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Moving Predatory Mites Into Apple Orchards For Biological Control

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Summary: Field trials were conducted to test whether two species of predatory mites could be successfully transferred into commercial apple orchards for biological control of European red mite. One experiment tested the transfer of *Typhlodromus pyri* at late bloom using burlap-lined paper bands that had been wrapped around trunks in the source orchard. Another experiment tested the transfer of *Zetzellia mali* in mid-summer using terminal shoots cut from the source orchard. Both experiments were conducted in separate blocks at each of 3 commercial orchards. The mite populations were evaluated at 3-week intervals. Transfer of *T. pyri* was successful at all three sites. Transfer of *Z. mali* was successful at all three sites although at very low density. Another field trial tested the pesticide tolerance of *Z. mali*. *Z. mali* was unaffected by bifenazate (Acramite) and indoxacarb (Avaunt) but was suppressed by Danitol and Agri-Mek.

Background: Two species of predatory mites have been under study in a research orchard at Columbus for the past few years. Either species can provide biological control of European red mite as long as certain pesticides are not used. One species is a slow-moving yellow mite, *Zetzellia mali* (family Stigmatidae), that is found naturally in Ohio; the other species is a fast-moving white mite, *Typhlodromus pyri* (family Phytoseiidae), that is not known to occur naturally in Ohio. Both species have the attribute that they are present earlier in the season than Ohio's most common local predator, the phytoseiid *Neoseiulus fallacis*. Specific orchard pesticides that *Z. mali* can or cannot tolerate have been recently documented. *Z. mali* does not tolerate endosulfan (Thiodan) or pyridaben (Pyramite). Of particular interst is the finding that *Z. mali* tolerates pyrethroids at low rates, which is in contrast to the well known susceptibility of phytoseiid mites to pyrethroids. The *T. pyri* population used in this project was brought to Ohio from western New York in 1999 and is a strain that has some pyrethroid tolerance. Work is now needed on whether these mites can be distributed to commercial orchards where biological control is desired but is not occurring naturally. A trial move of *Z. mali* into one commercial orchard in 2001 was somewhat successful, with mid-summer transfer of terminal shoots more effective than trunk band transfer at bloom. The project done in 2002 was designed to document transfers of both species at multiple locations. Better success was anticipated in 2002 because both species were available, trunk bands were placed in the source orchard 3 weeks earlier than in the previous year, bands were removed earlier before bouts of warm weather occurred, and the number of bands was greater.

Objectives: 1) To evaluate how well two different species of predatory mites (*Z. mali* and *T. pyri*) become established in commercial orchards for biological control of European red mite. 2) To compare two methods of moving *Z. mali* into an orchard: trunk bands at bloom versus transfer of terminal shoots in mid-summer. 3) To refine the pesticide tolerance guidelines for *Z. mali* by conducting a field trial to compare a standard organophosphate program with an organophosphate plus early pyrethroid program, as well as to evaluate the tolerance to new pesticides bifenazate (Acramite) and indoxacarb (Avaunt).

Methods: The experiment on *T. pyri* transfer used a randomized complete block design with four or five replicates of two treatments: trees seeded with *T. pyri* in bands at bloom, and trees not seeded. There was one tree per treatment replicate. Plots were as widely spaced as possible within each orchard block.

The source orchard for *T. pyri* was a research block of 8-year old Jonafree and Liberty apple trees at OSU's Waterman Laboratory in Columbus. To collect *T. pyri*, a band was stapled to the trunk of each of 110 trees on 1 October 2001 and removed on 21 January 2002. Harvested bands were rolled up and stored in zip-top plastic bags at 4.5 degrees C. The bands were 4 inches wide and made of an outer layer of paper tree wrap that was lightly glued to an inner layer of burlap. Four bands were randomly chosen from cold storage to determine the number of predatory mites per band; the mean $\pm$ SD was 49 $\pm$ 31 phytoseiid mites per band.

T. pyri was seeded at late bloom to early petal-fall at three commercial orchards. In each seeded tree, six bands were loosely wrapped around the base of scaffold branches and stapled. In Licking County (central Ohio), a 5-year old Suncrisp block was seeded on 3 May in five replicates. In Columbiana County (northeast Ohio), a 14-year old Red Delicious block was seeded on 9 May in four replicates. In Ottawa County (northwest Ohio), a 17-year old Red Delicious block was seeded on 13 May in five replicates. Mite populations on 25 randomly selected leaves per plot were evaluated at 3-week intervals from late June until early September 2002. Pesticide records for the three orchards are listed in Table 1.

The experiment on *Z. mali* transfer used a randomized complete block design with three or five replicates of three treatments: trees seeded with bands at petal-fall, trees seeded with branches in mid-summer, and trees not seeded. The source orchard for *Z. mali* was a research block of 18-year old Red Delicious and Melrose apple trees at OSU's Waterman Laboratory in Columbus.

Trunk bands were stapled on 50 Delicious trees; band construction and dates that bands were set up and removed were identical to those described above for *T. pyri*. Examination of bands in the lab showed that only 3 of 50 bands harbored any stigmaeid mites and these bands had only 1 to 3 stigmaeids per band. The experimental design was thus modified so that the seeding with *Z. mali* with bands was done at just one orchard and with just 3 replicates.

Transfers of terminal shoots were made in late July once density of *Z. mali* built to high levels at the source orchard. Ten Melrose trees were chosen as the *Z. mali* source based on preliminary sampling; there was a mean of 2.1 *Z. mali* per leaf in these trees on 22 July. A species determination in the Melrose trees on 22 July showed that *Z. mali* was the only stigmaeid species present; there was absence of another occasional stigmaeid species, *Agistemus fleschneri*. Terminal shoots 50-75 cm long were cut and held in large plastic bags in coolers for 2 to 20 hours before seeding in the commercial orchards. In each tree seeded with shoots, ten cut terminal shoots were placed on scaffold branches and held by wire twist-ties.

In Licking County, a Fuji block was seeded with *Z. mali* in bands on 17 May in three replicates and with *Z. mali* on shoots on 23 July in three replicates. In Columbiana County, a Red Delicious block was seeded with shoots on 24 July in five replicates. In Ottawa County, a Starkrimson Red Delicious block was seeded with shoots on 25 July in five replicates. Mite populations on 25 randomly selected leaves per plot were evaluated at 3-week intervals from late July until early September 2002. Pesticide records for the three orchards are listed in Table 1.

A field trial on insecticide tolerance of *Z. mali* was conducted at a 18-year old block of Scarlet Spur Delicious apples at OSU's Waterman Laboratory in Columbus. The experimental design was randomized complete block with four replicates of six treatments as detailed in Table 2. Plot size was three adjacent trees. All data were taken from one central tree per plot. Treatment sprays were applied by hand-gun sprayer. All plots including the checks were treated with Esteem 35WP at half-inch green for control of San José scale, which had been a significant problem the previous year. Action thresholds for mite control were 2.5 mites per leaf in early summer, 5 mites per leaf in mid-summer, and 7.5 mites per leaf in late summer. Due to above threshold levels, rescue treatment with Savey was needed in July in some treatments. Mite populations on 25 randomly selected leaves per tree were evaluated every 1 to 3 weeks from late April through late August. Leafhopper leaf damage ratings were taken and fruit were rated at harvest for insect damage, but these data are not included in this report.

All plots including the checks were treated with fungicides applied by an airblast sprayer. Fungicides used were Captan at quarter-inch green (4/11/02); Captan plus Nova at pink (4/17/02) and at bloom (4/24/02); Captan at petalfall (4/30/02); Captan plus Topsin-M at first cover (5/15/02), second cover (5/31/02), and third cover (6/14/02); Captan at fourth cover (6/28/02) and fifth cover (7/12/02); Captan plus Topsin-M at sixth cover (7/24/02) and seventh cover (8/16/02); and Captan at eighth cover (9/9/02).

Leaf samples from all trials were processed with a leaf-brushing machine to determine the number of European red mite motiles and eggs, and phytoseiid and stigmaeid motiles per leaf, as well as a rating of relative density of apple rust mite. Predatory mites were preserved and later mounted on microscope slides to determine species identification.

Data were subjected to analysis of variance and mean comparisons by least significant difference (LSD) tests in the ANOVA procedure of the SAS statistics program.

Results & Discussion: In the experiment on *T. pyri* transfer, phytoseiid mites were detected in seeded plots but not in check plots on the first sampling dates at the CO and LI sites, and in both treatments at the OT site (Table 3). The density of European red mite and phytoseiid mites was not significantly different ($P > 0.05$) in unseeded check trees than in seeded trees at any of the three sites on any of the four sampling dates (Table 3). Mite species identifications showed that *T. pyri* was found in all three orchards only in seeded trees, never in check trees (Table 4). In check plots, *Neoseiulus fallacis* was found at all three sites and an undetermined species was found at two of the three sites. Presence of phytoseiids at all three sites was somewhat surprising because the growers had been doubtful of their presence before this project was initiated.

In the experiment on *Z. mali* transfer, there were differences in the presence or absence of stigmaeids at all three sites (Table 5). There were no stigmaeids detected in unseeded check trees, but some stigmaeids were found at all three sites in plots seeded via shoots and at the one site that had plots seeded via bands. The density of European red mite and stigmaeids did not differ significantly among treatments ($P > 0.05$) at any site on any date (Table 5). Although the density of stigmaeids was extremely low, it indicates that the species achieved initial establishment. Although trunk bands were placed and removed in the source orchard at better times than in the previous year, the results in 2002 were similar to 2001 in that stigmaeids did not inhabit the bands, even in trees that had high density of stigmaeids in late summer. Stigmaeids consistently reach maximum density in mid- to late summer. At present, transfer of shoots in mid-summer is a useable method of transfer that is better than banding.

In the experiment on pesticide tolerance, periodic leaf sampling showed that European red mite reached density above threshold by mid-June in some treatments (Table 6); densities by mid-July were the highest seen in this orchard in several years. *Z. mali* was unaffected by Acramite or Avaunt (Table 7). *Z. mali* was suppressed by Danitol used at pink and petalfall but recovered to moderate levels by late summer. Unlike previous years, *Z. mali* was also suppressed in the standard treatment, probably due to use of Agri-Mek for the first time in several years. Some phytoseiids were also found in this orchard (Table 8) and surprisingly they rebounded to higher density in the Danitol treatment than in the standard treatment; inclusion of Agri-Mek in the standard program could have caused this suppression. Rescue treatment with Savey in mid-July had no negative effect on *Z. mali* (Table 7) but was associated with a sharp drop in phytoseiid density, possibly due to prey depletion (Table 8).

Table 1. Pesticides applied in three apple orchards where predatory mites transfered, 2002.

Stage	County; Date, product, and rate applied		
	Licking	Columbiana	Ottawa
1/2" green	4/10/02 oil 5.4 gal/A chlorpyrifos 1 qt/A Topsin 1 lb/A Dithane 6 lb/A	4/15/02 Pounce 6 oz/A Polyram 6 lb/A	4/15/02 oil 5 gal/A Polyram 6 lb/A Rubigan 8 oz/A
pink	4/16/02 Nova 6 oz/A Dithane 6 lb/A	4/24/02 Polyram 3 lb/A Nova 4 oz/A	4/29/02 Polyram 6 lb/A Rubigan 8 oz/A
bloom	5/1/02 Nova 6 oz/A Dithane 6 lb/A	-	-
petal-fall	5/10/02 Avaunt 5 oz/A Flint 2.5 oz/A	5/8/02 & 5/11/02 Guthion 1.5 lb/A Nova 4 oz/A Polyram 3 lb/A	5/10/02 Guthion 2 lb/A Provado 6 oz/A Nova 5 oz/A Captan 5 lb/A
1st cover	5/20/02 Provado 6 oz/A Imidan 2.2 lb/A Apollo 4 oz/A[S] Flint 2 oz/A	5/23/02 Imidan 2 lb/A Pyramite 4.4 oz/A[S] Agri-Mek 10 oz/A[P] Flint 2 oz/A Polyram 3 lb/A	5/28/02 Imidan 3 lb/A Captan 5 lb/A Flint 2.5 oz/A
thin	5/23/02 Sevin 1 qt/A NAA 10 ppm[P] Accel 100 ppm[S]	5/17/02 Sevin XLR 1 qt/A[P]	5/30/02 Sevin XLR 1 qt/A NAA 10 ppm
2nd cover	5/30/02 Imidan 2.2 lb/A Captan 4.5 lb/A	6/7/02 Asana 6 oz/A[S] (cicada) Imidan 2 lb/A[P] Flint 2 oz/A Polyram 3 lb/A[P]	6/14/02 Imidan 3 lb/A Apollo 4 oz/A Ziram 5 lb/A
3rd cover	6/17/02 Imidan 2.2 lb/A Captan 3 lb/A Ziram 2 lb/A	6/20/02 & 6/21/02 Asana 6 oz/A Captan 2 lb/A Ziram 2 lb/A	7/8/02 Imidan 3 lb/A Ziram 5 lb/A
4th cover	7/8/02 Imidan 2.2 lb/A Captan 3 lb/A Ziram 2 lb/A	6/25/02 Asana 6 oz/A Captan 2 lb/A Ziram 2 lb/A	7/29/02 Imidan 3 lb/A Ziram 5 lb/A
5th cover	8/1/02 Imidan 2.2 lb/A Captan 3 lb/A Ziram 2 lb/A	7/5/02 Imidan 2 lb/A Captan 2 lb/A Ziram 2 lb/A	9/6/02 Imidan 3 lb/A Ziram 5 lb/A
special	-	7/20/02: Acramite 1 lb/A[P]	-
6th cover	8/21/02 Imidan 2.2 lb/A Captan 3 lb/A Ziram 2 lb/A	8/22/02 Imidan 2 lb/A Topsin-M 12 oz/A	-

[P] used in pyri-release block only   [S] used in stigmaeid-release block only

Table 2: Timing and rates of mite and insect treatments on Delicious apples, Columbus, Ohio.

Timing >> *Treatment*	1/2" green (4/11)	Tight cluster (4/15)	Pink (4/18)	Petal-fall (5/1)	1C (5/16)	2C (5/31) 3C (6/14) 4C (6/28) 6C (7/24) 7C (8/16) 8C (9/9)	Extra sprays for mites
Check	Esteem 35WP, 4 oz/A	none	none	none	none	none	none
Standard	Esteem 35WP, 4 oz/A	none	Lorsban 50WP, 2 lb/A	Imidan 70WP, 3 lb/A	Imidan 70WP, 3 lb/A + AgriMek 0.15EC, 10.7 oz/A + SunSpray UF oil, 0.25%	Imidan 70WP 2.1 lb/A	7/16: Savey, 3 oz/A
Danitol	Esteem 35WP, 4 oz/A	oil 1%	Danitol 2.4EC, 10.7 oz/A	Danitol 2.4EC, 16 oz/A	Imidan 70WP, 3 lb/A	Imidan 70WP 2.1 lb/A	7/16: Savey, 3 oz/A
Avaunt	Esteem 35WP, 4 oz/A	oil 1%	Avaunt 30DG, 6 oz/A	Avaunt 30DG, 6 oz/A	Avaunt 30DG, 6 oz/A	Imidan 70WP 2.1 lb/A	7/16: Savey, 3 oz/A
Acramite early	Esteem 35WP, 4 oz/A	none	Lorsban 50WP, 2 lb/A	Imidan 70WP, 3 lb/A + Acramite 50W, 1 lb/A	Imidan 70WP, 3 lb/A	Imidan 70WP 2.1 lb/A	7/3: Acramite 50W, 1 lb/A + LI700 + Latron
Acramite late	Esteem 35WP, 4 oz/A	none	Lorsban 50WP, 2 lb/A	Imidan 70WP, 3 lb/A	Imidan 70WP, 3 lb/A	Imidan 70WP 2.1 lb/A	6/7: Acramite 50W, 1 lb/A at threshold 7/3: Acramite 50W, 1 lb/A + LI700 + Latron + Choice

Table 3. Mite density in experiment on transfer of *T. pyri* via bands at late bloom, 2002.

Site[a]	Date	Mean number per leaf					
		European red mite			Phytoseiid mites		
		Check trees	Seeded trees	*P*[b]	Check trees	Seeded trees	*P*[b]
LI	6/24	0.0	0.0	-	0.00	0.11	*0.11*
	7/23	1.8	0.4	*0.16*	0.13	0.16	*0.69*
	8/13	6.0	2.7	*0.18*	0.96	1.04	*0.79*
	9/4	0.1	0.1	*0.88*	0.72	0.44	*0.10*
CO	7/8	3.7	3.1	*0.50*	0.00	0.10	*0.28*
	7/24	15.9	7.5	*0.30*	0.76	0.55	*0.70*
	8/14	0.0	1.5	*0.32*	0.26	0.26	*1.0*
	9/10	0.02	0.3	*0.10*	0.16	0.14	*0.82*
OT	7/2	1.8	3.2	*0.50*	0.10	0.11	*0.75*
	7/25	5.6	8.0	*0.53*	0.11	0.08	*0.18*
	8/15	6.8	8.6	*0.58*	0.45	0.26	*0.31*
	9/9	2.9	0.5	*0.09*	0.24	0.35	*0.21*

[a] Sites: LI = Licking County; CO = Columbiana County; OT = Ottawa County.
[b] P = probability value for statistical test of ANOVA treatment effect.

Table 4. Species identification of phytoseiid mites found in random leaf samples in orchards seeded with *T. pyri* by bands in May 2002.

Site[a]	Date (2002)	Treatment	Number of specimens identified (% of total)[b]		
			T. pyri	*N. fallacis*	Undetermined species
LI	6/24	check	0	0	0
		seeded	5 (83%)	1 (17%)	0
	7/23	check	0	4 (50%)	4 (50%)
		seeded	8 (100%)	0	0
	8/13	check	0	29 (69%)	13 (31%)
		seeded	54 (86%)	9 (14%)	0
	9/4	check	0	2 (25%)	6 (75%)
		seeded	23 (92%)	2 (8%)	0
CO	7/8	check	0	0	0
		seeded	4 (100%)	0	0
	7/24	check	0	36 (100%)	0
		seeded	20 (74%)	7 (26%)	0
	8/14	check	0	18 (100%)	0
		seeded	7 (58%)	5 (42%)	0
	9/10	check	0	9 (100%)	0
		seeded	7 (100%)	0	0
OT	7/2	check	0	0	5 (100%)
		seeded	5 (71%)	1 (14%)	1 (14%)
	7/25	check	0	2 (40%)	3 (60%)
		seeded	4 (80%)	1 (20%)	0
	8/15	check	0	27 (96%)	1 (4%)
		seeded	5 (36%)	8 (57%)	1 (7%)
	9/9	check	0	13 (93%)	1 (7%)
		seeded	2 (9%)	20 (91%)	0

[a] S4ites: LI = Licking County; CO = Columbiana County; OT = Ottawa County.
[b] NA = not available yet (identifications in progress).

Table 5. Mite density in experiment on transfer of *Z. mali*, 2002.

Site[a]	Date	Mean number per leaf							
		European red mite				Stigmaeid mites			
		Check trees	Seeded trees		*P*[b]	Check trees	Seeded trees		*P*[b]
			shoots	bands			shoots	bands	
LI	7/23[c]	0.03	0.43	0.05	*0.48*	0.00	0.00	0.00	–
	8/13	0.3	0.3	0.3	*0.99*	0.00	0.05	0.00	*0.44*
	9/4	0.7	0.8	0.2	*0.42*	0.00	0.00	0.03	*0.44*
CO	7/24[c]	0.1	0.8	–	*0.41*	0.00	0.00	–	–
	8/14	0.3	5.1	–	*0.19*	0.00	0.06	–	*0.24*
	9/10	6.4	12.4	–	*0.32*	0.00	0.22	–	*0.16*
OT	7/25[c]	0.03	0.4	–	*0.38*	0.00	0.00	–	–
	8/15	1.5	1.7	–	*0.61*	0.00	0.03	–	*0.37*
	9/9	6.0	1.6	–	*0.27*	0.00	0.02	–	*0.37*

[a] Sites: LI = Licking County; CO = Columbiana County; OT = Ottawa County.
[b] P = probability value for statistical test of ANOVA treatment effect.
[c] Mite density on 7/23 to 7/25 was immediately before predators were seeded.

Table 6: European red mite density on Red Delicious apple leaves, Columbus, Ohio, 2002; mean of 4 replicates.

Treatment[a]	Number of motile European red mite per leaf on each of 10 dates									
	4/26	*5/14*	*5/29*	*6/4*	*6/12*	*6/19*	*7/1*	*7/15*	*7/31*	*8/26*
Check	0.7	0.9	1.7	4.6 AB	3.3 A	7.2	46	74 BC	6.8	0.18
Standard	0.1	0.6	0.2	0.3 B	0.1 B	1.1	4	40 CD	0.8	0.04
Danitol	0.3	0.1	0.04	0.1 B	0.7 B	1.0	13	126 A	1.0	0.08
Avaunt	0.1	0.7	0.5	1.9 B	4.0 A	9.5	48	96 AB	0.6	0.00
Acramite early	0.1	0.2	0.1	0.7 B	1.0 B	3.1	35	21 D	2.1	0.06
Acramite late	0.4	0.9	1.7	8.1 A	4.2 A	7.8	61	13 D	2.6	0.00
P (trt effect)	*0.35*	*0.10*	*0.12*	***0.04***	***0.001***	*0.28*	*0.45*	***0.0001***	*0.08*	*0.66*

[A] See Table 2 for pesticides included in each treatment.

Table 7: Stigmaeid density on Red Delicious apple leaves, Columbus, Ohio, 2002; mean of 4 replicates.

Treatment[a]	Number of predatory stigmaeid mite motiles per leaf on each of 10 dates									
	4/26	*5/14*	*5/29*	*6/4*	*6/12*	*6/19*	*7/1*	*7/15*	*7/31*	*8/26*
Check	0.04	0.06	0	0.02	0	0.06	0.04	0.62	2.70 A	0.70 AB
Standard	0.02	0	0	0	0.02	0	0	0.06	0.49 B	0.14 C
Danitol	0.02	0	0	0	0	0	0.02	0.02	0.25 B	0.16 C
Avaunt	0.08	0.06	0	0.08	0.10	0.20	0.14	1.77	1.43 B	0.16 C
Acramite early	0.10	0	0.06	0	0.06	0.12	0.52	1.56	2.80 A	1.00 A
Acramite late	0.04	0.02	0.02	0.08	0.04	0.10	0.20	1.10	1.39 B	0.45 BC
P (trt effect)	*0.59*	*0.10*	*0.15*	*0.20*	*0.09*	*0.13*	*0.17*	*0.15*	***0.001***	***0.005***

[A] See Table 2 for pesticides included in each treatment.

Table 8: Phytoseiid density on Red Delicious apple leaves, Columbus, Ohio, 2002; mean of 4 replicates.

Treatment[a]	Number of predatory phytoseiid mite motiles per leaf on each of 10 dates									
	4/26	*5/14*	*5/29*	*6/4*	*6/12*	*6/19*	*7/1*	*7/15*	*7/31*	*8/26*
Check	0	0	0	0.02	0.06 A	0.14 A	0.16	0.84	0.30	0.16
Standard	0	0	0	0	0.00 B	0.00 B	0.02	0.44	0.12	0.04
Danitol	0	0	0	0	0.02 AB	0.04 B	0.06	1.06	0.12	0.12
Avaunt	0	0	0	0	0.00 B	0.06 AB	0.20	1.03	0.20	0.12
Acramite early	0	0	0	0	0.02 AB	0.00 B	0.04	0.18	0.30	0.06
Acramite late	0	0	0	0	0.00 B	0.00 B	0.04	0.44	0.38	0.16
P (trt effect)	-	-	-	*0.45*	***0.05***	***0.05***	*0.24*	*0.19*	*0.91*	*0.79*

[A] See Table 2 for pesticides included in each treatment.