RESIDUAL EFFICACY OF PIRIMIPHOS METHYL (ACTELLIC™) ON *ANOPHELES SACHAROVI* IN ÇUKUROVA, TURKEY[1]

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ABSTRACT. Village-scale trials of 50% emulsifiable concentrate (EC) and 40% wettable powder (WP) formulations of pirimiphos methyl (Actellic™) were carried out against *Anopheles sacharovi* in Çukurova, Turkey. Susceptibility tests with wild caught, gonoactive and composite aged *An. sacharovi* over a range of chemical concentrations resulted in 100% mortality after exposure for 60 min to a 0.5% active ingredient concentration. Surface treatments of Actellic 50% EC at 0.9 g/m^2 caused a significant decrease in parous rate and a 96.9% reduction in resting density. Persistence on concrete, wood, zinc and plywood was still high at the time of the second spray round, more than 7 wk postspray and ranged from 73% (zinc) to 98% (plywood). More than 50% mortality was still recorded 8 wk postspray using 1.6 g/m^2 WP on wood, plywood, zinc and thatch substrates.

INTRODUCTION

Anopheles sacharovi Favre, the principle vector of human malaria in Turkey, is found in great numbers in the malaria endemic region of Çukurova. Many insecticides, both agricultural and public health, have been used since the introduction of chlorinated hydrocarbons in 1957. Since the development of resistance to DDT in 1959 and dieldrin in 1970–71 (Gökberg 1959, de Zulueta 1959, Curtis 1962, Ramsdale 1975, Kasap 1989), malathion was introduced for house spraying. Resistance among anopheline species to the organophosphorus (OP) insecticides fenithrothion and fenthion, the carbamate (CM) insecticides and to some synthetic pyrethroids was reported in 1974 (Ramsdale et al. 1980). Further susceptibility tests against *An. sacharovi* using the OP and CM insecticides chlorphoxim, phoxim, diazinon, chlorpyriphos, iodofenphos, dimethoate, mecarbam, carbaryl, dimetan, dimetilan and N-methyl carbamate indicated the presence of resistance (Davidson 1982). Resistance to dieldrin, propoxur and tolerance to malathion were also found in *An. sacharovi* (Kasap et al. 1983). The use of malathion as a residual agent against mosquito adults was discontinued in Turkey after 1984 for the dual reasons of evidence of low-level resistance in *An. sacharovi* and also because of the undesirable odor and staining characteristics of this pesticide (Ünsal 1984[6]). Since 1984, pirimiphos methyl became the agent of choice in the Turkish Malaria Eradication Program (NMEP). A full biochemical characterization of resistance in *An. sacharovi* from the Çukurova region found no resistance to pirimiphos methyl (Hemingway et al. 1985).

This paper reports the present efficacy of pirimiphos methyl after having been used against *An. sacharovi* in Turkey for 6 years.

MATERIALS AND METHODS

Insecticide spraying: Pirimiphos methyl (Actellic) was applied to all indoor sprayable surfaces and externally to all out buildings.

A large farm in Herekli with 10 occupants and comprising 4 houses and one large stable was sprayed with a target dose of 2 g AI/m^2 Actellic 50% EC (however, the "achieved" dose was 1 g AI/m^2 in spray round I and 0.8 g AI/m^2 in spray round II). One sector of Doğankent was left unsprayed for comparison.

In the Tarsus area, Yeniçay (population 138), a village comprising 21 houses and 13 stables was sprayed with a target dose of 2 g AI/m^2 Actellic 40% WP (however, the "achieved" dose was 1.8 g AI/m^2 in spray round I and 1.3 g AI/m^2 in spray round II). Hasanağa village in the same area was left unsprayed for comparison.

Two NMEP spray teams were employed, each of one chief and 4 spraymen; one team in area Herekli and one team in area Yeniçay. Insecticide formulations were applied with a Hudson X-pert sprayer (nozzle 8002). The 2 spray rounds were scheduled in each village at 8–10 wk intervals. In the remainder of Çukurova, either Actellic 40% WP or Actellic 50% EC was applied by NMEP teams at a nominal rate of 2 g/m^2. Before the first spray round, the area of

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Table 1. Distribution of ceiling and wall surfaces in Çukurova and spray coverage calculated on the surfaces sprayed against that targeted to be sprayed.

Area	Surface types										
	Lime-wash	Cement	Mud	Cement briquet	Wood	Zinc	Brick	Thatch	Plywood	Nylon, stone and tile	Total
Six villages (spray and comparison) with 161 dwellings											
Measured (m^2)	28,957	11,271	7,914	7,541	6,040	4,427	4,051	2,986	968	856	75,011
Rate (%)	39	15	11	10	8	6	5	4	1	1	100
Two spray villages with 22 dwellings											
Measured (m^2)	1,588	4,329	2,421	764	1,554	1,231	505	847	339	48	13,624
Rate (%)	12	32	18	6	11	9	4	6	2	0	100
Sprayable (m^2)[1]	804	2,318	1,367	732	1,524	1,230	497	889	268	200	9,829
Coverage (%)											
Round I[2]	92	57	92	71	39	36	61	90	91	19	
Round II[3]	100	52	80	41	27	24	81	52	92	4	

[1] Mean sprayable area per dwelling = 427 m^2.
[2] Mean sprayed area per dwelling at round I = 272 m^2 (coverage = 64%).
[3] Mean sprayed area per dwelling at round II = 227 m^2 (coverage = 53%).

sprayable surfaces was measured with a Solex UR-300 "Digitape" meter in 6 villages, including those to be treated.

Entomological assessments: Susceptibility tests were carried out with freshly prepared impregnated papers with 0.25, 0.5 and 1.0% technical grade pirimiphos methyl after the method described by the World Health Organization (WHO) (1975). Three groups of *An. sacharovi*: 1) wild caught and composite aged females, 2) 1–3 day old females (first generation of laboratory selection), and 3) 1–3 day old females of laboratory colony were tested.

Indoor diurnal resting density was estimated by hand captures. Collections began 4–5 wk prespray and continued for 8–9 wk postspray and were made at fixed locations selected for the largest number of mosquitoes collected during preliminary observations. The number of mosquitoes collected were expressed per man-hour, and percentage reductions in density of mosquitoes in treated areas were calculated following Fleming et al. (1983). Parous rates were determined by ovarian dissection.

Indoor and outdoor nocturnal density and activity were estimated through collections made hourly from dawn to dusk by outdoor human and animal baited traps, exit and entrance traps mounted on stable windows, and indoor and outdoor hand captures of mosquitoes landing on man.

Contact bioassays were carried out with standard WHO (1975) methods using composite aged *An. sacharovi* (collected from an unsprayed village) exposed for 30 min to one of 8 surfaces, and mortality was recorded after 24 h.

Airborne (fumigant effect) bioassays were performed on the same day as contact bioassays using similar mosquito material. Twenty mosquitoes were exposed for 4 h, within three 12 cm cylinder cages, suspended 25, 50 and 100 cm from the ceiling and walls. Mortality was recorded after 24 h. Bioassay results were presented as mean percent mortalities of 4 replicates of each individual test and as moving averages of 3 consecutive tests calculated to justify fluctuations.

RESULTS AND CONCLUSIONS

Surface types: The type and proportion of walls and ceilings in 6 villages (including 2 spray villages) was assayed and is shown in Table 1. Attitudes of local people toward residual house spraying were assessed. The greater reluctance to the spraying of sleeping and living quarters than to that of stores and external areas was noted and determined the spray methodology. Living rooms, bedrooms, kitchens and hallways were treated by a "bandage" spray, i.e., a single swath applied around the wall/ceiling junction together with a full ceiling spray. All other areas of the house were treated by a complete wall-to-floor and ceiling spray. Limewash, concrete, cement briquet, mud and wood surfaces comprised 83% of all surfaces in 6 villages and 79% in the 2 spray villages.

From the measurements of the sprayable surfaces the mean area of surfaces actually sprayed during 2 spray rounds was calculated. The proportion of sprayed area to sprayable changed depending on the partial or complete treatment of the surfaces. The mean sprayable area calculated per dwelling was 427 m^2, but the mean area actually sprayed for rounds I and II was

250 m^2 (coverage = 58.4%) (Table 1). An analysis of the results indicates that the coverages and dosages achieved in most instances were much lower than originally planned even though research scientists and zone staff were involved. These results are shown in Table 2.

Susceptibility tests: Composite aged *An. sacharovi* comprising: 1) wild caught, gonoactive from A. Kulak; 2) wild caught, prehibernating from Tabaklar; 3) laboratory selection from Tabaklar; and 4) laboratory colony from Adana, were exposed for 15, 30, 60 min against 3 concentrations of pirimiphos methyl. Exposure to 1% pirimiphos methyl for periods greater than 15 min resulted in 100% mortality of both wild caught and laboratory strains, whereas 60 min exposure at 0.5% resulted in 100% mortality of the wild caught, gonoactive strain from A. Kulak, suggesting that this should be the discriminating dose. Non-gonoactive prehibernating mosquitoes from Tabaklar showed a weak tolerance.

Diurnal density, parity and percent reduction of house resting: Diurnal resting densities and parous rates of mosquitoes in houses and stables untreated and treated, and percent reduction in resting densities of treated area are shown in Fig. 1.

At Herekli, prespray density and parous rate were high, decreasing substantially after each round. The mean density reduction was 97% during the 8 wk period in round I and 99% during the 16 wk period in round II.

At Yeniçay, prespray density and parous rate were also high and similarly decreased during the postspray period. The mean density reduction was 97% during the 10 wk period of round I, later rising to 100% reduction before slowly falling during the 16 wk postspray period of round II.

Nocturnal density of mosquitoes: Pre- and postspray collections of mosquitoes from human and animal baited traps, stable entrance and exit traps, and indoor and outdoor man landing captures clearly showed a significant reduction in the endophilic species *An. sacharovi* and *Culex pipiens* Linn., whereas no such population reduction was recorded with the exophilic species *Cx. tritaeniorhynchus* Giles and *Aedes caspius caspius* (Pallas). With respect to the 0.9 g AI EC/m^2 treatment, the reduction in biting index was 54% at 1 wk and 92% at 10 wk postspray round I.

Contact and airborne (fumigant effect) bioassay: Residual efficacy of pirimiphos methyl on 8 surfaces against wild caught, composite aged *An. sacharovi* as determined by contact bioassay tests is shown in Table 3). The mean percent mortalities and moving mean percent mortalities are listed according to weeks postspray, regardless of the spray rounds.

At a mean deposit of 0.9 g/m^2, the residual efficacy of the emulsifiable concentrate was high, ranging from 73 to 97% after 8 wk on several surfaces, but with a lower persistence on the highly alkaline "salted" slaked lime surface. At a mean deposit rate of 1.6 g/m^2, the residual efficacy of the wettable powder lasted more than 8 wk on wood, zinc, plywood and thatch, and up to 5 wk on the highly alkaline surfaces. High ambient temperatures increased the mortality levels at 8 and 9 wk postspray. The airborne effect of pirimiphos methyl persisted up to 9 wk, depending on the wall/ceiling surface combination and the application rate.

Table 2. Coverage (calculated on the sprayed area targeted to be sprayable) and dosage achieved with primiphos methyl (Actellic).

Village	Herekli		Yeniçay	
Spray round	I	II	I	II
Target sprayable area (m^2)	1,499		8,202	
Area sprayed (m^2)	981	985	5,567	4,258
Coverage achieved (%)	65.4	65.7	67.9	51.9
Formulation used				
WP 40% (kg)	—	—	25	13.8
EC 50% (liter)	2	1.5	—	—
Insecticide used (g AI)	1,000	750	10,000	5,500
Dosage achieved (g/m^2)	1	0.8	1.8	1.3
Dosage targeted (g/m^2)	2	2	2	2

DISCUSSION

Wild caught *An. sacharovi* from K. Karatas, Tabaklar and A. Kulak (Çukurova) showed up to 75% mortality at 15 min, up to 98% mortality at 30 min and 100% mortality at 60 min after exposure to pirimiphos methyl at 1.0% (Herath 1977). Similarly, a selected laboratory strain from "Soysalli-Çukurova" exposed to 1% pirimiphos methyl for 1 h at 26°C also showed 100% mortality (Ramsdale et al. 1980). Elevated temperatures during insecticide testing may increase mortality effects (Herath 1977, Ramsdale et al. 1980). The nature of the solvent used to prepare insecticide test papers may significantly modify observed mortality, e.g., as with the solvent dioctyl-phthallate (Davidson 1982). However, tests during the present study using wild caught *An. sacharovi* (from Tabaklar and A. Kulak), a laboratory strain (from Tabaklar) and

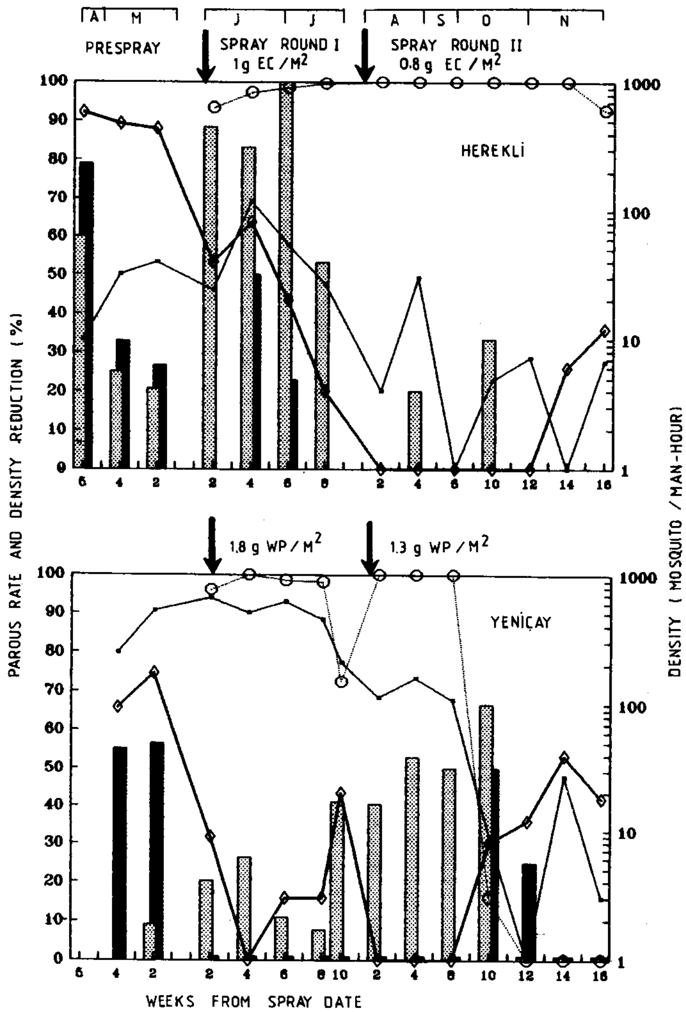

Fig. 1. Diurnal resting densities in untreated (—■—■—) and treated (◇—◇—) areas, parous rates in unsprayed (□) and sprayed (▨) areas, and estimated density reduction in sprayed (···○···○···).

a laboratory colony (from Adana) against 1% pirimiphos methyl at 1 h exposure, and wild caught females even against 0.5% at 1 h, resulted in 100% mortality. We conclude that *An. sacharovi* shows no sign of resistance to pirimiphos methyl (Actellic), that 0.5% at 1 h exposure can be accepted as the discriminating dose, and although different formulations will exhibit different control efficacies depending on the surface sprayed, a dose of 1 g EC/m^2 is recommended as the application dose in Çukurova. In this study the emulsifiable concentrate formulation performed better than the wettable powder formulation on surfaces such as mud, concrete, cement briquet and limewash.

Considering that *An. sacharovi* commonly rests at the top of the walls and ceilings (74–94% of mosquitoes occur within 75 cm of the ceiling [Babayigit and Kasap 1989]), and that pirimiphos methyl has a high fumigant effect, and only a low dose is needed, the selective "bandage" treatment noted in the text is fully justified. This successful use of the Actellic "bandage" for many years by the Turkish National Malaria Control Program is illustrated by the annual reduction of malaria incidence witnessed between the years 1985 and 1989 in the Doğankent (Adana) Health and Education Research Area (covering more than 45,000 people) from 56.6, 33.8, 12.8, 5.6 and finally to only 2.1 per thousand compared with an increase 30.2, 42.2, 38.6, 50.5 and 73.8 per thousand among migrant workers living in the unsprayed premises (Akbaba et al. 1990).

Table 3. Twenty-four hour mean percent mortality ($\bar{X}$) and moving averages (m$\bar{X}$) of *Anopheles sacharovi* exposed for 30 min to various surfaces sprayed with pirimiphos methyl.

			Surfaces															
			Lime-wash		Cement		Mud		Cement briquet		Wood		Zinc		Plywood		Brick	
C°	RH %	Weeks post-spray	$\bar{X}$	m$\bar{X}$	$\bar{X}$	m$\bar{X}$	$\bar{X}$	m$\bar{X}$	$\bar{X}$	m$\bar{X}$	$\bar{X}$	m$\bar{X}$	$\bar{X}$	m$\bar{X}$	$\bar{X}$	m$\bar{X}$	$\bar{X}$	m$\bar{X}$
Average 0.9 g EC/m² achieved																		
28	73	2	62	—	100	—	23	—	79	—	100	—	96	—	98	—	100	—
29	94	3	76	55	100	93	97	53	56	58	85	93	90	70	100	99	93	93
27	83	5	45	56	80	93	39	60	38	53	92	93	23	71	100	100	84	93
29	80	6	46	38	97	78	42	38	65	42	100	91	100	54	100	97	100	82
25	73	7	24	32	55	84	32	42	22	51	81	94	40	73	92	97	63	87
29	87	8	25		100		52		67		100		79		100		97	
Average 1.6 g WP/m² achieved																		
30	83	2	77	—	100	—	93	—	100	—	100	—	100	—	100	—	100	—
25	78	3	76	63	50	61	95	78	22	45	67	86	98	99	100	82	100	100
30	99	5	38	45	25	44	45	63	12	18	93	71	98	86	46	70	100	95
29	81	7	20	23	12	30	49	38	18	14	55	57	61	69	63	54	86	93
28	50	8	2	13	5	52	21	27	12	15	22	52	48	61	53	59	34	56
33	73	9	8		96		13		16		79		74		62		49	

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