Project title: Survey of codling moth organophosphate resistance and associated tolerances to other pesticides

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Objectives:
1. Survey codling moth populations throughout the state for levels of azinphosmethyl resistance.
2. Determine levels of cross-resistance to select insecticides.
3. Develop an adult bioassay for the chloronicotinyl insecticides and survey levels of tolerance around the state.

Significant findings:

1. Levels of azinphosmethyl (Guthion) resistance were low to moderate in codling moth populations throughout the state.
2. Populations high enough to screen against multiple chemistries had only low levels of resistance, preventing meaningful cross-resistance data for pyrethroids or chlorpyrifos (Lorsban).
3. A population with high azinphosmethyl resistance was identified near Manson during second-generation flight.
4. There is potential cross-resistance with acetamiprid (Assail), although the data are too variable to be conclusive.

Methods:

Levels of azinphosmethyl resistance in codling moth populations were sampled using standard bioassay techniques (Riedl et al. 1986). Adult males were collected using pheromone trap liners evenly coated with 1 ml of Tanglefoot®, loaded with a pheromone source (rubber septum permeated with 1 mg or 10 mg codlemone, depending on the presence of pheromone mating confusion), and placed in the upper third of the orchard canopy to maximize trap catch. Only male moths were collected, as the sex pheromone used in the traps only attracts male moths. During first and second codling moth flights, near the peak flight, between 200 and 400 traps were placed in an orchard prior to dusk and collected the following day at dawn. Traps containing moths were transported to the lab and immediately bioassayed using the topical application bioassay method (1 μg insecticide concentration per moth). Moths that oriented ventral side down in the traps were either repositioned dorsally or removed. Moths that did not respond with vigorous leg movements following the application of the pesticide were removed from the experiment.

Codling moth populations were sampled from 16 orchards from the major growing areas in the state. As time and resources permitted, orchards that experienced problems in past years and those experiencing unusually high trap catch (>20 moths per trap per week) were identified and sampled during the first flight. Some of those orchards were revisited during second flight, and newly identified orchards were also sampled.

Population responses were compared by probit analysis. Probit regression lines were estimated using the probit option of POLO (POLO 1987). Likelihood ratio tests were used to test hypotheses of equality and parallelism in response lines. Lethal concentration ratios were calculated according to

Robertson and Priesler (1992); ratios with confidence limits (CL) not encompassing 1.0 will be considered significantly different ($\alpha = 0.05$).

Results and discussion:

Unpredictable and unfavorable weather made sampling difficult in 2003, particularly because of extremely cold weather during the first flight. This limited the number of successful bioassays, and many trapping efforts (approximately 40%) did not yield enough moths for bioassay.

Despite some extremely high trap catches (both from trap counts provided by referring fieldmen, and from bioassay trap yield), all orchards sampled during the first flight were Guthion susceptible (Table 1). Thus, Lorsban (Table 3) and esfenvalerate (Asana) (Table 4) were tested only in orchards with susceptible populations, and data regarding cross-resistance were not found. Assail bioassays were conducted against Guthion-susceptible populations during the first flight. However, during the second flight, a Guthion-resistant population was identified in Manson. This allowed testing of Assail to determine potential levels of cross-resistance. Fenpropathrin (Danitol) and thiacloprid (Calypso) were not tested against any populations (trap nights were limited in the Guthion-resistant orchard, as the grower treated immediately after samples were collected).

Table 1. Bioassay results for Guthion tested against first flight (overwintering flight) of codling moth populations in Washington State, 2003. No statistically significant differences were found among populations.

Location	LC50 (µg ai/moth)	Resistance ratio
Prosser	0.09[1]	1.1[1]
Grandview	0.13	1.6
S. Wapato	0.26[1]	3.3[1]
Wapato	0.08	--
N. Wapato	0.20	2.5
Yakima	0.17	2.1
Quincy	0.25[1]	3.1
WSU-TFREC	0.12	1.5
East Wenatchee	0.23[1]	2.9[1]
Peshastin	0.15[1]	1.6[1]

[1] Estimates only; data do not fit probit model adequately for statistical analyses.

Table 2. Bioassay results for Guthion tested against second flight (summer flight) of codling moth populations in Washington State, 2003.

Location	LC50 (μg ai/moth)	Resistance ratio
Prosser	0.13	1.2
Grandview	0.16	1.5
S. Wapato	0.22[1]	na[1]
Wapato-1	0.15	1.4
Wapato-2	0.2[1]	na[1]
N. Wapato	0.25[1]	na[1]
Quincy	0.24	3.0
WSU-TFREC	0.11	--
East Wenatchee	0.21[1]	1.9[1]
Peshastin	0.13	1.6
Manson-1	0.54*	4.9*
Manson-2	0.31	2.8

[1] Estimates only; data do not fit probit model adequately for statistical analyses.
*Significantly different from the susceptible population (WSU-TFREC).

Table 3. Bioassay results for Lorsban tested against select codling moth populations in Washington State, 2003. No statistically significant differences were found among populations.

Location	LC50 (μg ai/moth)	Resistance ratio
Prosser	0.028	-1.8
Grandview	0.03	-1.7
WSU-TFREC	0.05	1.0

Table 4. Bioassay results for Asana tested against select codling moth populations in Washington State, 2003. No statistically significant differences were found among populations.

Location	LC50 (μg ai/moth)	Resistance ratio
Prosser	0.06	1.2
Grandview	0.03	0.6
WSU-TFREC	0.05	--

Table 5. Bioassay results for Assail tested against select codling moth populations in Washington State, 2003. No statistically significant differences were found among populations.

Location	LC50 (μg ai/moth)	Resistance ratio
Prosser	0.32[1]	na[1]
Grandview	0.11	1.0
WSU-TFREC	0.11	--
Manson-1	0.76[1]	6.9[1]
Manson-2	0.27[1]	2.5[1]

[1] Estimates only; data do not fit probit model adequately for statistical analyses.

Guthion resistance was found to be low to moderate in orchards sampled throughout the state. The lack of significant resistance in many orchards with high trap catch and unacceptably high infestation points toward operational factors as a likely cause. These factors include possibilities such as inadequate pest control measures leading to higher populations, failure to respond to higher populations with increased rates and decreased spray intervals, and low levels of resistance reducing residual activity of Guthion. Nevertheless, it appears that a rapid shift to Guthion resistance is not the cause of increased codling moth damage in many orchards.

However, identification of a significantly high Guthion-resistant population, along with observed damage following three Guthion applications in that orchard, indicates that Guthion resistance can and does occur at problematic levels in the region. The level of resistance in the Manson population is equal to some of the highest levels of resistance found in the Sacramento Delta in the 1990s. In those cases, codling moth control was marginally maintained at <2% infestation at harvest by using four Guthion applications at 3 lbs. each, with additional applications of other materials between flight peaks and prior to harvest.

The adult bioassay for Assail appears to be adequate; however, adjustments to the method should be examined in the future (such as increasing the exposure time, altering the moth holding temperature, etc.). Bioassay results for Assail were quite variable in this study. Unfortunately, the results for the Manson Guthion-resistant population were not precise enough to determine statistical confidence of cross-resistance with Assail. Thus, it cannot be concluded from this study that cross-resistance exists between the compounds. However, with the inference of cross-resistance between Guthion and Assail, additional studies should be conducted of field efficacy of Assail in Guthion-resistant orchards.