FINAL PROJECT REPORT

WTFRC Project Number: AE-06-600 (WSU Project No. 13C-3643-7386)

Project Title: Biology and Management of Secondary Pests of Apple

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Budget History:

Item	Year 1: 2006
Salaries	43,409
Benefits	8,864
Wages	7,000
Benefits	770
Supplies	2,000
Travel	1,500
Total	63,543

Objectives:

1. Woolly apple aphid.

1a. Test chemical control tactics for aerial colonies with field trials.

1b. Test chemical control tactics for root colonies with both greenhouse assays and field studies.

1c. Determine the life history of woolly apple aphid in different growing regions of Washington.

1d. Evaluate widely planted as well as newly developed rootstocks for resistance to local woolly apple aphid biotypes.

2. Rosy apple aphid.

2a. Determine the herbaceous hosts of rosy apple aphid in Washington.

2b. Determine if rosy apple aphid is capable of continuous reproduction on apple.

2c. Determine species and relative abundance of natural enemies of the rosy apple aphid on both woody and summer hosts.

2d. Determine the time of susceptibility of fruit to injury by rosy apple aphid colonies.

3. Western flower thrips.

3a. Determine source of thrips attacking fruit using protein markers.

3b. Determine phenology of thrips oviposition on apple around bloom.

3c. Determine the optimum timing of thrips control with insecticides.

Significant findings:

1. Woolly apple aphid.

1a. Oil+Lorsban at delayed dormant reduced infestation immediately, delayed population increase until late summer, and resulted in a lower population by late summer. Oil alone caused a temporary reduction. NNI-0101 and BeLeaf 50SG looked promising for summer control. The 1.5% v/v rate of Safe-T-Side oil was slightly more effective than the 1% rate. Tank-mixing oil with Assail improved the performance but increasing the rate did not. Diazinon 50W was consistently the most effective material for woolly apple aphid control.

1b. Venom and Admire Pro (soil drench) and spirotetramat (foliar spray) controlled root and shoot colonies on potted seedling apple trees. Results of field trials were more variable and generally less effective. Admire Pro provided the most consistent suppression of root and shoot colonies. Spirotetramat showed a (non-significant) trend to suppress woolly apple aphids in a foliar application in May.

1c. The peak period of upward woolly apple aphid crawler movement occurred nearly 7 wk later in 2006 (late July) than in 2005 (early June). Shoot colonies had a small peak in mid- to late June and a second, usually larger, peak in mid- to late August. Alate adults were found at only one site (mid-September to early October).

1d. Geneva 202, Geneva 41, and 4210 rootstocks are much more resistant than MM.111 to a Washington strain of woolly apple aphid. M.9, M.26, Bud 9, and Bud 118, and seedling rootstocks are highly susceptible.

2. Rosy apple aphid.

2a. Both broadleaf and narrowleaf plantain serve as summer hosts of rosy apple aphid in Washington.

2b. No populations of rosy apple aphid were found to survive on apple under ambient conditions past midsummer. A lab colony on apple was maintained under spring conditions for 15 months.

2c. *Lysiphlebus testaceipes* (Cresson) was the most common parasitoid on apple colonies, while *Aphidius spp.* were the most common on plantain colonies. Syrphids were the most common predators on both plants.

2d. Results of one year show dwarfed apples were caused by aphid feeding before, but not after, 30 May. 'Golden Delicious' and 'Fuji' appear to be particularly susceptible.

3. Western flower thrips.

There appears to be a window for control of thrips damage (pansy spot). Insecticide applications were effective from full bloom to 5.7-mm diameter fruit. When applied at the same timing, Success provided control equivalent to Carzol.

Methods:

1. Woolly apple aphid.

1a. Chemical control tactics of aerial colonies.

Delayed-dormant trial. This test was in apple orchards (replications) in Bridgeport, Brewster, and Quincy. At delayed dormant (6-11 April), growers applied 2 treatments: 1) Lorsban 4E + oil (2 qt+4-5 gal/acre); 2) oil alone (4-5 gal/acre). Treatments were applied with commercial airblast equipment to ca. 2-acre plots, and an additional 1-2 acres were left untreated at this timing as a check. Woolly apple aphid populations were evaluated within 4 wk after treatment and every 4-8 wk thereafter. Woolly apple aphid densities were assessed by conducting a 15-min search in the center row of each plot and recording the number of colonies.

Summer trials. Two randomized complete block trials were conducted in a commercial apple orchard near Royal City. Small plots (1-3 trees) were sprayed with a handgun to the point of run-off on 21 July. Larger plots (10 trees) were sprayed with an airblast sprayer at 200 gpa on 20 July. Live aphids, dead aphids, aphid mummies, and predators were counted before and at 3-7 d intervals after treatment.

Postharvest/dormant trials. A randomized complete block test and three single-block comparisons were started in the fall of 2006 in apple orchards near Quincy, WA. Three to four days before treatment, woolly apple aphid colonies were counted in a 3-min search per plot. Five colonies were collected per plot, and immature and adult aphids, aphid mummies, and predators were counted. In the randomized complete block trial, each block (5 rows × 20 trees) was sprayed with an airblast sprayer at 200 gpa on 10 October. In the single block comparisons, treatments were applied in the same manner to 3-5 rows of trees on 26 October 2006. Treatments at delayed dormant (2007) are planned for next spring.

1b. Chemical control of root colonies.

Bioassays. Two bioassays, randomized complete block design, were conducted in a greenhouse. Seedling apple trees (7/16 inch) were planted in 8-inch pots in a mixture of equal parts peat, perlite and vermiculite. After trees had grown shoots, twigs from infested trees were placed on exposed roots, and crawlers were allowed to settle on both roots and shoots. Solutions (250 ml) of Admire and Venom were poured onto moist potting mix on 10 July. Shoot colonies were assessed before treatment, then every 7 d. At 4 wk, all trees were lifted and root colonies assessed. A second bioassay was conducted using the same methods. Admire was applied as a soil drench. Movento (spirotetramat) with various adjuvants was applied to foliage to run-off with a 1-gal sprayer (ca. 50 ml per tree).

Orchard trials. Four experiments were conducted in three commercial orchards to evaluate systemic insecticides for control of root and shoot colonies. Two were in Mattawa, one in East Wenatchee, and one was near Royal City. Plot size ranged from 3-6 rows and 10-31 trees. Admire Pro 4.6F, Vydate 2L, Venom 20SG, NNP-515, and NNP-516 were applied to the herbicide strip. A swath 2.4 m wide centered on the tree trunk was sprayed 15-18 May with a boom sprayer calibrated to deliver 100 gpa. The trees were irrigated the day before the application to completely wet the soil profile, and then again for 45 min after the application to carry the pesticide into the root zone. Foliar applications of spirotetramat were made with a handgun to the point of drip on 19 May or 21 July.

Population density of root colonies was assessed with sticky bands to trap first instar woolly apple aphid crawlers moving on the trunk. Bands were made of 3 cm wide strips of aluminum foil sized to encircle the trunk, and attached with 3M Spray Adhesive. Aphid crawlers were trapped in a bead of Tree Tanglefoot adhesive placed around the band in a circle. Three trees per replicate plot were banded and bands replaced every month. The number of aerial colonies was evaluated in a 3-min search/plot.

Data from all pesticide evaluation trials were analyzed using the Statistical Analysis System (SAS 1988). Data were tested prior to analysis for homogeneity of variance using Levene's (1960) test. Variances found to be non-homogeneous were transformed [ln(y+0.5)] before analysis. PROC GLM was used to conduct an analysis of variance, and treatment means were separated using the Waller-Duncan *k*-ratio *t*-test.

1c. Life history of woolly apple aphid.

Overwintered colonies. One to five woolly apple aphid colonies were collected 30 March to 7 April from the trunks and surface roots of apple trees in Malott, Brewster, Bridgeport, Quincy, and Vantage. The percent parasitized, living aphids, dead aphids, and developmental stages of the aphids were determined.

Crawler movement. Crawlers were monitored in Bridgeport, Vantage and Quincy. Two sticky bands, described in Section 1b, were placed on three trees at each site. One band was placed 15 cm above the soil to trap nymphs moving up the trunk from the roots. A second band was placed 1 cm above the first to trap nymphs moving down from aerial portions of the tree. Bands were set out in April and replaced weekly until frost.

Aerial colonies. The average size and number of aerial colonies were recorded weekly on the three banded and three adjacent trees. On additional trees, up to five colonies were collected weekly. The number of aphid mummies, predators, and the developmental stage of aphids was determined. Predators were also collected at a second site in Quincy.

Fruit infestation. Fruit was sampled in two rows. Five hundred fruit were examined weekly *in situ* and the stem and calyx ends examined for woolly apple aphid. Any fruit with external infestation was cut open and examined for core infestation. Aerial colonies were counted in the same rows in a 3-min search. Samples were also taken weekly in an additional block in Vantage. Two other sites in Quincy and Royal City were sampled at harvest.

1d. Rootstock resistance.

Apple rootstock liners, from ¼- to ⅜-inch diameter, were planted in pots on 21 April. Ten replicates of 10 rootstock types were used: the Geneva line 4210, Geneva 41, Geneva 202, Bud 9, Bud 118, M.9, M.26, MM. 111, seedlings from Washington (Willow Drive Nursery), and seedlings from New York. Trees grew shoots approximately 6 cm long before infestation. Sections of infested shoots 4-6 cm long from an orchard in East Wenatchee, each with 50-200 aphids, were placed at the base of each tree on 19 May and again on 22 May. Trees were arranged on a greenhouse bench in a randomized complete block design.

Aphid densities were evaluated on 16 June. Two types of evaluations were performed, a rating system based on visual inspection and a photographic method. Trees were each digitally

photographed against a black backdrop. The area photographed remained a constant 73.5 cm × 49 cm. The resulting images were imported into a digital imaging program (Photoshop ver. 6.0, Adobe, Inc.) which was used to obtain a count of the number of white pixels in the image (representing woolly apple aphid colony mass). Because the total number of pixels in the image remained constant, the number of selected pixels was used as a direct measurement rather than as a proportion of the total number.

2. Rosy apple aphid.

2a. Determine herbaceous hosts.

No-choice experiments. Seedling domestic apple trees were planted 21 April and infested 10 May with rosy apple aphid from a WSU-TFREC orchard. Three herbaceous species, narrowleaf plantain (*Plantago lanceolata* L.), broadleaf plantain (*P. major* L.), and woolly plantain (*P. patagonica* Jacq.), were grown from seedlings in the greenhouse. Broadleaf dock (*Rumex obtusifolius*) was collected 5 May from an orchard in Brewster. Three replications of each apple-herbaceous plant combination were placed in insect cages on 15 May and grown under natural photoperiod. Trees were removed 4 July; then on 7 September new, uninfested seedling apple trees were placed in the cages. Aphid samples were collected 4 July, 21 July and 12 October. The entire broadleaf dock plants were placed in Berlese funnels to extract aphids. All aphids were identified at WSU-IAREC, Prosser.

*Alternate host surveys***.** Plantain and other weed species in apple orchards were sampled in the following counties (no. sites): Okanogan (2), Douglas (3), Chelan (2), Benton (6), Yakima (16), and Skamania (1) in Washington, and Umatilla (1) in Oregon. Plantain in areas at least 100 m from apple trees were also sampled in the following counties (no. sites) once during the season: Okanogan (3), Grant (2), Chelan (2), Douglas (1), Benton (3), Yakima (13), Klickitat (6), Skamania (4), Clallam (1), Jefferson (1), and Walla Walla counties (1) in Washington. Similar areas were also sampled in Umatilla (3) and Deschutes counties (1) in Oregon, and on Maui, Hawaii (1). At most sites, samples were collected every other week from July through the end of August, but some were sampled once. Plants were cut at ground level and sufficient plant material was collected to fill two 1-gallon plastic bags. The contents of one bag were placed in a Berlese funnel to collect aphids and natural enemies. Parasitoids were reared from both apple and plantain at sites in Okanogan, Douglas and Chelan counties. The contents of the second 1-gallon bag were transferred to 6-liter plastic boxes with ventilated lids and kept at room temperature for one month until adult parasitoids emerged. Parasitoids and aphids were identified as described previously.

Phenology of rosy apple aphid on summer hosts. Three orchards in Douglas and Chelan counties were selected for intensive sampling. Two orchards had narrowleaf plantain and the third had broadleaf plantain. Ten 1-gallon bags of the dominant plantain species were collected every two weeks from late May through October and aphids extracted as described previously.

2b. Continuous reproduction on apple. Three seedling apple trees were grown in a greenhouse as described in section 2a. Trees were infested in May with rosy apple aphid from Orondo and TFREC. Aphids were provided with fresh seedlings every 2-4 wk. The aphids in the indoor colony started in June 2005 were maintained on apple throughout the year under conditions typical of early April (15-20°C, 14:10 light:dark photoperiod).

2c. Natural enemies on apple and summer host. Natural enemies were collected from apple and plantain from sites in Okanogan, Chelan and Douglas counties. Apple trees were examined weekly for rosy apple aphid colonies at three sites beginning in late April until colonies could no longer be found, by early August. Predators were collected directly from colonies; immatures were stored in 70% ethanol and adults pinned. Parasitoids from apple colonies were reared as

described in Section 1. Natural enemies were collected from plantain from late May through October as described in Section 2a.

2d. Timing of injury to fruit. This study was conducted on 'Delicious,' 'Golden Delicious,' 'Fuji,' and 'Gala' apple trees in an experimental orchard at WSU-TFREC. Eight trees of each cultivar were infested at either pink (20 April), petal fall (9 May), 30 May, or 20 June. An additional eight trees were not infested and served as a check. A single fruit spur with a growing shoot was selected on each tree and inoculated with 10-20 rosy apple aphids. Attempts on 20 June failed to establish colonies. Colonies were assessed weekly for three weeks, then eliminated with Assail 70WP at 1.7 oz./100 gal applied with a 16-fl oz. hand-held spray bottle. No chemical thinning agents were applied to the block, and fruit was not hand-thinned.

The condition and circumference of fruit were assessed at harvest. Fruit within 10 cm of the infested shoot (1-10 fruit) were examined on each replicate tree. About 10 fruit were selected randomly from each uninfested tree. The influence of time of infestation on the occurrence of dwarfed/non-dwarfed fruit was examined for each cultivar with a goodness-of-fit test. Size of non-dwarfed (not misshapen) fruit was analyzed using the Statistical Analysis System (SAS 1988). PROC GLM was used to conduct an analysis of variance, and treatment means were separated using the Waller-Duncan *k*-ratio *t*-test.

3. Western flower thrips.

3a. Migration of thrips. This experiment was located in an orchard near Bridgeport, Washington. Plant tissues (and presumably thrips) were coated with protein markers to determine where the thrips originated. Two areas were treated with separate markers. With a hand-held fertilizer spreader, an area (50 × 342 ft) of native vegetation adjacent to the orchard was dusted with powdered skim cow's milk at a rate of 1 lb/1,000 ft^2. Four bands on the orchard floor, each 75 × 324 ft, were sprayed with a solution of 10% egg whites v/v at 134 gpa. Each band started at the edge next to native vegetation and spanned the width of the block. Treatments were applied at pink (24 April) and king bloom (1-3 May).

Blossoms from four arrowleaf balsamroot plants in treated native vegetation and 500-2,000 dandelion flowers from the orchard floor were collected before and after each treatment and at full bloom of apple. With the final sample, 150 apple flower clusters were collected in all four bands at the edge, then every five rows up to 24 rows into the block. All flower samples were immediately frozen.

Flowers were examined under a microscope and thrips were collected on a toothpick with a tiny drop of Stickum Special™ adhesive. Each insect was placed in the bottom of a 1.5 ml microcentrifuge vial. The marker was released from the insects with a buffer solution. This solution was tested with an ELISA procedure for the presence of both egg and milk proteins.

3b. Timing of insecticides. This experiment was a randomized complete block design conducted in a 'Cameo' apple block in Bridgeport. Four replicate plots (a single row of 15 trees) were sprayed with either Carzol 92SP or Success 2SC using an airblast sprayer at 200 gpa. Insecticides were applied at king bloom (28 April), full bloom (4 May), and at fruit diameters averaging 5.7 mm (12 May), 12.8 mm (17 May), 17.3 mm (25 May) and 26.7 mm (1 June).

Fruit (110-150/plot) were examined on 6 June for pansy spot. The proportion (p) of damaged fruit was transformed with arcsine [square root (p)]. Data were analyzed with ANOVA. Results from the two insecticides were analyzed at each spray date with a Least Significant Difference test. Data for insecticides were combined, and means for spray dates were separated with a Least Significant Difference test.

3c. Timing of oviposition. Reproductive tissue samples were taken at pink (24 April), then on approximately the same dates as the insecticide sprays in 3b, with an additional sample at

31.7 mm diameter fruit (9 June). One hundred blossom clusters or king fruit were collected from untreated trees next to the spray trial. Thrips were separated from plant material by filling the sample bag with water, adding a few drops of liquid detergent, and agitating for several seconds. Thrips and plant material were separated from the soapy water by pouring through two sieves. Both adult and immature thrips were counted. Average fruit diameter for each sample date after bloom was determined by measuring a subsample of 10 king fruit.

Eggs laid in blossom or fruit tissue were counted by direct observation. The king bloom or fruit was stained with McBride's stain for 12 h to color eggs. Small fruit (<15 mm) were covered with dense trichomes which made eggs difficult to see. These were treated with a clearing solution and skin was removed. Skin was studied under a dissecting scope illuminated from behind to reveal the dark eggs. Larger fruit (≥15 mm) were studied under a microscope without clearing the tissue. Oviposition sites were excised and studied more closely if necessary.

Results and discussion:

1. Woolly apple aphid.

1a. Chemical control tactics of aerial colonies.

Delayed-dormant trial. An application of oil+Lorsban at delayed dormant practically eliminated aerial woolly apple aphid in infested orchards, and populations did not begin to recover until late in the season. Even in mid-September, the density of woolly apple aphid colonies in the oil+Lorsban plots was significantly lower than the check or oil alone. Oil alone significantly reduced woolly apple aphid populations shortly after application, but the effect was transitory; these plots were not different than at any time after June.

Summer trial (handgun). NNI-0101+oil looked promising for woolly apple aphid control at the higher rates (1.59 and 3.19 fl oz /100 gal). Another new nicotinoid insecticide (flonicamid; BeLeaf 50SG at 1.75 lb/100 gal) also significantly reduced populations by 7 DAT.

Summer trial (airblast). Assail 30SG+oil provided better aphid suppression than oil alone; however, the 8 oz rate of Assail+oil was not better than the 4 oz rate. The inclusion of oil with Assail, plus the higher spray gallonages used in this test (200 gpa) may be responsible for the improved performance of this material. Safe-T-Side at 1.5% v/v was slightly more effective than the 1.0% rate. The standard, Diazinon 50W (4 lb/acre), provided the best control, reducing woolly apple aphid populations by 4 DAT which remained low for the rest of the test.

1b. Chemical control of root and aerial colonies.

Bioassays. Both Venom 20SG (21 oz/100gal) and Admire Pro 4.6F (14 fl oz/100 gal) significantly reduced aphids on shoots by 7 DAT, and within 4 wk eliminated woolly apple aphid on both roots and shoots of the seedling trees. The suppression of shoot colonies from soil drench applications is a clear indication that these products were translocated upward in the trees. In a second bioassay, Admire Pro provided the fastest and most complete control of shoot populations. Regardless of formulation or adjuvant used, Spirotetramat worked more slowly and left a small residual population. All treatments, however, gave virtually complete control of the root colonies at the time they were evaluated (5 wk after application).

Orchard trials. Success of treatments in field trials was poorer and more variable than in bioassays. Admire Pro 4.6F (7-10.5 fl. oz./acre) provided suppression of either root or shoot colonies in two trials. Spirotetramat 150OD (12 fl oz/100 gal) + Silwet L-77 applied to foliage in May showed a (nonsignificant) trend to suppress crawlers and aerial colonies. An application in July showed no effect. Soil applications of NNP-515 (1.5 qt./acre) provided good control in one orchard but had no measurable effect in another. Vydate 2L (1-3 gal/acre) was not significantly different from the check in all field trials, although it showed good activity in 2005 potted tree bioassays. Venom 20SG (21 oz./100 gal) and NNP-516 (1 pt./acre), both applied to soil, were not significantly different from the check.

1c. Life history of woolly apple aphid.

Peak upward movement of woolly apple aphid crawlers as evidenced by sticky bands occurred from late June to late July 2006 depending on the site. Peak movement at the site which was sampled for 2 years was nearly 7 wk later in 2006 (late July) than in 2005 (early June). These data indicate substantial year-to-year variation in crawler movement. Captures in the lower band (presumably upward movement) were generally much higher than captures in the upper band (presumably downward movement). Shoot colony development appeared to be bimodal in the study orchards in 2006, with a small peak in mid- to late June and a second, usually larger, peak in mid- to late August (Fig. 1). Immature aphids were the most prevalent form in the shoot colonies throughout the season, indicating potentially growing populations (Fig. 2). Alate adults were found at only one site (Vantage) and only in mid-September through early October. Mummies (aphids parasitized by *Aphelinus mali*) were present starting in mid-June for as long as active colonies were present in the orchard (late October in one study site).

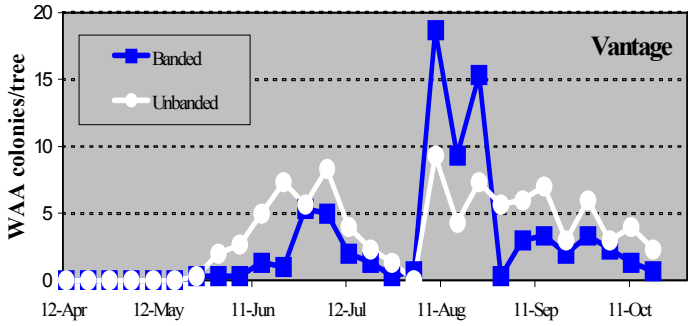

Fig. 1. Woolly apple aphid colonies on three banded and three unbanded trees at one of three sampled sites, 2006.

Fruit sampling. At one site, fruit became infested by woolly apple aphids settling in the stem and calyx ends after aerial colonies increased in late August, three weeks before harvest. A few fruit had woolly apple aphids inside the cores, where they had entered through a natural opening in the calyx end (Plate 1). The incidence of infested fruit appeared to depend on the proximity of aerial colonies; however, this relationship needs further investigation.

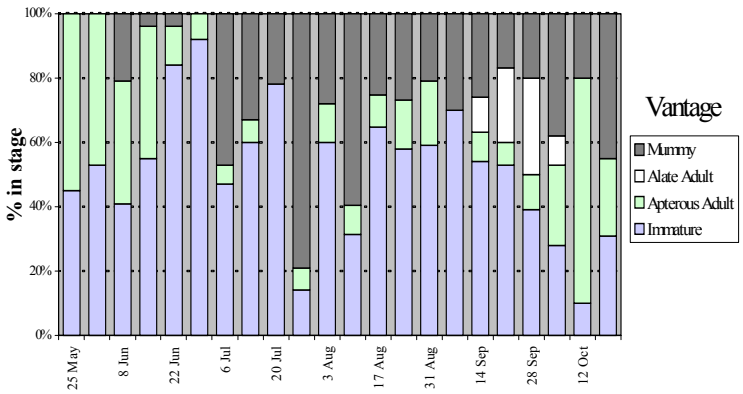

Fig. 2. Percentages of aphids in different stages in one of three sites sampled in central Washington, 2006.

Plate 1. Woolly apple aphid nymphs inside the core of a 'Fuji' apple at harvest.

1d. Rootstock resistance. Striking differences among the various rootstocks were apparent within a few weeks of artificial infestation. After 4 wk, the susceptible rootstocks (including M.9, M.26, Bud 9, Bud 118, and seedlings from New York and Washington) were heavily infested (Plate 2). On MM.111 (whose resistance is derived from 'Northern Spy'), colonies established successfully but were small and poorly developed. The majority of the replicates of the Geneva 'Robusta 5'-derived resistant rootstocks (G.202, G41, and 4210) were free from infestation (Plate 3), although some replicates had a few very small colonies.

Plate 2. Seedling rootstock heavily infested with woolly apple aphid.

Plate 3. Geneva series rootstock free of woolly apple aphid.

2. Rosy apple aphid.

2a. Determine herbaceous hosts.

No-choice experiments. Rosy apple aphid successfully migrated from apple to all three species of plantain. Alate aphids were observed on potted plantain in the cages from late May through early July, with colony formation of the pale yellow virginoparae starting in June. All woolly plantain plants produced seed and died by early August. Rosy apple aphid was not found on any replicate of dock (*R. obtusifolius)*. These results confirm those of 2005.

*Alternate host surveys***.** Rosy apple aphid was identified from broadleaf plantain at 4 of the 18 sites (22%) where this weed species occurred and on narrowleaf plantain at 5 of the 23 sites (22%) sampled in or directly adjacent to apple orchards. Plantain from 5 out of 42 extra-orchard locations sampled in Yakima and Klickitat counties contained rosy apple aphid. Two of the positive sites were the Bingen City Park and the grounds of the Maryhill Museum (both in Klickitat County). Analysis of the sites and proximity to woody hosts is in progress. The results from 2006 confirm the results from 2005, that is, that both narrowleaf and broadleaf plantain serve as a summer host for rosy apple aphid. The highest numbers of aphids in plantain samples occurred in June and July, and higher aphid populations were found on narrowleaf plantain than on broadleaf plantain.

Phenology of rosy apple aphid on summer hosts. Rosy apple aphid was detected on plantain as soon as sampling began in late May. An early peak occurred in July at TFREC, and a later peak occurred in August and September at TFREC and Stormy Mountain Orchard. The last sample positive for this species was 20 September, although sampling continued through late October. The absence on the summer host likely marks the migration back to the overwintering host, apple. Although these orchards received minimal pesticides, mowing and other cultural operations may have periodically disrupted aphid development.

2b. Continuous reproduction on apple. Access to new apple shoots did not prevent the typical summer decline of rosy apple aphid colonies from Orondo and Wenatchee when subjected to natural photoperiod and high temperatures in the greenhouse. A colony started from a field population in June 2005 was maintained on apple in a growth room under typical early April conditions throughout 2006.

2c. Natural enemies on apple and summer host. The natural enemy complex on plantain is different, both qualitatively and quantitatively, than that on apple. Several groups of generalist predators were collected feeding on apple colonies. These included earwig nymphs, cecidomyiid larvae, lady beetles, and *Campylomma verbasci* (Meyer-Dür). Syrphid larvae were the most commonly encountered predator. Three primary parasitoid species, *Lysiphlebus testaceipes* (Cresson), *Praon unicum* Smith, and an encyrtid were collected on colonies from apple, with *L. testaceipes* being by far the most common. All others collected were hyperparasitoids. On plantain, syrphid larvae were also the most common predator and *Aphidius* sp. (including *A. matricariae*) the most frequently encountered parasitoid. *L. testaceipes* was also found on plantain but much less commonly than on apple.

2d. Timing of injury to fruit. The four cultivars supported different levels of aphid infestations on the spur shoots from pink through petal fall. 'Golden Delicious' shoots had significantly higher cumulative aphid days than 'Fuji' and 'Delicious' shoots. 'Delicious' had the lowest levels of aphids, which may have been caused by a mild form of antixenosis in this tissue to rosy apple aphid. Aphid populations were not significantly different between cultivars during the other time periods.

Dwarfed fruit developed on 'Fuji' trees infested from pink through petal fall and on 'Golden Delicious' trees infested from petal fall through late May. No dwarfed fruit resulted from aphids feeding 30 May or later, although cumulative aphid days were higher during the late treatment. Among the remaining fruit of normal appearance, a small but detectable reduction in size sometimes occurred. 'Gala' apples were slightly smaller when shoots were infested from petal fall through late May. 'Golden Delicious' apples were slightly smaller on infested branches regardless of the time of infestation. 'Delicious' apples did not sustain any damage from rosy apple aphid treatments.

3. Western flower thrips.

3a. Migration of thrips. At the time of writing, thrips samples were being analyzed. Thrips positive for casein (cow's milk) and chicken albumen (egg white) have been detected in some apple flowers, indicating a successful marking procedure. A complete analysis of data will be done by 31 March 2007.

3c. Timing of insecticides. The effect of spray timing was highly significant, while the effect of insecticide used was not. No significant difference between Carzol 92SP (1 lb./acre) and Success 2SC (8 fl. oz./acre) treatments was found at any timing date. Fruit injury on trees treated at full bloom and 5.7 mm diameter king fruit was significantly lower than injury on trees treated at all other times (Fig. 3). Fruit injury was not significantly different among treatments applied at king bloom or at any timing after 5.7 mm diameter king fruit.

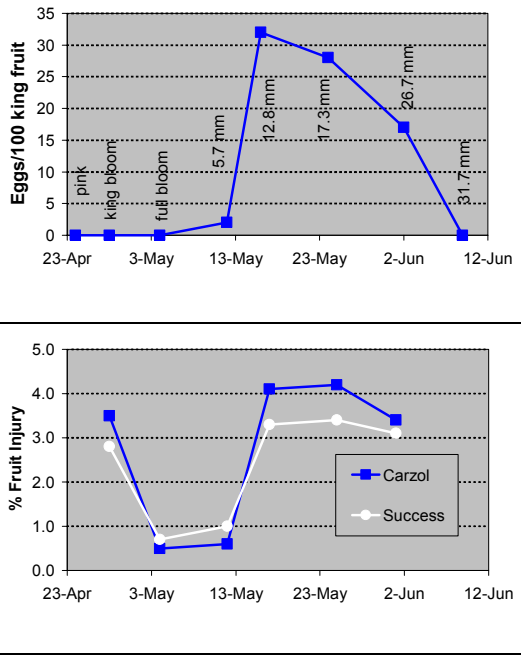

Fig. 3. (Top) Eggs laid in 100 king fruit. (Bottom) Percentage of fruit with pansy spot from trees sprayed with Carzol 92SP or Success 2SC on different dates. The x-axis indicates the spray date; all fruit were evaluated on 6 June 2006.

3b. Timing of oviposition. Adult thrips increased in flower clusters as blossoms opened, peaking at full bloom and declining as fruit grew. Some adults were still present on king fruit at 5- to 12-mm diameter. Immatures did not occur in samples until 12.8-mm diameter king fruit and did not follow the trend of oviposition in king fruit. It appears that immatures on fruit came from eggs laid elsewhere. Eggs were found in fruit beginning at 5.7-mm diameter king fruit and increased sharply by 12.5 mm. Stained eggs were detected in oviposition scars after 25 mm but were no longer found in scars by 31.7 mm in early June.

Two timings provided the best control of pansy spot damage from thrips, full bloom and 5.7-mm king fruit. Applications before or after these times were less successful. The later timing coincided with the period just before peak oviposition as determined by egg sampling. These data confirm previous experiments on the timing of oviposition and its relation to optimum control. This later timing would allow growers to tank- mix the insecticides with some types of early thinning sprays and would permit a greater range of choices in insecticides if applications are made after bees are removed from the orchard.

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