Effects of intraguild cues of ground-dwelling and foliage-dwelling spiders on lady beetle oviposition and aphid suppression

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Introduction

Wheat is an important crop for the economy of the United States, since it is one of the main export crops. Worldwide, wheat yields reach around 3 million tons per hectares (Allen et. al 2008). However, a major problem in any crop production system, including winter wheat, is management of pest species such as aphids. Controlling aphids in the early season is key to preventing an infestation. Aphids have a short generation period, so their growth is exponential if resources are abundant. One of the best ways to prevent an infestation is through the use of natural enemies. Specialist predators consume a specific kind of prey, and do so very efficiently. But, they only arrive after the outbreak has already began. Conversely, generalist predators often wait for their prey to arrive and thus have a stronger impact on early season biocontrol (Welch et. al 2012). Lady beetles, specialist predators of aphids, and spiders, generalist predators, are known biological control agents of aphids, (Obrycki et. al 2009, Kerzicnik et. al 2012). Understanding the complexity of feeding relationships is crucial to optimizing the biological control strategies.

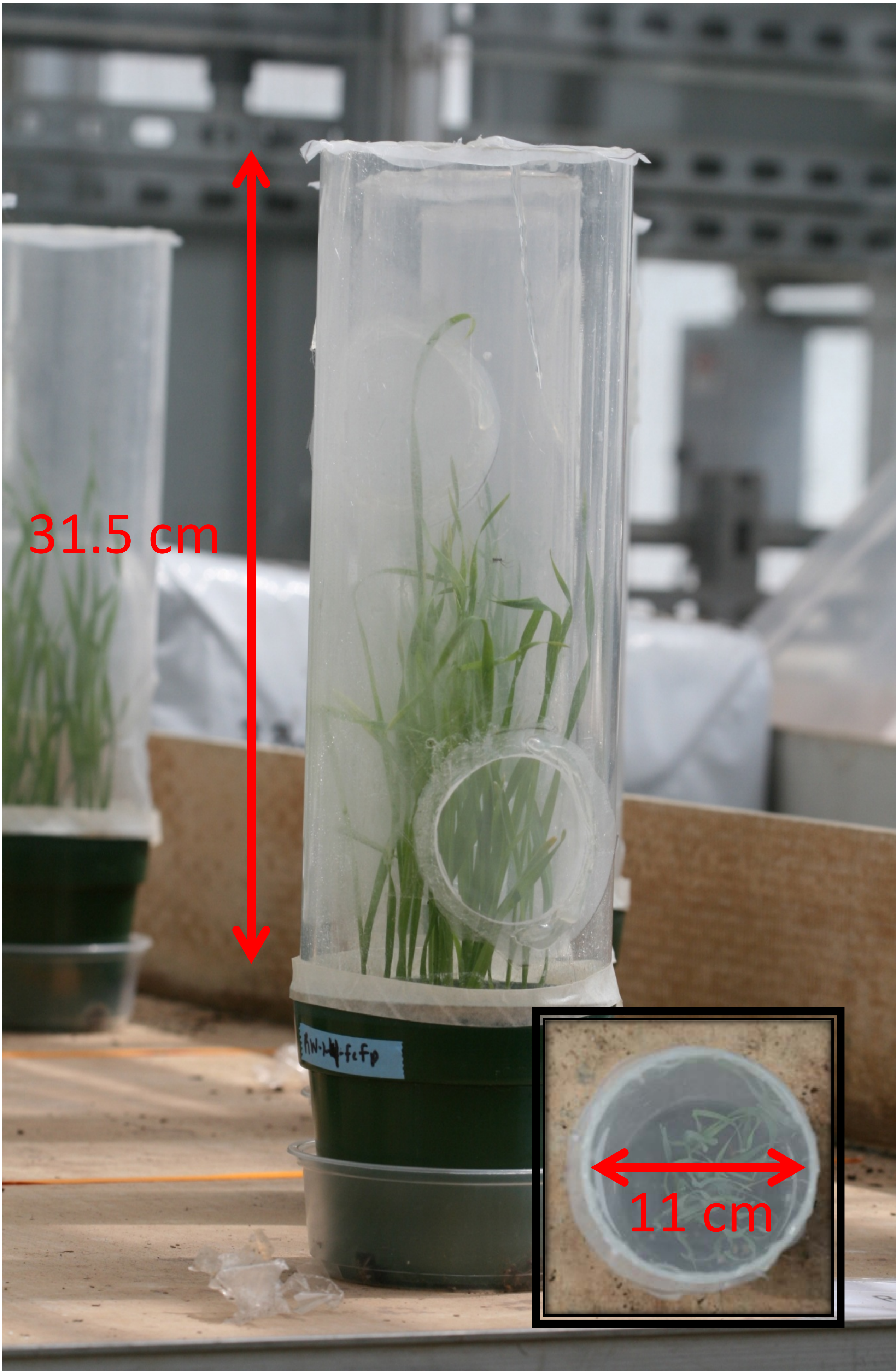
The presence of multiple predators in a system causes competition for resources, which can impact the life-history traits of competitors. One result of this competition is called intraguild predation, the act of one predator consuming another (Polis et al. 1987). These predators commonly consume similar food, and thus inhabit similar territories. Two such intraguild predators are lady beetles and spiders, both of which are known biological control agents of aphids. The intraguild interactions between these two arthropods could have additive or antagonistic effects on predation of pests. Thus, understanding the interactions between predators is important to improving the efficacy of biological control in agroecosystems.

Lady beetles are holometabolous insects, meaning the undergo complete metamorphosis before becoming adults. In the larval stage, lady beetles consume greater numbers of aphids than in the adult stage. The abundance of aphids can affect many aspects of the lady beetle's life history, including their reproductive cycle. When fewer aphids are present, the viability and number of eggs is diminished which suggests that low prey availability causes a stressful environment (Kajita et. al 2009). When more than one predator is in a particular area, there is a greater likelihood of positive or negative interactions. Different coccinellid species will avoid foraging and ovipositing in areas where there is high prey abundance (Synder et. al 2009). Lady beetles are more prone to oviposit in areas with higher aphid concentrations, but this also poses the risk of intraguild predation from other lady beetles. To circumvent these consequences, lady beetles avoid placing eggs in areas where other predators are present (Seagraves et. al 2009).

This study focuses on the effects of direct and indirect cues of foliar- and ground-dwelling spiders and their effects on lady beetle (*Hippodamia convergens)* oviposition and aphid suppression. The ground-dwelling spiders used in this experiment were *Pardosa milvina* and the foliage-dwelling spiders were *Frontinella communis*. The ground spiders lay silk as they run across the soil, whereas the foliage spiders build complex sheet webs and the top of the plants. Direct cues are the actual presence of a spider in the system and indirect cues are the chemicals that are found in the webs, such as excrement. The objectives were: 1) to determine the effect of direct and indirect cues on oviposition, and 2) to determine the effect of direct and indirect cues on pest suppression.

Methodology

Trials were performed in a greenhouse setting designed to simulate a winter wheat microhabitat with mild aphid infestation (16 light: 8 hr dark cycle, 22-25°C). Animals were collected at the Spindletop



Research Farm, College of Agriculture, 3250 Iron Works RD, Lexington, Kentucky. Prior to trials, coccinellids were maintained in the laboratory in an incubator and consumed a pea aphid diet. Aphids, *Rhopalosiphum padi,* were collected from the field and used to establish colonies in the greenhouse. Aphid colonies were grown on winter wheat (*Triticum aestivum*) seedlings.

An early season wheat seedling agroecosystem was simulated using microcosms (Fig 1). Four inch plastic pots were filled with soil up to the rim of the pot. 15 winter wheat seeds were then planted and the pots were covered to prevent greenhouse pest invasion. The pots were covered with 31.5 cm clear plastic tubes that had two mesh holes on the sides and one mesh hole covering the top for ventilation. Seedlings were provided water and allowed to grow for a one week period.

Trials were initiated by introducing 20 *Rhopalosiphum padi* aphids into the enclosed area. After an additional 4 days, 20 more aphids were added to the system.

Figure 1: Microcosm Design

We used a factorial treatment design to manipulate the presence/ absence of spiders and spider cues to the aphid established wheat system (Table 1). Spiders were then introduced in the microcosms to lay silk for 24 hours. Then, the spiders of the indirect cue treatment groups were removed whereas the spiders of the direct cue group remained in the microcosm for the duration of the trials. Immediately after spider removal, 1 female lady beetle was added to each microcosm. Spiders were removed and lady beetles were added through small openings in the mesh holes that were secured between animal exchange.

Table 1: Experimental design using factorial treatments of direct and indirect treatment groups

Treatments	Direct	Indirect
Ground-Dwelling	*Pardosa* spider present with lady beetles	*Pardosa* cues present with lady beetles

Foliage-Dwelling	*Frontinella* spiders present with lady beetles	*Frontinella* cues present with lady beetles
Ground-Dwelling and Foliage-Dwelling	Both *Pardosa* and *Frontinella* spiders present with lady beetles	Both *Pardosa* and *Frontinella* cues present with lady beetles

At 6, 24, 72, and 96 hours, the number of new egg masses was counted to assess how the direct and indirect cues change the levels of oviposition (Objective 1).To determine the effect of cues on aphid suppression (Objective 2), the total amount of aphids on each plant was counted after 96 hours.

Results

Direct effects of predator presence on beetle oviposition

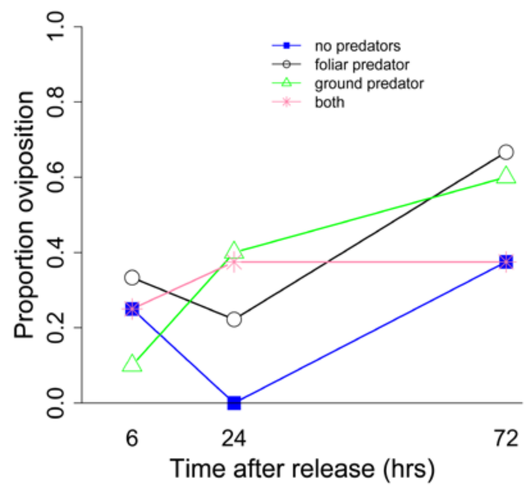
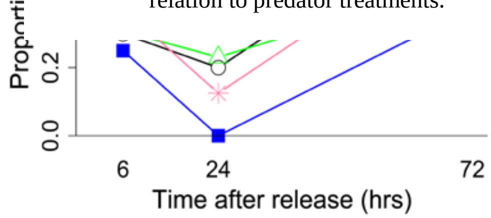


Figure 2: Rates of lady beetle oviposition, as measured by proportion of lady beetles producing egg masses, in relation to predator treatments.

Although there appears to be a predator effect on the frequency of oviposition, time is the only significant factor influencing the frequency of oviposition, where a greater percentage of lady beetles oviposited by 72 hours as compared to other time periods (rm-ANOVA $F_{2,92}$=4.121, p=0.0193; Figure 2).

Indirect effects of predator cues on beetle oviposition



A similar pattern to the effects of direct cues was apparent in the effects of spider silk cues on lady beetle oviposition rates. Lady beetles exposed to cues oviposit at higher frequencies than when no cues were present (rm-ANOVA $F_{3, 104}$ = 3.03, p=0.0300). Cues from ground or web-spider had similar effects on oviposition.

Figure 3: Rates of lady beetle oviposition, as measured by proportion of lady beetles producing egg masses, in relation to predator cue treatments.

Direct effects of predator presence on aphid abundance

In addition to the effects of predator treatments on lady beetle reproductive behavior, predator combinations had significant effects on aphid abundance (ANOVA $F_{7, 47}$=67.52, p<0.0001). When lady beetles are present, aphid populations are significantly lower and notably, web spiders or a combination of web and ground spiders have a slight effects on aphid abundance.

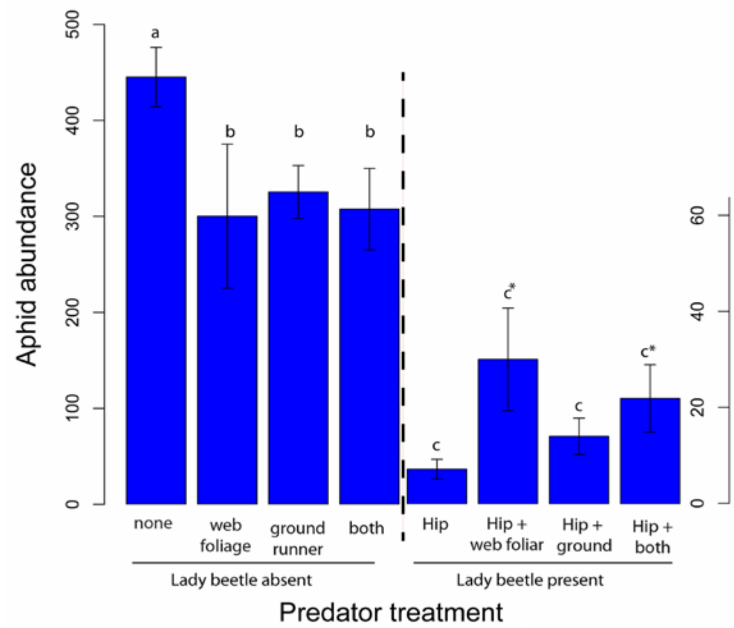


Figure 4: Aphid abundance, number of aphids on plants at the end of the 72 hour period in relation to predator treatments.

Indirect effects of predator cues on aphid abundance

To study indirect effects, spiders allowed to deposit silk and then were removed and just the silk cues were left in the enclosures. The results indicate that although foliar predator cues had non-significant effects on beetles foraging of aphids (ANOVA $F_{1,25}$=0.11, p=0.733), ground predator

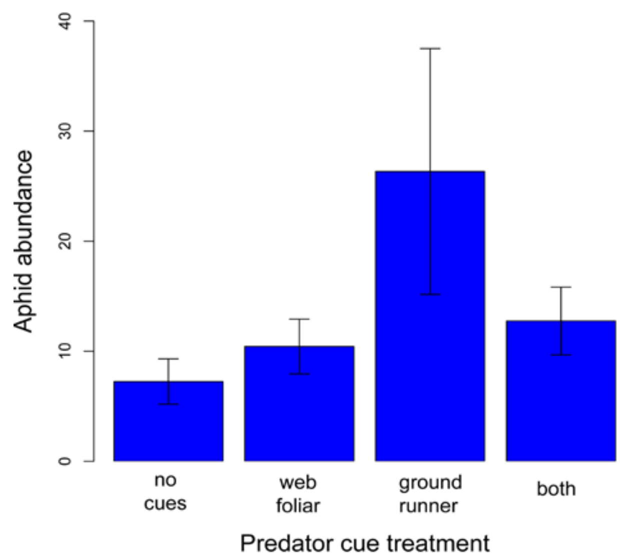


Figure 5: Aphid abundance, number of aphids on plants at the end of the 72 hour period in relation to predator cue treatments.

cues had significant effects on beetle foraging resulting in higher aphid abundance (ANOVA $F_{1,25}$=4.7147, p=0.0396).

Discussion

In the presence of predator cues, lady beetles oviposit at a greater frequency suggesting that the beetles are stressed in the presence of spiders. There is an indication that direct and indirect cues impact oviposition behavior. When only cues and predators are present, lady beetles forage less. These data suggest that predator cues elevate lady beetle oviposition and lower foraging rates on aphids, providing evidence that beetles detect and respond to multiple predators in the system.

These results suggest that the physical presence of a spider and the indirect cues have an effect on lady beetle reproduction. The lady beetles oviposited at a greater rate when spiders were present than when only cues were present, suggesting that the lady beetles are able to sense the presence of another predator and the presence of only their cues. Although the results were non-significant, the density of lady beetle oviposition increased with when direct and indirect cues are present (Figs 2,3). This may suggest that the presence of another predator could be a clue that there is an abundance of prey available. According to Seagraves, lady beetles will place their egg masses in areas where there is high prey density to possibly prevent cannibalism among offspring and thus enhance survival.

The presence of spiders also had an effect on the aphid population at the conclusion of the trial, suggesting that the spider presence has an effect on lady beetle foraging (Figs 4,5). Despite the fact that lady beetles have highly sclerotized exoskeletons, the risk of intraguild predation deterred the insect from foraging. Although no instances of intraguild predation were observed, there were multiple occasions where the lady beetle or spiders perished before the conclusion of the trial. Even with the spider generalist predators consuming aphids, the averages aphid population at the end of the trial was lower than the populations in which only the lady beetle was present and no direct or indirect cues were present. This suggests that the physical presence of spiders and simply the indirect cues cause the lady beetle to change its foraging behavior.

As described by Preisser, Orrock, and Schmitz, different hunting styles among spiders have been observed to illicit nonconsumptive effects of prey, including activity, growth, and reproduction. Ladybeetles actively pursue prey, while wolf spiders have a pursue-and-wait hunting style and web spinning spiders are sit-and-wait predators. Both sit-and-wait and sit-and-pursue predators cause high nonconsumptive effect of prey compared to the active hunting ladybeetles. The results of this study suggest that although the lady beetles forage and move around the entire microcosm, the presence of wolf spiders did act as a threat and reduced the beetles foraging domain. Evidence for this is that aphids were in higher abundance when wolf spiders were present and the observation that aphids preferred consumption in the lower areas of the plant.

This study shows that lady beetle reproductive and foraging behavior are both influenced by spider cues. These types of predator-predator interactions are important for promoting biological control in early season agroecosystems, as spiders often consume prey before specialist predators reproduce, thus curving aphid infestation.

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