Chemical and non-chemical solutions for managing twospotted spider mite, western tarnished plant bug, and other arthropod pests in strawberries

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Abstract

The twospotted spider mite, *Tetranychus urticae* and the western tarnished plant bug, *Lygus hesperus* are major arthropod pests of strawberries in California. Other important insect pests include the greenhouse whitefly, *Trialeurodes vaporariorum* and the western flower thrips, *Frankliella occidentalis*. Chemical pesticides play a major role in managing these pests, but not without the associated risk of pesticide resistance and environmental safety. Two field studies were conducted in Santa Maria to evaluate the potential of botanical and microbial pesticides in the integrated pest management (IPM) of strawberry. Chemical, botanical, and microbial pesticides were evaluated against *T. urticae* in a small plot study in 2013 and against *L. hesperus* and other insect pests in a large plot study in 2015 in commercial strawberry fields. Bug vacuums were also used in the 2015 study. Results demonstrated that non-chemical alternatives can play an important role in strawberry IPM.

Keywords: *Frankliniella occidentalis*, *Lygus hesperus*, *Trialeurodes vaporariorum*, *Tetranychus urticae*, entomopathogenic fungi, integrated pest management.

Introduction

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Strawberry is the fifth most valuable agricultural commodity in California with a crop value of $2.5 billion (CDFA, 2016). The twospotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae) and the western tarnished plant bug also known as lygus bug, *Lygus hesperus* Knight (Hemiptera: Miridae) are two major arthropod pests that cause significant yield losses every season (Zalom et al, 2014). Other important insect pests that can cause significant damage when populations are high include the greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood) (Hemiptera: Aleyrodidae) and the western flower thrips, *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae). Twospotted spider mite is generally found on the underside of the leaves scraping the epidermis and feeding on the plant juices. Mite damage reduces plant vigor and thus fruit yields. Severe mite infestations can also lead to plant death. Western tarnished plant bug nymphs and adults feed on developing fruit by inserting their stylets and sucking fruit juices. As the fruit develops, damaged tissues result in uneven growth and cause fruit deformity. Deformed berries are not marketable and contribute to yield losses. Populations of the greenhouse whitefly and the western flower thrips are usually kept below threshold levels with treatments targeted towards other pests, but can occasionally build up to damaging levels. Biological control of the twospotted spider mites by releasing commercially-produced predatory mites is a popular practice in California. Management of the western tarnished plant bug continues to be a major challenge for California strawberry growers. Although earlier studies show limited control of the western tarnished plant bug from vacuums, their use is becoming popular especially on some large farms (Pickel et al., 1995). However, strawberry is one of the crops where large quantities of pesticides are used and the twospotted spider mite and the western tarnished plant bug are important targets for miticide and insecticide applications (CDPR, 2015).

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Excessive use of chemicals leads to pesticide resistance, making it more challenging to control already difficult pests. Although several botanical and microbial pesticides are registered against these and other strawberry pests, they are used only to a limited extent and are primarily perceived as viable options in organic agriculture. Earlier field studies demonstrated that alternating or combining biopesticides with chemical pesticides are important in strawberry IPM for western tarnished plant bug management (Dara, 2016). Two field studies were conducted, in 2013 and 2015, to further evaluate the role of biopesticides in managing arthropod pests strawberry.

Twospotted spider mite

A small plot field study was conducted in 2013 at Manzanita Berry Farms in Santa Maria to evaluate the efficacy of various botanical, chemical, and microbial pesticides. Treatments included bifenazate (Acramite 50 WS at 1 lb/ac), abamectin (Agri-Mek SC at 4.29 fl oz/ac), entomopathogenic fungus *Beauveria bassiana* (BotaniGard ES at a lower label rate of 1 qrt/ac) + bifenazate (Acramite 50 WS at the lowest label rate of 0.75 lb/ac), rosemary and cotton seed oil (Eco-Mite at 1% concentration), fenpyroximate (Fujimite 5 EC at 2 pt/ac), fenpyroximate (Fujimite XLO at 2 pt/ac), *Chromobacterium subtsugae* strain PRAA4-1 (Grandevo at 2 lb/ac), *Burkholderia* sp. strain A396 (Venerate XC at 2 gal/ac), and cyflumetofen (Nealta SC at 13.7 fl oz/ac). A spray volume of 150 gallons/acre was used with 0.25% non-ionic surfactant (Induce) except for the treatment with *B. bassiana*, where an organo-silicon surfactant (Kinetic) was used. Each treatment was a 15' long strawberry bed and treatments were replicated four times in randomized complete block design. Treatments were applied on 16 and 23 May, 2013 using a CO_2 pressurized backpack sprayer and eggs and mobile stages of twospotted spider mites and predatory mites (*Phytoseiulus persimilus* and *Neoseiulus* spp.) were enumerated 3 and

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7 days after each application. On each sampling date, 10 mid-tier leaflets were collected from 10 random plants within each plot, eggs and mobile stages of mites were collected using a mite brushing machine (Leedom Enterprises, Mi-Wuk Village, CA) by passing each leaflet five times and counted under a microscope. Data were analyzed using ANOVA and significant means were separated using Tukey's HSD test.

Pre-treatment counts were not available due to a technical issue, so comparisons were made for pest and predatory mite (*Phytoseiulus persimilis* and *Neoseiulus* spp.) numbers after each spray application and the post-treatment period. Compared to untreated control, treated plots had fewer spider mites throughout the observation period, but the pest suppression was not statistically significant ($P \geq 0.05$, Table 1).

Western tarnished plant bug and other insect pests

A large plot study was conducted in 2015 at Sundance Berry Farms in the Santa Maria area. The following groups of treatment options were used in different combinations and rotations and evaluated for their efficacy against insect pests with a particular emphasis on *L. hesperus* (Table 3).

Chemical pesticides: Six chemical pesticides from different Insecticide Resistance Action Committee (IRAC) mode of action group were used.

IRAC Group 3A – Pyrethrins: Proprietary formulation and bifenthrin (Brigade)

IRAC Group 4A – Neonicotinoids: Acetamiprid (Assail 70 WP)

IRAC Group 4C – Sulfoximines: Sulfoxaflor (Closer)

IRAC Group 4D – Butenolides: Flupyradifurone (Sivanto)

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IRAC Group 9C – Flonicamid: Flonicamid (Beleaf 50 SG)

IRAC Group 15 – Benzoylureas: Novaluron (Rimon 0.83 EC)

Botanical pesticide: Azadirachtin is an insecticide, insect growth regulator, antifeedant, and a repellent. Different formulations of azadirachtin used in this study were – AzaGuard (3% azadirachtin), Neemix (4.5% azadirachtin), and Debug Turbo (65.8% of oils margosa and 0.7% azadirachtin). Cold pressed neem (37.5 or 75 ppm) or natural pyrethrum (0.5 or 0.75%) were also present in combination with *B. bassiana* in three products used in the study.

Entomopathogenic fungi: Three fungi used in the study include *B. bassiana* [three proprietary formulations with cold pressed neem at 75 ppm (XPULSE), pyrethrum at 0.75% (XPECTRO), or both cold pressed neem at 37.5 ppm and pyrethrum at 0.5% (XCEDE)], *Isaria fumosorosea* (Pfr-97 20% WDG), and *Metarhizium brunneum* (Met 52 EC).

Mechanical: Vacuuming was done with a commercial tractor-mounted bug vacuum twice a week with one pass each time at a speed of 2 mph.

The study included 12 treatments where Assail 70 WP alone and vacuuming alone were grower standards along with an untreated control (Table 3). Treatments were administered on 26 August, 2 and 9 September using a tractor-mounted sprayer. A spray volume of 100 gallons/acre was used for pesticide treatments. Each treatment had six 75' long (4 row) beds and four replications distributed in a randomized complete block design. Before the first treatment and 6 days after each treatment, 20 random plants from the middle two beds in each plant were sampled for insect pests and natural enemies. The number of young and old nymphs, and adult *L. hesperus*, adults and nymphs of *F. occidentalis*, adult *T. vaporariorum*, adults or immature

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stages of natural enemies including bigeyed bugs (*Geocoris* spp.), minute pirate bugs (*Orius* spp.), lace wings (*Chrysopa* spp. and *Hemerobius* spp.), damsel bugs (*Nabis* spp.), ladybeetles (Coccinellidae), parasitic wasps (*Anaphes iole*), predatory thrips (Thripidae), predatory midge larvae (Syrphidae), and spiders were counted from each sample plant. Data were subjected to ANOVA and significant means were separated using Tukey's HSD test.

Results and Discussion

Twospotted spider mite

When the percent reduction in treatments relative to untreated control was compared for both spray applications, Eco-Mite treatment caused a 49.3% reduction in egg and mobile stages followed by Venerate XC (48.3%), Nealta SC (47.6%), and Fujimite EC (46.1%) (Fig. 1). Control provided by the lower label rates of BotaniGard ES+Acramite 50 WS (34.6%) is comparable to the commonly used chemical pesticides Agri-Mek SC (34.7%), Fujimite XLO (34.3%) and Acramite 50 WS at the higher rate (31.2%). A 25.2% reduction in egg and mobile stages obtained by Grandevo is also important from the IPM perspective.

There were no statistically significant differences in predatory mite populations among treatments except in mobile numbers 7 days after the first spray ($P = 0.0046$, Table 2). Plots that were treated with Venerate XC and Nealta SC had a relatively higher numbers of predatory mites and Acramite 50 WS and Agri-Mek SC had lower numbers, in general. Considering the recent resistance issues with abamectin and bifenazate in *T. urticae* populations (personal communication with growers and PCAs), information on the efficacy of other chemical and non-

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chemical alternatives against *T. urticae* and safety to predatory mites is very important in developing IPM strategies.

Western tarnished plant bug

Populations of *L. hesperus* were very high during the study period (treatment threshold 1 nymph/20 plants) and control was difficult, in general (Table 4). Significant treatment differences ($P = 0.01$) were seen only for post-treatment counts of older nymphs. When the percent reduction in nymphs and adult western tarnished plant bugs was compared after three treatments, 29% reduction was seen in sulfoxaflor/flupyradifurone/flonicamid treatment compared to pre-treatment numbers (Fig. 2). Sivanto/Sivanto/vacuum treatment provided a 12% control. XPECTRO/vacuum/Rimon 0.83 EC+Brigade treatment prevented the population buildup. There was a 7.8 to 85.7% increase in *L. hesperus* numbers in all the remaining treatments. Bug vacuums, which are becoming more popular in the recent years, were also not effective in controlling *L. hesperus* populations but limited population buildup to 11.5%.

There were no significant difference ($P \geq 0.05$) in *F. occidentalis*, *T. vaporariorum*, or natural enemy populations (Table 5). However, pest and natural enemy populations increased, decreased or remained relatively unchanged post-treatment compared to pretreatment counts. *Frankliniella occidentalis* numbers increased in all treatments post-treatment except for a 41% in Rimon 0.83 EC+Brigade/Met52 EC+Debug Turbo/Met52 EC+AzaGuard treatment and 22% in XPULSE/XCEDE/XPECTRO treatment. In general, low numbers of *T. vaporariorum* adults were seen during the observation period. After three weeks of administering the treatments, reduction in numbers was seen in vacuum/Sivanto+Debug Turbo/Rimon 0.83 EC+Brigade, Sivanto/Sivanto/vacuum, and Rimon 0.83 EX+Brigade/Met52 EC+Debug Turbo/Met52

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EC+AzaGuard treatments. Percent change post-treatment indicated that natural enemy populations were relatively higher in Pfr-97 20% WDG+Neemix/Pfr-97 20% WDG+Neemix/vacuum followed by Closer/Sivanto/Beleaf 50 SG, and Closer/Closer/vacuum and XPULSE/XCEDE/XPECTRO treatments (Table 5).

These results show that both chemical and non-chemical alternatives vary in their efficacy depending on the combinations and rotation. There is a general perception that chemical pesticides are more efficacious and consistent in their control compared to non-chemical alternatives, but it was not the case in this study. Similar to the findings of Picket et al. (1995) vacuums provided limited control of western tarnished plant bug in this study. To reduce the risk of insecticide resistance development, effective chemicals from different mode of action groups and non-chemical alternatives such as botanical and microbial pesticides, should be considered. Some of the biopesticides are more expensive compared to chemical pesticides, but their long-term benefit in insecticide resistance management is very significant. Recent studies also showed that entomopathogenic fungi can also promote crop growth, health, and antagonize plant pathogens in addition to controlling arthropod pests (Sasan and Bidochka, 2012; Dara et al., 2017a, b). These additional roles can offer additional benefits and offset the higher costs of entomopathogenic fungi-based biopesticides.

While predatory mite releases are commonly practiced in California strawberries for spider mite control, using bug vacuums on some farms is the primary non-chemical alternative practice for managing *L. hesperus*. There is a need to integrate a variety of pest management practices both to improve the control efficacy against pests such as *L. hesperus* as well as to promote IPM practices. Earlier field studies showed combining and rotating chemical pesticides

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with botanical and microbial pesticides is an effective strategy for managing *L. hesperus* in strawberry (Dara, 2016). Although the combination of *I. fumosorosea* and *B. bassiana* with azadirachtin or pyrethrum did not result in statistically significant reduction in *L. hesperus* numbers, in general, there were fewer *L. hesperus* in these treatments compared to the untreated control in the current study. Similarly, the combination of *B. bassiana* and azadirachtin was more effective in controlling the rice root aphid, *Rhopalosiphum rufiabdominale*, and the honeysuckle aphid, *Hyadaphis foeniculi*, in organic celery (Dara, 2015). These studies demonstrate the efficacy of a variety of control options for managing major arthropod pests in strawberry, their impact on natural enemy populations, and present various ideas for developing IPM strategies.

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References

California Department of Pesticide Regulation (CDPR). 2015. Summary of pesticide use report data 2013: indexed by commodity. (http://www.cdpr.ca.gov/docs/pur/pur13rep/comrpt13.pdf)

California Department of Food and Agriculture (CDFA). 2016. California agricultural statistics review, 2014-2015. (https://www.cdfa.ca.gov/statistics/PDFs/2015Report.pdf)

Peer-reviewed version available at *Insects* **2018**, *9*, 156; doi:10.3390/insects9040156

Dara, S. K. 2013. Entomopathogenic fungus *Beauveria bassiana* promotes strawberry plant growth and health. UC ANR eJournal Strawberries and Vegetables, September 30, 2013. (https://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=11624)

Dara, S. K. 2015. Root aphids and their management in organic celery. CAPCA Adviser 18(4): 56-58.

Dara, S. K. 2016. Managing strawberry pests with chemical pesticides and non-chemical alternatives. Int. J. Fruit Sci. 16: 129-141. DOI: 10.1080/15538362.2016.1195311

Dara, S. K., S.S.R. Dara, and S. S. Dara. 2017a. Impact of entomopathogenic fungi on the growth, development, and health of cabbage growing under water stress. Amer. J. Plant Sci. 8: 1224:1233. DOI: 10.4236/ajps.2017.86081

Dara, S.S.R., S. S. Dara, S. K. Dara, and T. Anderson. 2017b. Fighting plant pathogenic fungi with entomopathogenic fungi and other biologicals. CAPCA Adviser 20(1): 40-44.

Pickel C, Zalom FG, Walsh DB, Welch NC. 1995. Vacuums provide limited lygus control in strawberries. Cal. Ag. 49: 19-22.

Sasan, R. K. and M. J. Bidochka, 2012. The insect-pathogenic fungus *Metarhizium robertsii* (Clavicipitaceae) is also an endophyte that stimulates plant root development. Amer. J. Bot. 99: 101-107.

Zalom FG, Bolda MP, Dara SK, Joseph S. 2014. UC IPM pest management guidelines: strawberry. University of California Statewide Integrated Pest Management Program. Oakland: UC ANR Publication 3468.

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Table 1. Number of eggs or mobile stages of twospotted spider mite per leaflet 3 and 7 days after first and second spray treatment along with post-treatment average.

Treatment	I Spray 3DAT		I Spray 7DAT		II Spray 3DAT		II Spray 7DAT		Post-treatment	
	Egg	Mobile	Egg	Mobile	Egg	Mobile	Egg	Mobile	Egg	Mobile
Untreated	109.05	23.25	111.60	20.40	133.00	22.20	85.00	23.8	109.66	22.41
Acramite 50 WS	87.60	15.6	75.80	7.80	94.00	14.00	57.80	10.80	78.80	12.05
Agri-Mek SC	72.45	10.80	69.20	12.80	84.20	19.40	56.40	19.60	70.56	15.65
BotaniGard ES+ Acramite 50 WS	90.90	12.15	79.00	8.20	86.40	15.80	32.40	20.40	72.17	14.14
Eco-Mite	42.45	5.25	66.80	11.40	69.00	10.80	48.20	14.00	56.61	10.36
Fujimite 5 EC	65.10	8.85	68.80	8.00	62.80	13.40	45.80	12.20	60.62	10.61
Fujimite XLO	71.25	19.50	85.00	11.60	91.20	15.00	43.40	10.40	72.71	14.12
Grandevo	75.60	14.40	85.80	12.40	111.20	14.80	64.60	16.20	84.30	14.45
Venerate XC	45.60	16.35	54.20	16.00	65.60	12.80	48.20	14.60	53.40	14.94
Nealta SC	66.00	18.30	51.00	8.80	82.60	8.40	31.40	10.40	57.75	11.47
***P* value**	0.2310	0.1702	0.4023	0.0490	0.1627	0.2441	0.2049	0.5918	0.0850	0.1073

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Table 2. Number of eggs or mobile stages of predatory mites per leaflet 3 and 7 days after first and second spray treatment along with post-treatment average.

	I Spray 3DAT		I Spray 7DAT		II Spray 3DAT		II Spray 7DAT		Post-treatment	
	Egg	Mobile	Egg	Mobile	Egg	Mobile	Egg	Mobile	Egg	Mobile
Untreated	0	1.65	1.00	0.60b*	1.80	2.20	2.60	4.20	1.35	2.16
Acramite 50 WS	0.45	0.60	1.00	0.60b	1.00	1.20	1.00	1.20	0.86	0.90
Agri-Mek SC	1.20	0.45	1.00	0.20b	0.60	1.40	0.40	2.60	0.80	1.16
BotaniGard ES+Acramite 50 WS	0.45	0.60	0.80	1.60ab	2.00	2.60	1.60	4.2	1.21	2.25
Eco-Mite	0.30	0.75	2.20	0.60b	0.80	1.60	2.00	3.00	1.32	1.48
Fujimite 5 EC	0.60	0.45	1.60	4.00a	1.00	1.00	2.00	2.60	1.30	2.01
Fujimite XLO	0.90	0.60	1.60	1.20ab	1.40	0.60	3.00	2.60	1.72	1.25
Grandevo	0.45	0	0.60	0.80b	1.80	0.60	1.80	2.40	1.16	0.95
Venerate XC	2.40	1.65	1.80	1.40ab	1.40	2.80	2.00	5.20	1.90	2.76
Nealta SC	0.90	1.35	1.80	0.40b	1.60	3.60	2.00	3.80	1.57	2.28
***P* value**	0.0570	0.3899	0.7879	0.0046	0.8894	0.5535	0.3962	0.6581	0.4953	0.3902

*Means followed by the same or no letter within each column are not statistically significant, Tukey's HSD.

Table 3. List of treatments and IRAC mode-of-action (MOA) groups used for managing *L. hesperus* and other insect pests.

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Treatment	**1st application (Rate/acre), MOA**	**2nd application (Rate/acre), MOA**	**3rd application (Rate/acre), MOA**
1	Untreated	Untreated	Untreated
2	Assail 70 WP (3 oz), **4A**	Assail 70 WP (3 oz), **4A**	Assail 70 WP (3 oz), **4A**
3	Vacuum	Vacuum	Vacuum
4	Rimon 0.83 EC (12 fl oz), **15** + Brigade (16 oz), **3A**	Met52 EC (16 fl oz) + Debug Turbo (104 fl oz)	Met52 EC (16 fl oz) + AzaGuard (16 fl oz)
5	Closer (4.5 fl oz), **4C**	Closer (4.5 oz), **4C**	Vacuum
6	Pfr-97 20% WDG (2 lb) + Neemix (9 fl oz)	Pfr-97 20% WDG (2 lb) + Neemix (9 fl oz)	Vacuum
7	Vacuum	Sivanto (14 fl oz), **4D** + Debug Turbo (104 fl oz)	Rimon 0.83 EC (12 fl oz), **15** + Brigade (16 oz), **3A**
8	Sivanto (14 fl oz), **4D**	Sivanto (14 fl oz), **4D**	Vacuum
9	Closer (4.5 fl oz), **4C**	Sivanto (14 fl oz), **4D**	Beleaf 50 SG (2.8 oz), **9C**
10	XPULSE (1 qt)	XCEDE (1 qt), **3A**	XPECTRO (1 qt), **3A**
11	XPECTRO (1 qt), **3A**	XPULSE (1 qt)	Beleaf 50 SG (2.8 oz), **9C**
12	XPECTRO (1 qt), **3A**	Vacuum	Rimon 0.83 EC (12 fl oz), **15** + Brigade (16 oz), **3A**

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Table 4. Number of *L. hesperus* nymphs (young and old) and adults per 20 plants before and after each treatment.

Treatment	Pretreatment				Post I Spray				Post II Spray				Post III Spray				Post-treatment Average			
	1–3 Instar	4–5 Instar	Adult	All Stages	1–3 Instar	4–5 Instar	Adult	All Stages	1–3 Instar	4–5 Instar	Adult	All Stages	1–3 Instar	4–5 Instar	Adult	All Stages	1–3 Instar	4–5 Instar	Adult	All Stages
1	18.50	2.50	2.00	23.00	25.50	5.75	2.50	33.75	24.00	6.75	6.75	37.50	33.50	6.25	12.00	51.75	27.67	6.25a*	7.08	41.00
2	20.75	3.75	2.50	27.00	21.00	4.00	1.50	26.50	22.00	5.50	4.75	32.25	20.00	2.25	6.50	28.75	21.00	3.92ab	4.25	29.17
3	21.25	2.50	2.25	26.00	15.50	3.75	1.50	20.75	22.75	6.25	4.25	33.25	25.25	3.25	4.50	33.00	21.17	4.42ab	3.42	29.00
4	20.75	2.50	1.25	24.50	14.25	2.50	2.25	19.00	16.25	1.25	5.25	22.75	30.25	1.00	6.25	37.50	20.25	1.58b	4.58	26.42
5	11.50	1.75	0.75	14.00	11.50	2.25	3.25	17.00	13.25	2.75	4.00	20.00	26.50	0.50	7.75	34.75	17.08	1.83b	5.00	23.92
6	21.25	2.00	1.50	24.75	19.75	4.75	1.75	26.25	21.00	3.50	6.00	30.50	32.50	2.00	7.25	41.75	24.42	3.42ab	5.00	32.83
7	17.25	1.00	1.00	19.25	21.00	3.25	2.50	26.75	18.75	3.25	2.50	24.50	15.25	1.75	5.25	22.25	18.33	2.75ab	3.42	24.50
8	30.00	2.00	1.75	33.75	23.75	4.00	2.75	30.50	16.75	6.25	5.25	28.25	21.50	3.50	5.25	30.25	20.67	4.58ab	4.42	29.67
9	31.50	3.50	0.75	35.75	12.50	4.50	1.75	18.75	23.25	4.75	7.50	35.50	15.25	1.50	5.25	22.00	17.00	3.58ab	4.83	25.42
10	15.00	1.25	1.25	17.50	22.00	4.00	2.25	28.25	24.00	5.00	3.00	32.00	29.00	2.25	6.00	37.25	25.00	3.75ab	3.75	32.50
11	17.00	1.50	0.75	19.25	20.75	3.75	1.75	26.25	24.50	5.75	5.50	35.75	16.25	2.00	4.50	22.75	20.50	3.83ab	3.92	28.25
12	32.50	3.50	1.50	37.50	31.00	7.00	4.00	42.00	26.00	7.25	7.00	40.25	18.00	3.00	9.25	30.25	25.00	5.75ab	6.75	37.50

*Means followed by the same or no letter are not significantly different, Tukey's HSD ($P \geq 0.05$).

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Table 5. Number of western flower thrips (*F. occidentalis*), greenhouse whiteflies (*T. vaporariorum*), and various natural enemies before and after each treatment. Differences among means were not statistically significant ($P \geq 0.05$).

Treatment	Western Flower Thrips						Greenhouse Whiteflies						Natural Enemy Complex					
	Pre-treat.	Post I Treat.	Post II Treat.	Post III Treat.	Post-treat. Avg.	% Change	Pre-treat.	Post I Treat.	Post II Treat.	Post III Treat.	Post-treat. Avg.	% Change	Pre-treat.	Post I Treat.	Post II Treat.	Post III Treat.	Post-treat. Avg.	% Change
1	7.00	15.75	13.25	12.25	13.75	96.43	0.25	1.00	0.25	1.75	1.00	300.00	1.25	2.25	4.75	2.25	3.08	146.67
2	9.00	21.00	13.25	13.50	15.92	76.85	0.25	0.25	1.25	0.50	0.67	166.67	2.25	5.25	3.75	2.00	3.67	62.96
3	4.75	20.50	15.50	15.75	17.25	263.16	0.75	1.25	0.75	0.75	0.92	22.22	2.00	3.00	3.00	1.00	2.33	16.67
4	18.25	12.25	8.25	11.50	10.67	-41.55	0.50	0.25	0.25	0.50	0.33	-33.33	2.00	3.50	1.75	2.00	2.42	20.83
5	5.50	17.75	14.75	18.25	16.92	207.58	0.00	0.25	0.00	0.50	0.25	-	0.75	3.00	3.00	2.75	2.92	288.89
6	13.25	18.50	15.25	13.50	15.75	18.87	0.00	1.00	0.25	1.00	0.75	-	0.25	2.50	2.25	2.50	2.42	866.67
7	5.50	14.25	11.75	6.25	10.75	95.45	0.75	0.00	0.00	0.00	0.00	100.00	1.00	2.25	2.25	2.25	2.25	125.00
8	9.75	12.50	11.75	10.50	11.58	18.80	0.25	0.00	0.00	0.25	0.08	-66.67	2.75	3.50	5.25	3.00	3.92	42.42
9	7.25	14.50	13.75	16.75	15.00	106.90	0.25	1.00	0.00	0.25	0.42	66.67	1.00	6.75	1.25	5.50	4.50	350.00
10	16.50	16.50	10.25	11.75	12.83	-22.22	0.25	1.25	0.00	0.25	0.50	100.00	0.75	3.50	2.00	3.25	2.92	288.89
11	6.00	17.00	8.75	10.25	12.00	100.00	0.00	1.25	0.50	0.75	0.83	-	2.50	3.75	1.75	2.00	2.50	0.00
12	9.75	18.00	9.00	14.50	13.83	41.88	0.00	0.25	0.00	1.00	0.42	-	1.75	5.75	4.25	2.75	4.25	142.86

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Fig. 1. Percent reduction in eggs and mobile stages of *T. urticae* in different treatments compared to untreated control after two spray applications.

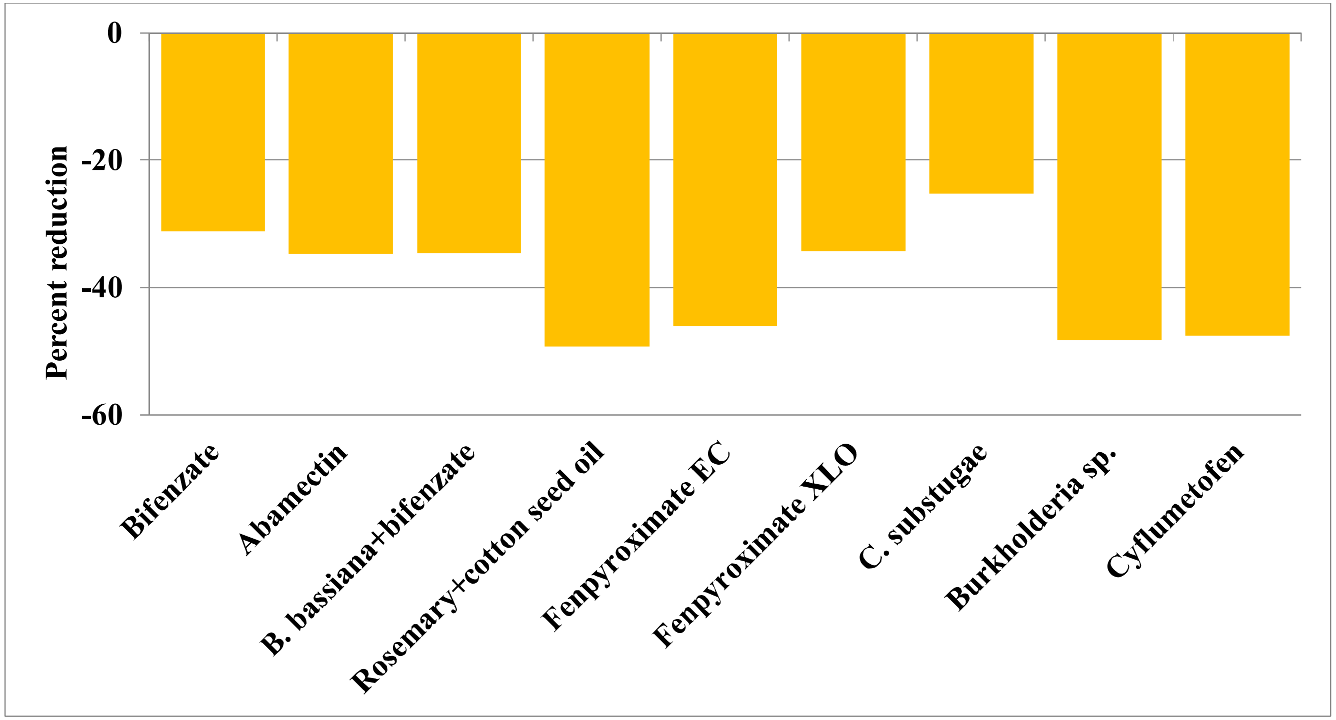

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Fig. 2. Percent change in nymphs and adult *L. hesperus* numbers in different treatments after three treatments.