Insecticide-treated Mosquito Nets (ITNs) and Curtains (ITCs)

One of the major innovations in the field of malariology during the past two decades is the development of the technology of insecticide-treated mosquito nets (ITNs). Mosquito nets or curtains have been in use since long in many civilizations including India. The Italian traveller Marco Polo had mentioned in his travelogue that nobles in southern India used the mosquito curtains made of light cane work in the 13th century AD. Although deliberate treatment on nettings with repellents and even DDT were tried to provide additional protection to individuals against blood sucking insects like mosquitoes, development of pyrethroids during the 1980s led to evaluation of pyrethroid-treated netting and clothing materials against mosquito vectors. Until 1990, several small-scale trials in various countries demonstrated the effectiveness of nets treated with pyrethroids in reducing malaria and vector populations. In China, nets treated with deltamethrin were in large-scale use around this period. As was being done in Africa and other endemic countries, contemporary laboratory and field trials with untreated and treated mosquito nets were carried out in endemic states of India as well.

ITN Trials in Assam

To evaluate effectiveness of mosquito nets in malaria control, the first field trial was carried out in Sonapur PHC, Assam during 1987 to 1991 in areas where *An. minimus* was the main malaria vector (Jana-Kara *et al*., 1995 & Sharma *et al*., 1996). Cotton nets treated with deltamethrin WP at 25 mg/m^2 were found effective in reducing *An. minimus* population and malaria incidence (Fig. 21). In villages

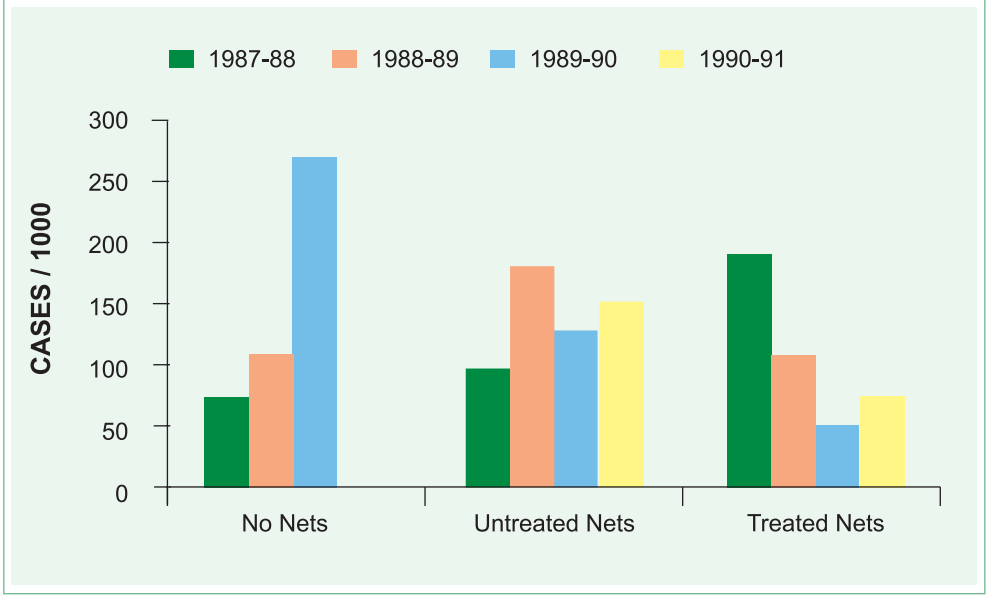

Fig. 21: **Impact of untreated and deltamethrin treated nets on malaria in Assam**

with untreated cotton nets malaria situation remained unchanged, whereas in villages without nets malaria incidence rose significantly during the trial period. General acceptance of nets by the communities was satisfactory.

Another trial comparing efficiency of nylon nets treated with deltamethrin (25 mg/m^2), lambdacyhalothrin (25 mg/m^2), untreated nets and no nets in Sonapur also showed a superior protection of treated nets over untreated nets or no nets (Fig. 22).

ITN Trials in Orissa

Most of the rural malaria in India is transmitted by *An. culicifacies* and in hill forests by *An. fluviatilis*. Thus, it was imperative to test efficacy of ITNs in areas where these species were the main malaria vectors. Hence, a trial was carried out from 1989 to 1994 in areas of north Orissa where above mentioned two species were the main malaria vectors. In tribal villages of Sundergarh district, nylon nets treated with deltamethrin SC or lambdacyhalothrin EC at 25 mg/m^2 reduced indoor densities of malaria vectors, *An. culicifacies* and *An. fluviatilis*, their biting rate

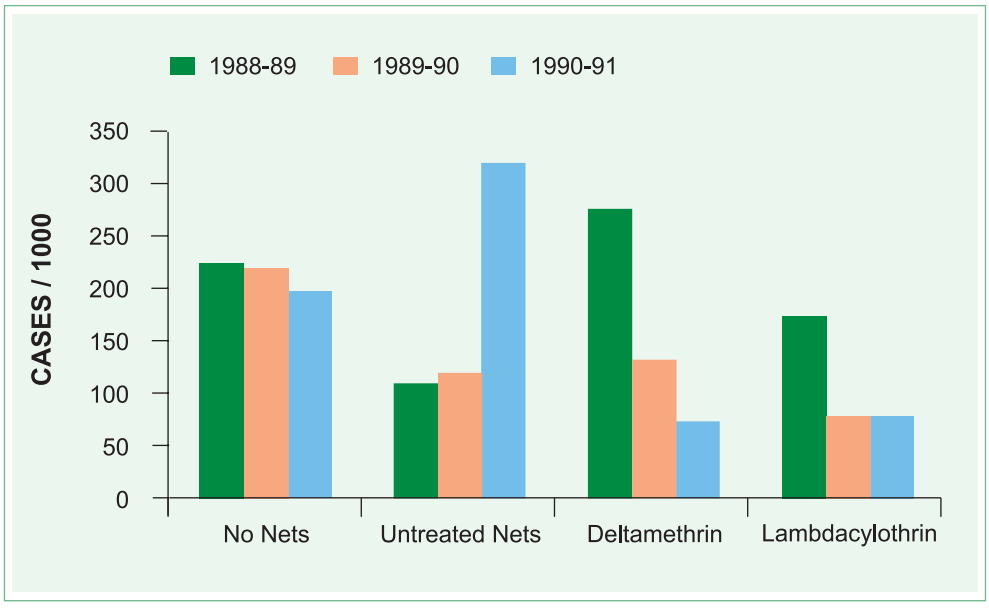

Fig. 22: **Impact of untreated nets and nets treated with lambdacyhalothrin and deltamethrin in another trial in Assam**

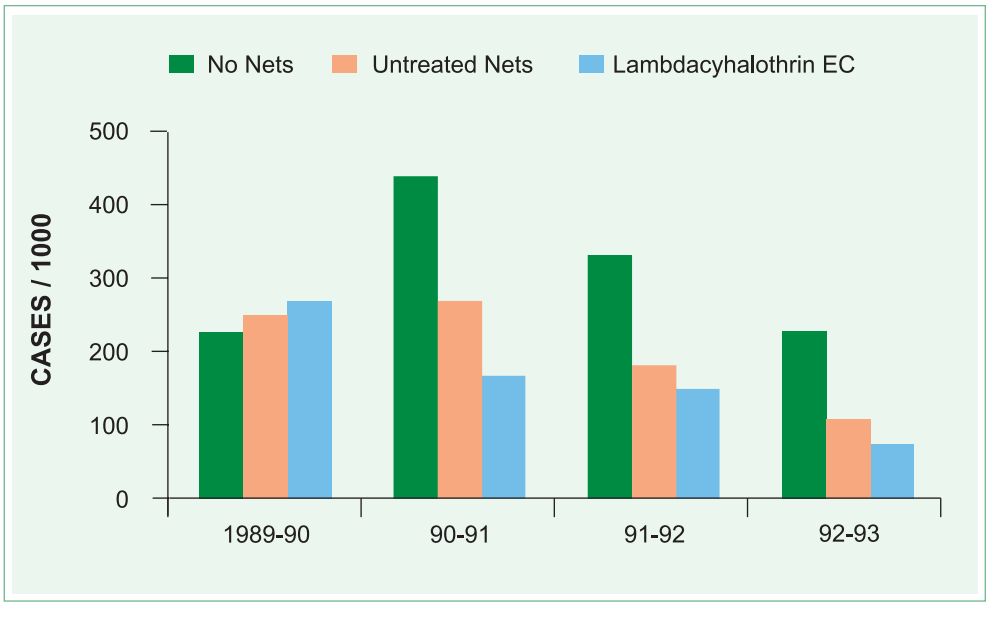

Fig. 23: **Impact of lambdacyhalothrin-treated nets on malaria in Orissa state**

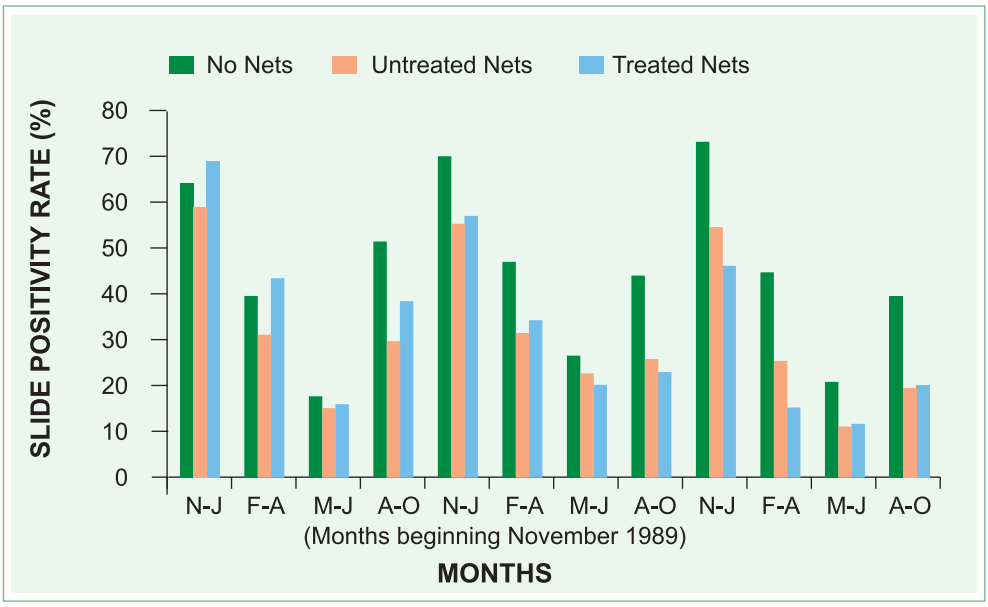

Fig. 24: **Impact of deltamethrin-treated nets on malaria in Orissa**

and the malaria incidence significantly (Figs. 23 & 24) (Sampath *et al.*, 1998 & Yadav *et al.*, 1998, 2001).

In the mining areas, where malaria caused tremendous economic loss due to loss in man days, use of cyfluthrin-treated nets resulted in considerable reduction in *An. fluviatilis,* and incidence of malaria (Fig. 25), as well as anaemia and spleen rates in protected children (Sharma and Yadav, 1995). Hospital occupancy due to malaria in two mining hospitals decreased. Minor communities accepted the treated nets very well and perceived that such nets even reduced other household insect pests besides mosquitoes. Human toxicity studies reported that the treated nets were safe to impregnators and users (Yadav *et al.*, 1996 & Satpathy *et al.*, 1997).

ITN Trials in Madhya Pradesh

Simultaneously during the years 1989–91 another trial conducted in some tribal villages of Mandla district in Madhya Pradesh, where *An. culicifacies* and *An. fluviatilis* are malaria vectors, showed a low impact of treated nets. The reasons for low impact were poor compliance by inhabitants due to their varied socioeconomic status and means of livelihood. Later, another trial in the villages of Jabalpur district,

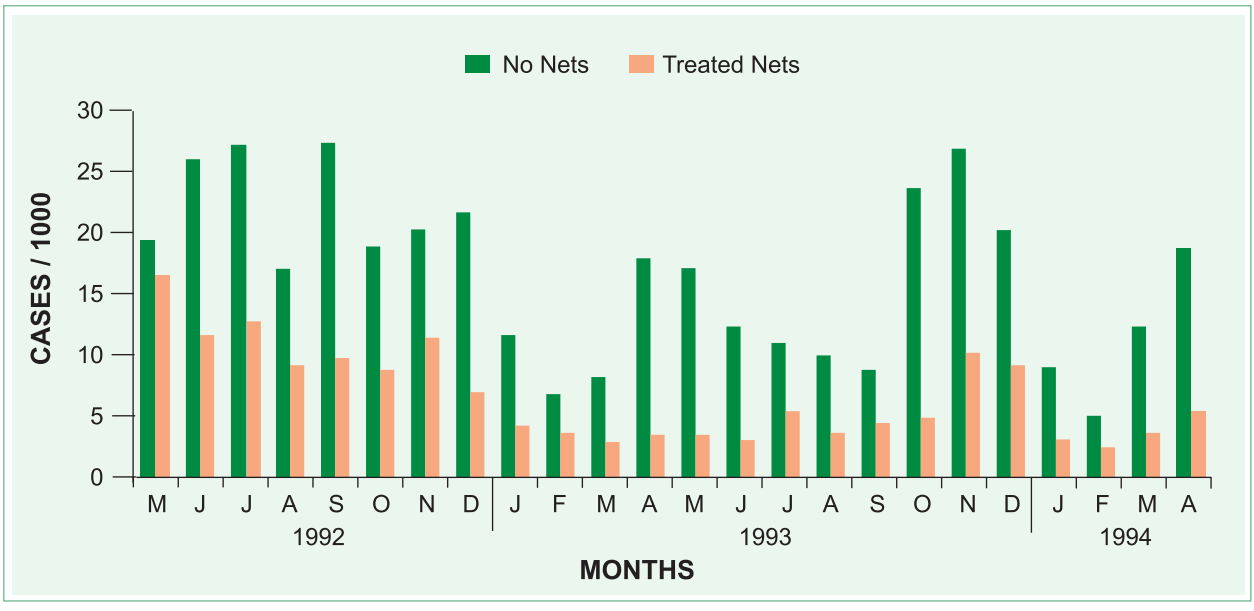

Fig. 25: **Efficacy of cyfluthrin-treated nets on malaria in mining settlements, Orissa**

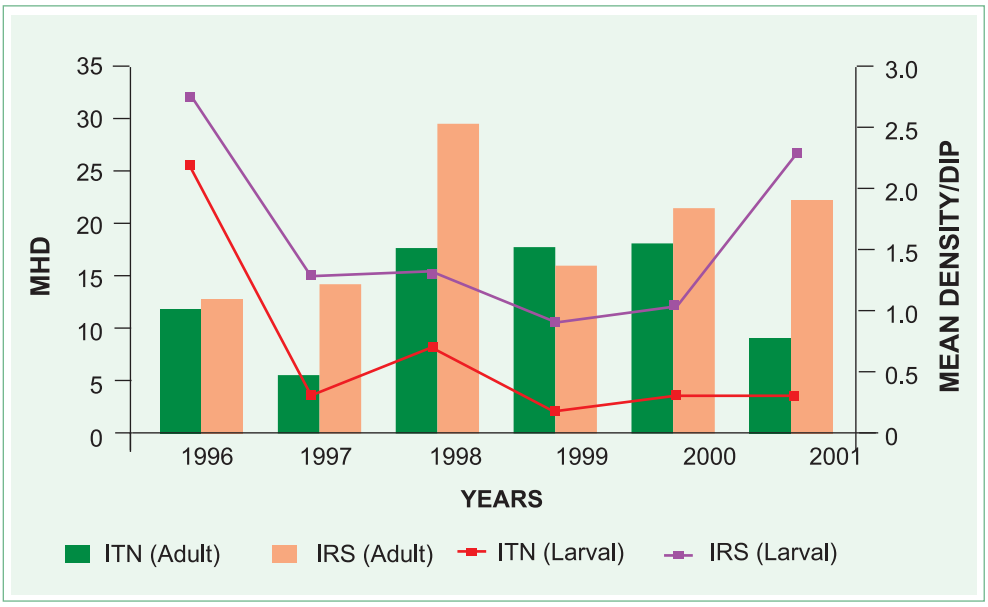

Fig. 26: **Comparative efficacy of ITN and IRS with cyfluthrin on adult and larval densities**

however, showed a marginally better efficacy of cyfluthrin-treated nets over routine or supervised spraying of DDT indoors.

Comparative efficacy of ITN and IRS in Karnataka

A study was carried out in PHC Kanakatte, District Hassan, Karnataka during the years 1995—2001. During the year 1995, baseline data was collected. Cyfluthrin impregnated mosquito nets @30 mg/m^2 were distributed to inhabitants in 7 villages in 1996. Compliance for the usage of bednets was ensured by imparting health education.

First impregnation was made by villagers under MRC supervision in March 1996 and subsequent re-impregnations were made in November 1996, May 1997 and December 1997 respectively. Entomological evaluations were done by MRC at regular intervals during the intervention period. Malaria surveillance was carried out by the State Health Department. PHC, Belagur, District Chitradurga, Karnataka was under IRS with cyfluthrin. Comparative efficacy of ITN and IRS areas was studied for these two areas.

It was observed that adult and larval densities of *An. culicifacies* (vector mosquito) were low in areas with intervention of ITN (Fig. 26). The results of the five year study indicated substantial decrease in malaria incidence in ITN area as compared to area with IRS (Fig. 27). During the years 1996—1998, in both bednet

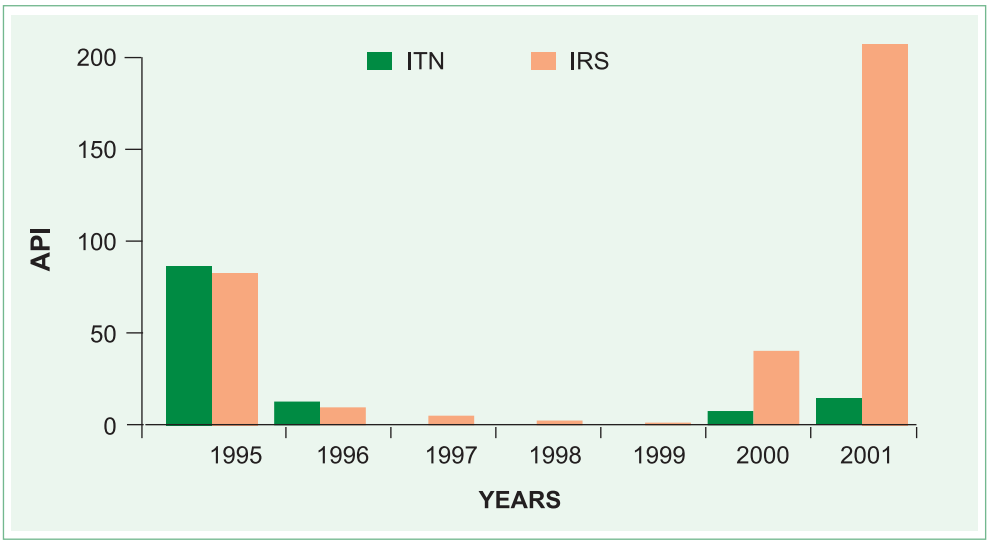

Fig. 27: **Comparative efficacy of ITN and IRS with cyfluthrin on malaria incidence**

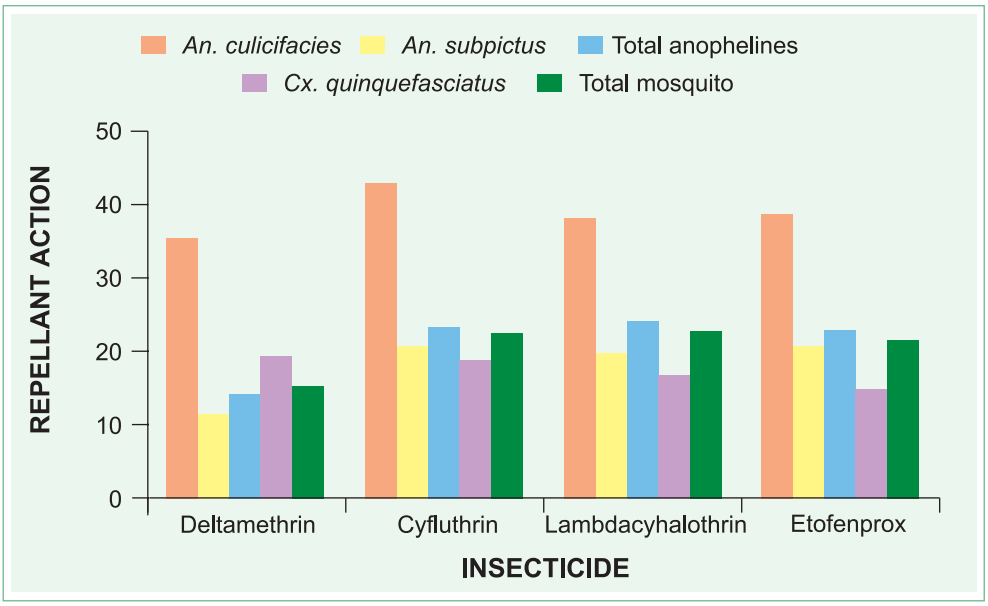

Fig. 28: **Repellent action of insecticide-treated mosquito nets against different species of mosquitoes under field conditions**

and IRS areas there was decrease in malaria incidence compared to 1995. It was observed that during the years 1999—2001, the malaria incidence in IRS areas in the absence of indoor spray increased substantially, while in ITN areas the incidence remained low even with the use of bednets without further re-impregnation after 1998.

ITN Trials in Ghaziabad

The relative efficacy of insecticide-treated mosquito nets was evaluated under field conditions in Dehra village of Dhaulana PHC, District Ghaziabad (U.P.), India during 1996. Nylon nets were impregnated with deltamethrin, cyfluthrin, lambdacyhalothrin and etofenprox at 25 mg/m^2 by standard methods. Repellency and excito-repellency, killing and airborne actions were monitored from dusk to dawn by hourly collection of mosquitoes that entered and rested in rooms and also females that landed on treated and untreated mosquito nets. Results revealed 15.3–22.9% repellent action, 98.3–99.3% excito-repellency action and 100% mortality of females that landed on treated fabrics (Ansari and Razdan, 2000). No significant differences were observed in the efficacy of different synthetic pyrethroids against anophelines (Fig. 28). However, against *Cx. quinquefasciatus* Say there was a significant difference between deltamethrin and etofenprox. Control of anophelines was more pronounced than *Cx. quinquefasciatus*. There was no pronounced airborne action with any insecticide tested. Synthetic pyrethroids with strong airborne action may be more appropriate for impregnation of mosquito nets.

ITN Trials in Haryana

A field trial was carried out in the year 2000 in villages of District Sonepat, Haryana to assess the efficacy of bifenthrin as an impregnant on mosquito nets. Phase II trial was conducted to assess the comparative efficacy between two formulations namely suspension concentrate and micro-emulsion. Efficacy was studied for both the formulations at three doses of impregnation, 10, 25 and 50 mg/sq m. Net bioassays to assess the persistence indicated bioavailability up to 11 fortnights (~ 5 months) at all the doses of the two formulations (Fig. 29). There was an estimated 50% reduction in the entry of the mosquitoes into the houses with intervention of treated nets compared to the houses without treated nets indicating the impact of the insecticide (Fig. 30). The excito-repellency rates in the mosquito were low in houses with nets impregnated with ME formulations and was marginally higher than the houses with non-impregnated nets. These results indicated increased human-mosquito contact in intervention with ME formulations (Fig. 31). Uniform bio-availability of the insecticide on nets was

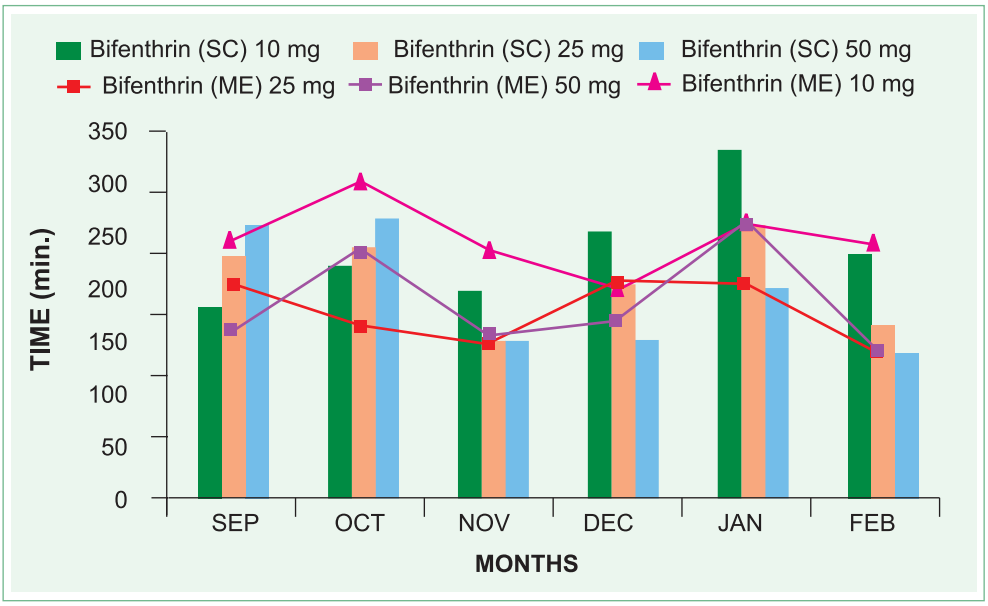

Fig. 29: **Average knock-down rates in mosquitoes in ring-net bioassays on treated nets in different months**

observed with all the doses of the two formulations including the ME formulation and in view of the increased excito-repellency rates with this formulation, Bifenthrin ME formulation was suggested for impregnation @ 10 mg/sq m. for future use.

ITC Trials in District Ghaziabad (U.P.)

In selected villages of District Ghaziabad, operational feasibility and efficacy of hessian curtains impregnated with deltamethrin @ 100 mg/m^2 was evaluated in comparison to indoor residual spraying of HCH @ 0.2 g/m^2. The impregnation was carried out before the onset of transmission and observations were continued up to two transmission periods. District Health Authorities sprayed HCH indoors. There was 87% reduction of *An. culicifacies* up to six months and 61.6% reduction in total mosquitoes in comparison to HCH indoor residual spraying (Ansari and Razdan, 2000). Follow-up studies revealed that the impact of deltamethrin impregnated curtains declined after 6–7 months. The results of bioassay tests revealed 100% mortality up to 6–7

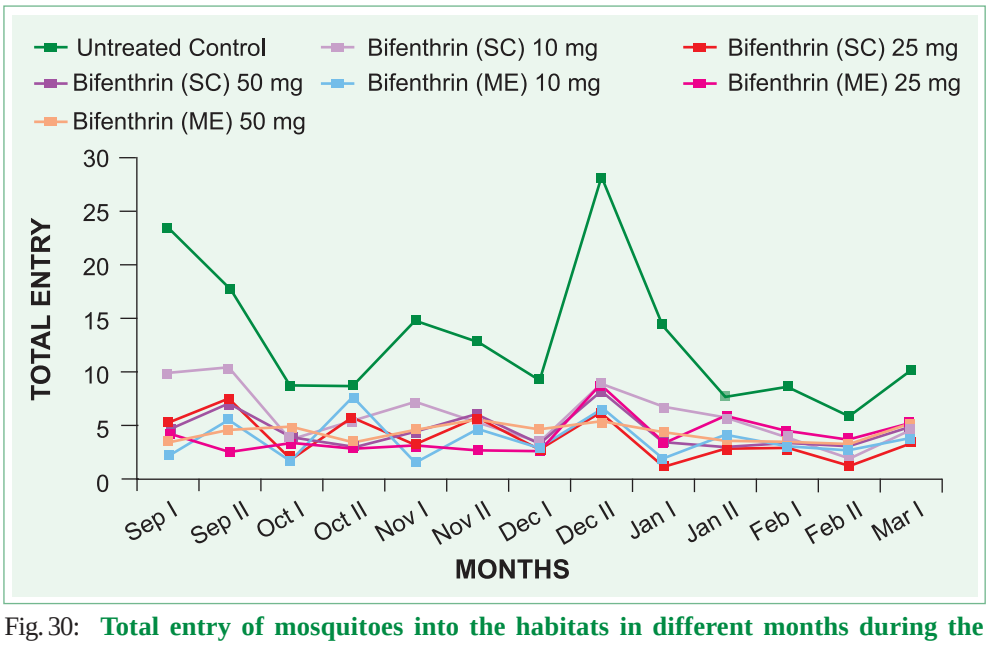

Fig. 30: **Total entry of mosquitoes into the habitats in different months during the intervention period**

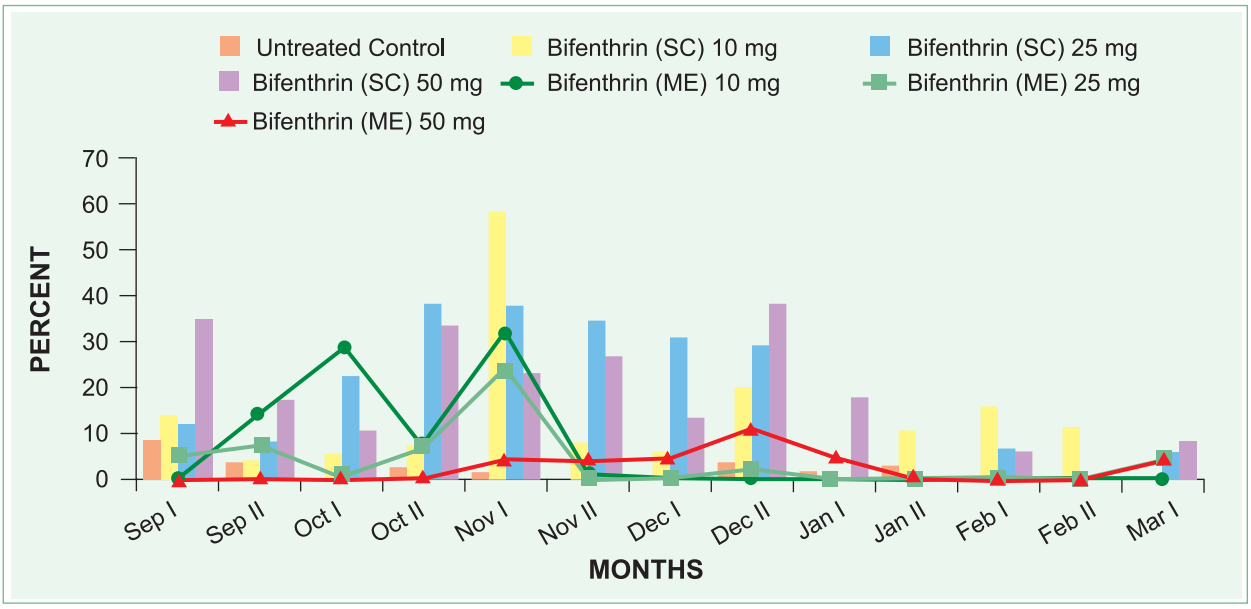

Fig. 31: **Excito-repellency rates in the mosquitoes with different insecticide formulations**

months. Epidemiological evaluation revealed 81.9% reduction in total malaria cases as against 88.5% with *P. falciparum* cases. Similar reduction was also observed when slide positivity rate (SPR), slide falciparum rate (SfR), cases/1000 and *Pf*/1000 were compared to corresponding village. Pilot studies have indicated to evaluate the efficacy of impregnated curtains on a large-scale as these are relatively cheaper than the conventional vector control method—insecticide residual spraying.

Relative Efficacy of Insecticide-treated Curtains (ITCs) against Mosquitoes under Laboratory Conditions

The relative efficacy of pyrethroid-impregnated fabrics was evaluated against *An. stephensi*, *Aedes aegypti* and *Cx. quinquefasciatus* under laboratory conditions (Ansari *et al*., 1998). Results revealed that deltamethrin(D) was significantly superior in comparison to lambdacyhalothrin(L) and cyfluthrin(C). Results of bioassay tests and relative toxicity index (RTI) revealed that deltamethrin was 1.5 and 1.9 times more effective than lambdacyhalothrin and cyfluthrin, respectively, against *An. stephensi* exposed to cotton fabric treated at 100 g/m^2. Similarly, deltamethrin was 3.9 and 4.6 times more effective than lambdacyhalothrin and cyfluthrin respectively against *Ae. aegypti* and 3.5 and 4.0 times more effective against *Cx. quinquefasciatus* respectively. Of the four fabrics—cotton, nylon, polyethylene and jute, cotton was the best on the basis of median lethal dose (LD_{50}) and 90% lethal dose (LD_{90}) values and persistence of insecticide (Fig. 32).

ITC Trials in Delhi

A field trial in an area in New Delhi Municipal Committee to demonstrate composite control of *An. stephensi* and *Ae. aegypti* by spraying deltamethrin at 100 mg/m^2 on window and door curtains of habitations showed 88–93% reduction of the vector species in the experimental area (Ansari and Razdan, 2001). The impact of deltamethrin-treated curtains was also evident against nontarget species (67.9–85.7%; $p < 0.05$). Treated curtains provided 100% kill of *Anopheles stephensi* and *Ae. aegypti* for 3–4 months, followed by a gradual decline in successive months. Use of deltamethrin-treated curtains resulted in 92% reduction in slide positivity rate and 95.4% reduction in malaria cases/1000 population (Fig. 33). The cost of deltamethrin treatment was Rs. 41.15 (< U.S. $1.00) per house per annum. Insecticide-treated mosquito window and door curtains, along with legislative measures, may provide cost-effective concurrent control of mosquitoes and other domestic pests.

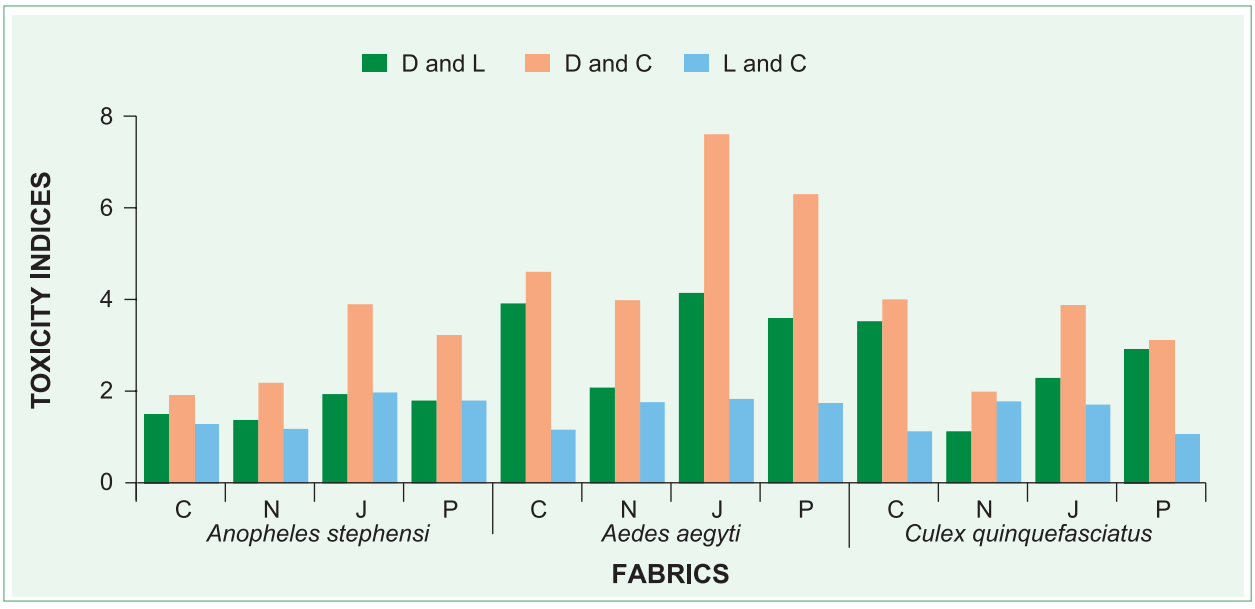

Fig. 32: **Relative toxicity indices on different fabrics (C: Cotton, N: Nylon; J: Jute and P: Polyethylene)**

Efficacy of water dispersible deltamethrin tablets for treatment of individual nets of different fabrics

Deltamethrin water dispersible tablets (K-O TAB®) offer operational advantages and ease in use over the liquid formulations of pyrethroids. K-O TAB were evaluated for bio-efficacy and persistence on different fabrics namely cotton, nylon and polyester nets against malaria vectors *An. culicifacies* and *An. stephensi* in Kheda, Gujarat during 2001—02. Mosquito nets treated @ 25 mg/m^2 were distributed in 3 villages, during June and July 2001. Both treated and untreated were distributed in three villages. A set of 4 nets (2 each treated and untreated) of each fabric was kept in the laboratory for evaluation of shelf life of treated nets. Cone bioassays were carried out at monthly interval using laboratory reared *An. culicifacies* and *An. stephensi* by exposing on the treated surface for 3 minutes. Impact of washing frequency on the efficacy and persistence of insecticide on different types of fabrics, at first wash at one-month and second wash at three months interval was studied.

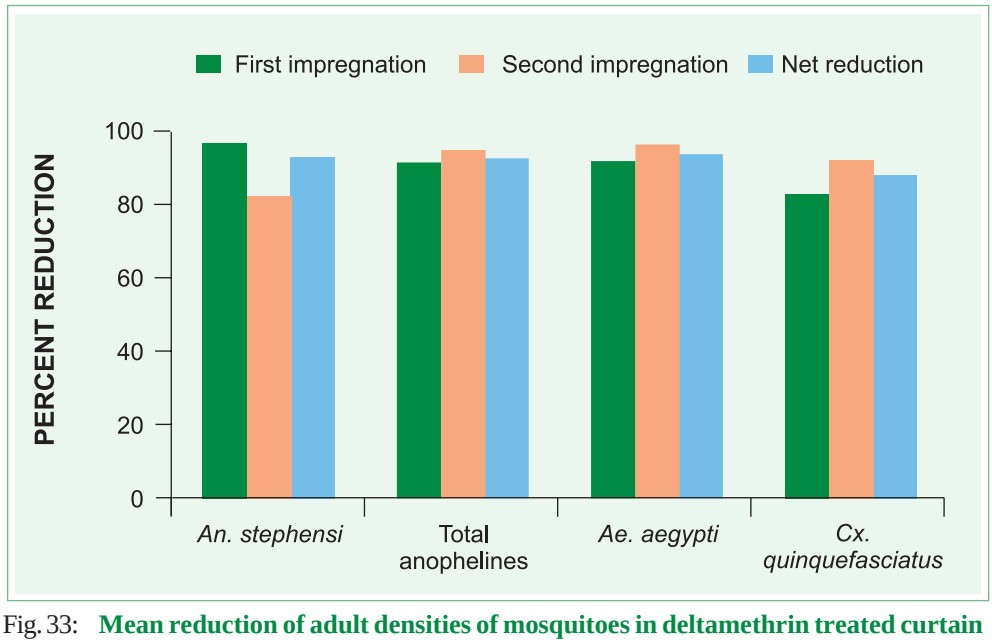

Fig. 33: **Mean reduction of adult densities of mosquitoes in deltamethrin treated curtain area—Moti Bagh, New Delhi**

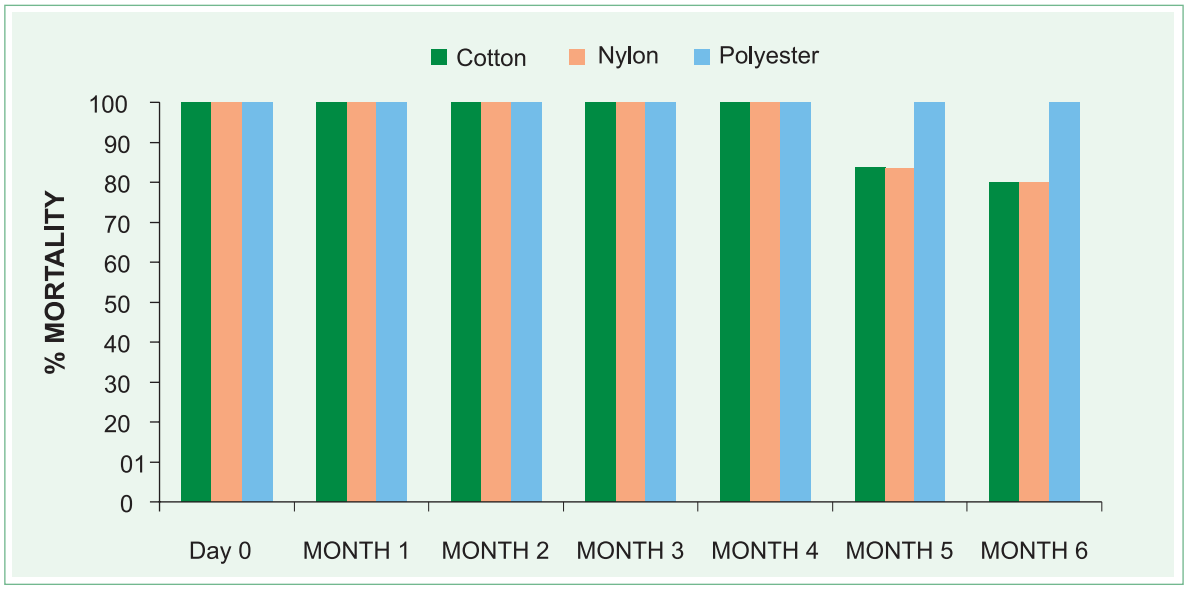

Fig. 34. **Bioassay of K-O TAB treated nets on *An. culicifacies.***

In cone bioassays on cotton and polyester nets distributed for field use indicated more tolerance in *An. stephensi* as compared to *An. culicifacies*. Bioassays on unwashed field used cotton, nylon and polyester nets registered 100% mortality in *An. culicifacies* up to 4 months after the treatment (Fig. 34) and in *An. stephensi* mortality ranged from 90–100% till that period (Fig. 35). Bioassays on unwashed cotton, nylon and polyester nets, 5 months after the treatment, produced 75, 91.7 and 83.3% mortality in *An. stephensi* and 83.9, 83.3 and 100% mortality in *An. culicifacies*, respectively.

Bioassays of *An. stephensi* on cotton nets washed once and twice produced 40 and 55% mortality respectively as against 75% mortality on unwashed nets after 5 months of treatment. Similarly, mortalities on washed polyester nets were 70% (1 wash) and 66.7% (2 washes) as against 83.3% on unwashed nets. Contrary to this, bioassays on nylon nets washed once and twice produced less mortality in *An. stephensi* (93.3 and 86.7% respectively) than in *An. culicifacies* (73.3 and 76.7% respectively). Washing had no significant impact on efficacy against *An. culicifacies* exposed to cotton nets washed once

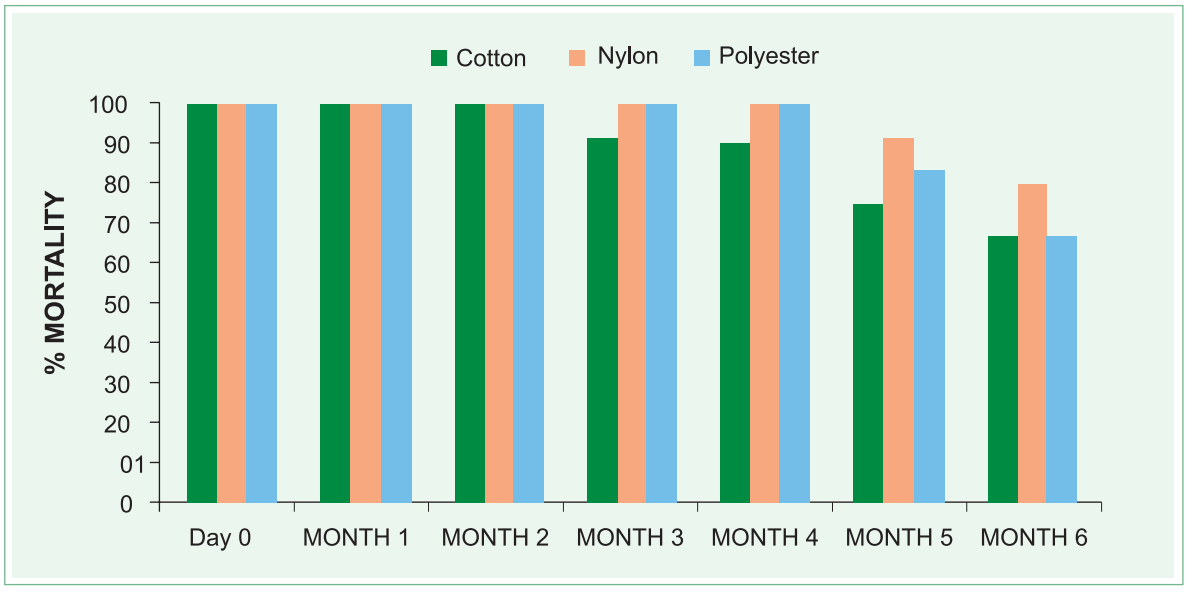

Fig. 35. **Bioassays of K-O TAB treated nets on *An. stephensi*.**

(81.7%) and twice (80%), and to polyester nets washed once (100%) and twice (75%).

Thus K-O TAB would help ensure a better community acceptability and sustainability.

Sustainability of ITNs

The efficacy of ITNs against malaria transmitted by local mosquito vectors in many areas has been proved in field by MRC but the question of sustainability needs to be addressed (Yadav and Sharma, 1997). A field project in collaboration with British Council Division (U.K.) and M/s. CARE India was undertaken in Keonjhar, Orissa in 1994 (Yadav, 1997). The project showed that it was possible to promote purchase and use of treated nets by community financing (sale of nets). The National Anti Malaria Programme adopted the ITN-technology and distributed ITNs in northeastern states. These are now being promoted through the antimalaria programmes of different states and this constituted a major advancement in vector and malaria control. Also, in National Anti Malaria Programme's Enhanced Malaria Control Project being implemented in 100 districts in eight states, sustainability of ITNs is being evaluated.

In considering sustainability, distinction needs to be made between programme sustainability from the managers' point of view, which is restricted to the programme cycle and overall sustainability of ITNs as a component of the antimalaria strategy. While sustainability is not easy to define or measure, three main indicators that could be used are: proportion of population using or willing to use ITNs; proportion of ITNs actually retreated; and decreased reliance on single-source external intervention and shift towards a greater community ownership/participation. Thus, sustainability of an ITN programme will depend upon various factors such as the acceptability, feasibility, affordability, technical support requirements, production, sale and distribution systems of nets.

Further studies on the issues like efficacy of better formulations of insecticides for treatment of nets are in progress at MRC, Delhi and its field stations in collaboration with WHO Pesticide Evaluation Scheme, and on development of resistance in local mosquito populations against pyrethroid insecticides.

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