Use of Insect Growth Regulators: A Sustainable Approach to Mosquito Control in Nigeria – A Review

[1]Okugbo, Osarhieme Tinuade* and [2]Kamaludeen Sahabi
[1]Department of Medical Biochemistry, College of Medical Sciences,
Benson Idahosa University, Benin City, Edo State, Nigeria.
[2]Department of Biological Sciences, Faculty of Science, Benson Idahosa University,
Benin City, Edo State, Nigeria
Corresponding author: ookugbo@biu.edu.ng; Phone number: +2348122898163
DOI: 10.56201/ijhpr.vol.10.no6.2025.pg11.20

Abstract
Mosquito-borne diseases remain a significant public health concern in Nigeria, with malaria alone contributing to high morbidity and mortality rates. Traditional vector control methods, which are primarily reliant on chemical insecticides, are encountering increasing challenges due to insecticide resistance, climate change, and non-target toxicity. This review critically examines the potential of insect growth regulators (IGRs), including both synthetic types and those derived from plants such as Neem (Azadirachta indica), as sustainable alternatives for mosquito control in Nigeria. IGRs disrupt the development of insects, including mosquitoes, by interfering with their hormonal processes, offering high species specificity and low toxicity to mammals, thereby presenting a promising eco-friendly approach to mosquito control. Laboratory and field studies illustrate the effectiveness of IGRs, particularly in targeting larval stages across diverse breeding habitats. However, challenges such as the high cost of IGRs, limited community awareness, and inadequate policy support from relevant bodies have impeded widespread adoption. This review highlights the mosquito burden in Nigeria, evaluates the limitations of conventional insecticides, and emphasises the need for updated regulatory frameworks, increased government investment, and public health education to facilitate the use of insect growth regulators (IGRs). It also examines the advantages and disadvantages of IGRs in national malaria control programmes. The paper further underscores the relevance of IGRs in the Nigerian context and discusses prospects for their broader application in sustainable vector control.

Keywords: *Insect Growth Regulators, Mosquitoes, Public Health, Neem, Nigeria.*

1.0 Introduction

Mosquitoes (Diptera: Culicidae) are primary vectors of numerous life-threatening diseases, including malaria, dengue, and lymphatic filariasis (Benelli, 2015). Other diseases transmitted by mosquitoes, including chikungunya, yellow fever, and leishmaniasis, cause long-lasting suffering, lasting morbidity, disability, and societal stigmatization (WHO, 2024). At least one child under five dies of malaria in Africa every 75 seconds (UNICEF, 2024). Nigeria accounts for approximately 27% of the world's malaria cases, making it the country with the most significant malaria burden (WHO, 2022). Approximately 80% of all malaria deaths are recorded in children under the age of five in the region (WHO, 2023). Children under five years of age are most susceptible to malaria due to their developing immune system and inability to produce sufficient antibodies to combat *Plasmodium* parasites (Chilot *et al.,* 2023; Ibeji *et al.,* 2022).

While recent advances have introduced malaria vaccines such as RTS, S/AS01 (Mosquirix), their use in Nigeria remains limited due to challenges including logistics, finance, and awareness barriers (Ibrahim *et al*., 2021; Chiziba *et al*., 2024). Consequently, vector control remains the cornerstone of malaria control strategies. Conventional approaches to mosquito control that utilise synthetic insecticides have achieved significant success. However, they are increasingly compromised by the rapid emergence of insecticide resistance, which has been recorded in many mosquito species. Furthermore, lasting harmful effects on non-target animals and other biotic components in the ecosystem have also been initiated (Al-Ghamdi, 2009; Alkenani, 2017; El-Heneidy and Shoeb, 2018).

In response to these challenges, sustainable, eco-friendly alternatives are gaining prominence. Insect growth regulators are compounds that interfere with mosquito development by disrupting their hormonal processes, thereby affecting development and reproduction, and represent a significant step in integrated pest management (IPM). The IGRs cyromazine, difubenzuron, and trifumuron are currently the most effective larvicides for controlling mainly dipteran pests, including mosquitoes (Lau *et al*., 2015; Bellinato *et al*., 2016; Reissert-Oppermann *et al*., 2019; Abbas and Hafez, 2021). Additionally, botanically derived agents, such as Neem (*Azadirachta indica*), which contains azadirachtin, exhibit IGR activity and are widely available in Nigeria and other parts of Africa.

IGRs are characterized by their high species specificity, low mammalian toxicity and minimal hazard threat to the natural enemies of the target, making them good candidates for integrated pest management (IPM) and sustainable vector control (Lahm *et al*., 2007; Liu *et al*., 2017; Santos *et al*., 2020). The use of selective larvicides and insect growth regulators (IGRs) in the breeding habitats of mosquitoes may be the most suitable strategy for controlling mosquitoes at their breeding sites (Batra *et al*., 2005; Nino, 2009). However, the adoption of IGRs in Nigeria faces several challenges, including high procurement costs compared to synthetic insecticides, limited community awareness, and gaps in policy and regulatory frameworks (Ekefan and Edge, 2013; Oruonye and Okrikata, 2010).

This review provides a comprehensive overview of the mosquito burden in Nigeria, as well as the advantages and disadvantages of insect growth regulators (IGRs) in integrated mosquito control strategies. Special attention is given to the Nigerian context, including climate and epidemiological factors, policy challenges and prospects for a broader application of IGRs in promising mosquito control strategies.

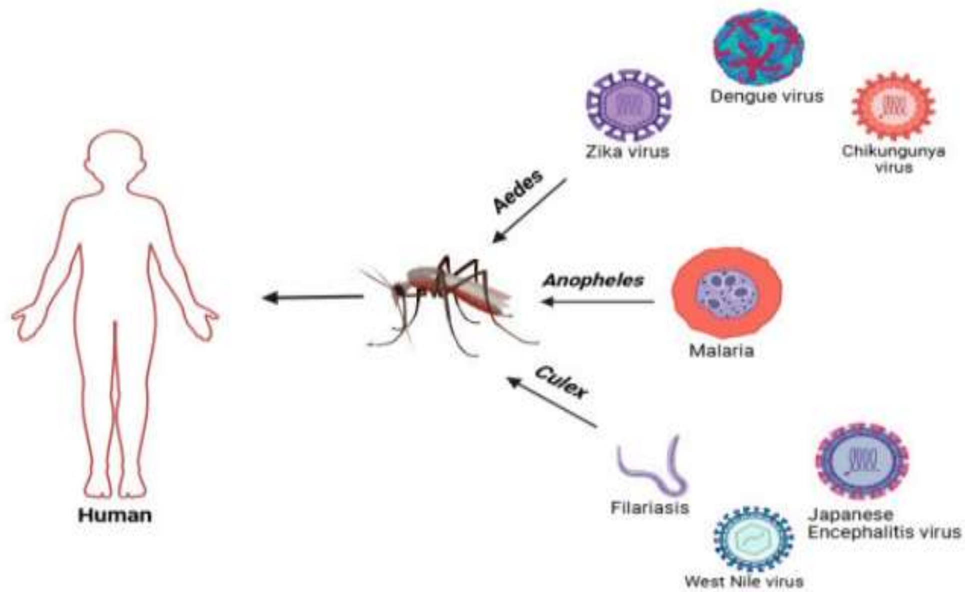

Figure 1: Major mosquito-borne diseases.
Source: Bharadwaj *et al.*, 2025

2.0 Methodology

2.1 Literature Search Strategy

A structured literature review was conducted using databases such as PubMed, ScienceDirect, Scopus, and Google Scholar to retrieve peer-reviewed articles from January 2000 to June 2025. Search terms included: "Insect Growth Regulators" AND "Malaria control in Nigeria", "Bio-pesticides", AND "Vector Control", among others. The inclusion criteria focused on studies addressing insecticide resistance (IGRs) in mosquito control, particularly in sub-Saharan Africa, as well as Nigerian policy documents post-2020, including the 2023 National Biosafety Management Agency guidelines. Exclusion criteria eliminated non-English articles and those unrelated to public health.

3.0 Results

The literature review identified relevant studies and technical reports addressing various aspects of mosquito control through insect growth regulators (IGRs), with some specifically referencing applications or implications for Nigeria and sub-Saharan Africa. The findings are presented in thematic sub-sections below.

3.1 Classification and Mechanism of Action of IGRs

IGRs were classified into three main categories based on their mode of action:

- Juvenile hormone analogues (JHAs): Examples include methoprene and pyriproxyfen. These mimic juvenile hormones and disrupt metamorphosis by maintaining larval stage hormone levels, leading to incomplete pupation and mortality.
- Ecdysteroid Agonists (EAs): Compounds such as tebufenozide and halofenozide induce premature, incomplete and lethal molting.
- Chitin synthesis inhibitors (CSIs): Agents like diflubenzuron and novaluron prevent exoskeleton formation during molting.

These compounds were reported to act specifically on insect developmental processes, with minimal toxicity to mammals and non-target organisms.

3.2 Efficacy of IGRs in Laboratory and Field Settings

In Nigeria-specific studies, neem-based bio-pesticides containing azadirachtin were found to disrupt larval development and oviposition in mosquitoes significantly. Pyriproxyfen and methoprene demonstrate high larvicidal efficacy at low doses in field trials (Lau *et al.,* 2015)

3.3 Environmental and Health Safety Profile

Across multiple studies, IGRs were consistently found to have low environmental persistence, low mammalian toxicity, and minimal impact on non-target organisms. Unlike conventional insecticides, IGRs did not bioaccumulate in aquatic environments or cause acute poisoning in fish, birds, or amphibians. However, isolated reports indicated potential sub-lethal effects on pollinators and aquatic arthropods, particularly with repeated applications or poorly timed interventions (Liu *et al.,* 2017).

3.4 Challenges in IGR Deployment in Nigeria

The cost of producing IGRs, as well as community awareness and participation in their use, is crucial for their effective incorporation in Nigeria. The cost associated with IGR applications may, in some cases, exceed the costs of neurotoxic insecticides, creating a sticking point in their adoption. Ekefan and Edge note that the lack of governmental interest and clear policies on biopesticide development, regulation, and implementation in Nigeria has hampered progress (Ekefan and Edge, 2013).

Furthermore, this has hampered investments in knowledge development, marketability, and accessibility to biopesticides in Nigeria. Additionally, the lack of government support and advocacy for biopesticides has deterred farmers in Nigeria from adopting biopesticides (Oruonye and Okrikata, 2010). Hence, pest management technologies and strategies have been abysmally low. While the fate of specific organisms will depend on the concentration and method of exposure as well as the insect species and life stage, the lethal and sublethal effects of IGR on non-target organisms should be considered when integrating IGR into new chemical control regiments.

3.5 Policy and Programmatic Gaps

Despite Nigeria's inclusion of IGRs in national malaria control guidelines, implementation at the state and local levels remains patchy. A lack of structured training, monitoring, and inter-agency coordination limits integration into Integrated Vector Management (IVM) programs. Most reviewed national documents lacked specific budgetary provisions or procurement guidelines for IGRs, further stalling operational deployment.

4.0 Discussion

Mosquito-borne diseases, particularly malaria, continue to pose significant public health challenges in Nigeria despite ongoing control efforts. This review highlights the increasing need for sustainable alternatives to chemical insecticides, as conventional approaches are facing diminishing effectiveness due to widespread insecticide resistance, ecological disruption, and human health risks (Meier *et al.,* 2022; WHO, 2023).

4.1 Advantages of Insect Growth Regulators in Vector Control

Juvenile Hormone Analogs (JHAs) and Ecdysteroid Analogs (EAs) induce premature molting, so insects stop feeding rapidly as they undergo the initial processes of molting (Retnakaran *et al.,* 1985; Martinez *et al.,* 2021). Compounds like methoprene, pyriproxyfen, and diflubenzuron have demonstrated high larvicidal efficacy in both laboratory and field studies, often at low concentrations (Mbare *et al.,* 2014; Hustedt *et al.,* 2017). The lack of cross-resistance between different IGRs and conventional insecticides enables the incorporation of IGRs with conventional insecticides to limit the proliferation of resistant genotypes (Cutler and Dupree, 2007). Compared to neurotoxic insecticides, IGRs offer several distinct advantages which include:

- Species-specificity, minimizing harm to pollinators and aquatic vertebrates (Bellini *et al.,* 2014)
- Low environmental persistence and mammalian toxicity, making them suitable for sensitive ecosystems (Liu *et al.,* 2017)
- Limited cross-resistance with conventional insecticides due to their unique modes of action (Ishaaya *et al.,* 2005)

These characteristics make IGRs valuable for use in densely populated and climate vulnerable areas, including Nigeria.

4.2 Relevance of Nigeria Climate and Malaria Burden

Climate change is playing an increasing role in reshaping malaria transmission in Nigeria. Rising temperatures, changing precipitation patterns, and high humidity have expanded the range and seasonal activity of malaria vectors (Villena *et al.,* 2024; Ibrahim *et al.,* 2021).

These shifts challenge the effectiveness of traditional control tools and necessitate adaptive, ecologically sound alternatives, such as IGRs. IGRs target immature mosquito stages and are well-suited for pre-emptive vector suppression, complementing reactive measures such as insecticide-treated nets and indoor residual spraying (IRAC, 2022).

Moreover, larviciding with IGRs is especially effective in stagnant and polluted water bodies, which are common in urban slum areas often underserved by other interventions (Lau *et al.,* 2015; Mondal and Mondal, 2012).

4.3 Limitations to IGR Adoption in Nigeria

One of the limitations of IGRs is the potential impact on non-target aquatic and terrestrial arthropods. This remains a concern, as arthropods provide vital ecosystem services (e.g., biological control, decomposition) across both terrestrial and marine systems. The cost of producing IGRs, as well as community awareness and participation in their use, is crucial for their effective incorporation in Nigeria.

The cost associated with IGR applications may, in some cases, exceed the costs of neurotoxic insecticides, creating a barrier to their adoption. High procurement costs and import dependency for synthetic IGRs, such as pyriproxyfen and methoprene (De-Silva and Mendes, 2007), have deterred their use in Nigeria.

Ekefan and Edge note that the lack of governmental interest and clear policies on biopesticide development, regulation, and implementation in Nigeria has hampered progress (Ekefan and Edge, 2013). Furthermore, this has hampered investments in knowledge development, marketability, and accessibility to biopesticides in Nigeria. Additionally, the lack of government support and advocacy for biopesticides has deterred farmers in Nigeria from adopting biopesticides (Oruonye and Okrikata, 2010). Hence, pest management technologies and strategies have been abysmally low.

While the fate of specific organisms will depend on the concentration and method of exposure as well as the insect species and life stage, the lethal and sub-lethal effects of IGR on non-target organisms should be considered when integrating IGR into new chemical control regiments.

4.4 Integrating IGRs into National Malaria Control Strategies

IGRs can complement Nigeria's malaria control initiative if adequately integrated into vector management frameworks. Priority actions include:

- Supporting local production and field validation of both synthetic and botanical IGRs (Ma *et al.,* 2024)
- Developing training modules and certification programs for IGR use among health workers and sanitation officers (Cloyd, 2003)
- Enhancing cross-sector collaboration among environmental, health, and agricultural stakeholders
- Promoting IGR adoption through community engagement, policy reforms, and inclusion in National Malaria Elimination Programme (NMEP) operational guidelines

Significantly, combining IGRs with the RTS, S/AS01 malaria vaccine and other innovations could enhance control outcomes. While vaccination rollout in Nigeria has been limited, IGR-based larval control can reduce vector density and transmission potential, creating a more supportive environment for vaccine impact (WHO, 2023; UNICEF, 2024).

5.0 Conclusion

Mosquito-borne diseases, particularly malaria, remain a formidable public health challenge in Nigeria, exacerbated by climate change, rapid urbanisation, and increasing resistance to conventional insecticides. Insect Growth Regulators (IGRs) present a viable, eco-friendly alternative to conventional insecticides in Nigeria's fight against mosquito-borne diseases. The novel modes of action of IGRs make them less prone to cross-resistance. In contrast, low mammalian toxicity, specificity, bio-degradability, safety profile, and compatibility with integrated strategies make them critical in modern mosquito management. However, their success depends on supportive policies, community engagement, and ongoing research. Research into cost-effective formulations, local production, and impact assessment under Nigerian ecological conditions is essential for long-term success.

Numerous challenges, including a lack of awareness, confidence, and acceptability hinder bio-pesticide development in developing countries. Other factors include a lack of data-driven standards and monitoring of field performance, which hampers marketability, product quality, and shelf life. Furthermore, the lack of regulatory framework and health and ecological risk assessment from policymakers and public health officials has all conspired to disadvantage IGRs and bio-pesticides in comparison with chemical pesticides. However, these challenges also present numerous opportunities for IGR development in Nigeria.

Lastly, Integrating IGRs with other control tools, including larval source management, environmental sanitation, and emerging malaria vaccines, can significantly strengthen Nigeria’s response to mosquito-borne diseases. As Nigeria moves toward its malaria elimination goals, investment in the development, standardisation, and deployment of IGRs will be crucial for reducing disease transmission and achieving long-term public health resilience.

6.0 Recommendations

Based on the findings of this review, the following recommendations are proposed to enhance the adoption and effectiveness of Insect Growth Regulators (IGRs) in mosquito control efforts across Nigeria:

- **Integrate IGRs into National Vector Control Policies**

IGRs are primarily used in larval source management (LSM). They are applied to water bodies where mosquitoes breed, targeting larvae before they emerge as adults. Evidence abounds that botanical pesticides, e.g. Neem and Insect Growth Regulators, are generally safe and effective (Okrikata and Auaso, 2008). The Federal Ministry of Health and the National Malaria Elimination Programme (NMEP) should formally incorporate IGRs into national guidelines for malaria vector control and allocate budgetary provisions for their procurement and use.

- **Raising Public Awareness About the Potential Risks of Pesticides**

The detrimental impact of pesticide use is especially alarming in Nigeria due to the inadequate regulatory framework for pesticide management, which has resulted in the influx of unregistered and banned pesticides in the country. Launch community education campaigns to promote understanding of IGRs and their role in larval control. Engaging local leaders and health workers will enhance the acceptance and sustainability of interventions.

- **Promote Local Production of Botanical IGRs**

To overcome the problems of synthetic chemical hazards, the use of plant origin products is considered the best control measure, which has become popular due to their degradability, least persistence and least toxicity to non-target organisms, economical and easy availability (Rosemary *et al.,* 2018). Support research institutions and agro-industrial sectors in developing standardized, affordable Neem-based IGR formulations to reduce dependency on imported products and stimulate the local economy.

- **Expand Field Trials Across Ecological Zones**

One of the significant challenges facing pesticide management in Nigeria is the lack of adequate laboratory testing (Okorie and Humphrey, 2016). This requires a robust laboratory testing framework that can detect the presence of banned or restricted chemicals in pesticide products. Conduct region-specific operational research and pilot studies to evaluate the effectiveness, residual activity, and environmental safety of IGRs in diverse Nigerian habitats, including urban, rural, and semi-arid settings.

- **Train Vector Control Officers and Environmental Health Personnel**

Establish nationwide training and certification programs on the correct application of IGRs, monitoring protocols, and integration into Integrated Vector Management (IVM) strategies.

- **Encourage Multi-sectoral Collaboration**

Foster coordination between public health, agriculture, environmental, and academic sectors to support a unified approach to mosquito control, regulation of biopesticides, and policy advocacy.

- **Monitor for Resistance and Environmental Impact of IGRs**

Although IGRs have proven to have low toxicity to non-target organisms, it is of paramount importance to implement regular monitoring of mosquito populations for emerging resistance to IGRs and to assess any ecological impacts on non-target aquatic species, thereby guiding responsible use.

REFERENCES

Abbas, N. and Hafez, A. M. (2021). Resistance to insect growth regulators and age stage, two-sex life table in Musca domestica from different dairy facilities. *PLOS One*, 16:e0248693.

Al-Ghamdi, K. M. S, Saleh, M. S, Mahyoub, J. A. and Al-Fifi, Z. I. (2009). Laboratory evaluation of the insect growth regulator dudim and the plant extract neem oil against Culex pipiens mosquitoes with reference to its side effects on aquatic non-target organisms. *Biosciences, Biotechnology Research Asia,* 6(2): 509–12.

Alkenani, N. A. (2017). Influence of the mixtures composed of slow-release insecticide formulations against *Aedes aegypti* mosquito larvae reared in pond water. *Saudi Journal of Biological Sciences*, 24(6):1181–5.

Batra, C. P., Mittal, P. K., Adak, T. and Ansari, M. A. (2005). Efficacy of IGR compound Starycide 480 SC (Triflumuron) against mosquito larvae in clear and polluted water. *Journal of Vector Borne Diseases*, 42(3): 109–116.

Bellinato, D. F., Viana-Medeiros, P. F., Araujo, S. C., Martins, A. J., Lima, J. B. P. and Valle, D. (2016). Resistance status to the insecticides temephos, deltamethrin, and difubenzuron in Brazilian *Aedes aegypti* populations. *BioMed Research International*, 2016: 8603263.

Bellini, R., Zeller, H. and Van Bortel, W. (2014). A review of the vector management methods to prevent and control outbreaks of West Nile virus infection and the challenge for Europe. *Parasites and Vectors*, 7: 323. https://doi. org/10. 1186/pp. 1756–3305-pp. 7–323

Benelli, G. (2015). Research in mosquito control: Current challenges for a brighter future. *Parasitology Research*, 114: 2801–2805.

Chilot, D., Mondelaers, A., Alem, A. Z., Asres, M. S., Yimer, M. A., Toni, A. T. and Ayele, T. A. (2023). Pooled prevalence and risk factors of malaria among children aged pp. 6–59 months in 13 sub-Saharan African countries: A multilevel analysis using recent malaria indicator surveys. *Plos One,* 18(5): e0285265.

Chiziba, C., Mercer, L. D., Diallo, O., Bertozzi-Villa, A., Weiss, D. J., Gerardin, J. and Ozodiegwu, I. D. (2024). Socioeconomic, demographic, and environmental factors may inform malaria intervention prioritisation in urban Nigeria. *International Journal of Environmental Research and Public Health*, 21(1): 78.

Cloyd, R. A., (2003). Effect of insect growth regulators on citrus mealybug *Planococcus citri* (Homoptera : Pseudococcidae) egg production. *Hort Science*, 38: 1397–1399.

Cutler, G. C., Tolman, J. H., Scott-Dupree, C. D. and Harris, C. R. (2005). Resistance potential of Colorado potato beetle (Coleoptera: Chrysomelidae) to Novaluron. *Journal of Economic Entomology*, 98(5):1685–1693. https://doi. org/10. 1093/jee/98. 5. 1685

De Silva, J. J. and Mendes, J. (2007). Susceptibility of *Aedes aegypti* (L) to the insect growth regulators diflubenzuron and methoprene in Uberlândia, State of Minas Gerais. *Revista da Sociedade Brasileira de Medicina Tropical*, 40:612–616.

Ekefan, E. and Eche, C. (2013). Indigenous biopesticides use and biodiversity management. In: Proceedings of the 9th National Conference on Organic Agriculture in Nigeria. Nigeria: NCOAN.

El-Heneidy, A. and Shoeb, M. (2018). Laboratory Evaluation of the Effect of Insecticides on Non-target Organisms: 2-The egg parasitoid, *Trichogramma evanescens* West. (Hymenoptera: Trichogrammatidae). *Egyptian Academic Journal of Biological Sciences*. A, Entomology, 11(3):35–44.

Hustedt, J., Doum, D., Keo, V., Ly, S., Sam, B., Chan, V., Alexander, N., Bradley, J., Prasetyo, D. B., Rachmat, A. and Muhammad, S. (2017). Determining the efficacy of guppies and pyriproxyfen (Sumilarv® 2MR) combined with community engagement on dengue vectors in Cambodia: study protocol for a randomized controlled trial. *Trials*, 18(1): 1–13.

Ibeji, J. U., Mwambi, H. and Iddrisu, A. K. (2022). Spatial variation and risk factors for malaria and anaemia among children aged 0 to 59 months: a cross-sectional study of 2010 and 2015 datasets. *Scientific Reports,* 12(1). https://doi. org/10. 1038/spp. 41598–022-pp. 15561–4.

Ibrahim, O. R., Lugga, A. S., Ibrahim, N., Aladesua, O., Ibrahim, L. M., Suleiman, B. A. and Suleiman, B. M. (2021). Impact of climatic variables on childhood severe malaria in a tertiary health facility in northern Nigeria. *Sudanese Journal of Paediatrics*, 21(2):173.

IRAC. (2022). Resistance basics. Insecticide Resistance Action Committee. https://iraconline. org/training-centre/resistance/

Ishaaya, I., Kontsedalov, S. and Horowitz, A. R. (2005). Biorational insecticides: mechanism and cross-resistance. *Archives of Insect Biochemistry and Physiology*, 58(4), pp. 192–199. https://doi. org/10. 1002/arch. 20042.

Lahm, G. P., Stevenson, T. M., Selby, T. P., Freudenberger, J. H., Cordova, D., Flexner, L., Bellin, C. A., Dubas, C. M., Smith, B. K., Hughes, K. A. and Hollingshaus, J. G. (2007). Rynaxypyr™: a new insecticidal anthranilic diamide that acts as a potent and selective ryanodine receptor activator. *Bioorganic and Medicinal Chemistry Letters*, 17(22): 6274–6279.

Lau, K. W., Chen, C. D., Lee, H. L., Norma-Rashid, Y. and Sofan-Azirun, M. (2015). Evaluation of insect growth regulators against field-collected *Aedes aegypti* and *Aedes albopictus* (Diptera: Culicidae) from Malaysia. *Journal of Medical Entomology*, 52:199–206.

Liu, Y., Gao, Y., Liang, G. and Lu, Y. (2017). Chlorantraniliprole as a candidate pesticide used in combination with the attracticides for lepidopteran moths. *PLoS One*, 12: e0180255.

Ma, L., Zhao, Z., Yang, R., Su, Q., Peng, Y. and Zhang, W. (2024). Dissecting the manipulation of lufenuron on chitin synthesis in *Helicoverpa armigera*. *Pesticide Biochemistry and Physiology*, 202, pp. 1–21. https://doi. org/10. 21203/rs. 3. rs-3870071/v1.

Martinez, L. C., Plata-Rueda, A. and Serrao, J. E. (2021). Effects of insect growth regulators on mortality, survival, and feeding of *Euprosterna elaeasa* (Lepidoptera: Limacodidae) larvae. Agronomy, 11(10). https://doi. org/10. 3390/agronomy11102002

Mbare, O., Lindsay, S. W. and Fillinger, U. (2014). Pyriproxyfen for mosquito control: Female sterilization or horizontal transfer to oviposition substrates by *Anopheles gambiae sensu stricto* and *Culex quinquefasciatus*. *Parasites and Vectors* 7:280.

Meier, C. J., Rouhier, M. F., Hillyer, J. F. (2022). Chemical Control of Mosquitoes and the Pesticide Treadmill: A Case for Photosensitive Insecticides as Larvicides. *Insects*, 13:1093. https://doi. org/10. 3390/insects13121093.

Mondal, T. and Mondal, D. (2012). A Review on Efficacy of A. indica. A Juss Based Biopesticides, an Indian Perspective. *Research Journal of Recent Sciences*, 35: 445–516.

Nino, E. L., Sorenson, C. E., Washburn, S. P. and Watson, D. W. (2009). Effects of the insect growth regulator, methoprene, on Onthophagus taurus (Coleoptera: Scarabaeidae). *Environmental Entomology*, 38(2):493–498.

Okorie A. and Humphrey A. (2016). Standards organisation of Nigeria and funding challenges to quality control. *Mediterranean Journal of Social Sciences*. 7(5), 67. doi, 10. 5901/mjss. 2016. v7n5p67 9.

Okrikata, E. and Auaso, C. E. (2008). Bio Efficacy of Various Neem Dust Formulations for the Control of Sorghum Stem Borers 11: Effect on Stalk and Peduncle in the Semi-Arid Zones of Nigeria. *Yobe Journal of Environmental Development*, 1: 29–38.

Oruonye, E. and Okrikata, E. (2010). Sustainable use of plant protection products in Nigeria and challenges. *Journal of Plant Breeding and Crop Science*, 2(9):267–272.

Reissert-Oppermann, S., Bauer, B., Steuber, S. and Clausen, P. H. (2019). Insecticide resistance in stable flies (*Stomoxys calcitrans*) on dairy farms in Germany. *Parasitology Research,* 118:2499–2507.

Retnakaran, A., Granett J. and Ennis, T. (1985). Insect growth regulators. In Kerkut, G., Gilbert, L. I. (Eds.), Comprehensive Insect Physiology, Biochemistry, and Pharmacology. Pergamon Press, New York. 12: Pp. pp. 529–601.

Rosemary, U. B., Nestor, A. J. F. and Abalis, O. R. (2018). Efficacy of *Azadirachta indica* Leaf Powder and Ethanol Extract on Adult *Periplanata americana* under Laboratory Conditions. Open Access Library Journal, 5: e4458. https://doi. org/10. 4236/oalib. 1104458.

Santos, V. S. V., Limongi, J. E., Pereira, B. B. (2020). Association of low concentrations of pyriproxyfen and spinosad as an environmentally friendly strategy to rationalise *Aedes aegypti* control programs. *Chemosphere*, 247:125795.

UNICEF, (2024). Nutrition. Accessed: Apr. 10, 2024. (Online). Available: https://www. unicef. org/nigeria/nutrition#: ~:text=Nigeria%20has%20the%20second%20highest, is%20currently%20reached%20with%20treatment.

Onwujekwe, O., Agwu, P., Onuh, J., Uzochukwu, B., Ajaero, C., Mbachu, C., Orjiakor, C. T., Odii, A. and Mirzoev, T. (2023). An analysis of urban policies and strategies on health and nutrition in Nigeria. Urban Research and Practice, 16(1): 66–91.

Villena, O. C., Arab, A., Lippi, C. A., Ryan, S. J. and Johnson, L. R. (2024). Influence of environmental, geographic, socio-demographic, and epidemiological factors on the presence of malaria at the community level in two continents. *Scientific Reports*, 14(1):16734.

The World Health Organization (2022). Report on malaria in Nigeria 2022, Geneva. Accessed: April. 10, 2024. (Online). Available: https://www. afro. who. int/countries/nigeria/publication/report-malarianigeria-2022#:~:text=Malaria%20is%20a%20major%20public,the%20country%2C%20all%20year%20round

World Health Organization (2023). World malaria report 2023, Geneva. Accessed: Apr. 10, 2024. [Online]. Available: https://www. who. int/news-room/fact-sheets/detail/malaria#:~:text=The%20WHO%20African%20Region%20carries,malaria%20deaths%20in%20the%20Region.

World Health Organization, (2024). Vector-Borne Diseases. Available online: https://www. who. int/news-room/fact-sheets/detail/vector-borne-diseases (accessed on 5 December 2024).