International Journal of Mosquito Research

ISSN: **2348-5906**
CODEN: **IJMRK2**
IJMR 2020; 7(3): 09-18
www.dipterajournal.com

Received: 04-03-2020
Accepted: 06-04-2020

Mostafa M Mahgoub
Department of Medicine and Surgery, University of Parma, Parma, PY, 43125, Italy

Maria Eugenia Colucci
Department of Medicine and Surgery, University of Parma, Parma, PY, 43125, Italy

Anna Odone
School of Public Health, Faculty of Medicine, University Vita-Salute San Raffaele, Milan, 20132, Italy

Corresponding Author:
Mostafa M Mahgoub
Department of Medicine and Surgery, University of Parma, Parma, PY, 43125, Italy

An updated checklist of mosquitoes (Diptera: Culcidae) of Sudan: Taxonomy, vectorial importance and pictorial keys

Mostafa M Mahgoub, Maria Eugenia Colucci and Anna Odone

Abstract
Among the two study sites, a total of 5847 mosquito larvae were sampled, of which 44.75% (n= 2617) were *Culex* (*Cx.*), belonging to this species *Cx. antennatus* (42%) *Cx. quinquefasciatus* (25%) *Cx. simpsoni* (14%) *Cx. tritaeniorhynchus* (8%) *Cx. theileri* (5%) *Cx. musarum* (4%) and *Cx. pipiens* (2%)) and 44.46% (n= 2600) *Anopheles* (*An.*) belong to six species which were *An. arabiensis* (38%) *An. funestus* (27%), *An. rufipes* (24%), *An. phronesis* (9%), *An. nili* (0.5%), and *An. dattali* (0.5%). However, all the *Aedes* (*Ae.*) larvae 5.26% (n= 308) collected were found to be *A. aegypti*.
This is my first-time reporting *An. funestus* in central Sudan. Its percentage observed among the *anopheline* species reported showed a great successful in its adaptation to new environmental setting of central Sudan; an observation showed new obstacle for malaria vector control in the country. Similarly, *Ae. aegypti* is now an important mosquito vector in the country and its role in the recent outbreaks of dengue fever and rivet valley fever call for an urgent investigation.

Keywords: *Anopheles, Culicine, Aede*s, Sudan

1. Introduction
In Sudan, about 106 species identified belong to *Culicidae*. These species represent about one third of Ethiopian region and are belonging to the three subfamilies *Toxorhynchitina*, *Anophelinae* and *Culicinae* [1].
In Africa there are about 10 *anopheline* species responsible for malaria transmission [2]. Mosquitoes within the *An. gambiae* complex, mainly *An. gambiae* (senso lato), addition to *An. funestus* are the most important vectors of malaria in Sub-Saharan Africa [3, 4, 2]. Further, *An. gambiae s. l.* and *An. melas* are also the major vectors of lymphatic filariasis (LF) which is caused by *Wuchereria bancrofti* in West Africa [5].
However, numerous studies confirm the *An. arabiensis* dominant *anopheline* species in Sudan and consider is main malaria vector and second potential vector for malaria is *An. funestus* which report in central Sudan. The great diversity of mosquitoes was observed in the southern part of Sudan compared to the north due to climatic variation, where the northern part of the country is arid desert, while the tropical in the southern parts [6-11]. The cultivate is microhabitats for malaria vectors and common in an irrigated channel with high vegetation density. The obvious variation in the density of mosquitoes during different weathers seasons and highest density in rainy followed by cool dry and then hot dry season. In the equatorial setting, this species was usually found peaked at the end of the rains and beginning of the dry season (Kelly-Hope *et al*, 2009). [12].
Gezira state is one of central Sudan States, located (14.8860° N, 33.4384° E) along Blue Nile banks, and includes the Gezira irrigation scheme that forms the state just like a large permanent mosquito breeding site of mosquitoes [7]. The recent outbreaks of rift valley fever (2003, 2007, 2010 and 2019) [13, 14] and yellow fever (2005) [15], which may correlate with environmental factors, are probably emerging as the result of the present of competitive mosquito vectors. The earlier survey for identifying mosquito species has been done by Lewis *et al*, (1956) [16].
This survey showed *Anopheles nili* (Theobald), *An. pharoensis* and only *An. arabiensis* form *An.* gambiae complex members have been confirmed in northern, eastern and central Sudan

[17, 18, 12]. Other mosquito species confirmed by Lewis (1956) included *Aedes scatophagoides* (Theobald), *Aedes metallicus* (Edwards), *Aedes unilineutus* (Theobald), *Aedes argenteopunctatus* (Theobald), *Aedes leesoni* subsp *verna* (Lewis), *Aedes dalzieli* (Theobald), *Aedes lineutopennis* (Ludlow), and *Aedes circumluteolus* (Theobald).
This study aims to update and identify the mosquito fauna *Culex*, *Aedes* and *Anopheles* genera in center Sudan, Gezira area.

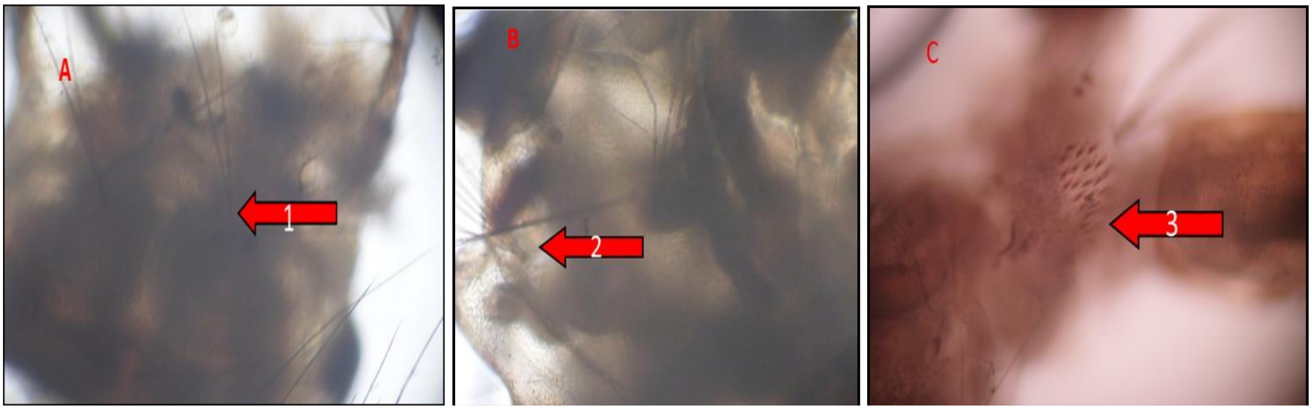
2. Materials and Methods
Cross-sectional surveys for larval breeding habitats were done weekly using standard dippers. The area covered each week was approximately 3 km2 for each village. The surveys were done during the year of 2011 to cover three seasons in the year, cold dry (January – February), hot dry (May – June) and rainy season (August – September). Density of immature stages was expressed as the number of larvae per dip accordingly to WHO protocol 2003. [19]

2.1 Mosquito's Identification
Some of sampled larvae were taken randomly from each positive habitat and kept in a labeled container, transferred to the laboratory and reared till adult emergence. All adult mosquitoes, including those found resting outdoors and sampled by respirator, were killed by chloroform, left to dry at room temperature and preserved in Eppendorf tube with silica gel for identifications. Few 4th instars larvae were dissected using compound microscopy and identified morphologically to species according to the computerized key system and pictorial key.

2.3 Data analysis
The data was analyzed using JMP version 5.0.1.2. software. Mean of larvae densities were compared among the different seasons and sites using ANOVA of Tukey-Kramer HSD test.

3. Results & Discussion
3.1 Species composition
Among the two sites, a total of 5847 mosquito larvae were sampled, of which 44.75% (n= 2617) were *Culex*, 44.46% (n= 2600) were *Anopheles* and 5.26% (n= 308) were *Aedes* mosquito species. [20]

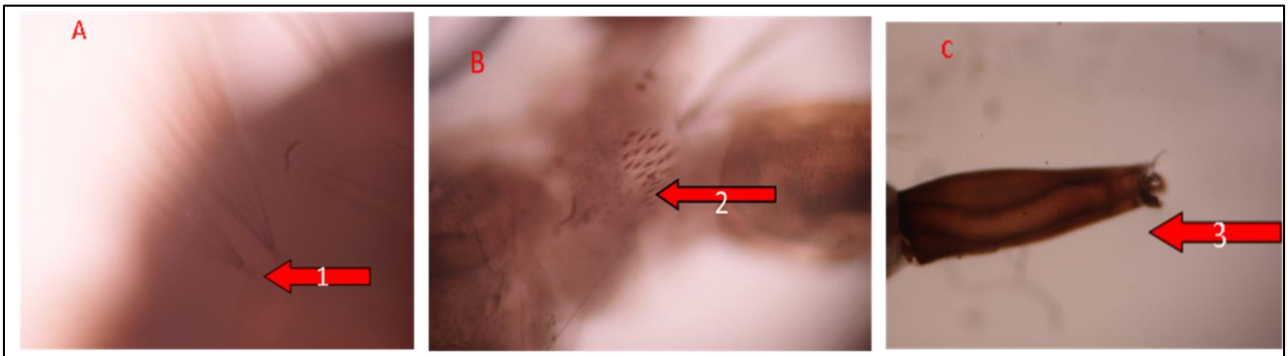
3.2 *Culicine* spp.
3.2.1 *Culex Antennatus* figure no (1)
Distribution: formerly occurred all along the Nile Sennar, Gezira areas [20], Khartoum White Nile Area [21]. and Talodi [22], The among the Culicine species identified *Cx. antennatus* (42%) is a dominant species and well-known potential vector for RVF in many regions in the world and incriminated during the outbreaks of the diseases in Egypt in 2002 [23-25].



Head Seta 5-c with tow branches (Fig.1a) Head Seta 7-c branched (6-8) branches (Fig.1b) The Abdomen combe scale number from (10-40) (Fig.1c)

Fig. 1: *Cx. antennatus*, classification features.

3.2.2 *Culex quenquifasciatus* say 1823 figure no (2),
Distribution: Gezira areas [20], El-Managil Town [26], Khartoum [27] and White Nile Area [21]. The second species in the density by (25%), a potential vector of West Nile virus, Saint Louis encephalitis virus, and lymphatic filariasis, distributed throughout the Sudan [28-30].

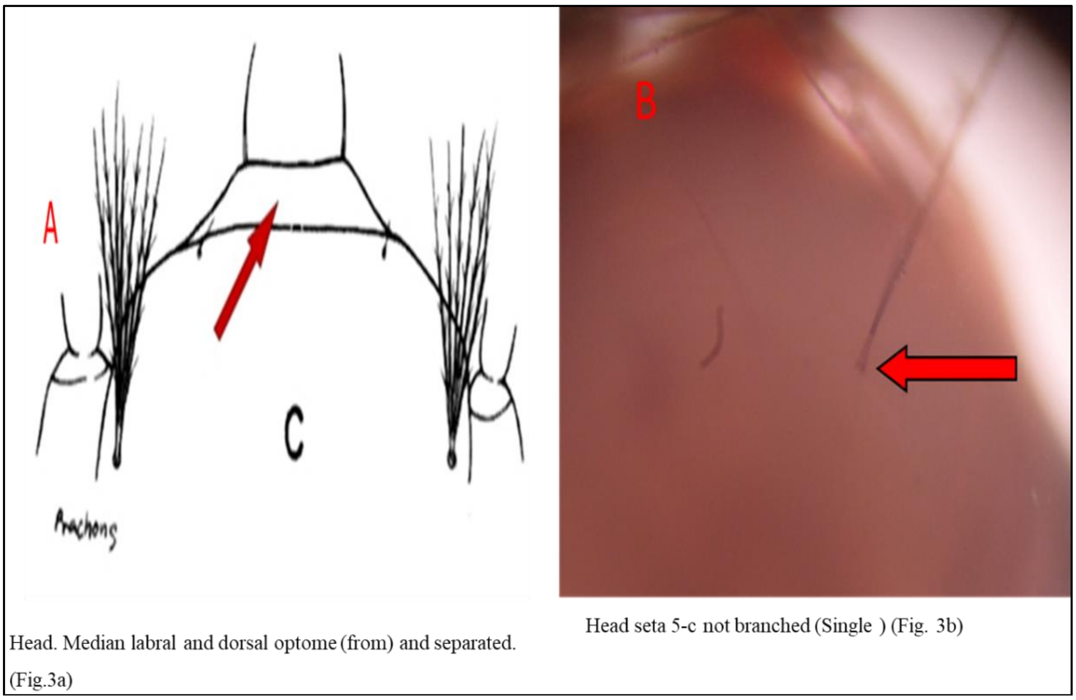


•Head seta 5-c (Number of branch more than 5 branches) (Fig.10a) •The Abdomen combe scale number (10-40) (Fig.10b) •Abdomen siphon form straight at the end (Fig.10c)

Fig 2: *Cx. quinquefasciatus* classification features

3.2.3 *Culex simpsoni* figure no (3)

Distribution: Gezira areas [20], Port-Sudan, Khartoum. Represent about fourteen percent from *Culex* spp. collected during the study courses. Belongs to the subgroup *Simpsoni* of Group Pipiens. according to the literature was recorded in Port-Sudan, Khartoum, and western Sudan. Incriminated vector to RVFV in Madagascar [31-34].



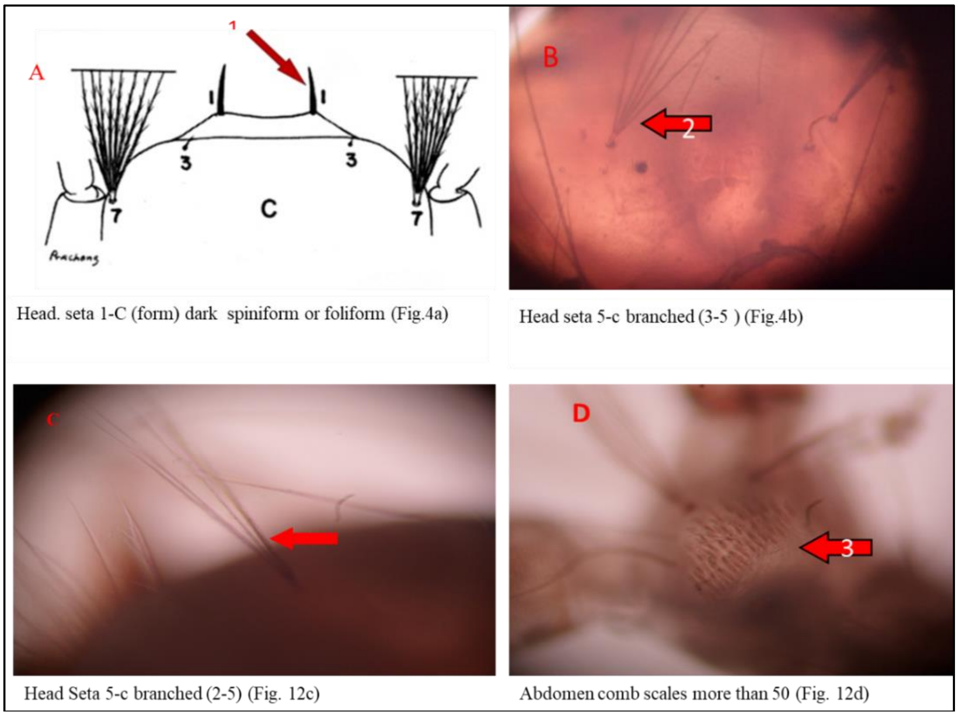
Head. Median labral and dorsal optome (from) and separated. (Fig.3a)

Head seta 5-c not branched (Single) (Fig. 3b)

Fig 3: *Cx. simpsoni* classification features.

3.2.4 *Culex* (*Culex*) *tritaeniorhynchus* Gilts., figure no (4)

Distribution: Gezira areas [20], and Malkal and Panamtin [22]. Represent about 8% of the total *Culex spp*. identified during the study course, incriminated as potential vectors of West Nile Virus (WN) by Ilkat *et.al* [35, 36]. And also consider is primary vector of JE virus in Asia. [37]. First recorded in South Sudan Malkal and Panamtin in the last century by Lewis 1944 [22] and migrated to north, recently was recorded in the Gezira area central Sudan.



Head. seta 1-C (form) dark spiniform or foliform (Fig.4a)

Head seta 5-c branched (3-5) (Fig.4b)

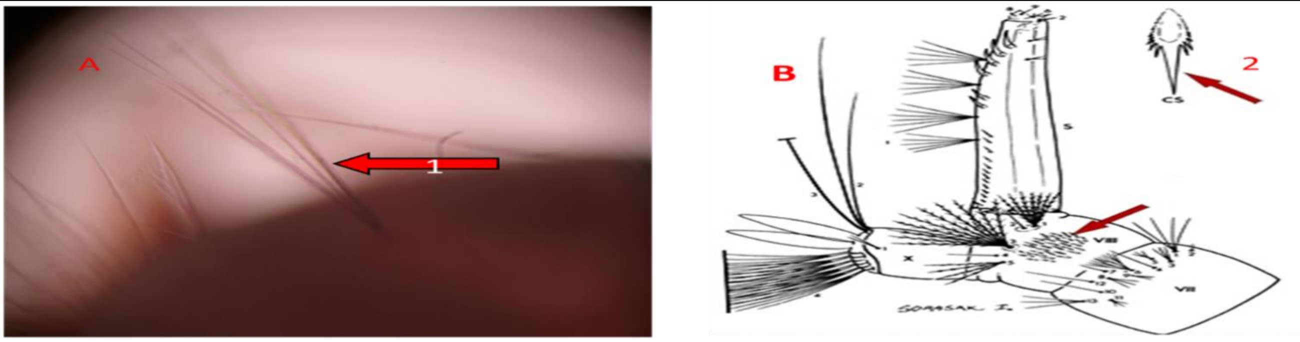
Head Seta 5-c branched (2-5) (Fig. 12c)

Abdomen comb scales more than 50 (Fig. 12d)

Fig 4: *Cx. tritaeniorhynchus* classification features

3.2.5 *Culex* (*Culex*) *Theileri* Theobald figure no (5)

Distribution: Gezira areas [20], El-Managil Town [26], Khartoum [38], Jebel Marra and Wadi Halfa area [22], and White Nile Area [21]. Represent about 5% of the total *Culex* spp. The species was recorded in my region in Sudan, and its potential vectors to West Nile virus (WNV) and dirofilaria immitis [39-42].



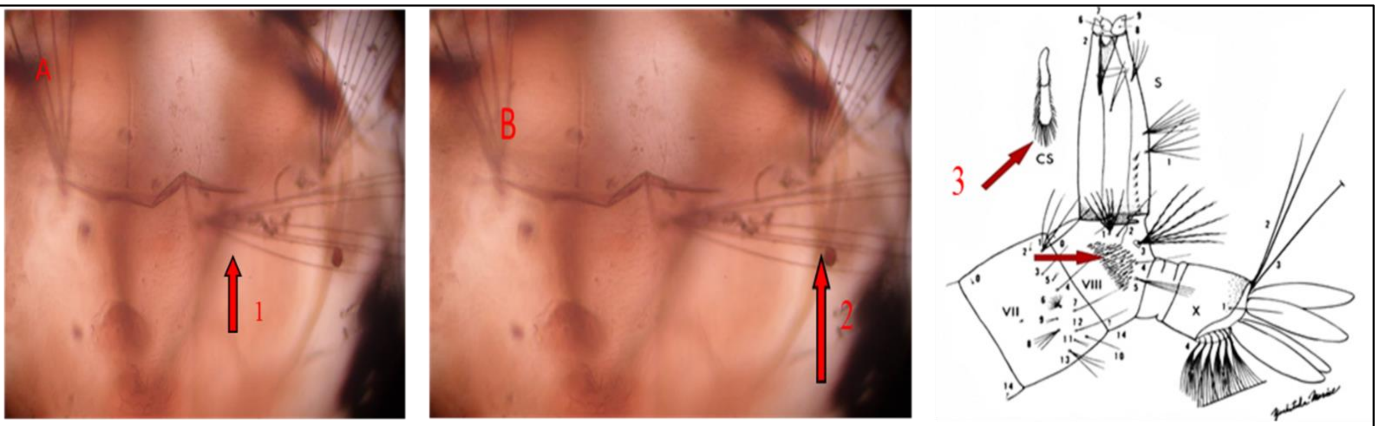
Head seta 5-c branched into 3-5 branches (Fig.5a).

Abdomen comb scale form pointed only (Fig.5b).

Fig 5: *Cx. theileri* classification features

3.2.6 *Culex musarum* Edward figure no (6)

Distribution: Gezira areas [20]. Represent about 4% of the total *Culex* spp. No medical important is record, most common in Nigeria and Uganda. [43, 44]



Head seta 5-c branched more than 5 branches (Fig.6a).

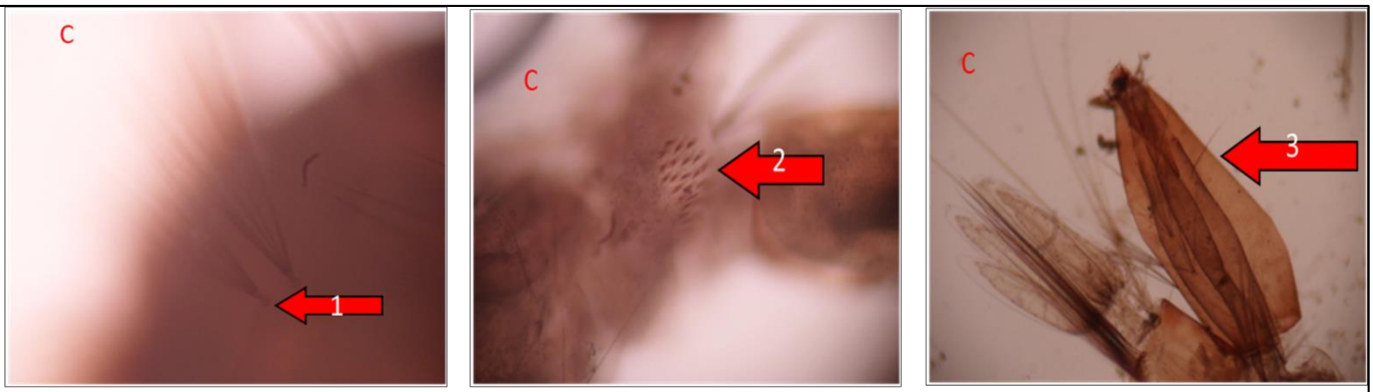
Head seta 7-c branched to 10 or more (Fig.6a).

The abdomen comb scales form not pointed (Fig.6a).

Fig 6: *Cx. musarum* classification features

3.2.7 *Culex* (*Culex*) *pipiens* Linnaeus. figure no (7)

Distribution: Gezira areas [20], El-Managil Town [26] distribution of *C. pipiens* in the Nile valley is largely dependent on man-made breeding places [43]. Only 2% of the total culicine identified were *C. pipiens*. However, this species is potential vector of RVFV in White Nile and Khartoum States [45]. Moreover, it's responsible of an outbreak of WNV in Southern Greece during July-October 2017 [46-48]. And RVFV outbreaks in Egypt in 1970 [49, 50].



Head seta 5-c, Number of branch more than 5 branches. (Fig.7a)

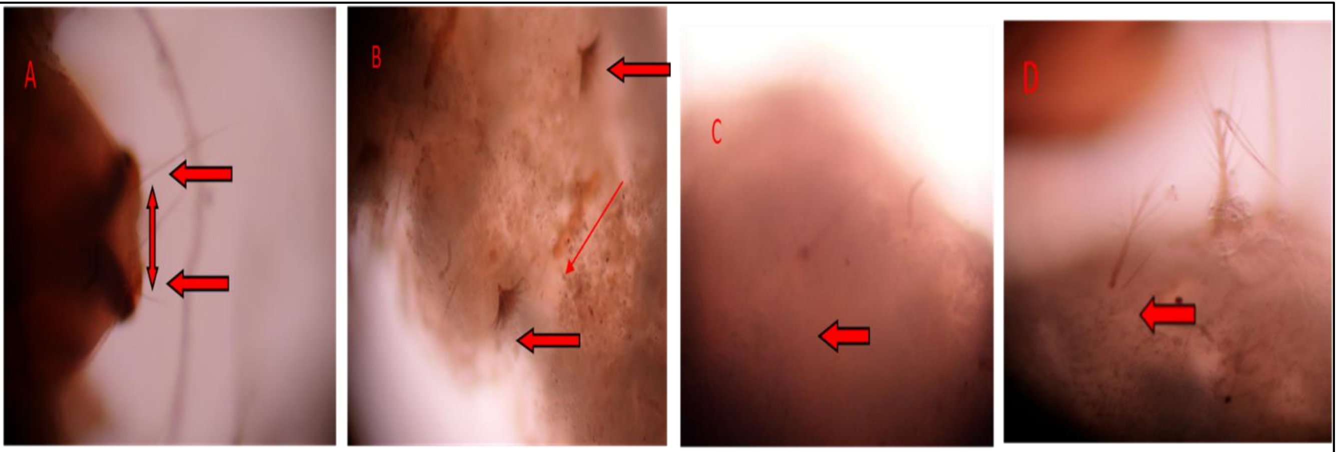
The Abdomen number of combe scale (10-40) (Fig.7b)

Abdomen siphon form curved at the end. (Fig.7C)

Fig 7: *Cx. pipiens* classification features

3.3 *Anopheline* spp.
The 2600 *anopheles* larvae collected belonged to six species: *An. arabiensis* (38%), *An. funestus* (27%), *An. rufipes* (24%), *An. phronesis* (9%), *An. nili* (0.5%) and *An. dattali* (0.5%).

3.3.1 *Anopheles arabiensis* figure no (8)
Distribution: Gezira areas [20], Khartoum [51], Northern State [52], El-Managil Town [26], eastern States [9], White Nile Area [21]. The *An. arabiensis* dominant *Anopheline* mosquitoes in Sudan, and consider is potential malaria vectors in Sudan for decades [53, 7, 9, 54].



Inner clypeal hairs widely separate outer clypeal simple or>8 branches, inner clypeal Simple frayed.(Fig.8a)

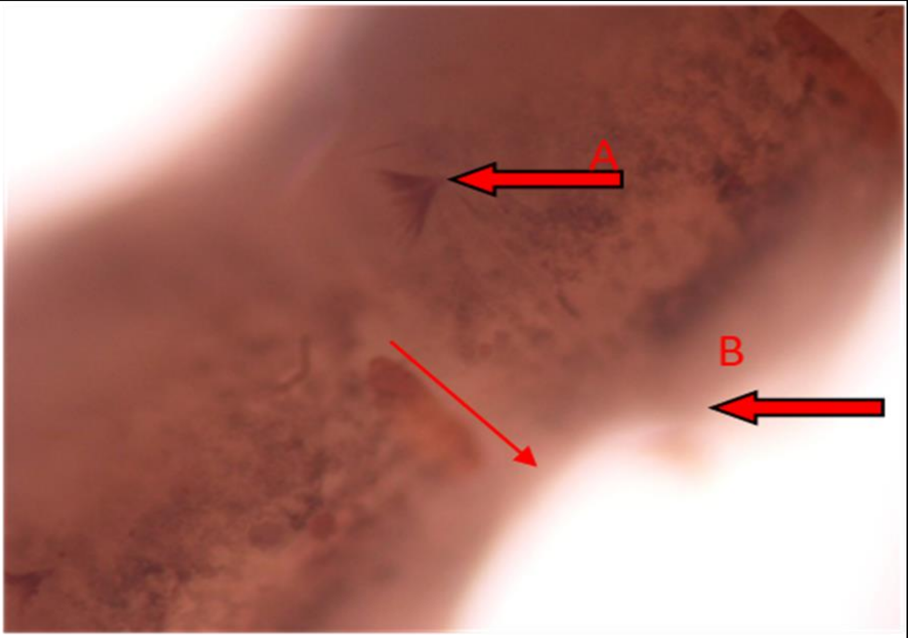
Abdominal Fig.segment "Not more than 2/3 distance between palmte teeth. (Fig.8b

Long mesopleural hairs simple occasionally one split into 1-3 branches. (Fig.8c)

Inner shoulder hairs poorly developed basal tubercles or non-existent. (Fig.8d)

Fig 8: *An. arabiensis* classification features

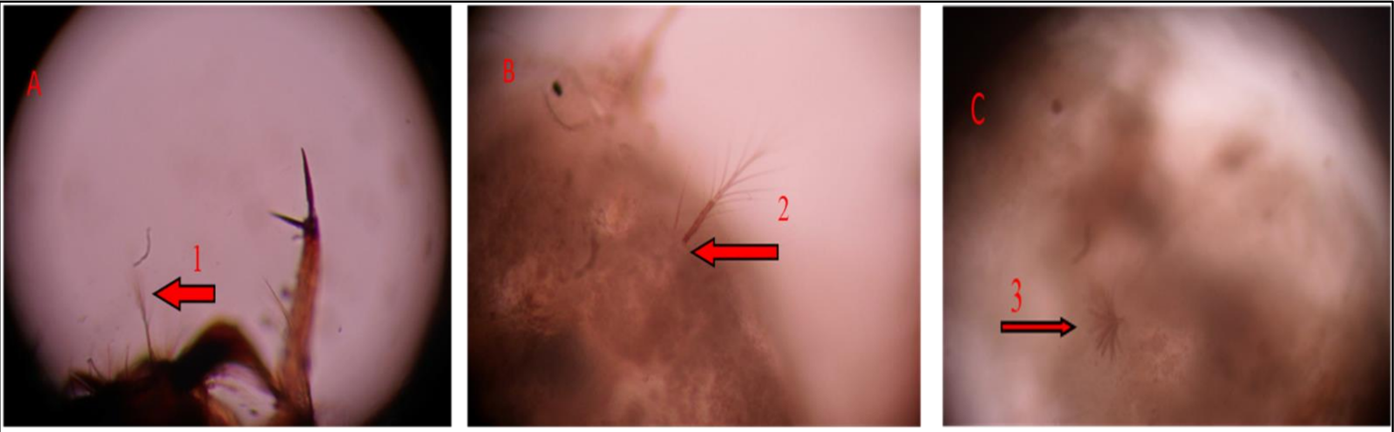
3.3.2 *Anopheles funestus* figure no (9)
Distribution: Gezira areas [20]. Previous research indicates species distribution in South Sudan and breed throughout the year and vector for malaria transmission. Further, Potential vectors for Plasmodium falciparum in multiple countries in African with highly infection rate confirmed by Ndo *et al*., preference to breed in cultivate area conform in previous study [55, 20, 56, 12].



- Inner clypeal hairs widely separate outer clypeal simple or>8 branches, inner clypeal Simple frayed.(Fig.8a)
- Abdominal Fig. on Segment ''at least ¾ distance between palmate hair; twice as large as deep''.(Fig.9b)

Fig 9: *An. funestus* classification features

3.3.3 *Anopheles rufipes* figure no (10)
Distribution: Gezira areas [20], El-Managil Town [26], Eastern Sudan' Rahad River basin' [57], it's widely spread throughout central and eastern Sudan, and previous research was recording the species in El-Managil [26], New Halfa [57], and Doka Alhauata, Alfua.



Inner clypeal hairs "strongly branched in apical half" (Fig. 10a).

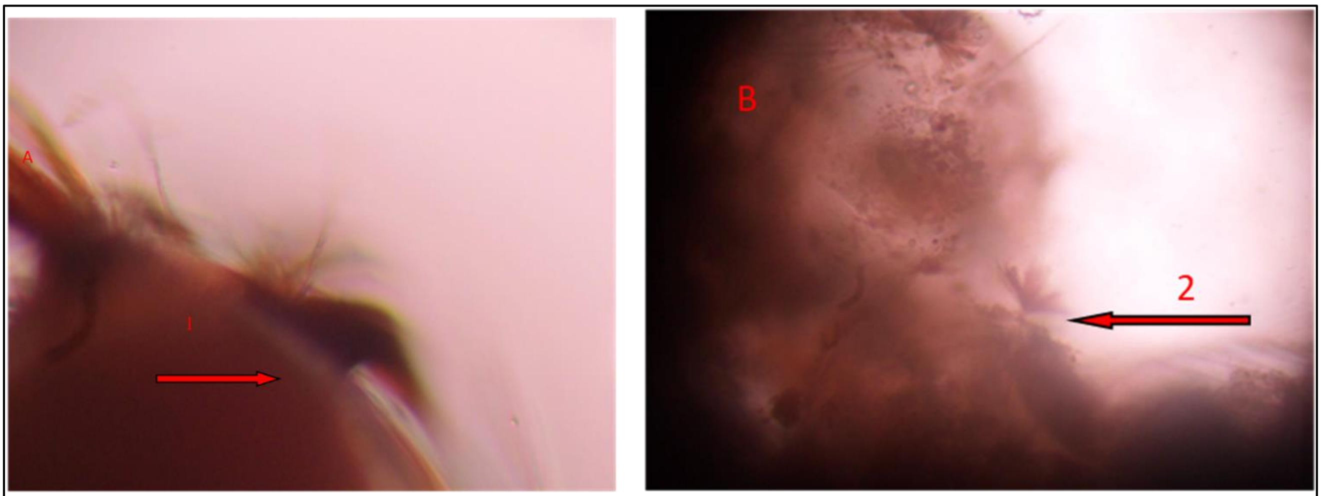
Long mesopleura hairs '' one feathered '' (Fig. 10b)

Palmate hairs with short blunt-tipped filaments (Fig. 10c)

Fig 10: *An. rufipes* classification features

3.3.4 *Anopheles phronesis* figure no (11)

Distribution: Gezira areas [20], El-Managil Town [26] and White Nile Area [21]



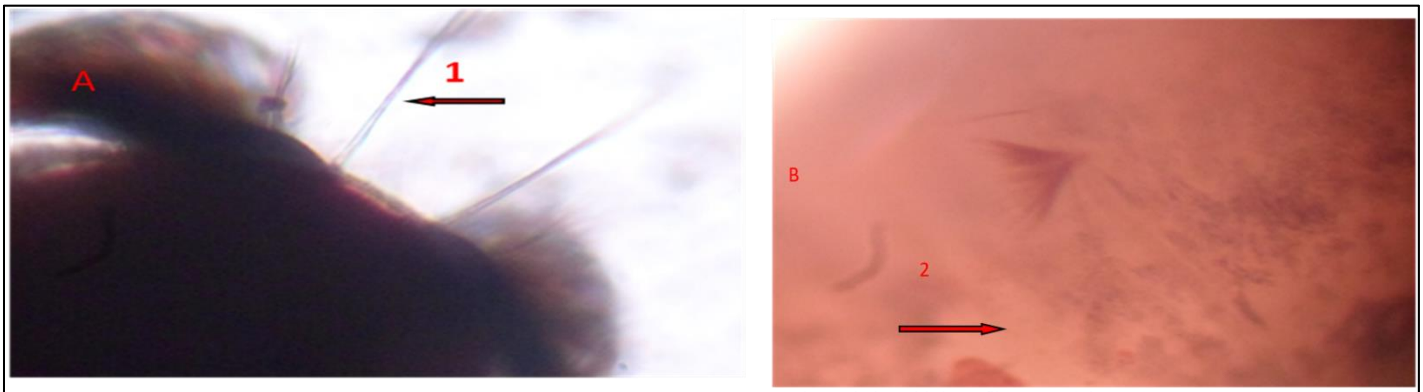
•Inner clypeal hairs '' widely separated (Fig.8a)
•Outer clypeal hairs '' with 8 or more branches (Fig.11a)

•Palmate hairs < 12 leaflets '' filaments of abdominal palmate hairs on segments 3-7 short and blunt. (Fig.11b)

Fig 11: *An. phronesis* classification features

3.3.5 *Anopheles nili* Theobald figure no (12)

Distribution: Jebelein and Kosti [1] and Gezira areas [20]. *An. nili* group the human preference feeding and contributing in the indoors and outdoors malaria transmission [58] and Gezira areas is known with a highly malaria transmission rate.



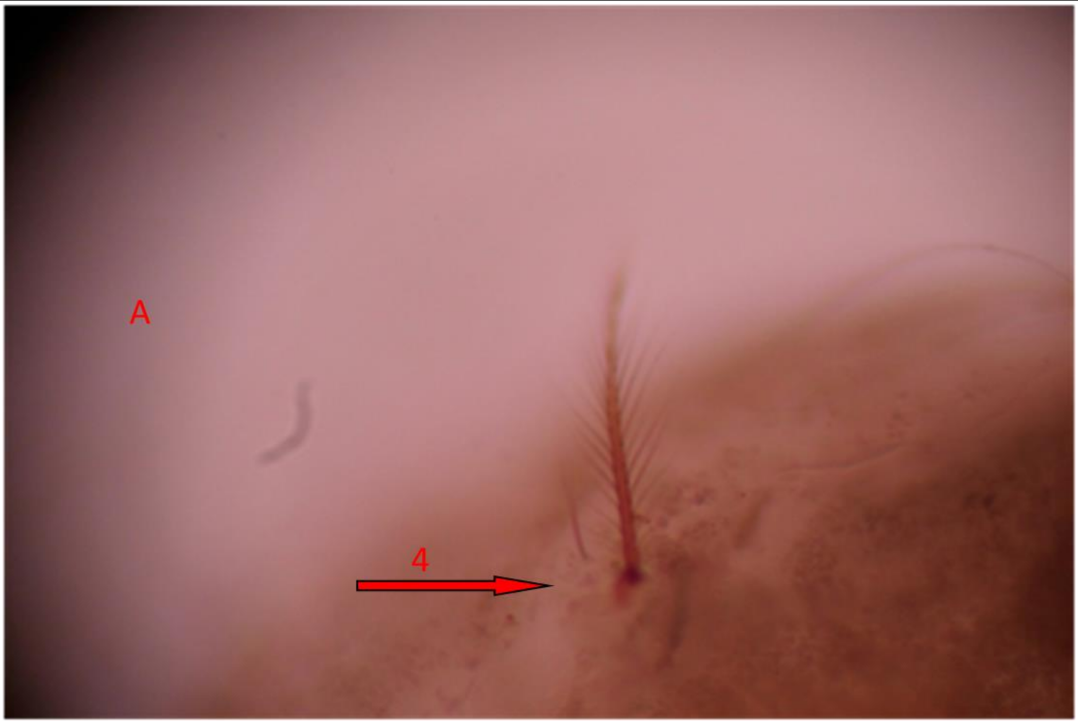
Inner clypeal strongly branched in apical. (Fig. 12a).

Palmate hairs with long filaments. (Fig. 12a).

Fig 12: *An. nili* classification features

3.3.6 *Anopheles dattali* figure no (13)

Distribution: Gezira areas [59, 20].



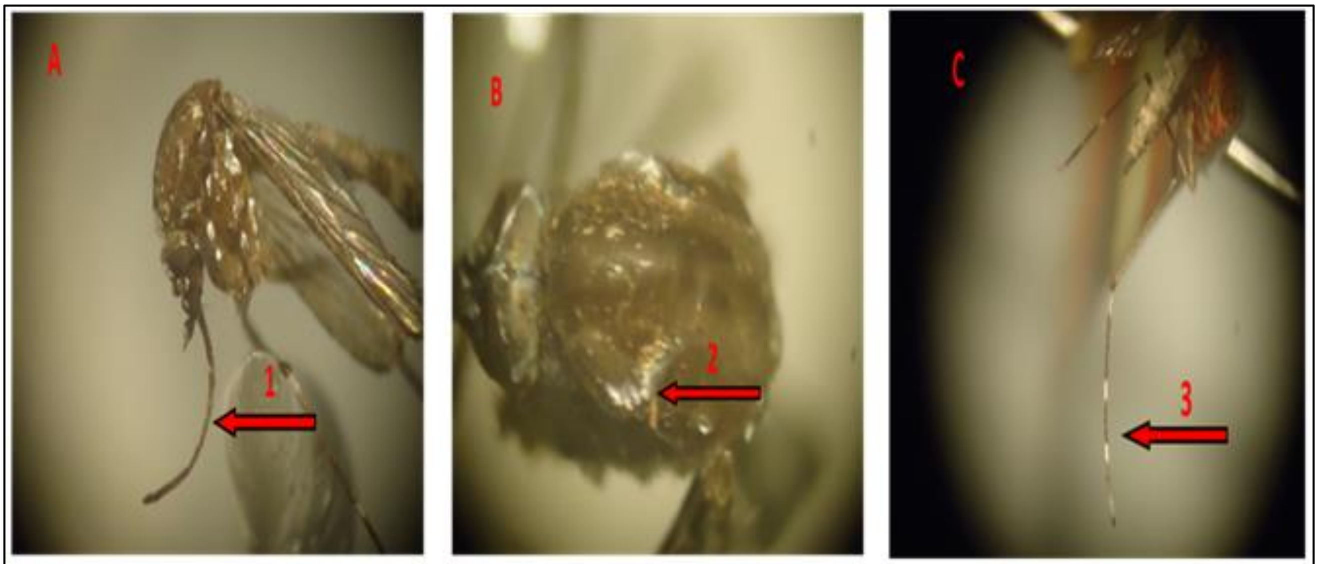
•Inner clypeal hairs widely separate outer clypeal simple or>8 branches, inner clypeal Simple frayed. (Fig.8a).
•Abdominal Fig.es segment "Not more than 2/3 distance between palmte tooth (Fig.8b).
•Long mesopleural hairs simple occasionally one split into 1-3 braches (Fig.8c).
•Inner shoulder hairs well developed, arising from well developing basal tubercles (Fig.13a) "distinct feature"

Fig 13: *An. dattali* classification features

3.4 *Aedine* spp.

3.4.1 *Aedes aegypti* L figure no (14)

Distribution: Widely distributed in the southern and central Sudan and recently observed in Gezira areas [20], Red Sea area [60]. The micro habitats were observed in septic tanks and jars. Its known that local habitats profile of *Ae. aegypti* was associated with human socioeconomic context [61].



Head proboscis without white band (Fig.14a).

The thorax. Scutum presence of lyre-shape white and have batch boarder crescent -shape white scales on fossal area) (Fig.14b).

Leg Hindtrasomere 5, all white (Fig.14c)

Fig 14: *An. aegypti* classification features

4. Conclusion

The mosquito fauna of Sudan currently comprises 106 species, among which three taxa. However, if we consider only species that have established reproductive populations, the resident culicinae fauna is composed of 7 species belonging to Culicinae subfamily, 6 species belonging to anopheline subfamily and only one species belonging to *Aedine* subgenus *stegomyia*.

Additional studies on the biogeography and ecology of Sudan mosquitoes are highly desirable, in particular on the relationships between historical and environmental factors, species richness and abundance of Culicidae on the different parts of the country. Furthermore, negative impacts of mosquito vectors on public health and the country's economy, but also on wildlife conservation, are worthy of extra investigation; this includes how to minimize the risks and introductions of new mosquitoes' species.

5. Acknowledgments

The technical assistance of staff at the Blue Nile National Institute for Communicable Diseases; University of Gezira, Sudan is greatly acknowledged.

6. Reference

1. Lewis D. Observations on the distribution and taxonomy of *Culicidae* (diptera) in the Sudan 1945; 95:1-24.
2. Sinka ME, Bangs MJ, Manguin S, Coetzee M, Mbogo CM, Hemingway J *et al*. The dominant *Anopheles* vectors of human malaria in africa, europe and the middle east: Occurrence data, distribution maps and bionomic précis. Parasite Vector 2010; 3:117.
3. Dandalo LC, Brooke BD, Munhenga G, Lobb LN, Zikhali J, Ngxongo SP *et al*. Population dynamics and plasmodium falciparum (Haemosporida: Plasmodiidae) infectivity rates for the malaria vector *Anopheles arabiensis* (Diptera: *Culicidae*) at mamfene, kwazulu-natal, South Africa. Journal of Medical Entomology. 2017; 54:1758-1766.
4. Konate L, Diagne N, Brahimi K, Faye O, Legros F, Rogier C *et al*. [biology of the vectors and transmission of *plasmodium falciparum, P. malariae* and *P. ovale* in a village in the savanna of west Africa (dielmo, senegal)]. Parasite 1994; 1:325-333.
5. de Souza D, Kelly-Hope L, Lawson B, Wilson M, Boakye D. Environmental factors associated with the distribution of *Anopheles gambiae* s.S in ghana; an important vector of lymphatic filariasis and malaria. PLoS One 2010; 5:e9927.
6. Dukeen MYH, Omer SM. Ecology of the malaria vector *Anopheles-arabiensis* patton (diptera, *culicidae*) by the nile in northern Sudan. B Entomol Res. 1986; 76:451-467.
7. El Gaddal AA, Haridi AA, Hassan FT, Hussein H. Malaria control in the gezira-managil irrigated scheme of the Sudan. The Journal of tropical medicine and hygiene 1985; 88:153-159.
8. Hamad AA, Nugud Ael H, Arnot DE, Giha HA, Abdel-Muhsin AM, Satti GM *et al*. A marked seasonality of malaria transmission in two rural sites in eastern Sudan. Acta Trop. 2002; 83:71-82.
9. Himeidan YE, Dukeen MY, El-Rayah el A, Adam I. *Anopheles arabiensis*: Abundance and insecticide resistance in an irrigated area of eastern Sudan. East Mediterr Health J. 2004; 10:167-174.
10. Himeidan YE, Muzamil HM, Jones CM, Ranson H. Extensive permethrin and ddt resistance in *Anopheles arabiensis* from eastern and central Sudan. Parasit Vectors 2011; 4:154.
11. Petrarca V, Nugud AD, Ahmed MA, Haridi AM, Di Deco MA, Coluzzi M. Cytogenetics of the *Anopheles gambiae* complex in Sudan, with special reference to *an. Arabiensis*: Relationships with east and west African populations. Med Vet Entomol. 2000; 14:149-164.
12. Petrarca V, Nugud AD, Ahmed MAE, Haridi AM, Di Deco MA, Coluzzi M. Cytogenetics of the *Anopheles gambiae* complex in Sudan, with special reference to *an. Arabiensis*: Relationships with east and west African populations. Med Vet Entomol. 2000; 14:149-164.
13. Himeidan YE, Kweka EJ, Mahgoub MM, El Rayah el A, Ouma JO. Recent outbreaks of rift valley fever in east Africa and the middle east. Front Public Health 2014; 2:169.
14. World Health Orgnization (WHO). Outbreak update – rift valley fever in Sudan, 2019.
15. Gould LH, Osman MS, Farnon EC, Griffith KS, Godsey MS, Karch S *et al*. An outbreak of yellow fever with concurrent chikungunya virus transmission in south kordofan, Sudan, 2005. Trans R Soc Trop Med Hyg 2008; 102:1247-1254.
16. Lewis DJ. The *Anopheline* mosquitos of the Sudan. B Entomol Res 1956; 47:475-494.
17. Ageep TB, Damiens D, Alsharif B, Ahmed A, Salih EHO, Ahmed FTA *et al*. Participation of irradiated *Anopheles arabiensis* males in swarms following field release in Sudan. Malaria J, 2014, 13.
18. Himeidan YE, Hamid EE, Thalib L, Elbashir MI, Adam I. Climatic variables and transmission of falciparum malaria in new halfa, eastern Sudan. East Mediterr Health J 2007; 13:17-24.
19. World Health Organization. Social M, Training T. Malaria entomology and vector control, Trial ed edn. World Health Organization: Geneva, 2003.
20. Mahgoub MM, Kweka EJ, Himeidan YE. Characterisation of larval habitats, species composition and factors associated with the seasonal abundance of mosquito fauna in gezira, Sudan. Infect Dis Poverty 2017; 6:23.
21. Nagwa E. Azrag aMMM. Dry season ecology and species composition of mosquito's fauna in white nile area central Sudan. International Journal of Applied and Natural Sciences (IJANS) 2018; 7:65-72.
22. Lewis D. Observations on the distribution and taxonomy of *Culicidae* (diptera) in the Sudan. Transactions of the Royal Entomological Society of London. 1944; 95:1-24.
23. Fawzy M, Helmy YA. The one health approach is necessary for the control of rift valley fever infections in Egypt: A comprehensive review. Viruses. 2019; 11:139.
24. Gideon Informatics I, Berger S. Rift valley fever: Global status: 2019 edition. Gideon Informatics, Incorporated, 2019.
25. Nepomichene TNJJ, Raharimalala FN, Andriamandimby SF, Ravalohery JP, Failloux AB, Heraud JM *et al*. Vector competence of *Culex antennatus* and *Anopheles coustani* mosquitoes for rift valley fever virus in madagascar. Med Vet Entomol 2018; 32:259-262.
26. Abubaker O, El-Rayah E. Mosquito fauna of El-managil

town and its adjoins. M.sc thesis, University of Khartoum, 2012.
27. El Rayah EA, Abu Groun NA. Competition between *Culex quinquefasciatus* say and *Anopheles arabiensis* patton in the khartoum area, Sudan. Int J Biometeorol 1983; 27:63-64.
28. Ali NO, El-Rabaa FM. Larvicidal activity of some plant extracts to larvae of the mosquito *Culex quinquefasciatus* (say 1823). Eur Rev Med Pharmacol Sci 2010; 14:925-933.
29. El Rayah EA, Abu Groun NA. Seasonal variation in numbers of eggs laid by *Culex quinquefasciatus* say (Diptera: *Culicidae*) at khartoum. Int J Biometeorol. 1983; 27:65-68.
30. Samy AM, Elaagip AH, Kenawy MA, Ayres CF, Peterson AT, Soliman DE. Climate change influences on the global potential distribution of the mosquito *Culex quinquefasciatus*, vector of west nile virus and *Lymphatic filariasis*. PLoS One. 2016; 11:e0163863.
31. Al Ahmad AM, Sallam MF, Khuriji MA, Kheir SM, Azari-Hamidian S. Checklist and pictorial key to fourth-instar larvae of mosquitoes (Diptera: *Culicidae*) of Saudi Arabia. Journal of Medical Entomology. 2011; 48:717-737.
32. Fontenille D. Arbovirus transmission cycles in madagascar. Archives de l'Institut Pasteur de Madagascar 1989; 55:1-317.
33. Kheir SM, Alahmed AM, Al Kuriji MA, Al Zubyani SF. Distribution and seasonal activity of mosquitoes in al madinah al munwwrah, Saudi Arabia. J Egypt Soc Parasitol. 2010; 40:215-227.
34. Le Goff G, Bousses P, Julienne S, Brengues C, Rahola N, Rocamora G *et al*. The mosquitoes (Diptera: Culidae) of seychelles: Taxonomy, ecology, vectorial importance, and identification keys. Parasit Vectors. 2012; 5:207.
35. Baqar S, Hayes CG, Murphy JR, Watts DM. Vertical transmission of west nile virus by *Culex* and *Aedes* species mosquitos. American Journal of Tropical Medicine and Hygiene. 1993; 48:757-762.
36. Ilkal MA, Mavale MS, Prasanna Y, Jacob PG, Geevarghese G, Banerjee K. Experimental studies on the vector potential of certain *Culex* species to West Nile Virus. Indian J Med Res 1997; 106:225-228.
37. Bhatt TR, Crabtree MB, Guirakhoo F, Monath TP, Miller BR. Growth characteristics of the chimeric japanese encephalitis virus vaccine candidate, chimerivax-je (yf/je sa14--14--2), in *Culex tritaeniorhynchus*, *Aedes Albopictu*s, and *Aedes Aegypti* mosquitoes. Am J Trop Med Hyg. 2000; 62:480-484.
38. Abu-Groun NAM. Studies on biology and population dynamics of mosquitoes of khartoum state. Ph. D. thesis, University of Khartoum, Sudan, 1988.
39. Demirci B, Durmaz E, Alten B. Influence of bloodmeal source on reproductive output of the potential west nile vector, *Culex theileri* (Diptera: *Culicidae*). J Med Entomol 2014; 51:1312-1316.
40. Jupp P, McIntosh B, Dickinson D. Quantitative experiments on the vector capability of *Culex* (*Culex*) *Theileri* theobald with west nile and sindbis viruses. Journal of medical entomology. 1972; 9:393-395.
41. Santa-Ana M, Khadem M, Capela R. Natural infection of *Culex theileri* (Diptera: *Culicidae*) with *Dirofilaria immitis* (Nematoda: Filarioidea) on madeira island, portugal. Journal of medical entomology. 2006; 43:104-106.
42. DEPM V, Mendes AM, Maurício IL, Calado MM, Novo MT, Belo S *et al*. Molecular detection of *Wolbachia pipientis* in natural populations of mosquito vectors of *Dirofilaria immitis* from continental portugal: First detection in *Culex theileri*. Med Vet Entomol 2016; 30:301-309.
43. Edwards FW. Mosquitoes of the ethiopian region. Iii.-culicine adults and pupae. London, Brit. Mus. (N. H.), 1941.
44. Okechukwu Anthony O, Adebote D, Oniye S. Studies on the proliferation of mosquitoes (diptera: *Culicidae*) in waste automobile tyres in parts of Nigeria's guinea savanna, 2010.
45. Abdelgadir DM, Bashab HMM, Mohamed RAE, Abuelmaali SA. Risk factor analysis for outbreak of rift valley fever in khartoum state of Sudan. J Entomol Sci 2010; 45:239-251.
46. Almeida APG, Freitas FB, Novo MT, Sousa CA, Rodrigues JC, Alves R *et al*. Mosquito surveys and west nile virus screening in two different areas of southern portugal, 2004-2007. Vector-Borne Zoonot 2010; 10:673-680.
47. Mavridis K, Fotakis EA, Kioulos I, Mpellou S, Konstantas S, Varela E *et al*. Detection of west nile virus - lineage 2 In *Culex pipiens* mosquitoes, associated with disease outbreak in greece, 2017. Acta Trop 2018; 182:64-68.
48. Munoz J, Ruiz S, Soriguer R, Alcaide M, Viana DS, Roiz D *et al*. Feeding patterns of potential west nile virus vectors in south-west spain. Plos One 2012, 7.
49. Eisa M, Kheir el-Sid ED, Shomein AM, Meegan JM. An outbreak of rift valley fever in the Sudan--1976. Trans R Soc Trop Med Hyg 1980; 74:417-419.
50. Kramer LD, Bernard KA. West nile virus in the western hemisphere. Curr Opin Infect Dis. 2001; 14:519-525.
51. El Sayed BB, Arnot DE, Mukhtar MM, Baraka OZ, Dafalla AA, Elnaiem DE *et al*. A study of the urban malaria transmission problem in khartoum. Acta Trop 2000; 75:163-171.
52. Ageep TB, Cox J, Hassan MM, Knols BG, Benedict MQ, Malcolm CA *et al*. Spatial and temporal distribution of the malaria mosquito *Anopheles arabiensis* in northern Sudan: Influence of environmental factors and implications for vector control. Malar J. 2009; 8:123.
53. Azrag RS, Mohammed BH. *Anopheles arabiensis* in Sudan: A noticeable tolerance to urban polluted larval habitats associated with resistance to temephos. Malar J 2018; 17:204.
54. Omer SM, Cloudsley-Thompson JL. Survival of female *Anopheles gambiae* giles through a 9-month dry season in Sudan. Bull World Health Organ. 1970; 42:319-330.
55. Kweka EJ, Munga S, Himeidan Y, Githeko AK, Yan G. Assessment of mosquito larval productivity among different land use types for targeted malaria vector control in the western kenya highlands. Parasit Vectors 2015; 8:356.
56. Ndo C, Kopya E, Donbou MA, Njiokou F, Awono-Ambene P, Wondji C. Elevated plasmodium infection rates and high pyrethroid resistance in major malaria vectors in a forested area of cameroon highlight challenges of malaria control. Parasit Vectors 2018;

11:157.
57. Himeidan YE, Elzaki MM, Kweka EJ, Ibrahim M, Elhassan IM. Pattern of malaria transmission along the rahad river basin, eastern Sudan. Parasit Vectors 2011; 4:109.
58. Ossè RA, Tokponnon F, Padonou GG, Sidick A, Aïkpon R, Fassinou A *et al*. Involvement of *Anopheles Nili* in *Plasmodium falciparum* transmission in north benin. Malaria J 2019; 18:152.
59. Awad OMAH. Knowledge, attitude and practices among public health spray-workers towards the use, application and hazard of insecticides in gezira state, Sudan (2014-2016), University of Gezira, 2017.
60. Seidahmed OM, Siam HA, Soghaier MA, Abubakr M, Osman HA, Abd Elrhman LS *et al*. Dengue vector control and surveillance during a major outbreak in a coastal red sea area in Sudan. East Mediterr Health J 2012; 18:1217-1224.
61. Seidahmed OM, Hassan SA, Soghaier MA, Siam HA, Ahmed FT, Elkarsany MM *et al*. Spatial and temporal patterns of dengue transmission along a red sea coastline: A longitudinal entomological and serological survey in port Sudan city. PLoS Negl Trop Dis. 2012; 6:e1821.