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Pharmacognosy, phytochemistry and pharmacological profile of *Gmelina asiatica* L.: A review

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Abstract

Gmelina asiatica L. is a small tree or a large shrub. Aerial parts of the plant used in many traditional medicines, but only few are validated till date. Our review throws light on microscopic characters of the *G. asiatica*. Phytochemical screening was also reported where chemical composition of leaf, stem, root and essential oil composition is discussed. Pharmacological analysis of stem, root, leaf and oil were reported. The plant has been reported to have various potential therapeutic activities like antipyretic, antibacterial, antimicrobial, anti-inflammatory, antioxidant, antifungal and many such activities performed on stem, leaf, root, aerial parts and oil obtained by various solvents. This shows wide applications of the plant products in various areas of pharmaceutical industry both internally and externally.

1. Introduction

Herbs are primarily used as a source of food and to treat health diseases since time immemorial. As there is a huge demand, they are identified and consumed for several potent health properties that play vital role in prevention of deleterious human diseases (Mohd Hafizur and Sayeed, 2019). In both developing and developed countries, usage of these plants for traditional herbal remedies to cure ailments and diseases is drastically increasing owing to their availability and less cost (Sevgi *et al.*, 2020). Exploration of traditional medicine is an interesting and challenging task for the ethnobotanists (Susmita *et al.*, 2020). Plants made a dynamic impact on culture, thought as well as on economic activity since ancient period (Monish *et al.*, 2022). Around 80% of the global population is dependent on plant extracts for primary healthcare. Almost 90% of prescriptions in traditional systems of medicine were based on drugs derived from plants (Bhuvaneswari *et al.*, 2021). Our present review focuses on one such medicinally significant plant.

Gmelina asiatica L., also called as *Gmelina parvifolia* Roxb., belongs to the family Verbanaceae which after phylogenetic studies declared to be belonging to Lamiaceae Family. The plant is called as 'Vikarini' in Sanskrit, 'Badhara' in Hindi, 'Nilakumil' or 'Kumil' in Tamil and Malayalam, 'Adavi Gummudu' or 'Challa Gummudu' in Telugu and Asian Bushbeech in English. It is used as a live fence on agricultural lands, dry lands, wastelands, *etc.*, and also on the sides of roads. Young branches and leaves are used conventionally in medicine. The plant parts have been extensively studied about their microscopic characters using transverse section of leaf, stem and powder characteristics of the same (Kirtikar and Basu, 1975). T.S of the stem in Figure 2 shows secondary phloem, central pith, secondary cortex (Kannan *et al.*, 2012). Parenchymatous secondary cortex contains starch grains. But, these features are absent in dried form. Bunches of cap fibers and sclerides are present in secondary phloem from primary vascular bundles. Vessel elements, tracheids, fibers are present in wood. Starch grains may be either simple or compound. Calcium oxalates shapes are either rectangular, or prismatic square and are discovered in ray and pith cells (Kannan *et al.*, 2012). Powdered plant consists of light reddish bark and appears pale brown. Xylem elements are abundantly observed in powder under microscope. Lignified pith cells, vessel element fragments, macrosclerides from secondary phloem region, groups of tracheid fibers and starch grains, cork cells, calcium oxalates are present throughout (Kannan *et al.*, 2012).

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Figure 1: Picture of *G. asiatica*.

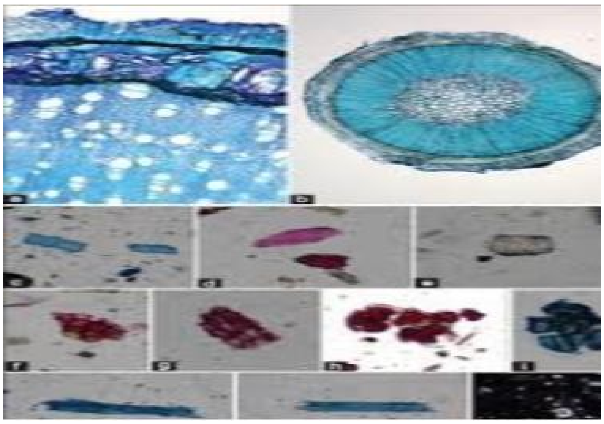


Figure 2: Microscopic characters of *G. asiatica*.

Phytochemical screening of *G. asiatica* have shown bioactive components such as alkaloids, carbohydrates, glycosides, coumarins, quinones, saponins, steroids, terpenoids, proteins, phytosterols, tannins and flavonoids. Total tannins content in the ethanolic leaf extract was estimated to be as 0.042 µg/µl and flavonoids content was estimated as 0.045 µg/µl. The findings of the study reveal the applications of *G. asiatica* in phytopharmaceuticals.

Pharmacological studies have been extensively studied to validate its role in the field of pharmaceuticals as shown in Figure 3. Whole herb as well as individual parts were studied for pharmacological uses. The following activities have been scientifically validated which will be discussed later in detail in this review. They are antipyretic activity, antimicrobial activity, antifungal activity, anti-inflammatory activity, antitumour activity, hepatoprotective activity, nephroprotective activity, nematocidal activity, antioxidant activity, and larvicidal activity. These activities were exerted by root, leaf, stem and whole herb of the plant. Different solvents were used for this purpose. Some of the activities were also performed on the cell lines to validate. The plant has many traditional uses/folklore uses. Many of them have been scientifically validated. Roots have medicinal property and are used in folklore medicine. Root's wood and bark are important parts used (Aiyer, 1951), leaves and young shoots also have made their mark in medicine (Kirtikar and Basu, 1935). Aerial and leaf parts are used in cure of hepatic and jaundice diseases by tribal people residing in Tamil Nadu (Apparanantham *et al.*, 1982) and other areas (Vikneshwaran *et al.*, 2008). In Sri Lanka, bark, roots, young shoots and fruits are used for variety of diseases/disorders (Jayaweera, 1980). *Gmelina arborea* is substituted by use of roots (Babu *et al.*, 2010). It is also mentioned in 'Anukta Dravya' drugs (Kusuma and Joshi, 2010). Roots and stem have antioxidative properties (Syed *et al.*, 1997; Girija and Ravindharan, 2016). Bark of stem exhibited hypoglycemic and antihyperglycemic properties (Kasi Viswanath *et al.*, 2005). Chloroform and ethanolic extracts of aerial parts were reported to have antioxidant and hepatoprotective activity (Merlin and Parthasarthy, 2011). But, stem is used in place of roots nowadays (Vishwanathan and Basvaraju, 2010; Poornima, 2010; Ujjaliya Nitin *et al.*, 2012).

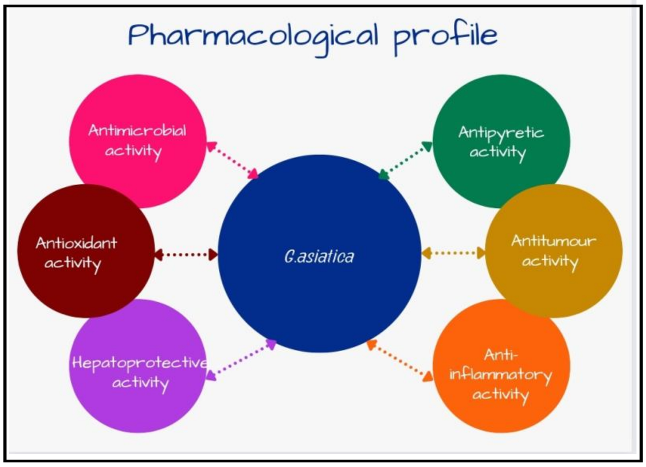


Figure 3: Pharmacological profile of *G. asiatica*.

2. Chemical composition of *G. asiatica*

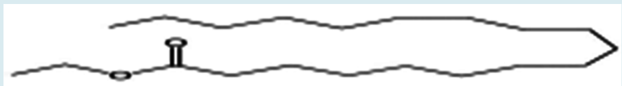
By using the spectrum oil, constituents of test compound were determined and compared with standard which is included in the National Institute Standard and Technology (NIST). The molecular weight, name and structure elucidation of the parts of the components were identified and confirmed.

Determination of active natural constituents present in essential oil of *G. asiatica* done by GC-MS analysis (Yayli *et al.*, 2005; Duke *et al.*, 2006). By using above spectra, eight phytoconstituents were identified from leaf volatile oil of *G. asiatica*. Volatile oils are (E)-9-octadecanoic acid, 1, 2-benzene dicarboxylic acid, E-11-hexadecanoic acid, linoleic acid, benzene, hexadecenoic acid, heptadecanoic acid and cholesterol trimethylsilyl ether. Some linoleic acid esters are linoleic acid and ethyl ester which may be used as anticancer, insectifuge, 5-alpha reductase inhibitor, anti-inflammatory, hypocholesterolemic and antihistaminic agent. (E)-9-Octadecanoic acid effects are anticoronary, antioxidant, antimicrobial, hypocholesterolemic, antieczemic antiandrogenic, antiarthritic, hepatoprotective, insectifuge, 5-alpha reductase inhibitor, nematicide. Hexadecanoic acid is regarded as a palmitic acid ester and it may used as hypercholesteremic, antioxidant, lubricant, flavor, antiandrogenic, pesticide, nematicide and antihemolytic agent. Oleic acid and linoleic acids were observed in the fruit oil of *G. arborea* (Moronkola *et al.*, 2009). Another group studied preparation of biodiesel from six chemical components of seed oil obtained from *G. arborea* seed oil

(Basumatary *et al.*, 2012). Adeyeye (1991) analyzed the *Tectona grandis* and seed oil of *G. arborea*. He found fatty acid which is isolated from the fresh leaves, dried fruits, roots of *Vitex negundo* and *Lippia multiflora* stem (Khokra *et al.*, 2008; Tsiba *et al.*, 2010; Vishwanathan and Basvaraju, 2010). Another group reported the appearance of chemical constituents from the *G. asiatica* oil consisting 2 monoglycerides (1.6%) and 10.1% of triglycerides (Gunstone and Qureshi, 1965; Lawrence,1988). Previous studies reported that chemical constituents of essential oil based on geographical origin of plants by genetic factors (Lawrence, 1988; Holm *et al.*, 1997; Vieira *et al.*, 2001; Thompson *et al.*, 2003), environmental conditions (Gil *et al.*, 2002; Curado *et al.*, 2006) and nutritional status effects of mechanical damage or herbivory (Maia *et al.*, 2001), climatic conditions, soil phase of vegetation, harvesting season, solvent types, methods of extraction, plant age and anatomical part of plant (Banchio *et al.*, 2005; Tetenyi, 2001). The type and concentration of chemical compounds in plant extract in each region is different whereas, the chemical composition of essential oil differs in different species (Adams and Sparkman, 2007).

Major compounds identified in the essential oil of *Gmelina asiatica* leaf is as follows:

Table 1: Major compounds identified in the essential oil of *Gmelina asiatica* leaf by GC-MS analysis

S.No	Name of the compounds	Structure
1	E-11-Hexadecanoic acid, ethyl ester	
2	Hexadecanoic acid, ethyl ester	
3	Linoleic acid, ethyl ester	
4	(E)-9-Octadecnoic acid, ethyl ester	
5	Heptadecanoic acid, ethyl ester	
6	1,2 Benzene dicarboxylic acid, diisooctyl ester	
7	Benzene, (1-butylhexadecyl)	
8	Cholesterol trimethylsilyl ether	

3. Phytochemical analysis of *G. asiatica*

The qualitative phytochemical analysis of *G. asiatica* leaf in aqueous, petroleum ether, chloroform, ethanol and acetone extracts has shown the presence of many phytoconstituents. Chemical constituents like flavonoids, carbohydrates, steroids, terpenoids, tannins, alkaloids and phytosterols are identified in the aqueous extract. The petroleum ether extract has shown glycosides, quinones, coumarins and phytosterols. Chloroform extracts have demonstrated secondary metabolite-glycosides, primary metabolite-carbohydrates, proteins, coumarins and phytosterols. The ethanolic fraction demonstrated different phytoconstituents like terpenoids, coumarins, proteins, flavonoids, saponins, glycosides, tannins, steroids and phytosterols. The acetone fraction has demonstrated different phytoconstituents: coumarins, glycosides carbohydrates, saponins, proteins and phytosterols. The highest phytochemical constituents were found in ethanolic extract and the base phytoconstituents were found in petroleum ether extract. This is on the grounds that ethanol is much polar when extracted with chloroform and $(CH_3)_2CO$ and henceforth increasing number of the active constituents can be isolated from the plant parts (Tunalier *et al.*, 2002). A few scientists recognized that most of the phytochemicals are found in the ethanolic extract than different solvents (Sefidkon *et al.*, 2004; Silvia and Satyanarayan, 2004). The above investigation shows that the plant has more measures of glycosides in all concentrates yet missing just in aqueous extract. Perceptions by (Savithramma *et al.*, 2012; Rajesh *et al.*, 2013) affirmed the non-appearance of glycosides in fluid concentrates which is additionally demonstrated in this investigation. The presence of glycosides demonstrates that *G. asiatica* might be utilized in restoring cardiovascular inadequacy, hack and circulatory issues and might be powerful as tranquilizers with antispasmodic properties (Sule *et al.*, 2010), while alkaloids were missing in all concentrates except from aqueous concentrate. Past works likewise upheld the nonappearance of alkaloids in *G. asiatica* leaf (Parekh and Chanda, 2007; Girija and Ravindharan, 2011). Phytosterols were observed in such a way to restrain the development and metastasis of prostate malignant growth (PC-3) cells (Awad *et al.*, 2001). The prior research on different parts of *G. asiatica* extracts were accounted for leaf. When contrasted with root and stem, leaf extricates contributed wide scope of optional metabolites, as supplements are all the more copiously found in leaves amid photosynthesis. It is obvious from this, that the leaf of *G. asiatica* contains distinctive sorts of optional metabolites. In quantitative phytochemical screening, the general flavonoids and tannins in the ethanolic concentrate of *G. asiatica* leaves was observed to be 0.045 and 0.042 µg/µl, respectively. These elements incorporate season, region of gathering site, impact of air contamination, supplement confinement of soil and furthermore sort of solution utilized, its focus, the response time, temperature and convergence of catechin and so forth. What's more, the nearness of phenolics and flavonoids differ as per plant parts, development at collect, developing soil conditions, conditions and post-reap treatment (Jeffery *et al.*, 2003).The substance of all out tannins and flavonoids in the methanolic separate is pretty much comparative with *Verbena venosa, Verbena rigda and Verbena tenara* (El-Heda and Abdullah, 2010). Previous examinations have affirmed the sum and structure of flavonoid and phenol mixes enhanced at the sub-cell level and inside plant tissues also (Randhir *et al.,* 2004).

4. Folkloric uses of *G. asiatica*

The juice of fruit applied to portions of the feet affected by "alipuga," a kind of eczema. The juice of fruit is also considered an "anti-limatik" (a species of leech of the genus Haemadipsa).The fruit poultice is mixed with lime and applied to the throat for the treatment of cough. The mixture of the fruit with lime and garlic applied to the body with agitation in cases of dropsy. Traditionally used for diabetes in India. It is used for dandruff where fruit juice applied every three days in the morning externally to the scalp. A paste is also made by pulverizing the fruit pulp of this plant with fruit of *Sapindus emarginatus*. The paste is applied on scalp as shampoo to wash hair to get relieved from dandruff (Ganesh and Sudarsanam, 2013).

5. Research on *G. asiatica*

Ikram along with a group of researchers investigated eight Pakistani therapeutic plants for antipyretic action in rabbits getting subcutaneous yeast infusions. One of them is *G. asiatica*. Hexane- and chloroform-solvent concentrates of *G. asiatica* roots showed noticeable oral antipyretic property. Toxicity studies showed no critical poisonous or antagonistic impacts for plant extracts up to the most astounding oral portions (Ikram *et al*., 1987).

Syed Ismail and his team have concentrated on the mitigating impact of *G. asiatica* root in male pale skinned rodents. Carageenan-initiated rodent paw oedema and cotton pellet granuloma (chronic irritation) strategies have been used. *G. asiatica* root powder was successful in lessening the edema amidst the shifted periods of intense aggravation. In ceaseless part the heaviness of cotton pellet tumor was furthermore diminished by *G. asiatica* treatment. It additionally diminished the lipid peroxide substance of granuloma exudate and liver, y-glutamyl transpeptidase in the granuloma. Serum egg whites in granuloma were brought to normal values. *G. asiatica* additionally directed or conveyed to normal the rise in levels of serum acid and alkaline phosphatase. The results have demonstrated that the *G. asiatica* may apply calming movement against proliferative, hostile oxidative and lysosomal film stabilization (Syed Ismail *et al.*, 1997).

Sudhakar and his team contemplated on antimicrobial activity. The ethanolic concentrates of the *G. asiatica* were tried for antimicrobial activity. It displayed a wide range of antimicrobial activity, especially significative against *Escherichia coli, Proteus vulgaris* and *Pseudomonas aeruginosa* (Sudhakar *et al.*, 2006).

Jigna Parekh and her team surveyed the antibacterial impact of ethanolic and aqueous concentrates of *G. asiatica* against bacterial strains like *Enterobacter aerogenes* ATCC13048, *Klebsiella pneumonia* NCIM2719, *Bacillus cereus* ATCC11778, *Staphylococcus aureus* ATCC25923 and *Escherichia coli* ATCC25922. Agar well dissemination and agar disc dispersion procedure were performed for *in vitro* bactericidal action. The concentrate of *G. asiatica* could not repress any of the bacterial strains examined (Jigna Parekh *et al.*, 2006).

Merlin and her team examined antifungal, anti-inflammatory and antibacterial activities of ethyl acetate, petroleum ether, chloroform and ethanolic concentrates of whole herb of *G. asiatica*. Each concentrate of *G. asiatica* was tried for antibacterial viability against *Bacillus subtilis*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Escherichia coli*, *Salmonella typhi* and *Micrococcus luteus* and antifungal adequacy against *Aspergillus niger* and *Candida albicans*. The antibacterial and antifungal impact displayed by oil ether, chloroform, ethyl acetic acid derivation and ethanol extract were compared with that of griseofulvin and amikacin. The chloroform fraction was observed to be extremely effective and indicated toxic effects on bacteria and fungus. Each one of the concentrates was screened for antimicrobial movement. The ethanolic concentrate of *G. asiatica* at (250 and 500 mg/kg) focuses showed mitigating action against carrageenan prompted rodent paw oedema, histamine induced edema, dextran initiated edema and cotton pellet instigated granuloma strategy and the outcomes were compared with that of indomethacin and control and observed to be noteworthy (p<0.001) (Merlin *et al.*, 2009).

Konathala Rajesh and his colleagues have contemplated pharmacognostic analysis on the stems of *G. asiatica*. The plant has been utilized in gonorrhea, catarrh of the bladder and ailment. In this investigation, air-dried stem powder was separated with various solvents, for example, hexane, chloroform, ethanolic and unadulterated water. Fundamental phytochemical examination was likewise performed alongside estimation of the leaf constants, fluorescence attributes and extractive qualities. Quantitative estimation of all out-slag esteem, corrosive insoluble fiery remains and water dissolvable cinder were additionally performed to help in distinguishing proof of the powdered medication (Rajesh *et al*., 2013).

Merlin and her peers have studied cytotoxic impact of *G. asiatica* and its mechanism of action on cell passing in human bosom cancer cell MCF-7 cells. These cells were seeded in 96 well culture plates within the sight of various centralizations of concentrates of *G. asiatica* to check the power of *G. asiatica* concentrate to demonstrate cytotoxic impact by utilizing MTT assay. Its system was assessed by chromatin buildup utilizing hoest recoloring and morphological changes utilizing contrast magnifying lens. Plant concentrates of *G. asiatica* were seen to prompt apoptosis of MCF-7 cells as identified in MTT cell multiplication assay, cell morphological changes and chromatin buildup. The cytotoxicity of chloroform extract was increasingly intense when contrasted with different concentrates. This investigation helped in recognizing the potency of *G. asiatica* in human breast cancer cell death (Merlin and Parthasarthy, 2010).

Merlin and her team have studied antitumor activity against Dalton's ascites Lymphoma (DAL) for chloroform concentrate of whole herb of *G. asiatica* (CGA) in swiss albino mice. Dalton's ascitic lymphoma cells were intraperitoneally infused (106 cells) to the mice. After two days of cells infusion, the animals were treated 14 days with 200 and 400 mg/kg of chloroform concentrate of *G. asiatica*. Fivefluorouracil (20 mg/kg) was utilized as standard medication. On day 15, pressed cell volume, disease cell number, decline in tumor load of the mice tumor weight, increment in life expectancy and hematological parameters were tried and compared with the standard and control. A noteworthy tumor weight diminishing in the malignancy cell number and increment in the life expectancy were determined in the tumor-instigated mice after treatment with chloroform concentrate of *G. asiatica*. The hematological parameters were additionally reached to normal by chloroform concentrate of *G. asiatica* in tumor-prompted mice (Merlin and Parthasarthy, 2010).

Merlin along with her team have considered hepatoprotective property of ethanolic and chloroform concentrates of aerial parts of *G. asiatica* on carbon tetrachloride incited hepatic harm in experimental rats. The extracts were given once in a day at a dose of 400 mg/kg b.w in aqueous suspension form. The serum enzyme levels were rise upon feeding with carbon tetrachloride which on treatment with concentrates of *G. asiatica* has been standardized. The parameters examined incorporate aspartate aminotransferase, alanine transaminase, serum soluble phosphatase and complete bilirubin content. Silymarin was utilized as standard hepatoprotective medication against carbon tetrachloride induced hepatotoxicity in rodents. Aside from biochemical parameters, histopathological investigations of rodent liver areas have additionally been examined to help the outcomes. This examination demonstrates that concentrates of *G. asiatica* have powerful hepatoprotective action against CCl_4 induced hepatotoxicity in rats. Ethanolic extract has strong action when contrasted with chloroform separate. *In vivo* antioxidant activity and free radical scavenging action was likewise examined for both the concentrates and it was demonstrated that both the concentrates have antioxidant action. Probable mechanism of action might be free radical scavenging action on account of the presence of flavonoids (Merlin and Parthasarthy, 2011).

Girija and her team have observed traditional uses and significant antioxidant activity in *G. asiatica*. Radical scavenging activity was found to be higher in root and leaf than in stem. Leaves, roots and stem of *G. asiatica* are the potential sources for antioxidants (Girija and Ravindharan, 2011).

Kannan and his team carried out detailed study on pharmacognosy of stem of *G. asiatica*. In this study, pharmacogenetic characters of stem and its differentiation from root was described. Bundle cap fibers, hollow pith, faint annual rings in extreme points and existence of huge number of calcium oxalates and starch grains in pith and ray cells are the characteristic microscopic characters of stem. It can be distinguished from roots by availability of tylosis in it (Kannan *et al.*, 2012).

Ganesh along with his team has carried out ethnomedicinal survey on plants used by Yanadi tribes in the Sesha Chalam biosphere reserve forest area of Chittoor district. It throws light on uses of traditional plants which were used by people over there. It also revealed therapeutic benefits of 70 medicinal plants in the form different formulations and also in crude form along with ghee, sesame oil, cow milk and goat milk to cure various diseases/disorders. It also throws light on ethnic practices of 70 plant species belonging to 44 families to cure various diseases/disorders like skin issues, liver disorders, rheumatism, antidotes, fevers, intestinal worms, menstrual disturbances, head-ache, hyperglycemia, tooth-pain, breathing disorders, eye issues, stomach-pain, digestive problems, sexual issues, pregnancy issues and so on (Ganesh and Sudarsanam, 2013).

Kiruba and his colleagues performed nephroprotective efficacy of *G. asiatica* by taking gallic acid and quercetin as references. *In vitro* anti-inflammatory activity was performed by inhibition of protein denaturation, proteinase inhibitory assay and membrane stabilization assay. The results revealed the therapeutic activity against free radical which is clear from the antioxidant assays. It has been found effective on proteinase inhibition and red blood cells against heat induced membrane disruption which clearly shown its part in balancing the integrity of the cell membrane. The excellent results helped to assess nephroprotective potential of plant various assay methods. Healthy kidney cells were used for DNA fragmentation assay and epifluorescence dual staining by making use of vitamin E as a reference standard (Kiruba and Brindha, 2014).

Vaidyanathan and his peers carried out survey on ethnomedicinal uses of plant among Malayali gounder tribals of Tamil Nadu, India. Hundred species of ethnomedicinal plants of 91 genera and 47 families were identified with the help of villagers. It is found in this survey that the plant *G. asiatica* was called as Mullu kumulu in local language and the part used was fruit. Fruit was used to treat wounds in head and also as substitute for soap (Vaidyanathan *et al.*, 2014).

Azhagumurugan and his team carried out research on exploration of use of native plants for the control of parasitic nematodes by various control methods. The extract of *G. asiatica* leaves at different doses was analyzed on *Meloidogyne incognita* egg masses and root-knot nematode. The nematocidal activity of the plant, larval mortality and inhibition of egg hatchability are indirectly proportional to the dose of the leaf extract. Larval death rate was directly proportional to the treatment concentrations and time of leaf extract. A rise in nematode worm larval death and a drop-in egg hatchability rate was reported (Azhagumurugan and Rajan, 2014).

Netala Silvia and her group have studied preliminary phytochemical screening and antioxidant profile of *G. asiatica*. Antioxidant profile was assessed by free radical scavenging activity of the *G. asiatica* against DPPH, nitric oxide and the percentage ferric reduction method. Preliminary phytochemical screening was also performed on the extract and found the availability of various phytoconstituents like alkaloids, tannins, glycosides, steroids and saponins. From the results, a positive linear correlation can be seen between polyphenols and free radical scavenging activities. These findings provide strong evidence that the crude extract is a potential source of many potent antioxidants (Silvia and Satyanarayan, 2014).

Muthukumaran and his group have carried out synthesis and characterization of silver nanoparticles using *G. asiatica* leaf extract. In this study, assessment of the larvicidal potential of leaf extracts and synthesis of silver nanoparticles (AgNPs) using aqueous leaf extract against arthropod larvae of *Aedes aegypti*, arthropod genus *Stephensi* and *Culex quinquefasciatus*. AgNPs were synthesized when larvae treated with different doses of leaf extracts for a day. The reports were obtained from FTIR, UV-visible spectroscopic analysis, SEM, energy-dispersive and transmission electron microscopy. X-ray spectroscopy studies assist the biosynthesis and characterization of AgNPs. The maximum effect was obtained in synthesized AgNPs against the larvae of *An. stephensi*, *Ae. aegypti* and *C. quinquefasciatus*, respectively. No death cases were found in the control (Muthukumaran *et al.*, 2015).

Azhagumurugan along with his colleagues tested the efficacy of leaves of *G. asiatica* against the *Meloidogyne incognita* in black gram, root knot nematode, *Vigna mungo* with different inoculum doses of egg masses (5, 10, 15, 20 and 25 egg masses). Plants were treated with various doses of leaf extract (5, 10, 15, 20 and 25 ppm). The test and control plants were assessed for population density and growth of root knot nematode subsequent to 65 days of inoculum. As a result, the growth rate was reduced as indicated by decreased H_2O content of the shoot, root and reduction in area of leaf with increasing levels of egg masses (Azhagumurugan and Rajan, 2015).

Mahendra and her colleagues have studied anti-dandruff property of supercritical fluid extracts of *G. asiatica* stem against causative fungi, *Malassezia furfur*. Results have shown that minimum inhibitory concentration (MIC) of *G. asiatica* is found to be (250 µg/ml) hence, supercritical fluid extracts of *G. asiatica* suggests that it may possess antidandruff properties against *M. furfur* but potency is little less (Mahendra *et al.*, 2015).

Florence and her team have investigated essential oils from the leaves of *G. asiatica* by hydrodistillation method using Clevenger apparatus. Fatty acids composition was identified by using GC-MS method of analysis. Eight bioactive compounds were identified as linoleic acid; E-11-hexadecanoic acid; (E)-9-octadecanoic acid; benzene, hexadecanoic acid; heptadecanoic acid; 1, 2-benzenedicarboxylic acid; (1-butylhexadecyl) and cholesterol trimethylsilyl ether. The bioactive compounds were used to treat various diseases by the traditional medics (Florence *et al.*, 2016).

Florence and her group detected presence of active constituents' available chloroform, ethanol, aqueous petroleum ether and acetone extracts of *G. asiatica* leaf. Phytochemical testing was done by using Harborne technique. Flavonoid content and total tannin were calculated by using $AlCl_3$ method and Folin ciocalteau reagent, respectively. Different fractions have shown bioconstituents like carbohydrates, alkaloids, coumarins, glycosides, saponins, quinones, flavonoids, terpenoids, steroids, proteins, tannins and phytosterols (Florence *et al.*, 2016).

Florence and her group of researchers studied antineoplastic effect on human breast cancer cell line MCF-7 of ethanolic leaf extract of *G. asiatica* by using MTT assay. Physical characters of cell were examined by using a phase contrast microscope. The results showed MCF-7 cancer cell lines treated with test drug decreased cell death with increasing dose. Approximately 8.4 % of cell growth was found at 1000 µg/ml dose of test drug (Florence *et al.*, 2016).

Research on pharmacological activities of *G. asiatica* has been tabulated as follows:

Table 2: Pharmacological actions of *G. asiatica*

S.No.	Part used	Solvent used	Pharmacological activity	References
1	Roots	Hexane and chloroform	Antipyretic property	Ikram *et al.*, 1987
2	Roots	Ethanol	Anti-inflammatory activity	Syed Ismail *et al.*, 1997
3	Whole herb	Ethanol	Antimicrobial activity	Sudhakar *et al.*, 2006
4	Whole herb	Ethanol and water	Antibacterial property	Parekh *et al.*, 2006
5	Whole herb	Ethyl acetate, petroleum ether, chloroform and ethanol	Antifungal, anti-inflammatory and antibacterial activities	Merlin *et al.*, 2007
6	Whole herb	Chloroform	Cytotoxic activity	Merlin and Parthasarthy, 2010
7	Whole herb	Chloroform	Antitumor activity	Merlin and Parthasarthy, 2010
8	Aerial parts	Ethanol and chloroform	Hepatoprotective property	Merlin and Parthasarthy, 2011
9	Whole herb	Water	Nephroprotective efficacy	Kiruba and Brindha, 2014
10	Leaf	Various solvents	Nematocidal activity	Azhagumurugan and Rajan, 2014
11	Whole herb	Water	Antioxidant activity	Silvia and Satyanarayan, 2014
12	Leaf	Water	larvicidal potential	Muthukumaran *et al.*, 2015
13	Leaf	Water	Nematode	Azhagumurugan and Rajan, 2015
14	Stem	Supercritical fluid	Anti-dandruff property	Mahendra *et al.*, 2015
15	Leaf	Water	Ailments	Florence and Jeeva, 2016
16	Leaf	Ethanol	Antineoplastic effect	Florence and Domettila *et al.*, 2016
17	Leaf	Ethanol	Antioxidant activity	Florence *et al.*, 2016
18	Fruit	Ethanol	Dengue, filariasis and treat hair fall	Srikanth *et al.*, 2016

Florence and her colleagues studied antioxidant activity of ethanolic leaf extracts of *G. asiatica*. The activity was assessed against DPPH, OH Þ, SO Þ and the ABTS radicals with the concentration in the range of 20-100 mg/ml. The result showed high antioxidant activity with the OH Þ (14.73 ± 0.09), IC_{50} value of DPPH (18.37 ± 0.07), SO (237.82 ± 8.95) and ABTS (12.12 ± 0.01 ìg/ml). The above values confirmed that the ethanolic leaf extract may act as a vital natural inhibitor due to its radical scavenging activity (Florence *et al*., 2016).

Srikanth and his group carried out screening of the phytochemical constituents present in the traditional medicinal plant, *G. asiatica* which has been used in the treatment of Dengue, Filariasis and treat hair fall diseases like dandruff around Andhra Pradesh, India. The qualitative phytochemical analysis was carried out by standard protocols and the same extract was analyzed using GC-MS for the identification of different phytochemicals present in the *G. asiatica*. The extract showed the positive results for the steroids, terpenoids, phenols, alkaloids, flavonoids, tannins and carbohydrates and the extract gave a negative result for saponins and oils. Fifteen (15) compounds were first time reported on *G. asiatica* fruit extracts using GC-MS analysis. From this it is evident phytochemicals isolated in the GC-MS have the tendency to cure many ailments (Srikanth *et al*., 2016).

Florence and her colleagues examined on the diagnostic features of the stems and leaves of the *G. asiatica* by making slices using a microtome and examined on photomicrographs. It depicts features such as anomocytic stomata, epidermal cells, glandular trichomes, phellem cells, calcium oxalate crystals, periderm cylinder and vascular (Florence *et al*., 2016).

6. Conclusion

G. asiatica is an essential and widely cultivated medicinal plant. It finds its use in many ayurvedic preparations such as folklore medicine. All parts of *G. asiatica* are useful in some or the other way both internally and externally. It has been reported to have many protective actions like anti-inflammatory, antioxidant, antineoplastic effect, nematocidal activity, larvicidal activity, nephroprotective efficacy, antibacterial, antifungal and antitumor activities. This shows that plant can be used for many ailments. Topically, it can be used in cosmetics as antidandruff agent which finds its applications in many shampoos as well as oils. This review provides information on the pharmacognostic studies carried out on the plant, phytochemical screening and emphasizes more on pharmacological profile with different parts and solvents which may help researches to acquire knowledge on the research being carried out.

Conflict of interest

The authors declare no conflict of interest relevant to this article.

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