ASIAN JOURNAL OF PHARMACEUTICAL AND CLINICAL RESEARCH

INNOVARE ACADEMIC SCIENCES
Knowledge to Innovation

Vol 10, Issue 3, 2017

Online - 2455-3891
Print - 0974-2441

Review Article

# ANTIMICROBIAL ACTIVITIES OF *LANTANA CAMARA* LINN.

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***Received: 28 November 2016, Revised and Accepted: 09 December 2016***

**ABSTRACT**

Herbal drugs are the potential sources of therapeutic aid for the treatment and prevention of number of ailments as recognized very early by Ayurveda, Unani, and traditional folk - medical practitioners. The rich biodiversity of plants makes them a treasure house for obtaining new and novel compounds either themselves as drugs or lead molecules for drugs with different mechanisms of action. *Lantana camara* L. belonging to the family Verbenaceae and universally known as wild or red sage is the most widespread species of the genus. It occurs in most parts of the world as an evergreen notorious weed species. It is also considered as an ornamental garden plant. It is widely used in different traditional medical practices for treating various health problems. Different parts of the plant are used in treating various human ailments. The plant extracts and essential oil of *L. camara* possess various bioactivities including antimicrobial activities. The therapeutic potential of the plant is due to the occurrence of many bioactive phytocompounds. In last decade, scientists and researchers around the globe have elaborately studied the chemical composition of the whole plant of *L. camara* as well as its biological activities. This article reviews the antimicrobial activities of *L. camara*.

**Keywords:** Antimicrobial activities, Essential oils, Nanoparticles, *Lantana camara*, Solvent extracts.

 DOI: http://dx.doi.org/10.22159/ajpcr.2017.v10i3.16378

## INTRODUCTION

Resistance to antimicrobial agents is a major global health problem, and the number of emerging multi-drug resistant microbial strains is continuously increasing. This situation has prompted researchers to develop efficient new antimicrobial agents, and thus the exploration of natural products to discover new drug molecules is continuously going on [1,2]. Medicinal plants could be a good alternative source for antibiotics in use (against which microbes have developed resistance), as most of the medicinal plants are safe with little or no side effects, cost-effective and have the ability to affect a wide range of antibiotic resistant microorganisms [3]. Medicinal plants contain several different phytochemicals or secondary metabolites that may act individually, additively or in synergy to improve human health [4]. Down the ages, essential oils (EOs) and other extracts of plants have evoked interest as sources of natural antimicrobial agents [5]. According to the WHO medicinal plants would be the best source to obtain a variety of drugs [6]. *Lantana camara* is one of the plants known for having many medicinal uses in traditional system of medicine, used in many parts of the world to treat a wide variety of disorders [7]. *L. camara* whole plant and plant parts, *viz.,* leaves, flowers, roots, fruits, and EOs have been thoroughly studied for their chemical compositions and bioactivities. The present review aims to document the antimicrobial properties of *L. camara.*

## LANTANA CAMARA

The genus *Lantana* (Verbenaceae) as described by Linnaeus in 1753 contained seven species, six from South America and one from Ethiopia. *Lantana* from the Latin *lento*, to bend, probably derives from the ancient Latin name of the genus *Viburnum. Lantana* is mostly native to subtropical and tropical America, but a few taxa are indigenous to tropical Asia and Africa. It is a genus of about 150 species. *L. camara* Linn., commonly known as wild or red sage, is the most widespread species of this genus [8]. It is planted as an ornamental plant and is now a highly invasive weed in many parts of the world. *L. camara* is found at altitudes from sea level upto 2000 m and can thrive very well under rainfall ranging from 750 to 5000 mm per annum and it grows up to 3 m height. It is a woody straggling evergreen, aromatic wild shrub (Fig. 1). The stems and branches are sometimes thorny. The leaves are arranged in opposite pairs and are broadly oval, bright green, rough with short hairs, with finely toothed edges along with a number of veins giving a wrinkled appearance. Flower heads contain 20-40 flowers, usually 2.5 cm across; the color of flowers varies from white, cream or yellow to orange pink, purple and red with small rounded heads, often in two colors. The fruits are fleshy berries in clusters, shiny and globose in shape, green in color which on ripening turns to black. The root system is very strong with a main taproot and a mat of many shallow side roots. *L. camara* is known by different names in different languages in India, *viz.,* Raimuniya (Hindi), Chaturangi and Vanacehdi (Sanskrit) and Kakke, Natahu and Unnigida (Kannada), etc. [7,9,10].

### Chemical constituents

*L. camara* is a rich source of bioactive compounds, *viz.,* flavones, isoflavones, flavonoids, anthocyanins, coumarins, lignans, catechins, isocatechins, alkaloids, tannin, saponins, and triterpenoids. The various bioactive molecules isolated from different parts of the plant and its EOs were reported, and these details of *L. camara* phytochemistry have been compiled by a few authors [8,10].

### Medicinal uses

In India, herbal medicines have been the basis of treatment and cure for various diseases in traditional methods practiced such as Ayurveda, Unani, and Siddha [11]. *L. camara* has been used as an herbal medicine since long back. All parts of this plant have been traditionally used for several ailments worldwide. The plant extracts have been used in folk medicine for the treatment of cold, headache, uterine hemorrhage, chicken pox, conjunctivitis, eye injuries, whooping cough, asthma, bronchitis, tumors, chicken pox, measles, ulcers, swellings, skin rashes, eczema, eruptions, high blood pressure, bilious fevers, catarrhal infections, tetanus, rheumatism, malaria, jaundice, fistula, and pustules. Further, used for the treatment of skin itches, leprosy, scabies, used as an expectorant and as an antiseptic for wounds. *L. camara* is considered to be antiseptic, antispasmodic, anti-inflammatory, antihypertensive, antipyretic, analgesic, hypolipidemic, carminative, and diaphoretic

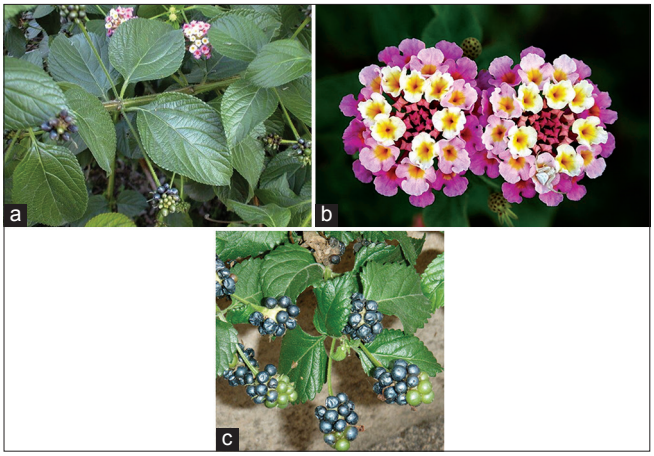


**Fig. 1: *Lantana camara* (a) Leaves:** Source: http://www.esc.nsw.gov.au/Lantana-camara, **(b) Flowers:** Source: https://en.wikipedia.org/wiki/lantana_camara, **(c) Fruits:** Source: http://www.plant-world-seeds.com/lantana camara

agent. The extracts are reported to have antimicrobial, mosquito repellent, termiticidal, insecticidal, and larvicidal activities [9,10,12].

## ANTIMICROBIAL ACTIVITIES

Antibacterial, antifungal, antiprotozoal, antinematode, and antiviral activities of *L. camara* were reported. Solvent extracts, EOs, and nanoparticles of *L. camara,* all are reported to have antimicrobial activity. Lantadenes present in *L. camara* is believed to be responsible for almost all the biological activities. However, constituents such as 1,8-cineole, sabinene, and caryophyllene and other minor constituents, *viz.,* E-nerolidol, bicyclogermacrene, and pinene identified in leaf EOs also found to be responsible for the biological activities. The presence of phenolics, anthocyanins, and proanthocyanidins in *L. camara* leaves could be responsible for the antibacterial properties of the *L. camara* [13]. The active principle of the extracts disrupts the permeability barrier of cell membrane structures and thus inhibits the bacterial growth [14]. EOs may interact with and affect the plasma membrane, interfering with respiratory chain activity and energy production [15].

### Antibacterial activity

Different solvent extracts, EOs, and nanoparticles of *L. camara* have significant antibacterial activity (Table 1). Crude extract of *L. camara* root was found to be active against *Staphylococcus aureus* and *Bacillus cereus* [16]. Petroleum ether, benzene, chloroform, and methanol fractions of *L. camara* leaves were tested against *Escherichia coli* (ATCC 10536), *Salmonella typhi* (ATCC 686), *S. aureus* (ATCC 6538), and *Pseudomonas aeruginosa* (ATCC 25619). Chloroform and methanol extracts showed activity against all the bacteria tested, while petroleum ether fraction only against *P. aeruginosa* and benzene fraction only against *S. typhi* [17]. Antibacterial activity of extracts of *L. camara* root-bark was evaluated. Chloroform and methanolic extracts of *L. camara* were found to be more specific toward the Gram-positive strains, although Gram-negative *P. aeruginosa* was also inhibited by the methanol extract, while the aqueous extract was found to be inactive [18]. Dichloromethane and methanol (1:1, v/v) extract of *L. camara* exhibited significant antibacterial activity against *E. coli* (ATCC 10536) and *P. aeruginosa* (ATCC 9027) at both 1000 and 500 µg/ml concentrations [19]. Begum *et al.* [20] reported antimycobacterial activity of flavonoid, *viz.,* linaroside and lantanoside and their acetyl derivative extracted from *L. camara* against *Mycobacterium tuberculosis*. These compounds exhibited 30%, 37% and 98% inhibition of the bacteria, respectively.

Extracts of root, stem, leaf, flower, and fruit of *L. camara* were screened for antibacterial activity. The leaf extract presented the highest antibiotic effect among all the parts tested, especially against *B. cereus* (zone of inhibition 13.0±0.0 mm, minimum inhibitory concentration [MIC]/minimum bactericidal concentration [MBC] 9.4±4.4 mg/ml) and *S. typhi* (zone of inhibition 13.5±2.1 mm, MIC/MBC 12.5±0.0 mg/ml) [21]. Leaf and flower ethyl acetate extracts of *L. camara* with yellow, lavender, red, and white flowers exhibited considerable antibacterial activities against the bacteria *E. coli* (MTCC 901), *P. aeruginosa* (MTCC 429), *Bacillus subtilis* (MTCC 1429) and *S. aureus* (MTCC 96), where the value of zone of inhibition ranged from 10-21 and 9-15 mm, respectively [13]. Chloroform and methanol extracts of *L. camara* were screened against three strains of *M. tuberculosis*-H37Rv, the rifampicin-resistant TMC-331 and a non-resistant wild strain (28-25271). The methanol extract showed the highest activity against all the three strains used, with zones of inhibition of 18.0-22.5 mm and MIC values of 20 µg/ml for H37Rv and 15 µg/ml for both TMC-331 and wild stain. The MBC value for the methanol extract of *L. camara* was 30 µg/ml for the H37Rv, and 20 µg/ml for both the TMC-331 and wild strains [22]. Antibacterial efficacy of flavonoids (free and bound) and crude alkaloids of *L. camara* extracted from roots, stem, leaves, and flower was determined by disc diffusion assay against three bacteria: *E. coli* (MTCC 46), *Proteus mirabilis* (MTCC 1425), and *S. aureus* (MTCC 87). The susceptibility was in the order of *P. mirabilis, S. aureus,* and *E. coli.* The range of MIC of tested extracts was 0.039-0.625 mg/ml while MBC ranged from 0.078 to 1.25 mg/ml [3].

Antagonistic effect of water and organic solvent (ethanol of 50% and 100%) extracts of *L. camara* was studied against 15 pathogenic strains of bacteria. Ethanol extracts showed antibacterial effect toward *P. aeruginosa, Staphylococcus* sp., *Bacillus thuringiensis*, *B. subtilis, B. cereus*, *E. coli*, *S. aureus*, *P. mirabilis* and water extract showed antibacterial effect toward *P. aeruginosa*, *Staphylococcus* sp., *Citrobacter freundii*, *Proteus* sp., *B. subtilis*, *Enterobacter aerogenes*, *Salmonella paratyphi*, *S. aureus,* and *Shigella dysenteriae.* Both extracts showed high antibacterial effect toward *S. aureus, Staphylococcus* sp., and *P. aeruginosa* [23]. Ethanolic extracts of *L. camara* leaves and roots were tested for antibacterial activity. The extracts exhibited activity against *S. aureus, Proteus vulgaris, P. aeruginosa*, *Víbrio cholerae*, *E. coli* and multiresistant strains of *E. coli* and *S. aureus.* Leaves ethanolic extract was more active against *P. vulgaris and V. cholera* with MIC of 128 µg/ml for both the strains; root extract was more effective against *P. vulgaris* and *P. aeruginosa* with MIC of 64 and 128 µg/ml, respectively [24]. The antibacterial activity of the ethanol and aqueous extracts of the *L. camara* leaves was investigated against *B. subtilis* (MTCC 441), *S. aureus* (MTCC 3160), and *P. aeruginosa* (MTCC 4673) using agar diffusion technique. Results showed that only ethanolic extract was effective against all the bacteria with MIC between 25 to 125 mg/ml [25]. Alcoholic and aqueous extracts of *L. camara* showed significant activity against *E. coli* and moderate activity against other bacteria (*P. aeruginosa, S. aureus* and *Bacillus* sp.). Alcoholic extracts showed more antibacterial activity than water extracts. The MIC values ranged from 100 to 210 µg/ml [26].

Crude ethanolic and aqueous extract of *L. camara* were evaluated for antibacterial activity by the agar-well diffusion method against *P. aeruginosa, Klebsiella pneumoniae, S. typhi, E. coli, Serratia marcescens, P. mirabilis, S. aureus,* and *Staphylococcus citreus.* Ethanol extract presented the best results while aqueous extract showed moderate inhibition of the bacterial growth [27]. Chloroform extract of *L. camara* leaves showed good antibacterial activity as compared to standard drug ciprofloxacin against MTCC cultures, *viz*., *Bacillus licheniformis* 429, *E. coli* 40, *P. vulgaris* 426, *P. aeruginosa* 424, *S. aureus* 87 [28]. Antibacterial activity of petroleum ether, methanol, chloroform, and distilled water extracts of *L. camara* leaf, stem, and root was determined against *E. coli, P. aeruginosa, S. aureus,* and *Staphylococcus saprophyticus.* Methanol extract of stem and leaf parts showed activity against all the bacteria tested while root extract showed no activity on *P. aeruginosa* [29]. Antibacterial activity of petroleum ether, chloroform, ethanol, and aqueous extract of *L. camara* leaves were evaluated on *S. aureus*, *B. subtilis,* and *E. coli*. *E. coli* was equally sensitive to all the extracts while *S. aureus* was resistant to ethanolic extract. Petroleum

**Table 1: Antibacterial activity of *Lantana camara***

| Sl. No. | Bacteria (activity against) | References |
|---|---|---|
| 1 | *Acinetobacter baumannii* | 37 |
| 2 | *Alcaligenes faecalis* | 31 |
| 3 | *Arthrobacter protophormiae* | 61 |
| 4 | *Bacillus subtilis; Bacillus cereus; Bacillus thurengiensis; Bacillus licheniformis; Bacillus sphaericus; Bacillus megaterium; Bacillus* sp. | 2, 13, 16, 21, 23, 25, 26, 28, 30, 31, 34, 36, 38, 39, 40, 43, 44, 46, 47, 54, 55, 58, 59, 62, 64-68, 71, 72, 73, 75, 76 |
| 5 | *Citrobacter freundii* | 23, 34 |
| 6 | *Corynebacterium minutissimum* | 35 |
| 7 | *Clostridium difficile* | 35 |
| 8 | *Enterobacter aerogenes* | 23, 49 |
| 9 | *Enterococcus faecalis* | 47 |
| 10 | *Escherichia coli* | 2, 3, 13, 17, 19, 23, 24, 26-31, 33, 34, 38, 39, 40, 42, 43, 45, 46, 47, 49, 50, 51, 53, 54, 55, 60, 62-67, 69, 71, 73-80 |
| 11 | *Haemophilus influenzae* | 37, 42 |
| 12 | *Helicobacter pylori* | 32 |
| 13 | *Klebsiella pneumoniae; Klebsiella* sp. | 2, 27, 31, 33, 34, 37, 39, 42, 44, 48, 49, 51, 52, 58, 66, 72 |
| 14 | *Micrococcus luteus* | 2, 49, 61, 64 |
| 15 | *Mycobacterium tuberculosis; Mycobacterium avium; Mycobacterium* sp. | 20, 22, 37, 70, 72 |
| 16 | *Pantoea* sp. | 34 |
| 17 | *Pasteurella multocida* | 43 |
| 18 | *Proteus mirabilis; Proteus* sp.*; Proteus vulgaris* | 3, 23, 24, 27, 28, 34, 39, 40, 41, 42, 50, 59, 60, 74, 79 |
| 19 | *Pseudomonas aeruginosa; Pseudomonas fluorescens; Pseudomonas* sp.*; Pseudomonas syringae* | 13, 15, 17, 18, 19, 23-29, 31, 33, 34, 35, 37, 38, 44, 47, 50, 54, 55, 56, 59, 60, 64, 66, 67, 73, 74, 76, 79 |
| 20 | *Rhodococcus rhodochrous* | 61 |
| 21 | *Salmonella typhi; Salmonella paratyphi; Salmonella setubal; Salmonella typhimurium; Salmonella gallinarum* | 17, 21, 23, 27, 33, 34, 39, 40, 42, 45, 48, 49, 52, 54, 55, 59, 69, 71, 72 |
| 22 | *Sarcina lutea* | 67 |
| 23 | *Serratia marcescens; Serratia liquefaciens* | 27, 36 |
| 24 | *Shigella dysenteriae; Shigella flexnerii* | 23, 34, 42 |
| 25 | *Staphylococcus aureus; Staphylococcus* sp.*, Staphylococcus epidermidis; Staphylococcus saprophyticus; Staphylococcus citreus* | 2, 3, 13, 15, 16, 17, 23--31, 33, 34, 36, 37, 40, 42-- 46, 49, 50, 51, 53, 54, 55, 58, 61--67, 69, 71--74, 76, 78, 79, 80 |
| 26 | *Streptococcus sp., Streptococcus agalactiae; Streptococcus pneumoniae; Streptococcus pyogenes; Streptococcus sanguinis; Streptococcus faecalis* | 31, 34, 37, 38, 45, 52 |
| 27 | *Víbrio cholerae; Vibrio parahaemolyticus Vibrio* sp. | 24, 31, 34, 35, 48, 60, 72 |
| 28 | *Xanthomonas axonopodis* | 35 |

ether and aqueous extracts did not produce zone of inhibition against *B. subtilis* [30]. The antimicrobial activity of crude ethanolic and acetone extracts of *L. camara* was determined against thirteen test bacteria such as *E. coli* (MTCC 443), *B. subtilis* (MTCC 1789), *S. aureus*, *Streptococcus* sp., *P. aeruginosa, V. cholerae, Alcaligenes faecalis, B. cereus, K. pneumoniae* (MTCC 2405), and *Vibrio parahaemolyticus.* Both the extracts exhibited good antibacterial activity against all the bacteria tested except *V. parahaemolyticus*. Alcoholic extract of leaves exhibited stronger antimicrobial activity in comparison with acetone extract [31]. Methanolic extract of *L. camara* leaves inhibited the growth of *Helicobacter pylori* with an inhibition zone of 20 mm [32].

Benzene, hexane, petroleum ether (40-60°C), chloroform, ethanol, and ethyl acetate extracts of *L. camara* leaves were screened for antibacterial activity against *S. aureus, S. typhi, P. aeruginosa, K. pneumoniae,* and *E. coli.* All the extracts exhibited good antibacterial activity against all the tested bacteria. Sensitivity was in the order of *S. aureus>P. aeruginosa>E. coli* [33]. Antibacterial activities of methanolic extracts of *L. camara* stem and leaves were investigated. The clinical isolates – *C. freundii, E. coli, K. pneumoniae, Pantoea* sp., *P. aeruginosa, S. typhi, Shigella flexneri, S. aureus, Streptococcus agalactiae, Staphylococcus epidermidis, V. cholerae* and standard strains – *B. cereus* (ATCC 9144), *E. coli* (ATCC 25922), *P. mirabilis* (ATCC 35659) and *S. aureus* (ATCC 25923) were used for the study. *L. camara* extract exhibited significant antibacterial activity against all the bacteria tested except *V. cholerae* and *E. coli* (clinical isolate) [34]. The efficacy of aqueous and chloroform extracts of *L. camara* against four bacterial species, *viz., Xanthomonas axonopodis*, *Pseudomonas syringae* (Gram-negative bacteria) and *Corynebacterium minutissimum*, and *Clostridium difficile* (Gram-positive bacteria) were studied *in vitro*. Both extracts showed similar activities (moderate) against all the bacteria tested [35]. Ethyl acetate extracts of *L. camara* leaves and pods were evaluated for antibacterial activity against *Bacillus circulans, B. subtilis, B. sphaericus*, *S. aureus,* and *Serratia liquefaciens.* Ethyl acetate extracts of pods showed the highest antibacterial activity against tested clinical isolates followed by ethyl acetate extracts of leaves [36].

Gram-negative bacteria *K. pneumoniae* (RSKK 574), *Haemophilus influenzae* (ATCC 49766), *P. aeruginosa* (ATCC 10145), and *Acinetobacter baumannii* (RSKK 02026); Gram-positive bacteria *Streptococcus pneumoniae* (ATCC 19615), *Streptococcus pyogenes* (ATCC 13615), *S. aureus* (ATCC 25923), and *S. epidermidis* (ATCC 12228) were assessed for the determination of antibacterial activity. For antimycobacterial activity, the strains of *Mycobacterium avium* (ATCC 15769) and *M. tuberculosis* H37Rv (ATCC 27294) were used. *L. camara* (orange flowers, orange, and pink flowers) extracts exhibited inhibitory activities against Gram-positive bacteria and Gram-negative bacteria, with MICs ranging from 16 to 64 µg/ml. The extracts also showed antimycobacterial activity against both *M. tuberculosis* and *M. avium* with MICs ranging between 8 and 32 µg/ml [37]. Petroleum ether and methanolic extracts of *L. camara* leaves were screened against *E. coli, P. aeruginosa, B. subtilis,* and *Streptococcus faecalis.* Both the solvent extracts showed good antibacterial activity against all the bacteria tested. The bacteria were more sensitive to petroleum ether extract than methanolic extract [38]. Aqueous extract of leaves and flower of *L. camara* showed positive activity against *E. coli, S. aureus, P. vulgaris, B. subtilis* and *S. typhi.* Aqueous extract of flower showed the highest activity against *E. coli* and *S. aureus,* i.e. 30 mm zone of inhibition whereas aqueous extract of leaves showed highest activity against *E. coli* (26 mm) and *P. vulgaris* (25 mm) [39]. Aqueous and alcoholic extracts of *L. camara* were evaluated for their *in vitro* antibacterial activity against *P. mirabilis* by serial dilution method. The reduction in pH, ammonia concentration and urease activity in aqueous and alcoholic extracts (pH: 8.9250, ammonia: 5.32, 5.94 µg/ml, urease:

0.010, 0.011 IU/ml, respectively) as compared to positive control (pH: 9.03, ammonia: 6.7 µg/mL, urease: 0.013 IU/ml) indicated antibacterial activity of *L. camara* extracts against *P. mirabilis* in broth culture [40].

The methanolic leaf extract was tested for its antibacterial activity against different human pathogenic bacteria *E. coli, H. influenzae, K. pneumoniae, P. mirabilis, S. typhi, S. flexneri,* and *S. aureus.* All the bacteria tested were inhibited at varying levels by the methanolic extract at different concentrations used such as 2, 4, 6, 8, and 10 mg/ml. *K. pneumoniae* was highly susceptible, followed by *E. coli* and *H. influenzae*, while *P. mirabilis* was least susceptible [41]. The antibacterial activity of *L. camara* flower extracts (ethanol and methanol) against four bacterial strains: *E. coli*, *S. aureus*, *Pasteurella multocida,* and *B. subtilis* was assessed by disc diffusion method. The results showed that all the extracts of *L. camara* flowers possessed notable antibacterial activity against all the tested bacterial strains [42]. Methanol, ethanol and water extracts of *L. camara* leaves were evaluated against four bacterial isolates (*S. aureus, P. aeruginosa, K. pneumoniae,* and *B. subtilis*). Methanol extract showed maximum antibacterial activity against *S. aureus* and *P. aeruginosa* and was also effective against other bacterial strains as compared to ethanol and aqueous extracts [43]. *In vitro* antibacterial activities of cold-ethanolic extracts of *L. camara* leaves were compared to the hot-ethanolic extracts of the same plant for antibacterial activity. The highest zone of inhibition was recorded against *S. pyogenes* (28 mm), while moderate zone of inhibition was recorded against *S. aureus* (25 mm) and *E. coli* (23 mm) and weak antibacterial activity was recorded against *S. typhi* (18 mm) with cold ethanolic extract. Hot extract recorded comparatively less zone of inhibition for all the bacteria tested. The cold extract was more effective compared to the hot extract [44].

Petroleum ether, methanol, ethyl acetate, and water extracts of *L. camara* leaves were screened against *E. coli, S. aureus,* and *B. subtilis*. Petroleum ether extract showed the highest antibacterial activity while methanol and ethyl acetate extracts showed moderate activity. All extracts showed maximum zone of inhibition at 200 µg/ml concentration [45]. Crude and column extracts of *L. camara* leaves and flowers were tested for antibacterial activity. The extracts showed activity against *E. coli, P. aeruginosa, B. subtilis,* and *Enterococcus faecalis* with 6.8-8.1 mm (crude) and 4.0-6.2 mm (column) zone of inhibition. The bioactive compound parthenin was isolated from the HPLC analysis of extracts [46]. Inhibitory effect of the solvent extracts (methanol, chloroform, diethyl ether and hot water) of *L. camara* roots against four different bacterial strains (*S. typhi, S. paratyphi, K. pneumoniae,* and *V. cholerae*) was studied. All the extracts inhibited bacterial growth at 5 mg/ml concentration except hot water extract which showed no activity against *K. pneumoniae*. Among all solvent extracts, the methanol extract showed the best inhibitory activity [47]. Methanol extract of *L. camara* fruit was assayed against six bacterial strains, *viz., S. aureus* (ATCC 6538), *Micrococcus luteus* (ATCC 10240), *Salmonella setubal* (ATCC 19196), *E. aerogenes* (ATCC 13048), *K. pneumoniae* (ATCC 1705), and *E. coli* (ATCC 5224). The extract showed good antibacterial activity against all the tested bacteria with inhibition zone ranging between 9 to 12.3 mm [48].

Antimicrobial activities of methanol, chloroform, acetone, petroleum ether and hexane extracts of *L. camara* seed was investigated against *S. aureus, P. aeruginosa, P. vulgaris* and *E. coli.* Methanolic extract showed maximum inhibition against *S. aureus, P. aeruginosa* and *E. coli* and no inhibition against *P. vulgaris*. Similarly, the acetone extract showed inhibition against *S. aureus, P. vulgaris* and lesser activity against *E. coli*. The other extracts had no antibacterial activity against any bacterial strains tested [49]. The antibacterial activities of leaf extract of *L. camara* alone or in combination with gentamicin or ceftriaxone were determined by *in vitro* study against *E. coli* (ATCC 25922), *S. aureus* (ATCC 25923) and fully characterized NDM-1 strains of *K. pneumoniae*. The results showed the inhibitory activity of extract against *E. coli* (3.5 mm), *S. aureus* (4 mm), and NDM1 strain (1.2 mm). The synergistic effect was observed, of extract and gentamicin against *E. coli* (5.5 mm), of extract and ceftriaxone against *S. aureus* (6.0 mm). Notable effect was obtained with extract and gentamicin against NDM1 strain with 2.2 mm zone of inhibition [50]. Antimicrobial activity of hexane extract of *L. camara* leaves was evaluated against *S. pneumoniae*, *S. typhi, and K. pneumoniae*. The hexane extract showed antibacterial activity only against *S. pneumoniae* in all the concentrations tested [51]. Aqueous ethanol extract (3:1) of *L. camara* leaves showed good antibacterial activity against *K. pneumonia* (MTCC 1320) and *V. parahaemolyticus* (MTCC 451), moderate activity against *E. coli* (MTCC 443) and *B. subtilis* (MTCC 121), and no activity against *Pseudomonas fluorescens* (MTCC 2421) [52].

The antibacterial activities of *L. camara* leaf and root ethanol extracts alone or in association with aminoglycosides were determined against bacterial strains by microdilution test. The extracts exhibited inhibitory activity against multiresistant strains of *E. coli* and *S. aureus*. The MICs for all antibiotics tested decreased in the presence of the extracts. The results indicated the antibacterial activity of *L. camara* extracts and their potential in reducing the resistance of bacteria to aminoglycosides [53]. Ethyl acetate, methanol, acetone, and chloroform extracts of *L. camara* leaves were effective against both Gram-positive (*S. aureus, B. subtilis, M. luteus*) and Gram-negative (*E. coli, K. pneumoniae*) bacterial strains tested, but their efficacy varied. Gram-negative bacteria were more susceptible to all extracts compared to Gram-positive bacteria. Methanol extract had the highest inhibition activity against all the tested microbes when compared to any other solvent extracts tested [2]. Ethyl acetate extract of *L. camara* root bark showed effective antibacterial activity with zone of inhibition of 31, 34, 40, 40 and 32 mm against *E. coli, S. typhi*, *Pseudomonas* sp., *S. aureus*, and *B. subtilis*, respectively [54]. Ethyl acetate and ethanol extract of *L. camara* flower possessed strong antibacterial effect against *E. coli, S. typhi, Pseudomonas* sp., *S. aureus,* and *B. Subtilis.* Ethyl acetate extract produced zone of inhibition 35, 34, 33, 32, and 32 mm against *E. coli, S. typhi, B. Subtilis, Pseudomonas* sp., *S. aureus,* respectively. The zone of inhibition for ethanol extract was found to be 34, 34, 30, 30 and 25 mm against *S. typhi, S. aureus, E. coli*, *Pseudomonas* sp. and *B. subtilis,* respectively [55].

### *EOs*

The EO of *L. camara* exhibited a wide spectrum of antibacterial activities against seven bacteria screened. Highest inhibition was observed against *P. aeruginosa* [56]. Kasali *et al.* [57] reported considerable antibacterial activity of *L. camara* leaves EO against both Gram-positive and Gram-negative bacteria tested at 5 mg/ml concentration. EO of *L. camara* was evaluated for antibacterial activity and the oil completely inhibited the growth of *Bacillus megaterium*, *S. aureus*, *Klebsiella* sp., at 1600 ppm [58]. The EO of *L. camara* leaves was tested against 6 strains, using disc diffusion method. The oil showed moderate activity against *B. subtilis* ATCC 33923, *S. typhi* ATCC 2785, *P. aeruginosa* ATCC 27856, *B. aureus* ATCC 14579, and *P. mirabilis* ATCC 21784 [59]. *L. camara* EOs exhibited considerable antibacterial activity against *E. coli* (ATCC 25922), *P. vulgaris* (ATCC 13315), *P. aeruginosa* (ATCC 15442), and *V. cholera* (ATCC 15748) [60].

EO of *L. camara* showed antibacterial activity by direct contact against *Arthrobacter protophormiae*, *M. luteus*, *Rhodococcus rhodochrous* and *S. aureus* with MBC of 50, 25, 12.5 and 200 µg/ml, respectively [61]. The EO of *L. camara* was tested against *E. coli*, *S. aureus* and *Bacillus* sp. *E. coli* (25 mm) and *S. aureus* (29 mm) were more susceptible toward EO in comparison to the *Bacillus* sp. (19 mm). The MIC was 1.25, 1.0 and 1.75 µg/ml for *E. coli, S. aureus* and *Bacillus* sp., respectively [62]. EO of *L. camara* leaves was examined for antibacterial and modulatory activity against two multiresistant strains, *E. coli* from sputum and *S. aureus* from surgical wound. The results showed inhibition of *E. coli* (MIC 512 µg/ml) and *S. aureus* (MIC 256 µg/ml). The synergism of the EO on aminoglycosides was observed with a significant reduction of MICs (1250 to 5 µg/mL) against *E. coli* [63]. Hydrosol of *L. camara* leaves obtained with waste of EO was studied for antibacterial activities. Gram-negative bacteria *E. coli* (MTCC 443), *P. aeruginosa* (MTCC 741) were resistant and Gram-positive bacteria *B. cereus* (MTCC 430), *S. aureus*

(MTCC 87) and *M. luteus* (MTCC 106) were sensitive to leaf hydrosol [64]. Volatile oils from the leaves of *L. camara* showed moderate antibacterial activity against *E. coli*, *S. aureus* and *B. subtilis* [65]. The EO of *L. camara* exhibited significant antibacterial activity against *E. coli, B. subtilis, B. cereus* and *S. aureus* and moderate activity against *K. pneumonia*e and *P. aeruginosa.* Gram-positive bacteria were more sensitive than Gram-negative bacteria [66].

The antibacterial activity of EO of *L. camara* leaves was assessed against *B. subtilis* ATCC 6633, *S. aureus* ATCC 6538 and *Sarcina lutea* ATCC 934, *E. coli* ATCC 8739 and *P. aeruginosa* ATCC 9027. The EO showed activity against *B. subtilis*, *S. aureus*, *E. coli* and *S. lutea* at MICs values of 500, 500, 500 and <250 µg/ml, respectively. It even showed activity against *P. aeruginosa* but at high concentration with MIC of 5000 µg/ml [67]. The EO of *L. camara* inhibited the growth of *S. aureus* and *P. aeruginosa* with MIC of 1 and >1 mg/l, respectively. The activity of the antibiotic amikacin was increased against *S. aureus* (by 29%) and *P. aeruginosa* (by 65%) in the presence of EO and the activity of gentamicin against *P. aeruginosa* by 21% [15]. The essential oil of flowers and leaves of *L. camara* species growing in Egypt exhibited *in vitro* antimicrobial activity against *B. cereus* (ATCC 33018) and *B. subtilis* (ATCC 6633) with MIC ranging between 1.25 to 5 mg/ml [68]. The essential oil of *L. camara* flowers exhibited antibacterial activity against *S. aureus*, *Streptococcus sanguinis, E. coli, Salmonella typhimurium* with MIC of 500 µg/ml [69]. EO from leaves of *L. camara* (EOLC) was evaluated against mycobacteria. The results revealed that the EO was not able to inhibit the growth of tested *Mycobacterium* sp., until 1250 mg/ml of EOLC [70]. *L. camara* leaf ethanolic fraction (EF) and EO demonstrated antibacterial activity against *S. aureus*, *B. subtilis*, *E. coli,* and *Salmonella gallinarum*. The MIC of EO ranged from 312.5 to 10,000 µg/ml and of EF from 1250 to 5000 µg/ml. *B. subtilis* was the most sensitive organism inhibited at 312.5 µg/ml while *S. gallinarum* showed less sensitivity [71].

**Nanoparticles**

The antibacterial activity of silver nanoparticles (AgNPs) synthesized from the aqueous extract of *L. camara* fruits was examined against six pathogenic bacteria such as *M. luteus* ATCC 4698, *B. subtilis* MTCC 1133, *S. aureus* MTCC 96, *V. cholerae* ATCC 14035, *K. pneumoniae* MTCC 109, and *S. typhi* MTCC 733. The maximum activity was 26 mm zone of inhibition for *B. subtilis* and 22 mm zone of inhibition against *S. typhi*. AgNPs were found to be more effective against Gram-positive bacteria than Gram-negative bacteria [72]. Biosynthesized AgNPs from aqueous extract of *L. camara* leaves showed significant antibacterial activity at 100, 200 and 300 µg/ml against *B. Subtilis, S. aureus, E. coli* and *P. aeruginosa* [73]. AgNP's of *L. camara* seed acetone extract had effective antibacterial activity against *S. aureus, P. aeruginosa, P. vulgaris* and *E. coli* in all concentrations tested [74]. Verma and Balasubramanian [75] immobilized the EO of *L. camara* on the nanocomposite polyacrylonite membrane and showed it to have exceptional antibacterial activity against *E. coli* and *B. subtilis* (7-10 mm zone of inhibition). The synthesized AgNPs of *L. camara* leaf extract exhibited good antibacterial activity against *E. coli, Pseudomonas* spp., *Bacillus* spp., and *Staphylococcus* spp. The leaf extract itself acted as both reducing and stabilizing agent at once for desired nanoparticle synthesis [76]. The AgNPs synthesized by leaf extract of *L. camara* showed strong antibacterial activity against *E. coli* [77]. 80% ethanolic extracts of *L. camara* leaves and copper oxide nanoparticles were mixed in different ratio to produce composites and then their antibacterial activity was assessed. The composites yielded a better result than the herbal particles or nanoparticles alone against the test organisms *S. aureus* (ATCC 11226) and *E. coli* (ATCC 6529), and the maximum activity was found to be around 30 and 33 mm zone of inhibition, respectively [78]. The AgNPs synthesized by aqueous extract of *L. camara* seed exhibited significant antibacterial activity against *S. aureus, P. aeruginosa, P. vulgaris,* and *E. coli.* Maximum zone of inhibition was absorbed against *P. aeruginosa* and minimum zone against *P. vulgaris* [79]. AgNPs of *L. camara* leaf extract showed very high antibacterial activity against *E. coli* and *S. aureus* at a very low concentration of 50 ppm nanoparticles. Inhibition was by leakage due to cell wall rupturing [80].

**Antifungal activity**

Although the synthetic fungicides are effective in controlling the plant diseases, the undesirable attributes of their use demand alternative treatments that are less hazardous to humans and animals and less impact on the environment. Extracts isolated from plants provide promising alternative. Antifungal activities of *L. camara* have been reported. Experiments on mode of action suggested that the extracts lyse the cells and alter the membrane integrity by depleting the ergosterol content, which avoid the reoccurrence [81]. Different solvent extracts, EOs as well as nanoparticles of *L. camara* have great antifungal activity (Table 2). Crude extract of *L. camara* root was effective against *Cladosporium sphaerospermum* [16]. *L. camara* extract significantly inhibited the radial growth of *Fusarium oxysporum* f. sp. *lini* causing wilt of linseed at 30% concentration and checked the wilt of linseed in wilt stil pots. Seed treatment with leaf powder drastically reduced the plant mortality even after 40 days of sowing [82]. Patel *et al.* [83] screened the antimicrobial activity of *L. camara* extract and reported antifungal activity against *Aspergillus niger* and *Aspergillus awamori.*

The methanol, diethyl ether, ethyl acetate, n-butanol, chloroform and aqueous extracts of *L. camara* leaves and flowers were screened against *Trichophyton rubrum.* Methanol extract showed maximum activity (98% inhibition) followed by ethyl acetate extract (85%), diethyl ether and n-butanol (80%), chloroform (60%) against *T. rubrum* at 100 µg/ml, while aqueous extracts inhibited the growth of this fungus at the same concentration by 32-44%. The activity of the methanolic extract was also determined against *Microsporum canis, Microsporum gypseum, Trichophyton mentagrophytes, Trichophyton verrucosum,* and *Epidermophyton floccosum.* Extract was very effective against all the tested fungi. The percent inhibition ranged from 50% to 80% [84]. Acetone extracts of different parts of *L. camara* were found to produce moderate to good antifungal activity against all phytopathogenic fungi (*Penicillium janthinellum, Penicillium expansum, Aspergillus parasiticus, A. niger, Colletotrichum gloeosporioides, F. oxysporum, Trichoderma harzianum, Phytophthora nicotiana, Pythium ultimum,* and *Rhizoctonia solani*) studied. Leaf extracts were more active than seed or flower extracts [85]. Antifungal efficacy of flavonoids (free and bound) and crude alkaloids of *L. camara* extracted from roots, stem, leaves, and flower was determined by disc diffusion assay against *Candida albicans* (MTCC 183) and dermatophytic fungi *T. mentagrophytes* (MTCC 7687). Most susceptible fungus was *C. albicans* followed by *T. mentagrophytes.* The range of MIC of tested extracts was 0.039-0.625 mg/ml while minimum fungicidal concentration ranged from 0.078 to 1.25 mg/ml [3]. Sharma and Kumar [86] reported antifungal potential of flavonoids of *L. camara* (flower) against *F. oxysporum* (MTCC 7678). Observations revealed that the free flavonoids were more effective than the bound flavonoids and alkaloids of the plant. Antifungal activity of ethanol and hot water extracts of *L. camara* was screened against wood destroying white and brown rot fungi (*Trametes versicolor, Oligoporus placenta*). Both extracts exhibited efficient antifungal activity against white and brown rot fungi, however, ethanol extract was highly potential at very low concentration (0.01%) [87].

Methanolic extracts from different parts of *L. camara* were evaluated for potential antimicrobial activity against *Alternaria alternata* (MTCC 1362), *A. niger* (MTCC 2723), *Macrophomina phaseolina* (MTCC 2165), and *R. solani* (MTCC 4633). *L. camara* extract showed highest activity (10 mm) against *A. alternata* and *M. phaseolina*, lowest activity against *R. solani* and no activity against *A. niger* [88]. Aqueous extract of leaf and seed of *L. camara* showed some potentiality to inhibit the growth of a few seed borne fungi, *Phomopsis vexans, F. oxysporum, Aspergillus flavus, A. niger, Curvularia lunata* and *Penicillium* sp., (seed infection was only 6.67%) and enhanced the seed germination of brinjal [89]. Methanolic leaf extract of *L. camara* showed minimal inhibition of mycelial growth of *A. flavus* (17%) at 10 mg/ml concentration but effective inhibition of aflatoxin B1 production (72.36%) at 25 mg/ml concentration [90]. The antifungal activity of ethanol extract of *L. camara* was evaluated against

**Table 2: Antifungal activity of *Lantana camara***

| Sl. No. | Fungi (activity against) | References |
|---|---|---|
| 1 | *Alternaria alternata; Alternaria* sp.*; Alternaria solani* | 31, 35, 43, 88, 92, 94, 96, 97, 99, 100, 101, 106, 108 |
| 2 | *Aspergillus niger; Aspergillus flavus; Aspergillus awamori; Aspergillus parasiticus; Aspergillus* sp.*; Aspergillus fumigatus* | 31, 35, 43, 44, 49, 52, 56, 73, 81, 83, 85, 88, 89, 90, 93, 96, 97, 99, 100 |
| 3 | *Botrytis cinerea* | 106, 108 |
| 4 | *Candida albicans; Candida dubliniensis; Candida krusei; Candida guilliermondii; Candida tropicalis; Candida parapsilosis; Candida glabrata* | 3, 31, 37, 38, 45, 56, 57, 59, 69, 73, 91, 100, 102, 107 |
| 5 | *Cladosporium cucumerinum* | 16 |
| 6 | *Colletotrichum gloeosporioides* | 85, 103, 104 |
| 7 | *Curvularia lunata* | 31, 89, 97, 100 |
| 8 | *Drechslera biseptata* | 35 |
| 9 | *Epidermophyton floccosum* | 37, 84 |
| 10 | *Fusarium oxysporum; Fusarium solani; Fusarium* sp.*; Fusarium moniliforme* | 31, 35, 49, 56, 58, 82, 85, 86, 89, 95, 96, 99, 106 |
| 11 | *Helminthosporium solani* | 108 |
| 12 | *Humicola grisea* | 108 |
| 13 | *Macrophomina phaseolina* | 88 |
| 14 | *Malassezia furfur* | 38 |
| 15 | *Microsporum canis; Microsporum gypseum* | 37, 84 |
| 16 | *Mucor* sp.*; Mucor hiemalis* | 49, 108 |
| 17 | *Penicillium funiculosum; Penicillium janthinellum; Penicillium expansum; Penicillium* sp.*; Penicillium digitatum* | 58, 85, 89, 98, 99 |
| 18 | *Phomopsis vexans* | 89 |
| 19 | *Phytophthora nicotiana* | 85 |
| 20 | *Pythium ultimum; Pythium aphanidermatum; Pythium* sp. | 85, 95, 96, 106 |
| 21 | *Rhizoctonia solani; Rhizoctonia bataticola* | 85, 88, 93, 95, 106 |
| 22 | *Rhizomucor tauricus* | 58 |
| 23 | *Rhizopus solani* | 43 |
| 24 | *Saccharomyces cerevisiae* | 31 |
| 25 | *Sclerotium rolfsii* | 31, 105 |
| 26 | *Trichoderma reesei; Trichoderma harzianum; Trichoderma* sp. | 58, 85, 99 |
| 27 | *Trichophyton mentagrophytes; Trichophyton rubrum, Trichophyton verrucosum; Trichophyton tonsurans; Trichophyton violaceum* | 3, 37, 52, 84, 97, 102 |
| 28 | *Verticillium dahliae* | 106 |
| 29 | White and brown rot fungi *(Trametes versicolor; Oligoporus placenta)* | 87 |

six species of *Candida* (*C. albicans, Candida dubliniensis, Candida krusei, Candida guilliermondii, Candida tropicalis* and *Candida parapsilosis*). Stem extract inhibited *C. dubliniensis, C. albicans* and *C. guillermondii* growth, while leaf extract inhibited *C. krusei.* Chromatographic studies revealed that the stem and leaves of *L. camara* contained flavonoids with antifungal effect [91]. Eleven fungal strains, *C. albicans* (MTCC 1022), *C. tropicalis, Saccharomyces cerevisiae* (MTCC 17322), *A. niger, A. flavus, Penicillium* sp., *F. oxysporum, A. alternata, Sclerotium rolfsii,* and *C. lunata* were used to test antifungal activity of *L. camara* ethanol and acetone extracts. The extracts were ineffective against *Candida* spp., tested and moderately effective against *S. cerevisiae*. All other fungal isolates tested exhibited maximum percentage growth inhibition at 1000 µg/ml concentration of both ethanolic and acetone extract. Acetone extract showed greater antifungal potential than the ethanolic extract [31]. *L. camara* was screened against *Alternaria* sp. which causes different plant diseases especially in vegetable plants. At 20 mg/ml dose *L. camara* exhibited significant antifungal activity against *Alternaria* sp. [92].

The antifungal activity of *L. camara* extracts was evaluated against *A. niger, A. flavus, Rhizoctonia bataticola,* and *R. solani*. *L. camara* exhibited moderate inhibition against all tested pathogens. Among the three solvents extracts highest inhibition of radial mycelial growth of all four pathogens was observed with ethanol extract, acetone extract showed moderate inhibition while minimum inhibition was recorded in water extract of the plant [93]. The efficacy of aqueous and chloroform extracts of *L. camara* against major seed-borne fungi *A. niger, A. alternata, Drechslera biseptata,* and *F. solani* were studied *in vitro*. Both extracts showed similar activities (moderate) against all the fungi tested [35]. *C. albicans* (ATCC 10231), *C. tropicalis*, *C. parapsilosis* (ATCC 22019), *C*. *krusei* and dermatophytic fungi *T. rubrum* (RSKK 486), *E. floccosum* (RSKK 3027), *M. gypseum* (NCPF 580) were used for antifungal activity. *L. camara* flower extracts showed better antifungal activity against *C. parapsilosis*, *C. albicans, C. krusei* and *C. tropicalis*, with MIC values ranging between 8 and 32 µg/ml. Significant antidermatophytic activity was also observed wherein MICs ranged between 16 and 64 µg/ml [37]. Petroleum ether and methanolic extracts of *L. camara* leaves were screened against *C. albicans* MTCC 227 and *Malassezia furfur* MTCC 1374. Both the solvent extracts showed good antifungal activity against the fungi tested [38]. The leaf extracts of *L. camara* in different organic solvents (methanol, acetone, ethanol and aqueous) were assessed *in vitro* for fungitoxic activity against phytopathogenic *A. alternata* isolated from potato (*Solanum tuberosum*) and tomato (*Lycopersicon esculentum*). Among the four extracts, ethanol and acetone extracts showed complete inhibition of growth of fungus; while methanol extract showed 50% inhibition and aqueous extract did not inhibit the fungus [94].

Methanolic extract from *L. camara* leaves was evaluated for its antifungal efficiency on tomato phytopathogenic fungi *F. oxysporum, Pythium aphanidermatum,* and *R. solani*. *L. camara* extract was very effective against *P. aphanidermatum* which was completely inhibited at 10 mg/ml, while moderately effective against *F. oxysporum* and *R. solani* with 28% and 17% inhibition respectively at 10 mg/ml [95]. Hexane, ethylacetate and methanol extracts of leaf and stem bark of *L. camara* were screened against *Aspergillus* sp., *Alternaria* sp., *Pythium* sp. and *Fusarium* sp. Ethyl acetate extract of leaf showed antifungal activity against all the tested fungi after 48h of incubation, while methanol extract against only *Pythium* sp. Ethyl acetate extract of stem bark inhibited growth of *Aspergillus* sp. and *Alternaria* sp., while methanol extract inhibited *Alternaria* sp. and *Fusarium* sp. after 48 hr of incubation. Hexane extracts had no inhibitory effect on any fungi tested [96]. Antifungal activity of ethanol, methanol and petroleum ether extracts of *L. camara* leaves was studied against important allergenic and pathogenic fungi *Trichophyton tonsurans, A. niger, A. alternata,* and *C. lunata.* Effective inhibition of mycelia growth of all tested fungi was observed with ethanol and methanol extracts while petroleum ether extract showed good activity against *A. alternata*

and *C. lunata,* and moderate activity against *T. tonsurans* and *A. niger* at 100 mg/ml concentration [97]. The antifungal activity of *L. camara* flower extracts (ethanol and methanol) against four pathogenic fungi: *A. flavus*, *A. niger*, *A. alternata* and *R. solani* was assessed by measuring MIC using the disc diffusion method. The results showed that all the extracts of *L. camara* flowers possessed notable antifungal activity against all the tested fungal strains [43]. Methanol, ethanol and water extracts of *L. camara* leaves were evaluated against two fungal strains (*Aspergillus fumigatus* and *A. flavus*). The methanol extract exhibited significant inhibition (71%) and (66%) against *A. fumigatus* and *A. flavus,* respectively [44]. *In vitro* antifungal activities of cold-ethanolic extracts of *L. camara* leaves were compared to the hot-ethanolic extracts of the same plant. The highest zone of inhibition was recorded against *C. albicans* (29 mm) with cold ethanolic extract. The cold extract was more effective compared to the hot extract [45]. Verbascoside purified from leaf extract of *L. camara* displayed effective *in vivo* inhibition of *Penicillium digitatum* on oranges [98]. Methanol extract of *L. camara* fruit was tested against three fungal strains *Mucor* sp., *A. fumigatus* and *Fusarium moniliforme*. The extract exhibited 40%, 38% and 48% growth inhibition of tested fungi, respectively [49].

The ethyl acetate extract of *L. camara* stem bark was divided into two fractions (A and B) by the thin layer chromatography (TLC) analysis. The antifungal bioassay was done to the above two fractions against *Aspergillus* sp., *Alternaria* sp., *Fusarium* sp., *Trichoderma* sp., and *Penicillium* sp. Fraction B showed higher antifungal activity than fraction A against all tested fungi. The fraction B was then divided into two fractions X and Y based on TLC analysis. The antifungal bioassay was also done to fractions X and Y against same fungi. Both fractions X and Y showed highest inhibition on *Fusarium* sp. with 25 and 32 mm and on *Penicillium* sp. with 26 mm and 34 mm, respectively, after 48 hrs of incubation. They also showed good antifungal activity against other tested fungi at 48 hr of incubation except fraction X on *Alternaria* sp., where no activity was observed [99]. Aqueous extract of *L. camara* leaves showed significant antifungal activity against *A. niger* ATCC 16888 with maximum growth inhibition of 14±0.142 mm at 30 mg/ml, while it was 37±0.124 mm for the standard antifungal agent vericonozole at 30 mg/disc. The MIC of the extract was 18 mg/ml [81]. Antifungal activity of hexane extract of *L. camara* leaves was evaluated against *A. niger* and *Trichophyton violaceum*. The hexane extract showed activity only against *A. niger* in all the concentrations tested [52]. Methanol extract of *L. camara* leaves showed antifungal activity against *A. alternata* (NCIM 718), *A. niger* (MTCC 2202), *C. albicans* (ATCC 10231), *C. lunata* (NCIM 716). The MIC and minimal lethal concentration (MLC) values were *A. alternata* (0.7 and 0.9 mg/ml), *A. niger* (0.4 and 0.9 mg/ml), *C. albicans* (0.3 and 0.5 mg/ml) and *C. lunata* (0.8 mg/ml). Least MIC and MLC was observed against *A. niger* and *C. albicans* [100]. Methanolic extracts of *L. camara* were screened *in vitro* for its antifungal activity against *A. alternata* at 5, 10 and 20% concentrations. At 5% concentration (50 mg/ml), up to 96 hrs, maximum mycelial growth inhibition (100%) was observed by the extract of *L. camara* [101].

Evaluation of antifungal activities of the ethanolic, methanolic and aqueous extracts of *L. camara* against the two fungal organisms *T. rubrum* and *C. albicans* was carried out. The ethanolic extract showed the most inhibition potential against the two fungi followed by methanol extract at all the three 10%, 20% and 30% concentrations tested [102]. *L. camara* extracts significantly reduced radial growth and conidia formation of *C. gloeosporioides*, and reduced anthracnose disease development on mango fruits. Thus, *L. camara* extracts could serve as an alternative means of post-harvest mango anthracnose disease management [103]. Ethanol leaf extract of *L. camara* possessed significant fungicidal effect on the radial growth of *C. gloeosporioides* causing post-harvest disease of papaya [104]. The antifungal activity of ethanolic and petroleum ether extracts of *L. camara* leaves and flowers were tested *in vitro* against phytopathogenic fungus *S. rolfsii* Sacc., using poison food method. Ethanolic extract of *L. camara* leaves showed 50% inhibition of the growth while the petroleum ether extracts of *L. camara* had no activity against *S. rolfsii* [105].

*EOs*

The EO of *L. camara*, tested against eight fungi, showed a wide spectrum of antifungal activities. Highest inhibition was seen for *C. albicans, Aspergillus* sp., and *F. solani* [56]. The EO of *L. camara* leaves exhibited considerable antifungal activity against *C. albicans* at 5 mg/ml concentration [57]. Volatile components extracted from the leaves, stems and flowers of *L. camara* were tested against *Alternaria solani*, *Botrytis cinerea*, *F. solani* f. sp. *cucurbitae*, *F. oxysporum* f. sp. *niveum*, *P. ultimum*, *R. solani,* and *Verticillium dahliae*. Volatile components extracted from the flowers of *L. camara* had the strongest antifungal effect (38%), followed by components from the leaves (27.1%) and stems (26.6%). Complete inhibition was achieved against *V. dahliae*. The weakest effect was against *P. ultimum* [106]. *L. camara* oil was effective in inhibiting the growth of *A. niger*, and reducing the growth of other fungi (*F. solani, Penicillium funiculosum, Rhizomucor tauricus, Trichoderma reesei*) [58]. The EO showed moderate activity against *C. albicans* MTTC 227 [59]. Antifungal activity of EOLC leaves was studied against *C. albicans* and *C. krusei* ATCC 6258. The EO remarkably inhibited the growth of the fungi tested [107]. The EO of *L. camara* flowers exhibited antifungal activity against *C. albicans* and *C. glabrata* in all the concentrations tested [69]. The antifungal activity of EOLC was tested against five phyto-pathogenic fungi *viz., A. alternata* (MTCC 149), *Mucor hiemalis* (MTCC 157), *Helminthosporium solani* (MTCC 1899), *Humicola grisea* (MTCC 352), and *B. cinerea* (MTCC 359). The EOs exhibited antifungal activity against all the tested fungi till 32 days of incubation which was equivalent to the standard fluconazole [108].

*Nanoparticles*

Biosynthesized AgNPs from aqueous extract of *L. camara* leaves showed good antifungal activity against *C. albicans* and *A. niger* at 100, 200 and 300 µg/ml [73].

**Antiprotozoal activity**

The root bark extract of *L. camara* showed *in vitro* activity against *Plasmodium falciparum* causing malaria [109]. Braga *et al.* [110] confirmed the antileishmanial activity of methanolic extract of *L. camara* leaves against *Leishmania amazonensis* and *L. chagasi*. Jonville *et al.* [111] investigated antimalarial activity of dichloromethane and methanol extract of *L. camara* through *in vitro* studies against the 3D7 and W2 strain of *P. falciparum* and *in vivo* studies against *Plasmodium berghei* infected mice and reported effective *in vitro* activity of the dichloromethane leaves extract against *P. falciparum* and moderate *in vivo* activity against *P. berghei*. Dichloromethane was found to posses more potent activity. Good antiplasmodial activity was found in *L. camara* leaf ethyl acetate extract ($IC_{50}$=19 µg/ml) against the tested strains of *P. falciparum* [112]. The EO of *L. camara* showed antiplasmodial activity similar to that of chloroquine against the multi-drug-resistant strain of *P. falciparum* FCM29, but not the high activity as achieved by quinine [113]. Oleanolic acid, ursolic acid, lantadene A, and lantanilic acid obtained from the aerial parts of *L. camara* showed significant leishmanicidal activities against promastigotes of *Leishmania major* with $IC_{50}$ values of 53.0, 12.4, 20.4, and 21.3 µM, respectively [114]. *L. camara* EO was very effective against *L. amazonensis* (IC50=0.25 µg/ml) and *L. chagasi* (IC50=18 µg/ml) [115]. The EO of *L. camara* inhibited *Leishmania braziliensis* and *Trypanosoma cruzi* with IC50 of 72.31 and 201.94µg/ml, respectively [116].

**Antinematode activity**

Leaf extracts of *L. camara* applied to *Meloidogyne incognita* killed all larvae up to $S_2$ concentration within 5 hr. At $S_1$0 the mortality was 96.59% which increased to 100%, 30 hr after treatment [117]. Lantanoside, linaroside, and camarinic acid isolated from the aerial parts of *L. camara* were tested for nematicidal activity against root-knot nematode *M. incognita* and showed 90%, 85%, and 100% mortality, respectively, at 1.0% concentration. The results were comparable to those obtained with the conventional nematicide furadan (100% mortality at 1.0% concentration) [118]. Aqueous, methanol, ethyl acetate, and hexane extracts of *L. camara* leaves caused significant

mortality of *Meloidogyne javanica* juveniles *in vitro.* Aqueous and methanolic extracts demonstrated greater inhibition (93% and 78% mortality at 10 mg/ml) compared to ethyl acetate or hexane extracts. Decomposing leaves of *L. camara* used alone or in combination with *P. aeruginosa* markedly suppressed population densities of *M. javanica* and subsequent root-knot development in mungbean [119]. Shaukat and Siddiqui [120] reported the nematicidal activity of *L. camara* against juveniles of *M. javanica* on mungbean. Concentrated and diluted root leachate of *L. camara* caused substantial mortality of *M. javanica* juveniles, the root-knot nematode. Application of the *L. camara* root leachates in combination with *P. aeruginosa*, a plant growth-promoting rhizobacterium, significantly reduced nematode population densities in roots and subsequent root-knot infection and enhanced plant growth [121]. Aqueous leaf extract of *L. camara* was very effective in complete inhibition of egg hatching and subsequent larval penetration of *M. incognita* in banana at 48, 96 and 144 hrs indicating ovicidal effects [122]. Lantanilic acid, camaric acid, and oleanolic acid were isolated from methanolic extract of the aerial parts of *L. camara* and these compounds exhibited 98%, 95% and 70% mortality; respectively, against root-knot nematode *M. incognita* at 0.5% concentration [123]. Begum *et al.* [124] isolated pomolic acid, lantanolic acid, lantoic acid, camarin, lantacin, camarinin, and ursolic acid from aerial part of *L. camara* and investigated their nematicidal activity against root-knot nematode *M. incognita*. Pomolic acid, lantanolic acid, and lantoic acid exhibited 100% mortality at 1 mg/ml concentration after 24 hr, while camarin, lantacin, camarinin, and ursolic acid produced similar effect after 48 hr at same concentration.

Aqueous leaf extract of *L. camara* was assessed *in vitro* conditions against juveniles of *M. incognita* from eggplant. The standard concentration 'S' of leaf extract was found to be highly nematostatic, where nematodes were completely paralyzed after 12 hr and after 48 hr of exposure, 96% of juveniles were killed at same concentration [125]. The nematicidal activity of the aqueous extract of *L. camara* flowers and leaves was tested against citrus nematode *Tylenchulus semipenetrans in vitro* and *in vivo*. *In vitro* the extract significantly caused juvenile mortality (96% at 100% concentration and 93% at 50%). In greenhouse experiment, the aqueous extract was effective against population density of juveniles, where the mortality was 78.7%, reduction of nematode females was 74.5% and reduction of egg-masses was 70.0% [126]. The root-dip treatment of the standard concentration (S) of aqueous extract of *L. camara* leaves effectively inhibited larval penetration in roots of tomato. Mixing organic residue of both test plants with soil at 0.5%, 1.0% and 3.0% (w/w) 5 days before tomato transplanting, improved plant growth response and reduced root-knot development in roots at a 6 and 12% moisture levels [127]. The saponin of *L. camara* was effective against the migration of second stage larvae of eggplant nematode, *Meloidogyne* sp., with EC50 value of 4906.8 ppm, and percentage inhibition of root galling formation was 100% at 5000 ppm concentration [128]. Oleanonic acid isolated from the aerial parts of *L. camara* exhibited 80% mortality against *M. incognita* after 72 hr at 0.0625% concentration, which is comparable with that of the standard furadan [129]. Aqueous leaf extract of *L. camara* was assessed against juveniles of *Meloidogyne* sp. for its nematicidal potency *in vitro*. 50% concentration of leaf extract at 48 hr of incubation period and above showed effective immobilization of *Meloidogyne* sp., larvae and 57.66% of nematode juveniles were found dead in 48 hr. Similarly, the 100% leaf extract was highly nematostatic and 98.66% of nematode juveniles were found dead in 48 hr [130].

**Antiviral activity**

Antiviral substances were extracted from *L. camara* with petroleum ether, benzene, diethyl ether, chloroform, ethyl acetate, methanol, ethanol, and distilled water separately. Each extract was tested for its activity against white spot syndrome virus (WSSV) in marine shrimp and fresh water crabs. Aqueous extract of *L. camara* showed partial antiviral activity against WSSV (40% mortality at 150 mg/kg of animal body weight) [131]. The aqueous extract from *L. camara* was screened for antiviral activities using cytopathic effect reduction assay, which showed antiviral activity against WSSV [132]. *L. camara* root extract was used to treat cell culture challenged with virus, polio virus Type I. The result indicated that the extract offered slight protection when the cells were treated with 100-200 µg/ml of the extract [133]. Cell culture challenged with polio virus Type I was treated with *L. camara* leaves extract. The result indicated that the plant leaves extract offered better protection when the cells were treated with 100 µg/ml of the extract [134].

## CONCLUSION

The information about natural healing methods has been passed from one generation to another. With growing knowledge on technology and civilization this information transfer is no longer taken seriously in the society, hence, endangering the knowledge of traditional methods of treatment, one of them is the use of medicinal plants. This calls for a great need to have the knowledge on medicinal plants documented and kept for future reference [135]. India has a rich tradition of plant based knowledge in health care. Among the large number of herbal drugs existing in India, very few have been studied systematically so far. *L. camara* is an evergreen plant found throughout India. Traditionally, it has been used in treating various ailments and they are supported by scientific data. However, most of the pharmacological studies were preliminary and requires intensive preclinical and clinical studies to evaluate the efficacy and toxicity of these plant products.

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