Research Articles

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Impact of residual spraying of Reldan against *Anopheles culicifacies* in selected villages of District Ghaziabad (Uttar Pradesh), India

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Background & objectives : Indoor residual spraying of Reldan 40% EC @ 0.5 and 1g/m^2 was done in Tatarpur and Chauna villages, respectively in Dhaulana PHC, Distt. Ghaziabad (U.P.) to evaluate its impact against *Anopheles culicifacies* and malaria incidence. Results were compared with that of Piyawali village which was taken as control area.

Methods : Four rounds of spray were done from 1999–2000 in human dwellings and cattlesheds in experimental villages. Entomological parameters — man hour density, parity rate, sporozoite rate, etc. were monitored using standard procedures. Epidemiological indicators such as SPR, SFR, cases/000, *Pf*/000 were also calculated. Cone bioassays as per WHO method were also carried out to assess the persistence of the insecticide on different surfaces.

Results : Entomological results revealed that spraying of reldan @ 0.5 g/m^2 resulted in significant reduction in adult densities of *An. culicifacies* in sprayed villages over the control village. Spraying also resulted in reduction of percent parous females, reduction in malaria incidence ($p < 0.05$).

Interpretation & conclusion : Reldan showed high efficacy @ 0.5 g/m^2 in controlling the densities of *An. culicifacies* and malaria incidence. However, double dosage of reldan @ 1 g/m^2 can be used for comprehensive vector control provided > 95% spray coverage is achieved.

Key words *An. culicifacies* – efficacy – malaria incidence – reldan

The strategy of malaria control in rural areas in India under National Anti Malaria Programme (NAMP) now National Vector Borne Disease Control Programme (NVBDCP) is to carry out indoor residual spraying (IRS) of insecticides in primary health centres (PHC) with >2 annual parasite incidence (API)[1]. As per National Insecticide Policy (NIP) of NVBDCP, DDT, malathion and synthetic pyrethroids are being selectively used to control *Anopheles culicifacies* (Diptera: Culicidae)—a principal vector of malaria in rural and peri-urban areas of northern plains of the country[1]. In areas with DDT resistant vectors malathion is sprayed and in areas having multiple resistant vectors synthetic pyrethroids are being used. These insecticides are being sprayed for last several years resulting in precipitation of wide spread resis-

tance in *An. culicifacies* to DDT, HCH and malathion in certain states and also to synthetic pyrethroids in certain areas of Maharashtra and Gujarat states[2-6]. Therefore, there is an urgent need to evaluate alternative insecticides to control malaria incidence to economic threshold when it no longer poses serious public health problem and to tackle malaria outbreaks especially in areas under the influence of multi-resistant *An. culicifacies*. In consonance with this policy, bioefficacy of reldan (*o,o*-dimethyl *o*-3,5,6-trichloro-2-pyridyl phosphorothioate) commonly known as chloropyripos-methyl a wide spectrum organophosphorous insecticide was evaluated to provide scientific support to the national programme. The study was undertaken to evaluate the efficacy of single (0.5 g/m^2) and double (1g/m^2) doses of reldan against DDT and HCH resistant populations of *An. culicifacies* and its impact in controlling malaria incidence in certain selected villages of District Ghaziabad (U.P.). Results of two years field trials are reported in this paper.

Material & Methods

Study areas : Tatarpur and Chauna villages of Dhaulana PHC, District Ghaziabad (U.P.), India were selected for this study on the basis of malaria endemicity and topography. These villages are located in the command area of the upper Ganga canal at a distance of about 40–45 km southeast of Delhi. The population of Tatarpur and Chauna villages were 2854 and 3230 respectively as per 1991 census record. There are about 132 human dwellings (HD), 136 cattlesheds (CS) and 51 temporary structures (TS) in Tatarpur village as against 240 HD, 211 CS and 47 TS in Chauna village. The man to cattle ratio is 1 : 1.8. Piyawali village was selected as control in Dadri PHC of the same district at a distance about 12 km from the experimental villages. The population of the control village was about 3260 as per 1991 census record distributed in 234 HD and 180 CS. The man to cattle ratio is 1:2. Experimental and control villages have more or less the same composition of mosquito fauna. *An. culicifacies* is the main malaria vector and is responsible for high malaria transmission in both Dhaulana and Dadri PHCs. The susceptibility tests carried out in earlier studies revealed that this species is resistant to both DDT and HCH, however, it was susceptible to deltamethrin[7].

Methodology : Baseline data of vector density and mosquito fauna along with malaria incidence were collected before carrying out the trial. Reldan 40% EC was supplied by the sponsoring agency "DeNocil Pvt. Ltd., East Mumbai, after obtaining the permission from Central Insecticide Board (CIB). Indoor residual spraying was carried out @ 0.5 g/m^2 (single) and 1 g/m^2 (double dose) with the help of stirrup pump after calibration of flat type nozzle to obtain correct discharge rate (26.5 Floz) of insecticide during the transmission period. Two rounds of spray were carried out in each year with reldan starting from 17 August 1999 in the experimental villages. Bioassay tests were performed using standard WHO procedures[8] on different surfaces in separate houses after obtaining assurance of house owners that they will not white wash or mud plaster the walls. Pre- and post-spraying man hour density (MHD) was monitored in both human dwellings and cattlesheds in control and experimental villages. Parity rate was calculated by dissecting and examining the ovaries of females collected randomly from reldan sprayed and control villages. Vector incrimination studies were also performed by examining mid gut and salivary glands for the detection of sporozoites. Door-to-door active surveillance on weekly basis was carried out in all villages and presumptive treatment was given to all fever cases. SPR, cases/000 and *Pf*/000 were calculated as per standard procedures. Student's 't' test was applied to see the statistical significance in between the control and experimental villages.

Results

Spray coverage in human dwellings and cattlesheds in each round are presented in Table 1. The spraying coverage in the villages was quite satisfactory. During the first and second rounds, spraying coverage was 100% in Tatarpur and Chauna villages. During the third and fourth rounds > 97% human dwelling cover-

Table 1. Reldan 40% EC indoor residual spraying coverage in different types of structures of Chauna and Tatarpur villages, District Ghaziabad (Uttar Pradesh)

Spray/Round (Dates)	Sprayed structures				% coverage				Quantity consumed (l)
	HD	RS	CS	TS	HD	RS	CS	TS	
				Chauna (reldan @ 1 g/m^2)					
I round (17–20 Aug 1999)	240	1957	211	47	100	100	100	100	79.5
II round (15–19 Oct 1999)	242	1669	245	50	100	100	100	100	91
III round (3–8 Jul 2000)	250	2000	235	43	97.6	97.6	100	100	81.5
IV round (11–14 Sep 2000)	251	2011	234	43	97.2	97.5	100	100	82
				Tatarpur (reldan @ 0.5 g/m^2)					
I round (21–23 Aug 1999)	172	1357	136	51	100	100	100	100	44
II round (19–21 Oct 1999)	193	1407	170	51	100	100	100	100	55
III round (9–11 Jul 2000)	190	1430	151	42	98.4	93.3	99.3	100	48
IV round (16–18 Sep 2000)	184	1536	150	46	99.4	99.4	100	100	48.5

HD—Human dwellings; RS— Rooms; CS — Cattlesheds; TS—Temporary structures.

age and > 93% room coverage were achieved in Tatarpur village, while in Chauna village > 97% human dwelling and room coverage was achieved.

Bioassay tests: Results of bioassay tests carried out on different surfaces are given in Table. 2 and the results revealed that with reldan spraying 100% mortality was observed in *Culex quinquefasciatus* Say (Diptera : Culicidae) and *An. culicifacies* up to 8–10 weeks on mud, cement and brick wall surfaces. However, marginal variation was observed with each surface and species tested. The persistence of reldan against *An. culicifacies* was observed (100% mortality) for about 10 weeks on all the three surfaces as against eight weeks in case of *Cx. quinquefasciatus* on different surfaces. Of the three surfaces tested, maximum persistence was observed on mud wall, followed by cement wall and brick wall.

Entomological evaluation : Pooled man hour density (MHD) of *An. culicifacies* and total mosquitoes in Tatarpur (reldan @ 0.5 g/m^2), Chauna (reldan @ 1 g/m^2) and Piyawali villages (control) for pre-spray and post-spray periods are presented in Table 3. The average MHD of *An. culicifacies* was 27.5 in the village sprayed @ 0.5 g/m^2, 28.8 in the village sprayed @ 1 g/m^2, and 28.3 in the control village during the pre-spray period. Pre-spray data revealed that density of *An. culicifacies* was more or less same in experimental and control villages. Spraying of reldan resulted in significant reduction in *An. culicifacies* densities in the experimental villages ($p < 0.05$). Of the two dosages tested, 0.5 g/m^2 was found appropriate in controlling *An. culicifacies.*

The impact of reldan spraying @1 g/m^2 was also observed on non-target species of mosquitoes, as there was substantial reduction of total mosquito density in the experimental village as compared to that of in control village.

Parity rate of An. culicifacies : Studies on determination of parity rates revealed that it was quite high during pre-spray period. However, reldan spray resulted in drastic reduction of parous females in experimental villages. The parity rate of *An. culicifacies* ranged from 72 to 84% in pre-spray period and it was drastically reduced during the post-spray period

Table 2. Results of bioassay tests against mosquitoes on different wall surfaces in reldan sprayed villages of District Ghaziabad (Uttar Pradesh)

Day/ Week	% corrected mortality											
	Mud wall				Cement wall				Brick wall			
	An. culicifacies		*Cx. quinquefasciatus*		*An. culicifacies*		*Cx. quinquefasciatus*		*An. culicifacies*		*Cx. quinquefasciatus*	
	@ 0.5 g/m^2	@ 1 g/m^2	@ 0.5 g/m^2	@ 1 g/m^2	@ 0.5 g/m^2	@ 1 g/m^2	@ 0.5 g/m^2	@ 1 g/m^2	@ 0.5g/m^2	@ 1 g/m^2	@ 0.5 g/m^2	@ 1 g/m^2
Day 0	100	100	100	100	100	100	100	100	100	100	100	100
II wk	100	100	100	100	100	100	100	100	100	100	100	100
IV wk	100	100	100	100	100	100	100	100	100	100	100	100
VI wk	100	100	100	100	100	100	100	100	100	100	90	100
VIII wk	100	100	100	100	100	100	100	100	100	100	80	100
X wk	100	100	85	100	100	100	73.3	93.3	100	100	60	100
XII wk	90	100	60	90	66.6	90	70	63.3	86.6	96.6	46.6	76.6
XIV wk	66	100	40	56.6	50	73.3	23.3	26.6	60	83.3	30	43.3

Table 3. Impact of indoor residual spraying of reldan 40% EC on indoor resting density of mosquitoes in experimental and control villages

Month/Year	MHD of *An. culicifacies*			MHD of total mosquitoes		
	Reldan @ 0.5 g/m^2	Reldan @ 1 g/m^2	Control	Reldan @ 0.5 g/m^2	Reldan @ 1 g/m^2	Control
Pre- spray						
Jan-Aug1999	27.5± 1.5	28.8 ± 2.1	28.3 ± 1.8	125.3± 3.2	133.1 ± 2.9	117.8 ± 2.6
Post-spray						
Sep–Dec 1999	1.8 ± 0.05	0.37± 0	68.5 ± 2.4	28.2 ± 1.2	16.7 ± 1	213.7 ± 3.8
Jan–Dec 2000	4.1 ± 2.6	1.8 ± 0.09	48.1 ± 1.3	30.9 ± 0.97	20.9 ± 0.71	155.5 ± 3.1
Jan–Mar 2001	0.66 ± 0	0.16 ± 0	22 ± 0.2	26.1 ± 1	19.8 ± 1.2	85.6 ± 2.5

Control & 0.5 g/m^2 —$p<0.05$ significant; Control & 1 g/m^2 —$p<0.05$ significant; Reldan @ 0.5 & 1 g/m^2—Nonsignificant.

Table 4. Record of parity rate and sporozoite rate in study villages in District Ghaziabad (Uttar Pradesh)

Year		*An. culicifacies*				
		No. dissected	Nulliparous	% parity rate	Oocyst rate	Sporozoite rate
		Reldan @ 0.5 g/m^2				
1999	Pre-spray	83	15	71.9	0	0
	Post-spray	14	13	7.6	0	0
2000	Pre-spray	16	15	6.2	0	0
	Post-spray	15	14	6.6	0	0
		Reldan @ 1 g/m^2				
1999	Pre-spray	110	22	80	0	0
	Post-spray	15	14	6.6	0	0
2000	Pre-spray	14	13	7.1	0	0
	Post-spray	16	15	6.2	0	0
		Control village				
1999	Pre-spray	140	12	81.4	0	0
	Post-spray	180	11	83.8	0	0
2000	Pre-spray	90	18	80	0	0
	Post-spray	210	12	78.2	0	0.47

(6–8%). Incrimination of vector species in experimental villages revealed nil sporozoite rate as against one female positive for sporozoite in October 2000, giving sporozoite rate of 0.47 in the control village (Table 4).

Epidemiological evaluation : Results of the epidemiological evaluation revealed that the endemicity of the disease was more or less same when SPR, cases/000 and *Pf*/000 were compared during the pre-spray period. Spraying of reldan showed a significant impact on malaria incidence in the experimental villages, as there was a clear decline in SPR, *Pf*/000 (Table 5). Further in the village sprayed @ 1 g/m^2 the impact was more pronounced as compared to the village

Table 5. Impact of indoor residual spraying of reldan 40% EC on incidence of malaria in experimental and control villages

Month/Year	Reldan @ 0.5 g/m^2 (Tatarpur)				Reldan @ 1 g/m^2 (Chauna)				Control (Piyawali)			
	TBS	SPR	Cases/000	*Pf*/000	TBS	SPR	Cases/000	*Pf*/000	TBS	SPR	Cases/000	*Pf*/000
Pre-spray												
Jan–Apr 1999	94	20.2±1.2	6.6±1	1.7±0.5	67	28.3±2.1	5.9±0.9	1.8±0.3	131	9.1±0.8	3.6±0.4	0.92±0
Post-spray												
Sep–Dec 1999	42	7.1±0.9	1±0	0	54	3.7±0.8	0.62±0.1	0	90	15.5±1.4	4.2±0.8	1.5±0.1
Jan–Dec 2000	115	7.8±0	3.1±0	1±0	114	2.7±0	1.4±0	0	314	33.1±4.2	31.9±0.1	22.6±0
Jan–Mar 2001	28	3.5±0.05	0.35±0	0	24	8.3±0.5	0.62±0	0	52	9.6±1.2	1.5±0.8	0.61±0

TBS — Total blood smears; Control & 0.5 g/m^2 — $p < 0.05$ significant; Control & 1 g/m^2 —$p<0.05$ significant; 0.5 g/ m^2 & 1 g/ m^2 —Nonsignificant.

sprayed @ 0.5 g/m^2. In the village sprayed @ 0.5 g/m^2, during the year 2000, three cases of *Pf* were recorded, while in the village sprayed @ 1 g/m^2 not even a single *Pf* case was recorded in the same year. Where as in the control village 74 *Pf* cases were recorded during the year 2000.

Discussion

Insecticide resistance and cross-resistance among mosquito species particularly malaria vectors are well-known problems hampering the sustainable and cost-effective vector control in several tropical and sub-tropical malaria endemic countries. There is need of alternative insecticides, which could be used selectively in areas having multi-resistant vector species to tackle malaria outbreaks. The study revealed that spraying reldan @ 0.5 and 1 g/m^2 was operationally feasible and socially acceptable as 97% room coverage was obtained consistently for two years and there was not a single refusal from the inhabitants. The spraying did not stain the sprayed surface and did not produce unpleasant smell, therefore, inhabitants had given overwhelming response. The spraying was also found safe as no adverse reaction in inhabitants or in spraymen was observed during the study period.

The efficacy of residual spraying of reldan was also demonstrated against target and non-target species of mosquitoes at both single and double doses on different surfaces for several weeks. On mud and brick wall surfaces reldan @ 0.5 g/m^2 showed, 10 weeks residual effect against *An. culicifacies* as also observed by earlier workers[9,10]. Substantial reduction was also observed in non-target species of mosquitoes.

The present study also demonstrated pronounced impact on the parity rate of malaria vectors as percent parity rate had reduced drastically in both the experimental villages suggesting thereby that reldan spraying has an impact on all entomological indicators. Similarly the oocyst and sporozoite rates were nil in both the experimental villages, indicating interruption in malaria transmission.

The spraying has also an epidemiological impact on malaria incidence. Considerable reduction in cases/000 and *Pf*/000 during post-spraying years particularly in second year indicated the interruption of transmission in reldan sprayed villages. In view of these observations it can be concluded that reldan @ 0.5 g/m^2 could be used for malaria control and spray @ 1 g/m^2 is recommended for comprehensive vector control. The cost of indoor residual spraying can be further reduced particularly against *An. culicifacies* which is basically a zoophilic species, by restricting the spraying only to human dwelling rooms and taking village API as a unit as recommended earlier by Ansari *et al*[7,11]. Long-term operational studies in relative efficacy of reldan vis-a-vis conventional insecticides alongwith safety to inhabitants and spraymen are desired to evaluate its sustainability and cost-effectiveness before changing insecticide policy in the country.

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