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Lantana camara: A review on ecology, invasion and management strategies

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Abstract
Lantana camara is an invasive perennial shrub indigenous to the subtropical and tropical regions of the Americas, with certain taxa also native to tropical Asia and Africa. This species has successfully naturalized in more than 60 nations and is regarded as one of the globe's 100 most notorious invasive weeds. The rapid propagation and adaptability of *Lantana camara* are ascribed to its powerful reproductive potential, efficient dispersal mechanisms and its competitive superiority over indigenous flora. The invasive nature of this weed has negatively affected the biodiversity, disturbed the ecosystem and displaced native plant species. Initially introduced either intentionally for its ornamental purpose or unintentionally through trade and agricultural practices, *Lantana* has flourished across a variety of habitats, particularly in regions situated between 35°N and 35°S latitude. The plant's capacity to alter ecosystems, exploit ecological niches and withstand adverse environmental conditions significantly enhances its potential for invasiveness. Furthermore, it presents challenges to agricultural practices, diminishes forage availability and modifies nutrient cycling and soil fertility. Effective management of *Lantana camara* necessitates a multidisciplinary strategy, encompassing preventive measures, mechanical eradication, chemical management and biological interventions. A comprehensive understanding of its invasion history, biological traits and dispersal mechanisms is imperative for the formulation of targeted strategies aimed at mitigating its spread. Insights into its introduction and population origins can assist in identifying vulnerable phases and enhancing the effectiveness of biological control agents. Thorough research and coordinated management initiatives are vital to alleviating the ecological and economic consequences associated with this invasive species.

Keywords: *Lantana camara*, invasive, biodiversity, ecosystem disruption, management, biological

Introduction

Invasive species encompass flora, fauna, or microorganisms that have been introduced to a specific geographical area where they were not previously reported (Anderson *et al.*, 2014) [1]. These organisms invade upon new territories and proliferate at an accelerated rate, often outcompeting native flora (Crowley *et al.*, 2016) [2]. Their introduction may occur either intentionally or accidentally through various activities such as commerce, transportation, tourism, contamination of agricultural products, and ornamental or pest management practices (DeGolia *et al.*, 2019) [3]. Following their introduction, invasive species demonstrate rapid population expansion owing to the absence of natural predators within their newly acquired ecosystems. A wide range of characteristics supports the vigorous proliferation of invasive species, including a high reproductive capacity, resilience to adverse environmental conditions, effective dispersal mechanisms, allelopathic traits and a lack of competitors. These species represent substantial threats to ecosystems and biodiversity by occupying ecological niches that were formerly utilized for agricultural purposes and displacing indigenous plant and animal populations (Bampfylde *et al.*, 2010; Barney *et al.*, 2010) [4, 5]. Their presence disrupts nutrient cycling, reduces soil fertility and frequently leads to competition with livestock for available forage resources. Furthermore, invasive species may pose public health threats, acting as allergens, irritants, or vectors for numerous diseases. On a global scale, various species have been introduced into different regions, either purposefully for their perceived benefits or inadvertently as contaminants.

Most common examples include *Lantana camara, Parthenium hysterophorus and Eichhornia crassipes* etc. These species have emerged as significant ecological challenges, necessitating effective management and control strategies to alleviate their impacts on native ecosystems and human livelihoods.

Lantana camara [L.] (Verbenaceae), commonly known as wild sage, is a perennial, broadleaf invasive species that belongs to the order Lamiales. The term *Lantana* is derived from the Latin term lento, signifying "to bend" (Ghisalberti, 2000) [6]. In the year 1753, the binomial nomenclature for this plant was established by Carl Linnaeus (Kumarasamyraja *et al.*, 2012) [7]. Under optimal conditions, this shrub can attain a height ranging from 0.5 to 2 meters (Negi *et al.*, 2019) [8]. *Lantana* is native to subtropical and tropical America; however, several taxa are indigenous to tropical Asia and Africa (Nayar, 1977) [9]. It has now naturalized in approximately 50 countries, where various species are cultivated for their floral attributes under hundreds of cultivar names. The total number of *Lantana* species varies from 50 to 270 specific and sub-specific entities (Munir, 1996) [10]. It has become established in roughly 60 countries or island groups located between 35°N and 35°S and is recognized as one of the world's 100 most notorious weeds (Lowe, 2007; Lui, 2011) [11, 12]. Its invasive characteristics are associated with significant declines in native species diversity through ecological limitations, competitive interactions and modifications to ecosystem structure and functionality (Bhatt *et al.*, 1994; Fensham *et al.*, 1994; Swarbrick *et al.*, 1995; Gentle and Duggin, 1998; Sharma *et al.*, 2005; Kohli *et al.*, 2006; Dobhal *et al.*, 2009) [13-19]. The geographic distribution of *Lantana camara* is not only expanding across various territories, but the intensity of infestations within its established range is also increasing, thereby being acknowledged as a potential ecological threat (Sharma and Raghubanshi, 2006; Kimothi *et al.*, 2010; Lui, 2011) [20, 21, 12].

The accelerated growth and dispersal of *Lantana* weed significantly enhance the likelihood of its successful establishment in new regions. Effective management of this invasive weed requires understanding its introductions and origin of its populations, as this provides critical insights for developing strategies, including the selection and application of biological control agents. By reviewing its invasion history, biological characteristics and dispersal mechanism, the most vulnerable stages during its introduction and spread can be identified. Managing this weed effectively requires a combination of preventive, mechanical, chemical and biological methods. To achieve this, it is essential to thoroughly study its biology, dispersal mode and interaction with environmental conditions.

Invasion history and distribution of *Lantana camara*

Lantana camara, a species indigenous to the Americas, extends its range from the southern United States (specifically Florida and Texas) to the northern regions of Argentina and Uruguay. Since its introduction into various regions for ornamental purposes, it has proliferated aggressively across Mexico, the Bahamas, the Greater Antilles and northwestern South America (Sanders, 2006) [22]. Currently, *Lantana* has become naturalized in approximately 70 nations, including India, situated within the latitudinal confines of 35°N and 35°S (Day *et al.*, 2003) [23]. The distribution of *Lantana camara* continues to broaden, with infestations documented in numerous new countries and islands over the preceding three decades (Waterhouse and Norris 1987; Denton *et al.*, 1991; Harley, 1992) [24, 25, 26]. The genus comprises four sections, including Sarcolippia and Rhytocamara, which contain a limited number of species; Calliorheas, which is more diverse and extensive than the first two (including the species *Lantana montevidensis*) and Camara, which encompasses three species: *Lantana urticifolia*, *Lantana hirsuta* and *Lantana camara*. *Lantana camara* displays a range of chromosome numbers, including 2n = 22, 33, 44 and 55, although the majority of invasive forms are tetraploids (Day *et al.*, 2003) [23].

This species shows luxuriant growth at altitudes reaching 1800 meters above sea level across tropical, subtropical and temperate biomes (Parsons and Cuthbertson, 1992) [27]. Dutch navigators imported *Lantana* from Brazil to the Netherlands during the latter part of the 17th century and subsequently explored its distribution across tropical, subtropical and temperate zones (Sharma *et al.*, 1988) [28]. Throughout the 18th and 19th centuries, horticulturists commercialized and distributed various cultivars of *Lantana*, resulting in its global cultivation as an ornamental entity. *Lantana camara* was introduced to India in 1809 at the Calcutta Botanical Garden, having been imported from the Kew Botanical Garden in London as an ornamental plant (Muniappan and Viraktamath, 1993; Brandis, 1882; Kumar, 2001) [29, 30, 31]. Following the introduction of several invasive alien species, including *Lantana camara*, these plants have proliferated across various regions within India, encompassing the Western Ghats and tropical moist rainforests (Murphy, 2001) [32]. *Lantana* has occupied nearly all ecological niches, including roadsides, railway corridors, wastelands, tea plantations and forests, resulting in considerable ecological and economic losses (Soumya and Sajeev 2020) [33]. In India, *Lantana camara* has been reported in various regions, including the foothills of the Nainital district (Hakimuddin, 1929) [34], Garhwal (Rajwar, 2007) [35], the Kumaun hills of Uttarakhand (Bhatt, 1990) [36] and the non-cropland hilly areas of Himachal Pradesh (Angiras, 2014) [37]. It has encroached upon approximately 13.2 million hectares of Indian pasture lands in addition to forest and fallow regions. *Lantana camara* is extensively distributed across tropical and sub-tropical zones, including the protected forested areas of India. In the Garhwal Himalaya (north India), two species, namely *Lantana camara* and *L. indica*, have been observed thriving abundantly across all habitats within the submontane and montane zones up to an altitude of 2000 meters (Dobhal *et al.*, 2010; Bisht *et al.*, 2012) [38, 39]. It is widely disseminated in both tropical and sub-tropical forests, primarily associated with *Acacia catechu, Dalbergia sissoo, Pinus roxburghii, Shorea robusta, Tectona grandis* and other evergreen and miscellaneous forest types (Ray & Ray, 2014) [40].

Ecology of *Lantana camara*

The phenological patterns of *Lantana camara* indicate that the initiation of vegetative bud production occurs during the last week of March and persists until mid-April, with leaf development continuing until mid-August (Bhatt, 1990) [36]. The duration of leaf longevity approximates 267 days, characterized by a mature leaf weight of 226 mg and a fully expanded leaf area of 18 cm². The onset of leaf senescence commences in early December, resulting in the complete loss of foliage by the end of February. *Lantana camara* exhibits an annual growth rate of up to 20 cm and can attain a height ranging from 1 to 2 meters (Shimizu, 1983) [41]. The robust growth and considerable foliage density of this invasive species effectively exploit the ecological niche during the warm and humid rainy season (Negi, 1989) [42]. The flowers of *Lantana*, referred to as umbels, showcase a vibrant blend of red, orange, yellow, pink and white shades. Upon maturation, the flowers undergo a color transformation, resulting in inflorescences that exhibit a combination of two to three colours. Flowering typically occurs throughout the year, although a significant frequency of blooming is recorded during the moist summer months, extending until mid-November. Following a two-week flowering period, fruit development occurs, with fruits producing on the bushes until mid-December. The presence of mature fruits and flowers on the bushes for a duration of 4-5 months provides opportunities for pollinators and seed dispersal agents, thereby facilitating the species' proliferation. The primary pollinators of *Lantana* include butterflies and thrips, with sunbirds being particularly prevalent in India (Schemske, 1976; Hilje, 1985) [43, 44]. *Lantana camara* exhibits both self-pollination and cross-pollination mechanisms, with nearly all cultivars being self-compatible and predominantly pollinated by thrips. Following pollination, the flower color transitions from yellow to pink, resulting in the formation of multi-coloured inflorescences. The fruits of *Lantana camara* are small, greenish-blue to black, globose structures with a diameter of approximately 5 mm, predominantly produced during the monsoon season. The fruits are typically hard and green, transitioning to a fleshy and purplish-black state upon maturation (Stone, 1970) [45]. Factors such as seed dormancy, low seed viability, and meiotic instability contribute to a germination percentage that ranges from 4% to 45% (Duggin & Gentle, 1998; Sahu & Panda, 1998) [46, 47]. Nevertheless, the low mortality rate of seedlings coupled with rapid vegetative growth compensates for this shortfall (Sahu & Panda, 1998) [47]. The warm temperatures, exposure to sunlight and high soil moisture content serve to stimulate germination in *L. camara*. Fruit dispersal predominantly occurs via frugivorous birds (most notably the Mynah bird), although it is also facilitated by goats, sheep, cattle, monkeys, foxes and rodents. *L. camara* exhibits a tendency for vegetative reproduction. The germination rate of fresh seeds is relatively low; however, passage through the digestive tracts of birds and mammals enhances germination percentage. High light intensity and soil temperature further promote seed germination, implying that deforestation, inappropriate burning and other disturbances may facilitate the spread of this invasive species. Seeds possess the capability to pass extreme heat during fires. Its growth is further encouraged by disturbances such as mild fires, cutting, pruning, and grazing. Raizada and Raghubanshi (2010) [48] reported that seeds subjected to smoke exhibit earlier germination compared to non-smoked seeds; thus, fire may serve to enhance seed germination in *L. camara*. Moreover, seedling mortality is observed to be lower in the case of seeds exposed to smoke.

Management Strategies

Various methods such as preventive, mechanical, cultural, chemical and biological, have been tried to control the Lantana proliferation.

Prevention

Prevention represents a highly efficient approach for the management of invasive species like *Lantana camara*, with the objective of preventing their spread and mitigating detrimental impacts on the environment, society and economy. An efficient method prioritizes the identification of introduction pathways and the execution of measures to control them, including the inspection of species at points of entry and the enhancement of public awareness to modify behaviours that facilitate their spread. The steps taken to prevent the proliferation of *Lantana camara* include the enhancement of cooperative efforts among agencies such as the Plant Quarantine Division, the National Bureau of Plant Genetic Resources (NBPGR) and the Ministry of Environment & Forests to enhance biosecurity initiatives. The enforcement of quarantine protocols, the regulation of import permits and the coordination of cross-border activities are imperative, in addition to the identification and targeting of invasion pathways through dedicated programs. The formulation of more stringent international standards for species exports, particularly in relation to principal trading partners, coupled with the execution of national risk assessments for the translocation of goods, can further mitigate associated risks. Systematic evaluations of border control mechanisms, transportation infrastructures and quarantine protocols are requisite to address technical deficiencies and enhance overall coverage. The dissemination of updates among agencies responsible for invasive species management ensures enhanced preparedness, while intergovernmental collaboration on road maintenance strategies may assist in curtailing the introduction and spread of *Lantana camara*. By emphasizing these preventive strategies, the potential threat posed by invasive species can be substantially diminished.

Mechanical control

This method involves the use of physical techniques, including manual cutting, uprooting, slashing and burning, to prevent the dissemination and reestablishment of *Lantana camara*. In proximity to agricultural terrains or water bodies where chemical control was not effective, mechanical control strategies are frequently utilized. *Lantana camara* predominantly regenerate from its rootstock, which constitutes the principal food reserve for the invasive species. For effective management, it is important that *Lantana* shrubs be entirely uprooted, ensuring that no rootstock remains within the soil (Tireman, 1916; Pereira, 1919) [49, 50]. Subsequent to uprooting, both the above-ground and below-ground biomass must be thoroughly burned, thereby eliminating any food reserves that could facilitate regeneration. For sustainable management of *Lantana camara*, regular surveillance and mechanical interventions are necessitated. An additional management tactic involves stumping the shrubs to a height of 30.5 cm during the months of February or March, followed by burning. During the monsoon period (June to September), when the soil exhibits porosity, the stumps ought to be uprooted. If regrowth occurs, uprooting must be done following each cutting for a duration of 2-4 years (Babu *et al.*, 2009; Love *et al.*, 2009) [51, 52].

In Himachal Pradesh, six cuttings of *Lantana camara* annually at intervals of 45 days commencing in March, or four cuttings at the same interval beginning in July, effectively depletes the nutrient reserves within the roots. This strategy has the potential to completely kill the plant, thereby preventing any chance of regeneration (Singh and Angiras, 2011) [53]. Among the mechanical methodologies, cutting and burning are notably effective for weed management; however, the combination of uprooting, alongside cutting and burning, is superior for fostering the recovery of indigenous flora (Sundaram *et al.*, 2018) [54]. While these approaches offer immediate, effective and environmentally sustainable management solutions, they are not devoid of certain drawbacks, including substantial labour demands, increased financial expenditure, soil disruption, biodiversity disturbance and the potential for regeneration from rootstocks. Therefore, to increase the efficacy of mechanical strategies, they are frequently integrated with herbicide applications and the cultivation of fast-growing grasses.

Chemical control: The chemical management of *Lantana* *camara* represents a prevalent methodology employed for the effective control of this invasive species. This approach proves particularly advantageous in regions where mechanical control yield suboptimal results. The application of herbicides presents a cost effective and efficient strategy to supress the proliferation of *Lantana camara*. Herbicides primarily function by disrupting essential physiological processes within the plant, ultimately resulting in the depletion of both above and below ground nutrient reserves. Systemic herbicides targeting broadleaf perennial weeds, such as glyphosate, fluroxypyr, 2,4-D and aminopyralid are effective in its management (Table 1). Notably, the timing of herbicide application is paramount in optimizing their effectiveness. Application of herbicides during active growth periods enhances the absorption and subsequent translocation throughout the plant system. For the sustainable management of this invasive species, the control regime is systematically divided into three distinct phases; the initial phase involves cutting bushes to ground level during the months of August and September, followed by the second phase where glyphosate (0.31%) and a surfactant (0.1%) are applied to the 30-45 cm regenerated foliage one-month post-cutting. Finally, the area is transitioned to cultivation of fast-growing perennial grasses such as Setaria, NB-37 and Guinea grass (Angiras 1988) [55]. Furthermore, an experimental study conducted by Ferrell *et al.*, (2011) [56] in Pasco County and Lake County, Florida, USA. In 2007, the herbicides used comprised aminopyralid (0.12 kg ha^{-1}), aminopyralid combined with 2,4-D (0.12 + 1 kg ha^{-1}), fluroxypyr (0.56 kg ha^{-1}) and fluroxypyr in combination with aminopyralid (0.56 + 0.12 kg ha^{-1}). These herbicides were applied either as a single treatment in the autumn or in a sequential manner, consisting of a fall application succeeded by an additional application in the spring. In 2009, the identical herbicides were employed, with the inclusion of aminocyclopyrachlor (0.21 kg ha^{-1}). Among all the herbicides assessed, *Lantana camara* can be proficiently managed through two applications of aminocyclopyrachlor, applied in both the fall and spring, achieving a complete control rate of 100 percent after one-year post-treatment. Nevertheless, the single application of herbicides is effective only for short-term. For long term control of *Lantana*, the repeated herbicide applications are necessary until the depletion of food reserves is fully achieved. A research study conducted in Kathua, Jammu & Kashmir revealed that the application of glyphosate (1%) to 30 cm regenerated shrubs of *Lantana camara*, followed by the introduction of improved grass species (Napier and Setaria), resulted in a significant and effective control of the weed, with a recorded biomass reduction of 99 percent (Sharma *et al.*, 2012) [57].

Tranter *et al.*, (2013) [58] undertook an investigation to assess three distinct treatment methodologies for addressing the infestations of the aggressive invasive alien plant species *Lantana camara* in Swaziland. The treatments comprised of cut stump treatment (picloram at 0.1 percent along with mineral oil at 0.5 percent), foliar application of herbicide (picloram at 0.75 percent along with mineral oil at 0.5 percent) and manual removal. Foliar application emerged as the most effective method for plants measuring less than 1.5 meters, while cut stump treatment demonstrated superior effectiveness in more densely populated areas. However, combinations of glyphosate with 2,4-D (Na) at 1.00 l + 0.5 kg ha^{-1}, glyphosate ammonium (79.2 percent) at 4.356 and 2.178 kg a.i. ha^{-1}, and glyphosate ammonium (71.0 percent) at 2.13 kg a.i. ha^{-1}, alongside glyphosate at 1.5 l ha^{-1}, recorded comparable efficacy in reducing the population of *Lantana camara* across all observational stages, with the exception of 30 days after the start of the experiment (DASE) during the monsoon season, as reported by Tanha *et al.*, (2019) [59].

At Shiwalik Hills of Punjab, chemical treatment (Glyphosate 1.0% spray at stump level) and the introduction of four fast-growing species, namely *Dendrocalamus strictus, Leucaena leucocephala, Albizia procera, and Melia azedarach* alongside Lantana, have indicated that the establishment of fast-growing species inhibits the growth of *L. camara* and contributes to the enhancement of biomass of palatable species within a brief timeframe of 2 to 3 years (Luna *et al*., 2009) [60]. In recent years various herbicides have been used for the management of Lantana camara. The application of 2,4-D (10%) to the cut ends has proven to be effective. The experiments conducted at India at the Agricultural Research Station in Ambalavayal and the Fruit Research Station in Kallar (Madras) have revealed that lantana bushes trimmed to a height of 60 cm above ground followed by spraying with 2,4,5-T using Teepol as a wetting agent, exhibited wilting within 15 days. In a trial at the Forest Research Institute in Dehradun revealed that 2,4,5-T n-butyl ester is effective on *Lantana* bushes in the absence of prior cutting.

Nevertheless, the spread of *Lantana camara* is extensive throughout India, including Himachal Pradesh, but its effective management remains a challenge. The most commonly used herbicides for its management include glyphosate, 2,4-D and aminopyralid, however, their utilization raises concerns regarding potential adverse effects on human health and environment. In light of above, there is need to assess novel herbicides that are not only effective but also improved the environmental safety and sustainability.

Table 1: Herbicides for the control of *Lantana camara*

Herbicides	Dosages	References
Picloram	0.1% and 0.75%	Tranter *et al.*, 2013 [58]
Glyphosate	1.5%	Luna *et al.*, 2009 [60]
Aminopyralid	0.12 kg ha^{-1}	Ferrell *et al.*, (2011) [56]
Aminopyralid + 2,4-D	0.12 + 1 kg ha^{-1}	Ferrell *et al.*, (2011) [56]
Fluroxypyr	0.56 kg ha^{-1}	Ferrell *et al.*, (2011) [56]
Fluroxypyr + aminopyralid	0.56 + 0.12 kg ha^{-1}	Ferrell *et al.*, (2011) [56]
Aminocyclopyrachlor	0.21 kg ha^{-1}	Ferrell *et al.*, (2011) [56]
Glyphosate + 2,4-D (Na) at	1.00 l + 0.5 kg ha^{-1}	Tanha, (2019) [59]

Biological control

Biological control of *Lanata camara* has constituted a unified global initiative since the year 1902, encompassing the utilization of 41 biocontrol agents across 50 nations (Julien & Griffiths, 1998) [61]. These bioagents function by specifically targeting the leaves, flowers, fruits, stems and roots of the plant, thereby reducing its growth and reproductive capabilities. Among the biocontrol agents are *Teleonemia scrupulosa* (lace bug), which consumes *Lantana* leaves, resulting in defoliation and weakening of the plant (Sharma *et al.*, 1988) [28]; *Asphondylia lantanae*, a flower-feeding organism that diminishes seed production through floral damage (Angiras, 2014) [37]; *Homona micaceana*, a fruit borer that devastates seeds, thereby limiting reproduction (Angiras, 2014) [37]; *Plagiohamus spinipennis* and *Epinotia lanata*, both stem and root borers that inflict damage upon vascular tissues, leading to structural deterioration (Angiras, 2014) [37]; *Orthezia insignis*, a sap-sucking insect that exhausts essential plant nutrients (Negi *et al.*, 2019) [8]; *Ophiomyia lantanae* (Negi *et al.*, 2019) [8], a seed fly that compromises the viability of *Lantana* seeds; and *Aceria lantanae*, a mite that induces galls, further inhibiting plant growth (Urban *et al.*, 2011) [62] (Table 2). The efficacy of these biocontrol agents has been somewhat constrained, as evidenced in Hawaii and Fiji, wherein *Teleonemia scrupulosa*, *Ophiomyia lantanae* and *Orthezia insignis* have managed to limit *Lantana* growth by as much as 40% (Cilliers, 1987; Day and Neser, 2000; Urban *et al.*, 2011) [63, 64, 62]. Similarly, Australia has witnessed the introduction of approximately 30 biocontrol agents; however, *Aconophora compressa*, *Epinotia lanata* and *Strymon bazochii* have not succeeded in significantly impacting *Lantana* populations and in certain instances, they have emerged as pests of other flora (Negi *et al.*, 2019) [8]. The biological control of *Lantana* has predominantly achieved limited success due to multiple factors, including inherent variability that renders *Lantana* resistant to numerous agents, climatic fluctuations that hinder the survival of biocontrol mechanisms in diverse climatic contexts and the implications for non-target plant species. The complete eradication of *Lantana* via biological control remains an enduring challenge. Although biocontrol agents effectively diminish growth and reproduction, their influence is inadequate for large-scale management, thereby necessitating an integrated approach that amalgamates mechanical and chemical methodologies.

Table 2: Biocontrol agents for the management of *Lantana camara*

Biocontrol agent	Mode of action	References
Teleonemia scrupulosa (Lantana lace bug)	Feed on internal tissues and extracting sap form leaf tissues	Sharma *et al.*, 1988 [28]
Octotoma scabripennis (Leaf miner)	Larvae creating mines and damages the mesophyll layer, thereby reducing the plant's photosynthetic ability	Cilliers, 1987; Day and Neser, 2000 [63, 64]
Uroplata Girardi (Leaf beetle)	Adult beetles scrape the surface of *Lantana camara* leaves, feeding on the upper epidermis and mesophyll, leading to skeletonization	Cilliers, 1987; Day and Neser, 2000 [63, 64]
Ophiomyia camarae (Gall fly)	Formation of galls on the stems and leaves of *Lantana camara* by feeding on the internal tissues	Urban *et al.*, 2011 [62]
Aceria lantanae (Mite)	Feeds on *Lantana camara* by piercing plant tissues causing the formation of galls on leaves, stems and flowers.	Urban *et al.*, 2011 [62]
Asphondylia lantanae (Gall midge)	Targets the flowers of *Lantana camara*, reducing seed production and reducing its reproductive capacity	Angiras, 2014 [37]
Homona micaceana (Leaf roller)	Affects the fruit, reducing seed viability and further limiting the plant's ability to spread	Angiras, 2014 [37]
Plagiohamus spinipennis (Leaf roller)	Roll *Lantana camara* leaves into tubes by tying them with silk threads and feed on the enclosed leaf tissues	Angiras, 2014 [37]
Epinotia lantanae (Fruit moth)	Feeding on the seeds and internal tissues	Angiras, 2014 [37]
Aconophora compressa (Mealy bug)	Infestations lead to yellowing of leaves, stunted growth and reduced reproductive capacity, particularly affecting flowering and fruit production.	Negi *et al.*, 2019 [8]
Epinotia lanata (Lantana Fruit Moth)	Larvae feed on developing fruits, causing damage to seeds and pulp, preventing fruit viability and limiting seed production	Negi *et al.*, 2019 [8]
Lantanophaga pusillidactyla (Lantana Stem Borer)	Larvae bore into the stems of *Lantana camara*, damaging the vascular tissues, weakening the plant, causing wilting and dieback	Negi *et al.*, 2019 [8]
Strymon bazochii (Lantana Skipper Butterfly)	Larvae feed on Lantana leaves, causing defoliation and reducing plant vitality	Negi *et al.*, 2019 [8]
Orthezia insignis (Lantana White Scale)	Sucks sap from leaves, stems and branches, leading to nutrient depletion, reduced growth and potentially causing plant decline	Negi *et al.*, 2019 [8]
Ophiomyia lantanae (Lantana Gall Fly)	Larvae induce gall formation on leaves and stems, diverting nutrients and weakening the plant, causing deformities and reducing reproductive capacity	Negi *et al.*, 2019 [8]

Conclusion

Over the course of the past few centuries, *Lantana camara* has affirmed its status as one of the most invasive species on a global scale, disseminating to over 60 nations through deliberate introductions for ornamental purposes as well as inadvertent dispersal via contaminated agricultural commodities, trade and various other conduits. Upon establishment, the species exhibits rapid proliferation, facilitated by its substantial reproductive capacity, resilience to environmental stress, causing significant ecological and economic impacts. The effective management of *Lantana camara* necessitates a comprehensive, multidisciplinary framework that includes prevention, early identification, containment and eradication strategies. Implementation of quarantine measures to stop new introductions, in conjunction with mechanical, chemical and biological control methodologies, constitutes fundamental components of its management strategies. Additional research is needed to identify its biological characteristics, dispersal mechanisms and interactions with environmental conditions. A proactive and coordinated methodology is essential to mitigate the persistent threats posed by *Lantana camara* to ecosystems, biodiversity and agricultural productivity.

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