FINAL PROJECT REPORT

Project Title: Best practices for predator releases: lacewings, beetles, and mites

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Other funding sources

Agency Name: WTRC Technology Subcommittee
Amount awarded: $19,000
Notes: For development of application of lacewing eggs in a foam carrier

Budget History: Total $237,530

Item	**Year 1:**	**Year 2:**	**Year 3:**
Salaries	$51,244	$52,125	$53,041
Benefits	$10,621	$10,695	$10,772
Wages	$8,580	$8,923	$9,280
Benefits	$172	$178	$185
Equipment	$0	$0	$0
Supplies	$3,500	$3,500	$3,750
Travel	$3,000	$2,000	$1,500
Plot Fees	$2,000	$2,000	$0
Miscellaneous	$0	$0	$0
Total	$79,117	$79,649	$78,764

OBJECTIVES

1. Interview organic orchardists and managers who have recent experience in predator release and producers and distributors of predators to discover problems associated with releases and supply, and revise research details accordingly.

   Managers of organic production for Zirkle Fruit Co. and Stemilt Growers Inc. were interviewed both in person and by phone to discover common practices their growers used to release predatory beetles, lacewings, and mites. Additional interviews with organic managers and onsite visits to ranches were conducted. Presentations made to interactions with attendees of the Wilbur Ellis organic growers meeting also identified common practices. These interactions showed high variability in practices used by growers. Use of predator release ranged from growers producing their own predator mites and making releases (ZIrkle) to releases of lady beetles when available. Four dominant vendors of lacewings, mites, and beetles were also interviewed by phone. They as well as Dr. Lynn LeBeck, representative of the National Association of Biological Control Producers, provided useful insights into availability issues. One specific problem was great variability in the availability of the Converse ladybeetle because it is a captive of the weather. Growers need it in spring but in some years with high snow pack in California, it cannot be collected. We dropped research on ladybeetles for this reason and general concerns of spread of disease into Washington from beetles in California. This objective is not discussed further.

2. Develop and verify our capacity to differentiate between insectary-reared/released and naturally occurring predators using morphological or molecular traits.

   We found that we can tell <u>Chrysoperla rufilabrus</u>, the lacewing we were releasing, from native lacewings in both larval and adults stages. The convergent ladybeetle requires marking prior to release in order to differentiate them from the local beetles of the same species. Because we dropped work on the beetle, marking studies were not pursued. However, the discovery of two species of <u>Galendromus</u> predator mites in orchards, together with a diversity of other predators mites, became a major part of our research efforts in 2011-12.

3. Make releases of lacewings and lady beetles, or predatory mites on two edges of several aphid-infested or mite-infested orchards and monitor populations of both pests and predators at release sites and non-release sites.

   Releases of predator spider mites were conducted in all three years of the project and results are presented in more detail below. Releases of lacewing eggs were tested in 2010 and 2011 but persistent problems in persistence of eggs on trees lead to redirecting the studies to methods of application. See results and discussion..

4. Conduct field experiments to optimize stages to release, release timing, and test the use of feeding attractants or arrestants to maximize lady beetle and lacewing activity.

   Experimental sprays of lacewing eggs were conducted in experimental settings only to test organic adhesives. <u>Galendromus occidentalis</u> were released in a conventional orchard to test methods of evaluating efficacy of releases. Ladybeetles were not released in the field and feeding attractants were not tested. Significant efforts were devoted to the development of a liquid formulation as a carrier and adhesive for the application of lacewing eggs. Hatch rate studies have continued and the use of foam as a carrier for egg application has been a focus and has been supplemented by funds from WTFRC Technology Subcommittee.

5. Conduct laboratory experiments to compare efficacy of different insectary-reared species on the target pests.

Feeding capacity of purchased Chrysoperla rufilabrus was compared to native Chrysopa nigricornis using both Rosy apple aphid and Woolly apple aphid prey. The feeding capacity at different temperatures were compared in 2011 as this information may be critical for relating efficacy to release numbers in early season releases.

SIGNIFICANT FINDINGS

- ✓ Growers manually apply lacewing eggs glued to on paper pieces, a labor-intensive approach.
- ✓ Only Beneficial Insectary Inc. produces *C. rufilabrus,* all others are resellers.
- ✓ Hibernating ladybeetles collected in spring or fall and cold-stored vary greatly in quality and may be unavailable in early spring.
- ✓ Pesticide residues prevented predator mite establishment in field studies.
- ✓ Honeydew and waxes produced by Woolly apple aphid kill many small green lacewing larvae
- ✓ Purchased *C. rufilabrus* shows feeding capacity similar to native *C. nigricornis*.
- ✓ *C. rufilabrus* will hatch at temperatures corresponding to late March.
- ✓ Moe than 50% of lacewing eggs sprayed onto trees in a liquid carriers are lost on impact
- ✓ Large release experiments of both lacewing eggs (2011) and mites (2010-2012) showed no increase in predators and in the case of lacewing eggs, no released *C. rufilabris* were recovered.
- ✓ The dominant predator mite found in 5 orchards was *Amblydromella caudiglans* – a big surprise.
- ✓ We conclude there is little evidence supporting release of predator mites in apples and lacewing releases still need technological improvement to apply the eggs.

RESULTS & DISCUSSION

Objective 1 - Grower practices and needs

Organic managers for Zirkle and Stemilt outlined standard practices on the ranches they manage. Lacewings were released as eggs glued to strips of paper, which are hung in the canopy by workers on trailers. Mites mixed with corncob grit were dispersed into trees with a pollen blower or placed into the crotch of trees on infested bean plants. Ladybeetles were released in paper bags or boxes placed in orchard typically at night and after orchard irrigation. Both companies agreed there was a need to improve release methods and to evaluate efficacy of the releases.

Four insectary managers were interviewed and two (Rincon Vitova; Beneficial Insectary) were particularly helpful in providing potentially proprietary information and providing beetles and lacewings at cost. From these interviews, we discovered that the availability of ladybeetles is at the mercy of the weather. In wet years (La Niña), the mountain overwintering sites of Convergent ladybeetle may be inaccessible due to snow pack well into early or mid-summer. During wet winters, beetles for spring releases are likely to be those collected in the previous spring or summer. In warm, dry years, beetles may be collected in both fall and late winter. The time of collection and time in storage will affect beetles energy stores (fat body) and their capacity to both fly and rapidly produce eggs after release. Figure 1 depicts differences in beetles collected in spring of 2009 and received in May of 2010 (10 months cold storage) and those collected in late June and received in August (2 months storage).

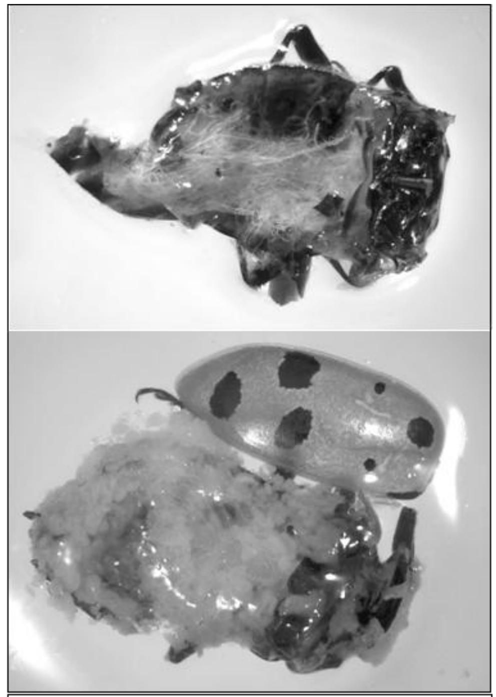

Figure 1. Convergent ladybeetle stored for 10 months (top) and for 2 months (bottom). Fat body completely obscures the strings of tracheae in beetle on bottom.

Objective 2. Differentiating species

Lacewings **-** Early in year 1 we found we could morphologically differentiate with some difficulty released *Chrysoperla rufilabrus* from endemic *C. plorabunda* as both adults and larvae and we could easily identify the abundant *Chrysopa nigricornis.*

Ladybeetles **-** Our plans to use protein marking to differentiate local *Hippodamia convergens* from released individuals were dropped when we found this species to be of unreliable quality in year 1 and unavailable in year 2. (See Objective 1)

Predator mites **-** We were able to identify phytoseiid females to species by slide-mounting mites in modified Berlese medium. Samples of 100 leaves were collected from different orchards or native plants throughout eastern Washington. These samples include apple, cherry, and wild blackberry leaves. Samples were taken from mid-June to early September. All phytoseiid mites were removed individually from the leaves using a paintbrush. The date, location, GPS coordinates, prey species available, and crop or plant species of the sample site were recorded. Identifications are in the process of being confirmed by Prof. James McMurtry (U.C. Riverside, emeritus).

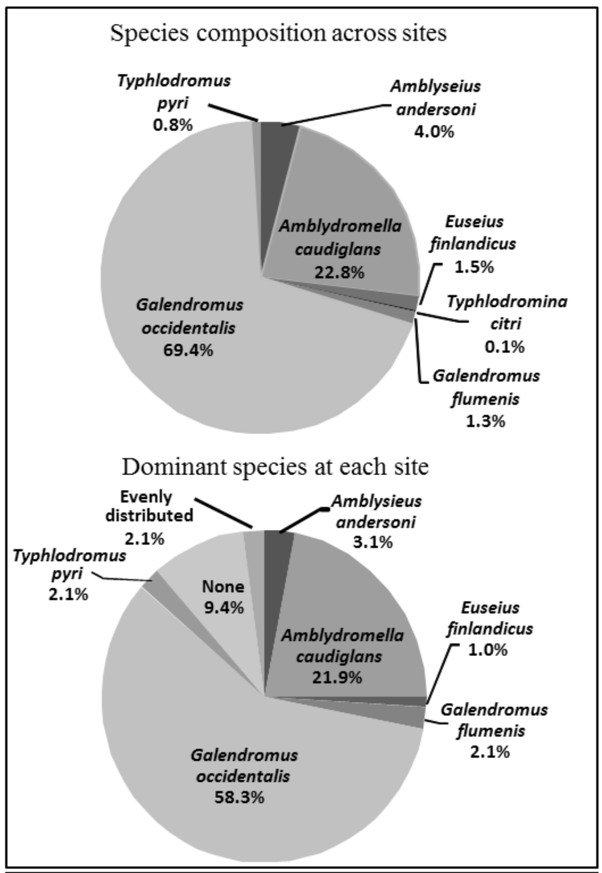

Figure 2. Phytoseiid species composition and dominance.

Seven species of phytoseiids have been identified from surveyed locations to date: *Amblydromella caudiglans, Amblyseius andersoni, Euseius finlandicus, Galendromus flumenis, Galendromus occidentalis, Typhlodromina citri,* and *Typhlodromus pyri*. The majority of the individuals found were *G. occidentalis,* but *A. caudiglans* was also present in significant numbers (Figure 2, top panel). Although *G. occidentalis* was also the dominant predator in the majority of sites, *A. caudiglans* was dominant at over 20% of the sites surveyed (Figure 2, bottom panel). The frequent occurrence of *A. caudiglans* was unexpected based on prior assumptions. However, it is possible that a shift in insect control programs, especially those for codling moth, could have resulted in the partial or complete replacement of *G. occidentalis* by *A. caudiglans*. *Galendromus occidentalis* has historically been shown to be highly resistant to pesticides (especially organophosphates or OPs) compared to other phytoseiid species. Implementation of softer programs could provide the impetus for the change in phytoseiid species composition. Additionally, European red mite (*Panonychus ulmi*) has replaced the McDaniel mite (*Tetranychus mcdanieli*) as the common outbreak pest-mite species in Washington apple orchards. While spider mites that spin copious webbing, like the McDaniel mite, are the preferred prey of *G. occidentalis, A. caudiglans* has difficulty moving through webbing and prefers spider mites such as *P. ulmi* that produce little webbing. Therefore, the transition to a new predominant pest mite species may have facilitated the increase in *A. caudiglans*.

Further research on *A. caudiglans* will facilitate the understanding of the role of this predator in our integrated mite management (IMM) programs. More selective pesticide use may promote the conservation of *A. caudiglans* as well as *G. occidentalis* reduce pest mite outbreaks. As a more generalized predator, *A. caudiglans* may be more efficient than *G. occidentalis* at maintaining higher densities because of its more omnivorous diet and thereby more reliably suppress pest mite populations, especially *P. ulmi*, below outbreak levels.

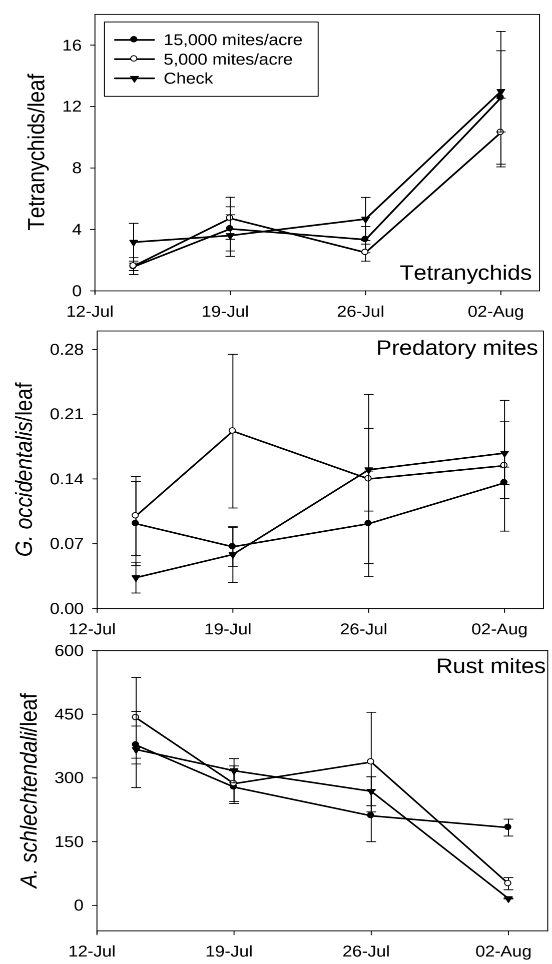

Figure 3. Mite densities in the 2010 releases.

Objective 3/4. **Releases in grower orchards**

Predator mites – *Methods:* In years 1 and 2, Western predatory mites, *Galendromus occidentalis* (Typhs) from the Sterling Insectary insectary were released in a mature blocks of 'Red Delicious' apples at a commercial orchard near Pasco, WA. Six plots of 9 trees per treatment. In year 1, predators were deployed onto the central release trees on 14 July at rates of 0, 5,000, and 15,000 mites/acre (= 0, 12, and 36 mites/tree). Adult female *G. occidentalis* were placed onto a bean leaf, and attached to the tree with a binder clip.

Higher release rates of 0, 15,000 and 50,000 predators/acre were used in year 2. This was done by placing an appropriate fraction of the leaf material from the insectary on each tree (0, 1, and 2.5 plant stems, respectively).

In year 3, mites were released in a mature block of mixed 'Red Delicious' and 'Golden Delicious' near Mattawa, WA. In this case, the effects of early (pest threshold of ~0.5 tetranychids/leaf) and late (three weeks later) releases were tested by releasing at a rate of 15,000 predators/acre or no release.

In year 1, the abundance of predator and prey mites were assessed first by visual counts in the field using OptiVisors and consisting of 15 leaves per tree without detaching the leaves. Only motile stages of

Tetranychus urticae, Panonychus ulmi, and *G. occidentalis* were counted. Second, we took five leaves from each of the four trees on the diagonal from the release tree standard and this 20-leaf sample was brushed onto sticky plates using a leaf-brushing machine. All stages of *T. urticae, P. ulmi, G. occidentalis, Aculus schlechtendali*, and *Zetzellia mali* were counted under a dissecting scope. On the final sampling date, *in situ* counts and leaf brush counts were made on the 9 sample trees, allowing us to compare the two sampling methods. In years 2 and 3, only brush counts were used to assess mite populations. Additionally, in these years, releases were performed on all trees within a treatment and a random sample of 100 leaves was taken from each replicate.

Each year, leaves from the release blocks were bio-assayed to determine if pesticide residues on the leaves affected the survival, fecundity of the commercially reared *G. occidentalis*. Release orchard leaves were compared to those from an untreated research orchard at WSU-TFREC. Leaf disks (2 cm diam) free of arthropods were placed on water-saturated cotton in small cups. Twenty female *T. urticae* were added to each leaf disk and allowed to oviposit for 24 h. After a sufficient number of eggs had been laid on each disk to provide the predators with food for the duration of the experiment, the *T. urticae* females were removed. One female *G. occidentalis* was placed onto each leaf disk. The bioassay was evaluated at 24 and 48 h for female mortality and fecundity. *G. occidentalis* females were removed after 48 h, and the position of each egg was marked with a felt-tip pen. On the fourth day after female removal, the number and status of eggs and larvae of *G. occidentalis* were counted.

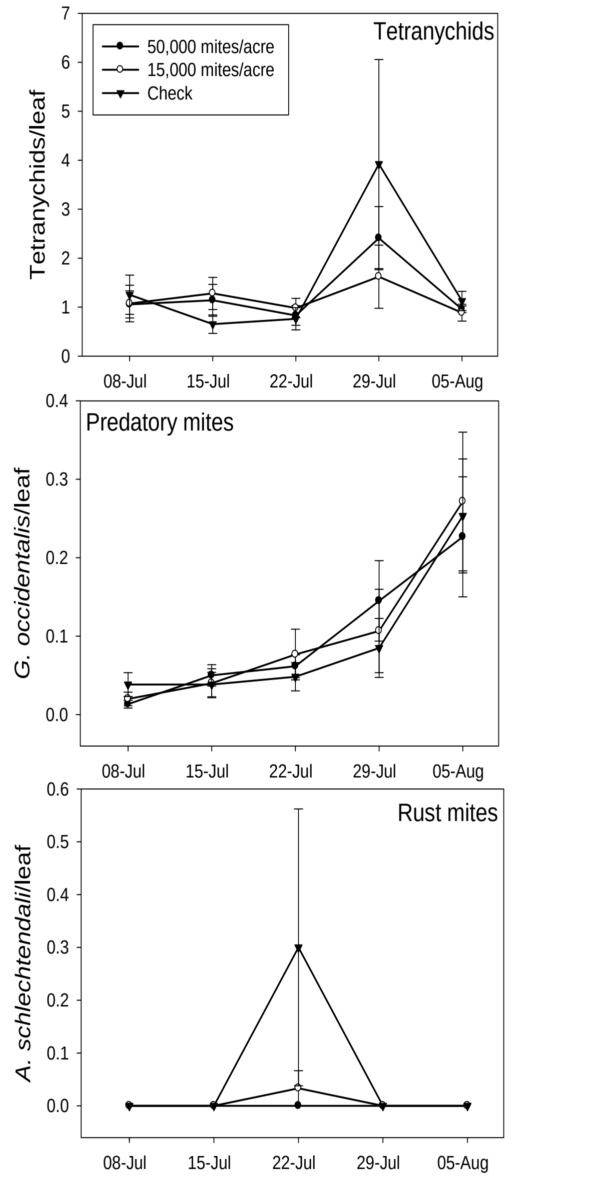

Figure 4. Mite densities in the 2011 releases.

<u>*Results:*</u> In year 1, counts of spider and rust mite were low at the time of predator release in mid-July. *Panonychus ulmi* was the dominant phytophagous mite species and it increased during the test despite an application of Zeal on May 24. Rust mite populations were moderate initially, but declined during July. There were no statistical differences between treatment means for any mite species or group on any date (Figure 3, above). These findings provide no evidence that the released predators became established or had any effect on pest mites. Similar results were found for years 2 and 3.

In year 2, *P. ulmi* was the dominant phytophagous mite species. Rust mite populations remained low throughout the sampling period. *Galendromus occidentalis* populations increased throughout the sampling period, but there were no differences in predator density between the three treatments (Figure4). There were also no differences in prey mite densities between the three treatments.

In year 3, *Tetranychus urticae* was the dominant phytophagous mite species. All phytophagous mite populations were low prior to releases. There were no differences between treatments in any of the mite species sampled (Figure 5). A comparison could not be made between the early and late releases because sprays of Epi-Mek, Envidor, and oil were used to control the rising phytophagous mite populations. No post-release sample was collected for the later release. The *in situ* optiVisor mite counts (not shown) had consistently lower numbers than the leaf brush counts.

In situ P. ulmi counts had the best correlation with leaf brush counts, likely because their red color differentiated them from the leaf color. We had hoped the non-destructive *in-situ* samples would work but our inability to count all stages of *G. occidentalis* precludes this method. Because of these results, *in situ* counts were not used to monitor mite populations in years 2 and 3. In year 1, leaves from the sprayed grower block and those from the untreated block were similar in effects on mortality and fecundity of the insectary-reared *G. occidentalis* (not shown). However, there was significantly poorer egg hatch and numbers of live larvae on the leaves from the release plots, indicating some residues present on the leaves were sublethally toxic to the predators (Figure 6). Of the materials applied to the release block both carbaryl and thiacloprid are known to have some level of toxicity to predators, although it seems unlikely that the toxic effect could have persisted for several months. The effects of other materials applied (emamectin benzoate, etoxazole, trifloxystrobin, and *Bacillus thuringiensis*) are not known. In years 2 and 3, bioassays of the release site leaves did not negatively affect *G. occidentalis* mortality, fecundity, egg hatch, or larval survival (not shown).In all three years, releases of predatory mites failed to increase predator populations or decrease phytophagous mite populations in release areas. Pesticide applications toxic to *G. occidentalis* are attributed to the lack of success in year 1. However, in years 2 and 3, the leaves did not have toxic residues, thus other factors must be responsible. Another possibility for the lack of success is the predator:prey ratio established by releases. Insectary recommendations suggested 5,000 mites per acre early in the season and 15,000 mites per acre to control outbreaks. However, even at 50,000 mites per acre, we failed to see predator or pest population effects.

Calculations were performed to determine the theoretical release rate needed to control a *P. ulmi* population of 3 mites per leaf. This value was chosen because at these levels, mite populations are noticeable but not damaging. Latham and Mills (2010) developed a method for calculating predator:prey ratios by using the following model: $N_{t+1} = N_t e^{rt} + gP/r(1 - e^{rt})$, where N_t and N_{t+1} represent prey population sizes at consecutive sampling dates, r is the growth rate of the prey, g is the

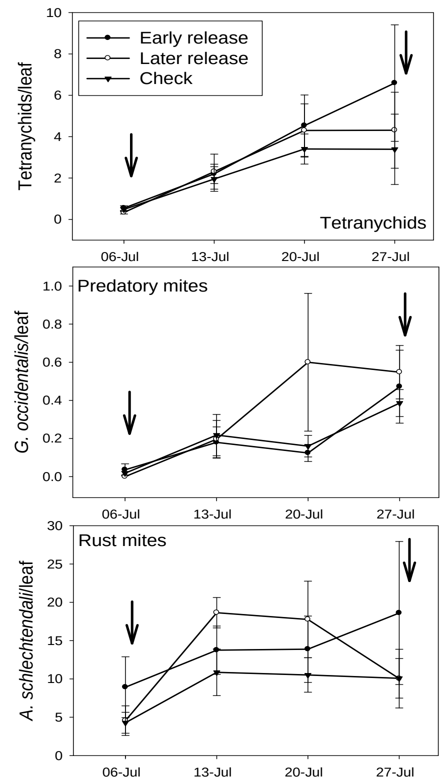

Figure 5. Mite densities in the 2012 releases; arrows indicate release dates

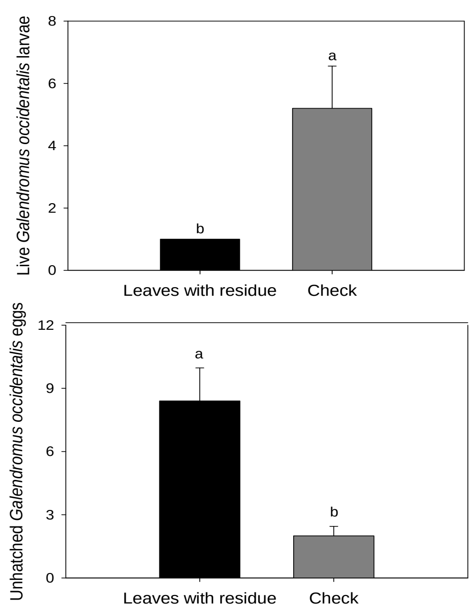

Figure 6. Effects of leaf residues on *G. occidentalis*, 2010.

daily per capita consumption capacity of the predator and P is the predator density. If N_t is assumed to be zero, this can be rearranged to $P=rN_{t+1}/g$. When N_t is given the value of 3 (mites per leaf), P can be calculated using known values of g (1.97, Lee and Davis 1968) and r. A value for r (0.122) was calculated using life table information for *P. ulmi* provided by Herbert (1981) and the PopTools application for Excel. This gives P=0.186 or a ratio of 1 predator to 16.1 prey per leaf. When a conservative estimate of leaves per tree and trees per acre was obtained using information taken from Wunsche and Palmer (1997) and Ferree and Barden (1971), this ratio requires nearly 400,000 predators per acre to control 3 *P. ulmi* per leaf, at an estimated cost of $6,000 per acre. These calculations indicate that apple canopy volume is sufficiently large to make predator releases economically unfeasible. The success of releases in other cropping systems, such as strawberry, is likely in part due to much smaller leaf canopy volume.

The results of our releases, as well as our predator:prey ratio calculations, indicate that inundative releases of predatory mites are not a cost-effective solution to controlling pest mite populations in apples. An inoculative release may help speed re-establishment of a decimated predator population, but it should be combined with a long-term strategy of predator conservation through selective pesticide use. Non-target effects of new pesticides should be evaluated for effects on pest and predatory mites. This is especially relevant in light of our discovery of large populations of *A. caudiglans* in Washington apple orchards. If current IMM programs can be adapted to conserve all common mite predators, we may see better control of pest mite species in the future.

Lacewings: In an experiment conducted in early November, hatch rates of lacewing eggs were observed in natural field temperatures (in ventilated white boxes). This timing was chosen because it closely mimics temperatures experienced in mid-March (Figure 7), the time of year at which releases are made. Insectary-purchased eggs were placed in an 8C incubator and a group of 200-250 eggs was placed out of doors on 7 consecutive days and hatch rates followed in relation to daily temperature. Figure 6 shows patterns for the eggs placed outside on the first 3 days after 1, 2, or 3 days of pre-incubation at 8C. The results show that after a delay of 3 days eggs hatch occurs synchronously with almost 50% hatch on the third day in the field. Hatch on subsequent days was more influenced by temperature patterns, with no hatch on November 9 due to low daytime temperatures. These results are positive, and show that *C. rufilabris* is likely to survive early spring temperatures.

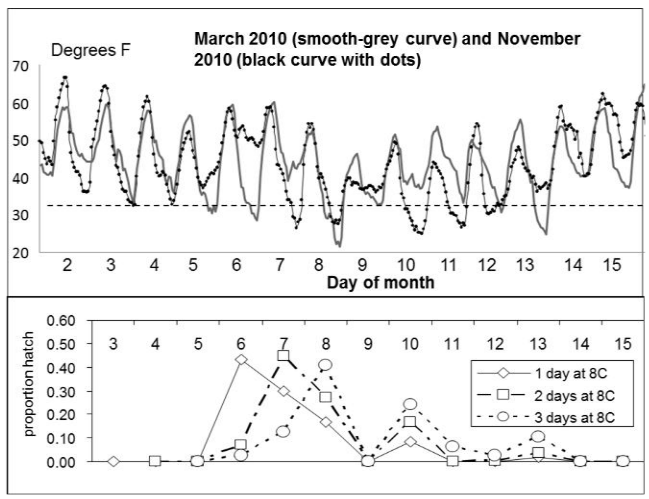

Figure 7. Pattern of lacewing egg hatch 1, 2, or 3 days after cold adaptation in Percival (46.4 F) outside in November temperatures

Lacewing eggs were released in an organic cherry and apple orchards. With large cherry trees, plots consisted of 7 adjacent trees in a row and 3 plots were created in each row. Treatment levels were 0, 7000, and 14000 *C. rufilabris* eggs and the three treatments were replicated in 6 rows. A similar design was used in small trellised apples but plots consisted of 29 trees. Again, the 3 treatment plots were placed in a single row with random assignment of 0, 7000, 14000 eggs/plot and 6 replicates. Pre-samples were 1) visual counts of rolled leaf colonies on each tree in the cherries and over whole plots in the apples, and 2) in cherries, 35 aphid colonies were removed from each plot, typically at 5 colonies per tree. In apple plots, 54 colonies were removed per plot. Colonies were placed in Berlese funnels to drive aphids and predators into a salt/soap bath to facilitate counts of predators. The same procedure to detect released predators was used 8 and 10 days after releases in cherries and apples. Guar gum (0.04% was used as a sticker because it is organically approved for application in the field. ***Results:*** No *C. rufilabris* were detected in either study on any date indicating the need for a better sticker method and sent us back to the drawing board. These results were a surprise because we did have better evidence of egg adhesion in small studies at the Moxee Farm. From this failure, we moved to studies of the use of foam solutions to assist egg retention to trees. We have developed foaming agent that do cause eggs to adhere to foliage and tree bark. A significant portion of studies developing this foam was supported by additional funding from the WTFRC Technology subcommittee. Results from these efforts will be present orally.

Objective 5 – Feeding studies of insectary and native predators

We assessed whether insectary-purchased green lacewings (*Chrysoperla rufilabris*) fed and survived on a diet of two target pests, rosy apple aphid and woolly apple aphid. **<u>Rosy apple aphid</u>.** Our first study examined development time and survival (from egg hatch to pupation or adult emergence) of *C. rufilabris* and a resident lacewing, *Chrysopa nigricornis*. Eggs of *C. rufilabris* (purchased) and *C. nigricornis* (field-collected) were allowed to hatch in the laboratory. Newly hatched larvae were moved immediately into snap petri dishes, and fed *ad libitum* upon a diet of field-collected rosy apple aphid (plus a small section of apple leaf). We recorded survival, days to pupation, and days to emergence (at 22 ^{o}C). *<u>Results</u>*: The insectary-reared species developed and survived well on rosy apple aphid (Figure 8). Development of *C. rufilabris* was slightly more rapid than that shown by the native species (Figure 8; upper panel), likely due to size differences between the two species. Survival rates were very high for both species (Figure 8; lower panel).

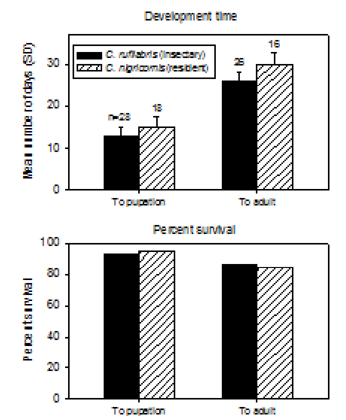

Figure 8. Upper panel: Development time (days) to pupation or adult emergence of *C. rufilabris* or *C. nigricornis* on a diet of rosy apple aphid; bottom panel: survival of both species on diet of rosy apple aphid.

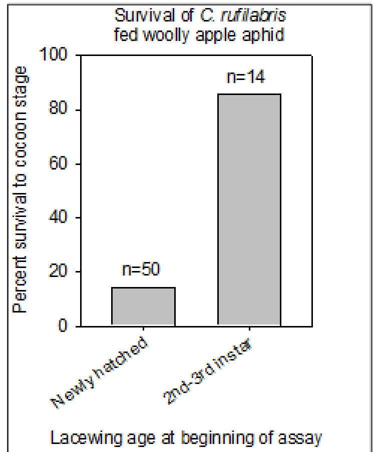

Figure 9. Survival of newly hatched or later instar *C. rufilabris* on diet of woolly apple aphid.

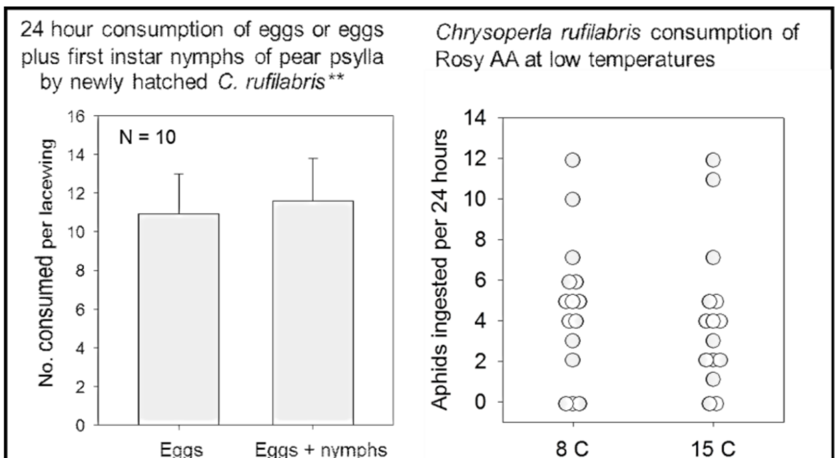

Figure 10. Feeding capacities of insectary produced neonates lacewings on pear psylla at room temperature and Rosy apple aphid at 8C (46.4 F) and 12 C (59 F)

<u>Woolly apple aphid.</u> Our second study explored survival of the insectary-reared lacewing (*C. rufilabris*) on a diet of field-collected woolly apple aphid. In this study, we also explored how age of lacewing larvae affected survival, due to early observations suggesting large differences in success of small and large larvae on a diet of this aphid (see below). Methods were similar to those used in the trial with rosy apple aphid, except that *C. nigricornis* was not included for comparison (we could not find *C. nigricornis* eggs in the field). *<u>Results</u>:* We found that newly hatched lacewings survived very poorly on a diet of woolly apple aphid (Figure 9), unlike what occurred in the previous study on a diet of rosy apple aphid (Figure 9 lower panel).

We discovered that mouthparts of newly hatched lacewings regularly became stuck in the aphid's waxy honeydew as the lacewing attempted to feed (not shown); over 80% of observed mortality was attributed to this honeydew factor. Conversely, large lacewing larvae (2nd and 3rd instars) were considerably more successful than newly hatched larvae, and showed excellent survival. Consumption rates of large larvae reached almost 25 aphids per day. These results suggest that releases of eggs or newly hatched larvae of lacewings may not be successful against woolly apple aphid, unless an alternative prey for hatchlings are also present in the trees.

Chrysopa rufilabris fed readily on Rosy apple aphid in reduced temperatures corresponding to conditions that would be experienced under typical early spring field releases (Figure 10). Neonates readily consumed pear psylla, which is of interest to Beneficial Insectary as a potential expansion of the market (Figure 10). Our conclusions from these studies are that *C rufilabris* is well fitted for release in both early spring and potential in late fall.

EXECUTIVE SUMMARY

Project Title: Best practices for predator releases: lacewings, beetles, and mites
Participants: Tom Unruh and Dave Horton USDA-ARS, Elizabeth Beers, WSU
Budget: $237,530 over 3 years.

OVERVIEW

The objectives of this research were to determine the needs of the grower community for better approaches to augmentative releases of beneficial insects for pest control. We found that almost 60% of organic growers use these practices and most of those that do would like to know if they are of value and if the process can be improved. Our conclusions from the studies described are that mite and ladybeetle releases are probably unwarranted. However, application of lacewing eggs appears to be a technological problem that may be close to solution. Also, during our studies of the mite predators in our orchards we encountered a much higher diversity of predator mite species that my underpin and much more stable form of biological control of spider mites in apple, warranting significantly more research

Species studied: We evaluated the three naturally enemy groups growers commonly released: the convergent ladybeetle, *Hippodamia convergens*, the green lacewing, *Chrysoperla rufilabris*, and the predator mite, *Galendromus occidentalis*. After the first year of studies, we dropped efforts on releases of the ladybeetle because of high variability of quality and unreliable availability of this species because it is harvested from the wild and is not always available or is in poor condition. In contrast, the predator mite and the lacewing are reared in insectaries.

Release studies: The predator mite predator, *G. occidentalis*, was experimentally released each year, but these experiments provided no evidence for the value of the releases. Two reasons were identified for this: first, the presence of pesticide residues prevented mite development in year 1; second, high abundance of predators in test orchards in years 2 and 3 caused releases to be of no value. These studies support one conclusion in the mite studies that there are no justifications for predator mite augmentation in the summer when spider mites can become abundant. However, we do not eliminate the possible value of early season inoculations of predator mites in orchards with chronic problems and free of insecticides. Releases of lacewings similarly provided no success but one reason alone seems responsible for this failure. Lacewing eggs applied in water solutions con do not readily stick on trees, with more that 60% loss on contact and additional loss over the day or two prior to hatch. However, due to additional funding by the WTFRC Technology Subcommittee this issue may be resolved in the near future.

Positive Discoveries: Washington apple orchards support a larger diversity of predatory mites that previously know and the second most abundant species, *Galendromus caudiglans*, is a more generalist species than is *G. occidentalis*. Its omnivorous eating habits (pollen and molds) make it more likely to persist at higher densities in the absence of a large number mite prey. There is a suggestion that they may be a superior predator in soft pesticide programs.

Studies of the lacewing, *C. rufilabris* show it to be capable of hatching very early in season (March temperatures) prior to bud break and before Rosy or Green apple aphids hatch; this augers well for early season releases (or autumn release). Similarly, laboratory studies show that the lacewing can consume aphids in relatively low temperatures that occur in that season. Finally, ongoing studies using foam for application of the lacewing eggs on tree trunks are highly promising.

Conclusion: We believe that studies of the predator mite complex in apple can provide useful insights into a biological control oriented management system. This is especially true with new, more selective approaches being used for key pests. Early and late season releases of releases of lacewing eggs still remains a potential approach to improving spring aphid control, particularly in organic production.