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Review article

Allelopathic invasion of alien plant species in India and their management strategies: A review

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Abstract: Invasion of alien plant species is a persuasive threat to the native plant diversity and caused habitat loss around the world. Invasions not only harm the native flora but have adverse impact on economic status as well as health of the country. A detailed study on allelopathy, allelochemicals and allelopathic mechanism of exotic invasive plants are reviewed. Main emphasis is given on the modes of invasion, reproductive characters, transmission modes, establishment, adaptability of weeds in the environment and the major exotic plants in India and their allelopathic effects on native vegetation. The allelopathy of most common exotic invasive plants in India such as *Ageratum conyzoides*, *Eupatorium adenophorum*, *Parthenium hysterophorus*, *Lantana camara*, *Mikania micarantha*, *Argemone mexicana* and *Eichhornia crassipes* has been described. Mechanical, chemical, biological and cultural control methods have been less effective individually, so integrated management with the participation of native people and proper land management have been proved beneficial. The various measures and management strategies to overcome and control the invasion of weeds have been discussed.
Keywords: Invasion - Exotic - Weeds - Allelochemicals - Management.

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INTRODUCTION

An invasive species are introduced as an alien, exotic, and non-indigenous species non-native to that location but very aggressive leading to damage to the other plant species, human health and economic structure, or the organisms from their native place immigrating to a new locality are referred as exotic species (Mack *et al.* 2000). Invasion of exotic plant species has emerged as a global problem causing adverse impact on the ecosystems, economy, and human health. Invasion is raised as one of the major causes of biodiversity loss (Inderjit *et al.* 2008, Rastogi *et al.* 2015). The invasive alien species is considered as one of the reasons of habitat destruction. In past, many losses to biodiversity have not been analysed but now a days they become necessary to record the biological invasion for conservation of biodiversity and to take effective measures for their control. More than 40% of the species are in the threatened and endangered lists due to invasive species (Wilcove *et al.* 1998). It is also estimated that about 20% of plant species are non-indigenous in many continents and more than 50% on several islands (Rejmanek *et al.* 1994). Thousands of alien plant species are known to invade globally and several exotic species are still unrecognised (Ruiz *et al.* 2000).

In India, among all alien flora 10% are Asian, 20% Asian and Malaysian, 15% of Europe and Central Asia and 55% of America (Nayar 1977). Due to enormous growth of invasive exotic species, India is facing significant environmental as well as economic problems. In India about 42% of the weeds in crop fields are aliens (Khuspe *et al.* 1982, Nandpuri *et al.* 1986). It is estimated that alien weeds have caused 30% loss in crop production (Singh 1996). In a study of the invasive alien flora in Uttar Pradesh, India comprises of 44 families including 109 genera and 152 species (Singh *et al.* 2010). The most common exotic species of India which has been discussed include *Ageratum conyzoides*, *Eupatorium adenophorum*, *Parthenium hysterophorus*, *Lantana camara*, *Mikania micarantha*, *Argemone mexicana and Eichhornia crassipes* (aquatic plant). Among which *Lantana camara*, *Parthenium hysterophorus*, *Ageratum conyzoides* are the worst, highly invasive and challenging (Kohli *et al.* 2004).

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For a successful invasion in the new habitat a plant species must defeat adversities and interact with native plants as competitors and have wide adaptability and physiological plasticity (Levine *et al.* 2004, Richardson *et al.* 2000). According to enemy release hypothesis (Colautti *et al.* 2004) the invasive plants are less prone to herbivores and pathogens hence attain large scale distribution and abundance. The mutualist facilitation hypothesis (Richardson *et al.* 2000) shows the replacement of the native mutualist species with several new mutual species in their range help invaders in proper establishment and invasion. The pollinators, seed dispersing organisms and mycorrhizal symbiosis sometimes help invasion of plants. Eltonian empty niche hypothesis, states that sometimes invaders make use of unused resources and occupy an empty niche when they are introduced into a new community (Elton 1958). The novel weapon hypothesis (Callaway *et al.* 2004) states that several invasive species have specific biochemical compounds which have allelopathic effects and act on plant and soil microbial interactions. The exotic plants get advantage in invasion due to the release of phytochemicals to which the native plants and soil microbes are not adapted.

This paper is based on the research done on the exotic plants worldwide. The major objective of this article is to explore invasive alien plants, reason of their fast invasion, establishment and effective growth harming native biodiversity and economy of the country. The measures of control of invasive flora including physical, biological and chemical modes have been also reviewed.

Allelopathy

The term allelopathy was first given by Molisch (1937), consist of two Greek words, allelon meaning 'mutual' and pathos meaning 'to suffer', harmful effects on each other . Allelopathy is a natural phenomenon in which different plant species affect the physiology of other plants existing in their vicinity, either negatively or positively (Rice 1984).

Allelopathy is defined as the adverse effect of a plant on another plant through the release of several secondary metabolites by plant parts into the soil (Inderjit & Callaway 2003). Allelopathy is a useful mechanism for alien plant invasion. Chemical exudates released from roots and other plant parts play crucial role which arbitrate mutualistic, competitive and pathogenic effects on native flora (Inderjit *et al.* 2005, Mitchell *et al.* 2006).

Causes of rapid dispersal of invasive plants

The small sized seeds weighing less than 50 mg, less than 10 years of juvenile life and short interval between crops are one of the reasons of their propagation and invasiveness (Sharma *et al.* 2005). *Parthenium hysterophorus* produces large number of small seeds which can travel long distance and cause fast invasion (Rejmanek & Richardson 1996). Most of alien invasive species have small seeds with wings or pappus, which facilitate them to cover a long distance through anemochory (Wan & Wang 1990). Sometimes C3 plants adapted to C4 mechanism and CAM (facultative CAM plants) if they invade arid areas with high temperature thus helps in successful invasion (Sage 2004). Dispersal through animals is also a major cause for the rapid invasion in disturbed and undisturbed habitats (Rejmanek & Richardson 1996, Binggelli 1996).

Geographical range of flora is also responsible for the invasion of the plant. The seeds and propagules of a species with widespread distribution have more chance of being transported and established in other countries and continents. (Forcella *et al.* 1984, Rejmanek 1995, Goodin *et al.* 1998).

The exotic flora with different modes of vegetative reproduction, along with sexual reproduction helps in fast invasion in which allelopathy plays a key role (Fig. 1).Vegetative propagation increases compatibility of exotic plants in the environmentand invasion in both terrestrial as well as in aquatic habitat (Pieterse & Murphy 1990). The invasiveness of *Eichhornia crassipes* mainly occurs by means of stolon (Barrett 1989). All exotic genera have a strong coping capacity against abiotic and biotic barriers in the invaded region which may be through various associations like root symbionts and non-specific mutualism (Richardson *et al.* 2000). Furthermore they have large tolerance in lower resources and thus make them more competitive and invasive (Noble *et al.* 1980).

Allelopathy is considered as the major cause of invasion of exotic plants. There is wide range of allelochemicals which are known to have both positive and negative effects on neighbouring plants. Secondary metabolites are classified as organic acids, alcohols, aliphatic compounds, cinnamic acid and its derivatives, terpenoids, aldehydes, ketones, lactones, fatty acids, alkynes, quinone compound, simple phenols, benzoic acid,

steroids, amino acids, peptides, alkaloids, sulfide, glucosinolates, nucleotides. Among these phenolic acids and terpenoid compounds are the most common forms of allelochemicals (Song 1990, Sun & Yu 1992). Allelochemicals released from invasive species harm native species through inhibition of nutrients uptake, disturbing cell division and root and shoot elongation (Cruz *et al.* 1998, Cruz *et al.* 2007), alteration in membrane permeability (Li *et al.* 2010), inhibition of chlorophyll formation and protein synthesis (Chen *et al.* 2002, Li *et al.* 2010, Wein *et al.* 2004) and inactivation of some hormones and enzymes (Li *et al.* 2010, Muzaffar *et al.* 2012). Allelochemicals also affect process of photosynthesis by interrupting photosystem II (Yang *et al.* 2002). Allelopathy has also been acknowledged as a mechanism which promotes plant to dominate and establish ecologically (Narwal *et al.* 2005).

Parthenium hysterophorus checks the germination and growth of other plant species by releasing certain allelochemicals or allelopathic interaction (Adkins & Sowerby 1996). *Lantana camara* is proved as a noxious exotic species which is capable to disturb the regeneration process of the other plant species by affecting their germination and survival through the allelopathy (Gentle & Duggin 1997). *Eupatorium adenophorum* is known to inhibit germination of seeds of other species like rye grass, maize and clover (Zang *et al.* 1993). *Mikania micarantha* has allelopathic effect on several plant species (Zang *et al.* 2002).

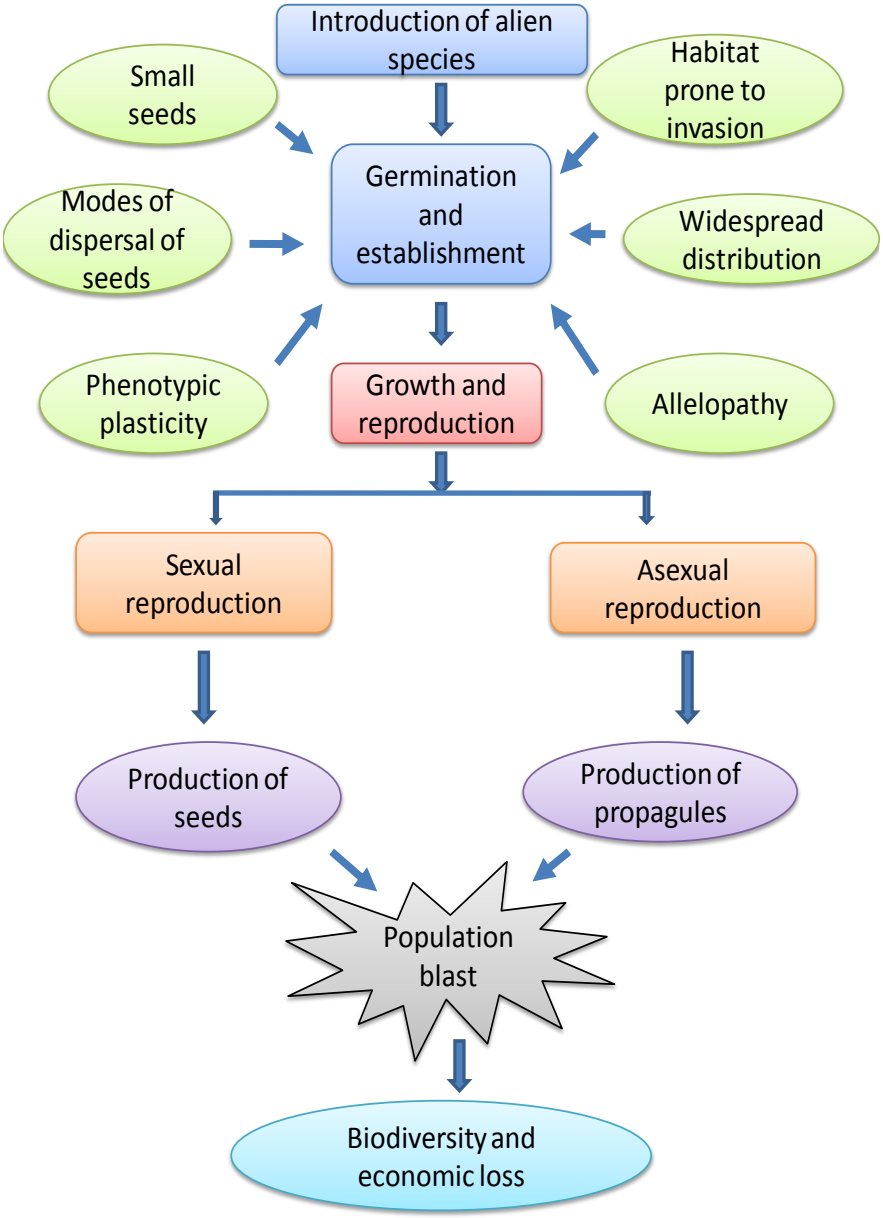

Figure 1. A Schematic representation showing the process of exotic plant invasion, establishment and reproduction.

Table 1. List of some major invasive flora and their impact.

S.No.	Species and Common name	Family and Habit	Native	Threats	References
1.	*Ageratum conyzoides* (Goat weed)	Asteraceae Herb	Tropical America	Allelopathic, highly invasive, threat to croplands of Himalayan region.	Dogra *et al.* 2009, Roder *et al.* 1998
2.	*Eupatorium adenophorum* (Crofton weed)	Asteraceae Shrub	Mexico	Allelopatic effect causes serious threats to native flora.	He & Liu 1990
3.	*Eichhornia crassipes* (Water hyacinth)	Pontederiaceae Aquatic herb	Tropical South America	Serious aquatic weed, allelopathic in nature, causes hindrance in navigation, reduces water quality and algal growth.	Raghubanshi *et al.* 2005, Sun *et al.* 1988
4.	*Lantana camara* (Lantana)	Verbeneaceae Shrub	Tropical America	Strongly allelopathic, serious threat to medicinal plants, responsible for forest fire.	Sharma *et al.* 2005, Raghubanshi *et al.* 2005
5.	*Mikania micrantha* (Mile-a-minute)	Asteraceae Herb	Sub-tropical zone of America	Known for its allelopathic potential, highly invaded forest areas.	Raghubanshi *et al.* 2005, Zhang *et al.* 2002
6.	*Parthenium hysterophorus* (Congress Grass or Carrot Grass)	Asteraceae Herb	Tropical America	Aggressive colonizer, highly allelopathic, allergic to animals and human being, threat cause to crops and other native flora.	Kohli & Rani 1994, Kanchan & Chandra 1980, Kohli & Batish 1994.
7.	*Argemone Mexicana* (Mexican Prickly Poppy)	Papaveraceae Herb	Tropical Central and South America	Harm native flora through allelopathy.	Reddy 2008

Certain plants have ability to amend their growth and development in association with changes in the environment (Dorken & Barrett 1981). This phenomenon is known as phenotypic plasticity. *Parthenium hysterophorus* has ability to grow in any soil because it shows wide phenotypic plasticity to any type of soil which leads to its establishment as a successful invader. Generally there are two types of invaders, one is tall, fast growing with small seeds suitable for rapid dispersal and the second is short heighted plants with high seed mass showing slow invasion but with high seed spread (Annapurna & Singh 2003). Habitat also plays a significant role in conferring invasiveness to exotic plants, however, it does not imply that any invasive species reaching that habitat will establish successfully. Habitat which is susceptible to invasion may have poor species diversity, poorly adapted native species, absence of predators and empty niches (Mantri *et al.* 2002). Some allelopathic invasive plants which are covering most parts of India have been discussed and listed in table 1.

Common invasive exotic species, their allelochemicals and allelopathic effects

Eupatorium adenophorum

Eupatorium is commonly called as crofton weed which is native of Central America (Song *et al.* 2000). It is a noxious invasive species with profusely branched stem. Crofton weed depends on few factors *i.e.* humidity, light, ecology and biodiversity of a particular area to invade (Meng *et al.* 2003). Allelopathy plays a vital role in its invasion. There are many allelochemicals identified and isolated from *Eupatorim adenophorum*. The essential oil of crofton weed contains 1-methyl-2(1-methyl) benzene, hedycaryol, cetral, bornyl acetate, p-cymene, lonipinene, copaene (Wu & Yang 1994). Ding *et al.* (1999) reported sesquiterpene lactone-euprtoranolide from the flowers of *E. adenophorum*.

It has been observed that it has severe allelopathic effect on the other neighbouring plants which is the key factor of its easy invasion. It inhibits the germination of seeds of several crop plants like clover, rye grass, and maize which are commercially very important crops (He & Liu 1990, Zhang *et al.* 1993). *E. adenophorum* leachate affects not only physiological characters but it also creates anatomical abnormalities in the plant by

destroying root cells of corn (Zhang *et al.* 1993). The allelopathic effects by using chloroform extracts of aerial parts of *Eupatorium*. Cadinenes and *b*-sitosterol were isolated and their effects were seen on the *Allium cepa, Raphanus sativus* and *Cucumis sativus* seeds (Baruah *et al.* 1994).

Mikania micrantha

Mikania micrantha is a perennial plant with small compact florets, invasive weed commonly known as plant killer and mile-a-minute which is a native of neotropical region (Xie *et al.* 2010, Tripathi *et al.* 2012) and now a days became in majority in natural habitats including forests, agricultural systems in north east India. It entered India at the time of World War II to mask airfields and for covering tea plantations (Tripathi *et al.* 2012).

Mikania is known to grow in forests, on bank of rivers and streams, in disturbed areas (Kong *et al.* 2000, Zan *et al.* 2000, Feng *et al.* 2002). It has covered most parts of Asia including India, Sri Lanka, Mauritius, Bangladesh, etc. (Deng *et al.* 2004). Raghubanshi *et al.* (2005) reported about 61% invasion in forests, teak plantations and disturbed forests. In north-east India, it has been observed that it climbs both small and tall trees, covering their canopy. It is the world's worst weed and is known for its allelopathic potentials. *Mikania* have a good reproductive capacity; can grow through its plant debris and underground rhizomes vegetatively (Rejmanek & Richardson 1996). Several allelochemicals like mikanin, eupafolin, luteolin, eupalitin. The essential oil of *M. micrantha* contains terpenolene, limonene, ocimene, caryophylene, etc. (But *et al.* 2009, Feng *et al.* 2004). The volatile oils of *Mikania micrantha* have allelopathic and inhibitory effects on several plants (Zhang *et al.* 2002). The water leachates of *Mikania* have allelopathic potential on various economically important crop plants like *Raphanus sativus*, *Lolium multiflorum* and *Trifolium repens* (Shao *et al.* 2003). Weng (1964) found that the biomass and nitrogen content of tomato seedlings and some legume crops are also inhibited by *Mikania micrantha.*

Lantana camara

Lantana camara is the one of the ten worst weeds of the world. It is an evergreen aromatic shrub which is native of Central and South America (Raghubanshi *et al.* 2005). Lantana has been introduced in many countries as ornamental plant and now a day has become serious problem for the native plants (Bever 1982). In India it was introduced during 1809–1810 as an ornamental plant in Calcutta's gardens (Kohli *et al.* 2006) and is now found all over India. This plant spreads fast due to human interference and disturbances (Sharma *et al.* 2005). It has invaded more than 13.2 million ha pasture land and other areas in India (Singh *et al.* 1996). Lantana is harmful to herbivores and the cost of its management is US$ 70 per hectare (Singh *et al.* 1996). Lantana is highly invasive due to fitness homeostasis, phenotypic plasticity, widespread geographical range, modes of reproduction and ultimately none and the most potent, the phenomenon of allelopathy (Sharma *et al.* 2005).

Various allelopathic compounds like salicylic acid, gentisic acid, coumarin, ferulic acid, p-hydroxybenzoic acid and 6-methyl coumarin were analysed in *Lantana camara* (Yi *et al.* 2006). Some other allelochemicals identified in *Lantana camara*are cytotoxic in nature found in the leaves are lantadene A and lantadene B (Ma *et al.* 2004). Pan *et al.* (1993) have reported presence of lantadene A, B, oleanolic acid, lantalonic acid, icterogenin from the leaves and lantolonic, ursolic acid and oleonolic acid from the roots of *Lantana camara*. *Lantana* density in forest, increases due to allelopathy which results in decline of species richness (Day *et al.* 2003). Allelochemicals present in *Lantana* decrease the vigour of native plants of region and results ultimately poor productivity (Sharma *et al.* 1988, Sharma & Sharma 1989). They are also responsible for wild fire in many forest rich parts of India (Raghubanshi *et al.* 2005). The leaf extract of *Lantana camara* inhibits the emergence and growth of leaf bud of water hyacinth and increases the superoxide dismutase activity, H_2O_2 accumulation and increase in membrane peroxidation (Zheng *et al.* 2006). Growth of commercially important vegetable crops like tomato, radish and cucumber has been inhibited by leachates of *Lantana camara.* (Liu & Jia 2002). The stem, leaf and fruit leachates of *Lantana* inhibit seed germination and seedling growth of some terrestrial plants (Quan *et al.* 2009.)

Eichhornia crassipes

Eichhornia is an aquatic floating plant which is popularly known as water hyacinth. It is the native of tropical region of South America. It was introduced in many countries as animal fodder and planted for purification of water bodies (Raghubanshi *et al.* 2005). Water hyacinth mainly invades polluted and nutrient rich water bodies particularly rich in nitrogen, phosphorus and potassium. This plant has become serious weed in most of tropical, warm and fresh water habitats. In India it was introduced during 1914–1916 AD, from Brazil.

It is floating hydrophytes which causes hindrance in navigation, block rivers, lakes and irrigation system and reduces the quality of water bodies (Raghubanshi *et al.* 2005).

The major allelochemicals found in water hyacinth are linoleic acid, glycerol -1, 9-12 (ZZ)-octa decadienoic acid and N-phenyl-2-napthylamine (Yang *et al.* 1992). N-phenyl-2-napthylamine is known to inhibit the growth of several aquatic floras. It increases the protein content and decreases superoxide dismutase activity in some aquatic flora. Hydroponic water of *E. crassipes* reduces the growth of alga (Sun *et al.* 1988). It is known for its anti-algal activity even more than that of popular algaecide copper sulphate (Sun *et al.* 1993).

Parthenium hysterophorus

Parthenium hysterophorus is an exotic species native of Tropical America and has invaded most of parts of India now a days. It bears a strong invasive potential and known for its strong allelopathic effects. *Parthenium hysterophorus* L. (commonly known as Congress grass or Carrot weed) and belongs to family Asteraceae. *Parthenium* is known to enter India in 1950–1960 A.D. along with common staple grains imported from United States of America. It was first seen in 1955 in Maharashtra. It is said that it has entered India accidently in 1810 and lived hidden till 1956 until Rao reported it in Pune, Maharashtra for the first time (Roxburgh 1984, Bennet *et al.* 1976).

It is a wasteland weed and aggressive colonizer with a higher productivity, plasticity, and high fecundity *i.e.* a single plant can produce thousands of viable seeds and successful invagination of these seeds found along wastelands, overgrazed areas, road sides, agricultural areas, railway tracks. *Parthenium* has first started invading upon extreme hilly regions of India and encroached in lower and middle Himalayan region and now engulfed almost whole of India (Dogra *et al.* 2009).). In last two decades *Parthenium* become major and common weed which has been covered urban as well as natural habitats and replaced native plant species (Dogra *et al.* 2009). The major phenolic compounds found in *P. Hysterophorus* are, o-coumaric, gentisic, ferulic, p-coumaric, caffeic, vallinic, salicylic acid, trans-cinammic and p-hydroxybenzoic acids and sesquiterpene lactone etc. (Kohli & Rani 1994). Allelopathy has played an important role in successful and massive invasion of the weed and helps this weed to colonize the native area successfully (Bais *et al.* 2003, Heirro & Callaway 2003). Native plant species are not habitual to the chemical released by these new plants hence they fail to survive, establish resulting in low density, stunted growth, and decrease in population. The microbes present in soil also are unable to detoxify these allelochemicals (Callaway & Aschehoug 2000). *Parthenium* affects the crops and other native flora by releasing phenolics and sesquiterpenes resulting into inhibition of their growth and development (Kanchan & Jayachandra 1980, Kohli & Batish 1994).

The pollen and dust material of *Parthenium* cause allergic dermatitis in human being (Gunaseelan 1987, Morin *et al.* 2009). It has been related to cytotoxicity of the allelochemical, sesquiterpene lactone found in *Parthenium* (Narasimban *et al.* 1984). It is also known to cause diarrhoea, breathlessness and choking (Maishi *et al.* 1998). Excess and close exposure to *P. Hysterophorus* pollen grains leads to allergic bronchitis (Towers & SubbaRao 1992).

Ageratum conyzoides

Ageratum conyzoides is popularly known as billy goat weed or goat weed or tropical white weed, belongs to family Asteraceae and is widely distributed on road sides, fields, cultivated areas, tropical and subtropical areas of the world, pastures interfering with the native vegetation, including crops, grasses and forage crops (Marks & Nwachuku 1986). *Ageratum* is highly adaptable and produces a huge number of seeds (8000–10000/plant). Its seeds are achenes which are dispersed easily and acquiring favourable conditions flourish freely (Marks & Nwachuku 1986). The seeds are photoblastic and remain viable for a year. It also spreads vegetatively (stolons). It has been found before 1882 in India which is evident from 'The British Flora of India' (Hooker 1882). It has been found that it affects the native plant and crops by releasing several phenolic compounds (Kong *et al.* 2003).

The allelochemicals reported in *Ageratum conyzoides* are ageratochromene (Wei *et al.* 2004), precocene I and precocene II have strong insecticidal effects (Lu 1982). Along with it, endo-borneol, farnesol, hexadecanoid-acid, linoleic acid, nerolidol and quercetin, kaempferol, and its glucosides are present (Sharma & Sharma 1995, Kong *et al.* 2002, Okande 2002). Precocene I and II are also known for insecticidal as well as anti-juvenile hormone activity (Okande 2002). In cultivated lands, *Ageratum* has reduced the yield of staple crops like wheat, corn, rice etc. Rice yield inversely proportional to the density of *Ageratum* (Roder *et al.* 1998). The farmers of Himalayan region (Shivaliks) have left their fields due to loss of croplands (Kohli *et al.* 2006).

Argemone mexicana

Argemone mexicana L. is native to Central America (Mexico) commonly known as Mexican prickly poppy, is one of invasive alien plant species invaded most parts of India (Reddy 2008). *A. mexicana* is widely distributed herbaceous plant mainly found by road sides, fields and croplands. *A. mexicana* is a member of family Papaveraceae with enormous seed production around 60 to 90 capsules per plant and each capsule carrying 300 to 400 seeds, can remain dormant for several weeks or months (Karlsson *et al.* 2003). Most seeds germinate to form seedlings, some seeds not even germinate the year after shedding and get accumulated to form seed bank (Karlsson *et al.* 2003, Sanaa 2012).

Study revealed the presence of several allelochemicals like salicylic acid, *p*-hydroxybenzoicacid, vanillic acid, cinnamic acid (Burhan & Shaukat 1999).The aqueous extract of *A. mexicana* checks the germination of *Lens culinaris* (Paul & Begum 2010). Chandra *et al.* (2007) found that germination and seedling growth of other plants were negatively affected by salicylic acid. It has been also reported that treatment with *A. mexicana* leaf aqueous extracts causes significant decrease in fresh and dry weight of sorghum (Alagesaboopathi 2013). Thus, the studies revealed that allelochemicals found in *A. mexicana* inhibit the growth of other plants and ultimately cause threat to native flora and biodiversity.

Impact of invasive plant species on environment and economy

The invasive plants have a perilous effect on biodiversity and ecosystem. They are responsible to destroy native biodiversity by decreasing the density and frequency of the native flora. The species above discussed have their allelopathic effect and are the worst weeds in India. They produce several allelochemicals which are not only eradicating native flora but also cause serious health hazards in livestock and humans. They are poisonous to cattles and small children if taken accidently. *Lantana* affects sandal wood forest and supports spreading of spike disease in sandal (Holm *et al.* 1997).

Other invasive plant like *Parthenium* is very injurious to plant species, livestock and human health. It is known to cause dermatitis, skin irritation, nausea, and several respiratory problems. It is also responsible for harsh taste of milk of cattles if feeded, due to presence of hepatotoxic compound parthenin (Kohli & Rani 1994) and if this milk is consumed by human beings it may cause deleterious problems.

There are two types of invasive species on economy; direct as well as indirect (Bigsby & Whyte 2001). The effect called direct when effect caused by the invader and the indirect effects produced by the presence of invader and its impact on human health. It has been identified that there are several major impacts of invasion, *i.e.* production, price and market effects, trade, food security and nutrition, human health and environment, financial cost. The cost estimated for the invasive species annually ranges from million to billion dollars (Pimentel *et al.* 2000).

Management strategies

The biggest challenge now a day is how to manage noxious weeds which are highly invasive and allelopathic enough to harm the native flora, vegetation, cropland, animals and ultimately human beings too. There are number of control measures known through which the invasive species can be managed up to some extent if applied properly. They may be mechanical, cultural, biological and chemical methods. Mechanical control includes hand picking, hoeing, mowing, tilling, etc. which are effective when soil is moist, and the roots of the weed are not very deep (Sheley *et al.* 1999a). Mowing can control harsh weeds effectively by reducing production of seeds, by preventing reserve food storage. Mowing has been done during flowering.

Other mechanical methods like chopping, cutting, ploughing can be used for shrubs or trees (Cross & Wiedmann 1985, Mchenry & Murphy 1985, Rasmussen 1991). Tillaging also controls growth of annual species (Young *et al.* 1998).

Biological control

Biological control is mainly used to reduce number and dominancy of a particular plant (Wilson & McCaffrey 1999). Insects, nematodes, pathogens can play important role in controlling noxious weeds. According to Blossey, biological control is cost effective and self-sustained option for controlling weeds (Blossey *et al.* 1994). These biological agents reduce the seed production hence control weeds to spread on large scale (Balciunas & Villegas 1999). In India, *Lantana* is known to be controlled by *Teleonemia scurpulosa* commonly popular as *Lantana* lace bug (Sharma 1988). There are various biological methods to be used to

eradicate these weeds, like Mexican beetle *Zygogramma bicolorata* is used to control *Parthenium* (Kohli *et al.* 2006). A weevil *Eochetina* spp. can be used for the removal of water hyacinth with a positive approach (Mandal 2011). *M. micrantha* can be inhibited by *Helopeltis theivora* the tea mosquito bug (Abraham *et al.* 2002).

Cultural control

There are several other practises are being used since many decades to control the invasion in which grazing, fire, planting of competitive plant species are the major cultural practises. Grazing is useful only upto some extent, depending on the nature of the invasive plant. If the species is palatable for cattle like *Cyperus, Cynodon* etc. can be consumed as forage then grazing works but in case of toxic weeds like *Parthenium, Lantana,* etc. which have adverse and harmful effects on livestock if consumed. Plant species producing allelochemicals are highly toxic to livestock (Kingsbury 1964).

Grazing is also affected by behaviour of cattle *i.e*. the pattern, habit and period of grazing. Cattle mostly feed on soft and non-flowering plants only while few of the cattle like goat also use to feed on plants with spines as well as flowers also (*Thomsen et al.* 1993). Grazing can be effective when done just before flowering period and defoliation (Kennet *et al.* 1992). Rotational grazing is practised to manage invasive species (DiTamaso 2000a). In this intensive grazing for few days is conducted.

Fire is another way to maintain and check invasion ultimately helps in maintaining the ecosystem (Hatch *et al.* 1991). Burning is proved to be successful in controlling the non- woody invasive species (Ueckert *et al.* 1988). The burning may be time dependent, which will help to check the dispersal of seeds and to destroy the viable seeds (DiTomaso *et al.* 1999a, Sheley *et al.* 1999a).

Another cultural practise which is employed to control the noxious weeds is re-vegetation which means planting a species which establishes strong competition between that species and the invasive flora. It has been proved a good long term scheme to curb the invasion of foreign flora and their dominancy (Borman *et al.* 1990). The limitation of the scheme is the selectivity of the plants. They must be more aggressive to the plant to be wiped out. Broad leaf plants can suppress the smaller weeds easily (Lee 1986). Various eco-friendly methods have also been used like antagonistic plants such as *Cassia sericea* (Joshi *et al.* 1991). Essential oil of *Eucalyptus* has potential to control *Parthenium hysterophorus* (Kohli *et al.* 1998, Singh *et al.* 2005).

In agriculture the inhibitory effects of allelochemicals itself are utilized for weed control (Kohli *et al.* 1998). The allelochemicals have both stimulatory and inhibitory effects that had on different crops which are concentration dependent. At low concentration, they have positive effect and they proved beneficial for the plants, but in higher concentration they have toxic effect which may be used to control foreign plants (Narwal 1994).

So allelopathy has broad prospect in increasing crop plant protection, biological control, etc. The research and application of allelopathy itself have the great significance on the prevention of exotic invasive noxious weeds.

Chemical control

The herbicides and weedicides are the most commonly used since decades to stifle the invasive species. The uses of chemicals are quite expensive but have rapid and satisfactory effect on unwanted plants. They can be applied on the vegetation by aircrafts, helicopters, sprayers and herbicide applicators. A number of synthetic chemicals like herbicides and weedicides are being used like paraquat, glyphosate, simazine, 2,4-D and 2,4,5-T,dicamba, triclopr, etc. which are usually growth regulators but when used in high dosages they kill the plants. Other herbicides which act on amino acid synthesis of plants are glyphosate, imazapyr, metsulfuron, etc. are also effective to control weeds by checking photosynthetic process of the plant (Bussan & Dyer 1999).

Prevention of invasion of alien species can be done with a proper management approach. For the purpose, to control and manage the invasive flora some continuous and effective steps should be taken for example, by preventing the introduction of seeds and propagules of invasive species, spreading awareness regarding invasion and its detrimental effects, early detection and their management through a proper and effective management strategy (DiTomaso 2000b). Invasion may occur through seed dispersal by water, wind, animals, insects and human activities. Alien seeds and propagules can also be imported through the seed purchase and a new species can be imported for ornamental purpose and for the programs to get rid of pollutants and pollution. The purity of the seeds and propagules should be checked and assured. The invasion also takes place through the soil. The soil

contains several seeds and propagules which invaded through roadsides and construction work (DiTomaso 2000b). The animals which feed on them and the seeds dispersed through their excretory wastes and produces viable seeds. Invasion also occurs through vehicles andtransportation through water, roadways and railways, etc. The disturbed and barren areas are more prone to invasion (Forcella & Harvey 1983, Tyser & Key 1988). The invasive species are more virulent for the disturbed areas to form dominant vegetation (Sheley *et al.* 1998). So it can be managed by re-vegetation of competitive species to control over invasive plants through allelopathy.

General awareness is another way to make people educate about the invasion, invasive species and their harmful effects. People should be informed through web, posters, papers and articles (DiTomaso 2000b). The farmers of the country should be aware to invasive flora and it is necessary to make them realise about the loss of vegetation and crop field through the effect of alien flora so that they can protect their fields and crops on their own level. Several education events should be organised to make aware about the economic and biodiversity loss. The most valuable and best method to control the invasive species is early monitoring. The weed should be detected as soon as possible and should be removed before it proliferate, reproduce and spread to become invasive and unmanageable. Ecologically exotic plants can be managed by developing a resistant plant community of various species which can cover several niches (Jacobs *et al.* 1999, Sheley *et al.* 1998).

Proper detection and monitoring can be done by professionals, management experts in a systematic way to control over invasion (Zamora & Thrill 1999). Regular visits, field surveying, photography and removal of particular weed from that particular area before establishment are convenient ways to control exotic species (Sheley *et al.* 1999b).

The biggest challenge now a day is to manage noxious weeds which are highly invasive and allelopathic enough to harm the native flora, vegetation, cropland, animals and ultimately human beings too. Once the plant species establishes itself in a particular habitat, it is hard to manage and remove permanently, then periodic strategy should be needed to manage them.

Earlier various screening systems have been developed independently all over the world. A screening system was developed for woody invasive plants (Reichard & Hamilton 1997). Developing screening system in an applied initiative to different regions may produce effective result if used properly (Curtis *et al.* 1999). A proper monitoring of invasion can be done through well- timed and quantitative approach using mapping methods (like map overlays or GPS). Along with it images can be taken through remote sensing satellites to estimate the level of invasion (Reddy 2008). Studies shows that first juvenile plants should be cleared then high density large plants should be eradicated (Higgins *et al.* 2000).

CONCLUSION

The exotic plants invasion is the major problem these days across the world and has adverse effect on vegetation and agricultural system. There are several factors which influence the invasion process of alien flora. Various hypotheses have been proposed through which invasion of exotic plants takes place. Studies around the world highlighted allelopathy which has major role in establishment and rapid invasion of alien plants. Studies also reveal that the allelochemicals found in these exotic plants are the major strength to compete them with any type of habitat and environment with successful invasion. Various strategies have been also discussed regarding control of the invasive plant species including biological, cultural and chemical practises. Sometimes allelopathy itself can be proved as a control measure against invasion. It is a long term process to completely eradicate and control over invasive alien flora but with proper management and time to time screening can help to overcome this problem in India as well as on global scale. The consequences of invasion are, however, still miserable and there is an immediate need of studies on biological invasions on large scale in India.

Public awareness is necessary regarding environmental change and biodiversity loss. People should make aware of sustainable use of land and the effects of invasive species on the native flora and biodiversity. According to Robertson *et al.* (2003) scientists should mark alien species according to the level of threat and rate of spread in each of the climatic zones. There is also a need to provide adequate sources and strategies through which proper management can be done to control the invasion process in future.

REFERENCES

Abraham M, Abraham CT & Joy PJ (2002) Natural enemies on *Mikania micrantha* H.B.K. in Kerala. *Journal of Tropical Agriculture* 40: 39–41.

Adkins SW & Sowerby MS (1996) Allelopathic potential of the weed *Parthenium hysterophorus* L. in Australia. *Plant Protection Quarterly* 1: 20–23.

Alagesaboopathi C (2013) Allelopathic Effect of Different Concentration of Water Extract of *Argemone mexicana* L. on Seed Germination and Seedling Growth of *Sorghum bicolor* (L.) Moench. *Journal of Pharmacy and Biological Sciences* 5: 52–55.

Annapurna C& Singh JS (2003) Phenotypic plasticity and plant invasiveness: Case study of congress grass. *Current Science* 85: 197–201.

Bais HP, Vepachedu R, Gilroy S, Callaway RM & Vivanco JM (2003) Allelopathy and exotic plant invasion: from molecules and genes to species interactions. *Science* 301: 1377–1380.

Balciunas J & Villegas B (1999) Two new seed head flies attack yellow starthistle. *California Agriculture* 53(2): 8–11.

Barrett SCH (1989) Waterweed invasions. *Scientific American* 260: 90–97.

Baruah NC, Sarma JC, Sarma S & Sharma RP (1994) Seed germination and growth inhibitory cadinenes from *Eupatorium adenophorum* Spreng. *Journal of Chemical Ecology* 20: 1885–1892.

Bennet SSR, Naithani HP & Raizada MB (1978) *Parthenium* L. in India -A review and history. *Indian Journal of Forestry* 1(2): 128–131.

Bever BO (1982) *Medicinal plants in West Africa*. Cambridge University Press, London, pp. 118.

Bigsby H & Whyte C (2001) Quantifying phytosanitary barriers to trade. In: Hooker N & Murano E (eds) *Interdisciplinary Food Safety Research.* CRC Press, New York.

Bingelli P (1996) A Taxonomic, biogeographical and ecological overview of invasive woody plants. *Journal of Vegetation Science* 7: 121–124.

Blossey B, Schroeder D, Hight SD & Malecki RA (1994) Host specificity and environmental affect of the weevil *Hylobius transversovittatus*, a biological control agent of purple loosestrife (*Lythrum salicaria*). *Weed Science* 42: 128–133.

Borman MM, Krueger WC & Johnson DE (1991) Effects of established perennial grasses on yields of associated annual weeds. *Journal of Range Management* 4: 318–326.

Burhan N & Shaukat SS (1999) Allelopathic Potential of *Argemone mexicana* L.—A Tropical Weed. *Pakistan Journal of Biological Sciences* 2: 1268–1273.

Bussan AJ & Dyer WE (1999) Herbicides and rangeland. In: Sheley RL & Petroff JK (eds) *Biology and Management of Noxious Rangeland Weeds*. Corvallis, OR: Oregon State University Press, pp. 116–132

But PPH, He ZD, Ma SC, Chan YM, Shaw PC, Ye WC & Jiang RW (2009) Antiviral constituents against respiratory viruses from *Mikania micrantha*. *Journal of Natural Products* 72: 925–928.

Reddy CS (2008) Catalogue of invasive alien flora of India. *Life Science Journal* 5(2): 84–89.

Callaway RM & Aschehoug ET (2000) Invasive plants versus their new and old neighbours: a mechanism for exotic invasion. *Science* 290: 521–523.

Chandra A, Anand A & Dubey A (2007) Effect of Salicylic Acid on Morphological and Biochemical Attributes in Cowpea. *Journal of Environmental Biology* 28: 193–196.

Chen L, Liao L, Wang S, Huang Z & Xiao F (2002) Effect of Vanillin and P-hydroxybenzoic acid on Physiological Characteristics of Chinese Fir Seedlings. *The journal of Applied Ecology* 13: 1291.

Colautti RI, Ricciardi A, Grigorovich IA & MacIssac HJ (2004) Is invasion success explained by the enemy release hypothesis? *Ecology letters* **7**: 721–733.

Cross BT & Wiedemann HT (1985) Grubbing for control of blackbrush acacia (*Acacia rigidula*) invading root plowed rangeland. *Weed Science* 33: 263–266.

Cruz-Ortega R, Anaya AL, Hernández-Bautista BE & Laguna-Hernández G (1998) Effects of Allelochemical Stress Produced by *Sicyosdeppei*on Seedling Root Ultrastructure of *Phaseolus vulgaris* and *Cucurbita ficifolia*. *Journal of Chemical Ecology* 24: 2039–2057.

Cruz-Ortega R, Lara-Núñez A & Anaya AL (2007) Allelochemical Stress Can Trigger Oxidative Damage in Receptor Plants: Mode of Action of Phytotoxicity. *Plant Signaling & Behaviour* 2: 269–270.

Curtis CD & Carino DA (1999) Threats of invasive plants to the conservation of biodiversity. In: Chou CH, Waller GR & Reinhardt C (eds) *Biodiversity and Allelopathy: From Organism to Ecosystem in the Pacific*. Academia Sinica, Taipei, pp. 21–27.

Day MD, Wiley CJ, Playford J & Zalucki MP (2003) *Lantana*: Current Management, Status and Future Prospects. *Australian Centre for International Agricultural Research* 5: 1–20.

Deng X, Ye WH, Feng HL, Yang QH, Cao HL, Xu KY & Zhang Y (2004) Gas exchange characteristics of the invasive species *Mikania micrantha* and its indigenous congener *M. cordata* (Asteraceae) in South China. *Botanical Bulletin of Academia Sinica* 45: 213–220.

Ding ZH, Guo YB & Ding JK (1999) Chemical constituents from the flower of *Eupatorium adenophorum. Acta Botanica Yunnanica* 21: 505–511.

DiTomaso JM (2000a) Irrigated pastures. In: Colbert F (ed) *Principles of Weed Control in California*. 3rd ed. Fresno, CA: Thomson Publishing.

DiTomaso JM (2000b) Invasive weeds in rangelands: Species, impacts, and management. *Weed Science* 48(2): 255–265.

DiTomaso JM, Kyser GB & Hastings MS (1999a) Prescribed burning for control of yellow starthistle (*Centaurea solstitialis*) and enhanced native plant diversity. *Weed Science* 47: 233–242.

Dogra KS, Kohli RK & Sood SK (2009) An assessment and impact of three invasive species in the Shivalik hills of Himachal Pradesh, India. *International Journal of Biodiversity* and *Conservation* 1(1): 4–10.

Dorken ME& Barrett SCH (2004) Phenotypic plasticity of vegetative and reproductive traits in monoecious and dioecious populations of *Sagittaria latifolia* (Alismataceae): A clonal aquatic plant. *Journal of Ecology* 2: 32–44.

Einhellig FA, Rasmussen JA, Hejl AM & Souza IF (1993) Effects of Root Exudate Sorgoleone on Photosynthesis. *Journal of Chemical Ecology* 19: 369–375.

Elton CS (1958) *The ecology of Invasions by animals and plants*. Methuen, London.

Feng HL, Cao HL, Liang XD, Zhou XX & Ye WH (2002) The distribution and harmful effects of *Mikania micrantha* in Guangdong. *Journal of Tropical and Suubtropical Botany* 10: 263–270.

Feng HL, Li Y, Ye WH, Yu Z & Huang ZR (2004a) The chemical component of the stem and leaves of *Mikania micrantha*. *Chinese Traditional and Herbal Drugs* 35: 17–18.

Feng HL, Yang CJ, Zhang X & Ye WH (2004b) Preliminary studies on the bioactivity of crude extract from *Mikania micrantha* on insect and plant, pathogen. *Acta Scientiarum Naturalium Universitatis Sunyatseni* 43: 82–85.

Forcella E & Wood JT (1984) Colonization potentials of alienweeds are related to their 'native' distributions: Implications for plant quarantine. *Journal of the Australian Institute of Agricultural Science* 50(1): 36–40.

Forcella F & Harvey SJ (1983) Eurasian weed infestation in western Montana in relation to vegetation and disturbance. *Madrono* 30: 102–109.

Gentle CB & Duggin JA (1997) Allelopathy as a competitive strategy in persistent thickets of *Lantana camara* L. in three Australian forest communities. *Plant Ecology* 132: 85–95.

Goodin BJ, McAllister AJ & Fahrig L (1998) Predicting invasiveness of plant species based on biological information. *Conservation Biology* 13: 422–426.

Gunaseelan VN (1987) Parthenium as an additive with cattle manure in biogas production. *Biological Wastes* 1: 195–202.

Hatch DA, Bartolome JW & Hillyard DS (1991) Testing a management strategy for restoration of California's native grasslands. In: *Proceedings of the Symposium on Natural Areas and Yosemite: Prospects for the Future*. Denver, CO: U.S. National Park Service, pp. 343–349.

He AJ & Liu LH (1990) Effect of water extract of *Eupatorium adenophorum* on the germination of several plants. *Chinese journal of Weed Science* 4: 35–38.

Heirro JL & Callaway RM (2003) Allelopathy and exotic plant invasion. *Plant and Soil* 256: 29–39.

Higgins SI, Richardson DM & Cowling RM (2000) Using a dynamic landscape model for planning the management of alien plant invasions. *Ecological applications* 10: 1833–1848.

Holm LG, Plucknett DL, Pancho JV & Herberger JP (1977) *The World's Worst Weeds: Distribution and Biology*. The University Press of Hawaii, Honolulu USA, pp. 609.

Inderjit (2005) Soil microorganisms: an important determinant of allelopathic activity. *Plant and Soil* 274: 227–236.

Inderjit & Callaway RM (2003) Experimental designs for the study of allelopathy. *Plant and Soil* 256: 1–11.

Inderjit & Seastedt TR, Callaway RM & Kaur J (2008) Allelopathy and plant invasions: traditional, congeneric, and biogeographical approaches. *Biological Invasion* 10: 875–890.

Jacobs JS, Carpinelli MF & Sheley RL (1999) Revegetating noxious weed-infested rangeland. In: Sheley RL & Perroff JK (eds) *Biology and Management of Noxious Rangeland Weeds*. Oregon State University Press, Corvallis, pp. 133–141.

Joshi S (1991) Biological control of *Parthenium hysterophorus* L. (Asteraceae) by *Cassia uniflora* Mill. (Leguminosae) in Bangalore, India. *Tropical Pest Management* 37: 182–184.

Kanchan SD & Jayachandra (1980) Allelopathic effects of *Parthenium hysterophorus* L. IV.Identification of inhibitors. *Plant and Soil* 55: 67–75

Karlsson LM, Tamado T& Milberg P (2003) Seed Dormancy Pattern of the Annuals *Argemone ochroleuca* and *A. mexicana* (Papaveraceae). *Flora-Morphology, Distribution, Functional Ecology of Plants* 198: 329–339.

Kennett GA, Lacey JR, Butt CA, Olson-Rutz KM & Haferkamp MR (1992) Effects of defoliation, shading and competition on spotted knapweed and bluebunch wheatgrass. *Journal of Range Management* 5: 363–369.

Kingsbury JM (1964) Poisonous Plants of the United States and Canada.Prentice-Hall, Englewood Cliffs, pp. 296–397.

Kohli R, Batish KD & Singh HP (1998) Allelopathy and its implications in agro ecosystems. *Journal of Crop Production* 1(1): 169–202.

Kohli RK, Batish DR, Singh HP & Dogra KS (2006) Status, invasiveness and environmental threats of three tropical American invasive weeds (*Parthenium hysterophorus* L., *Ageratum conyzoides* L., *Lantana camara* L.) in India. *Biological Invasions* 8: 1501–1510.

Kohli RK & Batish DR (1994) Exhibition of allelopathy by *Parthenium hysterophorus* L. in agroecosystems. *Tropical Ecology* 35: 295–307.

Kohli RK & Rani D (1994*) Parthenium hysterophorus*– a review. *Research Bulletin (Science) of Panjab University* 44: 105–149.

Kohli RK, Batish D & Singh HP (1998) Eucalypt oils for the control of *Parthenium* (*Parthenium hysterophorus* L.). *Crop Protection* 17: 119–122.

Kohli RK, Dogra KS, Batish DR & Singh HP (2004) Impact of invasive plants on the structure and composition of natural vegetation of northwestern Indian Himalayas. *Weed Technology* 18: 1296–1300.

Kong C, Hu F & Xu X (2002) Allelopathic potential and chemical constituents of volatile oil from *Ageratum conyzoides* under stress. *Journal of Chemical Ecology* 28: 1173–1182.

Kong CH, Xu T & Hu F (1998) Allelopathy of *Ageratum conyzoides* (II): Releasing mode and activity of main allelochemicals. *Chinese Journal of Applied Ecology* 9: 257–260.

Kong GH, Wu QG & Hu QM (2000) Appearing of exotic weed *Mikania micrantha* H.B.K. in China. *Journal of Tropical and Subtropical Botany* 8: 27.

Lee GA (1986) Integrated control of rush skeleton weed (*Chondrilla juncea*) in the western U.S. *Weed Science* 34: 2–6.

Levine JM, Alder PB & Yelenik SG (2004) A meta-analysis of biotic resistance to exotic plant invasions. *Ecology Letters* **7**: 975–989.

Li Z-H, Wang Q, Ruan X, Pan C-D & Jiang D-A (2010) Phenolics and Plant Allelopathy. *Molecules* 15: 8933–8952.

Lu RD (1982) Studies on anti-insect pheromone: chemical components of *Ageratum conyzoides* and their effects on insects. *Entomological Knowledge* 19: 22–25.

Ma WJ, Xiao DJ & Deng SZ (2004) Terpenoids constituents of the leaves of *Lantana camara*. *Guangzhou Chemistry* 29: 14–19.

Mack RN, Simberloff D, Lonsdale WM, Evans H, Clout M & Bazzaz FA (2000) Biotic invasion: Causes, epidemiology, global consequences and control. *Ecological Applications* 10: 689–710.

Maishi AI, Ali PKS, Chaghtai SA & Khan G (1998) A proving of *Parthenium hysterophorus* L. *British Homoeopathic journal* 87: 17–21.

Mandal FB (2011) The management of alien species in India. *International Journal of Biodiversity and Conservation* 3(9): 467–473.

Mantri A, Annapurna C & Singh JS (2002) Terrestrial plant invasion and global change. In: Tripathi G & Tripathi YC (eds) *Bioresource and Environment*.Campus Book International, New Delhi, pp. 25–44.

Marks MK & Nwachuku AC (1986) Seed bank Characterstics in a group of Tropical weeds. *Weed Research* 26: 151–157.

McHenry WB & Murphy AH (1985) Weed management of California rangeland. In: Kurtz EA & Colbert FO (eds) *Principles of Weed Control in California*. Thomson Publishing, Fresno, pp. 413–423.

Meng XX, Feng JC, Zhou YJ, Wang FM, Qu M, Lin G, Zhao CJ, Zhu YJ, Ying J & Yang H (2003) Ecological factor analysing of the invasion of crofton weed in southwestern Shichuan province. *Journal of central university for nationalities (Natural Sciences Edition)* 12: 293–300.

Mitchell CE, Agrawal AA, Bever JD, Gilbert GS, Hufbauer RA, Klironomos JN, Maron JL, Morris WF, Parker IM, Power AG, Seabloom EW, Torchin ME & Va´zquez DP (2006) Biotic interactions and plant invasions .*Ecology Letters* 9: 726–740.

Morin L, Reid AM, Sims-Chilton NM, Buckley YM, Dhileepan K, Hastwell GT, Nordblom TL & Raghu S (2009) Review of approaches to evaluate the effectiveness of weed biological control agents. *Biological control* 5: 1–15.

Muzaffar S, Ali B & Wani NA (2012) Effect of Catechol, Gallic Acid and Pyrogallic Acid and the Germination, Seedling Growth and the Level of Endogenous Phenolics in Cucumber (*Cucumis sativus* L.). *International Journal of Life Science Biotechnology and Pharma Research* 1: 51–59.

Narasimban TR, Murthy BSK, Harindramath N & Rao PVS (1984) Characterization of a toxin from *Parthenium hysterophorus* and its mode of excretion in animals. *Journal of Biosciences* 6: 729–738.

Narwal SS (1994) *Allelopathy in crop production*. Scientific Publishers, Jodhpur, India, 288 p.

Narwal S, Palaniraj R & Sati S (2005) Role of Allelopathy in Crop Production. *Herbologia* 6: 327–332.

Nayar MP (1977) Changing pattern of the Indian flora. *The Bulletin of the Botanical* Survey *of India* 19: 145–154.

Noble IR & Slatyer RO (1980) The use of vital attributes to predict successional changes in plant communities subject to recurrent disturbances. *Vegetation* 43: 5–21.

Okunade AL (2002) *Ageratum conyzoides* L. (Asteraceae). *Fitoterapia* 73: 1–16.

Pan WD, Mai LT, Li YJ, Xu XL & Yu DQ (1993) Studies on chemical constituents of the leaves of Lantana camara. *Acta Pharmaceutica Sinica* 28: 35–39.

Paul N & Begum N (2010) Allelopathic Effect of *Argemone Mexicana* L. on Germination and Seedling Growth Characteristics of Lentil (*Lens culinaris*). *Journal of Bio-Science* 18: 146–147.

Pieterse AH & Murphy KJ (eds) (1990) *Aquatic Weeds*, Oxford University Press, Oxford.

Pimentel D, Lach L, Zuniga R & Morrison D (2000) Environmental and economic costs of non-indigenous species in the United States. *Bioscience* 50: 53–65.

Quan G, Zhang J, Xu H, Mao D & Qin Z (2009) Allelopathic effects of different parts of invasive plant *Lantana camara*. *Chinese agricultural Science Bulletin* 25(12): 102–106.

Raghubanshi AS, Rai LC, Gaur JP & Singh JS (2005) Invasive alien species and biodiversity in India. *Current Science* 88(4): 539–540.

Rasmussen GA (1991) Oakbrush: classification, ecology, and management. In: James JF, Evans JO, Ralphs MH & Child RD (eds) *Noxious Range Weeds*. Westview Press, San Francisco, pp. 352–363.

Rastogi J, Rawat DS & Chandra S (2015) Diversity of invasive alien species in Pantnagar flora. *Tropical Plant Research* 2(3): 282–287.

Reichard SH & Hamilton CW (1997) Predicting invasions of woody plant introductions into North America. *Conservation Biology* 11: 193–203.

Rejmanek M & Richardson DM (1996) What attributes make some plant species more invasive? *Ecology* 77(6): 1655–1661.

Rejmanek M & Randall JM (1994) Invasive alien plants in California: 1993 Summary and comparison with other areas in North America. *Madrona* 41: 161–177.

Rice EL (1984) *Allelopathy, 2nd edition*. Academic Press, New York, USA.

Richardson DM, Allsopp N, D'Antonio CM, Milton SJ & Rejmanek M (2000) Plant invasions - the role of mutulasims. *Biological Reviews of the Cambridge Philosophical Society* 75: 65–93.

Rimando AM, Dayan FE, Czarnota MA, Weston LA & Duke SO (1998) A New Photosystem II Electron Transfer Inhibitor from *Sorghum bicolor*. *Journal of Natural Products* 61: 927–930.

Robertson MP, Villet MH, Fairbanks DHK, Henderson L, Higgins SI, Hoffmann JH, Le Maitre DC, Palmer AR, Riggs I, Shackleton CM & Zimmermann HG (2003) A proposed prioritisation system for the management of weeds in South Africa. *South African Journal of Science* 99: 37–43.

Roder W, Keobulapha B, Phengchanh S, Prot JC & Matias D (1998) Effect of residue management and fallow length on weeds and rice yield. *Weed Research* 38: 167–174.

Roxburgh W (1884) *Hortus bengalensis*. Mission Press, Calcutta.

Ruiz GM, Fofonoff PW, Carlton JT, Wonham MJ & Hines AH (2000) Invasion of coastal marine communities in North America: Apparent patterns, processes, and biases. *South African* Journal of *Science* 31: 481–531.

Sage RF (2004) The evolution of C4 photosynthesis. *New Phytologist* 161: 341–370.

Sanaa A (2012) Perspectives on the Relationship between Invisibility, Richness, Plant Size, Seed Production, Seed Bank and Community Productivity of Invasive *Argemone ochroleuca* Sweet in Taif, Saudi Arabia. *Life Science Journal* 9: 953–958.

Shao H, Peng SL, Zhang C, Xiang YC & Na P (2003) Allelopathic potential of *Mikania micrantha*. *Chinese Journal of Ecology* 22: 62–65.

Sharma GP, Raghubanshi AS & Singh JS (2005) Lantana invasion: An overview. *Weed Biology Management* 5: 157–167.

Sharma OP, Makkar HPS & Dawra RK (1988) A review of the noxious plant *Lantana camara*. *Toxicon* 26: 975–987.

Sharma OP & Sharma PD (1989) Natural products of the Lantana plant -the present and prospects. *Journal of Scientific & Industrial Research* 48: 471–478.

Sharma PD & Sharma OP (1995) Natural products chemistry and biological properties of *Ageratum* plant. *Toxicological and Environmental Chemistry* 50: 213–232.

Sharma OP (1988) How to combat Lantana (*Lantana camara* L.) menace? A current perspective. *Journal of scientific and Industrial research* 47: 611–616.

Sheley RL, Jacobs JS & Carpinelli ME (1998) Distribution, biology, and management of diffuse knapweed (*Centaurea diffusa*) and spotted knapweed (*Centaurea maculosa*). *Weed Technology* 12: 353–362.

Sheley RL, Manoukian M & Marks G (1999b) Preventing noxious weed invasion. In: Sheley RL & Petroff JK (eds) *Biology and Management of Noxious Rangeland Weeds*. Oregon State University Press, Corvallis, pp. 69–72.

Sheley RL, Kedzie-Webb S & Maxwell BD (1999a) Integrated weed management on rangeland. In: Sheley RL & Petroff JK (eds) *Biology and Management of Noxious Rangeland Weeds*. Oregon State University Press, Corvallis, pp. 57–68.

Singh CM, Angras NM & Kumar S (1996) *Weed management*. MD publications, New Delhi.

Singh HP, Batish DR, Setia N & Kohli RK (2005) Herbicidal activity of volatile oils from *Eucalyptus citriodora* against *Parthenium hysterophorus*. *Annals of Applied Biology* 146: 89–94.

Singh KP, Shukla AN & Singh JS (2010) State-level inventory of invasive alien plants, their source regions and use potential. *Current Science* 90(1): 107–114.

Song J (1990) Allelopathy Among Plants. *Chinese Journal of Ecology* 9(6):43–47.

Song QS, Fu JJ, Tang JW, Feng LZ & Yang CR (2000) Allelopathic potential of *Eupatorium adenophorum. Acta Phytoecologica Sinica* 24: 362–365.

Sun WH & Yu SW (1992) Allelopathy and Its Potential Application. *Plant Physiology Communications* 28(2): 81–87.

Sun WH, Yu SW, Yang SY, Zhao BW, Yu ZW, Wu HM, Huang SY & Tang CS (1993) Allelochemicals from root exudates of water hyacinth (*Eichhornia crassipes*). *Acta Phytophysiologica Sinica* 19: 92–96.

Thomsen CD, Williams WA, Vayssieres M, Bell FL & George MR (1993) Controlled grazing on annual grassland decreases yellow starthistle. *California Agriculture* 7(6): 36–40.

Towers GHN & SubbhaRao PV (1992) Impact of the pan-Tropical weed, *P. hysteroporus* L. on human affairs. In: Richardson RG (ed) *Proceedings of the first international weed control congress, Melbourne, Australia*. Weed science society of Victoria, pp. 134–138.

Tripathi RS, Khan Ml & Yadav AS (2012) Biology of *Mikania micrantha* H.B.K.: a Review In: Bhatt JR, Singh JS, Singh SP, Tripathi RS & Kohli RK (eds) *Invasive Alien Plants: An Ecological Appraisal for the Indian Subcontinent*. CAB International, MoEF, New Delhi, India, pp. 99–107.

Tyser RW & Key CH (1988) Spotted knapweed in natural area fescue grassland: an ecological assessment. *Northwest Science* 2: 151–160.

Ueckert DN, Petersen JL, Potter RL, Whipple JD & Wagner MW (1988) Managing prickly pear with herbicides and fire. In: *Texas Agricultural Experiment Station Report No. 4570*, pp. 10–15.

Wan F H & Wang R (1990) The biology and ecology characteristic of the malignancy harm grass *Ambrosia artemisiifolia*. *Journal of Weed Science* 4(1): 45–48.

Wei XY, Haung HJ, Wu P, Cao HL & Ye WH (2004) Phenolic constituents from *Mikania micrantha*. *Biochemical Systematics and Ecology* 32: 1091–1096.

Weir TL, Park S-W & Vivanco JM (2004) Biochemical and Physiological Mechanisms Mediated by Allelochemicals. *Current Opinion in Plant Biology* **7**: 472–479.

Weng WP (1964) Evidence for the presence of growth inhibitory substances in *Mikania cordata* (Brum. f.) B.L. Robinson. *Journal of Rubber Research Institute Malaya* 18: 231–242.

Wilcove DS, Rothstein D, Dubow J, Phillips A & Losos E (1998) Quantifying threats to imperilled species in the United States. *Bioscience* 48: 607–615.

Wilson LM & McCaffrey JP (1999) Biological control of noxious rangeland weeds. In: Sheley RL & Petroff JK (eds) *Biology and Management of Noxious Rangeland Weeds*. Oregon State University Press, Corvallis, pp. 97–116.

Wu TJ & Yang GZ (1994) Chemical constituents of the essential oil of *Eupatorium adenophorum* Spreng. *Jounral of Central China Norman University (Natural Sciences Edition)* 28: 87–97.

Xie LJ, Zeng RS, Bi HH, Song YY, Wang RL, Su YJ, Chen M, Chen S & Liu YH (2010) Allelochemical mediated invasion of exotic plants in China. *Allelopathy Journal* 25(1): 31–50.

Yan F, Yan Z-M & Han L-M (2000) Review on research methods for allelopathy and allelochemicals in plants. *Acta Ecologica Sinica* 20(4): 692–696.

Yang SY, Yu ZW, Sun WH, Zhao BW, Yu SW, Wu HM, Huang SY, Zhou HQ, Ma K & Lao XF (1992) Isolation and identification of antialgal compounds from root system of water hyacinth. *Acta Phytophysiologica Sinica* 18: 399–402.

Yang C-M, Lee C-N& Chou C-H (2002) Effects of Three Allelopathic Phenolics on Chlorophyll Accumulation of Rice (*Oryza sativa*) Seedlings: I. Inhibition of Supply-Orientation. *Botanical Bulletin of Academia Sinica* 43: 299–304.

Yi Z, Zhang MX, Ling B, Xu D & Ye JZ (2006) Inhibitory effects of *Lantana camara* and its contained phenolic compounds on *Eichhornia crassipes* growth. *Chinese Journal of Applied Ecology* 17: 1637–1640.

Young JA, Palmquist DE & Blank RR (1998) The ecology and control of perennial pepperweed (*Lepidium latifolium* L.). *Weed Technology* 12: 402–405.

Zamora DL & Thill DC (1999) Early detection and eradication of new weed infestations. In: Sheley RL & Petroff JK (eds) *Biology and Management of Noxious Rangeland Weeds*. Oregon State University Press, Corvallis, pp. 73–84.

Zan QJ, Wang YJ, Wang BS, Liao WB & Li MG (2000) The distribution and harm of the exotic weed *Mikania micrantha*. *Chinese Journal of Ecology* 19: 58–61.

Zhang XL, Wang JW & Zheng LP (1993) The allelopathic effects of maceration exctrat of *Eupatorium adenophorum* on roots of *Zea Mays*- Preliminary studies with electron microscopy and electron probe X-ray microanalyser. *Jounral of Yunnan University* 15(Suppl.2): 112–117.

Zhang MX, Ling B, Kong CH & Pang XF (2003) Chemical components of volatile oil from *Mikania micrantha*. *Chinese Journal of Applied Ecology* 13: 1300–1302.

Zheng HQ, Wei N, Wang LF & He P (2006) Effects of *Lantana camara* leaf extract on the activity of superoxide dismutase and accumulation of H_2O_2 in Water hyacinth leaf. *Journal of Plant Physiology and Molecular Biology* 32: 189–194.