Lantana camara: An Invasive Plant Species with Potential Health Benefits

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Abstract

Background: *Lantana camara* L. (*L. camara*), referred to as wild or red sage, is a tropical invasive plant commonly used for both medicinal and decorative purposes. It is a member of the Verbenaceae family and is a significant source of essential oils.
Areas Covered: Lantadenes A and B, two extremely concentrated pentacyclic triterpenes that are toxic to sheep, cattle, and cows, are mostly found in the leaves and berries of this plant. It is therefore recommended to utilize this plant sparingly. Despite having harmful compounds, *L. camara* also possesses a range of phytochemicals with therapeutic potentials, including flavonoids, terpenoids, and essential oils. These phytochemicals have been used in the treatment of cuts, wounds, inflammation, and as insect repellants, thus recognizing this plant with medicinal values.
Expert Opinion: Recent studies indicate that *L. camara* is formulated for use in cuts and wounds in a limited number of formulations (e.g., ointments and creams). This review focuses on traditional uses, phytochemistry, biological activities, formulations, and future prospects of *L. camara* for potential therapeutic effects.

Keywords: Formulations, Health benefits, Invasive plant, *Lantana camara*, Lantadenes

1 Introduction

Since time immemorial, plants are being used as a source of medicine for the treatment of various diseases such as cuts, wounds, inflammation, pain, diabetes, gastrointestinal problems, etc. (Gurung et al., 2021) due to the presence of phytochemicals such as alkaloids, glycosides, tannins, phenols, flavonoids, carotenes, etc. (Gurung et al., 2022). Various plant parts, including roots, stems, flowers, leaves, and fruits, are utilized as raw drugs owing to their easy accessibility, affordability, and minimal side effects (Verma, 2018). Although plants have been utilized for medicinal purposes since ancient times, there is no official documentation of these uses, and knowledge is only passed down orally from one generation to the next. Thus, it is imperative that scientific research be done, and that information on plants and their therapeutic applications be documented (Gurung et al., 2020).
Lantana camara Linn (*L. camara*), belonging to Verbenaceae family with tropical origin, is an important medicinal, ornamental, as well as essential oil producing plant (Shah et al., 2020) which is also known as wild or red sage. It is a woody straggling plant with different flower colors, including pink, red, yellow, violet and white (Lonare et al., 2012). It is indeed highly invasive, suppressive, and inherently poisonous in nature (Ghisalberti, 2000). From ancient times, *L. camara* has been used in the treatment of various ailments such as itches, cuts, ulcers, swellings, bilious fever, catarrh, eczema, tetanus, malaria, tumors, rheumatism, cold, headache, whooping cough, asthma, chicken pox, bronchitis, eye injuries, and arterial hypertension (Pour et al., 2011).
Different phytochemical constituents such as ursolic acid, oleanolic acid, linaroside, lantanoside, verbascoside, camarinic acid, phytol, and umuhengerin have been isolated from *L. camara* (Shah et al., 2020). To date, limited scientific studies have explored the antibacterial, analgesic, antioxidant, antipyretic, anti-inflammatory, insecticidal, antimicrobial, antidiabetic, and wound healing properties of *L. camara* (Ved et al., 2018). This review is mainly focused on ethnomedicinal uses, phytochemistry, biological activities and formulations of *L. camara* with future prospects for use in potential health benefits.

1.1 Taxonomic classification (Kalita et al., 2012)

Kingdom: Plantae
Subkingdom: Tracheobionta

Superdivision: Spermatophyta
Division: Magnoliophyta
Class: Magnoliopsida
Order: Lamiales
Family: Verbenaceae
Genus: *Lantana*
Species: *Lantana camara* Linn

Parts Used: Apart from the whole plant, seeds, stems, roots, leaves and flowers are also used.

1.2 Synonyms

Lantana aculeate, *Camara vulgaris*, *Lantana indica* Roxb., *Lantana salvifolia* Jacq., *Lantana trifolia*, *Lantana orangemene*, *Lantana tiliaefolia* Cham, *Lantana achyrantifolia* Desf., *Lantana montevidensis* Briq., *Lantana viburnoides* Vahl, *Lantana crocea* Jacq., *Lantana glandulosissima* Hayek, *Lantana mexicana* Turner, *Lantana mixta* Medik., *Lantana moritziana* Otto and A. Dietr., *Lantana sanguinea* Medik., *Lantana scabrida* Ait., *Lantana spinosa* L. ex Le Cointe, *Lantana undulata* Raf., *Lantana urticifolia* Mill., *Lantana x aculeata* f. crocea (Jacq.) Voss (Ved et al., 2019)

1.3 Vernacular names

Nepali name: Ban Fanda, Banmara; Sanskrit Name: Chaturangi, Vanacchedi; Hindi: Raimuniya; Marathi: Ghaneri; Tamil: Unnichedi; Kannada: Kakke; Manipuri: Samballei; Telugu: Pulikampa; English: Common lantana, Lantana, Lantana weed, Wild sage; Brazil and Uruguay: camará, cambará or chumbinho (Barreto et al., 2010; Shankar et al., 2019).

1.4 Distribution and habitat

L. camara Linn, derived from the Latin word 'lento' meaning "to bend", is a flowering ornamental plant belonging to family Verbenaceae. They are distributed worldwide which are native to America and found in Mexico, Trinidad, Jamaica, Brazil, Florida, Africa, India, and Nepal (Shankar et al., 2019). This plant is commonly known as wild sage or red sage, with 600 variations in 60 countries (Jamil et al., 2022). *L. camara* is regarded as noxious plant and is listed among the top 10 invasive weeds in the world. This weed is responsible for heavy mortality of livestock as well as the loss of agro and forest ecosystem (Sharma et al., 2007). Invasive species are exotic plant species with capability to flourish, establish in new environmental conditions, and bring a lot of detrimental effects on native plants and their habitat (Rejmanek et al., 1996). *L. camara* is not as popular as other medicinal plants for making drugs due to its invasive tendency (Jamil et al., 2022).

1.5 Plant description

It is an evergreen arboreous, potent smelling shrub having different flower colors i.e., pink, red, white, yellow and violet (Shankar et al., 2019). It grows to a height of 1-3 meters and can spread to 3 meters in width (Ved et al., 2019). It is a prickly, deciduous shrub with several stems. Descriptions of different parts of plant are given below (Sivakumar et al. 2022):
- Stem: Tetrangular stem, stout recurved pickles and covered with bristly hairs.
- Leaves: Opposite, simple, scented leaves with long petioles and rough, oval-shaped surfaces.
- Berries: Round, fleshy, two-seeded bean, poisonous.
- Seeds: Initially seeds are green colored, turn into purple and finally black when they get matured.
- Flowers: Small, flower held in clusters (called umbels). Color usually orange, sometimes varying from white, red, violet, pink and in various shades whose color change as they age. Flowering occurs in between March and August.
- Inflorescences: Pair of inflorescences are produced in the axils of opposite leaves which are compact, dome shaped 2-3 cm across and contain 20-40 sessile flowers.
- Roots: Yellowish-whitish in color with strong nature.

2 Traditional uses

Though *L. camara* is an invasive plant, several parts of the plant have been used traditionally for the treatment of various kinds of diseases as presented in Table 1.

Figure 1: a) Different colored flowers; b) Leaves; c) Single colored flowers; and d) Berries of *L. camara.*

Table 1: Traditional uses of *L. camara.*

Parts	**Traditional uses**	**References**
Leaves	Cuts, rheumatism, ulcer, catarrhal infection, tetanus, malaria, cancer, chicken pox, asthma, swelling, eczema, high blood pressure, bilious fever, ataxy of abdominal viscera, sores, measles, cold and fever	Chopra et al., 1956; Day et al., 2003; Kalita et al., 2012; Kensa, 2011
Whole plant	Bronchitis	Kalita et al., 2012; Kensa, 2011
Berries/Fruits	Fistula, pocks, tumors and rheumatism	Sharma et al., 1999
Flowers	Chest complaint in children	Chopra et al., 1956
Powdered root	Given with milk to treat stomachache and as a vermifuge, toothache	Kensa, 2011
Bark	Astringent and used as a lotion in cutaneous eruptions, leprosy ulcers	Kalita et al., 2012
Lantana oil	Skin infection, itches, and as an antiseptic for wounds	Kensa, 2011
Plant extract	Drought-tolerant plant so good candidate for xeriscaping. Employed in the folk drug for the treatment of cancers, chickenpox, measles, asthma, ulcers, swellings, eczema, tumors, high blood pressure, bilious fevers, catarrhal infections, tetanus, rheumatism and malaria	Sharma et al., 1999; Day, et al., 2003; Kensa,2011

3 Phytochemistry

Diverse types of bioactive compounds are found in different parts of *L. camara*, which possess therapeutic activity, namely saponins, alkaloids, tannins, anthocyanins, flavones, isoflavones, flavonoids, coumarins, lignans, catechins, iso-catechins, and triterpenoids (Shah et al., 2020). Wollenweber et al., 1997 have identified and reported the presence of two triterpenoid esters namely, camarilic acid and camaricinic acid (Wollenweber et al., 1997). Examples of those phytoconstituents are presented in **Table 2**.

4 Toxic compounds of *L. camara*

L. camara is ranked among the ten most dangerous plants that have been identified so far. There have been reports of *L. camara* toxicity from America, Australia, India, New Zealand, and South Africa (Kalita et al., 2012). The most toxic compounds identified are Lantadenes A and B, which are pentacyclic triterpenes (Kumar et al., 2016) mainly present in the leaves and green berries, reported to affect mainly cattle, sheep, horses, dogs, guinea pigs, and rabbits (Pour et al., 2011; Sharma et al., 2007). The most important reported clinical sign of toxicity is photosensitization, jaundice, loss of appetite (Kumar et al., 2016) and death of severely poisoned animal within two days of poisoning but usually death occurs after 1-3 weeks after poisoning (Lonare et al., 2012). Previous study also reported the toxicological effect of *L. camara* on liver i.e., elevation in the levels of serum aspartate aminotransferase (AST), alanine aminotransferase (ALT) and alkaline phosphatase (ALP), general reproductive performance and teratology in rats following prolonged treatment (Asadu et al., 2015).

Table 2: Phytoconstituents found in different parts of *L. camara*

Phytoconstituents	**Examples**	**References**
Flavonoids	Flavones, isoflavones, flavonoids, anthocyanins, coumarins,	(Saraf et al., 2011)
Tannins	Catechins, isocatechins	(Singh et al., 2012)
Triterpenoids	Lantacin, cimarin, camarinin, hederagenin and 25-hydroxy-3-oxoolean-12-en-28-oic acid, 3β, 19α-dihydroxyursan-28-oic acid, Δ12-oleanane triterpenoid, camarilic acid, camaracinic acid, oleanolic acid, oleanolic acid acetate, lantadene A, camaric acid, β-sitosterol and its glucoside, pomonic acid	(Begum et al., 1995; Singh et al., 1997; Misra et al., 2000; Begum et al., 2006)
Essential oils	α-phellandrene, germacrene-D, limonene, β -caryophyllene, sabinene, α-zingiberene and α -humulene, α-cadinene, β- and γ-elemene, α -copaene, 8-cineole, α-humulene, β -caryophyllene, hydroxybicyclogermaerene, and sesquiterpenoids humulene epoxide, gamma -terpinene, caryophyllene, germacrene D, gamma-murolene, β-copaene, guaia-1,11- diene, cubedol, germacrene B, 2,6,10- Trimethyl,14-ethylene-14-pentadecene (neophytadiene) and 3,7,11,15-tetramethyl-2- hexadecen-1-ol, caryophyllene, α-humulene, germacrene D, davanone and γ-curcumene	(da Silva et al., 1999; Rana, 2005; Banik et al., 2008; Kuhad et al., 2010; Zoubiri, et al., 2011; Pukalarasan et al., 2017)

5 Pharmacological activities

Table 3: Pharmacological activities of *L. camara* extracts.

Pharmacological activities studied	**Extract**	**Method used/ Against**	**Observation**	**References**
Antioxidant activity	Methanolic extract of *L.camara* leaves	Reducing power activity and 1, 1- diphenyl-2 -picrylhydrazyl (DPPH) radical scavenging assay,and nitric oxide free radical scavenging assay	The antioxidant activity of leaf extracts of *L. camara* might be attributed to the presence of phenolics and proanthocynidins.	Bhakta et al., 2009
	Ethanolic extract of *L. camara* leaves	Antioxidant activity against the hyperoxaluria-induced oxidative stress in male albino rats	Extract improved the amounts of antioxidant enzymes in the kidneys of urolithic rats by reducing the degree of lipid peroxidation, demonstrating its antioxidant efficacy against renal oxidative stress generated by hypercalciuria.	Mayee et al., 2011
Antibacterial activity	Leaves, flower extract of *L.camara*	*Escherichia coli*, *Bacillus subtilis*, *Pseudomonas aeruginosa*, *Proteus vulgaris*, and *Vibrio cholera* by microdilution method	*L. camara* flower extracts exhibited antibacterial activities with zone of inhibition values ranging from 10-21 mm. Leaves extract showed smaller zone of inhibition 9-15mm	Ganjewala et al., 2009
	Methanolic extracts of *L. camara* leaves	Gram positive *Bacillus cereus* and Gram-negative *Salmonella typhi* by disk diffusion method and broth microdilution method	The leaf extract presented the highest antimicrobial effect among all parts of plant, especially, against Gram positive *Bacillus cereus* (zone of inhibition 13.0 ± 0.0 mm, MIC/MBC 9.4 ± 4.4 mg/ml) and Gram-negative *Salmonella typhi* (zone of inhibition 13.5 ± 2.1 mm, MIC/MBC 12.5 ± 0.0 mg/ml).	Barreto et al., 2010; Pour et al., 2009
Anthelmintic activity	Methanolic Leaf, root and stem extracts of *L. camara*	Anthelmintic activity against *Pheritima posthuma*	Among the extracts, methanolic extract of the stem was found to be the most effective.	Girme et al., 2006
Antifungal activity	Ethanolic and hot water extracts of *L. camara*	White and brown rot fungi	Ethanolic extract was highly effective at very low concentrations (0.01%).	Tripathi et al., 2009
	Three different concentrations of extracts viz, 10 mg/ml, 15 mg/ml and 20 mg/ml of *L. camara* was screened.	Alternaria species by using food poison plate method	At 20 mg/ml dose, the extract exhibited significant antifungal activity against Alternaria sps.	Srivastava et al., 2011

Anti-filarial activity	Chloroform stem extract of *L. camara*	*Brugia malayi*	The extract killed adult *Brugia malayi* and sterilized the majority of the remaining female worms.	Sagar et al., 2005
Mosquitocidal activity	Methanolic and ethanolic extracts of the leaves and flowers of *L. camara*	Mosquito larvae in their third and fourth stage of *Aedes aegypti* and *Culex quinquefasciatus* species	At low concentrations 1 mg/ml), extracts were significantly more effective against *Ae. aegypti* than *Cx. quinquefasciatus*. Both extracts demonstrated significant larvicidal activity against both species of mosquitoes.	Kumar et al., 2008
	Essential oil from the leaves of *L. camara*	Larvicidal activity against *Ae. aegypti*, *Cx.quinquefasciatus*, *Anopheles culicifacies*, *Anopheles fluvialitis*, and *Anopheles* stephensi	Caryophyllene (16.37%), eucalyptol (10.75%), alpha-humelene (8.22%) and germacrene (7.41%) might be responsible for the arvicidal activity.	Dua et al., 2010
Anti-inflammatory activity	Aqueous extract of aerial parts of *L. camara*	Carrageenan induced paw oedema in rats	Anti-inflammatory activity was observed on albino rats at a dose of 500 mg/kg body weight in carrageenan induced paw oedema model.	Gidwani et al., 2009
Wound healing activity	Ethanolic extract of the leaves of *L. camara*	Adult wistar albino rats, experimental wound incision in the posterior neck area	Role of extract for wound healing was confirmed by histological analyses.	Mahmood et al., 2009
	Aqueous extract of the leaves of *L. camara*		Topical application of the extract on the wound (100 mg/kg/day) significantly enhanced the rate of wound contraction (98%) and synthesis of collagen, and reduced wound healing time.	Nayak et al., 2009
Hemolytic activity	*L. camara* aqueous extract and its solvent fractions	Human erythrocytes	*L. camara* aqueous extract and its solvent fractions, by modified spectroscopic method at four different concentrations (125, 250, 500, 1000 μg/ml), exhibited hemolytic activity against human erythrocytes. Extracts showed hemolytic activity in the following order: chloroform fraction >hexane and ethyl acetate fraction (50:50) >aqueous extract >ethanol fraction > methanol fraction	Kalita et al., 2011
Antithrombin activity	Methanolic extracts of *L. camara* leaves	In vitro experiment	Extract inhibited the formation of thrombus.	Sivakumar et al., 2022
Cardiovascular activity	Ethanolic extract of *L. camara* leaves	In vivo experiment	Ethanolic extract of *L. camara* leaves showed negative inotropic and chronotropic effects. The heart's workload was reduced by ethanolic extract of *L. camara* leaves, which also maintains ionotinic levels by having a negativechronotropic impact and relaxing the smooth muscles.	Sivakumar et al., 2022

Antihyperglycemic activity	Methanolic extractof leaves and aqueous extract of roots of *L. camara*	Alloxan induced diabetic rats	Oral administration of methanolic extract of *L. camara* (400 mg/kg body weight) leaves decreased the blood glucose up to 121.94 mg/dl, increased the body weight, HbA1c profile as well as aided in renewal of liver cells.	Zhang et al., 2002; Kensa 2011
Antimotility activity	Methanolic extract of *L. camara* leaves	Charcoal meal test	Intestinal motility was checked by charcoal meal test in mice at a dose of 1 g/kg body weight which resulted into complete inhibition and intraperitoneal management of 125 and 250 mg/kg body heaviness. The extracts considerably reduced fecal production in castor oil induced diarrhea in mice.	Bhatt et al., 2011; Begum, 2003
Antiurolithiasis activity	Leaves extracts of the *L. camara*	Ethylene glycol and ammonium chloride induced calcium oxalate urolithiasis in male albino rats	A significant reduction in the deposition of calcium and oxalate was observed. Furthermore, reduced urinary excretion of calcium, oxalate and creatinine was determined.	Thakur et al., 1992; Tucker 1979
Anticancer activity	Roots and leaves extracts of *L. camara*	In vitro tests in Jurkat Leukemia and Vero cell lines	Extracts exhibited statistically similar antineoplastic property (root IC50, 328.36 ± 53.08 μg/ml; leaf IC50, 394.41 ± 99.73 μg/ml) averagely 1/10th times activity compared to carboplatin.	Pour et al., 2009
		In vitro tests in Vero cell line	Leaves extract of *L. camara* were reported to exhibit cytotoxicity effects on Vero cell line.	Reddy, 2013
		Human cancer cell lines, A375 (malignant skin melanoma), Hep2 (epidermoid laryngeal carcinoma), and U937 (lymphoma), as well as a mouse tumor (ehrlich ascites carcinoma)	The anticancer properties of oleanonic acid extracted from *L. camara* were tested against three human cancer cell lines, A375, Hep2, and U937, as well as a mouse tumor. Enhanced cytotoxic effects were determined against A375 cells.	Ghosh et al., 2010; Das Sarma et al., 2010
Antiproliferative activity	Methanolic leaves extract of *L. camara*	In vitro tests on Hep-2 (laryngeal cancer) and NCI-H292 (lung cancer) cell lines	Extract exhibited antiproliferative activity against NCI-H292 cells (% living cells= 25.8±0.19) and exhibited in vitro cytotoxiceffects on Vero cell line.	Pour et al., 2009
Antimutagenic activity	Chloroform leaves extract of *L. camara*	Mytomycin C induced mutagenesis in mice by micronucleus test	Antimutagenic activity was shown by the compounds 22β- acetoxylantic acid and 22β- dimethylacrylacryloxy lantanolic acid.	Barre et al., 1997
Analgesic activity	Methanolic leaves and bark extracts of *L. camara*	Acetic acid induced writhing and Eddy's hot plate tests were performed	200 mg/kg of methanolic leaves and bark extracts showed better pain- relieving activity which might be due to inhibitionof inflammatory mediators.	Bairagi et al., 2017
Antipyretic activity	Ethanolic and ethyl acetate leaves extracts of *L. camara*	Hyperpyrexia induced in rabbits by Typhoid vaccine	Both extracts lowered the body temperature from 1.5 hour which might be due to the presence of flavonoids and other polyphenols, which inhibit cyclooxygenase (COX-1), (COX-2) enzymes and inhibit free radical scavenging activities.	Shonu et al., 2011

Antiulcerogenic activity	Methanolic leaves extract of *L. camara*	Aspirin-induced ulcer model of rats, gastric and duodenal ulcers in different animal models like pyloric ligated rats, ethanol-induced gastric ulcer, and cysteamine-induced duodenal ulcer	The extract possessed dose-dependent antiulcerogenic effects on different animal models.	Misra et al., 2007

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6 Formulations of *Lantana camara*

Although plant extracts exhibit a plethora of potential therapeutic activities, there is very limited literature on the formulation of *L. camara* plant extracts used for the treatment of diseases. Besides, the formulations' use has been extended to the insecticidal, herbicidal and other effects.

The efficacy of *L. camara* leaf extract ointment on *Staphylococcus epidermidis* infected dermal wound healing was assessed (Parwanto, 2017). Ethanolic extract of the leaf was prepared and a 5% extract ointment was formulated with the use of 5 gm leaf extract and 95 gm ointment base. Dermal wound, infected with *Staphylococcus epidermidis*, were developed in Wistar rats. The prepared ointment exhibited better wound healing effects with a significant reduction in the number of bacterial colonies as compared to non-treatment, 10% extract ointment, and 2% sodium fusidate treatments, suggesting the potential use of the formulation in the treatment of infected wounds (Parwanto, 2017).

A *L. camara* essential oil-loaded nano-emulsion formulation was prepared to determine its anti-mosquitocidal and antimicrobial effects (Udappusamy et al., 2022). The essential oils of *L. camara* leaf contained 12 bioactive compounds with caryophyllene oxide, n- hexadecanoic acid, davanone, and beta-sesquiphellandrene as the major components. Nanoemulsion of the essential oil was prepared with the use of Tween-20. The prepared nano-emulsion was effective against *Aedes aegypti* immature stage (larvae and pupae) and adult mosquitoes in laboratory conditions. The LC50 was determined to be 18.183 ppm (I), 23.337 ppm (II), 29.731 ppm (III), 38.943 ppm (IV) instars and 45.295 ppm (pupae), respectively. The LD50 and LD90 values for adult mosquitoes were 11.947 mg/cm2 and 47.716 mg/cm2, respectively. Overall, the results suggested the effectiveness of the *L. camara* essential oil-loaded nano-emulsion formulation in controlling the mosquito vectors (Udappusamy et al., 2022).

Furthermore, a cream was formulated with *Ocimum gratissimum* and *L. camara* crude extracts, which was used for the mosquito repellent activity against *Aedes aegypti* (Keziah et al., 2015). All formulations (single and mixture) were applied at 2, 4, 6, and 8 mg/cm2 in the exposed area of human hands. Evaluation was carried out in the net cages (30 x 30 x 30 cm) containing 60 blood-starved female mosquitoes. All the formulations presented good protection against mosquito bites without any allergic reaction to the human volunteers. Among the tested formulations, maximum protection was observed by methanol crude extract and hexane fraction mixtures of *Ocimum gratissimum* and *L. camara* with protection times of 150 min and 120 min, respectively. A synergistic mosquito repellent effect was observed from the mixture of plant extracts formulated as a cream (Keziah et al., 2015).

Effectiveness of the formulation of *L. camara*-based insecticides on looper caterpillar (*Hyposidra talacam*, *Ectropis bhurmitra*, *Biston suppressaria*) that affect tea plant was also assessed (Rayati, 2011). The treatments comprised: wettable powder (WP) formulation of *L. camara*-based insecticide with two doses (1.5 kg/ha and 3.0 kg/ha); emulsifiable concentrate (EC) of *L. camara*-based insecticide with two doses (1.5 l/ha and 3.0 l/ha); standard chemical insecticide (Decis 25 EC at 300 m/ha); and control. The *L. camara*-based insecticide and chemical insecticide were sprayed three times with one week interval, one day after plucking. Results showed that all of the *L. camara*-based insecticide formulation treatments were effective against tea-looper caterpillar and the effectiveness was comparable to standard chemical insecticide treatment. The results concluded that both WP and EC of *L. camara*-based insecticide could be used for controlling tea-looper caterpillar at lower dose, i.e. 1.5 kg/ha and 1.5 l/ha for the formulation of WP and EC, respectively (Rayati, 2011).

In a separate study, biologically synthesized copper oxide and zinc oxide nanoparticle formulation as an environmentally friendly wood protectant for the management of wood borer, *Lyctus africanus*, were prepared (Shiny & Sundararaj, 2021). The formulation of copper oxide nanoparticle and *L. camara* leaf extract effectively protected the treated rubberwood block from *Lyctus africanus* attack, when compared to zinc oxide nanoparticle *L. camara* leaf extract formulation, suggesting it as a stable, ecofriendly wood preservative (Shiny & Sundararaj, 2021)

7 Future prospects

L. camara exhibits numerous therapeutic properties, in addition to its effectiveness as a mosquitocidal, insecticidal, and herbicidal agent. While various studies have explored the therapeutic potential of extracts, predominantly derived from the plant's leaves, research pertaining to the formulation of these extracts or their active constituents remains scarce. As an invasive species, *L. camara* poses a threat to native plant species and ecosystem balance. However, harnessing the economic potential of such plants not only benefits the ecosystem but also provides a natural alternative to harmful chemicals.

There is a pressing need for future studies aimed at developing commercial formulations of *L. camara* for its therapeutic, mosquitocidal, insecticidal, herbicidal, and other beneficial effects. Comparative analyses focusing on formulation aspects, stability, and the development of viable formulations are imperative. While incorporating plant extracts into formulations holds promise, concerns regarding stability necessitate the isolation of active constituents for formulation purposes. Moreover, conducting comparative assessments between these formulations and commercial chemicals in terms of efficiency, formulation characteristics, and stability will lay the foundation for the widespread utilization of *L. camara.*

8 Conclusion

While acknowledged as an invasive plant species, *L. camara* presents a plethora of potential applications spanning therapeutic, mosquitocidal, insecticidal, herbicidal, and various other effects. Despite numerous studies supporting its potential, the economic exploitation of this plant is impeded by the absence of a standardized formulation for its active constituents. Consequently, there is a pressing need for future investigations focusing on the formulation and stability aspects of *L. camara* formulations. Comparative studies with commercially available chemical formulations are also warranted to establish the economic viability of utilizing this plant, while concurrently safeguarding the integrity of the plant ecosystem.

Authors' contribution

RG: Collection of information and manuscript preparation, arrangement of tables, figures, revision, finalization of manuscript, submission of manuscript
RKT: Collection of information, manuscript preparation, revision, finalization of manuscript

Conflict of interest

The authors declare that there is no conflict of interest among the authors of the manuscript.

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