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Herbal Nanoemulsion-Based Mosquitocidal Formulations: A Sustainable Approach for Controlling Aedes aegypti and Dengue Prevention

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Abstract: Dengue fever, a mosquito-borne viral disease, has become a major public health concern worldwide. The primary vector, Aedes aegypti, has shown increasing resistance to conventional insecticides, necessitating the development of eco-friendly and effective alternatives. Herbal nanoemulsions, formulated from plant-derived essential oils, present a promising solution due to their enhanced bioavailability, biodegradability, and potent larvicidal activity. This review explores the potential of herbal nanoemulsions as mosquitocidal agents, their mechanism of action, formulation techniques, and their advantages over synthetic insecticides. Furthermore, challenges in large-scale production, stability, and field applicability are discussed. The review highlights the need for further research and regulatory approvals to integrate herbal nanoemulsions into vector control programs effectively.

Keywords: Mosquitocidal nanoemulsion, Aedes aegypti, dengue vector control, herbal insecticides, essential oils

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INTRODUCTION

According to the globe Health Organization (WHO), dengue fever is the mosquito-borne illness that is expanding at the fastest rate in the globe. According to Paula et al. (2011), the worldwide distribution of dengue fever is equivalent to that of malaria, and there is still the chance of epidemic transmission. In his 2009 article, Bagachi brought attention to the incidence of dengue in India.

Currently, the globe Health Organization (WHO) believes that there might be fifty million cases of DF infection all over the globe each year (WHO, 2011). The development of vaccines is still in its early stages; hence, the only strategy that is now available for lowering the occurrence of the illness is the suppression of the mosquito that is the vector for the sickness.

The dengue virus, also known as DENV (DENV-1, DENV-2, DENV-3, and DENV-4), is an enclosed virus that has a single strand of RNA, a positive sense of RNA, and an envelope. It belongs to the family Flaviviridae and is classified as a member of the genus Flavivirus. The Aedes aegypti and Aedes albopictus mosquitoes are the most common vectors by which the disease is spread to humans (Dutta et al., 2006; Kamgang et al., 2011).

Since 1992, the Regional Medical Research Centre (ICMR) in Dibrugarh, Assam, has been conducting a viral sero-surveillance research. During this time, dengue virus antibody has been found in the districts of Dibrugarh, North Lakhimpur, Dhemaji, and Golaghat in the state of Assam. In the year 2010, the first fatality from dengue fever in the state of Assam was documented in Dibrugarh (Baruah and Dutta, 2012). Nevertheless, in the year 2012, there was an unprecedented number of dengue infestations in a variety of regions across the state of Assam.

CONTROL MEASURES OF AEDES AEGYPTI

Chemical control: Despite the fact that the involvement of mosquitoes in the transmission of illnesses among humans has long been recorded, there was still no scientific evidence accessible until the beginning of the 20th century. As a consequence of this, public health programs throughout the course of the last century have been aiming to limit the mosquito vector population to a certain level. In the past, the discovery of various insecticide chemicals, such as dichloro diphenyltrichloroe thane (DDT), carbamates, and pyrethroid, among others, offered a method for reducing the number of mosquitoes in the population. However, the persistent overuse of these chemicals had resulted in a significant setback, including the development of insecticide resistance as well as significant negative effects on the environment and other organisms that were not intended to be targeted. An increasing geographical range of dengue's vectors, Aedes aegypti and Aedes albopictus, along with the negative impact of insecticides and the absence of the appropriate vaccine have necessitated the search for an alternative measure that can reduce the vector mosquito population to a greater extent. The emerging risk of dengue epidemic, which is estimated to cause 390 million infections annually, has reached a point where 3.97 billion people are at risk. Biological control is a strategy that has been used widely in a variety of pest management programs owing to the fact that it is environmentally benign and does not have any other negative impact on creatures that are not the intended targets. Taking use of the predation, competition, or parasitism characteristics of arthropods, this strategy involves the utilization of live creatures in order to reduce the negative impacts that arthropods have on the environment, agricultural practices, or public health (Okamoto, 2012). It has been shown that environmental management, including the removal of breeding supplies, leads to positive results. Nevertheless, it needs ongoing upkeep, which makes it a challenging task to undertake in metropolitan contexts that are deficient in resources. The present dengue control tactics in resource-poor third world settings have been greatly reduced as a result of the use of biological control programs. It is possible to conduct extensive disease transmission control via the use of biological control, which also has the capability of implementing species-specific treatments with little to no impact on human beings.

Biological Control: The term "biological control" refers to a technique that utilizes a combination of natural agents, both biotic and abiotic, to regulate a population up to the level equivalent to the economic threshold. Control techniques for vector mosquito species have been implemented using natural agents such as entomopathogens, bacteria, viruses, bugs, mesocyclops, nematodes, protozoa, and fungus. These natural agents have been considered effective. For the purpose of mosquito control, the use of microorganisms like Bacillus sphaericus (Bs) and Bacillus thuringiensis israelensis (Bti) has been considered to be an essential armament (Pérez et al., 2012).

Use of botanicals: Within the aquatic stages of Aedes aegypti, the use of botanicals has been seen as a potentially effective biological control technique. According to Shaalan et al. (2005), hundreds of different plant species have been examined to see how effective they are against mosquitoes. It has been shown that the use of botanicals against Aedes aegypt is based on the by-products of plants that are currently being used for commercial advantage or on plants that are already recognized as therapeutic. In earlier research, it was shown that extracts from avocado seeds were capable of killing Aedes aegypti larvae (Leite et al., 2009). In a similar vein, extracts of unripe black pepper were shown to be efficient in eliminating pyrethroid-resistant Aedes aegypti (Simas et al., 2007). Twelve Mexican medicinal herbs were examined by Eyes-Villanueva et al. (2008), and they were found to have varying degrees of toxicity. Some of the plants were found to be quite poisonous, while others showed very little larvicidal activity. The medicinal herb Azadirachta indica is well-known for its effectiveness against mosquitoes, as shown by the extensive research conducted on the topic (Howard et al., 2009; Fallatah and Khater, 2010). at a study conducted by Wandscheer et al. (2004), it was discovered that neem was effective against dengue vectors even when administered at very modest levels.

Larvivorus fish: The number of mosquitoes that are capable of spreading several illnesses is significantly reduced by the presence of fish predators, which play a vital part in this process. It has been used as a mosquito predator since the early 20th century, and it is one of the most regularly used strategies of biological control against malaria in many countries (Scholte, 2004). Larvivorous fish have been used for this purpose. The first time that the Caribbean fish, namely Gambusia affinis and Gambusia holbrooki's, were shown to have a preference for mosquito larvae was in the year 1904. The introduction of Gambusia into Mississippi in 1918 led to a significant reduction in the number of cases of malaria that occurred after that. In spite of this, it has a detrimental effect on the habitats that are nearby, as well as the fact that it outcompetes local fish of comparable habitat and size, consumes the eggs of amphibians like frogs, and leads to a decrease in the number of arthropod populations. In addition, research has shown that mosquito larvae populations make up a very little fraction of the fishes' diet (Pyke, 2008).

Arthropod: Through a variety of scientific investigations, it has been shown that arthropods, namely Mesocyclops copepods, are effective biocontrol agents. According to Kay et al. (2005), the eradication of Aedes aegypti from 32 tiny settlements located in rural parts of Northern and Central Vietnam was achieved by the use of a bio-control agent that was used in public wells or big water containers.

Birds: There are few bird species that are somewhat effective at controlling mosquito populations. Tree swallows *Tachycineta bicolor* are the most effective in mosquito killing. The adult and juvenile of waterfowl species and migratory songbirds are reported as predator of mosquito larvae. Purple martins *Progne subis*) is regarded as an excellent predator of mosquito but detail studies have shown that mosquitoes comprise only 0 to 3 percent diet of it (Johnston 1967).

Mammals: Bats, which are classified as mammalian predators, play a vital role in the ecosystem and have the potential to act as natural pest control agents. However, their responsibility to control mosquitoes is not very large. Each hour, the bats may consume anywhere from 500 to 1200 insects. In addition to the fact that they are more likely to be located in vegetation rather than in regions where bats typically eat, mosquitoes only make up a tiny fraction of their diet. This is due to the fact that they only supply a little quantity of energy. In contrast, the Little Brown Bat Myotis lucifugus is far more likely to consume mosquitoes than the Big Brown Bat Eptesicus fuscus, which consumes hardly little food at all. Their food consists mostly of spiders, dipterous insects, and other insects, with the exception of mosquitoes.

Amphibia and Reptile: Unfortunately, neither amphibians nor reptiles are capable of effectively controlling mosquito populations. In spite of the fact that the cricket frog, the chorus frog, and the spring peeper consume mosquitoes, this does not have an effect on the population of these different species. In North America, studies have demonstrated that tadpoles and various species, such as the spade-foot toad (Barber and King 1927), the green tree frog (Ritchie 1982), and the giant tree frog (Spielman and Sullivan 1974), play a role in the predation of mosquitoes. In a similar manner, species from other regions of the world, such as the European green toad, the sandpaper frog, the Indian bullfrog, and the coroneted tree frog, among others, have been found to be predators of mosquitoes. Tadpoles have been shown to interact with mosquitoes in their natural surroundings (Barber and King 1927), and it has been suggested that this interaction has the potential to significantly decrease the number of mosquitoes in the environment (Ritchie 1982; Spielman and Sullivan 1974; Willems et al. 2005).

Controphic species: Even though the predatory creatures have been effective in limiting the mosquito population, they continue to have an impact on the aquatic biodiversity. This has led to the investigation of other potential solutions, such as the introduction of species that are classified as controphic. There are species that are considered to be controphic if they are found at the same trophic level in the food chain. There is a possibility that the introduction of this species into the environment of mosquito larvae might result in competition for resources and have an impact on the mosquito population. In the laboratory experiment, it was shown that the introduction of controphic species into a pool results in the species engaging in competition for food particles with mosquito larvae that belong to the same trophic level. This competition ultimately leads to a reduction in the number of mosquitoes in the pool (Blaustein and Chase, 2007). According to research conducted by Kershenbaum (2012), female mosquitoes are less likely to oviposit in breeding grounds that include larger concentrations of controphic species. There has not been a significant amount of study conducted on the ecological interaction between mosquito larvae and controphic species; thus, further research is required in order to get a better knowledge in the workplace.

Toxorhynchites mosquito: A number of researchers have looked at the possibility of using Toxorhynchites mosquitoes as a means of the biocontrol of Aedes aegypti. (Steffan and Evenhuis, 1981) Toxorhynchites are a kind of mosquito that are active during the day and exhibit a significant cannibalism. The largest larvae of their species are able to readily consume the smaller larvae of their own species. According to C. lark-Gil and Darsie (1983), toxorhynchites often lay their eggs in rock depressions and tree holes, as well as in the axils of bromeliads and cut bamboo cane, all of which are places where they can locate live mosquito larvae as food. Rubio and Ayesta (1984) discovered that Toxorhynchites mosquitoes lay their eggs in water containers, such as abandoned tires, buckets, cans, and cemetery flowerpots. These water containers included larvae of domestic mosquitoes, such as Culex spp. and Aedes aegypt and Aedes albopictus (Rubio and Ayesta, 1984). In the field, there were reports of a limited number of studies that evaluated the effects of Toxorhynchites adults that were released in regions that had containers constructed by humans that contained Aedes aegypti larvae. It was discovered that one fourth instar of T. revipalpis that lives in tires eats around twelve Aedes aegypti larvae over the course of twenty-four hours at temperatures ranging from twenty-two to twenty-five degrees Celsius, while in the laboratory, they ingest sixteen prey larvae on average at temperatures of twenty-six degrees Celsius (Trpis, 1972).

APPLICATION OF DIFFERENT FUNGAL STRAINS FOR MOSQUITO CONTROL

***Beauveria bassiana*:** One of the most significant insect pathogenic fungus, Beauveria bassiana, is a member of the deuteromycetes class and is responsible for the white muscardine illness that affects the host. A number of insect species, including vectors of tropical infectious diseases like the tsetse fly (Glossina morsitans), the sand fly (Phlebotomus sp.), various bugs like Triatoma and Rhodnius, agricultural pests like the colorado potato beetle, the codling moth, several genera of termites, Helicoverpa armigera, and others, are susceptible to its growth in the soil. Sandhu et al. (1993), Jain et al. (2008), and Thakur and Sandhu (2010) are among the insect species that are susceptible to its pathogenic properties. 22 of the 49 species of B. bassiana have been identified as being extremely pathogenic, according to a paper that was published in 2003 by Kirk and Terry.

In the year 1815, the species B. bassiana was identified for the very first time as a potential agent responsible for the muscardine sickness that affects silkworms. The use of B. bassiania as a powerful biocontrol agent against mosquitoes has also been documented. Culex tarsalis, Culex pipiens, and Anopheles albimanus were the three species of mosquitoes that were found to be infected with the fungus for the first time since it was initially reported by Clark et al. in 1968. Other species of the genus Beauveria, namely brongniartii (Saccardo) Petch, were responsible for an epizootic that occurred in the species of mosquito known as Ochlerotatus sierrensis (Pinnock et al. 1973). Spores, also known as conidia, are produced by the fungus Beauveria during the process of sporulation. These spores are hydrophobic and have a high level of effectiveness in eliminating mosquito larvae. Furthermore, the head of the mosquito is also an equally significant infection location, as was described before (Miranpuri and Khachatourians, 1991).

Leptolegnia spp.: Insect pathogenic fungus belonging to the genus Leptolegina, which is classified as oomycete, have been considered to be of significant importance. A small number of species belonging to the genus Leptolegina have consistently shown their ability to cause disease in a variety of insects, including mosquito larvae, while having little to no impact on creatures that are not the intended targets. According to McInnis and Zattau (1982), the two species of Leptolegnia, including L. caudata and L. chapmanii, have been isolated from insects like L. caudata.

Leptolegnia caudata was found to be isolated from Anopheles culicifacies, according to a paper that was published in 1996 by Bisht et al. It has been claimed that the inclusion of the fungus in biocontrol campaigns has been beneficial in reducing the transmission of malaria. This is due to the fact that the fungus has a harmful impact on Anopheles culicifacies larvae, which resulted in the same larvae dying at a rate of one hundred percent after being treated with seven times 103 L-1 zoospores within seven days. Similarly, Leptolegnia chapmanii is another virulent infection that was shown to be responsible for the death of one hundred percent of Aedes aegypti (L.) larvae in their first and second instars after being exposed to it for twenty-four hours. However, McCinnis and Zattau (1982) found that the efficiency of the treatment decreased to less than forty percent in the third and fourth instars of Aedes aegypti. The death rate of Anopheles gambiae larvae was reported to be one hundred percent by Nnakumusana (1986) after 72 hours of exposure to the fungus. In addition, a similar experiment was carried out in Florida on the salt marsh mosquito, which was identified as Ochlerotatus taeniorhynchus Wiedemann. The results of this experiment revealed that the fungal strain was not effective in causing infection in mosquito populations that were exposed to salt water (Lord et al., 1988).

***Pythium spp.*:** Despite the fact that the majority of the species belonging to the genus Pythium are known to cause disease in vascular plants, only a handful of these species are known to cause disease in insects (Van der Plaats-Niterink 1981). One of the members of the Oomycetes class is pythium. An experiment was conducted with a Pythium species that was not identified, and the results showed that the fungus is pathogenic to Aedes aegypti, Aedes africanus (Theobald), Aedes simpsoni (Theobald), Culex quinquefasciatus, Culex tigripes Grandpré and Charmoy, and Anopheles gambiae. Furthermore, fifty to one hundred percent mortality rates were recorded on Anopheles gambiae, according to Nnakumusana in 1985. It was reported that the fungus was highly pathogenic to the tree hole mosquito, Ochlerotatus sierrensis. The fungus was also considered to be an opportunistic entomopathogen due to the fact that it is more likely to infect larvae that have been mechanically wounded as opposed to larvae that are healthy. Those larvae which were mechanically injured and killed by the opportunistic entomopathogen are Anopheles freeborni Aitken, Ochlerotatus sierrensis, Ochlerotatus triseriatus (Say), Culex tarsalis Coquillet, Culiseta incidens (Thomson), Culiseta inornata (Williston), Orthopodomyia californica Bohart, and Uranotaenia anhydor (Clark et al., 1966).

***Nomuraea rileyi*:** While it is classified as a member of the Deuteromycetes class, Nomuraea rileyi is also considered to be a Fungi Imperfecti. The fungus has the potential to be an entomopathogen and has a widespread distribution. It mostly infects Noctuoideans, which include Spodoptera litura, Helicoverpa (Heliothis) armigera, Trichoplusia ni, Plusia etc., and other species. Following the formation of a budding bud from the germ tube of the connected conidium, the fungus will undergo its first stage of growth. Hyphal bodies are formed, and they create a growth that is sticky, creamy in color, and smells sweet and musty. Following this, sporulation takes place, which then makes its way throughout the colony.

Despite the fact that the fungus is mostly found in noctuoidean moths, caterpillars, and butterflies, there have been reports of two species of coleopters being vulnerable to the infection. During the course of an experiment conducted by Puttier et al. (1976), the conidia of Nomuraea rileyi were tested against the second instars of nine different species of caterpillars. The results of the experiment revealed that the species with the highest susceptibility to N. rileyi infection was spodoptera exigua (Hubner), while Anticarsia geimataiis (Hubner) had the lowest susceptibility. Only one species of cabbageworm, Artogeia rapae (L.), was not affected by the fungus. There was no other species that was affected. Onofre et al. (2002) conducted a research in which they used Nomuraea rileyi to synthesize peptides that were effective against Anticarsia gemmantalis larvae in their third instar. The results of this study showed that the greatest death rates ranged from 82.66% to 80.00% for the concentrations of 1.0, 0.2, and 0.1 mg/ml of the peptide concentration. Namasivayam et al. (2015) also reported the biocontrol potentiality of the fungus Nomuraea Rileyi (F.) Samson against the groundnut defoliator Spodoptera litura (lepidoptera; Noctuidae). They also revealed the impact of the fungus on all of the life stages, the duration of the larval stages, the mortality of the larvae, as well as the LC50 and LT50 values of the groundnut defoliator. As a result of the application of dosage concentrations of 106,105, 104,103, and 102 spores per milliliter, the total length of the larval periods was found to be shorter in comparison to the control, which recorded 17.1 days. In a similar manner, the adult emergence rate was recorded at 12.0 and 10.0 percent at a concentration of 103 to 102 Spores/ml, and the adult longevity rate was reported at 4.1 and 5.0 hours at the same concentration. The natural presence of the fungus N. rileyi in Helicoverpa armigera larvae in Brazil was described by Costa et al. (2015). This fungus was responsible for 33.1% of the overall mortality caused by the fungus.

***Aspergillus Niger*:** Aspergillus niger is a species that belongs to the phylum ascomycota and is regularly found on every continent of the globe. It is one of the most widely distributed species. The fungus known as Aspergillus niger has been isolated from every continent known to science and is mostly reliant on the circumstances of its habitat. A saprophytic style of life is shown by the fungus, which grows mostly on decomposing vegetations such as dead leaves, grain, compost heaps, and other decomposing vegetations. Furthermore, the fungus Aspergillus niger is responsible for the production of some toxins that may cause severe illness and even death in people who have a compromised immune system. After 96 hours of exposure, the entomopathogenic nature of the fungus was discovered by administering three different conidial concentrations to red spider mites: 1x106, 1x107, and 1x108 conidia/ml. The results showed that the mites died at a rate of 91.11% (Mazid et al., 2015). Aspergillus niger culture filtrate was reportedly tested on the larvae of Culex quenquefasciiatus, Anopheles stephensi, and Aedes aegypti. The results of these tests were published. The result showed that the culture filtrate of the fungus has the potential to control all the three vector mosquito species, with the LC50, LC90, and LC99 values like for Culex quinquefasciatus (0.76, 3.06, and 4.75), Anopheles stephensi (0.76, 3.06, and 4.75) and for Ae. aegypti (1.43, 2.2, and 4.1) after seven hours of exposure (Singh and Prakash, 2012). In a different study, the entomopathogenic fungus Aspergillus niger was applied to Dysdercus koenigii (Heteroptera: Pyrrhocoridae) in order to examine its impact on the haemocytes and the antioxidant enzymes SOD and catalase. The results of this investigation showed that the total haemocyte counts of the insect decreased in both sexes after the introduction of the fungus. (Kumari, 2015) discovered that the levels of the enzymes SOD and CAT were much higher in females than they were in males.

***Aspergillus fumigatus*:** Aspergillus fumigatus is a kind of saprophytic fungus that may be found almost everywhere in the soil, mostly in the organic matter that is decomposing. When it comes to the process of recycling carbon and nitrogen in the natural world, they are a very important component. Despite the fact that it was previously believed that they had an asexual method of reproduction, it was not until later in 2008 that it was discovered that they also have a sexual modes of life. It is possible that the mycotoxins and enzymes, such as catalase and elastase, that are produced by Aspergillus species might make it easier for the fungus to grow on the host tissue. In a similar manner, the immunosuppressive drug that is produced by the fungal species also creates material that assists in tissue penetration. As the fungus undergoes the process of sporulation, it produces thousands of conidia, each of which has a diameter of 2 to 3 µm. These conidia have the potential to reach the alveoli of the lungs, causing disorders related to allergies. Furthermore, they may even induce fungal disease of the cavities of the lungs, as stated by Dixon and Walsh in 1992 and Pennington in 1994. The fungal strain A. fumigatus ATCC 26933 was found to have the greatest levels of gliotoxin production (350 ng/mg hyphae), and it was also shown to be extremely harmful to Galleria mellonella (Reeves et al., 2004).

FACTORS AFFECTING PATHOGENICITY OF THE ENTOMOPATHOGENIC FUNGI

The effective application and exploitation of entomopathogenic fungi is contingent upon a variety of environmental circumstances. Temperature and relative humidity (RH) in the environment have been discovered to have a significant impact on the progression of fungal infections on the host, namely the germination of conidial cells and the establishment of colonies (Feng et al., 1994). According to Milner et al. (1997) and Luz and Fargues (1999), fungi have the ability to effectively infect the body of an insect if the environment presents the necessary conditions, such as a high relative humidity and an acceptable temperature. Entomopathogenic fungi, on the other hand, have their development and pathogenic potential severely restricted under harsh circumstances, such as high temperatures, photon irradiance, water stress, and fluctuating concentrations of organic and inorganic solutes (Inglis et al., 2001).

HERBAL NANOEMULSIONS: COMPOSITION AND MECHANISM OF ACTION

Nanoemulsions are stable, nanosized oil-in-water or water-in-oil dispersions that enhance the bioavailability and efficacy of active compounds. The inclusion of herbal extracts with mosquitocidal properties in nanoemulsions improves their stability, penetration, and targeted action.

- **Plant-Derived Bioactive Compounds:** Essential oils from neem (Azadirachta indica), citronella (Cymbopogon nardus), eucalyptus (Eucalyptus globulus), and other medicinal plants exhibit potent larvicidal and adulticidal effects.
- **Nanoemulsion Formulation:** The preparation process involves high-energy (ultrasound, high-pressure homogenization) or low-energy methods (spontaneous emulsification) to achieve nanosized droplets.
- **Mode of Action:** Herbal nanoemulsions disrupt mosquito larvae development by targeting their nervous system, respiratory mechanisms, and cuticle integrity.

ADVANTAGES OF HERBAL NANOEMULSION-BASED MOSQUITOCIDES

Compared to conventional insecticides, herbal nanoemulsions offer several benefits:

- **Enhanced Bioavailability:** Nanosized droplets ensure better dispersion and penetration into mosquito breeding habitats.
- **Reduced Toxicity:** Lower environmental impact and minimal toxicity to non-target organisms.
- **Resistance Management:** Alternative mode of action helps mitigate the development of insecticide resistance.
- **Eco-Friendly and Biodegradable:** Derived from natural plant sources, they pose minimal risk to human health and ecosystems.

EFFICACY OF HERBAL NANOEMULSIONS AGAINST AEDES AEGYPTI

Recent studies have demonstrated the potent larvicidal and adulticidal effects of herbal nanoemulsions:

- **Neem Oil-Based Nanoemulsions:** Effective at low concentrations, causing significant mortality in Aedes aegypti larvae.
- **Citronella and Eucalyptus Formulations:** Show prolonged residual activity and high repellency against adult mosquitoes.
- **Synergistic Combinations:** Blends of essential oils enhance efficacy through multiple modes of action.

CHALLENGES AND FUTURE PROSPECTS

Despite their advantages, several challenges must be addressed for large-scale implementation:

- **Stability and Shelf-Life:** Optimization of formulations for prolonged storage and effectiveness.
- **Regulatory Approvals:** Standardization and toxicological evaluations for commercial use.
- **Field Application Studies:** Large-scale trials to assess real-world efficacy and economic feasibility.
- **Integration with Vector Control Programs:** Combining with other mosquito control strategies for comprehensive dengue prevention.

CONCLUSION

Biological control is a technique that may be used to reduce or control the population of undesired insects, other animals, or plants. This is accomplished by the importation, encouragement, or artificial growth of their natural enemies to levels that are not economically significant. According to Weeden et al. (2007), it has been used extensively as a significant component of integrated pest management (IPM) systems. It is possible for biocontrol agents to take the form of predators, parasites, or diseases, and their primary function is to either eliminate dangerous species or disrupt the biological processes of those organisms (Freedman, 1976; Zhang et al., 2007; Van Lenteren, 2000; Luff, 1983). Biological control is considered to be one of the most secure ways of pest management owing to the fact that the agents used in biological control are non-toxic and do not leave any trace behind. The Mynah bird, also known as Acridotheres tristis, was brought to Mauritius from India in 1762 for the purpose of controlling the sugar cane red locust, also known as Nomadacris septemfasciata. This event marked the beginning of the history of biological control. (Shahid and others, 2012).

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