FINAL REPORT
WTFRC PROJECT # TR-02-235

Project Title: Reduction of Pesticide Inputs, Worker Exposure, and Drift Through Alternative Sprayer Technology

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Objectives:

The goal of our research has been to help growers reduce the cost of pesticide applications while simultaneously maintaining efficacy, reducing worker exposure, and off-target drift. This project was designed to help meet the goals of the 'technology roadmap' to reduce production costs while enhancing fruit quality and sustaining a quality environment. The following objectives were studied during a three year project that involved a combination of field and laboratory experiments.

1. Determine residue deposition from a reduced volume alternative sprayer (i.e., the Proptec tower) using reduced rates of active ingredient application.
2. Determine efficacy of reduced application rate residues deposited by a reduced volume sprayer and the conventional airblast sprayers.
3. Determine the residue decline rate of reduced application rates using chemical and biological assays.
4. Improve the accuracy of estimating worker exposure by determining the rate in decline of dislodgeable foliar residues after application of reduced active ingredient rates.
5. Determine the drift reduction potential of alternative sprayers.

Significant Findings:

- LC50/LC95 of azinphos-methyl (Guthion), acetamiprid (Assail), and methoxyfenozide (Intrepid) against neonate codling moth (CM) larvae were respectively 0.017/0.075 $\mu g/cm^2$, 0.007/0.166 $\mu g/cm^2$, and 0.077/1.130 $\mu g/cm^2$. The slopes of the dose-response curves for Intrepid and Assail were flatter than the curve for Guthion suggesting greater population variability in susceptibility to these new reduced risk insecticides.
- Neonate codling moths often died within 2-3 hours of exposure to leaf disks treated in the field or the lab with Guthion or Assail without any evidence of feeding. Thus, Assail seems to have good contact activity against codling moth larvae.
- During crop years 2002 and 2004 when five-rows were sprayed per plot, residues deposited by the Proptec sprayer were higher than by either a Rears airblast or Pak-blast sprayer. When spray plots consisted of only one row during crop year 2003, initially deposited residues were higher in the Pak-blast treatments.
- Fluorescent tracer dye photographs showed uneven coverage on apples from the second cover spray regardless of sprayer type. In July, the surfaces of treated apples often had large areas

lacking spray residues. In contrast, apples sprayed during May or early June had more uniform coverage around the whole fruit.

- Cessation of feeding activity, rather than lethality should be used as the appropriate field-relevant toxicological endpoint for Intrepid.
- Bioactivity of Guthion, Assail, and Intrepid as determined by the leaf disk and apple assay was not significantly affected by sprayer type (Rears airblast vs. Proptec), did not differ between leaves collected from mid canopy and leaves collected from the top of the canopy, and were equally efficacious at half-rates and full rates.
- Bioactivity of Guthion persisted for about one month (i.e., bioactivity generally reached ~90% neonate CM mortality) on treated foliage but only persisted for about two weeks on treated apples. Similar persistence in bioactivity of foliage and apples was observed for Assail.
- Intrepid (methoxyfenozide) bioactivity was lower than Guthion and Assail. Persistence of bioactivity (as evidenced by <50% mortality within 24 hours) lasted for less than three weeks on foliage and was poor on apples.
- Persistence of Guthion and Assail bioactivity generally paralleled persistence of residues. As residues dropped below the LC50 after 30 days, percentage mortality of neonates dropped significantly.
- Persistence of Guthion residues on foliage seemed shorter after the second spray than the first spray. This observation suggests that foliar residues may dissipate faster following applications in mid-summer than applications in early summer. Overhead irrigation increased the rate of dissipation.
- Alternate-row middle and skip-row spray patterns deposited sufficient Guthion and Assail residues to cause 100% mortality of larvae regardless of sprayer type. Residues were still above the LC50 for each insecticide 28 days after application.
- Dislodgeable foliar residues of Guthion observed after 21 days were at least two times lower than residues used by the EPA to assess post-application worker exposure at both the 0.5 and 1 lb AI rate/acre.
- Drift of Guthion, Phosmet, and Assail were detected to a distance of 200 feet in several drift trials during experimental plot applications and commercial scale applications.
- When nozzles were turned off on one side of an airblast sprayer, significant levels of spray drift still occurred on this "upwind" side due to the rotation of the axial fan. However, the Proptec sprayer did not drift significantly to the upwind side of the fans. These observations suggest that airblast sprayers applying chemical to outside rows need to shield the unused side of the axial fan to avoid inadvertent contamination outside of the orchard.

Methods:

All experiments were conducted at commercial orchards in the Quincy area during crop years 2002-2004. At each location, cooperators allotted a block of 'gala' apples for delineation of treatment plots. Plots consisted of five tree rows by 10 trees long. All experiments involved comparing the deposition, persistence, and bioactivity of several insecticides after application by either an axial fan airblast sprayer or a Proptec single tower sprayer. Two cover sprays were made during each growing season—late May or early June and during the third week of July. During 2002 and 2004, all five rows in a plot were sprayed, but in 2003, only a single row was sprayed from both sides. During 2003, alternate-row-middle and skip-row spray patterns were also tested.

Insecticide formulations (active ingredient; lbs AI/acre) applied in the various experiments included Guthion Solupak (azinphos-methyl; 0.25, 0.5, 1.0 lbs AI/acre), Assail 70WP (acetamiprid; 0.075, 0.15 lbs AI/acre), Intrepid 4F (methoxyfenozide; 0.125, 0.250 lbs AI/acre), and Imidan 70W (phosmet; 3.5 lbs AI/acre). Fluorescent dye was added to some spray tank mixtures to visualize the pattern of spray deposition on foliage and apples.

Following each insecticide application and at different intervals thereafter, foliage and apples were collected for laboratory bioassays with neonate codling moths (all insecticides) and for analysis of insecticide residues (Guthion and Assail treatments only). During 2002 and 2004, the tree canopy was divided into mid (waist high to extended arm length) and top (at least 2 ft above extended arm length) segments. Samples were kept separate by canopy location. Dose-response relationships (LD50/LD95) were also determined for each insecticide by exposing neonate CM to laboratory treated leaf disks.

For data analysis, the independent variables were sprayer type, canopy location, and insecticide rate. During 2003, row spraying pattern (i.e., alternate row middle or skip row) were also independent variables. Over all years, dependent variables were percent mortality of neonate CM exposed for at least 24 hours to leaf disks punched from field-treated foliage, percent reduction in entry holes on field-treated apples, and residues on leaves (expressed as $\mu g/cm^2$) and residues on apples (2002 and 2004 only [analyses of 2004 apple samples still in progress]).

Downwind drift and cross row movement of sprays during application were monitored during all years of the project. Downwind out-of-orchard drift was monitored by collecting residues on silica gel (SG) cards (20 cm x 10 cm) laid on the ground at different distances from the outside tree row (i.e., row one). To measure cross row movement SG cards were also laid at different distances from row one several rows inside the orchard. Cards were placed both in the tree rows and in the alleys between rows. During 2002, single row applications were made using either an airblast or Proptec sprayer traveling between rows one and two and between rows two and three. Only one side of the row was treated (toward the downwind side). During 2003 and 2004, both commercial applications (Phosmet, Guthion) and multiple row experimental applications (Assail, Phosmet) were monitored for drift. Data were used to determine the validity of the model AgDRIFT.

Results & Discussion:

<u>Objective 1.</u> *Determine residue deposition from a reduced volume sprayer (i.e., the Proptec tower) using reduced rates of active ingredient application.*

During crop year 2002, the Proptec sprayer was calibrated to deliver the insecticides at a volume rate of 100 gallons/acre and speed of ~4 mph. The airblast sprayer delivered insecticide at a volume rate of 100 gallons and speed of 1-2 mph. Initial deposition of Guthion residues was nominally higher in the Proptec treatments at both canopy levels except at mid canopy level after the second cover spray (Figure 1).

During crop year 2004, the Proptec was calibrated to deliver spray at a volume rate of 35 gal/acre and all five rows in a treatment plot were sprayed. Deposition of both Assail and Guthion residues applied at their nominal 1X rates (0.15 lb AI/acre or 1 lb AI/acre, respectively) was again higher in the Proptec treatment except for the mid canopy level of the first cover spray (Figure 2). However, during crop year 2003, when only one row was treated and no segmentation of the canopy used in sampling, initially deposited residues from the Proptec application were lower than residues from the airblast (Pak-blast) application (Figure 3, 4). Nevertheless, bioactivity (as measured by mortality) against neonate CM larvae was over 90% for all treatments.

<u>Objective 2.</u> *Determine efficacy of reduced application rate residues deposited by a reduced volume sprayer and the conventional airblast sprayers.*

Based on larval exposure to laboratory-treated leaf disks, LC50 and LC95 were estimated for Guthion, Assail, and Intrepid (Figure 5). Without any other food source, larvae would eat the leaves and would remain healthy through 3 or 4 instars. Furthermore, larvae would “weave” cocoons of frass and undigested leaf waxes around themselves. Contact toxicity as opposed to feeding activity was evident for all insecticides because larvae would die without any observable feeding on the leaf surface.

When exposed to leaves treated in the field with Guthion and Assail, especially after initial deposition and for at least two weeks thereafter, larvae would die or appear moribund within about four hours of exposure. On leaves treated with Intrepid, larvae would become lethargic and stopped feeding. Only after initial Intrepid deposition and one week later did larvae die within 24 hours, but they always became sick even months after application.

Initially deposited residues were significantly above the LC95 for Guthion at both the reduced and full application rates (Figure 1, 2, 4) but near the LC95 for Assail (first cover spray only) (Figure 2, 3). Nevertheless, after 24 hours of exposure to initially deposited residues off all insecticides, 80-100% of larvae generally died regardless of rate of application, type of sprayer, and row spray pattern.

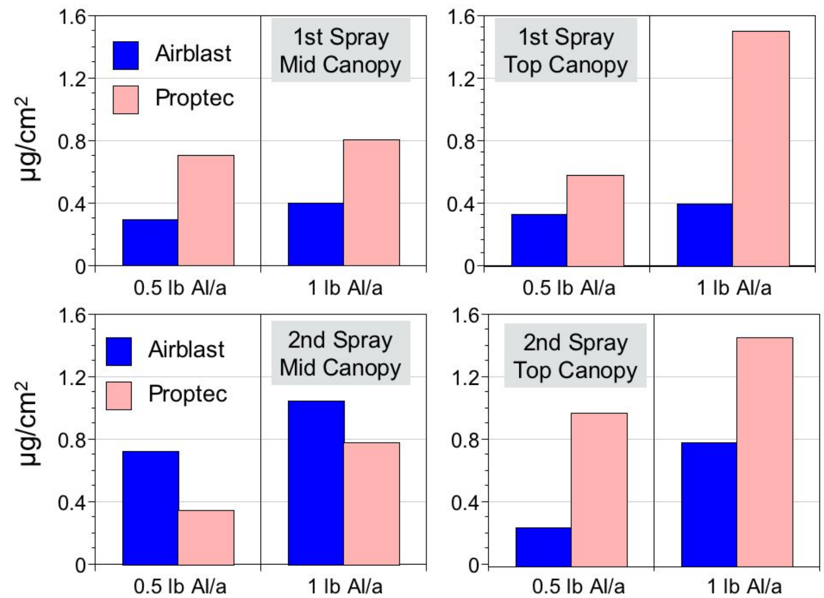

Figure 1. Deposition of Guthion residues (µg/cm^2) on foliage at mid canopy and top canopy levels after the first and second cover spray during crop year 2002.

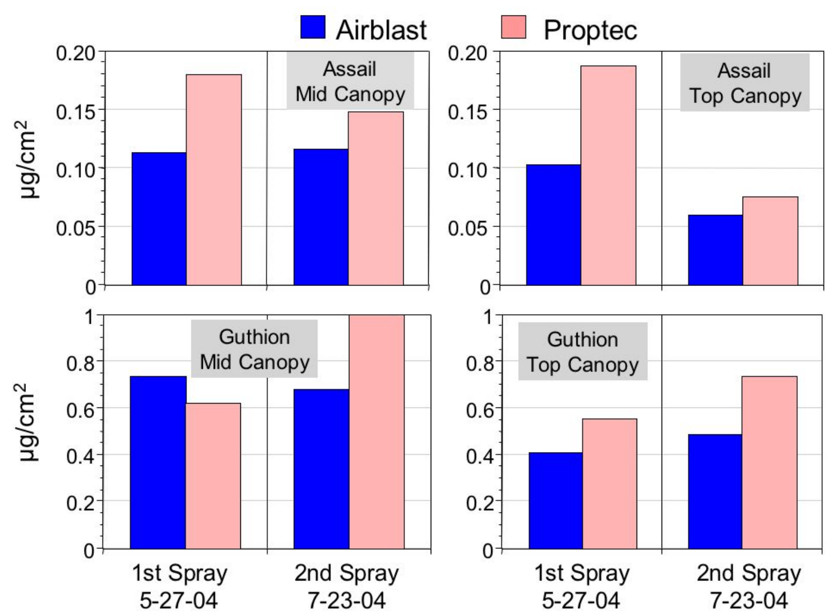

Figure 2. Deposition of Guthion (bottom) and Assail (top) in the mid and top canopy segments after spraying during crop year 2004. Both insecticides were applied at the rate of 1 lb AI/acre.

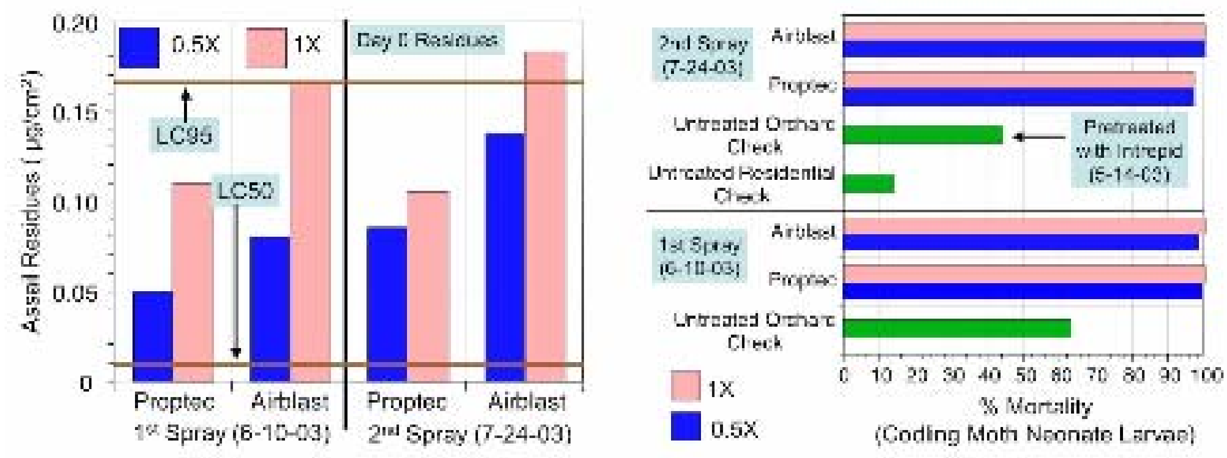

Figure 3. Initial deposition (µg/cm²; left side) on foliage and bioactivity (% neonate CM mortality; right side) of Assail residues applied during June and July 2003 by a Proptec and airblast (Pak-blast) sprayer. Both sides of a single row were sprayed. Note that foliage collected from the orchard had received a cover spray of Intrepid during May, and larval mortality was subsequently very high, even after two months. Therefore, leaves from an untreated residential apple tree were used to gauge larval mortality in the absence of insecticide. Percentage mortality was uncorrected for untreated control mortality.

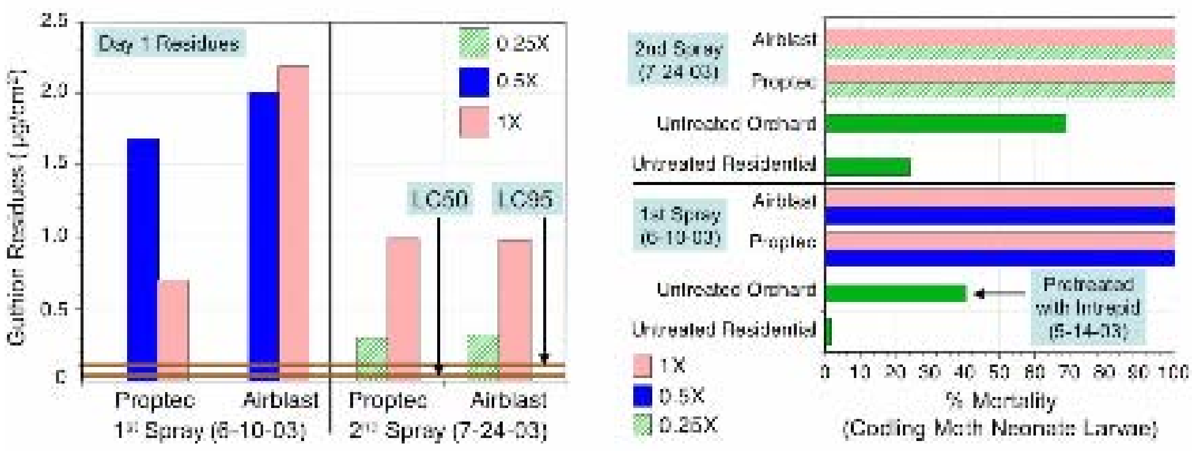

Figure 4. Initial deposition (µg/cm²; left side) on foliage and bioactivity (% neonate CM mortality; right side) of Guthion residues applied during June and May 2003 by a Proptec and airblast (Pak-blast) sprayer. Single rows were sprayed from both sides.

Objective 3. *Determine the residue decline rate of reduced application rates using chemical and biological assays.*

The dissipation of residues and change in bioactivity against neonate CM were monitored following both the first and second cover sprays during crop years 2002 and 2003 and during the first cover spray of crop year 2004. During crop year 2002 and 2003, Guthion residues generally remained above the neonate foliar LC95 for about one month following application (Figure 6, 8). During crop year 2002, foliar Guthion residues and bioactivity tended to be higher in the Proptec treatment plots than in the airblast sprayer plots. For both sprayer types, bioactivity dropped significantly when residues had declined below the LC95 (compare Figure 7 with the Proptec treatments in Figure 6). Patterns in dissipation of residues and bioactivity were the same in both the 0.5X (0.5 lb AI/acre) and 1X treatments (1 lb AI/acre) (Figure 6, 7).

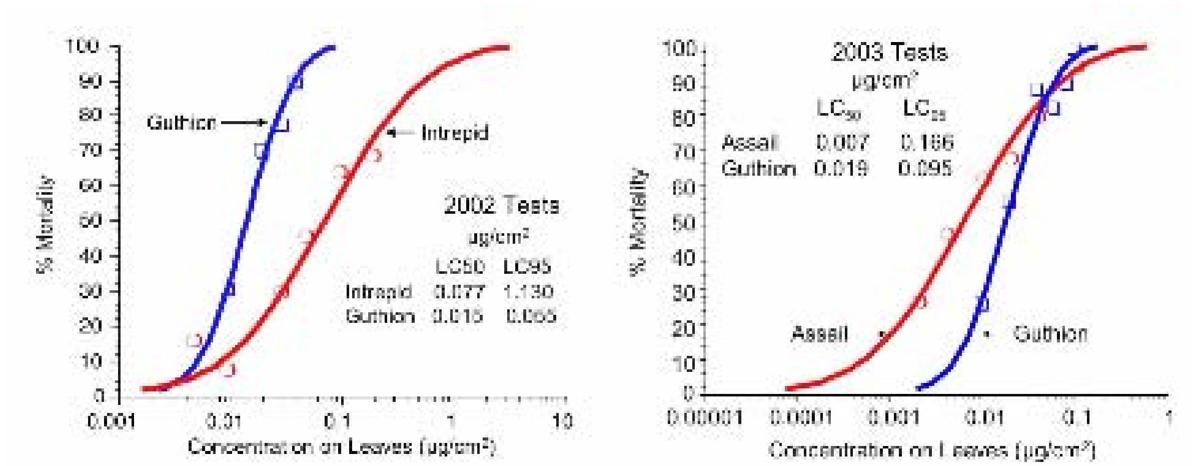

Figure 5. Dose-response relationships for neonate CM larvae exposed to laboratory-treated leaf disks for 24 h. One hundred microliters of insecticide formulated in a 2:1 acetone water solution was pipetted over the upper surface of individual leaf disks.

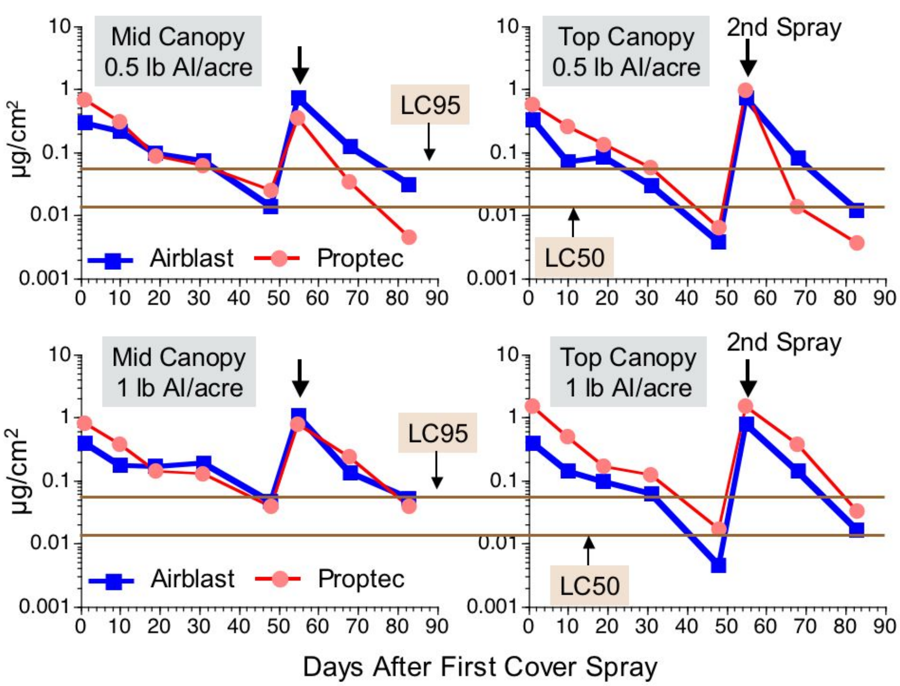

Figure 6. Persistence of Guthion residues (µg/cm^2) after two cover sprays in relation to the foliar LC50/LC95 against neonate CM. Experiments were conducted during crop year 2002, and five rows within each plot were sprayed at a volume rate of 100 gal/acre. This orchard

used overhead sprinkler irrigation, which was turned on more frequently following the second cover spray than following the first spray.

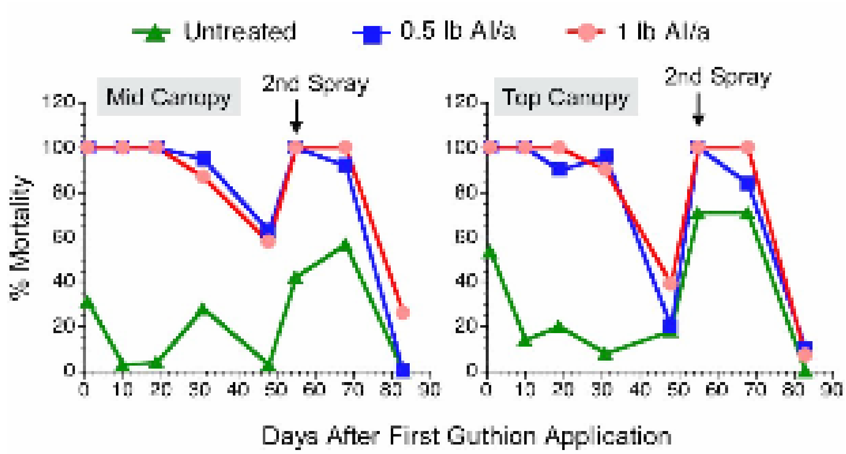

Figure 7. Persistence of bioactivity (% mortality) of Guthion residues against neonate CM larvae on field-treated foliage (crop year 2002). Application was made with a Proptec sprayer. Note that bioactivity dropped below 90% and 50% when residues had declined below the LC95 and LC50, respectively (see Figure 6).

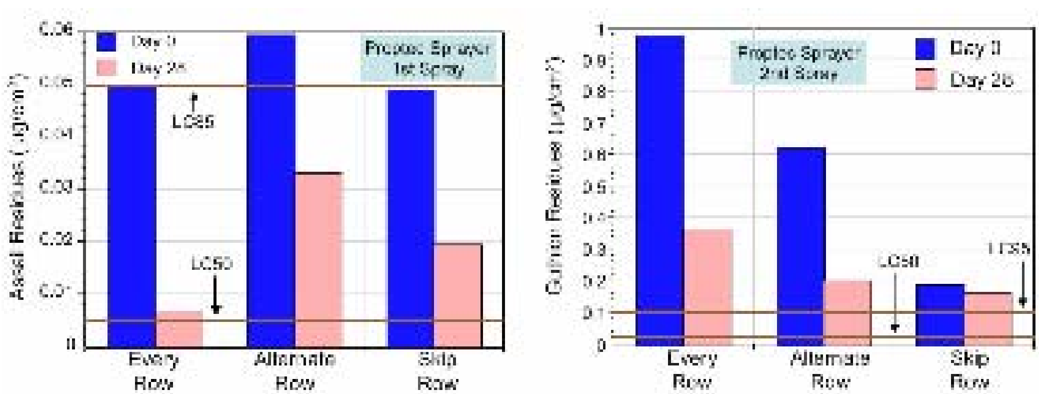

Figure 8. One-month persistence of Assail (left side) and Guthion (right side) residues on foliage in relationship to the LC50/LC95. Applications were made during crop year 2003 to single rows with the Proptec (35 gal/acre; ~4 mph) using conventional (every row) and alternative row spraying practices.

Assail residues following the Proptec sprayer treatment during crop year 2003 were lower than residues from the Pak-blast sprayer following the first and second cover spray throughout the monitoring period (Figure 9). Although the Assail residues from the Pak-blast treatment were significantly below the lab determined LC95, foliar bioactivity was generally around 90% or greater throughout the monitoring period, although lower than for the Pak-blast sprayer treatment.

Residues of Guthion following alternative row spraying practices with the Proptec sprayer remained above the LC95, even on foliage collected from a completely unsprayed row situated between two rows sprayed from the outer side only (Figure 8). Similar results (not shown) were noted for the airblast sprayer. For both sprayers, the skip-row treatments resulted in residues comparable to the 0.5X and 0.25X (0.25 lb AI/acre) treatment rates. Guthion residues from those reduced rate treatments were also above the LC95 after 28 days (data not shown). In contrast to

Guthion, Assail residues from all row-spraying practices made with the Proptec during 2003 were below the foliar LC95 but remained above the LC50, even after 28 days (Figure 8).

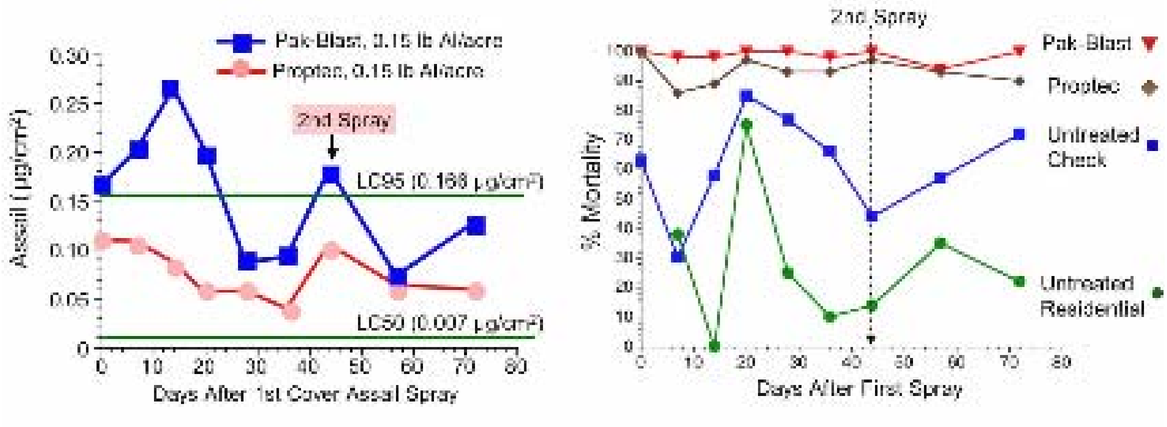

Figure 9. Persistence (left side) and bioactivity (right side) of Assail residues at the 1X rate (0.15 lb AI/acre) applied during crop year 2003 to single rows.

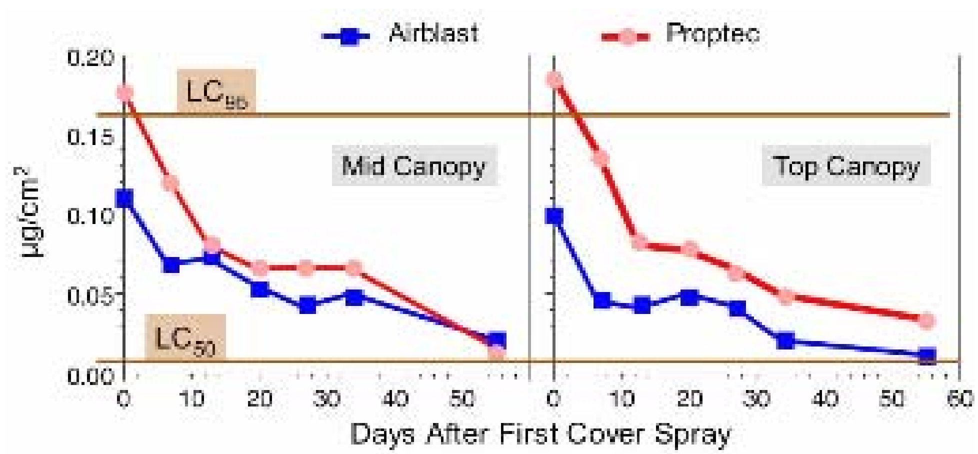

Figure 10. Persistence of Assail residues in relationship to the foliar LC95/LC50 after the first cover spray by a Proptec and Pak-blast sprayer during crop year 2004. Application was made to five rows within a treatment plot at a rate of 0.15 lb AI/acre and volume rate of 35 gal/acre or 100 gal/acre for the Proptec and Pak-blast sprayers, respectively.

During crop year 2004, Assail residues were above the foliar LC95 only immediately after application (Figure 10). Residues were higher in the Proptec treatments, especially at the top of the canopy. Residues remained above the LC50 for at least 35 days following application.

Biological activity against CM larvae on apples was measured using a larval entry hole assay. Persistence of biological activity (as measured by prevention of an entry hole) of deposited Guthion residues on apples was very short in comparison to persistence of bioactivity on leaves. Bioactivity dropped significantly after two weeks and paralleled a significant loss of pesticide residues (Figure 11). However, for apples collected from the top canopy level of the Proptec 1X treatment, over 80% reduction of entry holes was observed after two weeks. When apple residues dropped below 0.2 µg/cm^2, percent reduction of entry holes dropped to <60% (Figure 11). Trends were similar between 0.5X (data not shown) and 1X rate treatments. However, percent reduction in entry holes was initially lower in the 0.5X treatment than in the 1X treatment, and significantly lower after two weeks. The trend in loss of bioactivity on apples after two weeks was also observed in crop year 2004 (Figure 12).

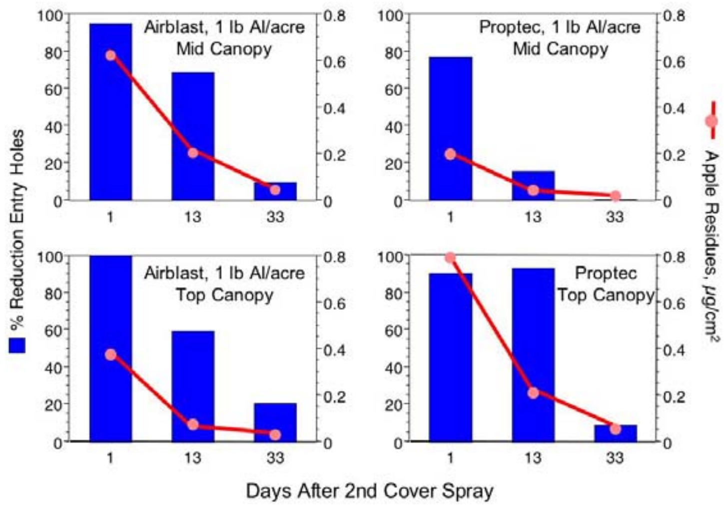

Figure 11. Percent reduction of neonate CM entry holes on apples in relationship to recovered surface residues of Guthion during crop year 2002. Multiple replicates of single apples were analyzed to derive an average surface residue.

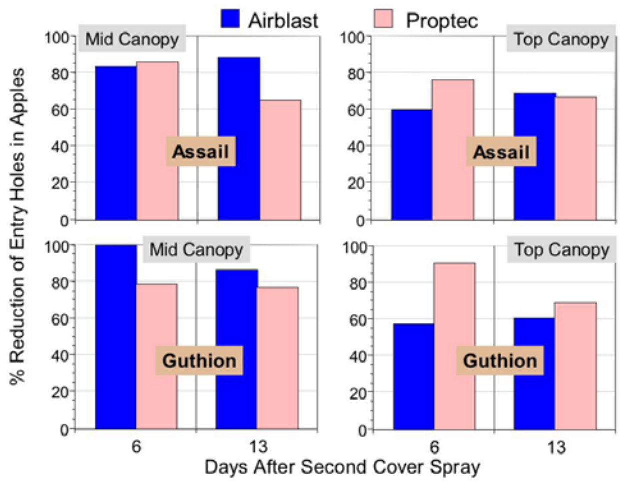

Figure 12. Percent reduction in neonate CM entry holes during crop year 2004 following 1X cover sprays of Assail and Guthion. No significant differences between sprayers were observed by the second week following application.

<u>Objective 4.</u> *Improve the accuracy of estimating worker exposure by determining the rate in decline of dislodgeable foliar residues after application of reduced active ingredient rates.*

In the Guthion Registration Eligibility Decision documents (REDs), EPA used DFR (dislodgeable foliar residue) values from 0.5 lb (0.5X) and 1 lb AI (1X) per acre rates to determine whether risk was acceptable to post-application workers. The agency used 21-day post application residue values of 0.35 and 0.7 µg/cm^2, respectively. Using a stronger extraction solvent than typically employed for agency mandated DFR studies (acetone:water compared to soap solution), we observed in all experiments that Guthion residues at ~21 days were at least two times lower than the EPA estimates. Our observations suggested that the EPA database should be updated with more DFR studies of Guthion to increase the accuracy of post-application worker exposure. We noted no significant differences in residues recovered three weeks post application due to the airblast and Proptec sprayers when multiple rows (compared to single rows) were sprayed (see Figure 6).

Objective 5. *Determine the drift reduction potential of alternative sprayers.*

The drift potential from the Proptec sprayer could be compared to the airblast sprayer only at the orchard used during crop year 2002 owing to the lack of an open field next to the orchard used during 2003 and 2004. However, further characterization of drift from airblast sprayers was studied at an orchard in the Yakima Valley with an adjacent open field (data not shown). During 2002, single rows were sprayed with Guthion with the tractors first going though rows one and two (Spray A) only and then through rows two and three (Spray B) only (Figure 13). Rows were sprayed only from one side, inside to outside. The airblast sprayer nozzles on the leeward side were shut off during spraying.

Downwind out-of-orchard drift was significantly greater for the Proptec sprayer than the airblast, but the Proptec was oriented to spray from the inside to the outside of the rows rather than the inside to the outside. Pertinently, however, the airblast sprayer, but not the Proptec, deposited significant residues on the ground of untreated rows within the orchard (Figure 13) even though the inner nozzles were shut off, but the Proptec did not. We hypothesized that the rotation of the axial fan on the airblast sprayer picked up spray and emitted it to the leeward unsprayed side. Thus, the data suggest that applicators should shield the unused side of the airblast sprayer when spraying the first two outside rows from only one side (i.e., the outside to inside direction). The Proptec sprayer should be operated on the two outside rows by spraying from outside to inside.

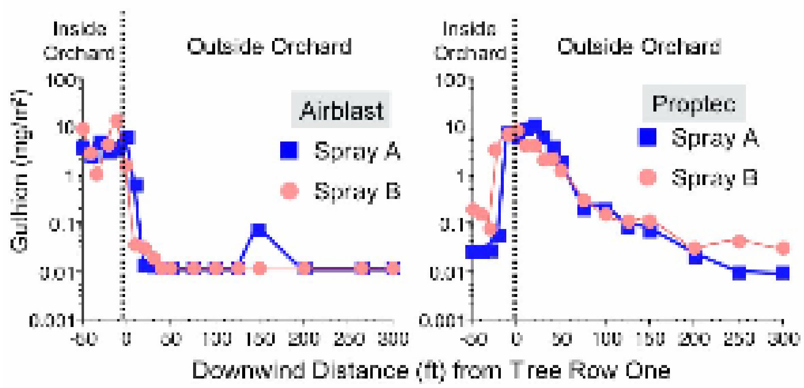

Figure 13. Downwind drift and cross row movement of Guthion applied by two sprayers during 2002.

Budget
Project Title: Reduction of Pesticide Inputs, Worker Exposure, and Drift
PI: Allan Felsot
Project Duration: 2002–2004 (3 years); **Project Total:** ($161,807)

Item	Year 1 (2002)	Year 2 (2003)	Year 3 (2004)
Salary (1.0 FTE)	17,730	21,072	35,115
Benefits (29%)	4,787	5,900	10,183
Wages [1/]	6,880	6,880	1,550
Benefits (16%)	1,101	1,101	248
Equipment	4,500	0	0
Supplies [2/]	16,550	18,403	7,010
Travel [3/]	900	897	1,000
Total	**52,448**	**54,253**	**55,106**