Pheromone Trap for Monitoring Insecticide Resistance in the Pink Bollworm Moth (Lepidoptera: Gelechiidae): New Tool for Resistance Management

K. F. HAYNES,[1] T. A. MILLER, R. T. STATEN,[2] W.-G. LI,[3] AND T. C. BAKER

Division of Toxicology and Physiology, Department of Entomology, University of California, Riverside, California 92521

Environ. Entomol. 16: 84–89 (1987)

ABSTRACT A rapid technique using sex pheromone and insecticide-laced traps was developed for measuring insecticide resistance in pink bollworm moth, *Pectinophora gossypiella* (Saunders). This method was developed in the laboratory by allowing males to fly upwind to a sex-pheromone source in a wind tunnel, and then trapping them on sticky cards (laced with various doses of pyrethroid insecticides) inserted into standard delta traps. Using this technique, populations of adult male *P. gossypiella* trapped in the field were shown to be more resistant to permethrin and fenvalerate in fields frequently treated with pyrethroids than in fields with little or no exposure to these insecticides. The new method eliminates handling of insects that is involved in other methods of assessing toxicity, and is compatible with the current practice of monitoring populations with pheromone traps. It was important to test and standardize duration of males' postcapture exposure to insecticide-laced sticker, temperature that males were exposed to after capture, quantity of sticker used, and age of males when captured

KEY WORDS *Pectinophora gossypiella*, sex pheromone, insecticide resistance, sticky traps, permethrin, fenvalerate

THERE IS AN immediate need for simple and effective methods to monitor insecticide resistance to help preserve the increasingly rare resource of effective chemicals for pest population control (Dover & Croft 1984). Resistance to pyrethroids has been detected in the pink bollworm moth, *Pectinophora gossypiella* (Saunders), in the Imperial Valley, Calif. (Bariola 1985), an area where pyrethroids have been used intensively since the late 1970's for suppression of this key pest. Because the larva stages of the moth are protected inside the cotton bolls, most control tactics are aimed at the exposed adult population, and, thus, resistance to insecticides should be manifested in adults.

We have devised a method for monitoring mortality induced by neurotoxic insecticides (such as the pyrethroids) that is rapid and requires little or no handling of insects and no need for topical applications of insecticides. It is effective at sampling insects even at very low population densities. The method depends on incorporating insecticides into the sticker used to capture males, and thus is compatible with the widespread use of delta traps for monitoring population levels.

Materials and Methods

The laboratory colony used in developing the insecticide-laced trap originated from cotton fields in the Coachella Valley, Calif.; no insects have been introduced into the colony since before 1979. Larvae were reared on a shredded wheat-germ diet similar to that of Adkisson et al. (1960). Pupae were segregated by sex and males were held in screened cages (25 by 25 by 30 cm) in a chamber with a 14:10 (L:D) photoperiod and temperature of ca. 26°C. Pupae were removed from the cage daily, leaving males that had emerged over the previous day. Adult males had access to 8% sugar water until the time of the flight-tunnel test.

Permethrin (Pounce 3.2 emulsifiable concentrate [EC], FMC, Philadelphia, Pa.) and fenvalerate (Pydrin 2.4 EC, Shell, Modesto, Calif.) were serially diluted in 90% hexane/10% ethanol. One ml of each of the resulting solutions was mixed for 5 min into 100 g of insect trapping adhesive (Tangle-trap, Tanglefoot, Grand Rapids, Mich.). This procedure resulted in a series of insecticide-laced stickers containing from 1.6 to 1,000 μg (AI)/g of sticker. For concentrations of insecticide >1,000 μg (AI)/g of sticker, the appropriate amount of EC was added to the sticker without this initial dilution. These high concentrations were used only when mortality was assessed at intervals <52 h. Approximately 5 g of sticker were spread evenly over an area (9 by 15 cm) on a wax-coated card

[1] Current address: Dep. of Entomology, Univ. of Kentucky, Lexington, KY 40546.
[2] USDA, APHIS, PPQP, 4125 E. Broadway, Phoenix, AZ 85040.
[3] Shanghai Inst. of Entomology, Academia Sinica, Chungkin Rd. (S.), Shanghai, People's Republic of China

(9.5 by 17 cm) that fit into and became the bottom surface of a sticker-free delta trap (Sandia Die and Cartridge, Albuquerque, N.M.).

For laboratory studies, males were captured on sticky surfaces by placing a single delta trap at the upwind end of a wind tunnel that has been described previously (Vetter & Baker 1983). Between 25 and 50 males were loaded into a screen cage (7.5 by 5.5 cm) ca. 22 h before the test. A rubber septum (5 by 9 mm, Arthur H. Thomas, Philadelphia, Pa.) impregnated with with 1 mg of gossyplure, a 1:1 blend of (Z,Z)-7,11- and (Z,*E*)-7,11-hexadecadienyl acetate, was hung from the top of the trap. During the peak hours of sexual activity, 7–9.5 h after darkness on a 14:10 photoperiod (Haynes & Baker 1985), a screen cage was opened 1.4 m downwind of the trap, giving males the opportunity to fly upwind, enter the trap, and become ensnared in the sticker. Several cages of males were released for each insecticide concentration, and ca. 50% were captured.

Trapped males were incubated at 21°C and continuous light. Mortality was evaluated at 52 h by gently probing each male and looking for any movement. Usually males were captured ventral side down, which allowed the antennae to move freely after probing. When males were captured dorsal side down, their legs were free to move. Mortality data were evaluated by probit analysis using a computer program (Raymond 1985). Percentages of mortality were compared by Ryan's (1960) multiple comparison test for proportions. Abbott's formula (1925) was used to correct for mortality in control traps. This standard procedure was followed for all subsequent tests unless noted.

Duration of Exposure. To determine the optimal duration of captured males' exposure to insecticide-laced sticker, a series of eight concentrations of permethrin and fenvalerate in sticker was prepared (ranging from 1.6 to 10,000 μg permethrin/g of sticker or 1.6–25,000 μg fenvalerate/g of sticker), as well as insecticide-free sticker. Mortality was observed 8, 24, 28, 48, 52, and 72 h after capture of the males.

Temperature. The effects of temperature on mortality were evaluated by incubating captured males at three temperatures: 15.5, 21, and 33°C for 52 h. Four concentrations of insecticides in sticker were used (8, 20, 40, 200 μg/g), as well as insecticide-free sticker.

Sticker Thickness. Since the absolute quantity of insecticide-laced sticker could influence mortality, we investigated the lethal effect of three thicknesses of sticker. Two, 4, or 6 g of sticker were coated evenly over an area (9 by 15 cm) of a trap insert. Only control and 20-μg/g concentrations of permethrin and fenvalerate were used in this experiment.

Age of Males. One biological variable that could influence the accuracy of our resistance-monitoring traps is a variable age distribution of captured males. We tested the impact of age on mortality by capturing males 1–2, 4–5, and 7–8 days old and determining mortality 52 h later in control, permethrin (20 μg/g), and fenvalerate (20 μg/g) traps.

Field Tests. Delta traps were placed in cotton fields in a randomized complete block design with >20 m between traps. Each trap was baited with 1 mg of gossyplure on a rubber septum (a commonly used lure in the field) by hanging the septum from the top of the trap. Five replications of seven treatments (1.6, 8, 20, 40, 200, 1,000 μg/g, and control) were tested for permethrin and fenvalerate in each field. In Blythe the highest and lowest insecticide levels were not tested. Experiments were conducted in August and September 1985. Tests of laboratory, Westmorland, and Mexicali populations were conducted on the same days using the same stock mixtures of insecticide sticker. Traps were retrieved from the fields at sunrise (0600 hours). Sticky liners were removed, placed in racks (seven liners per rack) in plastic boxes (11 by 19 by 13 [height] cm) that were in turn placed into an ice chest. The temperature in the ice chest was kept between 20 and 28°C during the ca. 3-h trip to Riverside, where the trapped males were incubated at 21°C in an environmental chamber. Because the presumed average time of response to pheromone occurred at 0400 hours in the field, mortality was evaluated at 0800 hours 2 days after retrieval, and thus corresponded to the 52-h period used for laboratory experiments. To determine if the addition of the insecticides resulted in any decrease in the number of males captured, an analysis of variance was run comparing mean number of males per trap per night for the different insecticide concentrations.

To determine if insecticide-laced sticky traps were as effective in detecting resistance as standard topical applications of insecticides, ca. 3,000 cotton bolls were picked at the time of the experiment in Blythe. Bolls were handled and stored as described in Haynes et al. (1984). Larvae that emerged from the bolls were collected semiweekly, and pupae were separated according to sex. The male pupae from the field and a corresponding number of male pupae from the laboratory colony were set up for emergence in 473-ml cartons with nylon mesh tops. When 40 male adults (2–7 days old) had accumulated from the Blythe population, 23 were treated with 0.05 μg of fenvalerate in 0.5 μl of acetone and 17 were treated with 0.5 μl of acetone alone. Twenty-five males of the same age distribution as those from the field were treated with the same solutions. The fenvalerate dose was selected because previously it had been determined to be about the LD_{90} for the laboratory population.

Results and Discussion

Duration of Exposure. Mortality induced by permethrin and fenvalerate on the sticky card changed rapidly between 24 and 28 h after cap-

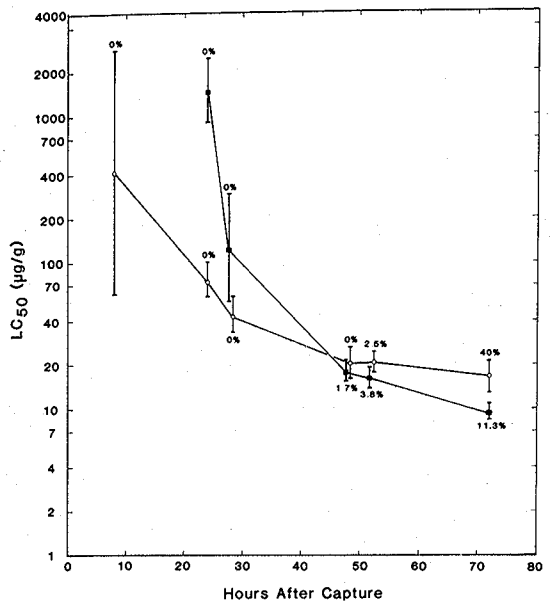

Fig. 1. Change in LC_{50} for permethrin (■) and fenvalerate (O) with time in male *P. gossypiella* captured in pheromone traps in the laboratory. Vertical bars indicate 95% CL, and percentages associated with each point are mortalities in control traps.

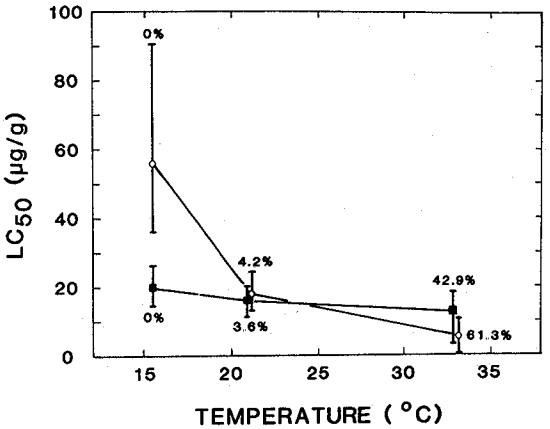

Fig. 2. Effect of different incubation temperatures on LC_{50} for permethrin (■) and fenvalerate (O) in male *P. gossypiella* captured in pheromone traps in the laboratory. Vertical bars indicate 95% CL. Percentages associated with each point are mortalities in control traps. Mortality was evaluated at 52 h.

ture in the wind tunnel (Fig. 1). Between 48 and 52 h, there was little change in LC_{50} and mortality in the insecticide-free traps remained low. By 72 h, mortality in control traps was highly variable (as high as 40%), which we viewed as unacceptable. The stability of the LC_{50} at 48–52 h and the relatively small 95% CL at these times are desirable properties for a resistance-monitoring trap. Lukefahr & Griffin (1957) reported that mating occurred in *P. gossypiella* between 0200 and 0500 hours under simulated field conditions. However, because temperature, photoperiod, and other environmental factors are likely to affect the timing of response of males to traps in the field, there is some uncertainty about the mean time of capture in pheromone traps. For this reason, it is important to evaluate mortality when the LC_{50} is relatively stable for several hours. We selected 52 h after capture as the time to evaluate mortality because of the aforementioned qualification as well as the convenience of evaluating mortality in field-trapped insects at that time.

Temperature. Because temperature is known to affect mortality induced by some of the pyrethroids dramatically, it was important to determine how deviation from our standard temperature (21°C) might affect the reliability of our test. When mortality was evaluated for fenvalerate at 15.5°C rather than 21°C, the result was a 3-fold increase in LC_{50} (Fig. 2). Similarly, at 33°C the LC_{50} was 3.6-fold less than at 21°C. Permethrin's toxicity was not affected as dramatically as fenvalerate's over the entire temperature range (15.5–33°C), because there was only a 1.6-fold drop in LC_{50} (compared with a 10.9-fold drop in LC_{50} for fenvalerate). Pyrethroids are known to be more toxic to some species at lower temperatures (Narahashi 1971). We did not observe this negative correlation between temperature and toxicity in the sticky traps, but we did in topical applications (K.F.H., unpublished data). Unlike exposure to topical applications, males ensnared in sticker are exposed to a continuous dose of insecticide for the entire period of incubation. One possible explanation of the difference between topical application and insecticide-laced sticker involves the nature of the sticky material. At lower temperatures the material is more viscous, and thus possibly would allow less penetration through the insect's cuticle, or there could be less of the insect's surface area exposed to the sticker. Reliable resistance-monitoring traps depend on careful control of the incubation temperature, 21°C being suitable, because 95% CL are small and control mortality is low.

Sticker Thickness. Another variable that could lead to inconsistent results is thickness of the sticker on the trap inserts. Initial tests used ca. 5 g of sticker per trap because this amount ensured that males could be trapped effectively. Thinner coats might lead to lower trapping efficiency and, possibly, lower mortality because males may not have as much body surface exposed to the insecticide-laced sticker. However, over the range from 2 to 6 g per trap insert, we found no significant differences in mortality for any of the groups tested (Table 1).

Age of Males. If the insecticide killed old males at lower doses than young males, then the LC_{50} values may change as the age distribution of the population shifts in the field. However, we found

Table 1. Effect of amount of sticker used to coat area (135 cm²) of the trap insert on mortality in male *P. gossypiella*

	Amount sticker/trap					
	2 g		4 g		6 g	
	n	%	*n*	%	*n*	%
Control	68	13.2a	63	14.3a	76	10.5a
Permethrin[a]	69	79.7a	79	77.2a	72	72.2a
Fenvalerate[a]	61	55.7a	67	58.2a	79	64.6a

Means in the same row followed by the same letter are not significantly different ($P < 0.05$; Ryan's [1960] multiple comparison test for proportions).

[a] 20 μg (AI)/g of sticker.

no significant differences in mortality in control or 20 μg/g doses of permethrin or fenvalerate (Table 2). The tested range of age classes presumably covers a large proportion of the reproductively active males. Flint & Merkle (1981) estimated survival (or ability to respond to pheromone traps) beyond 9 or 10 days to be very low based on capture of males marked with fluorescent powders or genetically marked males. Our traps may have been acting as filters, ensuring that only healthy, reproductively active individuals were used to assess mortality.

Field Tests. Using these pheromone traps, we successfully identified two populations of male *P. gossypiella* having resistance to permethrin and fenvalerate (Blythe and Westmorland, Calif.). Cotton growers in these two areas have relied heavily on pyrethroids for control of *P. gossypiella* (Table 3). In addition, fields where males were relatively susceptible to these pyrethroids were found (Kearny, Ariz., and Mexicali, Mexico). A population near Blythe, Calif., was 8.4-fold resistant to fenvalerate and 8.8-fold resistant to permethrin (Table 3). The highest level of resistance was found in a field near Westmorland, Calif., where there was 14.5-fold resistance to fenvalerate and 20-fold resistance to permethrin. Only 80 km away from the Westmorland site, males were captured on the same night in a cotton field near Mexicali, Mexico, with no exposure to pyrethroid insecticides. These males had a resistance ratio of 1.9 to fenvalerate and 2.6 to permethrin. In general, pyrethroids are rarely used in this region of Mexico because of their cost. The probit lines generated by this analysis of different populations of *P. gossypiella* most clearly illustrate the differences between resistant and susceptible populations (Fig. 3).

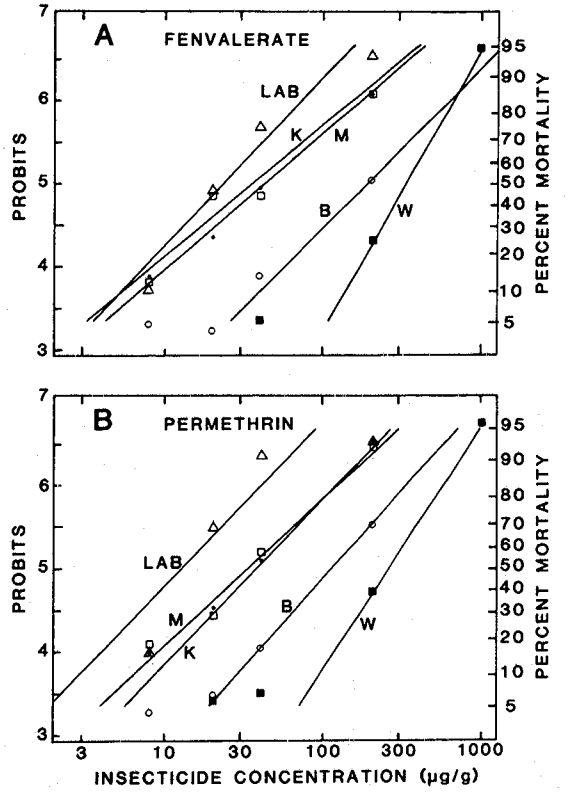

Fig. 3. Insecticide concentration versus mortality lines (probit transformation) with Abbott's (1925) correction for mortality in control traps for fenvalerate (A) and permethrin (B) in sticky traps. Male *P. gossypiella* were trapped in cotton fields near Kearny, Ariz (K, □); Mexicali, Mexico (M, ●); Blythe, Calif. (B, ○); and Westmorland, Calif. (W, ■). Males from the susceptible laboratory colony (lab, △) were collected in sticky traps in a laboratory flight tunnel, and mortality was evaluated at 52 h.

Table 2. Effect of age of male *P. gossypiella* on percentage of mortality in sticky traps

	Age[a] (days)					
	1–2		4–5		7–8	
	n	%	*n*	%	*n*	%
Control	96	5.2a	109	6.4a	152	3.9a
Permethrin[b]	106	70.8a	134	75.3a	129	71.3a
Fenvalerate[b]	114	59.6a	112	67.9a	119	68.9a

Means in the same row followed by the same letter are not significantly different ($P < 0.05$; Ryan's [1960] multiple comparison test for proportions).

[a] Age of males at time of capture in pheromone traps.

[b] 20 μg (AI)/g of sticker.

Laboratory data using topical applications of fenvalerate confirmed our diagnosis of resistance, but the magnitude of the resistance could not be determined by this method because of the small sample size available for this test. This is symptomatic of the problems faced in assessing resistance by having to collect insects in the traditional way. An intensive collection of ca. 3,000 cotton bolls from the Blythe population resulted in the emergence of only 100 male *P. gossypiella* over the course of several weeks (ca. 200 larvae emerged from the bolls, <10% infestation). We found only

Table 3. Results of probit analysis of mortality in sticky traps run for laboratory and field populations of male *P. gossypiella*

Insecticide	Population	n^a	% mortality control[b]	% mortality 200 μg/g	LC_{50} (95% CL) μg/g	LC_{90} (95% CL) μg/g	Slope ± SEM	Resistance ratio[c]
Fenvalerate	Laboratory[d]	355	8.5a	94.3a	23 (17–30)	100 (69–179)	2.0 ± 0.28	1.0
	Mexicali, Mexico[e]	2,277	3.0a	86.9a	42 (38–47)	262 (219–323)	1.6 ± 0.07	1.9
	Kearny, Ariz.[f]	80	7.7[i]	87.5[i]	36 (17–81)	244 (102–2,837)	1.6 ± 0.43	1.6
	Blythe, Calif.[g]	415	1.6a	52.9b	193 (149–275)	927 (560–2,120)	1.9 ± 0.25	8.4
	Westmorland, Calif.[h]	1,656	5.4a	29.4c	332 (296–370)	806 (696–966)	3.3 ± 0.24	14.5
Permethrin	Laboratory[d]	365	9.1a	93.8a	13 (9–17)	60 (43–99)	2.0 ± 0.28	1.0
	Mexicali[e]	1,916	4.0ab	93.4a	35 (31–39)	189 (156–238)	1.7 ± 0.09	2.6
	Kearny[f]	217	13.9a	93.8a	38 (25–55)	170 (107–376)	2.0 ± 0.34	2.9
	Blythe[g]	504	1.9b	70.2b	117 (94–153)	485 (328–866)	2.1 ± 0.23	8.8
	Westmorland[h]	1,508	3.0b	40.7c	266 (236–299)	742 (623–929)	2.9 ± 0.23	20.0

[a] Total number of males captured.
[b] Percentages in the same column not followed by the same letter are significantly different ($P \leq 0.05$ Ryan's [1960] multiple comparison test for proportions).
[c] LC_{50} for population ÷ LC_{50} for laboratory.
[d] Original population collected from Coachella Valley, Calif., before 1979; no history of exposure to pyrethroid insecticides; >50 generations in laboratory culture.
[e] No direct exposure to pyrethroids in 1984 or 1985.
[f] Treated three times with pyrethroids in 1985 before our test (twice with flucythrinate and once with fenvalerate).
[g] In 1985 exposed to eight applications of fenvalerate and one application of permethrin before the experiment. In 1984 this field was treated 5 times with fenvalerate and 11 times with permethrin.
[h] In 1985 the Westmorland field population was treated five times with pyrethroid (four times with cypermethrin and once with flucythrinate) before our test. No cotton was grown in this field in 1984, but cotton growers in this area have relied heavily on pyrethroid insecticides for several years.
[i] Percentages not included in multiple comparison because of small sample size.

9% (2/23) mortality in males dosed with 0.05 μg of fenvalerate at 48 h after dosing. The susceptible laboratory population had 92% mortality (23/25) at the same dose. No mortality was observed in 17 field-collected males or 25 laboratory males treated with 0.5 μl of acetone. This traditional approach to detecting resistance is impractical on a large scale because of the intensive labor involved and, in fact, is rarely used. In the same field, we caught 30 males per pheromone trap per night, illustrating the tremendous efficiency of this technique of resistance monitoring.

One potential problem with incorporating insecticides directly into the sticker would arise if males avoid entering the traps because of volatilization of the insecticide. Preliminary laboratory experiments indicated that males did not avoid traps laced with permethrin or fenvalerate (K.F.H., unpublished data). In addition, an analysis of trapping data from the field showed that the mean number of males captured in control traps was not significantly different from the number captured in traps containing 1,000 μg/g of permethrin or fenvalerate. For example, the control traps for the fenvalerate experiment in Westmorland caught 48.4 ± 17.4 (SEM) (five traps per treatment) moths per trap per night, while the five 1,000-μg/g traps caught 47.8 ± 3.7 moths per trap per night ($P > 0.05$; analysis of variance [ANOVA]). Similarly, control traps in Westmorland for the permethrin experiment caught 33.2 ± 18.4 moths per trap per night (five traps per treatment), while traps laced with 1,000 μg/g permethrin caught 38.4 ± 9.04 ($P > 0.05$; ANOVA).

Suckling et al. (1985) attracted male light brown apple moths, *Austrotortrix postvittana* (Walker), to a pheromone source where they were collected using a sweep net. Topical applications of azinphosmethyl allowed the determination of the distribution of resistance using this technique. Riedl et al. (1985) used pheromone-baited sticky traps to capture male codling moths, *Cydia pomonella* (L.), which were then treated topically with azinphosmethyl to determine susceptibility in wild populations. Our technique has the important added advantage of eliminating handling of the insects as well as equipment for topical application, which makes it a practical procedure for pest consultants and growers. In addition, the technique is compatible with current practices of monitoring population levels with pheromone traps for *P. gossypiella*.

For practical purposes, our technique could be simplified further by reducing the number of dosages used. An insecticide-free trap plus one impregnated with a single discriminating dose would very likely allow one to distinguish between resistant and susceptible populations. The wider array of doses is needed first to select such a single dose. For instance, our data show that the 200-μg/g concentration of permethrin would easily allow discrimination between the Westmorland population (40.7% mortality) and the susceptible laboratory population (95.3%) with a fairly small sample size

(Table 3). It is important to include control traps with no insecticide because they provide a good indication that the technique was carried out properly.

The availability of an effective resistance-monitoring trap for pink bollworm is a first step towards a resistance management system of "moderation" (e.g., Georghiou 1983). This technique can be used to determine the geographical extent and magnitude of resistance levels, which would be helpful in making regional decisions on pesticide use. In addition, because the technique is not labor-intensive, some resistance management decisions could be left up to the consultants or growers. A grower should be able to determine if an insecticide will be effective immediately before an application is needed. When early signs of resistance are detected, rotation to other control techniques or classes of insecticides could help to preserve the effectiveness of insecticides. In addition, monitoring a return to susceptibility caused by immigration, or a selective advantage to the susceptible phenotype, would allow the grower to begin to use a given insecticide again.

Simple adaptations of this technique should allow adult resistance to be monitored in hundreds of species for which sex pheromones and other chemical attractants have been identified. The technique is not limited to the species that respond to chemical attractants, because visually mediated attraction to yellow sticky-card traps to monitor permethrin and chlorpyrifos resistance in greenhouse populations of *Liriomyza trifolii* (Burgess) has been successful (K.F.H., unpublished data). In many of these species it will be necessary to establish the relationship between larval and adult resistance because the targeted stage may be one or both of these.

Acknowledgment

We thank C. A. Beasley, E. Quintero, R. Vetter, and R. Weddle for their assistance with field studies. The Cotton Pest Control Board, Pest Manage. Div. of the California Dep. of Food and Agric., Shell Development, CIBA-Geigy, and Wellcome Res. Laboratories provided support to the Resistance Management Lab. at Univ. of California, Riverside, which enabled these methods to be developed.

References Cited

Abbott, W. 1925. A method for computing the effectiveness of an insecticide. J. Econ. Entomol. 18: 265–267.

Adkisson, P. L., E. S. Vanderzant, D. L. Bull & W. E. Allison. 1960. A wheat germ medium for rearing the pink bollworm. J. Econ. Entomol. 53: 759–762.

Bariola, L. 1985. Evidence of resistance to synthetic pyrethroids in field populations of pink bollworms in southern California, p. 138. *In* Proceedings, Beltwide Cotton Production Research Conference.

Dover, M. & B. Croft. 1984. Getting tough: public policy and the management of pesticide resistance. World Resources Institute, Washington, D.C.

Flint, H. M. & J. R. Merkle. 1981. Early-season movements of pink bollworm moths between selected habitats. J. Econ. Entomol. 74: 366–371.

Georghiou, G. P. 1983. Management of resistance in arthropods. *In* G. P. Georghiou & T. Saito [eds.], Pest resistance to pesticides. Plenum, New York.

Haynes, K. F. & T. C. Baker. 1985. Sublethal effects of permethrin on the chemical communication system of the pink bollworm moth, *Pectinophora gossypiella*. Arch. Insect Biochem. Physiol. 2: 283–293.

Haynes, K. F., L. K. Gaston, M. M. Pope & T. C. Baker. 1984. Potential for evolution of resistance to pheromones: interindividual and interpopulational variation in chemical communication system of pink bollworm moth. J. Chem. Ecol. 10: 1551–1565.

Lukefahr, M. & J. Griffin. 1957. Mating and oviposition habits of the pink bollworm moth. J. Econ. Entomol. 50: 487–490.

Narahashi, T. 1971. Effects of insecticides on excitable tissues. Adv. Insect Physiol. 8: 1–93.

Raymond, M. 1985. Presentation d'un programme Basic d'analyse log-probit pour micro-ordinateur. Cah. ORSTOM. Ser. Entomol. Med. Parasitol. 23: 117–121.

Riedl, H., A. Seaman & F. Henrie. 1985. Monitoring susceptibility to azinphosmethyl in field populations of the codling moth (Lepidoptera: Tortricidae) with pheromone traps. J. Econ. Entomol. 78: 692–699.

Ryan, T. A. 1960. Significance tests for multiple comparison of proportions, variances, and other statistics. Psychol. Bull. 57: 318–328.

Suckling, D. M., D. R. Penman, R. B. Chapman & C. H. Wearing. 1985. Pheromone use in insecticide resistance surveys of lightbrown apple moths (Lepidoptera: Tortricidae). J. Econ. Entomol. 78: 204–207.

Vetter, R. S. & T. C. Baker. 1983. Behavioral responses of male *Heliothis virescens* in a sustained-flight tunnel to combinations of seven compounds identified from female sex pheromone glands. J. Chem. Ecol. 9: 747–759.

Received for publication 19 February 1986; accepted 9 September 1986.