**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 evolved 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 *lentus* 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 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].

**ANTIMICROBIAL ACTIVITIES OF LANTANA CAMARA LINN.**

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**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 phytochemicals. 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.

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**INTRODUCTION**

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**LANTANA CAMARA**

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**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, catarrah 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, antisapmosic, anti-inflammatory, antihypertensive, antipyretic, analgesic, hypolipidemic, carminative, and diaphoretic.
were reported. Solvent extracts, EOs, and nanoparticles of *L. camara* are reported to have antimicrobial activity. Chloroform and methanol extracts showed the highest activity against all the three strains used, with zones of inhibition ranged from 10.21 to 9.15 mm, respectively [13]. Chloroform and methanol extracts of *L. camara* were screened against three strains of *M. tuberculosis* (MTCC 3160), *P. aeruginosa* (MTCC 429), *Bacillus subtilis* (MTCC 1429) and *S. aureus* (MTCC 96), where the value of zone of inhibition ranged from 10.21 to 9.15 mm, respectively [13]. Chloroform and methanol extracts of *L. camara* were screened against *M. tuberculosis* (ATCC 331), and *M. paratuberculosis* (ATCC 25619). Chloroform and methanol (ATCC 10536) and *S. aureus* (ATCC 6863) were screened against *P. vulgaris* and *V. cholerae* sp. The MIC and MBC ranged from 0.078 to 1.25 mg/ml [3].

**ANTIMICROBIAL ACTIVITIES**

Antibacterial, antifungal, antiprotozoal, antimamotode, 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 6863), *S. aureus* (ATCC 6538), and *Pseudomonas aeruginosa* (ATCC 25619). Chloroform and methanol extract 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 methanol 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., linarinose 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 strain. 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*, *S. aureus*, *P. mirabilis* and water extract showed antibacterial effect toward *P. aeruginosa*, *Staphylococcus* sp., *Citrobacter freundii*, *Proteus* sp., *Bacteroides fragilis*, *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*, *Vibrio cholerae*, *E. coli* and multiresistant strains of *E. coli* and *S. aureus*. Leaves ethanol 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 ethanol 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 citeus*. Ethanolic 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, and *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]. Anti-bacterial 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 ether, chloroform, and ethanol extracts of *L. camara* leaves showed activity against all the bacteria tested, with MIC values ranging from 0.078 to 1.25 mg/ml [3].

**Fig. 1:** Lantana camara (a) Leaves: Source: http://www.css.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
Table 1: Antibacterial activity of Lantana camara

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

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. cholearae, 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, Pantoa sp., P. aeruginosa, S. typhi, Shigella flexneri, S. aureus, Streptococcus agalactiae, Staphylococcus epidermidis, V. cholearae 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. cholearae 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 antymycobacterial 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 coconcentration and urease activity in aqueous and alcoholic extracts (pH: 8.9250, ammonia: 5.32, 5.94 μg/ml, urease: 59.28, 64.14 mg/ml) were observed.
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. aeruginosa, S. aureus, and B. subtilis. 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 extract. 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) weak and 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 L. camara leaves and flowers were tested for antibacterial activity. The extracts showed antibacterial activity against E. coli, S. aureus, Pseudomonas sp., S. aureus, and B. subtilis, respectively [46]. 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, 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]. Kasai et al. [57] reported considerable antibacterial activity of L. camara leaves EO against both Gram-positive and Gram-negative bacteria. The results of L. camara leaves showed good antibacterial activity against 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. cholerae (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, 125 and 200 μg/ml, respectively [61]. The EO of L. camara was tested against E. coli and B. subtilis 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. cholerae (ATCC 15748) [60].

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Antimicrobial activities of methanol, chloroform, acetone, petroleum ether and hexane extracts of L. camara seed was investigated against S. aureus, B. subtilis, P. vulgaris and E. coli [50]. Ethanol and methanol extracts showed the 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 E. coli. The maximum inhibition with ethanol and methanol extracts showed good antibacterial activity. EO of L. camara leaves showed good 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. cholerae (ATCC 15748) [60].

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Girish  

(MTCC 87) and M. luteus (MTCC 106) were sensitive to leaf hydroxyl [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. pneumoniae 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 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 30318) 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 EF ranged from 31.25 to 10,000 μg/ml and of EF from 1250 to 5000 μg/ml. B. subtilis was the most sensitive organism inhibited at 31.25 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]. AgNPs 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 polycyclonelte 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 showed 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 against 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 still 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 nicotianae, 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...
The antifungal activity of *Lantana camara* leaves was evaluated against six species of *Candida* (*C. albicans*, *Candida dubliniensis*, *Candida kruzei*, *Candida guilliermondii*, *Candida tropicalis* and *Candida parapsilosis*). The antifungal activity of *L. camara* was screened against major seed-borne fungi and parasiticus. *Aspergillus* and *Cladosporium* were also observed to be effective against *C. albicans* and *C. kruzei*. Table 2: Antifungal activity of *Lantana camara*

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Fungi (activity against)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Alternaria alternata; Alternaria solani</td>
<td>31, 35, 43, 88, 92, 94, 96, 97, 99, 100, 101, 106, 108</td>
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<td>2</td>
<td>Aspergillus niger; Aspergillus flavus; Aspergillus awamori; Aspergillus parasiticus; Aspergillus sp.; Aspergillus fumigatus</td>
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<tr>
<td>3</td>
<td>Botrytis cinerea</td>
<td>97, 99, 100</td>
</tr>
<tr>
<td>4</td>
<td>Candida albicans; Candida dubliniensis; Candida kruzei; Candida guilliermondii; Candida tropicalis; Candida parapsilosis; Candida glabrata</td>
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</tr>
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<td>Cladosporium cucumerinum</td>
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<tr>
<td>6</td>
<td>Colletotrichum gloeosporioides</td>
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<tr>
<td>7</td>
<td>Curvularia lunata</td>
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<td>8</td>
<td>Drechslera biseptata</td>
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<td>9</td>
<td>Epidermophyton floccosum</td>
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<td>10</td>
<td>Fusarium oxysporum; Fusarium solani; Fusarium sp.; Fusarium moniliforme</td>
<td>31, 35, 49, 56, 58, 82, 85, 86, 89, 95, 96, 99, 106</td>
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<td>11</td>
<td>Helminthosporium solani</td>
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<td>Humicola grisea</td>
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<tr>
<td>13</td>
<td>Macrophomina phaseolina</td>
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<td>14</td>
<td>Malassezia furfur</td>
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<td>16</td>
<td>Mucor sp.; Mucor hiemalis</td>
<td>49, 108</td>
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<tr>
<td>17</td>
<td>Penicillium funiculosum; Penicillium janthinellum; Penicillium expansum; Penicillium sp.; Penicillium digitatum</td>
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<td>Phomopsis vexans</td>
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<td>Pythium ultimum; Pythium aphanidermatum; Pythium sp.</td>
<td>85, 95, 96, 106</td>
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<tr>
<td>21</td>
<td>Rhizoctonia solani; Rhizoctonia bataticola</td>
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<td>22</td>
<td>Rhizomucor tauricus</td>
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<td>Rhizopus solani</td>
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<td>24</td>
<td>Saccharomyces cerevisiae</td>
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<td>25</td>
<td>Sclerotium rolfsii</td>
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<td>Trichoderma reesei; Trichoderma harzianum; Trichoderma sp.</td>
<td>58, 85, 99</td>
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<td>27</td>
<td>Trichophyton mentagrophytes; Trichophyton rubrum; Trichophyton verrucosum; Trichophyton tonsurans; Trichophyton violaceum</td>
<td>3, 37, 52, 84, 97, 102</td>
</tr>
<tr>
<td>28</td>
<td>Verticillium dahliae</td>
<td>106</td>
</tr>
<tr>
<td>29</td>
<td>White and brown rot fungi (Trametes versicolor; Oligoporus placenta)</td>
<td>87</td>
</tr>
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</table>

C. parapsilosis, *C. albicans*, *C. kruzei* and *C. tropicalis*, with MIC values ranging between 8 and 32 μg/ml. Significant antifungal 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 *F. oxysporum* 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 48 h 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 h 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 mycelial growth of all tested fungi was observed with ethanol and methanol extracts while petroleum ether extract showed good activity against *A. alternata*. 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 efficacies 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. kruzei* and dermatophytic fungi *T. rubrum* (RSKK 486), *E. floccosum* (RSKK 3027), *M. gypseum* (NCFP 580) were used for antifungal activity. *L. camara* flower extracts showed better antifungal activity against *C. parapsilosis*, *C. albicans*, *C. kruzei* and *C. tropicalis*, with MIC values ranging between 8 and 32 μg/ml. Significant antifungal 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 *F. oxysporum* 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 48 h 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 h 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 mycelial 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]. Verbauscoside 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 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 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 1.4±0.142 mm at 30 mg/ml while it was 37±0.124 mm for the standard antifungal agent vermoconazole at 30 mg/disc. The MIC of the extract was 16 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]. Ethanolic 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, S. cucurbitae, F. oxysporum, T. 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 MTCC 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].

**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 anti-leishmanial 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 possess more potent activity. Good antiplasmodial activity was found in L. camara leaf ethyl acetate extract (IC₅₀=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 lantanolic acid obtained from the aerial parts of L. camara showed significant leishmanial activities against promastigotes of Leishmania major with IC₅₀ 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 201.94 µg/ml respectively [116].

**Antinematode activity**

Leaf extracts of L. camara applied to Meloidogyne incognita killed all larvae up to S₅ concentration within 5 hr. At S₀ the mortality was 96.59% which increased to 100%, 30 hr after treatment [117]. Lantanoside, linaronoid, and camamic acid isolated from the aerial parts of L. camara were tested for nematocidal activity against root-knot nematode M. incognita and showed 90%, 85%, and 100% mortality, respectively, at 1% concentration. The results were comparable to those obtained with the conventional nematocide fumadon (100% mortality at 1% 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 nematocidal 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]. Lantanic acid, camaric acid, and oleanic 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 pomoic acid, lanatic acid, laontic acid, camaric acid, lantanin, lantacinn, and ursoic acid from aerial part of L. camara and investigated their nematocidal activity against root-knot nematode M. incognita. Pomolic acid, lanatic acid, and laontic acid exhibited 100% mortality at 1 mg/ml concentration after 24 hr, while camaric, lantanin, camarin, and ursoic 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 nematocidal 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 70.7%, reduction of nematode females was 74.5% and reduction of eggs-masses was 70.0%. The root-dip treatment of the standard concentration (S) of aqueous extract of L. camara leaves effectively infiltrated larval penetration in roots of tomato. Mixing organic residue of both test plants with soil at 0.5%, 1% 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 EECO value of 4906.8 ppm, and percentage inhibition of root galling 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 nematocidal potency in vitro. 50% concentration of leaf extract at 48 hr of incubation period and above showed effective immobilization of Meloidogyne sp., larvae and 7.66% 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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