

MITES AND APHIDS IN WASHINGTON HOPS: CANDIDATES FOR AUGMENTATIVE OR CONSERVATION BIOLOGICAL CONTROL?

D.G. James, T.S. Price, and L.C. Wright

Department of Entomology, Washington State University, Prosser, Washington, U.S.A.

INTRODUCTION

Hop plants, *Humulus lupulus* L., are attacked by several arthropod pests, the most important being the hop aphid, *Phorodon humuli* (Schrank), and the two-spotted spider mite, *Tetranychus urticae* Koch (Campbell, 1985; Cranham, 1985). Currently, insecticides and miticides are routinely used to control these pests on hops grown in Washington state. In many horticultural crops, *T. urticae* is often an economic problem on crops only when its natural enemies are removed by the use of broad-spectrum pesticides (Helle and Sabelis, 1985). The degree to which pesticides induce or exacerbate spider mite outbreaks in Washington hops has not been studied.

Insect and mite management in Washington hops is currently being reevaluated due to increasing concerns over the cost-effectiveness, reliability, and sustainability of pesticide inputs. Chemical control of mites in hops is often difficult due to the large canopy of the crop and problems with miticide resistance (James and Price, 2000). Research to date on the biological control of mites in hops has centered on the use of phytoseiid mites through conservation or augmentation of populations (Pruszyński and Cone, 1972; Strong and Croft, 1993, 1995, 1996; Campbell and Lilley, 1999), but has not shown much commercial promise, despite some partial successes. While phytoseiid mites are undoubtedly important predators of *T. urticae* in hops, support from other mite predators may be necessary to provide levels of biological control acceptable to growers. The use of natural enemy assemblages in crop ecosystems, as opposed to single specialist type biological control agents, is receiving interest as a crop protection strategy (Murdoch *et al.*, 1985; Ehler, 1992; Reichert and Lawrence, 1997). Campbell and Cone (1994) showed that *P. humuli* on Washington hops is regulated by an assemblage of predators with good potential for economic control.

To determine the importance of the local natural enemy community in regulating populations of *T. urticae* and *P. humuli* on hops in Washington state, we monitored the abundance and phenology of *T. urticae*, *P. humuli* and their natural enemies monthly on commercial (pesticide-treated) and "volunteer" hops (not planted, pesticide-free) during two seasons. We also monitored *T. urticae*, *P. humuli*, and natural enemy populations weekly in an experimental, pesticide-free hop yard on Washington State University land in Prosser, Washington, during two seasons.

MATERIALS AND METHODS

Monitoring in Commercial Hop Yards and on Volunteer Hop Plants

Hops at 16 sites (commercial hop yards or escaped hops) were monitored in 1999. Paired sites (one commercial hop yard and one patch of volunteer hops) were established at each of eight locations in the Yakima Valley of central Washington from Prosser to Yakima. Seven of the locations were used in 2000. Sites in each pair were located within 5 km of each other. Escaped hop sites usually consisted of a small number of plants climbing along a fence or up a pole, usually at the side of a road. Mite and aphid populations were sampled by collecting 30 leaves randomly from each site monthly during June-October 1999 and April-October 2000. Leaves were placed in plastic bags and kept cool until

examined under a stereomicroscope. Numbers of motile *T. urticae*, and all Phytoseiidae were recorded. Samples of adult phytoseiids were placed in alcohol for later identification using a compound microscope. Non-phytoseiid predators of *T. urticae* and *P. humuli* (mostly insects) present on leaves were also recorded and identified. Data were analyzed using analysis of variance and Student's t test.

Monitoring in a Pesticide-Free, Experimental Hop Yard

A 2.7 acre hop yard at WSU-Prosser was monitored weekly from March to October in both 2000 and 2001 for *T. urticae*, *P. humuli*, and natural enemies. Populations were sampled by collecting 30 leaves randomly from the yard and examining them under the microscope. Searches were also made weekly for mite-damaged and honeydew-covered leaves to locate mite and aphid "hot spots." Some subsampling of 'hot spots' was conducted. Larger, more mobile mite and aphid predators (e.g., coccinellids, spiders, lacewings, predatory Heteroptera) were sampled in 2001 by taking weekly canopy "beating" samples from June to September. On each occasion nine vines (three vines in three randomly selected locations) were shaken vigorously for three seconds. Dislodged invertebrates deposited on a 1 m² collection tray were aspirated into collecting tubes for later sorting and identification in the laboratory.

RESULTS

Monitoring in Commercial Hop Yards and on Volunteer Hop Plants

All commercial sites received one to four applications of miticide each season (1999 mean, 2.3; 2000 mean, 2.1 applications). At least one application of an aphicide was also applied to all sites (late June), with some sites receiving another application in late July or early August (1999 mean, 1.4; 2000 mean, 0.9).

The mean abundance of *T. urticae* and *P. humuli* in both years when analyzed over the season, did not differ significantly between commercial and volunteer hops. In 1999, miticides at three hop yard sites failed to provide adequate mite control. This resulted in a mean population for the three yards of 300 mites per leaf in August, compared with means of 0.01 and 0.1 mites per leaf for the other hop yards and the volunteer hop sites, respectively (Anova, $df = 7$, $t = 6.4$, $P < 0.001$). In 2000, effective mite control was obtained in all hop yards, with mean populations generally being below 5 mites per leaf in all months except July, when there were 16.3 mites per leaf. Numbers of mites at volunteer hop sites did not exceed 5 per leaf in any month. The mean abundance of phytoseiids (primarily *Galendromus occidentalis* Nesbitt and *Neoseiulus fallacis* Garman) in both years when compared on a seasonal basis, did not differ significantly between commercial and volunteer hops. Peak aphid numbers (8-10 per leaf) occurred in June but populations were not economically damaging. At least six insect and one non-phytoseiid mite species known to be predators of spider mites were recorded from the leaf samples. Four of the species recorded were also aphid predators. The seven species (total number recorded from all sites during two seasons) were *Stethorus punctum picipes* Casey (Coleoptera: Coccinellidae) (195), *Chrysopa* spp. (Neuroptera: Chrysopidae) (81), *Hemerobius* sp. (Neuroptera: Hemerobiidae) (80), *Feltiella* sp. (Diptera: Cecidomyiidae) (53), *Orius tristicolor* (White) (44), *Scolothrips sexmaculatus* (Pergande) (Thysanoptera: Thripidae) (25), and *Anystis* sp. (Acari: Anystidae) (18). The incidence of non-phytoseiid predators in both seasons was more than three times greater at escaped hop sites (ratio, commercial: escaped hops: 1: 3.2 in 1999, 1: 3.6 in 2000).

Monitoring in a Pesticide-Free, Experimental Hop Yard

Observations in 2000. *Tetranychus urticae* and *P. humuli* were first seen on May 3, but populations remained at low levels for the next two months (Fig. 1). Numbers of *T. urticae* did not exceed one per leaf until July, although hot spots were observed in the yard during June. These consisted of single vines where mite populations sometimes exceeded 10 per leaf. However, in all instances significant populations of *S. punctum picipes* and *Orius* spp. were also present, effectively preventing the hot spots from spreading (Fig. 1). Predatory mites, primarily *G. occidentalis* and *N. fallacis*, did not occur in large numbers until July when they became a significant source of mortality for *T. urticae*. Large numbers of phytoseiids (up to 8 per leaf) occurred late in the season. Numbers of *T. urticae* peaked at 6 per leaf in mid-July and remained below 5 per leaf for the rest of the season. No mite damage was found in harvested cones (hop cones are used to flavor beer).

Aphid populations increased to about 12 per leaf in late June before declining rapidly in early July to 1-2 per leaf. Numbers increased to 5 per leaf in September (Fig. 1). Predators, particularly the ladybirds *Hippodamia convergens* Guerin-Meneville and *Harmonia axyridis* (Pallas) and the predatory bugs *Geocoris* spp. and *Orius* spp., appeared to be largely responsible for the generally low numbers of *P. humuli*.

Observations in 2001. Overwintered *T. urticae* were first seen on sprouting hops in late March along with *G. occidentalis*. The phytoseiids controlled the spider mites by mid-April when hop plants were “burned back” to synchronize growth for training on strings. No *T. urticae* were seen on new growth until late June when small numbers occurred in hot spots in association with *S. punctum picipes* and *Orius* spp. (Fig. 2). These predators and others (e.g., *Feltiella* sp., *S. sexmaculatus*) maintained *T. urticae* at low population densities throughout July. Phytoseiids were generally absent until late July. In late July and early August, *T. urticae* numbers increased to about 7 per leaf and then to 18-53 per leaf for a 2-3 week period. Phytoseiid populations also increased rapidly (up to 14 per leaf) bringing the *T. urticae* population under control by the end of the month (Fig. 2). No economic damage to hop cones was caused by the late season spider mite population increase.

Hop aphids appeared in mid-May but stayed at <1 per leaf until late June when they increased to 17 per leaf by mid-July and 25 per leaf by the end of the month (Fig. 2). Numbers fell dramatically in early August to <4 per leaf, mainly due to invasion by *H. axyridis*.

DISCUSSION

The results of this study on abundance and phenology of mites, aphids, and their natural enemies on pesticide-free and pesticide-treated hops in Washington indicate that biological control provided by an assemblage of natural enemies has the potential to provide effective management. We have demonstrated the importance of considering biological control of mites and aphids in hops from a community perspective. To date, all published research on biological control of mites in hops has focused on either augmentation or the conservation of phytoseiid mites. This study suggests phytoseiids are only part of the story. A diverse group of non-phytoseiid predators also appears to play an important role in regulating mite populations on hops in Washington in unsprayed situations. One of the major drawbacks to the use of natural phytoseiid populations on hops is their slow development during spring (Strong and Croft, 1993). Non-phytoseiid predators may effectively fill this early season “niche” as was the case when *S. punctum picipes* and *Orius* spp. suppressed expansion of mite hot spots in the hop yard at WSU-Prosser. Containment of early season mite populations, preventing hot spots from becoming area-wide infestations, may be the key to effective season-long biological control of mites on hops.

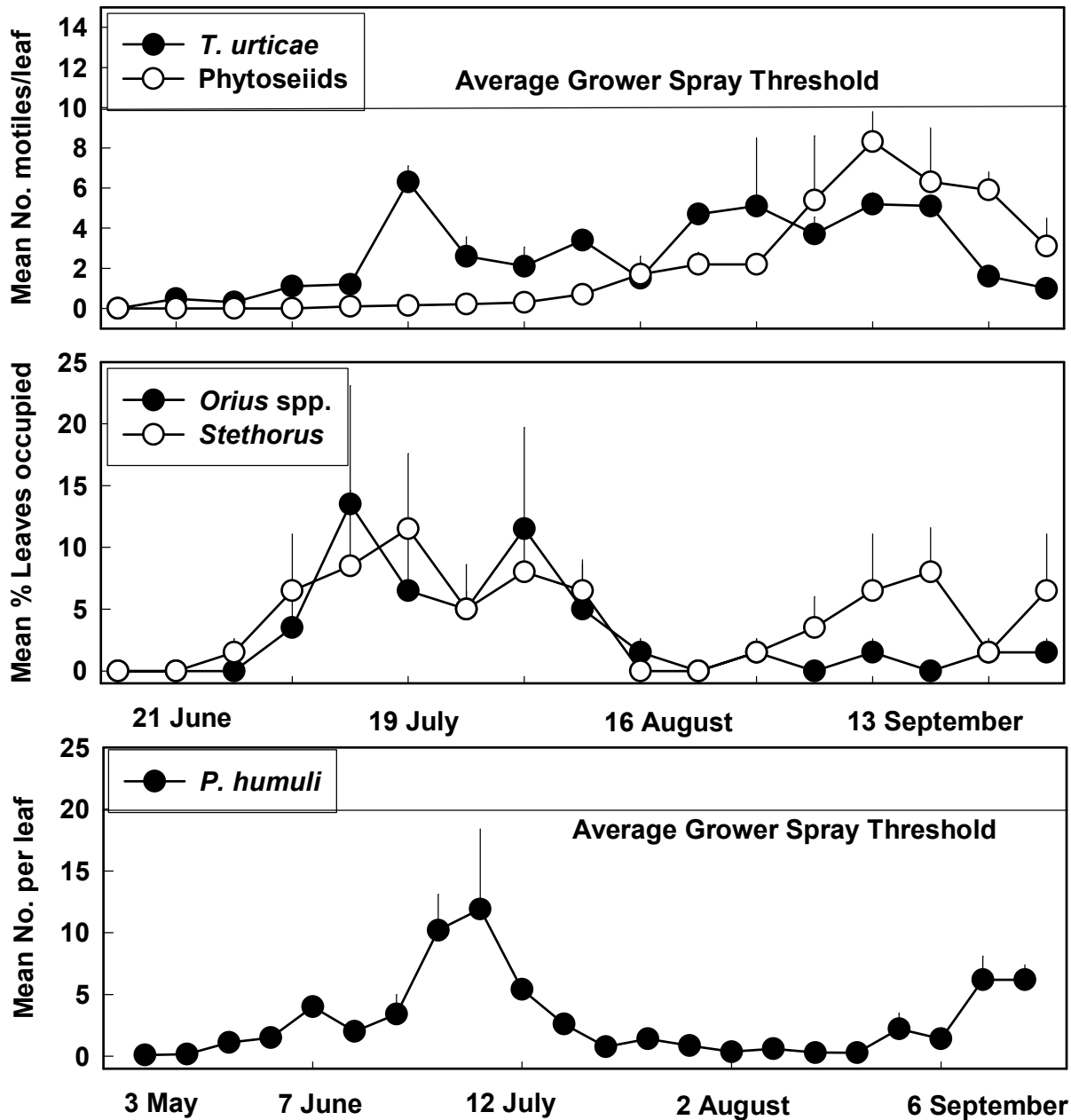


Figure 1. Mean (\pm SE) abundance and phenology of pest (*Tetranychus urticae* Koch, *Phorodon humuli* Schrank) and beneficial arthropods (*Stethorus punctum picipes* Casey, *Orius* spp.) in an unsprayed hop yard at WSU-Prosser in 2000.

Timely augmentative releases of phytoseiids or non-phytoseiids (e.g., *Stethorus* spp., *Orius* spp.) may also be effective if endemic populations of predators are not large enough. Similarly, augmentative releases of aphidophagous coccinellids could be used to limit early-season buildup of *P. humuli*. However, the appearance of *H. axyridis* in hop yards during 2000 and 2001 (this species was not recorded in Washington hops before 1999) may greatly improve the control provided by native coccinellids such as *Coccinella transversoguttata* Faldermann and *H. convergens* (Campbell and Cone, 1994).

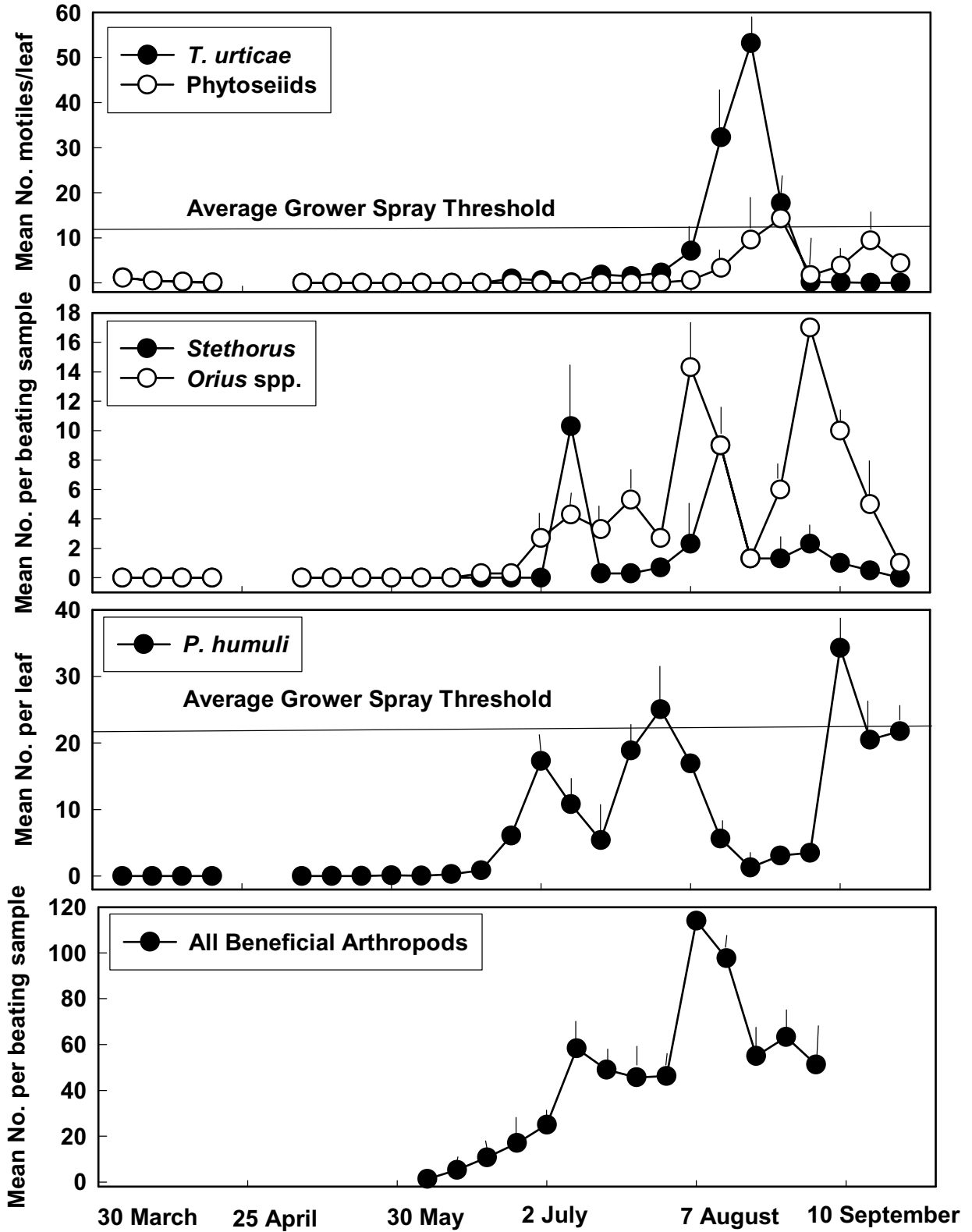


Figure 2. Mean (\pm SE) abundance and phenology of pest (*Tetranychus urticae* Koch, *Phorodon humuli* Schrank) and beneficial (*Stethorus punctum picipes* Casey, *Orius* spp.) arthropods in an unsprayed hop yard at WSU-Prosser in 2001.

The challenge for the future is to integrate community-based biological control of mites and aphids with current chemical controls used in commercial hop production. A program has been established at WSU-Prosser that will determine the compatibility of all pesticides currently used on hops with key biological control agents. Toxicity profiles for most hop insecticides have been developed for Washington strains of *G. occidentalis*, *N. fallacis*, *S. picipes*, and *H. axyridis* (James and Coyle, 2001). Currently used materials like abamectin and imidacloprid must be replaced by 'softer' alternatives for conservation biological control to work. Fortunately, there are alternatives available and the progressive introduction of these to Washington hop production will enhance the prospects of successfully using biological control as an integral part of hop pest management.

REFERENCES

- Campbell, C. A. M. 1985. Hops (*Humulus lupulus*), pp. 192-194. In Hussey, N. W. and N. Scopes (eds.). *Biological Pest Control: The Glasshouse Experience*. Cornell University Press, Ithaca, New York.
- Campbell, C. A. M. and W. W. Cone. 1994. Influence of predators on population development of *Phorodon humuli* (Homoptera: Aphididae) on hops. *Environmental Entomology* 23: 1391-1396.
- Campbell, C. A. M. and R. Lilley. 1999. The effects of timing and rates of release of *Phytoseiulus persimilis* against two-spotted spider mite *Tetranychus urticae* on dwarf hops. *Biocontrol Science and Technology* 9: 453-465.
- Cranham, J. E. 1985. Hops, pp. 367-370. In Helle, W. and M. W. Sabelis (eds.). *Spider Mites: Their Biology, Natural Enemies and Control*, Vol. 1B. Elsevier, New York.
- Ehler, L. E. 1992. Guild analysis in biological control. *Environmental Entomology* 21: 26-40.
- Helle, W. and M. W. Sabelis. 1985. *Spider Mites: Their Biology, Natural Enemies and Control*, Vol. 1B. Elsevier, New York.
- James, D. G. and T. C. Price. 2000. Abamectin resistance in mites on hops. *Agrichemical and Environmental News* 170: 4-5. (<http://aenews.wsu.edu>)
- James, D. G. and J. Coyle. 2001. Which pesticides are safe to beneficial insects and mites? *Agrichemical and Environmental News* 178: 12-14. (<http://aenews.wsu.edu>)
- Murdoch, W. W., J. Chesson, and P. L. Chesson. 1985. Biological control in theory and practice. *American Naturalist* 125: 344-366.
- Pruszyński, S. and W. W. Cone. 1972. Relationships between *Phytoseiulus persimilis* and other enemies of the twospotted spider mite on hops. *Environmental Entomology* 1: 431-433.
- Riechert, S. E. and Lawrence, K. 1997. Test for predation effects of single versus multiple species of generalist predators: spiders and their insect prey. *Entomologia Experimentalis et Applicata* 84: 147-155.
- Strong, W. B. and B. A. Croft. 1993. Phytoseiid mites associated with spider mites on hops in the Willamette Valley, Oregon. *Journal of the Entomological Society of British Columbia* 90: 45-52.
- Strong, W. B. and B. A. Croft. 1995. Inoculative release of phytoseiid mites (Acarina: Phytoseiidae) into the rapidly expanding canopy of hop for control of *Tetranychus urticae* (Acarina: Tetranychidae). *Environmental Entomology* 24: 446-453.
- Strong, W. B. and B. A. Croft. 1996. Release strategies and cultural modifications for biological control of twospotted spider mite by *Neoseiulus fallacis* (Acarina: Tetranychidae, Phytoseiidae) on hops. *Environmental Entomology* 25: 529-535.