Table 1. Comparison of mosquitoes captured by Shemanchuk and Magoon traps, Knox County, Tennessee, 1984.

	Trap type				
	Shemanchuk		Magoon		
Species	Total	%	Total	%	Total
Psorophora ferox	173	70	74	30	247
Aedes trivittatus	119	52	112	48	231
Ae. triseriatus	54	15	316	85	370
Ae. vexans	25	71	10	29	35
Culex salinarius	4	15	22	85	26

the laboratory, killed by freezing, and identified to species.

A total of 2,213 mosquitoes was collected: *Aedes triseriatus* (Say) 32.9%, *Ae. trivittatus* (Coquillett) 32.5%, *Psorophora ferox* (von Humboldt) 24.2%, *Culex salinarius* Coquillett 6.1%, and *Ae. vexans* (Meigen) 3.2%. *Aedes infirmatus* (Dyar and Knab), *Ae. sticticus* (Meigen), *Ae. thibaulti* Dyar and Knab, *Anopheles punctipennis* (Say), *An. quadrimaculatus* Say, *Cx. pipiens* Linn., and *Ps. cyanescens* (Coquillett) collectively accounted for 1.2% of the total.

The abundance of the five most commonly collected species was compared (Table 1). *Psorophora ferox* and *Ae. vexans* were collected more often in the Shemanchuk trap. *Aedes triseriatus* and *Cx. salinarius* were collected more frequently in the Magoon trap, while *Ae. trivittatus* was collected about equally in both traps. More than one kind of animal-baited trap is necessary to get a true picture of the potential disease vectors that are attracted to a particular host. In this instance, reliance on only one type of trap would have resulted in distorted results for four of the five most commonly collected species.

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SUSCEPTIBILITY OF DDT, DIELDRIN AND MALATHION RESISTANT *ANOPHELES CULICIFACIES* POPULATIONS TO DELTAMETHRIN

M. DAS, S. P. SRIVASTAVA, J. S. KHAMRE AND L. B. DESHPANDE

National Malaria Eradication Programme, 22, Shamnath Marg, Delhi-110054, India

Anopheles culicifacies Giles is an important malaria vector in rural areas of India. DDT and dieldrin resistance has been found widespread in this species. Malathion resistance is also spreading. The analysis of data obtained during the past few years revealed that in western India comprising most parts of Gujarat, Maharashtra and bordering districts of Madhya Pradesh, Andhra Pradesh, and Goa, *An. culicifacies* has become resistant to malathion.

Synthetic pyrethroids have been found to be effective for control of insects. Rishikesh et al. (1978) and Taylor et al. (1981) evaluated several pyrethroid compounds as residual insecticides against adult mosquitoes. Rajvanshi et al. (1982) reported laboratory evaluation of 2 pyrethroids against the larvae of Indian vector mosquitoes.

Involvement of the *kdr* (knockdown-resistance) gene in the manifestation of resistance to DDT and pyrethroid compounds is well recognized in insects (Tsukamoto and Suzuki 1964) including mosquitoes (Halliday and Georghiou 1985a, 1985b). DDT resistance is also conferred by the *kdr* gene supplementing the *deh* gene which control dehydrochlorinase activity.

The response of multiresistant adult field populations of *An. culicifacies* to deltamethrin (decamethrin), a pyrethroid compound, is not known. A study was undertaken to find out the susceptibility status of multiresistant *An. culicifacies* populations using the diagnostic dosage of deltamethrin. The results are reported in the present paper.

The diagnostic concentrations for detection of resistance to DDT, dieldrin, malathion and deltamethrin are 4.0% DDT, 0.4% dieldrin, 5.0% malathion and 0.025% deltamethrin (World Health Organization 1980). A diagnostic dosage is one which kills the susceptible individuals present in the population. All susceptibility tests were based upon the mosquitoes being exposed to filter paper linings impregnated with an oil solution containing the diagnostic concentration of the test insecticides following the WHO standard test procedures for adult mosquitoes. The exposure period was 1 hr in all the tests.

Fully fed *An. culicifacies* collected from the field were used for the tests. In some areas more than one test was carried out. Tests were carried out in 3 states involving 10 districts. Although the tests were carried out in various localities, they are grouped under the nearest Primary Health Centre (PHC). One PHC covers a human population of about one hundred thousand.

In all the areas sampled, *An. culicifacies* showed a very high degree of resistance to DDT. The test mortality ranged from nil to only 14.8% (Table 1). The species also showed a high degree of resistance to dieldrin; with mortality ranging from nil to 35.0%. Of the 9 areas where tests were carried out, 8 areas showed less than 12% mortality to the discriminating dose of dieldrin. Malathion resistance in *An. culicifacies* was also well pronounced (test mortalities ≤ 40%) in Gujarat and Maharashtra states except in one PHC in Gujarat (Kuladya of Rajkot district) and one in Maharashtra (Yellam of Beed district). Malathion was introduced as an indoor residual spray in 1969 in certain areas of Maharashtra. After a few years *An. culicifacies* showed resistance to malathion in such areas. In Karnataka state, the mortality to malathion of *An. culicifacies* was 74.2% in Hospet Akhal PHC in Belgaum district, and 94.4% in Kamasumudram PHC in Kolar district.

With deltamethrin, however, all the tests showed 100% mortality. Tests carried out in Karnataka using 15 to 30 minutes exposure also resulted in 100% kill.

Thus DDT and dieldrin resistance in *An. culicifacies* did not confer cross-resistance to deltamethrin. It is however not known if the *kdr* gene is present in the multiresistant field population of *An. culicifacies* of these states. Among the Indian anophelines tested as larvae, those of *An. stephensi* Liston which were resistant to DDT showed the highest LC_{50} value against deltamethrin (Rajvanshi et al. 1982). By contrast, the organochlorine and malathion resistant *An. gambiae* Giles in the

Table 1. Susceptibility status of *Anopheles culicifacies* to DDT, dieldrin (DL), malathion (MAL) and deltamethrin (DELT) in Gujarat, Karnataka and Maharashtra during 1984–85.

			DDT 4.0% × 1 hr			DL 0.4% × 1 hr			MAL 5.0% × 1 hr			DELT 0.025 × 1 hr		
State	District	P H C	No.[1]	Mosq.[2]	% Mort.[3]	No.[1]	Mosq.[2]	% Mort.[3]	No.[1]	Mosq.[2]	% Mort.[3]	No.[1]	Mosq.[2]	% Mort.[3]
Gujarat	Broach	Lachharas	3	200	11.0	1	60	11.7	3	240	12.1	1	80	100
	Panchmahal	Piplod	1	60	10.0	1	60	35.0	2	140	5.7	1	80	100
	Rajkot	Kuladya	1	40	10.0	1	40	10.0	1	80	75.0	1	80	100
	Surat	Ukhalda Jamkhedi Champawadi	2	140	9.3	2	120	10.8	1	50	11.7	3	220	100
Karnataka	Belgaum	Hospet Akhal	3	121	0.0	1	30	0.0	2	89	74.1	1	25	100
												1*	23	100
												2**	93	100
	Kolar	Kamasamodram	1	96	0.0	—	—	—	1	36	94.4	1	43	100
Maharashtra	Beed	Yellam	1	67	10.4	1	65	0.0	1	62	75.8	1	80	100
	Aurangabad	Kanned	3	188	9.0	2	124	4.8	1	62	24.2	1	50	100
	Buldana	Nandura Royapur and Janpur	2	121	9.1	2	122	3.3	—	—	—	3	180	100
	Chandrapur	Verur and Whugawadi	1	61	14.8	1	60	5.0	1	60	40.0	2	100	100

[1] No. of tests.
[2] No. of mosquitoes exposed.
[3] Percent mortality.
* Exposure period—30 minutes.
** Exposure period—15 minutes.

Gezira, Sudan was cross-resistant to pyrethroids (Davidson and Curtis 1979). A DDT-selected *An. stephensi* strain from Kasur, Pakistan, when further selected with DDT plus chlorophenyl plus piperonyl butoxide, showed pyrethroid resistance (Omer et al. 1980).

Field trials carried out with pyrethroid compounds for control of house flies showed an increase of resistance to pyrethroids (Keiding 1980, Sawicki et al. 1981, MacDonald et al. 1983), but a similar trial carried out with permethrin in 9 dairies in California and New York did not provide evidence of resistance. But when such a population was subjected to high selection pressure of permethrin, not only resistance to permethrin developed rapidly, but the resistance level to organophosphorus compounds and DDT also increased (Scott and Georghiou 1985). Immigration of susceptible house flies from the neighboring areas and some other factors such as existence of refuge could have been responsible for not precipitating resistance in the field during 3 years. The finding that multiresistant *An. culicifacies* populations remained highly susceptible to deltamethrin is an interesting phenomenon. The monitoring of the susceptibility levels shown by multiresistant *An. culicifacies* populations to deltamethrin should be carried out as this compound is used against cotton pests in India and in such areas *An. culicifacies* is the main vector of malaria.

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TOXICITY IN CARCASSES OF *BACILLUS THURINGIENSIS* VAR. *ISRAELENSIS*-KILLED *AEDES AEGYPTI* LARVAE AGAINST SCAVENGING LARVAE: IMPLICATIONS TO BIOASSAY

ARIEH ZARITSKY AND KAMAL KHAWALED

Department of Biology, Ben Gurion University of the Negev, P.O. Box 653, Beer Sheva, Israel 84105

Serotype H-14 of *Bacillus thuringiensis* (var. *israelensis*, or *B.t.i.*) was discovered a decade ago (Goldberg and Margalit 1977). Its mosquito larvicidal activity has been extensively studied since then and exploited as a specific and efficient biological control agent (Arata et al. 1978, Margalit et al. 1983, Kirschbaum 1985). The δ-endotoxin responsible for this activity is produced during sporulation of this gram-positive bacterium and accumulated as a parasporal, amorphous crystal in the sporangium (Bulla et al. 1980). The high specificity of the toxin and the absence of variants developing resistance to it led to optimism with regard to control of vectors of lethal diseases. This enthusiasm faded somewhat with the recognition that the toxic activity has low persistence in natural ponds (e.g., Margalit et al. 1983).

Recently, Larget-Thiery (1984) demonstrated that successive additions of *Culex pipiens* (Linn.) larvae to a jar, initially inoculated with *B.t.i.* spores, preserved toxicity and a high concentration of *B.t.i.*-colony formers in the jar for 60 days, provided the dead larvae were not removed. Since ingested *B.t.i.* spores are known to germinate, to multiply and to