Malaya Journal of Biosciences 2014, 1(2):117–125
ISSN 2348-6236 print /2348-3075 online

Malaya Journal of Biosciences
www.malayabiosciences.com

RESEARCH ARTICLE

Open Access Full Text Article

Distribution and Oviposition Dynamics of Mosquito (Diptera: Culicidae) in response to Ovitrap Substratal Material in Minna, Nigeria

Olayemi I K[1], Olupinla T[1], Ukubuiwe A C[1*], Odeyemi, M O[2] and Salihu I M[2]

[1]Applied Entomology and Parasitology Research Unit, Department of Biological Sciences, Federal University of Technology, Minna, Nigeria.
[2]Department of Zoology, University of Ilorin, Ilorin, Nigeria.
[3]Department of Science Laboratory Technology, Federal Polytechnic Bida, Niger State, Nigeria.
**For correspondence e-mail: azubuike383@gmail.com*

Article Info: Received 22 July 2014; Revised: 28 Aug 2014; Accepted 07 Sep 2014

ABSTRACT

The present study deals with oviposition responses of mosquito populations to larval breeding habitat substrata type and subsequent effects on development and survivorship of immature life stages were elucidated in Minna, North central Nigeria. Earthen pot ovitraps, lined with different substratal material type: clay, loamy, sandy and gravel, as well as, control experiments with bare substratum, were set up in representative spatio-ecological settings to attract ovipositing mosquitoes in the study area. Spatial distribution of the mosquito Genera encountered varied significantly among the sampling sites, with aggregate densities ranging from 28.89 ± 8.24 larvae/ovitrap (i.e., 20.76%), to 38.61 ± 18.61 larvae/ovitrap (27.75%). The most abundant mosquitoes in the area were *Aedes* (53.54%), followed by *Culex* (47.74%), while, the anophelines were scanty (0.87%). The results of the oviposition behaviour indicated significant ($p<0.05$) attraction of the ovipositing mosquitoes to ovitraps lined with earthen substrata relative to the control; as well as, significant discrimination amongst such ovitraps. The aggregate mosquito population bred significantly ($p<0.05$) highest in loamy ovitrap substratum (50.50 ± 20.26 larvae/ovitrap, 31.12%), followed by sandy ovitraps (34.50 ± 8.17 larvae/ovitrap, 21.26%) and least encountered in clay substratum (16.80%). With the exception of clay substratal ovitraps that were most attractive to *Aedes* mosquito (53.21%), all other types of substratum were most colonized by *Culex* individuals (range=55.07- 63.20%). Significantly higher densities of adult mosquitoes eclosed from loamy and clay substratal ovitraps (12.75 ± 3.09 adults/ovitrap, 28.68% and 11.25 ± 4.35 adults/ovitrap, 25.30%, respectively). However, proportional immature-adult development success was highest ($p<0.05$) among ovitraps lined with clay substratum (41.28%). The findings of this study suggest the need for site-specific approach for mosquito vector control in Minna, with great potentials for environmental management control tactics.

Keywords: *Adult emergence, Aedes, Anopheles, Culex, Larvae and pupa*

1. INTRODUCTION

The burdens of mosquito-borne diseases have continued to impact subtractively on public health and socio-economic well-being of people, in region where anthropogenic and ecological conditions favour the occurrence of the pathogens and proliferation of vector mosquitoes [1-3]. These diseases put more than 70% of the world's 6 billion at the risk of infection and may be responsible for as much as 4 million human deaths yearly [4-7]. In Nigeria, for example, malaria is hyper-endemic in all eco-zones, threatening the health of >90% of the country's 140 million people [8-11], and accounts for over 300,000 deaths every year [12,13].

The intensities of transmission of mosquito-borne diseases are largely influenced by vectorial density [14-16]. Several studies have established direct linear association between mosquito densities and availability of suitable immature breeding habitats [17-21]. Suitability of water receptacles for mosquito breeding is largely dictated by certain critical factors including, physico-chemical properties of water media [22-25] and edaphic parameters of the substratum [26-30]. The former factors have been thoroughly elucidated but very little is known about the roles played by substratal materials in the productivity of mosquito immature breeding habitats. Olayemi and Ojo [31] reported significant variation in organic matter content of the substratum of mosquito ovitraps which, in-turn, influenced the development of the inherent immature mosquitoes. Therefore, in order to elucidate the roles played by nature of substratal materials in breeding ecology of mosquitoes, this study was carried out to test the effects of different soil/stone substrata on the distribution and oviposition preferences of mosquito populations in Minna, North central Nigeria.

2. MATERIALS AND METHODS

2.1. Description of the study Area

The study was carried out in Minna, the capital city of Niger state in north-central Nigeria. Located within Longitude 6^0 33' E and Latitude 9^0 27 ' N. Minna has a human population of 2 million, and covers an estimated land area of 88 km^2. The climate of the area is characteristically tropical, with two distinct seasons namely, a rainy season from the month of May to October and dry season starting in December through March the following year. Inter-seasonal transition periods of semi wetness and dryness occur in the months of April and November, respectively. Mean annual weather conditions in Minna include, 30ºC, 65.00% relative humidity and 1,300 mm total rainfall. The vegetation of the area is traditionally grass-dominated with sparsely distributed woody species of the Sudan savannah type [32]. Minna is endemic for malaria [32], and harbored a rich diversity of Mosquito biota [25]. Mosquitoes in the area breed preferentially in man-made water receptacles with characteristic clement physico-chemical conditions [25].

2.2. Selection of Ovitrap Stations and Experimental Set-up

Four representative locations, separated by distance ranging from 8-13 km, were selected in the study area, for placement of mosquito ovitraps. Four substrate-materials namely, sandy, clay, loamy soils and gravel, were obtained from areas typical of such soil types within the city, and have their identities authenticated by a soil ecologist. The substrate materials were heated in an oven to 70ºC to eliminate wild mosquito eggs, after which 500 g of each substrate type was put in separate clay pots (32 cm maximum diameter x 25 cm height). The substrates were flooded with 2 litres of bore-hole water, to water depths ranging from 5-7 cm, depending on the absorptive capacity of the substrate. The clay pots were then screened with Muslin to exclude pre-experimental egg deposition by wild mosquitoes; and allowed to stand in the laboratory for three days to condition the ovitrap water and confirm absolute elimination of wild mosquito eggs. A Control experiment was set up, with bare clay pot substratum, i.e., devoid of the introduced substrate. Each substrate treatment, as well as the Control was set up in four replicates.

At 72 hours post-ovitrap constitution, the pots were deployed to the four locations earlier selected, and arranged in complete- randomized pattern. The ovitraps were allowed to stand in the field for 7 days; previous studies indicated that duration of mosquito immature development in the area ranged from 8 to 14 days, depending on the species [33, 34]. Therefore, the ovitraps were retrieved to the laboratory, screened with muslin net and monitored for survivorship and duration of development of inherent immature stages. At pupation, the mosquitoes were transferred to adult-holding cages for emergence.

2.3. Larvae and Pupae Culture and Adult Identification

The larvae were reared following standard techniques [16, 35, 36] in the water medium from the ovitraps which were labelled to aid identification. The larvae were fed with fish feed (Tetramin®), at the rate of 0.32 mg/larva every other day, sprinkled on the water surface. The mean temperature and relative humidity of the insectary, during the study period, were 28.0 ± 1ºC and 70.2 ± 2.82% respectively, with 17 L: 7 D photoperiod. The specimens were identified using the keys of [37, 38].

2.4. Statistical Analysis

Data collected were processed as Mean±SD for statistical analysis. Differences in means of entomological variables among sites, as well as, types of substrates, were compared for statistical significance using ANOVA. However, such means among the three mosquito genera were compared using Chi-square test. All statistical tests were done at P = 0.05 level of significance.

3. RESULTS

The spatial distribution and relative abundance of mosquito Genera in Minna during the study period are highlighted in Table 1. Distribution of mosquito populations among the locations varied significantly (P<0.05), with aggregate densities ranging from 28.89 ± 8.24 larvae/ovitrap (i.e., 20.76%) in Maikunkele, to 38.61 ± 18.61 larvae/ovitrap (27.75%) in Bosso. The individual Mosquito Genus demonstrated distinct distribution patterns among the locations, although, Anopheles and Culex mosquitoes were both statistically least encountered in Chanchaga and Maikunkele. While the anopheline mosquitoes were significantly most abundant in Gidan Kwanu, the culicine Genera had their highest densities in both Bosso and Gidan Kwano. On the whole, the most abundant mosquitoes in the area during the study period, were Aedes (53.54%), followed by Culex (47.74%), while the anophelines were scanty (0.87%).

The preferences of the mosquito Genera for ovitrap substratal materials are presented in Table 2. Ovitraps with bare substratum (i.e., Control) supported the least densities of Mosquito populations. Generally, the mosquitoes exhibited significant (P<0.05) preference for larval habitat substratal material type. The aggregate mosquito population bred significantly highest (50.50 ± 20.26% larvae/ovitrap, 31.12%) in loamy soil-lined substratum, followed by sandy substratum (34.50 ± 8.17 larvae/ovitrap, 21.26%), and were least but statistically equally encountered in clay and gravel substrata (16.80 and 19.26%, respectively). No anopheline mosquito was recovered from the clay substratum ovitrap, and the few specimens collected were distributed statistically uniformly among the remaining three substratal types namely, loamy, sandy and gravel. While, the density distribution of the Aedes mosquito ranged from 11.25 ± 3.40 larvae/ovitrap (15.96%) in gravel substratum, to 19.25 ± 7.41 larave/ovitrap (27.34%) in loamy; the Culex individuals were most abundant in ovitraps of Loamy substratum and least encountered in clay. The individual attractiveness of loamy, sandy and gravel substrata followed the same pattern, in the order of Culex (range=55.07-63.20%) > Aedes (36.00 to 42.75%) > Anopheles (0.80 to 3.47%). Ovitraps with clay substratum were distinctly most attractive to Aedes mosquitoes (53.21%), followed by Culex (46.79%).

The adult mosquito emergence rates and success from the different substratal types are presented in Table 3. Significantly (P<0.05) higher densities of adult mosquitoes ecloded from ovitraps lined with loamy substratum (12.75 ± 3.09 adults/ovitraps, 28.68%), and clay ovitraps (11.25 ± 4.35 adult/ovitraps, 25.30%), while, mosquito emergence from sandy and gravel substratal were not significantly different (P>0.05), with a range of 17.43 – 20.24%. Significantly, higher proportions (41.28%) of immature mosquitoes that colonized clay-lined ovitraps successfully emerged as adults, than those of the other types of substratal materials tested (range= 19.79% in the bare-substratal ovitraps (control), to 26.09% in sandy).

4. DISCUSSION

The distribution and densities of mosquitoes encountered varied significantly across the city, with the individual mosquito *Genus* demonstrating distinct population dynamics. Similar spatial heterogeneity in mosquito distribution has been severally reported [20, 39, 40], and attributed differential prevailing eco-anthropogenic conditions of mosquitoes in an area. Heterogeneity in mosquito vector distribution results in equally differential intensities of disease transmission [25, 44]. This finding, therefore, suggest that effective mosquito vector control in the study area may not be attained through common deployment of control interventions based on extrapolation of knowledge of vector density from one locality to another, as presently practiced by public health officials in the city.

Table 1. Spatial Distribution and relative abundance of mosquito populations in Minna, Nigeria

Location of Mosquito Collection	Mosquito Genera			Aggregate
	Anopheles	*Aedes*	*Culex*	
Bosso	0.33±0.71* (0.86)^{a**} (27.05)$_{b**}$	19.39±9.32 (50.22)^{b} (26.03)$_{b}$	18.89±8.11 (48.93)^{b} (28.43)$_{b}$	38.61±18.61 (100.00) (27.75)$_{c}$
Chanchaga	0.22±0.44 (0.95)^{a} (18.03)$_{a}$	23.00±11.41 (51.61)^{c} (30.82)$_{c}$	14.11±9.67 (37.79)^{b} (21.24)$_{a}$	37.33±21.52 (100.00) (26.82)$_{ab}$
Maikunkele	0.22±0.44 (0.77)^{a} (18.03)$_{a}$	13.44±4.22 (46.54)^{b} (18.04)$_{a}$	15.22±3.38 (52.69)^{b} (22.91)$_{a}$	28.89±8.24 (100.00) (20.76)$_{a}$
Gidan Kwano	0.44±1.01 (1.29)^{a} (36.07)$_{c}$	18.67±8.62 (54.37)^{c} (25.06)$_{b}$	18.22±6.89 (44.34)^{b} (27.42)$_{b}$	34.33±16.52 (100.00) (24.67)$_{ab}$
Aggregate	1.21±2.60 (0.87)^{a} (100.00)	74.50±33.78 (53.54)^{b} (100.00)	66.44±28.05 (47.74)^{b} (100.00)	139.16±64.89 (100.00) (100.00)

Values in parenthesis are percentage proportions of total mosquito collection.

*Mean ± S.D. of number of mosquito larvae collected per ovitrap.

Table 2. Influence of ovitrap-substratal type on mosquito larval abundance in Minna, Nigeria

Mosquito Genera	Ovitrap-substratal Type					Aggregate
	Bare (Control)	Clay	Loamy	Sandy	Gravel	
Aedes	10.75±11.44*(15.25)^{a**} (57.33)$_{c***}$	14.50±3.42(20.57)^{b} (53.21)$_{c}$	19.25±7.41(27.34)^{c} (38.12)$_{b}$	14.75±4.11(20.92)^{b} (42.75)$_{b}$	11.25±3.40(15.96)^{a} (36.00)$_{b}$	70.50±29.78(100.00) (43.45)$_{b}$
Anopheles	0.00±0.00(0.00)^{a} (0.00)$_{a}$	0.00±0.00(0.00)^{a} (0.00)$_{a}$	1.75±0.95(63.64)^{c} (3.47)$_{a}$	0.75±0.50(27.27)^{bc} (2.17)$_{a}$	0.25±0.50(9.09)^{b} (0.80)$_{a}$	2.75±1.95(100.00) (1.69)$_{a}$
Culex	8.00±4.69(8.99)^{a} (42.67)$_{b}$	12.75±1.71(14.33)^{a} (46.79)$_{b}$	29.50±11.90(33.15)^{d} (58.42)$_{c}$	19.00±3.56(21.35)^{c} (55.07)$_{c}$	19.75±2.63(22.19)^{c} (63.20)$_{c}$	89.00±24.49(100.00) (54.85)$_{c}$
Aggregate	18.75±16.13(11.56)^{a} (100.00)	27.25±5.13(16.80)^{b} (100.00)	50.50±20.26(31.12)^{d} (100.00)	34.50±8.17(21.26)^{c} (100.00)	31.25±6.53(19.26)^{b} (100.00)	162.25±56.22(100.00) (100.00)

Values in parenthesis are percentage proportions of total mosquito collection.
*Mean±SD of number of mosquito larvae collected per ovitrap.
**Values followed by same superscript alphabets, in a row, are not significantly different at P=0.05

Table 3. Influence of ovitrap substratal type on adult emergence success rates of Mosquito population in Minna, Nigeria

Larval Habitat Substratum	Developing Larvae/Ovitrap	Adult Emergence/Ovitrap	Percentage Emergence Success/Ovitrap
Bare	18.75±16.50 (11.76)[a]*	3.71±1.83 (8.34)[a]	19.79[a]
Clay Soil	27.25±5.13 (17.10)[b]	11.25±4.35 (25.30)[c]	41.28[c]
Loamy Soil	50.50±20.26 (31.68)[c]	12.75±3.09 (28.68)[c]	25.26[b]
Sandy Soil	34.50±8.17 (21.64)[b]	9.00±5.09 (20.24)[b]	26.09[b]
Gravel	31.25±6.53 (19.60)[b]	7.75±2.22 (17.43)[b]	24.80[b]
Aggregate	159.40±56.22 (100.00)	44.46±16.58 (100.00)	27.89

Values in parenthesis are percentage proportions of total Mosquito collections
*Values followed by same superscript alphabets, in a row, are not significantly different at P=0.05

While, the anopheline mosquitoes were most abundant in the semi-rural Gidan Kwano outskirt of the city, their Culicine counterparts had their highest densities in the highly urban but poorly planned Bosso segment of the area. These results agree with the conventional population ecology of the two mosquito Genera. According to Fillinger *et al.* [41], anopheline mosquitoes are more ubiquitous in rural areas, where less-polluted natural breeding habitats such as temporary sun-lit ground pools are readily available especially in the rainy season. On the other hand, while *Aedes* mosquitoes are the fore-most urban domestic-container breeders [42], the *Culex* individuals are known to breed preferentially in polluted habitats in urban slum, characterized by poor infrastructural amenities [25]. The aedine mosquitoes were the most abundant in Minna, during the study period, though they were closely rivalled by the *Culex* individuals. This finding contradicts those of earlier similar studies in North central Nigeria, Minna inclusive that consistently reported significantly higher densities of *Culex* mosquitoes relative to the other two vector Genera, i.e., *Anopheles* and *Aedes* [25, 21, 43].

The preponderance of Aedine mosquitoes in the study area, in this study, may be due to the oviposition-attractant bias that would be created by the use of earthen pot ovitraps for mosquito sampling; as *Aedes aegypti*, the dominant cosmopolitan aedine species, breeds preferentially in domestic containers. However, the relatively high densities of *Culex* and *Aedes* mosquitoes recorded in Minna indicate serious threats to public health in the area, especially, with respect to important human diseases, such s filariasis and yellow fever, transmitted by these mosquito Genera, respectively.

The mosquitoes bred significantly in higher densities in ovitraps with earthen substrata than the bare-substratal pots, and subsequently discriminated distinctly among the different types of substratal material. This result confirms earlier suspicions of Pfaehla *et al.* [30] and, Olayemi and Ojo [31], that the quality of earthen substrata of larval breeding habitats significantly influences mosquito productivity from such sites, through enrichment with discrete organic-particle larval diets and provision of suitable mineral content conditions for good phytoplankton growth and osmotic balance.

Aggregate larval densities were highest amongst ovitraps lined with loamy substratum, and least in those of clay and gravel substrata. This finding may be occasioned by the fact that soil types, even as investigated in this study, differ considerably in quality especially in terms of organic and mineral contents [25]; of the such that influence productivity of Mosquito larval habitats. Therefore, loamy soil being the most fertile type of soil is likely to provide a more attractive oviposition site to gravid mosquitoes. Clay soils though containing appreciable organic and mineral components is equally rich in certain chemical compounds, such as colloids that may possess mosquito oviposition-repellence effects. According to Olagbemiro *et al.* [45, 46], mosquito are sensitive to a number of physical, biological and chemical cues that guide the selection of optimum oviposition sites for immature development. Gravel ovitrap substratum may be totally devoid of organic materials and mineral salts, probably explaining the relatively low larvae encountered in such ovitraps.

Though, aggregate adult mosquito emergence was significantly highest in ovitraps with loamy substratum and least amongst those of gravel, results that are consistent with those of the distribution of larval densities amongst the types of substratum, proportional larval-adult developmental success, was significantly highest in ovitraps lined with clay substratum. This result is surprising, as the clay ovitraps attracted the least number of ovipositing mosquitoes, in terms of larval density amongst the earthen substratal types; been only more productive than the control ovitraps that had bare substratum. This observation suggests that either the discriminating-judgement of the ovipositing mosquitoes were far less that accurate in assessing the different ovitrap substratal types for maximum immature development potential, or consideration for factors other than success of immature development, play greater role in mosquito oviposition site selection. This finding, therefore, calls to question the conventional belief [27, 29, 47], that the likelihood of completion of immature development is the primary consideration in oviposition site selection by mosquitoes.

5. CONCLUSION

Spatial heterogeneity characterizes the distribution of mosquitoes in Minna, North central Nigeria, thus effective mosquito vector control in the area demands locality-specific type and tempo control interventions. Vectors of filariasis and yellow fever, namely, *Culex* and *Aedes* mosquitoes are relatively abundant in the study area and, therefore, surveillance and parasite control of these diseases must be vigorously implemented along-side those of the vectors. The mosquitoes bred significantly in ovitraps lined with earthen material substrata, with distinct discriminations amongst such ovitraps. This finding should provide useful clues for more accurate assessment of mosquito breeding habitats for targeted control. The preferred ovitrap substratal types (i.e., loamy) by the mosquitoes was not justified by larval-adult development success, thereby, calling to question established conventional knowledge of mosquito oviposition site selection decision-making by mosquitoes, to aid informed vector control larviciding interventions.

Acknowledgement

The authors wish to thank Dr. I. K. Olayemi, Head of Entomological Unit, Department of Biological Sciences for providing laboratory facilities. Authors also wish to thank Laboratory technicians for their co-operation in the extraction processes.

Conflict of Interest

The authors declare that they have no conflicts of interest.

References

1. Sachs J and Malaney P (2002). The economic and social burden of malaria. *Nature;* 415: 680-685.
2. Muturi EJ, Burgess P and Navak RJ (2008). Malaria vector management: Where have we come from and where are we headed? The *American Journal of Tropical Medicine and Hygiene*; 78: 536-537.
3. Olayemi IK (2008). Influence of land-use on the fitness of *Anopheles gambiae*, the principal vector of malaria in Nigeria. *Online Journal of Health and Allied Sciences*; 7(4): 3. *http://www.ojhas.org/issue 282008-4-3.htm.*
4. World Health Organization (2004). *Community participation and tropical disease control in resource-poor settings*. TDR/STR/SEB/ST/04.1, World Health Organization, Geneva, Switzerland, pp: 1-52.
5. Tetteh G and Adeya G (2005). Rapid Assessment of Antimalarial Drug Availability and Use in Nigeria, February-March 2004. Arlington: Rational Pharmaceutical Management plus Program (USAID), Management Sciences for Health.

6. World Health Organization (2011). "Lymphatic filariasis". http://www.who.int/mediacentre/factsheets/fs102/en/
7. Amiruddin R, Sidik D, Alwi A, Islam N, Jumriani P and Syafruddin A (2012). Socioeconomic factors and access to health services for malaria control in Mamuju District, West Sulawesi, Indonesia. *Asian Journal of Epidemiology; 5*: 55-61.
8. FMOH (2000). *Malaria desk situation analysis, Nigeria 2000*. Federal Ministry of Health, Abuja, Nigeria, pp: 27.
9. FMOH (2001). National strategies plan for roll back malaria. Federal Ministry of Health, Abuja, Nigeria, pp: 63.
10. FMOH (2005). Annual report on national malaria control programme in Nigeria. Federal Ministry of Health, Abuja, Nigeria, pp: 47.
11. Olayemi IK and Ande AT (2009). Life table analysis of *Anopheles gambiae* (Diptera: Culicidae) in relation to malaria transmission. *Journal of Vector Borne Diseases;* 46,295-298.
12. Salako I (1997). Malaria the Unending Saga. Keynote Address. In: Coping with Tratment Failures in Malaria, Obi, C. C. (Ed.). Mayer and Baker, Lagos, pp: 13-25.
13. Odaibo FS (2006). Malaria scourge: the facts, the lies and the politics. Available from:*www.gamji.com/article5000/News5145.htm* 2006.
14. Liehne PFS (1988). Climate Influence of Mosquito-borne disease in Australia. In Greenhouse: Planning for Climate Change, ed. G. I. Pearman, Australia, CSIRO.
15. Olayemi IK and Ande AT (2008). Survivorship of *Anopheles gambiae* in relation to malaria transmission in Ilorin, Nigeria. *Online Journal of Health and Allied Sciences*; 7(3): 1. Available at: *http://www.ojhas.org/issue272008-3-1.htm*
16. Olayemi IK and Ande AT (2009). Vectorial status and temporal variations in malaria transmission potential of anopheline mosquito species in Ilorin, Nigeria. *International Journal of Applied Biological Research*; 1 (1): 19- 26.
17. Minakawa N, Githure JI, Beier JC and Yan G (2001). Anopheline mosquito Survival strategies during the dry period in western Kenya. *Journal of Medical Entomology;* 38:388-392.
18. Minakawa N, Sonye G, Mogi M, Githeko A and Yan G (2002). The effects of climatic factors on the distribution and abundance of malaria vectors in Kenya. *Journal of Medical Entomology;* 39: 833-841.
19. Spencer M, Blaustein L and Cohen JE (2002). Oviposition habitat selection by mosquitoes (*Culiseta longiareolata*) and consequences for population size. *Ecology*; 83: 669–679.
20. Sattler MA, Mtasiwa D, Kiama M, Premji Z, Tanner M, Killeen GF, and Lengeler C. (2005). Habitat characterization and spatial distribution of Anopheles sp. mosquito larvae in Dar es Salaam (Tanzania) during an extended dry period. *Malaria Journal*; 4:4.
21. Olayemi IK and Ande AT (2008). Species composition and larval habitats of mosquitoes (Diptera: Culicidae) in Ilorin, Nigeria. *The Zoologist*; 6: 7-15.
22. Reisen WK and Meyer RP (1990). Attractiveness of selected oviposition substrates for gravid *Culex tarsali* and *C. quinquefasciatus* in California. *Journal of America Mosquito Control Association*; 6: 244-50.
23. Saini RK, Rai MM, Hassanali A, Wawiye J and Odongo H (1995). Semiochemicals from froth of egg pods attract ovipositing female *Schistocerca gregaria*, *Journal of Insect Physiology;* 41:711–716.
24. Piyaratne MK, Amerasinghe FP, Amerasinghe PH and Konradsen F (2005). Physico – chemical characteristics of *Anopheles culicifacies* and *Anopheles varuna* breeding water inadry zone stream in Sri Lanka. *Journal of Vector Borne Diseases*; 42, 61 – 67. 35
25. Olayemi IK, Omalu ICJ, Famotele OI, Shegna SP and Idris B (2010). Distribution of mosquito larvae in relation to physico-chemical characteristics of breeding habitats in Minna, North Central Nigeria. *Reviews in Infection*; 1(1): 49-53.
26. Smith WW and Jones DW (1972). Use of artificial pools for determining presence, abundance, and oviposition preferences of *Culex nigripalpus* Theobald in the field. *Mosquito News;* 32: 244-245.
27. Bentley MD and Day IF (1989). Chemical ecology and behavioural aspects of mosquito oviposition. *Annual Review of Entomology;* 34: 401-421.
28. Azzam MNA (1998). The effect of various manure suspensions (camel, cow and sheep) on the life cycle of *Culex pipiens. Saudi Journal of Biological Sciences;* 5(2): 58-63.

29. Blaustein L, Kiflawi M, Eitam A, Mangel M and Cohen JE (2004). Oviposition habitat selection in response to risk of predation in temporary pools: mode of detection and consistency across experimental venue. *Oecologia*; 138: 300–305
30. Pfaehler O, Oulo DO, Gouagna LC, Githure J and Guerin PM (2006). Influence of soil quality in the larval habitat on development of *Anopheles gambiae* Giles. *Journal of Vector Ecology*; 31(2):400-405. 2006. Doi: http://dx.doi.org/10.3376/1081-1710.
31. Olayemi IK and Ojo VO (2013). Immature Development of the Malaria Vector Mosquito, *Anopheles gambiae* s.l. (Diptera: Culicidae), in Relation to Soil-substrate Organic Matter Content of Larval Habitats in Northcentral Nigeria. *Pakistan Journal of Biological Science;* 16(3): 135-140.
32. Olayemi IK, Ande AT, Isah B and Idris AR (2009). Epidemiology of malaria in relation to climatic variables in Minna, Nigeria. *African Journal of Medical Sciences*; 2 (1): 5-10.
33. Ukubuiwe AC, Olayemi IK, Omalu, ICJ, Odeyemi MO, Jibrin AI and Oyibo-Usman KA (2012). Comparative assessment of immature survivorship and developmental duration of *Culex pipiens pipiens* (Diptera: Culicidae) populations in north central Nigeria. Biomed Central *Epidemiology;* 3(10): WMC003753.
34. Olayemi IK, Ande AT, Odeyemi MO, Ibemesi G and Emmanuel R (2014). Temporal Ecologic Adaptability of the Principal Vector of Malaria, Anopheles gambiae s.l. (Diptera: Culicidae), in Northcentral Nigeria. *Applied Science Report*. E-ISSN: 2310-9440/P-ISSN:2311-0139/www.pscipub.com/ASR DOI:10.15192/PSCP.ASR.2014.1.3.110117.
35. Gerberg EJ (1970). Manual for mosquito rearing and experimental techniques. *American Mosquito Control Association Bulletin*; 5:109.
36. Das S, Garyer L and Dimopoulos G. (2007). Protocol for mosquito rearing (*An. gambiae). Journal of Visualised Experiments;* 5: 221-225.
37. Gilles MT and De Meillon B (1968). T*he Anopheline of Africa south of the Sahara*, 54, 2nd Ed. The South African Institute of Medical Research, Johannesburg, South Africa.
38. Hopkins GHE (1952). Mosquitoes of Ethiopian Region. Larval bionomics of mosquitoes and taxonomy of Culicinae larvae. 2nd edition. Adlard and Sons Ltd. London.
39. Edillo FE, Toure YT, Lanzaro GC, Dolo G and Taylor CE (2002). Spatial and habitat distribution of Anopheles gambiae and Anopheles arabiensis (Diptera: Culicidae) in Banambani Village, *Malian Journal of Medical Entomology*; 39: 70-77.
40. Minakawa N, Mutero CM, Githure JI, Beier JC and Yan G (1999). Spatial distribution and habitat characterization of anopheline mosquito larvae in Western Kenya. *American Journal Tropical Medicine and Hygiene;* 61:1010–1016.
41. Fillinger U, Sonye G, Killeen GF, Knols BG and Becker N (2004). The practical importance of permanent and semi-permanent habitats for controlling aquatic stages of *Anopheles gambiae* sensu lato mosquitoes: operational observations from rural town in western Kenya. *Tropical Medicine and International Health;* 9 (12): 1274-1248.
42. Angerilli NDP (1980). Influences of extracts of vegetation on the survival and oviposition by *Aedes aegypti* (Diptera: Culicidae) *Canadian Entomology;* 112, 1249-1252.
43. Olayemi IK, Idris B, Omalu ICJ and Odeyemi, MO (2012). Dry season refugia breeding ecology of mosquitoes (Diptera: Culicidae) in Minna, North Central Nigeria. *Journal of Biological Sciences*; ISSN 1727-3048/DOI: 10.3923/jbs.2012
44. Spencer M, Blaustein L and Cohen JE (2002). Oviposition habitat selection by mosquitoes (*Culiseta longiareolata*) and consequences for population size. *Ecology;* 83: 669-79.
45. Olagbemiro TO, Birkett MA, Mordue (Luntz) AJ and Pickett JA (1999). Production of (5R, 6S)-6-acetoxy-5-hexadecanolide, the mosquito oviposition pheromone, from the seed oil of the summer cypress plant, Kochia scoparia (Chenopodiaceae). *Journal of Agriculture and Food Chemistry*; 47: 3411–3415.
46. Olagbemiro TO, Birkett MA, Mordue (Luntz) AJ and Pickett JA (2004). Laboratory and field responses of the mosquito, Culex quinquefasciatus, to plant-derived *Culex spp*. oviposition pheromone and the oviposition cue skatole. *Journal of Chemical Ecology*; 30: 965–976.
47. Li J, Deng T, Li H, Chen L and Mo J (2009). Effects of Water Colour and

Chemical Compounds on the Oviposition Behaviour of Gravid *Culex pipiens pallens* Females under Laboratory Conditions. *Journal of Agricultural and Urban Entomology*; 26(1): 23–30.