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Lantana (*Lantana camara*): A medicinal plant having high therapeutic potentials – A comprehensive review

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Abstract

Lantana (*Lantana camara*) is an important medicinal plant belonging to family Verbenaceae that is known to have high therapeutic potentials because of immense biological activities owing to unique chemical composition. It is also famous as ornamental garden plant having approximately 150 pantropical species that are widely used in traditional medicines all around the globe. Lantana is found native to tropical and subtropical areas of America and upto some extent in Africa and Asia as well. This plant is commonly known as red sage or wild plant due to relatively higher biodiversity even under unfavorable environmental conditions. Lantana is known to have both, sexual and asexual system for reproduction. Essential oil of this plant has approximately 163 active compounds among which monoterpenes and sesquiterpenes are the most abundant chemical constituents. The β-caryophyllene, D-nerolidol, spathulenol and caryophllene oxides are some of the major components of its essential oil. Furthermore, essential oil of roots of *Lantana camara* contains shanzhside methyl ester, geniposide 8-epiloganin and lamiridoside. Moreover, flavonoids, baphtoquinones, iridoide glycosides, phenylpropanoid glycosides and oligosaccharides compounds have been reported in different parts of this plant. Lantana possesses strong anti-motility, anti-diabetic, anti-fungal, anti-filarial, analgesic, anti-inflammatory, anti-hemorrhoidal, anti-mutagenic, anti-motility, wound healing, anti-bacterial and anti-oxidant activities. Therefore, it is widely used in number of commercial products.

Key words: *Lantana camara*, ornamental plant, red sage, essential oil, monoterpenes, sesquiterpenes, anti-fungal, anti-diabatic activities

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1. Botany

1.1 Introduction

Lantana camara belongs to Verbenaceae family. *Lantana camara* is commonly known as lantana. It is famous and well known ornamental garden plant. The genus lantana consists of 150 pantropical species used as traditional medicines all around the world. Lantana is native to tropical and subtropical region of America. Some taxa of lantana plant are also found in Africa and tropical Asia. Now, it grows approximately in 50 different countries of the world. Lantana can readily hybridize with other lantana species. For example, *Lantana depressa* is hybridized plant of lantana. Most of hybridized lantana plants show florescence that changes with age and flower colors, but a few hybridize species is not stable at ambient conditions. Lantana is commonly known as wild or red sage due to higher biodiversity under unfavorable conditions. The red saga has higher growth rate than other species of lantana genus. Lantana has both sexual and asexual system of reproduction. It mostly grows at 2000m elevations in temperate, sub-tropical and tropical regions. The genus lantana contains many plants while *Lantana angolensis*, *Lantana achyranthifolia*, *Lantana camara* and *Lantana achyranthifolia* are well known plants of lantana. Lantana is known by different names in world, such as "red-sage", "wild-sage", "white-sage" in Caribbean, "tick berry" in South Africa and "big-sage" in Malaysia, "camara" in Brazil and "Wandelroeschen" in Germany. Lantana is also known by different names in many countries such as "lanakana", "lakana", "mikinolia hihiu" and "mikinolia kuku" in Hawaii and "bands", "phullaki", "tantbi nagaairi" and "putus" in India. Lantana is a hairy aromatic shrub, erect, gregarious and half climbing plant. Height of plant is mostly 1.0-1.4 m. The branches of lantana are rising all 4 sided along recurved prickles. Leaves length of lantana is about 1.5 inches wide and 3 inches long. The most common flower colors are lilac, orange, pink, yellow and white, but their color usually changes with the age. The fruits of lantana have a berry-like drupe, which changes from green to dark purple when

mature. Weather and distribution are two major factors that affect essential oil contents in lantana.

There are many other factors such as origin, genetic type, soil and nature of nutrients that affect the chemical constituents of lantana essential oil and also growth rate of leaves, flowers, weeds, stems and branches. The lantana contains significant amount of essential oil while the concentration of essential oil in flower and leaves is higher than other parts of the plant such as roots and stem. Methanolic and dichloromethane leaves extracts of lantana showed significant variation in composition of lantana essential oil. Throughout the year, germination of seeds is possible. The drained soils are found to be the best for proper growth of lantana. Lantana is the most important plant having high medicinal potential. It is also being used in natural and modern synthetic products. Lantana essential oil obtained from different parts shows great variation in chemical composition thereby exhibiting number of variations in biological activities. Literature reports showed that lantana exhibited strong anti-inflammatory, anti-proliferative, larvicidal, anti-oxidant, anti-cancer, anti-bacterial and anti-ulcerogenic activities.

1.2 History/Origin

The genus lantana was first described by Linnaeus in 1753. Lantana comes from the Latin words "lento" which means "to bend". Lantana is the genus of Verbenaceae family having 600 varieties currently present all over the world. Lantana is a native species of Caribbean islands, south and Central America but also has its occurrence in Brazil, Trinidad, Florida, Mexico and Jamaica. Some species of lantana were also whispered to initiate from India and Africa. It was reported that beginning of lantana was evident in tropical regions of the Americas, but now it is also found in many African countries including some dry regions. Now, lantana is extensively found in Uganda, Tanzania and Kenya and has been used as ornamental plant since 300 years. In the late 1600s, Dutch explorers introduced lantana into Brazil then in Netherlands and later explorers spread the seeds in various other countries like Europe and Great Britain. In Hawaii, lantana was grown as a garden flower but in no time it spread in Pacific, the islands of Australia and Southern Asia. In a parallel way, lantana was speedily increased by flora and fauna to the warmer regions of South Africa. The nurserymen commercialized and popularized many colorful forms of lantana in the 18^{th} and 19^{th} century.

1.3 Demography/Location

Lantana is present in many Pacific Islands like New Zealand, Australia, China, Thailand, Cambodia, Malaysia, Indonesia, Viet Nam and Philippines, Africa, Southern Europe, such as Spain and Portugal, the Middle East, tropical Asia and Atlantic areas. In India, it is found on different places like Mauritius and Rodrigues. Lantana can grow in a broad range of climatic conditions, including heat, salt, different soil types and humidity. It is comparatively fire tolerant and can rapidly establish itself in freshly burnt places of forest. The growth of lantana is limited in the high volcanic islands in the Pacific. Lantana excretes chemicals (allelopathy) which reduce the growth of surrounding plants by root elongation and inhibiting germination [1]. It has been reported that lantana has ability to take essential nutrients from neighboring plants and thus effect their growth. Therefore it is increasing trend to control the biodiversity of lantana. Lantana became a famous plant in the world due to its destructive nature and unique flavor that is quite different from several other tree plants. The ability of weeds to response rapidly to prevailing weather conditions is an important factor contributing to their invasiveness. The global statistics for the production of dried lantana is difficult to obtain and no exact amount has been recorded so far. It has been estimated that lantana was grown upto 160,000 hectares in Hawaii and 4 million hectares in Australia. America and India is the largest producer of lantana essential oil in the world. New Zealand and some African countries also produce significant amount of essential oil. Since last few years, annual demand of lantana woody products is increasing instead of essential oil of this plant due to its anti-microbial repellent potentials.

1.4 Botany, Morphology and Ecology

Lantana is known as wild sage having a sharp multi-stem. It normally attains the height of about 2m (6ft) with deciduous hedge plant. The shrub of this plant belongs to the class of *Magnoliopsida*, order *lamiales*, family *Verbenaceae* and genus *lantana*. Stems are square in shape and are found enclosed with rough hairs. Lantana exhibits powerful root system. The roots even after repetitive cuttings make new flush of shoots. Leaves are contradictory, simple, with long petioles, egg-shaped blades which are irregular and hirsute and have curved toothed boundaries. Lantana leaves exhibit a strong aroma. Its flowers are small, colorful and opaque in flat-topped clusters. The flowers of lantana experience specific color and are used as natural anthesis. These flowers show different colors like pink lavender, yellow, white, red and orange. The yellow flush of flowers provide visual prompt to pollinators. Berries of lantana have shown great diversion in color with growth. The lantana berries are mostly round, thick and two-seeded drupe having green colour. However, the berries of lantana are very lethal in nature. Seed germination of lantana is easy and quicker. The seeds of lantana are dispersed by different ways. However, various frugivorous bird's species and foxes are most common sources of lantana seeds from one place to another. Germination rate of fresh seed is normally low, but the germ-inability gets superior when the seeds pass during the digestive system of birds and animals.

Soil temperature and high light intensity stimulates the germination of seeds which means that reimbursement of forest areas, unfortunate burning and other disorder will help in spread of the weed. Seeds are capable of surviving the hottest fires. Lantana is widespread specie in world and

various distributions have a manifestation in different ecological zones. Lantana can grow in a broad range of climatic conditions, including heat, salt, different soil types and humidity. It is comparatively fire tolerant and can rapidly establish itself in freshly burnt places of forest. The growth of lantana is limited in the high volcanic islands in the Pacific. Sometime, it is not found in some islands due to insufficient water, low rainfall and/or coralline soils with poor water-holding capacities; and high incidence of tropical hurricanes and its low tolerance to saline soils. The species of lantana occur in wide-ranging habitat and climates. The open or unshaded regions including wastelands, rainforest edges, beachfronts and forests are most favorable soils for growth of lantana species. The species also blossom well in disturbed areas which includes railway tracks, canals and roadside. Anthropogenic activity additionally aggravates the rate and allows it to extend further. The major two ingredients for flourishing establishment are its enlargement under a variety of climatic conditions and no restriction on temperature.

2. Chemistry

Different parts of lantana have different colors and smell as the flowers of lantana have different colors and pungent smell. The lantana gives strange taste, when eaten. The barriers of lantana are toxic in nature and killed many children and animals in past. Therefore, barriers of lantana are less likely to be use in food manufacturing products. But it is commercially important due to its essential oil contents. Total 163 compounds were identified in lantana essential oil. It has been reported that essential oil isolated from different parts of lantana show slight variation in composition. Leave's essential oil of lantana showed 134 compounds, but 127 compounds were reported in the oil obtained from flowers. The monoterpenes and sesquiterpenes are most abundant compounds present in lantana essential oil. Caryophllene oxide, spathulenol, D-nerolidol and β-caryophyllene are major components of essential oil. Similarly, roots essential oil of lantana contains geniposide 8-epiloganin, shanzhside methyl ester and lamiridoside. Moreover, flavonoids, baphtoquinones, iridoide glycosides, phenylpropanoid glycosides and oligosaccharides compounds have been reported in different parts of this plant.

2.1 Chemical Composition

The lantana plant has a terpene-like leathery, sweaty and fatty odour. Lantana contains low amount of fat contents and gives low caloric value. Bisabolene derivatives with traces of monoterpenes, fatty acid and vitamin are known to have their existence in lantana plant. Similarly, mineral compounds such as potassium, calcium, phosphorous, iron, cupper and zinc are also present in leaves of lantana plant. Amount of mineral compounds and vitamins are very low in lantana. Therefore, lantana plant cannot be used as energy source. Moreover, all parts of lantana exhibited sufficient amount of essential oil. Essential oil yield of lantana is less than one percent and yield of essential oil vary with type of nutrient available and parts of plant. Lantana is also well-known for flavonoids and anti-oxidants. Lantana ash is a rich source of potassium and manganese. They become useful for growing coconut trees. A tea prepared from the leaves and flowers of lantana is good against different diseases like fever, influenza and stomach-ache.

2.2 Phytochemistry

Phytochemistry of medicinal plant and exploration of major component for production of natural medicines has been a matter of great interest for several decades. Phytochemistry of plant is strongly affected with the solvent used during extraction and different parts of plant [2-3]. The chemical composition of lantana essential oil varies with part of lantana such as stems, leaves, roots and branches. The essential oil composition of lantana leaves shows that the sesquiterpene, β-caryophyllene and caryophyllene oxide were major components while α-humulene, ar-curcumene, germacrene-D and bisabolene were the minor compounds [4]. It was found that lantana leaves extract of petroleum ether and water had the least biological properties. But leaves extracts of lantana with methanol and dichloromethane reported the maximum biological activity. Phytochemical study of dichloromethane leaves extracts of lantana indicated the presence of glycosides, terpenoids, alkaloid, saponins, flavonoids and reducing sugar but the steroids were found absent. But methanolic leaves extract of lantana alkaloids, terpenoids, steroids, saponins and flavonoids were present, but tannins, glycosides and reducing sugars were absent [3]. The lantana had shown the presence of fatty acids like stearoyl glucoside of ursolic acid and urs-12-en-3β-ol-28-oic acids were also isolated from leaves of lantana. The stem extract of lantana showed the presence of oleanonic acid and oleanolic acid [5-6].

3. Post-Harvest Technology

The best harvesting time for lantana is early in the morning. The harvesting in warmer climate becomes a cause of reduction of lantana essential oil. It has been reported that early harvesting gives better essential oil yield than other time of day. The dried and fresh leaves of lantana showed great controversy. Morning timing harvest of lantana showed greater chilling injury than noon harvest time. This effect was only observed in summer but not in winter season [7]. The fresh leaves of lantana essential oils show strange and complex behaviour than dried leaves of lantana. The harvesting temperature and time are major factors which effect yield of lantana essential oil. Different essential oil yield is observed, when lantana harvested at different times as well as different temperatures. Increase temperature can reduce the essential oil yield of lantana. Moreover, the essential oil yield was affected by harvesting time in a day. The especially volatile components of essential oil are mostly affected by temperatures.

The cuttings trade involves a variety of species, therefore the damage occurring during shipment is manifested in various symptoms, including leaf yellowing, abscission and browning. Low-temperature storage causes discoloration and subsequent decay of cuttings. The mostly morning-harvested cutting of lantana was used for large scale production of essential oil. Cut pieces of lantana were packed in perforated bags made of dense polyethylene and stored the bags in insulated cardboard boxes lined with polyethylene bubble-rap sheets [7]. Lantana leaves can be stored for a year, if kept in closed jars away from heat and light. Freeze storage is another preferred method that is used to store lantana leaves for relatively long period of time. But sometimes, blackening of leaves takes place. It is also reported that lantana leaves can be preserved in refrigerator. Bacterial growth in lantana leaves preservation is another problem. They destroy natural flavor of green leaves of lantana. Therefore, high security must be ensured in products receiving, handling, processing and storing.

4. Processing

Lantana like various other plants is used in different processes in several different ways. In addition to fresh leaves and other parts of lantana plant such as flowers and roots, weeds can also be used to extract essential oils. Plant leaves can be stored or frozen, with or without oils, to be used for long time beyond its shelf life. Most common method that is used to preserve lantana is to store in salt. Leaves of lantana plant should be stored in sheet of paper or dark place to prevent oxidation, 1evapouration and discoloration because they changes their chemical nature as well as physical properties when exposed to sunlight. Steam/hydro-distillation is a common method used to extract oil from various parts of lantana. The plant stuff was sited into a still. The warmth from the steam is actually a driving force to extract essential oil from globules of plant. The plant was to burst and volatile components of essential oil were evaporated. The essential oil vapor or steam, then pass through cooled water pipe. The vapors of essential oil are condensed back to liquids. At this point, the essential oil separates from water and floats to top due to lighter density.

Essential oil of lantana contains number of volatile compounds. Therefore, essential oil must be stored in black color bottle in scale production. Temperature must be below 50ºC for preservation of lantana essential oil. The direct sunlight interaction must be avoided for dryness of lantana leaves. The leaves lost a lot of essential oil contents and might destroy many volatile compounds. These dried leaves were pulverized, weighed and stored under shades at room temperature. The powdered plant material was percolated sequentially for four days with different volume of methanol, chloroform and water respectively. Filtration of extract was done and dry extract was obtained by rotary evaporation. The temperature of 40°C must be maintained until lowest volume of extract remained which was then dried at room temperature. The dry extracts were kept at a temperature ranging from 15°C to 35ºC for minimum biodegradation of lantana essential oil.

5. Value Addition

Lantana is most commonly used in forage, fodder and animal feed. Lantana shows limited applications in food inhaling products, because there are many lethal components found in different parts of lantana that significantly reduces its biological applications. The flowers and leaves essential oil show many applications in drugs and perfumes industries [8]. It is reported that lantana has long been used as honey plant in many regions of the world [9]. Lantana is also showing many applications in bio-fluids and fuel woods. Lantana essential oil of different parts has wide range of applications in medicine and pharmaceutical industries. Different parts of lantana especially barriers show poisonous effects to mammals in case of maximum inhaling. However, lower concentration of lantana barriers extract does not affect organismic system of mammals. Lantana essential oil has strong aroma and wide range of applications in pesticide products. The pesticides products of lantana essential oil showed great property to kill insects and pests thereby enhancing the crop yield of plant.

6. Uses

Leaves and green fruits of lantana possess enough potential to produce photosensitization in animals and neurocirculatory collapse. Lantana is grown as hedge plant. Many herbs and spices contribute significantly to health despite the amount of consumption as they are full of anti-oxidant and certain mineral compounds. It is evident by excessive usage in various countries that lantana is an imperatively honey plant. The fruit of lantana exhibit different colors during different stages of maturity. Barriers of lantana should not be used as food as they have certain toxic compounds that are harmful for human health. They show dangerous effects on animals as well as on human beings. Anti-oxidant compounds of lantana essential oils have enough potential to neutralize free radicals, therefore prevent free radical mediated oxidative damage in the cell. A number of minor uses of lantana include usage of seeds as a source of food for lambs. Leaves extracts of lantana showed tremendous applications as anti-fungal and anti-bacterial agent.

6.1 General Uses

The essential oil of lantana are classified and considered as good economic material in the world. The essential oil obtained from flowers and leaves of lantana can be used in perfumes and pharmaceutical industry. But mostly its essential oil is used in making insect repellents for daily usage. The extract of plant and essential oil are also used in herbal medicines for the treatment of various diseases. Lantana leaves and flower's essential oils are being used to kill air suspended small microbes to get free polluted air for cleaner breathing since last few decades. Traditionally, lantana leaves are boiled and used for pain of the body and treatment of swellings. The barks of lantana

are biting and worn as a lotion in cutiginous eruptions. Alkaloidal fractions are obtained from lantana leave's essential oil that are used to accelerate deep respiration and lower blood pressure and stimulate intestinal movements in experimental animals. For example, in Ecuador, leaves are generally ingested to treat stomach disorders. Leaves extracts have strong insecticidal and anti-microbial potentials. Therefore, in third world countries, lantana leaves wrapped around potato to prevent from *Phthorimaea operculella*. In the African and American continents, lantana leaves are frequently used for treatment of rheumatism, stomachache, scratching, wound healing, biliary fever, toothache, bronquitis and as anti-septic [10]. Moreover, roots of lantana essential oils are used for treatment of rashes and malaria.

Lantana has useful hedge and proves to be an excellent source for preparation of crops as it layers the ground with well leaves mulch. The stalks of lantana are used as raw material for paper pulp and have wide range of applications for wrapping, printing and writing papers. It improves the fertility of rocky soils and serves to retain humus in deforested areas to checks the soil erosion. It can serve to nurse the parasitic sandalwood seedlings and in the Pacific islands has been used as a support material for yam vines. Lantana twigs and leaves are often used in India as green mulch. During last few years, research has been conducted to utilize the biomass for development of furniture products, baskets, compost, mulch, drugs and other biologically active agents [11]. Efficient heat transfer fluids have become essential support for the high-tech machines for their efficient operations. The thermal conductivity of Lantana weeds biofluids is found to be superior as compare to traditionally available fluids and nanofluids or nanoparticles based fluids. Weeds of Lantana can be used as coolants for heat transfer industries leading to an advantageous reduction in the overall consumption of water that is used in various industries. Thermal conductivity enhancement in lantana is much higher than *Phthorimaea hysterophorus*. These heat transfer fluids have diverse applications in automobile industry, nuclear reactors and microelectronics as coolants. Lantana straws when mixed with dung are used for production of biogas and its twigs are used as fuel. There is some evidence, although conflicting in nature that extracts from lantana may have value as biocides [12].

6.2 Pharmacological Uses

All the parts of lantana are traditionally used for treatment of several ailments. Leaves are mostly used as anti-septic, anti-tumor and anti-microbial agents whereas roots are used in the treatment of malaria, rheumatism and skin rashes. In Ghana, infusion can be used for bronchitis and the roots powdered in milk can be used for stomachache in children. In Central and South America, the leaves are used into a poultice to treat sores, chicken pox, measles, fevers, cold, rheumatisms and asthma. It is also used in high blood pressure contromentt. In Asian countries, leaves are used to treat cuts, rheumatisms, ulcers and as a vermifuge. There are also reports that lantana compounds can be applied as potential weed killers. The knowledge of old medicines and medicinal plants can be used to help in the innovation of newer and cheaper drugs. Lantana plant is well known to cure several diseases and used in various folk medicinal preparations. In last a few decades, researchers and scientists in various regions all over the world studied the chemical composition of whole plant of lantana. These investigations recognized that lantana has therapeutic potential in modern medicines and found possible applications for drug discovery.

Tuberculosis (TB) has shown global public health problem in many developing countries. It is estimated that more than one-third of the world's population (about 2 billion) is infected with the bacterium that causes tuberculosis. Approximately, nine million people are affected with the disease. Lantana is one of the plants that claimed to treat tuberculosis. Lantana leaves extract is used to treat various stomach diseases. Lantana leaves can be used for relief from headache, toothache and pains due to insect bites. The leaves of lantana are commonly used in snake bite areas to get instant relief rapidly. This is mostly practiced by the tribal people worldwide. Lantana leaves' tea gives relief from fever, flu, colds, cough and indigestion. The fresh leaves of Lantana give relief from joint pain, wounds, sprains and similar muscle and bones related problems Lantana is used to cure malaria, cough, influenza, mumps and gonorrhea. Decoction of dried flowers is used for curing pulmonary tuberculosis and hemoptysis. Lantana leaves are used commonly for generating a cooling effect to the body and skin. The above mentioned medicinal uses of lantana can be practiced as a home remedy only after proper consultation with the doctor.

Since the berries of lantana are known as toxic compound, it becomes essential to avoid the consumption of fruits of this plant. In India, much research work has been done to explore the chemical constituents of extract from the leaves, roots, seeds, stems and flowers of lantana. Lantanoside, linarosid and camarinic acid are isolated and investigated as potential nematocides. The leaves and roots essential oil of lantana demonstrated to have many biological activities such as anthelminthic, anti-protozoal, anti-ulcerogenic insecticidal, anti-inflammatory, anti-bacterial and anti-pyretic. The flavonoids rich fraction had an effect against gastric adenocarcinoma melanoma cell and human uterine carcinoma. Lantana essential oil are being used in medicines for the treatment of various human diseases such as skin itches, leprosy, cancer, chicken pox, measles, asthma, ulcers, tumors, high blood pressure, tetanus and rheumatism etc. Extracts of lantana leaves have been reported against anti-fungal, anti-bacterial, nematicidal, termicidal, anthelmintic, anti-cancer and anti-proliferative activities.

6.2.1 Anti-Motility Activity

The lantana leaves powder was used to test anti-motility activity against mice. The charcoal meal test was to determine the anti-motility activity. Neostigmine was used as a promotility agent that determines anti-motility effects. Anti-motility activity was dependent on dose concentration which was injected to mice. Like a dose of 1g/kg was completely inhibited neostigmine, while 500mg/kg dose of neostigmine was found to control only 26.46%. At upper doses, such as 500 and 1000 mg/kg, the lethal output was almost totally stopped. But lower dose concentration like 125 and 250 mg/kg showed significant control of treated mice. The flavonoids and triterpenes were major components of lantana leaves essential oil. The flavonoids and triterpenes might be responsible for anti-motility activity [13].

6.2.2 Anti-Diabetic Activity

The 3β-D-glucopyranosyl-4′-octadecanoate, urs-12-en-3β-ol-28-oic acid and stearoyl glucoside of ursolic acid and other compounds extracted from the lantana leaves essential oil and their anti-diabetic activity was tested on rats. The results showed that urs-12-en-3β-ol-28-oic acid, stearoyl glucoside of ursolic acid and 3β-D-glucopyranosyl-4′-octadecanoate compounds showed significant reduction in blood glucose level.

6.2.3 Anti-Fungal Activity

Lantana essential oil is known to have various medicinal uses in our daily life, but cyclic hexadepsipeptide, pentacyclic triterpenoid, b-caryophyllene and caryophyllene oxide compounds showed strong anti-fungal activity. To check the anti-fungal activity of lantana, essential oil was tested against different species including *Aspergillus Niger, Penicillium Digitatum, Aspergillus Nidulans, Cladosporium Herbarium* and *Rhizopusnigricans* by disc diffusion method. The essential oils of the lantana leaves showed strong anti-fungal activity against all fungal strains. Moreover, they reported that organic volatile compounds like cyclic hexadepsipeptide compound might be responsible for their anti-fungal activity. In another study, it was reported that lantana leaves essential oil showed anti-fungal activity against *Alternaria sp.* The anti-fungal activity of lantana essential oils was determined at different concentrations (10 mg/ml, 15 mg/ml and 20 mg/ml). They observed that essential oil showed anti-fungal activity at concentration dependent manner and highest anti-fungal activity was observed at 20 mg/ml. Furthermore, they reported that pentacyclic triterpenoid compound might be responsible for anti-fungal activity. Anti-fungal activity of lantana leaves essential oil was tested against *Sitophilus granarius* adults. Different dose concentrations 1, 5, 10, 50, 100 and 500 mg/l were used to inject to *Sitophilus granarius* to determine anti-fungal activity at different temperature. There results showed that temperature of *Sitophilus granarius* increased with increasing the concentration of essential oil. The studied oil was proficient only during 2 weeks for all dosage, ensuring the abolition of 70-100%. The β-caryophyllene and caryophyllene oxide compounds might be responsible for anti-fungal activity.

6.2.4 Anti-Filarial Activity

The stem extract was used to check anti-filarial activity of lantana. About 43.05% of adult *Brugia malayi* parasites were killed, when stem crude extract at 1 g/kg concentration was used for five days. The extraordinary anti-filarial activity of lantana stem essential oil was observed for adult *Brugia malayi*. About 80% of the adult worms were killed, when same dose concentration (i.e. 1 g/kg) was used in gerbil method. Oleanonic acid and oleanolic acid might be responsible for anti-filarial activity.

6.2.5 Analgesic Activity

Aqueous extract of lantana was used to determine analgesic activity by Eddy's hot plate method. Analgesic activity of lantana essential oil was confirmed in different rat's strains. In hot plate method, each rat was placed individually on the hotplate at 56 ±10°C temperature and the time for thrashing of the paws was recorded before and after 30 minutes. The oral administration of the aqueous extracts of lantana 300mg/kg and 500mg/kg were showed excellent analgesic activity.

6.2.6 Anti-Inflammatory Activity

The carrageenan induced paw oedema test was used to check anti-inflammatory activity of lantana extract. Hind paw inflammation was expressed in mm, considering as a variations. The variations were tested in rat**.** At the end, results had shown that lantana exhibited good ability of anti-inflammation. Another study showed that aqueous leaves extract of lantana showed anti-inflammatory activity in albino rats. Different extract doses were used, but dose extract of 500 mg/kg body mass appreciably reduced paw volume in carrageenan induced paw oedema test. Lantana leaves extracts showed promising analgesic and anti-inflammatory potentials.

6.2.7 Anti-Hemorrhoidal Activity

Anti-hemorrhoidal activity was carried out on patients using capsules prepared from dry aqueous extract of lantana 500 mg/kg and lactose 100 mg/kg. The capsules had ingested to 20 patients suffering from hemorrhoids diseases. The optimum concentrations (500 mg/kg) of lantana plant showed anti-hemorrhoidal potentials.

6.2.8 Anti-Mutagenic Activity

The β-dimethylacryloyloxy lantanolic acid and β-acetoxylantic acid were present in leaves and roots essential oil of lantana. Both compounds showed significant anti-mutagenic potentials in mice.

6.2.9 Anti-Motility Activity

Methanol leaves extract of lantana showed strong anti-motility activity. Different mice strains were used to determine anti-motility activity of lantana leaves extract. Lantana leaves contained many components such as tannins, triterpenes, saponins, alkaloids, flavonoids and sterols that are mainly responsible for this activity. The charcoal meal

test was used to explain intestinal motility in mice. Intra peritoneal administration of 125 and 250 mg/kg body weight the extracts extensively reduced the fecal productivity in castor oil induced diarrhoea in mice.

6.2.10 Wound Healing Activity

The lanatana leaves extract was used to determine wound healing activity in rats. The animals were separated into two classes. Each class contained 12 animals. The test class animals had treated with aqueous extract of lantana, especially 100 mg/kg/day was used and the control class animals were gone untreated. Wound healing activity was calculated by biochemical parameters and influential morphological parameters. The results showed that 98% wound healing was observed, when rats were treated with 100 mg/kg /day dose. The triterpenoids and flavonoids compounds of lantana extract might be responsible for wound healing activity in rats.

6.2.11 Anti-Bacterial Activity

The lantana crude extract was tested against 3 different strains; *Klebsiella pneumoniae Staphylococcus aureus* and *Escherichia coli* to determine anti-bacterial activity. The triterpenes contents of lantana were responsible for anti-microbial activity. Anti-bacterial activity of methanol extract of various parts of lantana was determined against 10 bacteria strains. The broth micro dilution and disk diffusion assays were used to determine anti-bacterial activity. Leaves extract of lantana showed higher anti-bacterial activity against gram positive *Bacillus cereus* than gram negative *Salmonella typhi*. Similarly, in another report aqueous leaves extract of lantana was tested against five different bacterial strains including *Escherichia coli, Micrococcus luteus, Staphylococcus aureus, Bacillus cereus* and *Pseudomonas aeruginosa.* The results of disc diffusion assay showed that aqueous extract showed good activity against all the test bacterial strains. Overall, aqueous extracts showed highest anti-bacterial activity against *Micrococcus luteus*. Sesquiterpene hydrocarbons and oxygenated monoterperpenes compounds might be accountable for anti-bacterial activity. The silver nanoparticles (AgNPs) of lantana leaves showed good anti-bacterial against different bacterial strains.

6.2.12 Anti-Oxidant Activity

The total phenolic contents are major compounds that showed great biological activities especially anti-oxidant activity. Anti-oxidant activity of lantana essential oil was tested by three different methods including xanthine oxidase inhibition, free radical scavenging activity and Griess method. Different parts of lantana including stems, leaves, roots and fruits were used for determination of total phenolic contents. The various ppm stock solution of each part of plant was used for determination of total phenolic contents by Griess method, free radical scavenging activity and xanthine oxidase inhibition. The method's results showed that when phenolic contents were in direct relation with values of anti-oxidant property of plant. The results of all three methods showed that leaves of lantana had highest anti-oxidant activity due to higher total phenolic contents than other parts of lantana. Leaves> stems>roots>fruits>flowers order of anti-oxidant activity of different parts of lantana was observed. Lantana leaves extracts exhibited many compounds such as phenolic compounds, flavonoids and tannins.

7. Summary

Lantana (*Lantana camara*) is an ornamental garden plant that belongs to the Verbenaceae family. It is widely growing plant throughout the world and used for thousands of years for food flavoring, essential oil production and in traditional system of medicines. It contains sesquiterpene, β-caryophyllene, caryophyllene oxide, germacrene-D and bisabolene contents. The extent of each of these chemical constituents varies depending on the type of species or cultivars as well as cultivation conditions such as soil type, weather, irrigation, pruning and other horticultural practices. Lantana essential oil shows various therapeutic properties. Barriers of lantana essential oil have been reported to be toxic for humans and animals. Several industrial applications such as foods, cosmetics and pharmaceutical products are most common products of lantana essential oil. The plant growth has been recognized as a recent thrust area for growth of other plants due to biodiversity. In recent times, there has been increased attention toward the study of conventional plants for pharmaceutical applications because of its small toxicity and economic capability. More uses and applications of lantana by-products are continuously being added. Further research on maximizing yield per hectares and optimum preservation and oil extraction methods are needed, particularly in the developing world. Traditionally harvesting and postharvest processing methods are commonly used for different parts of plant especially leaves and flowers of lantana.

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