

Generalist predator *Stratiolaelaps scimitus* hampers establishment of the bulb scale mite predator *Neoseiulus barkeri* in *Hippeastrum*

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In this study we investigate the hypothesis that presence of the generalist soil-dwelling predatory mite *Stratiolaelaps scimitus* (Womersley) results in lower densities of the phytoseiid soil-dwelling predator *Neoseiulus barkeri* Hughes in *Hippeastrum* (amaryllis). If true, this may increase risks of bulb scale mite *Steneotarsonemus laticeps* (Halbert) infestations in *Hippeastrum*, because *N. barkeri* predate on this pest, whereas *S. scimitus* does not. In a greenhouse trial we show indeed that the release of *S. scimitus* results in significantly lower densities of *N. barkeri* in a *Hippeastrum* crop. Moreover, analyses of soil and bulb samples from a commercial *Hippeastrum* farm suggest that this predator interference is facilitated by soil cooling techniques that drive the predators together to small 'islands' of higher surface temperatures.

Keywords: biological control, greenhouses, food web interactions, predator interference, hyperpredation

Biological control in greenhouses has evolved the past decades from relatively simple systems of a few specialist natural enemies to complex communities of multiple interacting natural enemies and pests (Janssen *et al.* 1998, Sabelis *et al.* 2008, Messelink *et al.* 2010). One of the reasons for this increase in complexity is the presence of generalist predators within biocontrol communities. Most of these predators not only eat several pests, but also other natural enemies. These interactions between natural enemies are classified as 'intraguild predation' when one predator species (the intraguild predator) kills and eats another predator species (the intraguild prey) with whom it also competes for shared prey (Polis *et al.* 1989). Intraguild predation seems to be a general phenomenon but usually does not disrupt biological control (Janssen *et al.* 2006, 2007, Vance-Chalcraft *et al.* 2007). However, generalist predators can also eat other natural enemies without sharing a prey. This so-called 'hyperpredation' can be very disruptive for biological control (Rosenheim 1998, Symondson 2002, Messelink *et al.* in prep).

Here we investigate the interaction between two species of soil-dwelling predatory mites: the larger predator *Stratiolaelaps scimitus* (Womersley) (often

marketed under the name *Hypoaspis miles*, Walter & Cambell 2002) and the smaller predator *Neoseiulus barkeri* Hughes. Both predators occur together (spontaneously or by releases) in Hippeastrum crops (Messelink *et al.* 2006). *Stratiolaelaps scimitus* can be used for controlling thrips (Berndt *et al.* 2004). In earlier studies we showed *N. barkeri* to be a promising candidate for biological control of the tiny bulb scale mite, *Steneotarsonemus laticeps* (Halbert) (Acari: Tarsonemidae) in greenhouse cultures of Hippeastrum (Messelink & van Holstein-Saj 2006, 2007). Since then, many growers started to use this predator for controlling bulb scale mites, but the results so far are mixed. Laboratory observations showed that *S. scimitus* does not attack bulb scale mites (Messelink & van Holstein 2006), but successfully attacks and kills the bulb scale mite predator *N. barkeri* (Fig. 1). We hypothesized that *S. scimitus* can hamper the establishment of *N. barkeri*, and thus increase risks on bulb scale mite infestations in Hippeastrum. We tested this by following the population dynamics of *N. barkeri* in Hippeastrum with and without additional releases of *S. scimitus*. Furthermore we followed the population dynamics of both predators on a commercial Hippeastrum farm where soil cooling is applied for flower induction.

MATERIAL AND METHODS

Effects of *Stratiolaelaps scimitus* on *Neoseiulus barkeri* establishment

A greenhouse experiment was set up to test whether the predator *S. scimitus* affects the establishment of *N. barkeri* in a Hippeastrum crop. On greenhouse tables, Hippeastrum bulbs cv. Lion were grown in 16 plastic boxes of 44 × 65 cm



Figure 1. The predator *Stratiolaelaps scimitus* feeding on the predator *Neoseiulus barkeri*

which were filled with a 20 cm layer of peat. Each box contained 15 bulbs, which were prior to the experiment cleaned with a hot water treatment of 2 h at 47 °C. The peat layer in the boxes was finally mulched with a 2 cm layer of sawdust, according to standard cultivation techniques. The predator *S. scimitus* was added to half of the boxes in densities of 1000/m², 5 weeks after planting the bulbs. Two weeks later, the second predator *N. barkeri* was released either by scattering 1000 mites/m² above the crop, or by adding one rearing sachet on the soil (slow release product, supplied by BioProduction, Denmark). These sachets released ca. 1400 predatory mites in 8 weeks in the laboratory. Thus in total there were 4 treatments: two release strategies of *N. barkeri*, each combined with or without *S. scimitus*. Each treatment was replicated 4×. Every single box with bulbs was isolated by a continuously present water layer on the tables, with the intention to avoid contamination among the treatments. The population dynamics of both predators and other soil organisms were followed by weekly analyses of one bulb and one soil sample (500 ml) per box. Microarthropods were extracted from these samples by heat and collected in ethanol, using Tullgren funnels, and counted under a binocular microscope (40×). Bulbs were prior to these analyses cut in smaller pieces. Predatory mites were mounted on glass slides for microscopic determination. For statistical analyses, a repeated measures ANOVA was performed on log(x+1)-transformed numbers of predators with the time since introduction of *N. barkeri* as the repeated measure variable. Differences among treatments were tested at a 5% level using Fisher's LSD.

Effects of soil cooling on predator dynamics

Commercial Hippeastrum farms in The Netherlands apply soil cooling techniques in summer till autumn in order to produce flowers in winter (Fig. 2). Flowering is induced by cooling the soil for 12 weeks to 12 °C by using cold water pipes in the soil. The high greenhouse temperatures in summer, result in strong

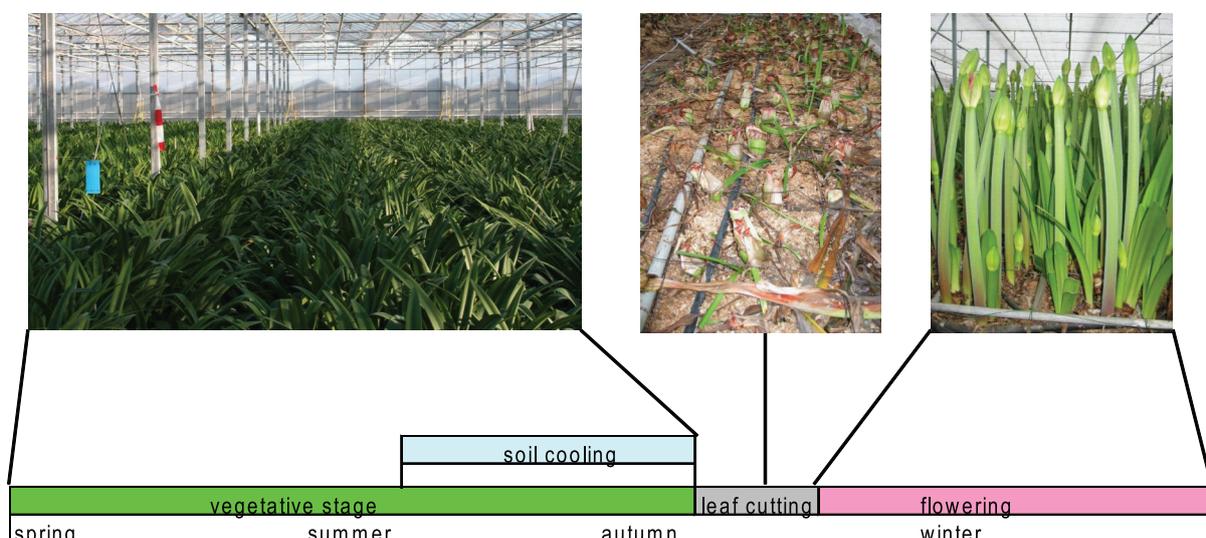


Figure 2. Illustrating the growing cycle of Hippeastrum on a commercial farm.

temperature differences between the bulb parts standing above soil and the bulbs parts standing within the soil. We tested whether soil cooling techniques affect the population dynamics of *N. barkeri* and its hyperpredator *S. scimitus*. Samples were collected from a Hippeastrum farm where both predators were established by earlier releases. On the farm, cv. Dancing Queen was cultured on a loamy soil. Nine bulb and soil samples (500 ml soil) were randomly collected in week number 26 (June) just before cooling, and the same number of samples in week number 36 (September) during the soil cooling period. The bulb and soil samples were analysed separately using Tullgren funnels as described above. Predator densities were analysed using a generalized linear model with a poisson distribution and soil cooling as factor.

RESULTS

Effects of *Stratiolaelaps scimitus* on *Neoseiulus barkeri* establishment

Densities of *N. barkeri* were significantly lower in treatments with *S. scimitus* than in treatments without this predator ($F_{3,9} = 19.14$, $P < 0.001$; Fig. 3). Also a spontaneously occurring smaller (ca. 350 μm) predator of the genus *Dendrolaelaps* was present in significantly lower densities in treatments where *S. scimitus* was not released ($F_{3,9} = 162.19$, $P < 0.001$). Other soil organisms such as oribatid mites and collembolans were present in all treatments in equal densities of 20 and 400 per sample respectively. The release method of *N. barkeri* was not significantly affecting the densities of this predator in absence of *S. scimitus*. However, in combination with *S. scimitus*, densities of *N. barkeri* remained higher when *N.*

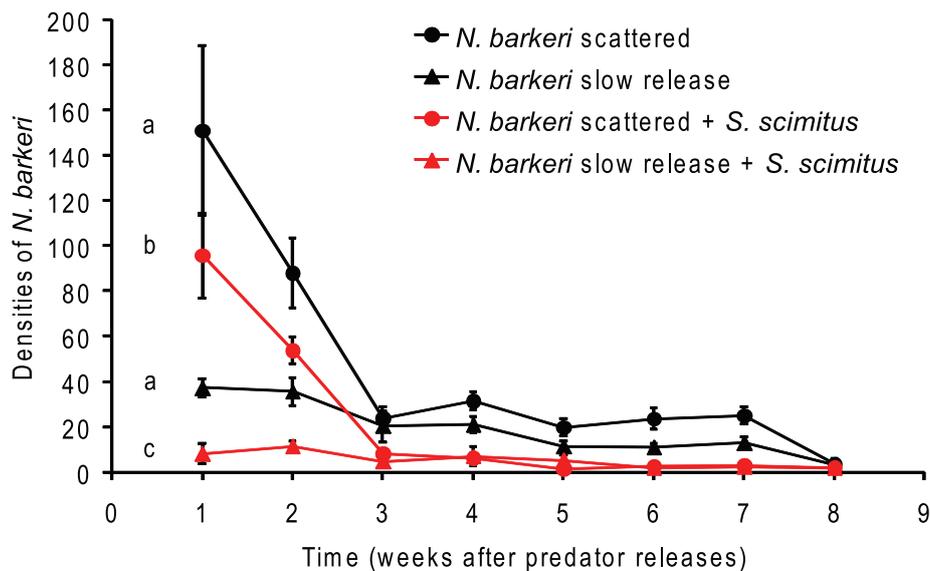


Figure 3. Population dynamics of *Neoseiulus barkeri* in Hippeastrum with and without the hyperpredator *Stratiolaelaps scimitus*. Shown are average (\pm s.e.m.) densities of juvenile and adult predators per soil + bulb sample.

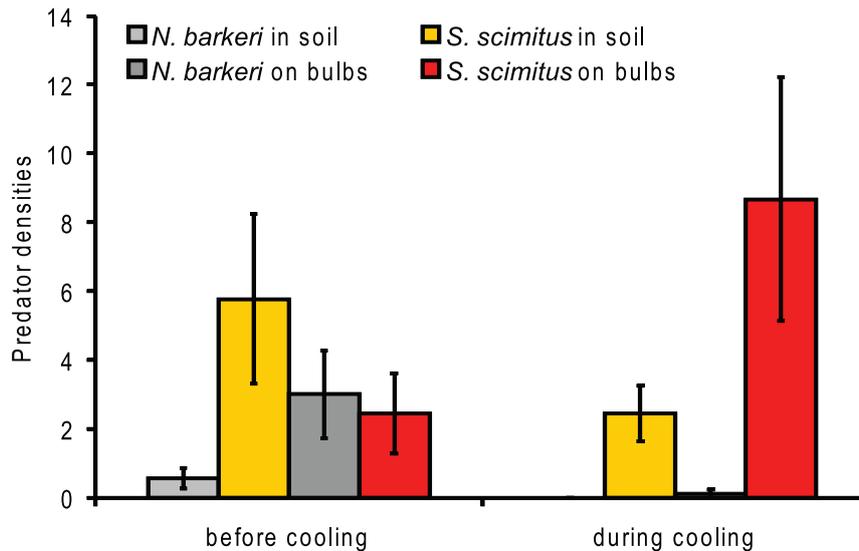


Figure 4. Population dynamics of *Neoseiulus barkeri* and its hyperpredator *Stratiolaelaps scimitus* on a commercial *Hippeastrum* farm before and during soil cooling (12 °C). Shown are average (\pm s.e.m.) densities of juvenile and adult predators per soil (500 ml) or bulb sample.

barkeri was scattered at once compared to the slow release rearing sachets (Fig. 3). *Stratiolaelaps scimitus* established very well in all treatments were they were released, resulting in average densities of 30 mites per sample (converted ca. 3400/m²).

Effects of soil cooling on predator dynamics

The predator *N. barkeri* was present in both soil and bulb samples before cooling, whereas densities in samples collected during the cooling period were very low (Fig. 4), resulting in significant differences between the two sampling dates ($F_{1,16} = 7.73$, $P = 0.013$). In contrast, overall densities of the larger predator *S. scimitus* did not differ between samples before and during cooling ($F_{1,16} = 0.39$, $P = 0.54$). However, there seems to be a shift in habitat preference of this predator (Fig. 4). Densities on bulbs seem to be higher during cooling than before cooling, although not significantly ($F_{1,16} = 3.06$, $P = 0.099$).

DISCUSSION

This study shows that interactions among soil-dwelling predatory mites may increase risks of disruption of biological pest control in the soil. Our laboratory observation that the larger predator *S. scimitus* eats the smaller predator *N. barkeri* was confirmed in a long term greenhouse trial where the addition of *S. Scimitus* reduced *N. barkeri* to very low densities. Besides this hyperpredation, competition for food might have played a role as well. However, the presence of high densities of collembolans and oribatid mites suggest there was sufficient

other prey present (for example, nematodes are excellent food sources for predatory mites, but not measured with Tullgren Funnels). Although we did not study the effect of the hyperpredation on bulb scale mite control, it is very likely that the lower densities of *N. barkeri* will release bulb scale mite from control. We showed earlier that *N. barkeri* can not totally eradicate bulb infestations, because the tiny tarsonemid mites are hidden deep inside the bulbs (Messelink & van Holstein 2007). However, we showed that *N. barkeri* can reduce the spread of this pest to other uninfested bulbs. A maximal effect is thus expected when *N. barkeri* is continuously present at sufficiently high densities. This study shows that *S. scimitus* almost eradicates *N. barkeri*. Hence, bulbs are less protected by infestations by bulb scale mites at these very low predator densities. Furthermore, studies where effects of hyperpredation on biological pest control was measured, show a strong disruption of this pest control (Prasad & Snyder 2004, Messelink *et al.* in prep.). For example, Prasad & Snyder (2004) found that large carabid beetles in the soil ate several smaller carabid beetles, which resulted in a lower predation rates on eggs of *Delia* spp.

Hyperpredation of *S. scimitus* on *N. barkeri* might even increase by culture techniques growers use for flower induction. Our data suggest that the application of soil cooling drive the soil-dwelling predatory mites from the soil to the bulbs. A plausible reason for this habitat shift is that the predators are driven by their preference for higher temperatures. For *S. scimitus* it is known that optimal temperature for development and reproduction is about 25 °C (Ydergaard *et al.* 1997) and that the minimum temperature for development is 10 °C, which is closely to the soil temperatures of 12 °C when cooled. Thus the lower soil temperatures may force the predators to the upper bulb parts, where temperatures are higher. Hence, soil cooling may facilitate hyperpredation of *S. scimitus* on *N. barkeri*. This could explain the absence of *N. barkeri* in samples collected during the soil cooling period.

Summarizing, this study provides evidence for predator interference between two soil-dwelling predatory mites, which may seriously disrupt the biological control of bulb scale mites in Hippeastrum. Such interactions should be considered when developing biological control programs with generalist predators.

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