Summary of the research presented and discussed follows:

I. Implementation Projects – Area-wide II, IFAFS/RAMP

Implementation of a pheromone-based multi-tactic pest management system in Washington apples and pears.

Jay Brunner, Elizabeth Beers, John Dunley, Vince Jones, Ted Alway, WSU-TFREC

Apples: All OP and NON-OP blocks maintained low pest populations and had very low fruit damage levels at harvest, in most cases lower than in 2001. The average number of pesticide applications and the cost per acre also declined, significantly so for the NON-OP blocks. The reduction in sprays probably stems from increased confidence in the efficacy of the new insecticides, primarily methoxyfenozide (Intrepid) and pyriproxifen (Esteem), used for codling moth and leafroller control in the NON-OP blocks.

The thorough monitoring of codling moth, leafrollers and lacanobia fruitworm provided growers with the information needed to respond with well-timed control measures where needed. Leafroller monitoring with standard and low-load pheromone lures showed similar population trends. The AA lure attracted very few leafrollers and will probably not be used in the AWII orchards next year. There were no surprises relative to secondary pests or their natural enemies in any orchards.

Pears: Effecting changes in pest and natural enemy populations, by shifting to a selective, less disruptive pest control program, can take one, two or more years until the new populations are established. The year 2002 can be considered Year 1 in this process, as new treatment protocols were adopted. The NCW pear orchards show reduced psylla numbers and increased natural enemy numbers in the SOFT blocks; no such trend is evident in the Yakima orchards. Good control was obtained of most pests in the SOFT blocks, including codling moth and leafrollers. However, potential pest problems are posed by grape mealybug and pear rust mite, particularly in SOFT blocks, and leafrollers, based on greatly increased catches in pheromone traps. The AWII pear orchards should be followed for at least two more years to clearly establish changes in pest and natural enemy populations with the use of selective insecticides.

Biologically intensive IPM programs for apples, pears and walnuts

Robert A. Van Steenwyk, UC California

Cooperators: Lucia Varela, Chuck Ingels, Bobby Nomoto, Koji Zolbrod and Steve Welter

Description of project: This project is aimed at the evaluation of new methods of pheromone application for CM mating disruption, large scale evaluations of reduced risk insecticide combined with CM mating disruption and the identification of new reduced risk insecticides for CM control.

Evaluation of sprayable CM pheromone: The trials were conducted in commercial 'Bartlett' pear orchards. Five orchards with low to moderate CM populations were used for the trial. Two orchards were in the Ukiah Valley of Mendocino County; two orchards were in the Delta, Sacramento County and one orchard in Fairfield, Solano County. There were five treatments in each orchard. The treatments were: a) 20 g/acre of Suterra sprayable pheromone applied every row, b) 20 g of sprayable pheromone applied every other row (resulting in a rate of 10g/acre skip row), c) 10 g/ acre of sprayable pheromone applied every row, d) grower standard and e) an untreated control.

Sprayable pheromone suppressed CM infestations. Overall, there was no statistical difference in CM infestation among the Suterra sprayable pheromone (CM-F) plots, the grower standard or untreated control. However, supplemental applications of conventional insecticides were needed to maintain grower acceptable infestation levels. It appears at this point that sprayable pheromones will have their use as supplemental pheromone applications in pears and apples. However, sprayable pheromones may have greater applicability in large canopy walnut orchards than pear or apples orchards.

Reduced risk insecticides for CM control in apples and pears: This trial was conducted in a commercial 'Bartlett' pear orchard in Hood, CA. Three treatments were replicated three times in a completely randomized design**.** There was no significant difference in the percent CM or GFW infested fruit between Assail and the grower standard of Imidan followed by Danitol. Although the grower standard had significantly more SJS and LB damage than the Assail treatment, the SJS and LB damage were well within grower acceptable levels for both treatments. The untreated control, which was adjacent to the test plot, had unacceptable CM damage. However, since the untreated control was not replicated within the test plot, statistical analysis using the untreated control was not possible.

New candidate reduced risk pesticides for CM control in pears or walnuts:
Pears: A trial was conducted on mature 'Bartlett' pear trees in a commercial orchard near Fairfield, CA. Fifteen treatments were replicated four times in a randomized complete block design. The compounds were tested against a against a very high CM population with over 56% of the fruit infested at harvest in the untreated control and with 0.9% CM infested fruit in the grower standard. This trial should be considered a rigorous test of the experimental materials. However, this year the CM population was not as high as in previous years. Assail and Assail combined with horticultural oil and Dimilin provided acceptable CM control that was very similar to the grower standard while at the same time suppressing TSSM, ERM and PP populations. Multiple applications of Novaluron were effective in suppressing CM but there is some indication of ERM flare-up. Two applications of Calypso followed by one application of Intrepid had increased levels of CM infestation compared to the grower standard.

Walnut: This trial was conducted in a commercial 'Payne' walnut orchard in Hollister, CA. Sixteen treatments were replicated four times in a randomized complete block design. Each replicate consisted of an individual tree. This study was conducted against a relatively high CM population that resulted in more than 10% infestation in the untreated control. Compared to previous years, the infestation level in this orchard was disappointingly low. The control achieved by all of the experimental treatments was acceptable compared to the untreated control.

Calypso at three rates, Calypso and Intrepid, and Lorsban and Intrepid all provided a high level of control. Assail and Success with Confirm also provided excellent control. Success by itself was not successful as a CM control treatment. Proclaim, combined with the R-11 spreader activator, also showed disappointing CM control.

Codling moth mating disruption programs using alternatives to organophosphates for supplemental control of key and secondary orchard pests.

Richard Hilton, Helmut Riedl, Philip VanBuskirk, and Steve Castagnoli, Oregon State Univ.

In Oregon, five sites of 20 to 30 acres each have been established. The northern Oregon demonstration sites consist of two pear and one apple block while the southern Oregon sites are all pear blocks. Orchards were monitored biweekly throughout the season using leaf scanning, leaf brushing, beating trays, attractant-baited traps and earwig domiciles. High pear psylla populations in southern Oregon required treatment in all demonstration blocks. In northern Oregon, one of the pear blocks required additional treatment for codling moth due to high trap catches. Damage levels at harvest were very low throughout with pear psylla russetting accounting for the majority of fruit injury in southern Oregon. Differences between the areas treated with Imidan and Intrepid did not appear to be significant.

With the exception of the one pear block in northern Oregon, codling moth trap catches were generally low. As in 2002 the kairomone lure did not catch as many moths overall as the pheromone, but in two southern Oregon pear blocks where the variety was primarily Comice, the kairomone did catch more moths than the pheromone, a result which was noted last year. In cooperation with Trece Inc., additional trials comparing lures baited with varying loads of pheromone and kairomone, both singly and in combination, were conducted in two pear blocks and an apple block in southern Oregon. Other demonstration blocks using mating disruption were followed and in one southern Oregon orchard, monthly applications of a sprayable pheromone were compared to a standard hand applied pheromone treatment with good results being observed in both cases. Mass trapping was also demonstrated using combination pheromone/kairomone lures and powder traps with very high numbers of moths being trapped in some instances.

Movement and dispersal of codling moth, Cydia pomonella, in rural and orchard areas

H.M.A. Thistlewood and G.J.R. Judd,
Pacific Agri-Food Research Centre, Agriculture & Agri-Food Canada,

The long-term success of the area-wide Okanagan-Kootenay Sterile Insect Release (SIR) Program for codling moth in British Columbia, and of Sterile Insect Technology for this insect elsewhere, depends upon an improved knowledge of the biology and movement of codling moth at very low levels of abundance and in heterogeneous landscapes such as urban and rural areas. The development of appropriate or cost-effective techniques for detecting and monitoring codling moth at very low densities is also a significant challenge. Most of the research on codling moth, its integrated pest management, or SIR, to date has occurred in commercial orchards, and the extent of the interplay between populations in adjacent orchard and urban areas is unknown. Recently, by field observation and in experiments using marked moths, we have measured the natural dispersal of codling moth or its passive movement by people, and the persistence and movement of sterile moths in a mixed landscape of 895 ha.

Area-wide management of codling moth, Cydia pomonella, at very low densities

H.M.A. Thistlewood and G.J.R. Judd,
Pacific Agri-Food Research Centre, Agriculture & Agri-Food Canada,

Area-wide programs for insect management are being developed in several regions of the world. In British Columbia, the Okanagan-Kootenay Sterile Insect Release (SIR) Program is an area-wide management program for codling moth, Cydia pomonella, in the key fruit-growing areas, and in neighboring urban, native, or public lands. In recent years the result has been, in both commercial and non-commercial situations, very significant reductions in frequency of detection and in density of codling moth, of damage at harvest, and of insecticide use. We presented an appraisal of some results from orchard and urban settings to 2002, and discussed some of the biological and ecological challenges, which have affected costs and progress, and measures taken to resolve those, which threaten long-term success.

Using statistical analysis and GIS to enhance the efficiency of SIR in managing codling moth, Cydia pomonella L., in British Columbia

R.S. Vernon, H.M.A. Thistlewood, C.A.S. Smith, T. Kabaluk, G. Frank and R. Batenburg

Pacific Agri-Food Research Centre, Agriculture & Agri-Food Canada

In 1999, all codling moth pheromone traps in Zone 1 of the Okanagan-Kootenay Sterile Insect Release (SIR) Program were geo-referenced along with associated orchard and topographical data. These data points were linked to moth counts and other data compiled by SIR staff in 1999 and 2000, and various statistical and spatial analyses conducted to determine how key activities in the SIR program could be streamlined. We presented the results of some analyses using a geographic information system to optimize monitoring procedures, and to identify topographic or other features linked with moth populations.

II. Monitoring systems, semiochemicals, attract and kill

Development of "attract and kill" and augmented mating disruption control methods using the codling moth kairomone in Californian walnuts.

Douglas M. Light, Alan Knight and Steve Welter, USDA and UC California

Semiochemical Properties of Kairomone DA2313: Female Moth Oviposition
The use of DA2313 lures to stimulated oviposition by the laboratory and a field-collected diapausing-strain of CM was compared using "dual-choice" and "no-choice" laboratory bioassays at the USDA-ARS YARL facility by Dr. Alan Knight, and are summarized here.

DA2313-treated rubber septa increased oviposition by CM females 2-3 times in four-day non-choice bioassays and was highly preferred (6-7 fold) in similar dual-choice tests *vs.* solvent (hexane) blank septa. Further, DA2313 kairomone increased egg laying by 50% over the lifetime of females reared from field-diapausing over-wintering moths. Thus, DA2313 kairomone appears to both elicit and promote egg deposition. Females laid nearly twice the number of eggs on apple leaves versus various plastic and waxed sheets. An optimal septa lure-load of DA2313 was found to be 1.0 and 3.0 mg, which increased egg laying 2-3 fold on foliage in proximity to the trap over foliage near unbaited control traps. Few eggs were laid directly on the trap's plastic surface.

Experiments in walnut orchards in 2002 were a disappointment and completely unsuccessful in using the DA-kairomone as an attractant and stimulant for ovipositional egg-traps. Not a single egg was found on these plastic, Para-film covered, tube traps that were hung for over a 3 1/2 month period. A wide range of DA-kairomone doses were tried in replicated trials. Also, the problem was not a lack of moth pressure because in these Chandler var. walnut orchards there was a moderate resident CM population, causing ca. 3% canopy count damage beginning in June. Orchard monitoring traps, both DA and pheromone (L2 lures, Trécé, Inc.), captured a range from 6- to 3 CM/trap/night during that period. Thus, additional experiments are needed to understand female ovipositional behaviors in the orchard context and to design a better more acceptable trap.

Attract and Kill DA2313: Insecticide Thixatropic Paste Formulations

Over the last four years we have conducted a series of experiments with a progression of attract and kill (AK) formulations – recipes of plastic matrix, paste-consistency chemical materials, or formulations. These "thixatropic" plastic matrix-pastes/gels formulations are intended to absorb, retain, stabilize, and then emit/evaporate the DA2313 attractant and a contact quick-killing insecticide. For the pesticide, we have focused primarily on pyrethroid insecticides, and primarily for our initial tests on permethrin that is highly toxic to both adult and larval CM. We focused on developing and applying the paste-matrix formulations either as large (ca. 40 mg) dabs/globs or as smaller droplets and testing these AK formulations for their attractancy and lethal activity against both adult and neonate CM. Pastes have been: 1) tested in sticky traps for their longevity and attractiveness to CM adults and 2) applied to filter paper and/or leaf surfaces for attraction and contact by both adult moths and crawling larvae.

Field aging – longevity tests in Washington State apple orchards showed that large dabs of the AK thixatropic black paste remained toxic for over five weeks, killing 100% of tested adult CM after three weeks field exposure of the paste. And these same dabs of DA2313 paste were highly attractive to CM adults for up to four weeks in the apple orchard when used as the lure in sticky traps. However, further close observations found that the majority of moths, especially females, do not contact these large, high concentration drops. Instead female CM were attracted to within a few inches of the AK DA2313 paste formulation when placed and tested in the field on various-sized sticky cards (ranging from 1 inch to 10 inches in diameter). However, we have encouraging laboratory data that demonstrates that CM adults and neonate larvae are attracted over short ranges (1 – 5 cm) to and contact tiny droplets (< 1 mg, *ca.* 1 μl) of AK paste on filter paper and apple leaf surfaces.

DA Micro-Encapsulated (MEC) Formulations: Attractiveness to Adult CM
Field screening of various micro-encapsulated formulations (MEC) of the pear ester kairomone determined that two formulations had good inherent attractiveness when assessed as a trap lure placed on filter paper. The best two kairomone-MEC formulations were tested for their release rates, stability, longevity and gender specificity/selectivity in attraction under orchard field conditions for over 2 1/2 months. Both the DA-MEC and the pheromone-MEC elicit dose dependent response curves showing increased CM capture (moths/trap/night) as applied dose increased. When placed in traps as lures, both formulations elicited good to fair capture rates over a range of doses for an acceptable exposure period of greater than a month. Moreover, these CM capture rates by the MEC-baited traps were very similar to the capture rates of both DA and pheromone standard monitoring traps that were located in the same orchard and during this same period. The 3 mg pheromone-MEC captured male CM at the same rate as the standard 3 mg pheromone L2 monitoring lure did, beginning at 5 males/trap/night and progressively dropping to 1 male/trap/night by the end of the test period.

Effects of Combined Application of Sprayable DA MEC and Sprayable Pheromone MEC
The ability of the kairomone MEC to augment and enhance the MD activity of the MEC sprayable pheromone was initially conducted in 2002 in two walnut orchards. The design was to test whether the sprayable MEC kairomone would 1) perform similarly to sprayable pheromone in "shutting-down" or decreasing CM capture in kairomone-baited monitoring traps and 2) effect the pheromone control efficacy. This initial field trial was conducted in two walnut orchards (Hartley var.) that were divided into five acre treatment blocks and sprayed (via standard fan sprayer) various MEC treatment rates per acre of: 10 grams of pheromone alone, 5 gm pheromone alone, 10 gm pheromone + 5 gm kairomone, 5 gm pheromone + 5 gm kairomone, and 5 gm pheromone + 2.5 gm kairomone. Overall, the DA-MEC had no observed effect, positive or negative, on the damage suppression of the Ph-MEC. However, the DA-MEC was applied to low rates of 5 and 2.5 gm/acre in combination with Ph-MEC rates of 5 and 10 gm/acre, the standard label rates. At higher rates or in larger plots, the combined impact of the two MEC's might be better resolved.

Feeding enhancements for insecticide targeting neonate lepidopteran larvae

M.A. Pszczolkowski & J.J. Brown, Washington State University

1. We finalized our characterization of Sweet'n Low®'s active ingredients.
2. We investigated hydrophobic glutamate receptor agonists that could be tank mixed by growers without commercial pre-formulation of additives by:
   - Characterization of glutamate receptor-related pharmacology of feeding by codling moth neonates.
   - Selection of *trans*-1-Aminocyclobutane-1,3-dicarboxylic acid (*trans*-ACBD) as a hydrophobic alternative for monosodium glutamate, and testing its potential for pesticide enhancement in the laboratory and in the field.

There were two more objectives for 2001-2002 year:

3. Acquire pre-formulated particle layer matrixes from commercial sources and test them under our sensitive bioassay system.

4. Explore spray technology to assure coverage of the underside of leaf to take advantage of neonate behavior and minimize lost of feeding stimulants to rain.

However, the success with characterization of glutamate receptor-related pharmacology of feeding, and very promising properties of *trans*-ACBD made us re-think the strategy of overall research, and postpone the realization of objectives 3 and 4.

III. Pheromone dispenser technologies and mechanisms of mating disruption

Alternative pheromone delivery technologies for mating disruption

Stephen Welter, Frances Cave, Matt Singleton and Bob Van Steenwyk, U.C. California

Sprayable pheromones
Replicated trials using a sprayable formulation of codlemone by Suterra was evaluated several ways: a) microcapsule longevity, stability, and EAG activity using artificial substrates under field conditions b) within replicated plots using multiple rates of pheromone per acre or different application patterns c) preliminary studies using aerial applications in walnuts.

In pears, 2 rates were examined with limited replication within large blocks within one orchard. Successful control of codling moth was achieved compared to a treated control with 3.5% damage. Trap suppression was observed for the season, but high counts did not occur until lat in the season for the untreated controls (starting July 7). Areas nearest the control plots experiments the higher rates of infestation in early July at 2.3%, however, damage fell to less than 1% for all other sample sites. Within walnuts, all treatments failed to show any clear difference between the treated plots and the control with damage ranging from 1.9% to 3.0% by late July, such that all treatments received a prophylactic application of insecticide to limit further damage. Harvest samples are expected to be less given that damage nuts often are eliminated during harvest operations.

Aging Trial
Multiple formulations of a sprayable material of codlemone produced by 3M, a formulation by Suterra, and a new formulation by Biocontrol were placed within aging chambers that either precluded significant light penetration or allowed for light penetration without significant reductions at all pertinent wavelengths. Over a 2 month period, samples were collected each week, frozen, and will be subjected to further extractions for determination of quantity and breakdown of codlemone. A chamber that allowed for airflow over the treated substrate has been built and connected to lab EAG equipment to determine changes in relative antennal activity from pheromones evolving from the differentially aged substrates. These data will be coupled with analytic assessments of each sample for residual codlemone and potential changes in product stability. These data are to be provided in collaboration with the manufacturer.

Aerial Applications
Preliminary work with sprayable formulations using aerial applicators was tested within an unreplicated trial in walnuts. One plot (ca. 5 acres) was treated with a fixed rate of the Suterra CM sprayable. Releases of sterile codling moths were made in each plot within 5 release points

in the center of each plot with ca. 5000 moth released within each plot. Traps were placed along the upwind and downwind sides of each release point. Moths were recaptured over the next 30 days. In addition, leaf samples were collected from 5 trees (3 subsamples per height) from 3 height levels. These leaf samples will be assayed for pheromone emission using antennal responses from an EAG as the dependent variable. Leaf samples have been collected and frozen for assays at a single point. Leaf sampling will be completed in late October just after harvest. These data will be used to compare the relative bead/emission distribution within the canopy using the 2 application techniques.

Aerosol emitters:
Large-scale trials were conducted in both walnuts and pears using low rates of dispensers per acre (ca. 1 dispensers per 3 acres). Up to 100 acres were treated with only codlemone from these high-dosage emitters. Damage was assessed several times throughout the growing season within spatial grids to determine patterns of damage. Dispensers were deployed within a grid within 4 pear orchards (ca. 40 acres, 19, 23, and 23 acres in size for the pheromone treated areas) and 2 walnut orchards (ca. 110 acres and 25 treated acres, respectively). Similar grids of pheromone baited traps (1 mg and 10 mg lures) or traps baited with lures loaded with a pear ester were used to monitor flights and potential risks. Traps baited with the pear ester were only placed in the walnut plots given the lack of proven efficacy in pear orchards.

Results in pears varied considerably with pressure, with 2 orchards failing to produce significant testable pressures. While damage was by definition very acceptable, the trial did not yield interpretable results. In contrast, one orchard undergoing a transition to organic produced damage at levels below significant thresholds for organic orchards, except adjacent to a commercial orchard. This commercial orchard experienced between 3-10% damage at harvest despite 2-3 insecticide applications and an application of Isomate pheromone dispensers. Damage in the blocks away from the orchard ranged from 0 to 0.7%, whereas the block adjacent to the commercial orchard experienced 0.9 to 3.7%. Highest damage estimates were along the area bordering the commercial orchard.

Similar results were obtained within another larger orchard with ca. 2.3% detected in the controls at harvest and low, but commercially acceptable damage levels found throughout the orchard (range 0.1 to 0.9%). However, as the second pick of pears was concluded, very strong flights were occurring, the control increased to ca. 50% damage and at least one unacceptable load of pears was pulled from the orchard. A lack of complete control was also observed in the conventionally treated portions of the orchard.

Evaluation of new mating disruption formulations in Michigan
Larry Gut

Trials conducted in Michigan in 2002 demonstrated that frequent application of very low rates of sprayable pheromones was a highly economical and effective tactic for control of OFM, and showed promise for other pests as well. The performance of OFM sprayable pheromone was significantly improved by adding Nu-Film 17. Sprayable pheromones could be readily incorporated into current programs that include a number of sprays for diseases, insects and mites. A sprayable product could be targeted for specific flights as opposed to the usual season-long approach. Formulations targeting different pest species could be tank-mixed. Under low-moderate pest pressure, hand-applied delivery systems that target multiple pest species also were found to be efficacious and may fit well in apple IPM programs in Michigan and elsewhere where several lepidopteran pests are a problem in apple.

Evaluation of new mating disruption formulations in Pennsylvania
Larry Hull and Greg Krawczyk

Microencapsulated sprayable pheromones were evaluated for their efficacy to disrupt mating of both OFM and CM under various application methods and rates of application. Sprayable pheromones for OFM applied using the alternate row middle method of application on a 10-14 day interval and at rates as low as 1.25 to 2.5 g ai/acre (50-75% below recommendations) were found to prevent male OFM from orienting to monitoring traps, and contributed to an overall lowering of apple injury when compared to broad-spectrum insecticides alone. Other large OFM mating disruption studies were conducted in both apples and peaches that included the products Isomate M-100® and Isomate Rosso®. All products prevented male moths from finding pheromone traps and prevented fruit injury by OFM. Sprayable pheromones for CM were not as effective as the OFM sprayables in preventing adult males from orienting to monitoring traps and from preventing fruit injury by this pest.

Long-lasting peripheral adaptation of leafroller moths to pheromone
Larry Gut, Lukasz Stelinski, and James Miller

The obliquebanded leafroller (OBLR), *Choristoneura rosaceana* (Harris), and the redbanded leafroller (RBLR), *Argyrotaenia velutinana* (Walker), share the major components of their pheromone blends; *Z*11-14:Ac and *E*11-14:Ac in 98:2 ratio for OBLR and 93:7 ratio for RBLR. The RBLR is reported to be easily disrupted, in some cases using only the main pheromone component, *Z*11-14:Ac. In contrast, the OBLR is often described as difficult to disrupt in the field as measured by lowered captures of males by synthetically baited traps and fruit and foliar damage investigations, and possibly requiring the full natural blend of pheromone components. We seek to understand the underlying explanations for the differences in susceptibility to mating disruption between these two sympatric tortricids.

Electroantennograms (EAGs) performed on moths prior to and post exposure to pheromone for various time intervals were used to characterize differences in the capacity for “long-lasting” peripheral adaptation and disadaptation between OBLR and RBLR. Pre-exposure of male OBLRs’ to *Z*11-14:Ac and traces of *E*11-14:Ac for durations of 15 and 60 min in sealed Teflon chambers with continuous air exchange significantly reduced peripheral sensory responses to these compounds as measured by EAGs. The EAG responses of OBLR to pheromone were lowered by as much as 60 % and made a linear recovery to 70-100% of the pre-exposure amplitude within 12.5 min at a rate of 3-4 % / min. In contrast, EAG responses of RBLR after pheromone exposure for up to 60 min yielded no long-lasting peripheral sensory adaptation as measured by EAGs.

Additional EAGs were performed on male OBLR after 24 h of exposure to pheromone under field conditions. Caging OBLR males in apple trees adjacent to 1,2 or 4 Isomate OBLR/PLR

Plus (Pacific Biocontrol Corporation) pheromone dispensers for 24 h periods resulted in long-lasting adaptation similar to that observed in laboratory experiments. Adaptation was not observed for moths caged at a distance of 2 m from dispensers in 1 ha plots that were treated with 500 dispensers per ha.

We postulate that the long-lasting peripheral adaptation observed for OBLR is a mechanism that impedes central nervous system habituation in this species. In contrast, RBLR may be more susceptible to central nervous system habituation because it lacks the capacity for minutes-long adaptation. We propose that "long-lasting" adaptation may be a mechanism explaining some of the variation in efficacy of pheromone-based mating disruption across taxa.

IV. True bugs

Stink bug behavior and control in orchards

Jay F. Brunner and Christian Krupke, TFREC, Wenatchee, WA

We found no evidence to support the concept that stinkbug populations are reproducing and building within orchards. D-Vac samples taken from orchard ground cover yielded very few stink bug nymphs compared with border samples, and damage counts conducted in the orchard once again revealed a trend of decreasing damage away from border rows.

Results of rearing experiments conducted with a variety of host plants indicate that stinkbugs are able to develop from egg to adult on common mallow, mullein and white clover only. These plants could be managed with effective broadleaf weed control. Since previous experiments have shown that stinkbugs are unable to develop upon apple, this may represent an ideal way to restrict stinkbug populations to areas outside orchard borders.

We conducted experiments to compare three in-orchard strategies for stink bug management: 1) application of a broadleaf herbicide (2,4-D) to orchard ground cover to remove potential stink bug host material; 2) application of Danitol to ground cover to kill developing nymph populations; 3) no ground cover treatment (check). Combined with results of previous experiments that indicate that stink bugs are unable to develop upon apple, this indicates that effective control of broadleaf weeds in the orchard may remove any potential hosts for stink bug nymphal development. However, in view of the lack of stinkbug nymphs found inside orchards in any of the plots, the emphasis of management efforts may be better confined to orchard borders.

Three pheromone dispenser types were tested in 2002, and two of these performed satisfactorily in field attraction of stink bugs. Both the Pherotech lure and the IPM Technologies lures attracted significant numbers of stinkbugs in the field. Lure effectiveness declines over time as the reservoir is depleted, but this may be remedied by adding more pheromone. We expect one or both of these companies to market a commercial lure in the near future.

Timing and targeting of Danitol for stinkbug control was evaluated. Applications of Danitol to entire orchards were significantly more effective at reducing stinkbug injury at harvest than applications to the border rows only. However, we will continue to evaluate the long-term differences between these modes of applying Danitol by assessing mite populations in treated areas. Trials aimed to improve timing of sprays revealed that the onset of damage occurred at the end of July and continued until harvest. These data demonstrate that there is not a discrete period of stinkbug injury that growers could target for spray applications. This is of interest in light of our other work showing that Danitol is extremely disruptive to mites after 1-2 applications, meaning that in-orchard prophylactic treatments may not be a viable option.

The Effect of Groundcovers on Key Natural Enemies of Pear Psylla and on the Management of the True Bug Pest Complex in Pear

Richard Hilton and Helmut Riedl, Oregon State University

Damage due to Lygus bug and other bugs comprised 35% and 21%, respectively, of the total insect related damage seen in Comice in the Areawide II pear blocks. No Lygus or other true bug damage was seen in the Bosc cultivar. Lygus was the only true bug pest observed in the beating tray sampling in Areawide II orchards, although numbers and corresponding damage levels were very low. It should be noted that in all the Areawide II blocks applications of broad-spectrum materials were made to control pear psylla, which likely contributed to the low Lygus levels. In other demonstration blocks being monitored in southern Oregon higher levels of Lygus damage were observed. In four blocks, all utilizing a mating disruption program with pear cultivars susceptible to true bug injury, fruit injury levels of greater than 0.5% were observed. In one case damage in a red pear cultivar measured 1.6% while the surrounding blocks with Bosc and Comice cultivars had Lygus injury levels of 0.1% or less. The highest level of Lygus damage observed in 2002 was 6.7% in an organically managed block of Seckel pears. Thus the potential for Lygus damage in pears was still present in 2002 though it was not evident in the designated Areawide II blocks. As seen in 2001 the most common predators observed in beating tray samples in the Areawide II blocks were spiders, earwigs, and lacewing larvae.

While the consperse stink bug could be found on potted mullein plants placed in the orchard, particularly when they were baited with high levels of the stink bug aggregation lure, the numbers seen were very low and virtually no damage attributed to stink bug was observed in any of the pear orchards sampled in 2002.

Management of true bugs, with particular emphasis on Lygus bug in pear, requires an understanding of where the bugs are originating and a means of monitoring them. The surrounding habitat and the orchard groundcover can serve as sources of Lygus and other true bugs. Modification in habitat, such as planting a non-attractive orchard groundcover, such as a complete sod, may be a means of minimizing the risk of true bug injury. However, for those instances when true bugs reach damaging levels, appropriate monitoring methods must be available. Sampling injured fruit is not a good option since damage expression develops over time. At present, as there is no attractant available for Lygus bugs, a combination of sweep netting and limb tapping are the best sampling means available and can serve to indicate relative population levels and trends. Over the past two years, the observed Lygus levels in the Areawide II blocks have been fairly low in the tree canopy, which corresponded to low fruit injury levels.

V. Efficacy of new pesticides

New Insecticides as controls for Codling Moth, Leafrollers and Lacanobia Fruitworm

Jay Brunner, Mike Doerr and Keith Granger, TFREC, Wenatchee, WA

There are several insecticides that have recently been registered for use on apple and pear that have a place in the pest management programs for Lepidoptera pests. The efficacy of these materials in Washington was discussed.

Esteem 35WP (pyriproxyfen)
This insecticide is an insect growth regulator. It functions as a juvenile hormone mimic. It has the possibility to be a highly selective insecticide providing control of leafroller and codling moth (not lacanobia fruitworm) without disrupting activities of biological control agents. Esteem has activity against the codling moth egg, that is it acts as an ovicide. Esteem is not considered at this time to be a strong codling moth control tool. It should always be used in a pest management program that includes codling moth mating disruption.

Esteem seems to work equally well against the pandemis or obliquebanded leafroller, however, experience against the latter in WA is limited. Esteem efficacy against leafroller is difficult to assess because the larvae do not die immediately and deformed larval-pupal intermediates or pupae that do not produce adults are extremely difficult to locate. Esteem was applied against leafrollers in large replicated plots at petal fall and followed by another application in 10 days. The other treatments were applied only one time at petal fall. The number of live larvae following the treatment was similar to those in the untreated control plot. However, when evaluating the Esteem treatment in summer no leafroller larvae were detected. The conclusion was that the Esteem treatment had prevented the successful development of leafrollers resulting in no larvae present the following generation.

Intrepid 2F (methoxyfenozide) and Confirm 2F (tebufenozide)
These products are in the same class, insect growth regulator, and have the same activity against codling moth, leafrollers and lacanobia fruitworm. While they are very similar Intrepid is by far the more potent of the two and most of the discussion will focus primarily on this product. Experience with Intrepid as a codling moth control has primarily been to target young larvae before they can enter the apple. Intrepid is considered an organophosphate replacement (OP replacement) by the Environmental Protection Agency (EPA). However, this product is not a simple replacement for Guthion. It does not provide the same amount of protection as a Guthion or Imidan under the same use pattern. To achieve control of codling moth approaching that achieved by Guthion or Imidan typically requires an additional application of Intrepid in each generation. Intrepid was applied in two different manners. The first treatment was started at the oviposition period (petal fall) of codling moth and repeated every 14 days for a total of 3 applications per generation (6 applications per year). It should be noted that this is an “off label” use but under research trials is permitted. After the first generation and more revealing, at harvest, there is more fruit injury from codling moth than in the Guthion or Imidan treatments. In addition there is more damage when Intrepid was used at the more traditional “hatch” timing than when it was used at the “ovipostion” timing. These data confirm our studies in the

laboratory where we are examining the ovicidal activity of Intrepid. If the ovicidal timing of Intrepid as good or better than the egg hatch timing it opens a new strategy for using this product.

Intrepid has good efficacy against leafrollers. In our laboratory bioassays that compare relative toxicity of products, Intrepid is 10 to 20 times more active than Confirm. Intrepid has mostly been evaluated at it full field rate against leafrollers, however, it is likely that reduced rates would also be effective and future research will focus on determining the efficacy of lower rates. Intrepid is effective against leafrollers in the spring from bloom to about 14 days after petal fall. When Intrepid was applied one time at petal fall it provided good control of leafrollers, preventing populations from redeveloping in the summer. Intrepid is also effective against leafroller larvae in the summer and the best timing is when larvae are young. When Intrepid was applied at 20% egg hatch of leafroller it provided excellent control, comparable to Success in this test.

Intrepid and Confirm are very effective against the lacanobia fruitworm. The best timing of Intrepid against this insect is prior to large larvae are present, at about 80% egg hatch. Intrepid provided good suppression of lacanobia fruitworm with only one application. Experience in the Areawide II project in 2001 showed that lacanobia fruitworm densities were suppressed in orchards that used Intrepid in multiple applications against codling moth. These timings overlapped with the optimal timing for lacanobia fruitworm control so both pests were controlled at the same time.

Assail 70 WP (acetamiprid) and Calypso 480 SC (thiacloprid)

Assail has performed very well against codling moth while Calypso does not appear to have a high degree of activity. In large replicated block tests in 2000 and 2001 Assail applied at the same timing interval as Guthion or Imidan, 2 applications per generation starting at egg hatch, provided codling moth control similar to these well-known industry standards. In the small plot test where treatments were applied by a handgun sprayer, Assail was statistically as good as Imidan or Guthion in preventing fruit injury. In a large plot test applied by an orchard air-blast sprayer Assail did not perform quite as well as Imidan. Both of these trials were conducted under extremely high codling moth pressure. One problem we have noted with Assail is its negative impact on integrated mite management. An increase in spider mites and a decrease in predatory mites have been observed in most trials with Assail. Calypso provided control equal to Guthion in a test in 2001, however, to achieve this level of control it was applied twice as often as Guthion, 4 versus 8 applications per season. In a trials conducted in 2000, Calypso applied 6 times did not provide as good of codling moth control as Guthion. It is unlikely that growers will be willing to apply the number of applications of Calypso required to achieve codling moth control.

We have not tested Assail or Calypso in the field against leafrollers. We have, however, conducted laboratory bioassays to assess the relative toxicity of these products to leafroller larvae. In these tests we find that the LC_{50}, the concentration of product that kills 50% of the larvae, of Assail and Calypso is high relative to the proposed concentration used in the field. For example, the LC_{50} for Assail and Calypso against first instar obliquebanded leafroller is 107 and 57 ppm, respectively. The recommended field concentration of Assail and Calypso is 44 and 45 ppm, respectively. Even the field concentration would not be expected to kill even half the first stage larvae so the possibility that either product would be effective against leafrollers is nil.

We have not tested Assail or Calypso in the field against lacanobia, however, we have conducted bioassays similar to those described above for leafrollers with Assail. The LC_{50} for Assail against first instar lacanobia larvae was 44 ppm, the same concentration as the field rate would provide in a dilute spray. The registrant if Calypso did not think based on their studies in other crops that it would work against an insect like lacanobia fruitworm so we did not even attempt any screening studies.

Avaunt (indoxicarb)
Avaunt was registered for use late in 2000 so last year was the first full year we could use this product. We have had several years of experience testing this product back to a time when it was a numbered experimental insecticide. Avaunt is a unique chemistry with a novel mode of action. It is a nerve poison to insects but has very low toxicity to mammals and is thus safe

Avaunt does not seem to be a good product for codling moth management in WA. In several tests it has not provided adequate suppression of codling moth even with several applications per generation. In laboratory bioassays against codling moth Avaunt also appears weak when compared to Guthion, Imidan or Assail.

We have had less experience in testing Avaunt against leafrollers. It appears to have good efficacy against larvae of the pandemis leafroller but NOT against the larvae of the obliquebanded leafroller. In laboratory bioassays larvae of both leafrollers from our colonies are highly susceptible to Avaunt. However, one field population of obliquebanded leafroller larvae show high levels of resistance to Avaunt while two field populations of pandemis leafroller were only slightly less susceptible than the laboratory colony. It seems likely that Avaunt may suffer from cross-resistance effects to organophosphate insecticides in leafrollers. Additional research is needed to confirm this suspicion.

Avaunt is very effective against the lacanobia fruitworm. In several field tests Avaunt has controlled larvae of the lacanobia fruitworm with only a single well-timed application. Even when used at reduced rates there has been little difference in the efficacy of this product against lacanobia fruitworm.

Success 2 SC (spinosad)
Success has activity against codling moth larvae. In field trials 3 applications of Success per generation provided suppression of codling moth but never as good as Guthion. The lack of strong activity of Success against codling moth is likely due to its shorter residual activity

Success is a very effective insecticide for the control of leafrollers. It works well as a single spray in the spring at petal fall to control the overwintering larvae. It also works well as a summer treatment timed to coincide with the presence of early stage larvae. If populations are high it might require two applications in summer to suppress the leafroller densities below damaging levels.

Success is effective against lacanobia fruitworm larvae but only against the young, first through third instar, larvae. If the timing is late control will not be as good as could be achieved with other products. In high populations 2 applications might be required to achieve adequate control.

Other reduced-risk options, Surround, Mineral oil, *Bacillus thuringiensis* (Bt) and Virus
Surround is a particle film technology developed by USDA researchers. The active ingredient is kaolin clay that is specially processed to maximize its pesticidal and horticultural activity. Research on Surround in WA has been conducted over the last 3 years and it has a fit in IPM programs but carries some potential negative impacts on natural enemies that will be discussed later.

Surround does have an impact on codling moth larvae. In several tests we have shown that 3 applications of Surround (50 pound per acre rate) will suppress codling moth damage 50-60%. It is possible that lower rates of Surround would be equally as effective but those studies have not been conducted.

Surround residue on leaves is avoided by leafroller larvae. The impact is greatest on young larvae so residues (applications) should be in place prior to egg hatch. If leafroller larvae do not have a choice to avoid Surround residues then some larval mortality has been observed. Summer applications of Surround have been shown to suppress leafroller densities.

Surround has a strong negative effect on lacanobia fruitworm populations. In the laboratory newly hatch lacanobia fruitworm larvae suffer high mortality if they are provided only Surround treated foliage and show a very strong preference to colonize foliage not treated with Surround when given a choice. In the field Surround has shown good efficacy in reducing lacanobia fruitworm densities. While more applications is better experience in recent years indicates that only two applications prior to egg hatch can reduce most lacanobia fruitworm populations below economically important levels.

Horticultural mineral oils act against the codling moth by suffocating the egg. The best timing strategy is therefore to allow as many eggs to be laid prior to making an application and then repeat the application again after more eggs have been laid but before they hatch. A timing that has worked well is to apply the first application 200, 400 and 600°D after BIOFIX of the first generation and 1200, 1400 and 1600°D of the second generation. Where high codling moth populations are present the interval of re-treatment should be shortened to 150°D intervals.

There are several products that contain the active ingredients produced by the bacteria *Bacillus thuringiensis* (Bt). We have evaluated Bt products against codling moth and they have very little activity. The main problem is associated with the short residual activity and the inability to uniformly cover the surface of the fruit thus allowing codling moth larvae to enter without becoming intoxicated.

Bt products have their best fit in apple IPM as leafroller controls. It is usually necessary to apply more than one Bt spray to obtain adequate leafroller suppression. We have consistently observed 50-60% control with one application and 80-95% control with two applications 7 to 10 days apart. In the summer Bt treatments last only 5 to 7 days, however, with good coverage it is possible to obtain good control.

The codling moth granulosis virus has been known for many years and different companies have attempted to formulate it as a biological pesticide. Most formulations have not provided consistent control. Virosoft is a newly registered codling moth granulosis virus. We have had only one year's experience with this product. We applied Virosoft against both codling moth generations at intervals of 7, 10 and 14 days. After the first generation there was some suppression of damage by the most frequent re-treatment interval but by harvest high levels of fruit injury were noted in all treatments.

Walnut husk fly (WHF) control with reduced risk insecticides

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Description of project: This project was aimed at the identification of reduced risk insecticides that can be incorporated with existing and improved adult attractant for control of WHF. The WHF is a serious pest of mid- to late season walnut cultivars. WHF control is required on about 1/3 of California's walnut acreage and consists of one to four insecticide and bait applications per season. The typical application is a combination of an organophosphate (OP) insecticide, e.g. Malathion and Lorsban, combined with a food lure, e.g. NuLure and Mobait. The pyrethroid insecticides provide adequate WHF control but may cause flare-ups of secondary pests, such as spider mites and scales. Spinosad, which has recently received registration on walnuts under the trade name of Success, is a reduced risk insecticide that had shown adult WHF efficacy in preliminary trials. GF-120 is a combination of spinosad and an improved fruit fly bait formulation that has show efficacy against other fruit flies.

Laboratory Evaluations: At 12 hours, Malathion with and without NuLure and Asana provided significantly greater WHF mortality compared to the other materials. At 24 hours, Malathion with and without NuLure and Success with NuLure provided significantly greater WHF mortality than Pyganic and Success without NuLure. Success with NuLure at 12 and 24 hours caused significantly more WHF mortality compared to Success without NuLure, while there was no noticeable effect of NuLure with Malathion. This shows that Success is slow acting and needs to be consumed to be effective while Malathion is fast acting and has contact activity. There was a rate response for Success with NuLure at 24 hours. Success at 0.1 oz plus 3 pt NuLure/100 gal produced about 25% mortality while mortality increased to about 65% with Success at 3 oz plus 3 pt NuLure/100 gal (Fig. 1).

Field Longevity: WHF mortality decreased rapidly from nearly 70% mortality at 0 days after treatment (DAT) to 20% at 3 DAT (Fig. 2). Five droplets per leaf caused slightly greater mortality than 1 droplet per leaf at 0 and 3 DAT. The short longevity may be the result of using wild flies and the hot dry conditions found in the westside of the San Joaquin Valley.

Field Efficacy: The WHF population in orchard No. 1 was extremely high and the orchard had over 75% infested fruit the previous year (Table 2). Repeated applications of GF-120 at 20 and 40 oz per acre applied weekly or every other week resulted in a significant reduction in fruit infestation compared to the blank bait or grower standard, but there was no significant difference among the GF-120 treatments. Despite the large reduction in fruit infestation, there was not a corresponding reduction in adult fly captures. Adult fly captures were extremely high with over 300 adult flies captured in the 40 oz of GF-120 applied every week. Therefore, it appears that GF-120 is slow acting and flies were trapped but oviposition was prevented. It should be noted that due to the irregular size of trees and missing trees, the application efficiency was about 60%, i.e. 40% of the final spray volume was not retained on the trees. Thus the amount of GF-120 required to control the population could be greatly reduced with a more uniform orchard.

The WHF population in orchard No. 2 was moderate and the orchard had less than 10% infested fruit the previous year. Repeated applications of GF-120 and blank bait at 10 oz per acre applied weekly and every other week resulted in a significant increase in fruit infestation compared to the grower standard while 20 oz per acre applied weekly or every other week was not significantly different than the grower standard. It appears that 10 oz per acre was not sufficient to suppress this moderate population. This orchard was much more uniform in size with few missing trees and the application efficiency was about 80%.

The WHF population in orchard No. 3 was very low and the orchard had less than 10% infested fruit the previous year. The initial application of GF-120 and the grower standard resulted in the complete elimination of adult WHF in all treatments including the blank bait control. Due to the reduction in WHF, the experiment was terminated in this orchard. Also this orchard was extremely uniform with few missing trees and the application efficiency was about 90 to 95%.

GF-120 provided effective control of WHF. The amount of GF-120 per acre and/or the number of applications needed to suppress a WHF population is dependent on the WHF density. GF-120 is slow-acting and has limited field longevity in the San Joaquin Valley. Until GF-120 becomes registered, Success combined with NuLure would be effective replacements for Malathion.