Effect of El Niño Rainfall on Aphid Winged Morphs

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ABSTRACT

Aphid interaction with pheromone cues, one of the strongest being aphid alarm pheromone. Excess rainfall may stress aphids and cause them to produce the alarm pheromone. Because of this, aphids may produce more stress pheromone, which can be observed in the field through percentage of aphid population with wings. Results showed that there was no significant findings and that no result could be concluded in the study.

KEYWORDS

Alarm pheromone, aphid stress, specialization.

INTRODUCTION

Aphids are well-known pests of plants worldwide. We all know them for the frustration they cause our family and neighbors when they affix themselves to plants that we want to grow, though they have a much larger role in urban environments. To start, aphid honeydew production serves as a great carbohydrate source for ants from the high level of sugars in the honeydew (Shik et all 2014). Ants of many species then have motivation to defend the aphids against predators that would normally eat them (Altfield & Stiling 2009). Aphids serve as food sources for carnivorous insects such as ladybird beetles, which can be observed directly in the spring. One role that is largely overlooked, however, is how they communicate with their environment.

Aphids and their environments interact in several ways, the strongest of which is pheromone response. When an aphid bites into a plant, the plant releases chemical signals that aphids have damaged the plant (Verheggen et all 2013). Aphids then receive the chemical signal and find undamaged plants to go to next. Aphids primarily release a pheromone commonly known as aphid alarm pheromone, E-Beta-Farnesene, as a reaction to most types of stressful interactions. Aphids most commonly release this pheromone when predators are feeding upon other aphids (Joachim & Weisser 2013). The response that aphids have to the pheromone depends on a large number of factors. For example, if the aphids have multiple alarm-pheromone producing stimuli, they adjust and become less sensitive to the pheromone (Thieme & Dixon 2015). If ants are present around the aphids, they are more likely to remain on the plants (Tegelaar & Leimar 2014).

The recent El Niño wet weather patterns provide a rare opportunity to observe how aphid winged morph development occurs. Since winged aphid morphs tend to increase in numbers in generations after a high level of aphid alarm pheromone (Tegelaar & Leimar 2014), I am interested in learning if the constant rain from El Niño stressed the aphids enough that they may have a significant increase in winged morph production. Aphid alarm pheromone also attracts ants to the position of the aphids (Verheggen et all 2012), so I am also interested in the effect of the rain on ant presence around the aphids. Also, since gas concentrations also have a measurable effect upon aphid response to alarm pheromone (Hentley et all 2014), air pressure differences through rainy weather may change the amount of winged aphid morphs per generation.

My hypothesis was that there would be a significantly higher percentage of winged aphids after the aphid populations sampled have time to react to the stress of the El Niño pattern rains than the percentage of winged aphids in populations right after the rains. I expected that if aphid samples have ants near them, that the percentage of aphid wing morphs in the sample would be lower than other sample populations. I also wanted to examine what differences in aphid winged morphs there could be in aphids living on several different plant species in the study area.

METHODS

Collection Site

I collected aphids from three sites to the southeast of the UC Berkeley campus. The first site I collected from was a geranium on Haste Street between Piedmont and College. The second site was from a small leafed maple tree on Durant between Piedmont and Channing. The last site was from a nasturtium further to the east on the same street as the maple. I collected aphids in two separate periods a month from each other to see the aphid population directly after the El Niño rainfalls and a month after when effects of the rainfall on aphid morphology were present. Aphids were collected on 3/16 and 3/19 for the first set and 4/19 for the second set.

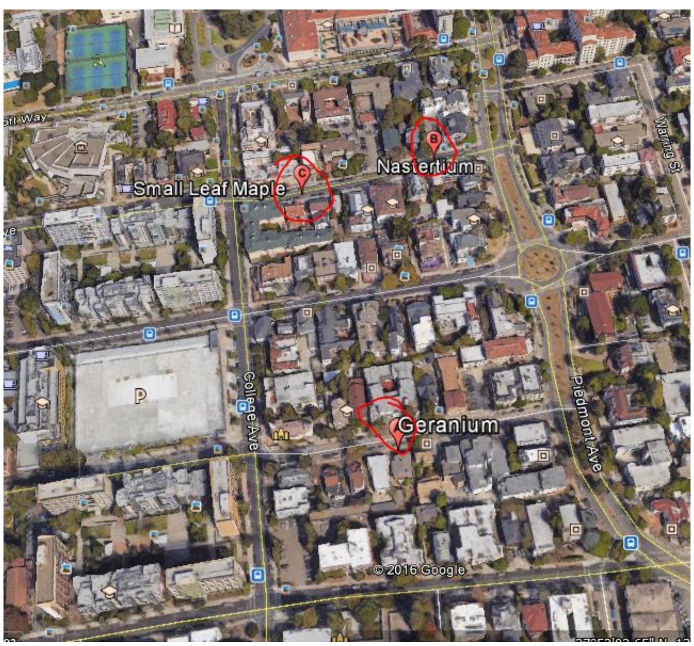

Figure 1. Map of Collection Sites.

Counting

Aphids were removed from sample bags onto a tray for counting. The aphids were then manually moved to a petri dish with four divisions and separated based upon the criteria of being a winged female, a wingless female, or a nymph wingless female. After one sample was completed, the petri dish and tray were cleared for use of another sample.

Analysis

Nonparametric single-sample Wilcoxian tests were used to see if the data collection was significant. P values of .05 or less were the criterion to reject a null hypothesis that the obervations in the data were significantly different. The programming software R was used for analysis and the program Microsoft Excel was used for data entry.

RESULTS

For the first set of samples, 772 aphids were counted in total from the three areas. Of those 772 aphids, 69 of them were winged, meaning 8.94% of the aphids sampled in the first set were winged. For the second set of samples, 358 aphids were counted in total and 7 of those aphids were winged, for 1.96 % of the sample being winged. For the geranium plant, the first sample had two winged aphids out of 39 aphids for 5.13% of the aphids having wings. The second sample had none of the 43 aphids with wings. For the nasturtium plant, 11 aphids with wings were found out of 499 aphids, for 2.2% of the aphids having wings. In the second sample, 4 out of 277 aphids had wings, leaving 1.44% of the population with wings. For the small-leafed maple, 56 out of 234 aphids in the first sample had wings for 23.93% of aphids in the sample with wings. For the second sample of the small-leafed maple, 3 out of 38 aphids had wings, for 7.89% of the aphids with wings.

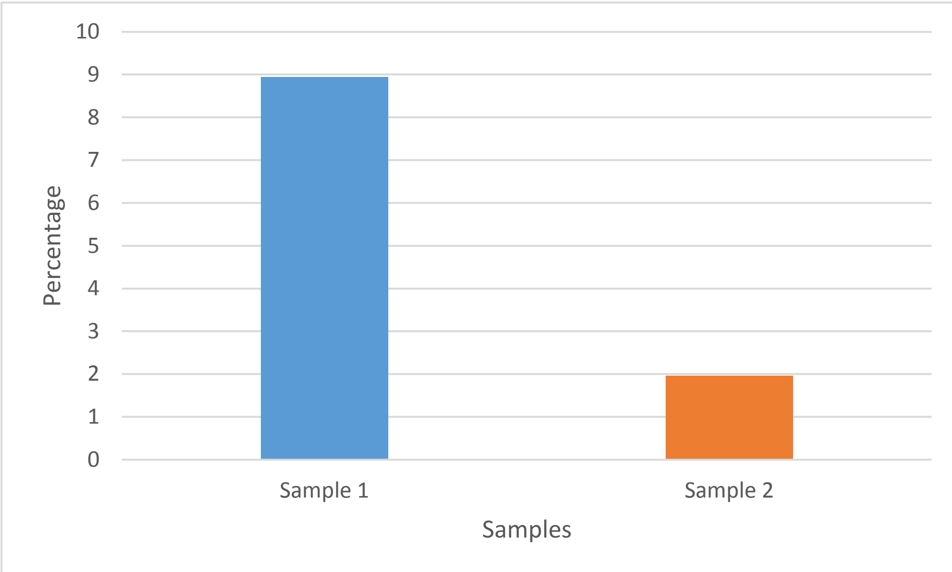

Figure 1. Percentage of Winged Aphids in First and Second Sample Periods

Table 1. Aphid Type and Count Per Plant and Day

Plant	Day	n Winged	n N W	n Total	W div total	p winged
1	1	2	37	39	0.05128205	5.1282
2	1	11	488	499	0.02204409	2.2044
3	1	56	178	234	0.23931624	23.9316
1	2	0	43	43	0	0.0000
2	2	4	273	277	0.01444043	1.4440
3	2	3	35	38	0.07894737	7.8947

Table 1: The letter n = number of aphids in a category. The letter p indicates the percentage of aphids in a category. The letter W indicates winged aphids and the letters N W indicate nonwinged aphids. Plant 1 is a geranium, plant 2 is a nasturtium, and plant 3 is a small-leafed maple.

Data Analysis

After a single-sample Wilcoxian test of the data, the difference between the two is suggested to be not significant with a p-value of .059. Even if the p-value was significant, the results would not prove my hypothesis.

DISCUSSION

My results did not prove that an increase in rainfall was correlated to higher numbers of aphid wing morphs in aphids. Instead, my results suggest a reverse in trend where the rains may have reduced the number of winged aphids present in populations in my project. This may be from aphid predation between the two collection periods, and is likely also contributed to by winged aphid departure from high stress. Also, there was a large gap in aphid numbers between plant species sampled from. This is most likely due to difference in aphid species strategy and to plant defense systems.

Lack of Aphids in Second Sample and Results Contrary to Hypothesis

The aphids sampled in my experiment did not show an increase in wing formation despite contrary findings in alarm pheromone studies like Tegelaar & Leimar 2014. One possible explanation for this is that aphid alarm pheromone acts as a repellant for aphids (Gao et. all 2015). If the alarm pheromone was in increased concentration through the rainfall, it is possible that the aphids with wings from the stress event were more motivated to find a new host plant than the aphids from the first sorting, leading to data contrary to my hypothesis. Another possible explanation may be that the fluctuating temperatures experiences throughout the month between sample collections had a stronger effect on aphid presence than the rain may have since warmer temperatures from what aphids are used to are observed to change aphid physiology (Wilkaniec et. all 2016). While the paper examines temperature effect on gender in aphids, it would not be unfeasible to think that temperature could also affect wing production in aphids as well. If this were the case, the fluctuating temperatures may have caused winged aphid morphs to fly off in search of different temperature conditions such as shaded plants or closer proximity to running water, since the areas where I collected had little shade or running water. One other possibility in the lack of aphid presence in my second sample is the cost that the emission of alarm pheromone has upon aphids. A past experiment has found that predation increase from release of alarm pheromone results in higher mortality rates of aphids than normal (Outreman et. all 2010), so the increase in stress pheromone may have led to increased predation of aphids and thus less aphids in general at the sites in my study over time. This would also provide a good reason for aphids with wings to vacate from the area, possibly explaining the lack of winged aphids in the second sample.

Aphid Samples and Plants

In my data, there is a large difference in the number of aphids located on each of the three different plants in my studies. Geranium plants had the least amount of aphids by far compared to the amount of aphids collected from nasturtium and small-leafed maple plants. One possible reason why the geraniums had lower aphid presence than the other two plants is because some geraniums have toxins that are produced in response to herbivory (Hurley and Dussourd 2014). These toxins reduce fecundity of herbivore eggs and thus could have kept the aphid population on the geraniums low compared to the other two plants. Additionally, since aphids would only be likely to survive on sick leaves with poor circulation and low ability to create toxins, aphids would be further incentivized to leave the geranium since aphids respond to poor plant health by finding a new plant to feed off of (Verheggen et. all 2013). Another large discrepancy noted is that the nasturtium plant sampled from had a larger amount of aphids than the other plants. One possible explanation of this is that the black-bean aphids on the plant could be specialized for growth on nasturtium plants and thus thrive on solely that plant (Mackenzie 1996). Other aphid species found on the other two plant species in the experiment were found in small quantities on other plants, suggesting that the other aphid species found are generalists. If this is true, then this would account for the large discrepancy in aphids between the other species in the study and the aphids on the nasturtium plants.

Limitations & Future Direction

Because I used an indirect method to examine stress levels in aphids, there are many potential confounding factors in my experiment. Because I chose differences in wing morph ratios in aphids as the main factor for determining aphid stress, any other factors in aphid wing morph determination will confound the data. Also, there is a tendency for aphids to gain a larger ratio of winged morphs over the season. Another limitation to consider is the effectiveness of pulling leaves from plants for a sample, since winged aphids could easily escape from the system and thus evade counting. Time served as the largest limitation in this project. Aphid populations have a physiological reaction to stress pheromone increases about two weeks after the stress event occurs, so my timing of right after the rainfall and a month after the rainfall prevented me from getting the best measurements.

In the future, I would like to produce more insightful projects on factors affecting aphids from bacterial associations that I have recently learned to be an important part of any organism's development. Papers like Zhang et. all 2015 show how bacteria presence may be much larger of a factor with aphid development than external factors by linking bacteria presence to significant change in aphid physiology. Another future direction would be to reproduce conditions like the El Niño rainfall in a laboratory setting and conduct a similar experiment there to reduce confounding factors and keep track of the aphids in the study.

Conclusion

Although I was not able to determine what the effect of the El Niño rainfall was upon aphid wing formation, the experiment did show that less aphids were present in general after the aphids had enough time for the physiological changes from the stress of the rainfall took place. In future research, the possibility of promoting stress pheromone release from aphids and thus forcing aphids to leave crops should be studied. Another promising future study subject is the effect of rainfall upon aphid bacterial symbioses, which should be examined as a new method of approaching aphid sensitivity to environmental changes. These are just a few of the factors that affect aphid wing production and aphid stress, leaving many new ways to investigate how to control aphid predation of crops through manipulation and non-damaging means to the ecosystems aphids are a part of.

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