Predation of Aphids (Aphis asclepiadis) by Syrphid Flies on Osha (Ligusticum porteri)

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Project Summary/Abstract

Insects are responsible for providing a wide range of both ecological and economical services. Some of these insects are better known than others, and with this study I hope to highlight some of the services provided by an often-overlooked group. The syrphid flies (Diptera*: Syrphidae*). There are many gaps in our knowledge of life history and interactions of syrphids with their natural environments. Previous studies have shown variables such as competition, predation risk, host plant/aphid species, and other factors all play into the oviposition of syrphid flies. The aim of this study is to determine if host plant quality plays a role in the oviposition preference of syrphid flies. The host plant of this study (*Ligusticum porteri)* commonly known as osha will be used along with *Aphis asclepiadis* colonies. Host plant quality will be evaluated by measurements of flowering stage and chlorophyll content. It is expected that female syrphid flies will select aphid colonies on plants in an earlier flowering stage and with higher chlorophyll content. These plants are expected to persist longest through the growing season, maintaining larger and more successful *A. asclepiadis* colonies providing adequate time and nutrients, therefore giving syrphid larvae the greatest chance of reaching maturity. Findings from this research point to an answer opposite to what was expected. Syrphid flies spent more time searching for aphid colonies at plants in later stages of phenology. Resource availability at early stage (flowering) plants seem to distract the syrphids from the aphid colonies, and the syrphids show resource prioritization to nectar and pollen over aphid colonies.

Introduction

Insects are integral contributors to both natural and developed ecosystems. [1] Most notably are the pollination services provided by them. In terms of agriculture, roughly 70% of crops worldwide rely on some amount of insect pollination. [2] It is estimated that insect pollinators provide an estimated $34 billion-dollar service in the US and $235 billion-dollar agricultural service worldwide. [3] However, the estimate for this value ranges greatly. [2] Insect pollination has been shown in some cases to increase both the yield and quality of crops. [2, 4] For natural habitats, pollinators are key for plant reproduction, genetic diversity, habitat diversity, and environmental stability. [5]

Aside from pollination services, predatory insects can also act as biological pest control agents. Farmers spend billions of dollars annually, of which would be considerably more if it weren't for the natural pest control provided by insects. [1, 2, 6] Reduction in the need for and use of chemical pesticides can provide a benefit not only to farmers but also to organisms and natural ecosystems often affected by pesticides. [6] Natural alternatives to pesticides would benefit both ecosystems and farmers by reducing the use of chemical pesticides while also lowering the cost of pest control for farmers by providing a natural alternative and lowering expenses.

Syrphids (Diptera: *Syrphidae*) are important as they provide dual ecosystem services as both pollinators and predators. [1] The adult flies visit flowers to feed on pollen and nectar. Adults tend to be specialists in terms of what pollen they eat but generalists of nectar. [7] Due to this nectar generalization, they can be found carrying many different species of pollen. This combined with other factors such as energy efficiency, range, and temperature resistance makes them important pollinators, especially at higher elevations. [8] While the adult syrphids are not predators, the larvae are. The larvae of many syrphid fly species predate on other insects, especially pest species including caterpillars, thrips, and aphids. The larval stages of approximately 1/3 of the 6,000+ known syrphid fly species are aphidopahgous. Female syrphid flies have been known to evaluate and use more information than just the presence of an aphid colony in determining where to commence oviposition. Factors such as host plant species, habitat, aphid species and availability, predation risk, competition, chemical signals and even female age can all affect oviposition site. [9, 10, 11] Female choice generally reflects an evaluation of these factors in how likely it would be for her larvae to survive.

Due to their importance as biological control agents, many of the studies done on syrphid fly predation have been conducted within agricultural ecosystems [1, 5, 6, 12] or with aphid species that carry agricultural importance. This has left considerable gaps in our understanding of predation relationships between syrphid flies and aphids in non-agricultural ecosystems. Developing our knowledge of the natural behaviors and interactions of syrphid flies with their environment can help us better implement their services into agricultural and economic settings.

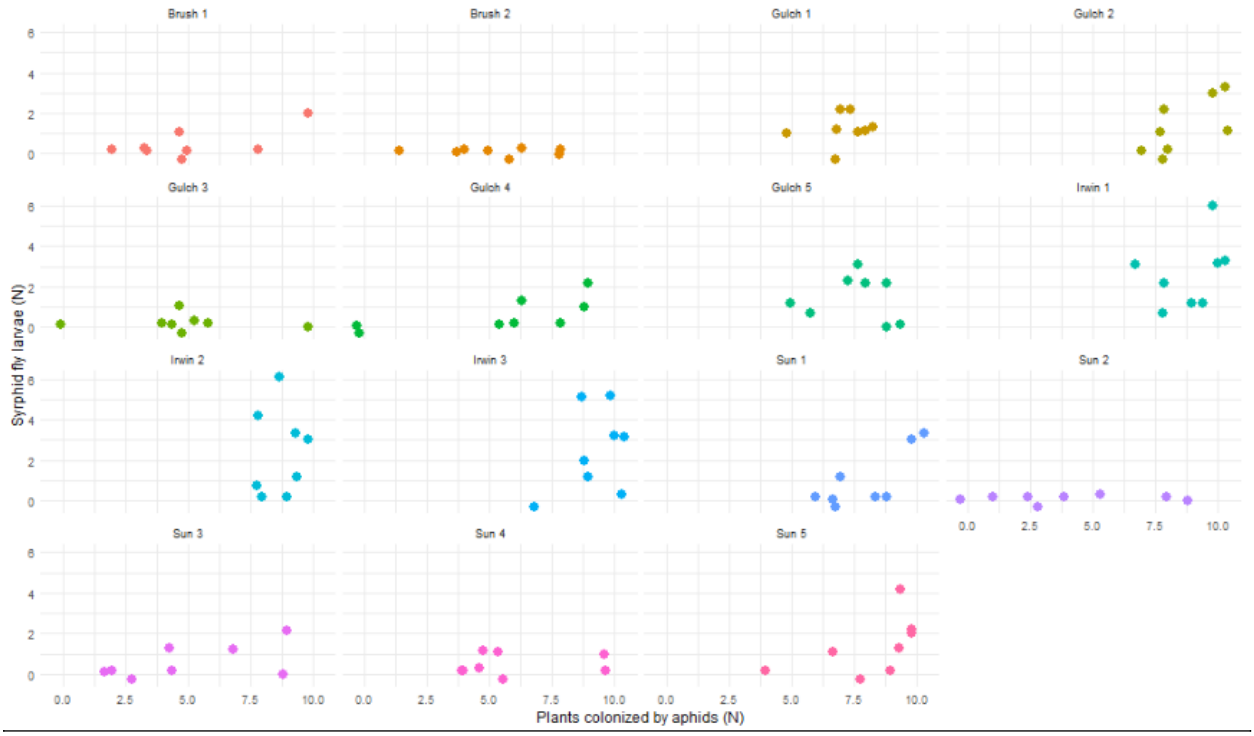
My overall objective with this study is to determine if host plant quality affects oviposition preference of syrphid flies. Syrphids carry importance both ecologically and economically. As pollinators, they are important to preserve even more in present times as other primary pollinator species like bees are coming under threat. [5, 13] Natural history studies of syrphid flies are few and far between, and therefore, it is hard to tell exactly how important these organisms are. Hopefully, this study can be implemented to bridge the gap between how syrphid flies interact with their natural environment and the information we have from previous studies on how they interact with anthropogenically developed land.

Methods

Study System—

Aphids of the species *Aphis asclepiadis* (syn. *helianthi*) can be found in colonial groups on the flowering stalks and occasionally the leaves of *Ligusticum porteri* (Apiaceae). [14, 15] The plant *L. porteri* is a subalpine plant species that ranges throughout the Rocky Mountains and is found most commonly at elevations between 7-10,000 ft. It is a rhizomatous perennial generally growing between 3-6 ft tall and producing compound umbels of small white flowers. [16, 17] *A. asclepiadis* colonies form mutualistic relationships with several ant species including *Tapinoma sessile*, *Formica fusca*, and *Formica rufa*. [18, 19] Other phytophagous insects that may be found feeding on *L. porteri* include *Lygus hesperus* (Hemiptera: *Miridae*) and other species within the tribe Mirini. [14] Syrphid fly larvae are a frequent predator of aphid colonies, and an eight-year monitoring study in this system shows variable rates of syrphid fly predation across study sites (Figure 1). Other aphidophagous species that can be found within the system competing with syrphids include adult lygus bugs, ladybird beetles (Coleoptera: *Coccinellidae*), and lacewings (Neuroptera: *Chrysopidae*). [10, 11]

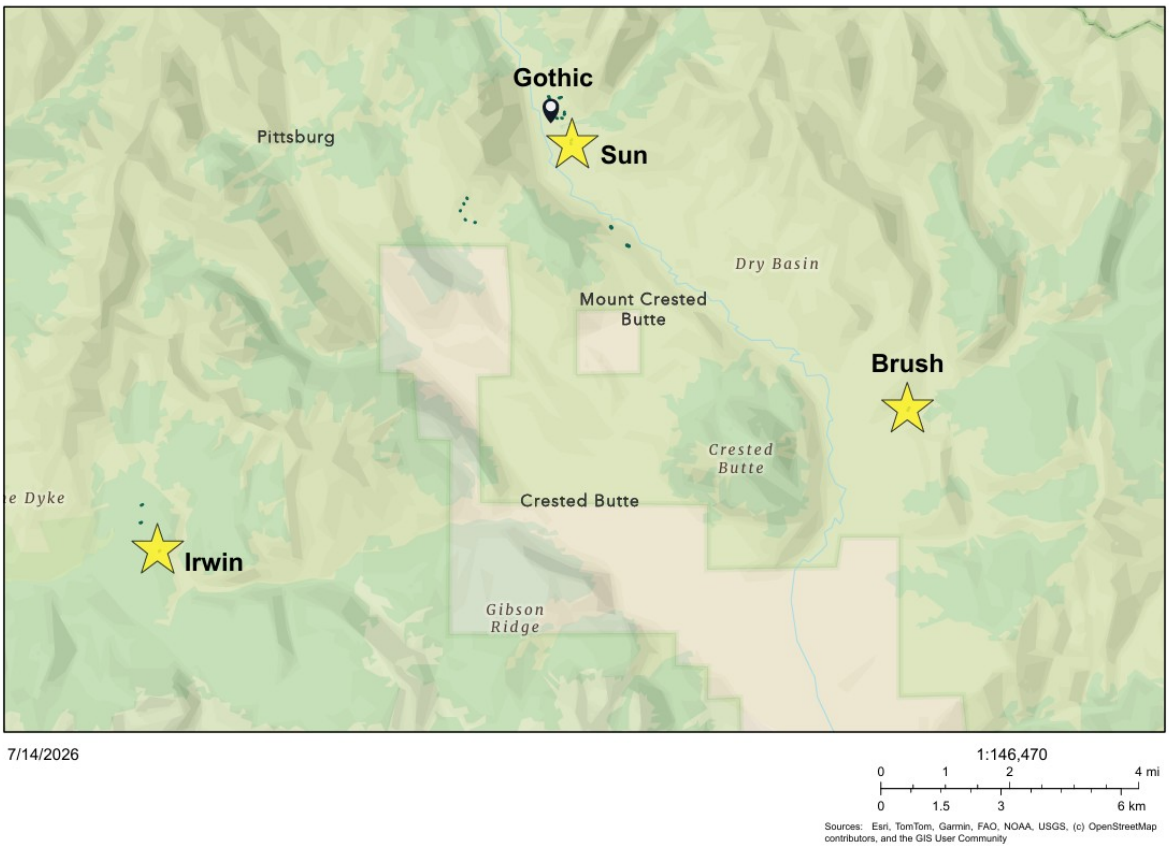
Figure 1: Number of aphid-colonized host plants (***Ligusticum porteri***) versus number of colonies with syrphid fly larvae in fifteen sites near Gothic, CO monitoring from 2017-2024.



Overall Study Design—

To determine if plant phenology is a driving factor in syrphid fly oviposition preference, I used a combination of observational and experimental methods. During this experiment, I collected data from multiple experimental sites along a 300m elevation gradient. These sites have been previously set, approved, and used by my mentor in prior years. The sites used in this study have all been mapped via a Trimble DA2 GPS unit and mapping was done in ArcGIS Online. [20] Any samples collected in the field have been analyzed either at RMBL or will be analyzed in the laboratory at UCCS in fall 2026.

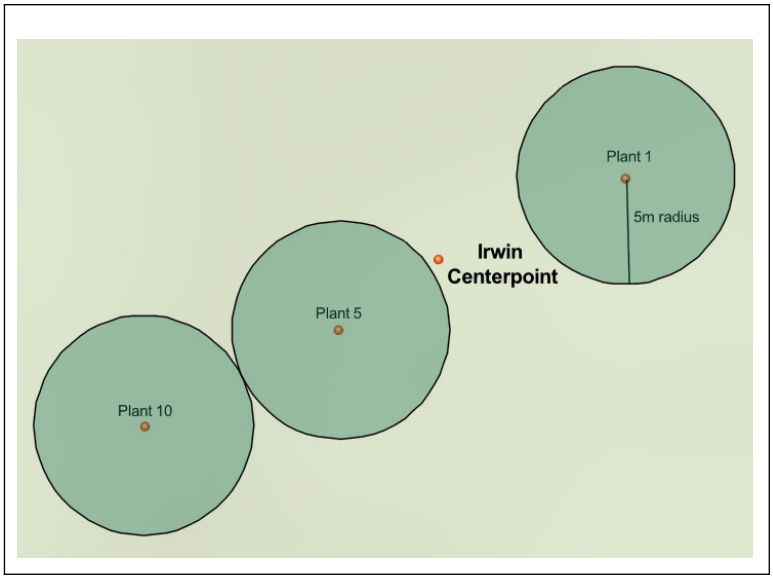
Figure 2: Research sites Sun, Brush, and Irwin in Gunnison County, CO 2026



Observational Study—

In addition to the weekly censuses of plant traits and insect abundance, I have assessed additional explanatory factors for each site that previous studies have indicated may be associated with syrphid fly abundance and activity. One possible explanatory factor that was measured is floral resource abundance (FRA). Past studies have shown that the availability of flowering resources may be a driving factor in syrphid fly abundance due to their reliance on pollen and nectar resources. [21, 22, 23]

Figure 3: Example of radius measurements around marked plants used to measure FSD and FRA at Irwin



Floral resource abundance was measured per site using a transect tape and creating a 5m radius around 3 separate marked plants. Marked plants had been previously chosen by my mentor for her research at these sites based on proximity to a 30m line transect through the site and labelled 1-10. The three radius measurements took place around plants 1, 5, and 10, as shown in Figure 3, ensuring that the radii do not overlap to avoid double counting plants. A count of the number of flowering plants was recorded and averaged for the three radii to determine the abundance of flowering resources in the site. An approximate flowering species richness was also accounted for per site. Flowering stalk density (FSD) of *L. porteri* was recorded via the same methods used for floral resource abundance. Flowering stalks of *L. porteri* present within each 5m radius were counted and averaged to produce flowering stalk density for each site. The presence of *L. porteri* flowering stalks is important in providing locations for *A. asclepiadis* to colonize.

Flowering stage per plant in combination with chlorophyll content was taken in combination to determine the overall host plant quality. Flowering stage measurements were based on a flowering phenology index developed by my mentor and used previously in her research [24]. The stages are on a 1-8 scale and can be broken into half stages ex. 6.5 for plants transitioning between stages. Turing brown (TB) or all brown (AB) can also be added onto the stage measurement both of which indicate beginning and later stages of plant senescence. Turning brown refers to plants with umbels in which the florets/fruit are beginning to turn brown and all brown for umbels in which all florets/fruits are completely brown. Chlorophyll content, measured via SPAD meter [25], was taken from three different leaves (preferably on three separate flowering stalks) to create an average measure of chlorophyll content for the plant. If there were not at least three flowering stalks to measure from then the measurement was taken from three separate leaves on one to two flowering stalks.

Every plant was censused before starting video data collection. Observations from these censuses included the number of flowering stalks, umbels, terminal phenology score (TPS), primary phenology score (PPS), and average chlorophyll content (ACC). Any presence of aphids, ants, mirids, and syrphids was recorded. Other arthropods were also made note of when present, ex. spiders.

Figure 4: Template used for the census of recorded *L. porteri* plants.

Site	Plant	# FS	# Umb.	TPS	PPS	ACC	# Aphids	# Ants	# Mirid N	# Mirid A	# SYR	Other
	1											
	2											
Date:	3											
Time:	4											
Comments:												

Experimental Study—

Visual observations and assessment of hoverfly abundance were completed at each site. A 30m transect line was created through the center point of each site and walked every other week to assess the local abundance of hoverflies. An entomological insect net was used to collect syrphids (Standard Insect Net, BioQuip, Rancho Dominguez, CA). Since syrphids are small, agile and elusive, the transect was walked once very slowly (~ 8-10 min per transect) from end to end, pausing every other step, making sure not to double back or count any individual fly more than once. [26] Careful attention was paid to nearby flowers where they may be found resting or pollinating. Syrphids that were unable to be caught were also counted and recorded. Any syrphids within reach of the net were collected. Hoverflies that were collected were euthanized in a kill jar with ethyl acetate, placed into plastic bags labelled with site and date information, and finally stored in a freezer to later be pinned and identified.

Video observations were made at plants with an artificial scent lure and/or a natural aphid colony when possible. The lure consisted of (E)-ß-Farnesene (EBF), methyl salicylate, and mineral oil in a microcentrifuge tube that was attached to a flowering stalk. The EBF was diluted in mineral oil to a concentration of 0.40 µg/µL and the methyl salicylate was diluted to 0.10 µg/µL. The two solutions were then combined in a 1:1 ratio of 0.1 mL (100 µL) each in a 0.2 mL microcentrifuge tube to create a completed bait. There are some studies that argue otherwise, [27] however, EBF has been shown to be an effective lure in attracting syrphid flies in past studies, even more so in combination with methyl salicylate. [28] The baits were monitored for syrphid activity by continuous recording cameras over a 1-hour period. Four ADGZCYS Mini Cameras were equipped with a macro lens (either KWTOUL wide angle 15x macro lens or GOWENIC 37mm x4 macro close-up lens). The macro lens was centered over the camera lens and secured with tape to create a clear close-up video. Video surveillance cameras were mounted to either a 0.5” squared or 0.5” x 1” and 3-4’ long wooden stake. The camera and stake were positioned so that the lens was roughly level and 7-8” from the flowering stalk and bait since the cameras equipped with the lenses had a fixed focal length clearest between 7-8”. The flowering stalk was stabilized by using a twist tie and attaching to a bamboo stake placed in the ground to create a stable and clear video.

An ethogram was set up and used to measure the total amount of time in seconds that each fly spent engaged in a behavior (Figure 5). Recorded behaviors by time included hovering, feeding, resting, searching, and oviposition. Behaviors were rounded to whole numbers in seconds. These were used to construct an activity budget, which is an important tool to visualize behavioral ecology of insects. [29]

Figure 5: Syrphid fly ethogram table used to classify syrphid fly behaviors

Site: ex. Brush	Date: MM/DD/YYYY	Plant ID: ex. 1		Syrphid ID: ex. L. lapponicus
Behavior Type	Behavior	Y/N	Time (s)	Description
Locomotion	Hovering	Y	ex. 13	Hovering or in flight at or near the plant and bait.
	Landing	N	X	Landing on the plant.
	Searching	N		Time spent after landing on the plant in motion ex. walking.
Foraging	Feeding	N		Feeding on pollen or nectar on the umbels.
	Resting	N		After landing on plant remaining still/not enacting other behaviors.
Reproduction	Oviposition	N		Laying eggs on the plant. Abdomen is extended and bent down to oviposit.
Time is only counted when the fly is visible in frame of the video				
Visits must be separated by at least 1 minute to count as a separate visit				

Specimens collected in situ were used as reference specimens to identify those seen on video. Specimens collected were placed in a freezer for at least 72hrs prior to being pinned. Pinned specimens are being kept in the RMBL Natural History Museum for reference and contribution to later studies. The specimens were all identified using the same syrphid fly dichotomous key to maintain consistency. [30]

Statistical Analysis—

To determine the influence of plant phenology [X] on syrphid fly oviposition [Y], I used generalized linear models to analyze my data. The first response [Y_1] for plant condition that I analyzed was total time. This was the total time in seconds that a syrphid was observed interacting with the host plant summed across all behavioral categories. I used two separate generalized linear models to determine (1) how total time varied with average chlorophyll content (ACC) and (2) host plant phenological stage. For the analysis, I used three categories of host plant phenological stage: flowering, fruiting, or senescent. Flowering plants had either terminal or primary umbels at flowering stages, i.e. less than an index of 7. Fruiting plants had a score greater than 7 but were not senescent, e.g. not scored as either turning brown or all brown. Finally, senescent plants had terminal or primary umbels at any numerical index (0-8) but were turning brown or all brown.

The second response was percent hovering time. This was the percent of the total time for a given observation that a syrphid spent hovering at a plant. For this response, I also tested how it varied with both ACC and host plant phenological stage. For all the above tests, I obtained test statistics and P-values using the 'Anova()' function from the *car* package. [31] All data analysis was performed in R. [32]

Results

Three species of aphidophagous hoverflies were observed during this study of which were L*apposyrphus lapponicus*, *Sphaerophoria philanthus*, and *Eupeodes volucris*. *L. lapponicus* was almost always the only species observed showing interest in the artificial EBF baits with a few instances of *E. volucris*. *S. philanthus* never showed up at plants with just artificial baits. They were only ever observed at plants with natural colonies. *S. philanthus* was also the only species that was observed ovipositing in one instance and on a plant that was baited and had a natural colony.

Overall Syrphid Activity Budget—

I collected a total of 58 hours of raw footage over a 3-week period. After analyzing the footage, I had 1,235 seconds or roughly 20 ½ minutes of syrphid fly activity. This footage was compiled and an overall activity budget (Figure 6). Across observations, syrphids spent the largest percentage of time (41%) feeding from nectaries on inflorescences. The next largest behavioral classes included searching and hovering, with 27% and 26% of time observed respectively. The remaining behavioral classes—resting and oviposition—were equally scarce, with only 3% of observed time spent in these classes.

Figure 6: (A) Overall syrphid fly activity budget showing the percentage of time syrphids engaged in five behavioral classes on plants with scent lures across all observations (B) Syrphid fly activity budget displayed site-by-site

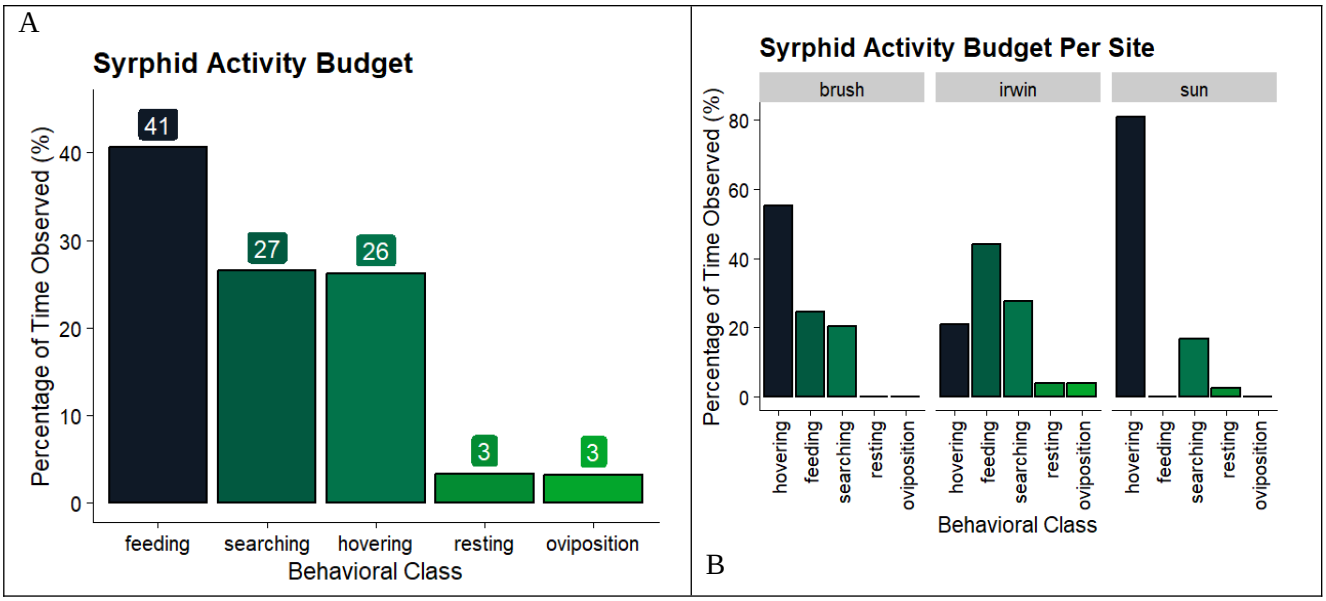
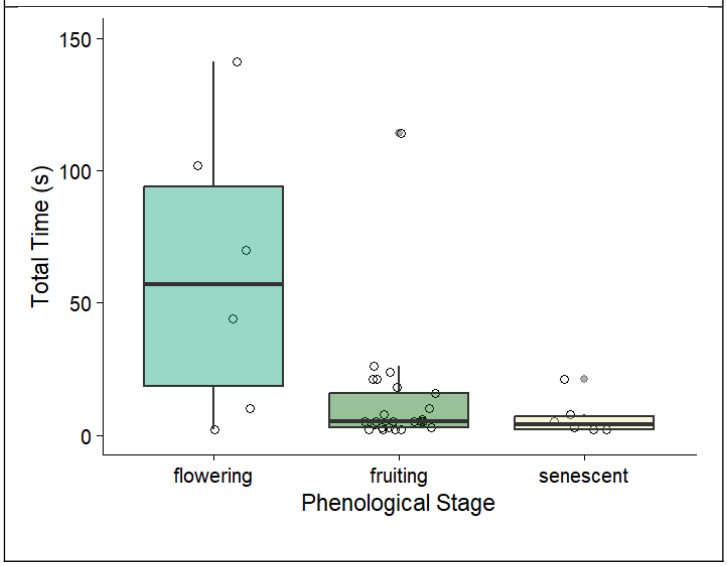


Figure 6B shows a site-by-site breakdown of syrphid fly activity by behavior. This graph shows more clearly the inverse relationship between hovering time and feeding time. Irwin was the site that contained plants in the earliest flowering stages while Sun and Brush had mostly plants in later fruiting and senescent stages.

Total Time at Inflorescence—

Figure 8: Total time spent at a plant vs. the phenological sage



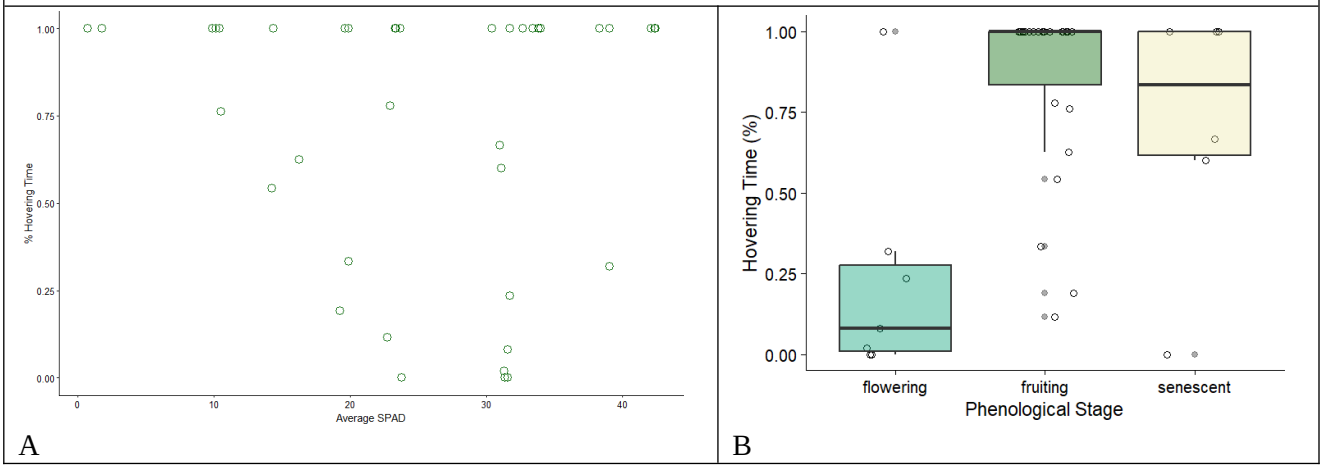
The total amount of time spent at host plants varied with phenological stage (Test Statistic = X. XXX, P = 0.0069). Syrphids spent more time at host plants in earlier phenological stages (flowering) vs. those at later stages (fruiting and senescent) (Figure 8). However, the EBF baits at these plants were shown much less attention by the syrphid flies.

Percent Hovering and Feeding Time at Inflorescences—

Percent hovering time at a host plant did not vary as a function of ACC (Figure 9A; F-Ratio = 0.5809, P-

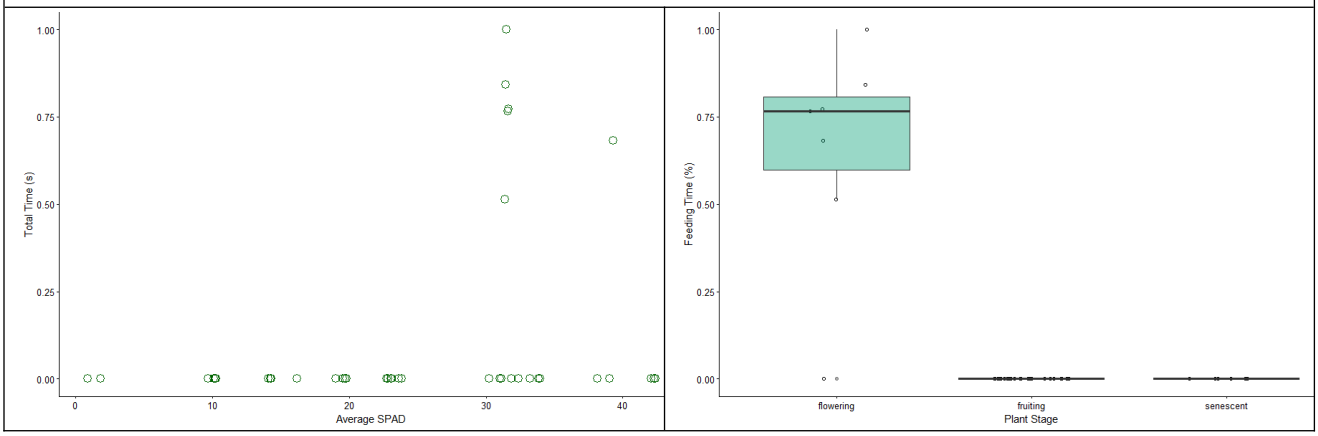
Value= 0.4508). In contrast, percent hovering time varied with phenological stage (Test Statistic = X. XXX, P = 0.0001). Percent hovering time was reduced for host plants at the flowering stage relative to either fruiting or senescent plants (Figure 9B).

Figure 9: (A) relationship between average chlorophyll content and % hovering time and (B) % hovering time by phenological stage.



There was a trend for the percent feeding time to be increased on plants with higher ACC (Figure 10A; F-Ratio = 3.346, P-Value= 0.07544). Percent feeding time was significantly impacted by phenological stage of the host plant (F-Ratio = 70.175, P-Value <0.0001). More time was spent by syrphid flies feeding on flowering host plants than host plants at the fruiting or senescent stages.

Figure 10: (A) relationship between average chlorophyll content and % feeding time and (B) % feeding time by phenological stage



Average chlorophyll content (ACC) of host plants ranged between X.X SPAD units and X.X SPAD units (Figure 10A). However, the total time a syrphid was observed at a host plant did not vary as a function of ACC (Test Statistic = X. XXX, P = 0.4391).

Discussion

Throughout this study I kept track of roughly 20 different variables alongside the main two plant stage and chlorophyll content that could possibly have significance in determining syrphid oviposition. Among

those variables I found about half of them to carry significance. The main results of this study bring to attention another major factor that may play a critical role in the oviposition selection of female syrphid flies. When flowering resources are present on the host plant, attention from the syrphid flies is diverted to feeding instead of reproduction. This benefits the aphid colonies by allowing a longer period, particularly the timeframe in which the host plants are flowering, for the aphid colonies to establish on *L. porteri*. Once *L. porteri* reaches its fruiting and senescent stages, the aphids become the only resource available to the syrphids on that particular plant, and their attention is focused solely on those colonies. This significantly raises the probability that an aphid colony present on the plant will be found and oviposited on. The syrphids could also be using presence of flowers as a time indicator in which it would be too early to lay on that colony.

When aphid colonies are struggling to establish on plants in late phenological stages and are found by predators in small establishing numbers, it can impact the populations of not only the aphids but the predators relying on these colonies. Previous studies on syrphids have shown that if larvae have insufficient food supply it can result in stunted growth, lower fecundity, and even complete sterility. [11] It would be particularly interesting to observe the populations of syrphids in a year following poor aphid abundance such as this one. This relationship between aphid establishment and plant stage may start to become an issue with our current climate. The recent trends of warming weather and lower precipitation have caused plant phenology to become much more advanced making it harder for these colonies to establish compared to previous years.

Another measured variable that seemed to have a significant effect on the total time spent at plants by syrphids is the flowering resource abundance (FRA). This is likely because the abundance of floral resources available for feeding affects the overall population of syrphids in the area. This is consistent with the higher population observed at Irwin based on the line transects completed at each site.
When hovering time was isolated from the total time and plotted against plant phenological stage, a graph is produced that is the opposite of that seen in Figure 8. Figure 9 represents a significant and distinct behavioral switch. This switch can be seen more easily as feeding time is removed from this total since a large proportion of time at the early-stage plants was being spent feeding. This implies that there is a resource prioritization happening. When pollen and nectar are available on early-stage plants, the syrphids prioritize those floral resources for feeding instead of thinking about reproduction and searching for aphid colonies. However, this could be an expression of the optimal foraging theory. When *L. porteri* flowers are available the syrphids may be spending all their time feeding before those resources become unavailable. The flowers of *L.porteri* produce large amounts of nectar and nectar availability can change their visitation and foraging preference. [33]

Another theory that may play into syrphid behavioral response includes reflectance. Syrphid flies will also use visual cues to inform some of their decisions with one of those being color reflectance. [33] The syrphid *Episyrphus balteatus* was found to prefer white and yellow flowers suggesting syrphids could be distinguishing plants by color not only by their flowers but possibly also the leaves which would mean a different response to greener plants compared to those senescing and turning yellow. Being such visual predators may also play into why I did not observe oviposition.

Syrphid fly age has also been a consistent factor across studies shown to affect oviposition. As the females get older, they start to lose preferences and will be more likely to oviposit in places that younger picker flies may not. [10,11,33] This could affect my results as the syrphids are aging along with the plants. Perhaps by the late season when plants are in late senescence the syrphids have lost their ‘hierarchy’ [11] of what plants and colonies they would normally oviposit on.

It would appear from these observations that *Sphaerophoria philanthus* is not attracted to the artificial scent lures. *Lapposyrphus lapponicus* on the other hand was attracted to the scent lures, but an oviposition

response was never recorded. Perhaps they use some other cue, scent, visual, or otherwise, to elicit an oviposition response which was not present in these baits. They may also prefer a different aphid species that these baits more closely resembled than the *A. asclepiadis* colonies and that could be why oviposition did not occur. This also lines up with possibly why the *S. philanthus* was not attracted to the baits but was attracted to *A. asclepiadis* colonies. Previous research has shown that syrphids will not oviposit without the presence of aphids, suggesting a visual cue. [34] However, this doesn't explain why *L. lapponicus* was appearing at natural colonies with baits and still not ovipositing. It has been shown in previous studies that females can be quite particular about the species in which they decide to oviposit on as well as even the size, presence, and density of colonies. [11]

Conclusion

Many different factors play into syrphid fly oviposition, and the results of this study suggest a few other factors that may be taken into consideration. The optimal foraging theory seemingly also affects syrphid oviposition by which females prioritize floral resources. Aphid colonies present on plants in later phenological stages are more likely to be predated on by syrphids. This study also brings to attention multiple other questions that are still left unanswered. Learning more about syrphid flies and how they interact with their environments can prove crucial to preserving hoverflies, species to which they interact, and discovery more effective ways to apply their services to our economy.

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