



Ecology and Use of *Lantana camara* in India

Girish C. S. Negi^{1,2} · Subrat Sharma¹ · Subash C.R. Vishvakarma¹ ·
Sher S. Samant¹ · Rakesh K. Maikhuri¹ · Ram C. Prasad¹ · Lok M. S. Palni¹

¹ G.B. Pant National Institute of Himalayan Environment & Sustainable Development, Kosi-Katarmal, Almora, Uttarakhand 263 643, India

² Author for Correspondence; e-mail: negigcs@gmail.com

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Abstract

In the Indian sub-continent *Lantana* has invaded vast tracts of dry-moist forests and other culturable wastelands, and has potentially altered biodiversity, landscape ecology and ecosystem services. It has invaded most Indian pasture lands (13.2 million ha) besides forest and fallow areas, and the cost of its control is estimated at US\$ 70 per ha. This invasive weed stands out because of its rapid spread, intensity of infestation, allelopathy, opportunistic growth behaviour, reproductive biology traits and tenacious resistance to cutting and burning. This paper reviews the current knowledge on *L. camara* with particular focus on its ecological attributes such as biomass productivity, reproductive biology, invasiveness, allelopathy, eradication measures and economic uses reported from India. Based on the literature review it can be pointed out that the positive impacts and economic uses of *Lantana* outweigh its negative impacts and require further studies on cost-benefit considerations for decision making for its eradication and management.

Keywords *Lantana camara* · Ecology · Invasion · Eradication, Positive and Negative impacts, India

Introduction

Lantana is a genus (family Verbenaceae) of about 150 species of herbs, under shrubs and shrubs growing to 0.5–2 m tall. The genus *Lantana*, as described by Linnaeus in 1753 in Species Plantarum contains seven species, six from South America and one from Ethiopia (Munir, 1996). *Lantana* is mostly native to subtropical and tropical America, but a few taxa are indigenous to tropical Asia and Africa. It now occurs in approximately 50 countries where several species are cultivated for its flowers under hundreds of cultivar names. The recorded number of *Lantana* species varies from 50 to 270 specific and sub-specific entities, but it appears that a better estimate is 150 species (Munir, 1996). The genus is a difficult one to classify taxonomically since species are not stable and hybridization is widespread, shape of inflorescence changes with age, and flower colours vary with age and maturity (Munir, 1996). *L. camara* L., commonly

known as wild or red sage, is the most widespread species of this genus, growing luxuriantly at elevations up to 1800 m asl. in tropical, sub-tropical and temperate regions (Parsons, 1992). The plant is native to tropical regions of the America and Africa (Nayar, 1977). However, as an introduced species they are found in various localities of the globe especially in the Australian-Pacific region. Dutch explorers introduced *Lantana* into the Netherlands from Brazil in the late 1600s and later explored from tropical, sub-tropical and temperate regions (Sharma et al., 1988). In the 18th and nineteenth century, nurserymen commercialized and popularized many colourful forms of *Lantana*, and it is now cultivated world-wide as an ornamental plant. Of the 650 cultivar names in the genus, the majority are associated with the *L. camara* complex. *L. camara* has been cultivated for its flowers over 300 years and now has hundred of cultivars and hybrids and distinguished morphologically, physiologically and genetically (Binggeli, 1999).

Lantana Introduction in India

L. camara var. *aculeata* Moldenke known as *Lantana* wild sage is a low, erect or sub-scandent woody perennial shrub (0.3-1.8 m or more in height) with stout recurved prickles and a strong odour of black currants. In India seven or eight species such as *L. camara*, *L. indica*, *L. veronicifolia* and *L. trifolia* have been reported, besides species of horticultural value (Rajendran & Daniel, 2002). Three varieties of *L. camara* have been reported from India. These are *L. camara* var. *aculeata* Moldenke, *L. camara* var. *mista* Bailey and *L. camara* var. *nivea* Bailey. Amongst these *L. camara* var. *aculeata* is the most common. Numerous varieties and types of *L. camara* are found; some of them are polyploids. *L. camara* is of hybrid origin and is a polyploid complex. In India it is composed of polyploids ranging from $2x$ to $7x$ ($x = 11$) (Kumar & Subramaniam, 1986). There is a marked variability in morphological features such as habit, thorniness, and characteristics of leaf, flower and inflorescence, and size of fruits among different populations of *L. camara*. The varieties and types are very difficult to differentiate on the basis of morphological features. Most of them have recurved prickles on the stem. But under cultivation they become less prickly or even unarmed, less vigorous in growth, and they set seeds less freely. Dwarf types have been developed for growing in hanging baskets and as a hedge along borders of houses.

Lantana was initially brought to India in 1807 as an ornamental plant at the National Botanical Garden (Kohli et al., 2006), and as an ornamental hedge plant in Calcutta in the early nineteenth century (Hakimuddin, 1929). But later this plant has spread out across all open areas along road sides, railway tracks, edges of crop fields and open forests all over the country. Now, it has become completely naturalized and found throughout India (https://en.wikipedia.org/wiki/Lantana_camara). In North West Himalayan region, *L. camara* was introduced during 1905 in Kathgodam, district Nainital (Hakimuddin, 1929; Hiremath & Sundaram, 2005). It has invaded about 13.2 million ha in Indian pasture lands besides forest and fallow areas. *L. camara* is widely distributed in the tropical and sub-tropical zones including the protected forest areas of India. In some places, it has also entered in the temperate zones (Kimothi et al., 2010). In the Garhwal Himalaya (north India) also, two species viz., *Lantana camara* and *L. indica* have been found growing profusely in all habitats of submontane and montane zone up to 2000 m altitude (Dobhal et al. 2010; Bisht et al., 2012). It is widely

distributed in the tropical and sub-tropical forests and mainly associated with *Acacia catechu*, *Dalbergia sissoo*, *Pinus roxburghii*, *Shorea robusta*, *Tectona grandis* and other evergreen and miscellaneous forests. Niche models have predicted its potential distribution almost throughout India (Ray & Ray, 2014).

Ecological Fitness

The diverse and broad geographic distribution of *Lantana* is a reflection of its wide ecological tolerance. It occurs in diverse climate, habitats and on a variety of soil types. It generally grows best in open unshaded situations such as wastelands, rainforest edges, beachfronts, and forests recovering from fire or logging. Disturbed areas such as beside roads, railway tracks and canals are also favourable habitats for this species (Thakur et al., 1992; Munir, 1996). The plant is found at altitudes from sea level to 1800 masl and can thrive very well under rainfall ranging from 750 to 5000 mm per annum. It grows in rich as well as poor soils, including gravel and laterite and low lying areas and on hills up to 1800 m asl. It is drought resistant, light loving and tolerates moderate shade. It does not grow at ambient temperatures below 5 °C. *Lantana* does not invade intact forests, but encroaches where natural forests have been disturbed through logging creating gaps. It cannot survive under dense, intact canopies of taller native forest species. The plant is susceptible to frosts and low temperatures, saline soils, boggy or hydromorphic soils, low rainfall, coralline soils with poor water-holding capacity (<http://www.fao.org/forestry>). It spreads rapidly through root suckers and profuse seeding every year and is toxic to ruminants (Sharma et al., 1988). In the *L. camara* shrublands of western Himalayan mountains, Bhatt (1990) found soil water holding capacity (range = 37.6-45.3%), soil moisture (14.4-19.6%), pH (6-6.5), total nitrogen (0.07% - 0.12%) and phosphorus (0.001–0.005%) across soil depth of 0-5 cm to 15-20 cm, respectively. Sites occupied by *L. camara* are found relatively rich in nutrients compared to sites without *L. camara* thus further facilitate invasion of this species (Manda & Joshi, 2015).

Reproductive Biology

Phenology of *L. camara* has been studied in detail in the Central Himalayan foothills of India (Bhatt, 1990). In this region, *L. camara* starts vegetative bud production in the last week of March that peaks in mid-April and leafing continues till mid-August with leaf longevity of about 267 days. The mature leaf weighs about 226 mg and leaf area at fullest expansion measures about 18 cm² (Bhatt, 1990). Leaf senescence starts in early December and by the end of February *Lantana* bushes become leafless. A rapid shoot growth (up to 20 cm per year), lengthy leafing period (5-6 months) and display of flowers and fruits during most of the growing period are some phenological traits, which indicate the tropical affinity of this shrub (Shimizu, 1983). This opportunistic growth pattern results in producing a considerable proportion of foliage and reproductive parts, which enables *L. camara* to exploit the ecological niche optimally during the warm and wet rainy season (Negi, 1989).

Aromatic flower clusters of *Lantana*, called umbels are a mix of red, orange, yellow, or blue and white flowers. The flowers typically change colour as they mature, resulting

in inflorescence that are two-three coloured. A common name for *L. camara* is “Ham’n Eggs” due to the adjacent pink and yellow inflorescences. *L. camara* flowers are small, 5 lobed, in flat rounded heads about 5 cm across, in dense umbel-like aggregations that are brightly bicoloured, tubular and sweet smelling. Flowers usually occur all year round, but are most prolific during wet summer months with one more flowering episode in mid-October. It takes about two weeks for fruiting after flowering, and ripened fruits can be found in the bushes till mid-December. Thus the mature flowers and fruits are available in the *L. camara* bushes for 4-5 months and present enough opportunity to pollinators and seed dispersal agents that helps in its proliferation. *L. camara* is primarily pollinated by butterflies (Schemske, 1976) or thrips, as well as sunbirds (in India) and hummingbirds (in Brazil) in some cases resulting in 85% fruit set (Hilje, 1985). Butterflies are the most frequent pollinators of *L. camara*, as they constitute 62% of the total visitors. Bees, wasps, moths and other insect groups also visit *L. camara* flowers, but are less frequent pollinators (<http://easternarc.org/tz/downloads/TBA-East-Usambara/reports-2005>). Kugler (1980) reported that over 38% of insect visitors on flowers were *Bombus hortorum*, nearly 20% were *Xylocopa violaceae*, 9% *Amegilla quadrifasciata* and 6% *Apis mellifera*. Pollination in *L. camara* consists of both self and cross-pollination. There are conflicting reports over the plant’s ability to self-pollinate (<http://www.tropical-biology.org/research/dip/species/Lantana.htm>). Since, nearly all cultivars of *L. camara* are self-compatible and are generally pollinated by thrips, mere observation and visual inspection of the flowers should give a good indication of their fecundity. Flower colour changes from yellow to pink after pollination, hence multiple colours in a single inflorescence are found, thus increases the optical attractiveness of the inflorescence that provide rewards for pollinators. The flowers are adapted to butterfly pollination (psychophilous flowers), open throughout the day with shorter tubes or spurs that provide a landing platform for the butterflies.

Large quantities of small greenish blue-black globose fruits of about 5 mm diameter are produced mostly during monsoon season. Fruits are hard and green when unripe, turning fleshy and purplish-black when ripe. The fruits have a single stony seed (Stone, 1970). The seed has two embryos, but germination of both happens only rarely. Germination of *L. camara* seeds is low (4 - 45%) due to seed dormancy, low seed viability, and meiotic instability (Duggin & Gentle, 1998; Sahu & Panda, 1998), low seedling mortality and fast vegetative spread compensate for this deficit (Sahu & Panda, 1998). Seed germination in *L. camara* is known to be stimulated by warm temperatures, exposure to light, and high soil moisture. When sown under thin cover at 20 °C in light, seed germinates in about two weeks. It re-sprouts readily on being burnt and it flowers and fruits year round, producing copious quantities of seeds (Hakimuddin, 1929). Fruit dispersal is mostly through frugivorous birds (often the Mynah bird); also sometimes by goats, sheep, cattle, monkeys, fox and rodents.

L. camara also reproduces and disperses vegetatively very easily. Germination rate of fresh seed is generally low, but the germinability gets improved when the seed passes through the digestive system of birds and animals (https://www.facebook.com/permalink.php?story_fbid). Therefore, such information regarding the behaviour and feeding preferences of birds on *Lantana* fruits may prove useful in terms of integrated control or selecting new agents. Also, birds tend not to eat fruits damaged by the seedfly *Ophiomyia lantanae*, so the impact of flower-feeding and seed-feeding insects on *Lantana* and the insect population levels that are needed to significantly

reduce seed set or damage seed needs to be studied (Day et al., 2003). High light intensity and soil temperature stimulates germination of seeds, which means that clearing of forest areas, inappropriate burning and other disturbances will help spread of the weed. Seeds are capable of surviving the hottest fires (<http://www.fao.org/forestry/13375-.pdf>). Its growth is stimulated by disturbances such as mild fire, cutting, pruning, and grazing. Raizada and Raghubanshi (2010) reported that smoked seeds germinate earlier than non-smoked seeds; hence fire could enhance seed germination in *L. camara*. Further, seedling mortality was found lower in the case of smoked seeds. Also, little is known about *Lantana*'s soil seed-bank dynamics. Anecdotal evidence suggests that seeds remain viable in the soil for about two years, but apparently no formal studies have been made that would assist in control and to know how long follow-up treatments would need to be implemented following the removal of *Lantana* by conventional means.

Biomass and Productivity

In the Himalayan foothills in north India the aboveground biomass of *L. camara* across shoot diameter (0.6–3.5 cm) classes was reported to be 2.15–33.4 T ha⁻¹, and that of *Lantana* shrubland community (that also consists of other shrubs and herbs) 6.34 to 43.29 T ha⁻¹, of this 85.8% was accounted for by aboveground parts and 14.2% by belowground parts (Bhatt, 1990). To the total shrub biomass of bushland vegetation, *L. camara* contributed 78%, other shrubs (19.5%) and herbs (2.5%) (Adhikari et al., 2009). Further, the seeds and reproductive parts accounted for a measurable portion (3.40%) of the biomass, showing its ruderal strategy. The net primary production of *L. camara* alone was 13.7 T ha⁻¹ (aboveground 10.7 and belowground 3.0 T ha⁻¹ yr⁻¹), of which shoot contributed 50%, followed by foliage (25%), roots (22%) and reproductive parts (1.5%), which is six to fourteen-fold higher than that reported for the shrub layers in the natural forest communities of the Central Himalaya, India (Chaturvedi, 1983; Rawat & Singh, 1988; Rana et al., 1989). The net primary productivity of *Lantana* was comparable to about 10–28 T ha⁻¹ yr⁻¹ for the sub-tropical and temperate forests (Singh & Singh, 1987). Vasudevan and Jain (1991) have reported that *Lantana* contains about 70–80% of woody biomass with annual production rate of 40–60 T ha⁻¹ yr⁻¹. In western Ghats (Tamilnadu, India) greater biomass of *L. camara* was recorded among many herbaceous communities that could be attributed to high degree of disturbance and open environment (Chandrasekaran & Swamy, 2002). Thus, *L. camara* productivity compares well with the potential forest communities, particularly in the degraded lands with nutrient poor soil.

Litterfall and Nutrients

Total annual litter fall (leaf + wood + reproductive parts) in *L. camara* is reported 3.82 T ha⁻¹ yr⁻¹, 80% of it occurs during November to February in the Himalayan foothills in north India (Bhatt, 1990). *Lantana* leaves decompose completely in about 13–14 months (Negi & Kandpal, 2003) and contain high concentration of nutrients in leaves ($N = 1.71\%$ and $P = 0.09\%$). The total quantity of nitrogen contained in *L. camara* biomass was recorded 289.7 Kg ha⁻¹, and phosphorus (16 kg ha⁻¹), and the total N and P returned via litterfall was 57.3 and 3.1 kg ha⁻¹ yr⁻¹, respectively,

which is comparable to the mature climax forests of the sub-tropical and temperate climate of India (Singh, 1992). *L. camara* has greater influence on the functioning of the shrub community in terms of nutrient cycling with high quantity of N retranslocation from senescing leaves ($73 \text{ kg ha}^{-1} \text{ yr}^{-1}$) and high N concentration in leaf litter that may help it in outcompeting other species. High productivity of *L. camara* on degraded land with poor soil fertility may be related to high nutrient extraction efficiency, which is the extraction of nutrients in net primary productivity relative to nutrients in soil and higher retranslocation of nutrients from the foliage (Singh, 1992). Sharma and Raghubanshi (<http://www.designsystems.in/currentconservation>) observed that high N and low lignin content of *Lantana* litter and the favorable microclimate beneath *Lantana* canopies favour faster decomposition and release of N leading to increase in soil N availability, N mineralization, and total soil N, leading to a positive feedback, and this, in turn, favours the growth of *Lantana*.

Negative Impacts on Ecosystems

Invasion by *L. camara*

Invasive plants are commonly recognized to have severe ecological impacts in a wide range of ecosystems throughout the world. They can alter ecosystem structure and function, trophic structure, resource availability and downgrade biodiversity of natural landscapes. *Lantana camara* is one such invasive alien species and considered by IUCN as one of the world's 100 most invasive species, and among the world's 10 worst weeds. Invasion by non-native exotic plant species poses a serious threat to native plant communities and ecosystem properties, such as population dynamics and community structure (Mooney & Drake, 1986; Pimentel et al., 2001), and alters native vegetation and causes threat to biodiversity (Vitousek et al., 1996; Mack et al., 2000). Habitat disturbance due to anthropogenic or environmental reasons (Heywood, 1989) modifies the microclimate, resulting in colonizing the invading species such as *Lantana*, particularly in dry deciduous environment (Heirro & Callaway, 2003). Some species of *Lantana* are invasive, and are considered to be noxious weeds, such as in Indian Sub-continent, Southern Africa and Australia. The plant is an aggressive, obligate out breeder weed that has invaded vast expanses of pastures, orchards and forest areas in many tropical and subtropical regions. *Lantana* has invaded most Indian pasture lands (13.2 million ha) besides forest and fallow areas, and the cost of its control is estimated to be US\$ 70 per ha (Sharma & Raghubanshi; <http://www.designsystems.in/currentconservation>). The *lantana*-infested landscapes not only are impoverished as habitats of wildlife but also contribute to human-wildlife conflicts owing to diminished ecosystem services. In the Himalayan foothills thick *Lantana* bushland provide shelter to wild Boar causing damage to crops that also poses hazards of attack to the local people (Singh and Singh, 1987).

India has witnessed negative impact on forest ecosystems posed by invasive species such as *Ageratum conyzoides*, *Eupatorium* sp., *Lantana camara*, *Mikania micrantha* and *Parthenium hystephorus* (Ramakrishnan, 1991; Saxena, 1991; Kohli et al., 2006). Among them, *L. camara* is one of the most serious invasive plant species and has colonized large areas of forests in the Himalayan foothills both in open and protected

areas such as Dudhwa, Corbett and Rajaji National Parks in India. Nearly 18% of the Indian flora is constituted by adventives aliens of whom 55% are American (Nayar, 1977). There are, however, no recent data regarding the exact number and incidence of these introduced invasive species in India (Love et al., 2009). *Lantana* has very vigorously invaded forest areas, which have been under high anthropogenic disturbances such as grazing and deforestation (Joshi, 2002; Love et al., 2009). In Indian conditions it is found nearly in all forest types in tropics and sub-tropics and make highly dense pockets (1500 – 3000 plants/ha), and height ranging from 1.5 – 3.0 m (Joshi, 2002). Due to its prolific growth and wide adaptability, *Lantana* has over run large area in India and has developed into a serious pest. Infested areas include cultivable and waste lands, forest areas, grazing and pasture lands and some plantations. The areas worst affected are parts of Deccan and portion of Coorg, Wynaad, Nilgiris and lower hills of Western Ghats. It has also invaded parts of Uttar Pradesh and tropical and sub-tropical zones of the Indian Himalayan region including parts of the North Eastern States.

In the foothills of Nainital district in north India, till 1911 *Lantana* was sparsely distributed and remained confined to hedges (Hakimuddin, 1929), and did not occur more than a few miles from its place of introduction. Within two decades, however, it has spread in a thick continuous mass to a distance of about 25 miles in all directions, indiscriminately taking over farms and pastures, fallow land and forests. Now after a century, this invasive species is a major ecological problem in Garhwal (Rajwar, 2007), and Kumaun hills of Uttarakhand (Bhatt, 1990), and this shrub is now truly native in this region. Jim Corbett (1944) in his book “Man-eaters of Kumaon” has observed the thickets of *Lantana* bushes as hiding shelters of leopard in foothills of Kumaon. It has become a menace and forms pure stands in protected areas. As a result of the removal of tree cover and continued grazing in the south facing landscapes in the tarai foothills, shivalik and mid-montane belt of north India, this light demanding species has successfully established. It has especially expanded along roads, footpaths and in lands around human settlements. Singh and Singh (1987) reported that much of the degraded slopes resulting from the deforestation and erosion, overgrazed lands and abandoned crop fields are heavily colonized by *Lantana*. Copious seed production and their efficient dispersal by birds make *L. camara* particularly invasive. The bush patch expands with the help of strong root system (Troup, 1921). In the Central Himalayan region this bush has assumed a permanent feature of the landscape and represents a kind of converted ecosystem and influences the landscape ecology of this region (Dobhal et al., 2010). In the *Pinus roxburghii* forests in Kumaun hills in India, *L. camara* (Importance Value Index = 91.0 & basal area = 1.1 m² ha⁻¹) was found dominant in the shrub layer (Bhatt et al., 1994; Rawat et al., 1994). In the Garhwal hills in India native shrubs such as, *Adhatoda vasica*, *Carissa opaca*, *Justicia adhatoda*, *Rubus biflorus*, *Murraya koenigii*, *Nyctanthes abortivis* etc. are being out competed by *Lantana* invasion (Sharma and Kumar, 2009). In lower Himalayas, Sharma and Raghubanshi (2009) reported that invasion and proliferation of *L. camara* causing a change in vegetation and drastic reduction in the grass biomass foraged by livestock. *L. camara* has been also reported to invade Pine (*P. roxburghii*) forests also in Pakistan (Siddiqui et al., 1995). In tropical dry forests of India many species exhibit declining or even severely depleted populations in *Lantana*-invaded locations (Raghubanshi & Tripathi, 2009). Examples of species with declining populations include *Acacia*

auriculiformis, *Adina cordifolia*, *Boswellia serrata*, *Briedelia retusa*, *Buchanania lanzan*, *Cassia fistula*, *Elaeodendron glaucum*, *Embllica officinalis*, *Eriolena quinquelaris*, *Hardwickia binata*, *Miliusa tomentosa*, *Schrebera swietenoides* etc.). Such invasions create demographic instability among native tree species, reduce tree diversity, and could even change the structure of the forest in the near future. In India and elsewhere *Lantana* undergrowth in Teak plantations has affected the growth of Teak plants, reducing the basal area increment by 33%. In the Garhwal hills in north India in the *Lantana* and *Eupatorium* infested habitats, specific decline in the populations of birds was recorded which feed on the ground (e.g., pheasants, partridges, doves, tree pie, thrushes, pipits, etc.), on insects (drongos, bush chats, tits, flycatchers, bee eaters), and on nectar, like sun birds (Bisht et al., 2012). It can be pointed out that the invasive species does not allow growth of suitable food material to the ground feeding birds, which had a very common appearance in this region earlier when there was least infestation of weeds. Also, phototoxic substances released by the *Lantana* roots damage the soil organisms and repel the insect fauna which constitute the diet of many bird species (Bisht & Dobriyal, 2002). Thus *Lantana* invasion is also harmful to the avifaunal diversity. In some areas, *Lantana* harbours injurious insect pests, including malarial mosquitoes (CSIR, 1962).

Lantana and Fire

Lantana has several characters that invites fire (Hiremath & Sundaram, 2005). It resprouts readily on being burnt (Pereira, 1919; Hakimuddin, 1929). The fire has favourable effect on the growth of *Lantana*. This not only increases coppicing potential of the species but also breaks the dormancy of the seeds and helps in massive new growth. *Lantana* affected with fire regenerate more vigorously than control (Joshi, 2002). Similarly, seeds exposed to surface fire have shown early sprouting than the seeds not exposed. Studies from other parts of the tropics confirm that *Lantana* may be favoured by disturbances such as fire and grazing (Duggin and Gentle, 1998; Gentle & Duggin, 1997). Climbing stems of *Lantana* can reach up to >20 m, getting into the forest canopy and resulting in crown fires when they burn (Tireman, 1916). *Lantana* has thus many adverse effects on forest ecosystems which include (i) loss of native biodiversity (Sharma et al., 2005; Day et al., 2003); (ii) replacing native plant communities in forests by forming dense impenetrable thickets, (iii) contributing to soil erosion (Day et al., 2003, FAO: <http://www.fao.org/forestry/media>), (iv) hampering regeneration of forests (Sharma et al., 2005; Day et al., 2003), (v) harbouring vectors that carry infectious diseases (Syed & Guerin, 2004) and (vi) promoting fire hazard (Hiremath & Sundaram, 2005).

Allelopathic Effect

Allelopathy is a phenomenon in which chemicals released by the invasive plant discourage growth of native plants (Heirro & Callaway, 2003). It represents the plant-plant interactions, a part of chemical ecology. The success of *Lantana* in different environmental conditions could also be due to its allelopathic effect on other plants. *Lantana* disrupts succession, decreases biodiversity, and can reduce vigour of native plants due to allelopathy (Day et al., 2003; Holm et al., 1979). Impact of *L. camara*

allelopathy is not universal, it may vary from crop to crop. Maiti et al. (2008) reported that the leaf extracts and leachates of *Lantana* reduce germination, speed of germination, seed viability and seedling emergence capacity of *Mimosa* seeds. The effect of *L. camara* aqueous leaf extracts of different concentrations shows significant inhibitory effect on germination, root and shoot elongation and development of lateral roots of food crops such as *Brassica juncea*, *Cicer arietinum*, *Cucumis sativus*, *Phaseolus mungo*, *Raphanus sativus* and *Vigna unguiculata* (Ahmed et al., 1972). Leaf extract of *Lantana* is highly toxic to water hyacinth (*Eichhornia crassipes*). It suppressed the emergence of leaf buds and cause decay of its leaves and chlorophyll content by foliar spraying. Leaf extracts of *L. camara* exhibit a phytotoxic potential against other plants, especially against the germination of spores of the liverwort *Asterella angusta* (Kothari & Chaudhary, 2001). Leaf extract of *Lantana* in high concentration inhibits the growth of *Parthenium hysterophorus* in flowering stage (Mishra, 2014). Sahid and Sugau (1993) studied the allelopathic potential of *Lantana* on germination and growth of five crops (Chinese cabbage, spinach, rapeseed, cucumber and chili) in laboratory, greenhouse, and field conditions, and found that emergence and dry weight of bioassay species were affected when *Lantana* debris was present on the soil surface or incorporated into the soil. Germination of Chinese cabbage, chili, and rapeseed decreased progressively when exposed to increasing concentrations of aqueous *Lantana* extract. The allelopathic effects of dried *Lantana* shoot residues on growth (shoot and root length and dry weight) over a 30-day period of wheat, corn, soybean, Virginia pepper weed and velvet leaf showed that corn was the most sensitive and wheat was least affected by *Lantana* residues (Mersie & Singh, 1987).

Lantana roots possess more inhibitory quality than shoots (Achhireddy & Singh, 1984). In soil amended with 1% (w/w) *Lantana* roots into 50% seedling of milkweed vine (*Morrenia odorata* Lindl.) died within 15 days after germination, higher seedling mortality was observed in higher concentrations of roots in soil. *Lantana* roots incorporated into the soil produced foliar symptoms such as wilting and desiccation, whereas *Lantana* shoots incorporated into the soil produced yellowing of the foliage of milkweed vine. *Lantana* residue showed more strong allelopathic effect after decomposition for 4 weeks prior to the planting of milkweed vine seeds. Root leachate of *L. camara* has potential to control soil borne root infecting fungi (Shaukat & Siddiqui, 2002). They found suppression effect of 44% and 51%, respectively against *Fusarium solani* and *Rhizoctonia solani* over control in soil amended with full strength root leachate on mung bean (*Vigna radiata*).

Impact on Cattle

The leaves of *Lantana* are toxic to most animals. *Lantana* has been major contributors to poisoning of cattle, buffalo, sheep and goats. The plant is not relished by cattle but is reported to be browsed when pasturage is scarce. Cattle fed leaves (12-16 oz.) develop symptoms of severe jaundice, exfoliation of skin near muzzle, profuse salivation, severe dermatitis and appear dull (CSIR, 1962). The leaves and seeds of this species supposedly contain "Triterpenoids" which cause poisoning and photosensitivity. *L. camara* contains pentacyclic triterpenoids that cause hepatotoxicity and photosensitivity when ingested by grazing animals such as sheep, goats, bovines and horses. Palatability of *Lantana* leaves as fodder is least because of presence of toxic material lantadenes in its leaves, which is not

reduced even after several weeks of anaerobic microbial reaction under silage making (Sastry & Mahadevan, 1963; Sharma, 1988; Sharma et al., 1980). In tropical countries, the ripe blue/black berries of *Lantana* are eaten, but ingestion of the green berry leads to human fatalities (Ross, 1999; Morton, 1994).

Positive Impacts of *Lantana*

Herbal Medicine

Presence of toxic compounds in certain *Lantana* spp. makes it an important species to study its phytochemistry. First systematic study on the chemical constituents of *L. camara* was undertaken in 1943 by P. G. J. Louw when he reported the isolation of its main active principle Lantanin with molecular formula $C_{32}H_{44}O_5$, which was renamed as Lantadene A by himself in 1948 when Lantadene B, with molecular formula $C_{33}H_{48}O_5$ was isolated from all parts of *Lantana* shrub (Louw, 1948). Lantadenes, is believed to be responsible for almost all the biological activities of *Lantana* (Barre et al., 1997) such as antipyretic, antimicrobial, antimutagenic, antimicrobial, fungicidal, insecticidal, nematocidal, and other biological activities. Secondary metabolites of *Lantana* such as alkaloids, terpenoids, phenolics, iridoid glycosides, furanonaphthoquinones, flavonoids, phenyl ethanoid glycosides and miscellaneous compounds could be held partially responsible for some of these biological activities (Barre et al., 1997). The early work on *Lantana* spp. was concerned with studies on the essential oils; the maximum yield obtained by hydro distillation from the leaves reached 0.2% and, from the flowers, up to 0.6% (Ahmed et al., 1972, Gildermeister & Hoffmann, 1961). The chemical composition of essential oils obtained from *Lantana* depends on season, geographical location, and developmental stage of the plant (Randrianalijaona et al., 2005). *Lantana* has 31% hot water soluble fiber, 26% cellulose, 21% hemi-cellulose and 16.2% lignin of dry weight. Throughout the world studies on antibacterial properties of *L. camara* has been carried out extensively (Singh et al., 1990; Siddiqui et al., 1995; Deena & Thoppil, 2000; Mello et al., 2005; Verma & Verma, 2006). It is used as a sudorific, intestinal antiseptic, diaphoretic, and in treatment of tetanus and rheumatism and malaria in Indian medicine (Ojha & Dayal, 1992). Extracts from the leaves exhibit antimicrobial, fungicidal, insecticidal and nematocidal activity (Begum et al., 2000; Day et al., 2003; Girish, 2017). It is useful for fistulae, pustule and tumours. A decoction of the plant is given in tetanus, rheumatism, malaria and atoxy of abdominal viscera (CSIR, 1962). Pounded leaves are applied to cuts, ulcers and swellings. A decoction of leaves and fruits is used as a lotion for wounds. An infusion of leaves is taken internally for bilious fever and catarrhal affections, externally it is used in the form of lotion or fomentation against eczema eruptions and rheumatism. An infusion of flowers is given as pectoral for children (CSIR, 1962; Singh et al., 1984). Stems are used as tooth brush and leaves for polishing wood.

Industrial Uses of *Lantana*

Originally introduced to most countries as a garden ornamental, in some countries it was planted as hedge to contain or keep out livestock (Bradely, 1988; Ghisalberti, 2000). While this plant has often described as 'weed', research community is exploring various

uses of the plant, particularly potential of chemical constituents, such as *Lantana* oil (Sharma & Sharma, 1989; da Silva et al., 1999). Plants in the Western Himalayan foothill zone of India yield 200 mg of essential oil (market price US\$ 91/kg) from hydro-distillation of 5 quintal of *Lantana* biomass. In addition to perfume ingredient, essential oil from the leaves possess adulticidal activity against the different mosquito species. Thus this species can be utilized for oil-based insecticides as supplementary to synthetic insecticides (Dua et al., 2010; Kumar & Maneemegalai, 2008). The leaves yield (0.2%) yellow and greenish yellow oil with a pleasant and lasting odour reminiscent of sage (*Salvia officinalis* Linn.) on steam distillation. On standing, the oil becomes viscid and insoluble in alcohol. The leaf oil is used in the treatment of itches of skin and also useful as an antiseptic for wounds. The bark of the stem and roots contain a quinine-like alkaloid, lantanine, with strong antipyretic and antispasmodic properties. Acid extracts of the shoots show antibacterial activity against *Escherichia coli*. Acetated buffer extracts are active against *Micrococcus pyogenes* var. *aureus*. *Lantana* flowers yield 0.07% of a volatile oil similar to that of leaf oil. The flower contains anthocyanin, a yellow flavone, a pink pigment and carotene. The seed contain oil (9%) with fatty acids components like linolenic, linoleic, oleic, stearic and palmitic. High content of cholesterol in leaves are also reported (Goyal & Kamal, 1984).

Roots of *Lantana* are rich source of oleanolic acid which shows anti-inflammatory, hepatoprotective, anti-tumour, anti-oxidant, and anti-hyperlipidemic activity (Sharma & Sharma, 1989). Uses of *Lantana* extract as herbal medicine are known in the folk medicine (Sastri, 1962; Kirtikar & Basu, 2000; Ghisalberti, 2000) for the treatment of chicken pox, measles, asthma, skin itches, antiseptic for wounds, and externally in leprosy. Extract from this plant exhibit promising cytotoxicity against A375 cells (malignant skin melanoma) and Jurkat leukemia cell line (Ghosh et al., 2010; Badakhshan et al., 2009). Thus this plant is a prospective candidate for designing novel therapeutic agent and identification to find new anti-cancer agents. In an experiment with rodents (*Mastomys coucha*) the crude extract from stem of *Lantana* by oral route shows antifilarial efficacy (Mishra et al., 2007) by killing 40% of adult *Brugia malayi* parasites and sterilizing three fourth of the female worms. Antimicrobial efficacy of the plant (flavonoids, crude alkaloids, leaf extract, and essential oil) has been well documented against various microorganisms (Ventataswamy et al., 2010; Kurade et al., 2010; Sharma & Kumar, 2009). Extracts of *L. camara* may be used for protection of members of brassicaceae family (e.g., mustard) against the aphid *Lipaphis erysimi* (Srivastava & Guleria, 2003). The acetone extract of leaf has a great value to control the harmful aquatic snails (*Lymnaea acuminata*), and other molluscan pests as shown by the molluscicidal potential (Chauhan & Singh, 2010) against freshwater snail (an intermediate host of liver fluke in cattle and livestock). Extract of leaves (5% chloroform) was found significantly effective against termite worker (Verma & Verma, 2006). The use of extract from plant has also been suggested as potential biocide against water hyacinth (Saxena, 2000) and nematodes (Begum et al., 2000).

Lantana biomass could be utilized as fertilizer, energy, fuel wood, pulp, paper fiber and developing roofing material (NAS, 1981). It could be a good raw material for paper and pulp industry. The stalks have been tried as raw materials for paper pulp and contain furfuroids (21.6%), lignin (14.0%), cellulose (30.6%) and ash (3.50%). Digestion with lime and kollerganging yield 63.7% of pulp suitable for wrapping paper and straw board. Pulp suitable for writing and printing paper is obtained by sulphate process

(Anonymous, 1970-1988). Pretreatment of *Lantana* wood further improves the uses (i) to produce pulp suitable for writing and printing (Gujral & Vasudevan, 1983), and (ii) low cost feedstock for bioethanol production (Pasha et al., 2007; Khud et al., 2010). *Lantana* biomass is used directly for various purposes and most important is as supplementary fuelwood for cooking and heating by people. *Lantana* wood has 18.53 MJ energy kg⁻¹, it yields 118 l biogas 1000 kg⁻¹ and 56 l methane 1000 kg⁻¹ dried biomass. In a few Himalayan mountain villages it accounts for about 20% of the total firewood consumption (Negi & Bhatt, 1993; Sharma & Singh, 1994). This plant has also been used as sole substrate for oyster mushroom cultivation, however bio-conversion was found lower than the wheat straw (Vats et al., 1994).

Growth potential of *Lantana* can be utilized for harvesting the solar energy utilization of biomass for various productive uses. This strategy could be useful in control of *Lantana* weed and simultaneously better utilization of alien species. It regenerates very fast even after lopping and attains high biomass yields (Joshi, 2002). Among other uses, making furniture from *Lantana* is a direct utilization of biomass from the wild. *Lantana* stems though are thin the wood is very tough and durable and thus useful for various handicrafts such as wickerwork. The Soliga of Karnataka is now-a-days utilizing *Lantana* in their wickercraft as bamboo resources are scarce and costly and the bamboo forests have been invaded by *Lantana*. By selectively harvesting *Lantana* for their craft, they are again able to make a living, as well as assisting the recovery of the native ecosystem and reducing the risk of wildfires (http://www.atree.org/lcc_products). Similarly, tribal communities around Mudumalai Tiger Reserve in India are making such furniture which resembles cane furniture in design and performance but cost almost half. Another initiative under the name WELFARE (Women Empowerment through *Lantana* Furniture and Artifacts and Restoration of Environment) in the fringe of Corbett National Park, India has been launched to explore business opportunity of *Lantana* weed through training to make furniture from this termite resistant weed. *Lantana* sticks are extensively used for making baskets for packing and transport of vegetables to distant markets in some parts of Himalayan mountains. Leafy twigs of *Lantana* are kept in the bottom of grain containers to avoid termites, mice and other insects. In the areas of dominant presence over the landscape it provides shelter and vital winter food for many birds. Many birds utilize *Lantana* thickets when their natural habitat is unavailable. *Lantana* is also a major source of nectar for many butterflies and moths. In view of its multiple uses and invasive nature it has been suggested that use of *L. camara* need to be promoted in herbal ethno-medicine, biofuels and handicrafts (Chaterjee, 2015).

Mulching for Soil Fertility

In spite of the invasive and allelopathic effects, *L. camara* provides a good covering to the ground with fine leaf mulch (Munir, 1996) that improves the fertility of rocky, grave, or hard laterite soils, and serves to retain humus in deforested areas and checks soil erosion (https://en.wikipedia.org/wiki/Lantana_camara). Leaves are rich in nitrogen (0.94%) and poor in lignin and decompose fast; thus leaves are good source of nutrients and can be utilized for biomass production in barren and infertile soils. The leaves and the twigs are occasionally used as green manure in forest areas and for paddy crops in Mysore; they can also be composted along with other materials. Analysis of

green materials revealed $N = 0.88\%$; $P = 0.15\%$; $K = 0.90\%$; and $Ca = 0.61\%$. *Lantana* ash (ash content = 10.29%) is rich in soluble potassium salts and useful for manuring coconut trees (Munir, 1996). It is also rich in manganese (0.3–0.4%), potassium (1.1–1.8%) and phosphorus (1.6–2.2%). The ash (10.9% of plant wt.) is rich in soluble potassium salts (Vasudevan & Jain, 1991) and enriches the soil (CSIR, 1962).

In the Western Himalayan mountains in India several workers have found *Lantana* (leaf) mulch improving soil fertility and moisture retention (Acharya & Bhagat, 1984; Sharma & Acharya, 2000), enhance root growth, nutrient uptake and grain yield of maize and wheat (Acharya & Sharma, 1994). Sharma and Parmar (1998) found that mulching with Pine and *Lantana* increased the phosphorus-use efficiency and yield of wheat. *Lantana* mulching has been found to improve soil hydraulic properties to the benefit of the wheat crop in a rice-wheat cropping sequence (Sharma & Verma, 2000; Bhushan & Sharma, 2005). In an experiment (Kumar et al., 2009) found that *Lantana* leaves could be suitably mixed with forest tree leaves for hastening decomposition and nutrient release, soil moisture conservation, soil fertility maintenance and increase in yield of wheat and rice in rainfed crop fields. Negi & Kandpal (2003) found that *Lantana* mulch improves soil fertility owing to fast decomposition (*Lantana* leaves take 323 days for complete decomposition) and nutrient release. Sharma and Acharya (2000) in wheat (*Triticum aestivum* L.)- maize (*Zea mays* L.) crop rotation in rainfed areas of north-west India using fresh *Lantana* biomass as mulch found most effective in conserving rainwater (range = 7.1 – 22.2 mm across different soil depths, tillage treatments and date of sowing) that ultimately increased the yield of wheat and maize. They found that after four cropping cycles, organic carbon content in 0–15 cm soil layer of mulched plots was significantly higher (11.3–12.3 g C kg⁻¹) than control (conventional practice) plots (9.0 g C kg⁻¹). In north-east India, cultivation of tuber crops and vegetables on hill slopes involve putting of dried vegetation mainly Khasi pine (*Pinus kesiya*) along with weeds like *Imperata cylindrica* and *L. camara* to control soil erosion and conserve soil moisture (Mishra & Saha, 2007).

Other Uses of *Lantana*

Some other positive aspects of *Lantana* include: (i) It accumulates mercury from the soil and transport it into the shoot, and after reduction releases the mercury vapour into the atmosphere (Vasudevan & Jain, 1991). Thus *Lantana* can be used in managing biochemistry of mercury both at reservoirs and in the transfer of the element between soil and atmosphere, (ii) Leaves of *L. camara* may act as biomonitoring tool for air quality by detecting suspended dust particles in air (Rai & Singh, 2015). This plant is recently used in advanced techniques such as phytoremediation of particulate pollution, phytoextraction of heavy metals (Kumar et al. 2016) such as lead (Saini et al. 2017), (iii) Larvicidal activity of *L. camara* leaf extract reported against three mosquito species has a potential to be used as biopesticide, Hemalatha et al, 2015 (iv) *Lantana* leaves have been tried as a substitute for tea. Fermented leaves possess a mild odour which is not unpleasant, and yield an inferior beverage. The leaves contain a powerful oxidase. They also contain catalase, amylase, invertase, lipase, tannase and glucosidase. Appreciable amounts of tannins and sugar, and a resin occur in leaves. A crystalline glucoside (probably C₂₇ H₄₂O₄) has been separated from the resin by ether extraction (https://en.wikipedia.org/wiki/Lantana_camara), (v) *Lantana* is useful as honey plants, and

Spanish Flag (*L. camara*), *L. lilacina* and *L. trifolia* are sometimes planted for this purpose, or in butterfly gardening. Butterflies which are attracted to *Lantana* flowers are most notably Papilioninae (swallowtail and bird wing butterflies). Hesperiiidae (skippers) and certain brush-footed butterflies, as well as some Pieridae and Lycaenidae, also like to visit the flowers, and (vi) The fruit is a delicacy for many birds like the Yellow-fronted White-eye of Vanuatu, the Superb Fairy-wren in Australia, or the Mauritius Bulbul, which help in the dissemination of seeds.

Eradication and Management of *Lantana*

Various methods such as mechanical, cultural, chemical and biological, have been tried to control the *Lantana* proliferation. Early records of *Lantana* control underscore the importance of completely uprooting *Lantana* after cutting and burning aboveground biomass to prevent it recolonising from the rootstock (Tireman, 1916; Pereira, 1919). Babu et al. (2009) and Love et al. (2009) devised a method for eradicating *Lantana* using knowledge about its ecology, and, subsequently, weed-free landscapes were restored to productive grasslands. Control measure by mechanical means include stumping of plants in February or March up to a height of 1 ft. above the ground and burning the cuttings; the stumps left behind are pulled out in the rainy season when the ground is soft. Frequent uprooting of regrowth, which appear after the first cutting; for 2-4 years is essential to keep the pest under control. Another method is to cut the branches and heap the debris around the roots to prevent regeneration of new shoots. The debris is then burnt, followed by digging up of the root system and burning (Babu et al., 2009). Among the removal techniques such as cutting, burning and uprooting the former two were found more effective but recovery of native vegetation across these three techniques was found almost similar (Sundaram et al. 2018). Also, uprooting followed by weeding after rainy season was found crucial to long-term *Lantana* eradication success (Prasad et al. 2018).

Control of *Lantana* by the use of chemicals has given useful results. Experiments conducted to control *L. camara* in Shivalik hills of Punjab through chemical treatment (Glyphosate 1.0% spray at stump level) and by planting four fast-growing species viz. *Dendrocalamus strictus*, *Leucaena leucocephala*, *Albizia procera* and *Melia azedarach* with *Lantana* showed that plantations of the fast growing species hinder the growth of *L. camara*, and help increase the biomass of palatable species within a short period 2-3 years (Luna et al., 2009). Another methods tried consists of cutting the plants close to the ground and painting cut ends with sodium arsenate. The treatment is effective but it is not recommended as it involves the hazards of poisoning livestock which may stray into the treated area. In recent years various herbicides have been applied and successful control has been achieved. Painting of cut ends with 2,4-D solution (10%) gives effective control. Trials carried out in India at the Agricultural Research Station, Ambalavayal and the Fruit Research Station, Kallar (Madras) have shown that shrubs cut to a height of 60 cm from the ground and sprayed with 2,4,5-T (20 lb) in a spray volume of 150 gal./acre, using Teepol as wetting agent, withered in 15 days. Spraying trials at the Forest Research Institute, Dehra Dun showed that Y.F. 2717-2, 4, 5-T, n-butyl ester is effective even when the plants are not cut back. Formulations containing 2, 4, 5-T alone or in combination with 2, 4-D are more effective than 2, 4-D alone,

especially in large bushes. Regrowth after cutting back, can be completely controlled by spraying with Dicotox, Esteron 44 (active principle, 2,4-D ester), MCPA and Fernoxone (https://en.wikipedia.org/wiki/Lantana_camara).

Biological control of *Lantana* has been attempted with limited success. In Australia, about 30 insects have been introduced to control the spread of *Lantana*, and this has caused problems of its own. For example, The *Lantana* Bug *Aconophora compressa* is a polyphagous species introduced in 1995 that feeds on dozens of plants, and not only has it failed to have a noticeable impact on the *Lantana* population, it has even become a pest in horticulture, parasitizing the related fiddlewoods (*Citharexylum spp.*). The small *Lantana*-feeding moths, *Epinotia lanata* and *Lantanophaga pusillidactyla*, while not becoming pests, have nonetheless failed to stem the spread of the invasive weed, as has the *Lantana* Scrub-hairstreak butterfly (*Strymon bazochii*) which was introduced to control *Lantana* on the Hawaiian Islands. Biological control of *Lantana* by insects is reported to have met with some success in Hawaii and Fiji island; *Lantana* bug (*Orthezia insignis* Dougl.), *Lantana* seed fly [*Ophiomyia (Agromyza) lantanae* Frog] and *Lantana* lace bug (*Teleonemia scrupulosa* Stal) feed on stem, leaves flowers and seeds and prevent the spread of the plant. The introduction of the foreign insects into India for *Lantana* control has been attempted, but it has not been pursued pending further knowledge on the effect of introduction on other plants. Complete eradication of *Lantana* over large areas is difficult and costly (CSIR, 1962). Cultural control has been attempted by planting *Ricinus communis* Linn. or *Leucaena glauca* Benth., while in Srilanka, *Tithonia diversifolia* A. Gray is reported to have given good results (CSIR, 1962).

Besides mechanical and chemical control methods, burning is used as a method to control *L. camara*. This practice needs to be discouraged because it could promote - rather than check - the spread of *L. camara* in burnt areas. In this way a positive feedback between invasive species and fire occurs, which can result in major community- and ecosystem-level effects, changing local community dynamics, altering biodiversity, and generating long-lasting consequences on biogeochemical cycles (Hiremath & Sundaram, 2005).

Ecological Success of *Lantana*

It is difficult to attribute the success of *Lantana* to any one factor alone. The ability of invasive species to preemptively take advantage of resources (light, soil nutrients, space) following a disturbance, species poor ecosystem, lack of natural enemies to keep it in check, freedom from enemies, and antimicrobial or allelopathic chemicals they exude from roots, which may inhibit germination and establishment of other species in their new environments are several factors which could be responsible for aggressive invasion of *Lantana* in India (Sharma & Raghubanshi; <http://www.currentconservation.org>). There are some chemicals, such as Lantadene A (the active principle of *L. camara*) and Lantadene B (Louw, 1948), when released in surroundings these chemicals interfere and inhibits germination and growth of many species (Ambika et al., 2003; Bais et al., 2006). Equipped with these features, *L. camara* has potential to prevent natural regeneration of some tree species, block natural succession and replace native species (Morton, 1994; Ambika et al., 2003). Thus ultimately it threatens biodiversity of naturalized areas (Kohli et al., 2004). Niphadkar et al. (2016)

have reported that moist deciduous forests facilitate the growth and spread of *L. camara* in tropical hotspot regions of India.

Lantana possesses unique traits to withstand environmental stress in new environment such as fast spreading ability through vegetative and reproductive growth, wide adaptability and ecological adaptations. It propagates readily from stumps and cuttings and from seed, which are disseminated by birds through droppings. It regenerates quickly after cutting, trampling or burning and forms a dense impenetrable thicket and it becomes nearly impossible to eradicate this weed. For wide adaptation in the new environment it could undergo to genetic changes due to selection pressure and respond quickly to anthropogenic disturbances like other invasive plants (Sakai et al., 2001). Its proliferation and spread are attributed to a number of factors including natural propagation, high tolerance to herbicides and decreased competition from other weeds (Phillips & Tucker, 1976), and non-palatability and toxic to cattle.

What are the ecological mechanisms underlying the success and persistence of *Lantana*? One potential mechanism relates to its tolerance to being burnt. Hiremath and Sundaram (2005) has hypothesised that there may be a positive feedback between present-day fires and invasion by *Lantana*, leading to a fire-*Lantana* cycle that can have deleterious compositional and functional consequences for forest ecosystems. Recent findings from other parts of the tropics confirm that *Lantana* may be favoured by disturbances such as fire and grazing (Duggin & Gentle, 1998). In fact, recent evidence suggests that *Lantana* actually regrows more densely in response to being burnt (Gentle & Duggin, 1997). The high productivity of *Lantana* rapidly yields large quantities of biomass, which can fuel further fires (Bingelli et al., 1998). Thus, forests once colonized by *Lantana* can well fall victim to a fire-*Lantana* cycle, perpetuating *Lantana* to the detriment of other vegetation. A second potential mechanism underlying the success of *Lantana* is its ability to compete for scarce nutrients. *Lantana* is exceedingly efficient at nutrient uptake and use, enabling it to grow on highly impoverished soils (Bhatt et al., 1994; Rawat et al., 1994; Sharma & Raghubanshi, 2009). Such an ability to extract and use nutrients efficiently would give it a competitive advantage over other species in low-fertility environments (Tilman et al., 1997), for example, in forests already degraded by frequent burning. Finally, a third potential mechanism underlying the success of *Lantana* is its colonizing ability. *Lantana*'s abundant perennially available flowers and fruits make it a good host for pollinators and frugivores, respectively, and ensure a year-round supply of well-dispersed propagules. Even in places where *Lantana* is completely uprooted, it regenerates profusely from seeds in the soil seed bank and root suckers for several years following its removal. Thus, a complete eradication of *Lantana* requires repeated uprooting of successive crops for several consecutive years (Tireman, 1916). Thus, Key biological attributes of *Lantana* that make this species among the world's 100 worst invasive weeds include fitness homeostasis, phenotypic plasticity, widespread dispersal by birds that feed on its fruit, a broad geographic range, vegetative reproduction, fire tolerance, ability to compete effectively with the native flora, and allelopathy (Munir, 1996).

Conclusion

This review on ecology and use of *Lantana camara* highlights its biomass productivity, reproductive biology, invasiveness, allelopathy, eradication measures and economic

uses reported from India. Among its negative aspects, invasion into agricultural landscapes, forests and wastelands are the most important that cause deteriorates biodiversity, and harms commercial interests of farmers and foresters. Its allelopathic impacts are also notable on certain food crops, and its toxic effect on cattle is also an issue. Thickets of *Lantana* also provide shelter to wild animals and promote man-wildlife conflicts. *Lantana* acting as a vehicle of forest fire is the most serious issue that demands further research. In large tracts of our country it has emerged as the most obnoxious weed that demands heavy efforts for its eradication.

Among the positive aspects its industrial use in medicine, cosmetics and insect repellents alone has a vast potential. Another major area of its use has been found in raising soil fertility and soil and water conservation thus beneficial for agriculture. Among other uses, its huge biomass production potential for bio-energy, substrate for growing mushroom, tensile sticks for furniture, basket making and insect repellent in traditional granaries hold good opportunities for utilization of this weed for cottage industry. Good butterfly diversity can be found around *Lantana* flowers as this species is mostly pollinated by butterflies. Fruits are delicacy for many birds. It is thus useful as a honey plant and used for butterfly gardening. It can be pointed out that the positive impacts and economic uses may outweigh the negative impacts and require further studies on cost-benefit considerations for its management.

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