

The effect of host plant chemical defenses on the consumption rate of aphids by lacewing larvae

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Abstract

The purpose of this study was to examine the effect of sequestered plant toxins in aphids on the feeding rate of *Chrysopidae carnea*, a predator of aphids. We observed whether the difference in host plant of the aphids affected the consumption of prey by *C. carnea*. We conducted feeding trials with *C. carnea* and aphids from *Asclepias syriaca* and *Populus balsamifera*. We found that there was not a statistical difference between the consumption rates of the two species of aphids by the predator. There was also no significant difference in the carbon and nitrogen composition of the aphids. The *C. carnea* larvae were generalist predators that were not deterred by the chemical toxins. In this trophic system the herbivores adapted to survive the plant's chemical defenses. Predators also suggested survival adaptations to the chemical defenses, which could lead to greater host plant viability by decreasing the population of aphids.

Introduction

Plant defenses have been shown to effect the interactions between producers and herbivores (Levin 1976). Pressure from herbivores can be devastating to the production of host plants. Plant defenses against herbivory can be structural or chemical. For structural defenses, plants can grow thorns or secrete resins to ward of herbivores. For chemical defenses, plants have a diverse range of secondary products produced from their metabolism, ranging from alkaloids to terpenoids. Secondary metabolites can be sequestered in the plant and released only when the cells are broken or epidermal glands can secrete the secondary metabolites (Levin 1976). With a wide range of toxins, plants are able to defend themselves against a wide range of herbivores.

Over time, herbivores have adapted to live with plant defenses. Chemical defenses can serve as a repellent or deterrent to herbivores based on the post-ingestive effects of some secondary metabolites to enable insects to learn to reject a plant (Bernays 1998). Specialists, herbivores that feed on one particular species, often show less deterrence to the toxins due to the fact that the specialist's sensitivity has evolved with the plant (Bernays 1998). One of the main defenses of herbivores against toxins is sequestration, when toxins are deposited into specialized glands or tissue in order to not affect the herbivore's behavior. With defenses against one another, the trophic interactions amongst plants and herbivores become more complex.

When adding a predator to these interactions, tritrophic interactions can be important in understanding the ecology of insect-plant interactions in ecosystems (Poppy 1997). Plants serve as the base of the trophic pyramid and their traits influence the stability of predator-prey complexes occurring on the plants (Messina and Hanks 1998).

This change in the stability of predator-prey complexes can come from plant traits such as secondary metabolites altering the herbivore feeding on the plant. With changes in the herbivore, there can be changes in predator-prey interactions and a subsequent change in the tritrophic interaction of the plant, herbivore, and predator.

A known tritrophic interaction is that between plants, aphids, and *Chrysopidae carnea* larvae (lacewings). Aphids are suckers that are known to sequester the chemical defenses of host plants and bypass their harmful effects (Malcolm 1990). The plant species *Asclepias syriaca* (common milkweed) is known to produce cardiac glycosides as a chemical defense. Cardiac glycosides are hormone mimics that can interfere with heart functions. Where as the plant species *Populus balsamifera* (poplar) is known to produce a general chemical defense, which has less toxic effects. The aphids that inhabit *A. syriaca* and *P. balsamifera* sequester the chemicals, which then could be transferred to the *C. carnea* larvae when the aphids are eaten (Birch et al. 1999). When aphids are exposed to increasing levels of toxicity they are known to have adverse effects on their predators (Birch et al. 1999). With differing levels of toxicity of each chemical defense of a host plant there are differing levels of toxicity sequestered by the herbivorous aphids, which create differing factors that could affect the overall tritrophic interaction occurring between the host plants, aphids, and *C. carnea* with *C. carnea* developing a preference of one host plant aphid species over another.

The purpose of this study was to examine the effect of sequestered plant toxins in aphids on the feeding rate of *C. carnea*. We asked whether difference in the host plant of the aphids affected the consumption of prey by *C. carnea*. Differences in chemical composition in the aphids may lead to greater consumption of the aphids on *P. balsamifera* due to its

lower toxicity. To test this, we conducted feeding trails with *C. carnea* and aphids raised on *P. balsamifera* or *A. syriaca*.

Methods

All experimentation was conducted at the University of Michigan Biological Station in Cheboygan County, Michigan between July 26, 2013 and July 27, 2013.

We conducted four feeding trials to determine the consumption rate of *A. syriaca* aphids and *P. balsamifera* aphids by *C. carnea*. In each feeding trail eight petri dishes were used per host plant, except for the last trial in which three petri dishes were used per host plant. A total of 26 replicates were produced for each host plant. Each trial was conducted in a petri dish with a piece of filter paper on the bottom. A 15-millimeter disk of the host plant was placed on the filter paper. We placed 10 aphids from *P. balsamifera* in each petri dish. In the *A. syriaca* dishes we placed 10, 12, or 15 aphids in the dish. We increased the number of *A. syriaca* aphids because they were smaller than the *P. balsamifera* aphids and we did not want the predator to run out of prey during the trial. Parafilm was wrapped around the outside of the petri dishes to inhibit the escape of the study organisms from the dishes. All petri dishes were placed in an environmental chamber set at 20°C for the duration of the trial.

After approximately one hour, petri dishes were opened and examined for surviving and dead aphids, which were then tallied to determine consumption rate. Time spent feeding was also noted to determine consumption rate. Aphids from each host plant were weighed to determine the average weight of each aphid to correct for size differences between aphid species.

Carbon to nitrogen ratio analysis was conducted on the two aphid species to determine the relative nitrogen content of each aphid. A measure of 0.0592 g of the *A. syriaca* aphids and 0.0625 g of the *P. balsamifera* aphids were freeze-dried in an ultra-low freezer for 24 hours. Samples were transferred to a lyophilizer for 24 hours to extract all the water. Once dried, samples were sent to a mass spectrometer to analyze the carbon to nitrogen ratios. Both samples were sent through the mass spectrometer twice. This was done to determine differences in nitrogen content between the aphid species. A t-test was performed on the means of consumption rates of the *A. syriaca* aphids and the *P. balsamifera* aphids by *C. carnea*.

Results

No significant difference in consumption rates of *A. syriaca* (N=26, $\bar{x} = 0.0014$) and *P. Balsamifera* (N=26, $\bar{x} = 0.0018$) aphids by *C. carnea* was observed (t-value=0.6903, d.f. = 50, p=. 2466; Figure 1). With *A. syriaca* aphids, the predation rates ranged from 0 to 0.0065 aphids per hour, while the consumption rates of *P. balsamifera* by *C. carnea* ranged from 0 to 0.0053 aphids per hour. The median predation rate of *A. syriaca* aphids was 0.00064 aphids per hour, and the median predation rate of *P. balsamifera* aphids was 0.0011 aphids per hour.

Carbon and nitrogen analysis of the aphids showed similar levels of carbon and nitrogen in the *A. syriaca* and *P. balsamifera* aphids. *A. syriaca* aphids had an average of 7.21% nitrogen content and an average of 49.92% carbon content. *P. balsamifera* had an average of 8.495% nitrogen content and an average carbon content of 49.625% (Table 1). The C:N ratio of *A. syriaca* aphids was 6.9:1, while the C:N ratio of *P. balsamifera* aphids was 5.8:1.

Discussion

We found no significant difference in the consumption rate of the toxic *A. syriaca* aphids and less toxic *P. balsamifera* aphids by the predator *C. carnea*. This is a result that disagrees with previous studies. In a previous study, spiders were given a choice of toxic *A. syriaca* aphids and nontoxic aphids, the spiders rerouted their web building to avoid eating the toxic aphids (Malcolm 1989). In a study conducted by Toft and Wise (1999), spiders also fed on *A. syriaca* aphids. When fed a high quality diet that included the toxic prey, the outcome was no better than if the spiders were fed only toxic aphids. We expected similar results in our study with the *C. carnea* larvae having lower consumption rates of the *A. syriaca* aphids, which would have shown avoidance of the toxins by the predator. Our results suggest that the larvae of *C. carnea* may not be as sensitive a predator as spiders used in previous studies.

In two other previous studies, though, *C. carnea* was used as a predator in aphid feeding experiments and showed the same sensitivity to toxins in aphids as spiders did. In both these studies conducted by Liu and Chen (2001) they found that the toxicity of the aphids did have a negative effect on the development and survival of the *C. carnea*, leading to a lower relative consumption of the greater toxic aphid species, which is what we expected to see in our own study. Instead our results suggest that the *C. carnea* larvae had no preference in aphid prey despite the differing levels of toxicity inside of them.

This suggested indifference to toxicity levels in our study may be due to the feeding habits of the *C. carnea* larvae. *C. carnea* larvae are prey sucking predators, they inject salivary secretions into the prey body while internal tissues are lacerated to obtain nutritive juice (McEwen et al. 2001). Our results show that there was no major difference

in the internal nitrogen composition of the *A. syriaca* and *P. balsamifera* aphids suggesting that both aphid species had relatively the same nutritional value, so it may be that there was an indifference to the aphid type not because of the sensitivity to toxins. It seems that variation in toxin level was not as important as nutrient value in prey choice.

The indifference to toxicity levels of the aphids may also be due to the fact that *C. carnea* larvae tend to be generalist predators and, when placed in a controlled experimental environment, tend to eat whatever is placed in front of them despite the prey's unsuitability for growth and survival (McEwen et al. 2001). It may be that since the *C. carnea* larvae were only presented with the one type of aphid that they ate what was presented to them despite the toxicity levels. With only one option of food and a need for energy, the *C. carnea* larvae could have ignored the toxicity of the aphids and ate the *A. syriaca* aphids anyway. Due to the smaller size of *A. syriaca* aphids than the *P. balsamifera* aphids, the *C. carnea* were able to consume a great amount of the *A. syriaca* aphids in the time amounted in the trial despite the toxic barriers.

Indifference to toxins from host plants could suggest an adaptation on the part of the predator, *C. carnea*, in order to get around the plant defenses and still be able to consume the prey of its choice. This adaptation could help the host plant in the future as past studies have shown. In a study conducted by Marquis and Whelan (2007) they found that predatory birds of herbaceous insects actually increased the viability of the host plant population due to the bird's ability to decrease the herbivore population feeding on the plants. The *C. carnea* larvae, due to its indifference to toxins, could be less selective with prey choice. This would suggest that the *C. carnea* larvae could be able to increase the viability of many host plants by decreasing the aphid populations present on each.

In order to better understand the effect of plant toxins on predators future studies should include a host plant like a mustard with a medium-level toxin containing nitrogen to look at how different levels of nitrogen in the toxins can effect prey choice. Also, future studies should feed the *C. carnea* with a non-toxic aphid between trials so that when trials occur they are eating more out of choice then out of hunger and that may lead to a significant difference in prey consumption. Trials that last more than two days may also give more insight into the overall effect of toxin consumption on the *C. carnea* larvae. Conducting the feeding trials on the host plant themselves, instead of in petri dishes, would allow future researchers to look at any effects of host plant structure on the ability of predators to consume prey, which could create differences in the tritrophic interaction that cannot be examined in a petri dish.

We determined that the host plant toxins did not have an effect on the consumption rate of the aphids by *C. carnea*. The greater toxicity of the *A. syriaca* aphids provided no greater hindrance to predation than the toxins of *P. balsamifera* aphids. Like the herbivorous aphids, the predators have adapted to surviving despite the chemical defenses produced by the plant. These adaptations could lead to *C. carnea* larvae being a less selective predator of aphids that increases the viability of the host plants.

References

- Bernays, E.A. 1998. Evolution of feeding behavior in insect herbivores. *BioScience* 48: 35-44.
- Birch, N.E., I.E. Geoghegan, M. Majerus, J.W. McNicol, C.A. Hackett, A. Gatehouse, and J.A. Gatehouse. 1999. Tri-trophic interactions involving pest aphids, predatory 2-spot ladybirds and transgenic potatoes expressing snowdrop lectin for aphid resistance. *Molecular Breeding* 5:75-83.
- Chen, T.Y. and T.X. Liu. 2001. Relative consumption of three aphid species by the lacewing, *Chrysoperla rufilabris*, and effects on its development and survival. *BioControl* 46:481-491.
- Levin, D.A. 1976. The chemical defenses of plants to pathogens and herbivores. *Annual Review of Ecology and Systematics* 7: 121-159.
- Liu, T.X. and T.Y. Chen. 2001. Effects of three aphid species (Homoptera: Aphididae) on development, survival and predation of *Chrysoperla carnea* (Neuroptera: Chrysopidae). *Applied Entomology and Zoology* 36: 361-366.
- Malcolm, S.B. 1990. Chemical defence in chewing and sucking insect herbivores: plant-derived cardenolides in the monarch butterfly and oleander aphid. *Chemoecology* 1:12-21.
- Malcolm, S.B. 1989. Disruption of web structure and predatory behavior of a spider by plant-derived chemical defenses of an aposematic aphid. *Journal of Chemical Ecology* 15: 1699-1716.
- Marquis, R.J. and C.J. Whelan. 1994. Insectivorous birds increase growth of white oak through consumption of leaf-chewing insects. *Ecology* 75:2007-2014.
- McEwen, P.K., T.R. New, and A.E. Whittington. 2007. *Lacewings in the crop environment*. Cambridge University Press.
- Messina, F.J. and J.B. Hanks. 1998. Host plant alters the shape of the functional response of an aphid predator (Coleoptera: Coccinellidae). *Environmental Entomology* 27: 1196-1202.
- Poppy, G.M. 1997. Tritrophic interactions: improving ecology understanding and biological control?. *Endeavour* 21: 61-65
- Toft S. and D.H. Wise. 1999. Growth, development, and survival of a generalist predator fed single and mixed-species diets of different quality. *Oecologia* 119:191-197.

Figures

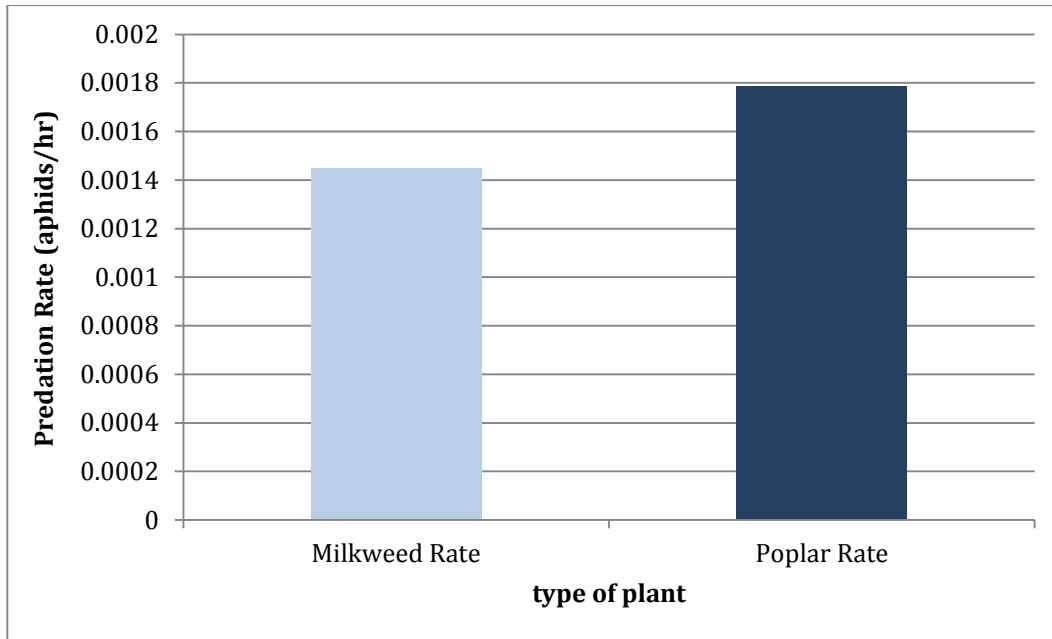


Figure 1. Aphids from milkweed and poplar plants were consumed by lacewing larvae. Predation was measured per hour. The t-value was 0.69 and the p-value was 0.25. Degrees of freedom were 50. The mean of milkweed aphid predation rate was 0.0014 and the mean of poplar aphid predation rate was 0.0018.

Table 1. Carbon and nitrogen composition of milkweed and poplar aphids. Composition was expressed as an average percentage of two samples of each type of aphid.

	Average Mass (g)	Average % Carbon	Average % Nitrogen
Milkweed Aphids	.771	49.915	7.21
Poplar Aphids	.6905	49.625	8.495

