MOSQUITO RESEARCH IN INDIA

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Mosquito research in India sprang up suddenly but vigorously just at the beginning of this century. Research on systematics of mosquitoes predominated till the beginning of the Second World War. After Independence, mosquito research in this country primarily centred round chemical control of mosquitoes. Important investigations on the reproductive behaviour of Anopheline mosquitoes have also been made.

FOLLOWING the great discovery by Sir Ronald Ross in 1897, mosquito research in India sprang up suddenly but vigorously just in the beginning of the twentieth century. Before 1900, the number of species of mosquitoes recorded from India was only four[15]. In 1900, G. M. Giles published his Handbook of Gnats or Mosquitoes[74]. He described mosquitoes as individual species. The first attempt to classify Indian *Anopheles* into natural groups was made by Stephens and Christophers in 1902[201]. The first monograph on the *Anopheles* mosquitoes of India was written by James and Liston in 1904[60]. The importance of larval characters in the classification of mosquitoes was pointed out by Christophers in 1906[35]. A second edition of the monograph of James and Liston, dealing with forty species of *Anopheles* appeared in 1911 and with this edition the recording of *Anopheles* mosquitoes of India was almost complete.

A proposal for the preparation of a volume on mosquitoes in the 'Fauna of British India' series was made in 1920[16]. In the beginning, Sir Arthur Shipley, the editor of the series arranged with Sir S. R. Christophers and F.W. Edwards to undertake the work. At about the same time Capt. P. J. Barraud had received a commission to make a general survey of the mosquitoes of the then Indian Empire. With the discovery of many new species of Culcini by Barraud, it was later decided to divide the work issuing one volume on Anopheline and the other on the Culicine mosquitoes. The former by Sir S. R. Christophers appeared in 1933 and that on Culicini and Megarrhini by P. J. Barraud in 1934[15,42]. From Barraud's account it is revealed that out of 239 described species of Indian Culicini, the larvae of 96 are unknown. The number of species of mosquitoes (including 43 Anophelini) has now reached a total of 288. This number has since increased only slightly.

A complete account of the early works on the systematics of Indian mosquitoes will be found in the bibliography of Sinton[197]. Several synoptic tables for the identification of Indian mosquitoes have been prepared.[41, 117, 123, 130, 202] Distribution of Indian mosquitoes has been recorded by about a dozen of authors[27, 31, 40, 102, 120, 131, 146, 150, 204].

Anatomy

Works on the anatomy of Indian mosquitoes started with two short notes[99, 203] followed by a series of studies on the genitalia[8, 38, 40, 41], thorax[9], wing[9, 43] larval appendages[86, 38] pharyngeal armature of adult mosquitoes[10, 199], abdominal tergite[113], histology of the midgut of the adults[110], female reproductive system[66], mouthparts[20, 59], salivary gland[21] and neurosecretory cells.[13, 190]

A monographic study on the musculature, innervation and the skeleton of the head capsule of a mosquito *Armigeres obturbans* Wlk. is in progress[64]. The central idea is to interprete the head capsule in terms of a new hypothesis called the remodelling hypothesis[54] and to underline the

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conflict between the Insect Morphology and the Theory of Natural Selection.

Physiology

Indian contribution to the physiology of mosquitoes includes studies on respiration[181], salivary secretion[15,158], role of mating and blood feeding on ovulation[53,160,182], oviposition[58,90,115,187], dessication of eggs[30], physiology of oesophegeal diverticula[158], influence of ambient temperature and hydrogen ion concentration on larvae[128], effect of heat and atmospheric humidity adults[103], influence of supernathecal stimulation on the physiological activity[161], Dyar's law[189], gynandromorphism[103] and alkaline phosphate activity[109].

A recent study[57] on the gut movement of the larva of *Chaoborus crystallinus* shows that the rate of gut movement is a physiological indicator of the larva whereas the heart beat is not. The gut movement of this larva is directly dependent on the previous state of feeding so that the rate of gut movement varies from individual to individual.

Embryology and cytology

No work has been done in India on the embryology of mosquitoes. However, efforts were made to study the maturation of ovum[76,162], post-embryonic development of the terminalia[40,41], thoracic imgginal buds[10], and optic[120], and cerebral ganglia[171].

Cytological studies on Indian mosquitoes are very recent and mention could be made of the works an golgi apparatus[78,124] salivary gland chromosomes[125,186] and chromosomal aberrations due to chemosterilising agents[76,137].

Behaviour

Investigations on the behaviour of Indian mosquitoes began in the beginning of this century[26,32,110,120]. Experimental researches were carried out on the behaviour of mosquitoes to artificial light[18] and on flight range[123]. Treehole breeding habit[11,38] and hibernation[34] of certain *Anopheles* were also noted.

A series of observations were made on the breeding habit of the following mosquitoes : *Aedes albopictus*[175], *Ficalbia* spp.[93], *A. stephensi*[12,159], *A. minimus*[205-209], *A. fluviatilis*[4,151,210,218], *A. culicifacies*[111,178,10], *A. sundaicus*[153] and *A. subpictus*[58]. Special investigations were made on *Anopheles* breeding in relation to rice cultivation[149,151,173,191]. Outdoor and indoor resting habits of *Anopheles* have been investigated by several workers[151,211,215,217].

Studies were also made on the emergence of adults[174], seasonal prevalence[21,140,212], dispersal[5,6,185], longevity of adults[116,118,119,222], swarming[61,62,154,188], phototrophism[60,63], larval biology[50,54,94,111] and preferential indoor resting habit of *C. B. fatigans*[41,221]. There are a few works, monographic in nature, on the behaviour of Indian mosquitoes[5,25,142,205,209,217].

Swarming of mosquitoes which had all along been a puzzle to the biologists has at last been explained. In *C. B. fatigans*, a positive reproductive role of swarming has been demonstrated[62].

Predators and parasites

Small fishes such as *Gambusia affinis*, *Aplocheilus lineatus*, *Panchax parvus*, *Discognathicthys rossicus* var. *nudirentralis* and recently introduced guppy fish (*Lebestes reticulatus*) are well-known predators of mosquito larvae[155,65]. Predation of larvae by *hydra*[85] and water corpion (*Laccotrephes maculatus*[81] and other insects[177], have also been reported.

Observations were made on the infections by *Actinomycetes* sp[72]., *Aspergillus parasiticus*[86], gregarine (*Lankesteria culicis* Ross)[82], ciliate (*Tetrahymena pyriformis*)[81] and other protozoa[17,89,176], algae[25], and tramtoda[198]. The sandfly, *Culicoides anopheles* Edw. has been reported as parasitising *C. fatigans*[68].

Mosquitoes as vectors

Malaria : Reviews on malaria written by competent authorities give an approximate picture of the total Indian effort to tackle this gigantic health problem[67,92,98,105,152,155,220].

The advancement of the malaria-cum-mosquito research in India could be classified into three phases. In the first phase (1900-1941) there were spectacular advances in researches on mosquitoes and their relationship to malaria and filariasis. The second phase (1942-1958) is a confused one which

was ultimately oriented to the control of mosquitoes. In the third phase (1958-1976) there is a general upsurge in almost all branches of mosquito research but with a tinge of tiredness. This tiredness is due to the fact that the eradication programme which had almost eradicated this disease did not succeed completely[55,126,188]. Malaria reappeared and it was freshly reported from high altitudes such as N.E.F.A[172] and Kashmir[121]. In 1975, there were 5000,000 cases of malaria in India, according to Samachar, the national news agency.

Filariasis

Two types of infections are concerned in the causation of filariasis in India, viz., *Wuchereria bancrofti* (transmitted by *Culex fatigans*) and *W. malayi* (transmitted by *Mansonioides*)[91,92]. The former infection is common in the urban while the latter in the rural areas[51,107,114,163].

Extensive studies on the mosquito transmission of filariasis have been made in India[28,80,91,92,104,147,148]. Recently quantitative studies on filariasis were carried out in Bangalore[192]. Banaras[112] and Calcutta[77]. The figures of Gubler and Bhattacharyya[77] on the biting density of *C. P. fatigans* at Calcutta (115,000 bites person annually) surpass all credibility.

Virus diseases

The yellow fever mosquito (*Aedes aegypti*) has been found to be a carrier of chikungunya virus which caused an epidemic of haemorrhagic fever in Calcutta during 1963-1965[29,75]. This mosquito is also known as a carrier of dengue. Short *et al.* were the first to cultivate the virus of dengue on the chorio-allantoic membrane of chick embryo[193]. Dengue is still a health problem and recently there were outbreaks of dengue in Rajasthan[73] and Gwalior[7].

Aedes w-alnus (Theo.) and *Anopheles stephensi* have been reported to be susceptible of the following abroviruses[196] : Gr. A. (chikungunya), Gr. B. (Japanese encephalitis, dengue type 2 and Kyasanur forest disease), one virus of vesicular stomatitis group and one ungrouped virus (Ganjam). Palyam, Kasba and Vellore viruses were isolated from mosquitoes belonging to the complex of *Culex vishnui* Theo[52].

Leprosy

B. Narayanan and his collaborators suspect the possibility of mosquito transmission of leprosy[122-123].

Mosquito Control

Physical : Depending on topographical situations, breeding of mosquitoes could be prevented by (a) periodic flushing of streams and drains by building dams and sluices across the stream or by siphoning ; (b) herbage packing of rice fields and drains, (c) shading of water surfaces with water hyacynth or by planting fast growing creepers and perineal shrubs on the banks of canal distributories ; (d) deweeding, clean edging and training streams ; (e) removal of vegetations from water surface and exposure of the latter to sunlight ; (f) filing, draining and tidying of channels ; (h) intermittent irrigation and (i) removing *Pistia*[155].

Chemical : The following three insecticides have been found very useful in the control of mosquitoes in India : (a) Pyrethrum[33,47,48,69,161,165,183,211], (b) Gammexane (BHC)[111,156,157,214] and (c) DDT[79,127,132,135,214]. Relative effectiveness of these insecticides have been studied carefully[111,156,157,214,224]. For better results in the control of malaria, DDT spray may be combined with anti-larval measures or suppressive drug treatment[107,195]. Combination of different methods has been proved to be more effective than a single one[155]. Presently, attention is being paid to the terrible problem of insecticide resistance of mosquitoes[101,113,114,178,189].

Biological : Predatory fishes, as noted earlier, are useful in the control of mosquito larvae[185]. Cover of aquatic plants such as *Lemma minor*[3] and water hyacynth[116] (*Eichhornia*) has been found useful as preventives against mosquitoes. Contrary to the popular belief, bats, clover and water lettuce have nothing to do with malaria or mosquito control[48].

The most expensive but futile experiments on the genetic control of mosquitoes

was made in India (GCMU of WHO and ICMR)[136,137,191]. Biology of mosquitoes is strongly forbidding to this method[62].

Technique

Techniques were developed on the collection[3,14,71,97] rearing[1,70,119] and mounting[19,37] of mosquitoes. For spraying insecticides different types of sprayers such as air-tanks, pressure outfits, hand atomisers and automatic distributors have been invented. [59,105,113,166,167,219] Other inventions include a constant humidity apparatus for mosquitoes[96], automatic siphon,[145] and an exposure cell for use in residual insecticidal studies on mosquitoes[22].

Most of the mosquito research in India has been sponsored by the government and the Indian people are yet to realise the nature and magnitude of the problem and the value of mosquito research. Even our universities, now totalling about 102 throughout showed absolute apathy to mosquito research. Taking advantage of this indifference our country was conveniently chosen as the testing ground for certain types of bacteriological warfare through the mosquitoes. Mosquito bomb, which is now an idea could easily be translated into a reality.

Although there is a general upsurge in almost all branches of mosquito research, the failure of *NMEP* (National Malaria Eradication Programme) launched in 1958, has told heavily on the morale of mosquito workers of this country. However, a bewildered NMEP is still continuing. To do away with this bewilderment we must proceed *de novo* to another Malaria Eradication programme which must be effective and consisting of the four wellknown phases : preparatory, attack, consolidation and maintenance. *But before launching another NMEP*, senso stricto, *it is essential to make a thorough investigation on the respective role of the factors leading to the failure of the previous NMEP.* The fire of malaria is spreading and it is considered that 25 crores of people could be easily attacked by malaria. Unless this fire is extinguished totally and a strict vigilance is maintained to prevent the import of any fresh spark, the danger will always remain potential.

Unfortunately, the genuine lions of mosquito research in India have either deceased or retired and now leaders are yet to emerge. But unless we awake and act India will remain a paradise of mosquitoes for centuries to come.

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