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Status of insecticide resistance in malaria vector, *Anopheles culicifacies* in Chhattisgarh state, India

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Successful eradication of malaria in different parts of the world was achieved mainly by chemical insecticides for vector mosquito control[1]. Generally, two types of vector control methods, namely indoor residual spraying (IRS) and long-lasting insecticide-treated nets (LNs) are used for controlling malaria transmission[2]. Development of insecticide resistance in malaria vectors to conventionally used insecticides has been a serious impediment experienced by many vector control programmes. Therefore, monitoring of insecticide resistance and its changing trend in target species are basic requirements to rationalize its use in malaria control programme.

In Chhattisgarh state, *Anopheles culicifacies* (Diptera: Culicidae) is the dominant malaria vector species supported by *An. fluviatilis* in the hilly forested regions of the state. To date, DDT (organochlorine), and synthetic pyrethroids have been used for IRS in the national malaria control programme in the state. Continuous use of DDT for IRS since the inception of the programme has led to widespread resistance in *An. culicifacies* in the country[3–5]. Later, in 1970s malathion and in 1990s synthetic pyrethroids were introduced for IRS and the species developed resistance to these insecticides as well[6,7]. The use of pyrethroids for vector control further increased as it was used in IRS and also for the treatment of mosquito nets (ITNs).

Chhattisgarh has a total population of about 25 million living in 16 districts and nearly 44% of the area is forested. Malaria is a major public health problem and the state contributes about 13% of the total malaria cases reported in the country[8]. The annual parasite incidence (API-cases/'000 population/year) during 2009 was 5.2 (Source: National Vector Borne Disease Control Programme). Due to high malaria endemicity in three southern most districts, IRS with two rounds of synthetic pyrethroids annually was introduced in the programme during mid-nineties. Rest of the districts with low (central) and high (northern) malaria endemicity continued to be sprayed with two rounds of IRS with DDT.

In the present study, susceptibility tests on *An. culicifacies* were carried out in 11 districts of the state. *Anopheles culicifacies* mosquitoes were collected from one or more villages either within the district or in the congruent 2–3 districts with similar ecotype, vector prevalence and vector control activities to assess susceptibility status to DDT, malathion and deltamethrin in the year 2009 (May, July–September and November) and 2010 (January). Female mosquitoes were collected in the early morning hours using an aspirator and a torch light[9] from human dwellings and cattlesheds and transported to field laboratory in a cloth cage covered with a moist towel. Mosquitoes were identified to species based on morphological characters using standard identification key. Mosquitoes were exposed to insecticide-treated papers of DDT (4%), malathion (5%) and deltamethrin (0.05%) procured from Vector Control Research Unit, University Sans Malaysia. After an exposure to insecticide for 1 h, mosquitoes were held for 24 h holding period at 27±2ºC temperature and 70–80% relative humidity and percent mortality was determined. Mortality was corrected using Abbott's formula when the mortality in control replicates was between 5 and 20%. Tests with control mortality of >20% were discarded. The data are interpreted in three classes as per the WHO criteria of susceptibility, status namely susceptible – mortality ≥98 and, verification required (tolerant) – 81 and 97%, and resistant—mortality ≤ 80%[10].

Results of the susceptibility tests are given in Table 1 and Fig. 1. In tests against DDT, the mortality in *An. culicifacies* varied from 3.2% (Kanker district) to 33.7% (Bilaspur, Korea and Korba districts). In tests against malathion, mortality varied from 39.4% (Jagdalpur district) to 73.5% (Raipur and Dhamtari districts). In tests against deltamethrin, mortality varied from 68% (Raigarh and Jashpur districts) to 98.7% (Dantewada district). Applying the WHO criteria for susceptibility status the species has developed resistance to DDT and malathion in all the districts surveyed in the present study. However,

to deltamethrin it was reported resistant in Jagdalpur, Raipur, Dhamtari and Raigarh districts[11]. Whereas verification was required (tolerant) in Kanker, Bilaspur, Korea and Korba districts. However, *An. culicifacies* was found susceptible to deltamethrin in Dantewada district (Table 1).

Development of insecticide resistance in disease vectors was seen as a threat for the sustainability of chemical based interventions for vector control. There are about 125 mosquito species with documented resistance to one or more insecticides[12]. Resistance in *An. culicifacies* against DDT has been reported in several parts of India[3,4]. About 128 fold increase in resistance to DDT was reported from Maharashtra[13]. In villages of Haryana, *An. culicifacies* was reported susceptible to malathion[14] and tolerant (VR) in Gumla district of Jharkhand[15], whereas widespread resistance was recorded from Maharashtra[16] Gujarat[17] and Uttar Pradesh[18]. *Anopheles culicifacies* was reported susceptible to deltamethrin in Uttar Pradesh[5,18] and Gumla district of Jharkhand state[15] and probably synthetic pyrethroids have not been used so far in these areas for IRS whereas in the present study, *An. culicifacies* recorded 98.7% susceptibility to deltamethrin in Dantewada district but was tolerant (VR) in Kanker district. In other districts, it was found either resistant or tolerant. Reported deltamethrin-resistance in some districts in the absence of its use in the malaria control programme needs further

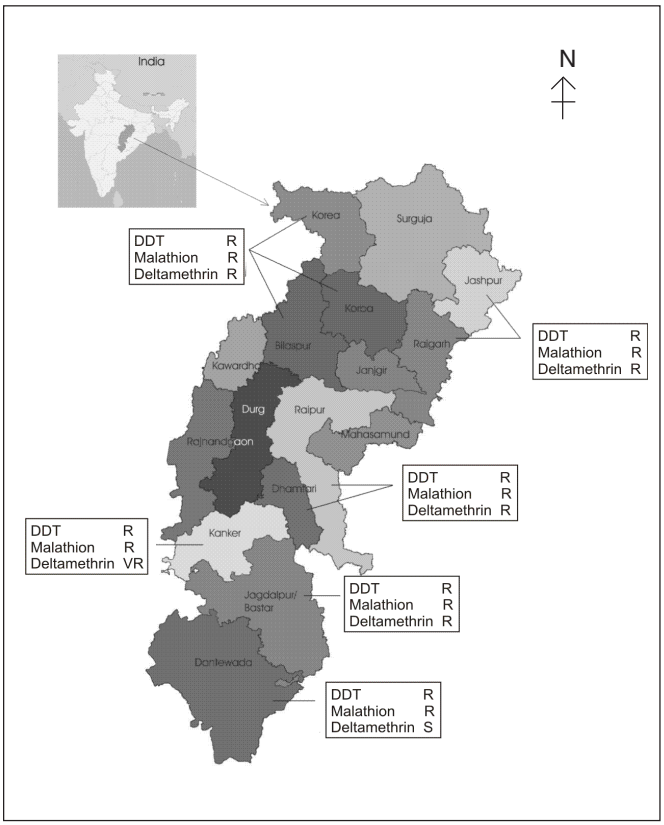

Fig. 1: Map showing insecticide resistance status of *An. culicifacies* in different districts of Chhattisgarh state, India (R = Resistant; S = Susceptible; and VR = Verification required or tolerant).

Table 1. Results of susceptibility tests of *An. culicifacies* to DDT, malathion and deltamethrin in different districts of Chhattisgarh state

Insecticide tested & concentration	District	PHC	No. of villages surveyed	No. exposed		No. dead in 24 h		% Mortality		Corrected mortality (%)
				Exp	Cont	Exp	Cont	Exp	Cont	
DDT (4%)	Dantewada	Dantewada	5	82	40	21	7	25.6	17.5	9.8
	Kanker	Dhaneli Kanhar/Kapsi	2	186	60	6	0	3.2	0	3.2
	Jagdalpur	Pharasgaon	3	100	30	21	1	21	3.3	21
	Raipur/Dhamtari	Rajim/Kareli	4	99	48	4	0	4	0	4
	Bilaspur/Korba/ Korea	Basti/Pali/Khadgaon	5	95	46	32	0	33.7	0	33.7
	Raigarh/Jashpur	Lailunga	10	60	30	6	0	10	0	10
Malathion	Dantewada	Dantewada	5	85	32	47	0	55.3	0	55.3
(5%)	Kanker	Dhaneli Kanhar	2	216	73	150	0	69.4	0	69.4
	Jagdalpur	Pharasgaon	3	100	40	47	5	47	12.5	39.4
	Raipur/Dhamtari	Rajim/Kareli	4	98	41	72	0	73.5	0	73.5
	Bilaspur/Korba/ Korea	Basti/Pali/Khadgaon	5	108	56	51	5	47.2	8.9	42
	Raigarh/Jashpur	Lailunga/Pathalgaon	10	66	30	28	0	42.4	0	42.4
Deltamethrin	Dantewada	Geedam	5	96	41	95	7	98.9	17.1	98.7
(0.05%)	Kanker	Dhaneli Kanhar/Kapsi	2	190	76	160	4	84.2	5.3	83.3
	Jagdalpur	Pharasgaon	3	100	40	77	0	77	0	77
	Raipur/Dhamtari	Rajim/Kareli	4	98	44	77	0	78.6	0	78.6
	Bilaspur/Korba	Basti/Pali	5	118	63	95	3	80.5	4.8	80.5
	Raigarh, Jashpur	Lailunga	10	75	30	51	0	68	0	68

Exp: Test replicates; Cont: Control replicates.

investigations and may be contemplated to its use in agriculture.

Development of pyrethroid resistance in *An. culicifacies* is of great concern for the malaria control programme in the present scenario of the prevalence of multiple insecticide-resistant vectors and the reports of pyrethroid-resistance is alarming. This is more so in view of the non-availability of new and effective insecticide molecules for the management of insecticide-resistant vectors. Since the introduction of pyrethroids in the 1980s, no new adulticide has been approved for vector control by the World Health Organization[19]. However, we have to rely upon the presently available insecticides for the management of malaria vectors till more effective alternatives are available. Therefore, to have appropriate vector control strategies, regular monitoring of insecticide susceptibility in malaria vector is needed for effective disease vector management. The results of the present study in some districts of the Chhattisgarh state clearly indicate the changing scenario of insecticide resistance in the major malaria vector *An. culicifacies*.

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