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Intraguild predation of *Neoseiulus cucumeris* by *Stratiolaelaps miles* and *Atheta coriaria* in greenhouse open rearing systems

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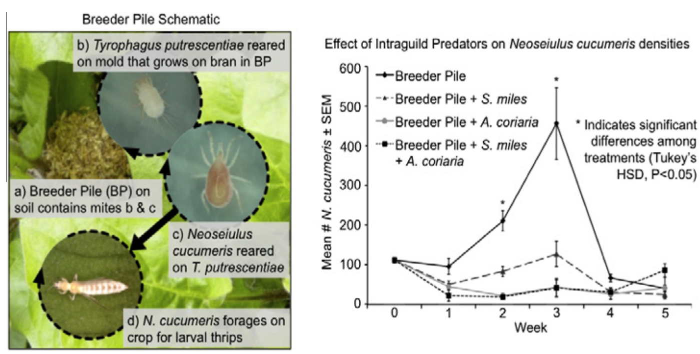
HIGHLIGHTS

- ▶ We investigated potential intraguild predation of *Neoseiulus cucumeris*.
- ▶ *Atheta coriaria* had negative impacts on *N. cucumeris* in breeder piles.
- ▶ *Stratiolaelaps miles* had negative impacts on *N. cucumeris* in breeder piles.
- ▶ Thrips densities were highest when all three predator species were present.

GRAPHICAL ABSTRACT



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ABSTRACT

We examined intraguild predation of *Neoseiulus cucumeris* Oudemans (Phytoseiidae) in breeder piles by the soil-dwelling predators, *Stratiolaelaps miles* (Berlese) (Laelapidae) and *Atheta coriaria* (Kraatz) (Staphylinidae) in a greenhouse microcosm study. Each microcosm contained a soybean plant (*Glycine max* (L.) Merrill) and a *N. cucumeris* breeder pile alone, a *N. cucumeris* breeder pile with either *S. miles* mites or *A. coriaria*, or a *N. cucumeris* breeder pile with both *S. miles* and *A. coriaria*. We measured numbers of *N. cucumeris, S. miles, A. coriaria*, and their shared prey: *Tyrophagus putrescentiae* (Shrank) (Acaridae) mold mites and incident thrips (Thripidae: *Frankliniella occidentalis* and *Thrips* sp.). Peak populations of *N. cucumeris* in breeder piles and soybean canopies lacking *S. miles* and/or *A. coriaria* predators were fourfold greater than when other predators were present. We observed more *N. cucumeris* mites in plant canopies in microcosms where other predators were absent. *S. miles* had a significant negative impact on *A. coriaria* and *A. coriaria* had numerical negative impacts on *S. miles*. There were fewer *T. putrescentiae* mold mites in microcosms containing *A. coriaria* ($\leqslant 1049.28 \pm 301.72$) compared with other treatments ($\geqslant 2428.16 \pm 452.24$) overall. We observed fivefold more incident thrips in microcosms containing all three predators compared with *N. cucumeris* breeder pile alone and *N. cucumeris* breeder pile with either of the other predators. Our results demonstrate that greenhouses seeking to biologically manage thrips should either utilize *N. cucumeris* alone or utilize alternative *N. cucumeris* release strategies – *i.e.* hanging sachets or repeated foliar applications.

1. Introduction

Augmentative biological control tactics using commercially available parasitoids and predators are commonly used in greenhouses. Many of these natural enemies are generalists that prey on or parasitize a spectrum of pests (Messelink et al., 2012). Releasing generalist predators to manage pests can be advantageous because they can persist on alternative prey in the absence of the target pest (Symondson et al., 2002; Messelink et al., 2012). Open rearing of natural enemies (i.e. a combination of augmentative releases and conservation biological control) promote

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the persistence of biological control agents in greenhouses (Stacey, 1977; Messelink et al., 2012). Lingering predators, however, increase the potential for direct and indirect interactions among concurrently present biological control agents (Janssen et al., 1998, 2007; Messelink et al., 2012).

Neoseiulus (=*Amblyseius*) *cucumeris* Oudemans is a foliar predator with proven efficacy against thrips (Thysanoptera: Thripidae) in greenhouse crops (Gillespie, 1989; Shipp and Wang, 2003). A recent development in open rearing of *N. cucumeris* in greenhouses is breeder piles. Breeder piles are small (1–3 g) piles of a mixture of bran, *Tyrophagus putrescentiae* (Shank) (Acaridae) mold mites, and *N. cucumeris* that are placed on the soil of plug trays, beds, and plant pots in greenhouses. *T. putrescentiae* mold mites feed on fungus that grows on the bran and are an alternate food source for *N. cucumeris*. Breeder piles serve as local population centers for *N. cucumeris,* potentially increasing the time needed between applications. Placing breeder piles on the soil surface may increase *N. cucumeris* vulnerability to intraguild predation from other biological control agents released to manage soil-dwelling thrips pupae (e.g. *Frankliniella occidentalis* (Pergande)) and fungus gnat (Diptera: Sciaridae, Mycetophilidae) larvae and pupae.

Intraguild predation occurs when two organisms that share a common host or prey kill or consume each other (Polis et al., 1989). In some cases intraguild predation is unidirectional, meaning that one predator feeds on another (Polis et al., 1989). This has been observed among several commonly used greenhouse biological control agents such as *Orius laevigatus* Fieber (Hemiptera: Anthocoridae), *N. cucumeris*, and *Iphiseius* (*Amblyseius*) *degenerans* Berlese (Acari: Phytoseiidae), where *O. laevigatus* preyed on both *N. cucumeris* and *I. degenerans* (Wittmann and Leather, 1997). Intraguild predation may also be bidirectional, where predators prey upon each other (Polis et al., 1989; Rosenheim et al., 1995), as observed between *N. cucumeris* and *Amblyseius swirskii* (Athias-Henriot) (Phytoseiidae) (Buitenhuis et al., 2009). These studies observed intraguild predation among predators that generally occupy similar areas in a crop – e.g. the plant canopy. Breeder piles introduce *N. cucumeris* mites onto the soil where they do not normally occur thus creating a situation for novel interactions among predators.

Two potential intraguild predators of *N. cucumeris* in breeder piles are the predaceous rove beetle, *Atheta coriaria* (Kraatz), and predatory mite, *Stratiolaelaps* (=*Hypoaspis*) *miles* (Berlese) (Laelapidae). Both predators are also commercially available biological control agents used in greenhouse pest management. *A. coriaria* is an effective predator of soil-dwelling thrips life stages and shore fly (Diptera: Ephydridae) and fungus gnat (Diptera: Mycetophilidae and Sciaridae) larvae (Carney et al., 2002; Birken and Cloyd, 2007). Similarly, *S. miles* mites inhabit the soil and are also effective for these pests (Wright and Chambers, 1994; Berndt et al., 2004). *A. coriaria* and *Hypoaspis aculeifer* are known intraguild predators (Jandricic et al., 2006). In a preliminary study that observed population dynamics of *N. cucumeris* in breeder piles, *A. coriaria* was found in breeder piles within 1 week of their application (Pochubay and Grieshop, unpublished). The presence of *A. coriaria* in breeder piles provides evidence for potential intraguild predation within the piles. Although there is little information on the intraguild predatory tendencies of *S. miles,* its polyphagous nature suggests that this interaction is likely to occur (Wright and Chambers, 1994).

Our objective was to determine the likelihood and impact of unidirectional intraguild predation by *A. coriaria* and *S. miles* on the temporal population dynamics of *N. cucumeris* and incident thrips populations. We hypothesized that (1) *A. coriaria* and *S. miles* will have direct impacts on *N. cucumeris* populations in breeder piles and soil thus resulting in fewer *N. cucumeris* in the plant canopy, (2) these interactions will affect *T. putrescentiae* mold mite prey populations, and (3) these interactions will also impact incident thrips prey populations.

2. Materials and methods

We conducted a 5 week greenhouse study utilizing caged soybean plant (*Glycine max* (L.) Merrill) microcosms to explore the potential of intraguild predation among *N. cucumeris*, *S. miles*, and *A. coriaria*. Our experiment took place in the summer of 2010 at a research greenhouse located at Michigan State University (MSU) (East Lansing, MI USA). We used a randomized complete block design with five blocks and the following treatments: Breeder pile, Breeder pile + *A. coriaria*, Breeder pile + *S. miles*, and Breeder pile + *S. miles* + *A. coriaria*. Breeder piles consisted of a 1 g mixture of bran, *T. putrescentiae* mold mites, and *N. cucumeris* mites.

2.1. Plant culture

Soybean seeds (variety: 92M33) were planted singly in 15 cm (1.33 l) pots containing potting medium. Pots were placed on trays and subirrigated every 1–2 days throughout the experiment. The average greenhouse temperature was 29.4 °C and ranged from averages of 27.8 °C at night to 31.7 °C in the late afternoon. No supplemental lighting or fertilizer was used throughout the experiment. We began our experiment one week after sowing the soybeans – when the hypocotyl was extended and the cotyledons were folded down.

2.2. Arthropod culture

We extracted experimental arthropods from 1 l tubes of *Amblyseius*-Breeding-System, *Hypoaspis*-System, and *Atheta*-System supplied by BioBest Biological Systems (Leamington, ON, Canada). We made 105 1 g *N. cucumeris* breeder piles by placing breeder pile material into a 59 ml diet cup. Breeder piles were held for approximately 2 h prior to introduction into microcosms. Initial Berlese funnel extractions from breeder pile material contained 112 ± 6 (SEM) per g and 881 ± 99 (SEM) per g *N. cucumeris* mites and mold mites, respectively. For treatments containing *S. miles* we made 55 1 g piles of *Hypoaspis*-System material consisting of a mixture of peat, vermiculite, and *S. miles* mites. These piles were treated identically to the *N. cucumeris*. Initial Berlese funnel extractions from *Hypoaspis*-System material contained 18 ± 3 (SEM) *S. miles* mites per g. For treatments containing *A. coriaria* we collected 55 groups of four adult beetles from *Atheta*-System consisting of peat, vermiculite, and *A. coriaria* beetles. Beetles were carefully collected using a natural fiber paintbrush, placed into 59 ml diet cups and held for approximately 2 h prior to introduction into microcosms. Voucher specimens are available in the A.J. Cook Arthropod Collection at Michigan State University (East Lansing, MI).

2.3. Microcosm design and set up

We constructed microcosms from potted soybean plants caged with 150 micron polyester multifilament mesh. We used a 40 cm tall 1 mm diameter wire frame to support cage material. One week after sowing the soybeans, we selected 100 healthy plants in similar developmental stage (i.e. extended hypocotyls and folded down cotyledons) for use in the experiment. The plants were randomly assigned in groups of 25 plants per treatment. The appropriate predator combinations were applied to the soil surface of the individual potted soybean plants at a rate of 1 g of *N. cucumeris* breeder pile material, 1 g of *Hypoaspis*-System and four adult *A. coriaria* beetles. The caged soybeans were placed on trays on