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Lantana camara: AN ALIEN WEED, ITS IMPACT ON ANIMAL HEALTH AND STRATEGIES TO CONTROL

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ABSTRACT

Lantana camara is one of the most commonly known noxious weed distributed worldwide. The red flower variety (*L. camara* var. *aculeata*) of this weed is mainly toxic and usually prevalent in tropical and sub-tropical countries. *Lantana* leads to hepatotoxicity, photosensitization and intrahepatic cholestasis almost in all the animals. LA is the main toxic pentacyclic triterpenoid present in this weed. Lantadene toxicity leads to fatty degeneration, bile duct hyperplasia, gall bladder edema, degeneration of parenchymal cells and portal fibrosis observed on histopathological examination. *L. camara* toxicity causes fluctuation in hematological as well as in biochemical parameters. The management of toxic effects can be achieved by activated charcoal, vaccination and supportive therapy but are not much effective. Besides the harmful effects of this plant, there are some beneficial effects also including anti-inflammatory, hepatoprotective action, antitumor action etc. The control of this weed is difficult because of its allelopathic action. Nowadays this plant is used in many recent advanced techniques like phytoremediation of particulate pollution, phytoextraction of heavy metals and many others. Thereby the use of this plant in the field of research can be an effective way to manage this alien weed. As far as the toxicity is concerned it can be prevented by the using conventional therapeutic methods along with immunological, nanotechnological and biotechnological approaches. The aim of this article is to discuss the information regarding its progression, mechanism by which it affect animals, pathological alterations, treatment and what strategies we can opt to get rid of this weed.

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1 Introduction

Toxic plants are of major concern to veterinarians because of their harmful effects to livestock in terms of causing mortality and reduction in productivity (Sharma et al., 2007; Diaz, 2011). The severity of toxic effects caused by poisonous plants varies among species and depends upon the nature, part and amount of toxic component taken, environmental conditions, species, age, size and body condition of the animals (Sharma et al., 2007). Along with the toxic effects to livestock, these invasive species are supposed to be the one of the major threat to biodiversity and ecosystem after habitat destruction (Drake et al., 1989; Holmes, 1990; Buckley & Roughgarden, 2004; De Milliano et al., 2010; Osunkoya & Perrett, 2011; Zhang & Chen, 2011). These invasive plants have turned to predators and are responsible for causing diseases in animals as well as in plants (Ehrenfeld, 2006; Chambers et al., 2007; Drenovsky et al., 2012).

Among poisonous plants *L. camara* is one of the most commonly known noxious (Pereira et al., 2003; Mello et al., 2005) and invasive weed worldwide (Palmer et al., 2000; Baars et al., 2003; Totland et al., 2005; Moura et al., 2009; Van Driesche et al., 2010). This weed is responsible to cause heavy mortality of livestock as well as responsible to cause loss of agro and forest ecosystem (Day et al., 2003; Mello et al., 2005; Sharma et al., 2007). *L. camara* Linn. was introduced as an ornamental shrub by a British in Calcutta Botanical Garden in year 1809, belongs to family Verbenaceae (Bouda et al., 2001; Kumar, 2001; Yadav & Tripathi, 2003; Munsif et al., 2007). The word Lantana is derived from a Latin word lento, which means "to bend" (Ghisalberti, 2000). This weed is locally known as *bunch berry*, *baraphulnoo*, *red or wild sage* (Sharma et al., 2007). This plant shows change in inflorescence with age and season that's why very difficult to classify taxonomically (Munir, 1996). The binomial name of this plant was given by Linnaeus in year 1753 (Kumarasamyraja et al., 2012). The main varieties of Lantana on the basis of flower colour includes Pink *L. camara*, White *L. camara*, Red *L. camara*, Pink edged red *L. camara* and Orange *L. camara*. Other important species of the genus lantana includes *L. indica*, *L. crenulata*, *L. trifolia*, *L. lilacina*, *L. involucrata* and *L. Sellowianse* but red flower variety (*L. camara* var. *aculeate*) is most toxic (Sharma et al., 2007). A pink variety of *Lantana camara* called as Taxon is usually grazed by animals in New Zealand and it is nontoxic (Black & Carter, 1985).

This plant attains a height of 2-3 m and the branches carry curved prickles. The leaves are oval, cuneate, rounded at the base and rugose and crenate at the upper portion, which are rough at maturity and give an offensive odor (Sharma et al., 2007). The fruits are greenish in early stages and become dark blue later on. The green immature fruits are poisonous, while the ripened dark blue fruits are tasty so often taken by birds as well as human beings (Sharma et al., 2007). Many species of lantana are native to Africa and America and has covered many of the neighboring countries (Day et al., 2003). But later

on this species has displaced the invertebrate population and other native populations in Africa (Samways et al., 1996). *Lantana camara* is among 100 most notorious weeds in the world and got entry approximately in 60 countries (GISD, 2010; Lüi, 2011). This weed has been found as a major weed in 12 countries and listed among the 5 most noxious weeds prevalent in Australia and has covered 60% pastures in Queensland (Holm et al., 1979; Anderson et al., 1983; Ghisalberti, 2000). This weed has replaced *Quercus leucotrichophora* and *Pinus roxburghii* forests in Kumaun hills (U.P.) (Bhatt et al., 1994); invaded the teak plantations in Tamil Nadu (Clarson & Sudha, 1997); covered Western Ghats (South India) (Muniappan & Viraktamath, 1993) and heart water region of Garhwal (U.P.) (Rajwar, 1998). In Himachal Pradesh, heavy outbreaks of lantana toxicity have been reported from Rampur Bushair and sporadic cases of toxicity have also been reported from cattle, buffaloes and small ruminants (Sharma, 1984).

In general for the success and impact of any weed many biotic and abiotic environmental factors are responsible (Sheppard et al., 2012). One of the most important factor for the huge prevalence of this weed throughout world is its phytotoxic or allelopathic action which is due to the presence of phenolic compounds (umbelliferone, methylcoumarin, salicylic acid etc.) and lantadenes i.e. LA (lantadene A) and LB (lantadene B) (Achhireddy et al., 1984; Jain et al., 1989; Singh et al., 1989; Ferguson & Rathinasabapathi, 2003). The suppressive allelopathic action of this plant has been seen on certain plant species like *Glycine max* (Linn), *Cyclosorus dentatus* Forsk, *Triticum aestivum* L., *Zea mays* L. and *Lolium multiflorum* Lam (Achhireddy et al., 1985; Sharma et al., 2007). This weed is mainly disseminated by droppings of moving animal flocks/ birds, cutting and pollination (Ghazoul 2002; Sharma et al., 2007).

2 Toxic components of *Lantana camara*

The most important toxic components present in this weed are lantadenes. Lantadenes are pentacyclic triterpenes (Table. 1) and often led to hepatotoxicity, photosensitization and jaundice (Sharma et al., 1979; Sharma & Makkar, 1981; Sharma et al., 2007). There are 2 forms isolated from lantana toxin i.e. crystalline and amorphous. The amorphous form is found to be icterogenic to guinea pigs (Sharma et al., 1988a). Among the known compounds present in lantana, LA is the most hepatotoxic component while certain other compounds like naphthoquinones, oil constituents (cital), iridoid glycosides (Theveside) and some of the oligosaccharides are of lesser importance as far as toxicity is concerned (Ajugose) (Dominguez et al., 1983; Abeygunawardena et al., 1991). The lantadenes are mainly present in the leaves of this plant (Sharma et al., 2007) having varying toxic effects among different species and strains of mammals/livestock. The toxic effects of this plant are evident both in ruminants as well as in non-ruminants (Sharma et al., 2007).

Table 1 Chemical compounds obtained from *Lantana camara* and their mechanism of actions.

S.No.	Action	Triterpenoids	References
1.	Hepatotoxic	LA, LB, LC, RLA and icterogenin	Brown et al., 1963; Johns et al., 1983a; Sharma et al 1991; Verma et al., 1997; Wachter et al., 2001; Khan et al., 2003; Srivastava et al., 2005; Kong et al., 2006; Parimoo et al., 2015
2.	Antimicrobial and antibacterial activity	LA, LB, oleanolic acid, ursolic acid, 4-Epihederagonic acid and 24-Hydroxy-3-oxours-12-en-28-oic acid	Brown et al., 1963; Sharma et al 1991; Inada et al., 1995, 1997; Verma et al., 1997; Wachter et al., 2001; Kong et al., 2006; Kumar et al., 2006; Barreto et al., 2010; Hussain et al., 2011; Sousa & Costa, 2012
3.	Protein kinase C inhibitor	Verbascoside	Herbert et al., 1991
4.	Anti-inflammatory	Oleanolic acid, ursolic acid and Oleanonic acid	Hart et al., 1976b; Johns et al., 1983b; Liu, 1995; Verma et al., 1997; Giner-Larza et al., 2001; Benites et al., 2009; Ghosh et al., 2010; Hussain et al., 2011; Sousa & Costa, 2012
5.	Antitumor	LA, oleanolic acid, ursolic acid, Camaraside and Lantalucratins A-F	Brown & Rimington, 1964; Seawright & Hardlicka, 1977; Mahato et al., 1994; Deena & Thoppil, 2000; Ghisalberti, 2000; Hayashi et al., 2004; Gomes de Melo et al., 2010; Bisi-Johnson et al., 2011
6.	Anxiolytic action (Psychiatric disorder)	UASG	Kessler et al., 1994; Awad et al., 2009; Kazmi et al., 2013
7.	Antitubercular	LA	Seawright & Hardlicka, 1977; Verma et al., 1997; Wachter et al., 2001; Kong et al., 2006
8.	Allelopathy	LA, Umbelliferone, Hydroxycoumarin, 6-methylcoumarin, Salicylic acid, gentisic acid, Vanillic acid and Quercetin	Brown et al., 1963; Johns et al., 1983a; Singh et al., 1989; Sharma et al 1991; Verma et al., 1997; Wachter et al., 2001; Kong et al., 2006; Verdeguer et al., 2009
9.	Antiviral	LA, LB, LC, RLA, RLB and 22beta-Hydroxy-3-oxolean-12-en-28-oic acid	Johns et al., 1983a; Inada et al., 1995
10.	Hepatoprotective	Oleanolic acid and ursolic acid	Hart et al., 1976b; Johns et al., 1983b; Singh et al., 1990, 1991; Liu, 1995; Siddiqui et al., 1995
11.	Leukotriene inhibitor	Oleanonic acid	Hart et al., 1976b; Johns et al., 1983b; Giner-Larza et al., 2001
12.	Anti-hyperlipidemic	Oleanolic acid and ursolic acid	Hart et al., 1976b; Liu, 1995; Liu, 2005; Mishra et al., 1997; Verma et al., 1997; Chen et al., 2005; Chen et al., 2006
13.	Antimutagenic	22beta-Dimethylacryloyloxylantanollic acid	Barre et al., 1997; Mello et al., 2005
14.	Nematicidal	Camarinic acid, Linaroside and Lantanoside	Siddiqui et al., 1995; Begum et al., 2000
15.	Antiprotozoal	Triterpnes from <i>Lantana montevidensis</i>	Mohameda et al., 2016
16.	Antithrombin	5,5-Trans-fused cyclic lactone containing euphane triterpenoids	O'Neill et al., 1998; Weir et al., 1998
17.	Antiproliferative	Apigenin, Cirsilineol, Eupafolin, Eupatorin and Hispidulin	Nagao et al., 2002
18.	Cardio active	Martynoside	Syah et al., 1998
19.	Insecticidal action	Bioactive molecules without any cross resistance	Seyoum et al., 2002; Dua et al., 2010; Rajashekar et al., 2012 a; Rajashekar et al., 2012 b; Rajashekar et al., 2012 c
20.	Anti-diabetic	UASG	Venkatachalam et al., 2011; Kazmi et al., 2013
21.	Inhibitor of larval hatch and exsheathing	Lantana decoction in combination with <i>A. zerumbet</i> , <i>M. villosa</i> and <i>T. minuta</i>	Macedo et al., 2012

Abbreviations: Lantadene A (LA), Lantadene B (LB), Lantadene C (LC), Reduced Lantadene A (RLA), Reduced Lantadene B (RLB), Ursolic acid stearyl glucoside (UASG)

Among ruminants cattle, buffalo and sheep are highly susceptible, while goats are little resistant to lantadene toxicity (Lal & Kalra, 1960; Sharma et al., 1988b; Sharma et al., 2007). Guinea pigs show most typical signs of lantana toxicity (Sharma et al., 1988b), while male rats are often resistant to lantana toxicity because of the action of testosterone (Pass et al., 1979a; Pass et al., 1985; Sharma et al., 1992; Sharma et al., 2007). The toxic effects of lantana have been seen in Kangaroos and Ostriches also (Johnson & Jensen, 1998; Cooper, 2007). Green fodder scarcity is the major causes of lantana toxicity in animals, mainly in those who are often sent to pastures without feeding any prior feed (Sharma & Makkar,

1981). In spite of having many toxic effects this weed is also having anticancer (Gomes et al., 2010; Sathish et al., 2011), antibacterial (Rwangabo et al., 1988; Barreto et al., 2010), antifungal (Sharma et al., 2007), anti-diabetic (Garg et al., 1997), anti-inflammatory, analgesic, antimotility (Ghosh et al., 2010), anti-feedant, larvae repellent (Moffitt et al., 2010), anticonvulsant (Bisi-Johnson et al., 2011), antiulcer and antioxidant actions (Sathish et al., 2011). Oleanolic acid and ursolic acid are the major components, while LA and LB are the minor constituents obtained from Townsville prickly orange variety of lantana (Hart et al., 1976a).

Figure 1 Flow diagram showing different chemical compounds present in *Lantana camara*.

Figure 2 Flow chart of absorption and mechanism of action of lantadenes.

3 Absorption and mechanism of action of lantadenes

This toxin has been found to be absorbed through entire GIT (gastrointestinal tract), mainly small intestine (Sharma et al., 2007). The retention time of lantadenes in GIT plays a significant role in progression of effect (Pass et al., 1981a). Bile has not been found to be having any role in toxin absorption.

L. camara mainly attacks liver and kidneys of ruminants and leads to photosensitization. The animals are died within 2-4 days in acute cases. In sub acute lantadene toxicity study a dose dependent mortality was reported (Parimoo et al., 2015). Sluggishness, weakness, bloody diarrhea, edematous ears and eyelids, cracks and fissures on muzzle and other non-hairy parts, conjunctivitis, ulceration of the tip and under surface of the tongue (if un-pigmented), pale conjunctival, vulvar or vaginal mucous membranes and sclera of eye are some of the clinical signs observed in lantana toxicity. The acute lantana toxicity can be induced either by the leaf powder or by partially purified lantadene powder (Sharma & Makkar, 1981). In sheep, the oral administration of lantadene leaf powder (at the dose of 4 and 8 g/kg body weight) leads to photosensitization, conjunctivitis and bile stained liver while administration of lantadene leaf powder in goats diarrhoea, anorexia and jaundice is evident, but no photosensitization has been seen (Obwolo et al., 1990). The LD₅₀ value of lantadene in sheep is 1-3 mg/kg body weight, when administered by intravenous route, while the LD₅₀ value is 60 mg/kg body weight when administered by oral route, because of show absorption (Nellis, 1997). The oral administration of lantadenes at the dose rate of

25 mg/kg body weight did not lead to mortality in guinea pigs, but produced hepatotoxic and nephrotoxic effects which were evident on histopathology and on biochemical estimation and were indicative of sub-acute toxicity (Parimoo et al., 2015). Transfer of lantana toxins to milk, placenta, or to the offspring has not been reported, but some teratological effects has been seen in rats (Mello et al., 2005; Sharma et al., 2007). Lantadenes are also having effect on reproductive system, as found to interfere with the sperm count, daily sperm production, and sperm morphology (Sharma et al., 2007).

4 Hepatotoxic action of lantadenes

Lantana toxins cause intrahepatic cholestasis along with the inhibition of bile secretions without widespread hepatic necrosis (Pass et al., 1979b). Hepatocellular damage precedes the intense and prolonged jaundice observed during lantana poisoning (Sharma et al., 2007). Significantly, in lantana toxicity, the cells located around the central vein remain normal, while parenchymal cells lying to the periphery of the liver are damaged. Generally, changes associated with intrahepatic cholestasis include dilation of bile canaliculi, loss of microvilli, alterations in enzyme activities and composition of the canalicular membrane (Trauner et al., 1998). Phylloerythrin, a degradation product of chlorophyll formed by the action of microorganisms in the GIT gets accumulated in the liver and leads to photosensitization (Rimington & Quin, 1934). This type of photosensitization is also called as hepatogenous photosensitization, which occurs due to the impaired hepatobiliary excretion (Kellerman & Coetzer, 1985). This impaired hepatobiliary excretion of phylloerythrin leads

to its accumulation in plasma. The inhibition of bile secretion leads to accumulation of bilirubin and ultimately leads to jaundice (Trauner et al., 1998). *L. camara* toxicity leads to collagen fibres formation in advanced stages, which extends into periportal areas of the liver and can be seen when stained with Foot's reticulin and Van Gieson stain (Gopinath & Ford, 1969).

5 Clinical signs (de Mello et al., 2003; Sharma et al., 2007)

The dose of lantadenes determines the severity of ictericity (Gopinath & Ford, 1969). The clinical signs follow a definite pattern as given below:

- I. Loss of appetite and decrease in ruminal motility (within 24 h)
- II. Photosensitization in un-pigmented areas leads to necrosis later on (within 24-48h)
- III. Icterus (yellowish sclera and other mucus membranes, within 48-72h)
- IV. In acute/ more severe cases (death within 2 to 4 days)
- V. In less severe cases (death within 1-3 weeks)
- VI. In female rats, fetal abnormalities, embryo toxicity and implantation losses have been reported

6 Pathology

Seawright (1965) was the first to study the effects of oral administration of lantana leaf extracts on guinea pigs and observed pathological lesions in heart, lungs, liver, gall bladder and kidneys.

C.

A. Gross pathology:

- I. Liver: Swollen, fragile, pale yellow, mottled with rounded edges (Sharma et al., 1991, 1992).
- II. Gall bladder: 3-4 times distended with dark opaque and viscous contents (Sharma et al., 2007).
- III. Kidneys: Swollen, pale and yellowish brown (Seawright & Allen, 1972).
- IV. Stomach: Gas accumulation (Sharma et al., 1991; Sharma et al., 1992).
- V. Mucus membranes: Pale (Sharma et al., 1991, 1992).

B. On histopathological examination lantadenes showed degeneration of the periportal parenchymal cells, distended bile canaliculi, fatty degeneration, portal fibrosis, hyperplasia of bile ducts, and edema of gall bladder walls in cattle (Dwivedi et al., 1971; Uppal & Paul, 1978). Hematological examination in cattle reveals, increase in blood clotting time and hematocrit values but decrease in erythrocyte sedimentation rate has been reported (Hussain & Roychoudhury, 1992). There was an increase in direct and total bilirubin, increase in the phyloerythrin levels, increase in serum AST, ALP, GLDH, serum total protein, serum albumin, and serum globulin and decrease in albumin/globulin ratio in cattle (Dwivedi et al., 1971; Seawright & Hrdlicka, 1977). The fibrous tissue formation is seen in chronic liver conditions irrespective of etiology, as in chronic diseases the myofibroblasts produce type 1 collagen which leads to fibrosis.

Table. 2 Histopathological alterations in different animal species.

S. No	Species	Histopathological alterations	References
1	Cattle	Degeneration of the periportal parenchymal cells, distended bile canaliculi, fatty degeneration, portal fibrosis, hyperplasia of bile ducts, edema of gall bladder in cattle.	Dwivedi et al., 1971; Uppal & Paul, 1978
2	Goats	Hemorrhages of inter-sinusoidal spaces, coagulative necrosis, cirrhosis and proliferation of bile ductules, fatty degeneration of proximal convoluted tubules of kidneys, proliferation of bile ductules in the liver occurs.	Sharma et al., 2007
3	Sheep	Centrilobular cells vacuolation with bile mainly in chronic cases.	Sharma et al., 2007
4	Guinea Pigs and Rats	Periportal vacuolar degeneration, fatty degeneration, haemorrhages, bile duct proliferation with yellow-brown bile plugs, portal fibrosis in liver. Fatty degeneration of PCT, vacuolar degeneration of tubular epithelium of cortex, hyaline cast in kidneys. Oedema and haemorrhagic ulcer in gall bladder. Subepicardial petechial haemorrhages in heart along with pulmonary oedema and haemorrhages in lung.	Sharma et al., 1992; Parimoo et al., 2015
5	Rabbits	Portal fibrosis, bile canaliculi dilatation, degeneration and swelling of hepatic cells, biliary hyperplasia, biliary cirrhosis in the liver. Tubular nephrosis, inflammatory interstitial reaction, degeneration of tubules in the kidneys.	Sharma et al., 2007

Table. 3 Hematological examination in different animal species.

S. No.	Species	Hematological parameters	References
1.	Cattle	Increase in blood clotting time and hematocrit values but decrease in erythrocyte sedimentation rate.	Hussain & Roychoudhury, 1992
2.	Sheep	Transient increase in the hematocrit value and neutrophils number but a decline in number of thrombocytes seen.	Seawright, 1963
3.	Goat	Progressive decrease in packed cell volume, hemoglobin, and total erythrocyte count while increase in leukocyte count and blood clotting time observed.	Ali et al., 1995
4.	Guinea pigs	Increase in hematocrit, erythrocyte and leukocyte number, hemoglobin and urea levels in acute lantana toxicity. Significant increase in PCV and TLC, but not in TEC observed in sub-acute lantadene toxicity study.	Sharma et al., 2007; Parimoo & Sharma, 2014

Table. 4 Biochemical Alterations in different animal species.

S. No.	Species	Biochemical Alteration	References
1.	Cattle	Increase in direct and total bilirubin, increase in the phylloerythrin levels, increase in serum AST, ALP, GLDH, serum total protein, serum albumin, and serum globulin and decrease in albumin/globulin ratio.	Dwivedi et al., 1971; Seawright & Hrdlicka, 1977
2.	Sheep	No change in the serum ALP, AST and ALT levels.	Seawright, 1963; Dwivedi et al., 1971
3.	Goats	Rise of serum bilirubin, AST, creatinine, GGT and BUN levels.	Obwolo et al., 1991
4.	Guinea pigs	Marked increase in conjugated form of bilirubin, AST, LDH, GLDH, BUN, ALT and SDH. No significant increase in total proteins, ACP and creatinine levels were observed in sub-acute toxicity of lantadenes while ALT, AST and ALP were significantly elevated.	Sharma et al., 1992; Sharma et al., 2007; Parimoo et al., 2015

7 Treatment

Specific treatment for lantana toxicity is still lacking, the preventive measures are more effective than curative measures to decline the harmful effects of this notorious weed (Oyourou et al., 2013), but there are some conventional treatment methods which can be applied (McSweeney & Pass, 1982; Sharma et al., 2007):

- I. Keep the intoxicated animals away from light; provide fluid therapy and adequate feed.
- II. Administration of activated charcoal 5g/kg body weight with electrolyte in stomach tube within 24h, which reduces the absorption of lantadenes.
- III. Administration of bentonite 5g/kg body weight. It is much cheaper than charcoal but takes longer time to show desired effect.
- IV. Administration of Tefroli powder obtained from *Tephrosia purpurea* plant.
- V. Oral administration of liver tonics like Liv-52.
- VI. Vitamin B-complex administration.
- VII. Enzymatic removal of bilirubin by bilirubin-oxidase, which is effective in jaundice.
- VIII. Herbal tea i.e. Yin Zhi Huang (YZH) from *Artemisia capillaries*, effective in neonatal jaundice.
- IX. Herbal plants like *Tinospora cordifolia*, *Ginkgo biloba*, *Berberis lycium* and *Hippophae salicifolia* also show ameliorative effect on *L. camara*-induced toxicity in guinea pigs. *Ginkgo biloba* has also shown the protective effect against CCl₄ (Shenoy et

al., 2001; Chavez- Morales et al., 2011) and rifampicin (Naik & Panda, 2008) leads to decrease ALT and AST levels when fed to rats. *Ginkgo biloba* also shows hepatoprotective action against glyphosate, uranium and CCl₄ toxicity, which are potent hepatotoxicant (Yapar et al., 2010; Cavusoglu et al., 2011; Guo et al., 2011).

- X. Vaccination can also be done but it is not an effective measure.
- XI. Bacterial strains like *Pseudomonas pickettii*, *Alcaligenes faecalis* and *Alcaligenes odorans* can be used which degrades the LA.
- XII. Rumenotomy can be done to evacuate the entire GI tract.

8 Prevention

It is the cost effective way of controlling the accidental introduction of lantana into the ecosystem. The different ways by which lantana infestation can be prevented includes (Priyanka et al., 2013):

- i. The international standards for trading partner countries in a well targeted form must be implemented.
- ii. The adequate surveillance and monitoring system for early detection of lantana infestation must be implemented.
- iii. Implementation of strict border controls, transport controls and quarantine methods should be followed.

- The biosecurity and quarantine system should be strengthened in an organized form.
- iv. Collaboration with government agencies, so that outline can be made to prevent the spread of lantana. Involvement of all the agencies concerned with invasive species management is must.
- v. Educate and communicate people regarding the harmful effects of this alien weed which can be done by organizing campaigns and training programs.

8 Control and Management

Against this alien weed 41 biological agents are introduced worldwide since 1902 which covers the largest and longest running control program for weed control, but no satisfactory success has been achieved till date (Baars & Naser, 1999; Sheppard, 2003; Zalucki et al., 2007). In past years a huge man power and different ways were used to eradicate lantana. Many mechanical, biological techniques, use of fire etc. were used in India but no success was achieved. In Australia (Haseler, 1979) and South- Africa (Marsh, 1978) efforts were made to eradicate this weed but everything was vain.

9 Strategies which can be opted for controlling *L. camara* includes

1. Monitoring of lantana population by mapping, remote sensing, GPS/GNSS techniques and satellite; assessment and implementation of control measures like crop rotation, sowing the pastures, plantation etc. are the key steps to be taken for successful control of this alien weed (Priyanka et al., 2013).

2. The maximum use of this weed in our routine life can decrease the incidences of its prevalence. So, the small scale research projects can be supported to utilize this plant in many different ways like:

- i. Train the people for making furniture, baskets, mosquito repellent cakes, incense sticks etc. from lantana. This method is followed in few states of India like Tamil Naidu.
- ii. This plant is a part of folk medicines for many ailments like cancers, asthma, respiratory infections etc. (Deena & Thoppil, 2000; Ghisalberti, 2000; Bevilacqua et al., 2011). In many parts of the world, this weed is used in the treatment of many ailments like wound healing, scratches, rheumatism, fever, toothache, rashes and malaria (Chharba et al., 1993; Ghisalberti, 2000; Silva et al., 2005). Because of its multifarious applications in health, this weed is also called as traditional and tropical folk medicinal plant (Taviano et al., 2007; Awad et al., 2009; Moffitt et al., 2010; Pour & Sasidhara, 2011).
- iii. In India because of human health concerns and environmental hazards the insecticides are never mixed with grains, and biofumigants are often proven as very good model against the insects and

have no risk of cross resistance as well (Rajashekar et al., 2012a; Rajashekar et al., 2012b). The extracts obtained from different parts of lantana have many beneficial properties like anthelmintic, antibacterial, anti-ulcerogenic, anti-inflammatory, termiticidal, antifungal, antiprotozoal, antipyretic and many more (Siddiqui et al., 1995; Barre et al., 1997; Kumar et al., 2006; Rajesh & Suman, 2006; Hussain et al., 2011; Sousa & Costa, 2012). The leaves of this weed contain many bioactive compounds and also have insecticidal activities (Khan et al., 2002; Dua et al., 2010; Rajashekar et al., 2012c).

- iv. Essential oils obtained from *L. camara* leaves have adulticidal activity against mosquitoes (Dua et al., 2010). The essential oils obtained from the leaves and flowers of this weed, also shows fumigant action (Alitonou et al., 2004; Zoubiri & Baaliouamer, 2012).
- v. The leaf extracts of this weed are having inhibitory effect on aquatic weeds like *Microcystis aeruginosa* and *Eichhornia crassipes* (Sharma et al., 2007; Rai, 2013) and are often used for controlling pests and almond moths in an environment friendly way (Gotyal et al., 2010; Rajashekar et al., 2012c; Rajashekar et al., 2013).
- vi. It also improves the hydraulic properties which is often beneficial to certain crops like wheat and rice (Bhushan & Sharma, 2005; Rai, 2013).
- vii. The fruit eating populations consume dark blue ripened fruits of this plant as a food (Gosper & Vivian-Smith, 2006; Sharma et al., 2007; Rai, 2013). So it can be used as a source of food.
- viii. The methanolic extract of *L. camara* can reduce lipid peroxidation and can elevate the level of glutathione, thereby can prevent free radicals induced damage (Loganayaki & Manian, 2010; Sathish et al., 2011). *L. camara* along with *L. montevidensis* shows antioxidant activity (Sousa et al., 2015).
- ix. This weed can be used as a bio-fuel and in Kraft pulping (Naithani & Pande, 2009; Bhatt et al., 2011).
- x. *Lantana camara* nowadays is being utilized for vermicomposting (Hussain et al., 2015).

3. Chemical control includes the use of chemical weapons like Brush killer 64, Gramoxone, Bladex-H etc. which can reduce the spread of lantana.

4. The biological control is supposed to be the cost effective and long term solution to get rid of this alien weed (Hunt et al., 2008). Risk assessment is most effective tool to check the stability of biological control agents used against lantana (Arnett & Louda, 2002; Baars, 2003; Berner & Bruckart, 2005; Briese, 2005; Sheppard et al., 2005; Wright et al., 2005; Ding et al., 2006; Hunt et al., 2008). Biological control includes:

Table. 5. List of some useful products obtained from different parts *L. Camara*.

S. No.	Part	Compounds	Action
1.	Leaves, stem	Oleanonic acid	Anti-inflammatory
2.	Leaves, stem, roots	Oleanolic acid	Antimicrobial, antitumor, anti-inflammatory
3.	Aerial parts	Camarinic acid, Lantanoside	Nematicidal
4.	Leaves	Lactones containing euphanes	Anti-thrombin
5.	Leaves	Apigenin	Anti-proliferative
6.	Leaves	Camaraside	Antitumor
7.	Leaves and branches	Martynoside	Cardioactive

(Sources: Sharma et al., 2007; Hussain et al., 2011; Sousa & Costa, 2012)

- i. Use of certain biological agents like plume moth (*Lantanophaga spp.*), seed fly (*Ophiomyia spp.*), fungus (*Corynespora cassiicola*) (Pereira et al., 2003) and Tingid bug (*Leptobyrsadecora*).
 - ii. Some of the plants like *Aconophora compressa* and *Citharexylum spinosum* can be introduced for the biological control of this weed as in Australia (Palmer et al., 1996; Dhileepan et al., 2006; Manners & Walter, 2009; Manners et al., 2010).
5. In some of the states like Himachal Pradesh the state forest department has introduced a "Cut Root Stock (CRS)" method for the eradication of this weed.
6. Use of lantana in research can be done e.g. the ripened berries of lantana are often used for preparing silver nanoparticles nowadays (Kumar et al., 2015).
7. In many metal polluted tropical and sub-tropical countries this weed is used in phytoextraction of heavy metals especially lead (Jusselme et al., 2012; Jusselme et al., 2013; Jusselme et al., 2015) and phytoremediation of particulate pollution (Rai, 2012; Rai, 2015a; Rai, 2015b).

10 Differential diagnoses

It is little bit difficult to differentially diagnose lantana toxicity from other plant toxicities, because almost similar kind of lesions and symptoms are produced by these plants e.g. *Senecia*, *Crotolaria*, *Helenium spp* (Sneezeweed) produce hepatotoxicity like lantana poisoning. The oak poisoning also produces similar signs. Therefore clinical history, clinical signs, presence of plant in feed and ruminal contents are quite informative to assess the lantana toxicity.

Conclusion

L. camara is an invasive toxic weed which is dominating globally and is capable of over-run neighbouring young

plantations. The allelopathic effect is the major contributor for hampering the growth of surrounding vegetation and flare up wherever it finds place. The lantadenes are the major toxic components present in this plant which are responsible to cause toxicity in almost all the animals thereby leads to economic losses to the farmers by causing diseases and mortality. Specific treatment for lantana toxicity is not available and only preventive measures are supposed to be more effective. Certain methods for the management of toxicity are often used but are not much effective. Besides many harmful effects this weed is having many advantages. But the harmful effects often supervenes the utility of this weed. So, it is very important to develop the measures to control this weed in a desirable and cost effective way. Many approaches are applied to destroy this weed but most of them are not effective. Only the utilization of this plant is supposed to be an effective method for managing this weed. This utilization approach can only be capable to get rid of the negative impact of this weed on environment and can help to promote economic upliftment of rural economy. It is also very important to develop rational therapies against lantana toxicity by using immunological and biotechnological approaches, so that along with utilization the therapeutic measures can be evolved for livestock treatment. Already many pharmacological effects of this weed have been known, but still there is a scope to use this plant in the field of nanotechnology and therapeutics which can provide long term solutions to avoid the cruelty of this weed to the livestock, mankind, vegetation and our ecosystem.

Conflict of interest

Authors would hereby like to declare that there is no conflict of interests that could possibly arise.

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