SPIDER MITE MANAGEMENT IN WALNUTS

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ABSTRACT

Over the last 10 years new classes of insecticides have been introduced as tools for the management of codling moth and walnut husk fly to replace the more traditional use of organophosphates. It is not clear that these 'reduced risk' products are selective in the context of the natural enemies that provide effective control of secondary pests such as web-spinning spider mites. The goal of this project is to gain a sufficient understanding of spider mites and their predators in walnuts to be able to enhance biological control for management of spider mites.

The main focus during this second year of the project was to repeat surveys of spider mites and spider mite predators in orchards throughout the main walnut growing regions to verify the complex patterns observed in 2013. A series of 13 orchards were surveyed regularly through the growing season to document seasonal and regional patterns of abundance and species representation. Three web-spinning spider mites were found with twospotted spider mite being the most widespread and abundant species, as was the case in 2013. A set of 10 phytoseiid mite predators were found in 2014 with *Amblyseius similoides*, *Euseius stipulatus*, *Galendromus occidentalis* and *Typhlodromus caudiglans* being the most widespread and abundant species. *A. similoides* occurred early in the season in the warmer regions of the valley, although it was absent from the southern San Joaquin valley in 2014. *E. stipulatus* was the dominant species on the eastern side of the Sacramento and northern San Joaquin valleys throughout the season. *G. occidentalis* was sporadic in occurrence throughout the valley and typically occurred only later in the season. *T. caudiglans* occurred early in the season in the cooler part of the southern Sacramento valley. These patterns were similar for both years, although one key difference between 2013 and 2014 was the total absence of phytoseiid mites from the three orchards sampled in the southern San Joaquin valley. While six-spotted thrips were more abundant in the Sacramento valley in 2014, in general, insect predators were uncommon.

Early-season releases of *G. occidentalis* were conducted in an orchard on the west side of the Sacramento valley where the pollen-feeding predator *E. stipulatus* was absent and a comparable orchard on the east side of the valley where *E. stipulatus* was present. The releases were successful in building a population of this specialist predator and suppressing the abundance of twospotted mites in the orchard where *E. stipulatus* was absent, but not in the orchard where this pollen-feeding predator was present. These field experiments suggest that early season activity of the specialist predator can be restored in a younger orchard with smaller trees, but it remains unknown whether the same result could be achieved in older orchards with larger trees. In addition, this experiment provides further evidence that the presence *E. stipulatus* may be an important constraint on the activity of *G. occidentalis*.

OBJECTIVES

The overall objective of this project is to gain a sufficient understanding of spider mites and their predators in walnuts to be able to enhance the existing biological control for management of spider mites. The specific objectives are:

1. Surveys of factors influencing the abundance of spider mites and their predators throughout the major walnut growing regions
2. Early-season releases of *Galendromus occidentalis* to test the potential to change the dominance of species in the predator mite complex
3. Bioassays to determine the laboratory toxicity and effect of field-aged residues of pesticides on predatory mites

In this second year of the project, the focus of our activities has been on the first two of these three objectives.

SIGNIFICANT FINDINGS

In 2014, the following significant findings emerged from our survey of spider mites and their predators in walnut orchards throughout the Central Valley and our early-season releases of *G. occidentalis* in two orchards in the Sacramento valley:

- Twospotted spider mite, *Tetranychus urticae*, was the dominant web-spinning spider mite throughout most of the Central valley. Pacific mite, *T. pacificus* was dominant in the southern San Joaquin valley where strawberry mite, *T. turkestani*, also occurred in small numbers. European red mite was generally less abundant during this warmer year.

- As an insect predator of spider mites, the six-spotted thrips was present in most orchards in the Sacramento valley, but absent from the San Joaquin valley. In one orchard it was sufficiently abundant to be suppressing spider mite abundance.

- Phytoseiid mite predators were totally absent throughout the season in the three orchards sampled in the southern San Joaquin valley. Whether this was due to changes in pesticide programs or newly introduced applications for navel orangeworm is unknown.

- Phytoseiid mite predators in other regions of the valley were surprisingly rich in species again in 2014. *G. occidentalis*, the specialist type II was sporadic in its distribution and typically occurred too late in the season to be of importance in suppressing spider mites. Generalist, type III, predators were well represented early season, but their potential for spider mite suppression remains unknown. Pollen-feeding generalist type IV predators dominate the predator community on the eastern side of the valley and may outcompete the more efficient predatory mite species.

- Early-season activity of *G. occidentalis* was successfully restored in small replicated plots in an orchard where type IV predators were absent by two augmentative releases in June of 1000 predators per tree. However, similar releases in an orchard where type IV predators were dominant failed to restore the activity of this specialist predator.

PROCEDURES

Objective 1. Surveys of factors influencing the abundance of spider mites and their predators throughout the major walnut growing regions

Surveys of spider mites, predatory mites and other mite predators were made in 13 orchards spanning the major walnut growing regions of the Central Valley in 2014 (Fig. 1). Orchards were selected to represent both the west (4 orchards) and east (3 orchards) sides of the Sacramento Valley and the northern (3 orchards) and southern (3 orchards) regions of the San Joaquin Valley. The orchards varied in size and age, but were focused on the major walnut cultivars; 5 Chandler, 4 Hartley, and one each for Serr, Tulare and Vina. For each orchard, the cultivar, age, ground cover, surrounding landscape, and pesticide treatments were documented.

For each of the orchards sampling for spider mites and predators was conducted once each month from June through October. Ten trees were randomly sampled in each orchard on each sample date, collecting the three terminal leaflets from four leaves from both the lower and mid canopies of each tree to give a total of 80 sets of terminal leaflets on each occasion. The leaflets from each tree were collected into separate paper sandwich bags and placed into coolers for return to the laboratory where the spider mites and predators were removed from the leaflets using a mite-brushing machine. Mites and predators from the 24 leaflets (8 leaves x 3 terminal leaflets) of each tree were combined onto a single plate and motile stages only (excluding eggs) were counted to provide estimates of densities per leaflet for the following categories: web spinning mites (*Tetranychus* species), European red mite (*Panonychus ulmi*), phytoseiid predators (all species combined), and insect predators (six-spotted thrips *Scolothrips sexmaculatus*, spider mite destroyers *Stethorus punctipes*, and minute pirate bugs *Orius minutus*). While European red mite is not an important pest species in walnuts it can be an important food source for mite predators.

Samples from all 10 trees combined were used for identification of the spider mite and phytoseiid mite species present in each orchard on each sample date. Identification of mature female spider mites was based on random sub-samples (up to 15 individuals from each orchard on each sample date) after slide mounting individuals in Hoyer's medium under cover slips and warming at 45 °C for 3-5 days to clear the body contents. All adult females of the phytoseiid mites collected from each orchard on each sample date were slide mounted for identification.

Objective 2. Early-season releases of Galendromus occidentalis *to test the potential to change the dominance of species in the predator mite complex*

To test whether the presence of pollen-feeding type IV generalist mite predators prevents *G. occidentalis* from establishing effective populations earlier in the season in walnut orchards augmentative releases were made in two orchards in the Sacramento. Surveys from 2013 had shown that orchards on the east side of the valley were dominated by *E. stipulatus*, whereas those on the west side were not. If type IV predators can suppress populations of *G. occidentalis* early in the season or prevent their successful colonization, then releases in replicate plots would be expected to be unsuccessful on the east side of the valley, yet successful on the west side of the valley. In contrast, if type IV predators have no influence on *G. occidentalis*, then releases should be equally successful in orchards on both sides of the valley.

A single young orchard on each side of the Sacramento valley (Winters and Nicolaus) were used to augment *G. occidentalis* populations in replicated release plots compared to control plots. Two releases of 1000 *G. occidentalis* per tree were made, one week apart, in early June using commercially produced source of predators. Each orchard was set up with four replicate release and control plots consisting of blocks of 6 trees in a row with 3 rows between each plot. In release plots, the mite predators in a cornmeal medium were placed into small paper bags that were stapled to the main trunk at the height of the main scaffold branches.

A single pre-release sample was taken from release and control plots in late May to determine the abundance of spider mites and resident predator mites before the releases of *G. occidentalis*. A single sub-terminal leaflet was sampled from 16 separate leaves in the lower canopy of the four central trees in each plot. The leaflets were placed in a cooler and returned to the lab where mites from each tree were brushed onto a plate, counted and identified. Post-release samples were taken 1, 3, 7, 11, 15 and 19 weeks after the first release of *G. occidentalis*. The outcome of the augmentative releases was measured as densities per leaflet of *T. urticae* and *G. occidentalis* and analyzed separately for each orchard.

RESULTS

Objective 1. Surveys of factors influencing the abundance of spider mites and their predators throughout the major walnut growing regions

The abundance of web-spinning spider mites (*Tetranychus* species) varied considerably among orchards in 2014, whereas European red mite was generally very low in abundance in all orchards sampled (Table 1). As in 2013, three different species of web-spinners were found in our surveys; twospotted spider mite (*T. urticae*), Pacific spider mite (*T. pacificus*) and strawberry spider mite (*T. turkestani*). Twospotted spider mite was the most abundant species in most growing regions with the exception of the southern San Joaquin valley where Pacific mite was the dominant species (Fig. 2). Pacific spider mite was found occasionally in the Sacramento valley, but was absent from the northern San Joaquin locations. As in 2013, strawberry spider mites were found only in small numbers and only at the southern San Joaquin locations. European red mites were much lower in abundance in 2014 in all regions (Table 1) probably due to the warmer, drier year.

In contrast to the 2013 season, there was a greater level of abundance of web-spinning spider mites in the San Joaquin valley in 2014 that matched the levels of abundance seen in the Sacramento valley (Table 1). Surprisingly, however, there were much greater populations of phytoseiid predators and six-spotted thrips in the Sacramento Valley, and a total absence of these predators in four of the six orchards sampled in the San Joaquin valley (Table 1). Since data on pesticide applications are not yet available for all of the orchards sampled, it is unclear why predators were absent from much of the San Joaquin valley in 2014. Nonetheless, the absence of predators may well account for the general rise in level of abundance of web-spinning spider mite populations in the San Joaquin valley in 2014.

The pattern of abundance of web-spinning spider mites and their predators varied considerably between orchards. In general, the spider mites reached peak abundance in July in both the Sacramento valley (Fig. 3) and in the San Joaquin valley (Fig. 4). Bronzing of walnut foliage was apparent when densities of spider mites reached approximately 5 motile stages per leaflet.

Densities of phytoseiid predators were often as high as that of the spider mites in the Sacramento valley (Fig. 3), but were either much lower or totally absent in the San Joaquin valley (Fig. 4). Generalist type III phytoseiids (Table 2) dominated the predator community early in the season, with type IV phytoseiids (Table 2) dominating the communities on the eastern side of the valley (Fig, 3C and D) to a much greater extent than on the western side of the valley (Fig. 3A and B). Data from both 2013 and 2014 suggest that the relative abundance of *G. occidentalis* declines very rapidly in orchards where the type IV phytoseiid *E. stipulatus* is present (Fig. 5). The extent to which pesticide applications influenced the seasonal patterns of spider mite and predator abundance has yet to be determined as spray records have not yet been obtained from growers.

Objective 2. Early-season releases of Galendromus occidentalis *to test the potential to change the dominance of species in the predator mite complex*

For the two orchards in which early-season releases of commercially-produced *G. occidentalis* were carried out, the seasonal patterns of web-spinning spider mite densities and *G. occidentalis* densities were very different (Fig. 6). The web-spinning spider mites in both orchards consisted of twospotted spider mite, *T. urticae*, only. The pre-release densities were low in both orchards and were the same in both control and release plots. For the orchard on the eastern side of the Sacramento valley, where *E. stipulatus* the pollen-feeding generalist predator was present, *G. occidentalis* appeared not to establish from the releases as densities remained almost non-existent throughout the season in the predator release plots. Predator densities were also low in the non-release control plots with the exception of a slight increase in these plots in August (Fig. 6A). Consequently, spider mite populations increased to densities of 2-3 motile stages per leaflet by late July without any difference in mean densities between release and control plots.

In contrast, for the orchard on the western side of the Sacramento valley, where *E. stipulatus* was not present, a very different pattern was observed (Fig. 6B). In this orchard predatory mite populations grew rapidly in the release plots while spider mite populations grew in the non-release control plots. By late June, predator-prey ratios in the release plots were 1:5 in the release plots and spider mite densities peaked at 7.0 per leaflet in late July. In contrast, predator densities were still zero in the control plots in late June, and spider mite densities peaked at 17.8 per leaflet in late July with predator-prey ratios of 1:35.

These results indicate that in the absence of *E. stipulatus*, the augmentative releases of *G. occidentalis* were sufficient to restore the activity of this specialist predator and to suppress the abundance of web-spinning spider mites in a younger orchard with smaller trees.

DISCUSSION

Spider mites are consistent secondary pests of tree fruit and nut crops worldwide. For many of these crops, spider mites are of marginal concern as their abundance is suppressed through natural biological control by phytoseiid mite predators. In some cases, such as almonds in California, spider mites are of particular concern as the trees are particularly susceptible to premature leaf drop in response to spider mite feeding damage. Most other tree fruit and nut crops are not as sensitive to spider mite feeding damage and natural biological control by resident predators provides consistent and sufficient suppression of damage, unless the predators are disrupted by pesticide used for the management of other pests and diseases. The well documented cases of spider mite outbreaks in apples in Washington state in the 1960s and in almonds in California in the 1980s were mitigated by the use of lower doses of more selective pesticides, and the introduction of pesticide-resistant western predatory mites.

From our surveys of spider mite and predator species in walnuts in 2013 and 2014, it is clear that twospotted spider mite is the species most frequently encountered in walnut orchards, with the exception of orchards in the southern San Joaquin, where Pacific spider mite can be an equally or more abundant species. European red mites were more widespread during the cooler season of 2013, but were very low in abundance in 2014. Web-spinning spider mites were less abundant in the San Joaquin valley than in the Sacramento valley in 2013, but were equally abundant in both valleys in 2014. So far we have been unable to find clear patterns between spider mite abundance in the walnut orchards surveyed and the prevailing pesticide management programs in these orchards. While disruption by pesticides seems the most likely cause of increased spider mite activity it is not yet clear whether this is due to disruption of natural enemies by insecticides or acaricides.

The resident predators of spider mites found during the two years of survey included only one insect predator (six-spotted thrips), but a wide range of phytoseiid predator species. The six-spotted thrips was more common in orchards in the Sacramento valley in 2014, but was absent from orchards sampled in the San Joaquin valley in 2014. It has been helpful to categorize the phytoseiid predator species into one of three different lifestyles according to the types of food sources that they use. The type II lifestyle includes specialist predators of web-spinning spider mites that are able to cut their way through the webbing produced by their prey, have a high reproductive potential and are known to be effective in the biological control of their prey. In walnuts, this lifestyle is represented by *G. occidentalis* only, and while this species is widespread in walnut orchards throughout the Central Valley it is neither abundant, nor active early enough in the season to be able to suppress spider mite populations. The type III lifestyle includes generalist predators that can feed on web-spinning mites, but are considered to be less effective in the biological control of such prey, being better suited for the management on non-webbing spider mites. This lifestyle is represented in walnut orchards by *A. similoides*, *M. citri* and *T. caudiglans* (Table 2). It appears that *A. similoides* is unique to walnut orchards, not having been collected from other crops and was a dominant early-season predator species in the warmer regions of both the Sacramento and San Joaquin valleys in 2013 and in the Sacramento valley in 2014. Due to its unique association with walnuts it may be are more important predator of web-spinning spider mites in California. The other two type III predators also appear to be more common in the earlier part of the season; *T. caudiglans* seems restricted to orchards that are cooled by the ocean influence that sweeps into the Central Valley through the Sacramento delta corridor, and *M. citri* is less frequent and associated with warmer region of the Central Valley. The type IV lifestyle includes pollen-feeding generalist predators in the genus *Euseius*, and is particularly well represented by *E. stipulatus* that often dominates the phytoseiid communities on the eastern side of the Sacramento valley and the north eastern section of the San Joaquin valley. They are not considered effective in the biological control of web-spinning spider mites, but have been implicated in reducing the abundance of specialist predators of web-spinning spider mites in Spanish satsuma orchards.

The absence of *G. occidentalis* from most of the walnut orchards sampled during the earlier part of the season in 2013 and the reduced levels of abundance of *G. occidentalis* in walnut orchards with a greater representation of *E. stipulatus* prompted an evaluation of whether this specialist predator could be restored in orchards through early-season releases in 2014. The results from our experimental augmentative releases suggested that successful colonization could result from early season releases in the absence of *E. stipulatus*. While these experiments were replicated within each orchard they were not replicated across orchards and thus caution is needed in interpreting the generality of this result. Additional early-season releases would be needed to verify this observation and to test whether early-season colonization of *G. occidentalis* can be achieved in orchards with larger trees.

Two other questions that have arisen from our surveys of spider mites and their predators in walnuts is whether we have a clear picture of action thresholds for spider mite management, and whether *G. occidentalis* can live year round in walnut orchards? Walnuts appear able to tolerate higher levels of spider mite abundance than are typically accepted by growers, suggesting that over use of acaricides may be having a longer term impact on local natural enemy populations. Consequently, a greater understanding of action thresholds and simpler monitoring protocols for spider mites and their predators in walnuts might be of value to walnut growers and PCAs. Our observation that *G. occidentalis* typically occurred in walnut orchards only later in the season suggests that even if it does overwinter in walnuts it may experience some difficulty in re-establishing populations successfully in the spring. As a late leafing tree crop, walnuts may not provide sufficient prey availability for *G. occidentalis* that undoubtedly resumes its activity in spring before bud burst. A failure to re-establish in spring might account for the absence of *G. occidentalis* earlier in the season until it can recolonize from other crops later in the season.

CONCLUSIONS

The survey of spider mites and predators in 2013-14 suggests that twospotted mite is the dominant web-spinning spider mite in walnuts and that a wide variety of phytoseiid predator species occur in walnuts throughout the Central Valley. Whether generalist, type III, predatory mite species can be effective in the suppression of web-spinning spider mites in walnuts remains unknown, but it is apparent that *G. occidentalis* as a specialist predator and insect predators such as the six-spotted thrips are often not sufficiently abundant to suppress spider mites before their populations increase in July. We have shown that *G. occidentalis* activity can be restored through early-season releases in a younger walnut orchard in the absence of *E. stipulatus* as a competitor, but this result needs to be further verified and tested in orchards with larger trees. Further research is also needed to better understand the biological control potential of type III phytoseiid predators, and potential disruptive effects of pesticide management programs on biological control of spider mites in walnuts.

Table 1. Seasonal abundance of the spider mites and predators found at different walnut locations in the Central Valley in 2014.

Location	Cultivar	Mean (±SE) web-spinning spider mites per leaflet	Mean (±SE) European red mites per leaflet	Mean (±SE) predatory mites per leaflet	Mean (±SE) predatory thrips per leaflet
Sacramento valley					
Red Bluff	Hartley	0.006 ± 0.006	0.000 ± 0.000	0.006 ± 0.003	0.000 ± 0.000
Winters	Tulare	3.450 ± 2.896	0.001 ± 0.001	0.085 ± 0.037	0.021 ± 0.011
Winters	Hartley	1.166 ± 1.143	0.001 ± 0.001	0.058 ± 0.016	0.067 ± 0.062
Durham	Chandler	1.597 ± 1.575	0.000 ± 0.000	0.175 ± 0.059	0.006 ± 0.004
Wheatland	Hartley	0.010 ± 0.002	0.000 ± 0.000	0.055 ± 0.016	0.000 ± 0.000
Nicolaus	Chandler	0.515 ± 0.317	0.021 ± 0.011	0.383 ± 0.122	0.108 ± 0.060
Davis	Mixed	22.403 ± 15.766	0.000 ± 0.000	0.705 ± 0.301	0.112 ± 0.073
San Joaquin valley					
Linden	Hartley	7.495 ± 4.563	0.001 ± 0.001	0.006 ± 0.002	0.000 ± 0.000
Farmington	Chandler	0.951 ± 0.665	0.000 ± 0.000	0.004 ± 0.002	0.000 ± 0.000
Atwater	Chandler	0.025 ± 0.024	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
Hanford	Vina	6.353 ± 6.067	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
Farmersville	Chandler	1.493 ± 0.962	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
Porterville	Serr	0.140 ± 0.071	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000

Table 2. The lifestyles (type II, III, and IV) of the main phytoseiid predator species found in walnuts, with color coding to match the relative abundance of the different predator lifestyles in Figs 3 and 4.

Type IV Pollen-feeding generalists	Type III Broad generalists	Type II Web-spinning mite specialists
Euseius quetzali	*Amblyseius similoides*	*Galendromus occidentalis*
Euseius stipulatus	*Metaseiulus citri*	
Euseius tularensis	*Typhlodromus caudiglans*	

Fig. 1. Location of the walnut orchards used in the spider mites and predator surveys in 2014.

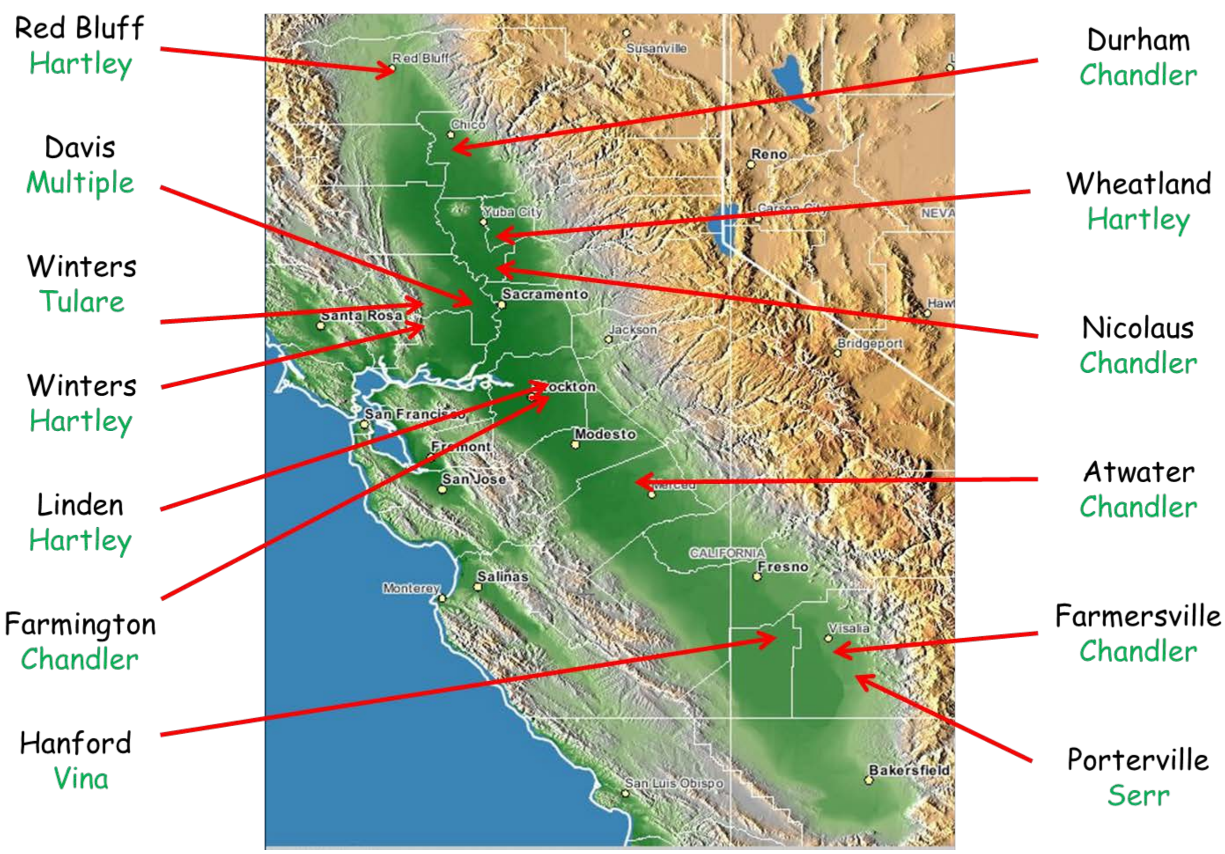
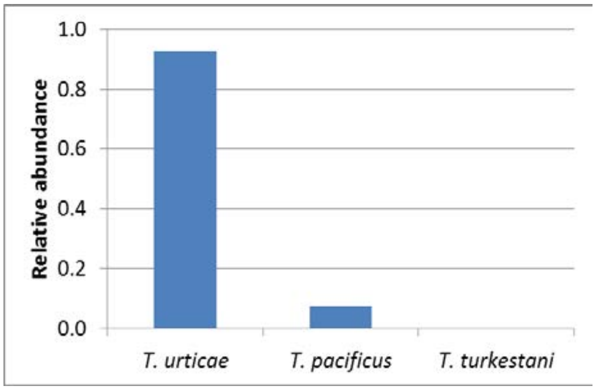
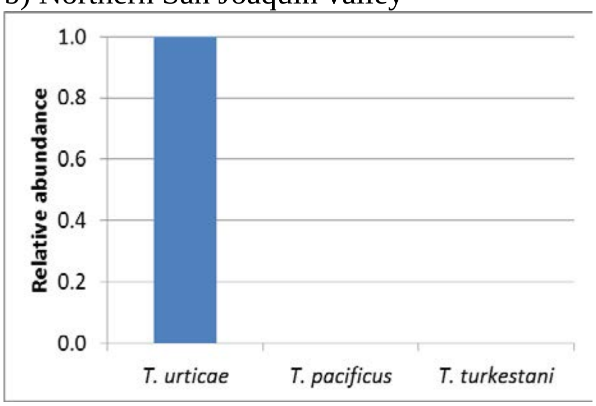


Fig. 2. Relative abundance of the different web-spinning *Tetranychus* species found in orchards in different walnut growing regions in 2014.

a) Sacramento valley



b) Northern San Joaquin valley



c) Southern San Joaquin valley

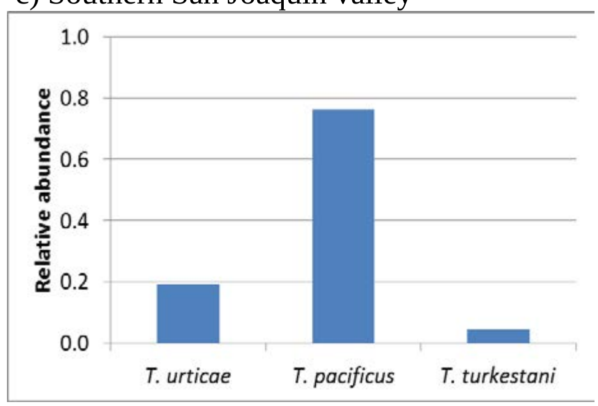


Fig. 3. Seasonal abundance of spider mites and their predators (top), and the relative abundance of phytoseiid predator lifestyles (bottom) for four example walnut orchards in the Sacramento valley in 2014.

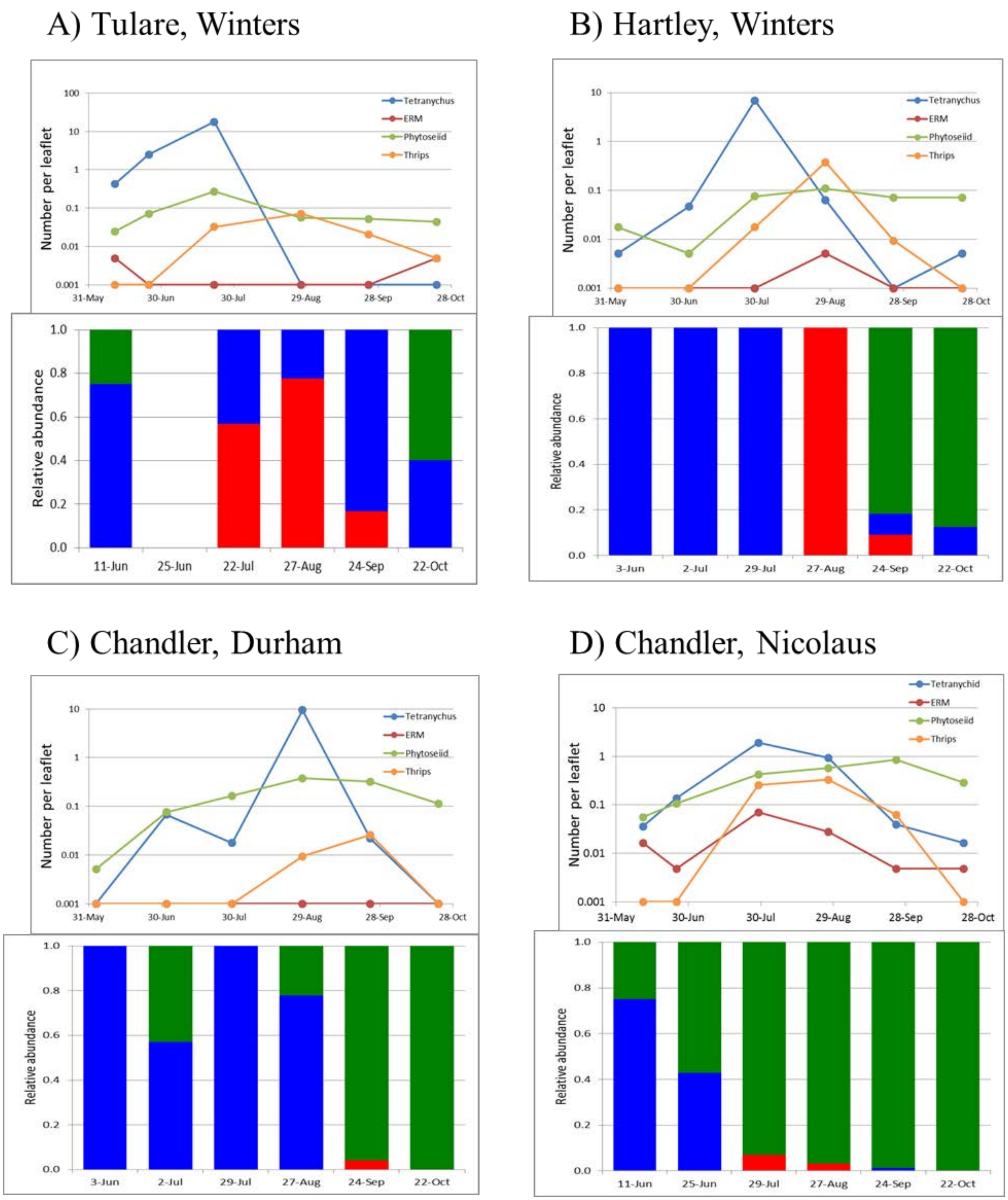
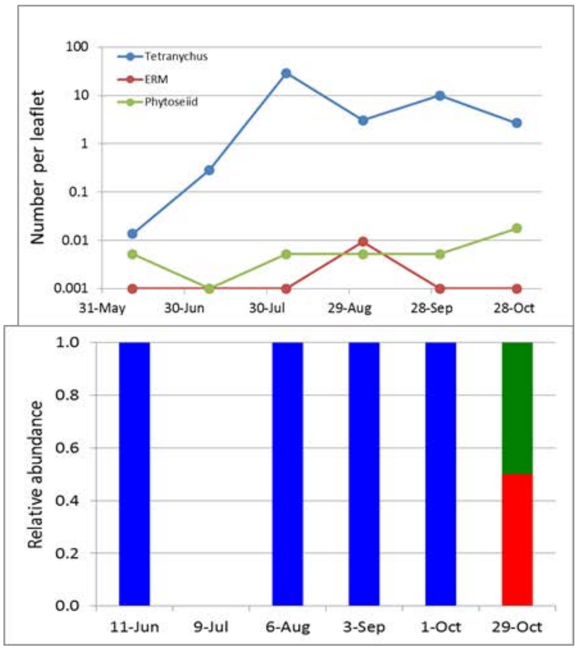
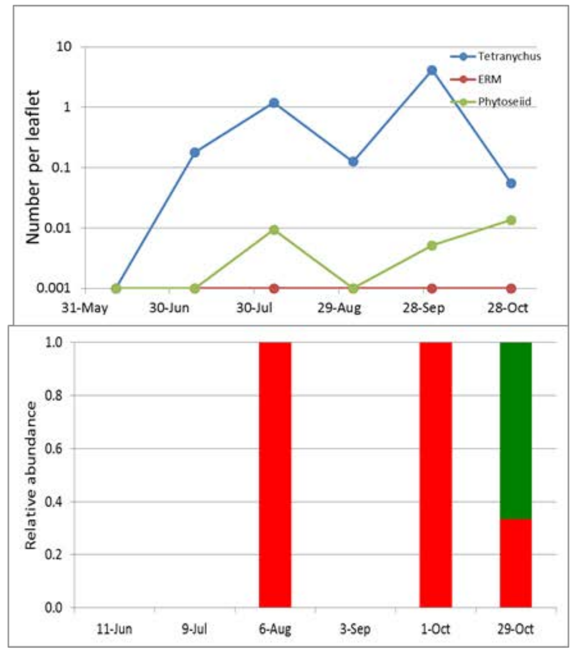


Fig. 4. Seasonal abundance of spider mites and their predators (top), and the relative abundance of phytoseiid predator lifestyles (bottom) for four example walnut orchards in the San Joaquin valley in 2014. Predator lifestyles graphs are missing for C and D due to total absence of phytoseiid predators from these orchards.

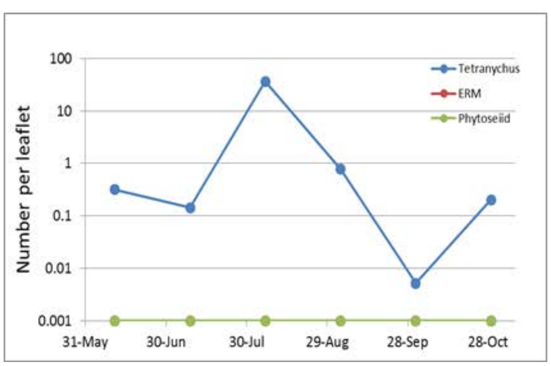
A) Hartley, Linden



B) Chandler, Farmington



C) Vina, Hanford



D) Chandler, Farmersville

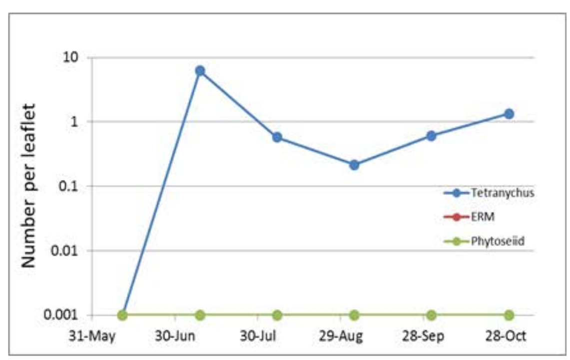


Fig. 5. The relationship between the relative abundance of *Galendromus occidentalis*, a specialist predator of web-spinning spider mites, and that of *Euseius stipulatus*, a pollen-feeding generalist mite predator in orchards on the eastern side of the Central Valley in 2013 and 2014.

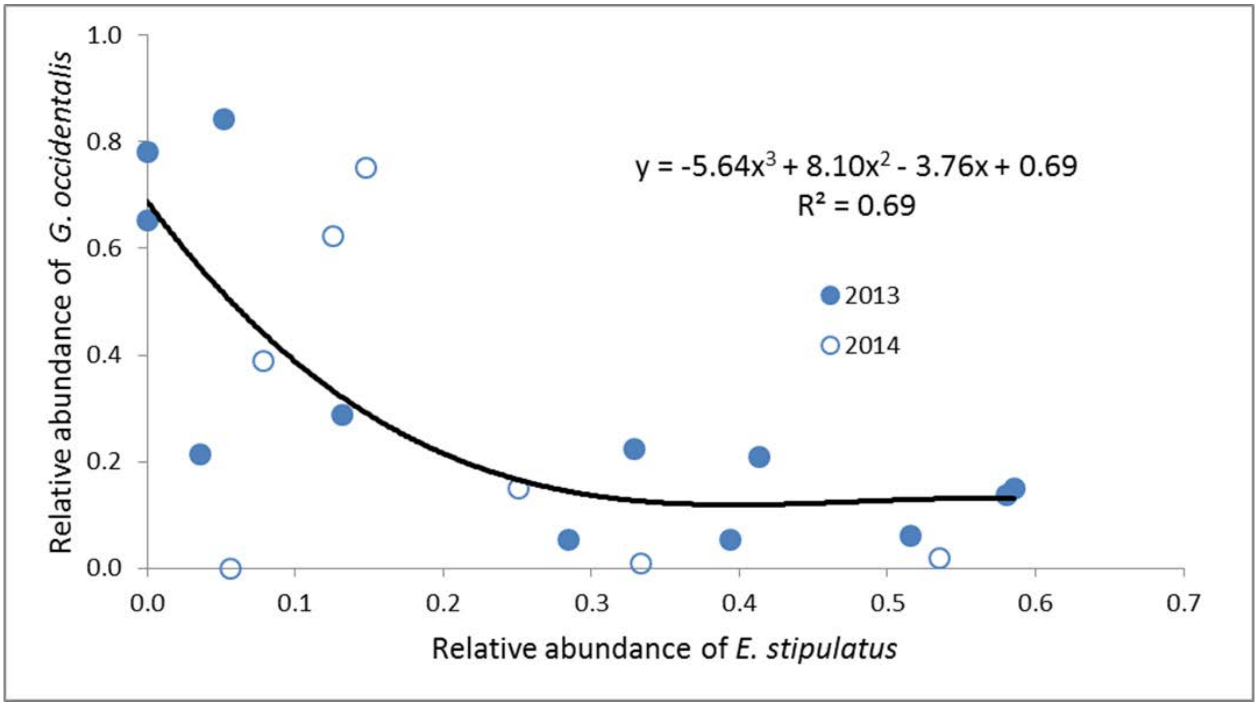
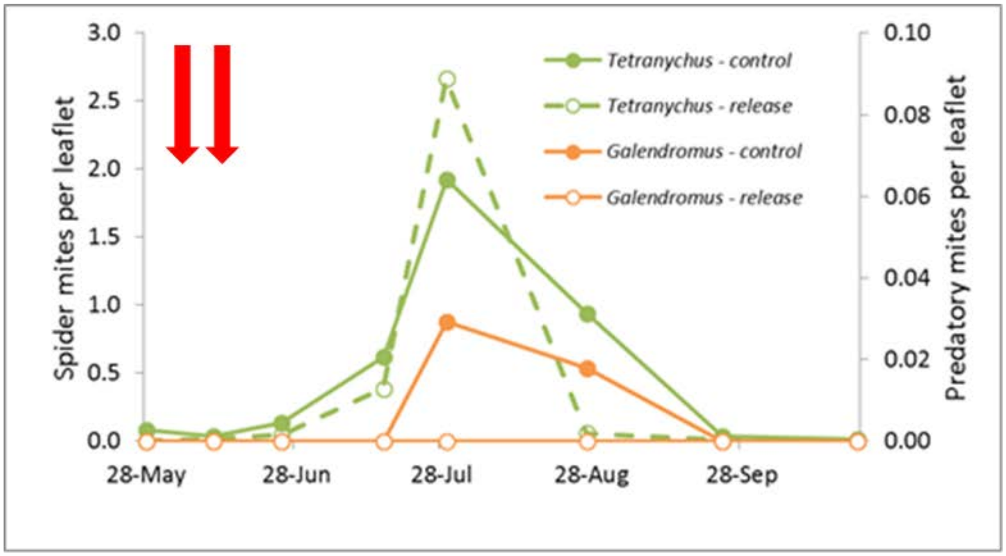


Fig. 6. The seasonal pattern of mean densities of twospotted spider mites and released predatory mites in two orchards used for early-season augmentative releases of *Galendromus occidentalis*. Red arrows indicate the timing of the predator releases, and the two orchards (A and B) differed by either having *Euseius stipulatus*, a pollen-feeding generalist predatory mite, present in the orchard or not.

A) Orchard with *Euseius stipulatus*



B) Orchard without *Euseius stipulatus*