, all Asteraceae species, maintain a similar average anther weight between their wet and dry anthers, indicating that they have a

higher proportion of pollen to water content. A reason this may occur is because Asteraceae species have their anthers more exposed than non-Aster species, which might cause the water to evaporate more quickly. This significant difference in variation between wet and dry anthers still remains true when looking at the total number of anthers instead of each species (Figure 3). This supports our claim that a majority of the plant species contain a large proportion of water to pollen in their anthers.

Although there is variation at the species level, when comparing between wet and dry meadows we discover that there is no significant difference in their variation (Figure 4). In terms of foraging decisions, this indicates that wild bees are not at a disadvantage if they gather pollen at one type of meadow over the other. However, this doesn't take into account the abundance of each plant species found in wet and dry meadows, so once we can include flower counts we can get a much more robust estimation of pollen availability at a landscape-scale.

The variation in pollen mass also changes over time. Average pollen mass reduced sequentially with each seasonal period (early, middle, and late season) (Figure 5), meaning that the early flowering season had the highest pollen mass, followed by the mid season, and ending with the late flowering season. Interestingly, even though the mid season had the highest number of species with 17, the early season still produced the highest amount of pollen with 9 species. Once again, these estimations will become much clearer once we can incorporate flower abundance. Additionally, these phenological changes in pollen mass should be further investigated to see if there are any significant effects on wild bumble bee life history traits and overall fitness.

Conclusion and Future Directions

In order to fully understand the nutrient landscape of wild bumble bee populations, it's essential to not only consider the nutritional quality of pollen, but its quantity as well. This more thorough comprehension of wild bee nutrition will improve our understanding of the basic ecology of these pollinators, let us better support their health, and improve our conservation efforts to combat their population declines.

In the future, we will attempt to incorporate flower count data of all 35 plant species to create more robust pollen mass estimates. In addition to this, it would be interesting to study how pollen mass phenology may affect wild bumble bee life history traits (i.e., foraging,

reproduction, life stages), and to carry out phylogenetic analyses of the chosen plant species to see if there are any relationships between plant families and their pollen mass content.

Land Acknowledgement

I'd like to honor and acknowledge that we are on the homelands of the Ute tribe, which were forcibly taken through the ratification of the Brunot Treaty in 1874. We must recognize the Indigenous peoples of the Ute nation as the original stewards of this land, and that they still have ties to their homelands. We must also acknowledge that our research has benefited and continues to benefit from access to land that was acquired through a painful history of genocide and forced removal. Knowing where we work won't change the past, but it allows us to better understand the continued injustice that has stemmed from it and can empower us to build a supportive community of ecologists that will help meet the rights and needs of Indigenous peoples.

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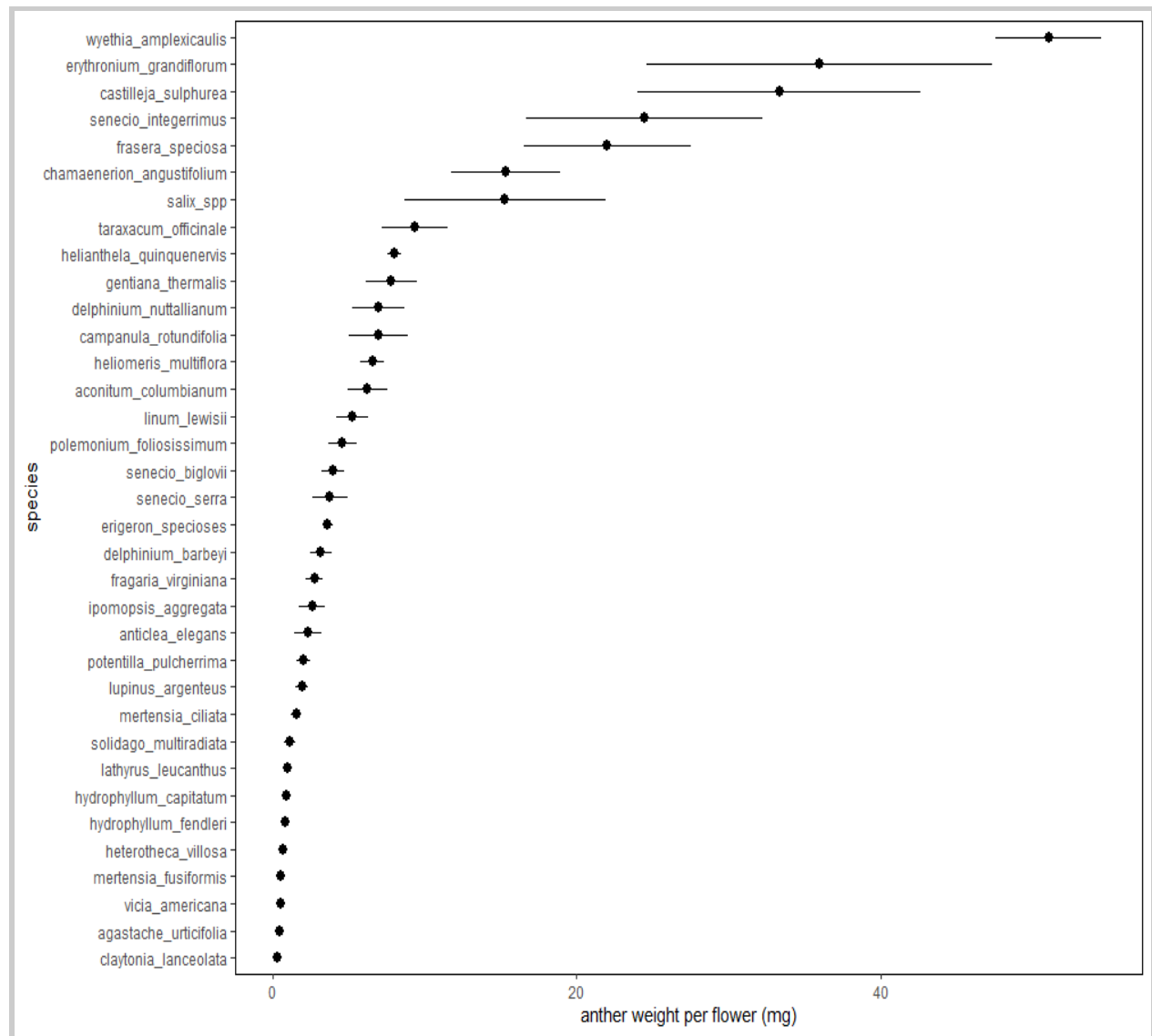


Fig 1. Visualization of the variation of pollen mass between the 35 different plant species. The x-axis measures the average anther weight per flower (mg), which is represented by the dot accompanied by an error bar that represents 95% confidence intervals. The y-axis is the list of plant species.

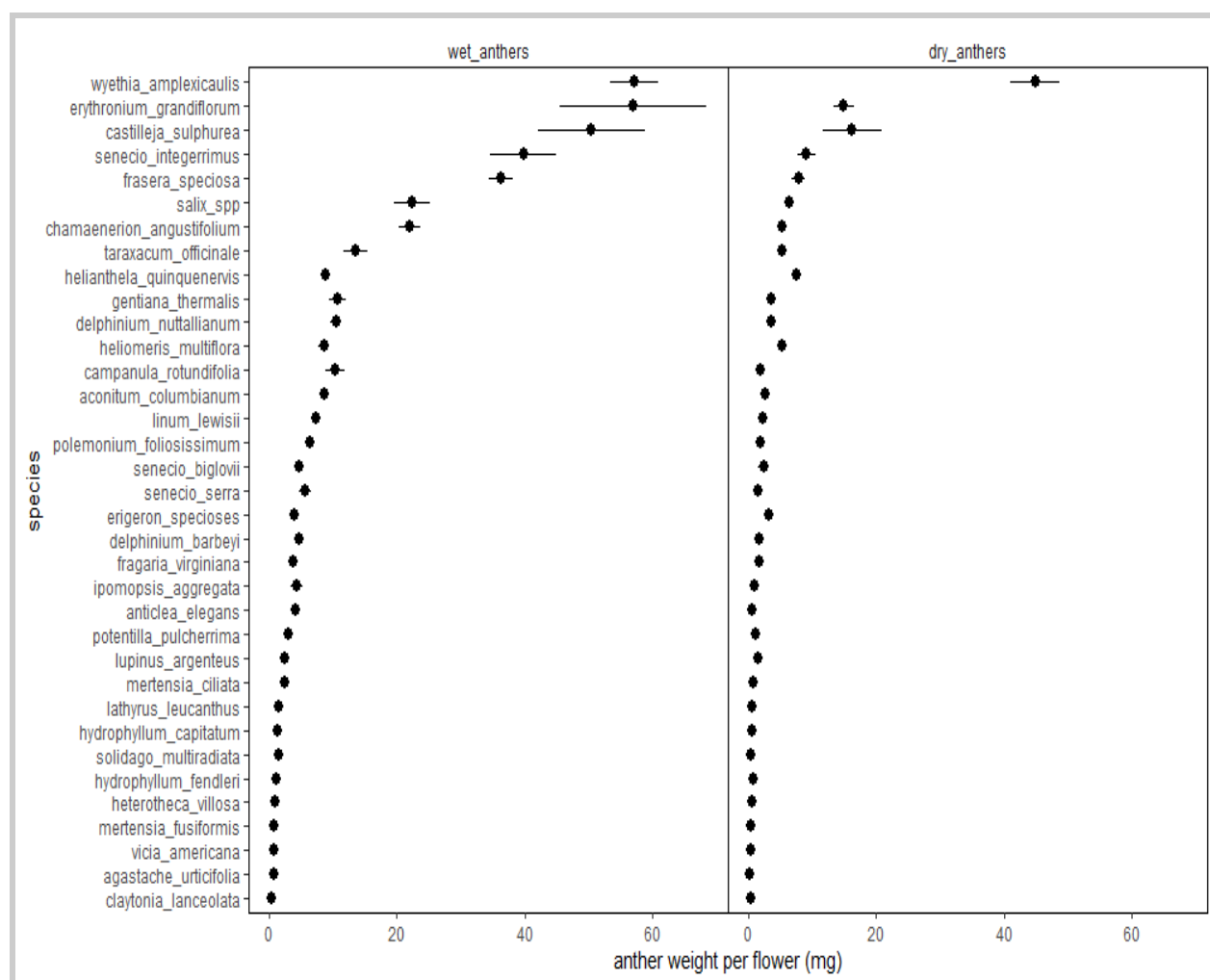


Fig 2. Variation of pollen mass between the wet anthers of the 35 different plant species (left). Variation of the pollen mass between the dry anthers of the 35 different plant species (right). The x-axis measures the average anther weight per flower (mg), which is represented by the dot accompanied by an error bar that represents 95% confidence intervals. The y-axis is the list of plant species.

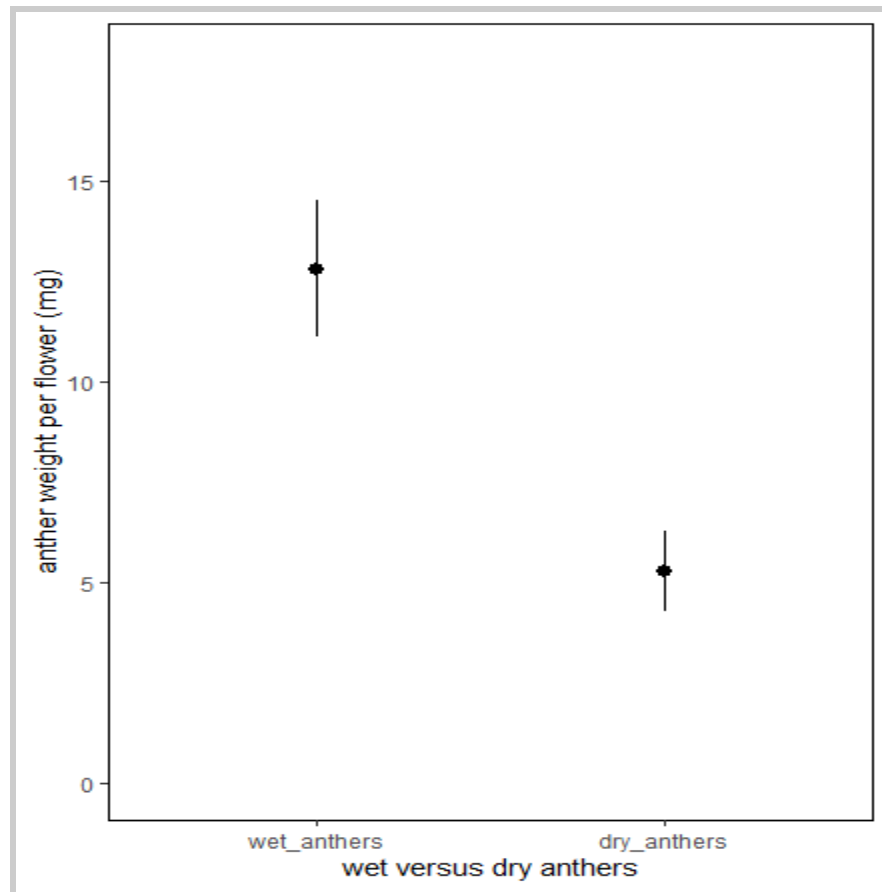


Fig 3. Difference in anther weight per flower (mg) between all wet and dry anthers of all 35 plant species. The dot represents the average anther weight per flower (mg), and the error bar represents 95% confidence intervals.

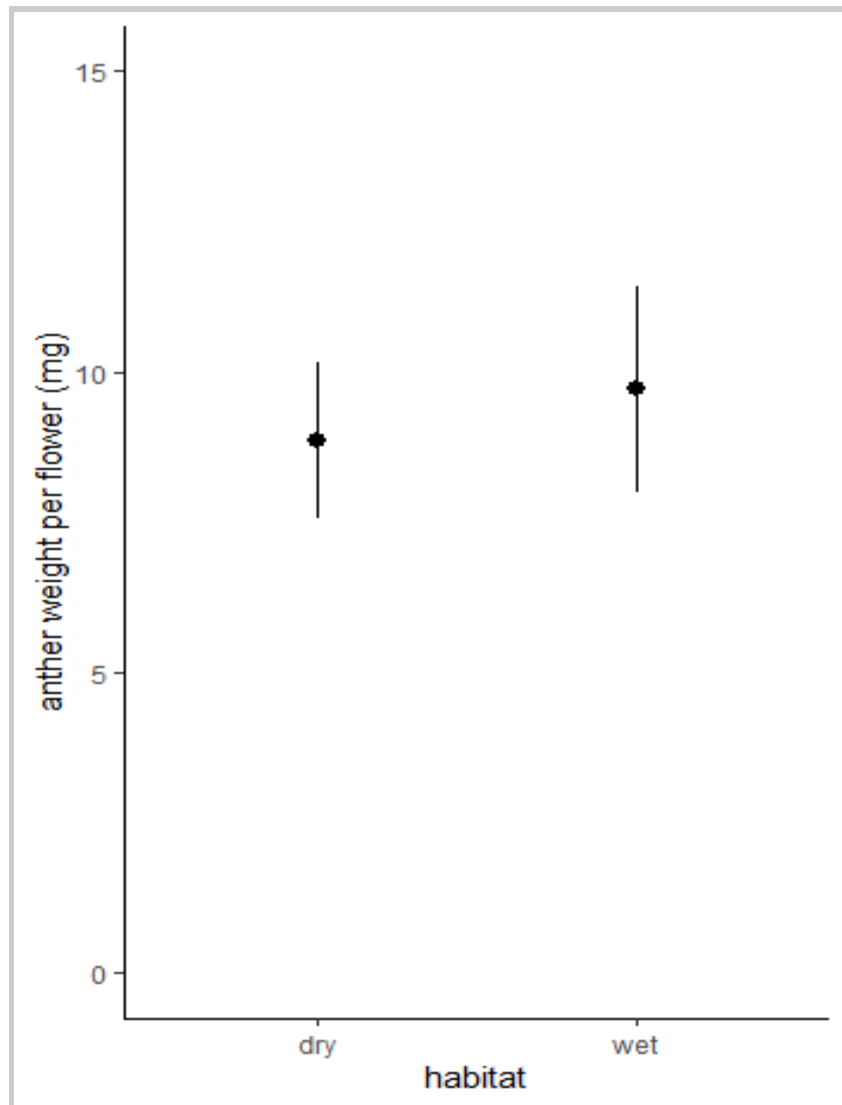


Fig 4. Difference in anther weight per flower (mg) between wet and dry meadows. The dot represents the average anther weight per flower (mg), and the error bar represents 95% confidence intervals.

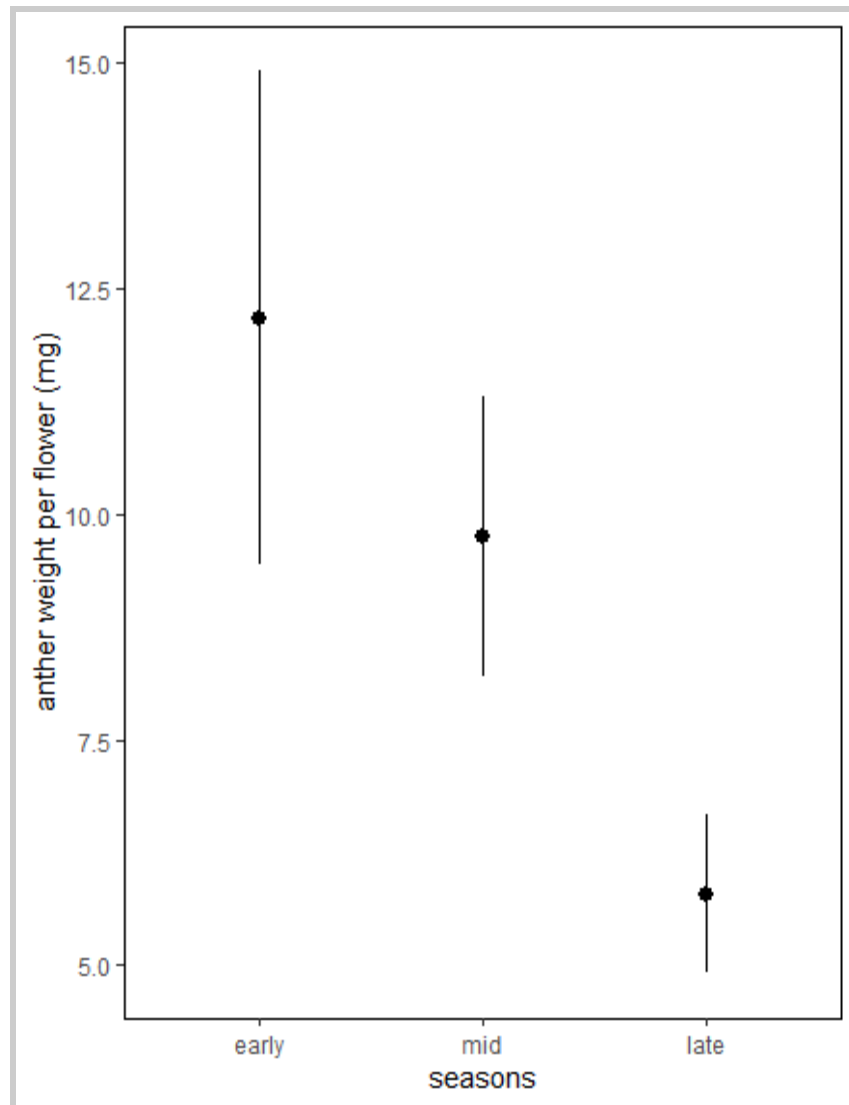


Fig 5. Difference in anther weight per flower (mg) between the early, mid, and late flowering seasons. The dot represents the average anther weight per flower (mg), and the error bar represents 95% confidence intervals.

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