

Handbook of **AGRICULTURAL BIOTECHNOLOGY**

Volume IV **Nanoinsecticides**



Edited By
Charles Oluwaseun Adetunji
Julius Kola Oloke

Handbook of Agricultural Biotechnology

Scrivener Publishing

100 Cummings Center, Suite 541J
Beverly, MA 01915-6106

Publishers at Scrivener

Martin Scrivener (martin@scrivenerpublishing.com)
Phillip Carmical (pcarmical@scrivenerpublishing.com)

Handbook of Agricultural Biotechnology

Volume IV Nanoinsecticides

Edited by
Charles Oluwaseun Adetunji
and
Julius Kola Oloke



WILEY

This edition first published 2024 by John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, USA and Scrivener Publishing LLC, 100 Cummings Center, Suite 541J, Beverly, MA 01915, USA
© 2024 Scrivener Publishing LLC
For more information about Scrivener publications please visit www.scrivenerpublishing.com.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, except as permitted by law. Advice on how to obtain permission to reuse material from this title is available at <http://www.wiley.com/go/permissions>.

Wiley Global Headquarters

111 River Street, Hoboken, NJ 07030, USA

For details of our global editorial offices, customer services, and more information about Wiley products visit us at www.wiley.com.

Limit of Liability/Disclaimer of Warranty

While the publisher and authors have used their best efforts in preparing this work, they make no representations or warranties with respect to the accuracy or completeness of the contents of this work and specifically disclaim all warranties, including without limitation any implied warranties of merchantability or fitness for a particular purpose. No warranty may be created or extended by sales representatives, written sales materials, or promotional statements for this work. The fact that an organization, website, or product is referred to in this work as a citation and/or potential source of further information does not mean that the publisher and authors endorse the information or services the organization, website, or product may provide or recommendations it may make. This work is sold with the understanding that the publisher is not engaged in rendering professional services. The advice and strategies contained herein may not be suitable for your situation. You should consult with a specialist where appropriate. Neither the publisher nor authors shall be liable for any loss of profit or any other commercial damages, including but not limited to special, incidental, consequential, or other damages. Further, readers should be aware that websites listed in this work may have changed or disappeared between when this work was written and when it is read.

Library of Congress Cataloging-in-Publication Data

ISBN 978-1-119-83617-9

Cover image: Pixabay.Com

Cover design by Russell Richardson

Set in size of 11pt and Minion Pro by Manila Typesetting Company, Makati, Philippines

Printed in the USA

10 9 8 7 6 5 4 3 2 1

Contents

Preface	xvii
1 The Contribution of Ethnobotany to the Discovery of New Plant-Based Repellents	1
<i>Edokpolor Osazee Ohanmu, Saheed Ibrahim Musa, Gloria Omorowa Omoregie, Anagwonye Uju, Etinfoh Hope, Ebiminor Gift Taramapreye, Alexis Ojeide and Beckley Ikhajiagbe</i>	
1.1 Introduction	2
1.2 Ethnobotany in the Discovery of New Plant-Based Repellents	2
1.2.1 Ethnobotany and Its Role in Plant-Based Repellents	3
1.2.2 Problems in Ethnobotanical Studies in Relation to Plant-Based Repellent	3
1.3 Plant-Based Repellent	4
1.3.1 Plant Products Used as Repellents	4
1.3.1.1 Citronella	5
1.3.1.2 Neem	5
1.3.1.3 Oil of Lemon Eucalyptus	5
1.3.1.4 Essential Oils	5
1.3.1.5 Catnip	6
1.3.1.6 Vanillin	6
Acknowledgements	7
References	7
2 Nanobioinsecticide Derived from Essential Oils of <i>Cymbopogon nardus</i>	9
<i>R. Vijayalaskshmi, D. Thilagavathi and T. Vennilavan</i>	
2.1 Introduction	9
2.2 Materials and Methods	11
2.2.1 Nanobioinsecticide	11

2.2.2	Essential Oil From <i>Cymbopogon nardus</i> , Its Chemical Constituents	12
2.2.3	GC-MS Analysis	13
2.2.4	Statistical Analysis	13
2.2.5	Nanoemulsion Formulation and Characterization	13
2.2.6	Formulating Gel from Econanoemulsion	14
2.2.7	Microencapsulation	15
2.2.8	Repellent Activity of Eco-Based Gels	15
2.2.9	Chemical Composition of Essential Oils	15
2.3	Root	16
2.3.1	Flower	16
2.3.2	Characterization of Nanoemulsion	16
2.3.3	Insecticidal Activity of Eco-Based Gel	16
2.4	Discussion	17
2.5	Conclusion	20
	References	21
3	Nanobioinsecticides Derived from Neem-Based Preparations Ojo, S.K.S., Ojo, A.M., Ayo, I.O., Oluwole, B.R. and Otugboyega, J.O.	27
3.1	Introduction	28
3.2	Conventional Farming and its Challenges	30
3.3	Insects	34
3.3.1	Insects in Crop Production	34
3.3.2	Detrimental Effects of Insects on Plants	35
3.3.3	Other Negative Effects of Insects	36
3.4	Pesticides	37
3.4.1	Insecticides	37
3.4.1.1	Synthetic Insecticides	38
3.4.1.2	Benefits of Synthetic Insecticides in Agriculture	39
3.5	Nanotechnology	40
3.6	Biomaterials	42
3.6.1	Bioinsecticides	42
3.6.1.1	Plant Extracts	43
3.6.1.2	Essential Oils as Bioinsecticides	44
3.6.2	Bioinsecticide Limitations	44
3.6.3	Nanobioinsecticides	45
3.6.3.1	Synthesis Routes of Nanobioinsecticides	46
3.6.3.2	Mechanisms of Action of Nanobioinsecticides	47
3.6.3.3	Advantages of Nanobioinsecticides	47
3.7	Description of Neem	47

3.7.1	Neem Oil	48
3.7.2	Bioactivities of Neem Leaf	50
3.7.3	Bioactivities of Neem Bark	50
3.7.4	Bioactivities of Neem Cake	50
3.7.5	Neem Bioactive Components	50
3.7.5.1	Azadirachtin	51
3.7.5.2	Nimbolide	51
3.7.5.3	Salannin	51
3.8	Farm Level Neem Bioinsecticide Preparation	52
3.8.1	Processing of Kernel Extract from Neem Plant	52
3.8.2	Processing of Neem Leaf Extract	52
3.9	Effects of Neem Compounds and Its Composites on Insects	52
3.9.1	Antifeedant	52
3.9.2	Insect Growth Regulation	53
3.9.3	Oviposition Deterrent	53
3.9.4	Neem as Repellent	53
3.9.5	Fecundity Suppression and Sterilization	54
3.9.6	Inhibition of Chitin Synthesis	54
3.10	Neem-Based Preparations	54
3.10.1	Biogenic Synthetic Route	54
3.10.2	Nanodelivered Bioinsecticide	55
3.10.3	Nanoencapsulated Bioinsecticide	55
3.10.4	Nanocomposite Bioinsecticide	56
3.10.5	Nanoemulsified Bioinsecticides	56
3.11	Conclusion and Future Perspectives	56
	References	57
4	Nanoinsecticides Derived from Poaceae Family	69
	<i>Ruth Ebinoluwa Bodunrinde and Charles Oluwaseun Adetunji</i>	
4.1	Introduction	69
4.2	Nanobioinsecticides Derived from Poaceae	70
4.3	Some Examples of Essential Oils Applied in Different Studies	71
4.4	Effectiveness/Efficacy of Essential Oils from Several Plants	72
4.5	Mechanism of Action of Essential Oils	72
	References	72
5	Nanoinsecticides Derived from Pennyroyal-Containing Compounds	77
	<i>Ruth Ebinoluwa Bodunrinde and Charles Oluwaseun Adetunji</i>	
5.1	Introduction	77
5.2	Nanobioinsecticides Derived from Pennyroyal	78

5.3	Effectiveness/Efficacy of Essential Oils from Several Plants	78
5.4	Mechanism of Action of Essential Oils	79
5.5	Conclusion	80
	References	80
6	Nanobioinsecticide Derived from Thyme Oil	83
	<i>Ruth Ebunoluwa Bodunrinde and Charles Oluwaseun Adetunji</i>	
6.1	Introduction	83
6.2	Effectiveness/Efficacy of Oils from Several Plants	85
6.3	Mechanism of Action of Essential Oils	86
6.4	Conclusion	86
	References	86
7	Nanobioinsecticides from Geraniol-Containing Compounds	91
	<i>Ruth Ebunoluwa Bodunrinde, Nyejirime Young Wike, Charles Oluwaseun Adetunji and Olugbemi T. Olaniyan</i>	
7.1	Introduction	91
7.2	General Overview	94
7.3	Nanobioinsecticides Derived from Geraniol	94
7.4	Effectiveness/Efficacy of Essential Oils from Several Plants	95
	References	96
8	Repellant Testing Methodology for Nanobioinsecticide	101
	<i>Babatunde Oluwafemi Adetuyi, Peace Abiodun Olajide, Oluwakemi Semiloore Omowumi and Charles Oluwaseun Adetunji</i>	
8.1	Introduction	102
8.2	The Antifeedant Management, Resources, and Reserve Capabilities of Nanotechnology-Based Antifeedant Delivery Systems for Insect Pest Control	105
8.3	Delivery System for Nanoparticle Antifeedant Formulation	110
8.4	Preventive Maintenance Dose (PMD) from Lemon Eucalyptus (<i>Corymbia citriodora</i>) Extract	113
8.4.1	Citronella	114
8.4.2	Oils and Emulsions Found in Nature	115
8.4.2.1	Using Aromatherapy Oils	116
8.4.3	Methodological Considerations for Testing Repellents	117
8.4.4	Misconceptions Regarding Natural and Plant-Based Insect Repellents	117
8.4.5	Exciting New Breakthroughs in Naturally Occurring Repellents	118
8.5	Conclusion	119

8.6	The Way Forward	120
	References	120
9	Nanobioinsecticide and Nanoemulsions: Recent Advances	129
	<i>Babatunde Oluwafei Adetuyi, Grace Odine, Peace Olajide Abiodun, Oluwakemi Semilore Omowumi and Charles Oluwaseun Adetunji</i>	
9.1	Introduction	130
9.2	Insecticide	130
	9.2.1 Different Kinds of Directly Attacked Insects	131
	9.2.2 Systemic Insecticide	131
	9.2.3 Ingested Insecticides	132
9.3	Bioinsecticide	132
	9.3.1 Types of Bioinsecticide	133
	9.3.2 Microbial Bioinsecticide	133
	9.3.3 Biochemical Insecticide	133
	9.3.4 GMO Products	134
9.4	Problems with Bioinsecticide	134
9.5	Mechanism of Action of Bioinsecticide	135
9.6	Nanotechnology	135
	9.6.1 Nanobioinsecticide	136
	9.6.2 Delivery of Nanobiotics that Kill Insects	137
	9.6.3 Environmental Susceptibility of Nanobioinsecticide	137
	9.6.4 Emulsion	138
	9.6.4.1 Classes of Emulsion	138
	9.6.4.2 Single Emulsion	138
	9.6.4.3 Multiple Emulsion	138
	9.6.4.4 Properties of Emulsion	139
9.7	Nanoemulsion	139
	9.7.1 Advantages of Nanoemulsion	140
	9.7.2 Disadvantage of Nanoemulsion	141
	9.7.3 Component of Nanoemulsion	141
9.8	Monomolecular Films	141
9.9	Multimolecular Films	142
9.10	Solid Particulate Films	142
9.11	Method of Nanoemulsion	142
	9.11.1 Ultrasonic Emulsification	142
	9.11.2 High Energy Method	143
	9.11.3 Homogenization of High Blood Pressure	143
	9.11.4 Microfluidization	143
	9.11.5 Low Energy Method	143

9.11.6	Phase Inversion Temperature Method	144
9.11.7	Phase Inversion Composition Method	144
9.11.8	Spontaneous Emulsification Method	144
9.11.9	Formulation of Nanoemulsion	145
9.12	Characterization of Nanoemulsion	145
9.12.1	Flocculation	145
9.12.2	Cracking	146
9.12.3	Miscellaneous Instability	146
9.13	Application of Nanoemulsion	146
9.13.1	Nanoemulsion in Drug Delivery	146
9.13.2	Nanoemulsion in Food Industry	147
9.13.3	Nanoemulsion as Building Blocks	147
9.13.4	Nanoemulsion in Pharmaceutical Industry	148
9.14	Recent Advances in Nanobioinsecticides and Nanoemulsion	148
9.14.1	Oral Drug Delivery	149
9.14.2	Parental Drug Delivery	150
9.14.3	Transdermal Drug Delivery	150
9.14.4	Ocular Drug Delivery	150
9.14.5	Intranasal Drug Delivery	151
9.15	Future Perspectives	151
9.16	Summary and Conclusion	152
	References	153
10	Roles of Improved Formulations and Fixatives in the Development of Nanobioinsecticide	165
	<i>Babatunde Oluwafemi Adetuyi, Peace Abiodun Olajide and Charles Oluwaseun Adetunji</i>	
10.1	Introduction	166
10.2	Biopesticides in Organic Farming	167
10.2.1	A Taxonomy of Botanical Insecticides	168
10.2.2	The Dangers of Using Botanical Insecticides	169
10.3	Natural Pesticide Mechanisms	169
10.3.1	Toxic to Insects But Not to Humans, Plant-Based Compounds	170
10.3.2	Insect-Killing Essential Oils	170
10.3.3	Insect-Killing Fatty Acids and Their Derivatives	171
10.3.4	Pesticides Derived from Plants (Biochemical Pesticides)	172
10.3.5	Appealing Odors and Pheromones	172
10.3.6	Eliminators of Pests	173
10.4	Antifeedants	175

10.5	Citronella	183
10.6	Neem	184
10.7	Naturally Occurring Oils and Emulsions	184
10.8	Fragrant Oils	185
10.9	Considerations for Repellent Testing Methodology	189
10.10	Several Misconceptions Regarding Natural or Plant-Based Repellents	189
10.11	Progress in Plant-Based Repellents that is Promising	191
10.12	Botanical Pesticide Formulations Nanotechnology Use	192
10.13	Conclusion	193
	References	193
11	Plant-Based Repellent Evaluation and Development	205
	<i>Edokpolor Osazee Ohanmu, Barka Peter Mshelmbula, Francis Aibuedefe Igiebor, Gloria Omorowa Omoregie, Precious Oselumese Agbi, Nathan Benjamin Iredia, Peace Achioya Isime, Oghenefegor Edheba and Beckley Ikhajiagbe</i>	
11.1	Introduction	206
11.1.1	Plants	206
11.1.2	Pests	206
11.1.3	Plant-Based Insect Repellent	207
11.1.4	Allelopathy	207
11.2	Plant-Based Repellents	208
11.2.1	Classification of Plant-Based Repellents	208
11.2.1.1	Essential Oils	208
11.2.1.2	Alkaloids	208
11.2.1.3	Flavonoids	209
11.2.1.4	Esters and Fatty Acids	209
11.2.2	Barriers in Maximizing the Potentials of Plant-Based Repellents	209
11.3	Mechanism of Action	210
11.3.1	Morphological Mechanism of Action	210
11.3.2	Biochemical Mechanism of Action	210
11.3.3	Physiological Mechanism of Action	210
11.3.4	Molecular Mechanism of Action	211
11.4	Development in Plant-Based Repellents	211
11.4.1	Current Strides in Harnessing Plant-Based Repellents	211
11.4.2	Eliminating Barriers Facing Plant-Based Repellents	212
11.4.3	Efficacy of Plant-Based Repellents	212

11.4.3.1	Citronella	212
11.4.3.2	Peppermint	213
11.4.3.3	Cinnamomum	213
11.4.3.4	Catnip	213
11.4.3.5	Thyme	213
11.4.3.6	Olive	214
11.4.3.7	Eucalyptus	214
11.4.3.8	Myrtle	214
11.4.3.9	Basil	215
11.4.3.10	Neem	215
11.4.3.11	Rosemary	215
11.4.3.12	Clove	216
11.4.3.13	Orange Oil	216
11.4.3.14	Turmeric	216
11.5	Conclusion	217
	Acknowledgements	217
	References	217
12	Techniques Involved in the Structural Elucidation and Characterization of Active Constituents That Could Serve as Repellent Products Containing Plant-Based Ingredients as Nanobioinsecticide	223
	<i>Babatunde Oluwafemi Adetuyi, Peace Abiodun Olajide and Charles Oluwaseun Adetunji</i>	
12.1	Introduction	224
12.2	Farming's Use of Nano-Agrochemicals	227
12.2.1	Prevention Against Weeds, Diseases, and Pests with Nanopesticides	227
12.3	Employing Natural Insecticides to Eradicate Serious Insects from Vegetable Crops	229
12.3.1	Coleoptera	232
12.3.2	Diptera	233
12.3.3	Hemiptera	234
12.3.4	Thysanoptera	235
12.3.5	Lepidoptera	235
12.4	Effectiveness of Natural Pesticides in Practical Situations	236
12.5	Sustainability in Action: Natural Insecticides for Vegetable Crop Production	238
12.6	Conclusions	241
	References	241

13 The Influence of Nanoinsecticides on the Social Economy and Its Bio-Economy Perspectives in Attaining Sustainable Development Goals	257
<i>Abere Benjamin Olusola and Charles Oluwaseun Adetunji</i>	
13.1 Introduction	258
13.2 Nanotechnology as a Potential Source of Modern Pesticides	261
13.3 Agriculture and Toxicology of Insecticides	261
13.4 Nanostructured Alumina: A Novel Pesticide Powder Developed Through Nanotechnology	262
13.5 Pesticides Made of Nanoparticles	263
13.6 Review of the Literature	264
13.7 The Impact of Nanoinsecticides on the Development of Sustainable Development Goals	268
13.8 Conclusion	271
References	272
14 Procedure Involved in the Evaluation of Several Repellent Compounds Used for the Fabrication of Nanobioinsecticide	277
<i>Babatunde Oluwafemi Adetuyi, Edward Kwame Opata, Peace Abiodun Olajide and Charles Oluwaseun Adetunji</i>	
14.1 Introduction	278
14.2 Insecticide Nanoparticles in a Variety of Forms	280
14.2.1 Nanoemulsions	280
14.2.2 Differences Between Conventional Microemulsions and Nanoemulsions	281
14.2.3 Nanoemulsion Formulation	282
14.2.4 Nanoemulsion Components	282
14.2.5 Nanoemulsion Types	283
14.3 Resources for Producing Nanoemulsions	283
14.3.1 The New Sonication Method	284
14.3.2 Using High Pressure as a Homogenizer	284
14.3.3 Microfluidization	284
14.3.4 Insecticides Made of Nanoemulsion	285
14.4 Nanosuspensions Production	286
14.4.1 Homogenization Under Pressure (HPH)	286
14.4.2 High-Pressure Hybridization and Lyophilization (h96)	287
14.5 Nanocapsules	288
14.5.1 Using Nanocapsules Has Advantages	288

14.5.2	Developing Miniature Bug-Killer Pills	288
14.5.3	Preparing for Polymer Production	289
14.5.4	Lactic Acid Direct Polycondensation	290
14.5.5	Insecticides Created From Nanoparticles	290
14.5.6	Temephos	290
14.5.7	Imidacloprid	291
14.5.8	Neem Oil, Castor Oil	292
14.5.9	Cypermethrin Nanocapsules	292
14.6	Nanoparticles	292
14.7	Classification of Nanoparticles	292
14.7.1	Organo-Nanoparticles	292
14.7.2	Inorgano-Nanoparticles	293
14.8	Silver Nanoparticle Production	293
14.9	Nano-Sized Silica Particles	295
14.10	Making Silica Nanoparticles: Techniques	296
14.11	Pest Control: The Role of Silica Nanoparticles	296
14.12	Conclusion	296
	References	297
15	Safety, Efficacy, and Facts on Testing of Plant-Based Repellants and Effectiveness of Nanobioinsecticides	307
	<i>Babatunde Oluwafemi Adetuyi, Oluwakemi Semilore Omowumi, Peace Abiodun Olajide and Charles Oluwaseun Adetunji</i>	
15.1	Introduction	308
15.2	Insects Repellants	309
15.2.1	Reasons for Using Insect Repellents	309
15.2.2	Optimal Insect Repellents' Properties	310
15.3	PMD Obtained from Concentrate of Lemon Eucalyptus (<i>Corymbia citriodora</i>)	311
15.3.1	Citronella	312
15.3.2	Neem	313
15.3.3	Regular Emulsions and Oils	314
15.3.4	Valuable Substances	314
15.4	Techniques to Consider While Assessing Repellents	315
15.5	Test Protocols for Repellents Based on Guidelines from (WHOPES, 2009)	315
15.6	Effectiveness, Safety of Toxic Chemical, and Plant-Based Insect Repellents	316
15.7	Insecticides Produced Using Plants	319
15.8	A Few Misguided Judgments with Respect to Normal or Plant-Based Repellents	319

15.9	The Fate of Plant-Based Repellents Looks Encouraging	320
15.10	Differentiating Bug Repellents Made of Synthetic Compounds and Plants	322
15.11	Bioinsecticides Based on Plant Science for Mosquito Control	323
15.12	Utilizing Insect Sprays to Control Mosquitoes	324
15.13	Mosquito Insecticide Resistance	326
15.14	Bioinsecticides Based on Plants	329
15.14.1	Phytochemicals and Mosquito Control	330
15.14.2	Essential Oils	330
15.14.3	Neem	333
15.14.4	Pyrethrum	334
15.14.5	Alkaloids	335
15.14.6	Other Plant Substances	336
15.15	Assessment of Plant-Based Bioinsecticides' Mosquito Control Effectiveness	336
15.16	Using Plant-Based Bioinsecticides to Control Resistant Mosquito Populations	338
15.17	How Might Plant-Based Bioinsecticides Be More Effective in Mosquito Control Techniques?	340
15.18	Conclusion	344
	References	344
16	Recent Advances in the Application of Biogenic Materials in the Formulation of Nanobioinsecticide Derived from <i>Azadirachta indica</i>	361
	<i>Kehinde Abraham Odelade, Babatunde Oluwafemi Adetuyi, Adetoro Inumidun Fasinyin, Oluwafemi Ajibola Abiona, Winnie Asuquo Andem, Dorcas Adebambo Odelade and Charles Oluwaseun Adetunji</i>	
16.1	Introduction	362
16.2	Chemistry and Function of Neem Oil	363
16.2.1	Composition and Extraction	363
16.3	Main Products of Neem	364
16.3.1	Oil from Neem	364
16.3.2	Bactericidal Properties of Neem Oil	365
16.3.3	Fungicidal Properties of Neem Oil	365
16.3.4	Antioxidative Nature of Neem Oil	365
16.3.5	Insecticidal and Pesticidal Properties of Neem Oil	366
16.4	Neem Oil Nanoemulsion	366
16.4.1	A High-Tech Distribution System	366

16.4.2	Techniques for Synthesizing Nanoemulsions	367
16.5	Food Preservation and Packaging Function of the Oil of Neem Oil and its Nanoemulsion	367
16.5.1	Preservation and Storage of Food	367
16.5.2	Sustainable Food Packaging Made from Biopolymers	368
16.5.3	Neem Seed Cake	368
16.5.4	Leaves of Neem	369
16.5.5	Bark of Neem	369
16.5.6	Roots of Neem	369
16.6	The Usefulness of the Pesticides of Neem as an Agonist against a Variety of Pests Found in Food Crops	370
16.7	The Anti-Insect Properties of Azadirachtin	370
16.8	Neem's Action Mode and Specificity	370
16.8.1	Deterrents to Ovulation	370
16.8.2	Repellent	371
16.8.3	Antifeedant	371
16.8.4	Growth Regulation	371
16.8.5	Sterility	371
16.9	Neem's Future Prospects	372
16.10	Conclusions	372
	References	372
	Index	383

Preface

Insect pests have been established as one of the critical factors contributing to the higher rate of loss of agricultural crops worldwide.

The application of synthetic insecticides is effective for the prevention of agricultural insect pests, but they can pose serious threats to human health and the maintenance of a healthy environment.

These synthetic pesticides also affect humanity due to drifting, and whenever they are ingested in contaminated foods and water.

Insecticide pollution is a global challenge whenever synthetic insecticides are applied for insect pest regulation.

This has led to a higher level of pest resistance to these synthetic pesticides, instabilities of the environment, lethal influence to non-target organisms, secondary-pest resurgence, and direct toxicity to the people who applied these synthetic insecticides.

Globally, large sums of money are spent on preventing the destructive action of agricultural pests by using synthetic insecticides, but there are several challenges.

This includes their non-biodegradable attributes, higher cost, and higher level of toxicity, as well as greater amount of insecticides that reside in the water, soil, and crops, all of which affect public health.

Hence, there is a need to search for biologically compatible, naturally available materials that can be used for effective management of agricultural pests. One solution is to use plant-based repellents, which is a sustainable technique and can result in an increased yield of agricultural crops. Their success is due to their effectiveness, biocompatibility, availability, sustainability, high repellency, biodegradability, environmental friendliness, and good consumer safety.

This book provides detailed information about the application of repellent products that contain plant-based ingredients known as nanobioinsecticides. It includes the pesticide evaluation scheme guidelines for repellent testing; relevant information about the procedures to evaluate several

repellent compounds and develop new products that offer high repellency; and guidelines for good consumer safety.

The chapters herein focus on a wide range of related topics. The book chronicles many traditionally repellent plants that could be used in ethnobotanical studies and provides valuable insight into the development of new natural products. It outlines the standardization and numerous investigations used to affirm the level of repellent compounds from various plants. Furthermore, it details the safety, efficacy, and facts about plant-based repellent testing, and reviews new developments in the field.

Finally, the book explores the sustainable techniques involved in the structural elucidation and characterization of active constituents found in nanobioinsecticides, and gives relevant information on the use of essential oils, derived from plants, in the preparation of nanobioinsecticides.

This book is a useful resource for a diverse audience, including global leaders, industrialists, food industry professionals, agriculturists, agricultural microbiologists, plant pathologists, botanists, agricultural experts, microbiologists, biotechnologists, nanotechnologists, environmental microbiologists and microbial biotechnologists, investors, innovators, farmers, policy makers, extension workers, educators, researchers, and many in other interdisciplinary fields of science. It also serves as an educational resource manual and a project guide for undergraduate and postgraduate students, as well as for educational institutions that seek to carry out research in the field of agriculture and nanotechnology.

I offer my deepest appreciation to all the contributors who dedicated their time and efforts to make this book a success. Furthermore, I want thank my co-editors for their effort and dedication during this project. Moreover, I wish to gratefully acknowledge the suggestions, help, and support of Martin Scrivener and the Scrivener Publishing team.

Professor Charles Oluwaseun Adetunji
(Ph.D, AAS affiliate, FRSB (UK) FNYA; FBSN; FNSM, MNBGN)
Director of Research and Innovation, Edo State University, Uzairue, Nigeria
December, 2023

The Contribution of Ethnobotany to the Discovery of New Plant-Based Repellents

Edokpolor Osazee Ohanmu¹, Saheed Ibrahim Musa²,
Gloria Omorowa Omoregie³, Anagwonye Uju⁴, Etinfoh Hope⁴,
Ebiminor Gift Taramapreye⁴, Alexis Ojeide⁵ and Beckley Ikhajiagbe^{4*}

¹*Department of Biological Sciences, Edo University, Uzairue, Benin City, Nigeria*

²*Department of Biology and Forensic Science, Admiralty University of Nigeria,
Delta State, Nigeria*

³*Department of Environmental Management and Toxicology,
Federal University of Petroleum Resources Effurun, Warri, Delta, Nigeria*

⁴*Department of Plant Biology and Biotechnology, Faculty of Life Sciences,
University of Benin, Benin City, Nigeria*

⁵*Botany Department, Ambrose Alli University, Ekpoma, Nigeria*

Abstract

Bug, mosquito, mite, tick, and lice are insects that pose a variety of issues for people. There is an ongoing want to produce novel deterrent and insecticide, especially in light of report of insect resistance and necessities to better eco-friendly societies. Traditional plant-based repellent ethnobotanical surveys give direct approach to identify plant for possible usage. A repellent is a chemical or plant-based agent that renders the insect's surroundings uninhabitable, preventing it from contacting the host. Repellents are chemicals that are applied to treated surfaces to prevent arthropods from settling or crawling. They are safe to use on exposed skin, clothing, and other surfaces. Repellents can be thought of as a specific tool for keeping humans safe from insect-borne illnesses because they aid in the prevention, reduction, and control of disease outbreaks.

Keywords: Ethnobotany, phytomedicine, secondary products, bioinsecticides, plant-based repellents

*Corresponding author: beckley.ikhajiagbe@uniben.edu

Charles Oluwaseun Adetunji and Julius Kola Oloke (eds.) Handbook of Agricultural Biotechnology: Volume IV Nano-insecticides, (1–8) © 2024 Scrivener Publishing LLC

1.1 Introduction

Bug, mosquito, mite, tick, and lice are hematophagous insects that pose a variety of issues for people. When they sting, they can result in necrosis, blister, or allergy in people [1]. Furthermore, hematophagous invertebrates can transmit infectious pathogens to humans, resulting in the spread of ailment. Humans have tried a variety of tactics to combat hematophagous insects. Native herbs have traditionally been applied in protection of people against bite. Oil derived from plant parts apply to the body, for example [2]. Traditional plant-based insect repellents are no longer practical in urban environments, but are exploited as source for recent pesticides and repellent. Pyrethrum and neem are two instances of actual current product derived through traditional botanicals [3]. Plant items, such as wood and leaves, are also commonly burned to deter insects.

Ethnobotany is the study of plants in a particular place, as well as their practical application based on local culture and expertise. Taxonomy, cultivation, and the usage of indigenous plants as food, medicine, and shelter are all covered. The use of ethnobotany to choose plants demands detailed documenting of indigenous communities' relationships with plants. Ethnobotanic knowledge is based on observation, relationships, requirements, and traditional ways of knowing and can be applied to both wild and domesticated species. New discoveries, ingenuity, and techniques are constantly added to the mix as knowledge advances. Ethnobotany is now acknowledged as an important subject dedicated to the study of all sorts of human-plant interactions.

1.2 Ethnobotany in the Discovery of New Plant-Based Repellents

Botanical knowledge of a specific ethnic group can be useful in a variety of situations. Plants used for fiber, color agent, poison, manure, construction material, watercraft, and plant-based repellents are among the natural products studied by ethnobotany. Plant-based repellents were use as private defense technique against mosquito for ages. Ethnobotanical research yields relevant information of traditional deterrent plant use in development of novel products [4]. In order to generate new plant-based repellents, ethnobotany is required.

Phytochemicals are produced by many plants to deter insects that feed on plant fluids. Mosquito repellents are required to protect humans from

mosquito stings [5]. Depending on their activity, phytochemicals can be extracted from whole plants or specific parts of plants. Photo-activated toxins found in certain phytochemicals have been shown to be effective against mosquitos [5]. Human-friendly plant-based insect repellents should be less harmful and have fewer adverse effects. As a result, using plant derivatives rather than chemicals in mosquito repellents could result in lower manufacturing costs and reduced environmental impact. The development of novel and more effective plant-based repellents has been aided by ethnobotanical research with indigenous peoples and their use of plants as repellents.

1.2.1 Ethnobotany and Its Role in Plant-Based Repellents

For decades, plant-based repellents have been used as a personal defense against mosquitoes looking for a place to lay their eggs [4]. Ethnobotanical research can be used to develop new natural goods based on traditional repellant plants [4]. In comparison to long-established synthetic repellents, consumers are becoming interested on repellent made from plant compound since they are observed to be safe [4]. With a few exceptions, the majority of newly emerging infectious illnesses are arthropod via tick or mosquito which are not vaccine-preventable. Plants are frequently used in the creation of effective plant-based repellents. Tobacco, corymbia, neem, and citronella are some examples.

1.2.2 Problems in Ethnobotanical Studies in Relation to Plant-Based Repellent

Traditional plant-based insect repellents are no longer practical in urban environments, but exploited as means for current pesticides and deterrent. Researchers have screened plants that may operate as natural repellents and characterized their activities and toxicities over numerous generations. Due to their low cost, few individuals in distant regions still employ old ways in control of insects [6, 7].

Also, traditional pest management knowledge is fast being lost because of increases in standard of living and lack of information [18]. Ethnobotany has yielded a harvest of unique, laboratory-proven therapeutic plants and chemicals in recent decades, but it has fallen short of its promise of producing a cornucopia of new and taxonomically focused plant-based repellant discoveries. Individual or group interviews are frequently used to obtain information about how different plant species are used in a community,

and range of information varies depending on method applied. Finally, a lack of funding for ethnobotanical research and studies is a barrier. When financing for ethnobotanical research is scarce, progress is stifled, providing a problem for the field's future growth.

1.3 Plant-Based Repellent

A plant-based repellent is an organic repellent that is created from plant extracts and concentrates or comes in the shape of a plant. Plants were used to deter and eradicate insects since prehistoric times, and many people continue to do so today in the world [8]. Traditional repellent plant knowledge can be applied to produce current natural repellents that can be used instead of synthetic repellents. Plant-based repellents provide a high concentration of bioactive phytochemicals that are both innocuous and non-toxic biodegradable byproducts that might be studied for insecticidal efficiency [2].

There is currently considerable agreement that plant-based products are safer and that phytochemicals degrade swiftly, piquing researchers' and the general public's curiosity [8]. One advantage of using a plant-based botanical is user acceptance. The majority of individuals prefer natural things to synthetics. Plant-based repellents are economical, widely accessible, well-known, and culturally suitable [8]. Ethnobotany plays an important role in the development of new plant-based repellents. It's a strategy of conducting in-depth interviews with key people knowledgeable about culture and traditional medicine in order to conduct a concentrated search for therapeutic plants. Plant by ethnic group is commonly studied using ethnobotanical research that combines scheduled discussions with plant voucher species collection. Plants that have been wounded or harmed release volatile odors into the environment, providing insect defense from afar. When these chemicals are used in repellents that are applied to the skin, their volatility becomes a concern.

1.3.1 Plant Products Used as Repellents

Plant repellents including citronella oil from *Cymbopogon nardus*, PMD from Eucalyptus *Maculata citriodora*, and fennel oil from *Foeniculum vulgare* do little to no harm in societies or human life, and might be a good alternative to artificial repellent like DEET [19, 20]. Some of these plants-derived repellents are discussed below:

1.3.1.1 *Citronella*

Citronella is a natural oil obtained from stem and leaf of many lemongrass specie (*Cymbopogon* sp) [9]. It's made of lemongrass and has a repellent effect on *Anopheles culicifacies* for 11 hours [10]. Mosquito coils with citronella oil or the citronellal component are also used to keep mosquitos out of outdoor spaces [11]. Citronella was first distilled for perfume use in 1858, and comes from French term Citronelle.

It is widely use natural repellent, with concentrations ranging from 5% to 10%. Although the concentration is low compare to that of most repellent, larger concentration could cause skin irritation. It's frequently used as an insect repellent in the outdoors. Citronella is available at 0.5–20% concentrations in lotions, oils, and hard wax infused candles and blazing pots. Due to its high volatility, citronella duration of effect is short, yet it can repel mosquito bites for up to 2 hours.

1.3.1.2 *Neem*

Neem oil, made from cold-pressed seeds, is efficient against a variety of insects and mites, as well as phytopathogens [11]. Despite the presence of over a dozen azadirachtin analogs in neem seeds, azadirachtin is the major form, and the other minor chemicals are unlikely to have a substantial impact on the extract's overall efficacy. Nimbin, salannin, and triterpene derivatives are among the other triterpenoids found in seed extracts. Other natural chemicals' functions are questionable, but azadirachtin appears to be the main functional principle.

1.3.1.3 *Oil of Lemon Eucalyptus*

P-menthane-3, 8-diol (PMD), sometimes known as lemon eucalyptus oil, is an organic or inorganic extract of the leaves of *Corymbiacitriodora*. PMD has similar insect repellent efficiency and length like DEET, *Andas picaridin* may provide superior tick guard than DEET. Centers for Disease Control (CDC) has recommended PMD as the only plant-based deterrent for use in disease zones [12]. It was discovered to be just as effective and long-lasting as DEET.

1.3.1.4 *Essential Oils*

They are one-of-a-kind combination of unstable organic chemicals produce as secondary metabolite by plant. Hydrocarbon (Sesquiterpenes and

Terpene) and oxygenated compounds (ethers, esters, ketones, aldehydes, alcohols, phenols, lactones, and phenol ethers) make up essential oils [12]. Several plant essential oils and concentrates, particularly for *Anopheles* species, could be utilized to make long-lasting and environmentally friendly repellents [13, 21–24].

Essential oils obtain through distilling aromatic plant have long been employed in the manufacture of colognes and aromatics in cologne and food products, and are now used for therapeutic and medicinal herbs [4, 5, 13–15]. Commercially available extracts of cinnamon, thyme, garlic, cedar, pine, fennel, peppermints, geranium, verbena oils, and lavender have been shown to repel numerous mosquito species, including *Aedes albopictus* [3] [13, 16, 23]. Prior to the discovery of efficient synthetic repellents, the military used aromatic oils as repellents. A lotion containing citronella, paraffin, and camphor was issued to the British Indian troops, but it barely lasted 2 hours [13, 17, 18, 21, 24].

1.3.1.5 *Catnip*

Catmint is a common name for a perennial mint plant in the Labiatae family called Catmint. This herb grows from central Europe through central Asia, as well as on the Iranian plateaus [17]. Catnip has long been known for its cat-stimulating properties. The active ingredient in catnip has been identified as nepetalactone, which is found in two isomers in the essential oil of the plant: E,Z (trans, cis) and Z,E (cis, trans), with Z,E-nepetalactone the most common. Catnip has a lengthy history of insect repellent use, with the majority of it being scientifically proven.

1.3.1.6 *Vanillin*

Asynthetic version of a natural occurring molecule present in vanilla seed pods. Vanillin (10%) has been found to enhance the repellent qualities of different volatile oils against *Aedes aegypti*. Addition of vanillin to an oil-based repellent reduces volatility and increases the natural repellent's lifespan. The increase in protection time with varied ratios of vanillin to repellents was not substantial, with the exception of diethyl toluamide (deet [diethyltoluamide]). In most cases, the length of protection was increased by more than 100%. According to studies, some mosquito repellents containing vanillin can provide protection from mosquito stings for up to a day [16].

Acknowledgements

Beckley Ikhajiagbe, our supervisor and professor, was instrumental in the drafting of the outline and guidelines for producing this review, as well as encouraging us all to write. Sir, thank you very much.

References

1. Ansari, M.A., Mittal, P.K., Razdan, R.K., Sreehari, U., Larvicidal and mosquito repellent activities of Pine (*Pinus longifolia*, family: Pinaceae) oil. *J. Vector Borne Dis.*, 42, 3, 92–99, 2005.
2. Asadollahi, A., Khoobdel, M., Zahraei-Ramazani, A., Effectiveness of plant-based repellents against different anopheles species: A systematic review. *Malar. J.*, 18, 436–456, 2019. <https://doi.org/10.1186/s12936-019-3064-8>.
3. Brown, M. and Hebert, A.A., Insect repellents: An overview. *J. Am. Acad. Dermatol.*, 36, 243–249, 1997.
4. Buckle, J., *Clinical aromatherapy: Essential oils in practice*, p. 416, Churchill Livingstone, Edinburgh, 2003.
5. Coppen, J.J.W., *Flavours and fragrances of plant origin*, p. 101, Food Agric. Org, Rome, 1995.
6. Covell, G., Anti-mosquito measures with special reference to India. *Health Bulletin.*, 11, 44–53, 1943.
7. Curtis, C.F., Lines, J.D., Ijumba, J., Callaghan, A., Hill, N., Karimzad, M.A., The relative efficacy of repellents against mosquito vectors of disease. *Med. Vet. Entomol.*, 1, 2, 109–119, 1987.
8. Debboun, M., Frances, S., Strickman, D., *Insect repellents-principles, methods, and uses*, CRC Press, Boca Raton, 2006.
9. Freeman, B. and Beattie, G., An overview of plant defenses against pathogens and herbivores. *Pathology*, 7, 66–78, 2008.
10. Gakuya, D.W., Itonga, S.M., Mbaria, J.M., Ethnobotanical survey of biopesticides and other medicinal plants traditionally used in Meru central district of Kenya. *J. Ethnopharmacol.*, 145, 547e553, 1973.
11. Grognet, J., Catnip: Its uses and effects, past and present. *Can. Vet. J.*, 19, 31–455, 1990.
12. Guenther, E., *The essential oils*, Krieger Publishing Company, Florida, USA, 1972.
13. Isman, M.B., Pesticides based on plant essential oils. *Pestic. Outlook*, 10, 68–72, 1999.
14. Isman, M.B., Problems and opportunities for the commercialization of botanical insecticides, in: *Biopesticides of Plant Origin*, C. Regnault-Roger, B.J.R. Philogène, C. Vincent (Eds.), pp. 283–91, Lavoisier, Paris, 2005.

15. Karunamoorthi, K., Mulelam, A., Wassie, F., Laboratory evaluation of traditional insect/mosquito repellent plants against anopheles arabiensis, the predominant malaria vector in Ethiopia. *Parasitol. Res.*, 103, 529–534, 2008.
16. Khan, A.A., Maibach, H., Iskidmore, D.L., Addition of vanillin to mosquito repellents to increase protection time. *Mosq. News*, 35, 223–225, 1975.
17. Kweka, E.J., Mosha, F., Lowassa, A., Ethnobotanical study of some of mosquito repellent plants in north-eastern Tanzania. *Malar. J.*, 7, 152, 2008.
18. Lara, M., Gutierrez, J., Timon, M., Andrés, A., Evaluation of two natural extracts (*Rosmarinus officinalis* L. and *Melissa officinalis* L.) as antioxidants in cooked pork patties packed in MAP. *Meat Sci.*, 88, 481–488, 2011.
19. Lavaud, F., Bouchet, F., Mertes, P.M., Allergy to the bites of blood-sucking insects: Clinical manifestations. *Allerg. Immunol. (Paris)*, 31, 311–316, 2009.
20. Maia, M.F. and Moore, S.J., Plant-based insect repellents: A review of their efficacy, development and testing. *Malar. J.*, 10, 1, S11, 2011. <https://doi.org/10.1186/1475-2875-10-S1-S11>.
21. Paluch, G., Grodnitzky, J., Bartholomay, L., Coats, J., Quantitative structure-activity relationship of botanical sesquiterpenes: Spatial and contact repellency to the yellow fever mosquito, *Aedes aegypti*. *J. Agric. Food Chem.*, 57, 7618–7625, 2009.
22. Quarles, W., Botanical mosquito repellents. *Common-Sense Pest Control.*, 12, 12–19, 1996.
23. Roberto, R., Guido, S., Giancarlo, M., Could malaria reappear in Italy? *Emerg. Inf. Disp.*, 7, 915, 2001.
24. Trongtokit, Y., Rongsriyam, Y., Komalamisra, N., Apiwathnasorn, C., Comparative repellency of 38 essential oils against mosquito bites. *Phytother. Res.*, 19, 4, 303–309, 2005.

Nanobioinsecticide Derived from Essential Oils of *Cymbopogon nardus*

R. Vijayalaskshmi^{1*}, D. Thilagavathi¹ and T. Vennilavan²

¹*Botany Department, Queen Mary's College, Chennai, India*

²*MTech Scholar, Department of Food Technology, Anna University Tamil Nadu, Chennai, India*

Abstract

Generally, for a long period of time chemically synthesized insecticides has played a major part in integrated pest management program. But recently eco-friendly bio pesticides based on essential oil has strongly replaced them. These nano-pesticides and insecticide are human and environment friendly and simultaneously increase the yield crop productivity. Essential oils derived exhibit toxic repellent and anti-feeding effect on different species of insects. Air, light, moisture and high temperature have special influence on the nano-bio-pesticides. But this problem can be solved by incorporating the plant derived oils into controlled and released nano-formulations.

Keywords: Nanobioinsecticide, cymbopogon nardus nano-formulant, essential oil, insect pest control

2.1 Introduction

There are many developments of novel technique of protection against urban pest agriculture storage and due to their increase of plant derived substance and nontoxic material. Food industries generally relies on authorized pesticides and these scientific community increases to use the eco-friendly formulation and novel application techniques [1].

There has been un controlled uses of synthetic pesticides which contributed to several hazards to environment and change the ecosystem.

*Corresponding author: rvijaya2799@gmail.co

Rebellion of resistance in some pest and their consequent drop of efficiency of the fungicide synthetic germicide can contaminate the environment there by polluting the whole food chain.

Likewise, there is a drop environmental diversity including non-targeting organism. Pest, parasites, insect pollinators, predators which may be linked to the application of artificial pesticide [2]. Generally methyl bromide and phosphene are used against the stored products, insects, pest hence they are highly reactive against non-entities. But the restriction of methyl bromide and the growing resistance to phosphene have determined the critical development of indispensable pesticide and insecticide for stored product in pest operations [3, 4].

Nanotechnology is an important exploration field which can be used for crop protection and to make new active constituents at nanoscale dimensions. Generally selected nanofungicide should retain certain characteristic features to overcome the limitations and also improve the bio activity of synthetic germicide [5, 6], hence promoting stability and continuity in the environment perfecting the toxic action towards the targeted pest but avoiding secondary effect on the non-target organism [7]. Generally, the majority of the commercial pesticides are neurotoxic and interfere directly or indirectly with the neurological system of the insect. Mammals and unintended insects may be at risk from this type of insecticide. Thus, the expression of nano-biopesticide with different modes of action increases the sustainability and safety pest control method [8].

Many biopesticides are plant based secondary metabolites that are thought to play a key role in plant protection against biotic and abiotic stress [9, 10]. Composites are the most prevalent secondary metabolites among alkaloids, phenols, and terpenoids [11]. The plant tissues solvent or heated distillation can uproot this substance, which contains a complex admixture of colorful compounds known as essential oils. Numerous essential oils are bioactive substances that have insecticidal, poisonous, and repellant properties against the target pest species sterility-infertility and developmental and behavioral differences [12]. Essential oils are a type of pest control that has been used for centuries. Botanicals were utilized to manage stored grain pests several million years ago, circa 2000 BC, across Asia, the Middle East, and Northern Africa [13]. The low toxicity of essential oils toward animals has sparked interest in their usage as a pest control tool [14, 15]. As a result, these compounds are utilized as food protection as well as insect control. Essential oils are predominantly made up of volatile lipophilic substances with fire breakdown property and poor water solubility [16–18]. Despite their potential and well-known insecticidal action, there are only few commercial essential oil-based bio pesticides are available due to some characteristic features.