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Laboratory wash-resistance and field evaluation of deltamethrin incorporated long-lasting polyethylene netting (Netprotect®) against malaria transmission in Assam, north-east India

V. Dev[a,*], S. Phookan[a], K. Padhan[a], G.G. Tewari[a], K. Khound[b]

[a] National Institute of Malaria Research (Field Station), Guwahati 781 022, Assam, India
[b] State Health Directorate, Government of Assam, Hengrabari, Guwahati 781 036, Assam, India

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ABSTRACT

North-east India is co-endemic for *Plasmodium falciparum* and *P. vivax* malaria, and disease transmission is perennial and persistent. This study reports the results of a field-based village scale trial of deltamethrin incorporated long-lasting polyethylene netting (Netprotect®) conducted in *P. falciparum* predominant pocket of Assam, north-east India to assess operational feasibility, acceptability and sustainability against disease vectors and malaria transmission. The study monitored the residual efficacy of the long-lasting net in relation to serial washings in the laboratory and malaria prevalence in experimental villages for the first year of investigations from September 2008 to June 2009. The mosquito vector populations of *Anopheles minimus* were observed to be highly susceptible to deltamethrin (0.05%), and follow up investigations revealed that the vector mosquito had virtually disappeared in Netprotect® intervention villages. Concurrently, there was consistent decline in malaria cases in Netprotect® villages and transmission reduction was statistically significant compared to untreated net (net without insecticide) and no-net control villages for the corresponding study period. The contact cone-bioassay investigations against malaria transmitting mosquito species revealed that the bioavailability of the insecticide on the net fiber was persistent up to 20th serial wash resulting in ≥80% mortality. Community compliance and acceptance were high, and users reported decreased nuisance due to biting mosquitoes. It was concluded that deltamethrin incorporated polyethylene long-lasting netting was safe, wash-resistant, and assessed to be an operationally feasible, community-based intervention for sustainable management of disease vectors to prevent malaria transmission.

1. Introduction

North-east India (22°4′–29°31′N lat.; 89°48′–97°25′E long.) is co-endemic for *Plasmodium falciparum* and *P. vivax* malaria and transmission intensity ranges from low to moderate (Dev et al., 2009). *Anopheles minimus* is the predominant mosquito vector species and DDT is the choice insecticide for the control of disease transmission in this part of the country (Raghavendra et al., 2011). However, high refusal rates to DDT indoor residual spraying by the communities (48–50%) resulting in persistent transmission have necessitated evaluation of new technologies that are more suitable and community-based (Prasad, 2009). Among alternative approaches, initial village scale studies using mosquito nets impregnated with pyrethroid were highly successful (Jana-Kara et al., 1995), but re-treatment of the community-owned mosquito nets that were deemed necessary at six monthly intervals remained <5% in the target population (source, State Health Directorate of Assam). The advent of long-lasting insecticidal nets (LLINs) is a welcome development in obviating the re-treatment exercises optimizing much needed community compliance. These nets are treated at the manufacturing level with insecticide that is either coated around fibers or incorporated into the fibers and is resistant to multiple washes. Multi-centre field-based studies in India on the bio-efficacy of LLINs against malaria vectors in different eco-epidemiological conditions have been reported to be promising resulting in appreciable disease transmission reduction (Ansari et al., 2006; Sreehari et al., 2007; Sharma et al., 2006, 2010; Dev et al., 2010a,b). In various efforts to roll back malaria, LLINs have been strongly advocated to reduce malaria transmission and are increasingly in demand for use in health systems to target high-risk population groups (WHO, 2010). We report the research findings of a trial designed to assess the residual efficacy of deltamethrin incorporated polyethylene netting (Netprotect®) in relation to serial washings against anopheline mosquito disease vector and

* Corresponding author. Tel.: +91 9435345154; fax: +91 361 2339131.
E-mail address: mrcassam@hotmail.com (V. Dev).

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suspected vector species, and to study the impact on disease transmission for the first year (September 2008–June 2009) of follow up investigations in valley area of Assam (north-east India).

2. Materials and methods

2.1. Study net specifications

Netprotect® LLIN is made of 100% polyethylene incorporated with insecticide deltamethrin at 2 g a.i./kg fiber equal to target dose of 65 mg a.i./m^2. The nets distributed were wrap knitted, monofilament 100 denier strength (mesh size 136, weight 35 g/m^2), white color, with dimensions (160 cm $W \times 180$ cm $L \times 150$ cm H). The majority of the insecticide is located inside the fiber, protecting it from degradation through activities such as rinsing and washing. The insecticide migrates to the surface of the fiber, through a controlled release system, where it is able to kill mosquitoes and other insects which come in contact with the net fiber. Untreated nets (nets without insecticide) of same specifications were used as control for comparative purposes.

2.2. Study populations and net distribution

The study was conducted in malaria endemic villages of the Bokajan Primary Health Centre (PHC) of Karbi Anglong hill district of Assam, north-east India (Fig. 1). The area is endemic for drug-resistant malaria against commonly used antimalarials including chloroquine and sulfadoxine-pyrimethamine, with a predominance of *Plasmodium falciparum* (>90% of cases), and remaining cases are due to *P. vivax*. Malaria which is largely transmitted by *A. minimus* (a perennial species), which is highly anthropophilic for predilection for human blood, rests indoors, and foothill seepage water streams are the preferred breeding habitats. Annual rainfall associated with the south-west monsoons is heavy (2–3 m), and much of it occurs during April–September/October (wet season), corresponding to high transmission period, and for rest of the year there is little rainfall (low transmission period). Many villages are inundated by recurrent floods rendering them inaccessible for healthcare services. The mean monthly relative humidity varies from 60 to 80%, and most of the year is hot and humid (22–33 °C) from March till October (minimum of 10 °C), which marks the winter season. The study population groups were ethnic tribal communities living in impoverished conditions with little awareness on disease prevention and control. Typically each household had two to three rooms made of bamboo with thatched roofing clustered in small hamlets. The livelihood is largely based on forest produce, handlooms and paddy farming for self-subsistence.

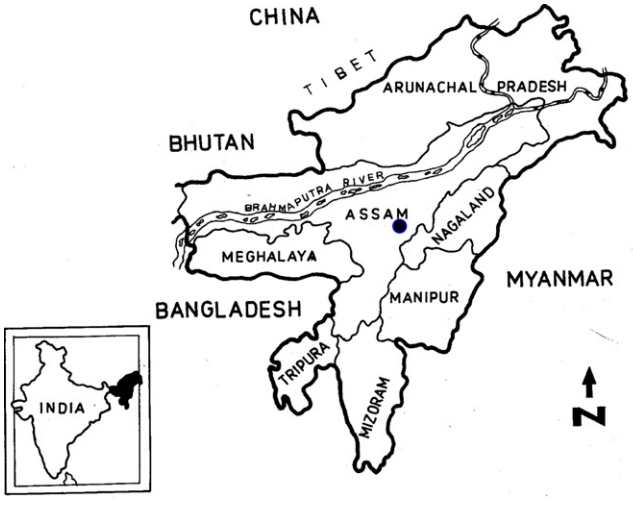

Fig. 1. Map of the north-eastern states of India. The study site located south of the Brahmaputra River is denoted by dot (•). The inset map shows the geographical location of the north-eastern region of India.

Taking cognizance of similar ecological characteristics and cultural practices, 11 villages were short listed, and randomized in three clusters based on comparable malaria prevalence and mosquito productivity with an target population of ~2000 each: (i) seven villages with Netprotect® LLIN (population 2100), (ii) two villages with untreated net (population 2068), and (iii) two villages of no-net control (population 2078), i.e., villages without net intervention but receiving DDT residual spraying routinely conducted by the state control programme. Given the consent for using mosquito net regularly in lieu of DDT spraying, each household was given 2–3 nets gratis ensuing that all members of the family had access for using the given mosquito net for personal protection. The study received approval by the Scientific Advisory Committee and Institutional Ethics Committee.

2.3. Data generation

Having ascertained the net requirement per household by population enumeration, the net distribution commenced 20 October 2008 and completed by 25 October 2008, and data were collected monthly thereafter for the period from November 2008 to June 2009. Since nets were introduced in third week of October, data for September and October, 2008 were taken as baseline for comparative purposes. To ensure proper use of the given mosquito nets, the communities were educated and supervised by village accredited woman social health activists and opinion leaders for compliance. The following investigations were conducted.

2.4. Insecticide susceptibility status of malaria vectors

Prior to the introduction of Netprotect® LLINs as alternative intervention to DDT spraying, the insecticide-susceptible status of *A. minimus* (the predominant mosquito vector species) was ascertained using WHO standard procedures against deltamethrin (the incorporated insecticide). Field collected mixed age adult females of *A. minimus* were exposed to a diagnostic concentration using WHO adult susceptibility test kit and mortality was recorded post 24 h recovery period. Data were pooled based on different replicates against the given insecticide, and corrected mortality was ascertained using Abbott's formula, if applicable.

2.5. Mosquito vector densities and relative abundance

Indoor day-resting catches were made in human dwellings indoors by experienced insect collectors in four fixed and four randomly selected houses in experimental villages using mosquito suction tube aided by torch battery light in the early morning hours (06:00–08:00 h) periodically. Mosquitoes were collected for 15 min in each selected structure those resting on walls, hanging clothes and other household articles. Mosquitoes collected were identified using standard taxonomic keys to the species level, and relative abundance was expressed as person-hour density, i.e., the number of mosquitoes collected per person hour. In addition, total indoors resting catches were made by pyrethrum spray method for which all windows, eves, doors and all other exit points were closed, and all mosquito knockdown 15 min post-spray were collected and identified.

2.6. Wash-resistance and residual bio-efficacy

To determine persistence and bioavailability of the insecticide on Netprotect® LLIN fiber, cone-bioassay tests were performed