



Journal of Applied Sciences

ISSN 1812-5654

science
alert

ANSI*net*
an open access publisher
<http://ansinet.com>



Research Article

Malaria Vector Abundance and Insecticides Susceptibility Status in Gidan-Yero Village, Sokoto State, Nigeria

¹M.A. Yahaya and ²S.A. Fana

¹Department of Biological Sciences, Unit of Zoology, Usmanu Danfodiyo University, Sokoto, Nigeria

²School of Medical Laboratory Science, Usmanu Danfodiyo University Sokoto, Nigeria

Abstract

Background and Objective: Malaria vector control interventions have been ongoing in Nigeria for several decades. The interventions are however undermined by the emergence and spread of insecticide resistance. This study investigated the malaria vector abundance, insecticide susceptibility status at Gidan-Yero village. **Materials and Methods:** Malaria vector abundance was determined monthly by morphological identification. The insecticides susceptibility status of *An. gambiae s.l.* was determined using the Centre for Disease Control and Prevention (CDC) bottle bioassay. Resistance intensity was investigated at $\times 1$, $\times 2$ and $\times 5$ of the diagnostic concentrations and scored at 30 min. A synergy test to determine the mechanism of resistance was performed using piperonyl butoxide (PBO). **Results:** *Anopheles gambiae s.l.* was found to be more abundant in August. The vector was found to be susceptible to all the insecticides with exception of alphacypermethrin and permethrin, the resistance intensity was at $2\times$ and $5\times$ concentration, respectively. The resistance to the two pyrethroids was however reverted with the application of PBO. **Conclusion:** *Anopheles gambiae s.l.* was abundant and susceptible to bendiocarb, deltamethrin and pirimiphos-methyl but resistant to alphacypermethrin and permethrin. Susceptibility monitoring guided the Ministry of Health's decision to rotate between IRS insecticide classes.

Key words: *Anopheles gambiae s.l.*, Gidan-Yero, vector abundance, susceptibility status, insecticide resistance, synergistic bioassay, intensity bioassay

Citation: Yahaya, M.A. and S.A. Fana, 2023. Malaria vector abundance and insecticides susceptibility status in gidan-yero village, Sokoto State, Nigeria. J. Appl. Sci., 23: 81-86.

Corresponding Author: S.A. Fana, School of Medical Laboratory Science, Usmanu Danfodiyo University Sokoto, Nigeria

Copyright: © 2023 M.A. Yahaya and S.A. Fana. This is an open access article distributed under the terms of the creative commons attribution License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited.

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Malaria remains a major global health challenge, a cause of morbidity and mortality in the world and an important health problem in Nigeria and Africa¹. In 2018 and 2019, Sub-Saharan Africa accounted for 93 and 91% of global malaria episodes, respectively, with the highest proportion of 25% occurring in Nigeria, while Congo^{2,3}.

Indeed, despite the interventions, the African region continues to carry a disproportionately high share of the global malaria burden⁴. Many vectors play an important role in malaria transmission across Africa, notably *Anopheles gambiae*s.s., *An. coluzzii*, *An. arabiensis* and *An. funestus*s.s.⁵ In their battle against malaria, most African countries rely heavily on two vector control interventions namely: Long-lasting insecticidal nets (LLINs) and indoor residual spraying (IRS). Resistance to LLIN exposure increases mosquito survival, which may lead to rising malaria incidence and fatality in Africa⁶. It has been estimated that since 2000 more than 670 million cases of malaria have been averted by combining IRS and LLINs with case management and community education⁷. Recent global efforts have been made to control and eliminate malaria leading to a significant reduction in malaria cases and mortality in Africa by 42 and 66%, respectively.

The emergence and spread of insecticide resistance are undermining/threatening the effectiveness of malaria vector control interventions⁸. It has been shown that insecticide resistance is spreading particularly in malaria-prone countries⁷. The situation is also complicated by the extensive use of pyrethroids in agriculture, which constitute an additional selection pressure on malaria vectors, for example via insecticide-contaminated groundwater that pervade mosquito larval habitats⁹.

With the calls by WHO for all countries to develop and implement insecticide resistance management strategies in their malaria control programme to curb the spread of resistance as well as preserve the effectiveness of insecticide-treated nets¹⁰, it is imperative to better understand the distribution of resistance, its mechanisms and impact on the effectiveness of control interventions and malaria transmission. This paper presents the findings of a study on the abundance and insecticide susceptibility status of *An. gambiae* s.l., to alphacypermethrin, bendiocarb, deltamethrin, permethrin and pirimiphos-methyl in Gidan-Yero village.

MATERIALS AND METHODS

Study area: The study was carried out in Gidan-Yero village of Wamakko, Local Government Area, Sokoto State located on the longitude 13.12131N and latitude 5.19466E. The people of the area are mostly farmers and a few fishermen. The horticultural activities include millet, guinea corn and rice cultivation. The research was conducted between June and September, 2019.

Mosquito larval collection: Mosquito larvae were collected in June through September, 2019 from different larval habitats using standard dippers (350 mL) into white plastic containers and brought to a malaria entomology laboratory of the Department of Biological Sciences, Usmanu Danfodiyo University, Sokoto. The larvae were fed with a yeast table ground with biscuits and reared to adults. All mosquito larvae were collected between 8 and 10 am. The emerging adult mosquitoes were transferred into cages and fed with a 10% sugar solution from cotton wool.

Susceptibility tests: Both larval collection and bioassay testing were conducted between June-September, 2019. The CDC bottle bioassay¹¹ was used in testing the susceptibility status of the malaria vector¹¹. Four replicates of twenty-five 3-5 days old adult mosquitoes were added to the CDC bioassay bottle coated with diagnostic concentration deltamethrin. This was repeated for permethrin, alphacypermethrin, bendiocarb and pirimiphos-methyl. For each test, another bioassay bottle coated with acetone only containing 25 adult mosquitoes was used as a control. Mosquitoes were considered dead when they could no longer stand, were immobile and slid along the curvature of the test bottle¹². Mortality was recorded every 15-30 and extended to 60 min for pirimiphos-methyl. All mosquitoes that die within the diagnostic time when exposed to insecticide-coated bottles are susceptible to a tested insecticide. Test mosquitoes surviving beyond the diagnostic time threshold are assumed to have some degree of resistance. Interpretation of CDC bioassay results at a diagnostic time is that <95% mortality indicates resistance.

Resistance intensity tests: Insecticide resistance intensity testing of *Anopheles* mosquitoes to permethrin and alphacypermethrin was performed by exposing them to CDC bottles coated with the diagnostic dosages and subsequently to doses of 2× and 5× of the diagnostic dosages.

Synergistic bioassay tests: Insecticide resistance mechanisms were investigated with a synergist, Piperonyl Butoxide (PBO), to the two insecticides that were resistant. Resistance mechanisms were determined by pre-exposing the mosquitoes to the oxidase inhibitor PBO at 100 µg/bottle for 1 hr before performing CDC bottle bioassay with bottles coated with diagnostic doses of alphacypermethrin and permethrin for 30 min.

Mosquito identification: All mosquitoes including exposed and unexposed were identified to species based on morphological characteristics¹³.

Statistical analysis: The mortality data were analyzed and expressed in terms of percentage and compared using Chi-square tests. The output provided estimated marginal means of mortality, 95% confidence intervals, standard errors and p-values.

RESULTS

Morphological identification: A total of 8918 mosquitoes both exposed and non-exposed were morphologically identified as *An. gambiae s.l.* and was more abundant in August (31.22%) and less in abundance in June (19.76%). *An. gambiae s.l.*, abundance in July and September was 27.30 and 21.72%, respectively (Fig. 1).

Susceptibility status: Mosquitoes were found to be fully susceptible to bendiocarb, deltamethrin and pirimiphos-methyl but resistant to alphacypermethrin and permethrin at a mortality rate of 87 and 68%, respectively (Fig. 2). The intensity of resistance is shown in Fig. 3. Resistance intensity of alphacypermethrin was reverted at 2× concentration, while that of permethrin extended to 5× concentration. The result for the synergistic assay is as shown in Fig. 4. Pre-exposure of *An. gambiae s.l.*, to PBO for 1 hr before exposure to discriminating doses of alphacypermethrin and permethrin-coated CDC bottles restored the efficacy of these two insecticides that were initially resistant to 1× concentration.

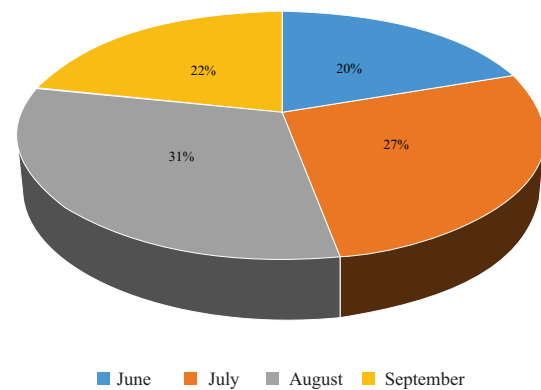


Fig. 1: Monthly abundance of *An. gambiae s.l.*, in Gidan-Yero village

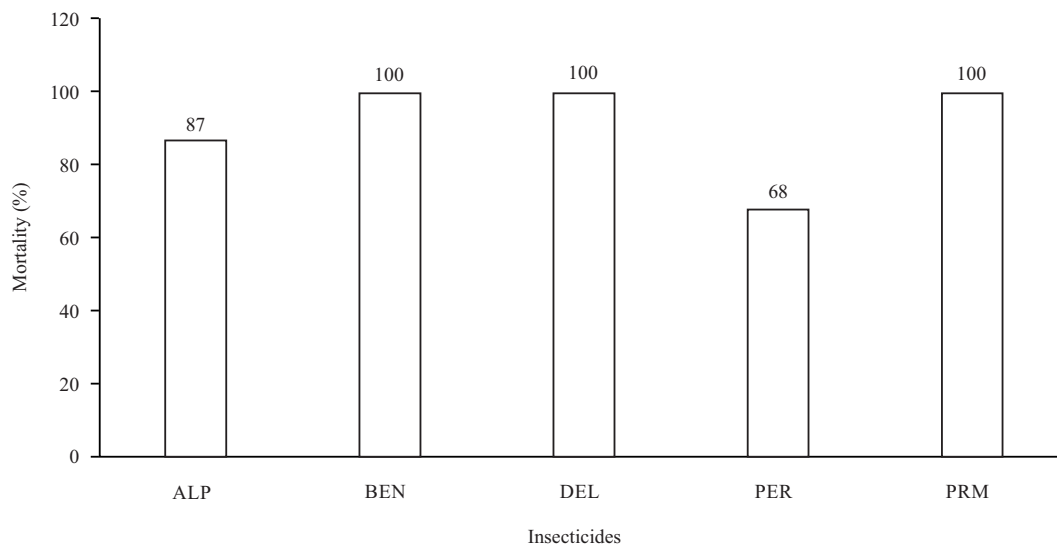


Fig. 2: Insecticides susceptibility status for malaria vector in Gidan-Yero village

Alp: Alphacypermethrin, Ben: Bendiocarb, Del: Deltamethrin, Per: Permethrin and Prm: Pirimiphos-methyl

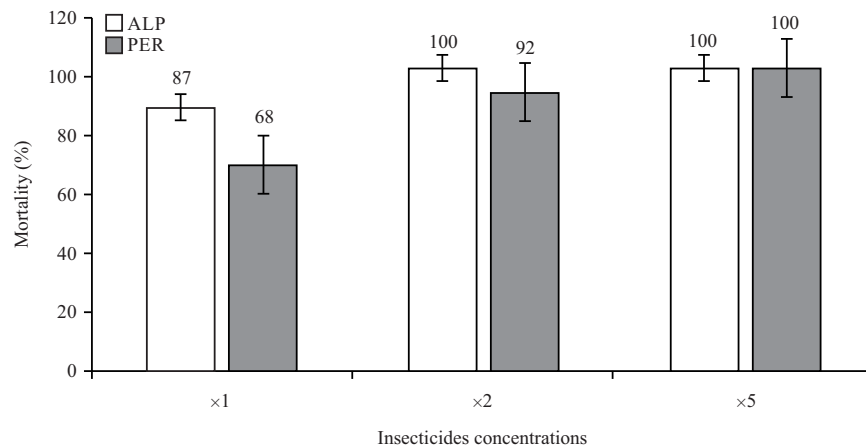


Fig. 3: Intensity of resistance of *An. gambiae s.l.*, exposed to alphacypermethrin and permethrin at the different concentrations at Gidan-Yero village

Alp: Alphacypermethrin and Per: Permethrin

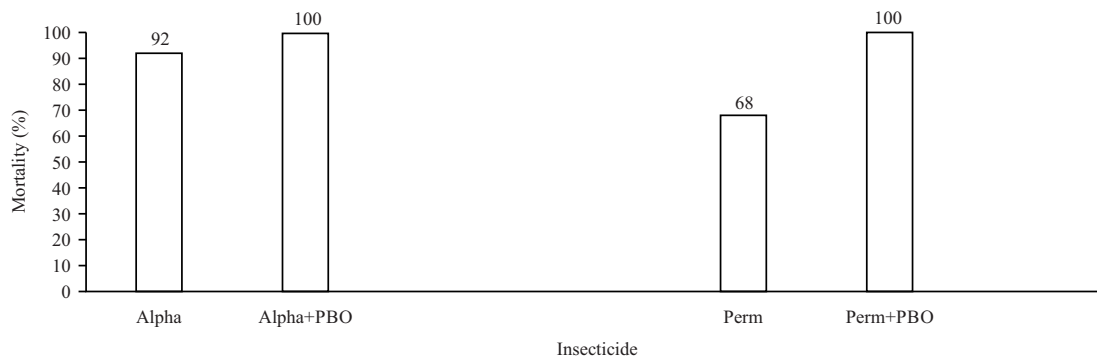


Fig. 4: Synergistic bioassay of *An. gambiae s.l.*, exposure to alphacypermethrin and permethrin with PBO at Gidan-Yero village

Alp: Alphacypermethrin, Ben: Bendiocarb, Del: Deltamethrin, Per: Permethrin and Prm: Pirimiphos-methyl

DISCUSSION

Monitoring *Anopheles* spp., vectors for susceptibility to insecticides is recommended by WHO in all countries that use LLINs or indoor residual spraying for malaria control⁵. In Nigeria, integrated malaria control interventions (artemisinin-based combination therapy (ACT), LLINs and targeted IRS) have been in use since 2006. This has contributed to a significant reduction in clinical malaria cases in the country. However, the gains made were not much because of reduced efficacy due to the development of resistance¹⁴. Nigeria achieved universal coverage with LLINs in 2011 but the major challenge is to maintain this coverage and ensure effective usage of the mosquito nets, especially after it was recently reported from Rwanda that LLIN effectiveness lasts less than 3 years due to the rapid loss of insecticidal activity and physical deterioration in the field¹⁵. LLIN deterioration

problems were also shown in recent findings from Senegal where damaged nets provided less protection to malaria compared to intact ones¹⁶.

However, continuous exposure of mosquitoes to treated nets and the extensive use of pyrethroids in agriculture contributed to the development and emergence of insecticide resistance¹⁷.

Anopheles gambiae s.l. was the only malaria vector found in the study site, from June through September. This finding is in support of the report that *An. gambiae s.l.*, abound in Gwagwalada, Abuja, Nigeria¹⁸ and western Kenya¹⁹ with a higher preponderance.

Mosquitoes were more abundant in August followed by July. This finding further confirmed the earlier report²⁰. However, the finding was in disagreement with the reported²¹ increase in abundance of *An. gambiae s.l.*, in September.

As in our study, in south-eastern Côte d'Ivoire, *An. gambiae* were found to be resistant to permethrin and alphacypermethrin but largely susceptible to deltamethrin²². *An. gambiae s.l.*, were found to be fully susceptible to bendiocarb, deltamethrin and pirimiphos-methyl. This finding is in support of the previous reports from the south, central and east coasts of Madagascar²³. The full susceptibility of bendiocarb and resistance to alphacypermethrin and permethrin observed in this study, was in concordance with the results of Gari *et al.*²⁰ but, contrary to our findings deltamethrin was resistant in Ethiopia¹² in northern Uganda also reported mosquitoes were fully susceptible to bendiocarb but resistant to deltamethrin and permethrin. As in this study, Rokotoson *et al.*²³ also reported resistance to alphacypermethrin, which was reverted after exposure to PBO. Permethrin efficacy was also restored in our study. This finding is however in contrast to the results of Okia *et al.*¹², who reported partial abolition of permethrin resistance after exposure of mosquitoes to PBO. Resistance intensity in this study was reverted after exposure to 2× and 5× concentrations for alphacypermethrin and permethrin, respectively. This finding contrasts the report that *An. gambiae s.l.*, exposed to permethrin survived 5× and 10× diagnostic concentrations¹². The study had its limitations being confined only to Gidan-Yaro village and did not take into cognisance the implication of the agrochemicals mostly used within the area to the development of resistance. This study for the first time reports the insecticide susceptibility status and malaria vector abundance in the study area. The results indicated that the pyrethroids alone are no longer effective in controlling the *Anopheles gambiae s.l.* The implication of this is that continuous usage of pyrethroids or pyrethroids based LLINs will only expose the populace to more mosquito bites and hence higher malaria infection. The importance of these findings is that the information provided would form the basis for detailed investigation on the effectiveness/durability of the nets and reason(s) for the development of insecticide resistance and its mechanisms. A combination of several methods should be considered as an effective and alternative way for vector control. It may also serve as a guide to the inhabitants of the community and the State Ministry of Health in planning and execution of its policies in vector monitoring, evaluation and control.

CONCLUSION

The results of the study show that resistance to pyrethroids is ever-increasing and spreading globally. To curb further spread of pyrethroid resistance and to preserve the

effectiveness of LLINs, an insecticide resistance management strategy shall switch to the usage of bendiocarb and pirimiphos-methyl for malaria vector control. There is also the need to implement a rotational strategy of insecticide usage every few years.

SIGNIFICANCE STATEMENT

The study discovers for the first time, the malaria vector abundance and insecticides resistance in the area. It also highlighted the fact that pyrethroids alone are no longer effective in controlling malaria vectors. The study will form the basis for detailed research on the effectiveness/durability of the nets and the mechanism of resistance in the area. It may also guide the community and State Ministry of Health in proper planning and execution of policies on vector control.

ACKNOWLEDGMENT

The authors are grateful to the President's Malaria Initiative of the US Government (PMI) and Vectorlink Nigeria for providing the technical grade insecticides used and the management of Usmanu Danfodiyo University, Sokoto for providing Laboratory space and other logistics needed.

REFERENCES

1. Maigemu, A.Y. and K.B.H. Hassan, 2015. Malaria as a cause of morbidity and mortality: A socio-economic overview. Res. Humanities social sci., 5: 100-104.
2. Liu, Q., W. Jing, L. Kang, J. Liu and M. Liu, 2021. Trends of the global, regional and national incidence of malaria in 204 countries from 1990-2019 and implication for malaria prevention. J. Travel Med., 10.1093/jtm/taab046.
3. Muhammad, A., S.S. Ibrahim, M.M. Mukhtar, H. Irving and M.C. Abajue *et al.*, 2021. High pyrethroid/DDT resistance in major malaria vector *Anopheles coluzzii* from Niger-Delta of Nigeria is probably driven by metabolic resistance mechanisms. PLoS ONE, Vol. 16. 10.1371/journal.pone.0247944.
4. Kapesa, A., E.J. Kweka, H. Atieli, Y.A. Afrane, E. Kamugisha *et al.*, 2018. The current malaria morbidity and mortality in different transition settings in Western Kenya. PLoS ONE, Vol. 13. 10.1371/journal.pone.0202031.
5. Sinka, M.E., M.J. Bangs, S. Manguin, M. Coetzee and C.M. Mbogo *et al.*, 2010. The dominant *Anopheles* vectors of human malaria in Africa, Europe and the Middle East: Occurrence data, distribution maps and bionomic precis. Parasites Vectors, Vol. 3. 10.1186/1756-3305-3-117.

6. Hemingway, J., H. Ranson, A. Magill, J. Kolaczinski and C. Fornadel *et al.*, 2016. Averting a malaria disaster: Will insecticide resistance derail malaria control? *Lancet*, 387: 1785-1788.
7. Bhatt, S., D.J. Weiss, E. Cameron, D. Bisanzio and B. Mappin *et al.*, 2015. The effect of malaria control on *Plasmodium falciparum* in Africa between 2000 and 2015. *Nature*, 526: 207-211.
8. Gueye, O.K., M. Tchouakui, A.K. Dia, M.B. Faye and A.A. Ahmed *et al.*, 2020. Insecticide resistance profiling of *Anopheles coluzzii* and *Anopheles gambiae* populations in the Southern Senegal: Role of target sites and metabolic resistance mechanisms. *Genes*, Vol. 11. 10.3390/genes11121403.
9. Yadouléon, A., R. N'Guessan, H. Allagbé, A. Asidi and M. Boko *et al.*, 2010. The impact of the expansion of urban vegetable farming on malaria transmission in major cities of Benin. *Parasites Vectors*, Vol. 3. 10.1186/1756-3305-3-118.
10. Hakizimana, E., C. Karema, D. Munyakanage, G. Iranzi and J. Githure *et al.*, 2016. Susceptibility of *Anopheles gambiae* to insecticides used for malaria vector control in Rwanda. *Malar. J.*, Vol. 15. 10.1186/s12936-016-1618-6.
11. Agumba, S., J.E. Gimnig, L. Ogonda, M. Ombok and J. Kosgei *et al.*, 2019. Diagnostic dose determination and efficacy of chlorfenapyr and clothianidin insecticides against *Anopheles* malaria vector populations of western Kenya. *Malar. J.*, Vol. 18. 10.1186/s12936-019-2858-z.
12. Okia, M., D.F. Hoel, J. Kirunda, J.B. Rwakimari and B. Mpeka *et al.*, 2018. Insecticide resistance status of the malaria mosquitoes: *Anopheles gambiae* and *Anopheles funestus* in eastern and northern Uganda. *Malaria J.*, Vol. 17. 10.1186/s12936-018-2293-6.
13. Coetzee, M., 2020. Key to the females of afrotropical *Anopheles* mosquitoes (Diptera: Culicidae). *Malaria J.*, Vol. 19. 10.1186/s12936-020-3144-9.
14. Ranson, H. and N. Lissenden, 2016. Insecticide resistance in African anopheles mosquitoes: A worsening situation that needs urgent action to maintain malaria control. *Trends Parasitol.*, 32: 187-196.
15. Hakizimana, E., B. Cyubahiro, A. Rukundo, A. Kabayiza and A. Mutabazi *et al.*, 2014. Monitoring long-lasting insecticidal net (LLIN) durability to validate net serviceable life assumptions, in Rwanda. *Malaria J.*, Vol. 13. 10.1186/1475-2875-13-344.
16. Gnanguenon, V., R. Azondekon, F. Oke-Agbo, A. Sovi and R. Ossè *et al.*, 2013. Evidence of man-vector contact in torn long-lasting insecticide-treated nets. *BMC Public Health*, Vol. 13. 10.1186/1471-2458-13-751.
17. Thomas, M.B., H.C.J. Godfray, A.F. Read, H. van den Berg and B.E. Tabashnik *et al.*, 2012. Lessons from agriculture for the sustainable management of malaria vectors. *PLOS Med.*, Vol. 9. 10.1371/journal.pmed.1001262.
18. Oduola, A.O., J.B. Olojede, I.O. Oyewole, O.A. Otubanjo and T.S. Awolola, 2013. Abundance and diversity of *Anopheles* species (diptera: culicidae) associated with malaria transmission in human dwellings in rural and urban communities in Oyo state, Southwestern Nigeria. *Parasitol. Res.*, 112: 3433-3439.
19. Ototo, E.N., A.K. Githeko, C.L. Wanjala and T.W. Scott, 2011. Surveillance of vector populations and malaria transmission during the 2009/10 El Niño event in the western Kenya highlands: Opportunities for early detection of malaria hyper-transmission. *Parasites Vectors*, Vol. 4. 10.1186/1756-3305-4-144.
20. Gari, T., O. Kenea, E. Loha, W. Deressa and A. Hailu *et al.*, 2016. Malaria incidence and entomological findings in an area targeted for a cluster-randomized controlled trial to prevent malaria in Ethiopia: Results from a pilot study. *Malaria J.*, Vol. 15. 10.1186/s12936-016-1199-4.
21. Abdullahi, Y.M., S.A. Fana, Y.S. Umar and U.S. Batagarawa, 2020. Prevalence of mosquitoes in Gidan Yunfa community of Usmanu Danfodiyo University, Sokoto, Nigeria. *Traektoriâ Nauki: Path Sci.*, 6: 8001-8006.
22. Sadia-Kacou, C.M.A., L.P.A. Alou, A.V.C. Edi, C.M. Yobo and M.A. Adja *et al.*, 2017. Presence of susceptible wild strains of *Anopheles Gambiae* in a large industrial palm farm located in Aboisso, South-Eastern of Côte d'ivoire. *Malaria J.*, Vol. 16. 10.1186/s12936-017-1804-1.
23. Rakotoson, J.D., C.M. Fornadel, A. Belemvire, L.C. Norris and K. George *et al.*, 2017. Insecticide resistance status of three malaria vectors, *Anopheles gambiae* (s.l.), *An. funestus* and *An. mascarensis*, from the south, central and east coasts of Madagascar. *Parasites Vectors*, Vol. 10. 10.1186/s13071-017-2336-9.