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Chapter- 2

Mosquitocidal Activity of Medicinal Plants

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Abstract:

Mosquitoes (Diptera: Culicidae) are one of the dangerous vectors that spread many life-threatening diseases like malaria, yellow fever, dengue, chikungunya, filariasis, encephalitis, West Nile Virus infection etc. To control these vectors, many chemical pesticides or insecticides are available in the market but recent works confirmed that these are actually very harmful to environment. It is also revealed that the mosquitoes are increasing their resistance power against these pesticides or insecticides. So, there has been growing interest in the use of extracts of medicinal plant parts as alternatives to insecticides or pesticides due to their biodegradability and adaptability to environmental as well as health conditions.

Introduction:

Medicinal plants are natives of the healthcare systems across cultures and civilizations as they are the foundation of them, celebrated and linked to nature for curing diseases (*Maiti* et al., 2010, 2013; Sarkar et al., 2016; Sarkar, 2017; Sanyal, 2022a, 2022b; Mandal, 2022; Jyotirmayee et al., 2023). Historically, medicine men and women have been exploring various ways of herbal treatments in ancient human history, from the very beginning of traditional Indian medicine (Ayurveda) to other traditional recipes of medicine, which were superbly preserved and are still popular in many parts of the world (Banerjee et al., 2014; Bose, 2018; Acharya et al., 2020, 2021, 2022; Bhattacharjee, 2021; Basu et al., 2022; Bhowmik et al., 2022; Darro & Khan, 2023). One of the most current pieces of evidence that research has supported is the usefulness of these botanical remedies to control pests, which has led to a kind of

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renaissance in their therapeutic impact (Erfani, 2021; Das et al., 2022; Ghosh et al., 2022; De & Sharma, 2023; De et al., 2023; Dhakar & Tare, 2023). Cultivated this material to achieve a general study of medical plants, including its historical overview, therapeutic use, cultivation and conservation (Pyne& Santra, 2017; Sarkar et al., 2021; Pal et al., 2022; Kar et al., 2022; Raha et al., 2022; Saha et al., 2022; Pimple et al., 2023; Sarkar et al., 2024).

Mosquitoes are the major vector for the transmission of many life-threatening diseases. In India, malaria, dengue and chikungunya are very common vector-borne diseases. Mosquito borne diseases are dominant in more than 100 countries, infecting about 300-500 million people and causing about one million deaths every year (Dahmana & Mediannikov, 2020). In India, more than 40 million people suffer from mosquito diseases annually (Tolle, 2009). A medicinal plant is any plant that contains substances that can be used for medical purposes or that are used for the synthesis of useful drugs (Madhu & Sarkar, 2015; Srivastava, 2018). Medicinal plants are an important natural resource for the recovery of more prevalent diseases. Several medicinal plants can be used to treat similar diseases, depending on the country in which the disease occurs. In some localities, medicinal plants are perceived according to their traditional uses and represent a low-cost alternative to treat various diseases (Ali et al., 2013; Madhu, 2018; Madhu et al., 2015). For these reasons, these medicinal plants are being used to control the different species of mosquito vectors.

Historical Significance:

At the very core of Botanic medications is the deep roots of their connection with human history and development of civilisation. The records of antiquity recorded that plants had been used for healing purposes & control of insects and provided information to civilizations such as Sumerians, Egyptians, Greeks and Romans. Traditionally, the in-depth knowledge of medicinal plants was closely guarded; the herbalists were the ones who passed it down generations, learning from their elders by word of mouth. Due to increased trade routes, knowledge of botanical subjects stretched beyond geographical boundaries. Thus, there was an exchange of medicinal plants and enrichment of traditional health systems & control of insects and pests. These past cures leave their abiding imprint that contemporary pharmacology, healthcare and toxicology extend to today.

Bioactive Compounds in Medicinal Plants:

Researchers have found that medicinal plants enclose mosquitocidal substances in many of the studies that they conducted. These bioactive compounds help in effective mosquito treatment. Chemical variations in such compounds cause different chemical structures and modes of action, which give them the capability to be exploited in the formulation of new-generation insecticides. Alkaloids, terpenoids, flavonoids, and essential oils are classified as natural compounds.

Alkaloid examples like pyrethrines and strychnine are found to be extremely strong insecticide agents. The use of plant products as insecticides is on the rise by obtaining them

from plants, including Chrysanthemum cinerariifolium, which causes the nervous system of the insects to malfunction and eventually lead to paralysis and death. In regards to similar considerations, the nicotine present in plants Nicotiana tabacum is neurotoxin, which affects insect neurotransmitters in some way.

Table 1. Name of different Mosquito species and their transmitted diseases.

(Source: Draw The Life Cycle of Anopheles Mosquito | PeepsBurgh.Com)

Scientific Names of Mosquito species	Founding Areas	Diseases	Biting Time
Culex tarsalis	Rural areas in North America	Encephalitis	Dusk, After dusk
Culex pipiens	Urban areas of tropical & sub-tropical	West Nile Encephalitis	Dusk, After dusk
Culex quinquefasciatus	Urban areas of tropical & sub-tropical	West Nile Encephalitis	Dusk, After dusk
Aedes aegypti	Tropical & sub-tropical areas	Zika, Yellow fever, Dengue, Chikungunya	Day
Aedes albopictus	Native to tropical areas of Asia Europe, Africa, America (recently introduced)	Zika, Yellow fever, Dengue, Chikungunya, Encephalitis	Day
Aedes vexans	US, Europe Asia & Northern Africa	West Nile Encephalitis	Late afternoon/night
Anopheles sp.	Everywhere (Except Antarctica)	Malaria (about 40 species transmit) Encephalitis (Some species)	Dusk, night

In addition to terpenoids, which are widespread in medicinal plants, monoterpenes and sesquiterpenes have insecticidal properties. Take, for example, citronellal, the product of citronella grass Cymbopogon nardus, which had a mosquito repellent as well as a larvicidal effect.

There is evidence that the flavonoids, most of which are from fruits and vegetables, are favorable as mosquito-targeting agents. Apart from stunting mosquito breeding, compounds like quercetin and kaempferol interrupt very important metabolic processes of mosquitoes through which they die.

Known to be a great source of mosquitoicides, the essential oils generated from medicinal plants represent a rich resource in the enclosed area. What makes plant oils like eucalyptus oil, neem oil and lavender oil unique is that they contain components called volatile compounds that repel and kill mosquitoes through different mechanisms such as messing with their olfactory receptors and affecting their physiology.

Mechanisms of Mosquitocidal Action:

Mosquitocidal properties in plants for treatment purposes arise due to a multitude of mechanisms, each targeting a different part of mosquito life. They involve disruption of the communication between nerve cells, blockade of the essential enzymes, disturbance of the metabolic processes, and interruption of the cuticular layer.

Certain chemicals as pyrethrins and nicotine affect greater functionality of sodium channels in mosquito neurons, which in result causing paralysis and death of them. In this way, the terpenoids and flavonoids are a major obstacle to critical enzymatic systems involved in energy production, breakdown, and removal processes, leading to the weakness and in the end, death of mosquitoes.

Beyond that, essential oils act to kill mosquitoes through different mechanisms like disturbance of mosquito smell, dealing with the respiratory enzyme incorporation, and inactivation of the channels that carry ions. These diverse modes of action are very productive in controlling mosquitoes and other insects, especially in the sense that there are fewer chances of developing resistance.

Table 2. Medicinal plant extracts and their mosquitocidal activity against various mosquito species

Scientific Name of Medicinal Plants	Common Name	Plant parts used (Extracted with)	Target life cycle stage of Mosquito species	Resources
Curcuma longa	Turmeric	Rhizomes (Hexane)	*Aedes albopictus (Larvae)*	Lim et al., 2023
Ocimum americanum	Hoary basil	Leaves (Hexane)	*Aedes albopictus (Larvae)*	Lim et al., 2023
Petroselinum crispum	Parsley	Leaves& Stems (Hexane)	*Aedes albopictus (Larvae)*	Lim et al., 2023
Annona squamosa	Custard apple	Bark (Ethyl acetate, Methanol)	*Anopheles subpictus* & Culex tritaeniorhynchus *(Larvae)*	Kamaraj et al., 2011
Chrysanthemum indicum	Indian chrysanthemum	Dried leaves (Ethyl acetate, Methanol)	*Anopheles subpictus* & Culex tritaeniorhynchus *(Larvae)*	Kamaraj et al., 2011
Tridax procumbens	Coatbuttons or tridax daisy	Dried leaves (Acetone, Ethyl acetate)	*Anopheles subpictus*& Culex tritaeniorhynchus *(Larvae)*	Kamaraj et al., 2011
Eucalyptus globulus	Southern blue gum	Leaves, seeds (Ethanol water)	*Anopheles stephensi* (Larvae & Adults)	Senthilkumar et al., 2008

Cymbopogan citratus	Lemon grass	Leaves, seeds (Ethanol water)	*Anopheles stephensi* (Larvae & Adults)	Senthilkumar et al., 2008
Artemisia annua	Sweet wormwood	Leaves, seeds (Ethanol water)	*Anopheles stephensi* (Larvae & Adults)	Senthilkumar et al., 2008
Justicia gendarussa	Willow-leaved justicia	Leaves, seeds (Ethanol water)	*Anopheles stephensi* (Larvae & Adults)	Senthilkumar et al., 2008
Myristica fragrans	Nutmeg	Leaves, seeds (Ethanol water)	*Anopheles stephensi* (Larvae & Adults)	Senthilkumar et al., 2008
Annona squamosa	Sugar apples	Leaves, seeds (Ethanol water)	*Anopheles stephensi* (Larvae & Adults)	Senthilkumar et al., 2008
Centella asiatica	Indian pennywort	Leaves, seeds (Ethanol water)	*Anopheles stephensi* (Larvae & Adults)	Senthilkumar et al., 2008
Vinca rosea	Pink periwinkle	Leaves, flowers, seeds & stems (Petroleum ether)	*Culex quinquefasciatus Anopheles stephensi Aedes aegypti (Larvae)*	Kalyanasundaram & Das, 1985
Leucus aspara	Thumbai	Leaves, flowers, seeds & stems (Petroleum ether)	*Culex quinquefasciatus Anopheles stephensi Aedes aegypti (Larvae)*	Kalyanasundaram & Das, 1985
Clerodendron inerme	Wild jasmine	Leaves, flowers, seeds & stems (Petroleum ether)	*Culex quinquefasciatus Anopheles stephensi Aedes aegypti (Larvae)*	Kalyanasundaram & Das, 1985
Pedalium murax	Bada Gokhru	Leaves, flowers, seeds & stems (Petroleum ether)	*Culex quinquefasciatus Anopheles stephensi Aedes aegypti (Larvae)*	Kalyanasundaram & Das, 1985
Turnera ulmifolia	Ramgoat Dashalong	Leaves, flowers, seeds & stems (Petroleum ether)	*Culex quinquefasciatus Anopheles stephensi Aedes aegypti (Larvae)*	Kalyanasundaram & Das, 1985

Parthenium hysterophorus	Santa-Maria	Leaves, flowers, seeds & stems (Petroleum ether)	*Culex quinquefasciatus Anopheles stephensi Aedes aegypti (Larvae)*	Kalyanasundaram & Das, 1985
Rauwolfia canescens	Devil peppers	Leaves, flowers, seeds & stems (Petroleum ether)	*Culex quinquefasciatus Anopheles stephensi Aedes aegypti (Larvae)*	Kalyanasundaram & Das, 1985
Croton sparsiflorus	Railway Weed	Leaves, flowers, seeds & stems (Petroleum ether)	*Culex quinquefasciatus Anopheles stephensi Aedes aegypti (Larvae)*	Kalyanasundaram & Das, 1985
Calotropis sp.	Milkweed	Leaves, flowers, seeds & stems (Petroleum ether)	*Culex quinquefasciatus Anopheles stephensi Aedes aegypti (Larvae)*	Kalyanasundaram & Das, 1985
Adathoda sp.	Malabar nut	Leaves, flowers, seeds & stems (Petroleum ether)	*Culex quinquefasciatus Anopheles stephensi Aedes aegypti (Larvae)*	Kalyanasundaram & Das, 1985
Aloe turkanensis	Aloes	Leaves (Ethyl acetate)	*Anopheles gambie* (Larvae)	Matasyoh et al., 2008
Aloe ngongensis	Aloes	Leaves (Hexane, Ethyl acetate, Acetone, Chloroform, Methanol)	*Anopheles gambie* (Larvae)	Matasyoh et al., 2008
Aloe fibrosa	Aloes	Leaves (Methanol)	*Anopheles gambie* (Larvae)	Matasyoh et al., 2008
Acacia concinna	Shikakai	Leaves (Ethyl acetate, Methanol)	*Culex quinquefasciatus Anopheles stephensi (Larvae)*	Kamaraj et al., 2011
Cassia siamea	Kassod tree	Leaves (Ethyl acetate, Methanol)	*Culex quinquefasciatus Anopheles stephensi (Larvae)*	Kamaraj et al., 2011

Coriandrum sativum	Coriander	Leaves (Ethyl acetate, Methanol)	*Culex quinquefasciatus Anopheles stephensi (Larvae)*	Kamaraj et al., 2011
Cuminum cyminum	Cumin	Leaves (Ethyl acetate, Methanol)	*Culex quinquefasciatus Anopheles stephensi (Larvae)*	Kamaraj et al., 2011
Lantana camara	Lantana	Leaves (Ethyl acetate, Methanol)	*Culex quinquefasciatus Anopheles stephensi (Larvae)*	Kamaraj et al., 2011
Nelumbo nucifera	Indian lotus	Leaves (Ethyl acetate, Methanol)	*Culex quinquefasciatus Anopheles stephensi (Larvae)*	Kamaraj et al., 2011
Phyllanthus amarus	Bhuiamla	Leaves (Ethyl acetate, Methanol)	*Culex quinquefasciatus Anopheles stephensi (Larvae)*	Kamaraj et al., 2011
Piper nigrum	Black pepper	Leaves (Ethyl acetate, Methanol)	*Culex quinquefasciatus Anopheles stephensi (Larvae)*	Kamaraj et al., 2011
Trachyspermum ammi	Ajowan	Leaves (Ethyl acetate, Methanol)	*Culex quinquefasciatus Anopheles stephensi (Larvae)*	Kamaraj et al., 2011
Coccina indica	Kanduri	Leaves (Ethyl acetate, Methanol, Chloroform)	*Culex quinquefasciatus Anopheles stephensi Aedes aegypti (Larvae)*	Senthilkumar et al., 2012
Albizia lebbeck	Siris	Leaves and seeds (Hexane, Benzene, Chloroform, Ethyl acetate, Methanol)	*Culex quinquefasciatus Anopheles stephensi Aedes aegypti (*Egg and adult)	Govindarajan & Rajeswary, 2015
Pseudocalymma alliaceum	Garlic vine	Leaves (Petroleum ether, Hexane, Methanol)	*Anopheles stephensi (Larvae)*	Shrankhla et al., 2012

Allium sativum	Garlic	Leaves (Petroleum ether, Hexane, Methanol)	*Anopheles stephensi (Larvae)*	Shrankhla et al., 2012
Clausena anisate	Horse wood	Leaves (Ethyl acetate)	*Culex quinquefasciatus Anopheles stephensi Aedes aegypti (Larvae)*	Jayaraman et al., 2015
Asparagus racemosus	Shatavari	Root (Hexane, Ethyl acetate, Benzene, Chloroform, Methanol)	*Culex quinquefasciatus Anopheles stephensi Aedes aegypti (Egg, Larvae, Adult)*	Govindarajan & Sivakumar, 2014
Vetiveria zizanioides	Ushira	Root (ethanolic)	*Anopheles stephensi* (ovicidal and oviposition)	Aarthi & Murugan, 2012
Ocimum basllicum	Basil	Leaves, flowers, seeds, stems (Petroleum ether)	*Culex quinquefasciatus* (Larvae)	Kalyanasundaram & Babu, 1982
Ocimum sanctum	Tulsi	Leaves, flowers, seeds, stems (Petroleum ether)	*Culex quinquefasciatus* (Larvae)	Kalyanasundaram & Babu, 1982
Azadirachta indica	Neem	Leaves, flowers, seeds, stems (Petroleum ether)	*Culex quinquefasciatus* (Larvae)	Kalyanasundaram & Babu, 1982
Lantana camara	Red sage	Leaves, flowers, seeds, stems (Petroleum ether)	*Culex quinquefasciatus* (Larvae)	Kalyanasundaram & Babu, 1982
Vitex negundo	Chinese chaste tree	Leaves, flowers, seeds, stems (Petroleum ether)	*Culex quinquefasciatus* (Larvae)	Kalyanasundaram & Babu, 1982
Cleome viscose	Asian spiderflower	Leaves, flowers, seeds, stems (Petroleum ether)	*Culex quinquefasciatus* (Larvae)	Kalyanasundaram & Babu, 1982
Bulmea sp.	Sanbong	Leaves, flowers, seeds, stems (Petroleum ether)	*Culex quinquefasciatus* (Larvae)	Kalyanasundaram & Babu, 1982

Albizia amara	Bitter albizia	Leaves (Methanol)	*Anopheles stephensi (P*upae, adult)	Vinayagam et al., 2008
Areca catechu	Betelnut palm	Leaves (Methanol)	*Anopheles stephensi (P*upae, adult)	Vinayagam et al., 2008
Ocimum sanctum	Tulsi	Leaves (Methanol)	*Anopheles stephensi (P*upae, adult)	Vinayagam et al., 2008
Abrus precatorius	jequirity bean	Leaves, flowers seeds (hexane, chloroform, ethyl acetate, acetone, methanol)	*Anopheles vagus, Armigeres subalbatus, Culex vishnui (Larvae)*	Bagavan & Rahuman, 2011
Croton bonplandianum	Bantulsi	Leaves, flowers seeds (hexane, chloroform, ethyl acetate, acetone, methanol)	*Anopheles vagus, Armigeres subalbatus, Culex vishnui (Larvae)*	Bagavan & Rahuman, 2011
Cynodon dactylon	Bermuda grass	Leaves, flowers seeds (hexane, chloroform, ethyl acetate, acetone, methanol)	*Anopheles vagus, Armigeres subalbatus, Culex vishnui (Larvae)*	Bagavan & Rahuman, 2011
Musa paradisiacal	French plantain	Leaves, flowers seeds (hexane, chloroform, ethyl acetate, acetone, methanol)	*Anopheles vagus, Armigeres subalbatus, Culex vishnui (Larvae)*	Bagavan & Rahuman, 2011
Syzygium aromaticum	Clove	Leaves, flowers seeds (hexane, chloroform, ethyl acetate, acetone, methanol)	*Anopheles vagus, Armigeres subalbatus, Culex vishnui (Larvae)*	Bagavan & Rahuman, 2011

Aristolochia indica	Sapsada	Dried leaves, rhizome (Hexane, ethyl acetate, methanol)	*Culex gelidus, Culex quinquefasciatus* (Adult & laevae)	Kamaraj et al., 2010
Cassia angustifolia	Indian Senna	Dried leaves, rhizome (Hexane, ethyl acetate, methanol)	*Culex gelidus, Culex quinquefasciatus* (Adult & laevae)	Kamaraj et al., 2010
Diospyros melanoxylon	Coroman del ebony	Dried leaves, rhizome (Hexane, ethyl acetate, methanol)	*Culex gelidus, Culex quinquefasciatus* (Adult & laevae)	Kamaraj et al., 2010
Dolichos biflorus	Horse gram	Dried leaves, rhizome (Hexane, ethyl acetate, methanol)	*Culex gelidus, Culex quinquefasciatus* (Adult & laevae)	Kamaraj et al., 2010
Gymnema sylvestre	Gymnem a	Dried leaves, rhizome (Hexane, ethyl acetate, methanol)	*Culex gelidus, Culex quinquefasciatus* (Adult & laevae)	Kamaraj et al., 2010
Justicia procumbens	Water willow	Dried leaves, rhizome (Hexane, ethyl acetate, methanol)	*Culex gelidus, Culex quinquefasciatus* (Adult & laevae)	Kamaraj et al., 2010
Mimosa pudica	Dormeder a	Dried leaves, rhizome (Hexane, ethyl acetate, methanol)	*Culex gelidus, Culex quinquefasciatus* (Adult & laevae)	Kamaraj et al., 2010
Zingiber zerumbet	Ginger	Dried leaves, rhizome (Hexane, ethyl acetate, methanol)	*Culex gelidus, Culex quinquefasciatus* (Adult & laevae)	Kamaraj et al., 2010

Blumea mollis	Soft Blumea	Leaves (hexane, choloroform, ethyl acetate, acetone, methanol)	*Culex quinquefasciatus*, *Aedes aegypti*, *Anopheles stephensi* (Larvae)	Jayaraman et al., 2015
Chloroxylon swietenia	Ceylon satinwood	Leaves (hexane, choloroform, ethyl acetate, acetone, methanol)	*Culex quinquefasciatus*, *Aedes aegypti*, *Anopheles stephensi* (Larvae)	Jayaraman et al., 2015
Clausena anisate	Samandua	Leaves (hexane, choloroform, ethyl acetate, acetone, methanol)	*Culex quinquefasciatus*, *Aedes aegypti*, *Anopheles stephensi* (Larvae)	Jayaraman et al., 2015
Feronia limnonia	Wood apple	Leaves (hexane, choloroform, ethyl acetate, acetone, methanol)	*Culex quinquefasciatus*, *Aedes aegypti*, *Anopheles stephensi* (Larvae)	Jayaraman et al., 2015
Lantana camera	Caturang	Leaves (hexane, choloroform, ethyl acetate, acetone, methanol)	*Culex quinquefasciatus*, *Aedes aegypti*, *Anopheles stephensi* (Larvae)	Jayaraman et al., 2015
Plectranthus amboinicus	Sugandha	Leaves (hexane, choloroform, ethyl acetate, acetone, methanol)	*Culex quinquefasciatus*, *Aedes aegypti*, *Anopheles stephensi* (Larvae)	Jayaraman et al., 2015
Tagetes erecta	Marigold	Leaves (hexane, choloroform, ethyl acetate, acetone, methanol)	*Culex quinquefasciatus*, *Aedes aegypti*, *Anopheles Stephensi* (Larvae)	Jayaraman et al., 2015
Mirabilis jalapa	Gulambasa	Leaves (Benzene, chloroform, ethyl acetate, methanol)	*Anopheles stephensi*, *Aedes aegypti*, *Culex quinquefasciatus* (Larvae)	Govindarajan et al., 2014
Alternanthera sessilis	Sissoo spinach	Leaves (Crude extract)	*Culex quinquefasciatus* (Larvae)	Rawani et al., 2014

Trema orientalis	Charcoal tree	Leaves (Crude extract)	*Culex quinquefasciatus* (Larvae)	Rawani et al., 2014
Gardenia carinata	Gardenia	Leaves (Crude extract)	*Culex quinquefasciatus* (Larvae)	Rawani et al., 2014
Ruellia tuberosa	Minnieroot,	Leaves (Crude extract)	*Culex quinquefasciatus* (Larvae)	Rawani et al., 2014
Phyllanthus acidus	Tahitian gooseberry tree	Fruits and leaves (Crude extract)	*Culex quinquefasciatus* (Larvae)	Gope & Rawani, 2022

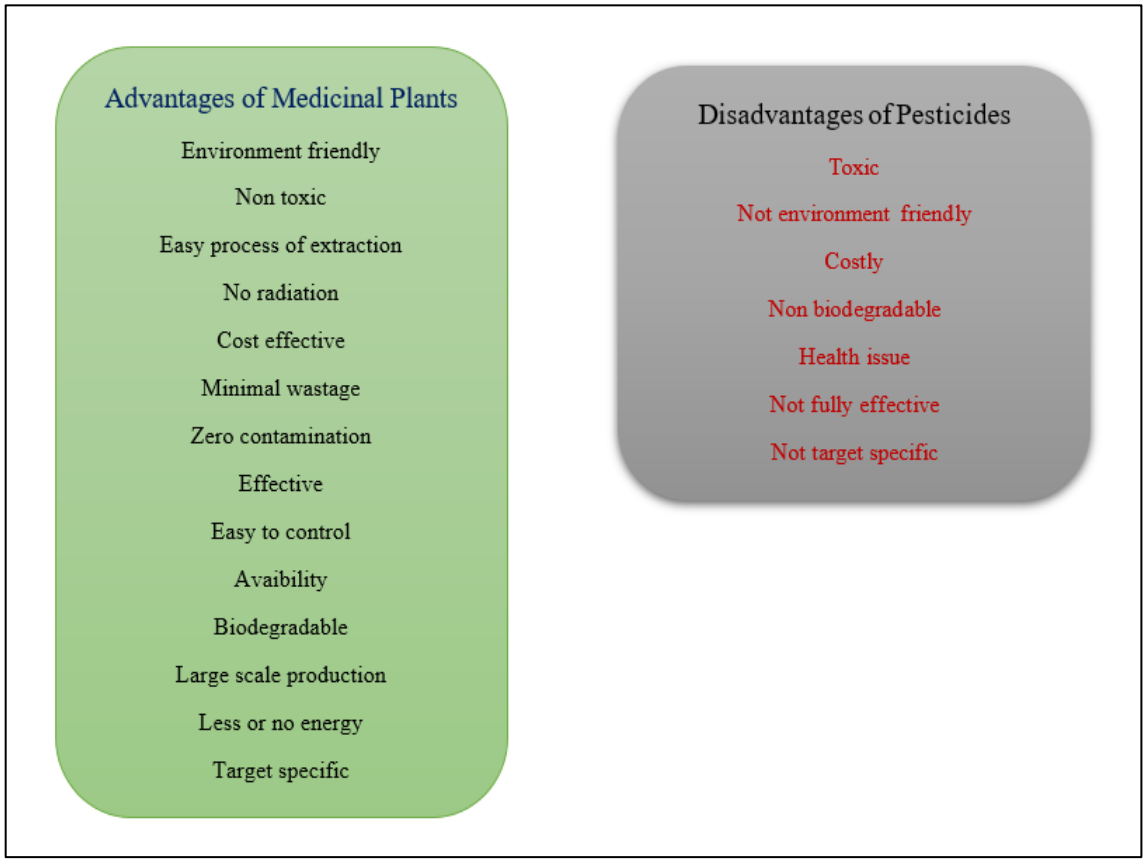

Figure 1. The advantages of using medicinal plant extracts & the disadvantages of using chemical pesticides

Discussion and Conclusion:

Presently, environmental safety is considered as the foremost important part. Using pesticides not only affects the foe of the environment, also causes health problems for people. Researchers found that medicinal plants have the potential for mosquitocidal activity. Different parts of plants, such as roots, stems, flowers, bark, leaves etc, can be used as extracts for this

novel purpose. Extracts of medicinal plants can be the alternative path to control mosquito species and mosquito-borne diseases. Though medicinal plant extracts are found to be effective, nature-friendly, and friendly, there are also some challenges. Large quantities of plants are needed for the extraction process, finding the antimicrobial effectiveness of plant extracts, drying methods of plant parts, choice and amount of solvents, temperature, and duration of extraction. However, medicinal plant extracts should have been given high priority not only as mosquitocidal agents but also as therapeutic tools. Thus, medicinal plants are the new hope for further use in different fields in the future.

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