AUGMENTATIVE RELEASES OF PREDATORY MITES ON PAPAYA IN HAWAII: FAILURE AND SUCCESS

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INTRODUCTION

Since the discovery of *Phytoseiulus persimilis* Athias-Henriot (Phytoseiidae) in 1959, predatory mites have been commonly used, effective biological control agents in greenhouses (van Lenteren and Woets, 1988). However, for various reasons, the efficacy of predatory mites has been much lower when releases have been made on outdoor crops (Olkin and Shaw, 1995; Walsh *et al.*, 1998).

Native to Central America, papaya (*Carica papaya* L.) (Caricaceae) was introduced to Hawaii about 200 years ago. Papaya is a fast-growing, hollow-stemmed, short-lived perennial crop. Trees can grow as tall as 10meters and produce fruits within the first year after planting. In commercial orchards, trees are grown over a period of three years, with fruits being harvested throughout the year.

Papaya foliage is attacked by a complex of herbivorous mites, among which the carmine spider mite (*Tetranychus cinnabarinus* Boisduval [Acari: Tetranychidae]) is one of the key pests. This species is a polyphagous pest worldwide, mainly distributed in semitropical and tropical areas (Jeppson *et al.*, 1975). Three specialist predators are commonly found feeding on carmine spider mites in papaya: the ladybeetle *Stethorus siphonulus* (Kapur) (Coleoptera: Coccinellidae) and two predatory mites, *Phytoseiulus macropilis* Banks (Acari: Phytoseiidae), and *P. persimilis*. None of these three species are native to Hawaii. *Stethorus siphonulus* was apparently released in 1894 by Albert Koebele (Perkins, 1925); *P. macropilis* has been known to occur in the state since 1947 (Smith and Summer, 1949); and *P. persimilis* was purposely mass-released in the mid 1970s (B. Kamashiro, Hawaii Dept. of Agriculture, pers. comm.). The introduced generalist predator *Nesticodes rufipes* Lucas (Araneae: Theridiidae), a sit-and-wait tangle-web building spider, is also very abundant on papaya leaves, and acts as a top predator because it can prey upon all members of the arthropod community.

We have observed that during the early spring, when the beetle *S. siphonulus* is abundant and *Phytoseiulus* mites are scarce, the spider *N. rufipes* can disrupt natural control of carmine spider mites by preying on *S. siphonulus*. As a result, natural control of spider mites by *S. siphonulus* is unpredictable. Later in the season, as the predatory mites build up and become dominant, they provide good control of spider mites, but important damage may have already occurred to the crop. Although *N. rufipes* can feed on the predatory mites, *Phytoseiulus* species are not as vulnerable as *S. siphonulus* larvae.

The objective of this study was to test the efficacy of an early-season augmentative release of *Phytoseiulus* species. against the carmine spider mite. More specifically, we wanted to determine (i) whether these predatory mites would establish following a release and (ii) whether the release of *Phytoseiulus* species would significantly suppress spider mites.

MATERIALS AND METHODS

Our general experimental approach was to make field releases, using no cages or enclosures, and then sample foliage to detect establishment and pest suppression. We conducted eight different experiments in the spring of 2000 and 2001 at the Poamoho Research Station of the University of Hawaii on the North Shore of Oahu. In this paper, we report the results of three of these experiments. Statistical analyses were performed for each sampling date on untransformed data using one-way ANOVA.

Experiment 1

In this test, the experimental units were single papaya leaves ("per-leaf" release). Leaves were randomly assigned to one of the three treatments: (1) no release (control); (2) two *Phytoseiulus* individuals released (equivalent to 15,000 individuals per ha); and (3) five *Phytoseiulus* individuals released (equivalent to 45,000 individuals per ha). Each treatment was replicated 15 times. Because our experimental papaya fields naturally harbored a mixture of *P. macropilis* and *P. persimilis* populations, we mass reared a mixed-species culture in the laboratory. Both adults and deutonymphs were released by placing them on papaya leaves with a paintbrush. Arthropods were recorded once a week via nondestructive, in-field counts. The experiment ran from 30 March to 1 May 2000.

Experiment 2

The experimental units were individual papaya trees ("per-tree" release). Trees were randomly assigned to one of the three treatments: (1) no release (control); (2) 10 *Phytoseiulus* individuals released (equivalent to 15,000 individuals per ha); and (3) 40 *Phytoseiulus* individuals released (equivalent to 60,000 individuals per ha). Each treatment was replicated 10 times. *Phytoseiulus* were mass-reared in the laboratory in a mixed-species culture (*P. persimilis and P. macropilis*), and both adults and deutonymphs were released from vials attached to the tree trunk. Four leaves per tree were sampled to record arthropod densities every other week, using nondestructive, in-field counts. The experiment was carried out from 24 May to 8 August 2000.

Experiment 3

The experimental units for Exp. 3 were individual papaya trees ("per-tree" release). Trees were randomly assigned to one of two treatments: (1) no release (control) and (2) 20 *Phytoseiulus* individuals released (equivalent to 30,000 individuals per ha). Each treatment was replicated 15 times. *Phytoseiulus* spp. (a mixture of *P. persimilis and P. macropilis*) were collected in a nearby papaya field on the day of release. Adults and deutonymphs were released using vials. Four leaves per tree were sampled to record arthropods every week. This experiment ran from 25 April to 5 July 2001.

RESULTS

In each of the experiments, *Phytoseiulus* spp. successfully established, and their populations increased following the release. However, in the first two experiments, the released predatory mites did not appear to contribute to spider mite population suppression. Data are reported as means ± 1 SE.

Experiment 1

During Exp. 1, predators established but did not exceed a mean density of 0.8 individuals per leaf (Fig.1). Eight days after the release, we noted a significant difference between the high release rate (5 predatory mites/leaf) and the low release rate (2 predatory mites/leaf) ($P < 0.0065$). Twenty-five days after the release, *Phytoseiulus* started colonizing our control treatment leaves (Fig. 1). The initial mean densities of spider mites were 7.5 to 9 adult females per leaf, and spider mite populations declined in all treatments after the release (Fig. 2). This leads us to speculate that another predator, likely the beetle *S. siphonulus*, might have suppressed spider mites (Fig. 3). A combination of other predators such as *Oligota* sp. beetles (Staphylinidae), lacewings, and cecidomyiid midges might also have contributed to this decline in spider mite densities.

Experiment 2

In this experiment, mean *Phytoseiulus* spp. densities were greater than 1.5 adult females per leaf in both release treatments 33 days after the initial release ($P < 0.05$), while the 'no release' trees had fewer than 0.5 predator per leaf (Fig. 4). There was no difference between the high (40 predatory mites per tree) and the low rate of release (10 predatory mites per tree) throughout the experiment (Fig. 4). The spider mite densities peaked at about 30 adult females per leaf on day 20 following the release, and then dropped to below 10 adults per leaf in all treatments (Fig. 5). Once again, we believe that the beetle *S. siphonulus* might be responsible for this experiment-wide reduction in spider mite populations. The population dynamics of *S. siphonulus* followed a similar pattern to its prey dynamics, first increasing until day 33, then decreasing (Fig. 6).
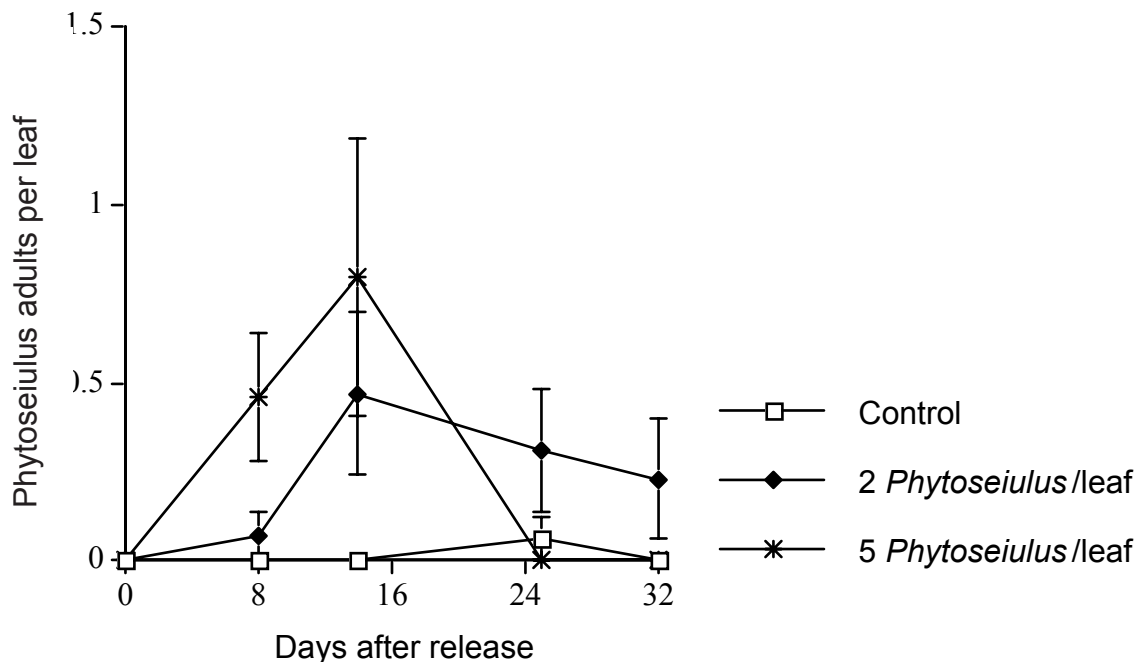

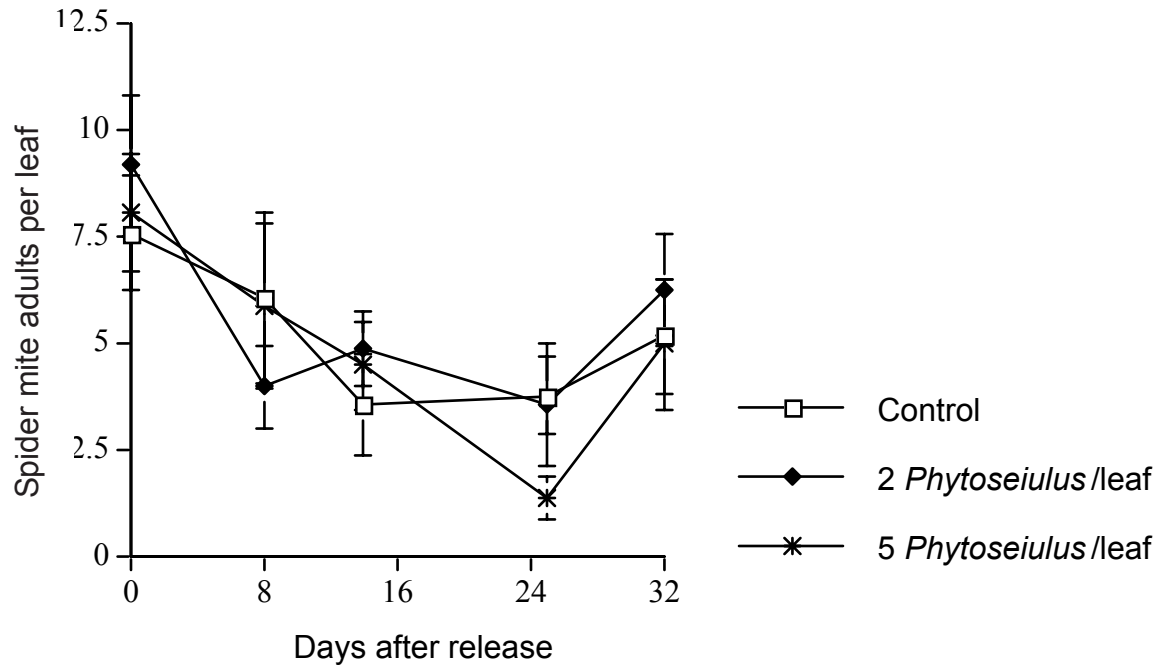**Figure 1.** *Phytoseiulus* spp. densities (adult female) on papaya leaves following release in Experiment 1.

Figure 2. *Tetranychus cinnabarinus* (adult female) densities (number/leaf) following the release of predatory mites in Experiment 1.
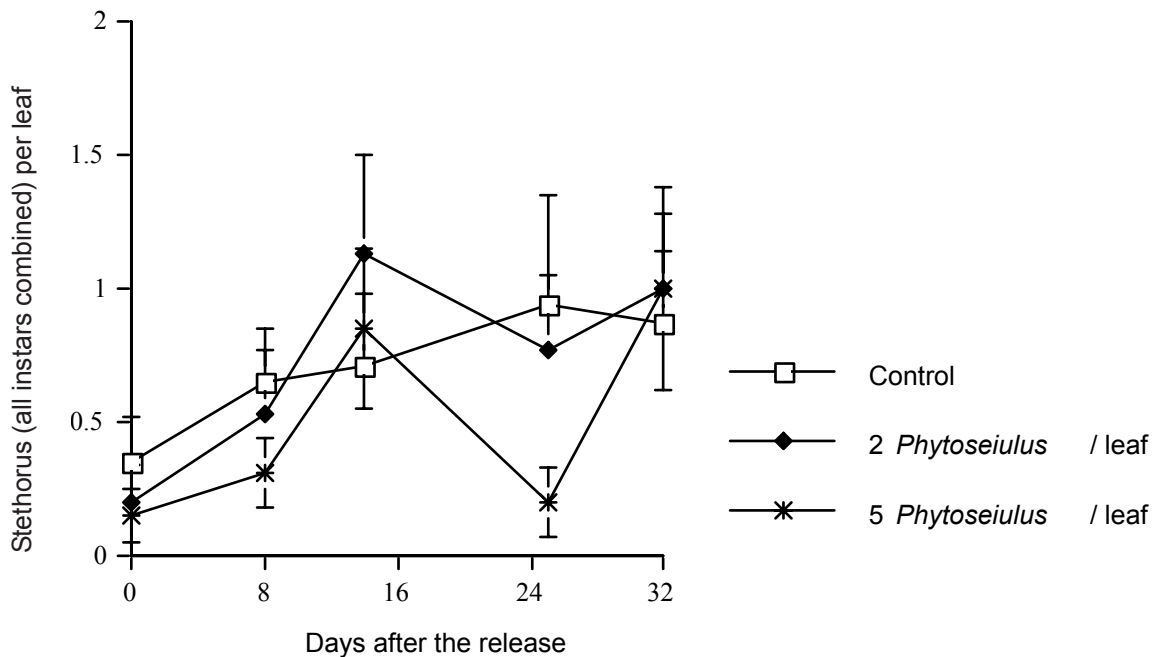

Figure 3. Population dynamics of *Stethorus siphonulus* (egg, larva, pupa, and adult) during the course of Experiment 1.
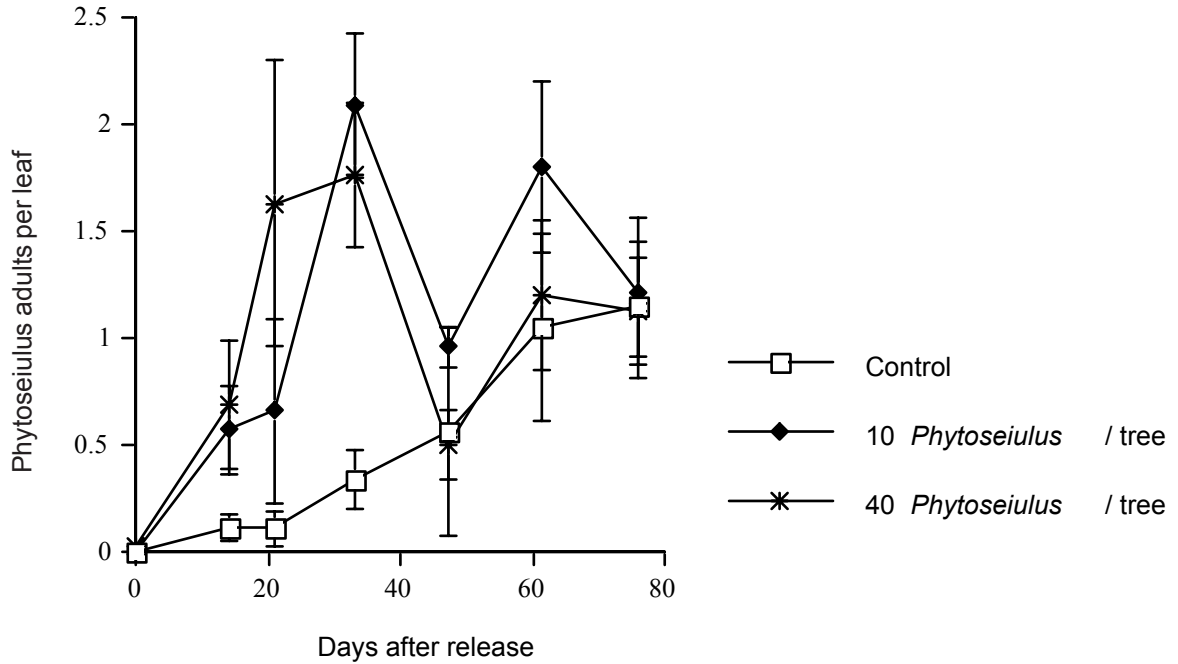
Figure 4. *Phytoseiulus* spp. (adult female) densities (number per leaf) on papaya leaves following the release in Experiment 2.
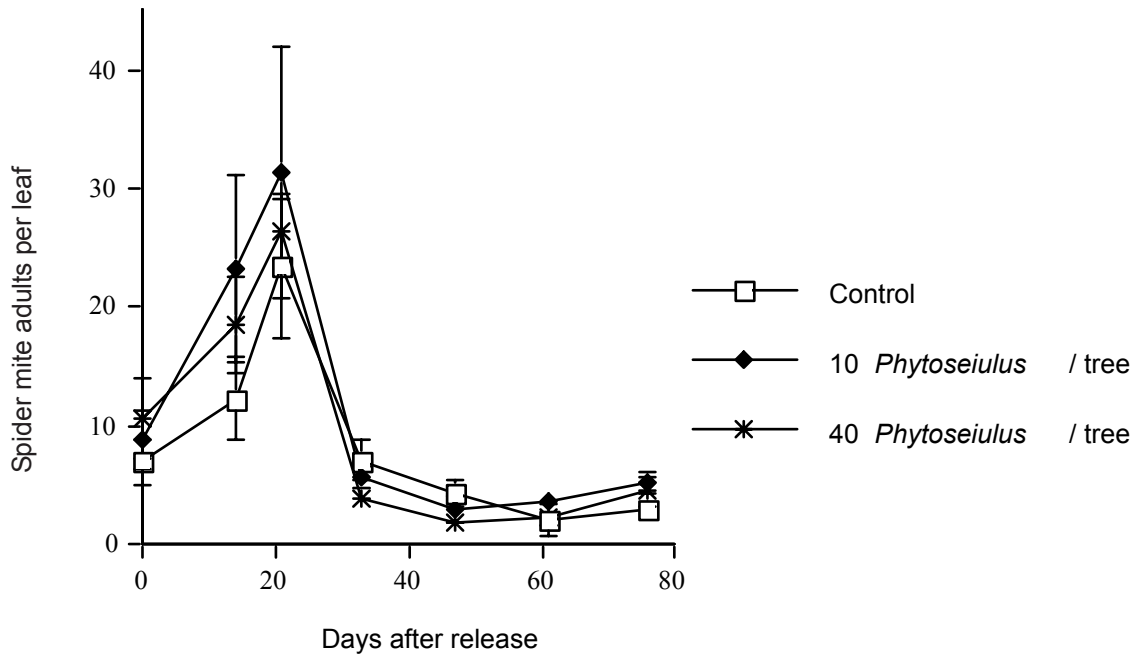

Figure 5. *Tetranychus cinnabarinus* densities (adult female) on papaya leaves following the release in Experiment 2.
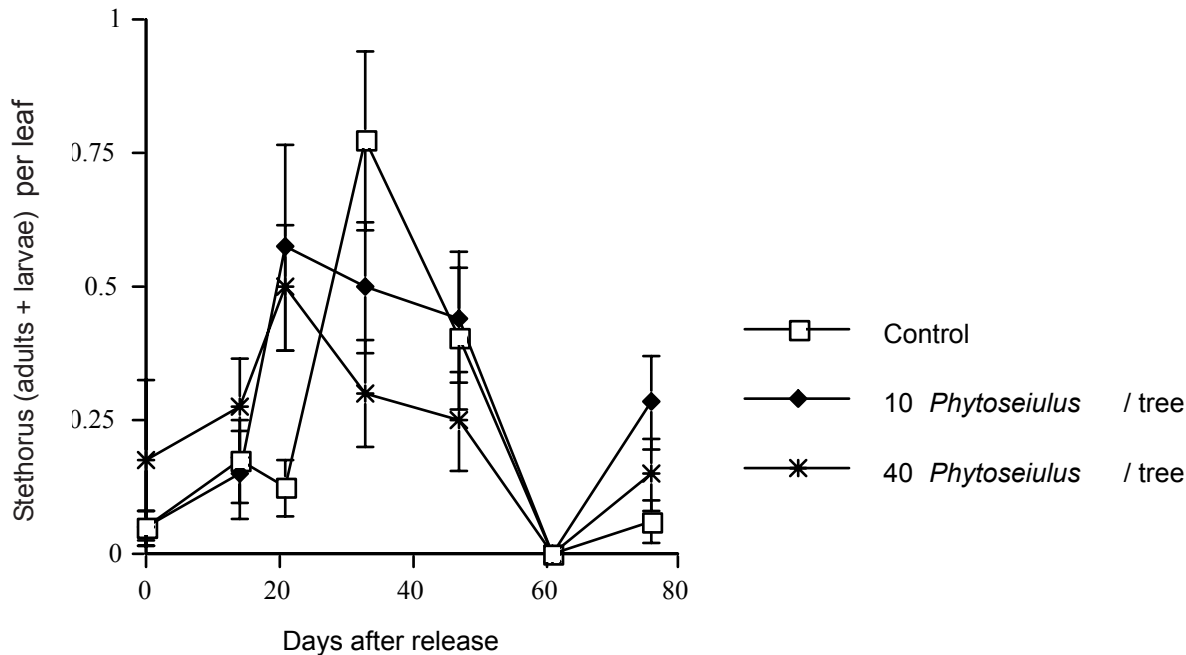
Figure 6. Population dynamics of *Stethorus siphonulus* (adult and larvae combined) during the course of Experiment 2.

Experiment 3

This experiment provided the first evidence that releases of *Phytoseiulus* species can significantly suppress spider mite populations. Predatory mite densities reached 4.4 adult females per leaf in the release treatment 22 days after the initial release, while the no release trees had fewer than 0.5 predators per leaf. Significant differences in predatory mite densities between the two treatments were maintained for up to 40 days ($P < 0.05$) (Fig. 7). The spider mite densities peaked at about 50 adult females/leaf on day 15 following the release and gradually dropped to 10 adults per leaf on day 71 in both treatments (Fig. 8). However, for a period of nearly 30 days, pest densities were significantly lower on the 'release' trees ($P < 0.05$) (Fig. 8). The beetle *S. siphonulus* reached very high densities, and probably also contributed to spider mite suppression (Fig. 9). *Stethorus siphonulus* population densities tracked the availability of spider mite prey, first increasing until day 22, then decreasing (Fig. 9). The control trees supported somewhat higher densities of *S. siphonulus* (day 36 to 43, $P < 0.05$) (Fig. 9).

DISCUSSION

In our experiments released individuals of *Phytoseiulus* spp. established successfully in papaya. In each of the experiments, the beetle *S. siphonulus* appeared to play a significant role in suppressing spider mite populations. This factor prevented us from evaluating predatory mite efficacy in two of the three experiments, as spider mite populations were strongly suppressed in all treatments. Although it has been demonstrated that *S. siphonulus* larvae are susceptible to spider predation, it appears that this interference is not always sufficiently strong in the system to preclude the ability of *S. siphonulus* to suppress spider mite populations, especially when beetle densities are high, as observed in years 2000-2001. The finding in Exp. 3 that *S. siphonulus* densities tended to be higher on leaves where we did not release predatory mite suggests that the beetle may compensate for the absence of *Phytoseiulus* species.
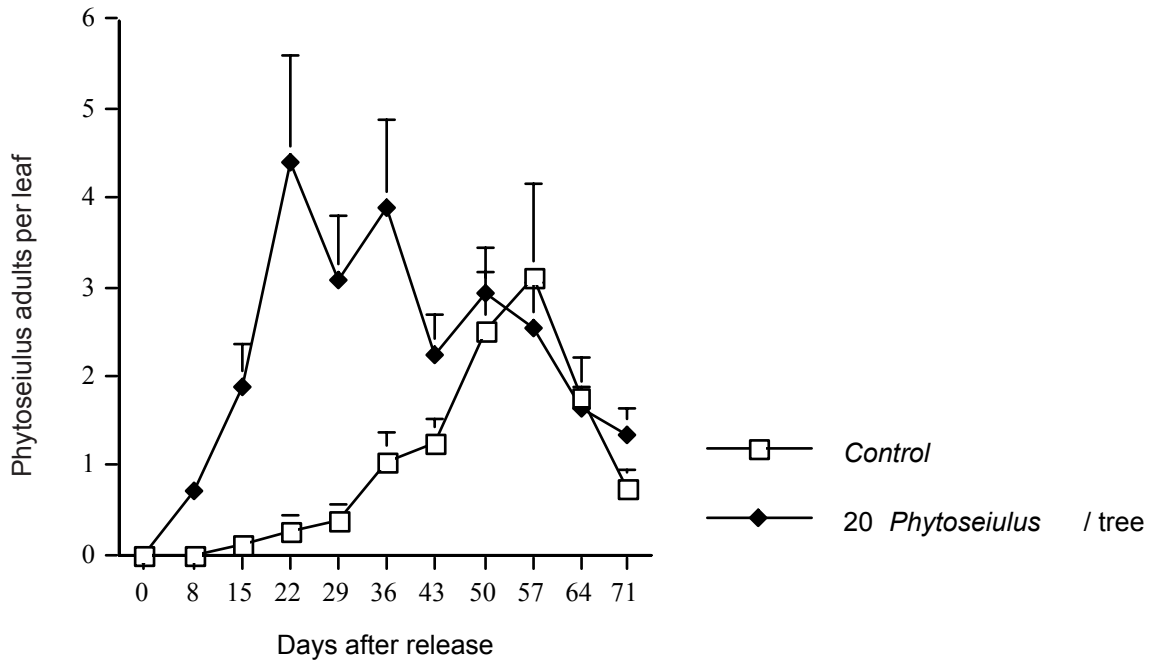
Figure 7. *Phytoseiulus spp.* (adult female) densities (number per leaf) on papaya leaves following the release in Experiment 3.
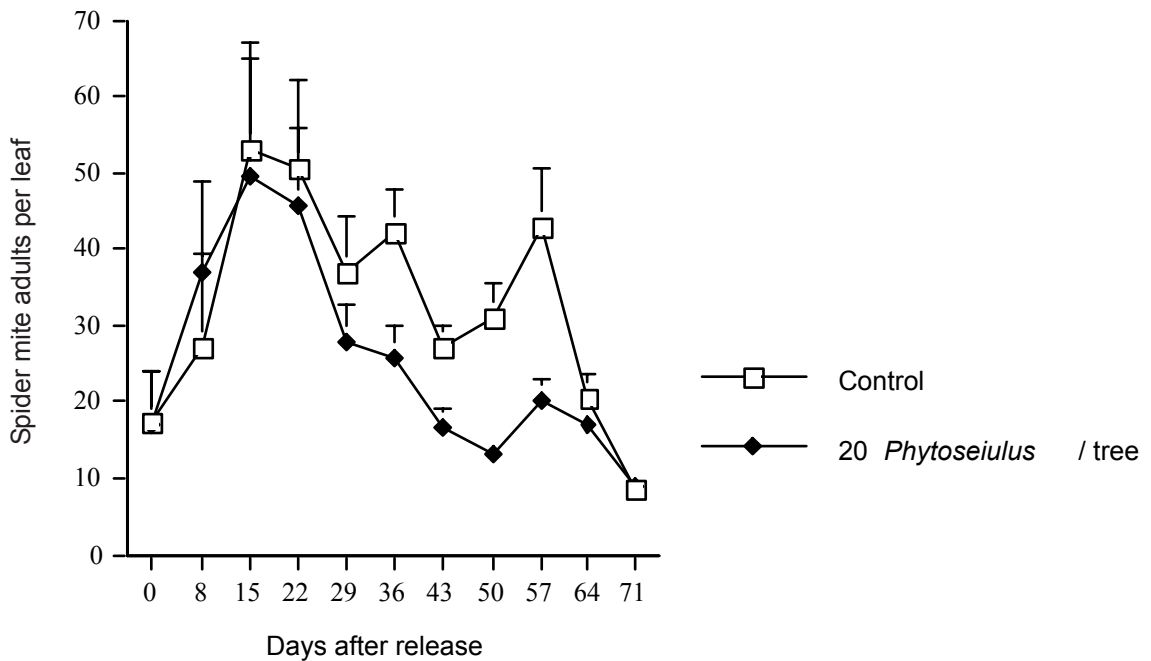

Figure 8. *Tetranychus cinnabarinus* (adult female) densities (number per leaf) on papaya leaves following the release in Experiment 3.
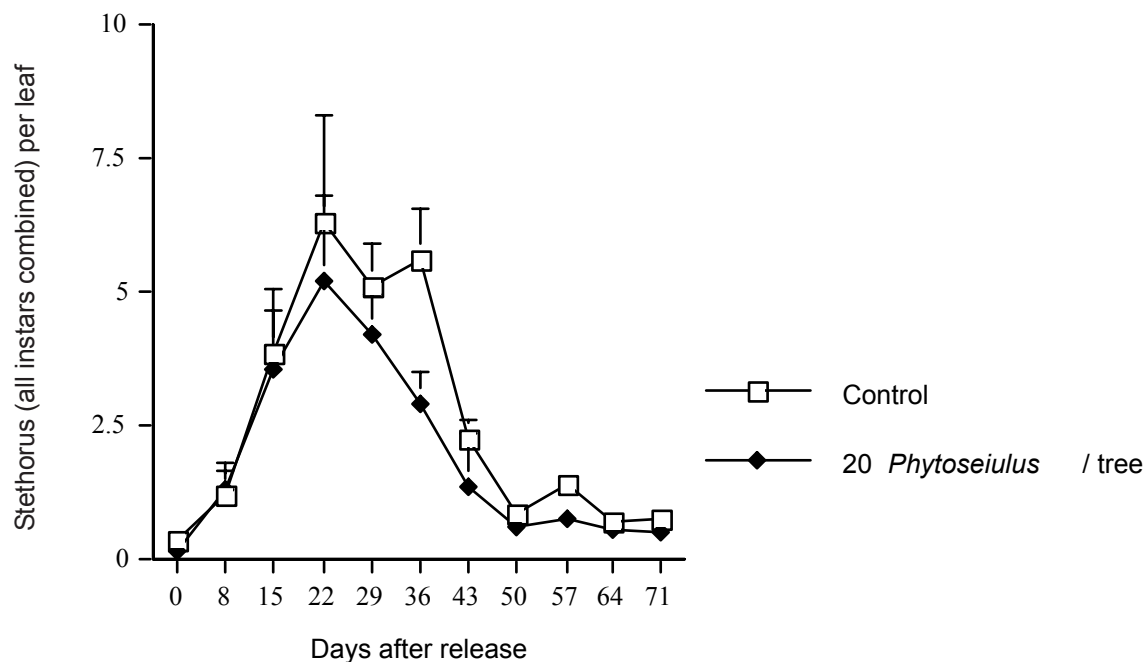
Figure 9. Population dynamics of *Stethorus siphonulus* (egg, larva, pupa, and adult combined) during the course of Experiment 3.

The third experiment suggests that augmentative releases of predatory mites in papaya do have potential for enhancing spider mite control when *S. siphonulus* are absent or present at low densities. We suggest therefore that the densities of all the major players, i.e., spider mite, *Phytoseiulus* spp., and *S. siphonulus* need to be assessed before a decision can be made to conduct augmentative releases. If a papaya field is already well colonized by *Phytoseiulus* species, or *S. siphonulus*, or both, releasing more predatory mites may do little to improve pest control, but would be an additional production cost for growers.

Future research in the papaya system should include (i) additional tests of *Phytoseiulus* spp. releases when *S. siphonulus* densities are low; (ii) releases in commercial orchards; (iii) tests of the compatibility of such releases with the agrochemicals commonly sprayed in papaya; and (iv) a comparison of the relative efficacy of *P. persimilis* versus *P. macropilis*. Grower education in the principles of biological control is also needed. Finally, a commercial insectary needs to be located in the State of Hawaii before augmentative releases of *Phytoseiulus* could be readily implementable, because current state regulations prohibit the importation of commercial biological control agents.

ACKNOWLEDGMENTS

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