

Investigating the air temperatures of different taxa in an alpine plant community

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Abstract

1. Ecology, like most science, is a rapidly progressing field in which new technologies are constantly being implemented in order to gain a wider and more holistic perspective on plant dynamics.
2. Plants can modulate their temperature via the process of transpiration and shading, which can also lead to modified air and surface temperatures.
3. One of the goals of this research was to investigate whether there is variation in air temperature modification across alpine plant taxa. Because climate change has been shown to have a larger effect on plants at higher elevations, we can use the information from this study to predict how plants will likely cluster in the future as their environment warms.
4. Our results showed minimal variation between the microclimate temperature of the plant and the microclimate temperature of the substrate. Consistently, the plants were in fact cooler than the bare substrate around them but there was no evidence suggesting that certain plant species were able to cool themselves better than others.
5. We didn't get the results we would have liked to see however, there is still a lot of value and potential that this data holds. This was also a very good preliminary year of conducting thermal research.

Introduction

The field of ecology has seen a rapid evolution in the understanding of plant systems. At first, it was thought that plants were always competing with one another for all of the viable resources, especially if the plants were of different species. This then changed with work from Bertness and Callaway as they began to find out plants can actually work together in order to survive changes in overall climate across years (Bertness et al. 1994). Now, the whole picture is that plants can modify how much they compete or help each other depending on fluctuations in the climate. Blonder et al. 2018 showed that both plant functional traits and microclimate are necessary to predict community dynamics. Up until now however, the demographic analysis of these plant communities has been missing detailed temperature data which could show differences between them.

Thermal imaging has made a major impact in the field of ecology as it has allowed for an expansion in the way we look at plant systems. Temperature differences between microclimates have been shown to be correlated with the types of species that are hosted within the microclimates. It has also been found that plant diversity in alpine plant communities has helped

these plants stave off the effects of climate change by being able to regulate soil moisture (Wright et al. 2020) as well as keep a much more consistent soil temperature range that fits in their preferred ecological niches (Ohler et al. 2020). Thermal imaging research will be very important in the coming years as climate change further progresses. It has been shown that the impact of climate change is far greater as elevation increases (Pepin et al. 2015). This means the plants we are researching are going to have larger climatic changes than plants at lower elevations making it vital to understanding how they will manage to mitigate these effects. This type of research could be vital in further expanding our knowledge on how plant communities function as their environments change.

We needed a way to investigate these temperature gradients in a close up and intensive way. Drone imaging would not work as the propulsion off the ground would only allow it to be however close to the ground before the drone itself would affect the micro climate. The propulsion would add a new factor of unnatural wind to the microclimate and could even stir up substrate. The drone also doesn't even have the resolution we needed as multiple plants could all fall under one pixel. The thermal imaging camera (FLIR 54) allows us to get detailed thermal images and, if done correctly, there is minimal to no effect on the microclimate of the plant(s) being investigated. One of the ways in which this technology can be used is to judge how different plant vegetation compositions affect the temperature in their direct vicinity.

There are so many factors that can be involved in the changing of microclimate temperature. Wind can blow in different temperature air which can have an immediate effect on the previous temperature of the microclimate. Wind also increases the process of transpiration, This is the process of water being taken from the plant through the stomata. This water is taken because it evaporates and when water evaporates, it cools down the surface it evaporated from. So, increasing wind will increase the level of evaporation from the plant thereby increasing the cooling factor of the evaporation. Next we have solar radiation. Solar radiation has a heating effect which boosts the temperature of the microclimate and then there are clouds which can limit this radiation and decrease the temperature of the microclimate.

I asked whether there are certain taxa that are more efficient in limiting these factors than others. I hypothesized that a plant taxon will likely be able to mitigate their microclimate's temperature more efficiently if that composition is denser as well as larger. I believe this will be the case because the transpiration from a compact plant with considerable vegetation may be more efficient in cooling and has a higher shading factor. This type of data could be key in understanding how these plants will interact as the climate changes year by year.

Methods:

The plants we worked with were found at a research site set up by Benjamin Blonder in 2014. The site is found on a ridgeline on the south east side of Mount Baldy. This site is

composed of 50 plots each being 2 meters by 2 meters. Each plot is spaced 2 meters from another in a grid pattern shown in figure 1.

This research site has been in use since 2014 so by using it, we can add this data into an ever growing and rich dataset on the microclimate of these species in the high alpine. There are a total of 18 species on the plot, 10 of which we gathered data for. Among these 10 species there was a large spectrum of variation when it came to composition. Plants like *Elymus lanceolatus* tend to be tall and thin whereas plants like *Eriogonum* tend to be short and dense.

We measured temperature from the plant's microclimate to the exposed substrate at least 10 centimeters away. We also had to make sure we were getting consistent temperatures of a large enough surface area to try and keep as many variables out as possible. This had to be done because both the substrate and plant have different emissivities meaning they have different levels of light radiating from them. To mitigate this, we decided to use what we have been calling fake plants. This is because the fake plants would give us a consistent emissivity level both on substrate and on the plant as the fake plants were made out of the same material. These "plants" were made out of green construction paper cut outs with a diameter of 1.25 inches. These were then placed on bamboo skewers in such a way that, when placed in the ground, the construction paper was 5 centimeters off the ground. For each thermal image we would place four fake plants. This is because, in order to try and mimic transpiration, we would wet the construction paper of two of the plants. This meant that a set of one wet and one dry fake plant would go both on the outside of the plant (substrate) and in the middle of the plant. We would allow for a calibration period of 1 minute in order to allow the fake plants to acclimatize. This then allowed us to gather more consistent areas to measure during the analyzation process.

In order to collect this data in a way that was consistent enough to analyze, we also had to collect microclimate data and the conditions in which we took the photos had to be quite similar. We decided it was best to collect data in sunny, and relatively warm conditions and we could only take pictures of the plants between 10 am and 2 pm. We ended up still taking photos in the clouds because we were also gathering solar data so it was possible to distinguish between which photos were taken under certain conditions. Before we started we would set up a pyranometer which we used to measure solar radiation. This would be set up so that the bottom gauge was 1.5 meters off the ground and they would also be facing due south. We also made sure the gauges were level. Once that was turned on and checked for accuracy, we would begin our data collection. We measured wind by using an anemometer and taking a 30 second average of the wind both directly above the plant and 50 centimeters above the plant. We then measured the height of the plant in centimeters and the air temperature in order to get a rough estimate of the plant's microclimate.

The first photo was taken without any of the fake plants and then the second photo had the fake plants placed accordingly. We would first place the two dry plants so one was inside the

plant and the other was at least 10 cm from any sort of vegetation. Then, we would take the other two plants and wet them using a sponge dauber. This would be done in such a way that both sides of the construction paper were evenly wet all around. Once this was done correctly, we would place the wet plants next to the dry ones in such a way that they were as downwind from the dry plant as possible. For the outside plants, this came second to being 10 centimeters away from any vegetation. Once the plants had been wetted correctly, we started a 1 minute timer and placed the wet plants as quickly as possible. As a final note on the fake plants, we tried to place the outside plants to the north of the actual plant but this was not always achieved if there were other plants that didn't make it possible to be 10 centimeters away. For all the photos, we had the compass within the photo in order to show the direction in which plants were placed. We would also make sure to take each photo at 150 centimeters above the ground in order to get consistent pixel sizes across the board. Some plant/plant clusters were large and required multiple photos in order to capture the whole thing. After each individual photo, a PAR reading was recorded. This measures the amount of photosynthetically active radiation per square meter at a given time. The PAR meter (along with the anemometer, pyranometer, height, and temperature) was recorded as a way to give us a rough estimate of the plant/plant cluster's microclimate at a given time.

Lastly, we had to take data for plants that weren't within the actual plot in order to get a large and diverse sample size. For plants not directly in the plot, we also had to measure their maximum length, maximum height, and the amount of inflorescence bundles they had.

Methods - analysis:

We analyzed the thermal images using Flir Photo Studio. The first thing I did was categorize each photo into the date it was taken. Once the photos were organized, I went through and analyzed them individually in the software. This entailed boarding the areas of the fake plant circles in each photo. For the most part, these were complete circles but for some photos, there was plant vegetation that covered some of the circle. In this case, I would do my best to gather an area of as much of the circle as possible without including any of the plant vegetation. These areas would then give me maximum, minimum, and average temperatures for what they enclosed. For my analysis, I only used the averages as a way to get an overall idea of the temperature that each fake plant was emitting (*Figure 2*).

Results:

Our first plot gives us an idea of the demographic that we collected (*Table 1*). We notice that some species (*Agoseris glauca*, *Arenaria congesta*, *Chaenactis douglasii*) don't even reach 10 individuals collected so it's safe to say that there is not enough data on these plants to get a strong conclusion of the thermal aspect of their microclimate.

Figure 2 compares the inside dry fake plant to the outside dry fake plant for each species investigated. This graph only takes into account the average temperatures of all the plants. Without any of the microclimate data, there isn't any significant conclusion that can be drawn from this figure. The only plant that seems to have statistical significance is *Elymus lanceolatus* showing that the outside dry fake plant (grey boxplot) had a much higher average temperature than the inside dry fake plant. Most plants show the outside plants having higher average temperatures however there is no statistical significance. *Figure 3* uses the same format as *Figure 2* only it compares the two wet fake plants. In this case, we see even less variation which makes sense as it takes longer to heat or cool water than it does air. We also see that the average temperatures across the board are much lower than the dry ones which, again, comes down to water being harder to heat up. Still, there is no statistical significance that supports my hypothesis.

We then thought it may help to categorize each plant into small, medium, or large depending on what species it is. We also decided to look at the difference in temperature between the outside and inside plant instead of comparing two box plots. This is how we derive *Table 4* and *Table 5*.

From *Table 4*, we notice that there seems to be a larger temperature fluctuation as the categories get bigger. The large category has the largest temperature fluctuations. Yet still, this isn't consistent with my hypothesis. If my hypothesis were to be true, we would have seen plants like *Eriogonum umbellatum* and *Heterotheca villosa* have far larger differences between inside and outside plants. We do however, see in the large category that some of the denser plants (*Lupinus argentus*, *Ivesia gordonii*, *Phacelia hastata*) begin to show a level of variation. *Table 5* is the same structure as *Table 4* only it analyzes the wet fake plants. The wet fake plants showed less overall variation but still showed more variation the larger the size of the plant was.

Discussion:

The key finding that came from this data was seen in the different sized plants seen in *Table 4* and *Table 5*. We end up seeing larger variation across species for the large individuals. This makes sense as larger plants have a far greater surface area which makes them more likely to see greater temperature difference between them and the substrate.

With this however, the results don't show any statistical evidence to back up my conclusion. The main reason for this is because the microclimate data has yet to be taken into account. I believed that I did not need to account for the microclimate data since I was taking differences between the inside and outside fake plants that were experiencing the same climate as one another so I thought it made sense that their difference would be about the same no matter the weather. Looking back I now see how this doesn't make sense because it isn't that the plant

will stay a set temperature below the substrate no matter the weather. It will fluctuate as temperatures rise or lower. This means microclimate data must be taken into account no matter what this data is being used for.

We would also need to do a more in depth analysis on the composition of each individual plant. Small, medium, and large is not a detailed enough analysis to break down each plant. Every plant would need a quantitative summary of its size and density in order to truly judge its composition. Unfortunately, I didn't catch this in time and so my hypothesis cannot be accepted. This does not mean that this data has no value.

Even though my hypothesis can't be accepted, this research still has a lot of potential. First off, it showed me just how much climate factors can affect the temperature and even in ways that are very unexpected. Being able to account for this with as detailed microclimate data as possible is more than necessary in order to truly find substantial information from this data. We can even implement this data and future thermal imaging data into the demographic microclimate study that Dr. Blonder is conducting. Every year, this research can become more refined and conducted in a more efficient way which will allow it to become more accurate, interesting, and fundamental in how we perceive plant interactions in an ever changing alpine environment.

Works cited:

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Figures:

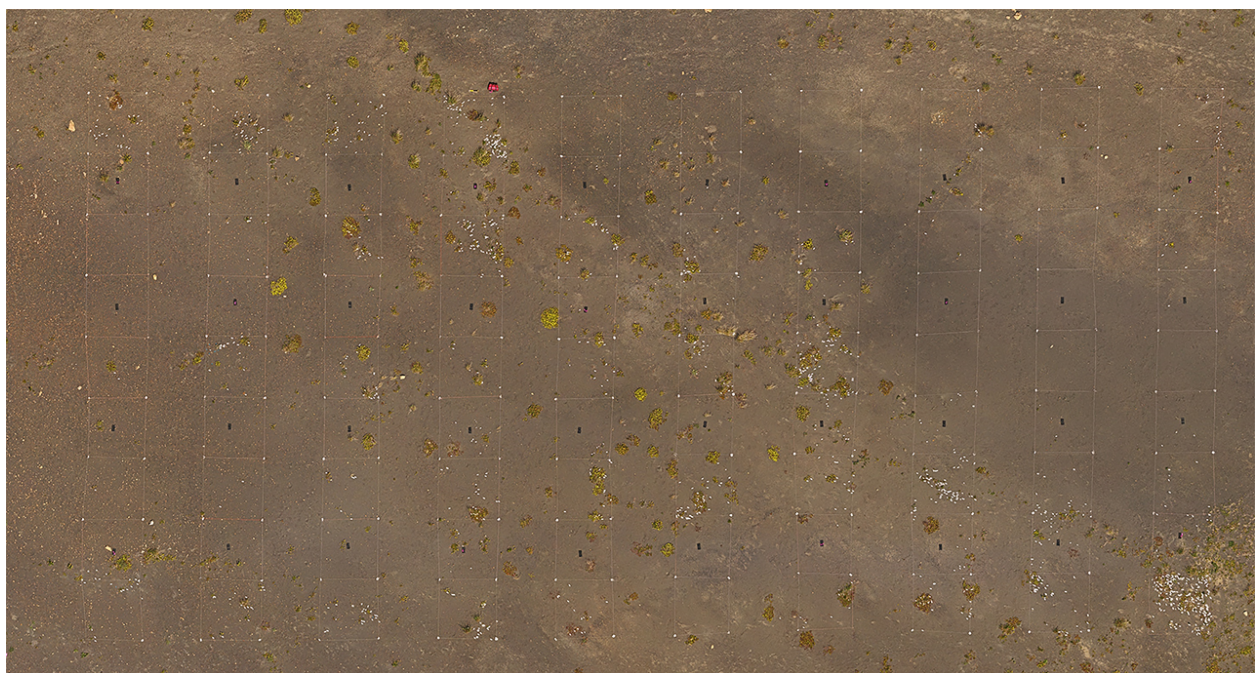


Figure 1

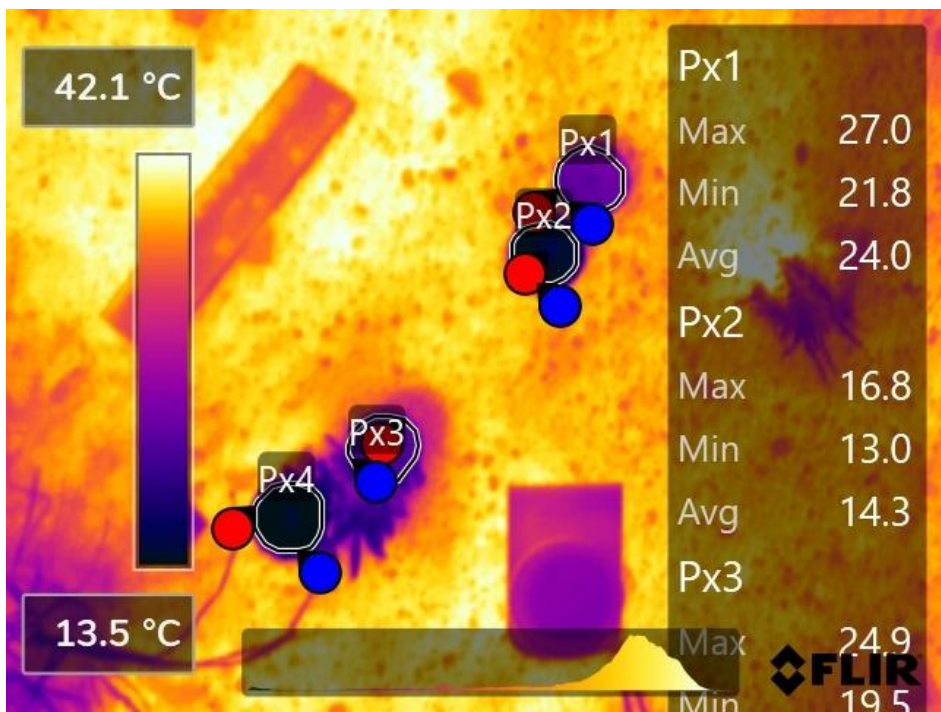
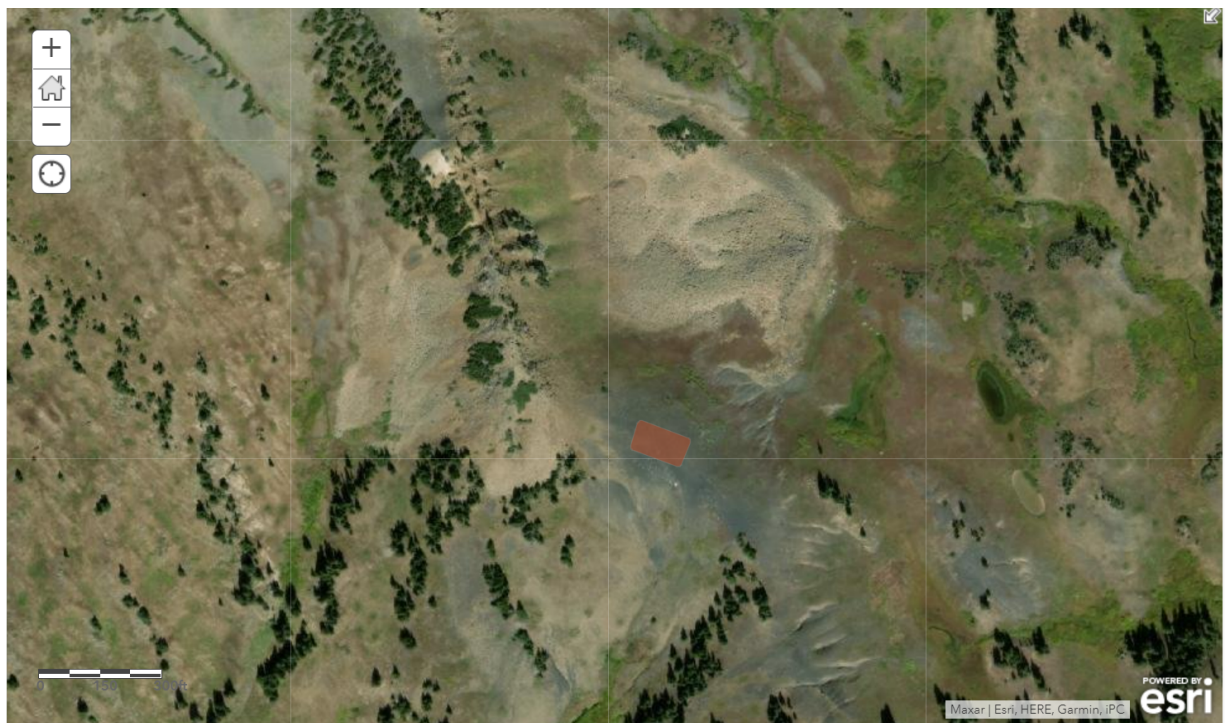


Figure 2 (Photo of *Lupinus argenteus*)



Map 1 (zoomed out)



Map 2 (zoomed in)

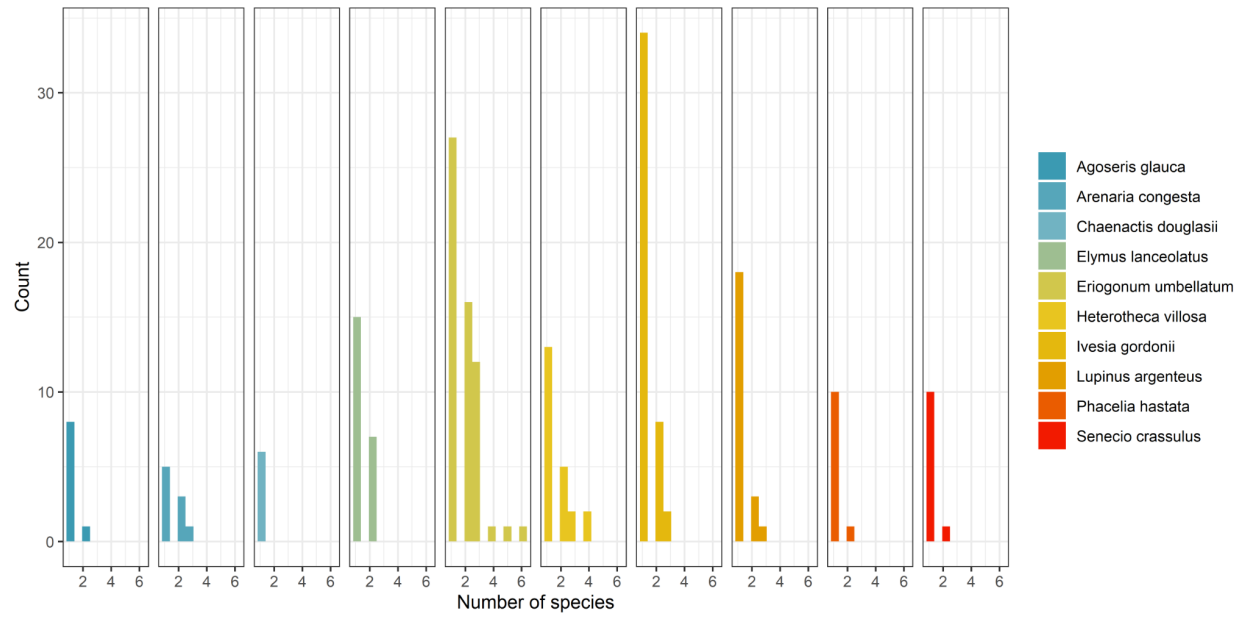


Table 1

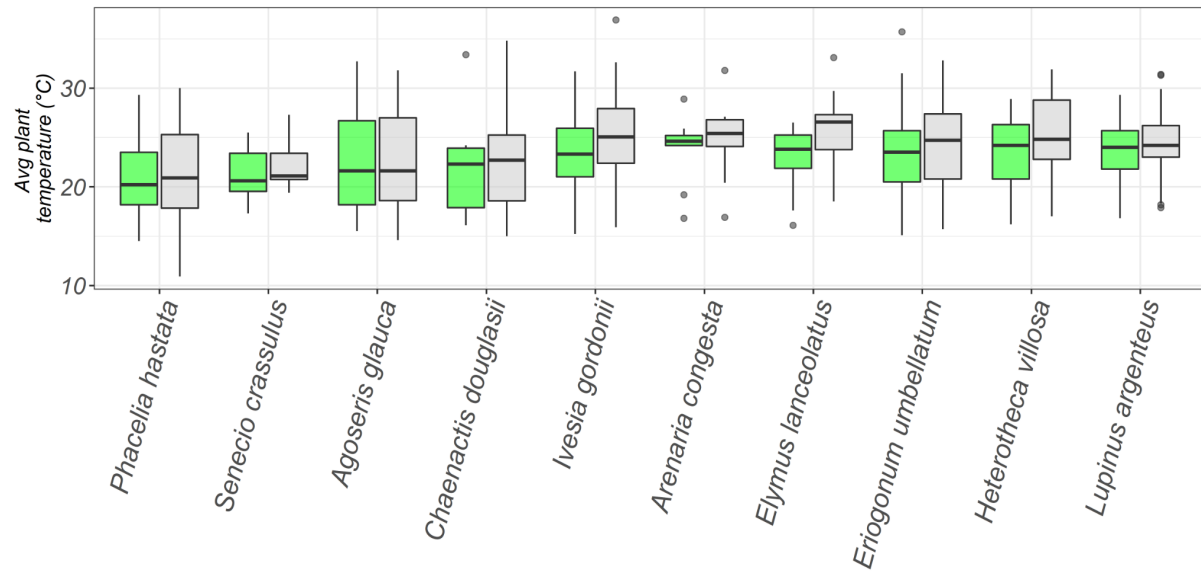


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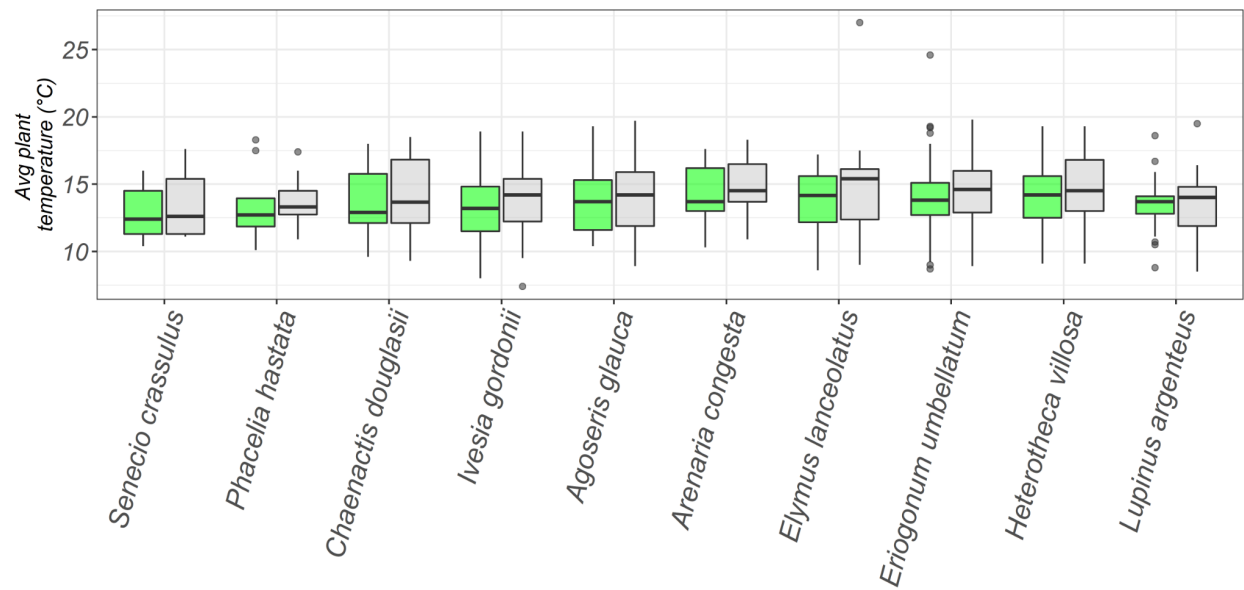


Table 3

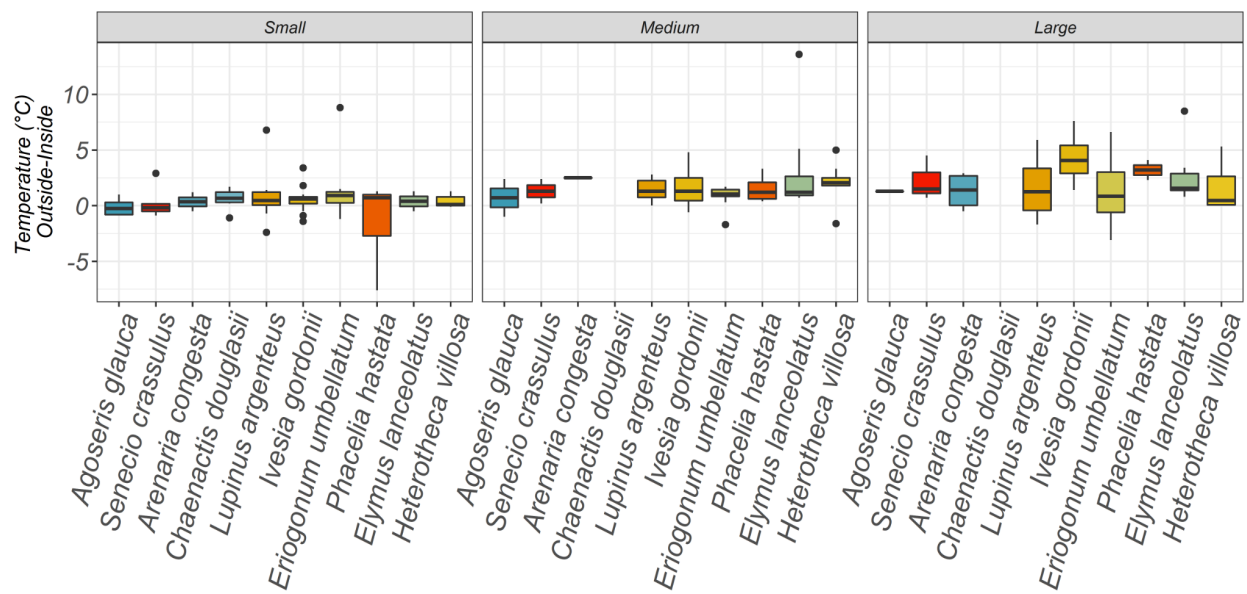


Table 4

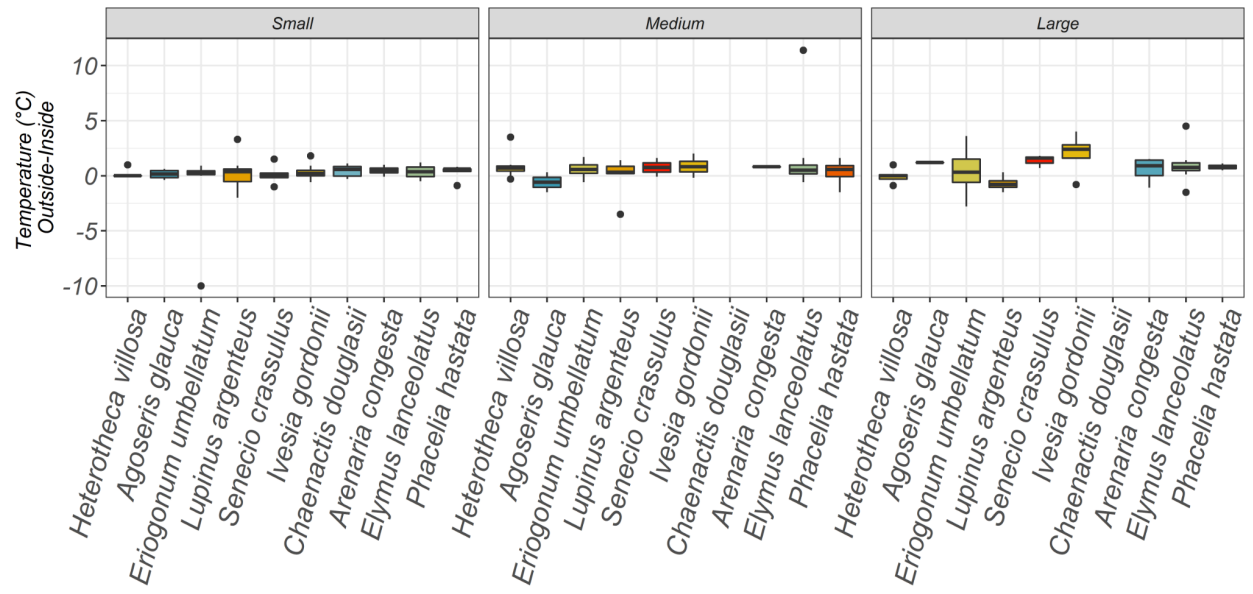


Table 5