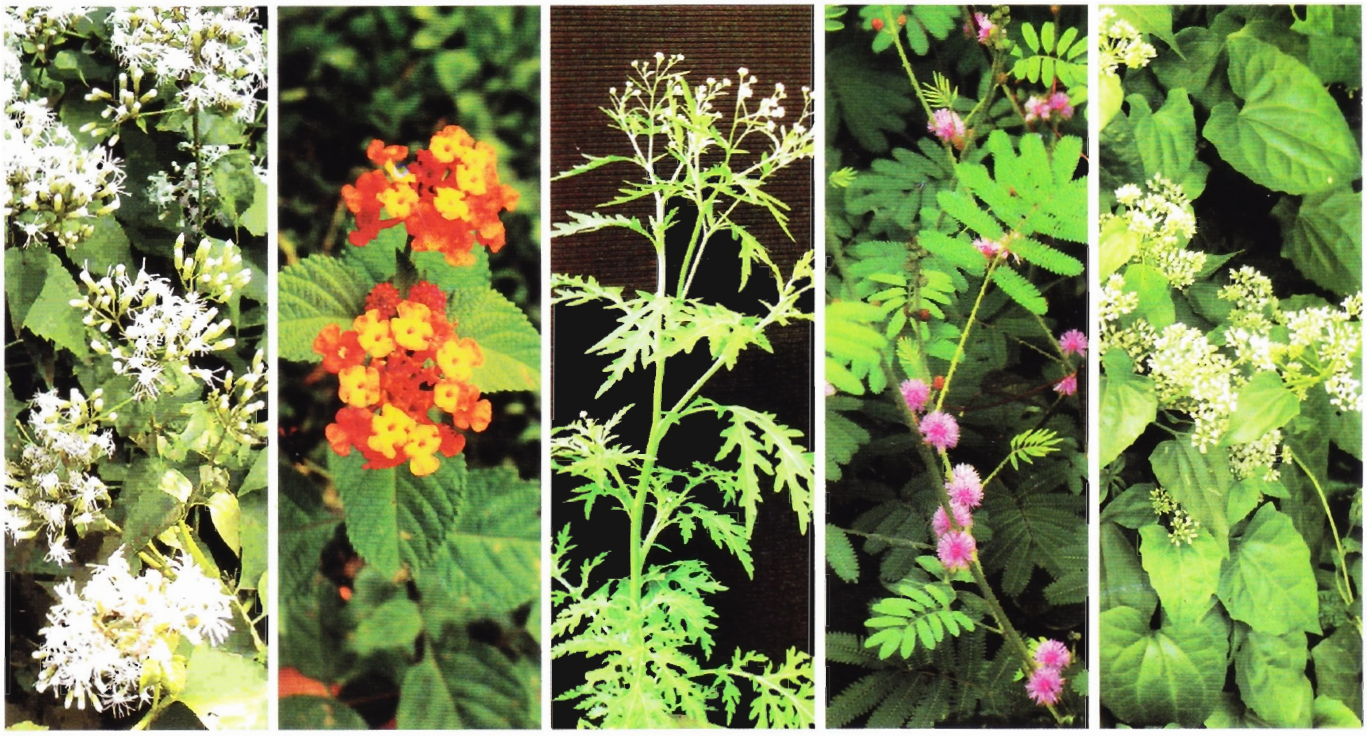
KFRI Research report 445

Major invasive alien weeds in India

Biology and Control

K.V. Sankaran, Carol A. Ellison, T.A. Suresh



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Cover photographs : Major invasive alien weeds in bloom. Left to right-
Chromolaena odorata | *Lantana camara* | *Parthenium hysterophorus* |
Mimosa diplotricha | *Mikania micrantha*

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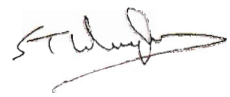
Preface

Invasive alien species are plants, animals and microorganisms that are non-native to a specific ecosystem, where they heavily colonize and adversely affect the functioning of that ecosystem. Their introduction imposes enormous costs in terms of ecological destruction, economic loss or detrimental social effects including harm to human health. Collectively, invasive species are known to cause a loss of nearly five percent of the global GDP. This loss is often overlooked due to the diversity of species involved and the lack of comprehensive mechanisms for their management.

The most significant factor influencing the success of invasive species is the absence of natural enemies in the new habitat. No longer suppressed by these herbivores and diseases, they can aggressively reproduce and expand their area of distribution. This spread is at the cost of local biodiversity and economics since it can impact on agricultural and forest productivity. With increased transcontinental traffic of man and goods, triggered by globalization of markets, the incidence of invasive species introductions is on the rise, the world over. It has also been predicted that global climate change will favor invasive species.

It is at this juncture that this handbook on ***Major invasive alien weeds in India: Biology and control*** reaches you. While politicians debate the issues at the global level, actions need to be taken at the local level. This handbook is designed as a guide to the identification of key invasive plant species, their biology and impact; and most importantly it provides insight into the variety of control options available to ameliorate their negative impact, highlighting the best methods.



Dr. Sean T. Murphy
Director
CABI Europe-UK

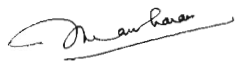
Egham, UK
22 August 2009

Contents

Invasive alien weeds have been a problem in India for almost a century and half. Some were introduced for specific purposes; e.g., as cover-crops, for soil stabilization and as living fences, without realising their potential to become weedy; while many others were accidentally introduced. Multiple introductions have also happened due to our negligence on stringent evaluation of the plant during its initial period of establishment. Within a large country like India which offers a range of climatic and topographic regions, there exists the opportunity for a wide variety of weedy species to become established. Their impacts on agriculture, by competing with crops, and on forests, by depleting the biodiversity, are of serious concern.

While many of the countries have taken up programmes to eradicate invasive weeds and put in place stringent quarantine measures to prevent further introductions, in India the approach has often been by appropriation rather than eradication. Rural Indians have not only learned to live with invasive species of weeds, but have also invented ways of using them - in composting, as cover crop, for fibre, as pest repellants, fuel, green manure, as nitrogen fixing plants and as medicinal plants. This process of appropriation is largely run by the rural populace, who tend and manage land for their living. However industrious this appears at face value, it should be noted that in many cases, the invasive species have replaced the native plants that were originally exploited for these uses, e.g., lantana is used in place of the outcompeted rattan. These methods of appropriation have seldom been successful in limiting the spread of invasive weeds or its adverse impact on many fragile ecosystems like the natural forests. In most cases, the economic loss inflicted by the weeds and their negative impact on biodiversity far outweigh their uses.

Major alien invasive weeds in India*: *Biology and control is intended to be used at the grass root level. The handbook gives information on five of the most important invasive alien weeds of India. The taxonomic position of the plant, its local names, native range, current global distribution, habit, seed dispersal, habitat, mode of infestation, threat and damage, uses and control measures - mechanical, chemical and biological, are presented here. It is intended that the information presented here will help the reader to be proactive in containing and managing these invasive weeds.



Thiruvananthapuram
22 August 2009

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Principal Chief Conservator of Forests
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Siam weed

Scientific name *Chromolaena odorata* (L.) R.M. King & Robinson

Synonyms *Eupatorium odoratum*, *E. affine*, *E. brachiatum*, *E. clematitis*, *E. conyzoides*, *E. divergens*, *E. floribundum*, *E. graciliflorum*, *E. sabeanum*, *E. stigmatosum*, *Osmia conyzoides*, *O. divergens*, *O. floribunda*, *O. graciliflora*, *O. odorata*

Common names Siam weed, bitter bush, triffid weed, Jack in the bush, Christmas bush, baby tea, communist weed and devil weed.

Local names Communist pacha, Assam pacha, Assam lota, German bane, Assam-lata (India), tawbizat (Myanmar), tontrem khet (Cambodia), French weed (Laos) kirinyu, kumpai jepang (Indonesia)

Siam weed in full bloom

Taxonomy

Chromolaena odorata (chromolaena) belongs to the family Asteraceae. Two different phenotypes of the weed have been recognized in Queensland, Australia.

Nativity

Native of tropical America, where it is found from Florida to northern Argentina in most areas below 1000 m altitudes except in undisturbed rainforests. It is not a serious weed in its native range since its growth is checked by more than 200 insect natural enemies and a plethora of fungal pathogens.

Current distribution

Widespread native plant in South and Central America; invasive throughout the Asia-Pacific region and Africa; patchy distribution in northern Australia, where a containment programme is in place. Chromolaena was first introduced into Asia in the 1840's probably via the Botanical Gardens in Calcutta (India) and has since spread throughout southeast Asia to the south Pacific. Its spread with in India has been attributed to the movement of people, equipment and materials during the Second World War.

Siam weed - shoot architecture

Habit

Chromolaena odorata is a fast growing, upright or scrambling perennial shrub that forms dense tangled bushes 1.5 - 3.0 m in height with 20 to 105 shoots/m^2. It occasionally grows to a maximum height of 6 m climbing on other plants. Stems and branches are glandular, pubescent, terete, branch freely, with lateral branches developing in pairs from the axillary buds. The older stems are brown and woody near the base; tips and young shoots are green and succulent. Leaves are opposite, flaccid-membranous, velvety-pubescent, deltoid or ovate, acute, 3-nerved, very coarsely toothed, each margin with 1-5 teeth, or entire in youngest leaves; base obtuse or subtruncate but shortly decurrent; petiole slender, 1-1.5 cm long; blade mostly 5-12 cm long and 3 - 6 cm wide. Leaves emit a pungent odour when crushed. The flower heads are borne in terminal corymbs of 20 to 60 heads on all stems and branches. The flowers are white or pale bluish-lilac, and form masses covering the whole surface of the bush; peduncles 1-3 cm long, bracteate; bracts slender, 10-12 mm long; involucre of about 4-5 series of bracts, pale with green nerves, acute, the lowest ones about 2 mm long, upper ones 8-9 mm long, all acute, distally ciliate, flat, apprised except the extreme divergent tip; florets all alike (disc-florets), pale purple to dull off-white, the styles

extending about 4 mm beyond the apex of the involucre, spreading radiately; receptacle very narrow; florets about 20 - 30, 10 - 12 mm long; ovarian portion 4 mm long; corolla slender trumpet form; pappus of dull white hairs 5 mm long; achenes more or less glabrous. The seeds of chromolaena are small, dark coloured, narrow, (3 - 5 mm long, ~1 mm wide) and oblong. The weed produces 0.45 to 1.90 million capitullum/m^2 and 9.0 to 47.5 m seeds/m^2 area. The root system is fibrous and does not penetrate beyond 20 - 30 cm in most soils. It possesses an underground stolon, which ensures the plant's survival in case of fire, drought or mechanical damage. The weed will normally dry-up during summer (February-April) and re-sprout soon after the onset of monsoon rains. Although the plant may re-sprout from the root crown following fire or death of old stems, it is not known to reproduce vegetatively.

Pollination

Seed dispersal

Seeds

Seed dispersal is through wind, water currents, clothing, animal fur, machinery, movement of vehicles and transportation of soil, seeds of crop plants and fertilizers. The primary long-distance vector responsible for the plant spread is human activity. The seed bears minute hooks, which can cling to animal hairs, clothing and vehicles and machinery. Movement of military equipment and personnel during the Second World War may have been responsible for much of the spread of the weed in the Asia-Pacific region. Seed production is prolific with up to 87,000 seeds produced by a mature plant. About 20 - 46% of seeds produced are normally viable. Seeds may survive up to 5 years, irrespective of whether on the surface of the soil or buried; three month-old seeds that have been buried will have about 50% viability compared to about 6% when on the soil surface. Plants can germinate and set seed within a 12-month period.

Habitat

Chromolaena grows on a wide range of soils and vegetation types. It is of common occurrence around peripheries of natural forests, in cultivated lands, abandoned or neglected fields, waste lands, grasslands, arid lands (annual

rainfall less than 500 mm), pastures, plantations, clearings, shrub jungles, nurseries, roadsides, riverbanks, thatched roofs, rocky areas and slash and burnt areas. The weed grows well if the annual rainfall is over 1500 mm, relative humidity between 60 - 70%, and at atmospheric temperatures between 25 to 30°C. It occurs mainly from sea level to 1000 m. Chromolaena doesn't tolerate shade and thrives well in open areas. It will not produce seeds under heavy shade. The weed has a negative relationship with tree canopy cover and appears to be most abundant on the edge of forested areas where canopy tends to be thin due to disturbance. In northeastern India, chromolaena is regarded as a nutrient-demanding early successional species. It takes advantage of the flush of soil nitrogen that becomes available after disturbance, such as fire or land clearing for agriculture; it exhibits relatively high foliar N, P and K contents. The plant will not grow in waterlogged or saline soils.

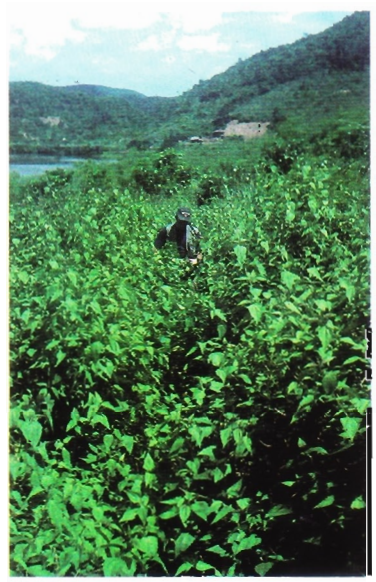
Chromolaena thickets

Mode of infestation

Chromolaena can out compete and smother crops and native vegetation because of its phenomenal growth rate (20 mm/day or 5 m per year) and ability to scramble up on taller plants.

Threat and damage

The aggressive fast growing nature, efficient root system, capacity to grow and establish under a wide variety of agro-ecological conditions, combined with high regeneration capacity and prolific seed production has enabled chromolaena to rapidly invade forest areas, plantations and field crops in many tropical countries. In Asia, chromolaena is a major weed of pastures, and agricultural and plantation cropping systems. It can depress growth, development and yield of several crops such as teak, rubber, cardamom, coffee, tea, citrus, oil palm, coconut, areca nut, cashew and mango. It can form dense stands preventing establishment of other species, both due to competition and allelopathic effects. Chromolaena increases the cost of production in nurseries and hampers harvesting operations in plantations. Its competitive ability is the highest in tropical wet-dry climates, where it burns readily or survives fires during summer to re-grow rapidly in the wet season. Chromolaena can also cause skin problems and asthma in human beings



Chromolaena infestation

and livestock in introduced ranges. In coconut plantations in Sri Lanka, chromolaena competes with the palm for nutrients and water resulting in poor setting of female flowers and premature abscission. In South Africa, the weed is reported to compete for natural resources with the indigenous flora suppressing their growth. In the Philippines, apart from affecting growth and yield of crops like coconut, corn, sweet potato, cassava, sugar cane and rice, the weed invades open fields and pasture lands forming impenetrable pure stands excluding all forage species. In Indonesia, invasion of grazing land by chromolaena resulted in reduction of grazing area for cattle. In Karnataka state, India, heavy infestation by the weed in plantations and natural forests in the hilly tracts is of serious concern causing huge economic loss. It is also a big fire hazard during the dry season in most areas in the Asia-Pacific region.

Chromolaena grows very luxuriantly in teak plantations at all stages of growth of the plantation species until the canopy closes. Once closed, the weed is then confined to the outskirts, or occasionally assumes a straggling habit within the plantation, sending their branches to the top of trees. Teak nurseries infested by the weed will normally have a few impoverished, sickly young teak plants. In forestland freshly cleared and planted with teak and soft wood seedlings, the weed smothers the crops completely. In older plantations of teak still with an open canopy, the weed overtops the trees leaving them slender with a few leaves. In addition to these negative traits, chromolaena is known to harbour a number of insects and mites, which are injurious to other crops.

Hand-weeding of chromolaena is known to cause skin allergy in labourers and the dry stumps left after the weeding operations often caused poisonous wounds on their feet. Incidence of fire destroys most of the upper parts of the weed, leaving the basal clump unaffected. These clumps regenerate soon after the beginning of monsoon enabling the species to become dominant in the new growing season. Chromolaena is endowed with allelopathic potentialities, the leaves having the high levels of allelochemicals. The impoverished growth of the crops growing in areas infested by the weed could at least partly be due to this allelopathic effect. The leaves and stems of the weed are also poisonous to most herbivorous animals causing severe liver damage.

Uses

Growth of chromolaena is encouraged in fields with shifting slash-and-burn agriculture to compete with another weed, *Imperata cylindrica*, which is harder to control. The anti-inflammatory, antipyretic and antibacterial properties of the aqueous extract of chromolaena are well documented. In Nigeria, the aerial parts of the weed are kept along with stored grain to control common storage pests such as the larger grain borer and maize weevil. The weed is also used in biogas production and for mulching, composting and as green manure. Its leaves and flowers contain an oil that exhibit antiseptic property and suppress sexually transmitted diseases, arrest bleeding from cut wounds and is used to induce abortions in women. Chromolaena is also known to control leaf rust disease of mulberry and quick wilt of black pepper. Dried chromolaena is used as fuel in certain countries.

Control

Mechanical and Physical: Cutting close to the ground, uprooting, slashing, controlled burning and cutting and digging out the root system are commonly used. Slashing and uprooting using motorized brush cutters and tractor drawn mowers are practiced in South Africa.

Mechanical control

Cultural: Planting of signal grass, *Brachiaria decumbens*, has been shown to replace chromolaena in pastures and oil palm plantations for a couple of years. Burning and over sowing grass and other native plants is practiced in South Africa. Use of cover crops such as *Tephrosia purpurea*, *Pueraria phaseoloides*, *Calopogonium mucunoides*, *Centrosema pubescens* and *Vigna unguiculata* is practiced in Sri Lanka, India and West Africa to control the weed. Planting of *Leucaena leucocephala* in pastures reduced the population of the weed in Philippines. Controlled burning of mature weeds during summer is not a viable option since vigorous re-growth can occur during the next rains.

Chemical control

Chemical: The common herbicides used are: glyphosate @ 0.72 kg a.i., glyphosate 0.36 kg + diuron 80 wp @1.8 kg a.i., diuron 1.5 kg a.i., atrazine 2 kg a.i., picloram 1 kg, imazapyr @ 0.5 kg a.i., paraquat @0.5 kg, triclopyr ester 480 g/l @ 37.5 ml/l of water and imazapyr 0.5 kg per ha. Use of herbicides at the seedling stage or on re-growth of the weed has given encouraging results. Triclopyr has proven to be one of the most effective herbicides. However, problems in herbicide use include the high cost of the chemicals and their application, ecological concerns and, non-compatibility in many cropping and other environmental situations. Chemical treatment is often used in combination with mechanical methods. Some of the herbicides are applied to prevent re-sprouting of cut stems or to kill seedlings geminating after a clearing operation. The advantage of cut stump methods is that the herbicide is placed on the target plant and thus the effect on environment is minimised.

Damage caused by the leaf feeding moth

Biological: A leaf-feeding moth, *Pareuchaetes psuedoinsulata* and a stem gall fly, *Cecidochares connexa*, have shown some success in controlling chromolaena, particularly in Indonesia. The leaf-feeding moth was also introduced in other countries including Malaysia, Nigeria, Thailand, Ivory Coast, South Africa and India but the results were mixed; the insect established in some countries but not in others. In Guam, the moth effectively defoliates pure stands of chromolaena: it is less successful on scattered plants and in patches. It was also introduced successfully into Mariana Islands and Sri Lanka where it has been effective in reducing the population of the weed. In India, the moth was released in 1973 (from Trinidad), but apparently did not establish. However, it has recently been relocated in Kerala state where it causes damage to the weed in isolated pockets.

Adults of ***Pareuchaetes psuedoinsulata***

The stem gall fly *C. connexa* (originally collected from Mexico, Brazil and Bolivia) was released in Indonesia in 1995 where it has now established. Since then, it has been released in Papua New Guinea, the Philippines and, in 2007, into India. Dieback and death of plants have been recorded at many sites within 3 to 5 years of release, especially in low altitude sites (less than 300m) with a short dry season. At higher altitude sites (over 600 m), cloudy conditions, cold temperatures or long dry seasons limit the number and activity of flies.

In 2000, a butterfly *Actinote anteas* was released in Indonesia but successful establishment of this butterfly has not so far been confirmed. A gall forming eriophyid mite *Acalitus adoratus*, which was accidentally introduced from Trinidad to southeast Asia is considered to be a good biocontrol agent. Release of a flower feeding weevil, *Apion brunneonigrum* in Malaysia, Nigeria, Ghana, India and Sri Lanka was not successful.

Pareuchaetes psuedoinsulata and *Cecidochares connexa*, particularly in combination, have been shown to significantly suppress chromolaena in many part of the invasive range of the weed. In those areas where chromoelana remains a problem, other biocontrol agents could be considered such as the rust fungus. In the medium term, an integrated approach, combining mechanical, cultural, chemical and biological methods, is still required to achieve effective control.

Larvae of *Pareuchaetes psuedoinsulata*

Sleeper weed

Scientific name *Lantana camara L.*

Synonyms *Camara vulgaris, Lantana scabrida*

Common name Sleeper weed, lantana, wild sage

Local names Panchfuli, banlakri, kukril, chudelbuti (north India), aripoo, kongini (Kerala state, India), ach man (Cambodia), angel lips, ayam, big sage, blacksage (Malaysia), pha-ka-krong (Thailand).

Taxonomy *Lantana camara* (lantana) belongs to the family Verbenaceae. The weedy lantana species complex consists of around 650 wild, cultivated and hybridized varieties occurring in over 60 countries. Lantana is considered as one of the world's worst weeds posing threat to several endangered plants and animals and ecological communities.

Nativity Tropical and subtropical regions of central and south America, the Caribbean and West Indies.

Lantana twig with flowers

Current distribution

Naturalized and invasive in approximately 60 countries or island groups between 35^0 N and 35^0 S latitudes. Widespread native plant in central and south America and West Indies; invasive weed in the Asia-Pacific region, Australia, New Zealand, and Africa. The plant is still widening its range. Lantana is widely distributed in India occurring in almost all states of the subcontinent.

Lantana camara- shoot habit

Habit

Lantana camara is a low erect or subscandent, vigorous shrub which can grow to 2 - 4 meters. Leaves are ovate or ovate oblong, 2 - 10 cm long and 2 - 6 cm broad, bright green, in opposite pairs, rough, finely hairy, margins serrate and emit a pungent odour when crushed. Stem in cultivated varieties is often non- thorny and in weedy varieties with recurved prickles, woody, square in cross section and hairy when young, cylindrical and up to 15 cm thick with age, able to climb to 15 m with the support of other vegetation. Flower heads are with 20 - 40 flowers, usually 2.5 cm across, colour varies from white, cream or yellow to orange pink, purple and red. Flowering occurs between August and March or all year round if adequate moisture and light are available. Pollinators of lantana include lepidopteran species and thrips. Fruits are greenish blue-black, 5 - 7 mm in diameter, drupaceous, shining, with two nutlets; seed setting is from September to May, 1 - 20 seeds occur on each flower head, mature plants produce up to 12,000 seeds annually. Seed germination occurs when sufficient moisture is present; germination is reduced by low light conditions. Root system is very strong with a main taproot and a mat of many shallow side roots.

Fruits of Lantana

Seed dispersal

Fruit dispersal is through frugivorous birds, fox and rodents. Germination rate of fresh seed is generally low, but is improved when the seed passes through the digestive system of birds and animals. High light intensity and soil temperature will stimulate germination of seeds which means that clearing of forest areas, inappropriate burning and other disturbances will help spread of the weed. Seeds are capable of surviving the hottest fires.

Fruit dispersal by birds

Habitat

The diverse and broad geographic distribution of lantana is a reflection of its wide ecological tolerance. It occurs in diverse habitats and on a variety of soil types. Lantana generally grows best in open un-shaded situations such as wastelands, rainforest edges, beach fronts, agricultural areas, grasslands, riparian zones, scrub lands, urban areas, wetlands and forests recovering from fire or logging. Roadsides, railway tracks and canal banks are favored by the species. It doesn't grow at ambient temperatures below 5°C, and is killed by frosts. Growing at altitudes from sea level to 2000 m, it can thrive very well under rainfall ranging from 750 to 5000 mm per annum. Lantana does not invade intact rainforests, but is found on its margins. Where natural forests are disturbed through logging creating gaps, lantana encroaches the gaps. Further logging aggravates the condition and allows lantana to spread or become thicker in growth. It cannot survive under dense, intact canopies of taller native forest species. Also, it cannot tolerate saline soils, boggy or hydromorphic soils, low rainfall and/or coralline soils with poor water-holding capacities and areas with high incidence of tropical hurricanes.

Lantana thicket

Mode of infestation

Lantana grows in impenetrable thickets that can suppress growth of native species. The plant can also grow individually in clumps or as dense thickets, crowding out desirable species. In disturbed native forests it can become the dominant under storey species, disrupting succession and decreasing biodiversity. As the density of lantana in natural forest areas increases, species richness decreases. Layering is a form of vegetative reproduction in lantana. Stems of lantana in contact with the soil are able to form roots, allowing it to quickly form very dense stands and spread short distances.

Threat and damage

Lantana threatens natural habitats and native flora and fauna. In Australia, 19 endangered species and 60 species of conservation significance are under threat due to the weed. It infests pastures, grazing lands, orchards and crops like, tea, coffee, oil palm, coconut and cotton, reducing their economic viability. Allelopathic effects of lantana reduce vigour of native plant species and limit productivity. Lantana infestations can sometimes be so persistent that it can completely stall regeneration of rainforests for several years. In the Galapagos Archipelago, lantana competition has caused extinction of the shrub *Linum cratericola* (Linaceae), and it is also a major threat to other endangered plants. The replacement of native pastures by lantana is threatening the habitat of the sable antelope

in Kenya. In plantations in south-east Asia and the Pacific Islands, besides reducing productivity of crops, lantana also interferes with harvesting. In Queensland, Australia, loss of pasture is the greatest single cost of lantana invasion in grazing areas (estimated at AU$7.7 m per year in 2002).

In dense stands of lantana, the capacity of the soil to absorb rain is lower than under good grass cover. This increases the amount of run-off and the subsequent risk of soil erosion in infested areas. Lantana has been implicated in poisoning of a number of animals including cattle, buffalo, sheep and goats since its leaves and seeds contain the toxic triterpenoids, Lantadene A and Lantadene B. Ingestion of the plant parts also causes 'pink nose' disease and jaundice of the muzzle in cattle. Heavy outbreak of lantana poisoning usually occurs during periods of drought. The plant has many secondary impacts, especially in tropical countries where it can harbour several serious pests. Malarial mosquitoes in India and tsetse flies in Rwanda, Tanzania, Uganda and Kenya shelter in lantana bushes and are the cause of serious health problems. In Indian sandalwood forests, it also has a role in the spread of the sandal spike disease.

Uses

Lantana has several uses, mainly in herbal medicine, and in some areas as firewood and as a mulch. In some countries, it is planted as a hedge to contain or keep out livestock. Leaf extracts of lantana exhibit antimicrobial, fungicidal, insecticidal and nematicidal properties. Verbascoside, which possesses antimicrobial, immunosuppressive and antitumor activities, has been isolated from the plant. Lantana oil is sometimes used for the treatment of skin itches, as an antiseptic for wounds and externally for leprosy and scabies. Also, the plant extracts are used in folk medicine for the treatment of cancers, chicken pox, measles, asthma, ulcers, swellings, eczema, tumors, high blood pressure, bilious fevers, catarrhal infections, tetanus, rheumatism and malaria.

Basket made using lantana stem

Lantana stem is used for making baskets and temporary shelters and as fuel for cooking and heating. In some areas, it provides shelter and vital winter food for many native birds. A number of endangered bird species utilize lantana thickets when their natural habitat is unavailable. In Australia, the vulnerable black-breasted buttonquail, *Turnix melanogaster*, feeds and roosts in lantana thickets adjacent to its more favored habitat, vine forest. While buttonquails prefer intact vine forest, lantana provides an important temporary refuge for them between forest remnants. In central Kenya, where natural riverine thickets have been almost completely cleared, the endangered bird *Turdoides hindei*, has become dependent on lantana thickets, and unless sufficient suitable natural habitat can be restored the survival of this species depends on the retention of lantana bushes. Apart from benefiting some bird species, lantana is a major nectar source for many species of butterflies and moths. The plant can prevent soil compaction and erosion and is a source of organic matter for pasture renovation. Ornamental lantana is an excellent source of income in the nursery sector in several countries.

Control

Fire as a method of control

Lantana is extremely widespread and abundant. Prevention of spread is the most cost-effective management tool. This would require restriction of further importation of lantana, restriction of sale and use of lantana in gardens and strategically controlling infestations wherever it currently occurs.

Mechanical : Stickraking, bulldozing, ploughing and grubbing (medium sized plants) are the main methods of control. Hand cutting using brush cutter, hand pulling, chain pulling and flame weeding are also used. Re-growth quickly occurs if the rootstock is not removed while weeding. In India, use of elephants to uproot Lantana was practiced. However, mechanical control is suitable only for small areas and is not recommended in areas susceptible to erosion. Fire is often used prior to mechanical or herbicidal control to improve their effectiveness; or as a follow-up to such methods. Fire itself can provide some control when used under the right conditions especially if the fires are hot and lantana is actively growing. However, while using fire as a management tool, risk to people and property must be avoided. Burning is not recommended in natural forest areas and vine thickets. Re-vegetation of a treated site by planting trees or encouraging naturally occurring seedlings is a key component of a lantana management program. Pasture seeds can also be sown that out compete and smother lantana; grazing should be prevented for the first six months to one year.

Mechanical control- bulldozing

Mechanical weeding

Chemical control

Chemical: At the actively growing period, use of fluroxypyr @ 0.5 to 1 liter / 100 l water, glyphosate @ 1l / 100 l water, triclopyr @ 1l / 60 l of water and Grazon DS (300 g/l triclopyr + 100 g/l picloram) @ of 350 ml/100 l water per ha is recommended. Post emergence application of glyphosate (2 kg/ha) may also provide good control of seedlings. Applications should be undertaken when there is good soil moisture and either in the morning or late in the afternoon.

Biological: Over 40 biocontrol agents have been released against lantana in 32 countries over nearly a century. Unfortunately, there has been limited success in controlling the weed. This has been due to extreme variability of the plants, poor climatic adaptability of the biocontrol agents in relation to that of the weed and high level of parasitism. In addition, many of the leaf feeding insects

(eg., *Falconia intermedia*) are unable to maintain high population to cause significant damage to lantana since it drops leaves to withstand extended periods of drought, and in colder areas during the winter. However, of the species that have established, some have had a major impact on the weed in particular areas; for example, the sap-sucking bug, *Teleonemia scrupulosa* (Hemiptera); leaf mining beetles, *Octotoma scabripennis* and *Uroplata girardi* (Coleoptera); the seed-feeding fly, *Ophiomyia lantanae* (Diptera); and the moths *Salbia haemorrhoidalis* and *Hypena laceratalis* (Lepidoptera). More recently, fungal pathogens have been released as control agents including the rust *Prospodium tuberculatum* in Australia. Currently under assessment is another rust, *Puccina lantanae*, which is known to be pathogenic to a wider range of weedy cultivars of lantana than *P. tuberculatum*. Several other insect agents are undergoing host specificity and potential impact studies.

The rust *Prospodium tuberculatum* sprinkled onto lantana leaves.

Sap sucking bug- *Teleonemia scrupulosa*

Leaf of lantana affected by *Puccina lantanae*

Biological control alone has not been effective in controlling lantana infestation in many areas. On the other hand, mechanical and cultural methods are expensive and most often ineffective. Chemical methods are effective in the short-term but herbicides are environmentally damaging and cannot be used in the long-term. In this situation, biological, mechanical, chemical and cultural methods will have to be used in an integrated way to control lantana infestation in our ecosystems.

Carrot weed

Scientific name	*Parthenium hysterophorus* L.
Common names	Carrot weed, white top, congress grass, star weed
Local name	Congress pacha, chatak chandani, ramphool, garghas (India), Santa Maria, feverfew (English), fausse camomille (French- New Caledonia), karottenkraut (German).
Taxonomy	*P. hysterophorus* (parthenium) belongs to the family Asteraceae. Within the genus *Parthenium*, only one species, *Parthenium argentatum* (guayule), is of potential economic value. *P. argentatum* is chemically and morphologically very different to *P. hysterophorus* and their insect and disease complexes are also different.
Nativity	Parthenium is a native of North and South America (from Mexico to Argentina).

Current distribution

Widespread native plant in Argentina, Cuba, Dominican Republic, Haiti, Honduras, Jamaica, Mexico, Puerto Rico, Trinidad, United States of America, Venezuela, and West Indies; invasive weed in Australia, Bangladesh, China, Ethiopia, India, Madagascar, Mauritius, Mozambique, Nepal, New Caledonia, Pakistan, Papua New Guinea, South Africa, Sri Lanka, Swaziland and Vietnam. Parthenium probably entered India before 1910 (through contaminated cereal grain) but went unrecorded until 1956: since then, the weed has spread like a wildfire through out India. Most of the Indian states are currently under the threat by Parthenium.It currently occupies over 5 m ha of land in the country.

***Parthenium hysterophorus*- basal leaves**

Habit

Parthenium is an annual herb, erect and up to 2 m in height. Stem is branched and covered with trichomes. Leaves are pale green, lobed, hairy, initially forming a basal rosette of strongly dissected leaves that are up to 30 cm in length, close to the soil, alternate, sessile, irregularly dissected and bipinnate having small hairs on both the sides, resembling leaves of carrot. Number of leaves per plant ranges from 6 to 55. Flower heads are creamy white, about 4 mm across and arises from the leaf forks. Flowering occurs about a month after germination. Each flower contains five seeds, which are wedge shaped, black, 2 mm long and with thin white scales. A large single plant produces up to 100,000 seeds in a season. It is estimated that more than 340 million seeds per ha may be present in the surface soil of a highly infested site. Seeds do not have a dormancy period and are capable of germinating anytime when moisture is available. The root system is composed of one main branched taproot and many finer roots.

Parthenium thickets

Seed dispersal

Parthenium seeds

The seeds are mainly dispersed through water currents, animals particularly livestock; movement of vehicles and machinery; grain, stock feed and other produce; and to a lesser extent by wind. Most long distance spread is through vehicles, farm machinery and flooding. Germination of parthenium seeds can occur at temperatures between 8 to 30°C, optimum temperature for germination being 22 to 25° C . Persistence tests demonstrated that more than 70% of parthenium seeds buried at 5 cm below the soil surface survived for at least 2 years; whereas seeds on the soil surface did not survive for longer than 6 months. Seed viability for 20 yrs has also been reported.

Habitat

Parthenium grows luxuriantly in wastelands and vacant lands, orchards, forest lands, flood plains, agricultural areas, shrub land, urban areas, overgrazed pastures and along roadsides and railway tracks. Drought and subsequent reduced pasture cover, creates the ideal situation for parthenium weed to establish. It prefers alkaline, clay loam to heavy black clay soils but tolerates a wide variety of soil types. The weed grows well in areas where annual rainfall is greater than 500 mm and fall dominantly in summer. It can grow up to an elevation of 2200 m above sea level.

Habit

Mode of infestation

Parthenium colonizes disturbed sites very aggressively, impacting pastures and croplands and out-competing native species. Allelopathic effect coupled with the absence of natural enemies, like insects and microbes, are responsible for its rapid spread in the introduced ranges. Growth inhibitors like lactones and phenols are released from parthenium to soil through leaching, exudation of roots and decay of residues. These growth inhibitors suppress growth and yield of native plants and crops.

Threat and damage

Infestation by parthenium degrades natural ecosystems. It aggressively colonizes disturbed sites and reduces pasture growth and depresses forage production. Its pollen is known to inhibit fruit set in many crops. Germination and growth of indigenous plants are inhibited by its allelopathic effect. In man, pollen grains, air borne pieces of dried plant materials and roots of parthenium can cause allergy type responses like hay fever, photo dermatitis, asthma, skin rashes, peeling skin, puffy eyes, excessive

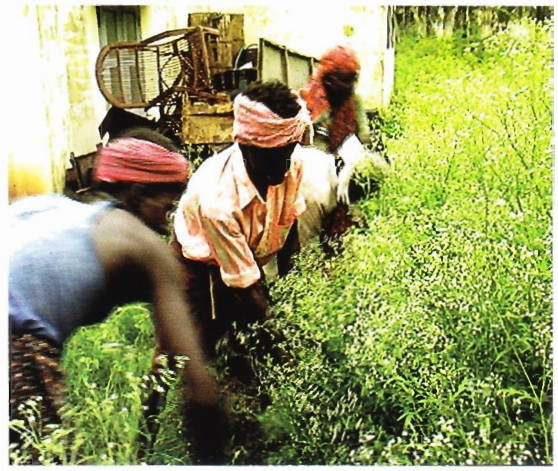
water loss, swelling and itching of mouth and nose, constant cough, running nose and eczema. In animals, the plant can cause anorexia, pruritus, alopecia, dermatitis and diarrhea. Parthenium can taint sheep meat and render diary milk unpalatable due to its irritating odour. In Queensland, Australia, losses to the cattle industry due to parthenium have been estimated to be AU$ 16 m per year in terms of control costs and loss of pasture. In India, an extensive outbreak of dermatitis caused by parthenium allergy involving around1000 patients with some deaths has been reported.

Uses

Parthenium is reported to have insecticidal, nematicidal and herbicidal properties. It is used for composting in several countries. Sub-lethal doses of parthenin, a toxin recovered from parthenium, exhibited antitumor activity in mice and the drug can either cure mice completely or increase their survival time after they had been injected with cancer cells. Parthenin is also found pharmacologically active against neuralgia and certain types of rheumatism. In the Caribbean and Central America, parthenium is applied externally on skin disorders and decoction of the plant is often taken internally as a remedy for a wide variety of ailments. In Jamaica, the decoction is used as a flea-repellent both for dogs and other animals.The large-scale utilization of parthenium can help reduce levels of the weed, in the short term. Parthenium has been well documented for its insecticidal, nematicidal and herbicidal properties. It is also used for mulching and for producing biogas, paper and compost.

Control methods

Mechanical and cultural: Manual uprooting of parthenium before flowering and seed set is the most effective method of control. This is easily done when the soil is wet. Uprooting the weed after seed setting will increase the area of infestation and, pulling a plant in flower will aid in dispersal of pollen grains causing allergic reactions. Ploughing the weed in before plants reach flowering stage and establishing pasture or other plants may be effective as a temporary control measure.



Mechanical control

Competitive replacement of parthenium can be achieved with *Cassia sericea*, *Croton bonplandianus*, *C. sparsiflorus*, *Amaranthus spinosus*, *Sida acuta*, *Tephrosia purpurea*, *Stylosanthes scabra*, *Cassia auriculata* and *C. tora* which compete with the weed and reduce its population. In certain parts of India, crop rotation using marigold during rainy season has been effective in reducing parthenium infestation in cultivated areas.

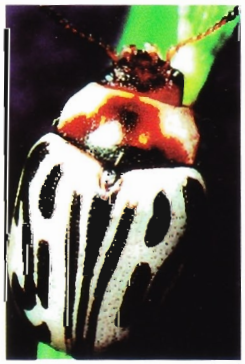
Preventing spread of parthenium is the most cost effective management strategy. There is a high risk of spreading parthenium by the movement of vehicles, livestock and crop produce. Washing down vehicles/machinery before entering in to a non-infested region will restrict spread of seeds. Movement of cattle during rainy season will aid in spreading of seeds in muddy soil. In such situations, it would be safe to hold cattle in yards or small paddocks to let seeds drop from their body and tails before releasing them in to larger areas. Also, cattle feed and crop seeds purchased from parthenium-infested areas should be checked for contamination by parthenium seeds.

Leaf infection caused by *Puccinia abrupta* var. *partheniicola*

Burning is not a useful control strategy for parthenium. However, burning for other purposes (to control woody weeds), may not result in an increased infestation, so long as the burned area is allowed to recover before other activities are carried out .

Chemical: A large number of herbicides have been tried. Of these, use of glyphosate (2.5 - 5 l per ha), atrazine (2.4 - 3.2 kg a.i. per ha), and metribuzin (0.2 - 0.35 kg a.i. per ha) has been promising. Timing of herbicidal application is critical. The plants should be treated before flowering and seed setting and when other plants especially grass are actively growing to recolonize the infested area. In open wastelands, non-cropped areas and along railway tracks and roadsides, spraying of a solution of common salt (sodium chloride) at 15 - 20% concentration has been found effective in controlling the weed.

Biological: Several insects and pathogens from the native range of pathenium have been released for biocontrol. The leaf feeding beetle *Zygograma bicolorata* and the stem galling moth *Epiblema strenuana* are widely used in several countries to manage parthenium. *Z. bicolorata* was released in India in 1984. It has spread to about 2 million ha in the country, with variable degrees of establishment. In Australia, both the insects have been successful in reducing the impact of the weed. The moth significantly reduces flower and seed production, especially at young age. It has a relatively high reproduction in a short period of time and its effectiveness has been validated in the central highlands of Queensland, Australia.



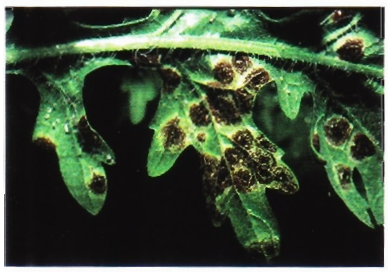
Zygograma bicolorata beetle

Damage caused by Zygograma bicolorata

Other major biocontrol agents that have been released are *Listronotus setosipennis* (stem boring weevil), *Semicronyx lutulentus* (seed feeding weevil),

Bucculatrix parthenica (leaf mining moth), *Platphalonidia mystica* (stem boring moth), *Conotrachelus albocinereus* (stem galling weevil) and *Carmenta ithacae* (root boring moth).

Two damaging rust pathogens have also been released in Australia; *Puccinia abrupta* var. *partheniicola* and *Puccinia melampodii*. *P. abrupta* var. *partheniicola* is known as the 'winter rust' performing better in drier conditions and *P. melampodii* is known as the summer rust preferring more humid conditions. Both are being considered for release in India to complement *Z. bicolorata*. Another on-going development on biological control of parthenium is the use of a rust fungus *Puccinia abrupta* var. *partheniicola*. Uredospore suspensions from 3-week old pustules of the rust have been applied to the foliage of Parthenium and a consistent control effect has been achieved. This fungus is now being evaluated for development as a mycoherbicide in Australia. Although as yet unevaluated, field observations of the white smut fungus, *Entyloma compositarum* from Mexico and Argentina, suggests considerable potential as a biocontrol agent for Parthenium. This fungus is capable of causing severe leaf necrosis through the coalescing of grey, senescing lesions. The impact of introduced biocontrol agents and other control methods, are likely to be enhanced by indigenous pathogens found infecting Parthenium in its invasive range, such as *Fusarium pallidoroseum* and *Oidium parthenii*. The latter pathogen cause severe defoliation of parthenium in parts of India.



Leaf infection caused by *Puccinia melampodii*

Parthenium offers a big challenge to all attempts of control because of its high regeneration capacity, production of huge amount of seeds, high seed viability and extreme adaptability to a wide range of ecosystems. A single biocontrol agent like *Z. bicolorata* may not be sufficient to manage the weed since its population build up is restricted to July-September where as parthenium can germinate through out the year. Therefore, insects, which remain active during most of the time of the year, would be more helpful in managing the weed. Attempts need be made to assess the potentials of indigenous insects through mass rearing and release.

Competitive replacement by plants, especially *Cassia tora*, could be treated as one of the avenues for further studies and implementation. Use of herbicides, side by side with other methods of control needs to be developed and standardized. Development of new cost-effective and persistent herbicides with less residual effects is the need of the day. Also, development of resistance against commonly used herbicides needs to be attended to. In general, management of parthenium may be possible only through an integrated approach involving mechanical, chemical and biological methods.

***Epiblema strenuana* - Adult**

Giant sensitive plant

Scientific name *Mimosa diplotricha* C. Wright

Synonym *Mimosa invisa*

Common name Giant sensitive plant, creeping sensitive plant, nila grass.

Local name Anathottawadi, padaincha (Kerala, India), banla saet (Cambodia), duri semalu (Malaysia), makahiyang lalaki (Philippines), maiyaraap thao (Thailand), co gadrogadro (Fiji).

Taxonomy *Mimosa diplotricha* (mimosa) belongs to the family Fabaceae - subfamily Mimosaceae. Three varieties have been recognized which are either spiny or non-spiny; *M. diplotricha* var. *diplotricha* (spiny, origin- tropical America), var. *odibilis* (Mexico), and var. *inermis* (spineless, tropical America).

Nativity *M. diplotricha* is a native of tropical America (Brazil, Paraguay, Argentina, Mexico, Panama). It was introduced in East Asia in the 1960's as a nitrogen fixing plant in tea gardens; it was first introduced in Assam for this reason. Both the varieties of the weed, var. *diplotricha* and var. *inermis*, occur in India.

Current distribution

Widespread native plant in south and central America; invasive weed in south and southeast Asia, the Pacific Islands, northern Australia, Hawaiian Islands, parts of Africa, Nigeria and Reunion. In India, it currently occurs throughout Kerala state and in certain parts of the northeast especially the state of Assam. Its occurrence in other states is unknown and needs to be ascertained. *M. diplotricha* has not attained weed status in Western Asia, East Africa and Europe.

Stem showing thorns

Habit

M. diplotricha is a fast growing erect shrub and a scrambling climber, which can form dense thickets in a short span of time. It is an annual although behaves as a perennial. Leaves are bright green, feathery, alternate, each leaf with about 20 pairs of small leaflets, bipinnate, sessile, opposite, lanceolate, acute, 6 -12 mm long and 1.5 mm wide, sensitive to disturbance. Stem is four angled, woody at the decumbent base, with re-curved thorns (3 - 6 mm long), up to 3 m in height. The inflorescence is a clustered fluffy ball, about 12 mm across, pale pink, occurs on short stalks (1 cm long) in leaf joints; corolla gamopetalous; stamen twice as many as petals. Flowering period in Kerala state, India is from August to February but can vary from region to region; flowers throughout the year in some tropical countries. Pods clustered, 10 - 35 mm long and 6 mm wide, linear, flat, clothed with small prickles, splitting transversely into one-seeded sections at groves. Seeds are flat, ovate, spiny, 2 - 2.5 mm long and 0.6 -1.4 mm thick, glossy and light brown. Seed production is in the range of 8,000 - 12, 000 per m^2. The weight of 1000 seeds is around 6 gm. Seed setting is from September to February. Roots are profusely branched and with root nodules.

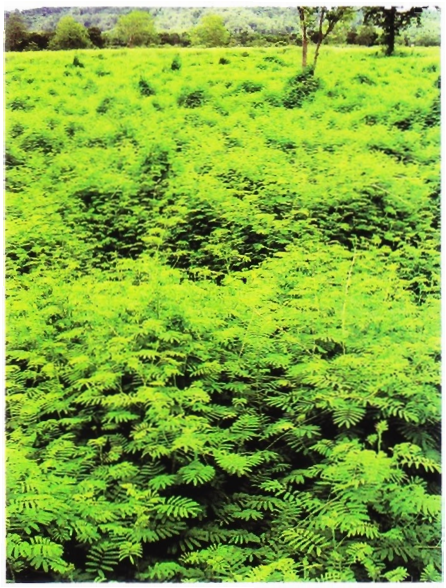
Flowers

Pods

Seed dispersal

Seed dispersal is through running water, animal fur, clothing, vehicles, agricultural implements and machinery and as contaminant of soil or seeds of crop plants. Dry heat promotes germination of seeds. Seeds are known to lie dormant up to 50 years.

Seeds



Mimosa thickets

Habitat

The weed can tolerate a wide range of soil conditions. It grows best in tropical regions in habitats such as wastelands, pastures, disturbed forests, plantations, agricultural systems and along roadsides and railway tracks; at an altitude of 0 - 2000 m above sea level. In evergreen and semi-evergreen forests, infestation is limited to the fringes of the forest wherever canopy is open due to disturbance. The weed is heliophytic in adaptation and cannot grow under closed canopy. It is drought resistant but senesce leaves during dry conditions. The spiny variety of the weed is apparently evolved from the spineless variety.

Mode of infestation

M. diplotricha scrambles vigorously over other plants forming dense tangled thickets up to 3 m in height. It smothers and kills indigenous flora. Sharp and recurved thorns of the weed make animals reluctant to graze on it and it also hampers their movement. In India, mimosa smothers other invasive weeds such as *Chromolaena odorata* and *Mikania micrantha* and replaces them.

Mimosa infestation on Coconut palm

Threat and damage

M. diplotricha is a big threat to forest ecosystems, agricultural land and pastures. It causes heavy damage in crops like sugar cane, coconut, rubber, cassava, tea, pineapple and upland rice. Thick growth of mimosa prevents regeneration, reproduction and growth of indigenous species in all infested areas. All parts of the plant are toxic to herbivores if ingested. It produces a toxin (mimosin- a non-protein amino acid), which, if ingested, can cause vascular endothelial damage, necroses of the heart and liver and anemia in cattle.

The tangled and thorny growth of mimosa hampers movement and access to food and other resources for wild animals like the one-horned rhinoceros (*Rhinoceros unicornis*) an endangered species, Asian elephant (*Elephas maximus*), swamp deer

(*Cervus duvauceli*) and tiger (*Panthera tigris*) in Kaziranga National Park in north-east India. In Australia, the weed chokes out cane and other crops and grassland causing crop and pasture loss. Crops infested with mimosa are difficult to harvest because of the thorns. Increased cultivation costs, reduced crop yield, loss of crops, reduced land value and soil degradation are the main economic impacts of mimosa.

Uses

It is used as a nitrogen fixing cover crop and green manure in several countries in the Asia-Pacific region. The spineless variety is an excellent soil improver and soil binder. In Indonesia it is used as a fodder to buffaloes.

Mechanical control

Control

Mechanical: Uprooting and burning, grubbing and slashing are the most common methods. Uprooting is the most efficient method to control the weed. This should be done at least twice a year to achieve a satisfactory level of control. The first uprooting is best done before flowering and seed set, and the second soon after the first showers when seedlings emerge from seeds already existing at the site or arriving via dispersal. Slashing is not advisable since the weed can easily re-generate from the cut stumps. Grazing by animals prevent dominance of mimosa in Queensland, Australia.

Chemical: Use of glyphosate (0.75 kg), paraquat (0.5 kg), diuron (2 - 4 kg), acetochlor plus atrazine (0.92 + 0.63 kg), starane (1.3 -1.5 l), atrazine plus metolachlor (0.82 + 1.68 kg) and atrazine - 500 g a.i. (4 - 6 l) per ha gives good control of mimosa. For best results, the applications are to be done before the onset of flowering and fruiting. However, the efficacy of herbicides is short-lived and applications may have to be done periodically depending on re-growth of the weed.

Biological: Several natural enemies of the weed have been reported from its natural range. A sap feeding bug, *Heteropsylla spinulosa* (Homoptera: Psyllidae) that causes growing tip distortion and reduces seed production in mimosa was introduced from Brazil into Queensland (Australia), Fiji and Papua New Guinea, with some successful suppression of the weed achieved. A coreid bug, *Scamurius* sp. that feeds on the shoots and cause them to collapse and inhibit vegetative growth and flowering, was introduced from Brazil to Queensland and Western Samoa but did not establish. A co-evolved moth, *Psygida walkeri*, which feeds on leaves, flower buds, tender seedpods and tender stems of mimosa in Brazil and Colombia was tested on 110 plant species from 29 families including Mimosaceae. Twenty-nine of these plant species supported some degree of larval feeding. Further studies are in progress.

A number of pathogenic fungi have been isolated from the weed in its invasive range, which show some potential as mycoherbicides. *Fusarium pallidoroseum*, a fungus isolated from diseased *M. diplotricha* in the Philippines, provided excellent control of mimosa seedlings when sprayed with crude culture filtrate or cell free filtrate. Further studies are warranted before recommending use of the fungus in controlling mimosa. *Corynespora cassiicola*, a cosmopolitan fungus, causes stem spot, defoliation and dieback of mimosa in Queensland and Papua New Guinea. It can be very damaging under hot humid weather conditions. The rust fungus *Uredo mimosae- invisae*, recorded from Venezuela and Brazil, may have potential as a classical biocontrol agent, but has yet to be tested for host specificity. In natural forest ecosystems, use of manual or mechanical control methods is comparatively safer than chemical methods. Long - term control method of the weed in other ecosystems requires use of mechanical, chemical and biological methods in an integrated manner. Any integrated management program should contain a strong extension and education component to ensure adoption of methods suitable to different ecosystems.

Heteropsylla spinulosa

Mile-a-minute weed

Scientific name *Mikania micrantha* H.B.K.

Common name American rope, Chinese creeper, mile-a-minute weed, South American climber (China), bittervine, mikania.

Local name American vally, silk vally, kaipu vally, Dhritharashtra pacha (Kerala, India), cheroma, ulam tikus (Malaysia), sembung rambat (Indonesia). Japani-lota, Japani-habi (Assam, India)

Taxonomy *Mikania micrantha* belongs to the family Asteraceae. The genus Mikania comprises of about 250 species of which only four: *M. scandens*, *M. cordifolia* (species native to the Americas) *Mikania cordata* (native to Asia) and *M. micrantha* are cited as being weedy. However, *M. micrantha* is the only species that causes a significant weed problem, throughout the Asia-Pacific region, where it is an invasive alien species.

Nativity *Mikania micrantha* is a native of tropical and subtropical zones of northern, central and southern America. It was introduced in northeast India sometime in the early 1900's as a cover crop in tea plantations.

Mikania micrantha

Current distribution

Widespread native plant in south, north and central America; invasive weed in Asia and the Pacific; present in Queensland Australia, but eradication programme underway. In India, it occurs in the states of Arunachal Pradesh, Assam, Karnataka, Kerala, Manipur, Meghalaya, Orissa, Tamil Nadu, Tripura, West Bengal and in the Union Territory of Andaman and Nicobar Islands.

Leaves

Habit

Mikania is a perennial twining herb, branches 5 ribbed, pubescent or glabrous, internodes 7.5 - 21.5 cm long. Leaves are opposite, ovate-deltoid, 6 -15 x 3 - 9 cm, base cordate, apex acuminate, margin coarsely dentate, crenate or sub-entire, glabrous on both sides, minutely glandular beneath, 3 - 5 nerved from base; petiole 3 - 7 cm long. Inflorescence is an axillary panicled corymb; capitula cylindrical, 1.5 mm across; flowers 4 per capitula; involucral bracts 4, oblong to obovate, acute, green, 1 - 3 mm long, the fifth smaller one 1 - 2 mm long; corolla 5 lobed, white, often with a purple tinge, 4 - 5 mm long; achens 2 - 3 mm long, narrowly oblong, 4-angled, black, glabrous; pappus capillary, uniseriate, connate at base, 3 mm long, white at first, becoming reddish-brown.

flowers

In Kerala state, India, flowering starts in August and continues up to January. Fruit setting occurs between September and February, initiated 17 - 21 days after flowering. A single stalk of mikania can produce 20,000 - 40,000 mature seeds in one season. Seeds are minute and bear pappus; dispersal of the seeds occurs between October and April. The mean number of seeds per mg is 108 ± 12. The plants can grow vegetatively from nodes and very small segments of the stem. Growth of young plants is extremely fast (8 - 9 cm in 24 h) and using trees as support, the weed rapidly forms a dense cover over entangled leafy stems.

Seed dispersal

Seeds are dispersed over long distances by wind and animals and water currents. Percentage germination of seeds is very low (8 - 12%) compared to other weedy species. Light, water, soil nutrients and fire affect the germination of seeds. The main mode of propagation is vegetative.

Mikania growth with mature seeds

Mikania infestations

Habitat

Mikania commonly occurs in wet places, forest borders and clearings, along the banks of streams and rivers, roadsides and railway tracks, in pastures, forest plantations, agricultural and agro-forestry systems, open disturbed areas and barren lands. It grows luxuriantly on leached and nutrient poor soils and sandy loam to clayey soils. Being a C3 plant, mikania can produce a large quantity of biomass in a single season. It shows positive response to high potassium levels in soils and conserves potassium in slash and burn agriculture system. Heavy grazing and browsing promotes spread of mikania into new ecosystems. The weed cannot tolerate shade and hence fails to penetrate undisturbed closed-canopy natural forest areas.

Mode of Infestation

Mikania can smother, penetrate crowns and choke and pull over plants. It thus causes significant reduction in growth and productivity of several crops. The plant competes with trees and other crop plants for soil nutrients, water and sunlight. Mikania can reduce light interception by covering the canopy of trees. Damage due to mikania is usually high in young plantations when compared to older ones since the weed can easily smother young trees. The adverse effect of mikania on crops and soil properties is through the production of inhibitory substances like phenolic and flavanoid compounds, which are released into the soil (allelopathic effect).

Threat and damage

Mikania reduces growth and productivity of several crops including oil palm, rubber, citrus, cassava, teak, eucalypt, acacia, albizia, pineapple, coconut and plantain in its introduced regions. The annual cost of controlling mikania in rubber, oil palm and cocoa plantations in Malaysia is estimated to be around 8 -10 million dollars. Besides the effect on crop yield, mikania also makes harvesting difficult because of its creeping and twining habit. It was estimated that mikania reduces 20% of oil palm yield in Malaysia during the initial five years of production. Retardation of tree growth in mikania-infested plantations is attributed to production of allelopathic substances by the weed. Infestation by the weed in natural forests in northeastern India caused reduction in species richness, habitat destruction, species monopolization and new microsite formation. The weed renders collection of non-wood products (e.g., reed) from natural forests less profitable since only small quantities could be collected in a day due to heavy overgrowth of the weed.

Uses

Economic gains due to mikania are meager compared to the loss due to its infestation. It is used as a fodder in many countries. Sheep preferentially graze mikania in Malaysia and other cattle will eat it if other fodder is unavailable. In Kerala, the weed is utilized as a fodder in some parts of the state, especially during summer when availability of grass is scarce. However, mikania is known to cause hepatotoxicity and liver damage in dairy cattle. The antibacterial effect of mikania and its efficacy in wound healing has been reported. In Assam (NE India), Kabi tribes use leaf juice of mikania as an antidote for insect bite and scorpion sting. The leaves are also known to be used for treating stomach ache. Use of juice of mikania as a curative agent for itches is reported from Malaysia. However, in all such cases therapeutic evidences are scarce or lacking. The weed has been used as a cover crop in rubber plantations in Malaysia. It is also planted in slopes to prevent soil erosion. Mikania green manure has been reported to increase yield of rice in Mizoram, India. Recent studies have shown that mikania is not suitable for mulching and composting due to high water content.

Control methods

Mechanical: Sickle weeding, uprooting and digging are the main mechanical control methods in practice. Sickle weeding before flowering and seed setting gives temporary control. But, quick re-growth from cut stumps frustrates this method. Uprooting during initial stages of growth (before flowering and fruiting) is the most effective mechanical control method. Slash and burning technique is also practiced widely. However, the weed stock may survive burning and produce young shoots in a couple of months. Mechanical control method is very labour intensive and uneconomical. One advantage of this method is that it reduces vegetative propagation of mikania. In Indonesia, the cost of mechanical control of mikania is estimated to be 125 -175% higher than that of herbicidal control.

Mechanical control

Chemical: Both pre-emergent and post-emergent herbicides are generally used for mikania control. Pre-emergence application of oxyflourfen (0.06 kg ha-1) + paraquat (0.24 kg ha1) is reported to be effective if applied before flowering or seed setting. Glyphosate is widely used in many countries against mikania especially in forest plantations. The dosage used varies widely (0.5 to 4.5 kg per ha or 0.75 to 8 l per ha) depending on the intensity of infestation and number of applications required for effective control. In general, application of glyphosate @ 2.5 - 5 l per ha may take care of even heavy infestations. This herbicide can also inhibit germination of seeds of the weed. Application of diuron at the rate of 1 - 2 kg per ha is also known to

Chemical control

be equally effective. Herbicides such as triclopyr + picloram (commercial name Grazon DS) @ 1.75 l per ha and triclopyr (commercial name Garlon 600) @ 500 ml per ha also give excellent control of mikania.

All herbicidal applications should preferably be carried out before flowering and seed setting. It should also be borne in mind that though a single and thorough application of any one of these herbicides may control the weed for a period of more than a year, re-growth will occur in most areas through wind-borne seeds especially after the onset of monsoon. It may therefore be necessary to repeat the annual application for the next few years, depending on the severity of re-infestation.

Leaf and petiole infection by *Puccinia spegazzinii*

Biological : Biological control using a natural insect enemy viz., *Liothrips mikaniae* from Trinidad was attempted in the Solomon Islands and Malaysia but successful establishment was not achieved. Recent studies carried out by CABI Europe-UK in collaboration with Kerala Forest Research Institute (India) and institutions under the Indian Council of Agricultural Research have shown that a highly damaging microcyclic rust, *Puccinia spegazzinii*, which naturally occurs and cause damage to mikania in the neotropics, has great potential as a biocontrol agent against the weed. The fungus was tested for host specificity against closely related members of Asteraceae and a number of economically important plants and proved highly specific to mikania. It was released recently in tea plantations in Assam and agricultural systems in Kerala and preliminary results have been very encouraging. Further releases of this biocontrol agent are currently being done and spread of the pathogen and damage caused to the weed are being ascertained.

Rust infection in the field population of mikania

BEST MANAGEMENT PRACTICES				
Name of weed	Mechanical	Cultural	Chemical	Biological
Chromolaena odorata	Cutting, uprooting, slashing or controlled burning	Planting signal grass, *Brachiaria decumbens*, replace the weed in pastures and oil palm plantations	Triclopyr ester 480 g/l @ 37.5 ml/l of water; glyphosate @ 0.72 kg a.i./ha; diuron 1.5 kg a.i/ha	Leaf feeding moth *Pareuchaetes psuedoinsulata*
Lantana camara	Stick raking, bulldozing, ploughing and grubbing	Unknown	Post emergence application of glyphosate (2 kg/ ha) or application of triclopyr @1l / 60 l of water/ha	Sap sucking bug *Teleonemia scrupulosa* and the leaf mining beetle *Octotoma scabripennis*
Parthenium hysterophorus	Uprooting plants before flowering	Competitive replacement of the weed with plants like *Cassia sericea*, *Croton sparsiflorus*, *Amaranthus spinosus*, *Sida acuta* or *Tephrosia purpurea*	Glyphosate, (2.5 - 5 l/ha); atrazine (2.4 - 3.2 kg a.i./ha); metribuzin (0.2 - 0.35 kg a.i./ha). Sodium chloride at 15 -20% concentration has also been found effective	Leaf feeding beetle *Zygograma bicolorata* and stem galling moth *Epiblema strenuana*
Mimosa diplotricha	Uprooting and burning, grubbing and slashing	Unknown	Glyphosate(0.75kg); paraquat (0.5kg); diuron(2-4 kg), acetochlor + atrazine-500g a.i.(in 4-6 l of water)/ ha	Sap feeding bug, *Heteropsylla spinulosa* which causes growing tip distortion and reduces seed production
Mikania micrantha	Sickle weeding, uprooting and digging	Unknown	Triclopyr + picloram @ 1.75 l /ha; triclopyr @ 500 ml/ l; glyphosate @ 2.5-5 l/ha; diuron 1-2 kg/ha	Leaf and stem rust causing fungus *Puccinia spegazzinii* is a potential candidate