DOI: https://doi.org/10.54083/978-81-980121-1-1-13

CHAPTER : 13

Alien Invasive Weeds of North Eastern States of India: Ecology, Distribution and Management

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Abstract

North East India with a full spectrum of geographical diversity is rich with a variety of vegetation types, enriching the biodiversity, ecology and economy of the region. It is the cynosure of the world as one of the mega biodiversity centres or a global biodiversity hotspot. This region is threatened by some common invasive weeds viz., *Mimosa* spp., *Mikania micrantha, Parthenium hysterophorus, Eichornia crassipes, Eupatorium odoratum, Lantana camara* etc. Rapid colonization and extreme adaptability of the invasives threatening the biodiversity, agricultural yields, trade, development plans, infrastructure and even biological health of the region. In fact, all the invasive weeds present in the region are distributed among all the agricultural and forest ecosystems including barren lands. *Mikania micrantha* is of significant importance in Tea ecosystems. Like wise, *Mimosa* spp in Kaziranga is of major significance. Mechanical and chemical methods of weeding are common practices but with a very limited range of success. Assessment of possible residual effect of herbicides in plant and soil warrant development of cost effective and environment friendly control measures. Microbes as weed control agent is anticipated to get more focus in future with the general upsurge of interest in biological control. A strict plan for exploiting exotic pathogens as classical biological control (CBC) agents and indigenous mycoherbicide developed for these weeds in a sustainable and inexpensive manner is the need of the hour.

Keywords Ecology, distribution, invasive weeds species, North East India, management

Introduction

Invasive weeds are those that are indigenous to a specific agro-climate but make invasion in areas other than its place of origin. Rapid colonization and adaptability over diverse habitat, variability are the characteristics features of invasive weeds. Because of its aggressive nature these weeds offer serious competition causing havoc both in cropped and non-cropped situations, forest areas with a wide range of impact in social amplitude. Invasive weed

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In: Current Trends in the Diagnosis and Management of Plant Diseases. (Eds.) Dutta, P., Upamanya, G.K., Pandey, A.K., 2024. Biotica Publications, Tripura, India.

species affect natural and agricultural ecosystem as soon as they arrive and start colonizing rapidly. They are thought as to be the biggest threat to biological diversity after habitat destruction, with immense, insidious and usually irreversible impacts. They may be as damaging to native species and ecosystems on a global scale as the loss and degradation of habitats. They represent the greatest threat to the preservation of global biodiversity after habitat destruction, which is a major concern in recent years. The value of the land for agricultural or commercial development can be seriously diminished because invasive species can damage human environments and livelihoods too. Invasive species are a global problem, they threaten agricultural yields, trade, development plans, infrastructure and even health. The IUCN estimates the global cost of invasive at US $ 400 billion per year to damage species and control measures.

Currently, mechanical and chemical methods are used to combat this weed. But on account of large area and high cost of chemicals and labour, weed control in forestry and agricultural land calls for an alternate strategy. There are few trials conducted under different projects for the control of these weeds through biological agents. But, no single method of weed control is exclusively effective against invasive weeds. All the available methods of weed control have their own limitations. For instance, in some cases even the basic information such as the phenology, autecology etc. of a species are not known. The extent of spread, survey and monitoring is seldom carried out and the practical difficulties in carrying out such a survey make it even more difficult to eradicate the invasive species. Research is mostly confined to laboratory conditions and applying them in the field can be difficult at times. Moreover, some of the solutions provided such as chemical control of weeds cannot be applied to the conditions in a protected area. A thorough field based, statistically sound research programme is therefore the need of the hour. The experiment should be carried out in near the natural conditions and the solutions suggested should preferable be financially and logistically feasible. Integrated management approach is therefore considered as the most effective management strategy against invasive weeds. In modern agriculture, development of eco-friendly weed management approaches are the need of the farm as the society is more conscious about the hazards of agro chemicals. Development of herbicide resistance in weeds, weed shifts and possible residual effect of herbicide in plant and soil indicate the warrant for development of cost effective and environment friendly control measures to overcome weed menace. Therefore, sound knowledge of biology of weeds, cultivation practices, crop varieties are important to formulate a sound integrated weed management strategy for a particular situation. Integration of effective, dependable and workable weed control measures should form a sound farm management practice. This approach aims at increasing production, reduce risk to human health and damage to flora and sustain quality of the environment.

North East India situated between 20°N and 29°30'N latitude, and 89°46'E and 97°30'E longitude comprises of seven states. It has a full spectrum of

geographical diversity ranging from wetlands, plains, plateaus and hilly terrain to very high altitude mountain range with the Brahmaputra river valley in Assam being the nucleus of the region. The plain areas and foothills are characterized by hot and humid climate (10 – 20°C) with high rainfall (150 – 200cm); medium altitude hilly regions have humid sub tropical climate while high altitude hilly region have cold humid climate (Table 1). The total area of the region is 2,62,382 km^2 with a population of 4 crore, of which 74 per cent area is covered by high lands of plateaus and hills and only about 26 per cent area is shared by the plains. Variety of vegetation types, significantly contribute towards enriching biodiversity, ecology and economy of the region. It has 5the typical sub-tropical climate of moderate temperature and high humidity. The minimum and maximum temperature ranges from below 10 °-22 ° C, where as during summer it ranges from 22 °– 34 ° C. During winter the region is experiences almost drought like

Table 1. Physiography and climate of North East Region

State	Area Sq. Km.	Forest Cover %	Area cropped ('000ha)	Range of altitude (m)	Max. Annual Rain fall (mm)	Temp. (°C) Min. Max.	Climate
Arunachal Pradesh	83743	61.55	182.7	200-7089	2000-5000	-10 – 34	Tropical to alpine
Assam	78438	39.07	2718.5	43-1736	300-3000	06 – 36	Tropical to sub-tropical
Meghalaya	22429	42.13	162.0	90-1961	2000-12000	10 – 30	Sub-tropical to temperate
Manipur	22327	67.53	133.0	205-2995	1400-4000	05 – 28	Sub-tropical to temperate
Mizoram	21081	75.55	59.20	330-2140	2000-3200	12 – 30	Sub-tropical to temperate
Nagaland	16579	17.44	170.0	1170-3100	1050-2000	03 – 27	Sub-tropical to temperate
Tripura	10486	54.51	288.6	63-783	1200-2800	10 – 34	Tropical to sub-tropical
Sikkim	7299	30.00		200-9330	1200-6000	-10 – 23.3	Tropical to alpine

Source: Hedge, N.S. (2000)

Table 3. Genera and species in some dominant families of higher plants occurring in N.E. India

Family	N. E. India	
	Genus	Species
Orchidaceae	104	700
Poraceae	160	500
Fabaceae	50	200
Cyperaceae	14	175
Rubiaceae	50	170
Euphorbiaceae	55	160
Acanthaceae	25	125
Lamiaceae	30	95
Zingiberaceae	18	73
Asteraceae	25	70
Urticaceae	15	45
Caesalpiniaceae	11	42
Scrophulariaceae	15	35
Mimosaceae	10	35

Source: Handique, P.J. (2000)

Table 4. Places of origin/ maximum diversity and world distribution of the species belonging to *Mimosa* occurring in North East India

Name of the species	Place(s) of origin or maximum diversity	Geographical distribution
Mimosa invisa var. *innermis*	Not available	India, Srilanka, and also introduced to many countries.
M. invisa var. *invisa*	Brazil	Widespread in Pacific Islands, S.E. Asia to Taiwan, Nigeria, Australia, India and Sri Lanka
M. prainiana	South India	South and North East India
M rubicaulis sp. *himalayana*	Himalayan region	Northern and north eastern India
M. pudica	Central America	Wide spread in tropical, subtropical and temperate areas of the world

condition with rainfall less than 200mm, but in summer the rainfall is between 4,000mm and 5,000 mm. More than 300 big and small rivers flow through the region and the main carrier of river water in the region is the mighty Brahmaputra in the Assam valley and Barak in the Cachar valley. The excessive rain water leads to severe flood in almost 40% area in Assam. The plain land of Assam has a common boundary with remaining six states, effectively acting a facilitator-cum-gateway to all of them. Evergreen mountain subtropical and mountain- temperate natural forests characterise the region. Almost 55% area is covered by forest vegetation, 10% snow clad wasteland and the remaining 35% area under crop cultivation. North East India is the cynosure of the world as one of the mega biodiversity centres or a global biodiversity hot spot. It also acts as a pocket for survival and spread of certain invasive species of weeds, insects and diseases thereby posing an increasing challenge to farmers, developers, planners, environmental agencies and the general public-there scale, impact and sustainable management are the real challenges.

The common invasive weeds of North Eastern States of India are *Parthenium hysterophorus, Eupatorium odoratum, Mimosa* species, *Mikania micrantha*, *Eichornia crassipes*, and *Lantana camara* etc.

***Parthenium hysterophorus*:**

Parthenium hysterophorus Linn. commonly known as white top/carrot weed /congress grass, (Family: Asteraceae), is one of the worst weeds of the world and was introduced to India in early fifties as contaminant of wheat consignment received from Mexico under PL480 scheme. Though this weed is primarily of fallow and wasteland, their rapid invasion to agricultural and

Table 5: Distribution of Mimosa spp. in ecosystem of Assam

Name of the species	Habitat	Associated crop/vegetation
Mimosa invisa var. *innermis*	Upland	Sugarcane, Tea, Thatch grass, and other species of Riparian grassland of Kaziranga National Park, railway tracks, roadside.
M. invisa var. *invisa*	Upland and Marshy Land	Tea, Riparian grass of Kaziranga National Park and Railway tracks.
M. prainiana	Upland and marshy land	Tea, Riparian grass of Kaziranga National Park and Railway tracks.
M. rubicaulis sp. *himalyana*	Upland and marshy land	Plants of foothills shurby jungles and forest edges, extended to Riparian grasslands, plantation crop like Tea and Citrus
M. pudica	Upland	Upland direct seeded autumn rice, other upland summer season crops, lawns, wasteland vegetation, roadsides, plantations crops.

forest has also been documented from various part of the world. Now it has become a menace in many forest areas of India including the North Eastern Part of the country.

In Assam, within a short span of time, the weed has spread in different places with varying degree of infestation, affecting primarily the roadside vegetation, amusement parks, railway tracks, industrial areas, city dwelling habitat, forest areas etc. High speed production ability as well as efficient dispersal mechanism, absence of natural enemies, completion of 3-4 life cycles in a year, adaptability to the extremes of the climate, possessing allelopathic effect etc. are some important factors enhancing rapid invasion and colonization of the weed.

An individual plant of this weed can produce more than 25,000 seeds having viability up to 20 years. The plant height varies from 50-200 cm and number of leaves per plant ranges from 6 to 55. Flowering takes place within 4-6 weeks of germination. Seeds are very much light and mainly dispersed by floating on water, wind or in the mud adhering to animal and farm machineries.

Table 6. Per cent weed control and weed dry weight of *Mimosa rubicaulis* as affected by different treatments

Treatments	Per cent control	Weed dry weight (g/m^2)
Glyphosate (0.75 kg/ha)	95	210.0
Gramoxone (0.50 kg/ha)	100	150.0
2,4-D (0.75 kg/ha)	90	200.0
Sodium chloride (20%)	90	242.0
Sodium Chloride (15%)	90	280.0
Sodium Chloride (10%)	90	355.0
Sodium Chloride (5%)	90	366.0
Control	-	375.0

Viewed from environmental, agricultural, animal and human health angles, *P. hysterophorus* is considered to be of foremost importance in the terrestrial habitat in India including the North Eastern Part of India. Very few countries, apart from India, such as Australia. Sri Lanka, Nepal and Ethiopia, suffer from this noxious weed. This weed causes severe human health problem. Long term exposure to *Parthenium* causes severe dermatitis, eczema, eczematous dermatitis, allergic reactions, allergic papules, fatigue. Severe cases can also lead to infections, septicemia and even death. It may also cause hay fever in man and livestock.

In view of these, it is thought worthwhile to study the present status of the weed in Assam and formulating effective control strategy for the weed. In a survey work conducted by Rajkhowa *et al.*, (2005) reported that in Assam the

occurrence of this obnoxious weed in almost all the districts with relatively high infestation in the District of Bongaigaon, Kamrup, Golaghat, Tinsukia, Dibrugarh, Jorhat and Nagaon. In general, the abundance of the weed was found comparatively less in the districts situated on the North bank of the river Brahmaputra. The weed, though at very low intensity was observed in the two hill district of Karbi Anlong and North Cachar of the states. During the survey work conducted in *Parthenium* infested areas a number of other weed species were found among which *Axonopus compressus* and *Chrysopogan acciculatus* were dominant (Table 7).

Table 7. Associated plants *Parthenium* infested area

Group	**Species**
Dominant Grasses	*Axonopus compressus*
	Chryosopogon aciculatus
Other grasses	*Ageratum houstonium*
	Amaranthus spinosus
	Borreria hispida
	Cassia hirsute
	Cassia occidentalis
	Cassia tora
	Chromolaena odorata
	Clerodendrum viscosum
	Crotolaria striata
	Croton bonplandianum
	Desmodium triflorum
	Hedyotis auricularia
	Leucas indica
	Mikania micrantha
	Mimosa pudica
	Sida acuta
	Solanum indicum
	Urena lobata

Source: Rajkhowa *et al.*, (2005)

The use of natural plants with allelopathic potential is gaining real attention in modern management systems. *Cassia uniflora* (Leguminaceae) had ability to replace *Parthenium* in original *Parthenium* infested areas (Singh, 1983; Kohli and Kumar, 1997).

Manual uprooting is not a common method employed in Assam. Mechanical cutting of plants is mostly practiced to clear the sides of railway tracks roads,

amusement park and play grounds. Since the weed is mostly confined to non-cropped areas, its control remains a sole affair of the government or concerned authority without much involvement and activity from the general public.

Chemical control of this weed is credited with providing immediate relief as compared to other methods, *viz.,* manual, cultural or biological. Spraying of glyphosate, chloromuron ethyl, metasulfuron methyl is effective in controlling this weed. Among the pre-emergence herbicides, atrazine, oxadiazon, simazine, metribuzin give excellent preventive control. For the control of the established growth, foliar application of both ethylamine and sodium salt formulation may also be applied. The seeds of this weed in infested soil can be effectively controlled with pre-emergence application of atrazine. The spraying of common salt is also reported to be a good source for production of organic manure.

Result of field trial conducted in two consecutive year by Rajkhowa *et al.,* (2005) showed that metribuzin 0.2% solution effectively controlled *Parthenium*, while the native grass species were not affected and regrowth of *Parthenium* was not observed up to three months (Table 8). Accordingly, metribuzin 0.2% solution may be used to control *Parthenium* in grasslands. Glyphosate 1.5 kg/ha, Paraquate 0.5 kg/ ha and 2,4-D 1.0 kg/ha though controlled *Parthenium*, also killed the other vegetation. However, regrowth of Parthenium was noticed after 30 days of spray of these herbicides necessitating repetition of herbicides spray.

Table 8. Percent control and regrowth

Herbicides kg ai/ha	**% Control (Visual)**	**Regrowth**
Glyphosate 1.5	95	Regrowth was noticed 30 days after spray
Paraquate 0.5	95	Regrowth was noticed 30 days after spray
2,4-D Na salt 1.0	95	Regrowth was noticed 30 days after spray
Mettribuzin 0.56	100	No regrowth was noticed up to 90 days after spray and native grass species were not affected.

Source: Rajkhowa *et al.*, (2005)

Biological control of *Parthenium* was initiated in Australia in 1977 and since then, nine species of insects and one rust fungus have been introduced (Table 9). The successful control of the weed was achieved by leaf feeding beetle, *Zygograma bicolorata* and by stem galling moth *Epiblema strenuana.* In India, defoliation by *Zygograma* beetle reduced *Parthenium* population up to 99% and *Parthenium* were replaced by 40 different plant species in

Table 9. Insect species for biological control of *Parthenium hysterophorus*, country of origin and year released in Australia

Species		Country of origin	First released
Coleoptera	*Conotrachelus* sp.	Argentina	1993
	Listronotus setosipennis	Brazil/Argentina	1983
	Smicronyx lutulentus	Mexico	1980
	Zygograma bicolorata	Mexico	1980
Homoptera	*Stobaera concinna*	Mexico	1983
Lepidoptera	*Bucculatrix parthenica*	Mexico	1984
	Epiblema strenuana	Mexico	1982
	Platplhalonidia mystica	Argentina	1992

Source: Bhowmik and Sarkar, 2005

fallow land (Jayanth and Visalakshy, 1996). The beetle *Z. bicolorata* may be an effective component of the integrated management strategies. An effort has already been initiated at AICRP on weed control, in Assam- Jorhat Center to release the beetle in selected pockets of the state for controlling *Parthenium*. Preliminary evaluation of the beetle in laboratory condition shows encouraging results but their effectiveness in field conditions is yet to be ascertained. The beetle *Z. bicolorata* also tried in several states (Table 10) against *Parthenium*. *Epiblema* moth was very effective in Australia, but erratic rainfall patterns disrupted the moth population and resulted in reduced *Parthenium* control. However, this moth was rejected because of attack on *Guizotia abyssinica*. Stem galling moth, *E. strenuana*, damaged the meristem at early growth stage and as a result prevented 32% of plants from producing any flower (Dhileepan, 2001).

Parthenium is host of two different pathogenic rust fungi *Puccinia abrupta* var. *partheniicola* (Jackson) Parm. and *Puccinia melampodii* (Diet and Holw.) (Navie *et al.,* 1996). Infection by the fungus hastened leaf senescence, significantly decreased the life span and dry weight and reduced flower production by 90% (Parker *et al.,* 1994). The pathogen was found highly host specific and it was released in Central Queensland after 1991 (Evans, 1997). Under a DFID-sponsored collaborative project between CABI Bioscience (UK) and ICAR, the exotic rusts, *P. melampodii* and *P. abrapta* var. *partheniicola* were evaluated against Indian biotypes of *Parthenium*. And found effective particularly *P. melampodii*. Interestingly, the autoecious rust, *P. abrupta* var. *partheniicola,* is also found in India at 930 m altitude (Evans and Ellison, 1987, cited in Parker *et al.,* 1994). The rust does not; however, seem to be a common pathogen of the weed in India. More work needs to be done

Table 10. States of India where *Zygogrmma bicolorata* supplied

Year	Centre/State	Number supplied
2001-02	Maharastra	4000
2002-03	Andhra Pradesh	700
	Assam	450
	Kerela	2300
	Maharashtra	200
	New Delhi	100
	Tamil Nadu	15100
2003-04	Bihar	200
	Kerela	100
	Maharashtra	500
	Tamil Nadu	7200
	Uttaranchal	200
2004-05	Haryana	190000
	Karnataka	1000
	Rajasthan	100
	Uttaranchal	2000

Source: Rabindra and Bhumannavar, 2005

on the rust strain/s present in India to know its/ their true potential in biological control of *Parthenium.* Other than rust fungi; a good number of phytopathogenic fungi were also reported (Table 11) from India. Amongst these for mycoherbicide development, *Myrothecium roridum* Tode ex Fr. appeared very promising against *Parthenium* in India (Pandey, *et al.,* 1992*).*

***Chromoleana* spp:**

Chromalaena odorata, native to West Indies and continental part of America, from Florida to Paraguay is a well established noxious weed in .various parts of India in open land, agricultural land and plantations of' trees and economic crop (Biswas, 1934; Subramainium and Raman, 1981) as well as in Northeast. In Nagarhole (Karnataka) Wildlife Sanctuary this species has invaded all the open spaces, competing out the indigenous grasses, thus adversely affecting the survival of herbivores in the sanctuary (Bakshi, 1977). It is also spreading in North Eastern region of India covering grass lands in forests, wild life sanctuaries and occupying fertile crop lands. Considerable time and money had been spent in eradicating this plant, both mechanically and chemically (herbicidal) but without much success. The weed is wide spread in high rainfall areas occurring around forest eco-system, wasteland, grasslands, causing bio-diversity and affecting the young

Table 12. Use pattern of pesticides on tea in North East India, 1991 (kg/ ha)

Pesticide	Region				
	Upper Assam	North bank	Cachar	Dooars	Darjeeling
Acaricide	3.96	2.43	2.48	3.38	4.29
Insecticide	3.04	3.32	3.61	5.35	4.60
Fungicide	1.67	1.25	-	0.19	1.28
Herbicide	3.97	4.02	4.82	8.05	3.73

Source: Hazarika *et al.*, 2002

plantations and hindering in the forest operations. *Chromolaena* has been reported as an aggressive weed of cultivated lands, abandoned or neglected fields, wastelands, road sides, all round peripheries of forest ecosystem, etc in North East India. In this region the weed is causing problem particularly in tea, coffee, forest ecosystem. It has high seed production potential and good mechanism for spread through rain splash, wind and moving vehicle. The weed perennates through thick stem, which sprout after each rain. This makes the plant to have perennial habit. The weed increases cost of seedling production in nurseries, hampers harvesting operations in the tea, coffee and forest plantations. It starts flowering during February-March onwards and stays in the field till next monsoon in May-June. Dried plant causing forest fire and destroy timber value of forest trees.

The weed can be used as mulching materials, green manure, medicinal purpose against sexually transmitted disease, arrest bleeding from cut wounds, to cure bacterial diseases. It has also insecticidal and fungicidal property and found effective against rice weevil, *Sitophilus oryzae*, rice moth, *Rhizopertha domainica* leaf spot and leaf rust of mulberry and also inhibited foot rot of black pepper. Dried stalks can be used as fuel.

Integrated method of control viz., mechanical, chemical and application of chemical herbicide can lower its menace in restricted field but this have proved uneconomical and ineffective, the possibilities of biological control are being investigated.

Mathur and Singh (1959) reported *Icerya purchasi* Maskell (Hemiptera) an indigenous insect defoliating the *Chromolaena odorata***.** In 1963 gallfly *Procecidochares utilis* Stone was introduced from New Zealand and released in Tamil Nadu, Assam, West Bengal and Uttar Pradesh to control *Eupatorium glandulosum* (Subramainium and Raman, 1981). Subsequently, in 1967 it was again released in large number in Darjeeling (West Bengal) and in some parts of Assam; The fly showed promising results and has now spread in the eastern India (Kapoor and Malla. 1978) No definite pathogen has been identified as a potential classical agent for *C. odorata* yet, although several fungal pathogens of the weed have been documented. Evans (1987) listed 18 important subtropical and tropical weed/ weed complexes, out of which

Lantana camara, Chromolaena odorata and *Mimosa invisa,* are potential new targets for CBC with pathogens in India.

The most effective management approach of *Chromolaena* spp. is to find a possible use for it. The excellent green and succulent biomass of the weed can be exploited as green manure since the shoots were found to contain 2.65% N, 0.03% P_2O_5 and 1.90 % K_2O on dry weight basis. Moreover, extracted oil from *Chromolaena* spp. can be used as an insect repellent. Profuse growth of this weed would be exploited as a soil cover to reduce soil erosion. This weed also can increase the nutrient status and humus content of soil.

In large stretch of land *Pareuchaetes pseudoinsulata* (Arctid larvae) feed on the leaves of *Chromolaena odorata* to a larger extent in South Africa and have been recommended for release as biological agent (Lluge and Cladwell, 1993). These larvae were released Kerala and Karnataka but could not establish. Rust fungi *Cionothrix prolonga*, In Trinidad and Tobago, *C. prolonga*, rust fungi showed strictly host specificity on this weed and could be exploited as bio herbicide (Elango *et al.*, 1993). This fungi needs further research for usage as biocontrol agent.

***Mimosa* spp:**

The plant, is a native of South East Asia, was introduced into the tea estates in Assam in the 1960s as an organic nitrogen fixer. The plants soon 'escaped' and have established themselves in the fertile grasslands. Available literature indicates the presence of 400 numbers of species of *Mimosa*, out of which about 6 species are found in India and four different species of *Mimosa* are prevalent in North Eastern Part of India, amongst which *M. rubicaulis* sub sp. *himalayana., M. prainiana, M. pudica,* (Table 5), *M. invisa.* The plants besides having dominancy in National parks, wild life sanctuaries of North East India *Mimosa* sp has dominated in upland rice, vegetable crops, lawn, roadside vegetation etc (Table 4).

The weed was brought to the area of Kaziranga National Park, North East Region of India by neighboring tea estates as a nitrogen fixer and for its soil replenishing and binding properties. The park has a long conservation history as reserve forest and open wild sanctuary since 1908 with a total area of 859.42 sq km forming a formidable reserve forest for all natural resources in the living world. The *mimosa* menace is an added concern for the Kaziranga sanctuary and other forest of North East India, which is already beset with other problems. The weed has been choking the grasslands and an estimated 120 hectares of the park have been affected by it. *Mimosa* spp. the thorny shrub has now created an impenetrable mat over three ranges of the park, choking edible grasses. It also releases a toxin called mimosin, which is said to be particularly harmful herbivores. It is posing a threat to the habitat of the rhinoceros (*Rhinoceros unicornis*), wild buffalo (*Bubalus bubalis*), swamp deer (*Cervus duvaucelli ranjitsinghi*), besides significant numbers of tigers (*Panthera tigris*), elephant (*Elephas maximus*) 14 other rare animals and over 500 species of resident and migratory birds (Vasu, 2003). All the species have dominated the grassland vegetation in the KNP. Mostly the

thatch grass (*Imperata cylindrical*(L.) Beauv.), elephant grasses viz., *Narenga porphyrocoma* (Hance) Bor, *Saccharum spontaneum* L. etc. along with other associated species of the grassland vegetation are being severely invaded by climbing *Mimosa* species by reducing the grazing areas for herbivores. In some areas, species belonging to *Paspalum, Cynodon, Digitaria, Setaria, Leea, Crotolaria* etc. are also smothered by these aggressive weeds. Amongst cropped land areas, mostly the tea and citrus plantations, sugarcane fields etc. are affected because of these climbing species.

M. rubicaulis and *M. invisa* two weed species have spread prolifically across the 430 sq. km with gregarious thickets posing a threat to the habitat, impairing the growth of other species specially the grasses, blocking the traditionally used path and trails by wild animals. Because of mimosine it is unpalatable to wild animals. Reports say rhinos have been nibbling on the *Mimosa* twigs, though they avoid mature creepers. Besides, serious affects of these weeds on crop ecosystem, plantations, other forest ecosystem, grassland, pastures have also been well reported (Hussain, 2002; Das, 2003).

In upland rice, *M. pudica* is one of top five problematic weeds while *M. invisa* var. *innermis* has appeared as one of the dominant weed in sugarcane fields posing a serious health hazards to the herbivores (Rajkhowa, *et. al.* 2003).

Mimosa species have been considered as problematic because of their thorny stems, woody or semi woody branches, deep to moderately deep tap root system, high seed production and dispersal ability, wider adaptability, faster growth rate and smothering ability. These species have also extended their infestation in other crops like sugarcane, tea, rubber, coconut, banana plantations and also other non-cropped areas like roadsides, industrial sites etc. in this North Eastern region. The seed production ability of *M. invisa-innermis* and *M. prainiana* is ranged from 8000-12,000 and 9,000-20,0000 per sq. meter respectively.

The productivity of grassland and pasture is seriously reduced due to infestation of *Mimosa*. Because of their fast spreading ability, the native vegetation including the grasses is badly smothered by the gregarious thicket of *Mimosa*. The very aesthetic value of roadsides, railway tracks, industrial sites, parks etc. are reduced due to the rapid infestation of these weeds and involves high expenditure for controlling such weeds.

Very recently *Mimosa* sp. have been emerged as most troublesome weed in different plantations like tea, coffee, rubber, coconut, banana etc., roadsides, parks and sanctuaris, other forest and non cropped areas. Due to nitrogen fixing ability, higher biomass production ability in less time and also due to highly thorny stems, and the weed was used in different tea estates in Assam for soil rehabilitation and fencing purposes which of course, is highly discouraged in view of its rapid invasion to new areas. Rapid multiplication, faster growth rate combined with high smothering ability, the weed has seriously affected the different ecosystems particularly by destroying the useful plants and other native vegetation and thus, threatens the bio diversity

of many regions. In national parks and sanctuaries, the grassland areas are badly affected thereby causing serious scarcity of fodder for the animals besides providing physical obstacles to the movement of animals due to its recurved thorns. *Mimosa* is also known to contain Mimosine- anon protein amino acid hazardous to the animals (Kulp and Vulliet, 1996). Death of cows is also recorded in Golaghat district of Assam, when fresh biomass of *M. invisa-innermis* is fed, showing the mimosine toxicity symptoms. In cropped ecosystems, the weeds offer tremendous competition for different growth factors with the crop besides causing serious difficulty in international operational and harvesting of the crops. Early infestation of *Mimosa* spp. in sugarcane fields causes significant reduction in cane productivity. Due to high regeneration capacity and lack of effective management practices for these species, high cost is involved in controlling these weeds particularly in cropped ecosystems. The study on morpho-physiological characters of *M. rubicaulis* revealed that the plant produce high biomass within a span of four months.

Due to the thorniness, semi-woody to woody stem, deep to moderately deep tap root system, high seed production ability, easiness in seed dispersal, high regeneration capacity, faster growth rate, climbing ability, etc. *Mimosa* spp. offer serious difficulty in their management. The dense ground cover and thickets formed by *Mimosa* spp. also prevent reproduction of other species. Manual and mechanical control is very much difficult due to presence of thorns, time consuming, cumbersome and needs frequent repetitions due to its high regeneration ability. Both of these methods is also involved high cost. *Mimosa* spp. Like *M. prainiana*, *M. rubicaulis* and *M. invisa* are growing in diversified land situations including waterlogged areas, the manual and mechanical removal is merely not possible. Manual cutting and removal with the help of bamboo fork is largely followed in Kaziranga National Park, where herbicide application is not advocated.

Herbicide like atrazine, diuron, hexazinonw, sodium arsenite, 2,4-D plus atrazine, fluroxypyr and glyphosate give effective control of *Mimosa.* Study at Assam Agricultural University, Jorhat showed that 2, 4-D Na salt (0.75 kg/ha), glyphosate (0.75 kg/ha), paraquat (0.5 kg/ha) were effective for control of *M. invisa, M. prainaina* and *M. rubicaulis.* Spraying of NaCl solution (10-20%) also found effective in controlling *Mimosa*(Table X). However due to high regeneration capacity of these species, repeated spraying of herbicides may be required. Spraying of herbicides may preferably be done before flowering stage of te weed for better control of these weeds. Experts at Assam Agricultural University are in favour of a combination of manual and mechanical methods to tackle the problem. Unless tea gardens around Kaziranga stop using mimosa as soil regenerator, the problem will persist. But for immediate future, experts have suggested an integrated approach using chemicals to kill the weed in areas not frequented by the animals, besides manually and mechanically removing the weed using tractors. Earlier there was a plan for the use of a weedicide to control the growth of this

weed, but the realization now is that the best way to deal with the problem is to physically uproot the plant. IFAW has committed US $ 15,000 for this purpose and work along with the WTI and the Assam Forest Department has already started. (**Source: 'Saving the rhino from other enemy', The Statesman, 23/11/02.** The International Fund for Animal Welfare (IFAW) and the Wildlife Trust of India (WTI) have announced plans to remove the invasive weed, *Mimosa*, from the Kaziranga National Park.

In the long term, biocontrol on its own offers the only cost-effective control option for treating very large infestations of *Mimosa*. It is very effective in attacking *Mimosa* regrowth and seedlings. Biological control can be initiated at any stage of the overall process. Best results will be obtained when biocontrol agents are released at the commencement of *Mimosa* control because these agents require a long time to be effective.

An advantage of biocontrol program is that once the biological control agents have established and become widespread, they will combine well with conventional control methods such as herbicides, bulldozing, grazing and fire. *Mimosa* control will always require an integrated approach including chemical, biological,conventional etc.

So far, 11 species of insects and two disease-causing fungi have been released as biological agents onto *Mimosa* in the Northern Territory. Of the agents tested, tip and stem borers have been the most effective because they do not require flowers or seed for survival and can therefore feed on the plant even during the dry season. The combined effect of these biological agents is to reduce seed production and seedling survival.

However, the present biocontrol agents are very slow acting and may provide effective control only after several decades. If more rapid treatment is required, biocontrol should be used in conjunction with mechanical and chemical methods as part of an integrated management plan.

All parts of the plant — the seeds, flowers, leaves, tips, branches and roots should have been targeted with at least one biological control species. This work is part of the Northern Territory Government / CSIRO joint project "Biological control of *Mimosa pigra* and integration with other control options", funded by the Commonwealth Government's Natural Heritage Trust. Four of these species have become effective in controlling *Mimosa* by reducing seed production and the size of the seedbank, and occasionally killing adult plants. The most successful insects are those that can feed on *Mimosa* all year round, notably stem miners.

Landholders are required by law to control *Mimosa* where it occurs. Its introduction in a new area must be banned and strictly quarantined.

Recent research and field experience indicates that *Mimosa* can be managed through careful and systematic control efforts. An integrated approach using several weed management techniques is the most effective way to deal with dense infestations of *Mimosa*. However, the characteristics of the infestation (eg size, density, location, position within the catchment) and

the availability of resources will determine the most appropriate course that control should take.

• Small outbreaks can be controlled with physical/ mechanical and/or chemical control.

• Single plants or small outbreaks of *Mimosa* can be removed by hand pulling or grubbing, ensuring that as many roots as possible are removed.

• For smaller infestations chemical spraying with an appropriate, registered herbicide is recommended.

• All treated plant material should be burnt to ensure it does not regrow, and these sites should be checked regularly for new plants over a number of years.

Mikania :

Mikania micrantha, commonly called the mile-a-minute weed is a 'sprawling' vine native to tropical South and Central America has become a serious weed in South Asia and South-East Asia particularly in plantations, forest trees and of economic crops life tea, oil palm, etc., (Parker, 1972; Holm *et al.,*1977). The economic damage caused is colossal in North-Eastern India (Rudra, 1958, Choudhury, 1972; Parker, 1972; Palit, 1981). The seeds of *Mikania* are dispersed, to far off areas through the air current. This factor adds another dimension to the complexity of the problem, as localized efforts to control the weed are often frustrated due to reinvasion through aerial dispersal of seeds. It is a neotropical invasive species, which affects agro forestry and natural forest ecosystems in India. In recent years it has become a troublesome weed in many plantation crops including the high-value tea, cocoa, rubber, plantain, coconut, etc. in the southwest and northeast regions of India. It is also becoming a constraint to certain crops such as sugarcane in Assam. Although the weed was reportedly introduced in the northeast as an air force runway camouflage way back during the Second World War, its economic importance could come to the fore only in the recent decades. The main reason for this has been the continuous destruction of natural forests from which the weed could pose a threat to the tea gardens and other plantations.

M. micrantha was first reported in 1940's in Assam. People of Assam believe that *M. micrantha* came to Assam along with Japanese Soldiers during World War II. Therefore, it is popularly known as '*Japani Habi*' in Assam (Dutta, 1977). The intensity of the same is increasing day by day. *M. micrantha* is now well distributed in Asia and South Pacific and is recognized as the main problem in Assam since Parker (1972) identified this as an invasive weed.

M. cordata (Burm F.) B.L. Robinson an exotic climber was also recorded in from this region in moist deciduous forest of Tripura in early 80's (Deb, 1981). The same species was also reported as a very common weed of Majuli, the biggest river island of the world by Islam (1990). Dutta (1977) reported that *M. micrantha* is generally found up to an elevation of 800m and *M. cordata*

up to an elevation of 2000 m above msl. In plantation crops like tea *M. micrantha* grows in drains, boundaries and crawl towards the vegetation from low lying areas (Puzari *et al.,* 2003). It has now become all too common a weed in the waste lands everywhere and also unfortunately on trees and shrubs in homestead land and in tea workers colonies. *M. micrantha* is also found to creep over the electric posts, telephone posts, buildings and boundary walls. The growth of plant is generally vigorous in swampy areas. It can also survive luxuriantly even in the immediate vicinity of stagnant water.

Survey work (Puzari, *et al.*, 2005) conducted during 2004-2005 by Fixed plot method in two gardens and geographical surveys conducted in three agro climatic zones of Assam results showed that a maximum of 1000 stalks/ ha of *Mikania* can present in Tea ecosystem of Assam which caused an yield loss up to 50%. Annual out break of *Mikania* varied in the different month of the year being found maximum infestation at the later part of August to September due to which an additional of 20% more labour is required than the normal practice.

Current practices to control *Mikania* in North Eastern region are mainly mechanical slashing and application of herbicides. Slashing in plantation as well as in field crops is a costly, labour intensive and ineffective operation. The aerial as well as the underground parts are to be destroyed completely because of its ability to grow even from a smallest fragment of plant parts. The creeping and climbing habits allow the plants to penetrate into the soft tissues, buds and crowns of the host plants where it is difficult to apply the mechanical slashing for its removal without damaging the softer tissues of crop plants.

Although mechanical weeding in the form of hoeing, sickling, hand removal and cheeling are practiced, they are not cost effective. It requires 75 man days/ha for young tea and a minimum of 35 man-days per hectare for mature tea. Manual weeding sometimes locks up the much needed labour force during the peak season.

A huge amount of chemical pesticides (Table 12) with a more amount of herbicides are used in Northeastern region of India (Hazarika *et al.,* 2002). Amongst which use of herbicide was maximum in all the regions except Darjeeling. The presently recommended practice for the control of this dreaded weed is the application of systemic herbicides. Herbicides mostly used in tea garden and some plantation crops are 2, 4-D, Sodium salt, Paraquat, Glyphosate, Durion, Oxyflourfen etc. (Table 13). All these are potentially hazardous and are not selective to the crops. Application of herbicides can not be done if the *Mikania* has sprawled on to the plucking table. Till now no selective herbicides for control of *Mikania* exists.

There are reports of 2, 4-D and Duiron toxicities in tea cause rolling of young leaves followed by chlorosis and browning. Paraquat produces leaf scorching, Oxyfluorfen produces leaf shrinkage in the next flush (Rao, 1978; Barbora and Chakravartee, 1994).

Table 13. Common herbicides application

Herbicides	Active ingredient (%)	Dilution (per 200 l water)	Concentration (in percentage)
2, 4-D Sodium salt	80	500 g	0.25
2, 4-D Dimethylamine salt	72	250 – 400 ml	0.12 – 0.20
Paraquat : First round	24	670 ml	0.33
: Second round	-	500 ml	0.25
Glufosinate ammonium	15	0.51	0.25
Glyphosate on : Polygonum, Saccharum etc.	41	1.51	0.75
On other perennials	-	1.01	0.50
Simazine	50	1.50 – 2.00 kg	0.75 – 1.00
Diuron	80	0.40 kg	0.20
Oxyfluorfen	23.5	0.51	0.25

Source : Dutta et al., 2003

However, the present practice for its control in tea gardens by spraying 2, 4-D at the rate of 0.75 kg active ingredient per hectare with 400 to 500 litres of water using hand sprayers. In non-tea areas it can be controlled by using 2, 4-D at the rate of 0.75 kg active ingredient per hectare with 100 to 150 litres of water. The first spray in either case should be given in March/ April and repeat application has to be given on regrowth stage. Sometimes locating the vines controls it and swabbing them with 2, 4-D or 2, 4-D is sprayed on the vines spreading on the ground.

Extensive evaluation of natural enemies attacking *M. micrantha* in North East India has not done. Although numerous insects were found to attack the creeping vine in different parts of the world, most of them have been reported to be pests of other economic crops. Anonymous (1994) from North Eastern region reported *M. micrantha* as an alternate host plant of *Helopeltis* spp. in which the insect breeds, is a serious pest of Tea plantation which severely affect the economic yield (20 – 25%) of the crop. Here the insect breeds and even can complete the entire emergence and post embryonic stages of its life cycle. He also reported that *M. micrantha* also harbour *Meloidogyne incognita*, a common Tea root knot/infested nematode with mild infestation. Among the other pests and diseases *Aphis gossypii*, *Cercospora mikanicola* and *C. mikaniae, Alternaria sp.* and *Rhizoctonia* are reported to attack this obnoxious climber.

The economic damage caused by *M. micrantha* is colossal in the North eastern region of India (Choudhury, 1972; Parker, 1972; Palit, 1981) as the seeds of *Mikania* are dispersed to far off areas through air current. This factor adds

a critical dimension to the complexity of the problem. The localized efforts to control the weed are often frustrating due to reinvasion through aerial dispersal of seeds. The operation of slashing is also not successful, as the weed regenerates profusely from small section of stems and roots. The use of herbicide is neither safe to the economic crop nor economical. It also causes environmental hazards and pollution. Production of plantation crop like tea has a significant impact on the economy of N.E. India. Herbicides are routinely applied in tea plantations in Assam for control of *M. micrantha* despite problems with tainting of Tea (H.C. Evans and S.T. Murphy, unpublished observation). In order to minimize the risk of pesticide residue in tea, some pesticide regulatory bodies have fixed the tolerance limits of some pesticides. European countries and Japan have fixed the MRL's for Glyphosate and Paraquat as 0.1 and 0.5 ppm, respectively. Both Choudhury (1972) and Palit (1981) reported successful application of 2,4-D against *M. micrantha* in plantation crops and forest trees in northern India. However, use of herbicides is an expensive option.

Hence there is ample justification to intensify research on biological control of weed to get a long-lasting effect. *M. micrantha* has been acknowledged as a major weed. The effort on its biological control tactics is justified and should be continued. The process and research for achieving biological control of weed is long term. For a single species of weed, the introduction of several biological control agents is often required.

The one biological control agent already used to a limited extent is the parasitic plant, dodder (*Cuscuta sp.*). In Assam and Ceylon it has been shown that *Cuscuta chinensis* suppressed *Mikania* and prevents its spread from marginal land to tea plantations. However, the parasite is not sufficiently selective to be used in the agricultural and plantation crops (Parker, 1972). Dutta (1977) also reported that *Cuscuta reflexa* can be used to control *Mikania* in Tea Estates without the possibility for its use in large scale application. A snail (*Achatina fulika*) is also found to feed on *Mikania* but like dodder its use as a biological control agent will not be useful as the snail itself is a pest of many crops. A particular species of caterpillar of *Diacrisia* sp was also noticed to cause large scale defoliation of *Mikania* under laboratory condition (Dutta, 1977).

A scheme for searching biological control agents' of *Mikania* was therefore mooted, under, the aegis of Commonwealth Institute of weed control, which assigned, the task to Dr. Cock who discovered eight, insect species *Viz. Acalitus* spp. (Acarina :Eriophyiidae, *Liothrips mikanae* (Priesner*)* (Thysanoptera : Pholeothripidae), *Teleonemia* sp. (Heteroptera : Tingidae), *Desmogramma conjucta* Bechyne *,Physimerus pygmaeus* Jacoby*, Omoplata* spp. (Coleoptera: Chrysomelidae), *Apion luteirosre* Gerst, (Coleoptera : Apionidae) and *Pseudoderelomus baridiiformis* Champ (Coleoptera : Curculionidae). as potentially major biocontrol agents of *M. micrantha.* Another 20 minor insects of *Mikania* were also discovered by him (Cock, 1982).

Classical biological control is the most sensible option for *Mikania* especially in Northeast and Southwest India. On the one hand, cultural control is ineffective and uneconomical and on the other, herbicides cannot be recommended in natural forests because of the unique ecology and possible damage to the non-target flora (Sreenivasan and Sankaran, 2001). Also, the fungal pathogens like *Myrothecium roridum, Corynespora cassiicoia, Ascochyta* sp. and *Phoma* sp. cause minor damage to *Mikania* in Kerela and have no potential as mycoherbicides (Sreenivasan and Sankaran, 2001). Similarly, other leaf-spotting pathogens such as *Cercospora mikaniacoia,* as prevailed in this region causing brown sunken frog eye spots, have no value as biocontrol agents (**Personal Observation**).

Classical biological control is particularly suited to this obnoxious creeper, which affects a wide range of farming systems (including rural farmers) as well as natural ecosystem because it is cheap, environmentally safe and self-sustaining. The classical or inoculative approach involves the importation and release of one or more natural enemies that attack the target weed in its native range, into areas where the weed is introduced and its troublesome and where its natural enemies are absent. The objective of classical biological weed control is generally not eradication of the weed species, but the self-perpetuating regulation of the weed population at acceptable low levels. During 1996-1999, an international collaborative programme on the biological control of *M. micrantha* funded by DFID resulted in documenting several fungal pathogens of the weed (Ellison, 2001). Explorative surveys in the native range of the weed (Brazil. Costa Rica. Argentina, Trinidad and Tobago and Ecuador) resulted in the identification of Three microcyclic rust species, viz. *Puccinia spegazzinii*, *Dietelia portoriensis* and *D. mesoamericana* were found to occur in association with the plant (Evans and Ellison, 2005). However, *P. spegazzinii* (W1761) was selected for use as a CBC agent in India after an extensive host-range screening and studies on the environmental requirements for the fungus in the CABI Bioscience quarantine in UK with funding from the Department for International Development (DFID), UK under a collaborative project between CABI Bioscience and research institutions in India during 1996-2000.A total of 17 biotypes of the weed from the southwest and northeast regions of India were screened for their susceptibility to the rust. Except for a few collections from Assam all other biotypes were found to be highly susceptible to *P. spegazzinii* (Ellison, 2001). Based on these work, DFID has sanctioned the Implementation Phase of the project. *P. spegazzinii,* has been officially imported and established in the Containment-cum-Quarantine Facility of the National Bureau of Plant Genetic Resources (NBPGR), New Delhi (Kumar *et al.,* 2004).

Puccinia spegazzinii was imported into the National Containment-cum-Quarantine Facility of the National Bureau of Plant Genetic Resources (NBPGR) in New Delhi during 2003-2004. After establishing the fungus in the NBPGR quarantine, an additional host-specificity screening, involving 74 plant species, including 18 species that were earlier tested in the UK, was done in India during 2004-05 and the results from the UK were reconfirmed.

The rust was highly pathogenic to populations of *M. micrantha* from 2 and 15 locations within Kerela and Assam, respectively, which indicated that *P. spegazzinii* has considerable potential as a CBC agent for *M. micrantha,* in India.

A limited field release of the rust was first made on 1st week of October 2005 at Assam Agricultural University tea garden, this was followed by another release at Cinnamora tea estate, Hatigarh division on 1st week of November, 2005. Two stakeholders' workshops were held on 24 and 28 November 2005 in Peechi (Kerela) and Jorhat (Assam), respectively, to provide a platform for discussions on the further course of action in the CBC of *M. micrantha* in India.

India has thus become the eighth country in the world to have intentionally released on continental Asia a plant pathogen (*Puccinia spegazzinii)* for the classical biological control of a weed. This is also the first time that a fungal pathogen is being used as a CBC for *M. micrantha*. An estimate made in the late 2004 (Barton, 2004) indicates that more than 26 species of fungi originating from 15 different countries have been used as CBC agents against more than 26 weed species in 7 countries. Following the Indian lead other Asian countries, are fast tracking. Similar programme (China) the Indian experience is a "**Pilot Project**" for this technology, this should aid future exploitation of pathogens for weed suppression in Asia particularly for managing *M. micrantha* using *P. spegazzinii*.

In 2006 the fungus was released in the mentioned sites at for four times and found that it can initially established in the field but after the completion of third generation infection decreases and disappear from the field. The probable reason for this may be that due to repeated passing through the semi resistant biotype of the host the fungus may loses its virulence at each time of passing (Personal observation). Recently Dr K.V Sankaran from Kerela reported that the fungus could able to established in the ecosystem of Kerela.

Eichhornia crassipes:

Water hyacinth (*Eichhornia crassipes*) is another exotic species that has invaded several of the water bodies inside the Kaziranga National Park and many cropped and uncropped areas of North Eastern part of India. It spread rapidly on the water surface forming a dense mat of its leaves and tuberous stems. Very soon the entire water bodies were clogged and the fishes as well as other aquatic flora and fauna were killed due to lack of air. It has also been noticed that sometimes during the floods wild animals such as hog deer and even rhinos sometimes get entangled in the weed and unable to escape from it eventually leading to their death. Although it is fed upon to some extent by the wild animals, still it is noxious weed that require urgent management interventions.

Eicchornia shows complete mortality 2, 4-D Sodium salt, glyphosate and 2,4 D + Paraquat under simulated conditions without any regeneration up to 42 days of herbicide application. However, in natural condition a higher

dose of herbicide is required. Application of other chemical like NaCl and Urea spray were found to be ineffective on the weed as they are contact in action and the weed has the thick waxy coating on the leaves. Chemical control though effective measures, but the ultimate decline in water quality is often a limitation.

Biological control of water hyacinth with pathogens through out the world got increased attention with the discovery of the blight disease and the description and characterization of the causal agent *Alternaria eichhorniae* by Nag Raj and Ponnappa (1970) from Bangalore and Assam for the first time in India. Their pioneering work on the utilization of fungal pathogens for water hyacinth control was initiated in the I 960s at CIBC (commonwealth Institute of Biological Control (CIBC) resulting in the isolation of many potential pathogenic fungi as reported by Nag Raj, (1965); Ponnappa, (1970); Rao (1970).

Under the IMPECCA programme some criteria are to be followed for selecting potential mycoherbicide as a basis for the selection of candidate fungi, which: l. must have been isolated from within the country, 2. were widely distributed across the regions where water hyacinth is found, and 3. have been shown to have good pathogenicity to water hyacinth in preliminary laboratory or field studies. In the order of preference they were: *A. eichhorniae, Acremonium zonatum, Cercospora piapori, C. rodmanii. Rhizoctonia solani, Alternaria alternata* and *Myrothecium roridum A. eichhorniae,* which is widely present in India, manifests itself as leaf spots and leaf blotches of varying sizes. Work on the biocontrol potential of this fungus in India and elsewhere has shown great promise. The other closely related species, A. *alternata* has also good potential as a biocontrol agent for water hyacinth (Aneja, 1998).

Two species of *Cercospora,* namely, C. *rodmanii* and C. *piaropi* have been reported to cause disease in water hyacinth in different parts of the world, including India. For biocontrol purposes, C. *rodmanii* should be regarded as a variant that differs from C. *piaropi* in cultural morphology and virulence (Charudattan, 1996). Epiphytotics of *Cercospora* appear year after year in different parts of India. Integration of C. *rodmanii* with insects such as *Neochetina* spp. is an ideal option to check the growth of water hyacinth. *Acremonium zonatum* zonal-leaf spot causing pathogen is usually found associated with the weed in high presence of the mite (*Orthogalumna terebrantis).* Its occurrence in India is still not clear, but with more research, there is a possibility of identifying the fungus locally for exploitation in combination with the later.

There stands a new debate on the selection of candidates for the development of mycoherbicides for water hyacinth. For example, how to determine the safety of a fungal pathogen based only on the host-range testing? Or in other words, how broad the host-range should be for a fungal pathogen to be considered for mycoherbicide development? This problem may be more relevant in the case of water hyacinth in the states such as Kerela and Assam where the weed goes place to place via waterways and irrigation channels,

thus carrying potential crop pathogens to different areas. According to Praveena and Naseema (2004), out of the 53 species of cultivated plants and 54 weed species falling under 47 families, 26 plant species were susceptible to *F. pallidoroseum* when inoculated with or without injury. Plants as economically important as amaranthus, tomato, banana, cashew, colocasia and papaya were among those that showed susceptibility. What are needed, however, are in-depth studies on the strainal differences within a fungal species, which in terms of its potential to control a weed, stands out from the rest.

In Assam Agricultural University, under AICRP biological control of crop pests and weeds successful control of the weed has been achieved by the exotic weevil *Neochetina eichhorniae* and *N. bruchi*. The dispersal of the weevil has taken place in eight districts of Assam through aerial migration and Brahmaputra river and its tributaries. In Sibsagar district of Assam more than 700 ha of water body has been cleared off by the action of this exotic weevil and control achieved is about 90%. The weevil was well adapted to the new environment very successfully as evidenced by the presence of larvae and adult weevils on the leaves (Basit, 2002).

According to Charudattan (1999) it is unrealistic to expect a single plant pathogen (as a classical biocontrol agent or a bioherbicide) to provide complete "knock-down" effect comparable to that provided by chemical herbicides such a glyphosate in developing plant pathogens as supplemental biocontrol agents. Endorsing this view, Den Breeyen (1999) from Paris concluded that not a single pathogens alone can control water hyacinth and better control can be achieved using combinations of pathogens viz., *A. zonatum, A. eichhorniae* and *C. piaropi.*

***Lantana camara*:**

Among the vast majority of the weeds found in India *Lantana* are exotic in origin. It was introduced in India in 1809 as an important ornamental and hedge plant in National Botanical Garden, Calcutta. Weed like *Lantana camara* were introduced deliberately much more have got into the country including the Northeastern part of India accidentally. Pathak, 2003 reported that this weed is one of the most familiar invasive facultative weeds of horticultural, plantations as well as field crops. In India it spread soon into the wasteland and pastures forming dense thickets and also invaded and naturalize along road and railway tracks in India. It is perennial straggling shrub with prickly stems spreading by seed, but regrowing vigorously after cutting. The plant flowers almost throughout the year except severe winter in North India. The flowers are attractive. Therefore, easy pollination occurs. It competes with young trees in forest areas and plantations thus not allowed then to grow. *Lantana* flowers throughout the year in warm areas. The seeds are eaten by birds like Indian Myna, the turtle dove which facilitate the rapid dispersal of the plant. Lantana is highly light demanding therefore, open forests clear felled forests and blanks are particularly vulnerable. It chokes all other vegetative because it is a dominant species. Apart from the

serious ill effects caused by this plant such as competitive displacement, it has been reported to be a symptom less carrier of sandal spike diseases which threaten the sandal wood forests. Natural regeneration of this weed is severely threatening plantation forestry. *Lantana* is also reported to be responsible for forest fire damaging standing crops as during the summer season; the weed is highly susceptible to fire on accounts of its dry leaves and twigs and fire spread to the holes and crowns of Trees through straggling shoots. *Lantana* has several varieties or forms which has complicated the introduction and establishment of exotic insects. It is an important weed which is very difficult to manage with herbicide.

A number of scientists working on weed control are still devoting much time to find out a effective control measure to combat the dreaded weed. In the same time *Lantana* is growing a fenced crop in the tea garden of Assam specially in the Sibsagar, Dibrugarh and Tinsukia district. Among the tea gardens Jalan Nagar, Tippuk, Khobang, Talap, Hansara, Hapjan, Bisakopier, Itakholi, Bokiel, Rajmai, etc are mentionable. From this area in near future, it will spread to the nearby areas. And within a very short period it will create a havoc to human and animal beings.

Earlier studies showed that the leaves of this plant contain the poisonous Lantedene A, which is extremely toxic to cattle and goats. Therefore, normally not being consumed by cattle, this species has a selective advantage over palatable native species. Due to all these ecologically advantage lantana is one of the major invaders in different man made and natural forest ecosystem including many protected areas causing serious problems in forest management.

Chemical control though successful by spraying of imazapyra 2g per lit followed by glyphosate at 180 g. from the biodiversity conservation points of view, spraying of herbicides to eradicate the weeds in any protected area is not acceptable until detailed studies confirm that the herbicides used do not affect the survival and growth of beneficial organism.

In the *Lanatana* dominated areas the normal course of vegetation development is arrested due to suppression of establishment of native species.

Out of the different control measures viz., cultural, mechanical, chemical, biological none of the methods is reported to be effective and involve heavy expenditure. In this situation, integrated management is the only viable option for management of *Lanatana*. Keeping all these in view, it can be concluded we should avoid to lantana as much as possible.

Scope and strategies other than classical biological control:

The two strategies of biocontrol other than classical 1. The Bioherbicide strategy and 2. The Augmentative strategy is commonly followed for the management of weeds and their complexes.

In Bio-herbicide Strategy or inundative approach, pathogens are applied to control weeds within a specific geographical site *(i.e.,* a single field) by an inundative application of inoculum. This approach is also known as the

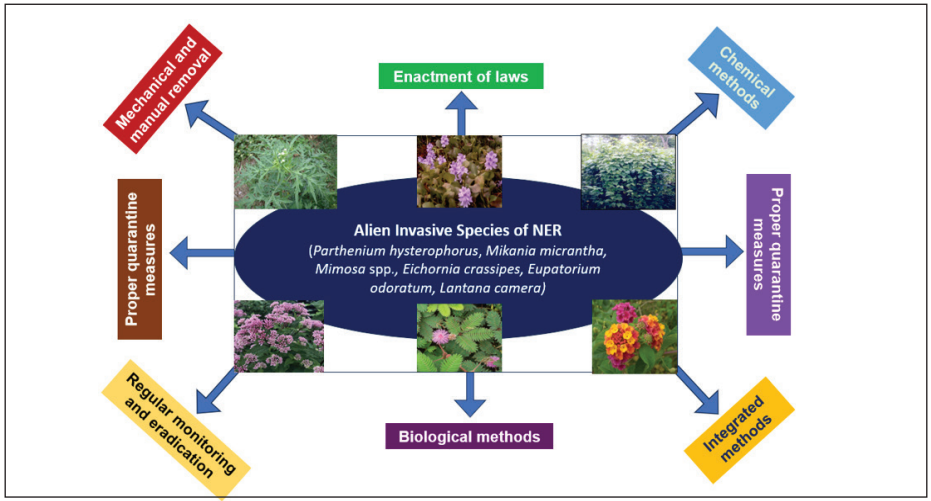

Figure 1: Integrated management approaches of alien invasive species of North-East India

mycoherbicide approach, because of the early popularity of fungi as candidate organisms. Inundative application of inoculum of pathogens, often to early stages of weed growth, results in the control of weed infestations without the disease developing beyond the initial lesions into epidemics. The initial lesions caused by the applied inoculum directly cause the death of infected weed seedlings (TeBeest, 1996).

It is interesting to note that, unlike in several other countries, environmental weeds like *Parthenium* and water hyacinth have been the targets for bioherbicide development in India. Choosing a wrong and unpractical strategy might be one of the many reasons for the failure of bioherbicide candidates reaching the ultimate step of commercial product development. There is ample scope for the identification of host-specific pathogens of serious weeds in agricultural and horticultural crops and their exploitation as bioherbicides in India. Similarly, pathogens having wide host-ranges but at the same time showing good biocontrol potential should be ideal for use in non. crop situations. Aggressive pathogens under the genera *Colletotrichum Phytophthora, Sclerotinia,* etc. have good scope as bioherbicide candidates.

The Augmentative Strategy:

The augmentative approach is a mixture of the classical and bioherbicide strategies. As in the classical approach, natural dispersal mechanisms are relied upon in the augmentative strategy to disseminate the fungus and control results frol11 the infections established by the dispersed inoculum (TeBeest, 1991). It has a similarity to the bioherbicide strategy because there is direct human manipulation and distribution of inoculum, although the inoculum is neither mass-produced nor applied as an inundative dose over

large areas (Charudattan, 1984). Control of the weed is achieved by means of the increase of disease through many disease cycles to reach threshold levels that cause the death of infected plants within treated areas (TeBeest, 1996). A notable example of the augmentative approach is the release of *Puccinia canaculala,* the rust of the yellow nutsedge, *Cyperus esculentus* (Pathak *et al.,* 1983). Although this approach has given encouraging results, the propagation and maintenance of rust cultures and the subsequent release of inoculum into the weed population requires relatively specialized facilities and techniques which would be difficult to coordinate and apply in subsistence agriculture (Evans, 1987).

Scope

In India *Uredo eichhorniae,* the rust of water hyacinth has the potential to be used in an augmentative manner. Charudattan (1996) advocated research on the lifecycle, host range and biocontrol efficacy of *U. eichhorniae* which is found only in South America, the original home of water hyacinth, as a high priority area.

Future Directions :

Microbes as weed control agent is anticipated to get more focus in future with the general upsurge of interest in biological control in India. A strict plan for exploiting exotic pathogens as CBC agent for forestry weeds and mycoherbicide developing for agricultural weeds needs of the hour considering al1 relevant aspects *viz.*, host-specificity, safety to human and animal beings, environment friendly, viable formulation with more shelf life, Release and establishment, evaluation, and feasibility and adoptability in a particular ecosystem of use. Most agricultural and forestry weeds including the invasive one have to be given priority for development of potential bioherbicides. Moreover, there is ample scope for the involvement of industry in research and development of bioherbicides ample.

Above all creating awareness among all the stakeholders in the society is the first step for effective containment of this weed. At present, majority of the people in the society are not aware about the weed and its threat to the environment, biodiversity and health of human and animals. Consequent upon this lack of awareness, the control and management of this weed still remains limited to few places, where also it is still done on its merit as a regular weed, but not because of its obnoxious nature. In view of the relatively lesser degree of infestation in terms of area, compared to some other states of the country, awareness programme may be clubbed together with suitable containment or preventive or eradication programme specific to different locations and sectors. Therefore, the systemic ways of approaches for eradication are:

- Mapping of invasive weed infested area.
- Large scale demonstration with people's participation in different districts of the state.

➢ Publication and distribution of leaflets in vernacular language.

➢ Involvement of Mass media for regular broadcasting /publishing information of all the possible management strategies and their spread.

➢ Regular monitoring and eradication of invasives in newly infested area.

➢ Proper quarantine measures are to be taken to prevent the infestation of weed in new areas.

➢ Possibility of utilizing the invasive weeds to be studied.

➢ Lectures/demonstration programme on control are to be organized among School/College students.

➢ Control of invasives needs to be ensured through Municipal corporation/ Gram Panchayat/ Development authority and Railway and other transport organizations.

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