Lantana camara

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Lantana camara L. (Verbenaceae) is native to tropical America and has been introduced into many other countries as an ornamental and hedge plant.

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1. Introduction

Lantana camara L., which belongs to the family of Verbenaceae, is known as wild sage and red sage (Figure 1). It is a perennial shrub 1–4 m tall and forms dense stands. The leaves are opposite with long petioles, oval blades, hairy, and serrate. The species flowers all year round if the condition is adequate. A pair of inflorescences occurs at leaf axils. The flowers are small, multi-colored, and dense in flat-topped clusters. Each inflorescence bears 10–30 fruits, which are small, round drupes containing 1–2 seeds [1][2][3][4].

Figure 1. *Lantana camara*. Photos were taken by Kato-Noguchi.

The species is native to tropical America and has been introduced into other countries as an ornamental and hedge plant. It adapts to varied habitats ranging from open, unshaded areas, such as pastures and crop fields, to disturbed areas, such as roadsides, railway tracks, and fired forests [3][4][5]. The plant has naturalized more than 60 countries as an invasive noxious weed and is considered to be one of the world's 100 worst invasive alien species [6]. For example, *L. camara* was introduced in India at the beginning of the 19th century and has been growing densely, occupying 13.2 million ha [7]. The plant was first reported in 1841 in Australia and has spread and formed a pure stand over 4 million ha across Australia [8]. The first introduction of the plant in South Africa was in 1858. The species occupied 2 million ha with condensed area of 70,000 ha in 1998 [9]. The species has globally invaded millions of hectares of pastureland and infested major crop plantations, such as tea, coffee, sugarcane, and cotton plantations [3][4]. The invasion of the species also causes the severe reduction of biodiversity in the invaded ecosystems. The species threatened the habitat of 83 indigenous plant species in New South Wales in Australia [10].

L. camara displays high morphological variation because of extensive breeding [11]. The genetic diversity of *L. camara* population is high [3][12]. The species has diploid (n = 22), triploid (n = 33), tetraploid (n = 44), and pentaploid (n = 55) varieties [13]. Different ploidy levels are of ecological significance in the invasive potential of the species. *L. camara* in the native range of tropical America generally grows as a small clump less than 1 m in diameter. However, it often forms dense monospecies stands in diameter of 1–4 m in the invaded range [2][14]. The requirement conditions for *L. camara* growth and survival are 4.5–8.5 soil pH, 1000–4000 mm annual rainfall, unshaded conditions (however, it is tolerant to shade), and tropical to temperate regions (it is intolerant to frequent freezing) [4]. Thus, the potential of ecological adaptation is very high. Morphological characteristics of the species may contribute to the invasion and naturalization into the nonnative range [15][16][17].

The plants usually flower at the first growing season after establishment in most places [3][18], and there is a range of pollinators, such as insects and birds [19]. It was recorded that one plant produced up to 12,000 fruits each year [20]. Frugivorous birds and other animals contribute to the distribution of the seeds with animal feces, which adds additional nutrients for seed development [19]. *L. camara* also reproduces asexually. Vegetative reproduction occurs by layering horizontal stems and generating root systems [2][21]. The characteristics of *L. camara* for high reproduction may also contribute to the success of its invasion.

2. Allelopathy of *L. camara*

Allelopathy is the interaction of one plant with another plant in its vicinity through releasing certain secondary metabolites, which are defined as allelochemicals [22]. The allelochemicals are released into the neighboring environments and rhizosphere soil of the plants by rainfall leachates, decomposition of plant residues, root exudation, and volatilization from living plant parts [22][23][24][25]. Therefore, the allelopathic potential of the extracts, leachates, residues, and rhizosphere soil of *L. camara* was evaluated by many researchers. In this chapter, the allelopathic potential of the extracts, leachates, residues, and rhizosphere soil of *L. camara* is summarized (Table 1).

2.1. Extract

Aqueous leaf extracts of *L. camara* inhibited the germination of *Lactuca sativa* L. due to the suppression of cellular membrane developments and increase in the production of reactive oxygen forms [26]. Aqueous leaf extracts of *L. camara* suppressed the development of leaf buds of *Eichhornia crassipes* Mart., increased the decay, and caused necrosis of *E. crassipes* leaves. The extracts also increased SOD activity in the leaves of *E. crassipes* concomitant with H_2O_2 accumulation and increased the membrane peroxidation level. The activity of catalase was decreased by the extract treatments. These observations indicate that leaf necrosis of *E. crassipes* may occur due to the oxidative stress caused by leaf extracts of *L. camara* [27].

Aqueous leaf extracts of *L. camara* inhibited the germination and growth of *Brassica juncea* (L.) Czern, *Cucumis sativus* L., *Phaseolus mungo* L., *Raphanus sativus* L., *Vigna unguiculata* (L.) Walp, *Cicer arietinum* L. [28], *Centroma pubescens* Benth. [29], and *Vigna radiata* (L.) R. Wilczek [30]. Aqueous extracts of *L. camara* leaves, stems, and roots also suppressed the germination and growth of *Cicer arietinum* L. [31], *Phaseolus mungo* (L.) Hepper [32], and *Lens esculenta* Moench [33]. In addition, the aqueous leaf extracts suppressed the regeneration of the moss species *Funaria hygrometrica* Hedw. [34].

Aqueous extracts of *L. camara* flowers suppressed the germination and seedling growth of *Eruca sativa* (L.) Cav. [35]. Aqueous extracts of flowers, fruits, and leaves inhibited the germination and seedling growth of *Raphanus sativus* L. and *Lactuca sativa* L. The inhibitory effect was more significant with flower and fruit extracts than leaf extracts [36]. Methanol extracts of stem and leaves of *L. camara* also inhibited the germination and growth of *Lolium multiflorum* Lam. [37]. The observations described in this section indicate that the extracts of *L. camara* possess inhibitory activity on the germination and growth of several other plant species and probably contain some extractable allelochemicals.

2.2. Leachate

Shoots and flowers of *L. camara* were cut into small pieces and soaked in water for 48 h. Filtered water was used as the leachates of *L. camara.* The leachates inhibited the growth of *Eichhornia crassipes* Mart. and finally killed *E. crassipes* 21 days after the treatment due to its high toxicity [38][39]. Leachates from *L. camara* leaves suppressed the germination and seedling growth of *Mimosa pudica* L. The concentrations of insoluble carbohydrate, proteins, and nucleic acids and the activities of dehydrogenase, catalase, and peroxidase in the seedlings were reduced by the leachates. However, the concentrations of amino acids and soluble carbohydrates were increased by the treatment [40][41]. Root leachates of *L. camara* inhibited the radical growth of *Cucurbita pepo* Linnaeus, *Phaseolus vulgaris* L., and *Lycopersicon esculentum* Mill. and altered the cytoplasmic protein synthesis in those radicals [42]. Leachates from *L. camara* roots also suppressed the germination and seedling vigor of *Triticum aestivum* L. [43]. Leachates from fruits and leaves of *L. camara* significantly inhibited the growth of *Pennisetum americanum* (L.) Tzvelev, *Setaria italica* (L.) P. Beauvois, and *Lactuca sativa* L. [44]. These observations suggest that some allelochemicals may be released into the soil under the trees from the leaves, shoots, flowers, fruits, and roots of *L. camara* by rain and irrigation water as leachates.

2.3. Residue

L. camara shoots were cut into small pieces and mixed with sand, and the seeds of *Triticum aestivum* L., *Zea mays* L., *Glycine max* (L.) Merr., *Lepidium virginicum* L., and *Abutilon theophrasti* Medik. were sown into the mixture. The growth of those seedlings was significantly suppressed by the residues of *L. camara* [45]. *L. camara* root and shoot residues and those decomposed residues also suppressed the growth of *Morrenia odorata* (Hook. & Arm.) Lindi. [46]. Decomposed leaf litter of *L. camara* inhibited the seedling growth of *Raphanus sativus* L., *Lactuca sativa,* L. *Bidens pilosa* L., *Bidens bipinnata* L., and *Urena lobata* L. [47]. These findings indicate that some allelochemicals were released into the soil during the decomposition process of *L. camara* residues.

2.4. Rhizosphere Soil

Rhizosphere soil of *L. camara* suppressed the growth of *Achyranthes aspera* L. and *Albizia lebbeck* [48]. Rhizosphere soil of *L. camara* also reduced the germination and seedling growth of *Avena sativa* L., *Cicer arietinum* L., *Hordeum vulgare* L., and *Triticum aestivum* L. [49]. These observations suggest that the rhizosphere soil of *L. camara* may contain some allelochemicals. The allelochemicals may occur during the decomposition process of plant residues in the soil and/or as leachates from living plant parts and root exudation.

Table 1. Allelopathic activities of the extracts, leachates, residues, and rhizosphere soil of *Lantana camara*.

Source	Inhibition	Stimulation	Reference
Extract			
Leaf	Germination, cellular membrane development	Reactive oxygen form	[26]
	Development of leaf buds, catalase, leaf necrosis	SOD activity, H_2O_2 accumulation, membrane peroxidation	[27]
	Germination and growth		[28]
	Germination and growth		[29]
	Germination and growth		[30]
	Regeneration		[34]
Leaf, stem	Germination and growth		[37]
Leaf, stem, root	Germination and growth		[31]
	Germination and growth		[32]
	Germination and growth		[33]
Flower	Germination and growth		[35]
Flower, fruit, leaf	Germination and growth		[36]
Leachate			
Shoot, flower	Growth		[38][39]
Leaf	Concentrations of insoluble carbohydrate, protein and nucleic acid. Activities of dehydrogenase, catalase and peroxidase	Concentrations of amino acid and soluble carbohydrate	[40][41]
Root	Growth, protein synthesis		[42]
	Germination and growth		[43]
Fruit, leaf	Growth		[44]
Residue			
Shoot	Growth		[45]
Root, shoot, decomposed	Growth		[46]
Decomposed leaf litter	Growth		[47]
Rhizosphere soil	Growth		[48]
	Germination and growth		[49]

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