International Journal of Mosquito Research 2022; 9(3): 01-12

International Journal of Mosquito Research

Review article on the synthesis of silver nanoparticles from plant extract and its larvicidal activity on the mosquito

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DOI: https://doi.org/10.22271/23487941.2022.v9.i3a.608

ISSN: **2348-5906**
CODEN: **IJMRK2**
IJMR 2022; 9(3): 01-12

www.dipterajournal.com
Received: 01-03-2022
Accepted: 05-04-2022

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Abstract

Mosquito-vector diseases are spreading worldwide, especially in tropical and sub-tropical countries, as the weather conditions in these countries are favourable for their growth. The larvicide and mosquito repellent are usually used to control the population of the mosquitoes. But using these chemically derived insecticides has made larvae resistant to it. Green-Nanotechnology is recently gaining attention, particularly silver nanoparticles. They are synthesized to control the mosquito population, and since it is synthesised using plant extract, the risk of exposure to any toxic chemical is reduced.

This review paper, discuss how silver nanoparticles are synthesized with phytoextract and its effects on the mosquito larval and pupal population. The Silver (Ag) nanoparticles show better larvicidal activity compared to the larvicidal activity of the crude plant extract. Furthermore, it is seen that the dose required to kill half the population of larvae /pupae is less in Green Ag Nanoparticles compared to plant extract.

Keywords: Silver nanoparticles, vector-borne diseases, larvicide, mosquito, green-nanotechnology

Introduction

Among arthropods, mosquitoes transmit the most diseases and are considered to be 'public enemy no. 1' by W.H.O [1]. Many life-threatening diseases like malaria, yellow fever, dengue fever, chikungunya, filariasis, encephalitis, West Nile virus infection are caused by mosquitoes [2, 3]. Out of 3500 species, nearly three-fourth is local to the humid tropics and subtropical regions [4]. Temperature, rainfall, and humidity are the factors that affect the development, behaviour, endurance of the mosquitoes, and the spread of disease.

Mosquito repellents like N, N-diethyl-meta toluamide (DEET), dimethyl phthalate (DMP), N, N-diethyl mandelic acid amide (DEM), and mosquito insecticide are used to control the mosquito population [5]. It is well known that these repellents are synthetically synthesized, which leads to the formation of mosquito-resistant strains and harms the environment and human health since they contain organophosphates, carbamates, and pyrethroids. Later, microbial insecticides were produced, for example, *Bacillus thuringiensis*, as control agents, but it was seen that mosquitoes become resistant to them too. Quinine-based drugs like chloroquine and artesunate, which are antimalarial, are very effective but eventually, the mosquitoes become resistant to these drugs. Even though many drugs are developed and are effective against these diseases, the main problem is that mosquitoes become resistant to them [5].

Other methods used to control the mosquito population include Mosquitocidal and mosquito coils. Eighty plant species have been used to synthesize mosquitocide successfully [6]. Fogging for pest control is also used to kill the larvae or the adult mosquitoes. Removing the cause of the mosquito breeding sites where the water gets collected can reduce the chance of disease spreading. Other methods which are still under research are oviposition deterrents. Oviposition deterrent is when we disturb the oviposition of the mosquito. It is well-known that oviposition is essential because it involves visual, olfactory, and tactile signals [7].

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The use of predators that feed on the larva and pupa is also one way. *Gambusia* and *Poecilia* have been commonly used for mosquito control [6]. Copepods like *Cyclops vernalis*, *Megacyclops formosanus*, *Mesocyclops* (*M.*) *aspericornis*, *M. edax*, *M. guangxiensis*, *M. longisetus* and *M. thermocyclopoides* are seen to prey upon the mosquito instar [6].

Nanobiotechnology, especially related to metal nanoparticles, has caught attention because of its cutting edge nature and its application in practically every field of science and technology, including biomedical sciences. Metal nanoparticles are gaining attention because of their catalytic activity, optical properties, electronic properties, antimicrobial activity, and magnetic activity sites for binding [8]. Silver is one of the most commercialized metals for the production of nanoparticles, with the estimation of five hundred tons of silver nanoparticles produced in a year [9].

If we see the history, silver was used in medicine until the discovery of antibiotics in the 1940s. But as the bacteria became resistant to the antibiotics, silver again became a topic of interest. The benefit of using silver was that the microorganism didn't become resistant to them and hence, used as an anticancer, antifungal, antiparasitic, and antimalarial agent [5].

Ag is antibacterial and toxic to cells. The Ag interacts with the macromolecules of the cell-like proteins and DNA, which break bacterial cell walls, inhibit bacterial cell growth, and disrupt cell metabolism [10].

Initially, they were synthesized using chemicals, but there was a drawback as toxic chemicals like the reducing agents and organic solvents were adsorbed on the nanoparticle's surface. This lead to unfavourable and harmful effects on its treatment. It then led to the scientists using an environmentally friendly method for its production [10].

Plants were used to synthesize Ag nanoparticles as it is faster, safer, and lighter, function at low temperature and only moderate and environmentally safe components are required. In addition, Ag nanoparticles weakens the outer membrane and breaks the plasma membrane, which causes a reduction of the intracellular ATP. As Ag has a high affinity towards sulphur and phosphorus, so molecules containing either of them are preferred for the synthesis [11].

Global scenario of diseases caused due to mosquito vector

Out of all the infectious diseases, 17% are vector-borne diseases caused by parasites, bacteria, or viruses. They cause more than 700,000 deaths a year, as reported by the World Health Organization (WHO). Anopheline mosquitoes transmit malaria, and 219 million cases are observed across the globe, with more than 400,000 deaths every year, with most deaths of children under the age of 5. Dengue, transmitted by the Aedes mosquito, affects 96 million people and causes 40,000 deaths every year [12].

Indian scenario of diseases caused due to mosquito vector

Among the South-East Asian countries, India has seen a considerable decrease in malarial cases from 20 million in 2000 to around 5.6 million in 2020. With constant control measures, malarial cases decreased by 28% and deaths by 41% in 2019. But the numbers are still disturbing. In 2019 alone, 338,000 people were affected by malaria and 175,000 people with dengue. India is on the list of the Top 11 countries highly affected by malaria. In 2020 alone, 86% of deaths due to malaria were caused in India in the South-East Asia region [13].

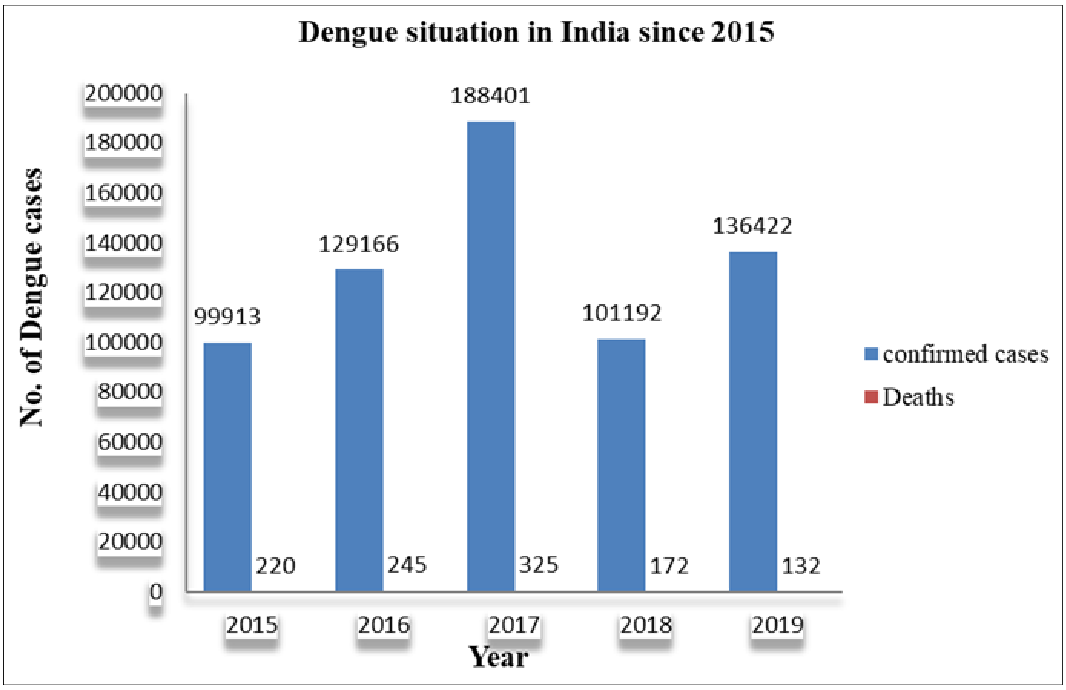

Fig 1: Epidemiological situation of Dengue in India since 2015 (NVBDCP)

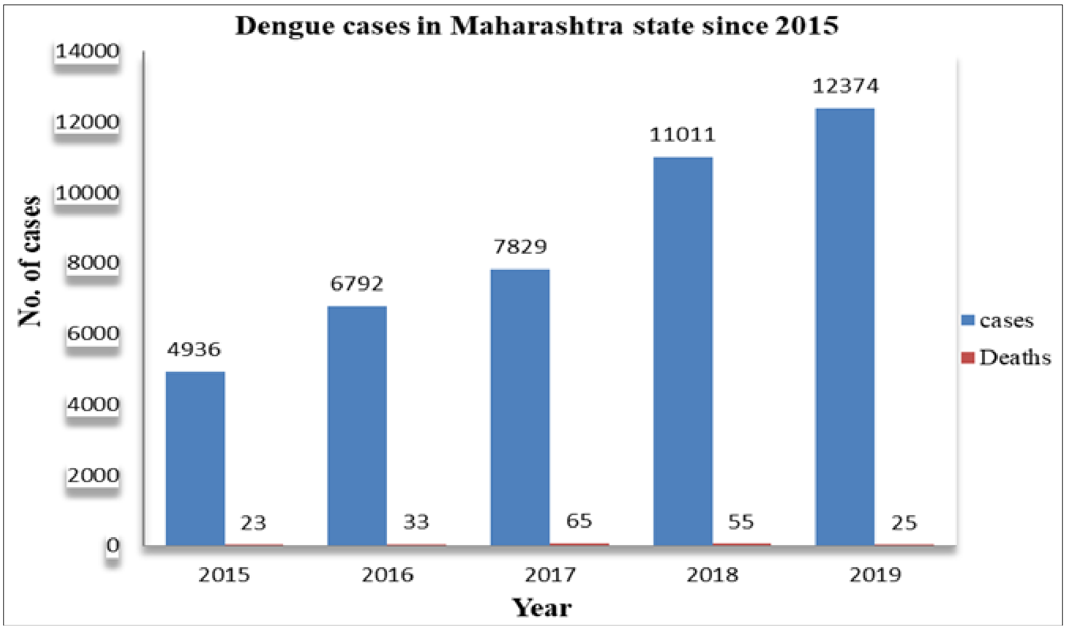

Fig 2: Epidemiological situation of Dengue in Maharashtra since 2015

Another mosquito-transmitted disease, chikungunya, is also one of the public health concerns in India. After 1973, the virus was observed again in 2005, and there was an outbreak affecting 13 states in India. The no. of cases has increased lately, especially from 2016 to 2017. 64,057 were reported in 2016 in India alone [13].

A study was done from January 2012 to December 2018, in which 7193 confirmed cases of malaria were reported in 22 districts of Punjab [13]. The highest no. of cases was reported in 2013, which was 1760. In 2015, 596 cases were reported, the lowest among all [13].

From 2012 to 2018, 58,729 cases of dengue were registered in Punjab [13]. The numbers notably decreased in 2014 and then increased from 2015 to 2018, with a peak in 2017. Eighty-five deaths have been observed in the last six years, with maximum deaths in 2013 and 2015 [13].

Two hundred and twenty-six cases of chikungunya have been reported between 2012 to 2018 in Punjab. The maximum number of cases was observed in 2017 [14].

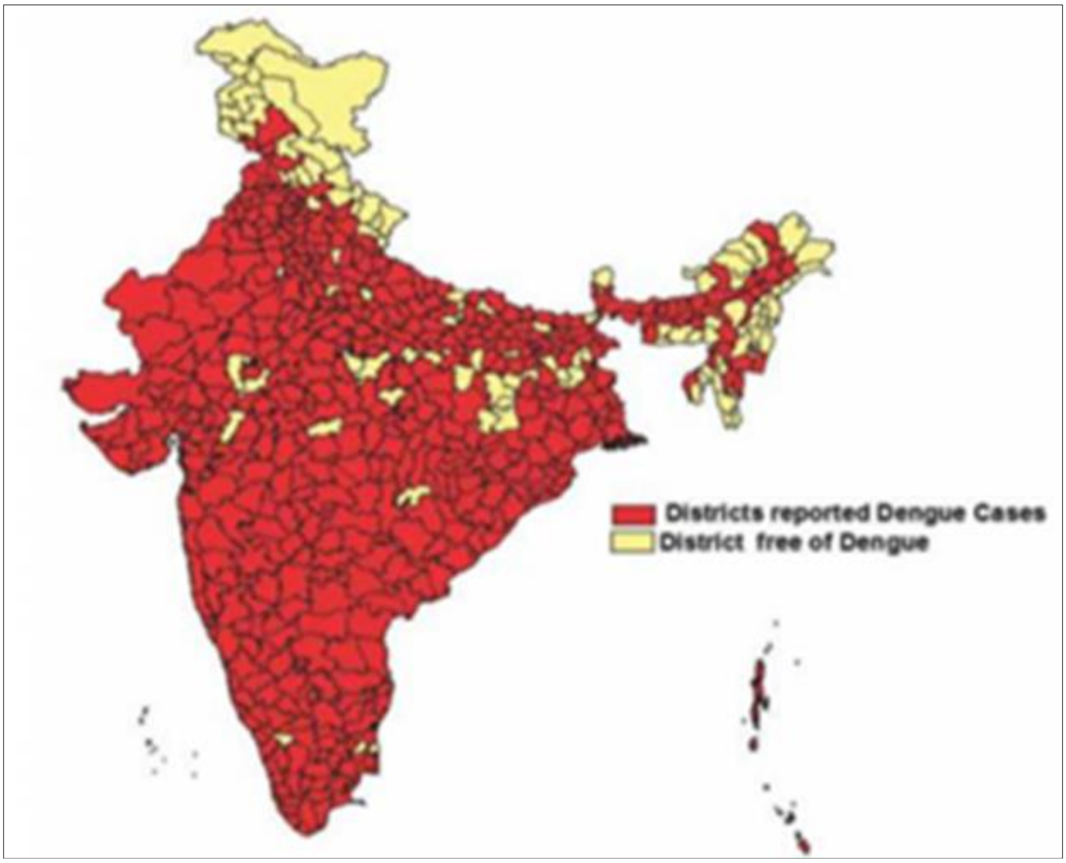

Fig 3: Dengue affected areas since 1991

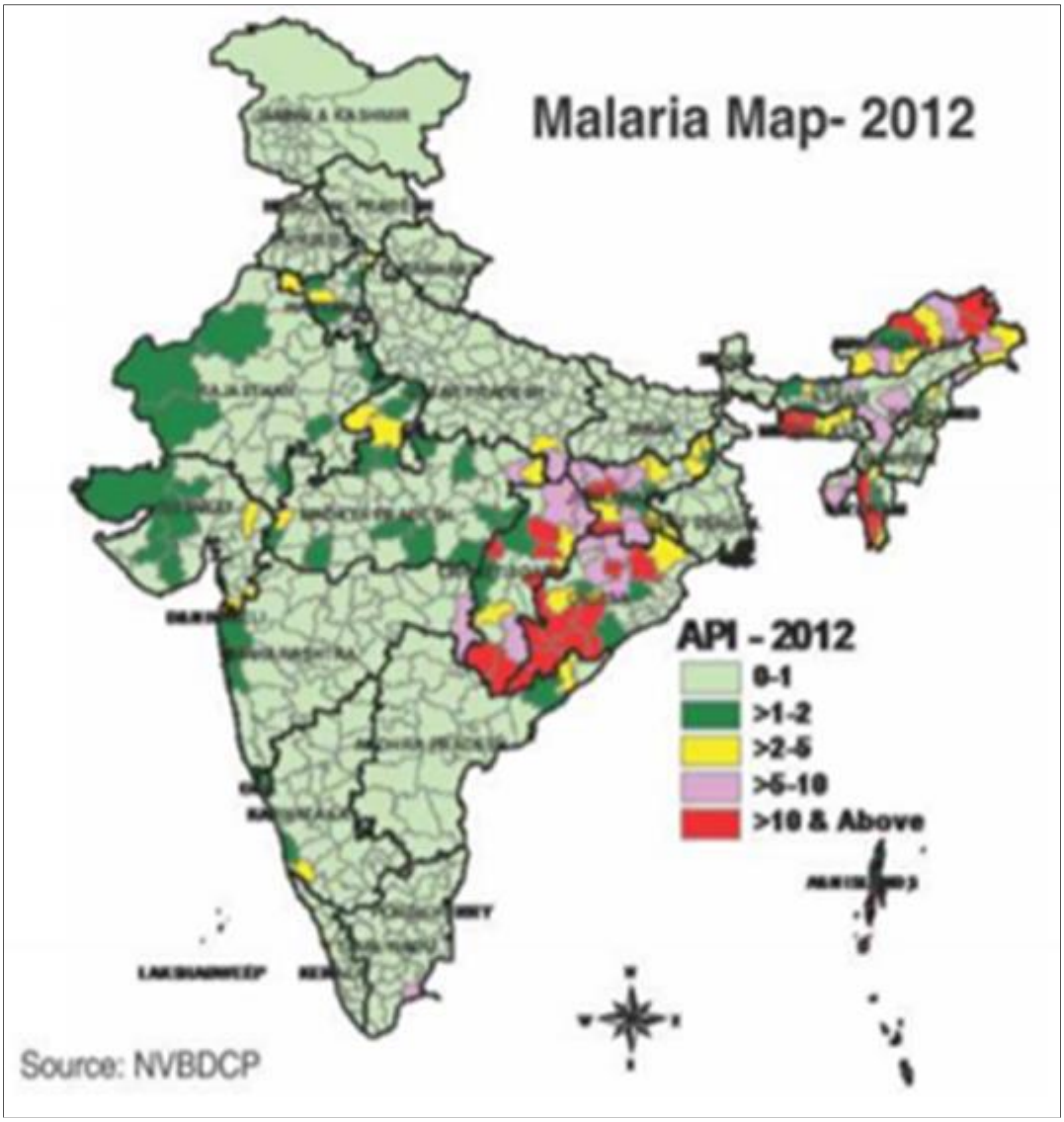

Fig 4: Malaria affected areas in India

Epidemiological situation of Chikungunya in India and Maharashtra

The epidemiological profile of Chikungunya fever in India since 2016 indicates a declining phase of confirmed cases of Chikungunya, though suspected cases may be following randomness in the situation. In 2015: 27,533 suspected and only 3342 confirmed cases of Chikungunya. It drastically increased during 2016 with 64057 suspected and 26364 confirmed cases and then followed declining in 2017, 2018 and 2019 with corresponding 67769, 57813, 65217 suspected cases and 12548, 9756 and 9477 confirmed cases of Chikungunya (Figure 5).

The epidemiological profile of Chikungunya fever in Maharashtra State also showed a similar pattern of the declining phase of confirmed cases of Chikungunya from 2016 (Figure 6). In 2015, the suspected and confirmed cases of Chikungunya were 391 and 207, respectively. The corresponding number of suspected cases from 2016 -2019 include 7570, 8110, 9884 and 4382, whereas confirmed cases during the same period 2016-2019 were 2949, 1438, 1009 and 1378 respectively (Source: NVBDCP).

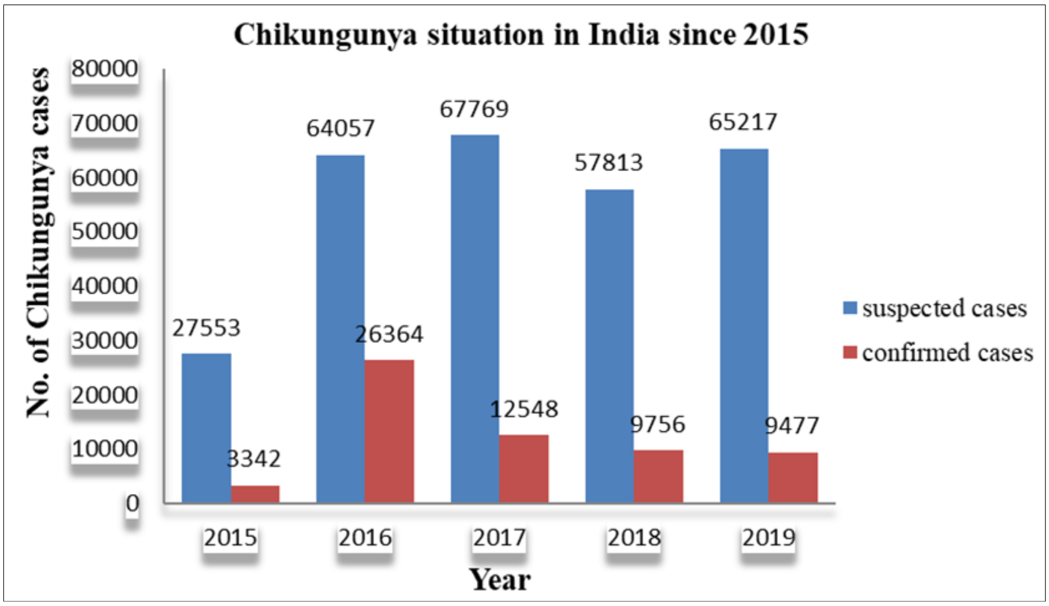

Fig 5: Epidemiological situation of Chikungunya in India since 2015

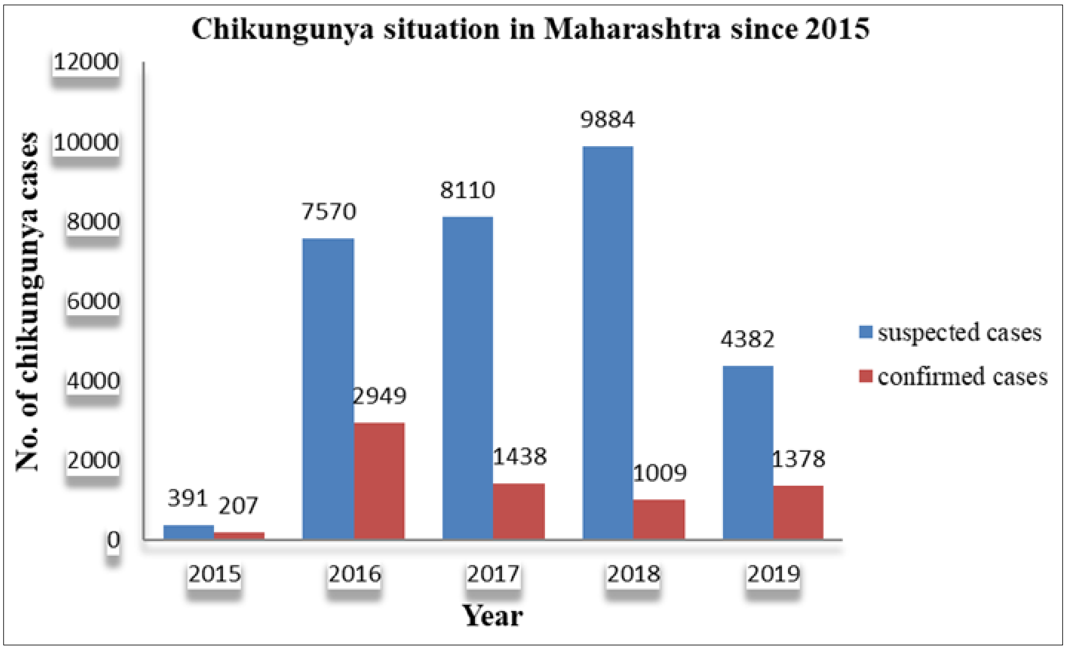

Fig 6: Epidemiological situation of Chikungunya in Maharashtra since 2015 (Source NVBDCP)

Recent Approaches in Vector Control

Effects of plant extract against the mosquito larvae

Insecticidal properties are observed in the alkaloids, flavonoids, and terpenoids. They are phytochemicals that are found in plants. Plant species, mosquito species, geographical varieties, parts used, extraction methodology used, and the polarity of the solvents used during extraction affects the larvicidal or insecticidal activity of the plant extract [2].

Table 1: Showing plant species, plant parts used for phytoextracts and its impact on mosquito species showing LC_{50} and LC_{90} values.

Scientific name of plant species	Plant part	Solvent Used	Mosquito species	Larval instar	LC_{50}	LC_{90}	Ref.
Annona squamosa	Leaves	Isoamyl acetate extract	*Aedes aegypti*	I	10.29ppm	31.22ppm	[15]
				II	10.72ppm	32.19ppm	
				III	11.09ppm	34.14ppm	
				IV	11.77ppm	35.20ppm	
	Leaves		*Culex quinquefasciatus*	I	10.59ppm	32.11ppm	
				II	11.10ppm	35.12ppm	
				III	11.90ppm	37.48ppm	
				IV	12.71ppm	42.17ppm	
Ficus racemosa	Bark	Aqueous extract	*Culex quinquefasciatus*	IV	67.72mg/L		[16]
			Culex gelidus		63.7mg/L	—	
Cyclamen alpinum	Tubers	Ethanol extract	*Culex pipiens*	I&II	289.7ppm (72hrs)	846.5ppm	[17]
					143.8ppm (96hrs)	498.8ppm	
				III & IV	503.6ppm (72hrs)	1300.7ppm	
					262.5 ppm (96hrs)	924.1ppm	
Cyclamen miracle				I&II	165.3ppm (72hrs)	493.8ppm	
					86.2ppm (96hrs)	253.7ppm	
				III & IV	294.8ppm (72hrs)	470.1ppm	
					161.3ppm (96hrs)	422.3ppm	
Artemisia nilagirica	Leaves	Aqueous extract	*Anopheles stephensi* (24 hours)	I	0.722	—	[18]
				II	0.599		
				III	0.381		
				IV	0.224		
				Pupa	0.066		
			Aedes aegypti (24 hours)	I	0.622	—	
				II	0.701		
				III	0.519		
				IV	0.363		
				Pupa	0.167		
Curcuma zedoaria	Essential oil	Essential oil	*Culex quinquefasciatus* deltamethrin–susceptible strain	III	36.32ppm (24 hours)	—	[19]
			Culex quinquefasciatus deltamethrin–resistant strain		37.29 ppm (24 hours)		
Ricinus communis	Leaf	Methanol extract	*Aedes aegypti*	III	191.54ppm (24 hrs)	60.68ppm	[20]
			Anopheles culicifacies		65.62ppm (24hours)	227.66ppm	
	Seeds		*Aedes aegypti*		15.52 ppm (24 hours)	45.256ppm	
			Anopheles culicifacies		9.37ppm (24hrs)	31.1ppm	
Moringa oleifera	Seeds	Aqueous extract	*Aedes aegypti*	I	151.97ppm	348.24ppm	[21]
				II	185.74ppm	390.39ppm	
				III	215.04ppm	433.07ppm	
				IV	241.92ppm	457.91ppm	
				Pupa	294.92ppm	519.06ppm	
Carica papaya	Leaf extract	Methanol crude (72hrs)	Dengue virus type 2	DENV-2 NS5 protein	13.09µg/mL	—	[22]
		Aqueous crude 30min			182.10µg/mL		
Solanum mammosum	Fruit	Aqueous extract	*Aedes aegypti*	III	1631.27ppm	4756.20ppm	[23]
Aquilaria sinensis	Essential oil	Essential oil	*Aedes albopictus*	I	44.23mg/L	397mg/L	[24]
				II	54.94mg/L	559mg/L	
				III	89.66mg/L	652mg/L	
				IV	118.7mg/L	809mg/L	
				Pupa	166mg/L	2258mg/L	
Pogostemon cablin	Essential oil	Essential oil	*Aedes albopictus*	I	32.49mg/L	287mg/L	[24]
				II	47.88mg/L	591mg/L	
				III	60.03mg/L	517mg/L	
				IV	90.05mg/L	602mg/L	
Cassia fistula	Fruit pulp	Fruit pulp extract	*Aedes albopictus* (24 hours)	I	1215mg/L	8762mg/L	[25]
				II	1458mg/L	11607mg/L	
				III	1644mg/L	11589mg/L	
				IV	1948mg/L	9172mg/L	
				Pupa	3939mg/L	13972mg/L	
			(72hours)	I	624mg/L	19241mg/L	
				II	822mg/L	25739mg/L	

				III	966mg/L	16026mg/L	
				IV	1288mg/L	21806mg/L	
				Pupa	3871mg/L	33556mg/L	
			Culex pipiens (24hours)	I	1074mg/L	11965mg/L	
				II	1455mg/L	13058mg/L	
				III	1622mg/L	13429mg/L	
				IV	2031mg/L	14648mg/L	
				Pupa	6620mg/L	48753mg/L	
			(72 hours)	I	493mg/L	3925mg/L	
				II	716mg/L	12167mg/L	
				III	896mg/L	21804mg/L	
				IV	1218mg/L	26979mg/L	
				Pupa	6126mg/L	185186mg/L	
Euphorbia milii	Plant latex	Aqueous extract	*Aedes aegypti*	II	281.28mg/L	752.27mg/L	[26]
				IV	638.11mg/L	1299.02mg/L	
			Anopheles stephensi	II	178.97mg/L	909.88mg/l	
				IV	761.11mg/L	1580.75mg/L	
Jatropha curcas	Plant latex	Aqueous extract	*Aedes aegypti*	II	746.98mg/L	1768.99mg/L	
				IV	798.89mg/L	1678.54mg/L	
			Anopheles stephensi	II	755.7mg/L	1772.58mg/L	
				IV	919.31mg/L	1930.6mg/L	

Effect of silver nanoparticle synthesized from plant extract against mosquito larva

Ag nanoparticles are produced using different methods like physical and chemical. But it is time-consuming and toxic chemicals are used. The methods used are laser ablation, photo-chemical preparation, etc. Alkaloids, flavonoids, and terpenoids are used as phytoconstituents which help in the synthesis as they reduce Ag^+ ions. Synthesis of Ag nanoparticles by plants is preferred because it is not expensive, environmentally friendly, easy to expand to large-scale processes, and does not need a particular technique [27, 28].

Table 2: Showing plant species, plant parts used for Green synthesis of Ag Nano particle and its impact on mosquito species showing LC$_{50}$ and LC$_{90}$ values.

Scientific name of plant species	Plant part	AgNp synthesis using phyto extract	Mosquito species and time of exposure	Larval instar	LC$_{50}$	LC$_{90}$	Ref
Polianthes tuberosa	Fresh Bud	Aqueous extract	*Culex vishnui* (24hours)	III	8.25ppm	17.99ppm	[29]
				IV	7.46ppm	23.26ppm	
			Culex quinquefasciatus (24 hours)	III	9.65ppm	27.18ppm	
				IV	7.94ppm	22.47ppm	
Carica papaya	Leaf	Methanol extract	Dengue virus type 2 (24hrs)	DENV-2 NS5 protein	9.20µg/mL	————	[22]
		Aqueous extract			126.20 µg/mL		
Vinca rosea	Leaf	Aqueous extract	*Aedes aegypti* (24 hours)	I	2.89mL	————	[30]
				IV	13.40mL		
				Pupa	25.20mL		
Annona reticulata	Leaf	Aqueous extract	*Aedes aegypti*	IV	4.43µg/mL	13.9643µg/mL	[31]
Solanum mammosum	Fruit	Aqueous extract	*Aedes aegypti*	III	0.06ppm	0.08ppm	[23]
Aquilaria sinensis	Essential oil	Essential oil	*Aedes albopictus*	I	0.81ppm	1.72ppm	[24]
				II	0.83ppm	2.33ppm	
				III	1.02ppm	2.49ppm	
				IV	1.12ppm	4.36ppm	
				Pupa	0.9ppm	2.07ppm	
Pogostemon cablin	Essential oil	Essential oil	*Aedes albopictus*	I	0.85ppm	1.79ppm	
				II	0.91ppm	2.26ppm	
				III	1.04ppm	2.85ppm	
				IV	1.19ppm	3.43ppm	
				Pupa	0.84ppm	2.15ppm	
Cassia fistula	Fruit pulp	Fruit pulp extract	*Aedes albopictus* (24 hours)	I	8.3mg/L	51.3mg/L	[25]
				II	9.3mg/L	47.1mg/L	
				III	12mg/L	56mg/L	
				IV	16.5mg/L	78mg/L	
				Pupa	33.1mg/L	519.3mg/L	
			(72hours)	I	1 mg/L	3.7mg/L	
				II	2mg/L	6.4mg/L	
				III	3.2mg/L	10.8mg/L	
				IV	3.6mg/L	20.6mg/L	
				Pupa	4.8mg/L	32.7mg/L	
			Culex pipiens (24hours)	I	1.1mg/L	4.7mg/L	
				II	1.2mg/L	11.6mg/L	

				III	4.6mg/L	94mg/L	
				IV	9.7mg/L	94mg/L	
				Pupa	18.8mg/L	234mg/L	
			(72 hours)	I	0.8mg/L	1.5mg/L	
				II	0.7mg/L	2.3mg/L	
				III	0.9mg/L	4.6mg/L	
				IV	1.7mg/L	8.4mg/L	
				Pupa	2.6mg/L	13.7mg/L	
Euphorbia milii	Plant latex	Aqueous extract	*Anopheles stephensi*	II	8.76mg/L	17.11mg/L	[26]
				IV	10.01mg/L	19.20mg/L	
			Aedes aegypti	II	8.67mg/L	17.62mg/l	
				IV	9.49mg/L	17.6mg/L	
Jatropha carcus	Plant latex	Aqueous extract	*Aedes aegypti*	II	9.6mg/L	17.63mg/L	
				IV	9.43mg/L	18.2mg/L	
			Anopheles stephensi	II	12.06mg/L	22mg/L	
				IV	10.01mg/L	19.01mg/L	
Swietenia mahagoni	Leaf	Aqueous extract	*Anopheles stephensi*	III (24hrs)	15.78 ppm	108.05 ppm	[32]
				III (48 hrs)	16.38 ppm	66.93ppm	
				III (72 hrs)	13.54ppm	55.34ppm	
			Culex vishnui	III (24hrs)	24.7ppm	135.6ppm	
				III (48 hrs)	22.59 ppm	133.12 ppm	
				III (72 hrs)	21.05 ppm	113.07 ppm	
			Culex quinquefasciatus	III (24hrs)	29.56 ppm	205.86 ppm	
				III (48 hrs)	21.41 ppm	256.46 ppm	
				III (72 hrs)	18.35 ppm	202.05 ppm	
Cadaba indica	Leaf	Aqueous extract	*Anopheles stephensi*	I	3.9mg/L	19.04mg/L	[33]
				II	4.67mg/L	27.06mg/L	
				III	10.20mg/L	47.27mg/L	
				IV	15.41mg/L	61.07mg/L	
				Pupa	25.27mg/L	78.32mg/L	
			Culex quinquefasciatus	I	4.39mg/L	17.37mg/L	
				II	5.07mg/L	20mh/L	
				III	8.21mg/L	35.76mg/L	
				IV	15.44mg/L	58.37mg/L	
				Pupa	28.37mg/L	75.33mg/L	
Annona squamosa	Leaves	Isoamyl acetate	*Aedes aegypti*	I	3.91ppm	10.12ppm	[15]
				II	4.11ppm	14.15ppm	
				III	4.27ppm	16.12ppm	
				IV	4.51ppm	16.66pm	
			Culex quinquefasciatus	I	2.96ppm	8.49ppm	
				II	3.33ppm	11.15ppm	
				III	3.70ppm	13.27ppm	
				IV	3.93ppm	16.28ppm	
Ficus racemosa	Bark	Aqueous extract	*Culex quinquefasciatus*	IV	12mg/L	—	[16]
			Culex gelidus		11.2mg/L		
Annona glabra	Leaves	Aqueous extract (1:10)	*Aedes aegypti*	III	5.29mg/L (24hrs)	—	[34]
					1.51mg/L (48hrs)		
			Aedes albopictus		3.02mg/L (24hrs)		
					1.14mg/L (48hrs)		
		(2:10)	*Aedes aegypti*	III	2.43mg/L (24hrs)		
					1.17mg/L (48hrs)		
			Aedes albopictus		2.51mg/L (24hrs)		
					2.10mg/L (48hrs)		
Artemisia nilagirica	Leaves	Aqueous extract	*Anopheles stephensi* (24 hours)	I	0.343mg/L	—	[18]
				II	0.169 mg/L		
				III	0.198 mg/L		
				IV	0.141 mg/L		
				Pupa	0.05 mg/L		
			Aedes aegypti	I	0.46 mg/L		

			(24 hours)	II	0.352 mg/L		
				III	0.331 mg/L		
				IV	0.217 mg/L		
				Pupa	0.16 mg/L		
Cinnamomum zeylanicum	Bark	Aqueous extract	*Anopheles stephensi*	I (4hrs)	2 mg/L	11 mg/L	[35]
				II (4hrs)	10 mg/L	15 mg/L	
				III (22hrs)	6 mg/L	11 mg/L	
				IV (22hrs)	10 mg/L	15 mg/L	
Annona squamosa	Leaf	Aqueous extract	*Aedes aegypti*	I	0.02ppm	—	[36]
				II	0.07ppm		
				III	0.19ppm		
				IV	0.3ppm		
				Pupa	0.56 ppm		
			Anopheles stephensi	I	0.16ppm		
				II	0.29ppm		
				III	0.48ppm		
				IV	2.12ppm		
				Pupa	3.74ppm		
			Culex quinquefasciatus	I	0.04ppm		
				II	0.13ppm		
				III	0.29ppm		
				IV	0.41ppm		
				Pupa	0.79ppm		
Curcuma zedoaria	Essential oil	Essential oil	*Culex quinquefasciatus* deltamethrin–susceptible strain	III	0.57ppm (24hrs)	—	[19]
			Culex quinquefasciatus deltamethrin–resistant strain		0.64ppm (24hrs)		
Belosynapsis kewensis	Leaf	Aqueous extract	*Anopheles stephensi*	IV	92.4ppm (12hrs)	181.6ppm	[37]
					78.4ppm (24hrs)	144.7ppm	
			Aedes aegypti		104.2ppm (12hrs)	166.7ppm	
					84.2ppm (24hrs)	117.3ppm	
Azadirachta indica	Leaf	Aqueous extract	*Aedes aegypti*	IV	1.25mg/L	—	[38]
Citrullus colocynthis	Fruit				0.3mg/L		
Moringa oleifera	Seeds	Aqueous extract	*Aedes aegypti*	I	10.24ppm	23.05ppm	[21]
				II	11.81ppm	26.8ppm	
				III	13.84ppm	31.24ppm	
				IV	16.73ppm	35.67ppm	
				Pupa	21.17 ppm	42.59ppm	

Discussion

Nanobiotechnology is gaining attention, and it can be used for various things like drug delivery, imaging, gene delivery, tissue engineering, parasitology, and pest management. Synthesis of silver nanoparticles through plant source is more favourable than the chemical and physical method because it is cheaper, single-step and does not require high pressure and temperature, and most importantly, does not use toxic chemicals, and is environmentally friendly [39]. It has not only affected the environment but also financially to economically backward families. The medical costs for the treatment and the days of labour lost have negatively impacted the families [40].

In this review paper, we observed the larvicidal activity of plant extract and Ag nanoparticles synthesized from plant extract against the larva and pupa of the mosquitoes when exposed to different period of time. We can see from the results obtained by other researchers that the amount of Ag nanoparticles required to kill 50 and 90% of the larva (and in some cases, pupa) is less than the amount of the plant extract used for the same purpose. Since the amount required is less and is synthesized by plants, one doesn’t need to worry about the toxic effects and their harmful effects on the environment, animals, and humans. It hasn’t been reported that there were any non-target effects. The lethal dose used to kill the mosquito larva has a negligible impact on the aquatic environment [39]. Not only that, but we can also observe that larvicidal activity is different for different plant species, the part of the plant used, the solvent used for extraction, time of exposure, and the mosquito species [41]. Hence, Ag nanoparticles as a biocontrol is an excellent step to keep the population of mosquitoes under control without worrying about any harmful effects on the environment and other living organisms.

Conclusion

The increase in the cases of mosquito-borne diseases led to the production of chemical insecticides, wiping out the breeding ground, or using indoor residual spraying. Later, these chemically synthesized products did more harm to the environment and living organisms. New strains were formed because these parasites became resistant to these insecticides, which led to the scientist synthesizing a new insecticide. This was a never-ending cycle. A novel idea of using silver nanoparticles synthesized from plants was introduced. Since it is cost-effective, environment-friendly, and does not require energy to synthesize [42]. This can solve the significant problem that those chemically synthesized insecticides cause. With no harm to the environment and minimal dosage requirement, the population of the mosquitoes can be controlled [43]. But still, study needs to be done in this field to accomplish a green future.

Acknowledgement

I would like to thank Principal Dr. Anushree Lokur, Life Science Head of the department Dr. Seema Shinde of Ramnarain Ruia Autonomous College, Mumbai for their motivation and encouragement. I express my sincere gratitude to Dr. Laxmikant Shinde of Applied Parasitology research center, JES College Jalna for his valuable guidance in writing this review article.

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