FINAL REPORT
WTFRC Project #AE-03-330 **WSU Project #13C-3643-3386**

Project title: Biology, migration, and management of western flower thrips in apple orchards
PI: Elizabeth H. Beers, Entomologist

Organization: WSU Tree Fruit Research and Extension Center, Wenatchee, WA

Co-PIs and affiliations:
Stephen D. Cockfield, Associate in Research, WSU Tree Fruit Research and Extension Center, Wenatchee, WA
David Horton, Research Entomologist, USDA-ARS, Wapato, WA
Gene Miliczky, Research Associate, USDA-ARS, Wapato, WA
Vince Jones, Associate Entomologist, WSU Tree Fruit Research and Extension Center, Wenatchee, WA
John Dunley, Associate Entomologist, WSU Tree Fruit Research and Extension Center, Wenatchee, WA
Rich Zack, Associate Entomologist, WSU Dept. of Entomology, Pullman, WA

Contract administrators: Mary Lou Bricker (mdesros@wsu.edu), 509-335-7667; Tom Kelly (kellytj@wsu.edu), 509-335-3691; Sally Ray (saray@wsu.edu), 509-663-8181 x221

Objectives:

1. Determine the mobility of thrips in orchards and between orchards and near-orchard habitats.
2. Determine the efficacy of managing alternate hosts in the orchard groundcover during apple blossom for management of the resident WFT population.
3. Determine the period of susceptibility of apple fruit to oviposition injury.

Significant findings:

1. The source of thrips in apple flowers, as revealed with protein markers, depended on the characteristics of a particular block. A block bordered by sagebrush steppe on two sides was influenced by migration from that habitat. A block with a high population of dandelions in the groundcover had more thrips originating from the orchard floor.
2. Although rubidium (Rb) was detected in thrips exposed to the element, not enough was present to mark individual thrips. Rb was therefore not chosen as a marking technique.
3. Populations of thrips in apple flowers were highest on the orchard border next to sagebrush steppe, supporting the hypothesis of significant migration from dry, uncultivated areas into the orchard. There was typically a decrease in density within 30 feet of the border, although some orchards did not show this trend. The overall relationship in thrips density was reflected in thrips fruit damage.
4. A large reduction in dandelion densities led to a small reduction in thrips densities in apple flowers and shoots and no significant reduction in fruit injury.
5. Sampling thrips eggs revealed that very few eggs were laid in fruit during bloom. Most eggs were laid after petal fall. Excluding thrips with cages, an insecticide reduced fruit injury before peak egg lay, in that trial a week after petal fall, after which the treatments were ineffective at reducing damage.

Methods:

1. Contribution of orchard floor and near-orchard uncultivated habitats to WTF populations on apple blossoms.

1a. Distribution of thrips within orchards bordered by sagebrush steppe habitat.
This investigation was done jointly by personnel from WSU-TFREC, Wenatchee, and USDA-ARS, Yakima.[1] Seven orchards from Bridgeport to Moxee were selected for their history of thrips problems and direct proximity to sagebrush steppe habitat. In 2003, all orchards were 'Granny Smith' and had one or more edges bordered by uncultivated land. Broadleaf plants were plentiful in some blocks while others had few weeds. Transects were measured from the edge bordering uncultivated habitat into the center of the orchards. Plant samples were taken along the transects at the orchard border, 100, 200 and 300 ft at four phonological stages (pink, king bloom, full bloom and petal fall). Twenty-five open apple flower clusters and 25 dandelion flowers, if available, were collected at each location and time. Adult and immature thrips were extracted from the samples by washing with soapy water. Bloom phenology was visually estimated at each location. Five blue sticky cards were placed just above the level of ground vegetation and in the lower canopy of the trees. Sticky cards were left in place during bloom, and total adult thrips were counted at petal fall.

In 2004, the number of orchards was increased to eight and the sample locations were increased to six: orchard border, 30, 60, 100, 200, and 300 ft. Samples were taken at the same four phenological stages as above. Twenty-five flower clusters were collected at each sampling location and phenological time. Up to 25 trees were sampled in a broad band at each distance. Thrips were collected and processed as described previously. Ten sticky cards were placed in the native vegetation during bloom to measure the relative population densities of thrips available to migrate.

Data were analyzed as repeated measures using ANOVA with each distance being a repeated measure within orchards. If the distance effect was significant at $P < 0.1$, paired contrasts of adjacent distances (e.g., edge vs. 30 ft) were examined for significant differences. Contrasts were used to determine where the populations ceased to change significantly.

1b. Mark-recapture to determine inter-habitat migration.
Preliminary studies: In 2003, a number of greenhouse studies were conducted to find effective methods of marking thrips in their native habitat with broadcast sprays. The objective was to select methods that could be used in field trials in 2004 and 2005. Two different techniques were tried, common non-arthropod proteins detected with enzyme-linked immunosorbent assay (ELISA) and a rare element, rubidium (Rb), detected with chemical analysis.

Protein markers: Proteins were used as an inexpensive, external insect marker that can be detected by ELISA, an assay technique commonly used in medical diagnosis. In a series of initial studies, three non-toxic protein solutions were used: soy milk (10-20%), egg whites (10%) and cow's milk (15%). Blooming potted plants (sweet alyssum, dandelion, and marigold) in insect cages in the greenhouse were sprayed with protein solutions. Thrips were collected after one week by hanging sticky cards in the cages, and thrips were removed individually from the cards for ELISA. In addition to the potted plants, bouquets of flowers from plants in or near orchards were tested in the greenhouse. Plant species included dandelion, bitterbrush, and arrowleaf balsamroot. The flower bouquets were artificially infested with thrips from the greenhouse colony, then sprayed with protein solutions. Thrips were collected as for the potted plants.

[1] Dr. Dave Horton and Gene Miliczky, USDA-ARS, Yakima Research Lab, Wapato, WA.

In a field trial, a sagebrush plant was sprayed with 10% egg whites in the fall to determine the success of the marker under field conditions. Thrips were again collected with sticky cards and tested for the presence of the protein marker with ELISA. Negative control samples of thrips were collected from naturally occurring field populations remote from the sprayed site.

Rubidium: In the second technique, rubidium chloride (RbCl) was applied to plants in a 500-ppm solution. Rb is incorporated into plant or insect tissues in place of potassium and becomes a permanent, internal marker that can be detected with atomic absorption spectrophotometry. Rb can also be acquired by a insect by feeding on an Rb-marked plant. RbCl was soil-applied to potted, greenhouse-grown dandelion and marigold plants that were infested with thrips. A composite sample of about 30 thrips was assayed at each sample date to determine the level of Rb marking. Thrips were sampled 1, 3, and 7 d, then weekly for 6 wk to determine the longevity of the mark.

Mark-recapture field trials with protein markers

Orondo site, 2004: This experiment was conducted in a 13-yr-old 'Granny Smith' planting of approximately 0.7 acres near Orondo, WA. The site is bordered by an extensive area of native vegetation on the east and north sides. The south side is bordered by a road and a cherry orchard, and to the west is a larger apple block. An area of 0.5 acres of native habitat was tagged adjacent to the orchard, extending approximately 50 m from the orchard border.

At pink (9 April), the tagged area in the native vegetation was sprayed with a high volume (400 gpa) of 17.5% milk solution with a handgun sprayer. The orchard drive row and weed-spray strip areas were sprayed with a 10% egg white solution at 286 gpa using a small boom sprayer. The volume used was sufficient to wet the soil, in addition to covering the vegetation. The protein spray applications were repeated at king bloom (13 April). Although the egg white concentration was not changed, the milk concentration was increased to 32.5%. Flower samples were taken after each spray as soon as the spray had dried. Flowers of four arrowleaf balsamroot plants in the native vegetation and four dandelion plants in the orchard were immediately frozen with dry ice to collect thrips. Samples of the solution in the tank were taken at each spray application timing.

A third sample of flowers of various plant species, including apple, was taken when the orchard was in full bloom (16 April). One hundred apple flowers were collected from each of six locations in the orchard. Dandelion flowers from the orchard floor were collected at the same locations as the apple flowers. Balsamroot flowers were collected from the native vegetation. Thrips samples were immediately frozen with dry ice. Negative control samples were collected from balsamroot flowers two miles from the test plot. Protective clothing was worn during spray applications and sample collections to prevent cross-contamination of the plots.

Orondo site, 2005: The experiment was repeated at the same site described above. Slight changes to the protocol included the addition of EDTA (7 fl oz/50 gal) to the spray water to improve longevity of the proteins and the substitution of 20% soy milk for cow's milk for the application to the native vegetation. Also, an additional 5 gal of the soy solution was applied with a small mist sprayer to individual flowers to increase the percentage of thrips marked. Egg white solution was applied to the orchard floor as above. Flower samples were taken at pink (11 April), king bloom (19 April) and full bloom (25 April) and processed as described above.

Bridgeport site, 2005: This site was located on a commercial orchard near Bridgeport which bordered sagebrush steppe habitat and had a very high dandelion population in the groundcover. A square area of 0.5 acres from the 4-acre block was selected for the experiment. An area in the adjacent sagebrush steppe measuring 0.35 acres was marked. The native vegetation had arrowleaf balsamroot, lupine and phlox in addition to sagebrush.

The protocol for this site was similar to the Orondo 2005 site. Spray applications were made at pink (15 April) and king bloom (22 April). Flower samples were taken at these dates and also at full bloom (26 April).

In late May, the dandelion density was estimated at the Orondo and Bridgeport sites. A 1-m square frame was placed randomly in the row middles of the experimental blocks and the number of dandelion plants counted. Dandelions were measured in 2 locations (at least 15 m apart) in each of the 8 drive rows (total of 16 samples).

ELISA analysis of thrips: All flowers were examined under a microscope and thrips were collected on a toothpick with a tiny drop of adhesive (Stickum Special™, Seabright Industries, Emeryville, CA). Each insect was placed in the bottom of a 1.5 ml microcentrifuge vial. Thrips in vials were washed with a buffer solution which put the marker in solution. This solution was placed in a tray of wells lined with a polymer which binds the egg, soy, or milk proteins. After these proteins are bound, the remaining surface of the well was filled with a neutral protein (bovine albumen). Next, the primary antibody was added: rabbit anti-chicken albumen for egg white; rabbit anti-casein for cow's milk; and rabbit anti-soy for soy milk. Then the secondary antibody (donkey anti-rabbit) was added to bind with the free end of the protein chain. Color was formed by the addition of a substrate reacting with the secondary antibody. Color was detected with spectrophotometry. Color greater than a certain intensity was declared positive for the marker. The original buffer solution was tested for all proteins sprayed at a given site.

2. Management of resident WFT populations by reducing alternate hosts in the orchard:
Four Central Washington orchards with a history of thrips problems were selected for inclusion in this experiment. Unlike the orchards used for the protein marker studies, the orchards in this study were not adjacent to native vegetation. The orchards consisted primarily of the cultivar 'Braeburn' in Quincy, Pateros and Brewster, and 'Granny Smith' in Bridgeport. Each orchard was approximately 5-10 acres. The orchard floor of one-half of each block received regular full-coverage broadleaf herbicide treatments, as well as spot treatments, to reduce the weed density. Both halves received full-spectrum herbicides (broadleaf and grasses) in the herbicide strips beneath the trees, as per the grower's normal management practices. The plots were managed and sampled for three years. At approximately 3-5 m intervals, ten 1-m square areas were randomly selected and marked in the center drive row of each treatment block. Flowering and non-flowering dandelion plants were counted in these areas to estimate dandelion density. Estimates were made monthly from April through November. In addition, dandelion plants (four flowering and four non-flowering) were collected monthly from random locations in the row middles to estimate thrips densities. In May 2003 and 2004, during full bloom but before insecticide applications were made, 25 individual open apple blossoms were selected from each of eight trees within the middle row. In 2005, due to low thrips populations, the number of flowers from each tree was increased to 300 at Bridgeport and 150 at all other sites. In June, July and August, 10 vegetative shoot tips were collected from each of eight trees. Plant tissue samples were washed with soapy water to dislodge adult and immature thrips. Specimens were slide-mounted for identification. Fruit injury was assessed in the summer by examining 500-1000 fruit *in situ* in the center row of each block. Data for thrips and dandelions were analyzed by date using ANOVA, followed by an LSD test for weedy and herbicide-treated plots. Data for proportion (p) of fruit with pansy spot injury were first transformed by arcsine(square root(p+0.001)), then analyzed using ANOVA.

3. Susceptibility of apple bloom stages to WFT damage:
Thrips exclusion, 2004*:* Starting at tight cluster, exclusion cages measuring 45 × 10 cm were placed on 100 branches of 'Delicious' trees in block 29S, TFREC. Each selected branch had 7-10 flower

clusters. Cages were placed on the branches (but not closed) by 2 April. The experiment was a completely randomized design with 10 treatments (exclusion periods) and 10 replicates (cages). At each exclusion period, thrips were killed and cages closed. Thrips were killed by spraying the branches to drip with a solution of ¼ lb of Carzol 92SP/100 gal. Material was mixed in a 16-oz spray bottle and applied to run-off. The cages were left closed until the start of the next bloom stage, about 3-4 d, then after bloom cages were closed for 7-d periods. Carzol applications were made at tight cluster (5 April), pink (9 April), king bloom (13 April), full bloom (16 April), petal fall, 2.6 mm fruit diam (20 April), 2.9 mm fruit (23 April), 5.6 mm fruit (27 April), 10.9 mm fruit, (4 May), and 15.8 mm fruit (11 May). Fruit in the cages were harvested on 24-25 May. The proportion (*p*) of fruit injured by thrips was transformed by arcsine(square root(*p*)), then analyzed using analysis of variance for a CRD. Treatment means were separated with a Least Significant Difference test, α=0.05.

Thrips phenology, 2004: Phenology of egg, immature and adult thrips was assessed in the same block used for the thrips exclusion study. Blossom clusters or, after petal fall, king fruit (100/sample) were collected at intervals corresponding to the developmental stages of the apple bloom. One sample was taken per tree. Sample timings were early tight cluster (2 April), late tight cluster (6 April), pink (9 April), king bloom (13 April), full bloom (14 April), petal fall (2.6 mm fruit diameter) (19 April), 2.9 mm fruit (23 April), 5.6 mm fruit (27 April), 10.9 mm fruit (4 May), and 15.8 mm fruit (11 May). Plant tissue was washed in soapy water and the contents poured through sieves to collect insects.

After plant tissues were washed, the tissue was trimmed so that only the king bloom fruitlet remained, and this was stained with an acid fuschin solution. Next, the tissues were cleared in another solution of lactic acid and glycerin heated in a double boiler under a fume hood for one hour. After clearing, the skin (0.5 mm thick) was trimmed from each fruit. Skin was placed between two glass slides and examined under a microscope for the presence of eggs.

Thrips exclusion, 2005: The trial was conducted in a commercial orchard in Omak, WA planted with 'Braeburn' apples. Treatments consisted of different timings of Carzol 92SP at a rate of 0.5 lb/100 gal. Each plot consisted of five trees in a single row, and treatments were replicated four times. Sprays were applied to run-off with a 4-gal. capacity knapsack sprayer. Treatment times were tight cluster (17 April), pink (20 April), king bloom (24 April), full bloom (28 April), petal fall (2.9 mm fruit) (1 May), 3.7-mm fruit (4 May), 5.8-mm fruit (8 May), 6.0 mm fruit, (11 May), 11.6 mm fruit (16 May), and 18.3 mm fruit (23 May). Up to 100 fruit were sampled per plot on 16 and 18 June and 1 July and checked for pansy spot. The proportion (*p*) of fruit injured by thrips was transformed by arcsine(square root(*p*)), then analyzed using analysis of variance for a randomized complete block design. Treatment means were separated using the Waller-Duncan *k*-ratio *t*-test.

Thrips phenology, 2005: Thrips phenology was studied in the 'Braeburn' orchard used for the 2005 thrips exclusion study, immediately adjacent to the spray trial described above. From tight cluster through bloom, 100 flower clusters (or, after petal fall, 100 king fruit) were sampled at intervals corresponding to the developmental stages of the apple bloom. After bloom, ten king fruit were randomly selected out of those sampled to measure the mean fruit diameter. Plant tissues were collected into plastic bags, then stored under refrigeration and processed within a week. Samples were processed as described for 2004.

Results and discussion:

1a. Distribution of thrips within orchards bordered by shrub-steppe habitat.
2003. Thrips densities 100 ft from the orchard border were significantly lower than those at the border (king bloom, *P*=0.03, and in samples summed over time, *P*=0.05). There were no significant differences between the densities at 100 ft and 200 or 300 ft.

2004. Thrips densities 30 ft from the orchard border were significantly lower than those at the border (king bloom, P=0.035, summed sample P=0.013). The same decrease was evident for fruit injury (P=0.018).

The results above are for the aggregate of orchards; not every orchard (replication) showed these trends. In some, there was no relationship between population density and location. Overall, these results were consistent with the hypothesis that sagebrush steppe habitat is a significant source of thrips that infest the flowers and damage the fruit of apple in many orchards.

1b. Mark-recapture to determine inter-habitat migration.
Preliminary studies: Adult thrips incorporated some Rb within a day of application. The strongest mark resulted from larvae feeding on Rb-treated plants throughout their development. The element was detected in composite samples of thrips more than a month after it was applied to the food plant. However, when individual thrips were tested, the amount of Rb was not significantly greater than the check. Thus, the Rb technique could not be used to mark individual thrips because the detection equipment was not sensitive enough. This method was abandoned in favor of the protein markers, where marks of individual thrips can be detected.

Orondo site, 2004: After the first spray of milk solution to the sagebrush steppe, 35% of the thrips in arrowleaf balsamroot were marked with milk protein. The number increased to 45% after the second spray and decreased to 24% at full bloom (3 d after the last spray). Too few thrips were collected from dandelion in 2004 to estimate the percentages, but egg white protein was detected after both sprays to the orchard groundcover. Of the thrips collected from apple flowers at full bloom, only 16% carried one or more marks. Of the total, 14% were marked with milk protein (from native vegetation), while only 2% were marked with egg white (orchard groundcover). Less than 1% was marked with both (Fig 1). Also, <1% of thrips collected in arrowleaf balsamroot at apple full bloom was marked with egg white protein (from orchard groundcover), indicating little movement out of the orchard. Thus, of the thrips that could be traced to a specific origin, the majority had come from the native vegetation between pink and full bloom.

Orondo site, 2005: With the first spray, 29% of the thrips in arrowleaf balsamroot were marked with soy protein (native vegetation). The number increased to 40% after the second spray and decreased to 21% at full bloom, 6 d after the second spray. In dandelion flowers, 79% were marked with egg protein after the first spray, 66% after the second spray, and 9% at full bloom. Thrips marked with egg protein (orchard groundcover) were also detected in balsamroot after the first spray (21%), the second spray (8%), and at full bloom (6%), indicating significant migration out of the orchard. Of the thrips collected from apple flowers at full bloom, 13% carried one or more marks; 12% were marked with soy protein (native vegetation), while only 1% were marked with egg white (orchard groundcover) (Fig. 1). The majority of thrips that could be traced to a specific origin had come from native vegetation. In spite of the increased spray coverage of flowers in the native vegetation, and the different protein used, results of both years' trials in Orondo were nearly identical.

Bridgeport, 2005: After the first spray, 43% of the thrips in arrowleaf balsamroot were marked with soy protein. The number decreased to 25% after the second spray and decreased to 13% in the flowers sampled at full bloom. In dandelion flowers, 50% were marked with egg white after the first spray, 82% after the second spray, and 20% at full bloom. Thrips marked with egg white protein were also detected in balsamroot after the second spray (3%), and at full bloom (44%), indicating significant migration out of the orchard. This is counter to what is believed to happen, viz., that thrips migrate into apple orchards during bloom. Of the thrips collected from apple flowers at full bloom, only 4% were marked with soy protein (native vegetation), while 7% were marked with egg white (orchard

groundcover) (Fig. 1). A slight majority of the thrips that could be traced to a specific origin had come from the orchard groundcover.

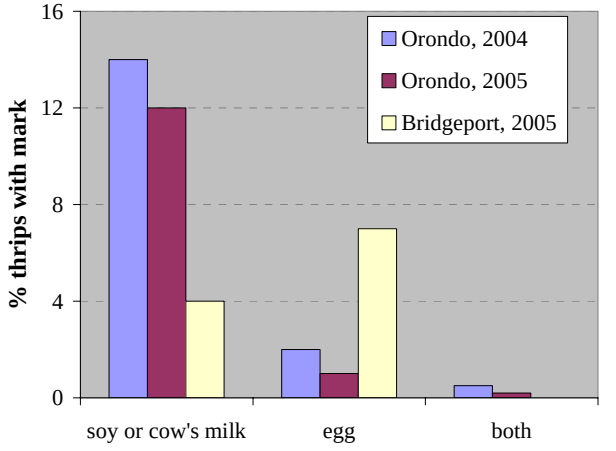

Fig. 1. Percentage of thrips in apple flowers marked with either soy or cow's milk (applied to sagebrush steppe) or egg white (applied to orchard groundcover) at two locations.

The Orondo site had fewer dandelions/m^2 (9.6) in 2005 compared with the Bridgeport site (32.6). The density of dandelions at the Orondo site in 2004 was similar to that of 2005, although no counts were made. This likely explains the higher percentage of thrips in apple flowers at the Bridgeport site originating from the orchard groundcover (Fig. 1). Thus, it appears that both the extra-orchard habitat and the groundcover may be a significant source of thrips in apple flowers, although more research is necessary to elucidate this under a broad range of conditions.

The highest number of thrips/sample collected in the three trials was at an edge of the orchard bordering native vegetation (data not shown). The highest percentage of thrips marked with soy or cow's milk (applied to native vegetation) was often distant from the edge. Apparently, thrips can move the distance of six rows or more within a short time, three to six days.

2. Management of resident WFT populations by reducing alternative hosts in the orchard.
All the thrips specimens collected from apple flowers were western flower thrips, *Frankliniella occidentalis* (Pergande). Apple shoots contained a mixture of species, including *F. occidentalis*. The most common species in dandelion flowers during the late spring and summer was *Thrips trehernei* Priesner. Only *F. occidentalis* were counted in this experiment.

Dandelions slowly decreased in the low-weed plots during the first and part of the second year (Fig. 2). By the summer of 2003 dandelion population density was significantly reduced in these plots but remained moderate to very high (10 to >100/m^2) in high-weed blocks. Thrips were found almost exclusively in open flowers, rather than in non-flowering dandelions. No difference in thrips density was found in individual dandelion flowers from either low-weed or high-weed blocks. However, the very low dandelion population, especially in 2005, meant that this source of thrips was nearly eliminated in treated blocks.

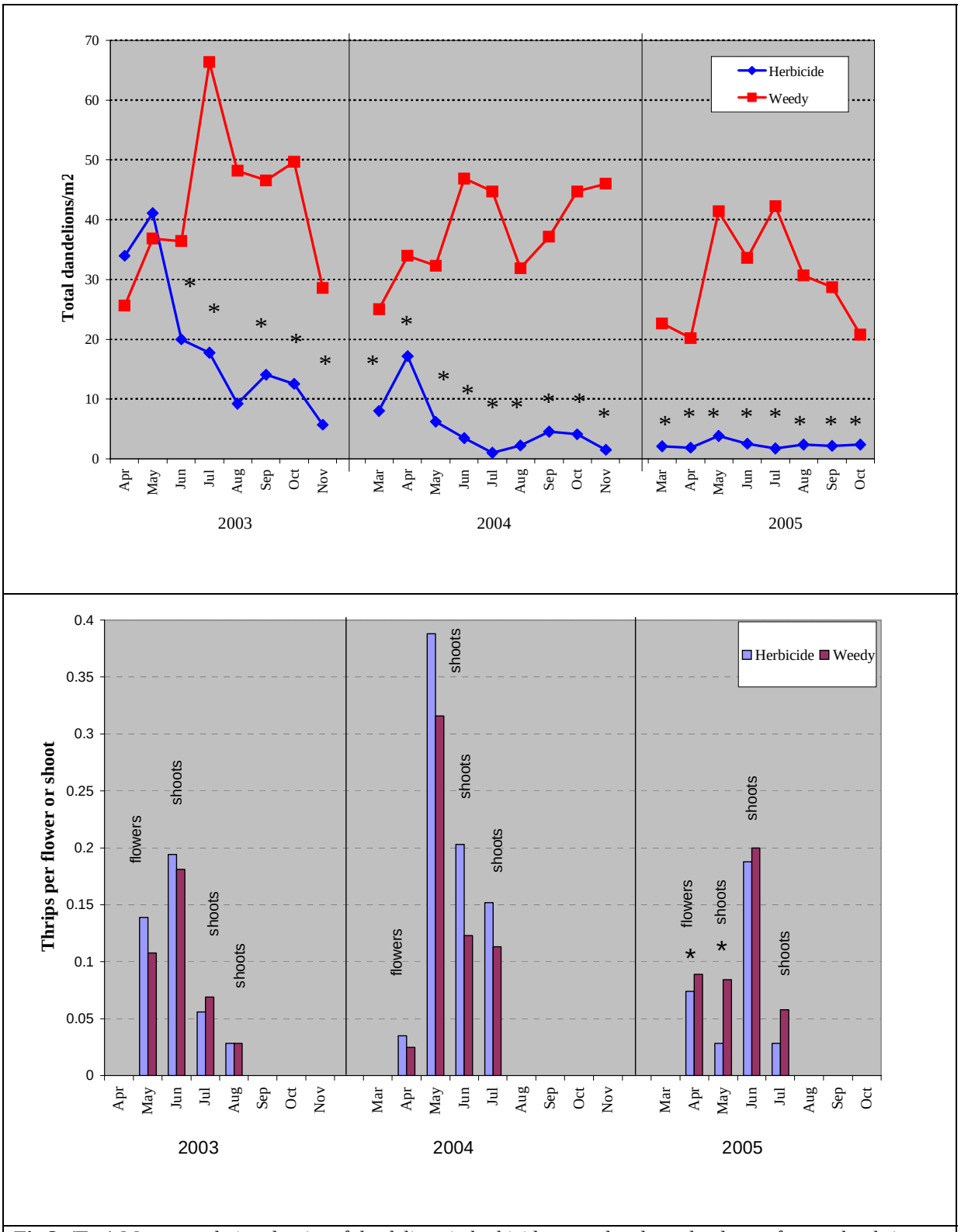

Fig 2. (Top) Mean population density of dandelions in herbicide-treated and weedy plots at four orchard sites. (Bottom) Thrips sampled from apple flowers or shoots in the herbicide-treated and weedy plots. Means marked with an asterisk (*) on a given date are significantly different, LSD test, α=0.05.

No significant differences in thrips populations were found in any of the apple flower or shoot samples in 2003 and 2004. However, in 2005, there was a significant difference in thrips populations in apple flowers between low-weed (0.074 thrips/flower) and high-weed blocks (0.089 thrips/flower). The significant reduction continued with thrips in the apple shoots after petal fall, with 0.028 thrips/shoot in low-weed blocks and 0.084 thrips/shoot in high-weed blocks. The effect was temporary, and no significant differences were found for the rest of the summer. The small decrease in thrips populations during bloom did not cause a significant reduction in fruit injury in any of the three years. The percentage of pansy spot was 1.8 (low-weed) v. 2.0 (high-weed) in 2003, 2.5 v 4.7 (2004), and 1.2 v. 0.8 (2005). Although dandelions can be a source of thrips in apple flowers (see Results, Section 1b), management of dandelions does not greatly improve management of thrips in apples or significantly reduce their damage. In spite of the loss of broadleaf weeds as alternate hosts and lack of access to native vegetation, thrips can still survive in the orchard during the summer (Fig. 2) and presumably find suitable hosts in the fall. The apple tree itself can serve as a host for months after bloom. Alternatively, in spite of the large blocks used in this trial, thrips could be moving from other habitats and colonizing the low-weed blocks.

3. Susceptibility of apple bloom stages to WFT damage.

Thrips exclusion, 2004: Exclusion of thrips after bloom was more effective in preventing fruit damage than those applied before or during bloom. Applications made when fruit was 10.9 mm or larger (2 wk or more after petal fall) were also less effective at preventing fruit damage. This timing of damage prevention corresponded to an increase in oviposition that occurred some time between 5.5 and 10.9 mm fruit size (1-2 wk after petal fall).

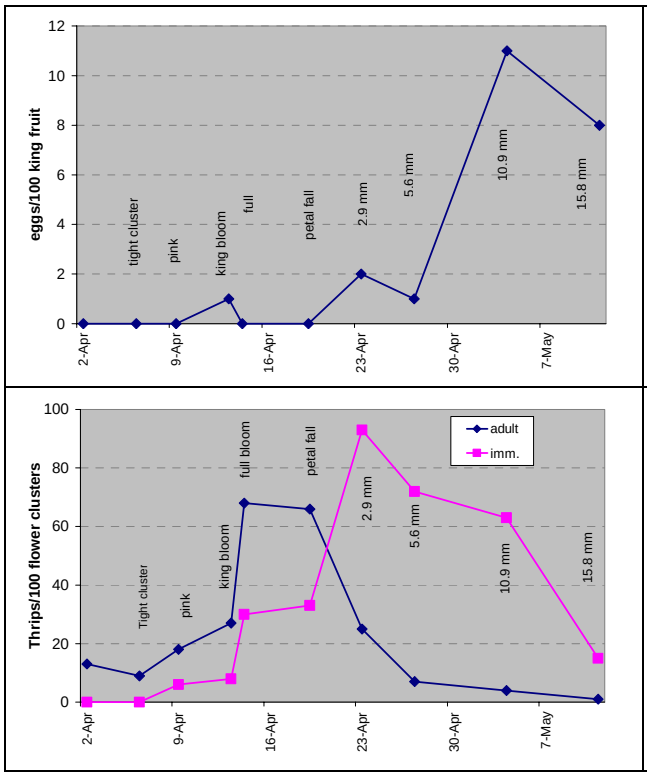

Fig. 3. (top) Eggs per 100 king fruit, TFREC, Wenatchee, WA, 2004. (bottom) Adult and immature thrips per 100 flower clusters.

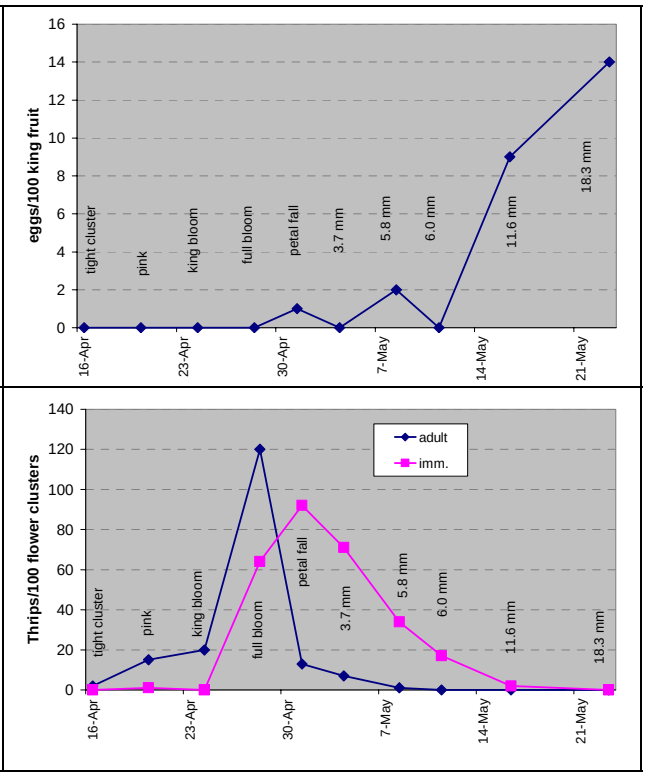

Fig. 4. (top) Eggs per 100 king fruit, Omak, WA, 2005. (bottom) Adult and immature thrips per 100 flower clusters.

Thrips phenology, 2004: Adult thrips were found in low numbers from tight cluster on; however, they increased in the blossom clusters as petals opened (Fig 3., bottom). There was a marked increase from king bloom to full bloom. Adults remained abundant until petal fall, then decreased rapidly. A low population remained on fruit clusters up to 15.8 mm, or 21 d after petal fall. Although eggs must have been laid on or near flower clusters well before bloom, judging from the presence of immatures at pink, very few eggs were laid on king fruit during bloom (Fig. 3, top). The majority were laid on king fruit shortly before 10.9 mm, or 14 d after petal fall. Immature thrips peaked just after petal fall, indicating substantial oviposition during bloom on vegetative tissue.

Thrips exclusion, 2005: Carzol applications did not significantly affect fruit damage on any date. Apparently either the knapsack sprayer used did not deliver sufficient insecticide into the interior of apple flowers to affect the population or the small block size allowed rapid reinfestation after a spray.

Thrips phenology, 2005: Adult thrips were found in low numbers at tight cluster and increased in the blossom clusters as petals opened (Fig. 4, bottom). There was a marked increase between king bloom and full bloom. Adults decreased rapidly after petal fall. The majority of eggs were laid on king fruit shortly before 11.6 mm fruit, or 15 d after petal fall. Immatures peaked at petal fall, before the peak of eggs found in the fruit, indicating the contribution of other (vegetative) tissues.

Impacts: Information gained by these studies has significantly enhanced our knowledge of thrips ecology and movement in near-orchard habitats and will influence management decisions and options in the future. The contribution of thrips hosts on the orchard floor can vary widely from site to site and may in some cases be as important as the contribution from surrounding native vegetation. However, there is little evidence that stringent weed control will significantly reduce thrips damage. Where immigration from native vegetation is the primary thrips source, border sprays may be a more appropriate management strategy. The evidence on timing of thrips oviposition is a significant indicator that pesticide applications should be timed much later than is currently recommended (pink-bloom), perhaps by several weeks; however, this needs further confirmation. Better timing provides more consistent control and optimal use of products with shorter residual activities.

Budget:

Project title: Biology, migration, and management of western flower thrips in apple orchards
PI: Elizabeth H. Beers
Project duration: 2003-2005
Project total (3 years): $107,084

Item	Year 1 (2003)	Year 2 (2004)	Year 3 (2005)
Total	36,953	35,131	35,000