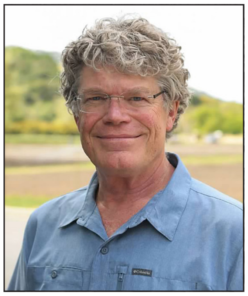
Assessing quality of Predatory Mites for Augmentative Biological Control in California Strawberries



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Summary

The overall goal of this study was to assess the quantity and quality of commercially produced predatory mites that California growers purchase and apply to their strawberry fields. Releasing predatory mites to control spider mites in strawberry is a relatively common practice, thus, it is important that these predatory mites arrive in amounts specified on the package label, are in good condition, survive and are capable of reproducing. Results from this study illustrated several points including that frequently, our estimates of numbers of live predator mites in containers were generally lower than was specified on container labels, that some containers contained large numbers of dead predator mites and that mites in some containers arrived in a stressed condition. We also observed that as the study progressed, it became more difficult to find large gravid female *Phytoseiulus persimilis*, which start to lay eggs soon after being provisioned with two-spotted spider mite prey. The reduced abundance of predator mites in containers and lack of early egg laying could negatively impact population establishment. A suggestion for the future would be to continue assessing the quantity and quality of predatory mites by developing a time-saving and cost effective procedure; maybe as a fee for service at the Cal Poly Strawberry Center or a small business start-up. Also, it is important to provide feedback to the distributors to enhance their quality control programs.

Introduction

Various mites attack strawberry plants including two-spotted, *Tetranychus urticae* Koch; Lewis, *Eotetranychus lewisi*; strawberry, *Tetranychus turkestani* Ugarov and Nikolski; and carmine, *Tetranychus cinnabarinus* (Boisduval) spider mites (Zalom et al., 2015). They feed on foliage and calyxes which leads to stippling, scaring, and bronzing. Spider mite damage that occurs within two to five months of transplanting can lead to significant yield losses by reducing berry abundance per plant. Managing mites in strawberry can be challenging which is why integrated management of mites is one of five high priority research areas listed in the California Strawberry Commission "Request for New and Continuing Research and Extension / General Support Proposals for 2019".

There are various tactics that growers use to manage mites including chemical, cultural, and biological control (Zalom et al., 2015). Augmentative biological control is a common practice that both conventional and organic strawberry growers use to help manage mites as a component of their integrated pest management (IPM) programs (California Strawberry Commission and California Minor Crops Council 2003). This involves growers purchasing and releasing commercially produced predatory mites. There are several kinds of predatory mites that can be purchased, including *Phytoseiulus persimilis*, *Neoseiulus californicus* and *Neoseiulus fallacis* and growers should be selecting the appropriate predator(s) to release based upon which mite species they are targeting.

Quality control is an important aspect for both producers of commercially reared biological control organisms and end-uses that purchase them (van Lenteren, 2003). Various production factors can impact the quality of these biological control organisms which can lead to changes in behavior, prey consumption, longevity, fertility, and sex-ratios. Problems that occur during shipment can lead to containers of dead or stressed organisms. This study assessed the quality of commercially produced predatory mites that arrived at growers' farms. We obtained shipped containers of predatory mites from growers and assessed their quantity and quality in the laboratory.

The objectives of this study were:

Objective 1. Assess abundance of commercially produced predatory mites shipped in containers to growers.

Objective 2. Assess the quality of these predatory mites in terms of fecundity and survivorship.

Materials and Methods

We obtained containers of commercially produced predatory mites that were shipped to growers and assessed whether the amount of mites received corresponded to the amounts stated on the label. In addition, for most of the samples, we assessed the quality of these mites several ways, including determining survivorship of female mites and how many eggs they laid over a five to six-day period. The California Strawberry Commission (CSC) arranged to collect bottles of mites directly from growers in Watsonville, Santa Maria, and Oxnard-Ventura for use in this study. The bottles were collected from the grower and delivered to Cal Poly on the same day.

The abundance of adult and immature predatory mites in containers of shipped mites were estimated based upon existing protocols (Lopez and Smith, 2016, van Lenteren, 2003) within a couple of hours of receipt of the containers at the Cal Poly Strawberry Center Entomology Laboratory. We determined the abundance of predatory mites using two different methods. When we began the study, we estimated the abundance of predatory mites using Berlese funnels to extract mites from the shipping media (vermiculite). Five 1-gram samples of vermiculite and mites were placed on screens in Berlese funnels. Twelve-watt light bulbs were placed about 5 inches above the samples and yellow sticky cards were placed under the sample to collect the mites that fell through the mesh as they escaped the heat from the lights. After 20 hours, the cards were removed, and the number of adult and immature predator mites were counted under a stereo dissection scope. The containers were weighed upon arrival and when emptied at the end of the study. The average number of mites per unit weight was used to estimate the abundance of mites in each container by multiplying the estimated number of mites per gram by the number of grams of mites plus shipping media per bottle.

Later, we switched to counting mites within the vermiculite shipping media directly. For this, we created a 5-inch diameter ring of liquid soap on a piece of hard black plastic. This soap ring served as a barrier to contain mites. From each bottle of mites received, we measured out five 1-gram samples and placed them one at a time within the soap ring where the number of mites and life-stages were counted. Counting mites directly also allowed us to estimate the number of dead mites in a sample; this was not possible with Berlese extraction.

Adult female survivorship and the average number of eggs laid per female predatory mite were investigated using 20 to 30 large gravid females per container. Individual female predatory mites were placed on a ¾ inch diameter bean leaf disk containing all life-stages of two-spotted spider mites that was placed on top of water-soaked cotton (Hoy and Ouyang, 1986). Surviving predator mites were transferred to fresh leaf disks with two-spotted spider mites if they consumed most of their prey. Survivorship was observed daily. Predatory mite eggs were counted and removed daily for five to six days and average female survivorship and egg abundance over this period was determined.

Results

We assessed 32 containers of predatory mites comprised of 25 samples of *P. persimilis* and seven samples of *N. californicus* (Tables 1-6). Several observations came out of this study. A common finding was that the number of live predatory mites we estimated from the containers was generally lower that what was listed on container labels. The estimated number of predatory mites in each container only exceeded the amount specified on the label three times for *P. persimilis* (Tables 1-3) and four times for *N. californicus* (Tables 4-6). We also observed early in the study, that it was easier to find large, plump gravid female *P. persimilis*, which we assumed contained fertilized eggs, for the survivorship and egg-laying studies. In the later samples, female mites were smaller and less likely to stay on the leaf disk and lay eggs compared with the larger female mites observed in earlier samples. The lack of retention on leaf disks by these smaller female *P. persimilis* prevented us from obtaining survivorship and egg laying data. This caused us to forgo these studies and instead concentrate only on predator mite abundance in the containers.

The switch to counting mites directly in soap-ring arenas allowed us to make two additional observations including estimating the number of dead mites in the bottles and determining that some bottles contained stressed *P. persimilis*. Some bottles contained a lot of dead *P. persimilis*; dead mites were assessed as having recently died (bodies were still soft) versus dead mites that were dried up and "crisp". In some cases, the estimated number of dead mites was significant: sample 20-21 had 1,642 dead mites, sample 20-22 had 2,610 dead, sample 20-23 had 3,054 dead, sample 20-27 had 3,626 dead, and sample 20-29 had 4,437 dead mites.

Stressed *P. persimilis* have a different coloration in their abdomen compared with non-stressed mites. *P. persimilis* that are stressed can have whitish streaks and coloration in their abdomens versus solid coloration in non-stressed mites. The following samples contained noticeable abundance of discolored mites which we characterized as being stressed: samples 20-21, 20-22, 20-23, and samples 20-29 through samples 20-33.

Survival of adult female *P. persimilis* placed on bean leaf disks containing two-spotted spider mites ranged from 0 to 80% during the 5-6 day assessment periods (Tables 1 and 3); 80% survival was the target for good quality predator mites. Surviving female *P. persimilis* laid on average between two to 12 eggs during that 5-6 day period with 10 eggs being the desired quality level. Of the 17 containers of *P. persimilis* that were evaluated for egg production, females from 10 containers met or exceeded the desired egg production level of 10 eggs (Tables 1 and 3).

The estimated abundance of *N. californicus* in the seven containers we examined exceeded the amount specified on the labels four times (Tables 4-6). Three of seven containers of *N. californicus* were assessed for female survival and egg production. Sample 20-24 exceeded the 80% survival level, sample 20-23 was close (78%) and survival was less than optimal in sample 20-15 (Tables 4 and 5). Egg production exceeded the desired level of 7 eggs per female in two of the samples (Table 4) but not in the third sample (Table 5).

Table 1. Assessment of commercially produced *Phytoseiulus persimilis*, Oxnard-Ventura, CA.

Date (2020)	Sample ID	Source	Label abundance	Estimated live mites ± SEM	% Survival	No. eggs produced (5-6 days)
1/14	20-1	E	4,000	3,360 ± 183.0	25	4.0
1/14	20-2	E	4,000	2,583 ± 493.1	40	7.0
1/29	20-7	G	2,000	947 ± 117.2	20	7.0
1/29	20-8	G	2,000	1,011 ± 46.1	75	10.0
1/29	20-9	E	4,000	3,572 ± 437.0	57	10.8
1/29	20-10	E	4,000	3,000 ± 148.0	80	10.0
2/3	20-11	G	2,000	1,041 ± 244.1	50	2.7
2/5	20-12	E	2,000	753 ± 128.2	57	12.0
2/6	20-13	D	4,000	1,504 ± 107.4	80	8.0

Table 1 (cont). Assessment of commercially produced *Phytoseiulus persimilis*, Oxnard-Ventura, CA.

Date (2020)	Sample ID	Source	Label abundance	Estimated live mites ± SEM	% Survival	No. eggs produced (5-6 days)
2/12	20-16	B	5,000	3,190 ± 6.6	71	17.6
2/13	20-17	D	2,000	736 ± 141.2	32	15.0
2/19	20-18	D	2,000	2,277 ± 359.1	55	10.3
2/19	20-19	D	2,000	842 ± 81.0	56	10.8
2/19	20-20	D	2,000	462 ± 93.0	53	12.1
2/24	20-21	D	2,000	1,636 ± 264.9	-	-
2/24	20-22	D	2,000	3,844 ± 140.7	-	-
2/25	20-23	G	2,000	2,113 ± 324.2	-	-

Table 2 Assessment of commercially produced *Phytoseiulus persimilis*, Santa Maria, CA.

Date (2020)	Sample ID	Source	Label abundance	Estimated live mites ± SEM	% Survival	No. eggs produced (5-6 days)
3/4	20-29	D	2,000	1,074 ± 135.3	-	-
3/4	20-30	D	200	73 ± 0	-	-
3/5	20-32	G	2,000	860 ± 96.6	-	-
3/13	20-33	F	4,000	947 ± 187.1	-	-

Table 3. Assessment of commercially produced *Phytoseiulus persimilis*, Watsonville, CA.

Date (2020)	Sample ID	Source	Label abundance	Estimated live mites ± SEM	% Survival	No. eggs produced (5-6 days)
1/29	20-5	D	2,000	3,925± 192.8	50	1.7
1/29	20-6	D	2,000	932 ± 147.7	0	2.7
2/10	20-14	D	2,000	1,067 ± 132.7	24	10.0
2/27	20-27	C	2,000	665 ± 120.7	-	-

Table 4. Assessment of commercially produced *Neoseiulus californicus*, Oxnard-Ventura, CA.

Date (2020)	Sample ID	Source	Label abundance	Estimated live mites ± SEM	% Survival	No. eggs produced (5-6 days)
1/15	20-3	E	25,000	38,143 ± 479.7	78	8.5
1/16	20-4	E	25,000	30,659 ± 210.8	91	9.0

Table 5. Assessment of commercially produced *Neoseiulus californicus*, Santa Maria, CA.

Date (2020)	Sample ID	Source	Label abundance	Estimated live mites ± SEM	% Survival	No. eggs produced (5-6 days)
2/12	20-15	G	2,000	694 ± 75.0	67	4.5

Table 6. Assessment of commercially produced Neoseiulus californicus, Watsonville, CA.

Date (2020)	Sample ID	Source	Label abundance	Estimated live mites ± SEM	% Survival	No. eggs produced (5-6 days)
2/25	20-25	A	2,000	1,101 ± 87.7	-	-
2/25	20-26	A	2,000	1,022 ± 51.2	-	-
2/28	20-28	C	5,000	11,294 ± 1154.6	-	-
3/4	20-31	A	2,000	2,249 ± 229.5	-	-

Discussion

For this study, we assessed containers of predatory mites from seven different distributors. Results show that a majority of containers had fewer live predatory mites than what was specified on the bottle labels. Switching from counting mites extracted from the shipping media using Berlese funnels to counting mites directly as they crawled out of the vermiculite also allowed us to estimate the numbers of dead mites that were present. In some cases, adding the numbers of live and dead predator mites brought the number of mites up to and over the level of mites specified on the label. However, one should assume that the number of mites specified on the label pertains to live mites.

Another finding was that a lot of containers had female *P. persimilis* that appeared younger, i.e., it was difficult to find large, plump gravid females which we assumed were laden with eggs. It was apparent that the larger female *P. persimilis* were more likely to lay eggs and remain on the leaf disks that were provisioned with two-spotted spider mites when compared with smaller (younger?) P. persimilis which tended to run off the bean leaf and not lay eggs. We hypothesize that these younger females were not mated and left to search for a mate. We were not able to test this hypothesis, though. Ideally, one would want to release predatory mites in strawberries that would start to lay eggs soon after placement on the plant rather than releasing unmated females that would instead start searching for mates instead of laying eggs soon after deployment.

We did find that some containers of *P. persimilis* and *N. californicus* did meet or exceed the levels of mites specified on the bottle labels with levels of gravid females that survived and produced eggs at levels that met established quality standards. However, inconsistencies in quantity and quality did exist in samples from most distributors.

A suggestion for the future would be to continue assessing the quantity and quality of predatory mites by developing a time-saving and cost effective procedure; maybe as a fee for service at the Cal Poly Strawberry Center or a small business start-up. Also, it is important to provide feedback to the distributors to enhance their quality control programs.

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