Exploring Alternatives to Organophosphate Insecticides with Apple and Pear: The Areawide-II Project in Washington State

Ted Alway

Washington State University Tree Fruit Research and Extension Center, Wenatchee, WA

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The Areawide II (AWII) program is investigating the use of new pest control and pest monitoring methods in Washington apple and pear orchards. With funding provided by the Washington Tree Fruit Research Commission and two federal government grants, 15 apple and six pear sites were established in the spring of 2001 in major fruit growing districts of Washington. The acreage and cultivar at each site are shown in Table 1. Seven tree fruit pest management consultants, with assistance by Washington State University Tree Fruit Research and Extension Center (WSU-TFREC) and the United States Department of Agriculture Yakima Agricultural Research Laboratory (USDA-YARL) personnel, collected the data on pests and natural enemies at all sites. The consultants recorded the data in the field with a PDA (hand-held computer) and sent data electronically to the WSU-TFREC where it was entered in the database from which weekly reports were generated.

One-half of each orchard was treated conventionally, including organophosphate (OP) insecticides as needed. The other half controlled pests without the use of any OP insecticides.

APPLES

The AWII apple program was comprised of 15 orchards, each 20 to 40 acres in size, and all using codling moth mating disruption. One-half of each orchard was treated conventionally, including organophosphate (OP) insecticides as needed. The other half controlled pests without the use of any OP insecticides (NON-OP). The NON-OP half of the orchard controlled the major lepidopteran pests (codling moth, leafrollers and lacanobia fruitworm) with pesticides such as Esteem (pyriproxifen) and Intrepid (methoxyfenozide). Other pests were controlled with registered NON-OP insecticides such as Provado (imidacloprid) and Carzol (formetanate hydrochloride).

A wide array of tools was used to monitor lepidopteran pests. A high-load pheromone lure (Super Lure Bubble Cap by Pherotech, Inc., designated BB) and a lure containing a non-pheromone, kairomone attractant from Trécé, Inc., called the DA-lure, were used in delta traps to monitor codling moth (CM) adults at one trap per 2-2.5 acres. Both pandemis (PLR) (*Pandemis pyrusana*) and obliquebanded (OBLR) (*Choristoneura rosaceana*) leafrollers were monitored using traps baited with a standard (1 mg) and low load (0.1 mg for PLR, 0.01 mg for OBLR) pheromone lures. A food-based attractant containing acetic acid (AA) for leafrollers was used in each orchard and a pheromone lure was used to monitor the lacanobia fruitworm (LAC) (*Lacanobia subjuncta*).

Field monitoring for damage was done at key times throughout the season in each orchard. Surveys were made in each block for the amount and location of damage by each of the lepidopteran pests. Secondary pests (campylomma, aphids, leafhoppers, leafminer and mites) were monitored throughout the season. Bins of fruit were checked for damage from lepidopteran pests and other insects during harvest.

PEARS

The objective of the AWII pear program is to determine whether eliminating certain insecticides known to be disruptive of many natural enemies in pear orchards could improve the biological control of several key pear pests, including pear psylla, spider mites and grape mealybug.

Six pear orchards (each from 15 to 20 acres in size) participated in the AWII program (Table 1). Each orchard was divided into two treatments: conventional (CONV), in which organophosphates and any other registered pesticides could be used, and selective (SOFT), in which pesticides disruptive to biological control were avoided, including organophosphates, pyrethroids, chloronicotinyls, abamectin and pyridaben. Treatment protocols were changed in 2002 from 2001, so year-to-year comparisons are limited.

Each orchard was monitored with both pheromone (BB) and DA traps for CM, and leafrollers were monitored with low-load pheromone lures. Every 2 weeks, each treatment block in each pear orchard was monitored separately for pear pests and natural enemies by taking a 20 beat-tray sample. Leaf samples were collected at 2-week intervals from each treatment block from fruiting spurs (mid-May through August) and top shoots (mid-June through August).

These leaf samples were brushed and counted at the WSU-TFREC. The consultants conducted harvest time examinations of fruit in each orchard (2500 fruits/treatment block).

RESULTS

Apples: Trap Data

Codling Moth (CM). Based on data from traps, CM populations in 2001 declined significantly between the first and second generations, and these populations were kept low or reduced further in 2002 (Table 2). The average seasonal codling moth catch in pheromone traps in 2002 declined 70% from 2001 levels (7.2 moths/trap to 2.1 moths/trap). In nine of the 15 orchards there was a decline in their seasonal catch and in the six orchards in which no decline was observed the average catch for the season was low, 1.4 moths/trap or less.

The DA lures attract both sexes of CM. Catch in DA traps was correlated with pheromone trap catch, e.g., blocks with high catch in pheromone lure-baited traps tended to have high catch in DA lure-baited traps.

Leafroller. A wide range of leafroller populations was noted in the AWII blocks. OBLR is the main species captured in the Columbia Basin, Quincy and Okanogan orchards. PLR tends to be the dominant species in north central Washington (NCW) and the

Yakima Valley. There was no significant difference in the average capture of moths between the OP and NON-OP treatments for either leafroller species.

Low load lure-baited pheromone traps for both OBLR and PLR were used at each site. Traps with these lures were used to investigate whether capture of moths in them better reflected in-orchard populations of leafrollers and the risk of fruit damage. Trends in moth numbers captured in the low load lure-baited pheromone traps were similar to those observed in standard load lure-baited pheromone traps, with average catches 25-45% of the standard trap averages.

The AA (acetic acid) lures contain a food-based attractant for leafrollers. There was nearly a 50:50 ratio of males and females captured in the AA baited traps. Total moth captures in AA traps were less than 2% of the standard lure-baited traps. AA lures will probably not be used further in the AWII program.

OBLR catches in standard load pheromone traps were similar in 2002 to those in 2001 but tended to be higher in the low-load traps in 2002 (Table 3). PLR catches were significantly higher in both standard and low-load pheromone traps in 2002; all ten orchards that had at least ten PLR moths/standard trap/season in 2001 had greater catches in 2002, with an average increase of over 100%.

Lacanobia fruitworm. This relatively new pest was monitored with a pheromone lure. There was a wide range of populations in the trap captures in the 15 orchards, though all orchards captured some moths. There was no significant difference in moth capture between the OP and NON-OP treatments in either generation. LAC catches were lower on average in 2002 (12 of the 15 orchards) than 2001 in the AWII orchards.

Field Damage Surveys. damage by lepidopteran pests four times during the growing season: late May (leafroller feeding on shoots), early July (codling moth damage to fruit and lacanobia/cutworm feeding on shoots), early August (leafroller feeding on shoots) and late August/September (codling moth damage to fruit). The surveys showed a range of pest injury among the AWII orchards.

Fruit and shoot damage levels in field surveys showed several changes between 2001 and 2002 (Table 4). Codling moth damage to fruit was significantly lower in the pre-harvest samples in 2002 when compared with 2001 in both the OP and NON-OP treatments. Leafroller shoot damage in 2001 had become significantly less in the NON-OP treatment blocks by the August sample. This difference was again apparent in the May 2002 samples, but by August there was no difference found between treatments. Shoot feeding levels by lacanobia (cutworms) in July were lower in 2002.

Secondary Pests and Natural Enemies. Personnel from the WSU-TFREC visited each orchard several times throughout the season to sample specifically for a number of secondary pests and natural enemies. These samples included:

1. Campylomma: beating trays at bloom and pheromone traps in late summer.
2. Aphids: infested shoot leaves in June and July, as well as aphid predators on shoots.
3. White apple leafhopper: overwintering eggs and parasitism in early April, and nymphs per leaf in late May.
4. Western tentiform leafminer: larvae per leaf in early June and mid-July, and parasitism in June.
5. Mites: tetranychid predator and apple rust mites per leaf in early June, mid-July and mid-August.

There were no significant differences found with any of the above pests in either treatment. Most secondary pest populations were low and did not require control with pesticides.

Harvest Fruit Exams. During harvest, fruit was checked for damage from major lepidopteran pests and other secondary pests. In 2002 codling moth damage was detected in only 9 of the possible 30 treatment blocks. The level of fruit damage was low and exceeded 0.2% in only five blocks. Overall there was no difference in the average percent CM damage between treatments.

Leafroller feeding on fruit was detected in

TABLE 1

The Areawide II sites, acreage and varieties.

Orchard	Region	Main cultivar	Acres
Apple			
A1	West Richland	Gala	18
A2	Vantage	Early Fuji	28
A3	Mattawa	Spur Red	30
A4	Wapato	Granny Smith	40
A5	Moxee	Spur Red	40
A6	West Yakima	Spur Red/Jonagold/others	17
A7	Quincy	Gala	16
A8	Quincy	Red Delicious	25
A9	Quincy	Golden Delicious	28
A10	Chelan	Red Delicious	30
A11	Orondo	Fuji	20
A12	Orondo	Golden Delicious	20
A13	Brewster	Granny Smith	40
A14	Brewster	Fuji	25
A15	Bridgeport	Granny Smith	25
Pear			
P1	Moxee	Bosc/Anjou	15
P2	Moxee	Red Anjou	20
P3	Naches	Bartlett	16
P4	Monitor	Bosc	17
P5	Dryden	Anjou	20
P6	Entiat	Anjou	16

TABLE 2

Average codling moth catches in pheromone (BB) and DA traps for all blocks in 2001 and 2002.

		Average moths/trap/season			
		BB		DA	
Year	Generation	mean	SEM[Z]	mean	SEM[Z]
2001	1st gen	5.6	2.15	2.9	1.15
	2nd gen	1.6	0.45	2.3	0.85
	Total	7.2	2.33	5.2	1.66
2002	1st gen	1.4	0.46	1.4	0.70
	2nd gen	0.7	0.21	1.1	0.34
	Total	2.1	0.61	2.5	1.01

[Z]Standard error.

TABLE 3

Obliquebanded (OBLR) and pandemis (PLR) leafroller catches in standard and low-load pheromone traps for first and second generations, 2001 and 2002.

		OBLR Std. lure		PLR Std. lure		OBLR Low load		PLR Low load	
Year	Generation	Avg.	SEM[Z]	Avg.	SEM[Z]	Avg.	SEM[Z]	Avg.	SEM[Z]
2001	1st gen	56	18.8	40	13.6	5	2.1	8	3.6
	2nd gen	135	29.7	36	13.1	29	13.7	3	0.8
	Total	191	45.9	75	25.1	34	15.5	12	4.0
2002	1st gen	79	22.4	64	14.7	17	3.8	25	6.0
	2nd gen	101	22.4	100	23.2	37	9.0	45	13.5
	Total	180	42.2	162	34.4	54	11.6	69	18.5

[Z]Standard error.

13 of the 30 treatment blocks; only in five blocks did the amount of damaged fruit exceed 0.2%. There was no significant difference between treatments. Fruit feeding by cutworms was seen in eight blocks but only in one did it exceed 0.2%; there was no difference in damage levels between treatments. Damage by other pests was sporadic and rare. Fruit damage levels in 2002 were quite low and similar to the levels found in 2001 (Table 5). Only in one case (leafroller damage in OP blocks) was there a significant decline in damage.

Pesticide Use. All AWII apple blocks used CM mating disruption, generally at rates close to 200 dispensers/acre. For the summary, CM mating disruption is included as a single foliar pesticide application with cost based on the number of dispensers per acre. Applications of carbaryl (Sevin) for chemical thinning are also included as foliar pesticides.

The main organophosphate (OP) insecticides used in the OP treatment blocks were chlorpyrifos (Lorsban) and azinphosmethyl (Guthion). For the control of lepidopteran pests the NON-OP blocks relied upon methoxyfenozide (Intrepid) with lesser use of pyriproxifen (Esteem). The use of the more selective "soft" insecticides was not limited to the NON-OP blocks; some OP blocks also received methoxyfenozide, generally applied soon after bloom for leafroller control. Spinosad (Success) was used mostly in the OP blocks for leafroller control. Chloronicotinyl insecticides were used in both treatment blocks, but to a greater extent in the OP blocks: imidacloprid (Provado), thiamethoxam (Actara), and acetimiprid (Assail).

The number and cost of pesticide applications were not significantly different between the OP and NON-OP treatment programs, although the NON-OP blocks tended to be lower in both areas. The total number of sprays varied with the cultivar (e.g., mildew-susceptible varieties received more fungicide applications) and the pest pressure at the site. For example, from zero to four codling moth sprays were applied depending upon trap counts and history.

In 2002 the total numbers of sprays and the cost per acre for both treatment types were reduced from the levels of 2001 (Table 6). This drop was most pronounced in the NON-OP blocks in which the reduction in sprays and costs was significant. In 2001, the NON-OP treatment blocks applied on average more sprays and at greater cost than the OP blocks; in 2002, this order was reversed.

Pears: Sample Data

Pear Psylla. Psylla is the major pest for most pear growers and was controlled well at all AWII sites. Psylla populations varied considerably and were consistently higher in the North Central Washington (NCW) sites than in the Yakima sites. Two of the NCW orchards had consistently lower psylla populations post-bloom in the SOFT treatment blocks.

Spider Mites. Two-spotted spider mite was the most common mite species found but occurred only at low levels. Counts were above 0.5 mites/leaf in only five of the 98 samples examined and never exceeded 1.0/leaf.

Grape Mealybug. This pest was found in all three NCW pear orchards but in none of the Yakima orchards. There was a trend for lower counts in the SOFT treatment blocks.

Pear Rust Mite. Rust mites were rarely detected in leaf samples but fruit russetting caused by this pest was found in two blocks at harvest.

Codling Moth. There was a wide range in codling moth (CM) populations among the six sites, as shown by catches in pheromone traps. DA lure-baited traps caught few moths in these pear orchards, never exceeding an average of 2.0 moths/trap season. The CM catches in DA traps showed little correlation with the catch in pheromone traps in these orchards.

Leafrollers. Pandemis leafroller was caught in all orchards and was the dominant species in five. Obliquebanded leafroller was caught in all orchards in NCW but was the dominant species only in one. Total pandemis catches on average were nearly four times greater in 2002 than in 2001; OBLR catch totals were double the 2001 amounts.

Natural Enemies. Ten types of predators and parasites were counted in this project: deraeocoris, campylomma, anthocorids, lacewings, lady beetles, stethorus beetles, spiders, *Trechnites* sp. (a key psylla parasitoid), other predators and parasitic hymenoptera in general. The most common and most significant in terms of potential biological control of pear psylla were deraeocoris, campylomma, lacewings, *Trechnites* sp. and spiders. Natural enemy counts were higher on average in the NCW orchards. This may be a result of more suitable nearby habitats (wooded and riparian areas that served as natural enemy reservoirs), more food (psylla) to attract and retain them and, in several blocks, less use of disruptive insecticides. There were few differences in natural enemy counts between treatments in the Yakima orchards, but the NCW orchards had consistently more natural enemies in the soft treatment blocks.

Fruit Damage. All treatment blocks had 2500 pears examined during harvest for pest damage. Russet caused by pear psylla was detected in 10 of 12 treatment blocks but in only one block did marked fruit exceed 0.4%. In the NCW orchards, psylla marking was consistently lower in the SOFT blocks, in line with the lower psylla adult and nymph counts found there. Fruit was considered marked if the cumulative area of psylla-caused russet exceeded the area of a nickel. Grape mealybug counts reflect fruits infested with nymphs, and these infestations were found only in NCW. Codling moth damage was low; the damaged fruit found was mostly on block edges. Leafroller damage was quite low, if it was found at all. Pear rust mite damage was noted on the fruit in two orchards and was particularly prevalent in the SOFT block of one; additional controls will be needed in 2003 to reduce this potentially serious pest. Other pest damage was found at low and variable amounts and appeared unrelated to the treatment program.

Pesticide Use. There was no significant difference in either the number of sprays or cost/acre between the conventional and soft blocks. The soft blocks applied none of the more disruptive insecticides (chloronicotinyls, organophosphates, abamectin, pyridaben),

TABLE 4

Fruit and shoot damage levels in AWII orchards from in-season orchard surveys, 2001 and 2002.

	Average percent shoot or fruit injury from 15 apple blocks				
	Late May % dam. shoots Leafroller	Early July % dam. fruit CM	Early July % dam. shoots LAC	Early Aug. % dam. shoots Leafroller	Late Aug/Sept. % dam. fruit CM
Year	OP/NON-OP	OP/NON-OP	OP/NON-OP	OP/NON-OP	OP/NON-OP
2001	0.20%/0.29%	0.02%/0.03%	1.35%/1.31%	0.40%/0.17%	0.22%/0.24%
2002	0.20%/0.07%	0.03%/0.04%	1.12%/0.72%	0.60%/0.67%	0.11%/0.08%

TABLE 5

Fruit damage by lepidopterous pests from bin samples during harvest in AWII orchards, 2001 and 2002.

	Codling moth		Leafroller		Lacanobia	
	2001 (%)	2002 (%)	2001 (%)	2002 (%)	2001 (%)	2002 (%)
OP	0.11	0.07	0.28	0.09	0.07	0.04
NON-OP	0.05	0.07	0.09	0.08	0.05	0.05

TABLE 6

Average number of foliar pesticide applications and costs for AWII apple orchards, 2001 and 2002.

	CM OP/NON-OP	Leafroller OP/NON-OP	CM+LR OP/NON-OP	Other OP/NON-OP	Total OP/NON-OP	Cost OP/NON-OP
2001	2.3/2.3	1.4/0.9	0.0/0.5	5.7/6.2	9.3/9.9	$219/$250
2002	1.9/1.5	1.6/0.9	0.0/0.1	4.7/4.8	8.2/7.3	$208/$189

while the conventional blocks averaged 2.6 applications/acre of these materials.

The Yakima pear orchards applied significantly fewer sprays and at less cost than the NCW orchards.

SUMMARY

Apples

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

The thorough monitoring of codling moth, leafrollers and lacanobia fruitworm provided growers with the information needed to respond with well-timed control measures where needed. Catches in the codling moth pheromone (BB) and DA lure-baited traps accurately represented CM populations; ongoing research with the DA lure will show how it can best be used to supplement monitoring with pheromones. Leafroller monitoring with standard and low-load pheromone lures showed similar population trends. The AA lure attracted very few leafrollers and will probably not be used in the AWII orchards next year.

There were no surprises relative to secondary pests or their natural enemies in any orchards. It often takes two to three years for either negative or positive effects of altered programs to be expressed. On average, in Year 2 the NON-OP treatment blocks were able to reduce costs and further reduce already low fruit damage levels. This is especially noteworthy in a year when many growers around the state encountered increased damage, especially from codling moth. The continuation of the AWII project at all apple orchard sites is critical in order to determine the full impact, positive or negative, of supplementing codling moth mating disruption with NON-OP controls.

Pears

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

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