

Review Article

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Key Factor of Invasion and Control Measures of Major Exotic Weed Species in Subtropical and Temperate Forest of North Western Himalaya

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ABSTRACT

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Invasion of weed into the forest has become the major concern now a day throughout the country. There are several weed species in the forest but *Lantana camara*, *Parthenium hysterophorus*, *Ageratum conyzoides* and *Eupatorium adenophorum* have spread markedly in a short period of time and affecting the floral and faunal diversity of forest. Several theories are given by different authors regarding the invasion of these weed species beside this, the key factor of invasion are wide geographical adaptability, ploidy level, high reproductive capacity, allelopathic effect etc. which favours the invasion. Control measures such as mechanical, chemical and biological measures are being undertaken to control the further spread to save the rich floral diversity of the forest.

Introduction

A weed can be defined as a plant growing well where it is not wanted. It can be harmful to human activities, such as farming or recreation, or it can be harmful to unique environment. A species can be an invasive alien species when it becomes established in the natural or semi-natural ecosystems outside its natural habitat (IUCN 2000). These exotic species when introduced unintentionally become invasive and cause harmful impact resulting in extinction of the indigenous species. Forest weeds are those plant species which interferes with germination and growth

of young forest plants (Vajda, 1973). The Common weeds of sub tropical and temperate forest are: *Lantana camara*, *Parthenium hysterophorus*, *Ageratum conyzoides*, *Eupatorium adenophorum*, *Clerodendron infortunatum*, *Indigofera pulchella*, *Flemingia strobilifera*, *Ardisia bumilis*, *Cynoglossum glochidiatum*, *Bidens pilosa*, *Cannabis sativa*, *Justicia adhatoda*, *Strobilanthes sp.*, *Jacobaea maritime*, *Dipsacus sp.*, *Impatiens glandulifera*, *Capsella bursapastoris*, *Stellaria media*, *Alternanthera sessili*, *Veronica persica*, *Rumax nepalensis*, *Circium verutum* etc. However, *Lantana camara*, *Parthenium hysterophorus*, *Ageratum conyzoides*,

Eupatorium adenophorum are the major exotic weed which have invaded the forest very intensively.

Distribution of major exotic weed species in the state of Himachal Pradesh, India

Hypothesis behind invasion of exotic weeds

Fluctuating Resource Hypothesis (FRH; Davis *et al.*, 2000): It states that “the plant community with increased amount of unused resources are more susceptible to invasion”. This could happen due to subsequent disturbance in the habitat.

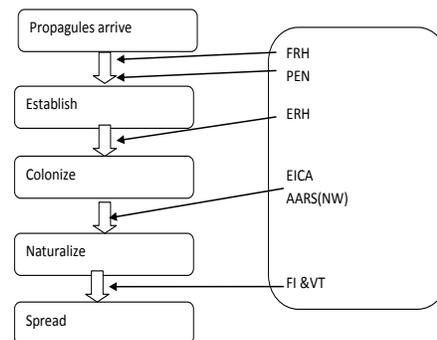
Presence of Empty Niche hypothesis (PEN; Mack *et al.*, 2000): It asserts that a species with poor habitat is more susceptible to invasion than a species with rich habitat, as new niche opportunities are created following by disturbance.

The Enemy Release Hypothesis (ERH; Keane & Crawley 2002): This hypothesis suggests that invader species performs better in their introduced range than in their native range because they lose their enemies during the process of colonization.

The Evolution of Increased Competitive Ability (EICA; Muller-Scharer *et al.*, 2004): This hypothesis implies that exotics species when released from their native specialized enemies, can allocate resources, otherwise used for costly traits that helped them resist those enemies, in the development of traits which provide the greater competitive advantage.

Allelopathic Advantage Against Resident Species (AARS) or Novel Weapon hypotheses (NW) (Callaway & Ridenour 2004): it suggest that invasive plants possess novel biochemical weapons known as

allelopathic agents. Once the plant gets naturalized, it can spread through interaction with the faunal diversity (FI) of the region and through the possession of its vegetative traits (VT) (Sharma *et al.*, 2005).



This figure suggests that no single theory is responsible for the success of weed invasion as different theories operate at different stages of the invasion process. For example, after the arrival of the propagules, FRH and PEN play a role in weed establishment. Once it gets established, ERH helps in colonization. Subsequently, EICA, through developed AARS (NW), gives a supportive advantage to naturalize, and FI and VT encourage weed spread.

General description, characteristics and control measures of major weed species

Lantana camara L. (Lantana, Fulnu-buti, Panch-phulli, Ujrhu)

This Tropical American species belongs to family Verbenaceae and has been declared as Weed of National Significance by more than 60 countries across the globe. It has come to occupy almost all the forest and non-forest areas in the sub-tropical belt and badly affecting the native floral diversity and availability of grass.

General characteristics

| Characteristics | Description |
|-------------------------|--|
| Native | Tropical region in Central and South America |
| Synonym | <i>Camara vulgaris</i> , <i>Lantana scabrida</i> |
| Distribution | Naturalized in countries/islands between 35 ⁰ N and 35 ⁰ S latitudes |
| Conservation Status | Alien |
| Plant Category | Annuals and biennials, ground covers, perennials, shrubs |
| Plant Characteristics | Poisonous |
| Foliage Characteristics | Fragrant, evergreen, poisonous |
| Foliage Color | Dark green |
| Flower Characteristics | Long lasting, showy, unusual |
| Flower Color | Pink, yellow, orange |
| Tolerances | Drought, heat and humidity, pollution, slope, wind |
| Propagation | From herbaceous stem cuttings |
| Pollinators | Lepidopteran species and thrip |

Habitat description

| Habitat Parameters | Requirements |
|-----------------------|--|
| Light Range | Sun to full Sun |
| pH Range | 4.5 - 8.5 |
| Temperature | Intolerant of frequent or prolonged freezing |
| Annual Rainfall Range | 1000 - 4000mm |
| Soil Range | Mostly sandy to clay loam |
| Water Range | Semi-Arid to Normal |
| Altitude | Less than 2000 m above sea level |
| Light conditions | Prefers unshaded habitats, can tolerate some shade |

Key factors for invasion

Fitness homeostasis and phenotypic plasticity

Fitness homeostasis can be defined as the ability of an individual or population to maintain relatively constant fitness over a range of environments. Whereas, phenotypic plasticity is the ability of a genotype to modify its growth and development in response to changes in the environment (Dorken & Barrett 2004). Lantana has wide range of fitness homeostasis as well as phenotypic plasticity.

Ploidy level

The ploidy level of lantana plays a major role in invasion and adaptation. In Australia,

most naturalized varieties are tetraploid (n = 44), but several varieties are triploid (n = 33), one is diploid (n = 22), and one is pentaploid (n = 55) (Everist 1981).

The ploidy levels of Lantana in India are similar to those in Australia, with the exception that no weedy variety has been found to be diploid in India (Sinha & Sharma 1984). It is now widely recognized that Lantana is morphologically distinct in different regions of its naturalized range compared to Lantana in its native range (Smith & Smith 1982).

Interaction with animals

The success of Lantana may be attributed to the presence of a range of pollinators,

accounting for the high percentage of fruit-set. The process of invasion is further improved by nutrient additions, with animal droppings, canopy removal, and soil disturbance creating a good seed bed. Lantana itself benefits from the destructive foraging activities of vertebrates, such as pigs, cattle, goats, horses, sheep, and deer, through enhanced vegetative propagation (Thaman 1974; Fensham *et al.*, 1994).

Geographical range

Lantana has a widespread distribution (35°N–35°S) beyond its native range, becoming naturalized in around 60 countries (Day *et al.*, 2003). The distribution of Lantana is still expanding, with many countries and islands that were listed in 1974 as not having lantana (Thaman 1974) being infested with Lantana more recently. The density of lantana infestations within its native range is also increasing, which has been recognized as an additional threat to ecosystems.

Vegetative reproduction

Once established, the rapid vegetative growth of Lantana facilitates the formation of large, impenetrable clumps (Van Oosterhout *et al.*, 2004) and high seed production.

The more common means of vegetative spread is through layering, where horizontal stems produce roots when they come in contact with soil (Swarbrick *et al.*, 1998); in addition, suckering also can occur. Prostrate stems can root at the nodes if covered by moist soil, fallen leaves or other debris.

In Australia, it is commonly well-spread by landholders dumping vegetative material in bushland (Day *et al.*, 2003). Lantana stems could develop roots and grow into plants and eventually flower.

Fire tolerance

Although Lantana burns readily during hot,

dry conditions, even when green (Gujral & Vasudevan 1983), moderate and low intensity fires can promote the persistence and spread of Lantana thickets, rather than reducing them.

Moreover, the removal of competing neighborhood plant species and increases in soil nutrients following burning can increase its germination (Gentle & Duggin 1997; Duggin & Gentle 1998).

Competitive ability

Under conditions of high light, soil moisture, and soil nutrients, the mortality rate of mature Lantana plants in its naturalized range is very low (Sahu & Panda 1998). Lantana infestations are very persistent and, in forest communities, have the potential to block succession and displace native species, resulting in a reduction in biodiversity (Loyn & French 1991; Duggin & Gentle 1998).

At some sites, Lantana infestations have been so persistent that they impede the regeneration of rainforest (Lamb 1991). Lantana is a very effective competitor with native colonizers (Duggin & Gentle 1998) and is capable of interrupting the regeneration processes of other indigenous species by decreasing germination, reducing early growth rates, and increasing mortality. This results in marked changes in the structural and floristic composition of natural communities. Therefore, as the density of Lantana in forests increases, species richness decreases (Fensham *et al.*, 1994). Lantana does not invade intact forests, but is found on its margins (Humphries & Stanton 1992).

Allelopathy

The allelopathic effect of Lantana results in severe reductions in seedling recruitment of

nearly all species under its cover. No growth or only stunted growth has been observed for other species growing close to Lantana due to allelopathic effects (Achhireddy *et al.*, 1985). Allelochemicals promote or inhibit the crop growth based on their concentration (Ambika *et al.*, 2003), and the concentration increases from root, stem to leaf (Chaudhary & Bhansali 2002), making the leaf toxic to grazing animals (Ambika *et al.*, 2003). Lantadene A and lantadene B as more potent allelochemicals. First systematic study on the chemical constituents of *Lantana camara* was undertaken in 1943 by P.G.J. Louw.

Control measures

Mechanical control

Stickraking, bulldozing, ploughing and grubbing (medium sized plants) are the main methods of control. Hand cutting using brush cutters, hand pulling, chain pulling and flame weeding are also used. Removal of adult clumps using 'Cut Root Stock' (CRS) method: This method involves cutting the main tap root of *Lantana* plant beneath the 'coppicing zone' (transition zone between stem base and rootstock). This method of removal involves engagement of 2–3 individuals to work in a group for the removal of *Lantana* if the clumps are too large to be handled by one individual after the rootstock is cut. The steps involved in the cut rootstock method are:

Using the specially designed digger, the person cuts the main rootstock of *Lantana* 3–5 cm below the soil surface by hitting the rootstock 3 or 4 times;

Lift the clump/(s) and place the clump/(s) upside down. If the clump is not placed upside down, the prostrate rooted branches and the aerial old branches having aerial roots at nodes may develop into adult plants when

they come in contact with the soil.

After drying the clumps, the clumps may be used as fuel or burnt at the same site or all the dried clumps may be collected at one place and then burnt. The best time for removal of *Lantana* is just before rainy season, i.e. when the plants are not in flowering and fruiting.

Chemical

During the active growing period, use of fluroxypyr @ 0.5 to 1 liter / 100 lt water, glyphosate @ 1lt / 100 lt water, triclopyr @ 1l / 60 l of water and Grazon DS (300 g/l triclopyr + 100 g/lt picloram) @ of 350 ml/100 lt water per ha is recommended. (Hannan-Jones 1998, Motooka *et al.*, 1991). Post emergence - 1 application of glyphosate (2 kg ha) may provide good control.

Applications are to be done when there is good soil moisture and during the active growing period, either in the morning or late in the afternoon. (Toth & Smith 1984).

Biological

Includes the sap-sucking bug, *Ophiomyia camarae* Spencer (Diptera: Agromyzidae) *Teleonemia scrupulosa* (Hemiptera), leaf mining beetles, *Octotoma scabripennis* (Coleoptera) and *Uroplata girardi* (Coleoptera) and the seedfeeding fly, *Ophiomyia lantanae* (Diptera), leaf feeder *Falconia intermedia*. Apart from these agents, a rust fungus, *Prosopidium tuberculatum* are used in Australia for the biocontrol of *Lantana*. *Puccinia lantanae*, a rust of tropical origin, is pathogenic to a wider range of weedy cultivars of *Lantana* than *P. tuberculatum*.

Parthenium hysterophorus (Carrot Weed, Congress Grass, Gajar ghas, Chatak Chandni) Congress Grass member of family Asteraceae is native to the region encompassing the

Central America, Southern North America, Gulf of Mexico, West Indies, and Central South America. This species has possibly entered India in 1910 (with infected cereals germplasm) however, went unrecorded until 1956. The weed was first revealed in India in 1955 (Rao, R S., 1956)

Habitat

This weed is spotted on bare lands, industrial areas, developing residential colonies, railway tracks, roads, drainage and around the ditch etc. High temperature is favorable for the development of this noxious weed production. Low temperature represses the development of the plant and the seed productivity (Pandey *et al.*, 2003). It invaded sites mostly have sandy loam soil with pH ranging from 5.4 to 7.4, water holding capacity 16.8 to 63%, total nitrogen 0.055 to 0.206%, organic matter 1.134 to 4.24%, phosphorus 31.86 to 69.93 kg/ha, potassium 74.72 to 746.5 kg/ha (Joshi, S., 1991).

Life cycle

It can flowered at any time of the year, but commonly occur during raining season. After 24-48 days of germination flowering takes place. The best alternating temperature regime for its weed seed germination is 21/16°C (day/night). Further its seeds can live for between 4-6 years in the soil as seed bank (Adkins, S and Shabbir, A., 2014).

Causes of rapid spread

Seeds of *Parthenium* can survive under harsh conditions and remain viable for a long time period. These qualities of this weed help in its fast spreading. Seeds of *Parthenium* can germinate any time of the year, when suitable moisture is available (Williams, JD, and Groves, RH., 1980).

Fast growth rate: It is vigorously growing

annual herbaceous weed. Generally, *Parthenium* flowered when it is only 4-8 week old and can flower for several months. Under unfavorable conditions like salt and drought stress, the weed can complete its life cycle within 4-5 weeks.

Allelopathic potential: This noxious weed suppresses the development of nearby plants by allelopathy. Leachate and extract of leaves and inflorescence prevent the germination and growth of associated economically important crops.

Unpalatable to animals: *Parthenium hysterophorus* is unpalatable to the animals. Generally animals do not eat *Parthenium hysterophorus* because of its bitter taste and intense odour (Javaid, A and Anjum, T, 2005). Earlier investigations in India had revealed its serious health hazards to the livestock in *Parthenium hysterophorus* invaded areas.

Control measures

Mechanical measures

Controlling overgrazing: Overgrazing decreases the vigor and diversity of grassland that enable the spread of *Parthenium hysterophorus* weed luxuriously. (Nigatu *et al.*, 2010). Grazing during winter is generally safe since the period has low risk of *Parthenium* spread. However, *Parthenium* may grow and germinate in this time also.

Burning: Mass vegetation of the weed can be destroyed by this practice. But it can not be considered as safe control strategy for the weed since there is great risk to soil, air and existing plant and animal diversity (Kumar, S. 2014).

Manual control: Manually, *Parthenium* weed can be controlled by simple hand plucking. But this is not recommended since it might cause serious health hazard. Further, the seeds

may drop off and increase the area of infestation.

Herbicide control/chemical management

Chemical herbicides which are commonly used are glyphosate @ 2.5 kg / ha⁻¹, atrazine @ 2.6 kg/ ha⁻¹, bromoxynil @ 0.56 kg/ ha⁻¹, common salt @ 20%, 2,4-D amine @ 3 l/ ha⁻¹, Floumeturon @ 2.24 kg/ ha⁻¹, Metribuzin @ 0.7 kg/ha⁻¹, Norflurazon @ 2.24 kg /ha⁻¹ and Paraquat 0.5 l/ ha-1. (Kathiresan et al.,2005, Reddy, K N and Bryson, CT., 2005, Singh *et al.*, 2003, Mishra, JS and Bhan, VM., 1994). Rosette stage is the right time to apply post emergent herbicides in wasteland, non-cropped areas, along railway tracks, water canals and roadsides (Khan *et al.*, 2011).

Biological control

Leaf and a seed feeding beetle (*Zygogramma bicolorata*)

Stem gallingmoth (*Epiblema strenuana*):

Zygogramma bicolorata

Capable of causing a defoliation of 85% to 100%, resulting a reduction of up to 99.5% of parthenium in the Bangalore region (Jayanth and Visalakshy, 1994) and other areas. It requires relatively warm temperatures and high humidity to remain active. It was first recorded in Pakistan by Javaid and Shabbir (2007) in March 2006.

Epiblema strenuana

Introduced from Mexico the moth's larvae feed on the stem of the weed and forms ball which inhibit the plant growth.

The most promising fungal agents to manage parthenium are: *Puccinia abrupta* var. *partheniicola*, *Puccinia xanthii*, *Entyloma compositarum* (*Ustilaginales*), *Plasmopara*

halstedii (Farlow)

***Eupatorium adenophorum*(Crofton Weed)**

Eupatorium adenophorum is a member of family Asteraceae native to Mexico but has now spread to Hawaii, Philippines, China, Thailand, Australia, New Zealand, India, Nepal, and California (Chen and Zhao, 1984). It was introduced as an ornamental plant to England in the 19th century (Auld & Martin 1975) and was later introduced into different parts of the world (Auld & Martin 1975; Muniappan *et al.*, 2009; Tripathi *et al.*, 2012).

It is found upto 2200 meters above mean sea level, in ravine slopes and grassy localities. The plant inhabits moist conditions, extremely aggressive competitor, especially in shaded conditions although seeds do not germinate in dense shade (Auld & Martin 1975). The plant increases its competitive advantage through allelopathic action (Dhyani 1978) and by altering the soil microbial (Yu *et al.*, 2005; Niu *et al.*, 2007). Rapid evolution in *Eupatorium adenophora* is likely to be constrained by apomixes and triploidy (Zhao *et al.*, 2012; Datta *et al.*, 2017). Flowering occurs in spring and summer around 10,000 to 100,000 seeds are produced per year when mature, mid to late spring with high Germination rates. It is reported to produce seed by means of apomixis (Noyes 2007). It is therefore likely that there is limited genetic variation within populations, especially in its introduced range, which in turn may make it easier to control.

Control measures

Mechanical measures

Manual uprooting

Mowing,

cutting with machete or burning of live plants. Furthermore, at the maturity stage, uprooting of plants results in dispersal of seeds to other areas.

Chemical control

There is not much published data dealing with chemical control of *Eupatorium adenophorum* but some studies have shown the effect of few chemicals e.g. Whittet (1968) states that a measure of control can be achieved by using 5% sodium chlorate spray or 0.3% 2,4-D and 2,4,5-T mixture. Whereas, Sheldrick 1968 recommend 2,4-D and 2,4-D/2,4,5-T mixture for control of *Eupatorium adenophorum*.

Biological control of *Eupatorium adenophorum*

The first surveys in Mexico for natural enemies of *Eupatorium adenophora* were conducted in 1923 and 1924, and resulted in the release of the shoot-galling tephritid fly *Procecidochares utilis* Stone (Diptera: Tephritidae) into Hawaii, as recommended by Osborn (1924). The fly was reported to be host-specific (Haseler 1965) and has been intentionally released in seven countries for the control of *Eupatorium adenophorum*. It failed to establish in only one of these countries, Thailand, and has further spread to Nepal from India (Julien & Griffiths 1998) and then on to China (Wan & Wang 1991; Muniappan *et al.*, 2009).

Since 2007, at least 11 coleopteran species, five lepidopteran species, two hemipteran species, two dipteran species and two pathogen species have been reared in the Pretoria ARC-PPRI quarantine facility from samples of *Eupatorium adenophora* that were collected in Mexico.

***Ageratum conyzoides* (Goat Weed, Neel-phulnu)**

Ageratum conyzoides is a noxious herb, a member of family Asteraceae present in many tropical and subtropical environments.

(Swarbrick 1997, in PIER 2008). It thrives best in rich, moist, mineral soils with high humidity and tolerates shading. *A. conyzoides* may grow from sea level to at least 2400 meters in altitude. It is present from sea level to at least 1300 meters in Hawaii (Wagner *et al.*, 1999, in PIER 2008) and in Himachal Pradesh, India, the weed is established up to 1800 meters (Dogra *et al.*, 2009).

Lifecycle Stages

It can complete its life cycle (germination to flowering) in less than two months. The plant flowers almost throughout the year, precisely from June to March. The seeds germinate in response to light (photoblastic) and are often no longer viable within 12 months. *A. conyzoides* has the potential to produce many seeds (94,772 seeds per plant) and to shed seeds over extended times (5 to 8 months), as well as its extraordinary physiological plasticity, has enhanced its persistence in arable fields (Ekeleme *et al.*, 2005). One plant of *A. conyzoides* may produce up to 40 000 seeds, with up to half of seeds germinating (Holm *et al.*, 1977, in PIER 2008).

Features imparting invasiveness

Fast growth and rapid spread
Wide ecological amplitude;
High reproductive potential
Long flowering and fruiting periods;
Absence of natural predators/enemies/competitors; resistance to predators;
Unpalatable due to high phytotoxin content; and resource competition along with novel weapons such as allelopathy.

Management

Physical methods

These include manual uprooting, mowing, cutting with machete or burning of live plants.

In general, these are of some use when the plant is at the vegetative stage. However, certain limitations are associated with these methods, for example the high cost of labour, ill-effects on workers' health, vegetative regeneration from stolons, etc. (Batish *et al.*, 2004a). Furthermore, at the maturity stage, uprooting of plants results in dispersal of seeds to other areas.

Chemicals

Pre-emergence application of simazine, atrazine, diuron, oxadiazon, oxyfluorfen, methazole or metribuzin provides excellent control of this weed. Post-emergence application of 2,4-D controls established infestations (Rao 2000).

On the other hand eco-based, environment-friendly strategies for the effective control of *A. conyzoides* are suggested. Plant extracts of *parthenium* and *eucalyptus* (volatile essential oils) may hold promise in controlling *A. conyzoides* (Batish *et al.*, 1997, Singh *et al.*, 2002, Batish *et al.*, 2004). For example, a study on the allelopathic effect of two volatile monoterpenes (cineole and citronellol) on *A. conyzoides* has revealed their potential for future weed management. Both the monoterpenes severely affected the germination, speed of germination, seedling growth, chlorophyll content and respiratory activity of *A. conyzoides* and after two weeks of exposure, the weed plants wilted. Cineole was the more toxic of the two monoterpenes (Singh *et al.*, 2002).

In conclusion *lantana camera*, *parthinium hetrophorus*, *Eupatorium adenophorum* and *Ageratum conyzoides* are highly invasive exotic weed in sub tropical and temperate forest of north western Himalaya. Lantana is recorded most dominating shrub in the forest ecosystem. The main reasons of their invasion are fast growth and rapid spread, wide

geographical range, high reproductive potential and allelopathic effect. Due to their allelopathic effect and gregarious habitat they affect the native biodiversity and also the regeneration process. Preventing the spread of these weed species is most cost effective management tool. However, various control measures (mechanical, chemical and biological) are being under taken throughout the world to reduce the further spread of these weeds. This would require the restriction of further importation to our country, sale and use of these weeds and strategically controlling infestations wherever it currently occurs.

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