



International Journal of Mosquito Research

ISSN: 2348-5906
CODEN: IJMRK2
IJMR 2019; 6(1): 95-100
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Received: 04-11-2018
Accepted: 08-12-2018

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A Pre requisite formulae for the identification of *Anopheline* mosquitoes described in the Indian Subcontinent with reference to the keys of Wattal and Kalra

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Abstract

Taxonomy or systematics is the branch of Biology deals the classification of animals and plants with the principles of unique characteristic features found on their morphology. Even though Taxonomists identified mosquitoes based on their external features as identification keys, only the degree of one' memory and keen observation would make expertise in the field of systematics. Probing the literature on the mosquito Taxonomy, there is no tool to remember the name of mosquitoes those classified under each groups at a glance as an abbreviation using the first letter of each species of *Anopheline* mosquitoes identified by Wattal and Kalra (1961). The total 31 *Anopheline* species have been divided into five groups as *Anophelines* without scales on their wings, Group-A; Group-B; Sub-group-I and Sub-group-II and all of them abbreviated in the order of English alphabets and make them as formulae. Since this tool has been provoking many fold to remember all species of these mosquitoes very easily, it is discussed in this paper.

Keywords: abbreviation, anopheline, formulae, taxonomy

Introduction

Taxonomy or systematic is the branch of Biology deals the classification of animals and plants with the principles of unique characteristic features found on their morphology. This branch of science was familiarized since 17th century by the Swedish Botanist Carl Von Linnaeus as he christened plants and animals based on the common and distinguished properties found on the morphology and given name in two words namely genus and species. This type of naming was called binomial nomenclature and some animals and plants have three parts in their naming called as trinomial nomenclature. In this type, name of sub-species is included in the third word.

The prime objective of Taxonomy is to be avoided confusion among biologists as this name should be the only one to each animal and plant throughout the world. Thus each and every organism of plants and animals has been classified in the universe adopting its principles. Becoming expertise in this branch of science, retention of memory is the capital as all names of species should be kept in mind. It is the pre requisite tool to distinguish animals and plants with their specific keys.

Hence, an attempt has been made in this paper to introduce a novel method to remember the names of a few *Anopheline* mosquitoes narrated by Wattal and Kalra (1961) [20] in their faunistic study made in different states and districts (Kerala, Madras, Mysore, Baroda, Gujarat, Maharashtra, Rajasthan, Bihar, Orissa, Delhi, Himachal Pradesh, Jammu and Kashmir, Punjab, Uttar Pradesh) in the Indian sub-continent.

The systematic of Indian *Anopheles* have been thoroughly dealt by Christophers (1933)^[4] and the 40 species that occur in India had been correctly determined with Puri' dichotomous table (1955). However, these and other works regarding the classification of *Anopheles* are neither easily available nor easily understood by the beginners and workers not well versed in Entomology. In view of these, the era of National Malaria Eradication Programme (NMEP) in 1958 took keen interest to study the region wise fauna of *Anopheline* mosquitoes in the Indian sub continent to map the existence of *Anopheline* malaria vectors. Thus, the keys for the

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identification of *Anopheline* mosquitoes developed by Wattal and Kalra in 1961^[20] with the intention of imparting training to workers in identifying species in an area and also they will not be confused with the species not present in a particular region. The first compilation of the world mosquitoes was attempted more than a century ago, but this catalogue enlisted very few species from the Indian subcontinent and hence it was compiled by Tyagi *et al* in 2015^[18] and stated that there were 404 species of mosquitoes identified so far in India. Of which 63 species were *Aonopheline* whereas 31 *Anopheline* species alone were described by Wattal and Kalra in 1961^[20]. Even though Taxonomists identified mosquitoes based on their external features as identification keys, only the degree of one's memory and keen observation will make expertise in the field of systematics. Probing the literature on the mosquito Taxonomy, there has not been found a tool to remember the name of mosquitoes those classified under each groups at a glance as an abbreviation using the first letter of each species of *Anopheline* mosquitoes (Christophers, 1933; Barraud, 1934; Wattal and Kalra, 1961; Wattal, 1963; Roy and Brown, 1970; Rao, 1984; Das *et al.*, 1990; Reuben *et al*, 1994; Nagpal and Sharma, 1995; Rajavel *et al.*, 2005a, 2005b, 2005c)^[4, 1 20, 19, 14, 12, 7, 13, 10, 15-17].

Hence the efforts would be made to remember mosquitoes keeping in mind very easily among field assistants, field workers and workers not well versed in Entomology. For this present study only 31 species described by Wattal and Kalra alone have been taken as a dip stick and it would be extended to all 63 Indian species after the comments of experts.

Materials and Methods

Wattal and Kalra (1961)^[20] published identification keys among mosquitoes collected from 14 states and they were divided as six regions into which the whole country has arbitrarily been divided under the NMEP. Each of these keys deals with the identification of only those species which have been recorded from the respective state comprising any particular region. The characters are not easily discernible to the beginner such as distinctions between narrow and broad scales, etc., have not been used in these keys. Also every character mentioned in the key is illustrated by an appropriate drawing. For convenience, both the dichotomous of Puri's (*loc.cit*) key as well as the groups used by Roy and Brown, (1954) have been used. For the present article, *Anopheline* mosquitoes identified by Wattal and Kalra (1961)^[20] alone taken.

Results

It was observed that *Anopheline* mosquitoes were grouped into five by Wattal and Kalra (1961)^[20] based on the scales presented on their wings and identification marks on the costa of wings. Thus we found that wings of four *Anophiline* mosquitoes found completely dark, five with scales in which three or less than three dark spots on costa involving vein I as Group -A and twenty two *Anophiline* mosquitoes found four or more than four dark spots on costa involving vein I. It is designated as Group-B with scales. Further, Group-B is divided into two sub-groups as Sub-Group-I and II based on speckling and not speckling on their hind legs and palpi. All these species of mosquitoes are thirty one altogether. To remember all these species, the first letter of each species taken and stringed in alphabetical order. If mosquito has begun from the same alphabet, the total number of such kind

species will be given in superscript of the respective alphabet (Fig-1).

The following *Anopheline* mosquito species collected in six regions from 14 states by Wattal and Kalra are *aconitus*, *aitkeni*, *annandalei*, *annularis*, *barbirostris*, *culicifacies*, *culiciformis*, *fluviatilis*, *gigas*, *hyrcanus*, *insulaeflorum*, *jamesi*, *jeyporieansis*, *karwari*, *leucosphyrus*, *lindesayi*, *maculatus*, *majidi*, *minimus*, *moghulensis*, *pallidus*, *phillippinensis*, *sintoni*, *splendidus*, *stephensi*, *subpictus*, *tessellates*, *theobaldi*, *turkudi*, *vagus* and *varuna*. To remember all these names, the following abbreviation/formula as an alphabetical order is determined

$$a^4bc^2 fghij^2kl^2m^4p^2s^4t^3v^2 = 31\text{species} \dots \quad (1)$$

Among them, further split would be made for different groups and thus oligo strings would be possible for fragmentation of the said abbreviation so as able to remember comfort fully and very easily.

There are four species of *Anophiline* mosquitoes (*aitkeni*, *culiciformis*, *insulaeflorum* and *sintoni*) are not having scales on their wings as that of Culicine. Hence these four mosquitos' wings look completely dark. In this regard basic external features of *Anophiline* should also be taken into an account to identify these species. This will be abbreviated as follows

$$acis = \text{four species (aitkeni, culiciformis, insulaeflorum and sintoni)} \dots \quad (2)$$

There are five *Anophiline* mosquitoes species categorized as Group-A based on three or less than three dark spots on costa involving vein I. They are *annandalei*, *barbirostris*, *gigas*, *hyrcanus* and *lindesayi*. It will be represented by the following formula

$$abghl = \text{five species (annandalei, barbirostris, gigas, hyrcanus and lindesayia)} \dots \quad (3)$$

To determine the species stated above, besides the general character 3/<3 dark spots on the costa involving vein I, the following characters are also taken into an account like, palpi completely dark/with white bands, hind femur completely dark/tuft of white and black scales at the femoro tibial joints of the hind leg/hind femur with white band and Inner quarter of costa with white interruption/without white interruption Remaining 22 species are come under Group-B based on wings with four or more dark spots on costa involving vein I, Femur and tibia speckled, Palpi speckled/unspeckled and Tips of hind leg white/not white

So the formula is

$$a^2cfj^2klm^4p^2s^3t^3v^2 = 22\text{species} \dots \quad (4)$$

(*aconitus*, *annularis*, *culicifacies*, *fluviatilis*, *jamesi*, *jeyporieansis*, *karwari*, *leucosphyrus*, *maculatus*, *majidi*, *minimus*, *moghulensis*, *pallidus*, *phillippinensis*, *splendidus*, *stephensi*, *subpictus*, *tessellates*, *theobaldi*, *turkudi*, *vagus* and *varuna*).

Group-B is divided further into two sub-groups based on hind femur and tibia speckled (sub-group-1) and hind femur and tibia not speckled (sub-group-2). Based on that there are two formulae have arisen from the formula 4 are

Subgroup-1 $jlms^2t^2 = 7 \dots$ (5)

(*jamesi*, *leucosphyrus*, *maculatus*, *splendidus*, *stephensi*, *tessellatus* and *theobaldi*)

To determine the above said species, specific characters described in Wattal and Kalra should be taken are 4/>4 dark spots on the cost of the wing involving vein-I, femur and tibia speckled, palpi speckled/unspeckled, palpi apical and sub apical bands are equal and unequal, Tips of hind leg white/not white, palpi with three white bands speckled and four white bands unspeckled, hind leg with broad white tibio-tarsal joint

and hind leg without such white tibio-tarsal joint
Likewise sub-group-II has the following formula in which all mosquitoes come under this group are not speckled on their hind legs and palpi. To determine the species, the above said most of specific characters should be taken.

Subgroup-2: $a^2cfjkm^3p^2stv^2 = 15 \text{ species} \dots$ (6)

(*aconitus*, *annularis*, *culicifacies*, *fluviatilis*, *jeyporiensis*, *karwari*, *majidi*, *minimus*, *moghulensis*, *pallidus*, *philippinensis*, *subpictus*, *turkudi*, *vagus* and *varuna*).

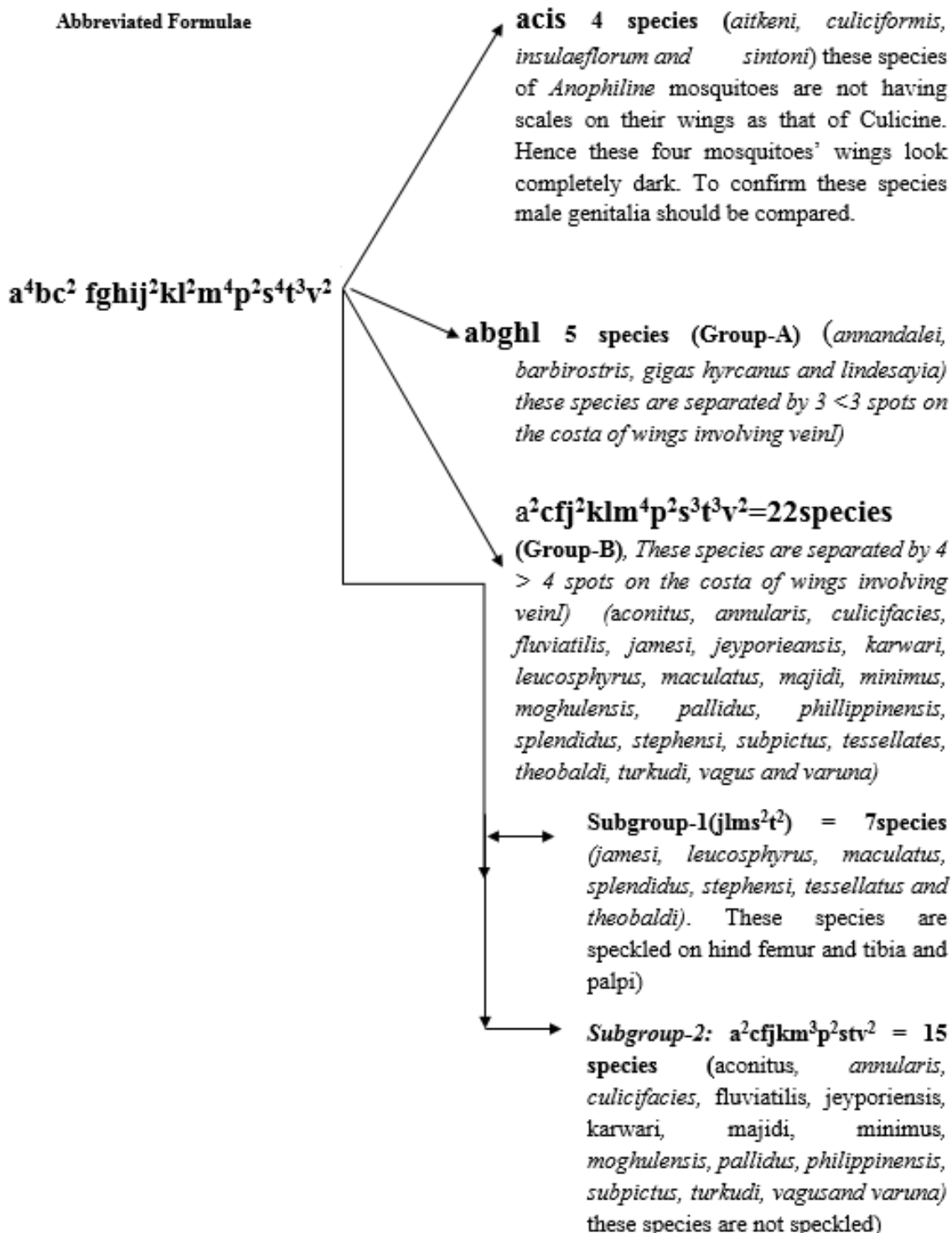


Fig 1: Details of the species under different groups with their

acis 4 species (*aitkeni*, *culiciformis*, *insulaeflorum* and *sintoni*) These species of *Anophiline* mosquitoes are not having scales on their wings as that of *Culicine*. Hence these four mosquitos' wings look completely dark. To confirm these species male genitalia should be compared.

abghl- (Group-A) annandalei, barbirostris, gigas,hyrcanus and lindsayia

- Wings with three or less than three dark spots on costa involving vein-I
- Hind femur with a prominent tuft of black and white scales at its distal end ...*A. annandalei*.
- Palpiare all dark and
- Hind femur without any white band ... *A.barbirostris*
- Palpi with white bands
- Inner quarter of costa with white interruptions ... *A.gigas*
- Palpi with white bands
- Inner quarter of costa without white interruptions...*A.hyrcanus*
- Palpiare all dark
- Hind femur with a white band ...*A.lindsayi*

Group-B (Sub-Group-I) (jlms^{2t}) = 7species (jamesi, leucosphyrus, maculatus, splendidus, stephensi, tessellatus and theobaldi). These species are speckled on hind femur and tibia and palpi.

A. jamesi

- Dorsum of 7th and 8th abdominal segments thickly clothed with golden hairs and scales and Inner quarter and outer third of costa chiefly pale... *A. jamesi*
- Palpi unspeckled and apical and sub apical white band unequal.

A. leucosphyrus

- Sixth wing vein with more than 3 dark spots
- Tibia tarsal joint of hind leg broadly and conspicuously banded with white

A. maculatus

- Less than two terminal hind tarsal segments completely white
- Sixth wing vein with 3 dark spots only; whole of the terminal hind tarsal segment and a part of the next white.

A. splendidus

- Dorsum of abdomen not so clothed, no lateral scale-tufts
- Three terminal hind tarsal segments completely white.
- Palpi speckled those of female with one narrow more proximal and two broad distal pale bands

A. stephensi

- Sixth vein with three or less than 3 dark spots.
- Dorsum of thorax clothed with obvious broad scales; scales on dorsum of nearly all the abdominal segments. Palpi of female with one narrow proximal and two broad distal pale bands. Palpi of both sexes usually speckled.

A. tessellatus

- Palpi with 4 white bands
- Hind leg without such white tibio tarsal joints.

A. theobaldi

- Only two terminal hind tarsal segments completely white, with a broad pale band above this,

Subgroup-2: a²cfjkm³p²stv² → =15
species(aconitus,annularis,culicifacies,fluviatilis,jeyporiensis, karwari,majidi,minimus,moghulensis,pallidus,philippinensis,subpictus,turkudi,vagusand varuna)These species are not speckled)

An. Aconitus (Not white foot)

- Apical white band on palpi equal to sub apical white band.
- Wing with a fringe spot at vein 6.

An. Annularis (white footed)

- Hind tarsi 5,4 and 3 are completely white.
- Wing vein 5 mainly dark, with a dark spot at the point of bifurcation.

An. culicifacies (Not white footed)

- Tips of the palpi white.
- Wing vein 3 completely dark.

An. fluviatilis (Not white footed)

- Inner quarter of costa without white interruption.
- Wing vein 6 with two dark spots, distal half being mainly dark.

An. jeyporiensis

- Apical white band on palpi longer than sub apical white band.
- Inner quarter of costa with white interruption.

An. Karwari (white footed)

- Hind tarsi 5 and part of 4 white
- Palpi with 4 white bands

An majidi(white footed)

- Hind tarsi 5 and part of 4 white
- Palpi with 3 white bands.

An. minimus

- Wing without a fringe spot at vein 6
- Inner quarter of costa with white interruption on at least one wing.

An. moghulensis

- Inner quarter of costa without white interruption.
- Wing vein 6 with three dark spots, distal half with pale interruption.

An. pallidus

- Wing vein 5 mainly white with no dark spot at the point of bifurcation.
- Distal end of hind tarsus I all dark.

An. philippinensis

- Wing vein 5 mainly white with no dark spot at the point of bifurcation.
- Distal end of hind tarsus I picked out with white

An. subpictus

- Tarsal segments of fore legs with broad bands
- Palpi with pre-apical dark band equal or nearly equal to the apical white band

An. turkudi

- Tarsal segments of fore legs unbanded or with very narrow bands
- Tips of the palpi Black

An. vagus

- Tarsal segments of fore legs with broad bands
- Palpi with dark pre-apical band not more than 1/2th length of the apical white band

An. varuna

- Wing without a fringe spot at vein 6
- Inner quarter of costa without any white interruption

Discussion

Mosquitoes belong to family Culicidae and order Diptera are a large group of insects present throughout the temperate and tropical regions and even beyond the Arctic Circle of the world (Harbach, 2007) [9]. Detailed information (distribution, identification and description) regarding the mosquitoes of India, it was first compiled by Christopher, 1933 on *Anophelines* and Barraud in 1934 [1] on Culicines in two monographs.

The total number of mosquito taxa in the world, is 3541, belonging to 50 genera and 2 sub families (12 tribes); secondly, it has organized all the taxa in a more modern and universally acceptable classificatory system proposed by Harbach (2014). All species identified so far followed the conventional procedure despite there is no approach to remember the name of species very easily. In the present paper, it has been attempted to recollect the names of mosquito species through abbreviation. It is a short form or fragmented form to represent a mosquito species with the first letter of each species. It is known that abbreviation is being remembered by people as it is a part of general knowledge. Hence, introducing this tool in taxonomy will make easier to remember the names of mosquito species in different groups described by Wattal and Kalra (1961) [20].

Further, if this tool is analyzed in-depth, (1) it is easy to remember as it is constructed by English alphabet. (2) if many species begun with same letter, it is easier to remember them with the number on the superscript (For example, the alphabet "a" and "m" and "s" has four *Anopheline* mosquitoes each. It is denoted by a⁴ m⁴ s⁴). Likewise three species are beginning with "t". two species are begin with c, j, l, p and v.. Remaining six species hold different alphabets like b, f, g, h, i and k. (3). From these formulae, it can be understood that species those have not been existing in India by missing alphabets in the formula. With reference to the keys of Wattal and Kalra (1961) [20], there are no species which begin with d, e, n, o, q, r, u, w, x, y and z whereas d, e, u and w are beginning with some species when the *Anopheline* keys of Puri and others were explored. Except these points of view, the specific characters of each and every species would also been easy to remember since the species name has been familiarized and remained in one's mind firmly.

Raveling the literature published on mosquito taxonomy both

national and international level, (Carpenter, *et al.* 1946, 1955; Darcy and Ward. 2000, 2005, Goddard, *et al.* 2010)^{3, 5, 6, 8} none of this kind of tool available to remember species name at a glance. Since the memory is the pre-requisite for making expertise in the field of systematic, it may be received attention.

Acknowledgements

The author is very grateful to Dr. K. Kolandasamy, Director of Public Health and Preventive Medicine, Chennai-6, Government of Tamil Nadu, India for his encouragements and supports for the research.

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