

Review

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Posted Date: 23 June 2023

doi: 10.20944/preprints202306.1686.v1

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Review

# Biotechnological Potential of Microorganisms for Mosquito Population Control and Reduction of Vector Competence

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**Simple Summary:** Mosquitoes carry pathogens that can cause diseases like malaria, dengue fever, chikungunya, yellow fever, and Zika fever, causing more than 700,000 deaths each year around the world. Chemical pesticides kill mosquitoes effectively, minimizing the spread of illnesses. However, these chemicals have disadvantages such as high production costs and negative impacts on the environment and other organisms, including humans. Furthermore, mosquitoes are becoming more resistant to chemical pesticides. Therefore, alternatives to commonly used insecticides are urgently required. In this review, we highlight the biotechnological potential of microorganisms to control vector mosquitoes and reduce disease transmission. In addition, we emphasize the importance of more basic research and improved translational research methods to bridge the gap between academic research on biopesticides and public health interventions.

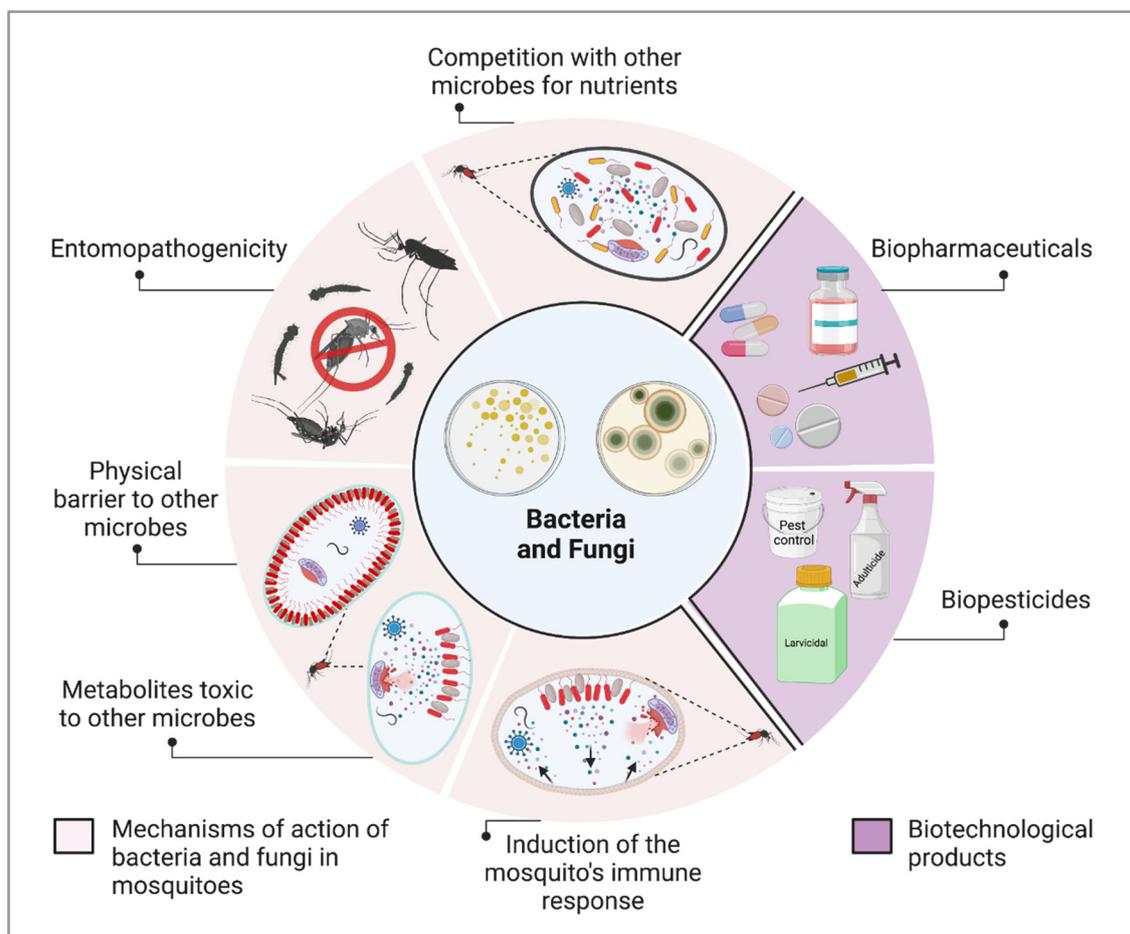
**Abstract:** Mosquitoes transmit pathogens that cause human diseases such as malaria, Dengue fever, Chikungunya, yellow fever, Zika fever, and filariasis. Chemical pesticides are effective instruments for reducing disease transmission and managing mosquito populations. However, these chemicals have drawbacks such as high production costs and negative effects on the environment and non-target organisms. Furthermore, as mosquitoes develop resistance to chemical insecticides, they become less effective. As a result, researchers are investigating novel insecticides. Advances in microbial biotechnology have resulted in a wide range of value-added products, including biopesticides for agricultural and public health purposes. In this review, we highlight the mainly untapped biotechnological potential of microorganisms for vector mosquito control and disease transmission reduction. Also, we underline the importance of more basic research and improved translational research methodologies, encouraging efforts to bridge the gap between academic research on biopesticides and public health interventions.

**Keywords:** biotechnology; microorganisms; bacteria; fungi; vector control; mosquitoes

## 1. Introduction

Microorganisms constitute a large group of genetically diverse biological entities found in a wide range of terrestrial and aquatic habitats, playing crucial roles in the balance of ecosystems [1–3]. Advances in microbiology, molecular biology, and genomics enabled the biotechnological exploration of microbes, allowing the discovery and production of antibiotics [4,5], foods [6,7], alcoholic beverages [8], bioremediators [9,10], fertilizers [11], and biopesticides [12,13]. The microorganisms associated with mosquitoes have drawn special attention for their potential applications in public health (Figure 1) [14–16]. In this review, we highlight the largely unexplored

potential of microbes for the control of mosquito-borne diseases and the need for better translational research strategies, encouraging efforts toward bridging the gap between academic research and public health interventions.



**Figure 1.** Environmental and symbiotic fungi and bacteria interact with mosquitoes and the mosquito microbiota, modulating the survival and development of both pathogenic microorganisms and the mosquito. Research that elucidates these interactions is essential for the development of novel biotechnological products for vector control and reduction of disease transmission. Created with [BioRender.com](https://www.biorender.com).

## 2. Bacteria for biological control of medically important mosquitoes

Today, chemical insecticides are used as the main tool for mosquito control [17,18], but are no longer as effective as in the past due to the selection of insecticide resistant individuals in mosquito populations worldwide [19–22]. Furthermore, chemical insecticides harm the environment, contaminating groundwater systems through infiltration into the soil, reaching riverbeds, accumulating in fish and other animals [23], and through spraying, contaminating the air, affecting human health [24,25]. These facts emphasize the prominent need to develop new, efficient, and environmentally safe tools for the control of vector mosquitoes and the diseases they transmit.

Bacteria of the Bacillaceae family infect insects and produce toxins with insecticidal properties. *Bacillus thuringiensis israelensis* (Bti) and *Lysinibacillus sphaericus* (Lbs), the latter formerly known as *Bacillus sphaericus*, are widely known for their larvicidal activity against several species of mosquitoes [26–30]. Due to their high efficacy, safety, and the well-characterized mechanisms of action of their toxins, several strains of Bti and Lbs are included in commercially available biological larvicide formulations endorsed by organizations such as the World Health Organization [31] and the Environmental Protection Agency (EPA) in the United States of America ([www.epa.gov/mosquitocontrol/bti-mosquito-control](http://www.epa.gov/mosquitocontrol/bti-mosquito-control)).

The toxins of Bti and Lbs and the mechanisms associated with mosquito mortality have been extensively studied [32,33]. Briefly, in Bti, the molecules responsible for the entomopathogenic action are mainly the crystal toxins Cry4Aa, Cry4Ba, Cry10Aa, and Cry11Aa, the cytolytic toxins Cyt1Aa, and Cyt2Ba, and the P19 and P20 proteins [34,35]. Cry and Cyt toxins, also known as  $\delta$ -endotoxins, when present in the midgut of mosquito larvae, are proteolytically activated by digestive proteases, bind to specific receptors on the host cell membranes, and cause cell rupture, resulting in death of infected larvae [36]. The Lbs Bin toxins [37–39], Mtx [40], Cry48Aa and Cry49Aa [41], display entomopathogenic mechanisms similar to those described above for the Bti toxins [42]. Acting synergistically, these toxins result in effective and potent toxic activity against mosquitoes [43–45].

Finding new microbes with larvicidal activities similar to those of Bti and Lbs has been the goal of several research groups around the world. However, this endeavor has been limited by the fact that culture media do not always meet the requirements for the growth of many species of bacteria [46]. Therefore, the search for entomopathogenic bacteria is often limited to those that grow in commercially available culture media. Despite these limitations, bacterial strains that are suitable for cultivation and have larvicidal activity have been identified. Unfortunately, most of them have not been further investigated, developed to applicable products, or tested under field or semi-field conditions. Additional research to understand their mechanisms of action, effects on non-target organisms and potential for large-scale production is needed.

Toward these goals, live bacteria, deactivated bacteria, and fractionated cells or culture media have been tested for their larvicidal activities. For example, *Bacillus safensis*, *Bacillus paranthracis*, and *Bacillus velezensis* culture supernatants and crude lipopeptide extracts were shown to be toxic to *Aedes aegypti* [47]. Whole genome sequencing and mass spectrometry analysis of those isolated bacteria strains revealed that these microorganisms synthesize bacteriocin, beta-lactone, and terpenes potentially toxic to mosquito larvae [47]. Nineteen *Bacillus sp.* strains and two strains of *Brevibacillus halotolerans* isolated from Amazonian environments showed larvicidal activity against *Ae. aegypti* [48]. The supernatant and pellet fractions of those strains were tested separately, revealing that cellular and secreted metabolites are toxic to mosquito larvae. *Bacillus mojavensis* kills *Ae. aegypti* larvae and its action was provisionally attributed to the biosurfactant surfactin thioesterase [49]. The testing of whole or fractionated bacteria and culture media is useful for defining procedures and formulation of new and promising biolarvicides. The identification of bacteria with mosquito larvicidal activities, in addition to Bti and Lbs (Table 1,) instigates their exploration as potential tools for mosquito control.

**Table 1.** Bacterial strains toxic to *Aedes*, *Culex* and/or *Anopheles* mosquito larvae.

Bacterium	Toxic formulation	Target mosquito genera			Refs
		<i>Aedes</i>	<i>Culex</i>	<i>Anopheles</i>	
<i>Bacillus thuringiensis var. israelensis</i> (Bti)	Extract (spores and crystals)	+	-	-	[50]
	Sporulated culture powder (Tablet formulation XL-47)	+	-	-	[51]
	Spores and crystals tablet	+	-	-	[52]
	Spores and crystals tablet	+	-	-	[53]
	VectoBac WG	+	-	-	[54]
	Formulated product	-	+	-	[55]
	Binary mixtures (Bti plus Deltamethrin)	-	+	-	[56]

	Cry2Aa and Cyt1Aa crystals	-	+	-	[57]
	Crystallogenic variants.	+	+	-	[58]
	Two recombinant proteins (Cry10Aa and Cyt2Ba)	+	-	-	[59]
	Xpp81Aa toxin combined with Cry2Aa and Cry4Aa	+	-	-	[35]
	Kappa-carrageenan and Vectobac 12 AS hydrogels	+	-	-	[60]
	Bti extracts	+	-	-	[61]
	Vectobac® AS	-	+	-	[62]
	Granular formulation (Vectobac G)	-	-	+	[63]
	Dispersible granule (strain AM65-52)	+	+	+	[64]
	Bti strain Becker Microbial Products (BMP)	-	+	+	[65]
	Bti product VECTOBAC TP® sprayed	-	-	+	[66]
	Bti Water Dispersible Granular (WDG) formulation	-	-	+	[67]
	Water dispersible granule (Bti strain AM65-52 formulation, VectoBac® WDG)	-	-	+	[68]
	Water-dispersible granule Bti VectoBac (WDG)	-	-	+	[69]
	Bti VectoBac® WG, AM65-52 strain	-	-	+	[70]
<i>Bacillus thuringiensis</i> (Other strains)	Total and lyophilised culture	+	+	-	[71]
	Bacterial cultures	+	+	+	[72]
	Bacterial suspensions (spores and crystals)	+	-	-	[73]
	Spores	+	+	+	[74,75]
	Parasporal crystalline inclusion bodies	+	-	-	[35]
	Culture supernatant	+	-	+	[29]
	Synergistic interaction (Purified Cry11Aa and Cyt1Aa Toxins)	+	-	-	[76]

	Synergistic action of the Cry and Cyt proteins	-	-	+	[77]
<i>Lysinibacillus sphaericus</i> (Lbs)	Culture supernatant	+	-	+	[29]
	Spores and vegetative cells	+	+	-	[30]
	Cell suspension plus glyphosate	+	-	-	[78]
	Spore crystals (lyophilized powder)	+	+	+	[79]
	Spores	-	+	-	[80]
	Granular formulation (Vectobac G)	-	+	+	[63]
	Vectolex G	-	+	-	[81]
	S-layer protein	-	+	-	[82]
	Purified BinA and BinB proteins	-	+	+	[83,84]
	Spore-crystals and purified S-layers protein	-	+	+	[85]
	Synergy of Mtx and Cry proteins	-	+	-	[44]
	Purified BinA and BinB proteins	-	+	-	[39]
	VectoLex® WG plus Pyrethroid Resigen®	-	+	-	[86]
	Cry48Aa and Cry49Aa proteins combined	-	+	-	[87]
	Synergistic interaction (S-Layer and spores/crystals)	-	+	-	[88]
	VectoLex (ABG-6185)	-	-	+	[89]
Suspension (Lyophilized bacteria)	-	-	+	[90]	
VectoLex® CG	-	-	+	[91]	
Bin toxin proteins	-	-	+	[92]	
<i>Acidovorax</i> sp.	Cell-Free Supernatant	+	-	-	[93]
<i>Aneurinibacillus aneurinilyticus</i>	Bacterial suspension	+	+	+	[94]
<i>Bacillus amyloliquefaciens</i>	Biosurfactant	+	+	+	[95]
<i>Bacillus cereus</i>	Culture supernatant	+	-	+	[29]
<i>Bacillus circulans</i>	Spores	+	+	+	[96]

<i>Brevibacillus halotolerans</i>	Supernatant and pellet fractions of bacterial cultures	+	-	-	[48]
<i>Bacillus licheniformis</i>	Dahb1 exopolysaccharide (BI-EPS)	+	-	+	[97]
<i>Brevibacillus laterosporus</i>	Suspension of sporulated cells	+	-	+	[98]
	Spore and the canoe-shaped parasporal body (CSPB) structure	+	-	-	[99]
	Purified protein crystals	+	-	+	[100]
	Pellets (cells and spores)	+	-	-	[101]
	Spores	+	-	-	[102]
<i>Bacillus paranthracis</i>	Pellets (cells)	+	-	-	[47]
<i>Bacillus safensis</i>	Supernatant and pellet fractions of bacterial cultures	+	-	-	[48]
	Pellets (cells)	+	-	-	[47]
<i>Bacillus subtilis</i>	Culture supernatant	+	-	+	[29]
	Crude cyclic lipopeptides (CLPs)	-	+	-	[103]
	Crude surfactin	-	-	+	[104]
	Bacterial biomass	+	-	-	[105]
	Biosurfactants	-	-	+	[106,107]
<i>Bacillus megaterium</i>	Bacterial culture	+	-	-	[48]
<i>Bacillus nealsonii</i>	Secondary metabolites	+	-	-	[108]
<i>Bacillus tequilensis</i>	Cyclic Lipopeptide Biosurfactant	-	-	+	[109]
<i>Bacillus velezensis</i>	Bacterial culture	+	-	-	[48]
	Pellets (cells)	+	-	-	[47]
<i>Chromobacterium sp.</i>	Hydrogen cyanide	+	-	+	[110,111]
<i>Chromobacterium anophelis</i>	Bacterial suspension	-	-	+	[112]
<i>Pantoea stewartii</i>	Silver nanoparticles	+	+	+	[113]
<i>Paraclostridium bifermentans</i>	Clostridial neurotoxin	-	-	+	[114]
<i>Peanibacillus macerans</i>	Bacterial biomass	+	-	-	[105]
<i>Photobacterium luminescens</i>	Secondary metabolites (Culture fluids)	+	-	-	[115]
	Secondary metabolites	+	-	-	[116]

<i>Photorhabdus luminescens subsp. akhurstii</i>	Bacterial cell suspension	+	-	-	[117]
<i>Pseudomonas sp.</i>	Bacterial cell suspension	-	+	-	[84]
<i>Priestia aryabhatai</i>	Silver nanoparticles	+	+	+	[113]
<i>Serratia marcescens</i>	Prodigiosin	+	-	+	[118,119]
	Bacterial suspension	+	-	-	[120]
<i>Serratia nematodiphila</i>	Bacterial cultures	+	+	+	[72]
<i>Saccharopolyspora spinosa</i>	Spinosad (Tracer®)	+	-	+	[121]
	Spinosad formulation	+	+	+	[122]
	Spinosad-based product (Laser®)	+	+	+	[123]
	Spinosad	+	-	-	[124]
	Spinosad - Tablet (DT) and granules (GR)	+	-	-	[125]
	Spinosad powder	-	+	-	[126]
	Spinosad formulation	-	-	+	[127,128]
	Natular T-30 formulation	-	+	-	[129]
	Formulation Emulsifiable Concentrate	-	+	-	[130]
	<i>Streptomyces sp.</i>	Secondary metabolites	+	-	-
<i>Xenorhabdus indica</i>	Bacterial cell suspension	+	-	-	[117]
<i>Xenorhabdus nematophila</i>	Secondary metabolites	+	-	-	[116]
	Secondary metabolites (Culture fluids)	+	-	-	[115]
<i>Xenorhabdus stockiae</i>	Bacterial cell suspension	+	-	-	[117]

This list is not exhaustive but provides ideas for future research and product development opportunities.

### 3. Fungi as vector mosquito biocontrol agents

Fungi, and their metabolites are also potentially useful for the control of medically important mosquitoes [132–137]. In fact, fungal strains have already been applied as complementary measures for the control of vector mosquitoes [138–141].

*Beauveria bassiana* strains infect and kill a variety of insects, including mosquitoes. Application of *B. bassiana* spores on surfaces where mosquitoes rest [142], the impregnation of spores in traps [143], association of the fungus with insecticides, such as the combination of *B. bassiana* and permethrin [144] and the spread of the fungus by females mating with pre-inoculated males [145] have been proposed as means of field applications of *B. bassiana* against mosquitoes. The attraction of *An. stephensi* to spores of *B. bassiana* present in dead and dying caterpillars infected with the fungus [146], has been proposed as a useful alternative to infect mosquitoes. Furthermore, experimental evolution has been applied successfully to increase the efficacy of *B. bassiana* to *Anopheles coluzzii* [147].

Exposure to lethal and sublethal doses of *B. bassiana* spores decreases *Ae. aegypti* and *Ae. albopictus* host-seeking behavior and fecundity [132,148]. Infected mosquitoes, while still alive, spread the fungus through the vector population. *Beauveria bassiana* spores and extracts are also effective against mosquito larvae [149–151]. As a result of this evidence, several strains of *B. bassiana* are authorized for use as biological insecticides, against vector mosquitoes, by regulatory agencies such as the EPA [152] and ANVISA in Brazil [153].

*Metarhizium anisopliae* is another fungus with biotechnological potential for mosquito control [154]. Its entomopathogenic mechanism is similar to that of *B. bassiana*. After contact, the spores germinate, producing hyphae, which in turn penetrate the insect exoskeleton, developing inside the host's body [155,156].

*Metarhizium anisopliae* CN6S1W1 is effective against *Ae. albopictus* and *Cx. pipiens* [157]. The fungus also affects the behavior of *An. gambiae* mosquitoes by inhibiting blood feeding and reducing fecundity and oviposition [158]. Concurrent infections with both *M. anisopliae* and *B. bassiana* shorten the lifespan of *Ae. aegypti* [142,159]. The synergistic actions of *M. anisopliae* and *B. bassiana*, together with the imidacloprid immunosuppressant, showed a greater larvicidal activity against *Cx. quinquefasciatus* than the respective entomopathogens alone [160]. The metabolites isolated from *M. anisopliae* are also active against *Ae. aegypti*, *An. stephensi*, and *Cx. quinquefasciatus* [135]. These metabolites represent a solution for mosquito larvae control, since *M. anisopliae* conidia are not effective in the aquatic environment [161].

In addition to *B. bassiana* and *M. anisopliae*, other fungi have been reported with high biotechnological potential for mosquito control. The killing activity of *Aspergillus nomius* spores toward adult *Ae. albopictus* was comparable to those of *B. bassiana* [162]. Crude and purified extracellular extracts of *Aspergillus* with larvicidal action against *An. stephensi*, *Cx. quinquefasciatus*, and *Ae. aegypti* were reported [163]. Di-N-Octyl phthalate, (1H-Benzoimidazole-2-Yl)-[4-(4-Methyl-Piperazin-1-Yl)-Phenyl]-Amine, and 6,8-Dimethyl-5-Oxo-2,3,5,8-Tetrahydroimidazo [1,2-A] Pyrimidine, secondary metabolites of *Aspergillus flavus* and *Aspergillus fumigatus* [164] and preg-4-en-3-one, 17.  $\alpha$ -hydroxy-17.  $\beta$ -cyano-, trans-3-undecene-1,5-diyne, and pentane, 1,1,1,5-tetrachloro-, from *Aspergillus tamaris* have been suggested to be responsible for larvicidal activity [165]. The biosafety of products derived from *Aspergillus spp.*, or the fungus itself, still needs to be investigated. Suspensions of *A. flavus* conidia exhibited considerable toxicity against non-target organisms present in aquatic environments of mosquito larvae [166].

Species of the genus *Isaria* also have entomopathogenic characteristics for mosquito control. *Isaria tenuipes* [167], *Isaria javanica* ARSEF 5874 and *Isaria cateniannulata* ARSEF 6241 strains showed high levels of pathogenicity toward *Ae. aegypti* [134]. Larvicidal activity against *Cx. quinquefasciatus* and *Ae. aegypti* were demonstrated with silver nanoparticles (AgNps), with secondary metabolites of *Isaria fumosorosea* (Ifr) [168]. Other fungal species of interest that may be useful for vector control include *Trichoderma asperellum* [169] and *Hyalodendriella sp.* [170] which produce metabolites toxic to mosquitoes.

**Table 2.** Fungal strains toxic to *Aedes*, *Culex*, and/or *Anopheles* mosquito larvae.

Fungus	Toxic formulation	Target mosquito genera			Refs
		<i>Aedes</i>	<i>Culex</i>	<i>Anopheles</i>	
<i>Beauveria bassiana</i>	Fungal suspensions	+	-	-	[142]
	Surfaces treated with conidia	+	-	-	[145]
	Spores	+	-	-	[132]
	Oil-formulated spores	-	-	+	[146]

	Fungal suspensions	-	-	+	[149]
	Spores	-	-	+	[147]
	Fungal suspensions	+	+	-	[171]
<i>Metarhizium anisopliae</i>	Conidial suspension	-	+	-	[172]
	Fungal conidia	+	-	-	[173]
	Fungal suspensions	+	-	-	[142]
	Conidial suspension	+	+	-	[157]
	Oil formulation	-	+	+	[174]
	Secondary metabolites	+	+	+	[175]
<i>Aspergillus niger</i>	Crude metabolites	+	+	+	[163]
<i>Aspergillus flavus</i>	Secondary metabolites	+	+	+	[164]
	Suspensions of conidia	+	-	-	[166]
	Culture filtrates	-	+	-	[176]
<i>Aspergillus fumigatus</i>	Secondary metabolites	+	+	+	[164]
<i>Aspergillus parasiticus</i>	Culture filtrates	-	+	-	[176]
<i>Aspergillus tamarii</i>	Endophytic Fungal Extracts	+	+	-	[165]
<i>Aspergillus terreus</i>	Mycelia (Ethyl acetate and methanol extracts)	+	+	+	[177]
	Emodin compound	+	+	+	[178]
<i>Aspergillus nomius</i>	Spores	+	-	-	[162]
<i>Beauveria tenella</i>	Blastospores suspensions	+	+	-	[179]
<i>Cladophialophora bantiana</i>	Secondary metabolites	+	+	-	[180]
<i>Chrysosporium lobatum</i>	Secondary metabolites	-	+	+	[181]
<i>Chrysosporium tropicum</i>	Secondary metabolites	+	+	+	[182]
<i>Fusarium moniliforme</i>	Isoquinoline type pigment	+	-	+	[183]
<i>Fusarium oxysporum</i>	Temephos + F. oxysporum extract	+	+	+	[184]

<i>Fusarium vasinfectum</i>	Culture filtrates	-	+	-	[176]
<i>Isaria javanica</i>	Conidial suspensions	+	-	-	[134]
<i>Isaria cateniannulata</i>	Conidial suspensions	+	-	-	[134]
<i>Isaria tenuipes</i>	Conidial suspensions	+	-	-	[167]
<i>Isaria fumosorosea</i>	Secondary metabolites	+	+	-	[168]
<i>Paecilomyces sp.</i>	Secondary metabolites	+	+	+	[131]
<i>Penicillium daleae</i>	Mycelium extract	+	+	-	[185]
<i>Penicillium falicum</i>	Culture filtrates	-	+	-	[176]
<i>Penicillium marneffeii</i>	Spores	-	+	-	[186]
<i>Penicillium sp.</i>	Ethyl acetate extract	-	+	-	[187]
	Ethyl acetate extract	+	+	-	[188]
<i>Pestalotiopsis virgulata</i>	Ethyl acetate mycelia (EAM) extracts and liquid culture media (LCM)	+	-	+	[189]
<i>Podospora sp.</i>	Sterigmatocystin compound	-	-	+	[190]
<i>Pycnoporus sanguineus</i>	Ethyl acetate mycelia (EAM) extracts and liquid culture media (LCM)	+	-	+	[189]
<i>Trichoderma asperellum</i>	Methanolic extract	-	-	+	[169]
<i>Trichoderma harzianum</i>	Mycosynthesized silver nanoparticles (Ag NPs)	+	-	-	[191]
<i>Trichoderma viride</i>	Culture filtrates	-	+	-	[176]
<i>Hyalodendriella sp.</i>	EtOAc extract	+	-	-	[170]
<i>Verticillium lecanii</i>	Spores	-	+	-	[186]

This list is not exhaustive but provides ideas for future research and product development opportunities.

#### 4. The role of insect-bacteria associations in vector competence

Associations between mosquitoes and their and microbiota have gained significant attention in scientific research due to their impact on vector competence [192–197]. Following, we discuss ways these associations can influence vector competence, including the blocking of pathogen infection through the distinctive properties of symbiotic microorganisms, stimulation of the vector's immune system, and the utilization of symbionts for paratransgenesis. Understanding these interactions is

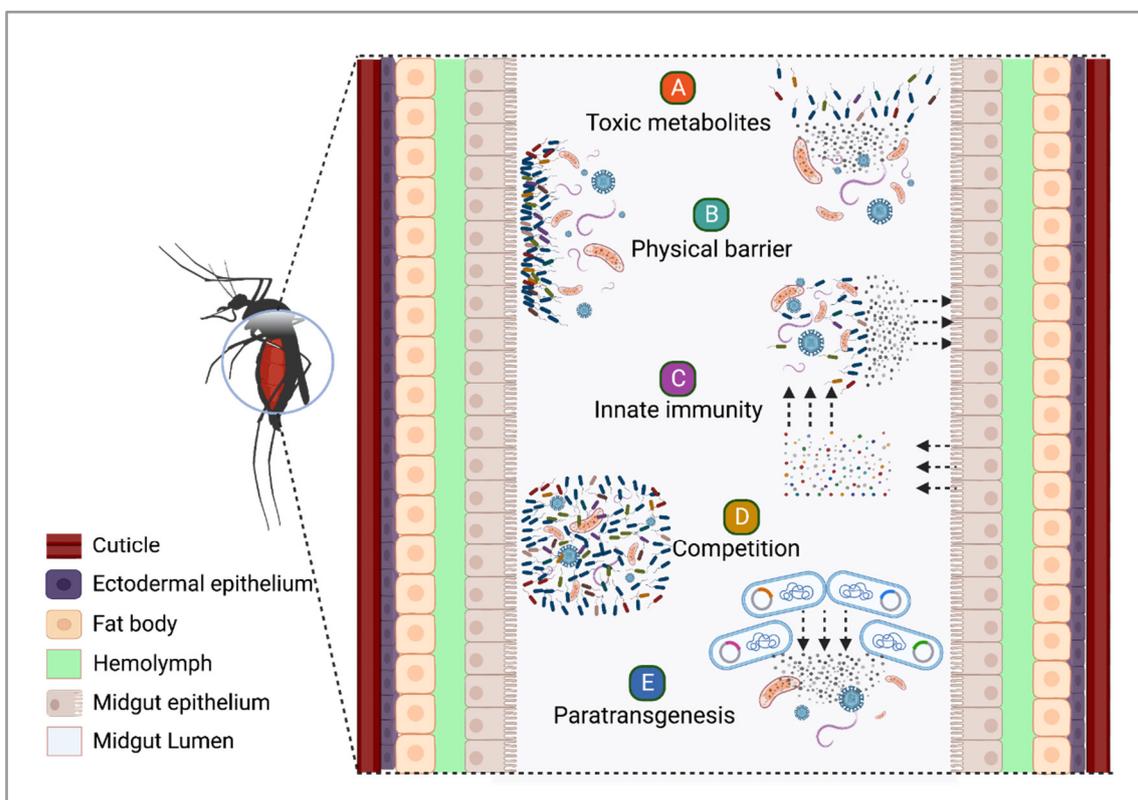
essential for developing effective vector-borne disease control strategies to reduce the impact of these diseases on public health.

#### 4.1. Symbiotic bacteria and their potential against infectious agents

The mosquito microbiota influences host development, nutrition, reproduction, and immune responses to invading organisms [198–201]. While the composition of the mosquito microbiota is largely defined by the environment in which they live [202–204], resident bacteria can modulate the development and replication of parasites and viruses within their vectors [205–212]. Although this modulation can enhance or reduce the survival and replication of pathogens within mosquitoes, those mosquito-microbiota interactions that negatively affect pathogens offer innovative possibilities to control arthropod-borne diseases.

For example, the gram-negative bacteria, *Escherichia coli* H243, *E. coli* HB101, *Pseudomonas aeruginosa* and *Ewingella americana* inhibit the formation of *Plasmodium falciparum* oocysts, in *Anopheles stephensi* [213]. *Enterobacter sp.* (Esp\_Z), isolated from the intestine of *Anopheles gambiae*, inhibited the development of malaria parasites when reintroduced into this same vector species [214,215]. The formation of oocysts of *Plasmodium berghei* was affected by the presence of *Serratia marcescens*-HB3 in *An. stephensi* [216]. In *Anopheles gambiae*, *Escherichia coli*, *S. marcescens*, and *Pseudomonas stutzeri* reduced the prevalence and intensity of *P. falciparum* infection [217]. The *Serratia* Y1 strain exerts inhibitory activity on *P. berghei* ookinetes by activation of the Toll immune pathway in *An. stephensi* [218]. *Serratia ureilytica* (Su\_YN1) produces an antimalarial lipase (AmLip) that inhibits the formation of *P. falciparum* oocysts in *An. stephensi* and *An. gambiae* [219]. *Asaia* SF2.1 also inhibits *Plasmodium* development in anophelines [220].

Virus replication in their vectors is also regulated by the mosquito microbiota. Bacteria of the genera *Proteus*, *Paenibacillus*, and *Chromobacterium* inhibited the replication of dengue virus serotype 2 (DENV-2) when administered to mosquitoes [110,221]. Some of the mechanisms by which symbiotic bacteria can hamper pathogen development have been elucidated and can be exploited to inhibit the spread of infectious agents by mosquitoes (Figure 2).



**Figure 2.** Biotechnological potential of mosquito symbiotic bacteria against infectious agents. **A**, Secretion of toxic substances that either kill or arrest the development and replication of viruses and parasites. **B**, formation of physical barriers through large population accumulation or rearrangements of molecules secreted into the midgut lumen, preventing the passage of parasites to organs essential for their successful development. **C**, activation of the mosquito immune system, which not only reduces the load of symbiotic bacteria but also leads to the elimination of invading parasites through the secretion of toxic molecules, preventing their propagation in the mosquito's body. **D**, competition with infectious agents for space and nutrients can have dire consequences for these pathogens as they must compete with a vastly larger population of symbiotic bacteria in the mosquito's midgut lumen. This results in limited resources for the pathogens, ultimately leading to their decreased survival and replication within the mosquito. **E**, paratransgenesis approach to synthesize and secrete antipathogen molecules. If this approach receives more attention and research funding from government agencies in endemic countries, it could have a significant impact on reducing the transmission of vector-borne diseases. This topic is further explored in topic 4.3 of this review. Created with [BioRender.com](https://www.biorender.com).

The *wMel* and *wAlbB* strains of *Wolbachia pipientis*, an intracellular bacterium, inhibit dengue, chikungunya, and Zika virus replication within mosquito cells [222–226]. However, another *Wolbachia* strain, *wPip*, does not inhibit virus infection in *Ae. aegypti* [227] and the mechanism by which *Wolbachia* interferes with virus replication has not been fully elucidated. Current hypotheses include competition between *Wolbachia* and the virus for physical space within mosquito cells and metabolite resources [228,229] and *Wolbachia* induced modulation of the host's immune system and immune priming [230,231].

Despite the lack of a complete understanding of the mechanism or mechanisms involved in *Wolbachia*-associated modulation of viral suppression, the *Wolbachia*-carrying mosquito-based strategy has been deployed as a public health intervention to control dengue transmission (The World Mosquito Program <https://www.worldmosquitoprogram.org/>). A randomized study carried out in the city of Yogiakarta, Indonesia, compared the areas where *Ae. aegypti* infected *Wolbachia* was released with areas without *Wolbachia* and revealed a 77% lower incidence of dengue cases, in the *Wolbachia*-treated area [232]. Another study conducted in the city of Niterói, Rio de Janeiro, Brazil, reported a 69% reduction in dengue, 56% in chikungunya, and a 37% reduction in Zika incidence three years after the beginning of the release of *Ae. aegypti* with *Wolbachia* [233].

Although these results bring optimism regarding the use of *Wolbachia* for the control of dengue transmission, these bacteria can have variable effects on mosquito-borne viruses. For example, the *Wolbachia* strain *wMel* strongly blocked Mayaro virus (MAYV) infections in *Ae. aegypti*, but another strain, *wAlbB*, did not influence on MAYV infection in this same vector. *Aedes aegypti* infected with *wAlbB* and *wMel* showed enhanced Sindbis virus infection rates [234]. The variable effects of *Wolbachia* on vector competence bring into question the safety of the current release of *Wolbachia*-infected mosquitoes. Furthermore, the potential impact of these bacteria on biodiversity has not been thoroughly investigated [235,236], and the risk of the emergence of DENV variants that escape virus-specific inhibition in *Wolbachia* infected mosquitoes [237,238], underscores the importance of further research on interactions between *Wolbachia*, mosquitoes, viruses, and other organisms.

The intracellular bacterium *Wolbachia pipientis* has also been used to create conditional sterility between released males and wild-type females through cytoplasmic incompatibility [239]. Large-scale trials of *Ae. aegypti* population suppression carried out from 2017 to 2018 in California and based on the release of 7.5 million and 14.4 million *Wolbachia*-infected male mosquitoes, resulted in mosquito population suppression rates of 69% and 95%, respectively. Since 2011 in the United States, the Environmental Protection Agency (EPA) has regulated *Wolbachia* as a biopesticide [240].

#### 4.2. Exploring the potential of fungi as anti-Plasmodium agents for malaria control

Fungi with potential antiparasitic properties, particularly against protozoa of the genus *Plasmodium*, have been researched as a potential tool to combat malaria. Endophytic fungi isolated from different organs of *Annona muricata*, a medicinal plant commonly used in traditional Cameroonian medicine against malaria, completely inhibited the growth of *P. falciparum* *in vitro*. Of

the 152 fungi tested, 17.7% showed activities against different strains of the parasite, with the strongest effects from fungi belonging to the genus *Fusarium*, *Thricoderma*, *Aspergillus*, *Penicillium*, and *Neocosmopora* [241]. Compounds such as oxylipin and alternarilactones from *Penicillium herquei* and *Alternaria alternata* respectively, demonstrated *in vitro* antiplasmodial activity [242,243]. A killer toxin purified from *Wickerhamomyces anomalus*, a symbiotic yeast of insects, when supplemented in a mosquito diet interfered with the development of ookines in the *An. stephensi* midgut [244]. *Aspergillus* also showed antiplasmodial activity when supplemented in the mosquito diet. This activity was shown to be related to inhibition of the interaction between parasites and fibrinogen-related protein-1 (FREP1), an agonist of gametocytes and ookinetes [245]. These authors identified the fungal metabolite orlandin as a candidate reagent to inhibit *P. falciparum* infection in *An. gambiae*.

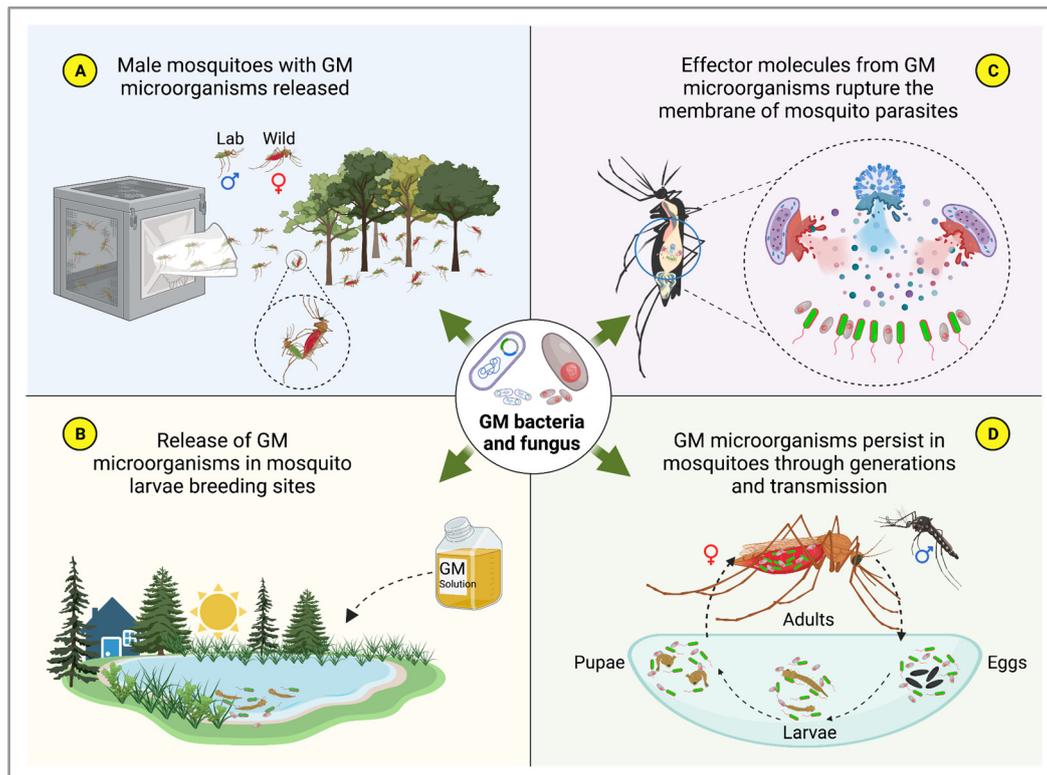
The topical application or spraying of *B. bassiana* on the mosquito cage mesh killed ~92% of *An. stephensi* on day 14 after exposure and reduced the number of *Plasmodium chabaudi* sporozoite positive mosquitoes. Although no impact on early stages of the parasite (gametocytes and oocyst stages) was noted, the combined effect of mosquito mortality and reduced sporozoite prevalence was estimated to result in the reduction of malaria transmission risk by a factor of about 80 [246]. However, other studies did not show an impact of *B. bassiana* or *M. anisopliae* on the development of *Plasmodium* species in *Anopheles* mosquitoes [247,248].

*Metarhizium anisopliae* has been genetically transformed to express anti-*Plasmodium* proteins. Mosquitoes treated with transgenic *M. anisopliae* had 71-98% fewer sporozoites present in their salivary glands [248]. Scorpine, one of the molecules expressed by transgenic *M. anisopliae*, also affects negatively dengue virus replication, expanding the application of genetically transformed fungi to control arbovirus transmission [249]. This study supports the concept of engineering fungi to express proteins that can impact the development of pathogens in mosquitoes and further their use as biopesticides.

#### 4.3. Symbiotic microorganisms and paratransgenesis

Paratransgenesis involves the colonization of vector insects with genetically engineered symbiotic microorganisms that are effective in inhibiting parasite development [250–253]. Ideal symbionts for effective paratransgenesis are easily manipulated genetically, colonize mosquitoes efficiently, spread into mosquito populations (vertical and horizontal transmission), and are efficient in inhibiting pathogen development in mosquitoes [254]. Proof-of-principle experiments demonstrated that genetically modified bacteria expressing antipathogen molecules are capable of interfering or blocking the development of malaria parasites in mosquitoes [255–257]. Among the mosquito symbiotic bacteria, strains of *Asaia*, *Pantoea*, *Serratia*, *Pseudomonas*, and *Thorsellia* have been evaluated as candidates for paratransgenesis [258–262].

Advances toward deploying paratransgenesis as a tool for blocking pathogen transmission by mosquitoes include the identification of anti-pathogen effector peptides [251,256]. The secretion of effector molecules from the cytoplasm of bacteria into the lumen of the mosquito intestine has been engineered using the *Escherichia coli* hemolysin-A secretion system [263]. The discovery of mosquito symbiotic bacteria [256,264–266], viruses [267–270] and fungi [271] is an active area of research. Safety concerns about the release of engineered bacteria into the environment and any uncertain consequences that might occur still need to be addressed when considering paratransgenesis field tests. Self-limiting paratransgenesis [254] has been suggested as an alternative for initial field trials. This approach proposes the utilization of transient expression of antipathogen compounds from a plasmid that is gradually lost, reverting bacteria to their original wild type. Risk assessment still needs to be carried out and laws and regulations need to be created and enacted before paratransgenesis can be tested in field conditions. However, the processes by which genetically modified microorganisms (GMs) can be spread in nature and how they should act to inhibit the development of target parasites in mosquitoes have already been envisaged. This is illustrated in Figure 3, which presents the paratransgenesis process as a multifaceted approach to combating mosquito-borne diseases using GM microorganisms.



**Figure 3.** Paratransgenesis: A multifaceted approach to combating mosquito-borne diseases using GM microorganisms. **A**, in the laboratory, male mosquitoes are fed a sucrose solution containing GM microorganisms and then released into the wild to mate with wild females. This enables the transmission of the GM microorganisms forward, allowing them to spread throughout the population of wild mosquitoes and helping to reduce the transmission of vector-borne diseases. **B**, release of GM microorganisms in natural larval breeding sites. GM microorganisms are ingested by larvae and remain associated until the adult phase. If the mosquitoes become infected with any virus or parasite, the GM microorganisms will interfere with the development of the pathogen, thus preventing their transmission. This would result in a reduction in the burden of diseases in the region. **C**, GM microorganisms can express effector molecules that act directly on the membrane of target parasites in the gut of adult female mosquitoes. These molecules can cause the parasite membrane to rupture, leading to their death or inability to develop. **D**, persistence of GM microorganisms in mosquitoes for generations through vertical and horizontal transmission. Vertical transmission occurs from parents to their offspring, while horizontal transmission occurs between mosquitoes during mating or sharing of breeding sites. The presence of GM microorganisms can continue to affect mosquito populations for a prolonged period. While it is important to carefully evaluate and monitor the release of GM microorganisms, it is also important to highlight their potential for controlling vector-borne diseases. Created with [BioRender.com](https://www.biorender.com).

## 5. Roadmap for the development of microbe-based products for controlling mosquito borne diseases

In this review article, we explored the biotechnological potential of microorganisms for mosquito population control and reduction of vector competence. We list many microbial agents with mosquito larvicidal activity and provide information on their active metabolites and mechanisms of action. However, most of these mosquitocidal microorganisms and their metabolites have not been developed into new products and marketed as tools and innovations that can be applied to public health interventions. The explanation for the few biolarvicides available on the market is complex and is determined by technical, regulatory, social, and economic factors.

For example, the Organization for Economic Co-operation and Development (OECD) provided a document with Data Requirements and Approaches to Biological Pesticide Registration (<https://www.oecd.org/env/ehs/pesticides-biocides/data-for-biopesticide-registration.htm>)

including Guidance for Registration Requirements for Microbial Pesticides ([https://one.oecd.org/document/env/jm/mono\(2003\)5/en/pdf](https://one.oecd.org/document/env/jm/mono(2003)5/en/pdf)). Accordingly, the Regulation of European Commission (EC) No. 1107/2009 regarding criteria for the approval of microbial pesticides emphasizes the importance of assessing the active substances or the microorganisms themselves for effects on the environment or harmful effects on human or animal health [272]. These directives require collaborative research efforts which may take years to complete. In the United States, the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) requires similar assessments, and the U.S. Environmental Protection Agency (EPA) evaluates biopesticides to assure they do not pose unreasonable risks of harm to human health and the environment.

In Brazil [273], the registration of new pesticides, including biolarvicides, requires evaluation by three federal government agencies that assess them independently and in a specific manner. The Ministry of Agriculture and Livestock (Ministério da Agricultura e Pecuária -MAP) evaluates efficiency and potential for use in pest control; the Brazilian Institute of the Environment and Renewable Natural Resources (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis-IBAMA) provides an environmental report; and the Brazilian Health Regulatory Agency (Agência Nacional de Vigilância Sanitária-ANVISA) conducts the toxicological dossier, assessing the product's toxicity for the population and the restrictions and requirements for pesticide use. Like in Europe, the USA, and Brazil, regulatory agencies around the world regulate the registration and application of biopesticides, monitoring efficacy and safety.

The main stages for discovering and developing new larvicides, based on the requirements set forth by the government entities mentioned above, have previously been reviewed [274–276]. In summary, the process consists of 1) Discover larvicidal microorganisms; 2) Identify the mechanisms of action of larvicidal microorganisms (live microbial fractions versus metabolites fractions); 3) Evaluating human toxicity and pathogenicity of microorganisms and evaluating their effects on nontarget organisms and the environment; 4) Determine the stability of the candidate larvicide product under field conditions and its shelf life considering its applications in tropical/subtropical, hot and humid environments; 5) Compare the activity of the candidate product with currently available larvicides; and 6) Cost analysis (production, storage, transportation, and field application costs) and research of market viability.

Similar considerations will be necessary for the applications designed for reducing disease transmission, such deployment of microorganisms with antiparasitic activity, including paratransgenesis discussed above.

We hope that this review will encourage additional research and investment in the development of new biopesticides, highlighting the need to follow the requirements established by regulatory agencies for the approval and registration of products that will assist in the control of mosquitoes and the diseases they transmit.

## 6. Final considerations

Biotechnological approaches using microorganisms have a significant potential to control mosquito populations and reduce their vector competence, making them alternatives to synthetic insecticides. The ongoing research has been crucial in identifying new products and approaches that can be used effectively to control disease transmission. However, the successful implementation of these newly proposed approaches requires a thorough understanding of the multipronged microorganism-mosquito-pathogen-environment interactions. The release of mosquitoes or microorganisms, genetically modified or not, into the environment requires an assessment of the associated risks and benefits. Therefore, environmental and ethical implications of these proposed releases are active areas of debate [277,278].

Although much has been done in discovering new entomopathogenic microorganisms, antipathogen compounds, and their mechanisms of action, reviewed above, only a few have been turned into viable products for mosquito control such as the Bti and Lbs. There is a discrepancy between the number of microorganisms with potential for the development of new products and the

actual available products, highlighting the need for investments in the intersection of research and biotechnology to improve the transition of basic into applied research.

**Author Contributions:** Writing - review and editing, R.M.K., E.M.R., O.M., B.C.B., A.M.C and J.A.S.N.; supervision, E.M.R and O.M.; All authors have read and agreed to the published version of the manuscript.

**Funding:** This work was supported by the Human Frontier Science Program Research Grant RGP0007/2017 to J.A.S.N.; by the São Paulo Research Foundation (FAPESP), 2020/06136-5 to J.A.S.N., and to Prodoc-AM/FAPEAM-003/2022 for providing the scholarship that benefited author RMK.

**Data Availability Statement:** Not applicable.

**Acknowledgments:** Not applicable.

**Conflicts of Interest:** The authors declare that they have no conflict of interest.

## References

- Onen, O.; Aboh, A.A.; Mfam, A.N.; Akor, M.O.; Nweke, C.N.; Osuagwu, A.N. Microbial Diversity: Values and Roles in Ecosystems. *Asian J Biol* **2020**, *9*, 10–22.
- Rousk, J.; Bengtson, P. Microbial Regulation of Global Biogeochemical Cycles. *Frontiers in Microbiology* **2014**, *5*.
- Rodríguez-Frías, F.; Quer, J.; Tabernero, D.; Cortese, M.F.; Garcia-Garcia, S.; Rando-Segura, A.; Pumarola, T. Microorganisms as Shapers of Human Civilization, from Pandemics to Even Our Genomes: Villains or Friends? A Historical Approach. *Microorganisms* **2021**, *9*, 2518.
- Raaijmakers, J.M.; Vlami, M.; De Souza, J.T. Antibiotic Production by Bacterial Biocontrol Agents. *Antonie van Leeuwenhoek* **2002**, *81*, 537–547.
- Uchida, R.; Imasato, R.; Tomoda, H.; Ōmura, S. Yaequinolones, New Insecticidal Antibiotics Produced by *Penicillium* Sp. FKI-2140. *The Journal of Antibiotics* **2006**, *59*, 652–658.
- Bintsis, T. Lactic Acid Bacteria: Their Applications in Foods. *J. Bacteriol. Mycol* **2018**, *6*, 89–94.
- Barzee, T.J.; Cao, L.; Pan, Z.; Zhang, R. Fungi for Future Foods. *Journal of Future Foods* **2021**, *1*, 25–37.
- Torres-Guardado, R.; Esteve-Zarzoso, B.; Reguant, C.; Bordons, A. Microbial Interactions in Alcoholic Beverages. *International Microbiology* **2022**, *25*, 1–15.
- Sevak, P.I.; Pushkar, B.K.; Kapadne, P.N. Lead Pollution and Bacterial Bioremediation: A Review. *Environmental Chemistry Letters* **2021**, *19*, 4463–4488.
- Cowan, A.R.; Costanzo, C.M.; Benham, R.; Loveridge, E.J.; Moody, S.C. Fungal Bioremediation of Polyethylene: Challenges and Perspectives. *Journal of Applied Microbiology* **2022**, *132*, 78–89.
- Jiménez-Gómez, A.; García-Estévez, I.; Escribano-Bailón, M.T.; García-Fraile, P.; Rivas, R. Bacterial Fertilizers Based on *Rhizobium Laguerreae* and *Bacillus Halotolerans* Enhance *Cichorium Endivia* L. Phenolic Compound and Mineral Contents and Plant Development. *Foods* **2021**, *10*, 424.
- Dunham, B. Microbial Pesticides: A Key Role in the Multinational Portfolio. *New Ag International* **2015**, 32–36.
- Ruii, L. Microbial Biopesticides in Agroecosystems. *Agronomy* **2018**, *8*, 235.
- Thongsripong, P.; Chandler, J.A.; Green, A.B.; Kittayapong, P.; Wilcox, B.A.; Kapan, D.D.; Bennett, S.N. Mosquito Vector-associated Microbiota: Metabarcoding Bacteria and Eukaryotic Symbionts across Habitat Types in Thailand Endemic for Dengue and Other Arthropod-borne Diseases. *Ecology and Evolution* **2018**, *8*, 1352–1368.
- da Silva Gonçalves, D.; Iturbe-Ormaetxe, I.; Martins-da-Silva, A.; Telleria, E.L.; Rocha, M.N.; Traub-Csekö, Y.M.; O'Neill, S.L.; Sant'Anna, M.R.V.; Moreira, L.A. *Wolbachia* Introduction into *Lutzomyia Longipalpis* (Diptera: Psychodidae) Cell Lines and Its Effects on Immune-Related Gene Expression and Interaction with *Leishmania Infantum*. *Parasites & Vectors* **2019**, *12*, 1–13.
- Caragata, E.P.; Short, S.M. Vector Microbiota and Immunity: Modulating Arthropod Susceptibility to Vertebrate Pathogens. *Current Opinion in Insect Science* **2022**, 100875.
- Chavasse, D.C.; Yap, H.H.; Organization, W.H. *Chemical Methods for the Control of Vectors and Pests of Public Health Importance*; World Health Organization, 1997;
- Wilson, A.L.; Courtenay, O.; Kelly-Hope, L.A.; Scott, T.W.; Takken, W.; Torr, S.J.; Lindsay, S.W. The Importance of Vector Control for the Control and Elimination of Vector-Borne Diseases. *PLoS Negl Trop Dis* **2020**, *14*, doi:10.1371/journal.pntd.0007831.

19. Rawlins, S.C.; Wan, J.O. Resistance in Some Caribbean Populations of *Aedes Aegypti* to Several Insecticides. *Journal of the American Mosquito Control Association* **1995**, *11*, 59–65.
20. Nauen, R. Insecticide Resistance in Disease Vectors of Public Health Importance. *Pest Management Science: formerly Pesticide Science* **2007**, *63*, 628–633.
21. Hamid, P.H.; Prastowo, J.; Ghiffari, A.; Taubert, A.; Hermosilla, C. *Aedes Aegypti* Resistance Development to Commonly Used Insecticides in Jakarta, Indonesia. *PLoS One* **2017**, *12*, e0189680.
22. Lopes, R.P.; Lima, J.B.P.; Martins, A.J. Insecticide Resistance in *Culex Quinquefasciatus* Say, 1823 in Brazil: A Review. *Parasites & vectors* **2019**, *12*, 1–12.
23. Kaushal, J.; Khatri, M.; Arya, S.K. A Treatise on Organophosphate Pesticide Pollution: Current Strategies and Advancements in Their Environmental Degradation and Elimination. *Ecotoxicology and Environmental Safety* **2021**, *207*, 111483.
24. Costa, L.G. Current Issues in Organophosphate Toxicology. *Clinica chimica acta* **2006**, *366*, 1–13.
25. Naughton, S.X.; Terry Jr, A.V. Neurotoxicity in Acute and Repeated Organophosphate Exposure. *Toxicology* **2018**, *408*, 101–112.
26. Margalith, Y.; Ben-Dov, E. Biological Control by *Bacillus Thuringiensis* Subsp. *Israelensis*. *Insect pest management: techniques for environmental protection* **2000**, 243–301.
27. Polanczyk, R.A.; Garcia, M. de O.; Alves, S.B. Potencial de *Bacillus Thuringiensis Israelensis* Berliner No Controle de *Aedes Aegypti*. *Revista de saúde pública* **2003**, *37*, 813–816.
28. Boyce, R.; Lenhart, A.; Kroeger, A.; Velayudhan, R.; Roberts, B.; Horstick, O. *Bacillus Thuringiensis Israelensis* (B Ti) for the Control of Dengue Vectors: Systematic Literature Review. *Tropical Medicine & International Health* **2013**, *18*, 564–577.
29. Balakrishnan, S.; Indira, K.; Srinivasan, M. RETRACTED ARTICLE: Mosquitocidal Properties of *Bacillus* Species Isolated from Mangroves of Vellar Estuary, Southeast Coast of India. *Journal of parasitic diseases* **2015**, *39*, 385–392.
30. Santana-Martinez, J.C.; Silva, J.J.; Dussan, J. Efficacy of *Lysinibacillus Sphaericus* against Mixed-Cultures of Field-Collected and Laboratory Larvae of *Aedes Aegypti* and *Culex Quinquefasciatus*. *Bulletin of entomological research* **2019**, *109*, 111–118.
31. Organization, W.H. Report of the Seventh WHOPES Working Group Meeting : WHO/HQ, Geneva, 2-4 December 2003 : Review of : Vectobac WG Permanet Gokilaht-S 5EC. **2004**.
32. Bravo, A.; Gill, S.S.; Soberón, M. Mode of Action of *Bacillus Thuringiensis* Cry and Cyt Toxins and Their Potential for Insect Control. *Toxicon* **2007**, *49*, 423–435.
33. Adang, M.J.; Crickmore, N.; Jurat-Fuentes, J.L. Diversity of *Bacillus Thuringiensis* Crystal Toxins and Mechanism of Action. In *Advances in insect physiology*; Elsevier, 2014; Vol. 47, pp. 39–87 ISBN 0065-2806.
34. Berry, C.; O'Neil, S.; Ben-Dov, E.; Jones, A.F.; Murphy, L.; Quail, M.A.; Holden, M.T.; Harris, D.; Zaritsky, A.; Parkhill, J. Complete Sequence and Organization of PBtoxis, the Toxin-Coding Plasmid of *Bacillus Thuringiensis* Subsp. *Israelensis*. *Applied and environmental microbiology* **2002**, *68*, 5082–5095.
35. Wu, J.; Wei, L.; He, J.; Fu, K.; Li, X.; Jia, L.; Wang, R.; Zhang, W. Characterization of a Novel *Bacillus Thuringiensis* Toxin Active against *Aedes Aegypti* Larvae. *Acta Tropica* **2021**, *223*, 106088.
36. Palma, L.; Muñoz, D.; Berry, C.; Murillo, J.; Caballero, P. *Bacillus Thuringiensis* Toxins: An Overview of Their Biocidal Activity. *Toxins* **2014**, *6*, 3296–3325.
37. Baumann, L.; Broadwell, A.H.; Baumann, P. Sequence Analysis of the Mosquitocidal Toxin Genes Encoding 51.4- and 41.9-Kilodalton Proteins from *Bacillus Sphaericus* 2362 and 2297. *Journal of Bacteriology* **1988**, *170*, 2045–2050.
38. El-Bendary, M.; Priest, F.G.; Charles, J.-F.; Mitchell, W.J. Crystal Protein Synthesis Is Dependent on Early Sporulation Gene Expression in *Bacillus Sphaericus*. *FEMS microbiology letters* **2005**, *252*, 51–56.
39. Tangsongcharoen, C.; Chomanee, N.; Promdonkoy, B.; Boonserm, P. *Lysinibacillus Sphaericus* Binary Toxin Induces Apoptosis in Susceptible *Culex Quinquefasciatus* Larvae. *Journal of invertebrate pathology* **2015**, *128*, 57–63.
40. Liu, J.-W.; Porter, A.G.; Wee, B.Y.; Thanabalu, T. New Gene from Nine *Bacillus Sphaericus* Strains Encoding Highly Conserved 35.8-Kilodalton Mosquitocidal Toxins. *Applied and Environmental Microbiology* **1996**, *62*, 2174–2176.
41. Jones, G.W.; Nielsen-Leroux, C.; Yang, Y.; Yuan, Z.; Fiuza Dumas, V.; Monnerat, R.G.; Berry, C. A New Cry Toxin with a Unique Two-component Dependency from *Bacillus Sphaericus*. *The FASEB Journal* **2007**, *21*, 4112–4120.

42. Opota, O.; Gauthier, N.C.; Doye, A.; Berry, C.; Gounon, P.; Lemichez, E.; Pauron, D. Bacillus Sphaericus Binary Toxin Elicits Host Cell Autophagy as a Response to Intoxication. *PLoS One* **2011**, *6*, e14682.
43. Filha, M.H.N.L.S.; Berry, C.; Regis, L. Lysinibacillus Sphaericus: Toxins and Mode of Action, Applications for Mosquito Control and Resistance Management. In *Advances in insect physiology*; Elsevier, 2014; Vol. 47, pp. 89–176 ISBN 0065-2806.
44. Wirth, M.C.; Berry, C.; Walton, W.E.; Federici, B.A. Mtx Toxins from Lysinibacillus Sphaericus Enhance Mosquitocidal Cry-Toxin Activity and Suppress Cry-Resistance in Culex Quinquefasciatus. *Journal of invertebrate pathology* **2014**, *115*, 62–67.
45. de Melo, J.V.; Jones, G.W.; Berry, C.; Vasconcelos, R.H.T.; de Oliveira, C.M.F.; Furtado, A.F.; Peixoto, C.A.; Silva-Filha, M.H.N.L. Cytopathological Effects of Bacillus Sphaericus Cry48Aa/Cry49Aa Toxin on Binary Toxin-Susceptible and-Resistant Culex Quinquefasciatus Larvae. *Applied and environmental microbiology* **2009**, *75*, 4782–4789.
46. Vartoukian, S.R.; Palmer, R.M.; Wade, W.G. Strategies for Culture of 'Unculturable' Bacteria. *FEMS microbiology letters* **2010**, *309*, 1–7.
47. Falqueto, S.A.; Pitaluga, B.F.; de Sousa, J.R.; Targanski, S.K.; Campos, M.G.; de Oliveira Mendes, T.A.; da Silva, G.F.; Silva, D.H.S.; Soares, M.A. Bacillus Spp. Metabolites Are Effective in Eradicating Aedes Aegypti (Diptera: Culicidae) Larvae with Low Toxicity to Non-Target Species. *Journal of Invertebrate Pathology* **2021**, *179*, 107525.
48. Katak, R.M.; Rocha, E.M.; Oliveira, J.C.; Muniz, V.A.; Oliveira, M.R.; Ferreira, F.A.; Silva, W.R.; Roque, R.A.; de Souza, A.Q.; Souza-Neto, J.A. Larvicidal Activities against Aedes Aegypti of Supernatant and Pellet Fractions from Cultured Bacillus Spp. Isolated from Amazonian Microenvironments. *Tropical Medicine and Infectious Disease* **2021**, *6*, 104.
49. Susetyo, R.D.; Nafidiastri, F.A.; Zain, R.A.; Sari, R.P.; Geraldi, A. Potential Biocontrol Agent of Indigenous Bacillus Sp. EG6. 4: Molecular Identification, Larvicidal Toxicity, and Mechanism of Actions. *Biodiversitas* **2022**, *23*, 5431–5438.
50. Maldonado, B.M.G.; Galan, W.L.J.; Rodriguez, P.C.; Quiroz, M.H. Evaluation of Polymer-Based Granular Formulations of Bacillus Thuringiensis Israelensis against Larval Aedes Aegypti in the Laboratory. *J Am Mosq Control Assoc* **2002**, *18*, 352–358.
51. Armengol, G.; Hernandez, J.; Velez, J.G.; Orduz, S. Long-Lasting Effects of a Bacillus Thuringiensis Serovar Israelensis Experimental Tablet Formulation for Aedes Aegypti (Diptera: Culicidae) Control. *Journal of Economic Entomology* **2006**, *99*, 1590–1595.
52. de Araujo, A.P.; de Melo-Santos, M.A.V.; de Oliveira Carlos, S.; Rios, E.M.M.M.; Regis, L. Evaluation of an Experimental Product Based on Bacillus Thuringiensis Sorovar. Israelensis against Aedes Aegypti Larvae (Diptera: Culicidae). *Biological Control* **2007**, *41*, 339–347.
53. de Melo-Santos, M.A.V.; de Araújo, A.P.; Rios, E.M.M.; Regis, L. Long Lasting Persistence of Bacillus Thuringiensis Serovar. Israelensis Larvicidal Activity in Aedes Aegypti (Diptera: Culicidae) Breeding Places Is Associated to Bacteria Recycling. *Biological Control* **2009**, *49*, 186–191.
54. Ritchie, S.A.; Rapley, L.P.; Benjamin, S. Bacillus Thuringiensis Var. Israelensis (Bti) Provides Residual Control of Aedes Aegypti in Small Containers. *The American journal of tropical medicine and hygiene* **2010**, *82*, 1053.
55. Kovendan, K.; Murugan, K.; Vincent, S.; Kamalakannan, S. Larvicidal Efficacy of Jatropha Curcas and Bacterial Insecticide, Bacillus Thuringiensis, against Lymphatic Filarial Vector, Culex Quinquefasciatus Say (Diptera: Culicidae). *Parasitology research* **2011**, *109*, 1251–1257.
56. Zahran, H.E.-D.M.; Kawanna, M.A.; Bosly, H.A. Larvicidal Activity and Joint Action Toxicity of Certain Combating Agents on Culex pipiens L. Mosquitoes. *Annual Research & Review in Biology* **2013**, 1055–1065.
57. Bideshi, D.K.; Waldrop, G.; Fernandez-Luna, M.T.; Diaz-Mendoza, M.; Wirth, M.C.; Johnson, J.J.; Park, H.-W.; Federici, B.A. Intermolecular Interaction between Cry2Aa and Cyt1Aa and Its Effect on Larvicidal Activity against Culex Quinquefasciatus. *Journal of microbiology and biotechnology* **2013**, *23*, 1107–1115.
58. Ermolova, V.P.; Grishechkina, S.D.; Belousova, M.E.; Antonets, K.S.; Nizhnikov, A.A. Insecticidal Properties of Bacillus Thuringiensis Var. Israelensis. II. Comparative Morphological and Molecular Genetic Analysis of the Crystallogenic and Acrytallogenic Strains. *Sel'skokhozyaistvennaya Biol.* **2019**, *54*, 1281–1289.
59. Valtierra-de-Luis, D.; Villanueva, M.; Lai, L.; Williams, T.; Caballero, P. Potential of Cry10Aa and Cyt2Ba, Two Minority  $\delta$ -Endotoxins Produced by Bacillus Thuringiensis Ser. Israelensis, for the Control of Aedes Aegypti Larvae. *Toxins* **2020**, *12*, 355.

60. Nasser, S.; da Costa, M.P.M.; de Mello Ferreira, I.L.; Lima, J.B.P. K-Carrageenan-Bacillus Thuringiensis Israelensis Hydrogels: A Promising Material to Combat Larvae of the Aedes Aegypti Mosquito. *Carbohydrate Polymer Technologies and Applications* **2021**, *2*, 100125.
61. Fernández-Chapa, D.; Luna-Olvera, H.A.; Ramirez-Villalobos, J.; Rojas-Verde, G.; Arévalo-Niño, K.; Galán-Wong, L.J. Viability and Reconstitution of Delta-Endotoxins from Bacillus Thuringiensis Var. Israelensis Extracts after Forty Years of Storage against Aedes Aegypti (Diptera: Culicidae). *Egyptian Journal of Biological Pest Control* **2021**, *31*, 1–7.
62. Gad, A.A.; Al-Dakhil, A.A. Efficacy of Bacillus Thuringiensis Israelensis (Bti) and Four Plant Extracts on the Mortality and Development of Culex Quinquefasciatus Say (Diptera: Culicidae). *Egyptian journal of biological pest control* **2018**, *28*, 1–5.
63. Shililu, J.I.; Tewolde, G.M.; Brantly, E.; Githure, J.I.; Mbogo, C.M.; Beier, J.C.; Fusco, R.; Novak, R.J. Efficacy of Bacillus Thuringiensis Israelensis, Bacillus Sphaericus and Temephos for Managing Anopheles Larvae in Eritrea. *Journal of the American Mosquito Control Association* **2003**, *19*, 251–258.
64. Pires, S.; Alves, J.; Dia, I.; Gomez, L.F. Susceptibility of Mosquito Vectors of the City of Praia, Cabo Verde, to Temephos and Bacillus Thuringiensis Var Israelensis. *PLoS One* **2020**, *15*, e0234242.
65. Derua, Y.A.; Kweka, E.J.; Kisinza, W.N.; Yan, G.; Githeko, A.K.; Mosha, F.W. The Effect of Coexistence between Larvae of Anopheles Gambiae and Culex Quinquefasciatus on Larvicidal Efficacy of Bacillus Thuringiensis Var. Israelensis. *East Africa Science* **2021**, *3*, 77–85.
66. Kroeger, A.; Horstick, O.; Riedl, C.; Kaiser, A.; Becker, N. The Potential for Malaria Control with the Biological Larvicide Bacillus Thuringiensis Israelensis (Bti) in Peru and Ecuador. *Acta Tropica* **1995**, *60*, 47–57.
67. Nartey, R.; Owusu-Dabo, E.; Kruppa, T.; Baffour-Awuah, S.; Annan, A.; Oppong, S.; Becker, N.; Obiri-Danso, K. Use of Bacillus Thuringiensis Var Israelensis as a Viable Option in an Integrated Malaria Vector Control Programme in the Kumasi Metropolis, Ghana. *Parasites & vectors* **2013**, *6*, 1–10.
68. Dambach, P.; Louis, V.R.; Kaiser, A.; Ouedraogo, S.; Sié, A.; Sauerborn, R.; Becker, N. Efficacy of Bacillus Thuringiensis Var. Israelensis against Malaria Mosquitoes in Northwestern Burkina Faso. *Parasites & vectors* **2014**, *7*, 1–8.
69. Demissew, A.; Balkew, M.; Girma, M. Larvicidal Activities of Chinaberry, Neem and Bacillus Thuringiensis Israelensis (Bti) to an Insecticide Resistant Population of Anopheles Arabiensis from Tolay, Southwest Ethiopia. *Asian Pacific Journal of Tropical Biomedicine* **2016**, *6*, 554–561.
70. Dambach, P.; Winkler, V.; Bärnighausen, T.; Traoré, I.; Ouedraogo, S.; Sié, A.; Sauerborn, R.; Becker, N.; Louis, V.R. Biological Larviciding against Malaria Vector Mosquitoes with Bacillus Thuringiensis Israelensis (Bti)—Long Term Observations and Assessment of Repeatability during an Additional Intervention Year of a Large-Scale Field Trial in Rural Burkina Faso. *Global Health Action* **2020**, *13*, 1829828.
71. Monnerat, R.G.; Dias, D.G.S.; Silva, S.F. da; Martins, E.S.; Berry, C.; Falcão, R.; Gomes, A.C.M.M.; Praça, L.B.; Soares, C.M.S. Screening of Bacillus Thuringiensis Strains Effective against Mosquitoes. *Pesquisa Agropecuária Brasileira* **2005**, *40*, 103–106.
72. Patil, C.D.; Patil, S.V.; Salunke, B.K.; Salunkhe, R.B. Insecticidal Potency of Bacterial Species Bacillus Thuringiensis SV2 and Serratia Nematodiphila SV6 against Larvae of Mosquito Species Aedes Aegypti, Anopheles Stephensi, and Culex Quinquefasciatus. *Parasitology research* **2012**, *110*, 1841–1847.
73. Soares-da-Silva, J.; Pinheiro, V.C.S.; Litaiff-Abreu, E.; Polanczyk, R.A.; Tadei, W.P. Isolation of Bacillus Thuringiensis from the State of Amazonas, in Brazil, and Screening against Aedes Aegypti (Diptera, Culicidae). *Revista Brasileira de Entomologia* **2015**, *59*, 01–06.
74. Soares-da-Silva, J.; Queirós, S.G.; de Aguiar, J.S.; Viana, J.L.; dos RAV Neta, M.; da Silva, M.C.; Pinheiro, V.C.; Polanczyk, R.A.; Carvalho-Zilse, G.A.; Tadei, W.P. Molecular Characterization of the Gene Profile of Bacillus Thuringiensis Berliner Isolated from Brazilian Ecosystems and Showing Pathogenic Activity against Mosquito Larvae of Medical Importance. *Acta tropica* **2017**, *176*, 197–205.
75. Fatima, N.; Bibi, Z.; Rehman, A.; Bukhari, D.A. Biototoxicity Comparison of Bacillus Thuringiensis to Control Vector Borne Diseases against Mosquito Fauna. *Saudi Journal of Biological Sciences* **2023**, *30*, 103610.
76. López-Molina, S.; do Nascimento, N.A.; Silva-Filha, M.H.N.L.; Guerrero, A.; Sánchez, J.; Pacheco, S.; Gill, S.S.; Soberón, M.; Bravo, A. In Vivo Nanoscale Analysis of the Dynamic Synergistic Interaction of Bacillus Thuringiensis Cry11Aa and Cyt1Aa Toxins in Aedes Aegypti. *PLoS Pathogens* **2021**, *17*, e1009199.

77. Roy, M.; Chatterjee, S.; Dangar, T.K. Characterization and Mosquitocidal Potency of a *Bacillus Thuringiensis* Strain of Rice Field Soil of Burdwan, West Bengal, India. *Microbial Pathogenesis* **2021**, *158*, 105093.
78. Bernal, L.; Dussán, J. Synergistic Effect of *Lysinibacillus Sphaericus* and Glyphosate on Temephos-Resistant Larvae of *Aedes Aegypti*. *Parasites & Vectors* **2020**, *13*, 1–6.
79. Almeida, J.; Mohanty, A.; Dharini, N.; Hoti, S.L.; Kerkar, S.; Kumar, A. A Report on Novel Mosquito Pathogenic *Bacillus* Spp. Isolated from a Beach in Goa, India. **2020**.
80. Nicolas, L.; Dossou-Yovo, J. Differential Effects of *Bacillus Sphaericus* Strain 2362 on *Culex Quinquefasciatus* and Its Competitor *Culex Cinereus* in West Africa. *Medical and veterinary entomology* **1987**, *1*, 23–27.
81. Andrade, C.; Campos, J.; Cabrini, I.; Filho, C.; Hibi, S. Susceptibilidade de Populações de *Culex Quinquefasciatus* Say (Diptera: Culicidae) Sujeitas Ao Controle Com *Bacillus Sphaericus* Neide No Rio Pinheiros, São Paulo. *BioAssay* **2009**, *2*, doi:10.14295/BA.v2.0.47.
82. Lozano, L.C.; Ayala, J.A.; Dussán, J. *Lysinibacillus Sphaericus* S-Layer Protein Toxicity against *Culex Quinquefasciatus*. *Biotechnology letters* **2011**, *33*, 2037–2041.
83. Kale, A.; Hire, R.S.; Hadapad, A.B.; D'Souza, S.F.; Kumar, V. Interaction between Mosquito-Larvicidal *Lysinibacillus Sphaericus* Binary Toxin Components: Analysis of Complex Formation. *Insect biochemistry and molecular biology* **2013**, *43*, 1045–1054.
84. Iftikhar, S.; Riaz, M.A.; Majeed, M.Z.; Afzal, M.; Ali, A.; Saadia, M.; Ali, Z.; Ahmed, S. Isolation, Characterization and Larvicidal Potential of Indigenous Soil Inhabiting Bacteria against Larvae of Southern House Mosquito (*Culex Quinquefasciatus* Say). *International Journal of Tropical Insect Science* **2023**, 1–11.
85. Allievi, M.C.; Palomino, M.M.; Prado Acosta, M.; Lanati, L.; Ruzal, S.M.; Sánchez-Rivas, C. Contribution of S-Layer Proteins to the Mosquitocidal Activity of *Lysinibacillus Sphaericus*. *PLoS One* **2014**, *9*, e111114.
86. Lee, H.L.; David, L.; Nazni, W.A.; Rozilawati, H.; Nurulhusna, H.; Afizah, A.N.; Rosilawati, R.; Roziyah, A.; Teh, C.H.; Seleena, B. THERMALLY APPLIED *LYSINIBACILLUS SPHAERICUS* AND PYRETHROIDS AGAINST *CULEX SITIENS WIEDEMANN* AND *CULEX QUINQUEFASCIATUS SAY* IN MALAYSIA. *Southeast Asian Journal of Tropical Medicine and Public Health* **2016**, *47*, 747–758.
87. Guo, Q.-Y.; Hu, X.-M.; Cai, Q.-X.; Yan, J.-P.; Yuan, Z.-M. Interaction of *Lysinibacillus Sphaericus* Cry48Aa/Cry49Aa Toxin with Midgut Brush-border Membrane Fractions from *Culex Quinquefasciatus* Larvae. *Insect Molecular Biology* **2016**, *25*, 163–170.
88. Lozano, L.C.; Dussán, J. Synergistic Activity between S-Layer Protein and Spore–Crystal Preparations from *Lysinibacillus Sphaericus* against *Culex Quinquefasciatus* Larvae. *Current microbiology* **2017**, *74*, 371–376.
89. Karch, S.; Asidi, N.; Manzambi, Z.M.; Salaun, J.J. Efficacy of *Bacillus Sphaericus* against the Malaria Vector *Anopheles Gambiae* and Other Mosquitoes in Swamps and Rice Fields in Zaire. *Journal of the American Mosquito Control Association* **1992**, *8*, 376–380.
90. Rodrigues, I.B.; Tadei, W.P.; Dias, J.M.C. da S. Larvicidal Activity of *Bacillus Sphaericus* 2362 against *Anopheles Nuneztovari*, *Anopheles Darlingi* and *Anopheles Braziliensis* (Diptera, Culicidae). *Revista do Instituto de Medicina Tropical de São Paulo* **1999**, *41*, 101–105.
91. Galardo, A.K.R.; Zimmerman, R.; Galardo, C.D. Larval Control of *Anopheles (Nyssorhynchus) Darlingi* Using Granular Formulation of *Bacillus Sphaericus* in Abandoned Gold-Miners Excavation Pools in the Brazilian Amazon Rainforest. *Revista da Sociedade Brasileira de Medicina Tropical* **2013**, *46*, 172–177.
92. Riaz, M.A.; Adang, M.J.; Hua, G.; Rezende, T.M.T.; Rezende, A.M.; Shen, G.-M. Identification of *Lysinibacillus Sphaericus* Binary Toxin Binding Proteins in a Malarial Mosquito Cell Line by Proteomics: A Novel Approach towards Improving Mosquito Control. *Journal of proteomics* **2020**, *227*, 103918.
93. Dhayalan, A.; Kannupaiyan, J.; Govindasamy, B.; Pachiappan, P. Extraction and Characterization of Secondary Metabolites from the Soil Bacterium, *Acidovorax* Sp. SA5 and Evaluation of Their Larvicidal Activity Against *Aedes Aegypti*. *International Journal of Environmental Research* **2019**, *13*, 47–58.
94. Das, D.; Chatterjee, S.; Dangar, T.K. Characterization and Mosquitocidal Potential of the Soil Bacteria *Aneurinibacillus Aneurinilyticus* Isolated from Burdwan, West Bengal, India. *Proceedings of the National Academy of Sciences, India Section B: Biological Sciences* **2016**, *86*, 707–713.
95. Geetha, I.; Aruna, R.; Manonmani, A.M. Mosquitocidal *Bacillus Amyloliquefaciens*: Dynamics of Growth & Production of Novel Pupicidal Biosurfactant. *The Indian journal of medical research* **2014**, *140*, 427.
96. Darriet, F.; Hougard, J.-M. An Isolate of *Bacillus Circulans* Toxic to Mosquito Larvae. *Journal of the American Mosquito Control Association-Mosquito News* **2002**, *18*, 65–67.

97. Abinaya, M.; Vaseeharan, B.; Divya, M.; Vijayakumar, S.; Govindarajan, M.; Alharbi, N.S.; Khaled, J.M.; Al-Anbr, M.N.; Benelli, G. Structural Characterization of Bacillus Licheniformis Dahb1 Exopolysaccharide—Antimicrobial Potential and Larvicidal Activity on Malaria and Zika Virus Mosquito Vectors. *Environmental Science and Pollution Research* **2018**, *25*, 18604–18619.
98. Favret, M.E.; Yousten, A.A. Insecticidal Activity of Bacillus Laterosporus. *Journal of invertebrate pathology* **1985**, *45*, 195–203.
99. Ruiu, L.; Floris, I.; Satta, A.; Ellar, D.J. Toxicity of a Brevibacillus Laterosporus Strain Lacking Parasporal Crystals against Musca Domestica and Aedes Aegypti. *Biological Control* **2007**, *43*, 136–143.
100. Zubasheva, M.V.; Ganushkina, L.A.; Smirnova, T.A.; Azizbekyan, R.R. Larvicidal Activity of Crystal-Forming Strains of Brevibacillus Laterosporus. *Applied Biochemistry and Microbiology* **2010**, *46*, 755–762.
101. Barbieri, G.; Ferrari, C.; Mamberti, S.; Gabrieli, P.; Castelli, M.; Sasseria, D.; Ursino, E.; Scoffone, V.C.; Radaelli, G.; Clementi, E. Identification of a Novel Brevibacillus Laterosporus Strain With Insecticidal Activity Against Aedes Albopictus Larvae. *Frontiers in microbiology* **2021**, *12*, 624014.
102. Bedini, S.; Conti, B.; Hamze, R.; Muniz, E.R.; Fernandes, É.K.; Ruiu, L. Lethal and Sub-Lethal Activity of Brevibacillus Laterosporus on the Mosquito Aedes Albopictus and Side Effects on Non-Target Water-Dwelling Invertebrates. *Journal of Invertebrate Pathology* **2021**, *184*, 107645.
103. Das, K.; Mukherjee, A.K. Assessment of Mosquito Larvicidal Potency of Cyclic Lipopeptides Produced by Bacillus Subtilis Strains. *Acta Tropica* **2006**, *97*, 168–173.
104. Geetha, I.; Manonmani, A.M. Surfactin: A Novel Mosquitocidal Biosurfactant Produced by Bacillus Subtilis Ssp. Subtilis (VCRC B471) and Influence of Abiotic Factors on Its Pupicidal Efficacy. *Letters in applied microbiology* **2010**, *51*, 406–412.
105. Ramathilaga, A.; Murugesan, A.G.; Prabu, C.S. Biolarvicidal Activity of Peanibacillus Macerans and Bacillus Subtilis Isolated from the Dead Larvae against Aedes Aegypti-Vector for Chikungunya. *Proceedings of the International Academy of Ecology and Environmental Sciences* **2012**, *2*, 90.
106. Geetha, I.; Paily, K.P.; Manonmani, A.M. Mosquito Adulticidal Activity of a Biosurfactant Produced by Bacillus Subtilis Subsp. Subtilis. *Pest management science* **2012**, *68*, 1447–1450.
107. Parthipan, P.; Sarankumar, R.K.; Jaganathan, A.; Amuthavalli, P.; Babujanathanam, R.; Rahman, P.K.; Murugan, K.; Higuchi, A.; Benelli, G.; Rajasekar, A. Biosurfactants Produced by Bacillus Subtilis A1 and Pseudomonas Stutzeri NA3 Reduce Longevity and Fecundity of Anopheles Stephensi and Show High Toxicity against Young Instars. *Environmental Science and Pollution Research* **2018**, *25*, 10471–10481.
108. Dahmana, H.; Sambou, M.; Raoult, D.; Fenollar, F.; Mediannikov, O. Biological Control of Aedes Albopictus: Obtained from the New Bacterial Candidates with Insecticidal Activity. *Insects* **2020**, *11*, 403.
109. Pradhan, A.K.; Rath, A.; Pradhan, N.; Hazra, R.K.; Nayak, R.R.; Kanjilal, S. Cyclic Lipopeptide Biosurfactant from Bacillus Tequilensis Exhibits Multifarious Activity. *3 Biotech* **2018**, *8*, 1–7.
110. Ramirez, J.L.; Short, S.M.; Bahia, A.C.; Saraiva, R.G.; Dong, Y.; Kang, S.; Tripathi, A.; Mlambo, G.; Dimopoulos, G. Chromobacterium Csp\_P Reduces Malaria and Dengue Infection in Vector Mosquitoes and Has Entomopathogenic and in Vitro Anti-Pathogen Activities. *PLoS pathogens* **2014**, *10*, e1004398.
111. Short, S.M.; Van Tol, S.; MacLeod, H.J.; Dimopoulos, G. Hydrogen Cyanide Produced by the Soil Bacterium Chromobacterium Sp. Panama Contributes to Mortality in Anopheles Gambiae Mosquito Larvae. *Scientific reports* **2018**, *8*, 1–13.
112. Gnambani, E.J.; Bilgo, E.; Dabiré, R.K.; Belem, A.M.G.; Diabaté, A. Infection of the Malaria Vector Anopheles Coluzzii with the Entomopathogenic Bacteria Chromobacterium Anophelis Sp. Nov. IRSSSOUMB001 Reduces Larval Survival and Adult Reproductive Potential. *Malaria Journal* **2023**, *22*, 122.
113. Wilson, J.J.; Harimuralikrishnaa, T.; Sivakumar, T.; Mahendran, S.; Ponmanickam, P.; Thangaraj, R.; Sevarkodiyone, S.; Alharbi, N.S.; Kadaikunnan, S.; Venkidasamy, B. Biogenic Synthesis of Silver Nanoparticles Using Pantoea Stewartii and Priestia Aryabhatai and Their Antimicrobial, Larvicidal, Histopathological, and Biototoxicity Potential. *Bioengineering* **2023**, *10*, 248.
114. Contreras, E.; Masuyer, G.; Qureshi, N.; Chawla, S.; Dhillon, H.S.; Lee, H.L.; Chen, J.; Stenmark, P.; Gill, S.S. A Neurotoxin That Specifically Targets Anopheles Mosquitoes. *Nature communications* **2019**, *10*, 2869.
115. Luiz Rosa da Silva, J.; Undurraga Schwalm, F.; Eugênio Silva, C.; da Costa, M.; Heermann, R.; Santos da Silva, O. Larvicidal and Growth-Inhibitory Activity of Entomopathogenic Bacteria Culture Fluids against Aedes Aegypti (Diptera: Culicidae). *Journal of economic entomology* **2017**, *110*, 378–385.

116. da Silva, O.S.; Prado, G.R.; da Silva, J.L.R.; Silva, C.E.; da Costa, M.; Heermann, R. Oral Toxicity of *Photorhabdus Luminescens* and *Xenorhabdus Nematophila* (Enterobacteriaceae) against *Aedes Aegypti* (Diptera: Culicidae). *Parasitology research* **2013**, *112*, 2891–2896.
117. Vitta, A.; Thimpoo, P.; Meesil, W.; Yimthin, T.; Fukrukxa, C.; Polseela, R.; Mangkit, B.; Tandhavanant, S.; Thanwisai, A. Larvicidal Activity of *Xenorhabdus* and *Photorhabdus* Bacteria against *Aedes Aegypti* and *Aedes Albopictus*. *Asian Pacific Journal of Tropical Biomedicine* **2018**, *8*, 31.
118. Patil, C.D.; Patil, S.V.; Salunke, B.K.; Salunkhe, R.B. Prodigiosin Produced by *Serratia Marcescens* NMCC46 as a Mosquito Larvicidal Agent against *Aedes Aegypti* and *Anopheles Stephensi*. *Parasitology research* **2011**, *109*, 1179–1187.
119. Suryawanshi, R.K.; Patil, C.D.; Borase, H.P.; Narkhede, C.P.; Salunke, B.K.; Patil, S.V. Mosquito Larvicidal and Pupaecidal Potential of Prodigiosin from *Serratia Marcescens* and Understanding Its Mechanism of Action. *Pesticide biochemistry and physiology* **2015**, *123*, 49–55.
120. Heu, K.; Romoli, O.; Schönbeck, J.C.; Ajenoe, R.; Epelboin, Y.; Kircher, V.; Houël, E.; Estevez, Y.; Gendrin, M. The Effect of Secondary Metabolites Produced by *Serratia Marcescens* on *Aedes Aegypti* and Its Microbiota. *Frontiers in Microbiology* **2021**, *12*, 645701.
121. Bond, J.G.; Marina, C.F.; Williams, T. The Naturally Derived Insecticide Spinosad Is Highly Toxic to *Aedes* and *Anopheles* Mosquito Larvae. *Medical and Veterinary Entomology* **2004**, *18*, 50–56.
122. Darriet, F.; Duchon, S.; Hougard, J.M. Spinosad: A New Larvicide against Insecticide-Resistant Mosquito Larvae. *Journal of the American Mosquito Control Association* **2005**, *21*, 495–496.
123. Romi, R.; Proietti, S.; Di Luca, M.; Cristofaro, M. Laboratory Evaluation of the Bioinsecticide Spinosad for Mosquito Control. *Journal of the American Mosquito Control Association* **2006**, *22*, 93–96.
124. Antonio, G.E.; Sanchez, D.; Williams, T.; Marina, C.F. Paradoxical Effects of Sublethal Exposure to the Naturally Derived Insecticide Spinosad in the Dengue Vector Mosquito, *Aedes Aegypti*. *Pest Management Science: formerly Pesticide Science* **2009**, *65*, 323–326.
125. Thavara, U.; Tawatsin, A.; Asavadachanukorn, P.; Mulla, M.S. Field Evaluation in Thailand of Spinosad, a Larvicide Derived from *Saccharopolyspora Spinososa* (Actinomycetales) against *Aedes Aegypti* (L.) Larvae. *Southeast Asian journal of tropical medicine and public health* **2009**, *40*, 235.
126. Jiang, Y.; Mulla, M.S. Laboratory and Field Evaluation of Spinosad, a Biorational Natural Product, against Larvae of *Culex* Mosquitoes. *Journal of the American Mosquito Control Association* **2009**, *25*, 456–466.
127. Aarthi, N.; Murugan, K. Larvicidal and Repellent Activity of *Vetiveria Zizanioides* L, *Ocimum Basilicum* Linn and the Microbial Pesticide Spinosad against Malarial Vector, *Anopheles Stephensi* Liston (Insecta: Diptera: Culicidae). *Journal of Biopesticides* **2010**, *3*, 199.
128. Prabhu, K.; Murugan, K.; Nareshkumar, A.; Bragadeeswaran, S. Larvicidal and Pupicidal Activity of Spinosad against the Malarial Vector *Anopheles Stephensi*. *Asian Pacific Journal of Tropical Medicine* **2011**, *4*, 610–613.
129. Su, T.; Cheng, M.-L.; Thieme, J. Laboratory and Field Evaluation of Spinosad Formulation Natular T30 against Immature *Culex* Mosquitoes (Diptera: Culicidae). *Journal of medical entomology* **2014**, *51*, 837–844.
130. Sadanandane, C.; Gunasekaran, K.; Doss, P.S.B.; Jambulingam, P. Field Evaluation of the Biolarvicide, Spinosad 20 per Cent Emulsifiable Concentrate in Comparison to Its 12 per Cent Suspension Concentrate Formulation against *Culex Quinquefasciatus*, the Vector of Bancroftian Filariasis in India. *The Indian Journal of Medical Research* **2018**, *147*, 32.
131. Vijayan, V.; Balaraman, K. Metabolites of Fungi & Actinomycetes Active against Mosquito Larvae. *The Indian journal of medical research* **1991**, *93*, 115–117.
132. Darbro, J.M.; Graham, R.I.; Kay, B.H.; Ryan, P.A.; Thomas, M.B. Evaluation of Entomopathogenic Fungi as Potential Biological Control Agents of the Dengue Mosquito, *Aedes Aegypti* (Diptera: Culicidae). *Biocontrol science and technology* **2011**, *21*, 1027–1047.
133. Blanford, S.; Jenkins, N.E.; Read, A.F.; Thomas, M.B. Evaluating the Lethal and Pre-Lethal Effects of a Range of Fungi against Adult *Anopheles Stephensi* Mosquitoes. *Malaria journal* **2012**, *11*, 1–10.
134. Ramirez, J.L.; Muturi, E.J.; Dunlap, C.; Rooney, A.P. Strain-Specific Pathogenicity and Subversion of Phenoloxidase Activity in the Mosquito *Aedes Aegypti* by Members of the Fungal Entomopathogenic Genus *Isaria*. *Scientific Reports* **2018**, *8*, 9896.
135. Vivekanandhan, P.; Bedini, S.; Shivakumar, M.S. Isolation and Identification of Entomopathogenic Fungus from Eastern Ghats of South Indian Forest Soil and Their Efficacy as Biopesticide for Mosquito Control. *Parasitology international* **2020**, *76*, 102099.

136. Pathan, E.K.; Ghormade, V.; Tupe, S.G.; Deshpande, M.V. Insect Pathogenic Fungi and Their Applications: An Indian Perspective. *Progress in Mycology: An Indian Perspective* **2021**, 311–327.
137. Renuka, S.; Vani H, C.; Alex, E. Entomopathogenic Fungi as a Potential Management Tool for the Control of Urban Malaria Vector, *Anopheles Stephensi* (Diptera: Culicidae). *Journal of Fungi* **2023**, 9, 223.
138. Scholte, E.-J.; Knols, B.G.; Samson, R.A.; Takken, W. Entomopathogenic Fungi for Mosquito Control: A Review. *Journal of insect science* **2004**, 4, 19.
139. Kanzok, S.M.; Jacobs-Lorena, M. Entomopathogenic Fungi as Biological Insecticides to Control Malaria. *Trends in parasitology* **2006**, 22, 49–51.
140. Fang, W.; Azimzadeh, P.; Leger, R.J.S. Strain Improvement of Fungal Insecticides for Controlling Insect Pests and Vector-Borne Diseases. *Current opinion in microbiology* **2012**, 15, 232–238.
141. Cafarchia, C.; Pellegrino, R.; Romano, V.; Friuli, M.; Demitri, C.; Pombi, M.; Benelli, G.; Otranto, D. Delivery and Effectiveness of Entomopathogenic Fungi for Mosquito and Tick Control: Current Knowledge and Research Challenges. *Acta Tropica* **2022**, 106627.
142. de Paula, A.R.; Brito, E.S.; Pereira, C.R.; Carrera, M.P.; Samuels, R.I. Susceptibility of Adult *Aedes Aegypti* (Diptera: Culicidae) to Infection by *Metarhizium Anisopliae* and *Beauveria Bassiana*: Prospects for Dengue Vector Control. *Biocontrol Science and Technology* **2008**, 18, 1017–1025.
143. Buckner, E.A.; Williams, K.F.; Marsicano, A.L.; Latham, M.D.; Lesser, C.R. Evaluating the Vector Control Potential of the In2Care® Mosquito Trap against *Aedes Aegypti* and *Aedes Albopictus* under Semifield Conditions in Manatee County, Florida. *Journal of the American Mosquito Control Association* **2017**, 33, 193–199.
144. Howard, A.F.; N’guessan, R.; Koenraadt, C.J.; Asidi, A.; Farenhorst, M.; Akogbéto, M.; Thomas, M.B.; Knols, B.G.; Takken, W. The Entomopathogenic Fungus *Beauveria Bassiana* Reduces Instantaneous Blood Feeding in Wild Multi-Insecticide-Resistant *Culex Quinquefasciatus* Mosquitoes in Benin, West Africa. *Parasites & Vectors* **2010**, 3, 1–11.
145. García-Munguía, A.M.; Garza-Hernández, J.A.; Rebollar-Tellez, E.A.; Rodríguez-Pérez, M.A.; Reyes-Villanueva, F. Transmission of *Beauveria Bassiana* from Male to Female *Aedes Aegypti* Mosquitoes. *Parasites & vectors* **2011**, 4, 1–6.
146. George, J.; Jenkins, N.E.; Blanford, S.; Thomas, M.B.; Baker, T.C. Malaria Mosquitoes Attracted by Fatal Fungus. *PLoS One* **2013**, 8, e62632.
147. Valero-Jiménez, C.A.; van Kan, J.A.; Koenraadt, C.J.; Zwaan, B.J.; Schoustra, S.E. Experimental Evolution to Increase the Efficacy of the Entomopathogenic Fungus *Beauveria Bassiana* against Malaria Mosquitoes: Effects on Mycelial Growth and Virulence. *Evolutionary applications* **2017**, 10, 433–443.
148. Shoukat, R.F.; Zafar, J.; Shakeel, M.; Zhang, Y.; Freed, S.; Xu, X.; Jin, F. Assessment of Lethal, Sublethal, and Transgenerational Effects of *Beauveria Bassiana* on the Demography of *Aedes Albopictus* (Culicidae: Diptera). *Insects* **2020**, 11, 178.
149. Veys-Behbahani, R.; Sharififard, M.; Dinparast-Djadid, N.; Shamsi, J.; Fakoorziba, M.R. Laboratory Evolution of the Entomopathogenic Fungus *Beauveria Bassiana* against *Anopheles Stephensi* Larvae (Diptera: Culicidae). *Asian Pacific Journal of Tropical Disease* **2014**, 4, S799–S802.
150. Bezalwar, P.; Gomashe, A.; Gulhane, P. Laboratory-Based Evaluation of the Potential of *Beauveria Bassiana* Crude Metabolites for Mosquito Larvae. *Annihilation (IOSR-JPBS)* **2014**, 9, 15–20.
151. Farida, B.; Sonia, H.; Hakima, M.-K.; Fatma, B.; Fatma, H. Histological Changes in the Larvae of the Domestic Mosquito *Culex Pipiens* Treated with the Entomopathogenic Fungus *Beauveria Bassiana*. *Scientific Research and Essays* **2018**, 13, 1–10.
152. US EPA, O. Biopesticide Active Ingredients Available online: <https://www.epa.gov/ingredients-used-pesticide-products/biopesticide-active-ingredients> (accessed on 12 April 2023).
153. ANVISA Listas de ingredientes ativos com uso autorizado e banidos no Brasil Available online: <https://www.gov.br/anvisa/pt-br/assuntos/noticias-anvisa/2017/listas-de-ingredientes-ativos-com-uso-autorizado-e-banidos-no-brasil> (accessed on 20 March 2023).
154. Zimmermann, G. The Entomopathogenic Fungus *Metarhizium Anisopliae* and Its Potential as a Biocontrol Agent. *Pesticide Science* **1993**, 37, 375–379.
155. Freimoser, F.M.; Screen, S.; Bagga, S.; Hu, G.; St Leger, R.J. Expressed Sequence Tag (EST) Analysis of Two Subspecies of *Metarhizium Anisopliae* Reveals a Plethora of Secreted Proteins with Potential Activity in Insect Hosts. *Microbiology* **2003**, 149, 239–247.
156. Schrank, A.; Vainstein, M.H. *Metarhizium Anisopliae* Enzymes and Toxins. *Toxicon* **2010**, 56, 1267–1274.

157. Choi, C.J.; Lee, J.Y.; Woo, R.M.; Shin, T.Y.; Gwak, W.S.; Woo, S.D. An Effective Entomopathogenic Fungus *Metarhizium Anisopliae* for the Simultaneous Control of *Aedes Albopictus* and *Culex Pipiens* Mosquito Adults. *Journal of Asia-Pacific Entomology* **2020**, *23*, 585–590.
158. Scholte, E.-J.; Knols, B.G.; Takken, W. Infection of the Malaria Mosquito *Anopheles Gambiae* with the Entomopathogenic Fungus *Metarhizium Anisopliae* Reduces Blood Feeding and Fecundity. *Journal of invertebrate pathology* **2006**, *91*, 43–49.
159. Pereira, C.R.; de Paula, A.R.; Gomes, S.A.; Pedra Jr, P.C.O.; Samuels, R.I. The Potential of *Metarhizium Anisopliae* and *Beauveria Bassiana* Isolates for the Control of *Aedes Aegypti* (Diptera: Culicidae) Larvae. *Biocontrol Science and Technology* **2009**, *19*, 881–886.
160. Koodalingam, A.; Dayanidhi, M.K. Studies on Biochemical and Synergistic Effects of Immunosuppressive Concentration of Imidacloprid with *Beauveria Bassiana* and *Metarhizium Anisopliae* for Enhancement of Virulence against Vector Mosquito *Culex Quinquefasciatus*. *Pesticide Biochemistry and Physiology* **2021**, *176*, 104882.
161. Butt, T.M.; Greenfield, B.P.; Greig, C.; Maffei, T.G.; Taylor, J.W.; Piasecka, J.; Dudley, E.; Abdulla, A.; Dubovskiy, I.M.; Garrido-Jurado, I. *Metarhizium Anisopliae* Pathogenesis of Mosquito Larvae: A Verdict of Accidental Death. *PLoS one* **2013**, *8*, e81686.
162. Jaber, S.; Mercier, A.; Knio, K.; Brun, S.; Kambris, Z. Isolation of Fungi from Dead Arthropods and Identification of a New Mosquito Natural Pathogen. *Parasites & vectors* **2016**, *9*, 1–10.
163. Soni, N.; Prakash, S. *Aspergillus Niger* Metabolites Efficacies against the Mosquito Larval (*Culex Quinquefasciatus*, *Anopheles Stephensi* and *Aedes Aegypti*) Population after Column Chromatography. *Am J Microbiol Res* **2011**, *2*, 15–20.
164. Balumahendhira, K.; Vivekanandhan, P.; Shivakumar, M.S. Mosquito Control Potential of Secondary Metabolites Isolated from *Aspergillus Flavus* and *Aspergillus Fumigatus*. *Biocatalysis and Agricultural Biotechnology* **2019**, *21*, 101334.
165. Baskar, K.; Chinnasamy, R.; Pandey, K.; Venkatesan, M.; Sebastian, P.J.; Subban, M.; Thomas, A.; Kweka, E.J.; Devarajan, N. Larvicidal and Histopathology Effect of Endophytic Fungal Extracts of *Aspergillus Tamarii* against *Aedes Aegypti* and *Culex Quinquefasciatus*. *Heliyon* **2020**, *6*, e05331, doi:10.1016/j.heliyon.2020.e05331.
166. Vasantha-Srinivasan, P.; Karthi, S.; Chellappandian, M.; Ponsankar, A.; Thanigaivel, A.; Senthil-Nathan, S.; Chandramohan, D.; Ganesan, R. *Aspergillus Flavus* (Link) Toxins Reduces the Fitness of Dengue Vector *Aedes Aegypti* (Linn.) and Their Non-Target Toxicity against Aquatic Predator. *Microbial pathogenesis* **2019**, *128*, 281–287.
167. Karthi, S.; Vasantha-Srinivasan, P.; Ganesan, R.; Ramasamy, V.; Senthil-Nathan, S.; Khater, H.F.; Radhakrishnan, N.; Amala, K.; Kim, T.-J.; El-Sheikh, M.A. Target Activity of *Isaria Tenuipes* (Hypocreales: Clavicipitaceae) Fungal Strains against Dengue Vector *Aedes Aegypti* (Linn.) and Its Non-Target Activity against Aquatic Predators. *Journal of fungi* **2020**, *6*, 196.
168. Banu, A.N.; Balasubramanian, C. Optimization and Synthesis of Silver Nanoparticles Using *Isaria Fumosorosea* against Human Vector Mosquitoes. *Parasitology research* **2014**, *113*, 3843–3851.
169. Podder, D.; Ghosh, S.K. A New Application of *Trichoderma Asperellum* as an Anopheline Larvicide for Eco Friendly Management in Medical Science. *Scientific reports* **2019**, *9*, 1–15.
170. Mao, Z.; Wang, W.; Su, R.; Gu, G.; Liu, Z.L.; Lai, D.; Zhou, L. Hyalodendrins A and B, New Decalin-Type Tetramic Acid Larvicides from the Endophytic Fungus *Hyalodendriella* Sp. *Ponipodef12*. *Molecules* **2019**, *25*, 114.
171. Lee, J.Y.; Woo, R.M.; Choi, C.J.; Shin, T.Y.; Gwak, W.S.; Woo, S.D. *Beauveria Bassiana* for the Simultaneous Control of *Aedes Albopictus* and *Culex Pipiens* Mosquito Adults Shows High Conidia Persistence and Productivity. *AMB Express* **2019**, *9*, 1–9.
172. Alves, S.B.; Alves, L.F.A.; Lopes, R.B.; Pereira, R.M.; Vieira, S.A. Potential of Some *Metarhizium Anisopliae* Isolates for Control of *Culex Quinquefasciatus* (Dipt., Culicidae). *Journal of Applied Entomology* **2002**, *126*, 504–509.
173. Scholte, E.-J.; Takken, W.; Knols, B.G. Infection of Adult *Aedes Aegypti* and *Ae. Albopictus* Mosquitoes with the Entomopathogenic Fungus *Metarhizium Anisopliae*. *Acta tropica* **2007**, *102*, 151–158.
174. Seye, F.; Ndiaye, M.; Faye, O.; Afoutou, J.M. Evaluation of Entomopathogenic Fungus *Metarhizium Anisopliae* Formulated with Suneem (Neem Oil) against *Anopheles Gambiae* SI and *Culex Quinquefasciatus* Adults. *Malaria Chemotherapy Cont Elim* **2012**, *1*.

175. Vivekanandhan, P.; Swathy, K.; Kalaimurugan, D.; Ramachandran, M.; Yuvaraj, A.; Kumar, A.N.; Manikandan, A.T.; Poovarasan, N.; Shivakumar, M.S.; Kweka, E.J. Larvicidal Toxicity of Metarhizium Anisopliae Metabolites against Three Mosquito Species and Non-Targeting Organisms. *Plos one* **2020**, *15*, e0232172.
176. Govindarajan, M.; Jebanesan, A.; Reetha, D. Larvicidal Effect of Extracellular Secondary Metabolites of Different Fungi against the Mosquito, *Culex Quinquefasciatus* Say. *Tropical biomedicine* **2005**, *22*, 1–3.
177. Ragavendran, C.; Natarajan, D. Insecticidal Potency of *Aspergillus Terreus* against Larvae and Pupae of Three Mosquito Species *Anopheles Stephensi*, *Culex Quinquefasciatus*, and *Aedes Aegypti*. *Environmental Science and Pollution Research* **2015**, *22*, 17224–17237.
178. Chinnasamy, R.; Govindasamy, B.; Venkatesh, M.; Magudeeswaran, S.; Dhanarajan, A.; Devarajan, N.; Willie, P.; Perumal, V.; Mekchay, S.; Krutmuang, P. Bio-Efficacy of Insecticidal Molecule Emodin against Dengue, Filariasis, and Malaria Vectors. *Environmental Science and Pollution Research* **2023**, *30*, 61842–61862.
179. Pinnock, D.E.; Garcia, R.; Cubbin, C.M. *Beauveria Tenella* as a Control Agent for Mosquito Larvae. *Journal of Invertebrate Pathology* **1973**, *22*, 143–147.
180. Ragavendran, C.; Balasubramani, G.; Tijo, C.; Manigandan, V.; Kweka, E.J.; Karthika, P.; Sivasankar, P.; Thomas, A.; Natarajan, D.; Nakouti, I. *Cladophialophora Bantiana* Metabolites Are Efficient in the Larvicidal and Ovicidal Control of *Aedes Aegypti*, and *Culex Quinquefasciatus* and Have Low Toxicity in Zebrafish Embryo. *Science of the Total Environment* **2022**, *852*, 158502.
181. Mohanty, S.S.; Prakash, S. Effects of Culture Media on Larvicidal Property of Secondary Metabolites of Mosquito Pathogenic Fungus *Chrysosporium Lobatum* (Moniliales: Moniliaceae). *Acta tropica* **2009**, *109*, 50–54.
182. Verma, P.; Prakash, S. Efficacy of *Chrysosporium Tropicum* Metabolite against Mixed Population of Adult Mosquito (*Culex Quinquefasciatus*, *Anopheles Stephensii*, and *Aedes Aegypti*) after Purification with Flash Chromatography. *Parasitology research* **2010**, *107*, 163–166.
183. Pradeep, F.S.; Palaniswamy, M.; Ravi, S.; Thangamani, A.; Pradeep, B.V. Larvicidal Activity of a Novel Isoquinoline Type Pigment from *Fusarium Moniliforme* KUMBF1201 against *Aedes Aegypti* and *Anopheles Stephensi*. *Process Biochemistry* **2015**, *50*, 1479–1486.
184. Vivekanandhan, P.; Karthi, S.; Shivakumar, M.S.; Benelli, G. Synergistic Effect of Entomopathogenic Fungus *Fusarium Oxysporum* Extract in Combination with Temephos against Three Major Mosquito Vectors. *Pathogens and global health* **2018**, *112*, 37–46.
185. Ragavendran, C.; Mariappan, T.; Natarajan, D. Larvicidal, Histopathological Efficacy of *Penicillium Daleae* against Larvae of *Culex Quinquefasciatus* and *Aedes Aegypti* plus Biototoxicity on *Artemia Nauplii* a Non-Target Aquatic Organism. *Frontiers in pharmacology* **2017**, *8*, 773.
186. Saady, R.H.; Mansoor, A.J. Laboratory Evaluation of the Entomopathogenic Fungi *Penicillium Marneffeii* and *Verticillium Lecanii* against *Culex Pipeins Molestus*. *Indian Journal of Forensic Medicine & Toxicology* **2021**, *15*, 2126–2133.
187. Arunthirumeni, M.; Vinitha, G.; Shivakumar, M.S. Antifeedant and Larvicidal Activity of Bioactive Compounds Isolated from Entomopathogenic Fungi *Penicillium* Sp. for the Control of Agricultural and Medically Important Insect Pest (*Spodoptera Litura* and *Culex Quinquefasciatus*). *Parasitology International* **2023**, *92*, 102688.
188. Ragavendran, C.; Manigandan, V.; Kamaraj, C.; Balasubramani, G.; Prakash, J.S.; Perumal, P.; Natarajan, D. Larvicidal, Histopathological, Antibacterial Activity of Indigenous Fungus *Penicillium* Sp. against *Aedes Aegypti* L and *Culex Quinquefasciatus* (Say)(Diptera: Culicidae) and Its Acetylcholinesterase Inhibition and Toxicity Assessment of Zebrafish (*Danio Rerio*). *Frontiers in Microbiology* **2019**, *10*, 427.
189. Bucker, A.; Bucker, N.C.F.; Souza, A.Q.L. de; Gama, A.M. da; Rodrigues-Filho, E.; Costa, F.M. da; Nunez, C.V.; Tadei, W.P. Larvicidal Effects of Endophytic and Basidiomycete Fungus Extracts on *Aedes* and *Anopheles* Larvae (Diptera, Culicidae). *Revista da Sociedade Brasileira de Medicina Tropical* **2013**, *46*, 411–419.
190. Matasyoh, J.C.; Dittrich, B.; Schueffler, A.; Laatsch, H. Larvicidal Activity of Metabolites from the Endophytic *Podospira* Sp. against the Malaria Vector *Anopheles Gambiae*. *Parasitology research* **2011**, *108*, 561–566.
191. Sundaravadivelan, C.; Padmanabhan, M.N. Effect of Mycosynthesized Silver Nanoparticles from Filtrate of *Trichoderma Harzianum* against Larvae and Pupa of Dengue Vector *Aedes Aegypti* L. *Environmental Science and Pollution Research* **2014**, *21*, 4624–4633.

192. Dennison, N.J.; Jupatanakul, N.; Dimopoulos, G. The Mosquito Microbiota Influences Vector Competence for Human Pathogens. *Current opinion in insect science* **2014**, *3*, 6–13.
193. Carlson, J.S.; Short, S.M.; Angleró-Rodríguez, Y.I.; Dimopoulos, G. Larval Exposure to Bacteria Modulates Arbovirus Infection and Immune Gene Expression in Adult *Aedes Aegypti*. *Developmental & Comparative Immunology* **2020**, *104*, 103540.
194. Gao, H.; Cui, C.; Wang, L.; Jacobs-Lorena, M.; Wang, S. Mosquito Microbiota and Implications for Disease Control. *Trends in parasitology* **2020**, *36*, 98–111.
195. Gabrieli, P.; Caccia, S.; Varotto-Boccazzi, I.; Arnoldi, I.; Barbieri, G.; Comandatore, F.; Epis, S. Mosquito Trilogy: Microbiota, Immunity and Pathogens, and Their Implications for the Control of Disease Transmission. *Frontiers in microbiology* **2021**, *12*, 630438.
196. Cansado-Utrilla, C.; Zhao, S.Y.; McCall, P.J.; Coon, K.L.; Hughes, G.L. The Microbiome and Mosquito Vectorial Capacity: Rich Potential for Discovery and Translation. *Microbiome* **2021**, *9*, 111.
197. Wang, J.; Gao, L.; Aksoy, S. Microbiota in Disease-Transmitting Vectors. *Nature Reviews Microbiology* **2023**, 1–15.
198. Douglas, A.E. Lessons from Studying Insect Symbioses. *Cell host & microbe* **2011**, *10*, 359–367.
199. Minard, G.; Mavingui, P.; Moro, C.V. Diversity and Function of Bacterial Microbiota in the Mosquito Holobiont. *Parasites & vectors* **2013**, *6*, 1–12.
200. Kumar, A.; Srivastava, P.; Sirisena, P.; Dubey, S.K.; Kumar, R.; Shrinet, J.; Sunil, S. Mosquito Innate Immunity. *Insects* **2018**, *9*, 95.
201. Ferreira, Q.R.; Lemos, F.F.B.; Moura, M.N.; Nascimento, J.O. de S.; Novaes, A.F.; Barcelos, I.S.; Fernandes, L.A.; Amaral, L.S. de B.; Barreto, F.K.; Melo, F.F. de Role of the Microbiome in *Aedes* Spp. Vector Competence: What Do We Know? *Viruses* **2023**, *15*, 779.
202. Saab, S.A.; Dohna, H. zu; Nilsson, L.K.; Onorati, P.; Nakhleh, J.; Terenius, O.; Osta, M.A. The Environment and Species Affect Gut Bacteria Composition in Laboratory Co-Cultured *Anopheles Gambiae* and *Aedes Albopictus* Mosquitoes. *Scientific Reports* **2020**, *10*, 3352.
203. Mosquera, K.D.; Nilsson, L.K.J.; de Oliveira, M.R.; Rocha, E.M.; Marinotti, O.; Håkansson, S.; Tadei, W.P.; de Souza, A.Q.L.; Terenius, O. Comparative Assessment of the Bacterial Communities Associated with *Anopheles Darlingi* Immature Stages and Their Breeding Sites in the Brazilian Amazon. *Parasites & Vectors* **2023**, *16*, 156, doi:10.1186/s13071-023-05749-6.
204. Santos, N.A.C. dos; Carvalho, V.R. de; Souza Neto, J.; Alonso, D.P.; Ribolla, P.E.M.; Medeiros, J.F.; Araujo, M. da S. Bacterial Microbiota from Lab-Reared and Field-Captured *Anopheles Darlingi* Midgut and Salivary Gland. *Microorganisms* **2023**, *11*, 1145.
205. Dong, Y.; Manfredini, F.; Dimopoulos, G. Implication of the Mosquito Midgut Microbiota in the Defense against Malaria Parasites. *PLoS pathogens* **2009**, *5*, e1000423.
206. Cirimotich, C.M.; Dong, Y.; Garver, L.S.; Sim, S.; Dimopoulos, G. Mosquito Immune Defenses against Plasmodium Infection. *Developmental & Comparative Immunology* **2010**, *34*, 387–395.
207. Wang, Y.; Gilbreath III, T.M.; Kukutla, P.; Yan, G.; Xu, J. Dynamic Gut Microbiome across Life History of the Malaria Mosquito *Anopheles Gambiae* in Kenya. *PLoS one* **2011**, *6*, e24767.
208. Gendrin, M.; Christophides, G.K. The *Anopheles* Mosquito Microbiota and Their Impact on Pathogen Transmission. In *Anopheles mosquitoes-New insights into malaria vectors*; IntechOpen, 2013 ISBN 953-51-1188-4.
209. Ricci, I.; Valzano, M.; Ulissi, U.; Epis, S.; Cappelli, A.; Favia, G. Symbiotic Control of Mosquito Borne Disease. *Pathogens and Global Health* **2012**, *106*, 380–385, doi:10.1179/2047773212Y.0000000051.
210. Eappen, A.G.; Smith, R.C.; Jacobs-Lorena, M. Enterobacter-Activated Mosquito Immune Responses to Plasmodium Involve Activation of SRPN6 in *Anopheles Stephensi*. *Plos one* **2013**, *8*, e62937.
211. Romoli, O.; Gendrin, M. The Tripartite Interactions between the Mosquito, Its Microbiota and Plasmodium. *Parasites & vectors* **2018**, *11*, 1–8.
212. Shi, C.; Beller, L.; Wang, L.; Rosales Rosas, A.; De Coninck, L.; Héry, L.; Mousson, L.; Pagès, N.; Raes, J.; Delang, L. Bidirectional Interactions between Arboviruses and the Bacterial and Viral Microbiota in *Aedes Aegypti* and *Culex Quinquefasciatus*. *MBio* **2022**, *13*, e01021-22.
213. PuMPUNI, Charle.B.; Beier, M.S.; Nataro, J.P.; Guers, L.D.; Davis, J.R. Plasmodium Falciparum: Inhibition of Sporogonic Development in *Anopheles Stephensi* by Gram-Negative Bacteria. *Experimental parasitology* **1993**, *77*, 195–199.

214. Cirimotich, C.M.; Dong, Y.; Clayton, A.M.; Sandiford, S.L.; Souza-Neto, J.A.; Mulenga, M.; Dimopoulos, G. Natural Microbe-Mediated Refractoriness to Plasmodium Infection in Anopheles Gambiae. *Science* **2011**, *332*, 855–858.
215. Dennison, N.J.; Saraiva, R.G.; Cirimotich, C.M.; Mlambo, G.; Mongodin, E.F.; Dimopoulos, G. Functional Genomic Analyses of Enterobacter, Anopheles and Plasmodium Reciprocal Interactions That Impact Vector Competence. *Malaria journal* **2016**, *15*, 1–15.
216. Bando, H.; Okado, K.; Guelbeogo, W.M.; Badolo, A.; Aonuma, H.; Nelson, B.; Fukumoto, S.; Xuan, X.; Sagnon, N.; Kanuka, H. Intra-Specific Diversity of Serratia Marcescens in Anopheles Mosquito Midgut Defines Plasmodium Transmission Capacity. *Scientific reports* **2013**, *3*, 1641.
217. Tchioffo, M.T.; Boissiere, A.; Churcher, T.S.; Abate, L.; Gimonneau, G.; Nsango, S.E.; Awono-Ambene, P.H.; Christen, R.; Berry, A.; Morlais, I. Modulation of Malaria Infection in Anopheles Gambiae Mosquitoes Exposed to Natural Midgut Bacteria. *Plos one* **2013**, *8*, e81663.
218. Bai, L.; Wang, L.; Vega-Rodríguez, J.; Wang, G.; Wang, S. A Gut Symbiotic Bacterium Serratia Marcescens Renders Mosquito Resistance to Plasmodium Infection through Activation of Mosquito Immune Responses. *Frontiers in microbiology* **2019**, *10*, 1580.
219. Gao, H.; Bai, L.; Jiang, Y.; Huang, W.; Wang, L.; Li, S.; Zhu, G.; Wang, D.; Huang, Z.; Li, X. A Natural Symbiotic Bacterium Drives Mosquito Refractoriness to Plasmodium Infection via Secretion of an Antimalarial Lipase. *Nature microbiology* **2021**, *6*, 806–817.
220. Cappelli, A.; Damiani, C.; Mancini, M.V.; Valzano, M.; Rossi, P.; Serrao, A.; Ricci, I.; Favia, G. Asaia Activates Immune Genes in Mosquito Eliciting an Anti-Plasmodium Response: Implications in Malaria Control. *Frontiers in Genetics* **2019**, *10*, 836.
221. Ramirez, J.L.; Souza-Neto, J.; Torres Cosme, R.; Rovira, J.; Ortiz, A.; Pascale, J.M.; Dimopoulos, G. Reciprocal Tripartite Interactions between the Aedes Aegypti Midgut Microbiota, Innate Immune System and Dengue Virus Influences Vector Competence. *PLoS neglected tropical diseases* **2012**, *6*, e1561.
222. Moreira, L.A.; Iturbe-Ormaetxe, I.; Jeffery, J.A.; Lu, G.; Pyke, A.T.; Hedges, L.M.; Rocha, B.C.; Hall-Mendelin, S.; Day, A.; Riegler, M. A Wolbachia Symbiont in Aedes Aegypti Limits Infection with Dengue, Chikungunya, and Plasmodium. *Cell* **2009**, *139*, 1268–1278.
223. Walker, T.; Johnson, P.H.; Moreira, L.A.; Iturbe-Ormaetxe, I.; Frentiu, F.D.; McMeniman, C.J.; Leong, Y.S.; Dong, Y.; Axford, J.; Kriesner, P. The w Mel Wolbachia Strain Blocks Dengue and Invades Caged Aedes Aegypti Populations. *Nature* **2011**, *476*, 450–453.
224. Aliota, M.T.; Peinado, S.A.; Velez, I.D.; Osorio, J.E. The WMel Strain of Wolbachia Reduces Transmission of Zika Virus by Aedes Aegypti. *Scientific reports* **2016**, *6*, 1–7.
225. Ryan, P.A.; Turley, A.P.; Wilson, G.; Hurst, T.P.; Retzki, K.; Brown-Kenyon, J.; Hodgson, L.; Kenny, N.; Cook, H.; Montgomery, B.L. Establishment of WMel Wolbachia in Aedes Aegypti Mosquitoes and Reduction of Local Dengue Transmission in Cairns and Surrounding Locations in Northern Queensland, Australia. *Gates open research* **2019**, *3*.
226. Nazni, W.A.; Hoffmann, A.A.; NoorAfizah, A.; Cheong, Y.L.; Mancini, M.V.; Golding, N.; Kamarul, G.M.; Arif, M.A.; Thohir, H.; NurSyamimi, H. Establishment of Wolbachia Strain WALbB in Malaysian Populations of Aedes Aegypti for Dengue Control. *Current biology* **2019**, *29*, 4241–4248. e5.
227. Fraser, J.E.; O'Donnell, T.B.; Duyvestyn, J.M.; O'Neill, S.L.; Simmons, C.P.; Flores, H.A. Novel Phenotype of Wolbachia Strain w Pip in Aedes Aegypti Challenges Assumptions on Mechanisms of Wolbachia-Mediated Dengue Virus Inhibition. *PLoS Pathogens* **2020**, *16*, e1008410.
228. Caragata, E.P.; Rancès, E.; Hedges, L.M.; Gofton, A.W.; Johnson, K.N.; O'Neill, S.L.; McGraw, E.A. Dietary Cholesterol Modulates Pathogen Blocking by Wolbachia. *PLoS pathogens* **2013**, *9*, e1003459.
229. Geoghegan, V.; Stainton, K.; Rainey, S.M.; Ant, T.H.; Dowle, A.A.; Larson, T.; Hester, S.; Charles, P.D.; Thomas, B.; Sinkins, S.P. Perturbed Cholesterol and Vesicular Trafficking Associated with Dengue Blocking in Wolbachia-Infected Aedes Aegypti Cells. *Nature communications* **2017**, *8*, 526.
230. Kambris, Z.; Cook, P.E.; Phuc, H.K.; Sinkins, S.P. Immune Activation by Life-Shortening Wolbachia and Reduced Filarial Competence in Mosquitoes. *Science* **2009**, *326*, 134–136.
231. Rancès, E.; Ye, Y.H.; Woolfit, M.; McGraw, E.A.; O'Neill, S.L. The Relative Importance of Innate Immune Priming in Wolbachia-Mediated Dengue Interference. *PLoS pathogens* **2012**, *8*, e1002548.
232. Utarini, A.; Indriani, C.; Ahmad, R.A.; Tantowijoyo, W.; Arguni, E.; Ansari, M.R.; Supriyati, E.; Wardana, D.S.; Meitika, Y.; Ernesia, I. Efficacy of Wolbachia-Infected Mosquito Deployments for the Control of Dengue. *New England Journal of Medicine* **2021**, *384*, 2177–2186.

233. Pinto, S.B.; Riback, T.I.; Sylvestre, G.; Costa, G.; Peixoto, J.; Dias, F.B.; Tanamas, S.K.; Simmons, C.P.; Dufault, S.M.; Ryan, P.A. Effectiveness of Wolbachia-Infected Mosquito Deployments in Reducing the Incidence of Dengue and Other Aedes-Borne Diseases in Niterói, Brazil: A Quasi-Experimental Study. *PLoS neglected tropical diseases* **2021**, *15*, e0009556.
234. Dodson, B.L.; Pujhari, S.; Brustolin, M.L.; Metz, H.C.; Rasgon, J.L. Variable Effects of Wolbachia on Alphavirus Infection in *Aedes Aegypti*. *bioRxiv* **2023**, 2023.01.20.524939.
235. Loreto, E.L.S.; Wallau, G.L. Risks of Wolbachia Mosquito Control. *Science* **2016**, *351*, 1273–1273.
236. Sanaei, E.; Charlat, S.; Engelstädter, J. Wolbachia Host Shifts: Routes, Mechanisms, Constraints and Evolutionary Consequences. *Biological Reviews* **2021**, *96*, 433–453.
237. Edenborough, K.M.; Flores, H.A.; Simmons, C.P.; Fraser, J.E. Using Wolbachia to Eliminate Dengue: Will the Virus Fight Back? *Journal of virology* **2021**, *95*, e02203-20.
238. Thi Hue Kien, D.; Edenborough, K.M.; da Silva Goncalves, D.; Thuy Vi, T.; Casagrande, E.; Thi Le Duyen, H.; Thi Long, V.; Thi Dui, L.; Thi Tuyet Nhu, V.; Thi Giang, N. Genome Evolution of Dengue Virus Serotype 1 under Selection by Wolbachia Pipientis in *Aedes Aegypti* Mosquitoes. *Virus Evolution* **2023**, vead016.
239. Crawford, J.E.; Clarke, D.W.; Criswell, V.; Desnoyer, M.; Cornel, D.; Deegan, B.; Gong, K.; Hopkins, K.C.; Howell, P.; Hyde, J.S. Efficient Production of Male Wolbachia-Infected *Aedes Aegypti* Mosquitoes Enables Large-Scale Suppression of Wild Populations. *Nature Biotechnology* **2020**, *38*, 482–492.
240. Dobson, S.L.; Bordenstein, S.R.; Rose, R.I. Wolbachia Mosquito Control: Regulated. *Science* **2016**, *352*, 526–527.
241. Toghueo, R.M.K.; Kemgne, E.A.M.; Eke, P.; Kanko, M.I.M.; Dize, D.; Sahal, D.; Boyom, F.F. Antiplasmodial Potential and GC-MS Fingerprint of Endophytic Fungal Extracts Derived from Cameroonian *Annona Muricata*. *Journal of ethnopharmacology* **2019**, *235*, 111–121.
242. Hayibor, K.; Kwain, S.; Osei, E.; Nartey, A.P.; Tetevi, G.M.; Owusu, K.B.-A.; Camas, M.; Camas, A.S.; Kyeremeh, K. Ghanaian Mangrove Wetland Endophytic Fungus, *Penicillium Herquei* Strain BRS2A-AR Produces (9Z, 11E)-13-Oxooctadeca-9, 11-Dienoic Acid with Activity against *Trichomonas Mobilensis*. *International Journal of Biological and Chemical Sciences* **2019**, *13*, 1918–1937.
243. Shi, Y.-N.; Pusch, S.; Shi, Y.-M.; Richter, C.; Maciá-Vicente, J.G.; Schwalbe, H.; Kaiser, M.; Opatz, T.; Bode, H.B. (±)-Alternarolactones A and B, Two Antiparasitic Alternariol-like Dimers from the Fungus *Alternaria Alternata* P1210 Isolated from the Halophyte *Salicornia* Sp. *The Journal of organic chemistry* **2019**, *84*, 11203–11209.
244. Cappelli, A.; Valzano, M.; Cecarini, V.; Bozic, J.; Rossi, P.; Mensah, P.; Amantini, C.; Favia, G.; Ricci, I. Killer Yeasts Exert Anti-Plasmodial Activities against the Malaria Parasite *Plasmodium Berghei* in the Vector Mosquito *Anopheles Stephensi* and in Mice. *Parasites & vectors* **2019**, *12*, 1–8.
245. Niu, G.; Wang, B.; Zhang, G.; King, J.B.; Cichewicz, R.H.; Li, J. Targeting Mosquito FREP1 with a Fungal Metabolite Blocks Malaria Transmission. *Scientific reports* **2015**, *5*, 1–18.
246. Blanford, S.; Chan, B.H.; Jenkins, N.; Sim, D.; Turner, R.J.; Read, A.F.; Thomas, M.B. Fungal Pathogen Reduces Potential for Malaria Transmission. *Science* **2005**, *308*, 1638–1641.
247. Heinig, R.L.; Thomas, M.B. Interactions between a Fungal Entomopathogen and Malaria Parasites within a Mosquito Vector. *Malaria journal* **2015**, *14*, 1–10.
248. Fang, W.; Vega-Rodriguez, J.; Ghosh, A.K.; Jacobs-Lorena, M.; Kang, A.; St. Leger, R.J. Development of Transgenic Fungi That Kill Human Malaria Parasites in Mosquitoes. *Science* **2011**, *331*, 1074–1077.
249. Carballar-Lejarazú, R.; Rodriguez, M.H.; de la Cruz Hernández-Hernández, F.; Ramos-Castaneda, J.; Possani, L.D.; Zurita-Ortega, M.; Reynaud-Garza, E.; Hernández-Rivas, R.; Loukeris, T.; Lycett, G. Recombinant Scorpine: A Multifunctional Antimicrobial Peptide with Activity against Different Pathogens. *Cellular and Molecular Life Sciences* **2008**, *65*, 3081–3092.
250. Wilke, A.B.B.; Marrelli, M.T. Paratransgenesis: A Promising New Strategy for Mosquito Vector Control. *Parasites & vectors* **2015**, *8*, 1–9.
251. Wang, S.; Jacobs-Lorena, M. Paratransgenesis Applications: Fighting Malaria with Engineered Mosquito Symbiotic Bacteria. In *Arthropod Vector: Controller of Disease Transmission, Volume 1*; Elsevier, 2017; pp. 219–234.
252. Ratcliffe, N.A.; Furtado Pacheco, J.P.; Dyson, P.; Castro, H.C.; Gonzalez, M.S.; Azambuja, P.; Mello, C.B. Overview of Paratransgenesis as a Strategy to Control Pathogen Transmission by Insect Vectors. *Parasites & Vectors* **2022**, *15*, 112.

253. Wang, S.; Jacobs-Lorena, M. Transgenesis and Paratransgenesis for the Control of Malaria. In *Mosquito Gene Drives and the Malaria Eradication Agenda*; Jenny Stanford Publishing, 2023; pp. 21–37.
254. Huang, W.; Wang, S.; Jacobs-Lorena, M. Use of Microbiota to Fight Mosquito-Borne Disease. *Frontiers in genetics* **2020**, *11*, 196.
255. Yoshida, S.; Ioka, D.; Matsuoka, H.; Endo, H.; Ishii, A. Bacteria Expressing Single-Chain Immunotoxin Inhibit Malaria Parasite Development in Mosquitoes. *Molecular and biochemical parasitology* **2001**, *113*, 89–96.
256. Wang, S.; Ghosh, A.K.; Bongio, N.; Stebbings, K.A.; Lampe, D.J.; Jacobs-Lorena, M. Fighting Malaria with Engineered Symbiotic Bacteria from Vector Mosquitoes. *Proceedings of the National Academy of Sciences* **2012**, *109*, 12734–12739.
257. Wang, S.; Dos-Santos, A.L.; Huang, W.; Liu, K.C.; Oshaghi, M.A.; Wei, G.; Agre, P.; Jacobs-Lorena, M. Driving Mosquito Refractoriness to Plasmodium Falciparum with Engineered Symbiotic Bacteria. *Science* **2017**, *357*, 1399–1402.
258. Villegas, L.M.; Pimenta, P.F.P. Metagenomics, Paratransgenesis and the Anopheles Microbiome: A Portrait of the Geographical Distribution of the Anopheline Microbiota Based on a Meta-Analysis of Reported Taxa. *Memórias do Instituto Oswaldo Cruz* **2014**, *109*, 672–684.
259. Bongio, N.J.; Lampe, D.J. Inhibition of Plasmodium Berghei Development in Mosquitoes by Effector Proteins Secreted from Asaia Sp. Bacteria Using a Novel Native Secretion Signal. *PLoS One* **2015**, *10*, e0143541.
260. Mancini, M.V.; Spaccapelo, R.; Damiani, C.; Accoti, A.; Tallarita, M.; Petraglia, E.; Rossi, P.; Cappelli, A.; Capone, A.; Peruzzi, G. Paratransgenesis to Control Malaria Vectors: A Semi-Field Pilot Study. *Parasites & vectors* **2016**, *9*, 1–9.
261. Raharimalala, F.N.; Boukraa, S.; Bawin, T.; Boyer, S.; Francis, F. Molecular Detection of Six (Endo-) Symbiotic Bacteria in Belgian Mosquitoes: First Step towards the Selection of Appropriate Paratransgenesis Candidates. *Parasitology research* **2016**, *115*, 1391–1399.
262. Rocha, E.M.; Marinotti, O.; Serrão, D.M.; Correa, L.V.; Katak, R. de M.; de Oliveira, J.C.; Muniz, V.A.; de Oliveira, M.R.; do Nascimento Neto, J.F.; Pessoa, M.C.F. Culturable Bacteria Associated with Anopheles Darlingi and Their Paratransgenesis Potential. *Malaria journal* **2021**, *20*, 1–9.
263. Tzschaschel, B.D.; Guzmán, C.A.; Timmis, K.N.; Lorenzo, V. de An Escherichia Coli Hemolysin Transport System-Based Vector for the Export of Polypeptides: Export of Shiga-like Toxin IiEb Subunit by Salmonella Typhimurium AroA. *Nature biotechnology* **1996**, *14*, 765–769.
264. Riehle, M.A.; Moreira, C.K.; Lampe, D.; Lauzon, C.; Jacobs-Lorena, M. Using Bacteria to Express and Display Anti-Plasmodium Molecules in the Mosquito Midgut. *International journal for parasitology* **2007**, *37*, 595–603.
265. Favia, G.; Ricci, I.; Marzorati, M.; Negri, I.; Alma, A.; Sacchi, L.; Bandi, C.; Daffonchio, D. Bacteria of the Genus Asaia: A Potential Paratransgenic Weapon against Malaria. *Transgenesis and the management of vector-borne disease* **2008**, 49–59.
266. Dehghan, H.; Mosa-Kazemi, S.H.; Yakhchali, B.; Maleki-Ravasan, N.; Vatandoost, H.; Oshaghi, M.A. Evaluation of Anti-Malaria Potency of Wild and Genetically Modified Enterobacter Cloacae Expressing Effector Proteins in Anopheles Stephensi. *Parasites & Vectors* **2022**, *15*, 63.
267. Ward, T.W.; Jenkins, M.S.; Afanasiev, B.N.; Edwards, M.; Duda, B.A.; Suchman, E.; Jacobs-Lorena, M.; Beaty, B.J.; Carlson, J.O. Aedes Aegypti Transducing Densovirus Pathogenesis and Expression in Aedes Aegypti and Anopheles Gambiae Larvae. *Insect molecular biology* **2001**, *10*, 397–405.
268. Carlson, J.; Suchman, E.; Buchatsky, L. Densoviruses for Control and Genetic Manipulation of Mosquitoes. *Advances in virus research* **2006**, *68*, 361–392.
269. Ren, X.; Hoiczky, E.; Rasgon, J.L. Viral Paratransgenesis in the Malaria Vector Anopheles Gambiae. *PLoS pathogens* **2008**, *4*, e1000135.
270. Johnson, R.M.; Rasgon, J.L. Densonucleosis Viruses (‘Densoviruses’) for Mosquito and Pathogen Control. *Current opinion in insect science* **2018**, *28*, 90–97.
271. Rasgon, J.L. Using Infections to Fight Infections: Paratransgenic Fungi Can Block Malaria Transmission in Mosquitoes. *Future microbiology* **2011**, *6*, 851–853.
272. Commission Regulation (EU) 2022/1438 of 31 August 2022 Amending Annex II to Regulation (EC) No 1107/2009 of the European Parliament and of the Council as Regards Specific Criteria for the Approval of Active Substances That Are Micro-Organisms (Text with EEA Relevance); 2022; Vol. 227;.

273. Rezende-Teixeira, P.; Dusi, R.G.; Jimenez, P.C.; Espindola, L.S.; Costa-Lotufo, L.V. What Can We Learn from Commercial Insecticides? Efficacy, Toxicity, Environmental Impacts, and Future Developments. *Environmental Pollution* **2022**, 118983.
274. Whitford, F.; Pike, D.; Burroughs, F.; Hanger, G.; Johnson, B.; Brassard, D.; Blessing, A. The Pesticide Marketplace, Discovering and Developing New Products. *PPP-71*. Available on-line at: <http://www.ppp.purdue.edu/Pubs/ppp-71.pdf> **2006**.
275. Roadmappers, T.I. A Roadmap for the Development of Ivermectin as a Complementary Malaria Vector Control Tool. *The American journal of tropical medicine and hygiene* **2020**, 102, 3.
276. Koul, O. Biopesticides: Commercial Opportunities and Challenges. *Development and Commercialization of Biopesticides* **2023**, 1–23.
277. Deshayes, C.; Siegwart, M.; Pauron, D.; Froger, J.-A.; Lapied, B.; Apaire-Marchais, V. Microbial Pest Control Agents: Are They a Specific and Safe Tool for Insect Pest Management? *Current medicinal chemistry* **2017**, 24, 2959–2973.
278. Beech, C.; Rose, N.; Dass, B. Regulation of Transgenic Insects. In *Transgenic Insects: Techniques and Applications*; CABI GB, 2022; pp. 493–517.

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