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Lantana camara L.: A Review of its Traditional Uses, Phytochemistry, Pharmacological Activities, and Toxicology

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ABSTRACT

Lantana camara L. (Family: Verbenaceae); native to America, is an invasive weed in many parts of the world. İt is famous for its highly scented, various color flowers and is planted as an ornamental plant species. Due to wide seed dispersal, high tolerance capacity, and allelopathic effect on native plant species, it has rapidly spread in non-native regions around the globe. Several reports of its negative ecological impact are well-known, and an effective management strategy is desired to combat this invasive plant. In this regard, utilization of its beneficial potential could be a better alternative to fulfill many of the sustainable development goals. The present article is, therefore, an attempt to assess its ethnomedicinal prospects, chemical constituents, and pharmacological potential in view of the scientific investigations undertaken so far. For this purpose, online scientific databases were thoroughly searched using notable keywords, and relevant information was compiled. *Lantana camara* is traditionally used in many cultures for the treatment of various diseases, for example, fever, arthritis, rheumatism, headache, respiratory infections, neurological disorders, gastrointestinal disturbances, etc. Phytochemical investigations have identified a variety of bioactive compounds such as lantadenes, humulene, caryophyllene, apigenin, quercetin, epicatechin, lancamarinic acid, lancamarin, etc. from its various parts. Besides, several important biological activities, for example, antioxidant, anti-inflammatory, anticancer, hepatoprotective, antimicrobial, spermicidal, anti-nociceptive, analgesic, etc., have been demonstrated in scientific studies carried out in different regions of the world. However, the plant has shown liver toxicity in animals and hence, for thorough assessment of its safety profile is warranted. This review aims to provide a comprehensive compilation of the currently available knowledge on the traditional uses, phytochemical, and pharmacological profile of *L. camara*, highlighting its therapeutic potential, toxicological risks, and the need for further research to validate its efficacy and ensure its safe medicinal use. It will be advantageous for policymakers to create a roadmap for the sustainable management of its menace in the non-native areas.

KEYWORDS

Lantadene, arthritis, antimutagenic, ethnomedicine, spermicidal

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INTRODUCTION

Throughout human history, plants have played a vital role as medicine. Traditional medicinal systems, namely, Ayurveda, Siddha, Unani, Sowa-Rigpa, Traditional Chinese Medicine etc., have relied primarily on plant-based remedies for the treatment of a variety of illnesses and health conditions. Plants are a rich source of natural compounds having therapeutic potential and serve as the foundation for modern pharmaceuticals[1].

Lantana camara L.; hereafter referred to as *Lantana*; is a member of the Dicot family Verbenaceae and called as Red Sage, Wild Sage, Pigeon berry, Large leaf *Lantana*, Ghaneri, Tontani, Landana chedi, Phul-lakri, Njandukali, etc. in various languages[2]. It is a perennial, aromatic, spiny shrub; native to Central and South America and now widely distributed throughout tropical and subtropical regions of the world. Usually, it grows luxuriantly in disturbed habitats, roadsides, and forest margins. Due to its aggressive growth and allelopathic behaviour, it is known as a Global Invasive Species (GIS), responsible for ecological disruption and the displacement of native flora in several countries. Its high adaptability to survive in drought conditions and showing resistance to browsing due to high tannin content, autocompatibility, pollination by different insects, high seed output, etc. are some of the important reasons for its global invasion. Being allelopathic, *Lantana* has affected native biodiversity of invaded regions, declined soil fertility, and altered ecosystem processes[3].

Plant invasions are predominantly a consequence of anthropogenic global climate change. Invasive species are not only causing a threat to native biodiversity but also disturbing agricultural productivity, depleting water and air quality, and affecting both below and above-ground microbial diversity[4]. Management of invasive species, therefore, requires a holistic approach. Shackleton *et al*.[5] suggest role of interdisciplinary and transdisciplinary collaborations to understand the perception of individuals and communities and provide a conceptual framework for the management of invasive species. Use of plants for therapeutic purposes could be an effective strategy to combat any negative impact associated with them. Given this, beyond the allelopathic behavior, *Lantana* also holds significant ethnobotanical and pharmacological interest due to its long-standing use in traditional medicine systems across various cultures.

In recent decades, several scientific studies have been carried out to explore the phytochemical constituents and pharmacological properties of *Lantana*[6]. Many bioactive compounds belonging to the category of triterpenoids, flavonoids, sesquiterpenoids, alkaloids, and phenolic acids have been isolated from the plant. Some of these phyto-pharmaceuticals have also exhibited valuable biological activities, for example, antioxidant, anticancer, antidiabetic, anti-inflammatory, anti-ulcer, analgesic, anti-ageing etc. These findings emphasize the potential of *Lantana* as a source of novel therapeutic agents.

The present paper aims to provide a comprehensive updated overview of the traditional knowledge, phytochemical constituents, and pharmacological properties of *Lantana*, highlighting recent advances, current challenges, and prospects. Despite its negative ecological impact in non-native regions, this review seeks to find out its pharmacognostic and pharmacological potential while assessing the toxicological profile. This will be helpful for its potential applications in drug development, agriculture, and the healthcare industry.

MATERIALS AND METHODS

Using several important keywords for example, phytochemistry, phytoconstituents, pharmacology, biological activity, traditional medicine, herbal medicine, chemical compounds, ethnobotany, etc., in combination with *Lantana camara*, the popular online databases such as Science Direct, Scopus, Pubmed, Springer Link, Taylor & Francis, Wiley, and Google Scholar were searched thoroughly.

Table 1: Ethnomedicinal uses of *Lantana camara* in India

Plant part	Ethnomedicinal uses
Root	Boil, Burn, Colic, Snakebite, Swelling, Toothache, Wound*
Root bark	Cold, Fever*
Stem bark	Malaria*
Leaf	Ringworm# Appetizer, Arthritis, Bleeding, Boil, Bruises, Burn, Cancer, Chicken Pox, Cold, Constipation, Cough, Cuts and Wounds, Dandruff, Diarrhea, Dysentery, Fever, Fistula, Headache, High Blood Pressure, Insect Repellent, Jaundice, Injury, Malaria, Pain, Piles, Rheumatism, Ringworm, Skin Disease, Stomachache, Snakebite, Swelling, Tetanus, Tongue Ulcer, Tuberculosis, Vomiting, Wound*
Flower	Itching# Arthritis, Bleeding Gum, Headache, Hepatitis, Toothache*
Fruit	Bleeding Gum, Giddiness*
Seed	Antidote against Poisoning*
Whole plant	Boil, Bronchitis, Cold, Cough, Cuts & Wounds, Dysentery, Fever, Jaundice, Joint Pain, Malaria, Rheumatism, Swelling, Tetanus*

*Jain and Jain[2] and #Jain[12]

Traditional uses: Man has been utilizing plants that grow in their vicinity for various purposes. *Lantana* is not an exception, and people are using it across the globe for diverse purposes, among which its role in ethnomedicine is well-known. Hernandez *et al.*[7] have reported *Lantana* as one of the 44 major plant species utilized by traditional healers of Zapotitlán de las Salinas, Puebla, in México to treat gastrointestinal diseases. In Hafizabad District, Punjab, Pakistan, leaf, flower, and root extracts of *Lantana* are used by local people for the treatment of headache, ringworm, injuries, toothache, malaria, rheumatism, cuts and wounds, cold and cough[8]. It is utilized for the treatment of wounds by the Kaili Inde tribe in Mantikole, located at Palu Central Sulawesi Indonesia[9]. Leaves of *Lantana* are utilized to cure body pain by local people dwelling in Ejisu-Juaben municipality, Southern Ghana[10]. Leaves and stem pieces are boiled and consumed to treat neurological and mental diseases, as reported by traditional medical practitioners in Ghana[11]. Different parts of *Lantana* are also used to treat several human ailments by local communities in India[2,12]. These ethnomedicinal uses are given in Table 1. Not only human ailments, leaves of *Lantana* are also used to heal wounds of animals by indigenous communities in Andhra Pradesh, Maharashtra, and Madhya Pradesh States of India[3].

Besides medicinal purposes, *Lantana* is also valuable for fulfilling many of the need-based and culture-based relationships existing between man and plants. For example, its fruits are consumed as edible in Rewalsar Himalaya, Nilgiris, Manipur, Eastern Rajasthan and Lakshadweep Islands in India[2,12] and western Chitwan, Nepal. Use of *Lantana* fruits as a Fish bait is also reported from the Khasi & Jaintia Hills, Meghalaya, in Eastern India. Twigs of *Lantana* are used as a toothbrush by tribal communities of Rajasthan in Western India[2]. Its stem and whole plant are used for making baskets and also used as a hedge by tribal people in Kalakad Mundan-Thurai Tiger Reserve, Southern India[13]. Flowers are used as a sacred thread (*Rakhi*) by tribal girls of Rajasthan for the *Rakshabandhan* festival[2].

Moreover, the traditional use of *Lantana* to repel insects is well-known in Asia and Africa. It is directly burnt in Rusinga Island and Rambira, Western Kenya, to repel mosquitoes[14] and North-Eastern Tanzania[15]. Bhardwaj *et al.*[16] have reported that its leaves and flowers are used as an insect repellant in the Aravalli Hill range of India. Similarly, leaves of *Lantana* have also been used by people of Budondo Subcounty, Jinja District, Uganda to repel House Fly[17].

Phytochemical profile: Different parts of *Lantana* have been subjected for phytochemical analysis and various bioactive molecules belonging to chemical classes like monoterpenes, sesquiterpenoids, triterpenes, steroids, alkaloids, essential oils, phenolic compounds, tannins, flavonoids, iridoid glycosides, phenyl ethanoid, furanonaphthoquinones, quinine, saponin etc., were found to be present[18] (Table 2).

Table 2: Phytochemical profile of various parts of *Lantana camara*

Plant part	Phytochemical compound	References
Whole plant	Lantandene A and B	Ramírez *et al.*[6]
Leaves	lantadene A, lantadene B, lantanilic acid, icterogenin, and 4',5-dihydroxy-3,7-dimethoxyflavone -4'-O-beta-D-glucopyranoside	Ramírez *et al.*[6]
	Stearoyl glucoside urs-12-en-3β-ol-28-oic acid 3β-D-glucopyranosyl-4'-octadecanoate	Kazmi *et al.*[19]
	Germacrene D (19.8%), *E*-caryophyllene (19.7%), bicyclogermacrene (11.7%) and α-humulene (9.3), α-copaene, epi-α-muurolol, α-muurolene, germacrene-A, cubeol, germacrene-D-4-ol, davanone, phytol, globulol, δ-cadinene, tetradecane, β-elemene, β-gurjunene, and β-E-farnesene	Passos *et al.*[20]
	Hexadecanoic acid, phytol, caryophyllene oxide, 9,12,15-octadecatrienoic acid, and methyl ester	Swamy *et al.*[21]
	Lantadene A, lantadene B, icterogenin, and lantadene	Shamsee *et al.*[22]
	α-Thujene, 3-Carene, β-Phellandrene, Limonene, β-Cymene, Eucalyptol, Geranyl formate, α-Copaene, β-Copaene, β-Caryophyllene, α-and β-Elemene, δ-Selinene, α-Muurolene, Caryophyllene oxide,	Sarma *et al.*[23]
	Espatulenol, Intermedeol, Humulene epoxide 2, β-Bisabolene	Etuh *et al.*[24]
	Alkaloids, Flavonoids, Phenol, steroids, cardiac glycosides, and carbohydrates	
	Resveratrol dimer, iso-humolones, oleuropein glucoside, quercetin-3-O-glycoside, myricetin, oleuropein, 12-deoxy-16-hydroxy-phorbol, aloeresin A, humulones, ursolic acid, viniferin, Epicatechin, oleanolic acid, 5-hydroxy-3, 4, 7-trimerthoxy-flavanone, Apigenin-6,8-di-C-β-D-glucoside, procyanidin A2, caffeoyl-O-hexoside, tansihnone IIA, and phillyrin	Ruslin *et al.*[25]
	Terpenoids, flavonoids, iridoid glycosides, phenolic acids, and their derivatives	El-Din *et al.*[26]
	13-docosenamide, alpha-hydroxyisocaproic acid, cyclo(L-prolyl-L-valine), 2,5-piperazinedione	He *et al.*[27]
	Dodecanal, Oxirane, tetradecyl, Cholestan-3-ol, 2-methylene-, (3á,5à), 1-Dodecanamine, n,n-dimethyl, 1-Chlorooctadecane, 9-Octadecenoic acid (z)-, methyl ester, Humulene, 1,6,10-Dodecatrien-3-ol, 3,7,11-trimethyl-, (e), Eudesma-4(15),7-dien-1á -ol, Benzene, (chloromethyl), 2-Methylenebrexane, 7-(Trifluoromethyl)naphthalen-1-ol, 1-Chloroundecane, Benzyl-(4-methylbenzyl)amine, 1-(n-Benzyl-n-methylamino)-4-methoxybutan-2-one	Baz *et al.*[28]
	Caryophyllene, humulene, sabinene, α-Pinene, β-Myrcene, β-Pinene, p-Cymene, α-Terpineol, β-Cubebene, γ-Muurolene, Bicyclogermacrene, Germacrene D, E-Nerolidol, Cubebol, Caryophyllene oxide, Isoaromadendrene epoxide, β-Bisabolene, Spathulenol, Davanone, Viridiflorol, β-Eudesmene, δ-Cadinene, Copaene, Eucalyptol, cis-Sabinene hydrate, Borneol, trans-β-Ocimene, D-Limonene	Dey *et al.*[29]
Aerial parts	Ursethoxy acid	Begum *et al.*[30]
	Camaryolic acid, mthylcamaralate, camangeloyl acid, beta-sitosterol	Begum *et al.*[31]
	3-O-beta-D-glucopyranoside, octadecanoic acid, docosanoic acid, palmitic acid, camaric acid and lantanolic acid	
	Lantanoic acid, camaranoic acid, lantic acid, camarinic acid, camangeloyl acid, camarinin, oleanonic acid and ursonic acid	Begum *et al.*[32]
	Camarolic acid and lantrigloylic acid	Begum *et al.*[33]
	28-norolean-12,17-diene triterpene lantigdienone	Begum *et al.*[34]
	Lancamarinic acid and lancamarinin	Ayub *et al.*[35]
Inflorescence	Bicyclosesquiphellandrene, E-beta-farnesene, E-beta-caryophyllene, gamma-muurolene, gamma-curcumene, alpha-zingiberene, alpha-gurjunene, gamma-amorphene, alpha-muurolene, sesquithujene, alpha-trans-bergamotene and trans-cadina-1,4-diene	Araqe *et al.*[36]
Flower	Luteolin 7-O-beta-galacturonyl-(2-->1)-O-beta-galacturonide	El-Kassem *et al.*[37]
	α-pinene, sabinene, linalool, thymol, E-β-caryophyllene, E-β-farnesene,	
	α-humulene, γ-muurolene, germacrene bicyclo (E,E), α-muurolene, isospathulenol	Nea *et al.*[38]
	Phenolic acid derivatives, phenylethanoid glycosides, and flavonoids	da Fonseca *et al.*[39]
	Bicyclogermacrene, (+)-epi-bicyclosesquiphellandrene, γ-elemene, α-muurolene, α-humulene, α-trans-bergamotene, and α-phellandrene, (−)-β-caryophyllene	El Hajj *et al.*[40]

Table 2: Continue

Plant part	Phytochemical compound	References
Fruit	*trans*-b-caryophyllene, sabinene, eucalyptol, a-humulene, bicyclogermacrene, germacrene D, *trans*-nerolidol	Ramírez *et al.*[6]
	Sabinene, linalool, neral, geranial, thymol, E-β-caryophyllene, E-β-farnesene, α-humulene, γ-muurolene, germacrène bicyclo (E.E), α-muurolene, isospathulenol	Nea *et al.*[38]
Stem	Sabinene, p-cymene, γ-terpinene, linalool, thymol, E-β-caryophyllene, E-β-farnesene, α-humulene, γ-muurolen, germacrene bicyclo (E,E), α-muurolene, palmitic acid, isospathulenol, phytol E	Nea *et al.*[38]
Leaves and flowers	3,7,11,15-Tetramethylhexadec-2-en-1-ol (14.72%), Methylhexopyranoside (13.83%), Linolenic acid (12.70%), 3-Deoxy-d-mannonic acid (7.97%), Palmitic acid (6.99%), Tiglic acid (6.47%), 2,3- Dihydrobenzofuran (6.25%), Tert-Butyl phenyl carbonate (4.18%), 2,6-Dimethoxyphenol (3.55%), and 9,12-Octadecadienoic acid (2.23%).	Mansoori *et al.*[41]

The two major chemical compounds isolated from *Lantana* are Lantandene A and B. These two compounds are responsible for many of the pharmacological activities reported from *Lantana*. *Lantana* is rich in pentacyclic triterpenoids and many other compounds have also been isolated from its aerial parts such as ursethoxy acid, camaryolic acid, methylcamaralate, camangeloyl acid, camaranoic acid, lantic acid, lantanilic acid, lantigdienone, camarinic acid, camarinin, camaroside, icterogenin, oleanonic acid, ursonic acid, beta-sitosterol 3-O-beta-D-glucopyranoside, octadecanoic acid, docosanoic acid, palmitic acid, camaric acid and lantanolic acid[30-34]. Recently, two new pentacyclic triterpenoids lancamarinic acid and lancamarinin have been isolated from aerial parts of *Lantana* by Ayub *et al.*[35].

Essential oil from leaves of *Lantana* contains major constitutents as sesquiterpenoids among which germacrene D (19.8%), *E*-caryophyllene (19.7%), bicyclogermacrene (11.7%) and α-humulene (9.3%) represent almost 60.5% of the oil. Besides these, oil also contains compounds such as α-copaene, epi-α-muurolol, α-muurolene, germacrene-A, cubeol, germacrene-D-4-ol, davanone, phytol, globulol, δ-cadinene, tetradecane, β-elemene, β-gurjunene, β-E-farnesene etc[20]. Oil is useful for treatment of skin itches and as antiseptic for wounds[6]. Phytochemical study on *Lantana* growing in Saudi Arabia revealed extraction of 134 compounds in essential oil of leaves with oxygenated sesquiterpenes accounting for the largest percentage (35.4%). sesquiterpene hydrocarbons and oxygenated aliphatic hydrocarbons as well as oxygenated monoterpenes were other major constitutents of oil. The other components, which made up only 4.9% of the total, were classified as aliphatic hydrocarbons, monoterpene hydrocarbons, and others. Flowers essential oil resulted in the isolation of 127 compounds, the majority of which were oxygenated sesquiterpenes (51%). The other major components were sesquiterpene and oxygenated aliphatic hydrocarbons[42]. Nutritional analysis of seeds of *Lantana* demonstrated that seeds possess 17.27% moisture, 1.81% ash, 11.0% fat, 6.3% crude protein and 80.9% carbohydrates besides minerals such as potassium, phosphorus, sodium, zinc, manganese, iron, and copper. The major component of seed oil was oleic acid along with abosorbance property in Ultraviolet B and C wavelengths[43].

Swamy *et al.*[21] demonstrated 32 bioactive components in methanolic extract of leaves of *Lantana* collected from Malaysia in GC-MS analysis showing major compounds such as hexadecanoic acid, phytol, caryophyllene oxide, and 9,12,15-octadecatrienoic acid and methyl ester. Mansoori *et al.*[41] evaluated total alkaloids, phenolics and flavonoids contents from leaves (LE) and flower extracts (FE) of *Lantana*. The total phenolics found in FE and LE were 614.79±.25 and 563.57±2.03 mg GAE/g dw, respectively. The FE has shown higher flavonoid content (254.69±0.88 mg/g) than LE (243.89±1.30 mg/g) and total alkaloid content in FE was found to be higher (2.9%) than LE (1.8%). Many of these chemical constitutents possess health-beneficial pharmacological activities such as antioxidant, anti-proliferative, anticarcinogenic, anti-inflammatory, antibacterial, vasodilatory, anti-hypertensive, immunomodulating, immunosuppressive etc.[6,18].

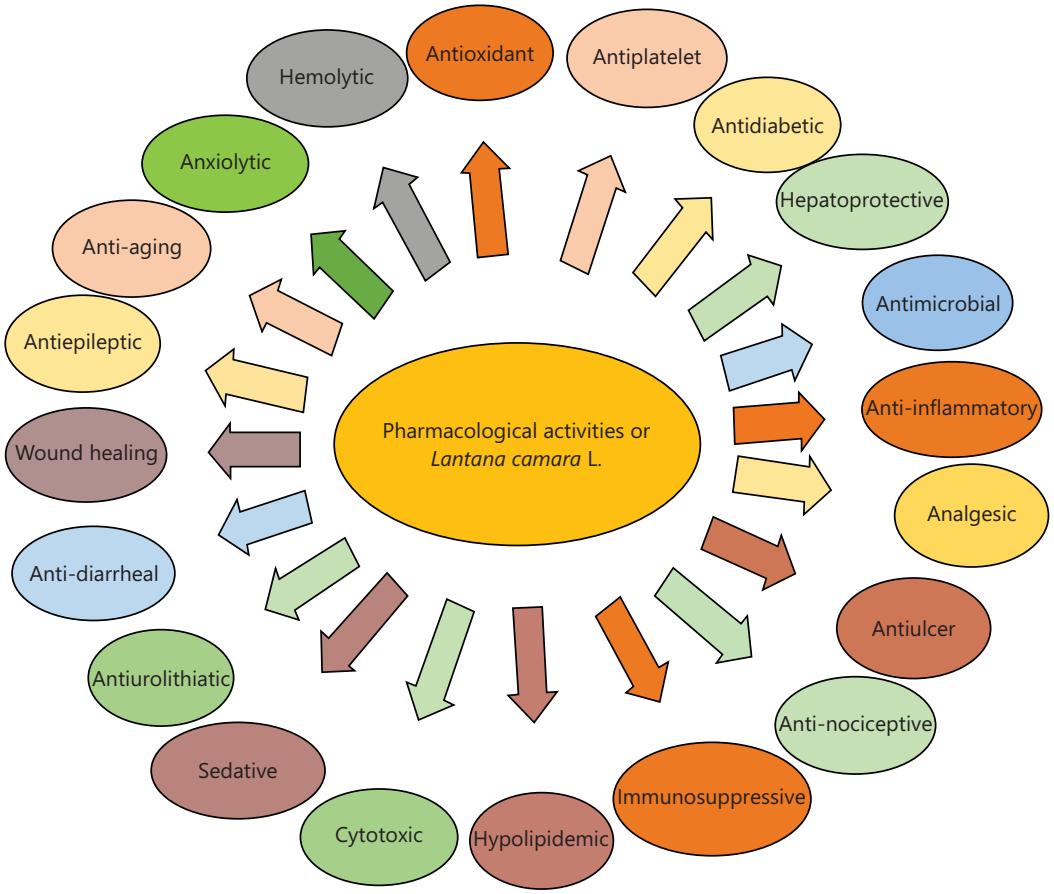

Fig. 1: Pharmacological profile of *Lantana camara* L. (Source: Authors' own work)

Pharmacological profile: *Lantana* has been focus of research world over for its pharmacological potential. Several biological activities have been reported in scientific investigations[6] (Fig. 1) as discussed below. Notably, some of these pharmacological activities also provide indirect evidences as scientific validation of its ethnomedicinal uses.

Antioxidant potential: Higher antioxidant status is considered beneficial in cardiovascular and neurodegenerative disorders. In this regard, natural antioxidants of plants and phytochemicals are proven as safe, cost-effective and reliable entities[1,6]. All parts of Lantana have shown to possess *in vitro* antioxidant potential and maximum potential has been demonstrated by leaf extract[44]. de Melo *et al.*[45] have also reported antioxidant activity of methanolic extract of leaves of Lantana against DPPH free radicals.

Antioxidant activity of methanolic extract of its leaves has also been demonstrated in DPPH, hydroxyl radical scavenging and reducing power assay by Naz and Bano[46]. Sousa *et al.*[47] have also demonstrated *in vitro* DPPH radical scavenging activity of the essential oil isolated from leaves as well as ethanolic leaves extract. Strong *in vitro* antioxidant activities of methanolic extract of Chandigarh Yellow and Palampur Red Variety of Lantana leaves were observed in DPPH, ferric reducing antioxidant power, 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid) and lipid peroxidation inhibition assay showing a strong correlation with total phenolic contents[48]. Among ethyl acetate, acetone and chloroform extracts, maximum total phenolic content 92.8 mg gallic acid equivalent/g and total flavanoid content 26.5 mg rutin equivalent/g was exhibited by methanolic extract which displayed maximum DPPH radical scavenging activity at a concentration of 500 µg/mL and hydroxyl radical scavenging activity with IC_{50} of 110 µg/mL[21].

The two compounds isolated from its leaves, Lantadene A & B have shown highest antioxidant activity and compounds icterogenin and lantadene C have shown less antioxidant effect in DPPH radical scavenging assay[22]. *In vitro* antioxidant activity of both leaves and flower extracts of Lantana (LE and FE) was demonstrated and significantly higher antioxidant capacity (1,376.41±3.02 mg ascorbic acid equivalent/g dw) of FE than LE (1,154.95±1.43 mg AAE/g dw) was observed. Both FE and LE were able to reduce DPPH radicals with IC_{50} values of 94.31±0.1 and 91.73±1.01, respectively[41]. *In vitro* antioxidant activity of leaves and flowers essential oil was evaluated by Nea *et al.*[38] using DPPH radical scavenging and the ferric-reducing antioxidant power (FRAP) assays. Results have exhibited that the essential oil from flowers showed higher radical scavenging activity with IC_{50} of 15.53±0.14 µg/mL than the leaves (IC_{50}: 21.96±0.25 µg/mL). In the FRAP assay, it was found that the floral essential oil had the highest absorption values, suggesting a greater reducing power.

Ruslin *et al.*[25] investigated the antioxidant activity of non nonpolar fraction of the methanolic extract of leaves of Lantana using the DPPH and FRAP assay. It was observed that leaves were extremely potent against FRAP and DPPH radicals with IC_{50} values of 4.93±0.22 g/mL and 12.79±0.09 g/mL, respectively. Methanolic extract of flowers of Lantana was investigated for antioxidant activity using DPPH radical scavenging assay, and 97.8% inhibition was observed at 0.25 mg/mL concentration of flower extract[39]. *In vitro* antioxidant activity of methanolic extracts of leaves of Lantana was evaluated by El-Din *et al.*[26] using DPPH, ABST, and superoxide anion free radicals assays. Results have shown IC_{50} of 34.01±1.32, 30.73±1.42, and 1.57±0.19 for DPPH, ABST, and superoxide anion radicals, respectively.

Khairan *et al.*[49] also demonstrated *in vitro* antioxidant activity from the ethanolic extract of Lantana leaves using DPPH and ABTS assays with IC_{50} values of 140 ppm and 163 ppm, respectively. El Hajj *et al.*[40] demonstrated *in vitro* dose-dependent antioxidant activity using DPPH assay from three different colored flowers of Lantana (white, pink, and orange) with IC_{50} values of 4.64, 2.79, and 1.21 mg/mL, respectively.

Lantadene A isolated from leaves of Lantana has shown *in vitro* antioxidant activities in nitric oxide scavenging, superoxide anion radical scavenging and ferrous ion chelating assay[6]. Luteolin 7-O-beta-galacturonyl-(2-->1)-O-beta-galacturonide; a digalacturonide flavone isolated from flowers has demonstrated significant antioxidant potential in DPPH radical scavenging assay[37]. Quercetin (48.6%), glutathione (67.7%), and ascorbic acid (55.9%), isolated from leaves essential oil have also shown antioxidant activity[6].

The methanolic extracts from different parts (root, stem, leaf, flower and fruit) of Lantana were evaluated for the antioxidant effect using DPPH assay. The maximum radical scavenging potential was demonstrated by flower extract (EC_{50} = 29.55±4.91 µg/mL) followed by leaf, root, fruit and stem extracts (53.88±6.40, 59.10±6.70, 92.33±8.15 and 171.90±20.00 µg/mL), respectively as compared with the standard ascorbic acid having an EC_{50} value of 11.7±2.99 µg/mL[50]. Recently, a concentration-dependent DPPH radical scavenging activity of 80% ethanolic leaves extract of Lantana was observed with an IC_{50} value of 17.80% as compared to ascorbic acid as standard with an IC_{50} value of 16.45%[6]. All these clearly indicate towards strong antioxidant potential of Lantana and its possible implication for treatment of cardiovascular disorders.

Antidiabetic activity: Long term high blood glucose levels are not considered good for human health as it may damage, heart, kidney, neurons, eyes etc. Synthetic antidiabetic agents have their own safety issues; hence, natural resources are explored to find out hypoglycemic agents.

Antidiabetic potential of a stearoyl glucoside urs-12-en-3β-ol-28-oic acid 3β-D-glucopyranosyl-4'-octadecanoate isolated from leaves of Lantana has been demonstrated in streptozotocin-induced diabetic rats[19]. *In vivo* dose-dependent anti-hyperglycemic activity of hydroethanolic leaf extracts

(200 and 400 mg/kg) of Lantana was observed after 21 days in streptozotocin-induced diabetic Sprague-Dawley rats[51]. Pandeya *et al.*[52] reported *in vivo* hypoglycemic activity of methanolic extract of Lantana leaves in transient hyperglycemic rats using oral glucose tolerance test. Results have demonstrated that oral administration of 400 and 800 mg/kg of extracts reduced blood glucose levels after 60 min by 46.58% and 38.38%, respectively. Karunakaran *et al.*[53] investigated *in vitro* antidiabetic activity from the ethanolic extract of flowers of Lantana. α-Amylase and β-glucosidase enzyme inhibition assays were conducted to evaluate the antidiabetic activity, with IC_{50} values of 318.95±2.73 and 313.95±2.45 µg/mL, respectively.

Anti-inflammatory and anti-nociceptive potential: The pathophysiology of many diseases has inflammation as a major role. In this regard, the search of anti-inflammatory potential in natural resources possesses immense significance. Petroleum ether, 95% ethanol, and distilled water extracts of leaves of Lantana have shown anti-inflammatory effect against carrageenan-induced paw edema as well as antipyretic effects in rats and antinociceptive effect in hot plate and acetic acid writhing tests in mice[54]. Its whole plant and ethanolic extracts inactivated phosphatases and transaminases, and stimulated adenosine triphosphatase activities in the plasma and exudates of rats in the cotton pellet anti-inflammatory bioassay, and activities were comparable with the standard drug phenylbutazone. Further studies have shown that ethanolic and ethyl acetate extracts of leaves of Lantana possess bovine red blood cell membrane stabilizing property against heat and hypotonic induced lyses. As a membrane stabilizer, Lantana thus could be used as an alternative natural bioresource for treatment of inflammatory diseases[6].

Silva *et al.*[55] demonstrated anti-nociceptive potential of dichloromethane extract of leaves of Lantana in male mice in hot plate, thermal-stimulated tail flick and acetic acid writhing tests without any mortality at the doses of 1.0 and 1.5g/kg Lantana extract diluted in Almond oil. *In vivo* anti-inflammatory activity of methanolic extract of leaf and bark of Lantana was evaluated by Bairagi *et al.*[56] using carragennan and histamine induced paw edema in swiss albino mice. Oral administration of 200 mg/kg of leaf and bark extracts have shown a dose dependent reduction of 1.46 and 1.48 mm, respectively in carragennan induced paw edema volume as well as significant ($p<0.01$) reduction of 1.60 and 1.62 mm, respectively was observed in histamine induced paw edema volume after 5 hrs. Nea *et al.*[38] identified essential oils from leaves, fruits, flower and stem of Lantana. *In vitro* anti-inflammatory activity of leaves and flower essential oil was demonstrated using the ability to inhibit lipoxygenase (LOX) and denaturation of bovine serum albumin. A significant ($p<0.0001$) inhibition in LOX was shown by flower essential oil with IC_{50} value of 17.23±0.10 µg/mL was observed whereas maximum denaturation in bovine serum albumin was shown by leaves essential oil with IC_{50} value 15.45±0.04 µg/mL.

In vitro and *in vivo* anti-inflammatory activity of isolated triterpenoids from aerial parts of Lantana was evaluated using inhibition of nitric oxide (NO) release in LPS-induced murine microglial BV-2 cells and LPS-induced zebrafish embryos model. In the cellular model, each isolate reduced inflammation by preventing NO release, and Lantrieuphpene B and Lantrieuphpene C exerted anti-inflammatory effects by preventing production of reactive oxygen species and NO in LPS-induced zebrafish embroys[57,58]. Sandhiutami *et al.*[59] investigated *in vivo* anti-inflammatory activity of Lantana leaves. The winter method was employed for the *in vivo* anti-inflammatory test, with 1% carrageenan used as the inducer intraplantarily. The dosages of 3.2 and 6.4 g/kg body weight exhibited 74.57 and 75.72% inhibition in inflammation.

El-Din *et al.*[26] reported *in vitro* anti-inflammatory activity of the methanolic extract of Lantana leaves using elastase release in fMLF/CB-induced human neutrophils. Results have shown prevention of the release of elastase from human neutrophils stimulated by fMLF/CB (IC_{50} = 2.40 0.16 g/mL), demonstrating a significant anti-inflammatory action. The ethanolic extract of *Lantana* leaves has demonstrated *in vitro*

anti-inflammatory properties, as shown by protein inhibition assays and protein denaturation assays, with IC_{50} values of 202.27 and 223.85, respectively[49]. The methanolic extracts of its root and leaves also showed anti-inflammatory activity by lowering the production of NO in LPS-induced BJ cells[50].

Antiulcer potential: Antiulcer property of Lantana has also been demonstrated in experimental studies. Its methanolic extract has shown gastric ulcer protective effect in aspirin, ethanol and cold restraint stress induced ulcer models. In experimental models of ethanol-induced gastric ulcers and aspirin-induced gastric ulcerogenesis in pyloric ligated rats, the methanolic extract of Lantana leaves has been demonstrated to cure gastric ulcers. Along with a considerable ($p<0.01$) decrease in lipid peroxidation and an increase in reduced glutathione levels, it has also significantly ($p<0.01$) decreased ulcer index, overall acidity, and improved gastric pH. Additionally, it has been demonstrated to prevent duodenal ulcers in rats by lowering the ulcer index of duodenal ulcers caused by cysteamine significantly ($p<0.01$)[60].

Analgesic activity: Bairagi *et al.*[56] investigated *in vivo* analgesic activity in the methanolic extract of leaf and bark of Lantana using the acetic acid-induced writhing test in Swiss albino mice and Eddy's hot-plate method. After oral administration of leaf and bark extracts (200 mg/kg), significant ($p<0.01$) inhibition in writhing responses of 39.5+0.42 and 40.16+0.40 were observed, respectively. However, Eddy's hot-plate assay demonstrated higher analgesic efficacy of leaf and bark extracts as 15.11+0.04 and 15.1+0.05, respectively, at the dose of 200 mg/kg after 60 min. *In vivo* analgesic activity was investigated in the methanolic extract of Lantana leaves by Pandeya *et al.*[52] using the tail immersion method in mice. Results have shown that the maximum analgesic activity was found to be 35.5, 28.07 and 19.13% at doses of 800, 600 and 400 mg/kg of extract after 60 min.

Antimutagenic potential: Triterpenes isolated from Lantana; 22 beta-acetoxylantic acid and 22 beta-dimethylacryloyloxy lantanolic acid have shown antimutagenic activity. Triterpene Lantadene and its esters have demonstrated *in vivo* tumor inhibitory potential on squamous cell carcinogenesis induced by 7,12-dimethylbenz[a]anthracene and promoted by 12-O-tetradecanoylphorbol-13-acetate in Swiss albino mice[6]. Kaur *et al.*[61] have demonstrated significant chemopreventive activity of Lantadene A and its methyl ester on squamous cell carcinoma in Swiss albino mice induced in two stages and a decrease in proteins c-jun, p65, and p53. Another compound, oleanonic acid, isolated from Lantana, has demonstrated promising cytotoxicity against A375 malignant skin melanoma cells[6]. Some novel C-2 arylidene congeners of lantadenes have demonstrated cytotoxicity in the micromolar range, as reported by Tailor *et al.*[62].

Compounds present in the essential oil of Lantana, such as β-caryophyllene and (E)-nerolidol, have also been shown to possess cytotoxic potential[63]. Hexane, methylene chloride, and methanol extracts of Lantana leaves, stem bark, and roots, and Lantadene A isolated from its leaves were subjected to cytotoxicity analysis in kidney epithelial cells of monkey and exhibited cytotoxic potential with an IC_{50} of 7.8 µg/mL for hexane and methylene chloride extract and 10 µg/mL for Lantadene A[63,64]. The compounds Lantadenes A, B, C, and icterogenin isolated from leaves of *Lantana* have shown a dose-dependent reduction in MCF-7 cell viability. Lantadene B showed the highest anti-cancer activity with an IC_{50} of 112.2 µg/mL, and significant release of caspase 9 in a dose-dependent pattern. It has also demonstrated induction of cell cycle arrest of MCF-7 cells in G1 and blocking the G1/S transition with a decrease in the MCF-7 population in G2/M phase[22].

Chauhan *et al.*[65] isolated Lantadenes from the weed Lantana and modified them semi-synthetically and examined for *in vitro* cytotoxicity, ligand receptor interaction, and *in vivo* anticancer investigations. The majority of the new analogues outperformed the parent Lantadenes and showed strong antiproliferative activity against the cancer cell lines A375 & A431. The most effective molecule was discovered to be 3-(4-Methoxybenzoyloxy)-22-senecioyloxy-olean-12-en-28-oic acid, with an IC_{50} value of 3.027 M against the A375 cell line, which had the lowest docking score (69.40 kcal/moL).

In vitro cytotoxic potential of methanolic extracts of stem, root, leaf, flower, and fruit of Lantana against four cancer cell lines, namely, HEp-2 (caucasian male larynx epithelial carcinoma), B16F10 (mouse melanoma), A-549 (small cell lung carcinoma), and DLA (Dalton's lymphoma ascites) and normal cell line, NRK-49F (normal rat kidney), using the MTT and SRB assays was evaluated. The higher cytotoxic potential was observed with leaves extract followed by the root, stem, fruit, and flowers extract. Ethyl acetate extract of leaves of Lantana has also demonstrated inhibitory activity against antiapoptotic protein Bcl-xL[66].

Methanolic extract of Lantana leaves has shown anti-proliferative potential with 55.98±0.74% of living cells in laryngeal cancer HEp-2 cell lines and 25.08±0.19% living cells in NCI-H292 mucoepidermoid cell line, which is derived from human lung carcinoma in MTT assay[45]. *In vitro* cytotoxic effect of methanolic leaf extract has been demonstrated at a concentration of 50 µg/mL by inhibiting the growth of Vero cells in MTT assay[67]. Methanolic extract of roots of Lantana has shown maximum lethality of brine shrimp larva (LC_{50} 940.7µg/mL) after 24 hrs and may exhibit anti-cancer potential[68]. Lantana extract has also demonstrated cell death in human breast cancer cell line MCF-7 and modulated caspase-8 and caspase-9, poly ADP ribose polymerase cleavage[69]. Essential oil from leaves of Lantana (500 µg/mL) has also shown cytotoxicity against NCTC929 fibroblast cell line grown in Minimal Essential Medium with an IC_{50} value of 301.42 µg/mL[70].

Cytotoxic activity of methanolic extract of leaves of Lantana was reported by El-Din *et al.*[26] against the triple-negative breast cancer cell line (MDA-231), colon cancer cell line (Caco), pancreatic cancer cell line (PCL), estrogen receptor-positive breast cancer cell line (MCF-7) and results have shown significant cytotoxic effect with IC_{50} values of 74.3±1.19, 45.65±1.64, 52.55±1.14, and 78.08±1.39 µg/mL, respectively. The methanolic extracts from different parts (root, stem, leaf, flower, and fruit) of Lantana have shown anti-leukemia activity on two acute myeloid leukaemia cell lines, MOLM-13 and MV4-11. The methanolic root extract showed significant potential against MOLM-13 and MV4-11 with IC_{50} values of 9.78±0.61 and 12.48±1.69, respectively[50].

Kljakić *et al.*[71] demonstrated cytotoxic activity of Lantana leaf extract with an IC_{50} range of 7.685-79.26 µg/mL against normal and tumor cells. El Hajj *et al.*[40] demonstrated *in vitro* dose-dependent antiproliferative activity of essential oils extracted from white, pink, and orange colored flowers of Lantana against breast cancer cell line MCF-7 (IC_{50} 0.3179±0.002, 0.4144±0.09 and 0.3397±0.027 g/mL) and MDA-MB-231cell line (IC_{50} 0.2800±0.023, 0.3931±0.058 and 0.3951±0.08 g/mL), respectively at 72 hrs. In comparison with normal immortalized human breast epithelial cell line MCF-10A, using the MTT assay. The ethanolic leaf extract of Lantana has shown dose-dependent cytotoxic activity against the triple-negative breast cancer cell line, MDA-MB-231. This extract not only inhibited the growth of MDA-MB-231 cells but also reduced their migration and induced G0/G1 cell-cycle arrest along with nuclear condensation[72]. Given these studies, further long-term *in vivo* studies are warranted to establish the antimutagenic potential of Lantana for treatment of various types of cancer.

Antiplatelet activity: Sandhiutami *et al.*[59] demonstrated *in vivo* antiplatelet activity of leaves extract of Lantana using platelet anti-aggregation test on mice. Lantana leaves extract at doses of 2.5 and 5 g/kg body weight significantly decreased ADP induced platelet aggregation by 5.47% and 12.28%, respectively.

Antiepileptic activity: Bora and Singh[73] evaluated antiepileptic activity of Lantana flowers in swiss albino male mice using maximum electric shock method (MES method) and pentylenetetrazole (PTZ)-induced method. The maximum protection of 61% and 76% was provided by ethanolic extract in the MES model of epilepsy and 57 and 74% protection was observed at doses of 100 and 200 mg/kg, respectively in PTZ induced test. Antiepileptic-like effects of an aqueous extract of Lantana leaves were evaluated by Kandeda *et al.*[74] using seizures induced by kainate in mice. Results demonstrated that the aqueous extract

of Lantana at dose of 460 mg/kg significantly ($p<0.001$) reduced both the frequency and duration of seizures as compared to standard sodium valproate. Furthermore, it markedly raised the GABA concentration in the prefrontal cortex and hippocampus protecting these tissues from oxidative stress. The amount of white blood cells in hippocampus was also significantly reduced by the extract at a concentration of 230 mg/kg.

Antiurolithiatic potential: Mayee and Thosar[75] have demonstrated antiurolithiatic activity of ethanolic extract of Lantana leaves in ethylene glycol and ammonium chloride induced calcium oxalate urolithiasis in male albino rats. It also decreased lipid peroxidation and increased renal antioxidant enzymes reduced glutathione and catalase levels. Antiurolithiatic activity of ethanolic extract of roots and oleanolic acid isolated from roots of Lantana has been demonstrated in a dose dependent manner in albino wistar male rats using zinc disc implantation induced urolithiatic model. Both have significantly reduced calcium output in a dose of 60 mg/kg of oleanolic acid and 200 mg/kg of ethanolic extract besides deposition of calcium and oxalate[76].

In vivo antiurolithiatic activity of ethanolic extracts of Lantana leaves, flowers and roots was evaluated by Ezzat *et al.*[77] in adult male Wistar rats. The flower extract at a dose of 200 and 400 mg/kg b.w. significantly decreased the kidney parameters (calcium, creatinine, urea, and uric acid) in response to ethylene glycol (EG) injuries and restored glutathione peroxidase (GPx), superoxide dismutase, and lipid peroxide malondialdehyde activity to the normal level.

Antimicrobial potential: Essential oil of Lantana has demonstrated resistance-modifying activity against multi-drug-resistant *E. coli* strain, besides exhibiting inhibitory activities against *Escherichia coli* (MIC 512 µg/mL) and *Staphylococcus aureus* (MIC 256 µg/mL) in microdilution test[78]. Methanolic leaf extract has also shown maximum antibacterial potential against *S. aureus* and *P. aeruginosa,* and also shown potential against *Klebsiella pneumoniae* and *Bacillus subtilis* strains in agar well diffusion assay[46]. In this regard, the presence of anti-quorum-sensing activity in leaves of Lantana demonstrated in *Chromobacterium violaceum* assay keeps significance in terms of increasing bacterial pathogenicity and resistance cases in today's world[79]. Its methanolic extract has also demonstrated antibacterial activity against *E. coli, K. pneumoniae, S. aureus,* and *B. subtilis*[21]. Ethyl acetate extract of its flowers has also shown significant antibacterial activity against *E. coli, B. subtilis,* and *P. aeruginosa* in agar well diffusion assay[80].

A triterpene, 22 beta-Acetoxylantic acid, isolated from Lantana has shown antimicrobial activity against *S. aureus* and *Salmonella typhi* bacterial strains. Potential antimicrobial efficacy of flavonoids (free and bound) and crude alkaloids of Lantana was observed against three bacteria, namely, *E. coli, Proteus mirabilis*, and *S. aureus,* and two fungi, *Candida albicans* and *Trichophyton mentagrophytes* in disc diffusion assay[6]. Compounds β-caryophyllene and (E)-nerolidol isolated from essential oil obtained from leaves of Lantana have also shown antimicrobial potential[63].

A significant antifungal activity of ethanol and hot water extract of root, stem and leaves of Lantana against wood destroying white rot fungi (*Trametes versicolor*) and brown rot fungi (*Oligoporus placentus*) was observed in Malt agar bioassay. Acetone extracts of leaves, flowers, and fruits of Lantana have demonstrated significant antifungal activity against *Penicillium janthinellum, Penicillium expansum, Aspergillus niger, Aspergillus parasiticus, Colletotrichum gloeosporioides, Fusarium oxysporum, Trichoderma harzianum, Phytophthora nicotiana, Pythium ultimum,* and *Rhizoctonia solani* in serial microdilution assay[81]. Lantana has also shown anti-dermatophytic potential against *Trichophyton mentagrophytes* fungus in mice[82]. Methanolic extract of its leaves has shown significant inhibitory activity against *Aspergillus fumigatus* and *A. flavus*[46]. Antifungal potential of aqueous extract of its leaves against *Aspergillus niger* ATCC 16888 strain through microdilution and disc diffusion methods has also been reported. Lantana plants have shown antibacterial potential against both Gram-positive and Gram-negative bacterial strains and, therefore, could be utilized for the isolation of antibacterial compounds and to prepare biofungicides.

In vitro antimicrobial activity of crude extract of leaves (LE) and flowers (FE) of Lantana was investigated by Mansoori *et al.*[41] against a fungus (*M. oryzae*) and two bacterial strains, *Xanthomonas axonopodis* pv. glycines (Xag) and *Xanthomonas oryzae* pv. *oryzae* (Xoo). Results demonstrated that maximum % inhibition of fungus growth of 39.02 to 46.60 % was observed at a dose of 25 mg/mL on 10th DAI (day after inoculation) by FE and LE, respectively. Whereas inhibition of 30.06-45.45% was observed for Xoo in FE and LE, while 11.42-34.28% was observed in FE and LE for Xag on 15th DAI. *In vitro* antimicrobial activity of the methanolic extract of leaves of Lantana was evaluated by. Pandeya *et al.*[52] using isolated strains of *S. aureus* and *E. coli*. The outcomes demonstrated that extracts were effective against *S. aureus*. In comparison to conventional Gentamicin (10mcg), the zone of inhibition for methanolic extract at 150, 200 and 400 mg/mL was determined to be 11, 12.33 and 13.67 mm, respectively, against *S. aureus* ($p<0.05$) and no zone of inhibition was obsereved against *E. coli*. *In vitro* antimycotic potential of aqueous, ethanol, and DMSO (dimethyl sulfoxide) extract of Lantana leaves was evaluated by Jangid and Begum[83] against *Mucor circinelloides* using the disc diffusion method. The percent zone of inhibition was observed as 75, 88 and 75% by aqueous, ethanol, and DMSO extract of leaves, respectively.

In vitro antibacterial activity of n-hexane, ethanolic, and methanolic extracts of aerial parts of Lantana was investigated against gram-positive *B. subtilis* and gram-negative bacteria, *Proteus vulgaris*. The MIC values of 100 and 400 µg/mL were obtained using a broth dilution assay for *P. vulgaris* and *B. subtilis*[84]. Recently, the ethanolic extract of Lantana fruits has shown antibacterial action against *E. coli* and *S. aureus* using the agar well diffusion method[6]. Hydroethanolic extract of Lantana leaves has also shown antibacterial action against *E. coli* and *S. aureus* in the agar well diffusion method, as demonstrated by Dwivedi[67].

Ethanolic and methanolic extracts of leaves of Lantana have shown dose-dependent antifungal activity against various wood-rotting fungi such as *Tramates hirsuta, Schizophyllum commune, Pycnoporus sanguieneus, Ganoderma applanatum, Fomes annonus, Oligoporus placentus,* and *Lenzites betulinus,* and 100% inhibition was observed at a concentration of 2.5%[85]. Leaf extract of Lantana has also shown *in vitro* antifungal activity against *Aspergillus flavus* with a maximum inhibition zone of 12 mm using agar well diffusion method[86].

Lantana has also shown promising activity against *Mycobacterium tuberculosis*. Flavonoids such as Linaroside and lantanoside isolated from Lantana and their common acetyl derivative have shown inhibitory activity against *M. tuberculosis* strain H(37)Rv. Its chloroform and methanol extracts have shown significant anti-mycobacterial potential against three strains of *M. tuberculosis*, H37Rv, the rifampicin-resistant TMC-331 and a non-resistant wild strain (28-25271) using the agar-well diffusion method. Patil and Kumbhar[87] have also demonstrated antimycobacterial potential of terpene terpene-rich extract of its leaves against *M. tuberculosis* (H37Ra) by the Resazurin Microtiter Assay method with a minimum MIC_{90} value up to 50 µg/mL. Tuyiringire *et al.*[88] evaluated *in vitro* antimycobacterial activity from crude methanolic extract of leaves of Lantana against Mycobacterium *smegmatis* (mc2155), pan-sensitive (H37Rv), and rifampicin-resistant (TMC-331) Mycobacterium *tuberculosis* using visual Resazurin Microtiter Assay (REMA) on 96 well plates. The methanolic leaves extract had stronger activity against rifampicin-resistant (TMC-331) strain with MIC of 176 µg/mL while *M. smegmatis* and H37Rv had lower activity with the same MICs of 574 µg/mL.

Anti-diarrheal potential: Aqueous extract of Lantana stem has demonstrated significant dose-dependent anti-diarrheal activity in castor oil induced diarrhea in mice with inhibitory action on intestinal secretion and gastrointestinal propulsion[89].

Anxiolytic potential: Anxiolytic effect of ursolic acid stearoyl glucoside isolated from leaves of Lantana has been demonstrated in a dose-dependent manner in an animal study carried out by Kazmi *et al.*[90].

Sedative potential: Dougnon and Ito[91] have demonstrated the sedative effect of essential oil isolated from leaves of Lantana growing in West Africa. Locomotor activity of mice was significantly decreased in a dose-dependent manner by inhalation of 0.0004 and 0.04 mg per 400 µL of triethyl citrate (TEC). Sabinene and 1,8-cineole-rich essential oil, thus could be better utilized for management of central nervous system-related disorders as dementia, insomnia etc.

Hepatoprotective potential: Aqueous methanolic extract of its flowers in doses of 25 and 75 mg/kg body weight has been shown to ameliorate the acetaminophen-induced liver damage in mice[37]. Administration of 50% ethanolic leaves extract (200 and 400 mg/kg) of Lantana once daily for 21 days significantly lowered the concentration of hepatic marker enzymes such as Aspartate Aminotransferase, Alanine Aminotransferase, and Alkaline phosphatase in Streptozotocin-induced diabetic Sprague-Dawley rats[51].

Hypolipidemic activity: Iridoid glycosides such as Geniposide and genipin isolated from Lantana have demonstrated hypolipidemic activity in hyperlipidemic rats[18]. A significant decrease in serum cholesterol and triglyceride levels was observed after administration of 200 and 400 mg/kg hydroethanolic leaves extract of Lantana in streptozotocin-induced diabetic rats after 21 days as compared with the diabetic control group[51].

Protein tyrosine phosphatase (PTP) 1B inhibition potential: Abdjul *et al*.[92] have demonstrated PTP1B inhibitory activity of ethanolic extracts from aerial parts of Lantana collected from Manado in Indonesia and Ishigaki and Iriomote islands, Japan. This property is significant as it is found to be associated with insulin and leptin signalling and a potential role in Alzheimer's disease.

Protein kinase C inhibition potential: Protein kinase C enzyme contributes to the pathology of many diseases like cancer, diabetes, ischemic heart disease, Alzheimer's & Parkinson's diseases. Verbascoside isolated from Lantana has demonstrated protein kinase C inhibitory activity in rat brain and thus could be helpful in the management of many diseases[93].

Hemolytic activity: Hemolytic activity of aqueous extract and its hexane and ethylacetate fraction (50:50), chloroform, methanol, and ethanol fractions from the leaves of Lantana against normal human erythrocytes is also reported[6]. The results showed that the chloroform fraction of the aqueous extract at a dose of 1000 g/mL possessed the highest hemolytic potential (20.51±0.98%), and the lowest activity (4.62±0.23%) was shown by the methanolic fraction of the extract.

Anti-aging activity: Etuh *et al*.[24] investigated the anti-aging activity of ethanolic leaves extract of Lantana in *Drosophila melanogaster* using survival and longevity (life span) assay. Ethanolic leaf extract was administered at 5, 10, and 20 mg/10 g concentration to the diet of fruit flies that were 1-3 days old (n = 50). The rate of young fruit flies emerging from the eggs placed by fruit flies treated with Lantana leaf extracts was also studied. The 168-hour LC_{50} for Lantana was likewise established to be 1135 mg/10 g diet. In comparison to control, Lantana considerably increased ($p<0.05$) both the survival rate and the lifespan of *D. melanogaster*. The rate at which young fruit flies emerged from fruit flies eggs was significantly increased ($p<0.05$) by Lantana.

Wound healing potential: Topical treatment of experimental rats by aqueous extract of Lantana in a dose of 100 mg/kg/day has shown significant enhancement in the rate of wound contraction, collagen synthesis and decreased mean wound healing time, and thus Lantana could be utilized as a therapeutic agent in tissue repair processes associated with skin injuries[94]. Similar results were obtained in adult male Wistar albino rats by the ethanolic extract of leaves confirming the wound healing potential of Lantana[6].

Table 3: An overview of various biological activities reported in *Lantana camara*

Plant part	Pharmacological Activity	References
Leaves	Antioxidant	Ruslin *et al.*[25]
	Antidiabetic	Pandeya *et al.*[52]
	Antibacteria	Naz and Bano[46]
	Antimycobacterial	Tuyiringire *et al.*[88]
	Antifungal	Mansoori *et al.*[41]
	Anti-inflammatory	El-Din *et al.*[26]
	Anti-nociceptive	Silva *et al.*[55]
	Antiulcer	Sathish *et al.*[60]
	Antimutagenic	de Melo *et al.*[45]
	Cytotoxic	El-Din *et al.*[26]
	Antiplatelet	Sandhiutami *et al.*[59]
	Anti-leukemia	Hoang *et al.*[50]
	Hepatoprotective	Venkatesh *et al.*[51]
	Antiepileptic	Kandeda *et al.*[74]
	Anxiolytic	Kazmi *et al.*[90]
	Sedative	Dougnon and Ito[91]
	Antiurolithiatic	Ezzat *et al.*[77]
	Analgesic	Bairagi *et al.*[56]
	Anti-aging	Etuh *et al.*[24]
	Wound healing	Nayak *et al.*[94]
	Immunosuppressive	Kumar *et al.*[95]
	Hypolipidemic	Venkatesh *et al.*[51]
	Spermicidal	Bhatia *et al.*[96]
Stem	Anti-diarrheal	Tadesse *et al.*[89]
	Antifungal	Mdee *et al.*[81]
	Antioxidant	Hoang *et al.*[50]
	Anti-leukaemia	Hoang *et al.*[50]
	Cytotoxic	Litaudon *et al.*[66]
All parts	Antioxidant	Mahdi-Pour *et al.*[44]
Flowers	Antioxidant	da Fonseca *et al.*[39]
	Antidiabetic	Karunakaran *et al.*[53]
	Antibacterial	Ganjewala *et al.*[80]
	Antifungal	Mansoori *et al.*[41]
	Antiepileptic	Bora and Singh[73]
	Hepatoprotective	Abou *et al.*[37]
	Antiurolithiatic	Ezzat *et al.*[77]
	Anti-inflammatory	Nea *et al.*[38]
	Anti-proliferative	El Hajj *et al.*[40]
	Anti-leukemia	Hoang *et al.*[50]
Fruits	Antifungal	Mdee *et al.*[81]
	Antioxidant	Hoang *et al.*[50]
	Anti-leukemia	Hoang *et al.*[50]
	Cytotoxic	Litaudon *et al.*[66]
Root	Anti-leukemia	Hoang *et al.*[50]
	Antioxidant	Hoang *et al.*[50]
	Cytotoxic	Litaudon *et al.*[66]
	Anti-inflammatory	Hoang *et al.*[50]
	Antifungal	Mdee *et al.*[81]
	Antiurolithiatic activity	Ezzat *et al.*[77]
Aerial parts	Anti-inflammatory	Wu *et al.*[57]
	Antibacterial	Al-Itbi and Aknur[84]
	Protein Tyrosine Phosphatase (PTP) 1B inhibition	Abdjul *et al.*[92]
Bark	Anti-inflammatory	Bairagi *et al.*[56]
	Analgesic	Bairagi *et al.*[56]
	Cytotoxic Activity	Ngwewondo *et al.*[64]

Immunosuppressive activity: Administration of leaves juice of Lantana in doses of 60, 600 and 1500 mg/kg daily for 14 days in rats significantly decreased total proteins, globulins as well as absolute and percent lymphocyte counts with significant increase in relative weights of adrenals[95]. The antilymphocytic and immunosuppressive activities of Lantana could be exploited for treatment of life-threatening diseases.

Spermicidal activity: *In vitro* spermicidal activity of aqueous and methanolic leaf extracts of Lantana was observed by Bhatia *et al.*[96] on healthy spermatozoa of human beings. This dose-dependent contraceptive action against sperm mobility, viability and count could be useful to develop plant-based natural anti-contraceptive agents.

All these biological activities show the immense therapeutic potential of Lantana. Table 3 provides a brief overview of various plant parts of Lantana and the associated biological activity as reported in scientific investigations.

Toxicity profile: Many cases of Lantana toxicity have been reported in grazing animals. Allelopathic effect of Lantana on neighboring vegetation is also evident. The pentacyclic triterpenoids isolated from Lantana, namely Lantadene A and B, are the most potent hepatotoxins and allelochemicals identified from the plant, and other phytotoxic allelochemicals are phenolic compounds, namely, umbelliferone, methylcoumarin, and salicylic acid[6]. Green unripe fruits of the plant are toxic for human consumption.

An experimental study in Red Kangaroos after ingestion of Lantana showed symptoms of severe hepatotoxicity and secondary photosensitization. Severe hepatotoxicity in the form of elevated liver enzymes has been demonstrated after administration of its leaf powder in female Wistar rats[6]. A study in guinea pigs has demonstrated dose-dependent hepato-and nephrotoxicity of Lantadenes after 90 days of sub-chronic administration with the highest dose (24 mg/kg body weight). It not only decreased the body weights of animals but also adversely affected enzymes such as alanine aminotransaminase, aspartate aminotransaminase, acid phosphatase, creatinine, and stress markers, lipid peroxidation, reduced glutathione, superoxide dismutase, and catalase in the liver and kidneys. It further showed signs of fibrous collagenous tissue proliferation in tissues[97].

Bora and Singh[73] studied the acute, short (two days) and long-term (14 days) toxicity profile of chloroform, petroleum ether, ethanol, and water extracts of Lantana flowers. All the extracts were found to be safe up to the dose of 2000 mg/kg body weight of animals. Pollen grains of Lantana have also been shown to significantly contribute towards respiratory allergy and elevated Immunoglobulin E levels[98]. Venkatesh *et al.*[51] demonstrated that hydroethanolic extract of Lantana leaves did not cause any mortality in Swiss albino mice up to a dose of 2000 mg/kg. No significant effect on fecal output, feeding behaviour, general motor activity, muscular weakness, etc. was observed after two weeks of administration of 5, 50, 300, and 2000 mg/kg extract in mice. The results obtained in these studies highlight the urgent need to carry out detailed studies regarding the toxicity assessment of various plant parts of Lantana before its launch as an effective drug.

CONCLUSION

Lantana is an ornamental shrub with variable flower colors. It has invaded both natural and agricultural ecosystems in many parts of the Palaeotropics. Despite some negative effects observed in its invaded areas, it has been shown to possess immense ethnobotanical and phyto-pharmaceutical potential. The phytochemical studies reveal the presence of various bioactive compounds belonging to flavonoids, alkaloids, sesquiterpenoids, etc. categories, which are responsible for its medicinal effects. The approach of exploring the therapeutic potential of Lantana could be useful to combat its menace in its non-native regions. However, in-depth mechanistic studies and standardization of extraction methods, dose, as well as clinical studies and detailed toxicological assessments are required to tap the complete potential of plant-based medicines in modern healthcare systems.

SIGNIFICANCE STATEMENT

The negative ecological impacts of a Global Invasive species, *L. camara,* is well-known. However, the plant possesses a long history of traditional use for various purposes, particularly for the treatment of different human ailments. This article provides a comprehensive overview of its traditional uses and highlights the main findings of various scientific investigations carried out to reveal its rich phytochemical composition and broad spectrum of biological activities, which could be further explored to develop novel therapeutic agents. Further, it draws attention to perform rigorous safety evaluations for its responsible use in modern medicine.

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