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Lantana camara L.: Transforming an Invasive Species into a Multifunctional Green Resource

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ABSTRACT
Invasive alien species are not considered a healthy component for the natural biodiversity of any invaded area. *Lantana camara* L. (Family-Verbenaceae); an ornamental shrub and native of America, is included in the category of Global invasive species. İts negative socio-ecological impacts have been observed in many parts of the world. However, there is still a need for providing sustainable solutions to curb the negative impact of Lantana, and therefore, the present review is undertaken to know about the currently available eco-friendly alternatives for better management of Lantana weed. For this purpose, an extensive literature search was carried out using various keywords related to the objective of the study on the online available scientific databases, for example, Scopus, PubMed, Springer, Science Direct, Google Scholar, Research Gate, etc. The relevant information thus retrieved is presented in this review article. This paper highlights the eco-friendly and economic utility of Lantana weed as a prospective sustainable green bioresource. Lantana has shown potential in form of production of bioethanol & biogas, bio-briquettes, particle boards, natural eco-friendly dyes from flowers, green synthesis of nanoparticles, green manure contributing to soil fertility, raw material for paper manufacture, phytoremediation of heavy metal polluted sites, biofumigant against pests of stored grains, biocontrol agent against biological organisms and as a bioherbicide etc. in many of the studies carried out in different regions of the world. Beyond industrial uses, local communities are also utilizing Lantana bushes for making sturdy furniture, toys, bee-keeping boxes, fish-catchers, hangers, domestic articles, etc. These diverse applications highlight its potential to transform from an ecological threat into a valuable green resource. Thus, the menace of this invasive weed could be better managed by leveraging this potential, which can not only support sustainable development goals but also offer additional income-generating opportunities for local communities.

KEYWORDS
Biofuel, phytoremediation, nanoparticles, furniture, bioherbicide, bioimaging

INTRODUCTION

Invasion of any biological species to a place apart from its natural habitat may have deleterious effects on various components of the ecosystem of that region. Invasive species are well known to out-compete native species by disrupting their regeneration and negatively affecting the biodiversity of invaded regions. Besides habitat destruction, invasive species also pose threats to the economy and human beings in myriad ways. Therefore, invasive alien species are not considered good for the native biodiversity[1,2].

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Lantana camara L. (Family-Verbenaceae); hereafter referred to as Lantana, is considered one of the most noxious weeds and a globally invasive shrub of the world[3]. It is commonly known as Wild Sage, Red Sage, Large Leaf Lantana, etc. Lantana is a highly variable perennial plant species tolerant of growing in diverse habitats with varying environments like wastelands, rainforest edges, beachfronts, dry forests, agricultural lands, pastures, and other anthropogenically disturbed regions[4]. It is a scrambling shrub reaching up to 4 m height, having a four-angled stem with simple and opposite decussate leaves, a cylindric spiked inflorescence with multicolor zygomorphic flowers developing into fleshy purplish-black color berries[5].

Its high adaptability to survive in drought conditions and showing resistance to browsing due to high tannin content, autocompatibility, pollination by different insects, high seed output, etc., are some of the major reasons for its global invasion. Crossing the boundaries of its native range of Central and Northern South America and the Caribbean Islands, Lantana has invaded many tropical and subtropical countries, mostly as an ornamental or hedge plant, and has reached more than approximately 60 countries or island groups between 35°N and 35°S. Its presence is also observed in protected areas such as in 12 National Parks of Java, Indonesia[6]. Lantana was introduced as an ornamental plant in India in the Calcutta Botanical Garden in 1809. Since then, it has spread to most parts of the country except a few regions, and a well-designed management plan is required to control this invasive species[7].

Being allelopathic, Lantana has affected native biodiversity of invaded regions, declined soil fertility, and altered ecosystem processes[8,9]. It has been shown to affect forage availability for livestock, reduction in crop yields, and native medicinal plant species with a profound impact on the livelihood of local people in Uganda, West Africa. Not only this, Lantana also exhibits several other negative socio-ecological impacts such as on tourism, aesthetics of a landscape, management stress on local communities etc.[10]. Among the all-negative impact reports of Lantana in non-native regions, a recent study by Mukherjee *et al.*[11] have demonstrated positive role of Lantana for conservation and maintenance of btterfly abundance in Purulia, West Bengal, India.

Effective management of invasive species requires a holistic strategy to eradicate the menace as well as the appropriate utilization of biomass. An integrative management strategy should be applied in order to combat with Lantana menace, which includes mechanical, biological, chemical, cultural, ecological, and economic approaches depending upon the locality and other variable factors. There are many studies and practices that exhibit the eco-friendly potential of Lantana in view of a resource-utilization perspective. The present article aims to explore the potential of Lanatna as a green bioresource for its better management in invaded areas while contributing to sustainable development.

Lantana: Prospects as a green bioresource: The ecological and economic benefits associated with a plant species can pave the way for its sustainable and value-added utilization across various sectors[12]. Lantana is among the plant species with a wide range of beneficial applications, such as bioenergy production, environmental remediation, and sustainable material development (Fig. 1). These are being discussed briefly as follows:

Biofuel: Biofuel is the demand in the 21st century. For this purpose, the plant kingdom and microbial world are being explored by scientists all over the world, and Lantana is one of the plant species that has shown the potential to produce biofuel. As Lantana contains 61.1% (w/w) holocellulose, it could be used as a cheap feedstock for bioethanol production. Dry stem wood pieces of Lantana have been shown to produce bioethanol after hydrolysis and fermentation by thermotolerant yeast[13]. Kuhad *et al.*[14] have shown the synthesis of bioethanol from Lantana after fermentation with yeast and *Pichia stipitis*. Production of biogas has also been observed from its biomass[15].

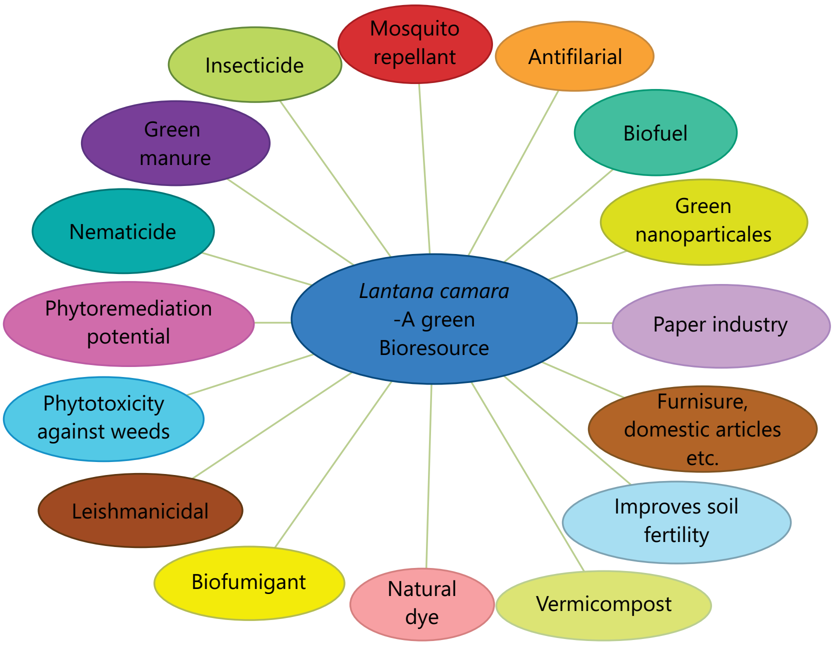

Fig. 1: Eco-friendly uses of *Lantana camara*

Lantana biomass is one of the most suitable, highly dense feedstocks for solid biofuels, having a low ash content (1.2%), low sulfur content (0.13%), low nitrogen content (1.04%), and a high calorific value (19.51 MJ/kg). Due to this, it could be easily utilized for manufacturing non-woody briquettes and help in the creation of a circular economy[16]. The eco-friendly briquettes possess promising fuel characteristics, which make them an environmentally friendly and efficient alternative for decentralized energy production, contributing to sustainable biomass utilization and rural energy solutions[17]. Recently, Bisen *et al.*[18] have shown the production of good-quality bio-briquettes from various proportions of Lantana biomass, along with cow dung and poultry feed, as binders. These briquettes could be further used for the production of biofuel and provide a sustainable solution for the effective management of Lantana.

Green nanoparticles: Nowadays, nanoparticles are the focus of research around the globe, having wide applicability in the fields of energy, environment, medicine, etc. In this regard, green synthesis of nanoparticles is an eco-friendly approach better than other physical and chemical methods. Various parts of Lantana have been utilized to synthesize therapeutic nanoparticles by scientists world over[19-21].

Mavukkandy *et al.*[22] have prepared platinum nanoparticles from leaves of Lantana. Nanogold particles have been prepared from flowers of Lantana[23]. Shriniwas and Subhash[24] used terpene-rich extract from leaves of Lantana to synthesize silver nanoparticles. These silver nanoparticles have shown antioxidant potential in the Dot blot rapid screening method and significant antibacterial activity against gram-positive *Staphylococcus aureus* as well as gram-negative bacteria *Escherichia coli* and *Pseudomonas aeruginosa* in agar well diffusion method. A dose-dependent cytotoxicity of the silver nanoparticles on Brine Shrimp *Artemia salina* napulii was also demonstrated.

Aritonang *et al.*[25] prepared silver nanoparticles from aqueous extract of its leaves, exhibiting significant antibacterial potential against *S. aureus* and *E. coli*. Recently, the silver nanoparticles developed from its leaves have shown anticancer efficacy against the A549 cell line of lung cancer (IC_{50} = 49.52 g/mL) and an IC_{50} of 46.67 g/mL against breast cancer (MCF7) cell line[26]. Lu *et al.*[27] highlighted potential role of silver nanoparticles developed from Lantana leaves for production of biodegradable biofilms. Recently, Kemala *et al.*[28] have developed the smallest silver nanoparticle (44 nm) from aqueous extract of Lantana leaves; the plant which was grown in extreme geothermal environment. The silver nanoparticle demonstrated antibacterial activity against Gram-positive bacteria *S. aureus* and *E. coli* but very less anti-fungal effect against *Candida albicans*.

Similarly, aqueous broth of roots of Lantana has been utilized to prepare gold nanoparticles by Ramkumar *et al.*[29]. These gold nanoparticles demonstrated antioxidant potential in 1,1-diphenyl-2-picrylhydrazyl (DPPH) free radical scavenging assay and cytotoxic potential on human breast cancer cells (MDA-MB-231) and on Vero cell lines. Thus, roots of Lantana could be a potential source of therapeutic gold nanoparticles against cancer and could be a source of additional income for countries engaged in its management through uprooting.

Copper nanoparticles synthesized using aqueous extract of leaves of Lantana by green bio-reduction method have shown 100% larval mortality of *Anopheles multicolor* mosquito vector at a very low concentration of 20 ppm[30]. This further emphasizes importance of nanoparticles over crude plant extracts. Recently, Swamy *et al.*[31] have prepared zinc oxide nanoparticles from flowers of Lantana for the first time by combustion method. These nanoparticles have shown strong anti-inflammatory activity against Phospholipase A2 with minimum inhibitory concentration of 41 µg/mL. Leaves of Lantana were also used to synthesize Yttrium oxide nanoparticles demonstrating antibacterial and anticancer properties[32].

Phytoremediation: Plants are also utilized to remove soil and water pollution through their heavy metal uptake capacity. Phytoremediation capacity of several plants including Lantana is reported in various scientific studies[33]. Lantana has shown the potential of phytoextraction of heavy metals such as Cu, Zn, Cr, and Mn from fly ash amended soil without any symptoms of toxicity in its morphology[34]. It also possesses high bioaccumulation and low translocation capacity of metal contaminants, which are dumped in the municipal solid wastes[35]. Lead uptake capacity of Lantana plants is increased by two to three times after the addition of Earthworms to the soil as shown in a study by Jusselme *et al.*[36]. Recent studies have shown Lantana plants to be a potential Cadmium (Cd) hyperaccumulator. It effectively tolerates high Cd concentration and co-ordinate photosynthesis along with reactive oxygen species scavenging and could be utilized for the amelioration of Cd-polluted soils[37].

Lantana is being utilized as an adsorbent of metals in wastewater for example Cr (VI) was adsorbed by activated carbon prepared from Lantana stem with an adsorption capacity of 26.25 mg/g[38] has also exhibited a potential role as an adsorbent of phenol from aqueous solutions[39]. Negi *et al.*[40] have shown biosorbent role of leaves of Lantana in removing Pb (II) ions from water. Biochar prepared from Lantana has also shown effective removal of Cu (II) from aqueous solutions indicating its potential role in removing heavy metals from wastewater[41]. Recently, Hassen *et al.*[42] developed biocarbon from leaves and seeds of Lantana which have shown removal of heavy metals, namely, Cd, Pb and Zn from floriculture wastewater in the Lake Ziway, Ethiopia. Thus, Lantana shows strong potential for conversion into biocarbon, offering a sustainable and economically viable approach to heavy metal remediation in industrial wastewater treatment.

Soil fertility: Lantana survives in conditions of drought and even on poor soils. It could be also utilized as a green manure as evident in many scientific studies[43]. Sharma and Raghubanshi[44] have observed that the Lantana litter is low in lignin content but high in Nitrogen (N) and a favorable microclimate beneath Lantana canopy favored faster decomposition and release of N by significantly altering soil N availability, N-mineralization, and total soil N. Due to this, Lantana canopy favors its growth cover by increasing the nutrients beneath its canopy. Fan *et al.*[45] studied soil samples underneath, on the edge, and 2-5 m out from Lantana plants and found that soil underneath the Lantana canopy had significantly higher pH, total N & Phosphorus (P), available N & P, with higher soil respiration, enzyme activities and microbial biomass.

Lantana has been shown to improve soil fertility, effective utilization of carbon substrates and thus, it could also improve soil quality for other plant species. A study on effect of Lantana on soil ecosystem in Nairobi National Park, Kenya has revealed its soil nutrient improving capacity as soils of Lantana invaded sites were rich in calcium, magnesium and potassium levels indicating the possible cause of its outcompeting potential than native ones[46]. Decmposed leaf litter of Lantana has shown to improve soil quality by improving soil enzymes, organic matter, NPK status and microbial richness[47]. A good quality of vermicompost could be prepared from leaf litter of Lantana and it could be also utilized as an organic fertilizer by vermicomposting[48,49]. Lantana has also shown to be a good food for microbes to produce methane gas[50].

Biocontrol agent: Allelopathic effects of invasive species could be very well utilized for biocontrol of some biological organisms. For example, aqueous lechate (3% w/v) of Lantana twigs has demonstrated allelopathic effect to the growth of *Eichhornia crassipes* (water hyacinth) and killed it after 21 days under the experimental conditions. Insufficient production of chlorophyll leading to chlorosis, necrotic patches and folding of the leaves and decreased growth were all observed in water hyacinth, along with signs of decomposing root pockets, blackening of root tips, shrinking of root hairs, and damaging roots[51]. The mechanism behind high toxicity after foliar spray of Lantana leaf extract to *E. crassipes* is suggested as oxidative stress[52]. Therefore, commercial application of Lantana could be done to control Water hyacinth plants on a large scale.

Phytotoxic activity of its essential oil has also been demonstrated against some common weeds *Amaranthus hybridus* and *Portulaca oleracea* by inhibiting germination and seedling growth[53]. Cold and hot aqueous extracts of leaves of Lantana effectively inhibited germination process of *Phalaris minor* and *Sorghum bicolor*[54]. This suggests that Lantana could also be utilized as a potential bioherbicide for control of weeds.

Lantana is recommended as a potent biofumigant against stored grain and household insect pests. Essential oil (0.5% v/w) isolated from leaves of Lantana has demonstrated 100% mortality rate against adults of maize grain weevil, *Sitophilus zeamais*[55]. Zoubiri and Baaliouamer[56] have also demonstrated adulticidal effect of essential oil against *Sitophilus granarius* which is an important stored product Beetle usually observed in the grain storage facilities. Rajashekar *et al.*[57] found acetylcholinesterase inhibitor activity of a coumaran isolated from leaves of Lantana against housefly, nervous tissue (ganglion) and the whole insect homogenate of stored grain insect. A significant fumigant and contact toxicity against the three most prevalent grain storage pests, namely, Rust red flour beetle, *Tribolium castaneum* Herbst, Rice weevil, *Sitophilus oryzae* L., and Adzuki bean weevil, *Callosobruchus chinensis* Fab. was demonstrated by methanolic extract of Lantana leaves[58]. Thus, a powerful biofumigant for pest management might be developed from Lantana plants.

Nematicidal action: Begum *et al.*[59] have reported presence of nematicidal compounds lantanoside, linaroside and camarinic acid against the root knot nematode *Meloidogyne incognita* in aerial parts of Lantana. Lantanilic acid, camaric acid and oleanolic acid isolated from the methanolic extract of the aerial parts of Lantana have also exhibited 98, 95 and 70% mortality against *M. incognita*, respectively at a concentration of 0.5 percent[60]. The nematode *M. incognita* was also used to assess the nematoidal activity of pentacyclic triterpneoids that were extracted from the aerial portions of Lantana. After 24 hrs, compounds lantanolic acid, lantoic acid and pomolic acid have shown 100% nematode death at a concentration of 1 mg/mL. After 48 hrs, compounds camarin, camarinin, lantacin, and ursolic acid also demonstrated 100% death of nematodes at the same dose[61]. Begum *et al.*[62] isolated triterpenoids from aerial parts of Lantana and observed that the most effective triterpene against the nematode *M. incognita* was Oleanonic acid which has shown 80% mortality after 72 hrs at 0.0625% concentration quite comparable to standard drug furadan. Recently, Abdul Ghafoor *et al.*[63] have shown 91% mortality of the root-knot nematode *M. incognita* by a pentacyclic triterpenoid, namely, 3-oxo-12α-hydroxyolean-22β-[β,β-dimethylacryloyloxy]-13β-28-olide isolated from Lantana roots at 0.125% concentration. Thus, the nematicidal property of Lantana could be utilized in agriculture fields to deter the side effects of synthetic nematicides.

Repellant/insecticide: Role of Lantana as insecticide and mosquito repellent is well known. *Lantana camara* is traditionally burnt to act as a mosquito-repellant plant on Rusinga Island, and in Rambira, western Kenya. In an experimental hut within a screenwalled greenhouse, Lantana has shown repellent activity against malaria vector *Anopheles gambiae*[64]. Flower extract of Lantana in coconut oil has exhibited 94.5% protection from *Aedes albopictus* and *Aedes aegypti* in human volunteers[65]. Kumar and Maneemegalai[66] have demonstrated larvicidal potential of methanol and ethanol extract of leaves and flowers of Lantana against three and four instar larvae of mosquito species *A. aegypti* and *Culex quinquefasciatus*. Kumar *et al.*[67] have demonstrated significant larvicidal activity (LC_{50} of 30.71 ppm) of hexane extract of Lantana leaves against fourth instar larva of *A. aegypti*, an Indian strain of Dengue fever mosquito collected from Delhi and surrounding areas.

Essential oil from the leaves of Lantana has shown to possess adulticidal activity against different mosquito species namely *A. aegypti*, *C. quinquefasciatus*, *Anopheles culicifacies, Anopheles fluvialitis* and *Anopheles stephensi*[68]. Essential oil from leaves has also shown larvicidal activity against fourth larval instars of *Culex pipiens*[69]. Essential oil isolated from leaves of Lantana has demonstrated strong repellant and fumigant activity against adults of storage pest Pulse Beetle *Callosobruchus maculatus* Fabricus[70].

Yuan and Hu[71] demonstrated repellent, toxic and antifeedant potential of chloroform extract of Lantana leaves against a subterranean termite *Reticulitermes flavipens*. Methanolic crude extract and hexane fraction of leaves of Lantana have shown repellent activitiy against female *A. aegypti* in combination with extract of *Ocimum gratissimum* leaves[72]. Hexane extract of Lantana stem has also demonstrated appreciable larvicidal activity against early fourth instar larva of *A. aegypti*, a vector of Dengue fever[73]. Hari and Mathew[74] have also demonstrated larvicidal potential of petroleum ether extract of leaves of Lantana against *C. quinquefasciatus* (LC_{50} 10.63 mg/L) and *A. aegypti* (LC_{50} 74.93 mg/L) larvae.

Essential oils obtained from leaves and flower of Lantana have also shown insecticidal activity against *Sitophilus granarius* using direct contact application[75]. Essential oils of Lantana has also demonstrated molluscicidal activity against *Pomacea canaliculata, Gyraulus convexiusculus*, and *Tarebia granifera*, which are snails of fresh water and act as agriculture pest. Larvicidal activity of essential oils was also demonstrated aginst mosquito such as *Aedes aegypti, Aedes albopictus,* and *Culex quinquefasciatus* with LC_{50} values ranging from 15.1-29.0 µg/mL, 26.4-53.8, and 20.8-59.3 µg mL mg/L, respectively[76]. Essential oil-loaded nano-emulsion formulation of leaves of Lantana was investigated for larvicidal and pupicidal activity by Udappusamy *et al.*[77] and effective activity was observed against larval and pupal stages of the *A. aegypti* mosquitoes. Leaf extract of Lantana at a concentration of 4% has shown repellent action against *Culex* Mosquitoes as the mosquito landing was reduced up to 90% providing protection for 2 hrs[78]. Recently, synergistic but strong mosquito repellant efficacy against *Anopheles gambiae* s.l. and *Anopheles funestus* of Lantana along with *Striga hermonthica* and *Hyptis spicigera* was demonstrated[79].

Acaricidal activity: de Sousa *et al.*[80] reported acaricidal activity of essential oils of Lantana against a tick *Rhipicephalus microplus*. A strong acaricidal activity with a LC_{50} of 2.9 mg/mL was observed against engorged females.

Antifilarial activity: The *in vivo* anti-filarial properties of Lantana stem were initially shown by Misra *et al.*[81]. In the rodent model, *Mastomys coucha,* 76% of the female worms were sterilized by ethanolic stem extract of Lantana in a dose of 1 g/kg as well as killed *Brugia malayi* parasites. The adulticidal activity was also demonstrated by its chloroform fraction apart from sterilising female worms. Additionally, against a subcutaneous filariid, *Acanthocheilonema viteae* in rodents, the extract demonstrated a mild macrofilaricidal effect along with considerable sterilisation (60.66%) and microfilaricidal (95.04%) efficacy. *In vitro* antifilarial efficacy against *B. malayi* parasites has also been demonstrated by two compounds, oleanonic acid and oleanolic acid, that were extracted from hexane and chloroform fractions.

Dry powder of leaves, stem bark and roots of Lantana were extracted with hexane, methylene chloride and methanol and subjected for in vitro testing on the bovine model parasite, *Onchocerca ochengi*, as well as *Loa loa* microfilariae. In primary screening against *O. ochengi*, all of the extracts showed 100% activity at a concentration of 500 µg/mL. The highest activity was observed with the hexane extract of leaves against *O. ochengi*. Lantadene A; isolated from the methylene chloride extract of its leaves has also demonstrated anti-filarial potential of Lantana[82].

Leishmanicidal activity: Braga *et al.*[83] have demonstrated leishmanicidal effect of methanolic extract of Lantana leaves against *Leishmania amazonensis* (IC_{50} 14 µg/mL) and *L. chagasi* (IC_{50} 250 µg/mL). Essential oil from leaves of Lantana has shown significant leishmanicidal activity against promastigote forms of *L. amazonensis* with an IC_{50} value of 0.25 µg/mL[84]. In both the studies, effect of Lantana on *L. chagasi* was less promising than *L. amazonensis*. Significant leishmanicidal activities were demonstrated by triterpenes oleanolic acid, ursolic acid, lantadene A, and lantanilic acid isolated from aerial parts of Lantana against promastigotes of *L. major*[85]. Barros *et al.*[86] also demonstrated leishmanicidal activity of essential oil from leaves of Lantana against the promastigote form of *Leishmania braziliensis* (IC_{50} 72.31µg/mL). It has also shown trypanocidal potential by exhibiting 67.39% inhibition against epimastigote form of protozoa *Trypanosoma cruzi* at a concentration of 250 µg/mL.

Looking to the wide insecticidal spectrum of Lantana, it could be used to develop some cost-effective mosquito repellents for domestic use. Overall, the Lantana menace can be effectively mitigated by utilizing it for the above-mentioned pursuits.

Other significant uses: Indigenous communities adapt to their surrounding bio-resources to fulfill their need and culture-based necessities[87,88]. For example, creation of an artificial limb from wood of Silk Cotton Tree is a novel use by a tribal person reported from Udaipur, India[89]. Similarly, local communities have started utilizing Lantana bushes for making sturdy furniture, toys, bee-keeping boxes, fish-catchers, hangers, domestic articles etc. in India which are helpful as an additional source of income[90,91].

Its flowers have shown to yield eco-friendly natural dye for cotton and silk material which could be utilized in textile industries[92]. Lantana has demonstrated good compatibility in bonding with cement and thus its ligno-cellulosic material could be utilized to prepare cement bonded particle boards of good strength suitable for various industries[93].

Somasundaram *et al.*[94] have explored potential of Lantana stem fibre for preparation of lightweight polymer matrix composites and observed synthesis of highly strong fibres with high cellulose content, high crystallinity and thermal stability. These could be used in secondary and tertiary structural applications such as door panels, furniture, garden products, packaging materials, and interior components. Overall, the integration of Lantana fibers into composite materials presents a sustainable and eco-friendly alternative to synthetic fibers, offering both environmental and economic benefits. By valorizing an invasive species, this approach not only supports the development of green composites but also contributes to waste reduction, resource efficiency, and the promotion of a circular economy.

It has also shown to provide raw material for paper making and thereby can reduce pressure on other woody plant species[95]. Ligno-cellulosic material obtained from Lantana has also proven to be a good substrate for cultivation of edible Oyster mushroom[96]. All of these properties may promote livelihood of locals and prove helpful in cost-effective management of this weed.

Bandi *et al.*[97] utilized berries of Lantana to synthesize highly fluorescent nitrogen doped carbon dots having low cytotoxicity and excitation dependent emission and thus could be utilized as multi-color bioimaging agent and also to detect Pb^{2+} in water and human sera. Seeds of Lantana could be utilized as animal feed and also as a potential source of edible oil along with industrial applications by producing broad spectrum Ultra Violet (UV) protectants. *In vitro* protection against UV light as measured through sun protection factor was observed by 90% hydroethanolic extract of Lantana leaves in a concentration-dependent manner. The sun protection efficacy could be utilized for development of natural sun-screens from Lantana providing a broader scope for cosmeceutical industry[98]. Though utilization alone is not the only solution for its management, but through many of these ecological approaches, problems arising by invasion of Lantana could be subsided as a part of appropriate management strategy.

CONCLUSION

Lantana is an ornamental shrub with variable flower colors and termed as ‘Global Invasive species. It has invaded both natural and agricultural ecosystems in many parts of the Palaeotropics. Despite some negative effects observed in non-native regions of its invasion, it possesses immense ecological and economic potential; which if utilized in proper manner; it could come up as an eco-friendly green bio-resource in myriad ways. It is recommended that potential uses of Lantana for example, as biofumigant, bioherbicide, biofuel production, phytoremediation, soil fertility enhancement, synthesis of green nanoparticles, raw material for paper manufacturing, making furniture, dyes etc. could be incorporated as a part of its management strategy which may benefit many local communities by generating additional income as well as helpful for a sustainable future.

SIGNIFICANCE STATEMENT

This article highlights the potential of *Lantana camara*, an invasive weed, as a multifunctional bio-resource, offering sustainable alternatives in bioenergy, bioremediation, and biomaterials. By utilizing its diverse applications, it offers an eco-friendly solution to invasive species management while supporting rural livelihoods and contributing to the circular economy and sustainable development goals.

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