APPENDIX

Abstracts from papers and posters presented at the 83rd Annual Meeting of the Pacific Branch, Entomological Society of America

June 20—23, 1999
Eugene Hilton & Conference Center, Eugene, Oregon

Graduate Student Symposium (#'s 1—6)

Symposium on Exotic Species Introductions (#'s 7—14)

MS and PhD student paper competition (#'s 15—28)

Tuesday Morning Session B Submitted Papers (#'s 29—41)

Tuesday Morning Session C Submitted Papers (#'s 42—55)

Posters (#'s D1—D24)

Symposium on Teaching with Insects (#'s 56—62)

Symposium on IPM in Small Fruit Crops (#'s 63—69)

Symposium on Insect Behavior (#'s 70—74)

GRADUATE STUDENT SYMPOSIUM

1. UNDERSTANDING THE BIOLOGY OF *OTIORHYNCHUS SULCATUS* AS A PRELUDE TO THE DEVELOPMENT OF AN IPM STRATEGY

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The control of *Otiorhynchus sulcatus* (F.), the black vine weevil, in commercial nurseries relies heavily on the use of conventional chemical insecticides. Before an integrated pest management strategy for the control of *O. sulcatus* can be developed, extensive research must be done in order to understand the biology of the weevil. Much of the lifecycle of the *O. sulcatus* is understood. The weevil is a parthenogenetic, typically univoltine insect in which the adults emerge in the early spring. The adults feed on the foliage of a number of different host plants (greater than 100 species) and lay eggs (500-1200 per adult) throughout the summer. The larvae hatch and immediately burrow into the soil where they feed on the roots of the plants. The larvae overwinter in the soil and it is the larvae's cryptic nature that often hides the damage it incurs until spring when the foliage proves to be stunted or the plants are dead due to girdling of the trunk. However, the spread of the weevil in a typical potted nursery operation in California has yet to be studied and the ability of adult weevils to overwinter has been mentioned in several papers but nothing further is discussed. Here we present preliminary data on the dispersal of *O. sulcatus* and the ability of adults to overwinter in California.

2. PREDATORY ROLE OF *NEOSEIULUS FALLACIS* (GARMAN) IN RED RASPBERRY FIELDS: SPATIAL DYNAMICS IN AN ACARINE PREDATOR-PREY SYSTEM

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The two tetranychid mites, *Tetranychus urticae* Koch and *Eotetranychus carpini borealis* (Ewing) co-occur on red raspberry, *Rubus idaeus* L. Laboratory and field studies were carried out to assess the predatory role of the shared predator, *Neoseiulus fallacis* (Garman), in regulating the two spider mite densities.

Dispersion patterns of the three mite species were investigated using Taylor's power law. Preference of *N. fallacis* to feed on either spider mite species was investigated by assessing the predator movement on potted plants and by using a choice assay. Hypergeometric variate and Yule's coefficient of association were used to investigate the spatial association between the predator and the two prey species in the field.

The three mite species had an aggregated distribution in the field. On a spatial scale, *N. fallacis* was associated with both prey species ($P<0.05$). Prey choice studies did not show a preference of the predator to either prey species ($P<0.05$). These findings are in accordance with temporal dynamics observed in the field.

3. CHALLENGES TO DEVELOPING A MASS REARING PROGRAM FOR *ANAGYRUS ANANATIS* GAHAN (HYMENOPTERA: ENCYRTIDAE)

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Pink pineapple mealybug (PPM), *Dysmicoccus brevipes* (Cockerell) (Homoptera: Pseudococcidae), is the most important pineapple insect pest worldwide. *Anagyrus ananatis* Gahan (Hymenoptera: Encyrtidae) is the most effective parasitoid of the PPM in Hawaii. Efforts are underway to develop mass rearing methods for this parasitoid for augmentative biological control of *D. brevipes.* Initial attempts to mass rear PPM for propagation of *A. ananatis* were unsuccessful because PPM produced excessive amounts of honeydew, which supported the growth of molds and mites leading to the rotting of substrate squash used for rearing. The unorthodox technique of submerging PPM infested squash in vermiculite, to absorb honeydew, facilitated mealybug production. *Anagyrus ananatis* typically parasitizes PPM third instar nymphs and adults. However, mated female parasitoids did not readily accept suitable PPM stages when offered on squash or alone in a petri dish. Parasitization was enhanced about 4-fold by providing cheesecloth within the petri dish with the mealybugs clinging to the cloth. Mealybugs mummified in ca. 10 days following parasitization, and took about 4 weeks to complete one generation at

23±1°C. After 6 generations, no obvious changes in parasitoid size were observed. The sex ratio was female biased being 1.8:1 and 1.9:1 F:M, respectively in generations five and six.

4. GEOGRAPHIC VARIATION IN MATING BEHAVIOR IN SEPSID DUNG FLIES (DIPTERA: SEPSIDAE).

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In several species in the dung fly family Sepsidae, ovipositing females are commonly accompanied by an escorting male. While the female lays a clutch of eggs into the larval substrate (fresh mammalian feces), the escorting male rides on her back, maintaining his mounted position by firmly clasping her wing bases with his forelegs. Immediately after oviposition, the female may mate with her escort, and the sperm transferred in this copulation will then have a chance to be used for the fertilization of eggs in one of her future oviposition bouts. The adaptive significance of the sepsid males' escorting behavior has not yet been studied in detail. Current hypotheses for the function of this trait include pre-copulatory mate guarding (the mounted male prevents rivals from gaining access to the ovipositing female until she becomes sexually receptive) and pre-copulatory courtship (females use the escorting phase in order to assess the mounted male's suitability as a potential mate).

In a survey of the phylogenetic distribution of escorting behavior in the Sepsidae, I have found that several species in the genus *Sepsis* show pronounced geographic variation in the expression of this trait. Focusing on divergent populations of one of these species, *Sepsis punctum* (Fabricius), I have conducted a series of comparative studies on the genetic, morphological, and ecological correlates of differences in mating behavior. The major results of this research are: (1) The observed behavioral variation has a genetic basis: the expression of escorting behavior is a quantitative trait with a significant sex-linked component of inheritance. (2) Escorting and non-escorting populations show distinct patterns of sexual size dimorphism, with males being significantly larger than females only in the escorting population. (3) There is a general concordance across populations between the occurrence of escorting behavior and more male-biased sex ratios at oviposition sites in the field. These patterns suggest that different populations of *S. punctum* vary significantly in the degree or nature of sexual selection acting both on the behavior and the morphology of males. I will discuss the implications of these findings for theories about the adaptive significance and the evolutionary history of escorting behavior in the Sepsidae.

5. VECTOR CAPACITY OF THE BITING MIDGE *CULICOIDES VARIIPENNIS SONORENSIS* WITH REGARD TO TRANSMISSION OF BLUETONGUE VIRUS

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Bluetongue is a disease of sheep, cattle, deer and other ruminant animals caused by infection with bluetongue viruses (BTV) transmitted by biting midges, particularly in the genus *Culicoides*. The disease has a worldwide distribution with twenty-six viral serotypes of BTV identifiable by serological neutralization tests. In the United States, viral serotypes 10, 11, 13, and 17 have been repeatedly isolated; and serotype 2 has been occasionally isolated in Florida. The primary vector of BTV in most of the U.S. is the biting midge *Culicoides variipennis sonorensis* (Diptera: Ceratopogonidae). This midge is primarily associated with large aggregations of animals and water polluted by animal waste.

Bluetongue is classified as a "List A" disease (most dangerous and contagious disease with severe economic consequences) by the Office International des Epizooties (OIE). The U.S. livestock industry loses an estimated $125 million annually due mostly to restrictions placed on the exportation of cattle, sheep, and their genetic products (primarily semen) to bluetongue-free countries outside the United States.

Vector capacity is a measure of the likelihood of disease transmission by an insect population to a susceptible host population. It is a population parameter given by the formula:

$$C = ma^2Vp^n / -\log_e p$$

where C = vector capacity, ma^2 = the insect biting rate, V = the susceptibility of the insect population for the

replication and transmission of virus (vector competence), p = the daily probability of survival, and n = the extrinsic incubation period of the virus (time required after infection of a vector until the vector is capable of transmitting the virus to a vertebrate host). Vector capacity is a relative value and must be measured during active disease transmission and when disease transmission is not occuring in order to be used in a predictive way.

Host-seeking midges were collected each week from January 1995 to December 1997 using CO_2-baited suction traps. Captured midges were counted to estimate midge biting rate and separated on the basis of parity (nulliparous or parous) to estimate their daily probability of survival. Captured nulliparous midges were fed on a blood-virus mix to measure vector competence of the field population for BTV 10, while parous flies were tested for the presence of BTV using an antigen-capture Enzyme-Linked Immunosorbant Assay (ac-ELISA). Actual BTV transmission in the field was monitored using sentinel herds of 88 cattle that were bled each month (every two weeks during BTV transmission periods) and tested for antibodies to BTV using a competitive ELISA.

Midge abundance was generally greatest during August and September of each year. Daily survivorship (determined by parous rate) was generally lowest during these same months. BTV transmission to sentinel cattle was highly seasonal with seroconversions occurring from early September to mid-November for each of the three study years (1995-1997). However, BTV was detected in field-captured insects as early as May and as late as December. Relative vector capacity values were determined for each month of the study and were generally higher during times of active disease transmission (late summer through early fall).

Host-seeking adult midges were captured year-round at this study site and overwintering of virus may occur in these active midges. Low level transmission of BTV in the dairy preserve may not be readily detectable using sentinel cattle herds. Virus detection in field collected host-seeking adults may provide a better indication of viral presence and transmission.

6. IMPACTS OF EDGE EFFECTS ON ARTHROPOD DIVERSITY AND TROPHIC STRUCTURE IN OLD-GROWTH DOUGLAS FIR FORESTS IN WESTERN OREGON

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Impacts of habitat fragmentation and consequent 'edge effects' on the abundance and diversity of ground arthropods in Old-growth Douglas fir forests was monitored in 1997 and 1998. Extent of edge effects between 10-20 year old regenerating clearcuts and Old-growth forests was monitored using pitfall traps placed along transects that extended from within the clearcut, through the forest edge, and 200 M into Old-growth forest. Pitfall traps were operated between 23 July and 30 September 1997 and 22 May and 30 August 1998 and collected more than 20,000 specimens representing over 150 taxa. Changes in community composition across edge-forest gradients were examined using multivariate non-metric multidimensional scaling (NMS). Trophic structure varied with distance from the forest edge. Although distributions of individual species varied along the edge-forest gradient, habitat-specific patterns within particular taxonomic groups were apparent. Community composition did not differ appreciably between 200 M and 50 M within Old-growth. Community composition along forest edges could be distinguished from areas further within forest stands suggesting edge effects were detectable up to 50 M into the forest.

Exotic Species Introductions into the Western United States

7. RED IMPORTED FIRE ANT IN CALIFORNIA: STATUS AND PLAN OF ATTACK

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8. 1998 DETECTION AND DELIMITING SURVEYS FOR EXOTIC PEST LEPIDOPTERA IN WESTERN WASHINGTON

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Cooperative Agricultural Pest Surveys (CAPS), funded by USDA APHIS, were conducted by WSDA in 1998 to detect or delimit the distribution of several exotic defoliator pests in Western Washington. Pheromone-trap and light-trap survey results for exotic target and non-target exotic species collected are summarized.

The carnation tortrix, *Cacoecimorpha pronubana* (Hübner), a polyphagous African leafroller pest of many field and greenhouse crops in Europe, was found throughout western Washington, and in high numbers in urbanized areas of the Puget Sound region and Clark County. The straw-colored tortrix, *Clepsis spectrana* (Treitschke, 1830), a highly polyphagous European defoliator pest, was found only in the contiguous northern counties of Whatcom, Skagit, and Snohomish. Delimiting survey for the cherry bark tortrix, *Enarmonia formosana* Scopoli, found an increase in southern distribution since 1995, to include Lewis County. A port-area survey to detect the white-spotted tussock moth, *Orgyia thyellina* (Treitschke), an Asian defoliator of many deciduous trees, did not find that species. A light-trap survey of port-area locations in Seattle, Tacoma, and Olympia did not find any previously unknown exotic species.

9. INVASIVE FRUIT FLY ACTIVITY IN CALIFORNIA

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10. EXOTIC WHITE FLIES IN THE WESTERN U.S.—PAST, PRESENT AND FUTURE

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Whiteflies comprise the hemipteran family Aleyrodidae and number approximately 1200 described species worldwide. The western United States is home to fewer than 100 native species of whiteflies, only one or two of which is an occasionally pest. The western U.S. is also home to 11 introduced species of whiteflies, 7 of which have come to this country since 1981. Almost without exception, introduced whiteflies become serious agricultural or urban pests. This paper reviews the experiences of the western United States in dealing with invasion by whiteflies: their pest status, the crops and settings that are affected, and the outcome of control efforts at containment, eradication, and biological control against them. We then turn our attention to the potential for further future invasions by whiteflies, including both whiteflies of known pest status elsewhere and those not known to be pests elsewhere. Several whiteflies of serious pest status currently occur in areas surrounding the western United States, and all are candidates for unintentional introduction. Vigilance, knowledge, and preparation are our best key defenses for limiting the impact of exotic whiteflies in our native, urban and agricultural sectors.

11. NEW EXOTIC THREAT TO NORTH AMERICAN URBAN LANDSCAPES: AN ASIAN LONGHORNED BEETLE, *ANOPLOPHORA GLABRIPENNIS*

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Numerous exotic organisms are unintentially transported from country to country each year, primarily as a result of world trade. One of the latest hitchhikers to enter the United States is the Asian longhorned beetle, *Anoplophora glabripennis*. This wood-boring beetle, native to northeast, northcentral China and Korea, was discovered in the New York City area in August 1996 and again in Chicago in July 1998 attacking various hardwood trees, especially maples (*Acer*), along streets, and in parks and yards in the urban landscape. This represents the first known infestation of any member of the lamiine genus *Anoplophora* in North America. Evidence strongly suggests that this exotic cerambycid gained entry into North America through wood crating and palleting, or other large-dimensional wood blocking used in bracing and stacking cargo during transport from the Far East, and particularly China. Since the winter of 1996/1997 in New York and winter of 1998/1999 in Chicago, federal and state quarantine officials have attempted to eradicate this new exotic forest pest from the known infested sites. To date, nearly 3000 trees in New York and approximately 700 trees in Chicago, showing symptoms of attack by this beetle, have been removed and destroyed because all other control methods at this time are ineffective for this pest. Additional details about the biology and habits of this exotic wood-boring beetle, newly discovered host trees in the United States, known interceptions at U.S. ports of entry and at U.S. importer warehouses, new emerging control or management strategies for this pest, and resulting North American trade restrictions with China and their ramifications will all be discussed.

12. MONITORING HIGH-RISK SITES FOR EXOTIC WOOD-BORING BEETLES AND WOOD WASPS IN OREGON

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Increasing concern over the introduction of exotic wood-boring insects via imported timber, wood products and dunnage prompted surveys of high-risk sites in Oregon in 1997 and 1998. Forty sites at or near mills, ports and businesses known to have received or handled imported wood products were monitored using Lindgren funnel traps and Scots pine bait logs. Over 26,000 specimens comprised of 261 species of wood-associated beetles and six species of wood wasps have been identified to date. Of these, ten species of beetles and one species of wood wasp are species recorded from Oregon, the Pacific Northwest, the western U.S., or North America for the first time. They originate from several regions of the world, including the eastern U.S., the American tropics and sub-tropics, Europe and Asia. Most are believed to pose little threat to the overall health of our forests, agricultural systems and urban and rural environments. A few remaining 1998 specimens awaiting confirmation may provide additional new exotic species records for Oregon, including *Hylastes opacus* Erichson (Scolytidae), known to be a pest of pines in nurseries and tree farms. Over 2,000 individuals and 45 species of Cerambycidae (all indigenous) were also trapped.

Seventy percent of these new species have hardwood hosts, implicating dunnage and packing material as probable sources. This underscores the need for continued monitoring of imported wood products and packing materials as major pathways for introduction of exotic wood-boring insects, from foreign as well as domestic sources. Roughly one-third of the sites including port, mill, warehouse and dunnage sites produced one or more new records. Systematic surveys, particularly in high-risk areas such as these, are essential to assess the efficacy of port inspection, certification and quarantine programs, and to determine what introduced organisms may already be established. One could expect that as other surveys are conducted, detections of new non-indigenous species will continue. Monitoring of high-risk sites in Oregon for exotic wood-borers continues in 1999.

13. FEDERAL RAW WOOD IMPORTATION REGULATIONS: WHAT PATHWAYS FOR INTRODUCING EXOTIC PESTS ARE STILL OPEN?

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The purpose of the 1995 USDA regulations on importation of logs, lumber and other unmanufactured wood articles is to "establish an organized system for importing unmanufactured wood articles under conditions adequate to prevent the introduction into the United States of plant pests and pathogens." These regulations were a significant improvement over previous regulations requiring only inspection of raw wood as miscellaneous cargo at the port of entry or interim regulations covering the importation of radiata pine and Douglas fir from New Zealand and Chile. Since 1991, almost 50 million board feet of softwood have been imported from Brazil, Chile, Honduras, Mexico, New Zealand and Russia into Oregon alone. Discovery of Asian longhorned beetles in New York and Illinois recently has highlighted the danger associated with untreated solid wood packing material (SWPM) from China. The USDA modified its regulations, effective December 17, 1998, to require the treatment of all SWPM from China for exotic insect pests.

Except for special restrictions against raw wood from certain portions of east Asia, provisions of the regulations contain windows of opportunity for plant pests and pathogens to enter and establish in the United States. Raw SWPM from countries other than China may carry live plant pests and pathogens to the United States. Raw radiata pine and Douglas fir logs (de-barked and fumigated) from New Zealand (NZ) and Chile may be in the U.S. 60 days before the required heat treatment occurs. Our Imported Wood Inspection Team has identified live plant pathogens and dead exotic insects and insect damage from such fumigated logs from NZ. Local Oregon wood borers capable of vectoring exotic fungal pathogens to Oregon trees have also been found on NZ logs in Portland. Raw temperate softwood lumber and railroad ties (without bark or fumigation) may be in the United States 30 days before the required heat or chemical treatment occurs. Raw railroad ties and lumber imported from native stands have been of particular concern. For example, plant pathogens and insect pests were killed by a methyl bromide fumigation provided voluntarily in Portland by the importer in Oregon's first railroad tie shipment from western Russia. For lumber, railroad ties, and NZ and Chilean logs, we are concerned that plant pathogens and deep wood pests could escape before effective heat or chemical treatment occurs. Fumigation alone is allowed for temperate hardwood logs and lumber and for temperate wood and bark chips, wood mulch, compost, humus and litter. Efficacy of fumigation against plant pests and pathogens in these commodities has not been demonstrated. No treatment is required for tropical woods.

Protection of our natural resources from exotic plant pests and pathogens is best achieved when mitigation methods demonstrated to be effective are applied at origin (or before exposure to the U.S. environment) and then the wood is protected against re-infestation. Inspections should monitor whether effective mitigation measures are consistently applied and assess if new situations with possible new pathways are developing.

14. THE INCURSION OF EXOTIC ARTHROPOD SPECIES INTO HAWAII: (AND WHY WE NEED MORE…)

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Hawaii at times seems inundated with exotic, invasive arthropods. With high levels of both tourist and military traffic, this "Crossroads of the Pacific" is invaded by an average of 17 new insect and mite species each year. Because of its isolation, many of Hawaii's native plants and animals have few defensive or competitive adaptations to cope with the new species. Thus, many invasive arthropods become ecologically and economically serious pests of agricultural, urban, and natural environments.

Despite the prevalence of invasive species throughout the islands, there is a logical rationale for deliberately introducing even more exotic arthropods into Hawaii: classical biological control remains one of the most cost effective and environmentally benign methods of mitigating damage caused by invasive pests. Carefully screened, relatively host-specific natural enemies should continue to be imported to attack exotic pests. There is a danger that the stringent regulations established to protect the state against accidental exotics may hinder the importation of useful species.

Student Paper Competition

M.S. Papers

15. ARTHROPOD EFFECTS ON STAND ESTABLISHMENT OF SUGARBEETS IN CALIFORNIA

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Stand establishment is a significant problem facing sugarbeet producers in California. Poor stand establishment results in direct losses to growers through higher seed costs and also in indirect costs through increased weed competition and yield reductions. The exact causes of poor seedling establishment are unknown in California, although seed germination is apparently good, seedling establishment still lags. Abiotic factors such as heat, wind, and improper soil moisture undoubtedly play a role in poor establishment in some cases but biotic factors, including arthropods are believed to be important. In this study, continued from similar work we did last year, various exclusion cages were built around newly planted sugarbeet seeds to determine which arthropods can be implicated in stand loss. The field cages were designed to exclude specific groups of arthropods (distinguished by their biology) from migrating to newly planted seeds.

16. DEVELOPING A STINK BUG MONITORING PROGRAM ACCEPTABLE TO PROCESSING TOMATO PEST CONTROL ADVISERS

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Consperse stink bug, *Euschistus conspersus* Uhler, population abundance was determined by stratified random sampling in 6 commercial processing tomato fields over 2 growing seasons. A mail survey obtained information from processing tomato pest control advisers (PCAs) about their stink bug sampling methods and expectations of University developed sampling programs implemented under commercial field conditions. A sample size formula incorporating field sampling data and mail survey response was used to estimate required stink bug sample size and treatment decision certainty under various sampling time frames. Principle conclusions of this study illustrate a gap between pest sampling programs developed by researchers and programs that PCAs are willing to apply at the commercial field level. Scenarios for adjusting sample size to approach time constraints imposed on field practitioners by commercial production schedules while maintaining a practical level of reliability are discussed. A pheromone based stink bug monitoring program is proposed as an alternative tactic to achieve reliable stink bug population estimates with a relatively time intensive, but streamlined, field sampling effort. Based on results of our survey, this sampling program may be compatible with commercial time constraints of some processing tomato PCAs.

17. POTENTIAL IMPACT OF ACORN FEEDING LARVAE ON TWO SOUTHERN CALIFORNIA OAKS

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In January of 1998, acorns were collected from the ground beneath of Engelmann oaks, *Quercus engelmanni*, and Coast Live oaks, *Quercus agrifolia*, in a southern Califonia oak savanna. They were placed in individual chambers and checked daily for emergence of all insects. The extent of initial acorn root growth was also measured. After the emergence period, each acorn was dissected to identify any additional acorn inhabitants and extent of feeding damage. The two most common larvae found were *Curculio occidentis* and *Cydia latiferreana*. Larval weights varied with acorn size and number of additional larvae within a given acorn. Acorn damage varied with type of acorn inhabitant and increased with increasing number of weevil per acorn. The results of this study provide information concerning insects damaging acorns in two southern California oaks and suggest the potentially severe impact of this damage to germination.

18. DIFFICULTIES OF DEVELOPING AN IGR BIOASSAY FOR PEAR PSYLLA

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Pear psylla is an important pest of pear fruit trees. A major problem with trying to control it is the resistance that it has developed to many of the products used in its management. Because of this fact and the almost certain loss of many products currently in use to control it, new management techniques are being examined. Insect growth regulators (IGRs) are one of the most promising. Resistance risk assessments are used to establish baseline levels of susceptibility using a bioassay, monitor levels of susceptibility in natural populations and implement management tactics accordingly. This study has focused on the first of these steps by developing an effective IGR bioassay, then using it to establish baseline levels of susceptibility for three JH analogs and three chitin inhibitors. There were many difficulties in the development of the IGR bioassay, which will be discussed. Despite these barriers baseline levels of susceptibility were established for all the chemicals examined. One of the most interesting patterns seen in the study is an increase in variation over the two to three month period that the bioassays were run. This was thought to be caused by the increase in leaf age over time. A secondary set of bioassays was run to test this hypothesis. The leaves in this bioassay were all the same age and still there was a significant amount of variation. This suggested that leaf age is not the cause of the variation observed. Another hypothesis is that the age of the pear psylla females may affect the variation in the bioassay. Experiments are currently being run to test this hypothesis.

19. STRUCTURAL DIFFERENCES BETWEEN PARAPATRIC SAGEBRUSH-BUNCHGRASS AND CHEATGRASS COMMUNITIES

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Undisturbed shrub-steppe is dominated by sagebrush (*Artemesia* sp.) and bunchgrasses, and typically has a bryophyte crust. Grazing and agricultural conversion have removed sagebrush community across the Columbia basin, displacing native plants with cheatgrass (*Bromus tectorum*). As pristine shrub steppe habitat has dwindled, accurate information describing the ecology of remaining sagebrush-bunchgrass communities is vital to land-use planning.

Pitfall trapping was used to sample the epigeal fauna of low-level shrub-steppe communities located on the Arid Lands Ecology Reserve in central Washington State. The sample communities consisted of a cheatgrass dominated site and an adjacent sagebrush-bunchgrass community with a well developed cryptogammic crust. The sites are separated by a 20 meter wide cement road. Traps were collected weekly from March 1998 until present. Diversity and evenness indices were computed using the families Tenebrionidae, Carabidae, Curculionidae, Silphidae, and Boreidae. We find dynamic differences in both species composition and numbers between communities. Cheatgrass Carabidae are dominated by typically anthropophilic species, which other workers have found to be indicative of a degraded or disturbed community. Also, the sagebrush community supports a more even species assemblage. Several species were excluded from the cheatgrass community altogether, suggesting that this habitat is now unable to support native insect populations.

20. HOST SUITABILITY OF *THRIPS PALMI* (KARNY) (THYSANOPTERA:THRIPIDAE) ON SELECTED *FICUS* SPECIES

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Melon thrips (*Thrips palmi)* (Karny) (Thysanoptera:Thripidae) are pests of many Solanaceous vegetable crops. This species have also been implicated as pests on *Dendrobium* orchids and *Ficus* species--the latter primarily in the Netherlands. The purported pest status on *Ficus* has led to regulatory action to insure that *T. palmi* did not spread into vegetable crop production within the Netherlands. To better understand the relationship between *T. palmi* and *Ficus*, a series of experiments were conducted on the host plant relationships of this thrips in a production greenhouse in Southern Florida. Experiment (#1) monitored *T. palmi* movement and distribution throughout a 20 acre *Ficus* production facility adjacent to field vegetable production. Experiment (#2) provided data on descriptive biology after adult female thrips (taken from eggplant) were moved onto *Ficus*, eggplant and *Dendrobium*. The final experiment (#3) monitored the movement of *T. palmi* from heavily infested

eggplant onto 11 *Ficus* species. Results demonstrate that eggplant is an excellent host, *Dendrobium* orchids are a marginal host, and *Ficus* is a non-host of *T. palmi*. Although *T. palmi* were found on *Ficus* in the movement studies (#1 and 3), no immature stages were ever found. The data strongly suggest the *Ficus* spp. evaluated are not acceptable host plants of *T. palmi*.

21. REGIONAL ANALYSIS OF SPIDER MITES AND PREDACEOUS MITES ON GRAPE IN WESTERN OREGON

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In humid (Willamette) and arid (Rogue, Hood River) valleys of western Oregon, grape inhabiting mites such as two-spotted spider mite (*Tetranychus urticae*), Willamette mite (*Eotetranychus willametti*) and grape bud mite (*Colomerus vitae*) often are held in check by a complex of predators. Predaceous phytoseiid mites usually are the agents that are most effective at keeping these pests at low densities. If non-selective pesticides are used to control other disease or insect pests, spider mites can reach outbreak levels and cause severe plant damage. Spider mite control in grape is affected by immigration of mites that are resistance to pesticides and come from other crops surrounding vineyards, such as hops, corn, strawberries, caneberries, peppermint and vegetables. Pesticide-resistant spider mites build up early in one treated crop, then move to another. Overwintering of predatory mites and their movement among crops greatly affects spider mites densities on grape. Understanding the population dynamics and biological control of spider mites on grape and nearby crops will help identify IPM strategies that are effective and economical.

22. THE CONTRIBUTIONS OF FRANK BENTON TO BEE IMPORTATIONS IN THE 1880'S

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The last thirty years of the nineteenth century were a particularly active time in the growth of the American apicultural industry. Among the changes was an effort by many queen breeders of the time to import European and North African stock to improve honey production. Frank Benton was among the most productive of those working to import bees to North America. During ten years spent in the Middle East and Europe, Benton bred and shipped thousands of queens from several sub-species of *Apis mellifera* to the United States and Canada. During this time, Benton regularly corresponded with the American Bee Journal and beekeepers in North America. In 1881, Benton embarked on an ill-fated trip to Indonesia and Sri Lanka with the intention of bringing *Apis dorsata* to Europe and America. His correspondences and letters by American beekeepers, which were published in the American Bee Journal, chronicle Benton's experiences and paint a picture of excitement, apprehension and tension surrounding the endeavor. The talk will focus on the correspondence Benton maintained throughout his trip and the importance of the publication of these letters in documenting the history of apiculture.

23. BEHAVIORAL RESPONSES OF *HIPPODAMIA CONVERGENS* (CONVERGENT LADYBIRD BEETLE) TO INSECTARY PLANTS

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Hippodamia convergens is a generalist predator on aphids and is used in biological control programs. Much popular literature states that certain "insectary" plants used in gardens or in cropping systems attract ladybird beetles. Attraction of *H. convergens* to insectary plants has not been formally studied in controlled experiments. We conducted laboratory experiments using a Y-shaped olfactometer to test relative attractiveness of the following flowering plants to adult female *H. convergens*: dill, brown mustard, buckwheat, alfalfa, clover, and hairy vetch. Non-flowering wheat was also measured for relative attractiveness when plants were 30 days old. We also measured relative attractiveness of winter wheat with aphids, without aphids and artificial damage caused by placing pinholes on the leaf. A commercially available (*E-B* farnasene) product, Ladybug Lure (SureFire Products), served as a standard for comparison. None of the insectary plants tests were attractive to *H. convergens*, nor was the commercial lure.

24. THE DEVELOPMENT OF A MARKER TO DETERMINE THE FORAGING RANGE OF ARGENTINE ANT POPULATIONS

Stephanie Young and Michael K. Rust

Department of Entomology, University of California, Riverside, CA 92521-0314

Ph.D. Papers

25. INDUCED RESPONSE OF RED RASPBERRY PLANTS TO SPIDER MITE FEEDING (ACARI: TETRANYCHIDAE)

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The red raspberry, *Rubus idaeus* L. is inhabited by two closely related spider mite species, the yellow spider mite *Eotetranychus carpini borealis* (Ewing) and the twospotted spider mite *Tetranychus urticae* Koch. *E. carpini borealis* dispersed earlier to the upper part of the canes than did *T. urticae*. This behavior allowed *E. carpini borealis* to exploit young leaves before *T. urticae* did.

Greenhouse and laboratory studies were conducted to test the hypothesis that red raspberry plants previously infested by *E. carpini borealis* will not harbor populations of *T. urticae*. These plants showed an induced response to two weeks of spider mite feeding. Population growth was reduced on plants that were infested by conspecifics. On the other hand, plants previously infested by one species harbored the same densities of the other species as control plant. Moreover, *T. urticae* populations did not go to extinction even if introduced after *E. carpini borealis*, whereas, *E. carpini borealis* populations did go extinct when this species was second to colonize the leaflet. The initial state of colonization of red raspberry plants has an impact on subsequent population dynamics of the two species.

26. SPATIAL DISTRIBUTION OF FORMOSAN SUBTERRANEAN TERMITE FORAGING IN A LABORATORY ARENA

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A laboratory arena was developed to model foraging behavior of the Formosan subterranean termite, *Coptotermes formosanus,* under conditions comparable to a field situation with multiple food resources. Objectives were to evaluate the arena design for usefulness in longer-term behavioral and modeling studies and to determine if all foraging sites within the arena were of equal preference to foraging termites. The arena consisted of two 65 cm square pieces of clear acrylic with a 2 to 3 mm space in between filled with moistened sand. A total of 16 foraging sites were uniformly set up in the arena in a grid pattern. Data were collected on termite presence, construction, and total wood consumption at each site for a period of 47 days. No mortality was observed and individual termites and tunnels were visible throughout the course of the study. Eleven of the 16 foraging sites were discovered, and 8 of these sites showed termite feeding. Sites closest to the central initiation point were fed upon more than sites farther away even though some of the farther sites were discovered before nearer sites. More observations are needed to draw conclusions concerning foraging behavior. However, this initial trial suggests that *C. formosanus* foragers explore a large area but may show a preference for feeding on resources closest to the colony nest.

27. POTENTIAL IMPACTS ON CONTROL: TOXICITY OF PHLOXINE B TO *CERATITIS CAPITATA* AND ITS PARASITOID*, FOPIUS ARISANUS*

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With the enforcement of the Food Quality Protection Act, organophosphates such as malathion, may lose registration. Malathion is important in controlling and eradicating *Ceratitis capitata* (Wiedemann)(Diptera: Tephritidae) (Medfly) infestations. The xanthene dye, phloxine B, is currently being evaluated as a

replacement for malathion in these programs. Several tephritid parasitoids have been established in Hawaii with the braconid *Fopius arisanus* (Sonan) being the most prevalent natural enemy of the Medfly. Because of potential pesticide effects on beneficial species, the toxicity of phloxine B to the Medfly and *F. arisanus* was assessed. Lethal concentrations of the dyes causing 50% mortality of test populations (LC_{50}) were determined for both species. Phloxine B LC_{50} values for female Medflies and parasitoids 12 hours after exposure were 0.10 mM and 1.67 mM, respectively. However, 24 hours after exposure the LC_{50} values of phloxine B for female Medflies and parasitoids were similar at 0.07mM and 0.19mM, respectively. Laboratory studies on *F. arisanus* show that sublethal doses of phloxine B reduce progeny production and searching behavior efficiency. This study illustrates the importance of screening potential pesticides for effects on nontarget organisms.

28. UNINTENDED TRITROPHIC CONSEQUENCES OF CROP DOMESTICATION: THE CASE OF SUNFLOWERS

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Crop domestication of the sunflower, *Helianthus annuus* L., has altered many plant characteristics that increase its suitability to agronomic conditions. These changes may have unintentionally altered interactions between sunflowers, herbivores and their insect natural enemies. The sunflower moth, *Homeosoma electellum* H., is a major pest in agricultural sunflower fields in the San Joaquin Valley. In contrast, moth population densities in nearby native sunflower fields are typically much lower, possibly due to abiotic and plant population differences. Moreover, parasitism was shown to be higher in wild fields than in agricultural fields. Results from a common garden study found a signficant genotypic effect on moth abundance. Mean number of larvae of *H. electellum* increased with greater head diameter, whereas parasitism rates declined.

Tuesday, June 22, Morning Session B
Submitted Papers

29. SAMPLING AND CONTROL OF GRAPE MEALYBUG IN TABLE GRAPES

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A sampling procedure is being developed to determine how effective dormant treatments are at controlling mealybug and to predict severity of damage at harvest. The procedure involves searching the basal area of two spurs on each of two vines. Each spur is searched for two minutes during late May or June. The number of mealybugs or egg sacs is counted and this figure is related to cluster infestation at harvest. Harvest evaluation of clusters is based on sampling 5 to 10 clusters per vine which are in contact with the wood. This procedure was followed in 1997 and 1998 and the trial allowed for a range in mealybug populations on vines. A simple regression analysis was performed using mealybugs per spur as the independent variable and number of infested bunches as the dependent variable. The analyses resulted in an r value of .967 ($P<0.01$) for 1997 and an r value of .869 ($P<0.01$) in 1998. This technique could be used by pest control advisors to predict severity of mealybug infestation and to determine if further chemical control is needed.

30. USE OF SUCCESS™ NATURALYTE INSECT CONTROL AS AN IPM TOOL IN TREE NUTS

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Peach twig borer, *Anarsia lineatella*, is a major pest of almonds and stone fruit in California's fruit and nut growing regions. Studies conducted since 1992 showed that application of Success at "dormant" or "May spray" timing provided excellent control of this pest relative to commercial standards. Studies were conducted, during the 1997, 1998 and 1999 seasons, to evaluate the efficacy of at-bloom applications of Success relative to dormant applications. Honey bee safety of these applications were evaluated in separate studies during 1997 and 1999 seasons. Results showed that at bloom or delayed dormant applications of Success at comparable rates provided significantly better control of peach twig borer than early dormant or dormant applications. A single application of Success™ during bloom was more effective than two applications of a Bt product. Night applications of Success at pink bud or full bloom stages of almonds did not cause significant mortality of pollinating honey bees compared to the untreated. Application of Success™ did not result in mite outbreak.

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31. CONTROL OF FOLIAR FEEDING PESTS WITH *BEAUVERIA BASSIANA* AND REDUCED RATES OF BT OR IMIDACHLOPRID

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The mycoinsecticide *Beauveria bassiana* (Bb) has demonstrated commercial efficacy against greenhouse and nursery pests. Attempts to use Bb in field crops have been frustrated by application issues and Bb spectrum. Where pests have increased tolerance to *Bacillus thuringiensis* or where resistance management is favored, Bb has demonstrated useful supplemental efficacy.

32. EFFECT OF OIL-BASED PROGRAMS ON APPLE PESTS AND PREDATORS IN CENTRAL WASHINGTON

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Two large plot experiment were conducted to determine the effect of oil (Orchex 796, 1% v/v) on arthropod pests and diseases. Treatments in Block A were 1) oil (3 applications/generation) timed for codling moth; 2) oil targeting indirect pests as needed; and 3) check (some codling moth control). Treatments in Block B (4 cultivars) were 1) oil targeting mildew; 2) oil targeting codling moth; and 3) check (some codling moth control). WALH populations were low during 1st

generation in these plots; however, some effect of oil applications was detected on nymphs. During the 2nd generation populations were higher and oil treatments produced a significant control of nymphs. Predatory mites were suppressed somewhat by oil applications. Woolly apple aphid increased dramatically on Block A in July, but oil plus predators provided control. Codling moth damage was moderate on both blocks. Mildew damage seemed to be more associated with cultivar susceptibility than to treatments. Thrips and Campyloma accounted for most of the damage at harvest in Block B, and the same happened with leafhopper tarspots in Block A. Green aphids, mites, leafrollers and leafminer populations were too low to detect significant differences between treatments.

33. DEVELOPMENT OF ATTRACT AND KILL (A&K) PRODUCT FOR CONTROL OF CODLING MOTH AND OBLIQUEBANDED AND PANDEMIS LEAFROLLER

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A&K technique is a relatively new alternative to control codling moth, and it is a potential alternative for controlling leafrollers on apple orchards under central Washington conditions. A&K efficacy is based on the attraction of synthetic sex pheromones present in the formulation; control depends on mortality and sublethal effects produced by insecticide contact. Previous data indicated that A&K formulations (Sirene-CM) used as a lure in conventional pheromone traps attracted significant numbers of males. However, observation using night vision goggles suggested that not all individuals attracted to the A&K drops actually contacted the source. Results reported from field trials have been variable. The success of A&K formulations depends on the pheromone blend and number of A&K sources per area as well as competition with wild females and repellent properties of insecticides utilized. The optimum pheromone blend in A&K formulations will be identified for the obliquebanded and pandemis leafroller using wind tunnel and caged field studies. The registered A&K formulation for codling moth will be evaluated against new A&K formulations using wind tunnel studies. Leafroller mating behavior will also be characterized as a part of this study. Mortality and sublethal effects are being evaluated with a bioassay developed last summer.

34. OVERWINTERING LIFE HISTORY OF THE COTTON APHID, *APHIS GOSSYPII,* IN THE SAN JOAQUIN VALLEY

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The cotton aphid, *Aphis gossypii*, has developed into a significant pest of cotton in California and the status of this pest has changed from an occasional pest in the mid-1980's to an annual pest around which management programs must be focused. The wide host range of this pest, and the corresponding high level of crop diversity in the San Joaquin Valley, allows this insect to effect several crops throughout the growing season. Cotton, melons, other vegetables, citrus, and ornamentals are common hosts. However, information on overwintering strategies, host plants utilized for overwintering, and densities of overwintering cotton aphids is lacking. Knowledge of cotton aphid seasonal life history may be useful in designing alternative management schemes, such as parasite introductions, importance of weed control, etc. Studies started in September 1998 which were designed to monitor cotton aphid populations on key annual and perennial crops and on weeds throughout the year; the initial phase of this project dealing with overwintering cotton aphids has been completed. Populations were monitored on cotton (prior to fall harvest), melons, winter annual weeds, citrus, and other potential perennial hosts.

35. CONTROL OF MITES AND APHIDS WITH THE NATURAL PRODUCT CINNAMIC ALDEHYDE

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Cinnamic aldehyde (CA), a widely used food grade fragrance and flavoring, is exempted from tolerance by the EPA. Research over several years has lead to the use of a 30% CA flowable product as a pest control agent. Data from field trials conducted during 1997 and 1998 demonstrate significant efficacy on mites and aphids.

36. A SURVEY OF THE TERMITES OF THE HAWAIIAN ISLANDS: OAHU, MAUI, MOLOKAI AND MIDWAY ISLANDS

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Until recently it was assumed that there were four resident termite species in the islands, one subterranean termite, *Coptotermes formosanus* and three drywood species, *Cryptotermes brevis*, *Incisitermes immigrans* and *Neotermes connexus*. The survey has revealed that the indigenous termite fauna is distributed throughout the islands, beyond previous reports. Since 1996, three additional species have been discovered in Hawaii. Our survey has revealed that the ranges of the three species are fairly restricted with *Incisitermes minor* and *Cryptotermes cynocephalus* on the island of Oahu and *Zoootermopsis angusticollis*, in the Kula region of Maui. These restricted distributions suggest that the introductions occurred during past 10-15 years. Two of the introductions have been linked to imported wood products and thus it appears that an absence of quarantine inspections of these wood products resulted in the introductions. Although these termites have not yet had any economic impact in Hawaii, it can be assumed that these species will eventually reach pest status because all of them are pests within their native ranges.

37. THE IMPACT OF BLACK PEPPER AND CHAMOMILE EXTRACTS ON THE EUROPEAN CORN BORER

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The European corn borer, *Ostrinia nubilalis* (hubn.) is one of the main pests of many important crops causing severe damage and loss in quantity and quality of yield. Extracts from two plants, black pepper (*Piper nigrum*) and Hungarian chamomile (*Matricaria chamomilla*) were evaluated against different instars of *O. nubilalis*. Four solvents (petroleum ether, chloroform, acetone and water), were successively used for extraction and three concentrations 5, 10 and 15% of each were tested. Observations were made on mortality and change in body weight as measures of efficiency.

The 3rd and 4th larval instars were found more sensitive than 5th instar. Water and petroleum ether extracts were the most effective. The highest mortality, 79.5%, was reached after 5 days in 3rd instar larvae treated with 15% *P. nigrum* in water. The lowest mortality, 4%, was that in 5th instar after one day after treatment with 5% *P. nigrum* in acetone. For *M. chamomilla*, the highest mortality, 67%, was reached in 3rd instar larvae 5 days after treatment with 15% concentration in water. The lowest mortality, 8.5%, was that one day after treatment of 5th instar larvae with 5% in acetone.

Larval weight was considerably reduced by treatment.

38. RESISTANCE TO THE SILVERLEAF WHITEFLY, *BEMISIA ARGENTIFOLII*, TRANSMITTED COTTON LEAF CRUMPLE DISEASE IN UPLAND COTTON

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Cotton cultivars and breeding-lines were evaluated in 1998 in California for resistance to the silverleaf

whitefly-transmitted cotton leaf crumple disease, caused by cotton leaf crumple geminivirus (CLCV). Results showed differences in whitefly infestation levels and virus disease symptoms among cotton entries. The breeding-line C95-387 had a lower CLCV disease rating than other entries, and no CLCV was detected by squash and dot blot hybridization with a general geminivirus DNA probe. Breeding-lines C95-383 and C95-483 had lower CLCV disease rating than other entries, except C95-387, and CLCV was detected. Stoneville 474 had a higher CLCV disease rating than other entries and CLCV was detected.

39. USING IMIDACLOPRID TO CONTROL CALIFORNIA RED SCALE AND CITRICOLA SCALE IN CITRUS

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California red scale, *Aonidiella aurantii*, is a primary pest of citrus in the San Joaquin Valley, and one of the more difficult to control. Broad-spectrum insecticides have been used effectively for many years to control this armored scale. However, continuous use of insecticides with similar modes of action, specifically the organophosphates and carbamates has resulted in the development of resistance in many of the armored scale populations. Many growers must now use multiple sprays in one growing season where formerly, a single spray in alternate years was sufficient to control the pest. Some citrus growers who have discontinued use of the organophosphate and carbamate insecticides have experienced outbreaks of a secondary pest, citricola scale, *Coccus pseudomagnoliarum*, which had been coincidentally controlled by the sprays. These events have created a need for alternative insecticides that are efficacious against the California red scale and citricola scale. For resistance management purposes, new insecticides need to have different modes of action than the cholinesterase inhibiting organophosphates and carbamates. Efficacy trials have been conducted for several years in San Joaquin Valley citrus using the chloronicotinyl insecticide imidacloprid. Two formulations of imidacloprid, applied to either soil or foliage, were used to control both California red scale and citricola scale in citrus.

40. LEAFMINER CONTROL ON LEGUME VEGETABLES AND CUCURBITS WITH SUCCESS™ IN CALIFORNIA AND ARIZONA

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Small-plot field studies were conducted on cantaloupes and blackeyed cowpeas in 1997 and 1998 to evaluate the performance of Success™ (spinosad) on Agromyzid leafminers, *Liriomyza trifolii* and *L. sativae*. On cantaloupes in Arizona, larval control was excellent both years. Success treatments in 1998 resulted in plants that were measurably healthier than Agri-mek and Trigard treatments. In California, poor control of *L. trifolii* was achieved on blackeyed cowpeas in 1997 when Success was applied without the benefit of a surfactant in the spray solution. However, excellent results were obtained in 1998 when an oil-based surfactant was utilized. Side-by-side comparisons with and without a surfactant in 1998 demonstrated the value of adding such products to Success for leafminer control on blackeyed cowpeas. Lower leafminer densities were apparent on both crops in 1997 compared to 1998.

41. OPTIMUM TIMING FOR LEAFMINER CONTROL IN APPLE WITH SUCCESS™

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Tests on western tentiform leafminer, *Phyllonorycter elmaella* (Doganlar and Mutuura) control in apple were performed with spinosad (Success) from 1995-1999. Not all stages of the leafminer are susceptible, thus timing is critical. Typcially, the sapfeeders (first 3

larval instars) are the most susceptible to conventional insecticides, and this timing was tested, along with those having a higher proportion of eggs or tissuefeeders (last 2 larval instars). Although the timing for conventional insecticides (90% sapfeeders, 10% tissuefeeders) is effective in most cases, there may be some benefit to earlier timing.

Tuesday, June 22, Morning Session C
Submitted Papers

42. BIORATIONAL MANAGEMENT OF BLACKHEADED FIREWORM, *RHOPOBOTA NAEVANA* (LEPIDOPTERA: TORTRICIDAE) IN CRANBERRY

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Trials were conducted at fifteen Washington State commercial cranberry bogs to demonstrate new biorational insecticides against the blackheaded fireworm, (BHFW), Rhopobota naevana (Tortricidae: Lepidoptera). The insect growth regulator, tebufenozide (Confirm®, Room and Has), the B.T.-based insecticides (Crymax®, Ecogen or Mattch®, Mycogen) and microencapsulated female sex pheromone Z-11-tetradecenyl acetate (No-Mate®, Ecogen) were applied in different combinations. The biorational programs resulted in lower percentages of bud and fruit damage relative to untreated bog portions in all but one trial, where pesticide coverage was poor due to a faulty chemigation system. Mating was disrupted according to abundance of male moths in pheromone traps baited with both standard strength septa and septa equivalent to a single female moth ('decoy septa') in No-mate treated bogs and conventionally-treated bogs. Results led to the development of season-long integrated programs of blackheaded fireworm management currently under investigation.

43. ANTAGONISM BETWEEN HERBICIDE AND INSECTICIDE IN SPRING CANOLA

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Empirical observations indicated antagonism between sulfonyl urea herbicide (Harmony) and insecticides where a sub-lethal herbicide drift has occurred prior to insecticide application or where a seed treatment insecticide is present e.g. Imidacloprid (Gaucho 480). A RCBD trial of 9 treatments was established in 1998: Imidacloprid in treatments of 10 oz ai cwt, with 2 oversprayed with 2 rates of Harmony (1/1000 and 1/100 field rates) at the rosette stage; 3 treatments of bifenthrin (Capture 2E) treated with Harmony in a like manner to Imidacloprid; 2 rates of Harmony applied to untreated Canola; and an untreated check. Severe cabbage aphid and cabbage seedpod weevil populations appeared at full bloom, at which time bifenthrin was applied and insect counts began. Significant differences in insect control (ANOVA 0.5 LSD) occurred between insecticide treatments and the herbicide/insecticide treatments at both rates of Harmony, Harmony alone, and the check. Yield was higher for the insecticide treatments alone compared to all other treatments. These data lead to the conclusion that some sort of antagonism does occur to reduce insecticide efficacy where Harmony in sub-lethal doses drifts onto Canola or where air-mass contamination occurs. Research continues to determine the mechanism of antagonism.

44. INCREASING THE EFFICACY OF NEEM FOR CONTROL OF APHIDS

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A series of studies was conducted to test whether surfactants would increase the efficacy of the commercial neem product, Neemix, for control of aphids. Combinations of neem, the selective aphicide, Pirimor and surfactants were also evaluated against aphids. Results indicated that two silicone surfactants greatly increased the effectiveness of neem against aphids. Interestingly, surfactants did not increase the

effectiveness of Pirimor. Pirimor and neem worked synergistically, the toxicity being much greater than simply additive. Results indicated that concentrations of Pirimor could be greatly reduced and still get the same level of control after the addition of Neemix. Although the addition of the most effective surfactant to neem and pirimor resulted in a lower number of aphids than the neem and pirimor treatment alone, statistically significant differences were not found. The implications of these finding for future use of neem for control of aphids will be discussed.

45. THE PHEROMONE MICROSPRAYER FOR FRUIT PEST MATING DISRUPTION: WHERE NEXT?

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The Microsprayer is a new device for releasing defined quantities of pheromone to achieve mating disruption of pest insects in commercial agriculture. Field tests conducted in apple orchards during 1998, with two units deployed per acre, demonstrated that release of the major sex pheromone component of obliquebanded and redbanded leafroller provided a high level of pheromone trap shutdown, coupled with significant reduction in damage to fruit at harvest. Addition of a pesticide-treated border to the pheromone plots produced fruit with only 2% damage, compared to 13% in the untreated controls. Release of codlemone for disruption of codling moth did not produce either trap shutdown or fruit protection, indicating that pheromone stability is critical for effective use of the low-density high-load approach to mating disruption. Field trials during 1999 will further explore the efficacy of the Microsprayer against complexes of Tortricid fruit pests in a range of commercial fruit crops in Michigan.

46. BIZARRE CYTOGENETICS IN THE SOCIAL MEXICAN BUTTERFLY *EUCHEIRA SOCIALIS* (PIERIDAE)

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E. socialis occurs in the mountains of Mexico and is characterized by larvae that build a silken communal nest and an extremely male-biased primary sex ratio. There are two subspecies of *E. socialis*, *westwoodi* found in northern Mexico and *socialis* occurring in Mexico's southern states. Using squash and air dry methods, I studied male and female mitosis and meiosis using fifth instar male larvae and young female pupae. *E. s. socialis* has 26-27 bivalents in male meiosis and 52 chromosomes in female mitosis. In male eupyrene meiosis *E. s. westwoodi* exhibited extreme variability in chromosome number and element type from cell to cell within an individual and among individuals within the same population. Chromosome number varied from 69 to 84. Additionally, lagging elements in male meiosis and the presence of micronuclei in sperm bundles were common in *E. s. westwoodi*. Female mitosis revealed an invariable chromosome number of 70. Based on these chromosomal differences between the northern and southern subspecies, I propose elevating the subspecies to the species level.

47. PHANTOM® TERMITICIDE-INSECTICIDE

S. Burkart, C.Klein, D. Colbert and T. Alby

American Cyanamid Company, P.O.Box 400, Princeton, NJ 08543

Chlorfenapyr termiticide-insecticide, trade name Phantom®, is a pro-insecticide with a novel mode of action that interrupts energy production and does not involve the nervous system. It has a broad spectrum with good contact activity, roughly equal to organophosphates or carbamates, and has excellent activity when ingested. Several important features and benefits have been identified. Phantom® is not repellant. Due to its unique mode of action, no cross-resistance has been identified. It has a low vapor pressure, and provides excellent residual control. In research and EUP trials, excellent control of a number of species of cockroaches, ants and subterranean termites has been demonstrated.

48. JERKING BEHAVIOR AMONG PHYTOSEIID MITE SPECIES (ACARI: PHYTOSEIIDAE)

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Several species of phytoseiid mites exhibit a jerking behavior. Jerking is a pronounced, and often repeated, lunging of the entire body. This behavior occurs most frequently in immature stages. With *Neoseiulus fallacis* (Garman) larvae, jerking was most often triggered by direct contact with con- and heterospecific predators, and also by contact with the pest mite, *Tetranychus urticae* Koch. No differences in jerking frequency per contact or median number of jerks per jerking event were found among any particular life stage of *N. fallacis* or with *T. urticae* as the contact agent. A larva was more likely to jerk when approached rather than when it was the approaching member. When jerking was observed in approaching larvae, it was often executed aggressively. Repeated jerking events occurred for extended periods when larvae were aggregated, and probing each other with their front legs. Across 7 phytoseiid species studied, larval jerking frequency and median number of jerks did not differ among age groups. The tendency of a species to aggregate was found to be correlated with frequent jerking ($p<0.001$, from a simple linear regression). *N. fallacis* jerked more frequently than all other phytoseiid species.

49. EFFICACY OF LACEWING LARVAE IN CONTROLLING RUSSIAN WHEAT APHIDS ON SUSCEPTIBLE AND RESISTANT WHEAT

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Plant traits that confer resistance to insect pests may simultaneously enhance or reduce the efficacy of natural enemies as biological control agents. Cage experiments were used to compare the ability of lacewing larvae (*Chrysoperla plorabunda*) to control populations of the Russian wheat aphid (*Diuraphis noxia*) on susceptible and resistant seedlings of wheat. On winter wheat, the percent reduction in aphid density due to predation was significantly higher on the resistant cultivar than it was on the nearly isogenic susceptible cultivar. We did not observe such an interaction in experiments using a cultivar of spring wheat, as the effects of plant resistance and lacewing predation were mostly additive. In no case was the effectiveness of lacewings diminished by the resistant cultivar. We propose two mechanisms by which even moderate levels of plant resistance may significantly improve the efficacy of lacewings in suppressing populations of the Russian wheat aphid.

50. BIOLOGY OF *NEUROCOLPUS LONGIROSTRUS* KNIGHT (HEMIPTERA: MIRIDAE) IN CENTRAL CALIFORNIA

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Neurocolpus longirostrus is one of several mirids that cause epicarp lesion damage to commercial pistachios, *Pistacia vera*, in California. The primary native breeding host for *N. longirostrus* is California buckeye, *Aesculus californica* (Spach) Nutt. (Hippocastanaceae) which grows in the Sierra Nevada and Coast Range foothills up to 1300 m. Adult *Neurocolpus* migrate from buckeye into pistachio orchards planted in foothill areas and develop endemic populations that must be controlled in early spring.

Eggs are laid in new growth twigs of pistachio or buckeye between buds and leaf petioles during May-July. Bugs reared on fresh *Aesculus* flower panicles at 23 ± 1.5˚C in petri dishes completed nymphal development in 17.8 days; adults lived an average 27.4 days. Egg hatch in the field is closely synchronized with flowering and nut development in April-May.

Several egg parasites have been reared from *Neurocolpus*, including a species of *Chaetostricha* (Trichogrammatidae) and a species of *Erythmelus* (Mymaridae).

51. REPRODUCTIVE AND SURVIVORSHIP ATTRIBUTES OF *ANAPHES IOLE*, AN EGG PARASITOID OF *LYGUS HESPERUS*

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Anaphes iole, an egg parasitoid of *Lygus hesperus*, has potential as an augmentative biological control agent for use in commercial strawberries on the Central Coast in California. In field trials, with weekly and semi-weekly releases, we obtained < 65% *L. hesperus* suppression, which was lower than expected based on cage studies. To determine if there were biological constraints that explained the submaximal performance of the parasitoid in the field, we examined the reproductive and survivorship attributes of *A. iole.* In this study we were interested in determining whether: 1) egg load varied with age 2) survivorship and fecundity changed in the presence of an adult food source, and low and high host densities. We observed that egg load at emergence ranged from 30 - 60 eggs / female and there was no increase with age indicating that *A. iole* is pro-ovigenic. In the absence of honey, females died within 2 days but, when exposed to high host densities, females laid majority of their eggs within this period. In the presence of honey, fecundity was higher but only marginally so, and appeared to be due to increased survivorship rather than an increase in egg production. Impacts of *A. iole* survivorship and fecundity in field situations with variable host and food availability, and implications for augmentative biological control of *L. hesperus* in strawberries are discussed.

52. WALNUT PEST MANAGEMENT ALLIANCE

Carolyn Pickel[1] and Walt Bentley[2]

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A Walnut Pest Management Alliance (PMA) funded by California Department of Pesticide Regulation (DPR) was formed to demonstrate an interdisciplinary approach to reduced-risk practices under FQPA. The Pesticide Use Database compiled by the Department of Pesticide regulation (DPR) from pesticide use reporting (PUR) shows a 10.4% increase in FQPA risk applied to walnuts from 1990 to 1995. Growers are finding that more and more pesticides are required each year to keep codling moth damage under control. The Alliance consists of the Walnut Marketing Board, Biological Integrated Orchard Systems (BIOS), DPR, UCIPM, UC researchers, UCCCE advisors, growers, PCA's, insectaries and local farm advisors. The management team consists of representatives from each group and expertise for the major walnut pests and disciplines. There are 3 regional implementation teams for the state. These regional implementation teams allow for interaction and planning between the members of the alliance, CE advisors, and cooperators. The funding is used for monitoring the 12 paired-comparison demonstration sites in California. Developing and implementing a reduced risk management program using multi-tactic approach for codling moth could result in a major reduction of pesticides in walnuts.

53. THRESHOLD ACTIVITY LEVELS OF STRUCTURAL TERMITICIDES

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Minimum activity threshold levels for selected common and proprietary termiticides was determined against the western subterranean termite, *Reticulitermes hesperus* Banks, and the desert subterranean termite, *Heterotermes aureus* (Snyder). Both are destructive species, the latter being prevalent in desert areas of Arizona, southeastern California, and Mexico. The clinical knockdown activities of low rates of permethrin (Dragnet FT), bifenthrin (Talstar SC), and deltamethrin (DeltaGard TC) mixed into clean soil were determined by direct contact and by degree of tunneling. Contact knockdown (KD) was determined 5 days after 1-hr exposure. Termites were also allowed to tunnel into treated soil. KD and inhibition of tunneling indicated effectiveness. Worker *H. aureus* tended to tolerate contact with soil containing a higher % insecticide than *R. hesperus*, even though it is much smaller. Relative activity tended to be deltamethrin >> bifenthrin > permethrin, with as low as 1.0 ppm deltamethrin providing significant KD. Termite tunneling was prevented by approximately 1/10 the concentration that produced KD by contact. Termiticide producing fastest KD by contact was the most repellent, allowing the least amount of tunneling and greatest survivorship. Mortality, per se, is therefore not a good measure of termiticide efficacy. Long-lasting protection of a structure may be attained by treatment with repellent termiticides that do not necessarily kill the termites.

Coupled with chemical analysis of the soil, minimum threshold activity determination may predict the longevity of termiticides applied to control or suppress termites.

54. ARGENTINE ANT CONTROL AROUND URBAN STRUCTURES

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Argentine ants are the most important ant pest species in urban areas in southern and central California. Control recommendations include the use of baits and perimeter sprays around structures. Our research over the past five years has focused on evaluating the efficacy of perimeter sprays against Argentine ants. A monitoring system quantifying the removal of sugar water solutions was developed to determine the ant foraging activity before and after treatments. One advantage of the system is that it monitors activity over a 24-hour period. Factors such as irrigation, excessive temperatures, and adverse substrates severely reduce the residual activity of most sprays. Thorough applications and maximum label rates are typically required to prevent ants from gaining access to treated areas within 30 days. The best control was achieved when sites around the home and property likely to harbor nesting Argentine ants were treated.

55. RESPONSE OF OMNIVOROUS LEAFROLLER AND ONION THRIPS TO LOW TEMPERATURE STORAGE

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Mean percentage survival to the adult stage of omnivorous leafroller, *Platynota stultana* Walshingham, eggs and 1st-5th instars was 60.7-95.2% for non-exposed immatures and 14.5-54.3% for immatures exposed to 1 wk at 0-1^{o}C. Two to 5 wk exposures resulted in 0-6.7% survival and a 6 wk exposure caused <1% survival of all stages tested. A significant reduction in survival occurred between 0 and 1 wk and between 1 wk and 2-6 wk exposures for all larval stages. Survival of eggs after 0 and 1 wk exposures was significantly different than survival after 2-6 wk exposures. The 2nd instar was the least susceptible stage to low temperature storage. Adults that were exposed to low temperature for 1 wk in the 3rd through 5th instars laid a mean of 120-289 eggs per female, and the mean percentage viability of the eggs ranged from 56.2 to 71.4%. Mean percentage survival of onion thrips, *Thrips tabaci* Lindeman, adults and nymphs was inversely related to the duration of exposure from 1 through 3-6 wks at 0-1 and 5^{o}C and was lower at 0-1 (0.2-52.5%) than 5^{o}C (17.6-66.6%). Exposure to 0-1^{o}C for 4 wk attained 91.2% control which increased to 99.8% after 6 wks. Low temperature storage has potential to control omnivorous leafroller in table grapes, *Vitis vinifera* L., and onion thrips in onions, *Allium cepa* L.

STUDENT POSTER COMPETITION

M.S. Poster Display Competition

D1. OVIPOSITION BEHAVIOR AND ESTABLISHMENT OF HESSIAN FLY ON RESISTANT AND SUSCEPTIBLE SPRING WHEATS

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and Edward J. Souza

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Hessian fly, *Mayetiola destructor* (Say) (Diptera: Cecidomyiidae), damage has been increasing in northern Idaho for the last decade. The use of resistant varieties has been a principal control measure. Resistance to Hessian fly in wheat has relied on antibiosis. However, this has resulted in the evolution of Hessian fly biotypes capable of overcoming resistance. Antixenosis, which focuses on non-preference by the ovipositing female, has the potential to reduce selection for new biotypes. Field experiments (1998) and greenhouse experiments (1999) were conducted to examine oviposition behavior of Hessian fly and to monitor establishment of fly larvae in resistant and susceptible wheat varieties. Percentage of infested tillers (with eggs and first instar larvae) was used as an indicator of Hessian fly ovipositional preference in field experiments. In these experiments, a trend was observed which suggested infestation differences among three wheat genotypes. 'Jefferson' and 'WPB926' had fewer infested tillers than did 'A88673S-2'. In greenhouse cage studies conducted in 1999, number of eggs per plant, establishment and survival of first instar larvae were recorded on these three varieties. Results from these greenhouse studies will be presented.

D2. RESPONSE OF WOOD-BORING BEETLES (COLEOPTERA: BUPRESTIDAE, CERAMBYCIDAE) TO PRESCRIBED BURNING IN SOUTHWESTERN OREGON

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Wood-boring beetle larvae are important to nutrient cycling, decomposition, and wildlife species as a source of food. Adult wood-boring beetles are thought to be attracted to fire and burned logs by heat and smoke. Because prescribed burning is increasingly being used as a management tool to remove downed wood and other fuels, it is important to understand how these beetles react to this alteration of habitat. We conducted two studies to monitor response of wood-boring beetles to prescribed burning. First, individual logs were placed in a prescribed burn and burned to various degrees of severity. Adult beetles flying to the logs were monitored using flight intercept traps. Bark samples were taken to determine percent utilization by beetle larvae. Results were compared across severity classes of burning. Second, a retrospective study was conducted by monitoring adult wood-boring beetles in eight sites, spanning one to fifteen years since burning. Overall abundance and diversity was compared over time with adjacent check plots. The goal of these two studies is to determine the effect of prescribed burning on the habitat of wood-boring beetles and to aid in the development of coarse woody debris and fire management programs.

D3. PHENOLOGY AND HOST PLANTS OF *LACANOBIA SUBJUNCTA* (LEPIDOPTERA: NOCTUIDAE) IN TREE FRUITS OF THE PACIFIC NORTHWEST

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Larvae and adults of Lacanobia fruitworm, *Lacanobia subjuncta* (Grote & Robinson) were collected from

commercial orchards in central Washington and north central Oregon during 1998. Weekly sampling of adults at three locations indicates two generations per year in this region. Lacanobia fruitworm overwinters as a pupa, and adults emerge, mate and lay eggs through late April and May. First generation larvae were sampled from mid-June into late July. The second flight occurs from mid-August into September, and second generation larvae are present from late August through September.

Systematic sampling of weed plants in apple orchards found larvae on mallow, curly dock, and dandelion. Sampling of other fruit tree orchards found Lacanobia fruitworm on prune, cherry, pear, and apricot. No larvae were found on peach or plum, lambsquarters, smartweed, plantain, red clover, sowthistle, buckwheat, broadleaf plantain or redroot pigweed. Although Lacanobia fruitworm has the potential to feed on a variety of other plants, the number of larvae collected on apple is much higher than those collected on alternate host plants. This suggests that the population may be developing on apple foliage in commercial apple orchards.

D4. THE BASIC BIOLOGY OF BLACK VINE WEEVIL, *OTIORHYNCHUS SULCATUS* , IN CALIFORNIA COMMERCIAL NURSERIES

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Black vine weevil, *Otiorhynchus sulcatus* (F.), is a flightless, parthenogenetic weevil (Coleoptera: Curculionidae) with primarily one life cycle per year. A single adult can lay between 500-1200 eggs. The eggs are laid over the summer months where they hatch into small larvae that immediately burrow into the soil. There, the larvae feed on the roots of the plant causing poor growth and often death of the plant from girdling of the stem. The larvae overwinter and pupate in the early spring. The adults emerge around May and feed on the foliage causing distinct notched areas that on plants grown for aesthetic reasons may pose a problem for sale.

Integrated pest management (IPM) strategies have been developed and used successfully for many different agroecosystems. The control of *Otiorhynchus sulcatus* in commercial nurseries, however, relies exclusively on the use of conventional chemical pesticides such as carbofuran and multiple applications of acephate. Understanding the biology of black vine weevil is the first step towards the development of pest management tactics that reduce or eliminate the need for conventional pesticides.

D5. WESTERN LARCH (*LARIX OCCIDENTALIS*) RESISTANCE TO DOUGLAS-FIR BEETLE (*DENDROCTONUS PSEUDOTSUGAE*) ATTACK SUCCESS

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Under favorable conditions, the Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopkins, can reach densities high enough to kill large numbers of Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco. The host selection and colonization behavior of this beetle is regulated by a complex communication system that involves both pheromones and host tree volatiles. The level of attractiveness and the synergistic characters of many tree volatiles have been well documented. However, the repellent or aggregant inhibitory effects of other tree volatiles deserve further investigation. The subversion of olfactory perception and the prevention of aggregant pheromone production using non-host tree volatiles are potential bark beetle management supplements. Live western larch, *Larix occidentalis* Nutt., a tree species resistant to Douglas-fir beetle attack, has a significantly higher concentration of the volatile, 3-carene, compared to Douglas-fir. This study compares the effects of western larch resistance, 3-carene exposure, and Douglas-fir resistance on Douglas-fir beetle and bark beetle predator performance. Flight interception traps monitored relative attractiveness. Bark samples revealed relative gallery formation and brood production success. Death of attacked trees evaluated overall Douglas-fir beetle attack success. The goal of this study is to determine the extent that 3-carene influences the resistance of western larch to Douglas-fir beetle attack success.

D6. EVALUATION OF *CHRYSOPERLA RUFILABRIS* AS A COMPONENT OF *SCIRTOTHRIPS PERSEAE* IPM IN AVOCADOS

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The avocado thrips, *Scirtothrips perseae* Nakahara, was first found in California avocado orchards in 1996 and has since been detected in several of the state's avocado-producing counties. Until the arrival of *S. perseae,* California avocado production was challenged by only occasional pests which were managed effectively with low-input strategies. The severity of damage caused by *S. perseae* is potentially so great that it threatens to shift the California avocado industry toward more consistent and heavy chemical pesticide use in order to maintain economic yields. Currently, there are few effective pesticides registered for use against *S. perseae* in avocados. Overdependence on these compounds may induce rapid resistance development in *S. perseae* field populations. The development of an effective biological control agent against *S. perseae* will contribute directly to reducing pest populations, and may further enhance management by reducing the number and/or rates of pesticide applications required for economic control. The green lacewing, *Chrysoperla rufilabris*, is a strong candidate for biological control against *S. perseae*. It is an actively searching, voracious, generalist predator with natural tolerance to several classes of pesticides. Lab studies show that *C. rufilabris* larvae readily feed and develop on a diet of *S. perseae* . The potential for *C. rufilabris* to reduce *S. perseae* populations in avocado orchards will be evaluated and discussed.

Ph.D. Poster Display Competition

D7. SEARCHING AND OVIPOSITION BEHAVIOR OF *ANAGRUS NIGRIVENTRIS* (HYMENOPTERA: MYMARIDAE)

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Anagrus nigriventris is a dominant and effective egg parasitoid of the beet leafhopper on sugar beets in California. We conducted a study to investigate the searching behavior of this parasitoid on five host plants of the beet leafhopper (sugar beet and four winter-spring annuals) from the southern part of the San Joaquin Valley. In addition, the oviposition behavior of *A. nigriventris* on sugar beet was assessed with the aim of establishing some indices of oviposition without the requirement of destructive dissections of host eggs. *A. nigriventris* spent more time searching for host eggs on the relatively glaborous host plants (sugar beet, London rocket, and peppergrass) than on the pubescent host plants (plantago and red stem filaree). Moreover, the parasitoid destroyed a much lower proportion of host eggs on the pubescent hosts. Since the pubescent hosts are dominant members of the complex of winter annuals (reproductive hosts of the beet leafhopper) in the foothills of the southern San Joaquin Valley, augmentative releases of *A. nigriventris* in this area to control the beet leafhopper could prove unsuccessful in suppressing populations of this pest. Our research has shown that abdominal vibrations of female *A. nigriventris* and durations of ovipositor probes above a specific threshold were highly correlated with ovipositions and could be used successfully to predict the occurrence of oviposition without the need for laborious and destructive dissections. Finally, we formulate a picture of the processes involved in the searching and oviposition behavior of *A. nigriventris*, which could be typical of parasitoids attacking concealed host eggs.

D8. TESTING THE CARBON/NUTRIENT BALANCE HYPOTHESIS UNDER ELEVATED ATMOSPHERIC CO_2

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The Carbon/Nutrient Balance Hypothesis (CBN) predicts that plants grown in elevated CO_2 should allocate relatively more resources to carbon-based defenses when compared with plants grown in ambient CO_2 levels. Conversely, nitrogen-based defenses should be lower. We tested the CBN using a novel system that allowed us to test allocation to carbon-based and nitrogen-based defenses at the same time, relating these results with potential impacts on herbivorous insects. The experimental design used *Bt* transgenic cotton plants as well as a near isogenic line without the *Bt* genes, grown in both ambient (370 µL/L) and elevated (900 µL/L) CO_2 levels. We used a split-plot design with a 2 x 2 factorial for two levels of nitrogen fertilization and two levels of nitrogen-based defenses. We analysed

and quantified the carbon-based compounds in cotton (condensed tannins and gossypol) and the nitrogen-based compound (the *Bt* toxin). Therefore, the complete defensive chemistry was quantified. We examined the response of the insect herbivore *Spodoptera exigua* (Hübner) using foliar bioassys. The performance of the CBN hypothesis and the biological significance of the observed changes in defensive compounds is discussed.

OTHER SUBMITTED POSTER DISPLAYS

D9. *ALYMA*, A NEW CHILEAN TAXON (COLEOPTERA: ELATERIDAE)

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Alyma Arias, a new genus of Elateridae from Chile, with a single included species *A. pallipes* (Solier 1851**) n. comb**., is herein described and illustrated. *Alyma* is characterized by having the following: body stout, frontoclypeal carina complete, nasale present, prosternal sutures double, elytra convex, and absence of metathoracic wings.

Se describe e ilustra, *Alyma* Arias, un nuevo género de Elateridae de Chile, con una especie *A. pallipes* (Solier 1851) **n. comb.** El género *Alyma* presenta las siguientes características: cuerpo robusto, carena frontoclipeal completa, clípeo presente, suturas prosternales dobles, élitros convexos y ausencia de alas metatoráxicas.

D10. CONTROL OF ROOT WEEVILS IN CONTAINER-GROWN AZALEA WITH ENTOMOPATHOGENIC NEMATODES

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The use of entomopathogenic nematodes, particularly *Heterorhabditis marelatus*, a newly described species described from Seaside, OR, has high potential for biological control of root weevils in container-grown nursery crops. In greenhouse studies on potted azalea, *H. marelatus* applied at 25 or 50 IJs/cm^2 killed significantly more black vine weevil larvae than the untreated pots ($P < 0.001$). *H. marelatus* persisted up to five weeks in pots treated with 25 and 50 IJs/cm^2, but only three weeks in pots treated with 12.5 IJs/cm^2. In field studies on potted azalea, *H. marelatus* significantly reduced strawberry root weevil larvae at a rate of 25 IJs/cm^2 compared with untreated containers ($p \leq 0.02$). Efficacy was significantly higher when nematodes were sprayed over the pots than when applied as a drench treatment ($p \leq 0.007$). There was no significant difference in the number of nematodes or quantity of water collected in cups placed inside or outside the pots in the spray treatments. *H. marelatus* persisted in the treated pots up to six weeks based on mortality of waxworm larvae in the potting mix, although persistence decreased dramatically after four weeks.

D11. ALTERNATIVE TREATMENT EFFICACY FOR TWO QUARANTINE PESTS ON LYCHEE IN HAWAII

Peter A. Follett

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The probit 9 standard for quarantine security (maximum 32 survivors in a million treated individuals) was initially recommended with fruit flies and heavily infested fruit in mind. This standard may be too stringent for commodities that are rarely or poorly infested. The “alternative treatment efficacy” approach measures risk as the probability of a mating pair, gravid female, or parthenogenic individual surviving in a shipment. This will be a function of many factors including infestation rate, culling and other post-harvest removal of infested fruit, shipping and storage conditions and the mortality they exact on the pest, shipment volume, and other biological and nonbiological factors. The main quantitative argument for deviating from probit 9 is low infestation rate of the commodity. Lychee is an example of a commodity that is a poor host. Two regulatory pests, *Cryptophlebia* (a tortricid moth) and *Bactrocera dorsalis* (oriental fruit fly) typically have infestation rates in the range of 1-3% and and 1%, respectively, on lychee in Hawaii. A quantitative argument for lowering the probit 9 standard for these pests on this crop is presented.

D12. DEVELOPMENT OF *CIRROSPILUS* N.SP. (HYMENOPTERA: EULOPHIDAE) ON CITRUS PEELMINER, *MARMARA* SP. (LEPIDOPTERA: GRACILLARIIDAE)

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The citrus peelminer is a cyclical pest in the desert areas of southern California and Arizona. The larvae mine the surface of citrus fruits, rendering the fruit unacceptable for the fresh fruit market. A new species of *Cirrospilus* (Hymenoptera: Eulophidae) was found to be the major parasitoid in the system and seemed to be responsible of the declines in the populations during the summer in 1996 and 1997 in the Coachella Valley (CA). The influence of temperature on development of *Cirrospilus* on citrus peelminer under controlled temperature conditions has been determined in the laboratory. Thermal requirements such as a temperature threshold of 12.1˚C and 171.8 degree-days were calculated. Developmental times in the field along the year were estimated and compared with those of its host.

D13. CUTICULAR HYDROCARBONS OF *PTEROMALUS CEREALELLAE* (HYMENOPTERA: PTEROMALIDAE)

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The cuticular hydrocarbons of males and females of the pteromalid parasitoid *P. cerealellae* reared on either larvae of cowpea weevil or Angoumois grain moth have been identified and quantified. The total quantity of hydrocarbon on the parasitoid cuticle is a function of both gender and larval host, with males having less hydrocarbon than females and parasitoids reared on the moths having less hydrocarbon than those reared on the beetles. Males and females show gender specific hydrocarbon quantitative differences irrespective of larval host. Identified hydrocarbons include homologous series of n-alkanes, monomethyl-, dimethyl- and trimethylalkanes.

D14. DISPERSAL PATTERNS OF THE WHITEFLY PARASITOID, *ERETMOCERUS EMIRATUS*, FROM CENTRAL POINT RELEASES

Glen Jackson[1], James Hagler[1] and Juli Gould[2]
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Dispersal behavior is an important aspect in understanding the population dynamics of insects and, in the case of minute parasitoids, can be challenging to measure. Using immunomarking techniques, we marked *Eretmocerus emiratus*, released them in the field, then recaptured them in battery-powered fan traps arranged in a grid around the release point. Traps were placed at 2 or 3 heights within or above the plant canopy. Studies were conducted in 1997 and 1998 to test and validate the techniques in the field, as well as to gather data on parasitoid movement.

In cotton 4-feet high there was little difference in numbers of parasitoids captured at the 3 different trap heights. Larger numbers were trapped within a short distance of the center so movement away from the release site appeared to be limited. Most of the parasitoids were recaptured in the early morning between 5:30 and 9:00 AM.

D15. THE ROLE OF DELAYED MATING ON DEMOGRAPHY OF *CRYPTOPHLEBIA ILLEPIDA*: A POSSIBLE MECHANISM FOR MATING DISRUPTION

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Mating disruption is being used in several different crop systems as a management tool for pest insects, primarily in the Lepidoptera. Although studies have proposed different physiological mechanisms by which mating disruption acts, the effects on population dynamics have not been well described. We use laboratory derived life tables to determine the effect of delaying mating of adult females 3 and 5 days on population growth rates. We then used a simple Leslie Matrix model to project the effects for 1-5 generations. Our studies show that in 1 generation, the population size where mating was delayed 3 and 5 days was 75 and

69% of the control populations, respectively. When projected out 5 generations, the population sizes for 3 and 5-day delays were reduced to 24 and 15.9% of the control populations. The implications of this mechanism and the effect of it on developing mating disruption management programs are discussed.

D16. EFFECTS OF TEMPERATURE ON DEVELOPMENT OF ENTOMOPATHOGENIC NEMATODES

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Temperature is one of the most important environmental factors for the development of entomopathogenic nematodes. Each nematode species or strain has well-defined thermal niches, which may affect the performance of nematodes when they are applied for biological control of soil-dwelling insect pests.

Steinernema feltiae and a newly described species from Grants Pass, OR, *S. oregonense*, are temperate in origin while *S. riobravis* is from a subtropical region. Waxworm larvae were treated with 30 infective juveniles (IJs) of each species in Petri dishes and kept at 10˚ to 38˚C.

S. riobravis had the widest thermal range for both infection (14˚-38˚C) and reproduction (16˚-34˚C). *S. feltiae* and *S. oregonense* had similar thermal ranges. *S. feltiae* infected waxworm larvae between 10˚-28˚C and reproduced between 10˚-26˚C. Infection and reproduction for *S. oregonense* ranged from 10˚-26˚C and 10˚-24˚C, respectively.

Lower temperatures severely slowed development of all three nematode species. For example, eggs of *S. oregonense* hatched three weeks after treatment at 14˚C, but they hatched five days after treatment at 24˚C.

D17. TESTING BIODIVERSITY IMPLICATIONS OF OLD-FOREST STAND REMNANTS SURROUNDED BY CLEARCUTS

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We are studying the distribution of terrestrial invertebrates in old-forest (late successional and old-growth) remnants and adjacent clearcuts in the Washington Cascades to test hypotheses of the role of such remnants in a managed forest landscape. We are analyzing percent occurrence, relative frequency, and relative biomass of terrestrial arthropods from soil/litter sampling, pitfall traps, and beat-and-sweep sampling of low vegetation. Data are analyzed to classify each species into one of six categories: old-forest obligate, old-forest source (found mainly in old-forest remnants but disperses into clearcuts), clearcut obligate, clearcut source, edge obligate, or forest-clearcut facultative user. Results determine how old-forest remnants and clearcuts serve as key habitat refugia and as sources of inocula of dispersers. Analysis of species by functional group can help pose hypotheses on the organisms' roles in soil and plant productivity. Implications are to be used to validate the Northwest Forest Plan management guidelines on leaving 15% old-forest cover during timber operations, and on the future management of resulting old-forest remnants.

D18. APHIDS OF GUAM, SAIPAN, AND TINIAN AND ASSOCIATED PARASITOIDS

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All species of aphids currently recognized from the islands of Guam, Saipan, and Tinian (all part of the Mariana Islands) are introduced. In total, 21 species of aphids have been identified based on authors' collections (600+) and previous published records. Some of the aphid species (*Aphis craccivora* Koch, *Aphis gossypii* Scopoli, *Pentalonia nigronervosa* Coquerel, and *Toxoptera* spp.) are problematic on island crops (e.g., beans, melons, taro, bananas, citrus). A few natural enemies are operating against these aphids, but often not at adequate levels. Aphidiid parasitoids are being introduced as biological controls to strengthen the existing pool of beneficials. Aphidiids presently occurring on Guam (undetected as yet on Saipan or Tinian) are *Aphidius matricariae* Haliday [rare], *Lipolexis scutellaris* Mackauer, and *Lysiphlebus testaceipes* (Cresson); new introductions include *Aphidius colemani* Viereck and *Diaeretiella rapae* (M'Intosh). The new species were cleared for use by USDA-APHIS and the PPQ office of the Territory of Guam. Parasitoids introduced on Saipan and Tinian were cleared by the CNMI Dept. of Land and Nat. Resources, Div. of Agric. Mass production was done at Wash. State Univ. in insectaries at Pullman (NW Biocontrol Insectary and Quarantine [T. Miller, Manager]) and Prosser. After transshipment, species purity was reexamined at the federally certified W. Pacific Biological Control Quarantine Lab. (WPBQL), Univ. of Guam, Mangilao.

D19. DRIP APPLICATION OF 1,3-DICHLOROPROPENE FOR GRAPE PHYLLOXERA MANAGEMENT

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1,3-Dichloropropene EC at 100 and 200 ppm, applied at approximately monthly intervals, provided statistically significant reductions in populations of grape phylloxera (*Daktulosphaira vitifoliae*; Homoptera: Phylloxeridae) at four vineyards in California. At locations with a significant nematode infestation, 1,3-D treatments also significantly reduced populations of several plant parasitic nematode species. No foliar or root phytotoxicity was observed in any of these applications. Post-harvest root vigor evaluations revealed that the 1,3-D treatments resulted in significantly more root development during the post-harvest root flush, relative to untreated areas and areas treated with currently registered products. Two of the three products currently registered for grape phylloxera management in California may be affected by the Food Quality Protection Act. Because of the long time frame involved in developing and disseminating tolerant rootstocks, and because there is limited information on the genetic variability of phylloxera, population

management using chemicals will continue to be a primary management tactic.

D20. CONTROL OF WILD MEDITERRANEAN FRUIT FLIES USING BAIT SPRAYS OF SPINOSAD AND THE PHOTOTOXIC DYE PHLOXINE B

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Fruit fly control programs are trying to keep the Mediterranean fruit fly from becoming established in the United States. Because of concern for human health, and the potential of Malathion being limited under the Food Quality Protection Act by the USA Environmental Protection Agency (EPA), action agencies are looking for alternatives to Malathion. We compare two Malathion replacements, spinosad and phloxine B, for use in controlling wild populations of Mediterranean fruit fly in coffee on the Hawaiian island of Kauai using eight weeks of protein bait sprays composed of Mazoferm, a sugar source, and adjuvants. We found Malathion to be the most effective treatment, but the two replacements gave impressive levels of control. Because the alternatives are environmentally safer, they should be considered in controlling incipient populations of the Mediterranean fruit fly.

D21. AVOCADO THRIPS FIELD BIOLOGY, FRUIT DAMAGE, AND TENTATIVE ECONOMIC THRESHOLD

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Since its introduction three years ago, *Scirtothrips perseae* has become the number one pest in southern California avocado production. It is primarily dependent upon young foliage for feeding and reproduction. An unknown proportion of pupation occurs in the typical 10 to 15cm deep leaf litter, with over 90% occurring in the upper 5cm. All stages over-winter, generally concentrated on an occasional sprig of new growth. There are typically two surges in population growth corresponding with flushes of foliage in March and again in June. The June foliar populations of thrips are best correlated with levels of damage on young fruit and may be used to predict the potential for crop loss due to rind scarring. Peak thrips populations of 5 or more thrips per leaf were associated with subsequent economical levels of fruit damage. Thrips feeding and reproduction directly on the young fruit occurs for only a few weeks until the fruit reaches a length of between 4 and 5cmin early August, after which populations crash. Thrips population dynamics are related to leaf and fruit length as a function of tissue age. The typical thrips population crash in early August is unlikely a direct function of rapid changes in temperature and humidity that occur at this time of year. Thrips population dynamics are more likely a function of feeding substrate availability that in turn is directly associated with the rapid meteorological changes that occur in August.

D22. A PHEROMONE SYSTEM FOR MONITORING ACTIVITY OF PEA LEAF WEEVIL AND ALFALFA WEEVIL

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A 2-year field study was conducted to determine the effectiveness of an aggregation pheromone for monitoring activity of the pea leaf weevil, *Sitona lineatus* (L.), in the Pacific Northwest. Relationships between pheromone trap catches, damage to pea seedlings, and time of plant emergence were examined. Traps with and without pheromone lures were set along the edges of fields before planting of peas and were monitored at 5-7 day intervals in the spring of each year. Seedling damage was estimated by counting the number of feeding notches on seedlings at the 3-node stage of development. Highest mean trap catches occurred around 25 April in both years. The aggregation pheromone also attracted alfalfa weevil, *Hypera postica* (Gyllenhal), but in much lower numbers than pea leaf weevil. Number of pea leaf weevil collected in traps was not related directly to seedling damage at a local or regional level. Seedling damage was related to the time of plant emergence; plants emerging before 15 May, closer to the time of high flight activity, sustained much more damage than plants emerging later.

D23. THE NEED FOR UNDERSTANDING MECHANISMS OF RESISTANCE: THE EXAMPLE OF CELERY

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Classical plant breeding has a long history of successful control of insects and diseases. Yet many scientists have some serious concerns regarding the application of this technique. How often do we breed for insect or disease resistance without knowing the mechanism? How often do we report the chemical responsible, but have no idea of the potential toxicity to humans? In the case of celery, such an approach is not only dangerous, but unethical and irresponsible. Celery and related species are capable of producing excessive quantities of the carcinogenic and mutagenic linear furanocoumarins. In a series of bioassays with the leafmier *Liriomyza trifolii*, celery and backcrosses with wild species, several accessions/lines appeared to have good-excellent leafminer resistance. Line 91A-25, which offered excellent leafminer resistance was found to have nearly 450 µg/g fresh weight of linear furanocoumarins. This is some 25 times the levels known to cause an acute dermatitis in humans. The implications for use in a breeding program for *A. graveolens* are discussed.

D24. ARTHROPODS DEPICTED ON MILITARY INSIGNIA

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Although uncommon, arthropods are depicted as symbols on a wide variety of military insignia. As one might expect, most commonly found taxa are those that conjure danger, attack, or general fear. These would include scorpions, spiders (almost exclusively widow spiders), and various Hymenoptera such as “wasps,” “hornets,” yellowjackets, and “bees.” Occasionally, arthropods more representative of the military unit’s geographic area of origin are used. Examples of this latter category would include scorpions and grasshoppers. The great majority of arthropods are found on Air Force insignia. This primarily is a function of the tremendous number of insignia that have been used by the Air Force over the last half-century. Insignia, primarily “unit” patches are shown and descriptive notes, when available, are presented.

56. "A BUG A WEEK"—A MODULE FOR DISCOVERING INSECTS

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Curricula in the elementary and middle school levels can be enhanced by using living insects in classroom activities. A six-week workshop for teachers is offered in Spokane to assist them with the use of insects in the classroom. Each week of the workshop living insects are distributed with instruction for rearing and maintenance plus suggestions for classroom activities. Observation chambers and rearing containers are constructed during the workshop for the teachers and students to house their insects for various activities. When classroom activities are completed, teachers are encouraged to release the insects if they are native to the area or to return the insects to the workshop to be maintained until classes have a project where the bugs can be used again.

"Bugs" distributed include praying mantis egg cases, *Mantis* and *Stagmomantis* spp.; ladybird beetles, Family Coccinellidae; crickets, *Acheta domestica;* mealworms, *Tenebrio* spp.; blow flies, Family Calliphoridae; painted lady butterflies, *Vanessa cardui;* walking sticks, *Carausius morosus* or *Extatosoma tiaratum;* and Madagascar hissing cockroaches, *Gromphadorina protentosa.* These insects are available through biological supply companies, local sporting goods stores that handle fish bait, gardening stores or pet stores.

The use of live insects is stressed with teachers and activities appropriate for elementary and middle grades have been developed. These include insect identification to major groups (Orders); identification of various arthropod groups (Classes); insects in ecosystems as predators and beneficials; insect movement; insect life cycles and insect growth. These activities are correlated to other parts of the curriculum. In language arts, classroom activities include journaling of observations of insect behavior and life cycles, creative writing, dramatics, and research activities to study how insects are related to man. In math, computations and graphing are used to view population growth, speed of insects, size of insects, growth of insects, and distances of insect movement. Insects are also used in projects involving art and music. Special activities involve the use of insect nutrition both as to what insects eat and to serving insects and insect products as food.

57. OUTREACH PROGRAMS TEACHING ABOUT TROPICAL RAIN FORESTS AND PROTECTION OF BIODIVERSITY USING LIVE INSECTS

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An arthropod zoo, consisting of a small, low-maintenance rearing facility with indigenous and tropical species, was recently developed on the Washburn University campus. Once its existence became known, I received frequent requests from schools and various other groups in the community to give presentations involving the animals. My initial outreach objectives included teaching about insect biology, encouraging recruitment into the sciences and involving my own students in these teaching/service opportunities. As the number of requests for presentations increased, however, I began focusing on another objective which now ranks as my top priority: to increase understanding of the tropical rain forest ecosystem, and the vast biodiversity it sustains, in order to encourage preservation of those organisms. The presentations include characteristics of tropical rain forests, strata of vegetation, competition for light and nutrients, the enormous number of species involved, loss of the forests and associated human impact, and results of that loss. A variety of presentation techniques is used, including showing of slides of the forests and other visual presentations, plus interactive questions. Then the various live arthropods are presented, handled, and used for more dialogue. Presentations are modified for different age levels, and post-presentation assessment is done. The live insects stimulate interest greatly and focus attention on the principal objective of educating about the value of organismal diversity.

58. THE YOUNG AND THE RESTLESS: MAGGOTS WITHOUT A CAUSE!

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The Master Gardener Program, in association with the Oregon State University Extension Service, helps Oregon citizens learn more about the art and science of growing and caring for plants within the home and outdoors. Currently there are 26 Oregon counties that have active Master Gardener programs. Volunteers receive extensive training of topics that include methods of growing and maintaining healthy gardens, lawns, fruit trees, landscape and house plants; diagnosis of plant problems; and pest identification and management strategies for dealing with ‘beasts’ that master gardeners encounter.

The first rule of combat is to know the enemy and beneficials and, armed with good information about life cycles and biology, master gardeners set out to study the habits and haunts of the insects that cross their paths. However, there’s the size thing—most often the critter is too small to examine closely and a good number of insects move so quickly that even if they are readily visible without magnification it is difficult to get more than a general impression. The hands-on insect training utilizes large-scale models of immature specimens and adults, complimented with live specimens including pest damage, to offer a close-up view of the most commonly asked pest questions brought to Master Gardeners’ desks.

59. HOW INSECTS STIMULATE SCHOOL AGE CHILDREN IN WRITING

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The writing of the French entomologist Henri Fabre was the inspiration for Children of Summer (Farrar, 1997). Charles Darwin called Fabre "the incomparable observer." His observations on insect behavior generated ten volumes of Souvenirs Entomologiques. With Fabre as a role model, I conduct writing workshops for elementary and middle-school students where the children have the chance to observe and experience live insects. After handling live hissing cockroaches, caddisflies, etc. and being given a few tips on how to grab and hold the reader's attention, even students who are not usually keen on creative writing produce some interesting fiction, nonfiction and poetry.

60. THE PAVILION OF WINGS—A TURN-KEY BUTTERFLY EXHIBIT

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The Natural History Museum has created a temporary exhibit featuring live butterflies. The 36’ x 90’ greenhouse features a butterfly garden, pond and retail space. Several simple educational themes are presented through panels and brochures, including classification, metamorphosis, defense, morphology, conservation and monarch migration. Up to 40 domestic species of butterflies and saturniid moths are featured. The design and temporary nature of the exhibit may be an alternative to institutions that lack the capital to finance a permanent exhibit featuring exotic species.

61. INSECTS AS HUMAN FOOD

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62. INVOLVING VOLUNTEERS IN ENTOMOLOGICAL RESEARCH AND EDUCATION

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Positions and money for entomological work are shrinking while the demand for entomological skills and knowledge is increasing. Integrated pest management, ecological pest management and biocontrol are knowledge intensive, requiring new research and dissemination of new ideas. There is a considerable pool of college-trained entomologists, and serious amateurs, who are employed in other

professions. Greater involvement with non-professional entomologists can provide additional help for researchers and educators and meaningful learning or work experience for the volunteer. Even those without an entomology background may have other skills to contribute (such as data entry or record keeping). Volunteers have been successfully teaching the public about insects and assisting in various entomological research activities for many years. With minimal but consistent training, volunteers have monitored wasp populations and identified wasps and assisted in identifying and collecting root weevils. Volunteers have assisted in educational events such as Bug Days for Kids or displays at public events, taught classes for the public and have written extension publications, newspaper columns and fact sheets. The professional and non-professional partnerships can be an effective way to advance research, foster interest in insects and disseminate research based information.

IPM in Small Fruit Crops Symposium

63. LYGUS BUG CONTROL ON CALIFORNIA STRAWBERRIES

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Over $650 million of fresh market strawberries are harvested on 24,000 acres annually in California. Late-spring, summer, and fall production is concentrated on the central California coast in the Santa Maria, Salinas, and Pajaro Valleys. The Lygus bug is a significant insect pest of strawberries from June through October. Lygus feeding causes a deformation of strawberries called "cat-facing". The damage threshold for Lygus on strawberries is extremely low at fewer then 1 insect per 10 plants. When Lygus populations are not suppressed their feeding can cat-face 40% to 60% of the strawberries in a plantation.

Lygus control is achieved and economic returns are increased with well-timed insecticide applications based on careful monitoring. A phenology model developed by the UCIPM program is available via the World Wide Web (www.ipm.ucdavis.edu) that can effectively predict hatch periods when insecticide application will prove most effective. Historically organophosphate and carbamate insecticides have been applied to suppress Lygus populations. Registration of many insecticides that had been available for insect control on strawberries have been cancelled. Mechanical control with insect vacuum devices were attempted in the late 1980's and early '90's. These "early" insect vacuums proved marginally effective and are no longer used. Some growers currently use powerful hydraulic fan vacuums. Fruit injury and spread of pathogens are concerns associated with the use of these devices. Augmentative bio-control has proven commercially risky.

The registrations of the synthetic pyrethroid insecticides fenpropathrin in 1996 and bifenthrin in 1997 increased strawberry producers' Lygus control options. Imidacloprid is now available to strawberry producers for whitefly control via a Section 18 registration. Treatment with imidicloprid for whiteflies will likely suppress Lygus populations.

Given the likelihood that few effective insecticides will become registered for application on strawberries, we have focused our recent efforts on maintaining the effectiveness of currently registered insecticides. In insecticide dose-response bioassay surveys conducted during midsummer 1996, 1997, and 1998 we evaluated California Lygus populations in or near strawberries for susceptibility to insecticides registered for use on strawberries. We then compared our results from California with insecticide dose-response bioassay surveys conducted on insecticide susceptible Lygus populations from Utah. Tolerance to the organophosphate malathion and the pyrethroid fenpropathrin was elevated in all surveyed California populations; and tolerance to the organophosphate naled, the carbamate methomyl, and the pyrethroid bifenthrin was elevated in populations surveyed in Salinas and Santa Maria. Observing tolerance to the pyrethroids fenpropathrin and bifenthrin so rapidly is alarming since they have only been registered for use on strawberries for such a short time.

Lygus overwinter in and complete a springtime generation on a diverse group of native plants, introduced weeds, and cultivated crops. A mixing of the regional gene pool occurs annually during this period of time. Lygus infesting strawberries in any given season may be descended in part from Lygus that had infested other field and forage crops and have a genealogy that includes a history of exposure to a variety of insecticides. The use of the pyrethroid esfenvalerate has increased substantially over the past 5 years in lettuce and other vegetable crops that are grown adjacent to strawberries on the central coast. We speculate that this may be a factor in our observation of rapidly developing tolerance to fenpropathrin and bifenthrin in Lygus populations in or near central coast strawberries, although the mechanism(s) of this tolerance in each of these pyrethroids remains unknown.

Through industry newsletters and extension meetings we have conveyed to strawberry producers that they must use insecticides judiciously to prolong their effectiveness. However, the insecticide use patterns of producers of other horticultural crops adjacent to strawberries will profoundly affect the effectiveness of insecticides registered on strawberries.

64. PROGRESS TOWARDS MANAGING WEEVILS IN SMALL FRUITS

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Many species of weevils are pests in most small fruits grown commercially or by hobbyists in the PNW. Economic damage results from feeding by the larvae on roots and canes immediately above the crowns. Reduced plant vigor, fruit yield and stand life is most serious in strawberries. Adult weevils contaminate mechanically harvested caneberries, which may result in dockage or rejection of fruit delivered to processors. Adults can girdle new cane growth of blueberries. This can kill young transplants or make training of canes difficult. Injury in vineyards has been attributed to feeding in the spring by adult black vine weevil on newly grafted plant material.

Otiorhynchus species such as the Black vine weevil, strawberry root weevil, "rough strawberry root weevil" and *Sciopithes obscutus* Horn, the obscure root weevil are the most commonly encountered weevils. Numerous strategies for managing these various species have been researched at OSU and WSU through the years. Extension has helped industry to implement some of the more effective ones. Cultural, biological and chemical controls—successes as well as shortcomings—are reported.

65. ASSESSING THE IMPACT OF CARABID GROUND BEETLES ON PESTS IN RED RASPBERRY: HOW MANY ACTIVE BEETLES ARE THERE PER ACRE?

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Pitfall traps are probably the most simple and cost-effective method of sampling carabid ground beetles in field crops. They provide a relative index of carabid abundance. However, quantitative predation studies require absolute estimates of density of both prey and predator, i.e. numbers per unit area. We used laboratory studies to develop a model of movement for *Pterostichus melanarius* (Illiger), the predominant species in commercial raspberry fields in the Lower Fraser Valley, BC. The model was calibrated and validated using mark-release-recapture studies in a commercial raspberry field. It was then used to determine a relationship between pitfall trap counts and density. The next challenge is to determine exactly what prey the beetles are consuming.

66. POTENTIAL OF SOME FALL PLANTED COVER CROPS FOR WEED SUPPRESSION AND BENEFICIAL INSECT HABITAT

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The objective of this study was to identify plants with pollen and nectar attractive to a variety of beneficial insects, which could establish well after fall seeding (the time when cover crops are usually planted between raspberry rows) and provide a succession of flowering times. The following plants were seeded into replicated plots at the North Willamette Research and Extension Center on September 23, 1997: achillea (yarrow), hesperis (dame's rocket), chierianthus (wallflower), phacelia, caraway, 'Amity' winter oat, and a mixture of all six. All plants, with the exception of caraway, survived the winter and flowered the next spring. With the exception of the achillea and oats, all plots became quite weedy. Wallflower was the first to flower (early April-May) followed by hesperis (mid April-May), phacelia and oat (May-June) and achillea (June-Sept.). Among beneficial insects vacuumed from blossoms were several braconid, ichneumonid, and chalcid wasps, in addition to lacewings, ladybird beetles, spiders and bees. The ultimate goal of this work is to create a mix which can be seeded in fall and serve as an in-field insectary between raspberry rows or at field perimeters for enhanced control of two-spotted spider mites and the orange tortrix.

67. COOL CLIMATE GRAPE INTEGRATED PEST MANAGEMENT

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The region included as representing a cool climate for grape production consists of Washington, Oregon, Idaho, western Montana, and southern British Columbia. With minor variation, the grape pest complex throughout this region is the same. Major pests include the grape mealybug, *Pseudococcus maritimus* (Ehrhorn), the black vine weevil, *Otiorhynchus sulcatus* (F.), two species of leafhoppers, *Erythroneura elegantula* and *E. ziczac*, and two climbing cutworms, *Amathes c-nigrum* and *Euxoa ochrogaster*. The grape phylloxera, *Daktulosphaira vitifoliae* (Fitch) reported from locations throughout the region appears to be most important in western Oregon. Other pests occasionally important include several thrips species, notably the western flower thrips, *Franklinella occidentalis* (Pergrande) and a tetranychid mite, *Tetranychus pacificus* McGregor. Other sporadic pests are the grape twig borer, *Psoa quadrisignata* Horn, the leadcable borer, *Scobicia declivis* (Le Conte), the consperse stinkbug, *Euchistus conspersus* Uhler, the cottony maple scale, *Pulvinaria vitis* L., and several species of click beetle (Elateridae) are early season bud feeders. Natural enemies include the leafhopper egg parasitoid, *Anagrus epos* Girault; the western predatory mite, *Galendromus occidentalis*; several green lacewings (Chrysopidae); and a brown lacewing, Hemerobius sp. Coccinellids are early season predators of grape mealybug, and a Tachinid fly is an occasional cutworm parasitoid. Serious grape pests found in other areas of the U.S. (grape berry moth - northeastern U.S. and several lepidopterous defoliators - California) do not occur in this region. Sampling methods vary widely according to the specific pest involved, and these will be discussed for several important pests. Economic thresholds and injury levels are poorly defined, but the current status will be presented and discussed. Grapes grown in the cool climate of the Pacific Northwest have relatively few serious arthropod pests when compared with other grape growing regions.

68. TOXICITY OF SELECTED PESTICIDES TO *NEOSIEULUS FALLACIS* IN THE LABORATORY AND IN FIELD OBSERVATIONS

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The following pesticides were evaluated in the laboratory for their toxicity to the predator mite, *Neosieulus fallacis*, at rates commonly applied in strawberries: insecticides/miticides – Vendex, Guthion, Thiodan, Alert, Lorsban, Metasystox-R, Diazinon, Brigade, and Kelthane; fungicides – Benlate, Captan, Rovral, Thiram, Ridomil, and Aliette; herbicides – Devrinol, Simazine, Goal, Poast, and Sinbar. Of these, the following materials were highly toxic (90% or greater mortality): Alert, Metasystox-R, Lorsban, Diazinon, Thiodan applied at the rate recommended for cyclamen mite control, and Brigade. Ridomil, the most toxic of the fungicides, resulted in 74% mortality. Although Benlate killed only 6% of the adults after 48 hours, there was no egg production among survivors. This supports earlier speculation that Benlate sterilizes adult female *N. fallacis*. A similar response was seen after application of the herbicide Goal. In late summer, 1997 populations of *N. fallacis* were released into five strawberry fields (one organic) in which *N. fallacis* and two-spotted spider mite (tssm) populations were monitored through harvest, 1998. Cool, wet weather resulted in low tssm populations in all fields monitored. However, prey/predator ratios were consistently narrower throughout the spring in the organic field than in the four conventionally grown fields in which growers applied Lorsban or Metasystox-R for aphid control in early spring. The organic field also had greater numbers and a greater variety of beneficial insects than the other fields.

69. CONTRASTING IPM SYSTEMS IN CALIFORNIAWINE GRAPES AND STRAWBERRIES

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California producers of wine grapes and strawberries utilize many tactics that fall along a continuum of IPM practices. Professional scouting is utilized on a majority

of hectarage of both crops. Risk assessment models and thresholds have been developed for many key pests and diseases. Reduced risk pesticides and more efficient application approaches are available and becoming more widely utilized. Preventative approaches such as sanitation and host removal are also widely practiced.

Significant differences exist between these crops, however, that have resulted in the evolution of far different management strategies and implementation of reduced risk practices. Wine grape, for example, is a perennial crop. The value of the crop varies by production region, and can be of relatively low to high value. Cosmetic standards are low, although grape quality characteristics can be important. Export considerations in terms of pest presence is not an issue. Strawberries, on the other hand, are typically grown as an annual planting. The value of the fresh crop is very high. Cosmetic standards are very high, as are export considerations. In general, tolerance for pest damage in strawberries is much lower than in wine grapes.

Wine grapes and strawberries are among the highest of all California crops in terms of pesticides used per acre. Sulfur, for control of powdery mildew, represents the majority of kilograms applied to wine grapes. Methyl bromide and chloropicrin, primarily for control of soil borne diseases, represent the majority of kilograms applied to strawberries. The application of sulfur to wine grapes and methyl bromide/chloropicrin to strawberries affects the arthropod complex present.

Specific IPM practices are described for key insect pests including the grape phylloxera (*Daktulosphaiara vitifoliae*), leafhoppers, spider mites, and sharpshooters in the wine grape system, and lygus bug (*Lygus hesperus*), spider mites, Lepidoptera and vinegar flies (*Drosophila* spp) in the strawberry system. Because of the extensive use of annual plantings and soil fumigation, most of the damaging insects under current California production are those which feed directly on the fruit and those which feed on the plant, reducing fruit quality and yield.

Extensive support for wine grape IPM programs exist in California, and many of these are described including the development of community-based programs that have been developed by grape growers in many regions of California.

70. INSIGHTS TO MECHANISMS OF MATING DISRUPTION USING FIELD WIND TUNNELS

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How the application of formulated pheromone interferes with mating in moths has remained elusive. We have used the pink bollworm moth (PBW), *Pectinophora gossypiella*, as a model to establish the contribution of several mechanisms. Walk-in, field wind tunnels 6.2 m long were placed over two rows of cotton in 0.4 ha cotton fields. Formulated pheromone was applied using high-dose (78 mg A.I.) sealed polyethylene dispensers (PBW ropes, Shin-Etsu). Treatments consisted of a control, a tunnel in a field free of disruptant formulation; a 3-rope treatment, in which the field was free of pheromone but one of the cotton rows in the wind tunnel was treated with 3 PBW ropes; and a rope-grid treatment, in which the field was treated with PBW ropes at the standard density of 1000 ha-1 and one of the cotton rows inside the wind tunnel was treated with 3 PBW ropes. We released marked males into the tunnels near sunset or held them in field cages for 24 h prior to assay. Two pheromone traps at the tunnel's upwind end monitored the ability of males to locate point sources of pheromone. In the 3-rope tunnel, traps placed upwind of the cotton row treated with disruptant pheromone captured far fewer males than those placed upwind of the untreated cotton row. In the tunnel situated in the center of the rope-gridded field, very few males were caught in traps in both rows, indicating a camouflage of the pheromone plumes from the traps by the background of airborne disruptant drawn into the tunnel from the field. Activity of moths near the synthetic pheromone sources was video-recorded. Males oriented to, landed on or near, and walked on or near, PBW ropes, indicating competition between pheromone sources as a mechanism of mating disruption. Most males visiting PBW ropes became quiescent or disappeared from the field of view after a few minutes, suggesting a habituation of response. The rhythm of attraction of males held in the field for 24 h before release was comprised of a small peak of activity near 2000 h, with the majority of attraction between 2300 and 0300 h. Much of the attraction before 0100 appears to be an advancement of the male's normal diel rhythm, caused by the presence of disruptant. Together these findings indicate that mating disruption of pink bollworm using the PBW ropes is achieved by a combination of mechanisms: a camouflage of natural plumes, competition between pheromone sources, habituation, and some advancement of the male's rhythm of response. The field wind tunnel technique has the advantage of a natural exposure to formulation and allowing us to document the behavior of individuals of known history.

71. DISRUPTING PHEROMONE COMMUNICATION AMONG LEAFROLLERS: FLIGHTS FROM WIND TUNNEL TO FIELD AND BACK

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Implementation of pheromone-based management of lepidopteran tree-fruit pests, like codling moth, *Cydia pomonella* L., has been highly successful and relatively easy, making this technology almost common place in pome fruit orchards of the Pacific Northwest. This shift away from organophosphates is creating new obstacles for fruit growers, as once minor pests, like the leafrollers, *Pandemis limitata* (Robinson) and *Choristoneura rosaceana* Harris, are now causing serious crop losses. Attempts at pheromone-based management of this complex of species has presented a serious challenge to pheromone researchers and has raised some questions about our understanding of the exact mechanisms of communication disruption. Hypotheses about mechanisms of pheromone-mediated mating disruption have largely emerged from our understanding about orientation to pheromones in wind tunnels. Our research on leafrollers has focussed on testing these disruption hypotheses directly and has taken us from the wind tunnel to field and back again. We now have a clearer understanding why disruption of codling moth has been so successful and leafrollers will be more challenging.

72. DEVELOPMENT AND USES OF FEEDING ATTRACTANTS FOR TREE FRUIT INSECTS

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Many insects, including several pests of tree fruit crops, appear to use odorants to locate food sources and can be trapped with various fermented sweet baits. Studies of the odor chemistry of fermented molasses and jaggery solutions have revealed combinations of chemicals that are attractive to social wasps, noctuid moths, tortricid moths, and muscoid flies. Generally, these chemicals are attractive to both sexes of these insects. Lures for female insect pests may provide more valuable means of monitoring oviposition and population thresholds, compared to many sex pheromones that are attractive strictly to males. Attractants for females may also have potential as control tools, if incorporated into strategies to eliminate attractive females from the population.

73. REPRODUCTIVE BEHAVIOR OF TRUE BUGS AFFECTS RESPONSES TO PHEROMONE TRAPS

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True bugs can be significant pests in all types of crops, ranging from forage and fiber crops, through row crops, to tree fruits and nuts. Bug infestations may be particularly problematic because a number of species are both polyphagous and highly mobile, and may migrate rapidly into crops from surrounding native vegetation, or between crops. Bug problems in several crops (e.g., cotton, pome fruits) have been unintentionally exacerbated recently by the implementation of highly selective insect control strategies which control one or more primary pests in a particular crop, but provide no control of secondary pests such as bugs. Furthermore, unlike the situation for many of the major pests in other insect orders, only a few sex attractant or aggregation pheromones for bugs have been identified and developed for use as trap baits. Thus, bug sampling methods are still relatively primitive and laborious, consisting primarily of visual inspections in combination with beating tray or sweep net sampling.

Over the past several years, we have been working to identify the attractant pheromones used by several key pest species, including mirid bugs, stink bugs, and leaf-footed bugs, all of which differ in their use of pheromones and reproductive behaviors. For example, for bugs in the family Miridae, females are the attractive sex, and there does not appear to be an extended courtship; males appear to mate rapidly and opportunistically with females, and copulation duration is short. In contrast, in several species of phytophagous Pentatomidae, males are the attractive sex, there is extensive courtship of responding females by males, and bugs not infrequently remain in copulation for more than 24 h. Both sexes of Pentatomids also mate multiple times. These distinct differences in patterns of reproductive behavior and pheromone usage may be critically important to the development and implementation of pheromone-based sampling systems for various bug species. The design of traps or other sampling methods must include consideration of factors such as whether responding insects fly or walk into traps, the mean distance of closest approach to a pheromone source, and the physical and visual aspects of the trap. Problems that we have encountered in the implementation of pheromone-baited traps for bugs and possible solutions to these problems will be discussed.

Special Presentation

74. IMPROVING SPRAYER TECHNOLOGY: TIMING, TARGETING AND TOWERS

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Our North American tree fruit production system is currently dependent on air-carrier orchard sprayers to apply plant protectants to combat pests. The objective of our MSU research team is to improve orchard spraying technology. That means concurrently to reduce drift, maintain fruit quality and tree vigor, reduce quantity of needed pesticides, increase deposition efficiency and uniformity on the target, and maintain economic viability for the grower. Air-carrier sprays use water and air to carry agricultural chemicals to the target canopy. In an effort to reduce operating cost and loading time many growers have reduced the volume of water in the spray solution. This trend towards "low volume" spraying has tempted growers to

purchase sprayers with too small an air delivery system. The result is inadequate spray coverage, increased pesticide use, loss of fruit quality, and/or higher operating cost. The three primary factors to improve application technology are: Timing, Targeting and Towers.

Timing consists of two components. First, full implementation of Integrated Pest Management (IPM) strategies assures that pesticides are applied only "as needed." It is no longer efficient to apply protectant sprays following the traditional "spray calendar." Second is availability of high capacity sprayers to cover the critical production area within a narrow window of concurrent "as needed" and "acceptable weather" conditions (typically 24 to 48 hours). Less pesticides are required to provide control if they are effectively applied at the optimum time.

Targeting consists of three operations. First, manually close all the nozzles that direct spray either above or below the target canopy. Second, adjust the application rate of each nozzle to match the density of the canopy it targets. Third, install an automated canopy sensing system, "electric eyes," that turns a nozzle or group of nozzles "on" when it senses a target canopy.

Tower sprayers have a radically different air distribution system that produces three significant benefits. First, a conventional air-carrier orchard sprayer directs the air radially out from one central source. Many small droplets are carried through the canopy and released as "drift" in the atmosphere above the trees. An ideal tower sprayer is taller than the target canopy and produces a continuous curtain of "straight stream," uniformly spray laden air. The top of the tower focuses the air slightly downward toward the center of the canopy as well as providing a boundary of clean air above the canopy. This boundary of clean air traps the spray laden air into the target canopy, thus minimizing drift. Second, a tower sprayer moves the spray laden air horizontally, parallel to the ground. The horizontal air movement provides each spray droplet the maximum opportunity to deposit on a target surface before it evaporates or lands on the soil.

Third, a tower sprayer typically provides smaller size spray droplets. Because of the greatly expanded length of the air outlet on a tower sprayer, the manufacturer needs to install many more, smaller nozzles to atomize the spray. Smaller nozzles produce smaller drops which result in improved deposition uniformity. Pest problems start in the areas where it is the most difficult to deposit spray droplets (i.e., back sides of leaves and fruit). Careful observation of the target canopy will reveal that big drops tend to deposit on the front side of the first layer of leaves and only small drops land in the hard-to-reach areas. Spraying smaller drops decreases deposition on the outside edge of the tree where there is excess and increases deposition in the hard-to-reach areas of the fruit canopy. Some tower sprayers use mechanical rotary atomizers with individual peristaltic metering pumps to minimize nozzle plugging, maximize the number and uniformity of small spray drops, and provide a wide range of continuously variable application rates.

Compact canopies like grapes, blueberries and dwarf apples enable a grower to use a "tunnel" or "covered" sprayer. Conceptually, this is the same as putting two tower sprayers into a portable, three-sided enclosure. The tunnel sprayers tend to be expensive, bulky and awkward to maneuver in the field. Some units show promise by providing good spray coverage and reducing spray drift. They are particularly effective in minimizing the effect of ambient wind. Catching and recycling the excess spray that drips from the canopy has presented significant problems. Spraying at ultra-low volume and recycling the spray within an air vortex inside the tunnel look promising.

In conclusion, many growers are spending far too much money on pesticides because they are not investing enough money in a quality sprayer. Improved chemical application equipment when properly integrated with an IPM program produces high quality fruit, reduces pesticide use, reduces spray drift, lowers maximum fruit residues and returns cash dividends.