Experimental and Applied Acarology **23:** 995–1009, 1999.

Assessment of *Amblyseius fallacis* (Acari: Phytoseiidae) for biological control of tetranychid mites in an Ontario peach orchard*

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(Received 9 March 1999; accepted 4 October 1999)

Abstract. We introduced a mass-reared pyrethroid-resistant strain of the predatory phytoseiid mite *Amblyseius fallacis* (Garman) into an Ontario peach orchard in an attempt to control populations of the phytophagous mites *Panonychus ulmi* Koch and *Tetranychus urticae* Koch (Acari: Tetranychidae). Releases of 1,000 and 2,000 mites per tree were made, at three different times. The release of 2,000 mites per tree in June and in July resulted in significantly higher phytoseiid densities than was observed on control trees. However, densities of *P. ulmi* or *T. urticae* were not significantly affected by any release rate or by timing. The release of 1,000 *A. fallacis* per tree, or of any density in August, did not significantly increase phytoseiid abundance. In the following year, population dynamics of both phytoseiid and phytophagous mites were not significantly affected by the previous year's release. *Amblyseius fallacis* can be a useful predator in some fruit orchards. However, further research is necessary into the timing and rate of release, modified spray programmes, and with different crops, in order to clarify the role of this species for biological control in Ontario peach orchards.

Key words: release, establishment, *Amblyseius fallacis*, biological control, *Panonychus ulmi*

Introduction

Predatory mites of the family Phytoseiidae are critical to the biological control of the phytophagous mites *Panonychus ulmi* Koch and *Tetranychus urticae* Koch (Acari: Tetranychidae) in orchards worldwide, including peach orchards of the Niagara Peninsula, Ontario (Putman and Herne, 1966). The use of chemical sprays, however, can severely disturb the predator–prey relationships providing biological control.

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One such group of chemicals are the pyrethroids, which reduce or temporarily eliminate phytoseiid mites from sprayed orchards, often provoking outbreaks of tetranychid mites (e.g. Hull *et al*., 1983; Hardman *et al*., 1988; Li and Harmsen, 1992). The recent development of highly organophosphate-resistant Oriental fruit moth, *Grapholitha molesta* Busck (Lepidoptera: Tortricidae), has led to the recommended and substantial use of pyrethroids in Ontario peach orchards.

The discovery of populations of phytoseiid mites with resistance to organophosphate (Hoyt, 1969; Croft and Barnes, 1971) and pyrethroid (Avella *et al*., 1985; Hoy and Ouyang, 1989; Markwick *et al*., 1990) insecticides has led to their introduction into commercial orchards in some countries, usually on cut foliage as mass-reared individuals. *Amblyseius fallacis* (Garman) is a common predator of tetranychid mites in unsprayed Ontario apple and peach orchards (Putman, 1962; Thistlewood, 1991), and several other crops in North America (Croft and Nelson, 1972). Thistlewood *et al.* (1995) discovered and further selected an *A. fallacis* strain with resistance to the pyrethroid permethrin. They found this *A. fallacis* strain to be cross-resistant to several pyrethroids including cypermethrin and deltamethrin, which are the pyrethroids most used in Ontario orchards (Anon., 1996). The availability of this strain, commercially mass-reared since 1993 for experimental application in the control of tetranychid mites on a variety of crops, offered us an opportunity to examine its potential in peach orchards.

We evaluated the potential of pyrethroid resistant *A. fallacis* for biological control of tetranychid mites in peach orchards using the criteria of Hoy (1982). These criteria include the ability of the predator to establish soon after release, survive the spray regime, affect biological control of the target pests, disperse to pest sub-populations, over-winter, and to achieve biological control in the following year. Other factors important in the effectiveness of releases of biological control agents include the number and the timing of release (Beirne, 1975). Our aim was to manipulate the timing and release number of *A. fallacis* in order to determine whether its release would hold any promise for control of high numbers of the tetranychid mites *P. ulmi* and *T. urticae*, in peach orchards under pyrethroid programmes.

Methods and materials

Releases of *A. fallacis* were made in 1995 into the foliage of mature peach cv. ‘Loring’ trees, spaced 4.3 m by 6.1 m, in an experimental orchard in Jordan, Ontario. Single trees (three replicates per block) were selected using random numbers and assigned to three release rates (0; 1,000 or 2,000 *A. fallacis*) within a design employing three blocks along the prevailing wind direction, for a total of 27 trees. At least two guard trees separated treatment trees within rows. To examine the effects of release date the treatments were repeated three times: on June 16, July 12 and August 9–17, and the control trees were pooled, providing a total of seven treatments.

Mite sampling and release

To determine both predatory and phytophagous mite densities and any effects of the releases, 50 leaves per tree were selected at random from the entire foliage, at approximately two-week intervals from mid June until late September of 1995 and 1996. Mites were brushed from the leaves onto a glass plate using a Henderson-McBurnie mite-brushing machine (Henderson and McBurnie, 1943), and the entire plate examined using a binocular microscope. Eggs and motile stages were counted and analysed separately. Phytoseiid mites were mounted on slides in Hoyer's medium, cleared for one week on a slide-warmer at approximately 45 °C, and identified.

Pyrethroid resistant *A. fallacis* (Applied Bio-Nomics Ltd., Sidney, British Columbia) were mass-produced on *T. urticae* on kidney bean plants, *Phaseolus vulgaris* L. Bean leaves were picked with both *A. fallacis* and *T. urticae* present, placed in plastic containers and shipped to Ontario inside polystyrene boxes together with frozen ice packs to keep the contents cool. On arrival (usually within 36 h of being picked), at least five individual leaves were taken at random from each container and the number of predators estimated by counting under a binocular microscope. Leaves were then allocated to release treatments according to the number of predators required per treatment.

To release mites in the orchard, peach leaves on limbs were wrapped around the bean leaves, and a 'twist-tie' used to gently secure them into place. 'Twist-ties' were a metal wire strand with an outer plastic coating. Two to three bean leaves were attached to a branch at any one time, with the bean leaves evenly spaced around each peach tree.

Statistical analysis was undertaken separately for each year, and in each year mobile and egg stages of each taxon were analysed separately. Two-factor repeated measures ANOVA were used, after a square-root transformation to normalize the data. The independent variables were release date (June, July or August) and release number (0, 1000 or 2,000 *A. fallacis* per tree). Tukey tests ($p < 0.05$) were used to separate means. The residuals from each ANOVA were examined for normality and homogeneity of variance. The distribution of the dependent variable was examined for fit to a normal distribution using Chi-square and Kolmogorov-Smirnov tests. All results are given as mean of the three replicates ± standard error per leaf.

Spray programmes

Deltamethrin was sprayed in the Jordan research farm on seven occasions in 1995, and four occasions in 1996 (Table 1), as part of an assessment of a pyrethroid-based programme of insect control. Throughout the summer, the orchard received the fungicides captan, ferbam, or iprodione.

Table 1. Spray records from the release trials

Pesticide	Rate (g A.I. ha^{-1} or L ha^{-1})	Date	Target
1995			
Mineral oil	60 l	1 May	*P. ulmi*
Deltamethrin	10 g	24 May, 1 June, 6 and 17 July, 3 and 15 August, and 25 September	*Grapholitha molesta* (Busck)
Iprodione	750 g	9 August	Fungicide
Captan	3000 g	9 September	Fungicide
1996			
Deltamethrin	10 g	31 May, 22 July, 2 and 3 August	*G. molesta*
Ferbam	5130 g	18 April and 30 November	Fungicide
Iprodione	750 g	3 August	Fungicide

Results

Releases in 1995

Two weeks after the June 16 release, the density of mobile stages of *A. fallacis* on release trees was higher (1,000 mite treatment = 0.08 ± 0.03; 2,000 mite treatment = 0.06 ± 0.03) than for the control trees (0.00 ± 0.00) (Figure 1). It remained higher on release trees than on control trees for each subsequent sample, except the last, on September 26. The highest density of *A. fallacis* mobiles was observed in that sample at 0.29 ± 0.11, 0.30 ± 0.11, and 0.45 ± 0.17 leaf^{-1}, for control, 1,000 and 2,000 release treatments respectively (Figure 1). Phytoseiid egg density following the June release showed similar trends to the mobile stages, except that in the control treatment, phytoseiid eggs were observed only in the last two samples. Comparatively high densities were observed in the release treatments earlier in the season, and egg densities peaked at 0.07 ± 0.02, 0.13 ± 0.07 and 0.23 ± 0.18 leaf^{-1}, for control, 1,000 and 2,000 release treatments respectively (Figure 2).

Following the mid-July release, the number of phytoseiid mobiles on release trees increased after two weeks to densities above those observed on control trees. Their peak density was observed in the last sample of the season at 0.37 ± 0.02, 0.41 ± 0.16, 0.45 ± 0.15 leaf^{-1}, for control, 1,000 and 2,000 release treatments respectively (Figure 1). The peak density of phytoseiid eggs was observed in the 1,000 release treatment at 0.19 ± 0.06 leaf^{-1}, on 29 August. Phytoseiid eggs were only observed in the control treatment of the July 12 release in the last two samples (Figure 2).

By contrast, after the August 17 release, no obvious differences were observed in the density of phytoseiid mobiles or eggs between any treatment. The highest density of phytoseiid eggs was observed in the control treatment in the last sample of the season, at 0.66 ± 0.27 leaf^{-1} (Figure 1). At this time, peak densities were observed in release treatments at 0.23 ± 0.06 leaf^{-1} and 0.42 ± 0.13 leaf^{-1}, in 1,000 and 2,000

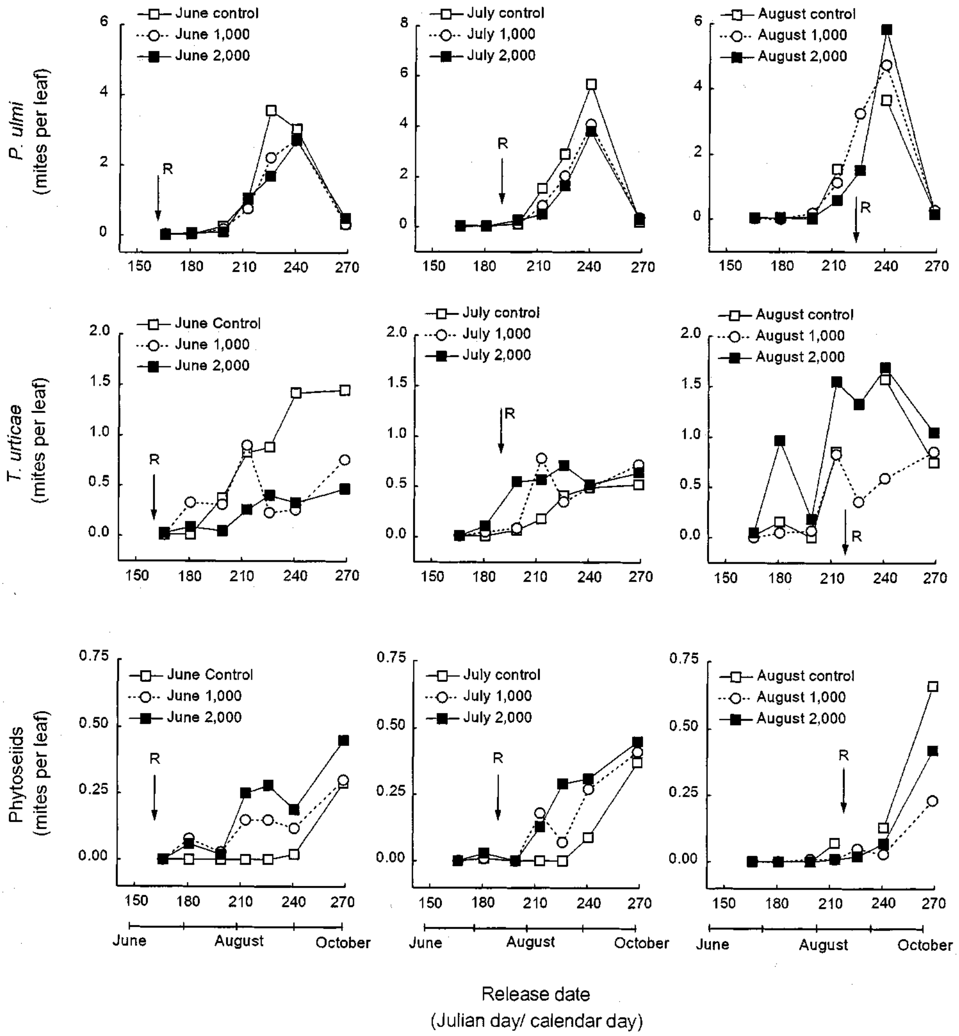

Figure 1. Effects of the June, July or August (1995) *A. fallacis* releases on mobile stages of *P. ulmi*, *T. urticae*, and phytoseiids in the Jordan research farm. Releases of 1,000 or 2,000 per tree indicated by ‘R’ and arrow. Means (± SE) of three samples are shown.

release treatments respectively. Very few phytoseiid eggs were observed in any treatment of the August release (Figure 2).

Significant differences among density of mobile stage of phytoseiids were observed according to the number released and the date of release (Table 2). The mean number of phytoseiids in the 1,000 and 2,000 release treatments was similar at 1.57 leaf^{-1} and 1.84 leaf^{-1} respectively, but significantly higher (Tukey test, $p < 0.05$), than in the controls (0.99 leaf^{-1}). Thus, releasing 2,000 mites rather than

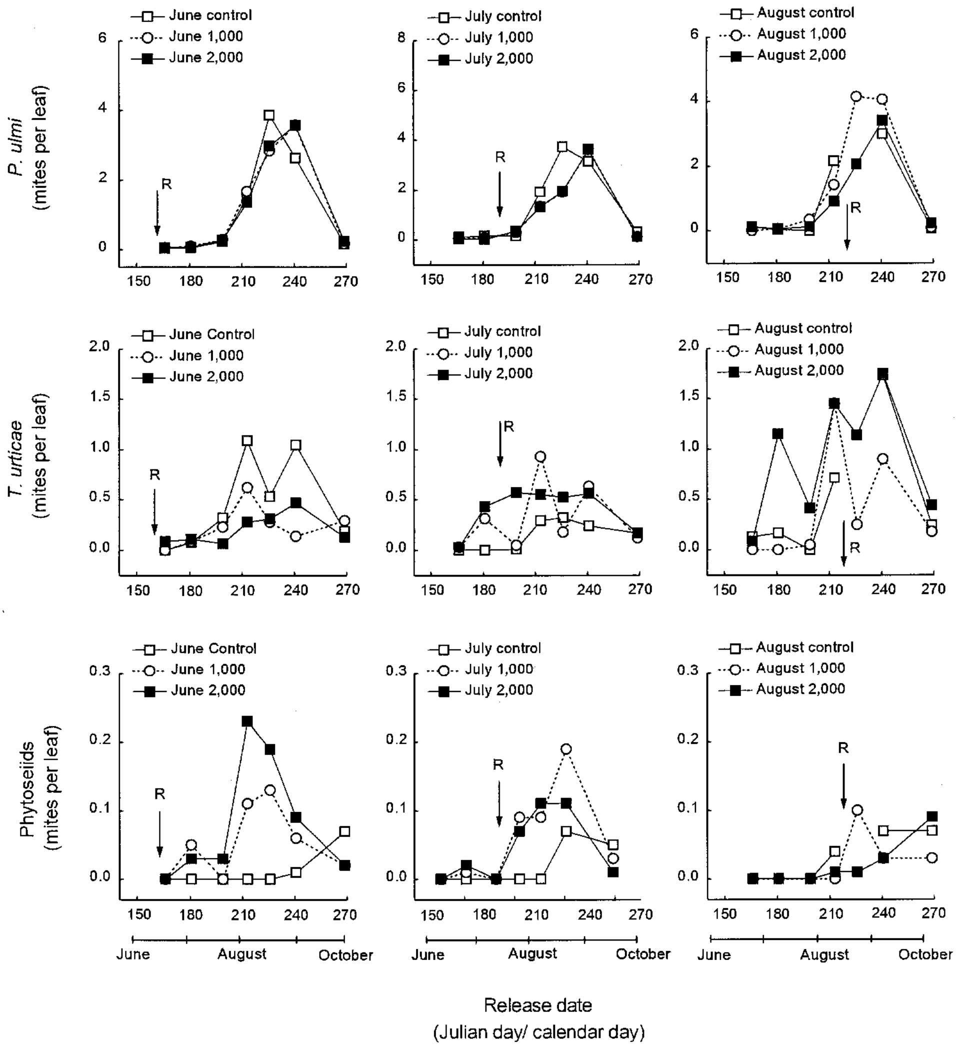

Figure 2. Effects of the June, July or August (1995) *A. fallacis* releases on eggs of *P. ulmi*, *T. urticae*, and phytoseiids in the Jordan research farm. Releases and means as Figure 1.

1,000 did not result in significantly higher densities of phytoseiids. Changing the date of release led to a significantly higher mean density of phytoseiid mobile stages following the June (1.62 leaf^{-1}) and July (1.65 leaf^{-1}) releases than after the August (1.12 leaf^{-1}) release. This result may be due to better establishment or to the phytoseiids having more time to reproduce following the earlier releases than after the August release treatment. For mobile stages of phytoseiids, a significant interaction between the number released × date of release was observed (Table 2).

Table 2. F values from two-way, repeated measures ANOVA on the effects of releases of *A. fallacis* on the phytoseiid and tetranychid mite densities in the Jordan research farm orchard. N: number of *A. fallacis* released (control, 1,000 or 2,000). D: date of *A. fallacis* release (June, July or August). T: the time factor in the repeated measures ANOVA, measured every 2 weeks. No release was made in 1996, but all trees were again sampled to determine the effects of the release in the previous year

Year	Taxa	Stage	N (2, 18)	D (2, 18)	T (6, 108)	N × D (4, 18)	N × T (12, 108)	D × T (12, 108)	N × D × T (24, 108)
1995	Phytoseiids	Eggs	3.32	1.78	20.30***	1.69	4.00***	2.26**	1.21
		Mobiles	7.60**	3.61*	58.52***	4.62**	2.77**	2.14*	0.85
	P. ulmi	Eggs	0.32	1.0	104.42***	1.1	0.89	1.03	0.79
		Mobiles	0.32	0.29	140.12***	1.19	0.8	1.78	1.09
	T. urticae	Eggs	1.83	2.2	16.07***	1.85	0.85	0.71	1.06
		Mobiles	0.98	1.49	24.06***	2.31	1.75	0.59	0.92
	A. schlechtendali	Mobiles	0.6	0.13	22.9***	1.34	1.15	1.4	0.99
1996	Phytoseiids	Eggs	0.86	0.23	10.72***	0.76	0.62	0.24	0.78
		Mobiles	1.27	0.03	37.31***	1.22	0.74	0.49	1.4
	P. ulmi	Eggs	0.91	0.55	41.23***	0.43	0.6	0.68	0.39
		Mobiles	2.15	0.92	27.37***	2.12	0.63	1.3	1.98
	T. urticae	Eggs	1.03	0.19	11.51***	0.72	1.13	0.61	0.79
		Mobiles	0.01	0.04	24.00***	0.19	0.1	0.21	0.7
	A. schlechtendali	Mobiles	2.52	3.6	55.01	0.76	2.12	0.69	0.89

Significance of *F* statistics: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Values in brackets are the degrees of freedom from the ANOVA (effect, error).

Analysis of means via Tukey tests indicated this result was due to only three release-date and release-number treatments (1,000 in June, 2,000 in June, 2,000 in July) having a significantly higher mean density of mites than the control treatment of June.

By contrast, for phytoseiid eggs, different release dates caused no significant effects (Table 2). A non-significant ($p = 0.059$) trend was observed for higher numbers of phytoseiid eggs in the two release treatments relative to the control.

The significant interaction between number released × time for both phytoseiid stages (eggs, mobiles) indicated that the effects of the number of phytoseiids released were different at different sampling dates (Table 2). For example, during sample dates 4–6, similar numbers of eggs were observed in 1,000 and 2,000 release treatments, but these densities were significantly higher (Tukey tests, $p < 0.05$) than those in the control treatment. In contrast, in weeks 1–2, no significant differences were observed between any treatment. A significant interaction between release date × time which was present for both phytoseiid eggs and mobiles, was likely due to the higher abundance of these taxa early in the season in the June release but not in the August release treatment.

The population dynamics of *P. ulmi* mobiles and eggs in 1995 were low and similar, irrespective of the release treatment. In the June releases, the highest density of *P. ulmi* was in the control treatment at 3.56 ± 1.27 leaf^{-1}, compared to 2.75 ± 0.85 and 2.71 ± 0.64 leaf^{-1} in the 1,000 and 2,000 release treatments, respectively (Figure 1). The density of *P. ulmi* eggs was similar to the mobiles (Figure 2). For the July releases, the highest density of *P. ulmi* mobiles and eggs was observed in the control treatment, but was only slightly higher than the release treatments. After the August release, the peak density of mobile *P. ulmi* was observed in the 2,000 treatment at 5.83 ± 0.50 leaf^{-1} (Figure 1), while the highest density of eggs was observed in the 4.45 ± 2.21 leaf^{-1} (Figure 2).

Low densities of the two-spotted spider mite, *T. urticae* were also observed in 1995. No significant or clear effects of the *A. fallacis* releases were observed on *T. urticae* densities, which were generally less than 2 mobile or egg stages per leaf (Figures 1 and 2).

To conclude, neither factor of release date nor predator number produced significant effects on densities of either life stage (egg or mobile) of the phytophagous mites counted (Table 2). A significant sample date effect was observed for all taxa, but no significant interactions between release treatment and sample date was observed other than those discussed above for phytoseiid mites.

Mite densities in 1996

Low densities of phytoseiids were observed throughout the 1996 growing season, and no significant differences were observed between any treatments. In all treatments, the highest density of phytoseiid mobiles and eggs was observed in the last sample of the season on 16 September (Figures 3 and 4). Prior to that date, densities in all but one sample were less than 0.05 mobile mites per leaf (Figure 3); the exception being the control treatment of the August 1995 release which had 0.21 ± 0.13 leaf^{-1}. Similarly, the density of phytoseiid eggs was less than 0.02 leaf^{-1} for all samples except in two samples at the end of the season (Figure 3). Unfortunately, trees in the 1995 release treatments of the July and August controls became heavily infected with a foliar pathogen in 1996, and the last sample of the season in these trees could not be taken. In 1996, the phytoseiid species we observed on the peach trees primarily included *A. fallacis* and *Typhlodromus caudiglans* (Schuster). A single *Amblyseius andersoni* (Chant) was the only other species observed. Of these, *A. fallacis* made up between 27% and 70% (Table 3). Unfortunately, phytoseiids were not mounted for identification in 1995.

The dynamics of phytophagous mites in 1996 were very similar between release treatments, but attained higher densities than in 1995. The highest density of *P. ulmi* was again observed in the August release trees of 1995, at 17.64 ± 11.46 leaf^{-1}. The peak densities in the other treatments were also much higher than in 1995, ranging between 7.33 and 15.71 leaf^{-1} (Figure 3). The density of *P. ulmi* throughout 1996 also did not show distinct effects of the 1995 release. Ironically, the highest density of *P. ulmi* eggs in the June (1995) treatments was observed in the release trees (Figure 4).

The densities of *T. urticae* in 1996 were also much higher than in 1995. The highest density of mobile stages in each treatment were observed later in the season and ranged between 1.64 and 13.79 leaf^{-1} (Figure 3). The peak density of *T. urticae* eggs was much lower, at between 0.34 and 1.07 leaf^{-1} (Figure 4). Similarly to *P. ulmi* populations, no clear differences were observed in 1996 between the release treatments of 1995.

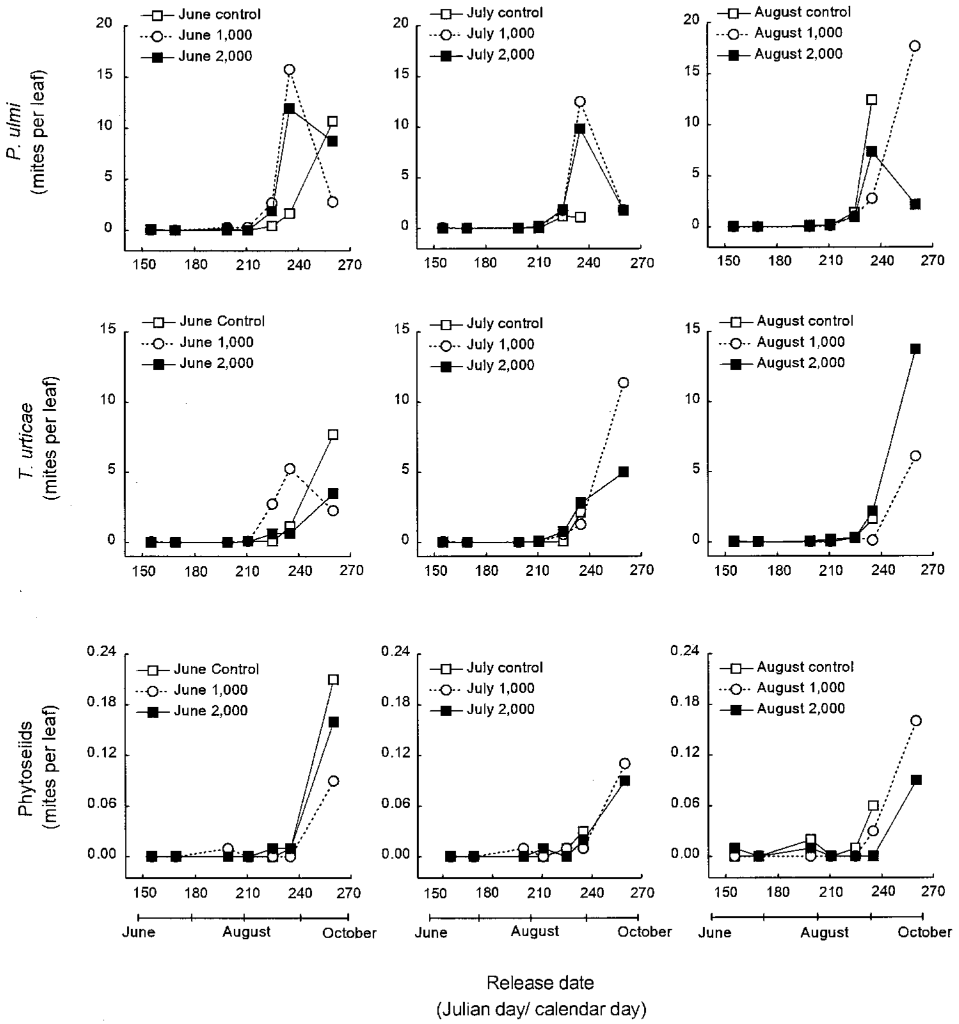

Figure 3. Effects of the 1995 *A. fallacis* releases on the 1996 population dynamics of mobile stages of *P. ulmi*, *T. urticae,* and phytoseiids in the Jordan research farm. Means as Figure 1.

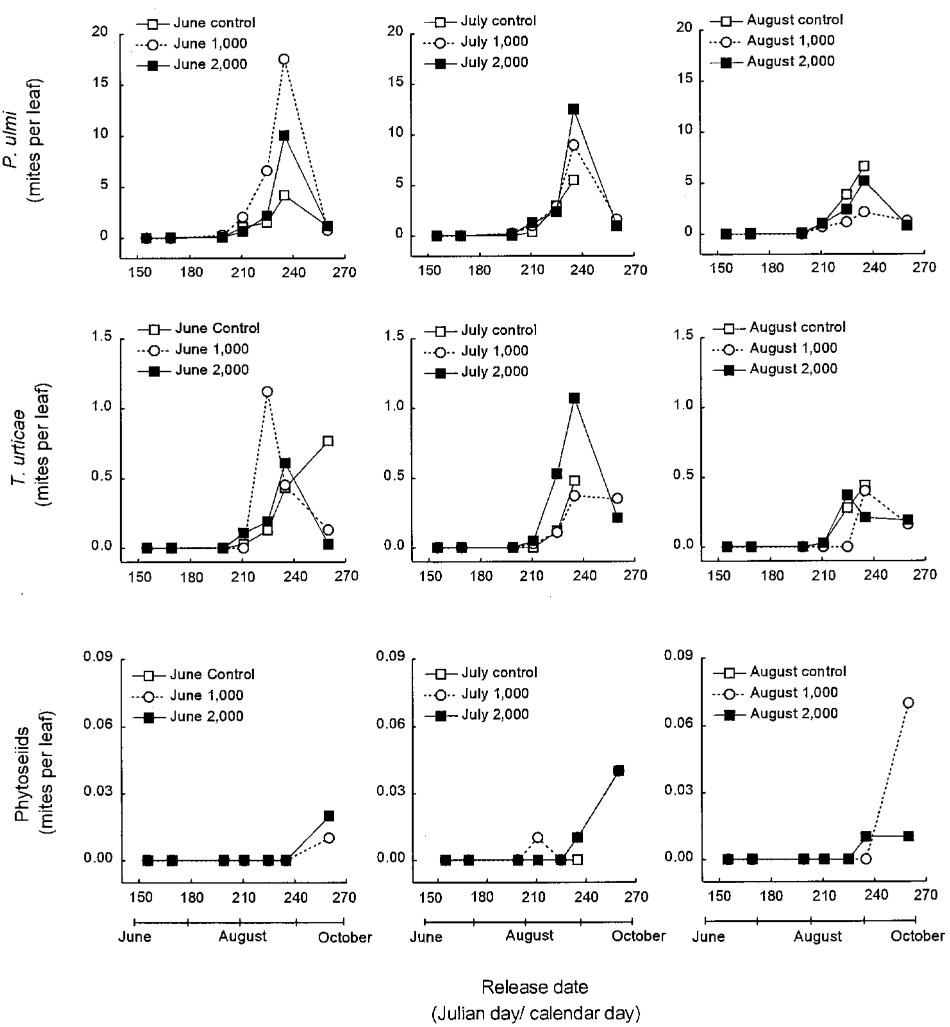

Figure 4. Effects of the 1995 *A. fallacis* releases on the 1996 population dynamics of eggs of *P. ulmi*, *T. urticae*, and phytoseiids in the Jordan research farm. Means as Figure 1.

Statistical analysis showed no differences between the release date or number treatments for any life stage of any taxon in 1996, no significant sampling date effect for most taxa, and no significant interaction terms (Table 2).

Discussion

Hoy (1982) defined the criteria for a successful predator release as the ability of the predator to establish soon after release, survive the spray regime, effect biological

Table 3. Mean number of *A. fallacis* and mean total number of phytoseiids per treatment, and percentage of *A. fallacis* from predators mounted on slides from the September 16, 1996 collection. SE, standard error

Treatment, number released	*A. fallacis* mean ± SE	Mean total phytoseiids ± SE	Percentage of *A. fallacis* (total)
June 0 (control)	2.00 ± 1.87	5.00 ± 3.67	40% (15)
June 1,000	1.00 ± 0.71	3.33 ± 0.82	30% (10)
June 2,000	1.33 ± 0.41	4.33 ± 0.82	31% (13)
July 1,000	1.00 ± 0.00	3.67 ± 1.78	27% (11)
July 2,000	1.00 ± 0.71	3.67 ± 1.08	27% (11)
August 1,000	7.00 −	15.00 −	47% (15)
August 2,000	3.50 ± 2.50	5.00 ± 3.00	70% (10)

control of the target pests, disperse to pest sub-populations, over-winter, and to achieve biological control in the following year. The first of these was met following the release of *A. fallacis* in the peach orchard. Significantly higher densities of phytoseiid predators were observed after release in June and July of 1995. For the June sample, *A. fallacis* populations in this treatment increased to 0.13 ± 0.11 leaf^{-1} (combined egg and mobile stages), and in July to 0.27 ± 0.22 leaf^{-1}, within two weeks after the release of predators. Control trees at this time had 0 predators per leaf. This result indicates that there is some potential for released *A. fallacis* to establish in trees relatively quickly. The released mites also appeared to survive the spray regime applied to this orchard. Releases later in the season in August, however, resulted in no significant increase in phytoseiids above control populations. Although some released mites may have established, the population dynamics of mites on release trees treatments at this time were similar to those on non-release trees. From these results, it appears that if *A. fallacis* were to be employed in Ontario peach orchards, they should be released in June or July. Inoculations of 1,000 or 2,000 *A. fallacis* resulted in similar densities on trees, and it is possible that release of fewer may also result in establishment. Establishment of phytoseiid predators within four weeks of release has been observed with releases of 256 (Croft and McMurty, 1972), 300 (Penman and Chapman, 1980) and 1,000 predators per tree (Hoy *et al.*, 1983).

Nevertheless, the increased *A. fallacis* population in 1995 did not have significant effects on either *P. ulmi* or *T. urticae*. The population dynamics of *P. ulmi* on release trees closely followed those observed on the control trees, and biological control of *P. ulmi* by *A. fallacis* was unlikely to have occurred in this orchard because of the low predator:prey ratio. Croft (1990) created a decision-making index for *P. ulmi* control by *A. fallacis* in apple orchards. This index includes predictions on the likelihood of biological control and thresholds for grower action, and may be extrapolated to peach orchards for the present discussion. The peak *P. ulmi* density observed in the 1995 release was just over the threshold of seven mites per leaf, and with the density of *A. fallacis* at that time, the Croft (1990) index predicted a probability of biological control equal or less than 10%. Although devised for apple orchards rather than for peach, these ratios give further evidence that biological control of *P. ulmi* by *A. fallacis* is unlikely to have occurred in this orchard during 1995.

Another criterion for a successful release is over-wintering and survival of the predator in the years subsequent to release (Hoy, 1982). In 1996, the average density of *A. fallacis* was 0.019 mites leaf^{-1} and no significant differences were observed between treatments. We are unsure if this population of *A. fallacis* spread from the 1995 releases or originated from naturally occurring populations of *A. fallacis*, because some of these phytoseiid populations were observed in the control trees in 1995. Although not identified, they may have been *A. fallacis*. The single tree plot design of this study was somewhat flawed because of the high dispersal rates of *A. fallacis*, resulting in high levels of tree to tree movement (Johnson and Croft, 1976, 1981), but native strains were unexpected owing to the intensive pyrethroid programme (Thistlewood *et al.*, 1995). Toxicological or molecular methods would be needed to determine the origin of the 1996 mites. Using these methods, Thistlewood and Navajas (1996; unpub. results) showed that this mass-reared strain of *A. fallacis* can over-winter in an intensively pyrethroid-sprayed apple orchard after release and maintain pyrethroid resistance even in the presence of a susceptible native *A. fallacis* strain. Other studies have found over-wintering *A. fallacis* on Ontario peach trees and in orchards (Putman, 1959).

In the following summer of 1996, the phytophagous mite densities in the Jordan research farm were much higher than in 1995. The peak *P. ulmi* density for the entire orchard was 16.4 leaf^{-1}, well above the action threshold defined by Croft (1990). With the observed predator and prey ratios the probability of biological control was predicted to be ‘very low’ (Croft, 1990). Subsequent to the peak density of *P. ulmi*, *A. fallacis* increased to reach its peak density in the last sample. No statistical differences were observed between any of the 1995 release size or date treatments in 1996, for any mite taxa or life stage. As in 1995, *A. fallacis* dispersion from release to control trees may have contributed to this result.

Thus, only in 1995 did the release of *A. fallacis* appear to boost phytoseiid numbers early in the season. The year after release, they appeared to arrive on the trees far too late in the season to be of use for biological control. This result has been observed with other multi-year studies of *A. fallacis* releases in New Zealand, Australia and in Quebec, Canada (Thomas and Chapman, 1978; Williams, 1978; Penman and Chapman, 1980; Bostanian and Coulombe, 1986). This result may, in part, be due to *A. fallacis* over-wintering primarily near or in the ground cover around the trees, then migrating up into the trees canopy consuming prey lower down (Putman, 1959; Croft and McGroarty, 1977). Such an effect has also been observed in Ontario, where significant densities of *A. fallacis* have only been noted in peach orchards later in the summer (Putman and Herne, 1966; Lester *et al.*, 1999a). Other phytoseiid species which over-winter on the peach trees in Ontario, such as *T. caudiglans* (Putman, 1959), may be present on the leaves earlier in the season and thus more suited for biological control of *P. ulmi*. Due to this late arrival on trees from over-wintering populations, *A. fallacis* may be of some use for biological control in peach orchards, but if so would appear to be primarily of use for inundative release and biological control in the same season as release.

Lester *et al.* (1999b) reported high levels of cypermethrin repellency against susceptible and resistant strains of *A. fallacis* in laboratory experiments, which significantly reduced the functional response of the predator when preying on *T. urticae*. However, in the 1995 release, significant densities of *A. fallacis* were observed on release trees, which may indicate that this pyrethroid resistant strain of *A. fallacis* can withstand pyrethroid applications. Other chemicals applied in orchards, including fungicides, can act to repel or kill *A. fallacis* (Hislop *et al.*, 1981; Bostanian *et al.*, 1985, 1998). Such spray regimes may also contribute to *A. fallacis* arriving on the trees too late in the season in 1996 to be of use for biological control (Croft and McGroarty, 1973; Bostanian and Coulombe, 1986). Climatic factors such as low humidity may also reduce the ability of *A. fallacis* to establish, survive and effect biological control (Boyn and Hain, 1983; Berry *et al*., 1991).

In terms of the criteria of Hoy (1982), the release of *A. fallacis* in these peach orchards cannot be considered a success. In this study, although significant increases in phytoseiid abundance were observed after some release treatments, biological control as a direct result of an *A. fallacis* release was not observed. Several other studies with *A. fallacis* have also shown problems with *A. fallacis* releases, and releases of this strain in Ontario apple orchards from 1994 to 1997 have failed to result in the establishment of significant numbers of this predator in either pyrethroid sprayed or unsprayed apple orchards (Lester *et al*., 1999b; Villanueva, 1997; HMAT, unpub. data). Elsewhere, *A. fallacis* has failed to establish in orchards (Seymour, 1982a,b), or when established has failed to give biological control of *P. ulmi* or *T. urticae* (Bostanian and Coulombe, 1986; Prokopy and Christie, 1992). Yet these results clearly conflict with the overwhelming evidence from earlier studies of Croft and others (reviewed in Croft, 1990) which show that *A. fallacis* can control both *P. ulmi* and *T. urticae* in the orchard ecosystem. Further studies are necessary to ascertain what happens to the predators after release, and why biological control may not occur.

Acknowledgements

We thank Barry Kemp for assistance in orchard maintenance and Don Elliot and Applied Bio-Nomics Ltd., Sidney B.C., Canada, who donated predators. Two anonymous referees made significant improvements to a draft of the manuscript. This research was partially funded by OMAFRA, Food Systems 2002, the National Agricultural Biotechnology Initiative, and the Ontario Apple Marketing Commission.

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