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Integrated Approach for Mosquito Control

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Mosquito is an important vector in tropical and subtropical areas of the world that transmit numerous diseases affecting human beings as well as animals. The most common being malaria, Chikungunya, Dengue, Filariasis, encephalitis, and Zika virus in human beings. In animals they transmit dog heart worm, bird malaria, Eastern equine encephalitis and West Nile encephalitis. The most prevalent mosquito species are *Plasmodium vivax, Anopheles culicifacies, Plasmodium falciparum, Anopheles stephensi, P. malariae , Aedes ageypti, P. ovale* and *P. knowlesi.*

To control the menace of mosquitoes, researchers have attempted and formulated strategies to control mosquitoes and thereby the vector borne diseases. There is lack of effective treatment for these diseases in the form of vaccines or drugs, so vector control is the only possible way for prevention (Benelli et al., 2016). The control is directed mainly against the developing larvae or adults and removal of breeding sites. An integrated control strategy employs different types of control like chemical control,biological control, environmental control and genetic control.

CHEMICAL CONTROL

- Larvicidal compounds: Larvicides target larvae in the breeding habitat before they can mature into adult mosquitoes. Larvicidal treatment of breeding habitats helps reduce the adult mosquito population, these compounds are sprayed periodically during the breeding season over the breeding places like Paris green mixed with kerosene. Larvicidal films are generally used for controlling mosquito pupae. Mosquito pupae live in water but do not feed, which makes other larvicides ineffective. Oils and films are usually applied to standing water's

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surface, reducing the surface tension of the water which makes it difficult for mosquito larvae and pupae to attach to the surface and breathe.

- Adulticides may be applied as space sprays, mists, or fogs to kill adult mosquitoes and includes the groups like
- Organophosphates - Malathion, Difenphos, Fenthion etc,
- Chlorinated hydrocarbons like Dieldrin, Chlordane, Hexachloro cyclohexane, BHC, Lindane
- Pyrethrins and pyrithroids- Pyrethrins are plant-derived insecticides that work by altering nerve function in insects. The end result is that the insect is paralyzed and eventually dies. Eg- Allethrin, Permethrin, deltametrin, cypermethrin.
- Insect Growth Regulators- Methoprene is an insect growth regulator widely used which mimics an insect hormone to prevent immature insects from shedding its exoskeleton and emerging into adults. As it is unable to develop into adults, the mosquitoes die in the pupal stage.
- Use of mosquito repellent -The repellent activity help avoid the bites of disease carrying mosquitoes like Indalane, Dimethyl phalate, DEET (N, N-diethyl-m-toluamide), Picaridin and 2-undecanone (methyl nonyl ketone)

ENVIRNMENTAL CONTROL:

It is holistic approach to eliminate mosquito breeding by environmental modification and manipulation. It is ecofriendly, cost effective and can tackle the problems of insecticide resistance.

Source reduction/Habitat management: Destruction of mosquitoes breeding sites

- Removal of standing water in gutters, old tyres, puddles, burrow pits or any other container where mosquitoes can breed.
- Emptying and changing the water in bird baths, fountains, pools, barrels and plant trays to eliminate potential mosquito habitats.
- Drainage of temporary pools of water or fill with dirt.
- Discarding old containers which hold water
- Proper covering of stored water
- Canalizing drains prevent water stagnation.
- Periodical emptying of domestic water containers,
- Sealing of overhead water tanks
- Filling of pot holes

Environmental modification and manipulation:

- Leveling of land or filling of depression, construction of soakage pits held in prevention of mosquito breeding.

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- Good engineering practices especially in dam construction, irrigation, channels, seepage water management provide permanent solution for mosquito control.
- Use of expanded polystyrene beads (EPS) in confined water bodies viz. in abandoned wells completely prevents mosquito breeding.
- Use of Physical barriers like screens, bed nets

BIOLOGICAL CONTROL:

Biological control agents include a wide variety of pathogens, parasites and predators. mosquitoes can be controlled using natural enemies such as bacteria, virus, protozoa, fungi, plants, nematodes, larvivorous fishes.

Predators

- Natural enemies feeding on mosquito larvae and pupae in aquatic environments Fish, copepods (small crustaceans), dragonfly and damselfly nymphs, and frogs will eat mosquito larvae. Frogs, dragonfly and damselfly adults, birds, and bats will eat adult mosquitoes. Depending on seasons and habits, some natural predators co-exist with mosquito larva like water beetle, mesocyclops, notorectial bugs etc. These have shown anti- larval activity (Mahar and Ridgway ,1993). Further odonates such as Anax, Brachydiplax etc, water bugs such as Diplonychus, and some lizards like Hemidactylus may also use in integrated vector management of mosquitoes
- The larvae of beetle *Acilius salcatus* is an efficient predator of mosquito larvae and may be useful tool for biocontrol of mosquitoes.
- Adult frogs are carnivorous and consume annelids, gastropods and arthropods including mosquitoes. The tadpoles of Bufo, Ramanella, Euphlyctis, Hoplobatrachus, Polypedates species etc actively prey on the eggs of *Aedes aegypti*.
- Larviparous fishes like *Gambusia affinis* (mosquitofish.,common guppy), *Poecilia reticulate*, *Lepomis* sp, *Cyprinus* sp, *Tilapia* cyprinids , *Centrarchus* sp, *Fundulus* species, *Ctenopharyngodon idella*, *Esomus dandricus*, *Clarias fuscus* , *Nothobranchius* sp , *Cynolebias* sp, *Ahanius dispar* (Dispar topminnow), *Aplocheilus lineatus* (Malabar killie), *Colisa fasciatus* (Giant gourami), *Colisa lalia* (Dwarf gourami), *Oryzias melastigma* (Estuaring ricefish), *Carassius auratus* (Gold fish), *Xenentodon cancila* (Freshwater gar fish), *Oreochromis niloticus* (Nile Tilapia) etc. fish consume mosquito larvae and pupae and can survive in varying water conditions. They are mostly surface feeders and efficient mosquito predators, consuming more than 100 mosquito larvae per day. and are capable of quickly populating a source if conditions are favourable (Chandra et al.,2008).
- Copepods are aquatic crustaceans that eat early instars of mosquito larvae and can be added to areas where water is not drained drain. Copepods like *Cyclops vernalis*, *Megacyclops*

formosanus, *M aspericornis* , *M. guangxiensis*, and *M. thermocyclopoides* can be used in control of mosquitoes,

- The larvae of some Culicidae species like Toxorhynchites (elephant mosquito /mosquito eater) is a large, cosmopolitan genus of mosquitoes that does not consume blood but fed on larvae stages of other mosquito species and often turn cannibalistic. It can consume 400 larval mosquitoes during their larval growth

Microbial Insecticides

A common naturally occurring soil bacterial larvicide *Bacillus thuringiensis israelensis* (Bti) is a bacterium that produces a protein crystal that, when eaten by a mosquito larva, destroys the larvae's intestinal lining and it only affects mosquitoes if ingested with no effect on other organisms. Spinosad is another microbial larvicide that suppress late instars and outgrowing pupae ,destroy larval stomach by endotoxin protein production They rapidly colonize the male reproductive system and female eggs of many mosquito vectors

Bacillus sphaericus (Bs) larvicides are also produced in various formulations and are very target specific to mosquito larvae., it is highly effective in controlling mosquitoes of the *Culex* genus, not as effective in control of *Aedes*.

Bacillus thurigiensis @ 250 gm / 10 liter of water sprayed 20ml/ sq meter twice. Bacillus sphaerieus @ 500 gm/ 10-liter water sprayed 20ml/sq meter thrice in a week.

Protozoa:

Many protozoa group like flagellates, ciliates,Schizogregarians, Microsporidians etc. attack mosquito larva.

Nosema algerae: Microsporidian is highly infective for Anopheles larva.

Lamborella: Cilliate protozoa found to infect Anopheles larva in nature.

Oocyst of Ascogregarina (a parasitic protozoon) releases sporozoite that disrupts the gut wall of mosquito larvae.

Viruses:

Several viruses like Cytoplasmic polyhydrosis virus (CPV), Nuclear Polyhydrosisvirus(NPV), baculoviruses , densoviruses , iridoviruses are entomopathogenic viruses that are active against insect pests have been described, but still only very few are commercially accessible.

Nematodes:

Some of these nematodes like Mermithid nematodes have their potential as biological control agents. In addition to Mermithidae, families such as Allantonematidae, Tetradonematidae, Diplogasteridae, Neotylenchidae, Sphaerulariidae, Steinernematidae, Heterorhabditidae, and Rhabditidae, include species that attack, kill, and sterilize insects, or alter host growth (Petersen, 1985). Most promising mermithids is *Romanomermis culicivorax* that infect by infiltration of the cuticle, have a high reproductive potential, are free swimming and can be distributed easily in the infective stage to control mosquitoes. They also interfere in the mosquito reproductive behavior causing biological castration

Endosymbiotic Bacteria

Wolbachia are endosymbiotic bacteria that naturally infect insect species and induce a reproductive phenotype in mosquitoes known as cytoplasmic incompatibility (CI), resulting in the generation of inviable offspring when an uninfected female mates with a Wolbachia-infected male. Wolbachia-infected females, however can produce viable progeny when they mate with both infected and uninfected males. Natural Wolbachia infections are present in some major mosquito disease vectors such as Cx. quinquefasciatus and Ae. Albopictus. This incompatible insect technique (IIT) depends on releasing large numbers of Wolbachia-infected male mosquitoes that compete with wild type males to induce sterility and suppress the mosquito population.

Entomopathogenic fungi

Entomopathogenic fungi produce infective spores (conidia) that attach to and penetrate the cuticle of mosquitoes, releasing toxins that result in mosquito death. They act upon direct contact with the mosquito cuticle and affect the mosquito feeding, behavior and fitness conditions.They elevate the mosquito immune response and promote the production of secondary metabolites . Entomopathogenic fungi strains include Metarhizium, Microsporidia Coelomomyces, Lagenidium and Culicinomyces *B. bassiana*, *M. anisopliae*, *Isaria fumosorosea*, *I. farinosa*, *I. flavovirescens*, and *Lecanicillium* spp. are considered as potential biological control agents of *Aedes aegypti* (Evans et al., 2018)

GENETIC CONTROL:

Sterile insect technique (SIT)- It involves sexual sterilization of male by radial exposure by rearing large numbers of males of the target species and either irradiating or treating them with chemo sterilizing agents to generate chromosomal aberrations and dominant lethal mutations in sperm. These sterilized male insects are released and when they mate with wild females producing no progeny. A sustained SIT programme results in an increasing ratio of released sterile males to wild males eventually leading to elimination of population. Other genetic methods also involve cytoplasmic incompatibility, chromosomal translocations, sex distortion and gene replacement (Alphey et al.,2010)

Genetically Modified Mosquitoes/Transgenic Mosquitoes

A self-limiting gene is introduced into mosquito populations through genetic engineering known as Release of Insects carrying a Dominant Lethal (RIDL). The lethal gene can be repressed using an antidote (tetracycline) so that mosquitoes can be reared to adulthood in rearing facilities prior to the release of males into wild populations, which then mate with wild females, producing offspring that die at the larval stage in the absence of tetracycline. This approach has the advantage of being species-specific

Another potential method to suppress or eliminate mosquito populations is to induce an extreme male-biased sex ratio. Genetic modification can provide a bias towards male gamete production by inducing preferential breakdown of the X chromosome during male meiosis. Breakdown of the paternal X chromosome in An. gambiae prevents it from being transmitted to the next generation, resulting in fully fertile mosquito strains that produce >95% male offspring. These synthetic distorter male mosquitoes suppress caged wild type mosquito populations, providing evidence for potential new strategies for mosquito vector control (Powell,2022).

PUBLIC AWARENESS

Disseminating knowledge to people regarding the disease and vectors through various media agencies like television., radio, social media, public meetings, awareness camps etc

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