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

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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 led 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].

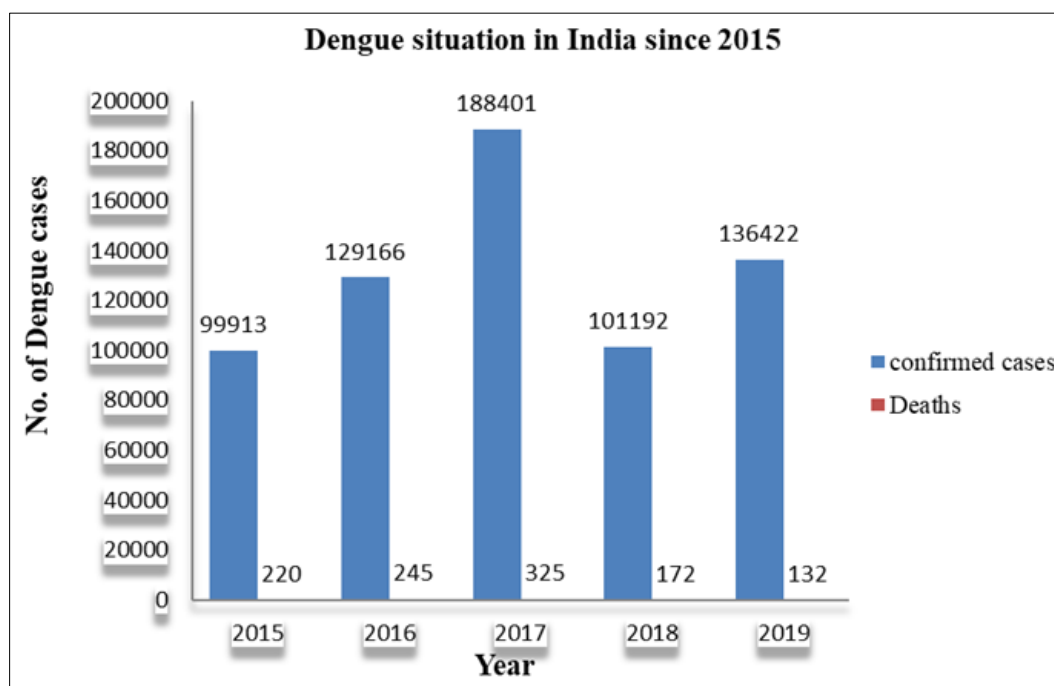
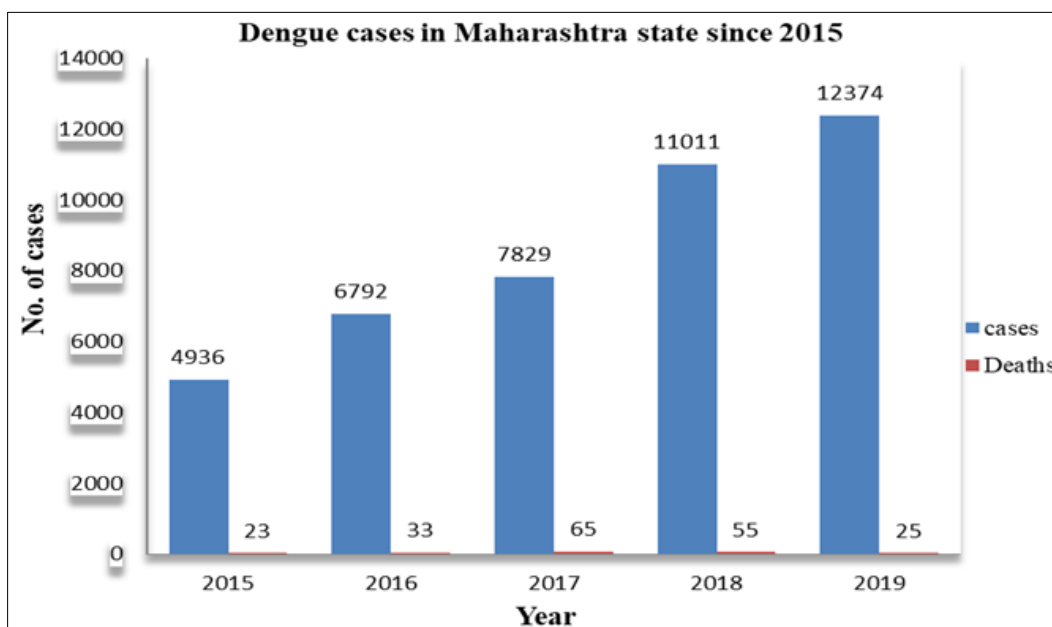


Fig 1: Epidemiological situation of Dengue in India since 2015 (NVBDCP)



**Fig 2:** Epidemiological situation of Dengue in Maharashtra since 2015

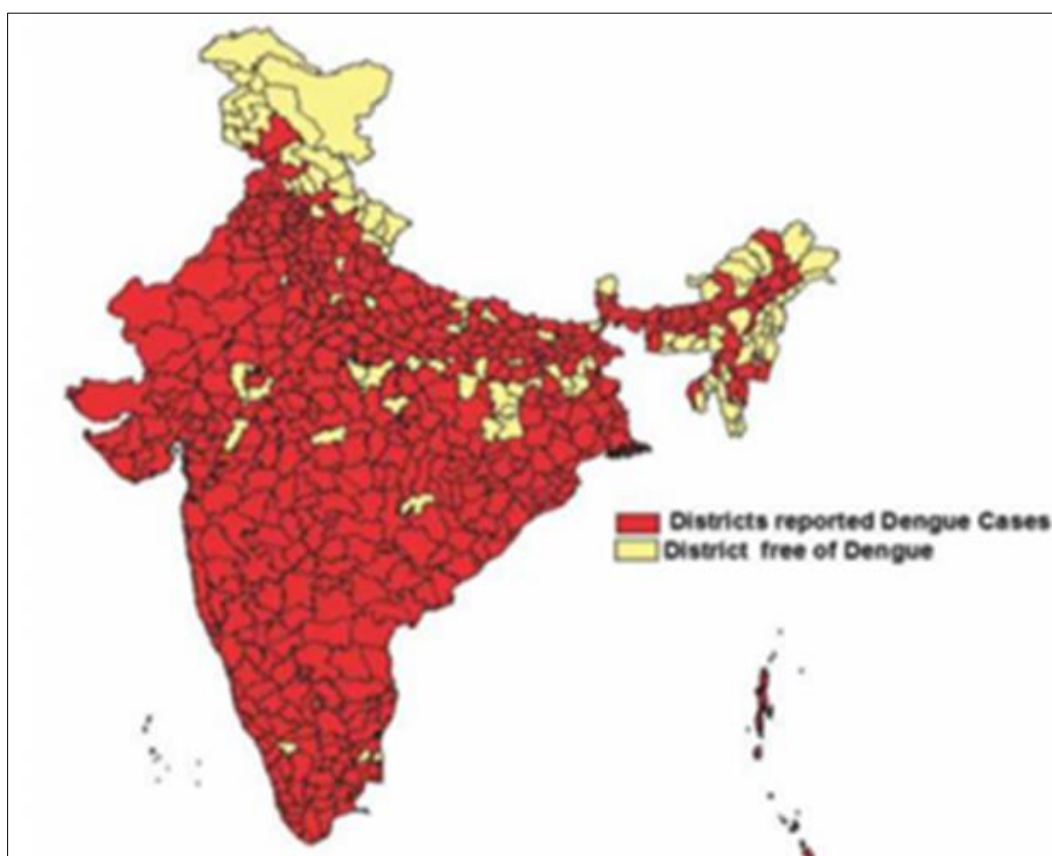
Another mosquito-transmitted disease, chikungunya, is also one of the public health concerns in India. After 1973, the virus was observed again in 2005, and there was an outbreak affecting 13 states in India. The no. of cases has increased lately, especially from 2016 to 2017. 64,057 were reported in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

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

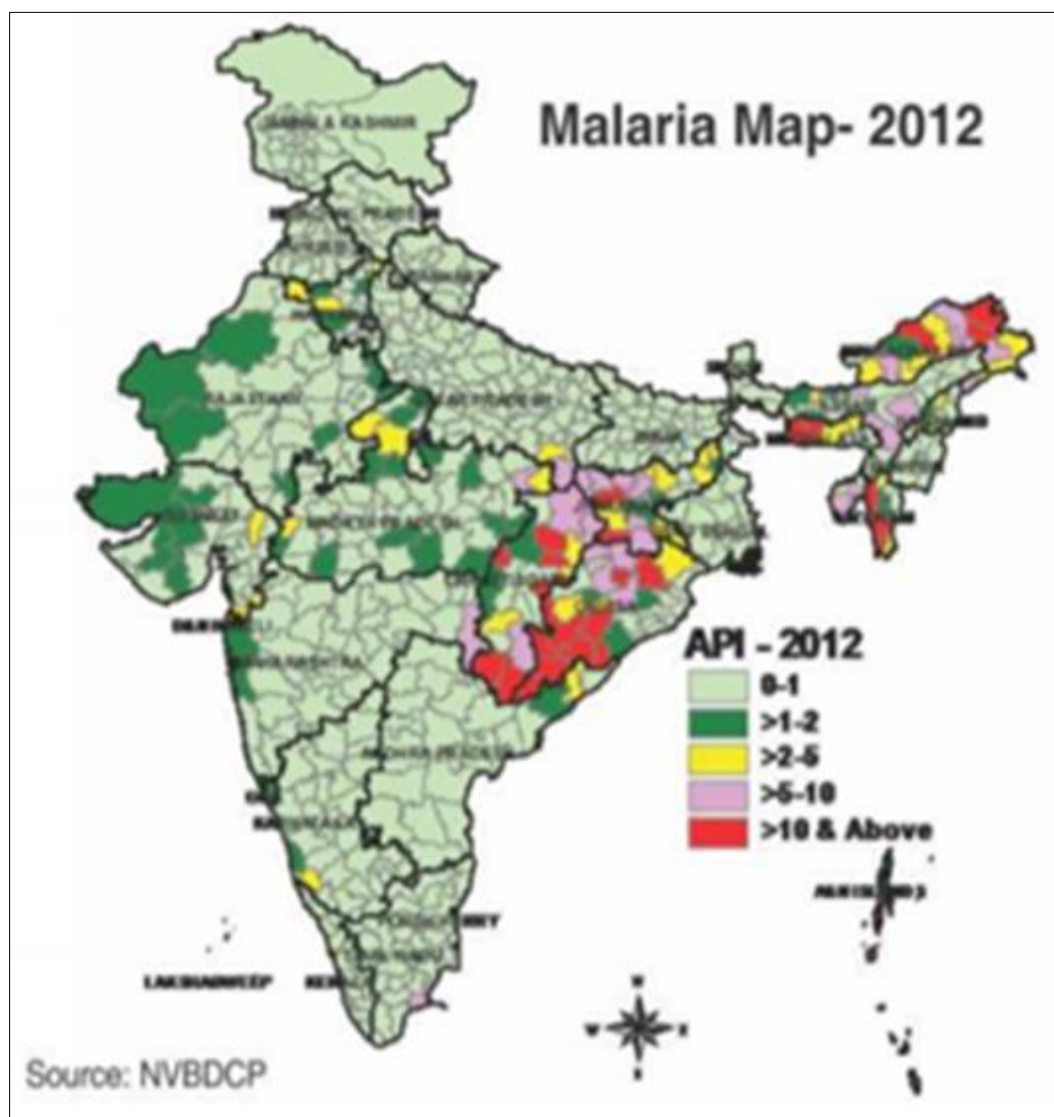
the lowest among all <sup>[13]</sup>.

From 2012 to 2018, 58,729 cases of dengue were registered in Punjab <sup>[13]</sup>. 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 <sup>[13]</sup>.

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 <sup>[14]</sup>.



**Fig 3:** Dengue affected areas since 1991



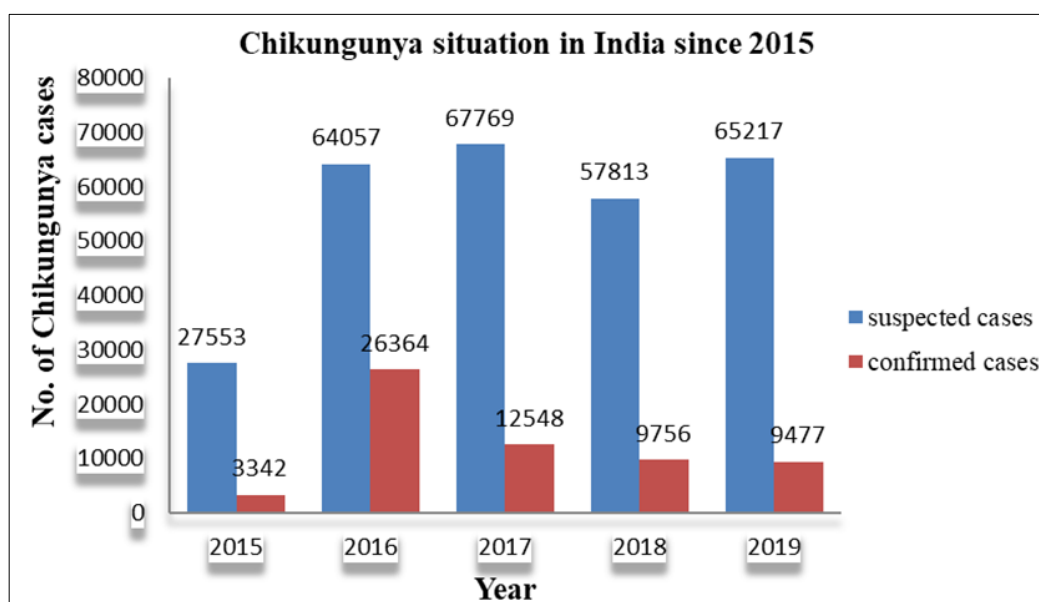
**Fig 4:** Malaria affected areas in India

#### **Epidemiological situation of Chikungunya in India and Maharashtra**

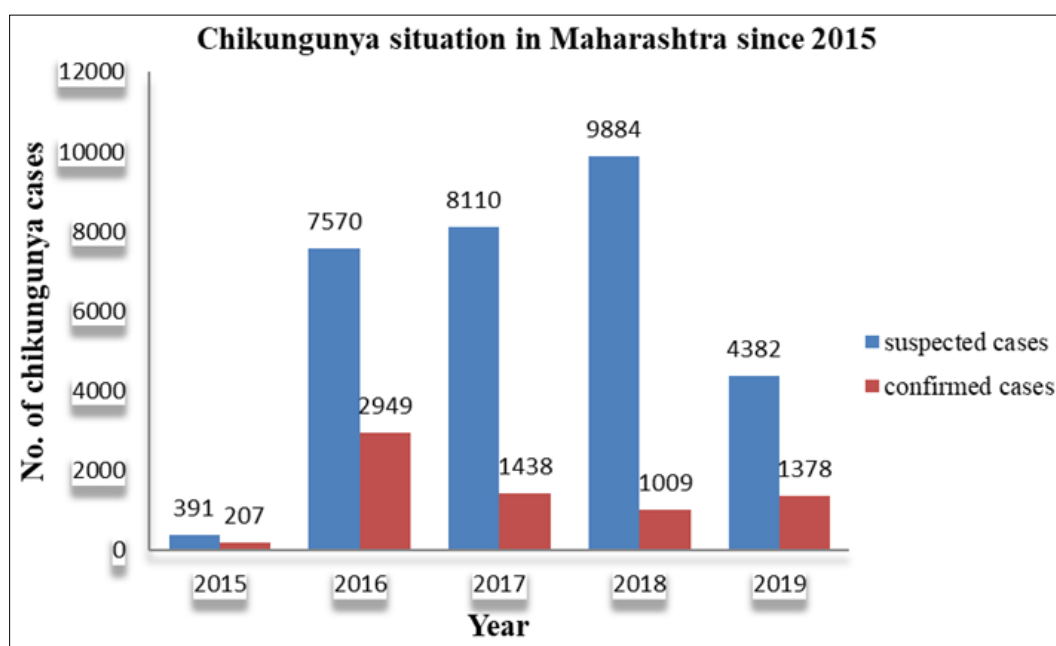
The epidemiological profile of Chikungunya fever in India since 2016 indicates a declining phase of confirmed cases of Chikungunya, though suspected cases may be following randomness in the situation. In 2015: 27,533 suspected and only 3342 confirmed cases of Chikungunya. It drastically increased during 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 <sup>[2]</sup>.



**Table 1:** Showing plant species, plant parts used for phytoextracts and its impact on mosquito species showing LC<sub>50</sub> and LC<sub>90</sub> values.

Scientific name of plant species	Plant part	Solvent Used	Mosquito species	Larval instar	LC <sub>50</sub>	LC <sub>90</sub>	Ref.	
<i>Annona squamosa</i>	Leaves	Isoamyl acetate extract	<i>Aedes aegypti</i>	I	10.29ppm	31.22ppm	[15]	
				II	10.72ppm	32.19ppm		
				III	11.09ppm	34.14ppm		
				IV	11.77ppm	35.20ppm		
	Leaves		<i>Culex quinquefasciatus</i>	I	10.59ppm	32.11ppm		
				II	11.10ppm	35.12ppm		
				III	11.90ppm	37.48ppm		
				IV	12.71ppm	42.17ppm		
<i>Ficus racemosa</i>	Bark	Aqueous extract	<i>Culex quinquefasciatus</i>	IV	67.72mg/L		[16]	
			<i>Culex gelidus</i>		63.7mg/L			
<i>Cyclamen alpinum</i>	Tubers	Ethanol extract	<i>Culex pipiens</i>	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			
I&II				165.3ppm (72hrs)	493.8ppm			
				86.2ppm (96hrs)	253.7ppm			
III & IV				294.8ppm (72hrs)	470.1ppm			
				161.3ppm (96hrs)	422.3ppm			
<i>Artemisia nilagirica</i>	Leaves	Aqueous extract	<i>Anopheles stephensi</i> (24 hours)	I	0.722		[18]	
				II	0.599			
				III	0.381			
				IV	0.224			
				Pupa	0.066			
			<i>Aedes aegypti</i> (24 hours)	I	0.622			
				II	0.701			
				III	0.519			
				IV	0.363			
				Pupa	0.167			
<i>Curcuma zedoaria</i>	Essential oil	Essential oil	<i>Culex quinquefasciatus</i> deltamethrin-susceptible strain	III	36.32ppm (24 hours)		[19]	
			<i>Culex quinquefasciatus</i> deltamethrin-resistant strain		37.29 ppm (24 hours)			
<i>Ricinus communis</i>	Leaf	Methanol extract	<i>Aedes aegypti</i>	III	191.54ppm (24 hrs)	60.68ppm	[20]	
	Seeds		<i>Anopheles culicifacies</i>		65.62ppm (24hours)	227.66ppm		
			<i>Aedes aegypti</i>		15.52 ppm (24 hours)	45.256ppm		
			<i>Anopheles culicifacies</i>		9.37ppm (24hrs)	31.1ppm		
<i>Moringa oleifera</i>	Seeds	Aqueous extract	<i>Aedes aegypti</i>	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		
<i>Carica papaya</i>	Leaf extract	Methanol crude (72hrs)	Dengue virus type 2	DENV-2 NS5 protein	13.09µg/mL		[22]	
		Aqueous crude 30min			182.10µg/mL			
<i>Solanum mammosum</i>	Fruit	Aqueous extract	<i>Aedes aegypti</i>	III	1631.27ppm	4756.20ppm	[23]	
<i>Aquilaria sinensis</i>	Essential oil	Essential oil	<i>Aedes albopictus</i>	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		
<i>Pogostemon cablin</i>	Essential oil	Essential oil	<i>Aedes albopictus</i>	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		
<i>Cassia fistula</i>	Fruit pulp	Fruit pulp extract	<i>Aedes albopictus</i> (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					

			<i>Culex pipiens</i> (24hours)	III	966mg/L	16026mg/L	
				IV	1288mg/L	21806mg/L	
				Pupa	3871mg/L	33556mg/L	
				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	
<i>Euphorbia milii</i>	Plant latex	Aqueous extract	<i>Aedes aegypti</i>	II	281.28mg/L	752.27mg/L	[26]
				IV	638.11mg/L	1299.02mg/L	
			<i>Anopheles stephensi</i>	II	178.97mg/L	909.88mg/L	
				IV	761.11mg/L	1580.75mg/L	
<i>Jatropha curcas</i>	Plant latex	Aqueous extract	<i>Aedes aegypti</i>	II	746.98mg/L	1768.99mg/L	
				IV	798.89mg/L	1678.54mg/L	
			<i>Anopheles stephensi</i>	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<sub>50</sub> and LC<sub>90</sub> values.

Scientific name of plant species	Plant part	AgNp synthesis using phyto extract	Mosquito species and time of exposure	Larval instar	LC <sub>50</sub>	LC <sub>90</sub>	Ref
<i>Polianthes tuberosa</i>	Fresh Bud	Aqueous extract	<i>Culex vishnui</i> (24hours)	III	8.25ppm	17.99ppm	[29]
				IV	7.46ppm	23.26ppm	
			<i>Culex quinquefasciatus</i> (24 hours)	III	9.65ppm	27.18ppm	
				IV	7.94ppm	22.47ppm	
<i>Carica papaya</i>	Leaf	Methanol extract	Dengue virus type 2 (24hrs)	DENV-2 NS5 protein	9.20µg/mL	—	[22]
		Aqueous extract			126.20 µg/mL	—	
<i>Vinca rosea</i>	Leaf	Aqueous extract	<i>Aedes aegypti</i> (24 hours)	I	2.89mL	—	[30]
				IV	13.40mL	—	
				Pupa	25.20mL	—	
<i>Annona reticulata</i>	Leaf	Aqueous extract	<i>Aedes aegypti</i>	IV	4.43µg/mL	13.9643µg/mL	[31]
<i>Solanum mammosum</i>	Fruit	Aqueous extract	<i>Aedes aegypti</i>	III	0.06ppm	0.08ppm	[23]
<i>Aquilaria sinensis</i>	Essential oil	Essential oil	<i>Aedes albopictus</i>	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	
<i>Pogostemon cablin</i>	Essential oil	Essential oil	<i>Aedes albopictus</i>	I	0.85ppm	1.79ppm	[24]
				II	0.91ppm	2.26ppm	
				III	1.04ppm	2.85ppm	
				IV	1.19ppm	3.43ppm	
				Pupa	0.84ppm	2.15ppm	
<i>Cassia fistula</i>	Fruit pulp	Fruit pulp extract	<i>Aedes albopictus</i> (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	[25]
				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	
			<i>Culex pipiens</i> (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			
<i>Euphorbia milii</i>	Plant latex	Aqueous extract	<i>Anopheles stephensi</i>	II	8.76mg/L	17.11mg/L		
			<i>Aedes aegypti</i>	IV	10.01mg/L	19.20mg/L		
				II	8.67mg/L	17.62mg/l		
				IV	9.49mg/L	17.6mg/L		
<i>Jatropha carcus</i>	Plant latex	Aqueous extract	<i>Aedes aegypti</i>	II	9.6mg/L	17.63mg/L	[26]	
			<i>Anopheles stephensi</i>	IV	9.43mg/L	18.2mg/L		
				II	12.06mg/L	22mg/L		
				IV	10.01mg/L	19.01mg/L		
<i>Swietenia mahagoni</i>	Leaf	Aqueous extract	<i>Anopheles stephensi</i>	III (24hrs)	15.78 ppm	108.05 ppm	[32]	
				III (48 hrs)	16.38 ppm	66.93ppm		
				III (72 hrs)	13.54ppm	55.34ppm		
			<i>Culex vishnui</i>	III (24hrs)	24.7ppm	135.6ppm		
				III (48 hrs)	22.59 ppm	133.12 ppm		
				III (72 hrs)	21.05 ppm	113.07 ppm		
			<i>Culex quinquefasciatus</i>	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						
<i>Cadaba indica</i>	Leaf	Aqueous extract	<i>Anopheles stephensi</i>	I	3.9mg/L	19.04mg/L		
				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		
			<i>Culex quinquefasciatus</i>	I	4.39mg/L	17.37mg/L	[33]	
				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		
<i>Annona squamosa</i>	Leaves	Isoamyl acetate	<i>Aedes aegypti</i>	I	3.91ppm	10.12ppm	[15]	
				II	4.11ppm	14.15ppm		
				III	4.27ppm	16.12ppm		
				IV	4.51ppm	16.66pm		
			<i>Culex quinquefasciatus</i>	I	2.96ppm	8.49ppm		
				II	3.33ppm	11.15ppm		
				III	3.70ppm	13.27ppm		
IV	3.93ppm	16.28ppm						
<i>Ficus racemosa</i>	Bark	Aqueous extract	<i>Culex quinquefasciatus</i>	IV	12mg/L	_____	[16]	
			<i>Culex gelidus</i>		11.2mg/L			
<i>Annona glabra</i>	Leaves	Aqueous extract (1:10)	<i>Aedes aegypti</i>	III	5.29mg/L (24hrs)	_____	[34]	
					1.51mg/L (48hrs)			
			<i>Aedes albopictus</i>		3.02mg/L (24hrs)			
					1.14mg/L (48hrs)			
		(2:10)	<i>Aedes aegypti</i>		III			2.43mg/L (24hrs)
								1.17mg/L (48hrs)
			<i>Aedes albopictus</i>	III	2.51mg/L (24hrs)			
					2.10mg/L (48hrs)			
<i>Artemisia nilagirica</i>	Leaves	Aqueous extract	<i>Anopheles stephensi</i> (24 hours)	I	0.343mg/L	_____	[18]	
				II	0.169 mg/L			
				III	0.198 mg/L			
				IV	0.141 mg/L			
			<i>Aedes aegypti</i>	Pupa	0.05 mg/L			
				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		
<i>Cinnamomum zeylanicum</i>	Bark	Aqueous extract	<i>Anopheles stephensi</i>	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	
<i>Annona squamosa</i>	Leaf	Aqueous extract	<i>Aedes aegypti</i>	I	0.02ppm		
				II	0.07ppm		
				III	0.19ppm		
				IV	0.3ppm		
				Pupa	0.56 ppm		
			<i>Anopheles stephensi</i>	I	0.16ppm		
				II	0.29ppm		
				III	0.48ppm		
				IV	2.12ppm		
				Pupa	3.74ppm		
			<i>Culex quinquefasciatus</i>	I	0.04ppm		
				II	0.13ppm		
				III	0.29ppm		
				IV	0.41ppm		
				Pupa	0.79ppm		
<i>Curcuma zedoaria</i>	Essential oil	Essential oil	<i>Culex quinquefasciatus</i> deltamethrin-susceptible strain		0.57ppm (24hrs)		[19]
			<i>Culex quinquefasciatus</i> deltamethrin-resistant strain	III	0.64ppm (24hrs)		
<i>Belosynopsis kewensis</i>	Leaf	Aqueous extract	<i>Anopheles stephensi</i>		92.4ppm (12hrs)	181.6ppm	
					78.4ppm (24hrs)	144.7ppm	
			<i>Aedes aegypti</i>	IV	104.2ppm (12hrs)	166.7ppm	[37]
					84.2ppm (24hrs)	117.3ppm	
<i>Azadirachta indica</i>	Leaf				1.25mg/L		
<i>Citrullus colocynthis</i>	Fruit	Aqueous extract	<i>Aedes aegypti</i>	IV	0.3mg/L		[38]
<i>Moringa oleifera</i>	Seeds	Aqueous extract	<i>Aedes aegypti</i>	I	10.24ppm	23.05ppm	
				II	11.81ppm	26.8ppm	
				III	13.84ppm	31.24ppm	
				IV	16.73ppm	35.67ppm	[21]
				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 <sup>[42]</sup>. 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 <sup>[43]</sup>. But still, study needs to be done in this field to accomplish a green future.

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