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Evaluating Spiders for Their Potential To Control Cabbage White Butterflies (*Pieris rapae*)

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Summary
A field experiment was conducted three times during two seasons (twice in winter and once in spring) to evaluate the impact of spiders on the survival of the cabbage white butterfly, *Pieris rapae* (= *Artogeia rapae*). The proportion of *P. rapae* eggs surviving to the first caterpillar stage was significantly reduced on spider treatment plants compared to check treatment plants. During the three experiments, the percentage of *P. rapae* eggs surviving to the fifth caterpillar stage was increased 1.7-, 2.7-, and 1.3-fold, respectively, on check plants compared to spider plants. Additionally, by completion of the the experiment, above-ground plant biomass of spider-"protected" plants was increased by 80, 121, and 28 percent compared to check plants.

Introduction
Although several studies have shown that spiders can significantly reduce insect pest populations and the associated crop damage (Agnew and Smith 1989, Hooks et al. 2003), their ability to suppress insect pest populations and enhance plant productivity has received limited attention in cropping systems. On several occasions, spiders were observed feeding on eggs and caterpillars of lepidoptera prey inhabiting broccoli (*Brassica olearacea* L.) plants, and although their densities were recorded, no attempt was made to quantify their predatory impact (Hooks and Johnson 2002). Hooks et al. (2003) found significantly fewer large *P. rapa*e caterpillars on plants where spiders were allowed to forage freely, compared to control plants in which spiders were removed daily. However, during that study the amount of mortality spiders inflicted upon *P. rapae* was not estimated. Therefore, field experiments reported here were conducted to quantify the impact of spiders on *P. rapae*'s survivorship and broccoli plant biomass. The objective of this study was to address two questions: (1) Does caterpillar survival differ on plants containing spiders? (2) Do spiders indirectly increase broccoli plant size through suppression of caterpillars?

Procedures
Experimental design
Three field trials were conducted to assess the impact of spiders on *P. rapae*'s survival. Experiments were conducted during 2003 and 2004 at the University of Hawai'i at Mānoa's Poamoho Research Station. For each trial, 5-week-old greenhouse-grown broccoli plantlets were transplanted and randomly assigned to two treatments: (1) spiders present, and (2) a check (spiders removed). Twelve plants were assigned to each treatment during each trial period.

Spiders were removed daily from check treatment plants at 10:00 and 13:30 during the duration of each trial. Immediately after the 13:30 removal, a sleeve cage constructed of a transparent fabric was gently placed over each check plant to prevent spiders from foraging them. During the initial 16 days after planting (DAP), the cages were removed from the plants daily from 09:00 until 13:30 to allow oviposition on the test plants by *P. rapae*.

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Sampling

The proportion of *P. rapae* eggs reaching the first caterpillar stage was assessed during spring 2003 and winter 2004. Twelve plants were randomly selected and assigned to the check or spider treatment for each trial. All *P. rapae* eggs found on these plants during the initial 16 DAP were counted and recorded, and their location was marked with a permanent marker. Each egg was checked daily to determine if it reached the caterpillar stage. At the experiment's completion, the percentages of the 16-day egg cohort reaching the caterpillar stage were calculated for each treatment.

The percentage of *P. rapae* eggs reaching their final (fifth) caterpillar stage was measured on 12 additional randomly selected check and spider plants during three field trials (i.e., winter and spring 2003, and winter 2004), respectively. Similarly, as mentioned above, *P. rapae* eggs laid during the initial 16 DAP were monitored to determine the percentage reaching their final caterpillar stage.

To determine if whole-plant biomass differed between check and spider plants, upon the experiment's completion test plants from each treatment were cut at soil level, transported to the laboratory, oven-dried, and weighed to measure above-ground dry vegetative biomass.

Statistical analysis

Treatment effects on the number of eggs oviposited, plant weight, and percentage of eggs reaching the first and final caterpillar stages were assessed using analysis of variance (Proc GLM, SAS Institute, Cary, NC 1990). To fulfill assumptions regarding normality and equal variances, data were transformed when necessary.

Results

Spiders

Over the course of the trial, spiders removed from the check plants included *Nesticodes rufipes*, *Oxyopes* sp., *Cheiracanthium mordax* Koch, *Neoscona oaxacensis* Keyserling, and an unidentified linyphiid. The average number of spiders found per broccoli leaf during the three trials ranged from 0.25 to 0.69, 0.17 to 0.60, and 0.17 to 0.46 for the winter 2003, spring 2003, and winter 2004 trials, respectively. During each trial the number of spiders found per plant increased during the broccoli growth cycle.

Pieris rapae

During the spring egg mortality experiment, the proportion of *P. rapae* eggs reaching their first caterpillar stage was significantly higher on check (83%) compared to spider (56.5%) treatment plants. However, no significant differences were found during the winter experiment (Fig. 1). For all three trials, the percentage of *P. rapae* eggs reaching their final caterpillar stage was significantly reduced on spider plants compared to check plants (Fig. 2).

Whole plant biomass

During the 2003 trials, the average plant weight was significantly greater for spider plants than for check plants (Fig. 3). During the 2004 winter experiment, spider plants were larger than check plants, but the difference was not statistically significant.

Discussion

During one of the two field trials, the percentage of eggs reaching the first caterpillar stage was significantly lower on spider treatment plants compared to check plants. Furthermore, the proportion of eggs reaching the fifth instar stage was significantly lower on spider plants compared to check plants during all three field trials. Broccoli whole-plant biomass of spider plants was significantly greater than that of check plants during the first two field experiments.

Spiders were rarely observed feeding on *P. rapae* eggs, but the results suggest that spiders had a significant impact on *P. rapae* egg mortality. A number of cabbage looper (*Trichoplusia ni*) eggs were also encountered on spider plants during the spring, but no larva of this species was observed during the trial, suggesting that spiders also fed on *T. ni* eggs. The wandering spider (*Oxyopes* sp.) appears to be the most important spider for suppressing populations of *P. rapae* and *T. ni*. Suppression of *P. rapae* was greatest when populations of *Oxyopes* sp. were high and least when they were low.

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Figure 1. Percentage (± S.E.) of *Pieris rapae* eggs reaching the first caterpillar stage on spider-removed and spider-present treatment plants during two field trials. Different letters above a bar for each trial indicate that treatments are significantly different at the 5% level ($P < 0.05$).

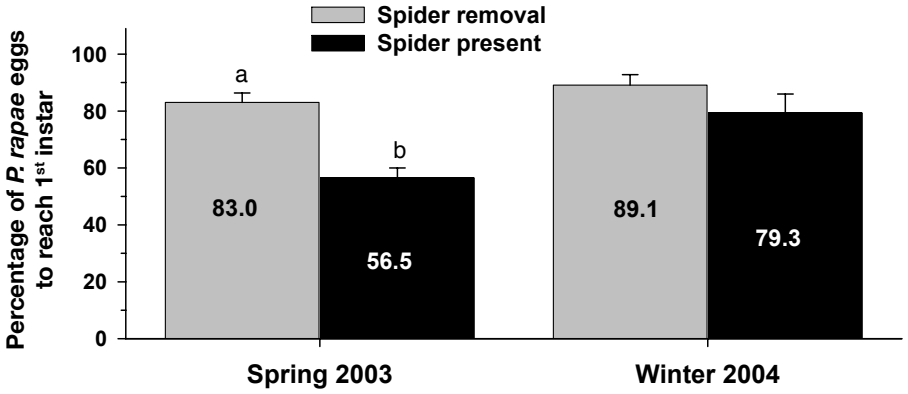


Figure 2. Percentage (± S.E.) of *Pieris rapae* eggs to reach the fifth caterpillar stage on spider-removed and spider-present treatment plants during three field trials. Different letters above a bar for each trial indicate that treatments are significantly different at the 5% level ($P < 0.05$).

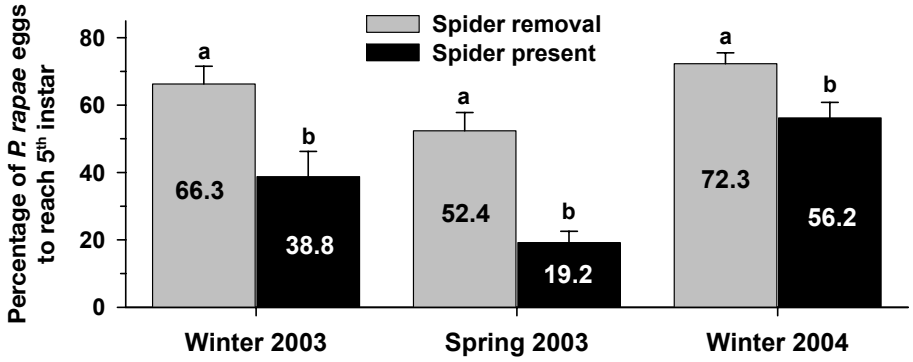
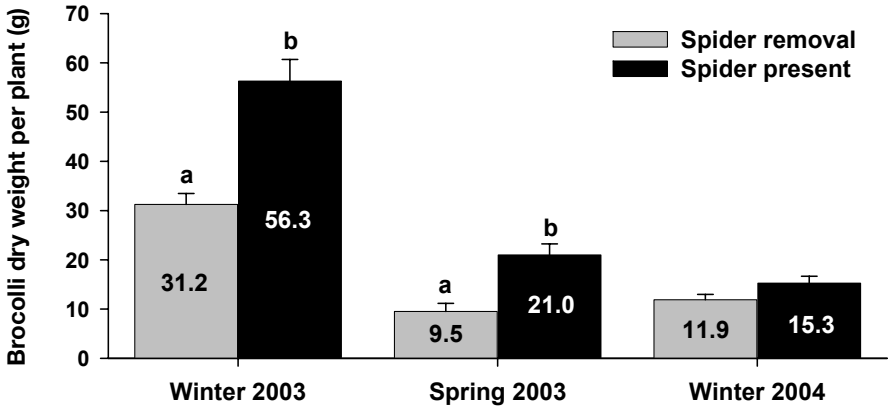


Figure 3. Average (± S.E.) dry whole-plant biomass on spider-removed and spider-present treatment plants during three field trials. Different letters above a bar indicate that treatments are significantly different at the 5% level ($P < 0.05$).



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