Monitoring insecticide resistance with insect pheromones[1]

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Summary. A novel pheromone-baited sticky trap laced with insecticides proved to be a simple and effective means of monitoring insecticide resistance in the pink bollworm moth. Adult males from fields treated frequently with pyrethroid insecticides showed up to 20-fold resistance to permethrin and up to 14.5-fold resistance to fenvalerate.
Key words. *Pectinophora gossypiella*; pink bollworm moth; insecticide resistance; pheromones; sticky traps; permethrin; fenvalerate.

Resistance to insecticides in one of the most serious problems facing agriculture today[4-7]. The problem is often noticed by a loss of effectiveness of an insecticide in controlling a population, but by then genes conferring resistance have spread throughout the population. Recently, because of the pressing need for control of insecticide resistance, labor-intensive methods have been used to detect emerging resistance in field populations, but there is an immediate need for quick and effective methods for monitoring resistance[5].

Pheromones already have proven to be invaluable for monitoring population levels, timing insecticide sprays, and disrupting mating[8]. We report here a novel use of pheromone traps for detecting the buildup of resistance to insecticides in field populations. This new concept of insecticide-laced sticky traps for monitoring resistance in *Pectinophora gossypiella*, a major pest of cotton, has a significant advantage over labor-intensive methods for detecting resistance[9-11], and is compatible with widespread use of pheromone to monitor population levels in *P. gossypiella*. Information from the resistance-monitoring traps could be used to time the rotation of other chemical, cultural, or biological means of insect control. With effective monitoring and management of insecticide resistance, one could decrease the insecticide burden on the agroecosystem by maintaining susceptible individuals in pest populations.

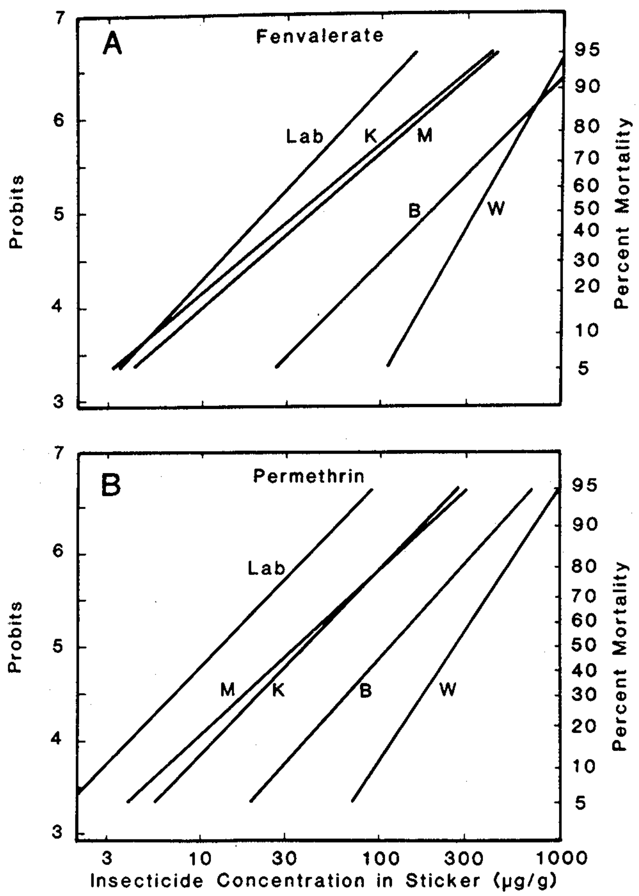
The emulsifiable concentrates of permethrin (Pounce®3.2 EC, FMC Corp., Philadelphia, Pennsylvania, USA) and fenvalerate (Pydrin®2.4 EC, Shell, Modesto, California, USA) were serially diluted in 90% hexane/10% ethanol. 1 ml of each solution was thoroughly mixed into 100 g of sticker (Tangle-trap, Tanglefoot Co., Grand Rapids, Michigan, USA), resulting in a series of sticker-insecticide mixtures from 1.6 to 1000 µg active ingredient per g of sticker. In addition, 1 ml of hexane-ethanol was added to

Results of probit analysis of mortality in sticky traps run for laboratory and field populations of *Pectinophora gossypiella*

Insecticide	Population	n[a]	LC_{50} (95% CI[b]) µg/g	LC_{90} (95% CI[b]) µg/g	Slope (± SE)	Resistance ratio LC_{50}pop/LC_{50}lab
Fenvalerate	Laboratory[c]	355	23 (17–30)	100 (69–179)	2.0 ± 0.28	1.0
	Mexicali,[d] Mexico	2,277	42 (38–47)	262 (219–323)	1.6 ± 0.07	1.9
	Kearny,[e]Arizona	80	36 (17–81)	244 (102–2,837)	1.6 ± 0.43	1.6
	Blythe,[f] California	415	193 (149–275)	927 (560–2,120)	1.9 ± 0.25	8.4
	Westmorland,[g] California	1,656	332 (298–370)	806 (696–966)	3.3 ± 0.24	14.5
Permethrin	Laboratory[c]	365	13 (9–17)	60 (43–99)	2.0 ± 0.28	1.0
	Mexicali[d]	1,916	35 (31–39)	189 (156–238)	1.7 ± 0.09	2.6
	Kearny[e]	217	38 (25–55)	170 (107–376)	2.0 ± 0.34	2.9
	Blythe[f]	504	117 (94–153)	485 (328–866)	2.1 ± 0.23	8.8
	Westmorland[g]	1,508	266 (236–299)	742 (623–929)	2.9 ± 0.23	20.0

[a] Total number of males captured; [b] 95% confidence intervals; [c] Original population collected from Coachella Valley before 1979. No exposure to pyrethroid insecticides; [d] The Mexicali field population had no direct exposure to pyrethroids in 1985; [e] The Kearny population was treated 3 times with pyrethroids in 1985; [f] In 1985 the Blythe population was exposed to 9 applications of pyrethroids before our test; [g] In 1985 the Westmorland population was exposed to 5 applications of pyrethroids before our test.

100 g of sticker serving as the control sticker. Approximately 5 g of sticker was evenly coated over a 9.5 by 17 cm wax-coated card that fitted into, and formed the inner bottom surface of a sticker-free delta trap (Sandia Die and Cartridge, Albuquerque, New Mexico). The traps were baited with the sex pheromone of *P. gossypiella* (1 mg of gossyplure on a rubber septum), and set out in cotton fields in a randomized complete block design with at least 20 m between traps. Five replications of each treatment (6 concentrations and 1 control for each insecticide) were run in each field, except the experiment near Blythe where the highest and lowest concentrations were not included. Cotton fields were selected for different histories of pyrethroid use (table). Male *P. gossypiella* on sticky cards were retrieved at sunrise of the following day, and were incubated at 21 °C until 08.00 h two days later, at which time mortality in the sticker was evaluated by gently probing each male and checking for any movement. Males from a susceptible laboratory colony were flown in a wind tunnel[12] and trapped in identical set of sticky traps. By carefully controlling excessive exposure to heat, mortality in the sticky traps without insecticides usally could be kept below 10%.



Insecticide concentration versus mortality lines (probit transformation) for fenvalerate (A) and permethrin (B) in sticky traps. Field sites were cotton fields near Kearny, Arizona (K), Mexicali, Mexico (M), Blythe, California (B), and Westmorland, California (W).

The traps successfully identified field populations of male *P. gossypiella* having resistance to two pyrethroid insecticides. A field population near Blythe, California had 8.4-fold resistance to fenvalerate and 8.8-fold resistance to permethrin (table). The highest level of resistance was found in a field near Westmorland, California where there was 14.5-fold resistance to fenvalerate and 20-fold resistance to permethrin. 80 km away from the Westmorland site males were captured on the same night in a cotton field near Mexicali, Mexico with no historical exposure to pyrethroid insecticides. Pyrethroids are rarely used in this area because of their expense. These males had a resistance ratio of only 1.9 to fenvalerate and 2.6 for permethrin. The log-concentration probit lines (fig.) illustrate clearly the difference between these populations. A fenvalerate or permethrin dose sufficient to kill 95% of the susceptible laboratory population is essentially non-toxic to the most resistant field population.

The high correlation between LC_{50}'s for fenvalerate and permethrin ($r=0.985$, 3 df, $p<0.01$) suggests cross resistance between pyrethroids for this species. Cross resistance is common for the pyrethroids[7], but independent evolution of resistance cannot be excluded because the two most resistant field populations come from areas with histories of both fenvalerate and permethrin use. Further support for cross resistance between pyrethroids comes from the most resistant field population (Westmorland) that was not treated with either fenvalerate or permethrin in 1985, but rather was treated with cypermethrin and flucythrinate (two other pyrethroids).

Using these pheromone traps pest controllers can easily and effectively detect local resistance to pyrethroids. Management of insecticide resistance may be accomplished by rotation of several classes of insecticides[5,7], thereby minimizing the duration of selection pressure imposed by a single compound. Without an effective technique for monitoring resistance at its early stages, the switch to a new control agent would have to be on a scheduled basis. With a reliable resistance monitoring method, rotation to a new insecticide or other control tactics could become a routine pest management decision. The pheromone trap for resistance monitoring in *P. gossypiella* should allow cotton growers to make rational decisions in selection of control tactics.