Invasive Alien Species

U. P. STATE BIODIVERSITY BOARD

National Conference on

Invasive Alien Species

A threat to native Biodiversity

SOUVENIR

on the occassion of

International Day For Biological Diversity

22nd May, 2009

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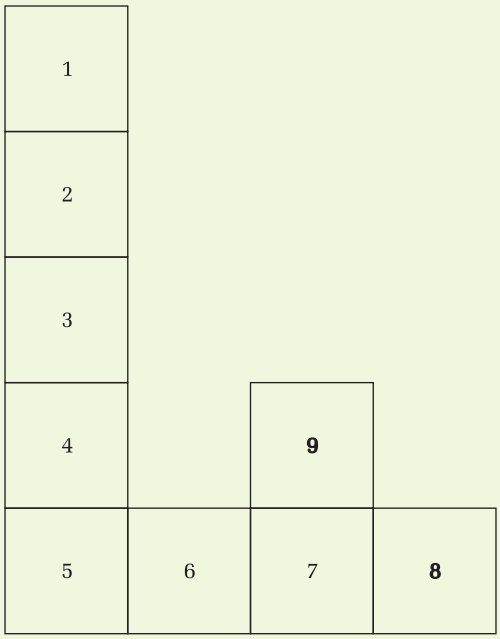

1. *Martynia annua*
2. *Oxalis corymbosa*
3. *Boiga irregularis*
4. *Ipomoea carnea* subsp. *fistulosa*
5. *Asterias amurensis* (sea star)
6. *Acridotheres tristis*
7. *Cleome burmannii*
8. *Bufo marinus*
9. *Anoplophora glabripennis*

Courtesy :
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9 http://www.cbd.int &
1, 2, 4, 7 Dr. D. C. Saini

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आई.ए.एस.
प्रमुख सचिव

वन विभाग
उ.प्र. शासन
लखनऊ

सन्देश

प्रसन्नता का विषय है कि विगत वर्षों की भांति इस वर्ष भी 22 मई को ''अन्तर्राष्ट्रीय जैव विविधता दिवस'' के अवसर पर हमारे अस्तित्व की रक्षा में जैव विविधता का महत्त्व, भूमिका व आवश्यकता से प्रदेश वासियों को अवगत करवाकर जैव विविधता संरक्षण में जन सहभागिता व जन सहयोग प्राप्त करने हेतु प्रदेश में विभिन्न कार्यक्रमों का आयोजन किया जा रहा है।

आज सम्पूर्ण विश्व जैव विविधता संरक्षण की आवश्यकता व महत्त्व का अनुभव करते हुए, उपलब्ध जैव विविधता की रक्षा हेतु सजग व प्रयासरत है। जीन्स, जातियों, प्राकृत–वासों तथा पारितन्त्रों का विश्व व्यापी समूह हमारे लिए धन से अधिक महत्त्वपूर्ण है। देश व प्रदेश में अधिसंख्य लोगों की आधारभूत आवश्यकताओं की पूर्ति करने के कारण जैव विविधता का सर्वाधिक महत्त्व है। आज भी बहुत से पारम्परिक समुदाय अपने भोजन, आवास, वस्त्र, गृहोपयोगी वस्तुओं, दवाओं, उर्वरक तथा मनोरंजन की आवश्यकता पूर्ति हेतु आंशिक या पूरी तरह से अपने आस–पास उपलब्ध प्राकृतिक संसाधनों पर निर्भर हैं।

जैव विविधता क्षरण के विभिन्न कारणों में बढ़ती आवश्यकताएं व अनियोजित विकास, प्राकृतिक संसाधनों का संकुचन, बदलती कृषि तथा वानिकी पद्धतियाँ, व्यावसायिक लाभ के लिए अत्यधिक दोहन, पर्यावरण प्रदूषण, पारम्परिक ज्ञान की कमी, विधिक एवं प्रबन्धन तन्त्र की प्रकृति एवं अन्तर्राष्ट्रीय व्यापार शामिल है।

प्रदेश सरकार उपलब्ध जैव विविधता के संरक्षण व संवर्धन हेतु सतत् प्रयत्नशील है। इस हेतु वन्य प्राणियों के प्राकृत–वास–वनों का संरक्षण, संरक्षित क्षेत्रों (राष्ट्रीय उद्यान व वन्य जीव विहारों) का प्रबन्धन, उत्तर प्रदेश राज्य जैव विविधता बोर्ड की स्थापना की गई है।

जैव विविधता संरक्षण हेतु जन–जागरण के सतत् प्रयासों की आवश्यकता के दृष्टिगत ''अन्तर्राष्ट्रीय जैव विविधता दिवस'' के अवसर पर आयोजित कार्यक्रमों की तरह सम्पूर्ण वर्ष निरन्तर जन जागरुकता अभियान की आवश्यकता है ताकि जैव विविधता संरक्षण का लक्ष्य प्राप्त करने में सफल सिद्ध हो सकें।

(परमेश्वरन अय्यर)

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सन्देश

अत्यन्त हर्ष का विषय है कि 22 मई, 2009 को ''अन्तर्राष्ट्रीय जैव विविधता दिवस'' के अवसर पर जैव विविधता संरक्षण की आवश्यकता व महत्त्व के प्रति जन सामान्य को शिक्षित व जागरूक करने हेतु वन विभाग द्वारा विभिन्न कार्यक्रमों का आयोजन किया जा रहा है।

हमारा देश व प्रदेश जैव विविधता की दृष्टि से अत्यन्त समृद्ध है। दुर्भाग्यवश धरती के अन्य हिस्सों की भांति देश व प्रदेश में भी प्राकृतिक सम्पदा व अमूल्य धरोहरों का क्षरण हो रहा है। इस क्षरण का दुष्प्रभाव हमारे जीवन में भू–मण्डलीय तापमान में वृद्धि, जलवायु परिवर्तन, धरती व समुद्र के जल में आक्सीजन की कमी व कार्बन डाई ऑक्साइड की मात्रा में वृद्धि के रूप में परिलक्षित हो रहा है।

जैव विविधता संरक्षण हमारे अस्तित्व की रक्षा हेतु आवश्यक है। देश व प्रदेश की अमूल्य जैव विविधता हमारे वन क्षेत्रों में संरक्षित व सवंर्धित हो रही है। अतः भू–मण्डलीय तापमान व जलवायु परिवर्तन की दर में कमी लाने व वेटलैण्ड के संरक्षण व संवर्धन हेतु प्रत्येक प्रदेश वासी को सजग रहना होगा।

प्रदेश में जैव विविधता संरक्षण हेतु किये जा रहे प्रयासों में उत्तर प्रदेश राज्य जैव विविधता बोर्ड का गठन एवं प्रदेश में वनों व संरक्षित क्षेत्रों का सघन प्रबन्ध शामिल है।

प्राकृतिक सम्पदा–वन, वन्यजीव व जैव विविधता का संरक्षण मात्र राजकीय प्रयासों व दण्डात्मक प्राविधानों से नहीं हो सकता, अपितु इस हेतु जन–जन की सहभागिता, सहयोग व समेकित प्रयासों की आवश्यकता है। अन्तर्राष्ट्रीय जैव विविधता दिवस जैसे अवसर हमें इस दिशा में प्रयास करने हेतु प्रेरित करते हैं।

कार्यक्रम की सफलता हेतु शुभकामनायें।

(फतेह बहादुर सिंह)

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सन्देश

प्रत्येक प्रजाति अपने आप में विशिष्ट गुणों की संरक्षक है और हर प्रजाति को बने रहने का अधिकार है। बौद्धिक रूप से विकसित होने के कारण मानव जाति को किसी प्रजाति को नष्ट करने का अधिकार नहीं है। 1982 में संयुक्त राष्ट्र द्वारा स्वीकार किए गए नेचर चार्टर के अनुसार ''जीवन का प्रत्येक स्वरूप अनूठा है और सम्मान का अधिकारी है, बिना इस बात की परवाह किए कि वह मनुष्य के लिए कितना उपयोगी है अथवा किसी अन्य जीव की तुलना में उसकी स्थिति क्या है ?मानव को आदर्श आचार से प्रेरित होकर कार्य करना चाहिए।''

हमारे देश में प्रजाति, पारितन्त्र तथा जीनिक जैव विविधता का विशाल भण्डार है। भारतीय उप महाद्वीप तीन भौगोलिक संगम क्षेत्र में स्थित होने के कारण यहां अफ्रीकी, यूरोपीय व चीनी मूलों के लक्षणों से युक्त वनस्पति व जन्तु पाए जाते हैं।

बीसवीं शताब्दी के पूर्वार्द्ध में विश्व युद्धों का हमारी प्राकृतिक सम्पदा पर प्रतिकूल प्रभाव पड़ा। जनसंख्या वृद्धि के कारण विभिन्न क्षेत्रों में बढ़ती मांग के कारण प्राकृतिक संसाधनों व विकास के मध्य सन्तुलन स्थापित करने का महत्त्व बढ़ता जा रहा है। वह आर्थिक विकास स्थायी नहीं हो सकता जिससे वे संसाधन ही नष्ट हो जाए जिन पर यह आधारित है। समय की आवश्यकता के दृष्टिगत विकास मानव केन्द्रित न होकर पर्यावरण व पारिस्थितिकीय केन्द्रित होना चाहिए।

जैव विविधता संरक्षण के समक्ष आने वाले खतरों में प्राकृतवास की क्षति, अत्यधिक विदोहन व जलवायु परिवर्तन प्रमुख हैं। आज सम्पूर्ण विश्व जैव विविधता की रक्षा हेतु प्राकृतिक वन क्षेत्रों में अवांछित प्रजातियों के कारण वन संपदा की गुणवत्ता ह्रास के करण चिन्तित है। इस समस्या के निवारण हेतु सजग रहकर समुचित प्रबन्धन की आवश्यकता है। प्रदेश में उपलब्ध प्राकृतिक सम्पदा के संरक्षण व संवर्धन हेतु वन विभाग द्वारा वन क्षेत्र व वन क्षेत्र के बाहर विभिन्न योजनाएं संचालित की जा रही हैं। इस कार्य में जन सहभागिता व सहयोग प्राप्त कर समाज के समस्त वर्गों के समर्पण व योगदान से हम अपनी अमूल्य धरोहर, समृद्ध जैव विविधता को संरक्षित कर सकते हैं।

(डी.एन.एस. सुमन)

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सन्देश

जैव विविधता हमारी पृथ्वी की सर्वाधिक उल्लेखनीय पहचान है। धरती के पर्यावरण में लगभग एक करोड़ छोटी बड़ी प्रजातियाँ विद्यमान हैं जिनमें अभी तक लगभग पन्द्रह लाख जीव जातियों को ही पहचाना जा सका है। धरती की जैव विविधता को दो भागों– पालतू एवं जंगली में बाँटा जा सकता है। पालतू जीव जातियों की तुलना में जंगली जीव जातियों की संख्या बहुत अधिक है तथा जंगली अर्थात् वन्यजीव जातियाँ, पालतू पशु–पक्षियों एवं वनस्पतियों की जातियों के परिवार के ही सदस्य हैं। जैव विविधता संरक्षित रखने के दृष्टिकोण से ही विश्व के समस्त देश अपनी भौगोलिक सीमाओं में पायी जाने वाली वन्यजीव जातियों को पहचानने और संरक्षित रखने हेतु प्रयासरत हैं।

विद्यमान प्रजातियों का विनाश व नई प्रजातियों का विकास एक प्राकृतिक घटना है। पुरानी प्रजातियों के विकास द्वारा नई प्रजातियां बनती हैं। विकास तथा विनाश की प्रक्रिया बहुत धीमी गति से होती है तथा इन्हें पूर्ण होने में काफी समय लगता है किन्तु वर्तमान में मानवीय हस्तक्षेप के कारण विनष्ट होने वाली प्रजातियों की संख्या विकसित होने वाली प्रजातियों की संख्या से बढ़ गई है। जैव विविधता का यह क्षरण सम्पूर्ण विश्व के लिए चिन्ता का विषय है।

प्रदेश में पाए जाने वाली जैव विविधता के संरक्षण के लिए वन क्षेत्रों व संरक्षित क्षेत्रों– राष्ट्रीय उद्यानों व वन्यजीव विहारों का सघन प्रबन्ध किया जा रहा है। अवनत वनों की पुनर्स्थापना, वनों के घनत्व में वृद्धि, गैर वन क्षेत्र में वृक्षारोपण सृजन, वन्यजीवों का संरक्षण व बेहतर प्रबन्ध, प्राकृतिक वन क्षेत्रों से अवांछित व बाह्य प्रजातियों का उन्मूलन, वनों पर निर्भर व्यक्तियों की आय व आजीविका विकल्पों में सुधार कर एवं जैव विविधता को आर्थिक लाभों से जोड़कर व न्यायिक, वैज्ञानिक, साम्यपूर्ण व चिरन्तन उपयोग से ही देश व प्रदेश को बहुमूल्य प्राकृतिक सम्पदा ''जैव विविधता'' का संरक्षण व संवर्धन करने में सफलता प्राप्त कर सकते हैं।

(बी.के. पटनायक)

Editorial

Since ancient days, it is the tendency of human beings to travel around the globe. During such long voyages, travellers collected and introduced several non-native species in the new areas. Some of these species are presently the back-bone of economy for specific countries such as Wheat, Potato, Soybean, Sugarcane, etc. But, alternatively some of these alien species which were left uncontrolled in the new location became invasive in due course of time and are now slowly wiping out the indigenous species of the area. Moreover, some of the Invasive Alien Species can even harm human livelihoods and exacerbate poverty by altering ecosystem services, reducing sustainable uses of biodiversity and by replacing natural resources traditionally used by individuals and communities. Economics and public health may be harmed by Invasive Alien Species which can clog waterways, damage powerlines and reduce energy production, decrease agricultural and timber output, depress tourism and spread disease to people, domestic animals and cultivated plants.

The perceptible impacts of the Invasive Alien Species are wide spread, encompassing community, population, ecosystems and above-all the economy of the nation. To overcome these threats the 'Convention on Biological Diversity' (CBD) has suggested a blue-print for the assessment and management of Invasive species.

As per the CBD blue-print, the very first step is to create awareness among the masses for the Invasive Alien Species . The awareness once created will help in checking the future spread of these species in the protected areas. It is also commented that the level of threat of Invasive Alien Species in any area needs to be assessed for chalking-out the management plans. The management plans should be framed in conjunction with innovative technologies to control the Invasive Alien Species in such an economic way that the sustenance of the programme is ensured. Early detection and rapid response will be the key to success.

The restoration of the Invasive Alien Species affected area for economic use is yet another key point which involves policy issues. The policy solutions or interventions include the practices, laws, agency policies and regulations, committed funding and so on.

With the changing global atmosphere, the importance of Invasive Alien Species may increase in the years to come. It is now high-time to frame policies for the management of the Invasive Alien Species on the lines suggested by the 'Convention on Biological Diversity'. The necessary frame-work, key issues and the economic aspects need thorough discussions and planning. The present Souvenir on 'Invasive Alien Species' is a compilation of the articles and research papers from the scientists, policy makers and those who are concerned with this problem and is expected to provide a frame-work for future strategic management programmes.

Finally we wish to thank all the contributors who whole heartedly responded to our request by providing specialised information in a very short time, and in a simple easy to understand language. We are thankful to Dr. P. K. Singh of PPV & FRA, New Delhi for providing valuable suggestions in framing the souvenir. Sri. Ashok Kashyap, Sri Krishna Kant Tiwari, Sri Santosh Kumar, Sri Satyendra Bahadur Singh and Sri Hemant Srivastava of U.P. State Biodiversity Board deserve appreciation for their valuable help in bringing out the souvenir.

– Editors

INTERNATIONAL DAY FOR BIOLOGICAL DIVERSITY

22 MAY 2009

INVASIVE ALIEN SPECIES

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Are Our Staple Food Crops Under Threat From Invasive Alien Species?

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Invasive alien species are species that are introduced as a consequence of human activities to new geographic areas, where they become established and then proliferate and spread, to the detriment of human interests and natural systems (www.gisp.org) . Invasive species cause loss of biodiversity including species extinction, and changes in hydrology and ecosystem function.

Reddy (2008) reported a comprehensive list of invasive alien species in flora of India with background information on family, habit and nativity. Total 173 invasive alien species belonging to 117 genera under 44 families were documented. Tropical America (74%) and Tropical Africa (11%) contribute maximum proportion to the invasive alien flora of India. Habit-wise analysis shows herbaceous of the species in the Indian flora are alien, of which 25% are invasive.

Major adventives weeds

This includes Asteraceae weeds such as *Parthenium hysterophorus, Eupatorium adenophorum, Eupatorium odoratum, Mikania micrantha, Ageratum conyzoides, Galinsoga parviflora* etc.

- *Parthenium hysterophorus* L., which is an exotic species from Tropical America that has naturalized most of India because of its strong invasive potential.
- *Mikania micrantha*, a perennial fast growing weed of Neotropical origin, has become a major menace in natural forests, plantations, agricultural systems in north-east and southwest India.
- *Lantana camara*, one of the ten worst weeds of the world, which is a native of tropical and subtropical America. The species was introduced in India as an ornamental shrub during AD 1809-1810. It is now found all over the Indian sub-continent, stretching from the subroutine regions of the outer Himalaya to southernmost part of India.
- *Ageratunm conyzoides* L. is an annual weed native to South America that has invaded and now naturalized several parts of southern Asia including India.
- Species of parasitic dodders (*Cuscuta* spp.) are becoming a serious problem in agro-ecosystems of south India and are being seen increasingly on many plants, including rice, throughout the country.

Recent entry of IAS in India:

In recent years, five new species of Invasive Alien Weeds namely *Ambrosia trifida* (Giant Ragweed - fig. 1) *Cenchrus tribuloides* (Spiny Burr Grass - fig. 2), *Cynoglossum officinale* (Hound's Tongue - fig. 3), *Solanum carolinense* (Horsenettle - fig 4), *Viola arvensis* (European field Pansy - fig. 5) have entered in India, specially in Chhattisgarh, Orissa, West Bengal, Maharashtra, Kerala, Karnataka, Andhra Pradesh, Tamil Nadu and Madhya Pradesh. The seeds of these five IAS have been carried along with wheat imported by government of India in 2006-07 from Europe, Russia, Australia, Canada, Hungry, France,

Argentina, Romania, Netherlands, Kazakhistan and Bulgaria and was distributed in above ten states through public distribution system (PDS). The surveillance of these weeds in the states is going on at large scale to check the expected losses as had been experienced earlier due to invasion of weeds like *Parthenium hysterophorus, Lantana camara, Eicchornia crassipes* etc.

Threat to Biodiversity and Food Crops:

Modes of resource acquisition and consumption of these species may cause a change in soil structure, its profile decomposition, nutrient content of soil, moisture availability etc. It also has better fitness homeostatic, phenotypic plasticity, benefits from destructive for aging activities, widespread geographical range, vegetative reproduction capabilities, fire resistance, better competitive ability and allelopathy. Invasive species are thus a serious hindrance to conservation and sustainable use of biodiversity, with significant undesirable impacts on the goods and services provided by ecosystems. Probable traits favouring invasiveness in terrestrial plants includes high tolerance against environmental extremes and greater adaptability in wide range of environmental conditions; high water, light and nutrient use efficiencies; zero or very short dormancy period, high productivity; and high reproductive potential, which gives a serious competition to food crops.

The Policy for the control of invasive alien species in India and related policy initiatives has listed number of crops for pest risk analysis which includes red beans, black gram, wheat, maize, sorghum, mustard, linseed, chickpea, green gram, rice, potato, sunflower, cotton, barley, pearly millet etc. It is widely recognized that the accidental introduction of new pest organisms or Invasive Alien Species, poses a major threat to the well-being of millions of people in developing as well as developed countries. The threat varies between mere nuisances to a direct menace of life. One of the major emerging threats for mankind as well as for biodiversity is the increased occurrence of IAS through global trade and travel. Complicated and expensive quarantine regulations are implemented to prevent the accidental introduction of possible IAS into agriculture and other ecosystems. However, international trade of goods and travel of people has reached a level and ease that these quarantine measures are incapable to rule out the introduction of exotic organisms. No country or region is safe from this threat.

Invasive alien species are increasingly seen as a threat not only to biodiversity and ecosystem services, but also to economic development and human well-being. They reduce yields of agricultural crops, forests and fisheries, decrease water availability, cause costly land degradation, block transport routes and contribute to the spread of disease.. They also reduce the effectiveness of development investments by choking irrigation canals, fouling industrial pipelines and impeding hydroelectric facilities. Invasive species therefore contribute to social instability and economic hardship, placing constraints on sustainable development, economic growth, poverty alleviation and food security. Moreover, the spread of invasive species has increased with global trade and development and is likely to be further exacerbated by continuing global change, especially climate change.

Monetary losses

IAS already causes billions of US$ in damages and losses in agriculture with an increasing tendency. Data from the GISP report (Anonymous, 2006) on invasive species and poverty show the enormous values lost through IAS: In 1993, the Office of Technology Assessment of the US Congress estimated that the 70 most harmful invasive species had caused damage of US$ 97 billion in the USA since 1906. The other studies indicated annual losses to pests were estimated at US$ 6.24 billion in Australia, US$ 91.02 billion in

Fig. 1 : *Ambrosia trifida* (Giant Ragweed)

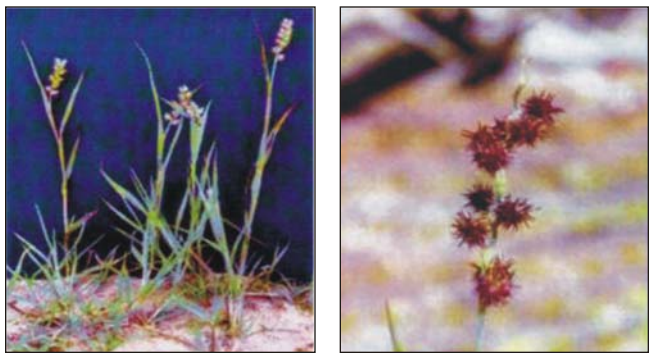

Fig. 2 : *Cenchrus tribuloides* (Spiny Burr Grass)

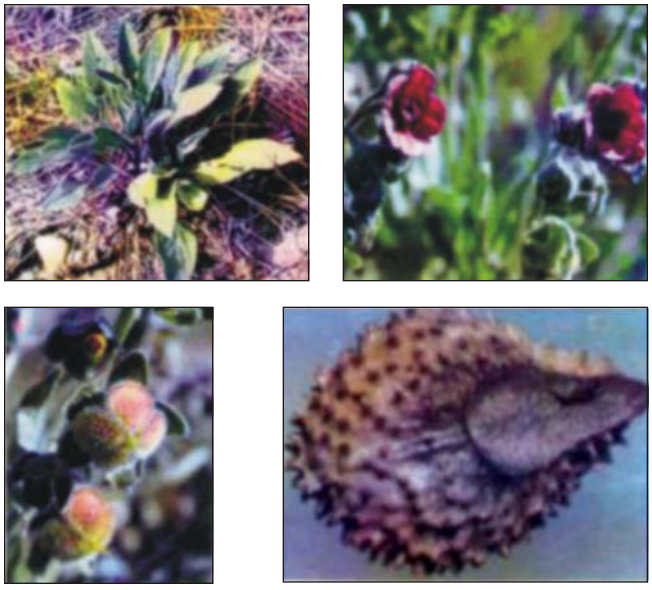

Fig. 3 : *Cynoglassum officinale* (Hound's Tongue)

Fig. 4 : *Solanum carolinense* (Horsenettle)

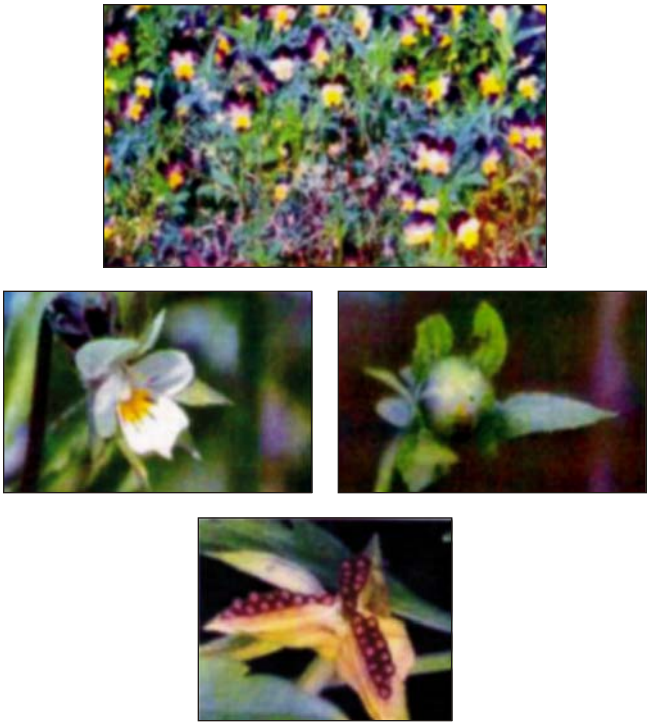

Fig. -5 : *Viola arvensis* (European Field Pansy)

India and US$ 4.30 billion in South Africa. Globally, the costs of damage caused by invasive species has been put at USD 1.4 trillion per year - close to 5% of global GDP.

Remedial approaches:

With the increase in global trade, invasive species are gaining more and more prominence around the world. However, the level of awareness amongst decision-makers, and in particular those in developing countries are still relatively low. Recent reports of unknown disease in the south on sugarcane just highlight the issue. The severity of the white woolly aphid infestation, recorded in 2002 in over 200 000 ha of sugarcane is another example.

Control by Utilization:

A significant number of plants on lists of underutilized crops are also on lists of invasive species, and these can have massive negative impacts on rural livelihoods, the environment and biodiversity. Thus, professionals involved with underutilized crops, and especially those considering introductions to new areas, must be aware of the potential invasiveness and take the necessary steps to address it. In contrast, those involved with invasive species must also note the potential uses of invasive plants, and acknowledge the emerging concept of 'control by utilization' as a means of management.

Social Awakening:

Invasions are usually successful when weaknesses and opportunities in communities are successfully exploited. Invading species and the habitants they invade can both influence invasion outcomes. In plant communities, the nichs that allow avenues of introduction for invading -plants can be reduced by careful agronomic management (*Harker et al.* 2005). For effective management of invasive species, knowledge about their ecology, morphology, phenology, reproductive biology, physiology and phytochemistry is essential. A better planning is needed for early detection and reporting of infestations of spread of new and naturalized weeds to monitor and control.

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Invasive Alien Species

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The theme for this years' International Day on Biological Diversity (IDB) is Invasive Alien Species (IAS), which are considered to be one of the greatest threats to biodiversity and to the ecological and economic well-being of society and the planet.

Invasive species is a phrase with several definitions. The first definition expresses the phrase in terms of non-indigenous species (e.g. plants or animals) that adversely affect the habitats they invade economically, environmentally or ecologically. It has been used in this sense by government organizations as well as conservation groups such as the IUCN. The second definition broadens the boundaries to include both *native* and *non-native* species that heavily colonize a particular habitat.

As detailed by CBD, Invasive alien species are plants, animals, pathogens and other organisms that are non-native to an ecosystem, and which may cause economic or environmental harm or adversely affect human health. In particular, they impact adversely upon biodiversity, including decline or elimination of native species - through competition, predation, or transmission of pathogens - and the disruption of local ecosystems and ecosystem functions.

Invasive alien species, introduced and/or spread outside their natural habitats, have affected native biodiversity in almost every ecosystem type on earth and are one of the greatest threats to biodiversity. Since the 17th century, invasive alien species have contributed to nearly 40% of all animal extinctions for which the cause is known (CBD, 2006).

The problem continues to grow at great socio-economic, health and ecological cost around the world. Invasive alien species exacerbate poverty and threaten development through their impact on agriculture, forestry, fisheries and natural systems, which are an important basis of peoples' livelihoods in developing countries. This damage is aggravated by climate change, pollution, habitat loss and human-induced disturbance.

Typically an introduced species must survive at low population densities before it becomes invasive in a new location. At low population densities, it can be difficult for the introduced species to reproduce and maintain itself in a new location, so a species might be transported to a location a number of times before it become established. Repeated patterns of human movement from one location to another, such as ships sailing to and from ports or cars driving up and down highways, allow for species to have multiple opportunities for establishment.

An introduced species might become invasive if it can out-compete native species for resources such as nutrients, light, physical space, water or food. If these species evolved under great competition or predation, the new environment may allow them to proliferate quickly. Ecosystems in which all available resources are being used to their fullest capacity by native species can be modeled as zero-sum systems, where any gain for the invader is a loss for the native. However, such unilateral competitive superiority (and extinction of native species with increased populations of the invader) is not the rule. Invasive species often coexist with native species for an extended time, and gradually the superior competitive ability of

an invasive species becomes apparent as its population grows larger and denser and it adapts to its new location.

An invasive species might be able to use resources previously unavailable to native species, such as deep water sources accessed by a long taproot, or an ability to live on previously uninhabited soil types. For example, Barbed Goatgrass (*Aegilops triuncialis*) was introduced to California on serpentine soils, which have low water-retention, low nutrient levels, a high Mg/Ca ratio, and possible heavy metal toxicity. Plant populations on these soils tend to show low density, but goatgrass can form dense stands on these soils crowding out native species that have not adapted well to growing on serpentine soils.

In ecosystems, the amount of available resources and the extent to which those resources are utilized by organisms determines the effects of additional species on the ecosystem. In stable ecosystems, equilibrium exists in the utilization of available resources. These mechanisms describe a situation in which the ecosystem has suffered a disturbance which changes the fundamental nature of the ecosystem. When changes occur in an ecosystem, like forest fires in an area, normal succession would favour certain native grasses and forbs. With the introduction of a species that can multiply and spread faster than the native species, the balance is changed and the resources that would have been used by the native species are now utilized by an invader. This impacts the ecosystem and changes its composition of organisms and their use of available resources. Nitrogen and phosphorus are often the limiting factors in these situations.

Every species has a role to play in its native ecosystem; some species fill large and varied roles while others are highly specialized. These roles are known as niches. Some invading species are able to fill *niches* that are not utilized by native species, and they also can create niches that did not exist.

When changes occur to ecosystems, conditions change that impact the dynamics of species interaction and niche development. This can cause once rare species to replace other species, because they now can utilize greater available resources that did not exist before, an example would be the edge effect. The changes can favor the expansion of a species that would not have been able to colonize areas and niches that did not exist before.

Although an invasive species is often defined as an introduced species that has spread widely and causes harm, some species native to a particular area can, under the influence of natural events such as long-term rainfall changes or human modifications to the habitat, increase in numbers and become invasive.

All species go through changes in population numbers, in many cases accompanied by expansion or contraction of range. Human landscape alterations are especially significant. This anthropogenic alteration of an environment may enable the expansion of a species into a geographical area where it had not been seen before and thus that species could be described as invasive. In essence, one must define "native" with care, as it refers to some natural geographic range of a species, and is not coincident with human political boundaries. Whether noticed increases in population numbers and expanding geographical ranges is sufficient reason to regard a native species as "invasive" requires a broad definition of the term but some native species in disrupted ecosystems can spread widely and cause harm and in that sense become invasive.

Non-native species have many *vectors*, including many natural ones, but most species considered "invasive" are associated with human activity. Natural range extensions are common in many species, but the rate and magnitude of human-mediated extensions in these species tend to be much larger than natural extensions, and the

distances that species can travel to colonize are also often much greater with human agency.

Ecological impacts of Invasive Alien Species:

Biological species invasions alter ecosystems in a multitude of ways. Worldwide, an estimated 80% of endangered species could suffer losses by competition with, or predation by, invasive species. Reports indicate that introduced species, such as corn, wheat, rice, cattle, and poultry, provide more than 98% of the U.S. food system at a value of approximately $800 billion per year. As highly adaptable and generalized species are introduced to environments already impacted by human activities, some native species may be put at a disadvantage to survive while other species survival is enhanced.

Land clearing and human habitation put significant pressure on local species. This disturbed habitat is prone to invasions that can have adverse effects on local ecosystems, changing ecosystem functions.

Multiple successive introductions of different non- Multiple successive introductions of different non-native species can have interactive effects; the introduction of a second non-native species can enable the first invasive species to flourish. Native species can have interactive effects; the introduction of a second non-native species can enable the first invasive species to flourish.

Invasive species can change the functions of ecosystems. For example invasive plants can alter the fire regime, nutrient cycling, and hydrology in native ecosystems. Invasive species that are closely related with rare native species have the potential to hybridize with the native species. Harmful effects of hybridization have led to a decline and even extinction of native species.

Natural, wild species can be threatened with extinction through the process of *genetic pollution*. Genetic pollution is uncontrolled hybridization and introgression which leads to homogenization or replacement of local genotypes as a result of either a numerical or fitness advantage of the introduced species. Genetic pollution can bring about a form of extinction either through purposeful introduction or through habitat modification, bringing previously isolated species into contact. These phenomena can be especially detrimental for rare species coming into contact with more abundant ones where the abundant ones can interbreed with them, creating hybrids and swamping the entire rarer gene pool, thus driving the native species to extinction. Attention has to be focused on the extent of this problem, it is not always apparent from morphological observations alone. Some degree of gene flow may be a normal, evolutionarily constructive process, and all constellations of genes and genotypes cannot be preserved. However, hybridization with or without introgression may, nevertheless, threaten a rare species' existence.

Economic impacts of Invasive Alien Species

Often overlooked, economic benefits from so-called "invasive" species should also be accounted. Invasive species can become such a common part of an environment, culture, and even diet that little thought is given to their geographic origin.

Economic costs from invasive species can be separated into direct costs through production loss in agriculture and forestry, and management costs of invasive species. In addition to these costs, economic losses can occur through loss of recreational and tourism revenues. Economic costs of invasions, when calculated as production loss and management costs, are low because they do not usually consider environmental damages. If monetary values could be assigned to the extinction of species, loss in biodiversity, and loss of ecosystem services, costs from impacts of invasive species would drastically increase.

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Weeds cause an overall reduction in yield, though they often provide essential nutrients for subsistence farmers. Weeds can have other useful purposes: some deep-rooted weeds can "mine" nutrients from the subsoil and bring them to the topsoil, while others provide habitat for beneficial insects and/or provide alternative foods for pest species. Many weed species are accidental introductions with crop seeds and imported plant material. Many introduced weeds in pastures compete with native forage plants, are toxic to young cattle (older animals will avoid them) or non-palatable because of thorns and spines.

The unintentional introduction of forest pest species and plant pathogens can change forest ecology and negatively impact timber industry. Forest Invasive Species (FIS) are of direct relevance to the forestry sector. Many of the plant and insect species intentionally introduced in various countries in the past have become major threats to the forest biodiversity and their control measures consume substantial financial resources. A few countries have formulated/are formulating strategies and establishing institutions to exclusively deal with FIS. Realizing this serious threat to forest ecosystems, the Asia Pacific Forestry Commission (APFC) has formally launched a 'Asia Pacific Forest Invasive Species Network' (APFISN) at the 20th session of the APFC held at Nadi, Fiji, from April 17-21, 2004 with the following objectives:

- Promote exchange and sharing of information on forest invasive species among the member countries;
- Facilitate access to expertise and resources such as research and education and training opportunities;
- Strengthen capacities of the member countries to conduct research and management of forest invasive species;
- Increase coordination and cooperation among the member countries by developing regional strategies for forest invasive species;
- Raise awareness of invasive species as a significant issue throughout the Asia and Pacific Region.

Invasive species can have impacts on recreational activities such as fishing, hunting, hiking, wildlife viewing, and water-based recreation. They negatively affect a wide array of environmental attributes that are important to support recreation, including but not limited to water quality and quantity, plant and animal diversity, and species abundance.

An increasing threat of exotic diseases exists because of increased transportation and encroachment of humans into previously remote ecosystems. This can lead to new associations between a disease and a human host (e.g., AIDS virus). Introduced birds (e.g. pigeons), rodents and insects (e.g. mosquitoes, fleas, lice and tsetse fly) can serve as vectors and reservoirs of human diseases. The full range of impacts of invasive species and their control goes beyond immediate effects and can have long term public health implications. For instance, pesticides applied to treat a particular pest species could pollute soil and surface water.

The CBD and Invasive Alien Species

The Convention on Biological Diversity and its members (there are 191 Parties, as of October 2008) recognize that there is an urgent need to address the impact of invasive alien species. Article 8(h) of the CBD states that, "Each contracting Party shall, as far as possible and as appropriate, prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species". The CBD sets global priorities, guidelines, collects information and helps to coordinate international action on invasive alien species.

The CBD has adopted guidance on prevention, introduction and mitigation of impacts of alien species that threaten ecosystems, habitats or species, which can be accessed on the CBD website (Decision VI 23). The website also provides further information on invasive species and relevant decisions of the Conference of the Parties to the CBD.

Tackling the Problem (As per CBD)

Prevention is the most cost-efficient and effective method against invasive alien species. Halting the establishment of potentially invasive species in the first place is the first line of defense. Governments conduct customs checks, inspect shipments, conduct risk assessments and set quarantine regulations to try to limit the entry of invasive species. However, global inspection and risk analysis capacity is usually not sufficient.

It is also important to develop economic tools and incentives for the prevention of introductions, and to educate the general public and raise awareness so that informed decisions can be made about how to limit introductions and their spread. Invasive alien species are a global issue that requires collaboration among governments, economic sectors and non-governmental and international organizations. Individuals also have a large part to play, including policymakers, consumers, horticulturalists, landowners, educators, youth and recreationists.

Some important Invasive Alien Species

Acacia farnesiana (shrub):
(Ban baburi; Needle bush)

Probably a native of tropical America, *Acacia farnesiana* was introduced to many tropical countries for its bark, gum, seed and wood. It is often planted as an ornamental or to check erosion, and is also used in the perfume industry because of its scented flowers. This thorny, deciduous shrub grows to 4m in height forming impenetrable thickets or sometimes a more open cover and prefers dry habitats between sea level and 1000 m. In Australia it occurs along watercourses on rangeland and farmland limiting access to water. It has also become an invasive species in Fiji, French Polynesia, New Caledonia, Solomon Islands, and Vanuatu.

Acacia mearnsii (tree):
(Acácia-negra; Australian acacia)

Acacia mearnsii is a fast growing leguminous (nitrogen fixing) tree. Native to Australia, it is often used as a commercial source of tannin or a source of fire wood for local communities. It threatens native habitats by competing with indigenous vegetation, replacing grass communities, reducing native biodiversity and increasing water loss from riparian zones.

Acacia melanoxylon (tree):
(Australian black wood; Blackwood acacia)

Acacia melanoxylon is native in eastern Australia. This tree grows fast and tall, up to 45m height. It has a wide ecological tolerance, occurring over an extensive range of soils and climatic conditions, but develops better in colder climates. Control of its invasion of natural vegetation, commercial timber plantations and farmland incurs considerable costs, but its timber value and nursing of natural forest succession provides a positive contribution.

Eugenia uniflora (tree):
(Barbados cherry; Brazilian cherry)

Eugenia uniflora is an evergreen shrub that can reach tree like proportions. It is a hardy species that can thrive in a variety of habitats, both in its native and introduced range. Eugenia uniflora can quickly reach thick densities which affect under storey light levels, subsequently changing micro-environments. It is also known to host recognized pests and pathogens.

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Alternanthera philoxeroides (aquatic herb): (Alligator weed; Pig weed)

Alternanthera philoxeroides, commonly known as alligator weed, is a *perennial stoloniferous* herb that can be found in many parts of the world, infesting rivers, lakes, ponds and irrigation canals, as well as many terrestrial habitats. The aquatic form of the plant has the potential to become a serious threat to waterways, agriculture and the environment. The terrestrial form of *Alternanthera philoxeroides* grows into a dense mat with a massive underground rhizomatous root system. The canopy can smother most other herbaceous plant species. It has proven to be extremely expensive to attempt controlling *Alternanthera philoxeroides*.

Ambrosia artemisiifolia (herb): (Carrot-weed; Hay-fever weed; Common ragweed)

Ambrosia artemisiifolia is a summer annual herbaceous plant that is native to temperate North America in the United States and Canada. Also commonly known as ragweed this forb establishes easily in human impacted and disturbed areas in high abundance. It is considered an invasive species in Europe, parts of Asia and Australia, although it is not an extremely competitively aggressive species and is mainly considered a noxious weed that interferes with other cultivated crops. The main impact of this plant is the copious amount of pollen produced from male flowers that are allergens to sensitive people, compounding health problems like *rhinitis*, *oculorhinitis*, asthma and causing skin irritations.

Asparagus densiflorus (herb): (Asparagus Fern; Regal fern)

Asparagus densiflorus, commonly known as asparagus fern, is not a true fern. It reproduces by seed. A. densiflorus is known to invade a variety of habitats, and its impacts include smothering of forest understory and ground cover and preventing the regeneration of canopy species.

Chromolaena odorata (herb): (Bitter bush; Rumput golkar)

Chromolaena odorata is a fast-growing perennial shrub, native to South America and Central America. It has been introduced into the tropical regions of Asia, Africa and the Pacific, where it is an invasive weed. Also known as Siam weed, it forms dense stands that prevent the establishment of other plant species. It is an aggressive competitor and may have allelopathic effects. It is also a nuisance weed in agricultural land and commercial plantations.

Cirsium arvense (herb): (Californian thistle; Canada thistle)

Cirsium arvense is an herbaceous perennial in the Aster family. It occurs in nearly every upland herbaceous community within its range, and is a particular threat in grassland communities and riparian habitats. *C. arvense* is shade intolerant and can tolerate soils with up to 2% salt content. It grows on all but waterlogged, poorly aerated soils, including clay, clay loam, silt loam, sandy loam, sandy clay, sand dunes, gravel, limestone, and chalk, but not peat. It spreads primarily by vegetative means, and secondarily by seed. The seeds spread as a contaminant in agricultural seeds in hay and in cattle and horse droppings and on farm machinery. It produces an abundance of bristly-plumed seeds that are easily dispersed by the wind and they may also be transported by water.

Cryptostegia grandiflora (vine, climber): (India rubber vine; Purple allamanda)

Cryptostegia grandiflora is a self supporting,

many-stemmed vine that is capable of growing over trees up to 15m high, smothering and pulling them down. It occurs in dry and moist forests in disturbed situations where there is temporary or permanent water, such as in rainforest openings and along roadsides. *C. Grandiflora* is poisonous to stock when consumed and it forms impenetrable thickets that may restrict stock access to water. It decreases water catchments due to increased transpiration resulting in a loss of trees and native vines, which in turn leads to a loss of biodiversity and habitat.

Eichhornia crassipes (aquatic plant):
(Jal kumbhi; Water hyacinth)

Originally from South America, *Eichhornia crassipes* is one of the worst aquatic weeds in the world. Its beautiful, large purple and violet flowers make it a popular ornamental plant for ponds. It is now found in more than 50 countries on five continents. Water hyacinth is a very fast growing plant, with populations known to double in as little as 12 days. Infestations of this weed block waterways, limiting boat traffic, swimming and fishing. Water hyacinth also prevents sunlight and oxygen from reaching the water column and submerged plants. Its shading and crowding of native aquatic plants dramatically reduces biological diversity in aquatic ecosystems.

Elaeagnus umbellata (shrub): (Silverberry)

Elaeagnus umbellata is valued as an ornamental because of its silvery foliage and flowers and its hardiness under dry conditions. It invades grasslands and disturbed areas adjacent to the plantings, and encroachment can be rapid because of its high seed production and germination rate. It grows well on a variety of soils, including sandy, loamy, and somewhat clayey textures. It does very well on infertile soils because its roots can fix nitrogen, which has also fostered its use as a nurse plant in walnut orchards. E. umbellata seeds are ingested with fruit and dispersed by birds and mammals. Seeds are also used in some places for wildlife plantings.

Eupatorium cannabinum (herb):
(Water agrimony)

Eupatorium cannabinum is a woody perennial herb that prefers to inhabit and invade moist habitats such as swamps, marshes and stream banks. It forms dense monotypic stands that compete with and eventually crowd out native species. This species also has the ability to alter the nutrient structure of habitats it invades.

Cabomba caroliniana (aquatic plant):
(Fish-grass; Washington-grass)

Cabomba caroliniana is a submerged perennial aquarium plant that grows in stagnant to slow flowing freshwater. It spreads primarily by stem fragments and forms dense stands that crowd out well-established plants. *C. caroliniana* may clog ecologically, recreationally or economically important water bodies and drainage canals. Depending on its location (ie: drinking water supply or small closed water body) it may be managed by a number of control techniques including mechanical removal (being careful not to spread fragments to new locations) and habitat modification to increase shading (via planting trees) or decrease hydration (via draining).

Kappaphycus spp. (algae): (Agar-agar; Red alga)

Kappaphycus spp. are red algae species that have been introduced in various parts of the world for the purpose of harvesting the gelling agent kappa carrageenan, which is used in industrial gums and as a smoothening agent used in ice cream, toothpaste, jellies, medicines and paint. This species can regenerate from fragments as small as 0.5cm making it an extremely difficult species to control.

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Lantana camara (shrub): (Lantana wildtype)

Lantana camara is a significant weed of which there are some 650 varieties in over 60 countries or island groups. It is established and expanding in many regions of the world, often as a result of clearing of forest for timber or agriculture. It impacts severely on agriculture as well as on natural ecosystems. *L. camara* is a significant weed of which there are some 650 varieties in over 60 countries or island groups. It is established and expanding in many regions of the world, often as a result of clearing of forest for timber or agriculture. It impacts severely on agriculture as well as on natural ecosystems. The plants can grow individually in clumps or as dense thickets, crowding out more desirable species. In disturbed native forests it can become the dominant understorey species, disrupting succession and decreasing biodiversity. At some sites, infestations have been so persistent that they have completely stalled the regeneration of rainforest for three decades. Its allelopathic qualities can reduce vigour of nearby plant species and reduce productivity in orchards. *L. camara* has been the focus of biological control attempts for a century, yet still poses major problems in many regions plants can grow individually in clumps or as dense thickets, crowding out more desirable species. In disturbed native forests it can become the dominant under storey species, disrupting succession and decreasing biodiversity. At some sites, infestations have been so persistent that they have completely stalled the regeneration of rainforest for three decades. Its allelopathic qualities can reduce vigour of nearby plant species and reduce productivity in orchards. It has been the focus of biological control attempts for a century, yet still poses major problems in many regions.

Leucaena leucocephala (tree):
(Horse/wild tamarind)

Leucaena leucocephala is a 'conflict tree' being widely promoted for tropical forage production and reforestation, whilst at the same time it is spreading naturally and is widely reported as a weed. This thornless tree can form dense monospecific thickets and is difficult to eradicate once established. It renders extensive areas unusable and inaccessible and threatens native plants.

Limnocharis flava (aquatic plant):
(Sawah-lettuce; Manja payal)

Limnocharis flava is a clump-forming, emergent aquatic plant that is native to the American continent. The Greek words "Limno" and "charis" mean "pond" and "grace", respectively. The attractiveness of this plant, with its inflourescenes of pale yellow flowers, has lead to its cultivation in gardens, which has facilitated its dispersal to new locations.

Ludwigia peruviana (aquatic plant):
(Water-primrose)

Ludwigia peruviana is a wetland species that has been introduced as an ornamental for its bright yellow and showy flowers. Once established, however, it forms dense, monotypic stands along shorelines and banks and then begins to sprawl out into the water and can form floating islands of vegetation. At this point *L. peruviana* can clog waterways, damage structures and dominate native vegetation.

Macfadyena unguis-cati (vine, climber):
(Yellow trumpet vine; Cat-claw creeper)

Macfadyena unguis-cati is a perennial, climbing liana found primarily in tropical forests. It is native to the Central and South Americas and the West Indies, but currently is represented on every continent except Antartica. It is an invasive species in much of its range and is said to be "one of the most destructive exotic vines". *M. unguis-cati* affects

all layers of infected forest ecosystems by rapidly spreading both vertically and horizontally across everything with which it makes contact, overwhelming both the understorey plants and the canopy trees. *M. unguis-cati* species becomes established quickly and is difficult to eliminate due to its rapid growth, extensive root system, and prolific seed production. Methods of manual, chemical and biological control for *M. unguis-cati* are available.

Mikania micrantha (vine, climber):
(American rope)

Mikania micrantha is a perennial creeping climber known for its vigorous and rampant growth. It grows best where fertility, organic matter, soil moisture and humidity are all high. It damages or kills other plants by cutting out the light and smothering them. A native of Central and South America, *M. micrantha* was introduced into India after the Second World War to camouflage airfields and is one of the most widespread and problematic weeds in the Pacific region. Its seeds are dispersed by wind and also on clothing or hair.

Mimosa diplotricha (vine, climber, shrub):
(Giant sensitive plant)

Mimosa diplotricha (also referred to in the literature as M. invisa) is a serious weed around the Pacific Rim, where it is the subject of several eradication programmes. Early detection and control is recommended to prevent large infestations from establishing.

Mimosa pudica (shrub):
(Action plant; Laajaalu; Chuimui; Lajjavanthi)

Mimosa pudica is native to South America, but has become a pan-tropical weed. It was introduced to many countries as an ornamental plant and is still widely available for sale. *M. pudica* has become a pest in forest plantations, cropland, orchards and pasture. *M. pudica* is used as a medicinal plant in many regions.

Parthenium hysterophorus (herb):
(Congress grass; Parthenium weed; Ragweed parthenium)

Parthenium hysterophorus is an annual herb that aggressively colonises disturbed sites. Native to Mexico, Central and South America, *P. hysterophorus* was accidentally introduced into several countries including Australia, India, Taiwan and Ethiopia. In some areas it has become an extremely serious agricultural and rangeland weed. *P. hysterophorus* is also known to be allergenic to some people and consumption by livestock can taint meat.

Pennisetum clandestinum (grass):
(West African pennisetum)

Pennisetum clandestinum is a creeping, mat-forming grass that originates from tropical eastern Africa. It gets its common name, kikuyu grass, from the fact that it is native to the area in which the Kikuyu tribe live. *P. clandestinum* is an aggressive invader of pasture, crops and natural areas. It spreads via an extensive network of rhizomes and stolons, and smothers all other vegetation. It is difficult to control manually, but the use of herbicides can yield good results.

Pittosporum undulatum (tree, shrub):
(Australian cheesewood; Mock orange)

Pittosporum undulatum is an evergreen tree that is often used as an ornamental plant, due to its attractive fragrant flowers. It is native to south-eastern Australia but has now spread to a number of islands in the Pacific and Caribbean, as well as islands in the Atlantic and to South Africa. It is also invasive In Australia outside its native range. Research is being carried out in Jamaica to determine the most effective methods of control for this species.

P***rosopis spp.*** (tree, shrub):
(Cashew; Shouk shami)

Members of the genus *Prosopis spp.*, which are commonly known as mesquite or algarrobo, include at least 44 defined species and many hybrids. This leads to problems with identification. For this reason, information about different species in the Prosopis genus is presented in this genus-level profile. Native to the Americas, Prosopis species are fast growing, nitrogen fixing and very salt and drought tolerant shrubs or trees. Most are thorny, although thorn-less types are known. Animals eat the pods and may spread seeds widely. Trees develop a shrubby growth form if cut or grazed. The four main species that have presented problems as weeds world-wide are *P. glandulosa* and *P. velutina* in more subtropical regions and *P. juliflora* and *P. pallida* in the truly tropical zone.

Ricinus communis (shrub):
(Castor; Castor bean)

Ricinus communis is a perennial shrub that can assume tree-like status if it establishes in a suitable climate. It is frequently found invading riparian areas where it displaces native vegetation. The seed of this species is toxic to variety of species including humans. Consuming only a few seeds can be fatal.

Solanum mauritianum (herb):
(Wild tobacco; Tobacco weed)

Solanum mauritianum is a widespread invasive weed belonging to the nightshade family. It has the ability to crowd out native plants if growing densely, but, if occurring sparsely, it may act as a nursery crop. All parts of *S. mauritianum* plant are poisonous to humans, especially the berries. This plant is dispersed by birds, with the fruit being especially favoured by some species. Biological control of this species has been undertaken in South Africa.

Solanum sisymbriifolium (herb):
(Wild tomato; Sticky nightshade)

Solanum sisymbriifolium is a viscid, hairy herb native to South America that is currently distributed throughout the world. It is valued for its many uses, which include its use as a trap crop for potato cyst nematodes, and the use of its fruit as both a source of solasodine (used to synthsise hormones) and as a food for birds and humans. However, it acts as an invasive weed in some parts of its range by out-competing local vegetation. Biological control methods for *S. sisymbriifolium* have been determined and applied in some regions.

Solanum viarum (shrub): (Tropical soda apple)

Solanum viarum is an aggressive perennial shrub native to Brazil and Argentina that has been introduced to other parts of South America, North America, Africa and Asia. The primary means of dispersal seems to be by livestock (cattle) and wildlife, such as raccoons, deer, feral hogs and birds that feed on its fruits. Intra- and inter- county and state movement of livestock that have recently fed on *S. viarum* may be the primary vector for its spread. However, contaminated hay, seeds and bags of manure for composting also serve as a means for its dispersal.

Triadica sebifera (tree):
(Popcorn tree; Chicken tree; Vegetable tallow)

Triadica sebifera is a tree in the Euphorbiaceae family which typically reaches a maximum height of 15m at maturity. It is adapted to a variety of disturbed sites and a wide range of soil conditions. *T. sebifera* aggressively displaces native plants and forms monospecific stands within decades of its appearance. It is also able to alter nutrient cycles by enhancing productivity in ecosystems by the addition of nitrogen and phosphorous from the rapid decay of its leaves which produce tannins. *T. sebifera* is shade, sun, drought, flood, freeze and salt tolerant

and is also suspected of reducing nesting habitat for a variety of avian species. Management of this species is an arduous process and not suitable for all infested sites.

Gymnocoronis spilanthoides (aquatic plant):
(Senegal teaplant; temple plant)

Gymnocoronis spilanthoides is a freshwater or marsh-growing emergent perennial herb. It has been introduced through the aquarium trade. It grows very quickly and can rapidly cover water bodies with a floating mat that excludes many animals and plants from native vegetation. Localized flooding increases because *G. spilanthoides* blocks drainage channels. Recreational activities, irrigation and navigation may also be affected. And if large-scale die-offs of this species occur, water quality may decline.

S***alvinia molesta*** (aquatic herb):
(African payal; Water fern)

Salvinia molesta is a floating aquatic fern that thrives in slow-moving, nutrient-rich, warm, freshwater. A rapidly growing competitive plant, it is dispersed long distances within a water body (via water currents) and between water bodies (via animals and contaminated equipment, boats or vehicles). *S. molesta* is cultivated by aquarium or pond owners and it is sometimes released by flooding, or by intentional dumping. *S. molesta* may form dense vegetation mats that reduce water-flow and lower the light and oxygen levels in the water. This stagnant dark environment negatively affects the biodiversity and abundance of freshwater species, including fish and submerged aquatic plants. *S. molesta* can alter wetland ecosystems and cause wetland loss and also poses a severe threat to socio-economic activities dependent on open, flowing and/or high quality water bodies, including hydro-electricity generation, fishing and boat transport.

Spartina alterniflora (grass):
(Salt-water cordgrass)

Spartina alterniflora commonly known as smooth cord grass is a species that inhabits marsh habitat in its native range, where introduced It is known to establish itself in wave-protected mud and sand flats and grow very quickly into dense impenetrable stands. When introduced this species can have a negative effect on native species including some endangered ones. It can also hybridize with native non-invasive species of *Spartina* and offspring are known to have increased vigor and growth rates than either parent.

Cryphonectria parasitica (fungus):
(Chestnut blight)

Cryphonectria parasitica is a fungus that attacks primarily *Castanea* spp. but also has been known to cause damage to various Quercus spp. along with other species of hardwood trees. American chestnut, *C. dentata*, was a dominant over-storey species in United States forests, but now they have been completely replaced within the ecosystem. *C. dentata* still exists in the forests but only within the under-storey as sprout shoots from the root system of chestnuts killed by the blight years ago. A virus that attacks this fungus appears to be the best hope for the future of *Castanea* spp., and current research is focused primarily on this virus and variants of it for biological control. Chestnut blight only infects the above-ground parts of trees, causing cankers that enlarge, girdle and kill branches and trunks.

Anoplolepis gracilipes (insect):
(Crazy ant; Maldive ant; Yellow crazy ant)

Anoplolepis gracilipes (so called because of their frenetic movements) have invaded native ecosystems and caused environmental damage from Hawaii to the Seychelles and Zanzibar. On Christmas Island in the Indian Ocean, they have formed multi-queen

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supercolonies. They are also decimating the red land crab (*Gecarcoidea natalis*) populations. Crazy ants also prey on, or interfere in, the reproduction of a variety of arthropods, reptiles, birds and mammals on the forest floor and canopy. Their ability to farm and protect sap-sucking scale insects, which damage the forest canopy on Christmas Island is one of their more surprising attributes. Although less than 5% of the rainforest on Christmas Island has been invaded so far, scientists are concerned that endangered birds such as the Abbott's booby (*Sula abbotti*), which nests nowhere else in the world, could eventually be driven to extinction through habitat alteration and direct attack by the ants.

Bemisia tabaci (insect): (Sweet potato whitefly; Cotton whitefly)

Bemisia tabaci has been reported from all continents except Antarctica. Over 900 host plants have been recorded for *B. tabaci* and it reportedly transmits 111 virus species. It is believed that *B. tabaci* has been spread throughout the world through the transport of plant products that were infested with whiteflies. Once established, *B. tabaci* quickly spreads and through its feeding habits and the transmission of diseases, it causes destruction to crops around the world. *B. tabaci* is believed to be a species complex, with a number of recognized biotypes and two described extant cryptic species.

Monomorium pharaonis (insect): (Pharaoh ant)

Monomorium pharaonis (the pharaoh ant) is native to Africa and has successfully invaded areas on every continent except Antarctica. It is concentrated in tropical regions but is also commonly found in temperate zones within suitable human infrastructure, especially buildings associated with the distribution or storage of food. Due to *Monomorium pharaonis'* ability to act as a vector for some bacterial human pathogens, its presence in hospitals is of great concern as it may increase infection rates.

Quadrastichus erythrinae (insect):
(Erythrina gall wasp)

Unusual growths, caused by Erythrina gall wasp (*Quadrastichus erythrinae*), on leaves and young shoots of coral trees (*Erythrina* spp). Alerts to the presence of this emerging invasive species. *Q. erythrinae* measures a mere 1.5mm and may be spread easily via infected leaves from infected Erythrina specimens.

Technomyrmex albipes (insect):
(White-footed ant; White-footed house ant)

Native to the Indo-Pacific area, *T. albipes*, commonly known as the white-footed ant, has spread to Australia, Africa, North America, Caribbean and Asia. *T. albipes* are often found on cut flowers and other imported plants. It's penchant for invading houses and nesting in wall cavities distresses homeowners. The unusual colony structure of *T. albipes* allows them to reproduce rapidly, especially in warm weather, reaching numbers in the millions in some locations. Management of *T. albipes* is difficult when populations abound, as chemical poisons are not transferred between workers.

Solenopsis geminata (insect):
(Fire ant; Ginger ant; Tropical fire ant)

Solenopsis geminata has spread almost world-wide by human commerce. It usually invades open areas but can easily colonise human infrastructure and agricultural systems, such as coffee and sugarcane plantations in hot climates. Its greatest known threats are its painful sting and the economic losses due to crop damage caused by its tending of honey-dew-producing insects. *S. geminata* is known to reduce populations of native butterfly eggs and larvae. It has the potential to displace

native ant populations, but is susceptible to competitive pressures from some other ant species.

Ascidiella aspersa (tunicate):
(Dirty sea squirt; European sea squirt)

Ascidiella aspersa (European sea squirt) is a solitary marine and estuarine tunicate that is native from Norway to the Mediterranean. It is a suspension filter-feeder and was introduced via fouling on the hulls of ships to the northwest coast of the Atlantic, India, Australia and New Zealand. Commonly called the European sea squirt, it has become a moderate to serious threat by displacing native fauna.

Bugula neritina (bryozoan): (Common bugula)

Bugula neritina (brown bryozoan) is an erect, bushy bryozoan. It is an abundant fouling organism that colonises any freely available substratum, including artificial underwater structures and vessel hulls.

Carassius auratus (fish):
(Edible goldfish; Golden carp)

Native to Asia, goldfish (*Carassius auratus*) have been introduced worldwide due to their popularity as pond and aquarium fish. Releases, both intentional and unintentional, have meant that this species has formed wild populations in many new locations. Concerns have been raised about the impacts that goldfish have on the aquatic community, including increasing turbidity, predation upon native fish, and helping to facilitate algal blooms.

Ctenopharyngodon idella (fish):
(Chinese carp; White amur)

Grass carp (*Ctenopharyngodon idella*) is a large cyprinid introduced worldwide as a biological control of aquatic vegetation as well as a food fish. It is a voracious feeder which is incredibly efficient at removing aquatic weeds. However they can completely eliminate vegetation from water systems, resulting in widespread ecological effects. Grass carp are also known to compete with native fish, carry parasites such as Asian tapeworm (*Bothriocephalus opsarichthydis*), and induce other harmful effects to introduced waters.

Cyprinus carpio (fish):
(German carp; Saran; Scale carp)

The common carp (*Cyprinus carpio*) has been introduced as a food and ornamental fish into temperate freshwaters throughout the world. It is considered a pest because of its abundance and its tendency to reduce water clarity and destroy and uproot the aquatic vegetation used as habitat by a variety of species.

Columba livia (bird):
(Domestic dove; Domestic pigeon)

Columba livia is native to Europe and has been introduced worldwide as a food source, or for game. These pigeons prefer to live near human habitation, such as farmland and buildings. They cause considerable damage to buildings and monuments because of their corrosive droppings. They also pose a health hazard, since they are capable of transmitting a variety of diseases to humans and to domestic poultry and wildlife.

Equus asinus (mammal): (African wild ass; Ass)

Equus asinus (donkeys) resemble horses and are characterized by their large head, long ears and cow-like tail. They can be found in tropical savannas and arid hill country in Australia and other arid and desert habitats elsewhere in its range. In its invasive range, *E. asinus* have deleterious and potentially irreversible impacts on native flora and fauna. Damage has been documented in plant communities, soils, wildlife and water quality. Management of this species can be difficult. Cultural pressures prevent lethal methods of management from being used. Typical

management techniques involve removing the species from their natural habitat and placing them in reserves where they will not pose a threat. The growing number of feral donkeys, roaming free across Sudan, Eritrea and Somalia propitiate extensive hybridisation with their wild relative *E. africanus* and thus contribute to the extinction of the *E. africanus*.

Euglandina rosea (mollusc): (Cannibal snail)

Native to the southeastern United States, the predatory snail *Euglandina rosea* was introduced to islands in the Pacific and Indian Oceans from the1950s onwards as a biological control agent for another alien species, the giant African snail (*Achatina fulica*). However, it is neither host specific nor an effective control for *Achatina fulica*. In French Polynesia, the fast moving E. rosea rapidly eliminated local endemic species. One group threatened by *E. rosea* is the Partulid tree snails, which evolved separately from each other in isolated valleys and exhibit a variety of unique characteristics. Many Partulid tree snails have been lost already and today the survivors exist in zoos and in the world's first wildlife reserves for snails. This invasion by a biological control agent has caused a significant loss of biodiversity.

Achatina fulica (mollusc):
(Giant African land snail)

Achatina fulica is a threat to the sustainability of crop systems and native ecosystems, having a variety of negative impacts on native fauna, from competition for resources to the spread of diseases to direct herbivory of native plants. Native snails in fragile island ecosystems such as Hawaii and the French Polynesian islands are particularly susceptible to the negative effects of *A. fulica* and other introduced snails.

Mytilopsis sallei (mollusc):
(Black striped mussel; False mussel)

Mytilopsis sallei, commonly known as the black striped mussel, is an opportunistic r-strategist mussel species, which is found in intertidal and shallow waters. It has similar impacts to the zebra mussel *Dreissena polymorpha*. *M. sallei* is a major fouling species, forming dense monocultures which can lead to a substantial reduction in biodiversity.

Gambusia affinis (fish):
(Mosquito fish; Gambusia)

Gambusia affinis is a small fish native to the fresh waters of the eastern and southern United States. It has become a pest in many waterways around the world following initial introductions early last century as a biological control of mosquito. In general, it is considered to be no more effective than native predators of mosquitoes. The highly predatory mosquito fish eats the eggs of economically desirable fish and preys on and endangers rare indigenous fish and invertebrate species. Mosquito fish are difficult to eliminate once established, so the best way to reduce their effects is to control their further spread. One of the main avenues of spread is continued, intentional release by mosquito-control agencies. *G. affinis* is closely related to he eastern mosquito fish (*G. holbrooki*), which was formerly classed as a sub-species. Their appearance, behaviour and impacts are almost identical, and they can therefore be treated the same when it comes to management techniques. Records of *G. affinis* in Australia actually refer to *G. holbrooki*.

Aristichthys nobilis (fish): (Bighead carp)

Aristichthys nobilis commonly known as bighead carp are carp species native to Asia. They have been introduced around the world for aquaculture purposes and also because they can be used to control excessive growths of phytoplankton in natural waters. These species have the potential to reduce native diversity by competing for and depleting

zooplankton populations thus altering the food web. *A. nobilis* have also been found to carry and transmit various diseases. *A. nobilis* is also known by its synonym *Hypophthalmichthys nobilis*.

Gambusia holbrooki (fish): (Eastern gambusia)

Gambusia holbrooki (eastern gambusia) is a small, aggressive live-bearing fish that originates from the southern United States. It has been spread worldwide as a mosquito-control agent. *G. holbrooki* has been implicated in damage to native fish, amphibian and invertebrate populations. The usefulness of *G. holbrooki* as a biological control agent is doubtful, since many species of native fish may be just as effective at controlling mosquitoes while avoiding the negative side-effects on the biota.

Hypophthalmichthys molitrix (fish): (Silver carp)

Hypophthalmichthys molitrix is a carp, native to Asia. *H. molitrix* have been introduced around the world for aquaculture purposes and also for controlling excessive growth of phytoplankton in natural waters. *H. molitrix* have the potential to reduce native diversity by competing for and depleting zooplankton populations, altering the food web. *H. molitrix* have also been found to carry and transmit the disease *Salmonella typhimurium*.

Oncorhynchus mykiss (fish): (Brown trout; Coast angel trout; Summer salmon)

Oncorhynchus mykiss (rainbow trout) are one of the most widely introduced fish species in the world. Native to western North America, from Alaska to the Baja Peninsula, *O. mykiss* have been introduced to numerous countries for sport and commercial aquaculture. *O. mykiss* is highly valued as a sportfish, with regular stocking occurring in many locations where wild populations cannot support the pressure from anglers. Concerns have been raised about the effects of introduced trout in some areas, as they may affect native fish and invertebrates through predation and competition.

Oreochromis mossambicus (fish): (Mojarra)

Oreochromis mossambicus (Mozambique tilapia) has spread worldwide through introductions for aquaculture. Established populations of *O. mossambicus* in the wild are the result of intentional release or escapes from fish farms. *O. mossambicus* is omnivorous and feeds on almost anything, from algae to insects.

Oreochromis niloticus (fish): (Chikadai)

Oreochromis niloticus (Nile tilapia) is a highly invasive fish that plagues a variety of ecosystems, particularly those located in the tropics. *O. niloticus*' effective mouth brooding reproductive strategy allows it to increase in numbers at a rate which, not only crowds native species, but pollutes and unbalances the water column. *O. niloticus* is a frequently farmed aquatic species, due to its relative ease of culture and rapid reproduction rates. Most infestations are a result of aquaculture.

Oreochromis spp. (fish): (Freshwater snapper)

Tilapia (*Oreochromis* spp.) is the common name applied to three genera of fish in the family Cichlidae: Oreochromis, Sarotherodon and Tilapia. These include over 70 species of fish, at least eight of which are used for aquaculture. Tilapia belongs to a family of fish known as cichlids, among which most African members are mouth brooders. The cage culturing of tilapia results in a reduction of water quality in the surrounding environment, which is particularly worrying when close to ecologically important areas. The unavoidable escape and establishment of wild tilapia from cages has sometimes resulted in other serious problems, such as the decline of culturally valued native fish species, particularly

cichlids, and the alteration of natural benthic communities.

Salmo trutta (fish): (Brown trout)

Salmo trutta has been introduced around the world for aquaculture and stocked for sport fisheries. It is blamed for reducing native fish populations, especially other salmonids, through predation, displacement and food competition. It is a popular angling fish.

Salvelinus fontinalis (fish):
(Lord-fish; Square-tail)

Introduced as a highly desirable fish for both angling and aquaculture throughout the world, *Salvelinus fontinalis* (brook trout) is an invasive that threatens native amphibians and fish, as well as the ecology of lakes and streams. Several native fish and amphibians face threatened or endangered status as a result of their introduction. Removal of *S. fontinalis* has been conducted in many places to allow for the recovery of endemic species.

Tinca tinca (fish): (Doctor-fish)

Tench (*Tinca tinca*) are a widespread species of freshwater fish native to temperate Europe and Asia. Popular as an angling species, they have been introduced to a number of countries as a sport fish. Their omnivorous diet and tolerance of a wide range of environmental conditions has lead to some countries labeling tench as an invasive species, due to concerns over competition with native fish.

Rattus exulans (mammal):
(Maori rat; Pacific rat)

The Pacific rat (*Rattus exulans*) is the smallest of the three rats closely associated with humans. The fur is brown and its tail length is only slightly longer or shorter than the combined head and body length. *R. exulans* is recognized as a predator of native insects, lizards and birds, a browser of native flora and an agricultural pest. There appears to be no island groups reached by the Polynesians that did not receive *R. exulans*, although not all islands in a group were necessarily colonized.

Vibrio cholerae (micro-organism):
(Asiatic cholera; Epidemic cholera)

Vibrio cholerae is the bacteria that causes cholera; a potentially epidemic and life-threatening secretory diarrhoea characterized by numerous, voluminous watery stools, often accompanied by vomiting and resulting in hypovolemic shock and acidosis. It can also cause mild or unapparent infections. *V. cholerae* occurs in both marine and freshwater habitats in mutualistic associations with aquatic animals. *V. cholerae* is endemic or epidemic in areas with poor sanitation; it occurs sporadically or as limited outbreaks in developed countries. Cholera is transmitted by the fecal-oral route. In coastal regions it may persist in shellfish and plankton. Long-term convalescent carriers are rare.

Pycnonotus jocosus (bird): (Crested Bulbul)

Pycnonotus jocosus (red-whiskered bulbul) is a bird native to Asia which has become invasive to several parts of the world. It has been found to damage crops, compete with native species and spread invasive plants.

Zosterops japonicus (bird): (Japanese white-eye)

Zosterops japonicus (Japanese white-eye) is a small songbird that has been introduced to the Pacific region from Asia. It is an arboreal species that can be found in a wide variety of habitats. It is known to consume the fruit of certain species of invasive plants and aids in their dispersal. There is reason to believe that some competition may occur between *Z. japonicus* and native bird species that inhabit similar ecological niches, but current research has found very little evidence of negative impact.

Preliminary Investigation on Invasive Alien Species of Uttar Pradesh

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Introduction:

According to World Conservation Monitoring Centre (WCMC), 1,604,000 species have been described at the global level. Thus India accounts for 8 % of the global biodiversity. India has a characteristic geographic location at the junction of the three major biogeography realms, namely, the Indo-Malayan, the Eurasian and the Afro-tropical (60 45' to 370 6'N latitude and 680 7' to 970 25' E longitude). The flora of India shows close affinity with the flora of Indo-Malayan and Indo-Chinese region. For a long time it was believed that India has no flora as a separate entity but is an admixture of the floras from adjacent countries (Hooker 1904). According to Nayar (1977) 35% of Indian flora has south-east Asian and Malayan, 8% temperate, 1% steppe, 2% African, and 5% Mediterranean- Iranian elements. The cultivated and naturalized aliens constitute only 18%. Chatterjee (1939) reported 6,850 species as endemic to India for the first time. After critical analysis of flora of India it has been convincingly concluded by phytogeographers that India has a flora of its own and as many as 6,850 (33%) taxa of Indian flora are endemic to present Indian boundaries.

Plant invasions have been recognized as one of the most serious global processes impacting the structure, composition, and function of natural and semi-natural ecosystems (Mooney and Hobbs, 2000; Vitousek *et al.*, 1997). Ecologists are now paying more attention to plant invasions, including their history and impacts. Several conclusions, concepts, and hypotheses have been put forward and evaluated, especially those related to biogeographical settings, historical events, and biological traits. For example, it has been shown that a species that invades one place tends to be invasive also in other areas (Meyer, 2000); some characteristics possessed by particular groups of species can be used to predict their invasiveness (Reichard and Hamilton, 1997; Rejmánek and Richardson, 1996); and plants of different geographical origin seem to differ in their success (Huston, 1994).

The introduction and naturalized of foreign weeds on Indian soil has greatly influenced the pattern of Indian flora. Though India has got a flora of her own (Chatterjee 1940), nevertheless, immigration provides a continual source of new diversity for region. How important it is depends on the balance between the number of propagules that come from outside and the number produced by resident individuals. In most cases, such introductions are unsuccessful, but when they do become established as an invasive exotic species (defined by IUCN (2000) as "an alien species which becomes established in natural or semi-natural ecosystems or habitat, is an agent of change, and threatens native biological diversity"), the consequences can be catastrophic. The special dispersal devices on seeds of some plant ensure long-distance dispersal through wind. Man is greatly responsible for the introduction and subsequent spread of these weeds through important of food grains, seeds of foreign garden plants and fodder, imported packing material, vehicles and living animals although migratory

birds in some case are also responsible. Distribution of notorious weeds has placed a strong effect on the native flora, since many of these have replaced much of the indigenous species, probably because of their strong harmful effect. (Nayar 1977). According to the Convention for Biological Diversity, invasive exotic species are the second largest cause of biodiversity loss in the world and impose high costs to agriculture, forestry, and aquatic ecosystems. In fact, introduced species are a greater threat to native biodiversity than pollution, harvest, and disease combined.

It is very difficult to choose exotic species, from all over the country, that really are "invasive" or "worse" than any others. Species and their interactions with ecosystems are very complex. Therefore, Uttar Pradesh state has been selected for preparation of inventory of invasive species.

Uttar Pradesh state is situated in north central part of India. The northwestern section of the state was carved in 2000 by creation of a new state of Uttarakhand. The climate of the state is tropical monsoon. The moderate rainfall is supplemented by an extensive system of canal irrigation. Forests constitute about 12.8% of the total geographical area of the state. The northern part of the state, formed by the Yamuna, Ganges, and Ghaghara rivers is known as Gangetic Plain. This region has highly fertile alluvial soils and flat topography broken by numerous ponds, lakes and rivers. The tarai and bhabhar area in the Gangetic Plain have moist deciduous forests. The Vindhyan Hill and plateau in the southern region bears hard rock strata; varied topography of hills and plains; valleys and plateau and limited water availability. The Vindhyan forests consist mostly of scrub. Having unique geographical position, topography, sufficient rain and moisture the state harbours a very rich and diverse flora. Although the state has been botanically surveyed since long, and large numbers of publications have been appeared during the last four decades, however a complete flora of the state is not yet available.

After an extensive review of literature on global invasive species and of India and field study, it has been observed that many of the plants which are adventives in nature have altered the floristic composition of many areas. The preliminary list of about 173 common plant species has been prepared.

The goals of this study are:

(1) to compile a comprehensive list of naturalized taxa in Uttar Pradesh; and

(2) to summarize their basic biological characteristics and geographical sources.

Obsevation:

Acanthospermum hispidum DC.

A native of South America. Frequent in Moist places along the bank of rivers. It is reported from Andhra Pradesh and Himachal Pradesh.

Aeschyomene americana Linn.

Native of tropical America. Rare; in the paddy fields. It is reported from Bihar.

Ageratum conyzoides Linn.

This is a South American species that has spread fairly common throughout the country. The species is seen along forest margins, road-sides and in waste fields.

A. houstonianum Mill.

It is a native of Mexico. Common in waste fields in association with A. conyzoides Linn. These species is reported from Tamil Nadu, Assam, Nilgiri and Puney Hills, Sikkim, Dehra Dun, Madhya Pradesh, Nepal, Bengal.

Alternanthera polygonoides (Linn.) H.B. & K. Ex Roem and Schult

A native of tropical and subtropical America but now completely naturalized in many parts of the Upper Gangetic Plain. Also reported from West

Bengal, Coimbatore, Tamil Nadu, Europe, Java and Philippine.

A. pungens Kunth.

A native of tropical America. Common along road-side and railway-tracks. The species is reported from Coimbatore, Bangalore, Madras, Andhra Pradesh, Bombay, Orissa, Delhi.

Argemone ochroleuca Sweet

A native of Mexico. Common along road-sides and in waste places. It has also been reported from Delhi and Madhya Pradesh.

Bacopa procumbens (Mill.) Greema.

A native of tropical America. Now it has become naturalized in Assam, West Bengal, Madhya Pradesh and Bihar. Frequent in grasslands and gardens.

Chenopodium ambrosioides Linn.

A native of tropical America. It is found gregariously in moist places. Earlier reported from Karnataka, Delhi, Nepal and Burma etc.

Cleome burmanni Wt. & Arn.

A native of West Africa. Rare in moist and shady places.

Coronopus didymus (Linn.) SM.

A native of tropical America. Frequent in the moist and shady places.

Croton bonplandianum Baill.

A native of South America but now naturalized in the country. It is common weed along road-sides and waste fields. It has been reported from Tamil Nadu, Orissa, Madhya Pradesh, Punjab, Delhi and Assam.

Eichhornia crassipes Solms.

A native of Brazil. Common weed of ponds and ditches. It is reported from Kerala, Karanataka, Maharashtra, Tamil Nadu, Andhra Pradesh, Madhya Pradesh, Assam, Bengal and Orrisa.

Ergeron bonariensis Linn.

A Native of South America and now naturalized in various parts of the country. Abundantly found in open places on moist soil. It has been reported from Madhya Pradesh and Delhi.

Euphorbia geniculata Orteg.

A native of tropical America. Common, in open places on moist soil.

E. heterophylla Linn.: A native of Mexico and Antilles. Commonly found in the vicinity of garndens.

Galinsoga parviflora Cav.

A native of tropical America. Found along the banks of rivers.

Gomphrena celosioides Mart.

A native of South America. Common in grasslands. Reported from Karnataka, Madhya Pradesh and Maharashtra.

Ipomoea fistulosa Mart. Ex Choisy.

A native of South America. Common in the area on various types of habitats. Reported from Madhya Pradesh and Rajasthan.

Jatropha curcas Linn.

A native of tropical America. Found in waste places and along forest margins.

J. gossypifolia Linn.

A native of Brazil which has become naturalized in various parts in India and Burma. Commonly found as undergrowth in forests and along road-sides.

Lippia alba (Mill.) N.E. Brown Ex Britton & Wilson

A native of tropical America and West Indies.

Common along margin of lakes and ditches. It has been reported from Andhra Pradesh, Bihar, Orissa, West Bengal, Assam and Andmans.

Martynia annua Linn.

A native of Mexico. Reported from Bihar, Madhya Pradesh and Andhra Pradesh. Commonly found in waste places, along road-sides and waysides.

Merremia dissecta (Jacq.) Hallier. F.

A native of tropical America. Rare, along the road-sides.

Nicotiana plumbaginifolia Viv.

A native of Mexico and West Indies. Common in moist shady places. A Common weed of Northern India reported from Assam, Punjab and Delhi.

Opuntia elatior Mill.

A native of tropical America, now naturalized in Delhi and Andhra Pradesh. Found on dry places.

Oxalis corymbosa DC.

A native of South America. Naturalized in Eastern Himalaya, Mungpoc, Assam, Dibrugarh, Pulney Hills and Delhi. Found in the garden beds.

O. pes-carpae Linn.

A native of cape of Good Hope and of recent introduction in this country. It is widely spreading on the Niligiri and Pulney Hills. Collected along road-sides in the area.

Parthenium hysterophorus Linn.

The plant is native of tropical America. In India, it is presumed to have been introduced in 1956 along with food grains, especially wheat. This has spread in many part of the country (Karnataka, Maharashtra, Madhya Pradesh, Delhi, Jammu and Kashmir, etc.). Found along road-sides, railway-tracks and cultivated fields.

Peperomia pellucida (Linn.) H.B. & K.

A native of tropical America. Now naturalized in various part of the country. Commonly found in the crevices of walls under shady and moist situations.

Rauvolfia tetraphylla Linn.

A native of West Indies, found cultivated and as an escape in various parts of the country (Andhra Pradesh, Bihar and Uttar Pradesh). Found along the bank of rivers of the area.

Ricchardia scabra Linn.

The plant is native of tropical America. Now it has been naturalized in India (Bihar, Uttar Pradesh, Assam, Andhra Pradesh, Karnataka and Rajasthan). The plant is found along the bank of Banganga river.

Ruellia tuberosa Linn.

Native of Brazil. Now naturalized in various parts of the country. It is found in open places in the area.

Solanum viarum Dunal.

A native of Brazil. Naturalized in Assam, West Bengal, Bihar, Orissa, Tamil Nadu and Sikkim. Found along road-sides and bank of rivers.

Solvia anthemifolia (Juss.) R. Br. Ex Lessony

A native of America. Recently introduced in our country and naturalized in various part of Uttar Pradesh (Dehra Dun, Agra, Bahraich, Naipalganj Road, Hardwar, Moradabad, Roorkee, Azamgarh, Gorakhpur, Meerut, Buland Shahar). Found in damp places in the area.

Tithonia diversifolia (Hemsl.) A. Gray

A native of Mexico and Central America. Commonly cultivated and naturalized in the Sub-Himalayan tract near Dehra Dun and Bengal.

Found on waste grounds in the area.

T. rotundifolia (Mill.) Blake.

A native of Mexico. Found as an escape along road-sides in the area.

Tridax procumbens Linn.

A native of Mexico. Reported from Bengal, Bihar, and Assam. The plant is found on old monuments and in grasslands on gravelled soil.

Volvulopsis nummularis (Linn.) Roberty

A native of West Indies, now naturalized in various parts of Bengal, Orissa and Madhya Pradesh. Common in grasslands.

Exotic species commonly cultivated for food / forage / timber / ornamental / other economic purposes in Uttar Pradesh

a. Introduced plants from Australia:

Acacia dealbata, A. melanoxylon, Arucaria sp., *Callistemon lanceolatus, Casuarina equisetifolia, Eucalyptus* sp., *Grevillea banksii, G. robusta, Melaleuca leucodendron, Thuja occidentalis, T. orientalis.*

b. Introduced species from Western Asia and Europe:

Allium cepa, A. sativum, Althaea rosea, Asparagus officinalis, Avena sativa, Brassica oleracea, Cicer arietinum, Coriandrum sativum, Ficus carica, Lactuca sativa, Lens culinaris, Medicago sativa, Morus nigra, Nerium oleander, Papaver somniferum, Pisum sativum, Spinacea oleracea.

c. Introduced species from the Mediterranean rea and Africa:

Aloe variegata, Antirrhinum majus, Asparagus plumosus, Avena fatua, Calendula bicolor, Capsella bursa-pastoris, Carthamus tinctorius, Catharanthus roseus, Chenopodium album, C. murale, Cichorium intybus Convolvulus arvensis, Cyperus flabelliformis, Foeniculum vulgare, Haworthia coarctata, Hordeum vulgare, Ipomoea batatas, I. cairica, Lathyrus sativus, Nasturtium officinale, Nerium indicum, Oxalis corymbosa, Pennisetum typhoides, Plantago major, Poa annua, Raphanus sativus, Ricinus communis, Salvia officinalis, Sansevieria trifasciata, Senecio vulgaris, Sisymbrium officinale, Spergula arvensis, Stellaria media, Taraxacum officinale, Verbena officinalis.

d. Introduced species from Europe/America/ Mexico/West Indies/Brazil:

Abroma augusta, Adenocalyma alliacea, Agave americana, A. sisalana, Allamanda cathartica, A. violacea, Anacardium occidentale, Arundo donax, Annona muricata, A. reticulata, A. squamosa, Arachis hypogaea, Asclepias currasavica, Averrhoa carambola, Bauhinia blakeana, Begonia manicata, Beta vulgaris, Bignonia venusta, Bixa orellana, Bougainvillea glabra, B. spectabilis, Brassica rapa, Brownia hybrida, Brunfelsia americana, Caesalpinia coriaria, C. pulcherrima, Caladium bicolor, Capsicum annuum, C. chinense, C. frutescens, Carica papaya, Cassia grandis, C. biflora, Catesbaea spinosa, Ceiba pentandra, Centaurea cyanus, Cereus caesius, C. hexagonous, Cestrum diurnum, C. nocturnum, Chenopodium ambrosioides, Chorisia speciosa, Cleome spinosa, Clitoria ternatea, Cocos nucifera, Conyza bonariensis, Coreopsis lanceolata, C. stillmanii, Coriandrum sativum, Cosmos bipinnatus, Crescentia cujete, Cuphea lanceolata, Dahlia variabilis, Datura stramonium, Daucus carota, Delonix regia, Delphinium ajacis, Dianthera secunda, Dianthus barbatus, Dieffenbachia seguine, Duranta repens, Eruca sativa, Eschscholtzia californica, Euphorbia pulcherrima, Furcraea foetida, Gaillardia pulchella, Godetia amoena, Gossypium herbaceum, G. hirsutum, Guazuma tomentosa, Hamelia patens, Helianthus annuus, Hibiscus elatus, H. liliiflorus, H. sabdariffa, Hygrophila ringens, Iberis amara, Ipomoea aquatica, I. fistulosa, Iresine herbstii, Jacaranda mimosaefolia, Jacquemontia pentantha, J.

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22 MAY 2009
INVASIVE ALIEN SPECIES

paniculata, Jacquinia ruscifolia, Jatropha panduraefolia, J. multifida, Kigelia pinnata, Lathyrus aphaca, Lychnis coeli-rosa, Lycopersicon esculentum, Magnolia grandiflora, Malpighia coccigera, Malpighia glabra, Malva parviflora, Malvaviscus arboreus, Manihot esculenta, Manilkara achras, Medicago lupulina, Medicago polymorpha, Mentha piperita, Millettia ovalifolia, Monstera deliciosa, Morus nigra, Musa acuminata, Myosotan aquaticum, Nicotiana plumbaginifolia, N. tabacum, Nopalea cochinellifera, Ochroma pyramidale, Oenothera rosea, Opuntia elatior, Opuntia vulgaris, Oxalis latifolia, Papaver rhoeas, Parkinsonia aculeata, Passiflora edulis, P. suberosa, Pavonia hastata, Persea americana, Petrea volubilis, Petunia axillaris, Phoenix dactylifera, Physalis peruviana, Pinus spp., Pisonia grandis, Pithecellobium dulce, Plumeria alba, P. rubra, Portlandia grandiflora, Portulaca grandiflora, P. afra, Prunus domestica, Psidium guajava, Punica granatum, Pyrostegia venusta, Rauvolfia tetraphylla, Rhoeo discolor, Rivina humilis, Russelia equisetiformis, Russelia infundibuliformis, Salvia splendens, Salviacoccinia, Solanum purpuraeliniatum, S. tuberosum, Solidago canadensis, Spergula arvensis, Stellaria media, Tabebuia chrysantha, Tabebuia pentaphylla, Tabebuia rosea, Tagetes erecta, Talinum portulacastrum, Talinum paniculatum, Tamarindus indica, Tecoma argentea, Tecoma stans, Tecomaria capensis, Tecomella undulata, Theobroma cacao, Thevetia peruviana, Thunbergia alata, T. erecta, Thyrallis glauca, Tithonia rotundifolia, Tropaeolum majus, Vaccaria pyramidata, Verbena pinnatufida, Vernonia elaeagnifolia, Vicia hirsuta, Viola odorata, V. tricolor, Yucca gloriosa, Zebrina pendula, Zea mays, Zephyranthes grandiflora, Zinnia elegans.

List of plats included in “One Hundred of the World's Worst Invasive Alien Species”

Acacia mearnsii (shrub)
Arundo donax (grass)
Ulex europaeus (shrub)
Eichhornia crassipes (aquatic plant)
Hedychium gardnerianum (herb)
Hiptage benghalensis (shrub)
Imperata cylindrica (grass)
Lantana camara (shrub)
Leucaena leucocephala (tree)
Ligustrum robustum (shrub)
Melaleuca quinquenervia (tree)
Mikania micrantha (vine, climber)
Mimosa pigra (shrub)
Opuntia stricta (shrub)
Pinus pinaster (tree)
Prosopis glandulosa (tree)
Pueraria montana var. *lobata* (vine, climber)
Rubus ellipticus (shrub)
Spartina anglica (grass)
Spathodea campanulata (tree)
Tamarix ramosissima (shrub)
Ulex europaeus (shrub)

Conclusion and discussion:

Of these, some species may have invaded only a restricted region, but have a huge probability of expanding, and causing great damage. Some species are ready colonizers in disturbed areas and may have less impact on natural populations. Other species may already be globally widespread and causing cumulative but less visible damage.

Most naturalized taxa in Uttar Pradesh are herbaceous. Geographical origin of naturalized taxa is often difficult to discern. Many references to origin in the literature employ rather ambiguous terms, such as “old world,” “cosmopolitan,” or “pantropical.” Many species introduced from Europe also occur in West Asia and/or North Africa. Many of them were very likely brought to the area from Europe and are treated here as European. Most naturalized species are from the Americas, especially from the American tropics. Asia is the second most important source of naturalized species, followed closely by Europe. In general, this is in agreement with the belief that species might adapt well to a new environment with a climate similar to their “homeland” (Corlett,

1988). India has both tropical and subtropical climates, and most of the naturalized American, Asian, and African species are of tropical origin.

Some African, Asian, and European species were probably brought onto the area by traders and immigrants during the nineteenth century or even earlier. However, it is still not clear how so were introduced. Since many taxa were introduced to Uttar Pradesh as ornamentals or for forage, increased trading may bring in more potential invasive species.

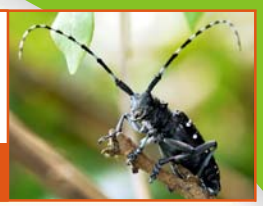
One explanation is that species with more localities have been spread by human activities (Williamson, 1996); a second explanation is that the taxa differ in their invasiveness. Inevitably, long-term monitoring of naturalized species is needed because some invaders have prolonged lag phases lasting hundreds of years (Crooks and Soulé, 1999).

Most of the naturalized leguminous species reported from Uttar Pradesh seem to be of minor economic importance. Only two are listetd among the world's worst weeds: Mimosa pudica and Senna occidentalis. The major destructive plant species observed among the invasive species of Uttar Pradesh are : *Medicago lupulina, Mimosa pudica, Parthenium hysterophorus, Mikania scandens, Lantana camara, Alternanthera philoxeroides, Eichhornia crassipes, Enydra fluctuens, Ipomoea fistulosa, Tiliacora acuminata, Pistia stratioites, Salvinia natans, Lemna minor and Wolfia arrhyza.* However, several other naturalized species are well known as exotic pests or environmental weeds (pests in natural or semi-natural areas).

Establishment of a database of naturalized species is the first step in the development of invasion biology in Uttar Pradesh and also a stepping-stone to further detailed studies on the biology and impact of individual species.

In addition to negative impact on indigenous flora and economy, some exotic plants were very much useful to local people. A prominent examples are *Prosopis juliflora, Borassus flabellifer and Leucaena leucocephala*. Among the reasons for the admiration expressed for these plants are: adaptability, rapid growth and multiple uses. *Prosopis juliflora* used for coal extraction, firewood, erosion control, fencing. Borassus flabellifer is an economically important species, introduced to India in ancient times. The cut flower stalks yield sugar and toddy, the fruits are roasted and eaten, leaves are used for thatching. Leucaena leucocephala used for firewood, erosion control, fodder, green manures, providing shade and shelter for other crops. Several exotic weedy plants like *Argemone mexicana, Cassia tora, Cleome viscosa, Chamaesyce hirta, Croton bonplandianum, Eclipta prostrata, Ipomoea carnea, Malachra capitata, Mimosa pudica, Physalis angulata, Tridax procumbens* were used in native medicine. *Alternanthera philoxeroides* and *Portulaca oleracea* were used as leafy vegetables.

India is mainly a tropical country but due to great altitudinal variations, almost all climatic conditions from hot deserts to cold deserts exist. India's rich vegetation wealth and diversity is undoubtedly due to the immense variety of the climatic and altitudinal variations coupled with varied ecological habitats. The extreme diversity of the habitats has resulted in such luxuriance and variety of flora and fauna that almost all types of forests.



Invasive Alien Species: Major threats for Food and Agricultural Commodities

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Biological invasions by non-native species constitute one of the major threats to natural environment and biodiversity including forestry, livestock and agro-ecosystem (Wittenberg and Cock, 2000). Subsequently they can also impose huge cost on agriculture, forestry, fisheries, and other human activities including social organization and human health. Rapidly expanding and accelerating trade, travel, transportation and tourism all across the world over past century have dramatically exposed the risks of invasive alien species, allowing them to surmount the natural geographical barriers. In fact the majority of the species being used in agricultural, forestry and fisheries across the national boundaries are non-indigenous and therefore, may be referred as alien species, but their impacts are not harmful. Thus, the first and foremost initial step is to distinguish among beneficial, harmless and harmful alien species and identify the impacts of the latter on native biodiversity and agricultural productivity in our eco-regional context.

The ways in which invasive species affect the native species and natural ecosystems are numerous, some times massive and usually irreversible. Non-indigenous species often consume or prey on native ones, attack and overgrow, infect them or act as insect/disease vectors, compete with nutrition or some times hybridize with them. Invaders can change eco-regional biodiversity as a whole and may alter hydrology, fire regimes, nutrient cycling, wild life, pests/diseases, indigenous microorganisms and natural pests/predators (Pimentel, 2002). They not only cause threats to agriculture and ecosystems but also damage natural resource industries. *Lantana camara*, zebra mussel (*Dreisenna polymorpha), Pueraria lobata*, Brazillian pepper (*Schinus terebinthifolius*), *Parthenium* and rats (*Ratuus* sps.) are several examples from all over the world that have are all economic and ecological catastrophes. Invasive species are taxonomically diverse and thousands of native species have been extinguished or are at the verse of extinction due to heavy bioinvasions. Weeds alone cause almost 25% loss in agricultural productivity and degrade agricultural fields and food quality. Chemicals used as weedicides also work in a similar manner in degrading the agro-ecosystem and affecting native species of crops and beneficial flora and fauna. Further, environmental degradation including global climatic changes, disrupted rain patterns, temperature rise in many parts of the world, habitat fragmentation, and contamination of the natural water bodies extends the range of invading species and increase the risks.

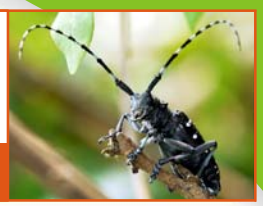
However, it is not that all non-indigenous species are impact-wise harmful. During the course of the journey of the human civilization and along with the expansion of geographical boundaries, a great majority of plants, microbes and animals are introduced as food, feed and fodder. Many productive plants, microorganisms (fungi, bacteria and cyanobacteria, algae, fisheries and livestock based productive industries are based on introduced species. Similarly, many micro-organisms are being introduced in the non-native environment in the form of biological control of crop pests and diseases which has resulted in savings in pesticide use and crop loss. But, it is

equally true that agronomic originality, horticultural variety, microbial profile and zoological novelties of the natural agro-ecosystems have become destructive and invasive due to unintentionally and un-managed introduction of invaders. Many of the invasive insects have now become pests, microbes like bacteria and fungi have become pathogenic, fishes introduced for human consumption have extirpated many native species and even biological control introductions have become awry. The rapidly developing science of invasion biology is now paralleling or even competing the biology of natural organisms. The growing worry for the present day agriculture is that the intentional introduction of harmful invasive alien species in to the agro-ecosystem with the help of growing technologies can provide major threats, so long as the scientists, public and the policymakers are aware of them. The event of September, 11, 2001 and the subsequent attacks of anthrax brought such kinds of bioterrorism to the forefront of the world consciousness (Meyerson and Reaser, 2002).

Biological invasions- the routine importation (both accidental and deliberate) of harmful non-native organisms (Meyerson and Reaser, 2002) are occurring daily and are estimated to cost more than $100 billion per year worldwide (Inderjit, 2005). Nonetheless, the scientists, policymakers and the public over the whole world including India are paying considerably less attention and spending far fewer resources to identify and address bioinvasions and their manifold impacts that include chronic damage to societal infrastructure, agro-ecology, fisheries, the environment and human health (Pimentel, 2002). It is therefore, a formidable challenging task for the scientists all over the world to convince policy makers, industry and the public to produce and subsequently adopt a comprehensive approach to biological security at the time when the prominent threats and the tangible benefits from the protection are not readily apparent.

Thus, looking into the potential threats of the bioinvasions, there is an urgent need to raise multifold awareness dedicated to substantial resources to address daily biological incursions in the country as these have a substantial impact on human and animal well-being. Scientific communities can help to identify and develop a comprehensive biosecurity system to combat the chronic problems posed by the threats of bioinvasion and bioterrorism. It is a contention that a strong national strategy based on the evaluation of the human dimensions of the invasive alien species problems and an assessment of the current situation should be needed to identify the process at the very beginning and to ensure the responsibilities of all stakeholders involved in all phases of preparing the strategy. The very initial step towards a national strategy should be to identify a scientific competent group who will have to collect, assess and present the evidence that how invasive alien species are a major threat to the biodiversity and the economy and what actions should be needed to avoid, prevent or eradicate bioinvasion and even if it has taken place, how the associated risks will be minimized? Besides this, an inventory of existing invasive species along with their molecular, phylogenetic and biochemical taxonomic profile, ecological and economic impacts and the ecosystem they have invaded should also be prepared. The next step is to involve the stakeholders, policymakers and public to make them aware through nation wide campaign about conspicuous invasive species problems in the country.

An invasive alien species may be found in all taxonomic groups from prokaryotes to the higher plants and animals. These groups include blue green algae, green algae, bacteria, fungi, plants, invertebrates, fishes, amphibians, reptiles, birds and mammals. In different eco-regional domains of the same country or in other countries, the definitions, terminologies and the peculiarities of such alien species may vary widely, but in general terms used by the scientific community, their definition and properties need to be documented with clarity. Therefore, the scope of national strategic framework should concern on two basic aspects: eco-regional (geographic) expansion and



species coverage. It should be noted that all parts of a national territory may be affected or be at risk if a bioinvasion takes place; such invasions should therefore be regulated for all ecosystems and biomes. Special attention should necessarily be given for island, oceanic territories or isolated ecosystems that are more vulnerable to such invasions. For practical and legislative purposes, a distinction must be drawn between unintentional (through trade, tourism, and transport in the sectors of agriculture, forestry, fisheries, horticulture) and intentional introductions (in the form of agriculture and food contamination, and biological and chemical hazards in unlawful manner). Unintentional bioinvasion may take time to be spread and therefore, the impact would be rather slow and associated risks would appear during a long span, may be even after generations. The spread of Parthenium on Indian soil is an example. On the other hand, intentional bioinvasions are a kind of bioterrorism where a harmful alien species may be introduced with an ill intention to harm the society and disrupt normal life very quickly. Early detection and alert systems are therefore, essentially required to fight potential bioinvasions.

Bioterrorism in Food and Agricultural Commodities

Food terrorism has been defined as "an act or threat of deliberate contamination of food for human consumption with chemical, biological or radionuclear agents for the purpose of causing injury or death to civilian population and/or disrupting social, economic or political stability" (WHO, 2002). Here, chemical agents refer to manufactured or natural toxins, biological agents refer to infectious or non-infectious pathogenic organisms including viruses, bacteria, parasites and radionuclear agents are defined as radioactive materials causing harm, injury or death, when present in excess amounts. There are so many things in our surroundings that can directly or indirectly damage food and make it unhealthy for consumption. The objectives of the intentional food sabotage such as food adulteration using chemical, biological and or radioactive materials, is therefore, to cause widespread health destruction, inducing terror and panic in society to disrupt social order (Steinbruner, 2000).

Food adulteration can have major diverse implications in the society. Contamination or Sabotage at production units, centralized food processing, and government distribution outlets could effect a wide range of population, even in diverse regions. Thus, food borne diseases caused by intentional or unintentional contamination can be characterized by a huge human population exposure.

In terms of biosecurity, risk refers to the probability or probability distribution of agricultural contamination. Risks are also associated with the introduction of unidentified non-indigenous microbial species that may result in undesirable agricultural contamination. With the increased trade and easy mobility of commodities from one place to another, the risks of bioinvasion by the detrimental species are going to maximize.

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INVASIVE ALIEN SPECIES

Invasive Alien Species and Climate Change

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Invasive species are non-indigenous species that heavily colonize a particular habitat and affect adversely the ecology and environment. These are the introduced species, which increase in number and become invasive under the influence of natural events, such as long term rainfall changes or human modifications to the habitat, but all the introduced species are not invasive. An introduced species may be invasive if it competes with native species for resources such as space, light and nutrients.

Introduction of species can be either intentional or accidental. Intentional introductions have been motivated by individuals or groups who believe that the newly introduced species will be in some way beneficial to humans in its new location. These species can be successfully established in two ways, in the first case, organisms are purposely released into the wild for successful establishment and are directly facilitated by human beings. In the second case, organisms may escape from cultivated populations and establish independent breeding populations. Unintentional or accidental introductions are most often a by-product of human movements and are, thus, not bound to human motivations. There are certain characteristics that make a species as potentially invasive. These traits are rapid reproduction, fast growth, high dispersal ability, phenotypic plasticity, tolerance of wide range of climatic conditions, etc.

Introduction of species into new place is for economic gain, but introductions have also resulted in some unforeseen costs, especially when introduced species behaves like a invasive species. Invasive species have capacity to facilitate the environment for themselves allowing the species to thrive while making the environment less favourable for competitor species. An invasive species might be able to use resources previously unavailable to native species, such as, deep-water sources accessed by long taproot or an ability to live on uninhabited soil or making the soil uninhabitable for the competing species by secreting chemicals (allelopathy). For example *Parthenium hysterophorus* L. commonly known as Congress weed whose root extract of 120 and 180 hours have been identified as most harmful extracts for Chickpea (Oudhia, *et al.*, 1997). However, allelopathic effect of one of the most worst weed *Lantana camara* L. has some useful effects on Rice, as it increased chlorophyll content and grain yield while at the same time significantly reducing the growth of other associated weeds of rice; i.e. *Panicum psilodium* Trin. and *Commelina benghalensis* L. (Bansal, 1998). Disturbances changes the fundamental nature of ecosystem, when changes occur such as forest fire, normal succession favour those species which can multiply and spread faster, the traits shared by invasive species. Invasive species changes the fire regimes also. They spread rapidly after burning and increase the frequency and intensity of fires. *Lantana camara* L. is favoured by fire and it has several characteristics that might give it an advantage under conditions of frequent fire. In Biligiri Rangan Hills of South India the initial spread of *Lantana* sp. coincides with the last mass flowering and dieback of Bamboo, which was followed by widespread fires.

When changes occur to the ecosystem, conditions change that impact the dynamics of species interactions and niche development. These changes can favour alien species that would not have been able to colonize the area and niches. There is evidence linking ecosystem invisibility to disturbance, more disturbed ecosystem are more vulnerable to invasions by alien species than less disturbed areas. Ecosystem invasibility has also been related to species diversity. It is thought that species poor biotas and "empty niches" easily make them vulnerable to colonisation by alien species.

Effect of climate change on IAS:

In today's scenario, biological invasions and climate change are the two biggest threats to biodiversity. However, studies on biological invasion in relation to climate change are meagre but it is estimated that biological invasions can have strong effects on the structure and function of ecosystems that are responding to a changing climate and climate change is also changing the context in which potential invasive species succeed or fail. There are ample reasons for accepting that climate change will favour invasive alien species because they can tolerate a wide range of climatic conditions and can extend their ranges quickly. Invasive species tend to be generalists, which may increase their success and threaten the native species. Generalist species may have greater competitive success when species shift ranges and habitat composition changes in response to climate change. The range of invasive species is directly influenced by climate and less by biotic interactions. Anthropogenic factors also facilitate the invasion through land clearings and human habitation, which put significant pressure on native species. It is clear, that the changing climate is favouring the expansion and survival of invasive alien species, but still it is difficult to predict how much changing climate will benefit invasive species. Studies are urgently needed to minimize the benefits that invasive species might draw from a changing climate.

The common Indian invasive species are *Lantana camara* L., *Bombax ceiba* L., *Cannabis sativa* L., *Ageratum conyzoides* L., *Ipomea carnea* Jacq., *Argemon mexicana* L., *Calotropis procera* (Ait.) R. Br., *Parthenium hysterophorus* L., *Solanum nigrum* L., *Cymbopogon martini* Wats, *Eucalyptus X hybrid*, *Tectona grandis* L., *Prosopis juliflora* (Sw.) DC., etc. and aquatic weeds are *Nelumbo nucifera* Gaertn., *Hydrilla verticellata* (L.f.) Royle, *Eichornea crassipes* Solms., *Pistia stratiotes* L., etc. (Fig. 1-6). Among these Indian invasive species *Lantana camara* L., originally native of South and Central America has extended its distributions most widely in Indian region from dry to moist deciduous forest, foothills of Himalaya and coastal areas. It was introduced in India as a ornamental and hedge plant in early nineteenth century. It has been observed that it has replaced several high medicinal and potential plant species from the high altitudes of western Himalaya and South India and continuously expanding its ranges towards higher elevations at the cost of threat of native species. Lantana camara L. is known to produce secondary compounds toxic to ungulates and also to suppress regeneration of native species (Sharma *et al.*, 1981). It has potential to compete for scarce nutrients, it uptakes and uses nutrients from highly impoverished soil and low fertility environment. Secondarily, potential mechanism underlying the success of *Lantana camara* is its colonising ability. Its perennial flowers and fruits make it good host for pollinator and ensure well-dispersed propagules. It regenerates profusely from seeds in the soil seed bank for several years after its removal. So it needs repeated uprooting of successive crops for several years.

Impacts and Prevention of IAS:

Several serious effects of Invasive alien species have been seen in the ecosystem. It can alter the ecosystem in a multitude of ways. It is estimated that 80% of endangered species are threatened by invasive species worldwide. The invasive species have interactive effects on multiple successive

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introductions of non native species. These alien species can alter the functions of ecosystems such as fire regimes, nutrient cycling, hydrology. Invasive species cause genetic pollution through uncontrolled hybridization and introgression which leads to homogenization or replacement of local genotypes as a result of either numerical or fitness advantage of the introduced species. The unintentional introduction of invasive species into agricultural fields and forests contribute significantly to reduce farm and forest productivity and land degradation. Prevention is the most effective method of dealing with Invasive species. Preventing the entry of new Invasive species, to stop the pathways for spread in agricultural fields, by encouraging the beneficial vegetation growth and by avoiding disturbance as much as possible in the natural environment, Early detection and eradication before their establishment, identification and enlisting of weeds of national interest are the few steps which may be taken at earliest to save the ecosystem from horror effect of invasive alien species.

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Figs. 1 & 2 Lantana camara, 3. Ipomea carnea, 4. Calotropis procera, 5. Ageratum conyzoides, 6. Parthenium hysterophorus

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Invasive alien species: An impact of globalization

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Introduction

Humans have been introducing plants, animals, and other organisms around the world, in a relatively slow process of globalizing the Earth's biota for hundreds of years. However, intentional or accidental biological invasions of plants, animals and microorganisms have been intensified due to globalization and growth in the volume of trade and tourism, coupled with the emphasis on free trade. These unwanted by products of globalization are non-native species and are also called invasive alien species (IAS), i.e., alien species that have been introduced into an area from other parts of the world and have become established in natural or semi-natural ecosystems or habitat consequently displacing the indigenous species. Common invasive species traits include: the ability to reproduce both asexually as well as sexually, fast growth, rapid reproduction, high dispersal ability, the ability to alter one's growth form to suit new conditions, tolerance of a wide range of habitats, ability to survive in wide range of food types, and association with humans. Over 1,20,000 non-native species of plants, animals and microbes have invaded just six countries - the US, UK, Australia, South Africa, Brazil and India. These IAS are emerging as one of the major threats to native biological diversity as well as sustainable development, on a par with global warming and the destruction of life-support systems. Furthermore, IAS is also prone to effect on economy, environment and human health. To meet the challenges associated with IAS it is mandatory to apply the scientific research, integration of other disciplines, engagement of policy makers and among Governments, economic sectors and non-governmental and international organizations. The Convention on Biological Diversity is addressing the threat of IAS by setting global priorities and guidelines, sharing information and expertise, and helping to coordinate international action. The most cost-effective and feasible method of control is prevention for which a knowledge about undesirable and invading species, their origin and management.

Factors facilitating biological invasions

For millennia, the natural barriers of oceans, mountains, rivers and deserts provided the isolation essential for unique species and ecosystems to evolve. In just a few hundred years these barriers have been rendered ineffective by major global forces that combined to help alien species travel vast distances to new habitats and become IAS. Customs and quarantine practices, developed in an earlier time to guard against human and economic diseases and pests, are often inadequate safeguards against species that threaten native biodiversity. Thus the inadvertent ending of millions of years of biological isolation has created major ongoing problems that affect developed and developing countries.

Biological invasions are thus facilitated by environmental changes, habitat destruction and propagule pressure arising due to modern technology, trade and travel. These factors are listed below:

- The threats due to IAS are aggravated by alteration of environment by some species using chemicals or manipulating abiotic factors, allowing the species to thrive while making the environment less favourable to other species with which it competes. One such facilitative mecha-

nism is allelopathy, also known as chemical competition or interference competition, i.e., making surrounding soil uninhabitable or at least inhibitory for competing species by secretion of chemicals.

- At the global scale, commercial trade drive rising annual and cumulative rates of invasion due to the development of new source and recipient regions, trade routes, and markets, as well as new products, larger and faster ships, and increased air transport. These rates of invasion are expected to increase, as are the associated environmental and social costs. Although many vectors are responsible for species introductions, the rising volume of air and ship transport has been identified as the primary driver of invasions and the spread of IAS.
- Propagule pressure has been implicated in successful species invasions. It includes both the absolute number of individuals introduced to a new system and the number of introduction events that occur. Propagule pressure occurs at regional and local scales, but often results directly from international trade and globalization. Understanding the role of propagule pressure in invasion success requires examination at both the species and population levels. Typically an introduced species must survive at low population densities before it becomes invasive in a new location. At low population densities, it can be difficult for the introduced species to reproduce and maintain itself in a new location, so a species might be transported to a location a number of times before it become established. Repeated patterns of human movement from one location to another, such as ships sailing to and from ports or cars driving up and down highways, allow for species to have multiple opportunities for establishment. Distinct populations reflect particular trade patterns and transport vectors, which supplement existing introduced populations in terms of absolute numbers and genetic variation. Repeated introductions of the same species increase propagule pressure (including the genetic diversity of introduced populations), so that there is an increased probability that a species or genotype will become invasive in the recipient site.
- Disturbance at both global and local scales is clearly an important factor in facilitating species invasions. Even disturbances occurring more than 100 years ago may influence current invasions. Positive interactions occur between propagule pressure and disturbance.

Impact of IAS

IAS are found in all taxonomic groups, including viruses, bacteria, fungi, algae, mosses, ferns, higher plants, invertebrates, fish, amphibians, reptiles, birds and mammals. The impacts of IAS are immense, subtle and usually irreversible. IAS may become invasive when introduced deliberately or unintentionally outside their natural habitats into new areas where these express the capability to establish, invade and out-compete native species for resources such as nutrients, light, physical space and water. If these species evolved under great competition, the new environment may allow them to proliferate quickly. Invasive species often coexist with native species for an extended time, and gradually the superior competitive ability of an invasive species becomes apparent as its population grows larger and denser and it adapts to its new location. Thus IAS are damaging to native species and ecosystems on a

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global scale as the loss and degradation of habitats however, various alien species may support our farming and forestry systems in a positive way. The impacts of IAS may be global and enormous with respect to ecology, economy, health, genetic pollution and loss of biodiversity. These factors are discussed below:

- IAS are widely distributed in all kinds of ecosystems throughout the world, and include all categories of living organisms including microorganisms. Biological species invasions have affected native biota in virtually every ecosystem type on Earth in a multitude of ways. These include change in functions of ecosystems, for example alteration of the fire regime, nutrient cycling, and hydrology in native ecosystems. IAS can out-compete native flora and fauna, including species at risk, alter or destroy the natural habitat of native species, prey on native species, eat or defoliate native flora (herbivory), cause, carry and disseminate diseases, hybridize with native species, initiate complex effects and combinations of effects, weakening native species and altering natural, ecosystems and through synergism with other alien species, lead to invasional meltdown. The ecological cost is the irreparable loss of native species and ecosystems.
- Natural, wild species can be threatened with extinction through the process of genetic pollution, i.e., uncontrolled hybridization and introgression leading to homogenization or replacement of local genotypes as a result of either a numerical or fitness advantage of the introduced species. IAS that are closely related with rare native species have the potential to cross-pollinate with the native species leading to a decline and even extinction of native species. Genetic pollution can bring about a form of extinction either through purposeful introduction or through habitat modification, bringing previously isolated species into contact.
- IAS can become a common part of an environment, culture, and even diet that little thought is given to their geographic origin. Collectively, non-native crops and livestock comprise 98% of world food. Economic costs from invasive species can be separated into direct costs through production loss in agriculture and forestry, and management costs of invasive species. Economic costs of invasions, when calculated as production loss and management costs, are low because they do not usually consider environmental damages. If monetary values could be assigned to the extinction of species, loss in biodiversity, and loss of ecosystem services, costs from impacts of IAS would drastically increase.
- Invasive species can have impacts on recreational activities such as fishing, hunting, hiking, wildlife viewing, and water-based recreation. These negatively affect a wide array of environmental attributes that are important to support recreation, including but not limited to water quality and quantity, plant and animal diversity, and species abundance.
- An increasing threat of exotic diseases exists because of increased transportation and encroachment of humans into previously remote ecosystems. This can lead to new associations between a disease and a human host.
- Biotic invasion is one of the five top drivers for global biodiversity loss. These may be as damaging to native species and ecosystems on a global scale as the loss and degradation of habitats. Loss of

biodiversity due to IAS includes species extinctions, and changes in hydrology and ecosystem function. Differences between native and exotic plant species in their requirements and modes of resource acquisition and consumption may cause a change in soil structure, its profile, decomposition, nutrient content of soil, moisture availability, etc. IAS is thus a serious hindrance to conservation and sustainable use of biodiversity, with significant undesirable impacts on the goods and services provided by ecosystems.

Conclusions

Creeping changes which were viewed as positive progress a generation or two ago are now piling up, sometimes with devastating impacts on biodiversity, ecosystems, society and the economy. IAS should be investigated in both their native and introduced ranges to better disentangle the species traits and other factors that contribute to invasion and invasibility. As scientists and planners, our responsibility is to apply our best minds and tools to understanding the synergistic impacts of these changes, and helping managers and decision makers respond appropriately. As consumers and citizens, however, our responsibility is to help all our fellow citizens appreciate the severe choices we face ahead. Ecologists are attracted to the study of species introductions because they provide opportunities for addressing research questions that run the range from evolution to historical patterns of natural species spread to applied questions in control and restoration. Biotechnologists may adopt techniques for early characterization of native and non-native species at the molecular level, for example, by using molecular markers. Information networks can also serve an invaluable function tools for data on IAS around the globe. National- and regional-level monitoring may assist with populating these accessible databases and, ultimately, identification, mapping, and modelling of IAS distributions, abundance, and impacts at local, national, and global scales. Individuals, too, have a responsibility. Abiding by local and international quarantine and customs regulations will prevent the spread of insect pests, weeds and diseases.

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Ageratum conyzoides & Parthenim hysterphorus : Alternate host of Begomovirus and Phytoplasma

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Ageratum conyzoides is a commonly occurring weed in South Asia. The plants widely grown in agricultural lands, fallow lands, roadsides, railway tracks in India. In the province Uttar Pradesh, *A. conozoides* very frequently grows in the agricultural lands and the control of this weed species is very difficult as it reproduced vegetatively with a very high regeneration potentiality. The plant has very adverse effect on most of the agriculturally important crops as the nutrient/fertilizer supplied to the main crop is being absorbed by this weed species resulting in the poor yield of the crop. On the other hand, the plants also harbor natural infection of various plant viruses. The infected plants often show prominent symptoms of begomovirus like: yellow vein net, yellow mosaic, swelling of veins and curling of the leaves and has been found to be the alternate hosts of several economically important virus viz. *Ageratum enation virus* on grain amaranth (*Amaranthus cruentus*) from Lucknow, Parwal (*Trichosanthes dioica*) from Gorakhpur and *Pepper leaf curl virus* (*Capsicum annuum*) from Bangladesh. These reports strongly suggest that *A. connizoides* work as a green bridge and might play key role in the dissemination of the begomoviruses to other economically important crop species.

Parthenium hysterophorus is one of the worst weeds in the world. It is an herbaceous plant and a native of tropical America. In India, *Parthenium* is locally called 'Congress grass'. It is believed that it entered India accidentally in the mid-1956 and is now considered as one of the most feared noxious weed species (Rao, 1956). Parthenium is also known to cause asthma, bronchitis, dermatitis and hay-fever in man and livestock. The natural occurrence of virescence and witches'-broom was noticed on ~10-15% of *P. hysterophorus* plants growing wildly along the road side in Bahraich and Gorakhpur districts of Uttar Pradesh, India (Raj *et al.*, 2007). The infected plants showed excessive green, tiny narrow leaves, shortening of internodes and witches'-broom-like symptoms.

The other recent reports carried out at molecular virology laboratory NBRI, Lucknow in between 2003-2009 suggests that *Candidates phytoplasma* asteris is a most prevalent species of the *Phytoplasma* in India which has been found to be infecting a wide range of plant species.

Since, *Candidatus phytoplasma asteris* has also been found to be infecting *P. hysterophorus*, suggest the natural alternate host of this widely occurring Phytoplasma species and might also be playing important role of the phytoplasma disease to several other plants to be caused by the "*Candidatus phytoplasma* asteris" 16SrI group, the most prevalent species of the phytoplasma in India and other countries.

Collection and alignment sequences

The nucleotide sequences of coat protein (AV1) gene from various plants were retrieved from http://www.ncbi.nlm.nih.gov/. The relatedness of sequences deposited in databases was evaluated by BLAST (http://www.ncbi.nim.nih.gov/blast) (4).

Construction and analysis of phylogenetic tree

The nucleotide sequence of coat protein (AV1) gene was used to search for homology using

BLAST and homologous sequences were also retrieved from NCBI Genbank. The AV1 sequences were aligned in CLUSTALX (5) and using the passion correction equation implemented in the MEGA4 (6) program for construction of phylogenetic tree by neighbor-joining method. Total 100 bootstrapped values were sampled to determine a measure of the support for each node on the consensus tree.

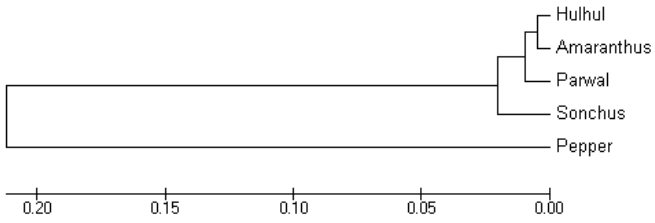

Fig. 1. Phylogenetic tree (generated by MEGA 4.0 tool with 100 bootstrap values) showing close phylogenetic relationships between Ageratum infecting different commercial crops.

Viruses are known to be the major threats to the cultivation of economically important crops among other known plant diseases. Sometimes, the loss caused by the viruses raises up to 100% yield resulting into huge economic loss / to the cultivators/ growers. Phytoplasmas are also major limiting factors of several plants/crops which have been detected to be the causative agents of several diseases from a diverse plant species across the world. However, there are no effective control measure/methods of these pathogens till date as both are very small infectious and intracellular entities. Hence, clean cultivation (weed free)/ resistant/tolerant varieties are highly recommended for the growing of important crops to avoid the infection of the virus from their alternate hosts and also the loss directly caused by these invasive alien species.

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Invasive Alien Species : Strategic Management of Some Species

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A major contributor to depletion and extinction, second only to habitat loss, is the unnatural introduction of species into new environments. Species have sometimes invaded new habitats naturally (e.g. when land bridges have become established) but human exploration and colonization has dramatically increased the spread of species. Whenever man has settled far away from home, he has intentionally introduced his familiar animals and plants. Many other species (e.g. rats) have been accidentally transported around the world. These forms that have been transplanted as a result of human actions are called **exotic, alien, introduced** or **non indigenous** species.

A large number of wild animals and plants, especially those that do well in urban or disturbed areas, are introduced species that have become established. For example, the starling, cabbage-white butterfly, eucalyptus tree, mustard, many grasses, etc. Most insect and plant pests are exotic species.

Many exotics have disastrous effects on native flora and fauna. They often leave behind the factors that have evolved with them and that control their population and spread. In their new habitat there may be fewer predators or diseases, so their populations grow out of control. They are then called invasive exotics. Prey organisms may not have evolved defense mechanisms and native species may not compete successfully for space or food, so are often pushed to extinction. Since exotic species are self-perpetuating, they can be more permanent problems than other threats to biodiversity including overexploitation and habitat loss. Exotics are a factor contributing to the endangered or threatened status of 42% of animals and plants on the endangered species list.

The spread of exotics replaces healthy, diverse ecosystems with biologically impoverished, homogeneous landscapes. For example, places with a Mediterranean climate in southern Australia, the U.S. west coast, Chile and South Africa previously had few plant species in common (although they did show many examples of convergent evolution, leading to similar landscapes). They now share hundreds of weedy exotic species, mainly from the Mediterranean region. Exotic plants often develop a monoculture landscape in which one species completely or almost completely predominates.

Most exotic plants causing environmental problems today were introduced accidentally, either as the result of “hitch-hiking” seeds or of “escaped” ornamental plants. The national losses in agricultural production plus the costs of their control were recently estimated at over Rs. 30 crores annually. Many insect species accompanied these plant introductions and subsequently became pests. Between 1800 and 1980 the number of introduced insect species in India grew from about 36 to more than 1200.

The invasion of alien species is recognized as a primary cause of global biodiversity loss. The Convention on Biological Diversity (CBD), 1992 visualized 'biological invasion of alien species as the second worst threat after habitat destruction'. Biodiversity loss caused by invasive species may soon surpass the damage done by habitat destruction and fragmentation. Biological invasion

may be considered as a form of biological pollution and a significant component of the human-induced global environmental change. In fact, introduced species are a greater threat to native biodiversity than pollution, harvest and disease combined.

Some of the important Indian invasive plant species are *Salvinia molesta, Ipomia carnea, Prathenium hysterphorus, Mikania micrantha, Eupatorium adenophorum, E. odoratum, Ageratum conyzoides, Galinsoga parviflora Lantana camara, Cuscuta* sp., *Prosopsis juliflora* in land and *Microcystis, Caulerpa, Cladophora* and *Eicchornia crassipes* in water. Majority of these invasive species belong to family Asteraceae (Compositae). Asteraceae is the largest and most widely distributed family of flowering plants producing large no of both endemic and alien spp. This is because of very efficient adaptation for survival and distribution on land viz.:

(1) Flower arrange in a group - Capitulum or Head -saving energy by massing small florets together ensuring pollination by visit of single insect .

(2) Flower effectively protecting nector and pollen and producing a large no of seeds.

(3) Use of pappus and persistant calyx as a parachute mechanism for far and wide dispersal of plants.

(4) Plants are mainly herbs and shrubs ensuring quick completion of life cycle and formation of large number of progeny in short time.

Some of the invasive alien plant species belonging to family Asteraceae are :

Mikania micrantha (Mile a minute ; Tataiya baur)

Native range : Central and South America

A smothering vine. Disturbed forest, stream banks, roadsides, pastures, plantations and

cultivated crops. Humid, sunny or shaded habitats; 0-2000 m altitude. Thought to interfere with soil nitrification processes. A major weed in plantations, pastures and along roadsides, and an intermediate weed in crops and forestry. It grows best where fertility, organic matter, and soil and air humidities are all high. Mile-a-minute tolerates some shade, and very rapidly overgrows abandoned areas .

Galinsoga parviflora (*Tridax parviflora*; Galant Soldier)

Native Range : Peru

The flowers are hermaphrodite (have both male and female organs) and are pollinated by insects. The plant is self-fertile. The plant prefers light (sandy), medium (loamy) and heavy (clay) soils. The plant prefers acid, neutral and basic

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(alkaline) soils. It can grow in semi-shade (light woodland) or no shade. It requires moist soil.

The leaves, stem and flowering shoots - raw or cooked and eaten as a potherb, or added to soups and stews. They can be dried and ground into a powder then used as a flavouring in soups etc. A bland but very acceptable food, it makes a fine salad either on its own or mixed with other leaves. The fresh juice can be mixed and drunk with tomato or vegetable juices. Juices rubbed onto the body, the plant is useful in treating nettle stings. The juice of the plant is applied to treat wounds, It helps to coagulate the blood of fresh cuts and wounds.

Eupatorium adenophorum (*Ageratina adenophora*; *E. odoratum*)

Native range : Mexico

Eupotorium adenophorum is a perennial herbaceous shrub which may grow to 1 or 2 m (3-7 ft) high. It has opposite trowel-shaped serrated leaves that are 6-10 cm (2.4-4 in) long by 3-6 cm (1.4-2.4 in) in width. The small compound flowers occur in late spring and summer, and are found in clusters at the end of branches. Each flowerhead is up to 0.5 cm in diameter and creamy white in colour. They are followed by a small brown seed with a white feathery 'parachute'.

The plant contains many types of terpenes, alkaloids, and phenols such as flavonoids, phenylpropanoids, and coumarins. *Cadinene sesquiterpenes* play a role in the plant's allelopathy. It is also poisonous to horses; in as little as eight weeks of consuming it, they may develop respiratory symptoms of breathlessness, known as blowing disease, from the blowing horses may exhibit, and may collapse from respiratory failure. Even in non-fatal cases, lung damage may be irreversible.

Parthenium hysterophorus

Parthenium weed, also known as white top, whitehead, congress grass or carrot grass, is an erect annual herb with alternate, deeply-dissected leaves,

ces bearing white bovoid, smooth and

The allelopathic potential of *Parthenium* weed results from the release of phytotoxic substances such as, ferulic, caffeic, vanillic, chlorogenic, *p*-coumaric and *p*-hydroxybenzoic acids, parthenin, ambrosin and coronopilin, which inhibit the germination and growth of several crop plants and multi-purpose trees and also cause allergic eczematous contact dermatitis and respiratory problems in humans and livestock. Parthenium is also a host of several pests and diseases harmful to various crops. Reciprocal

infection of *Xanthomonas campestris pv. phaseoli* between parthenium and bean plants has been established. Infection occurred with beans becoming infected at the pre-flowering and pod formation stages.

Ageratum conyzoides

Ageratum is an annual herb that grows about 60 cm high and produces small pretty pink flowers at the top of its hairy stems.

Ageratum is widely utilized in traditional medicine systems where ever it grows. In Brazil an infusion is prepared with the leaves or the entire plant and employed to treat colic, colds and fevers, diarrhea, rheumatism, spasms, and as a tonic. It is also highly recommended there for burns and wounds. In other countries in Latin and South America the plant is widely used for its antibacterial properties for numerous infectious conditions and bacterial infections. In Africa, *Ageratum* is used to treat fever, rheumatism, headache, pneumonia, wounds, burns and colic. Extracts of the whole plant have an antibacterial action against *Staphylococus aureus, Bacillus subtilis, Eschericichia coli*, and *Pseudomonas aeruginosa*.

All these species become a threat because of their tremendous survival traits and have to be controlled , prevented and diminished by Physical, Chemical and Biological means. Area of concerns are :

(1) Physical means are not very effective as most of these species regrow rapidly.

(2) Chemical treatments have its own polluting affect on soil and air. Beside there is incidence of development of resistance in IAS of herbicides.

(3) Biological control appear effective and less detrimental today. Introduction of *Puccinia spegazzinii* and *P. abrupta* from S. America and their development as myco-herbicide is an innovative idea but we know *Puccinia* species as a major problem with our cereal crops.

Secondly, biological control by bioagents viz. Thrips (*Liothrips mikaniae*), Stem galling moth (*Epiblema sternuana*), Leaf feeding chrysomelid (*Zygogramma bicolorata*), Stem boring weevil (*Listronotus setosipennis*) which are mostly introduced in India from different part will themselves have chances of becoming IAS in due course of time .

Therefore it becomes more and more imperative to look for :

- Need of introduction of species and discrete introduction of species and its implication in future In some situations it is useful to determine the economical threshold of IAS in affected crop areas as an aid to decision- making on the need for costly chemical control. If not controlled at the indicated density and crop period, unavoidable yield loss will occur and the weed seed bank will be increased.
- Globalization facilitates the spread of invasive alien species (IAS) as international commerce develops new trade routes, markets, and products .New technologies increase the pace at which humans and commodities can move around the world.
- Recent research on IAS at the global scale

has examined commerce and travel in order to inform predictions, risk analyses, and policy. Due to limited data, regional-scale studies have primarily focused on invasion patterns rather than impacts.

- Local-scale experimental research can identify mechanisms and impacts of biological invasions, but the results may not be applicable at larger spatial scales. However, the number of information networks devoted to IAS is increasing globally and may help integrate IAS research at all scales, particularly if data sharing and compatibility can be improved. Integrating ecological and economic factors with trade analysis to explore the effectiveness of different approaches for preventing invasions is a promising approach at the global scale.

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Utilization of U.P. Biodiversity Database for Inventory & Study of Invasive Alien Species

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Introductio n

Invasive alien species (IAS) have recently been a cause of concern as they pose inevitable threat to ecological balance & modify the ecosystem processes such as hydrology, nutrient cycling, gene pool etc. Management of IAS involves study on their ecological habitat, climatological settings & edaphic and other environmental factors. Satellite remote sensing along with GIS tools provides a reliable basis of inventorying & assesses the extent & spread of IAS especially plants, thereby providing useful information for management (Narumalani, 2003). Various image interpretation and feature extraction techniques are available to cater different spatial / spectral/ radiometric/ temporal resolution satellite imageries for classification & mapping of IAS habitats.

A state level study is currently being carried out by the authors in the purview of National Remote Sensing Centre (NRSC), supported by Department of Space (DOS) and Department of Biotechnology (DBT). The study aims at classification and mapping of various ecological habitats using satellite imagery and other ancillary information at 1:50,000 scale. A national level classification scheme prepared for the study indicates that four major vegetation classes are observed in the state of Uttar Pradesh. Of the total 22 vegetation classes; 6 classes such as dry deciduous, Sal mixed dry deciduous, Thorn forest, open scrub, *Prosopis scrub*, degraded forest accommodate many of the IAS such as *P. juliflora, L. camara, E. adenophorum, E. odoratum, P. hysterophorus* which has also been enumerated from the field sampling. The vegetation type & field sampling database generated through Biodiversity project provides a first hand information on the ecological habitats of IAS and their distribution pattern. Various important information like biogeographical maps, protected area network maps, Climate etc. have been stored and integrated in GIS domain, that characterize the ecological spectrum as a whole.

However species-wise studies on IAS are possible using high resolution satellite imagery. We advocate remote sensing based characterization of ecological habitats of IAS at species level & their monitoring in every 5 years interval for effective management of IAS and their habitats. All other species level important information derived from various sources can be integrated into a GIS enabled "IAS Information Management System (IIMS)" which will be useful for addressing the issue of IAS.

What is Biodiversity Database?

Sustainable management of natural resources has become a key issue for survival of life on the earth, so conservation of biodiversity has been put to the highest priority by the government & conservation agencies across the globe. The major threats to the biodiversity include habitat alteration, pollution, climatic change, spread of IAS etc. The main causes of habitat alterations are deforestation, habitat loss & degradation due to various factors. In order to take a step forward in conservation of biodiversity a study entitled "Biodiversity characterization at landscape level" has been undertaken by Department of Space and

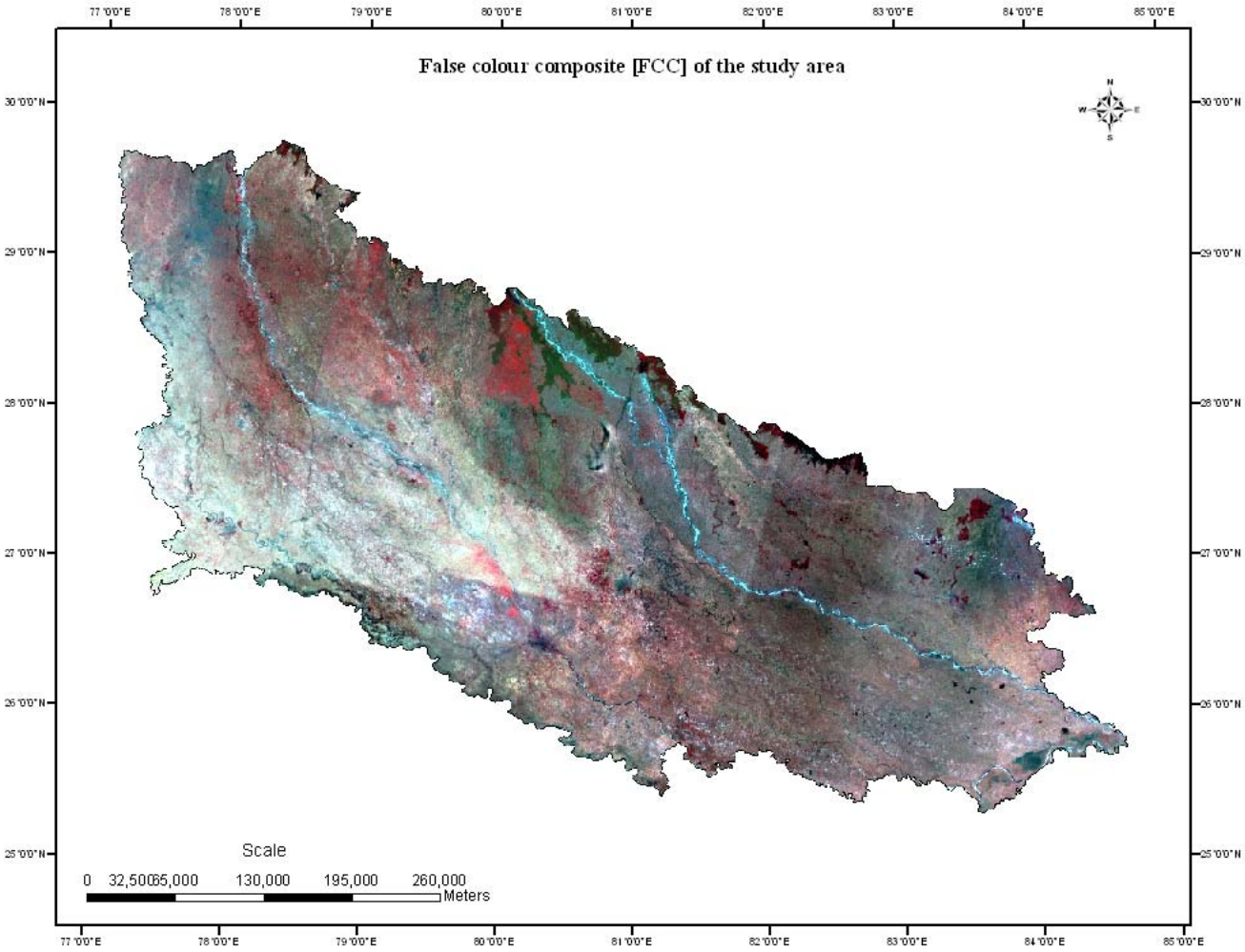

Fig. 1 : False colour composite [FCC] of the study area.

Department of Biotechnology, Government of India. The study involves 2 major tasks i.e., (i) forest mapping based on advanced geospatial techniques like remote sensing & GIS and (ii) phytosociological analysis, which involves extensive field sampling in different vegetation types in the project area.

The basic principle of phytosociological analysis is to collect field data based on the vegetation type distribution and to bring out vegetation type specific & habitat specific relative species abundance information, along with other economically important variables. The phyto-sociological analysis of Uttar Pradesh will form the basis for assessing the species diversity, ecosystem factors & economic importance of the native flora. Further this analysis would facilitate to combine the state level database across major bioclimatic zones and analyze at regional level. Hence prior to distribution, the state of U.P. has been divided into three divisions i.e., *Terai, Gangetic plain & Semi-arid*. Terai is hilly area at the foothills of Himalayas stretching from Saharanpur to Kushinagar, along the boundaries of Uttarakhand, Nepal and Bihar. Major native vegetation types

occurring in *Terai* are moist deciduous forest, lowland swamp forest, Savannah grassland, Marshy grassland etc. It can be said that Terai accommodates higher biodiversity due to its unique geography and climatic conditions, few important wildlife sanctuaries and a national park are located in that area. *Gangetic plain*, as the name suggests is the area under influence of the Ganga river. This alluvium rich area is of immense importance as it plays an important role in wheat production, hence many times responsible for deforestation & intrusion along the forest boundary. Gangetic plain accommodates vegetation types like dry deciduous forest, open scrub, Prosopis scrub and degraded areas of forest. *Semi-arid* region is desert alike land devoid of major vegetation that allows scrub species like *Prosopis juliflora* to grow in the area due to its ability of the species to grow in extreme hot weather conditions.

Invasive Alien Species

An alien plant referred as exotic, introduced, foreign, non-indigenous or non-native, is one that has been introduced by humans intentionally or otherwise through human agency or accidentally from one region to another. (Reddy *et al.*, 2008). Invasive alien species are the second largest cause of biodiversity loss in the world and impose high costs to agriculture, forestry, and aquatic ecosystems (CBD, 1993). In fact, introduced species are a greater threat to native biodiversity than pollution, harvest, and / or disease combined. Monitoring of invasion can be done through species inventory (seasonally), quantitative approach using phytosociological methods and mapping using ground-based methods (via map overlays or GPS), remotely-sensed images (aerial photos, high resolution multispectral digital data).

How Biodiversity Database is being developed?

Vegetation type mapping

The IRS P6 LISS III data with spatial resolution of 23.5 m × 23.5 m was used on temporal basis that facilitated delineation of major mixed phenological formations, gregarious species formations, edaphic and disturbance formations of larger spatial extents. On-screen visual interpretation method was followed to prepare the vegetation type map, following interpretation keys.

Phytosociological analysis

Extensive field sampling has been carried out in all vegetation classes present in the study area for two seasons. Stratified random sampling approach was implemented during the process of sampling. In the view of the extensive studies conducted in forest ecosystems in different parts of the world, the plot size of 0.04 ha (20 × 20 m) and modified Whittaker's plot (50×20 m) were decided for the forested areas and for grasslands respectively using nested quadrate approach. The random distribution of small size plots (0.04 ha) across various habitats is useful in statistically analyzing the diversity patterns across a given vegetation type (Biodiversity Characterisation at Landscape Level using Remote Sensing & GIS, NRSC, 2008). Based on the vegetation phenology it may be undertaken for additional seasons in order to cover maximum number of occurrence e.g. mixed moist deciduous forests in Terai. Within each plot nested quadrate technique was applied to collect the data about trees, herbs, shrubs etc. The sampling plot was reached on ground based on GPS locations. The field performa forms were filled up to keep the record of each sampling plot. The sampling strategy varied as per the vegetation type. The major vegetation types of U.P. are moist deciduous forest, dry deciduous forest, gregarious formation - Jamun (*Eugenia caryophyllata*), degraded forest, lowland swamp forest, Prosopis scrub, open scrub, savannah grassland, swampy grassland and forest plantations etc.

The phytosociological data gathered from field was entered into digital format using MS-Excel, which made it easier for further analysis. The

details of the geographic location of each plot were entered into the database alongwith the information about the plant species and also about wildlife evidences like pugmarks etc. The phytosociological data was then arranged in districtwise format so as to make it useful for any query at district level. Various IAS were encountered during the vegetation sampling in the following vegetation types: Moist deciduous, dry deciduous, degraded forest, thorn forest, Prosopis scrub, open scrub etc. It has been found during the sampling that a particular IAS does not dominate in any particular bioclimatic zone, e. g, *Prosopis juliflora* can be found in Semi- arid as well as in *Gangetic plains*. Same is the case with *Lantana camara* which occurs in mostly degraded forests and dry deciduous forest to some extent. Many other IAS like *Eupatorium adenophorum*, *Eupatorium odoratum*, *Parthenium hysterophorus*, *Mikania micrantha* were also enumerated during the field sampling. At many places the sheets aquatic Invasive species like *Eicchornia crassipes* was found in the wetlands.

What does the Biodiversity database offer?

The vegetation analysis helped in enlisting the IAS occurring under different vegetation types. The integration of Phytosociological data in GIS results in spatial representation of the field data and hence the location & spread of the IAS in particular vegetation type and also collectively as a whole for the study area. The database would be useful to explain the presence of the Invasive plant species on district / state level. By using the details of geographical location of the plot the species occurrence can also be located on georeferenced satellite imagery.

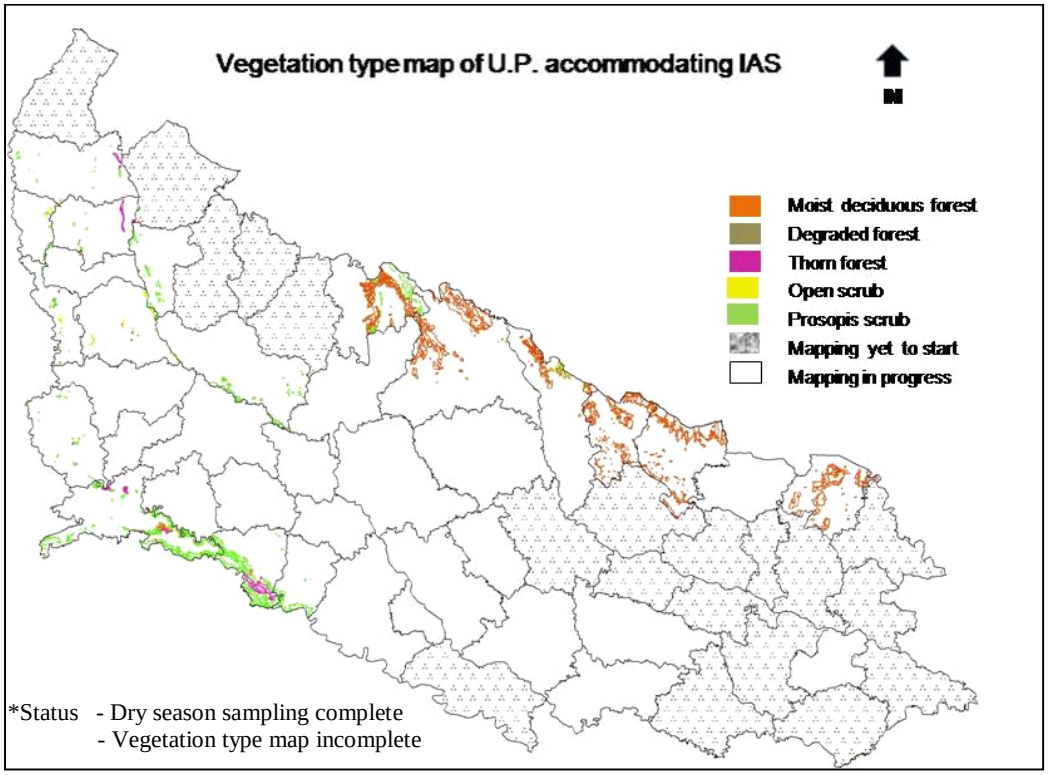

Fig. 2 : Vegitation type map of U.P. accommodating IAS

What promises does the Biodiversity database hold?

The biodiversity database that has been generated under the project entitled "Biodiversity characterization at landscape level using Remote Sensing and GIS for U.P state (except Vindhyan hills)" would be helpful in different types of analyses like inventory and study of IAS occurring in various areas of U.P., distribution of economically important plants of U.P. etc. Due to the arrangement of the phytosociological data in an information system the query & assess of data becomes easier. The scale at which the database is being created may not be helpful for studies at species level, but it would definitely be helpful in refining the query and would provide information at landscape level. The biodiversity that has been created for various states of India, under previous stages of the project (Biodiversity Information System) that has been undertaken by Department of Space / Biotechnology, Govt. of India., has been made available in public domain to promote the studies in the field of biodiversity. However species level studies can also be carried out using high resolution and also hyperspectral satellite data. Hyperspectral remote sensing images provide more complete and detailed spectral information about ground coverage and have a great potential to identify specific plant species including IAS. (Fuan Tsai *et al.*, 2005). However, the major of higher spatial resolution & hyper spectral resolution data holds great promises for identification & mapping of IAS at species level.

Acknowledgements

This research is a part of project "Biodiversity Characterisation at Landscape Level using Remote Sensing & GIS techniques for U.P. (except Vindhyan hills)" undertaken by DOS/ DBT, Government of India, the work is being carried out at IIT Kharagpur, (W.B). The authors would like to thank Uttar Pradesh Forest Department for their kind co-operation & excellent support during field visit.

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Invasive Alien Plant Species of Azamgarh District, Uttar Pradesh

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ABSTRACT

Invasive alien plant species are colonizing day by day, threatening the native biodiversity. The successful invasion of alien plant species is mainly due to anthropogenic activities, absence of natural enemies and their allelopathic competitive strategies. In the present study 27 alien plant species belonging to 12 families are being reported from various agricultural fields of Azamgarh District, U.P.

Introduction

Invasive alien plant species are dominating day by day and threatening not only to the biodiversity and ecosystem service (Ricciardi et al., 2000) but also to the economic development and human well-fare. They decline the yields of agricultural crops, forests, decreases water availability and also contribution to the spread of disease. The term 'invasive species' denotes plants and animals that:

(i) have been introduced into ecosystems where they are not native by either intentional or unintentional human activity

(ii) have established self-reproducing populations

(iii) have caused significant changes in pre-existing natural or artificial ecosystems (Richardson, 1998). To understand the mechanism by which exotic plant species invade plant community is key to limiting their affect on agricultural production and biodiversity (Levine *et al.*, 2003). The best explanation for invasion is an increase in the availability of plant resources (Davis et al., 2000; Shea & Chesson, 2002) and components that diminishes resource uptake (e.g. disturbance that remove plant biomass or reduction in plant diversity) enhance resource availability and tend to increase plant invasion (Hobbs & Huenneke, 1992; Levine, 2000)

Azamgarh District occupies 4234 sq. km of Uttar Pradesh. It is located between 25° 38' and 26° 27' North of latitude and the meridians of 82° 40' and 83° 52' East of longitude. It comes under the Upper Gangetic Plain (Duthie, 1929; Raizada, 1976) and is bounded by Mau on the east, Gorakhpur on the north, Ghazipur on the south-east, Jaunpur on the south-west, Sultanpur on the west and Ambedkar Nagar on the north-west. So to see the status of alien species in Azamgarh District, we made a field survey and selected only the agriculture land areas which are economically very important. During the survey we have collected a large number of alien plants species from the agricultural land areas.

Materials and methods

The work was undertaken through field survey in agricultural land areas particularly wheat, sugarcane and paddy fields during the period 2006-2008 in the whole district. The information regarding the alien plants has been gathered mostly from local farmers, several age-

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old persons and traditional practitioners. The alien species were collected in its flowering stage in most of the cases. The plant samples were collected and processed following the routine method of plant collection and herbarium technique (Jain & Rao, 1977). The specimens have been identified using relevant floras and standard literatures (Duthie, 1929; Hooker, 1989; Maheshwari, 1963; Raizada, 1976).

Observation

During the field survey about 27 alien plants species from different agricultural land areas belonging to 12 different families were recorded, their details of habit, period of flowering and fruiting has been presented in (Table-1.)

Table-1 : Showing the listing of alien plant species.

S. No.	Alien plant names	Family	Habit	Flowering/ Fruiting
A.	**Wheat fields**			
1.	*Ageratum connyzoides* L.	Asteraceae	Annual herb	Jan.-June
2.	*Anagalis arvensis* L.	Primulaceae	Annual herb	Dec.-April
3.	*Avena sterilis* L.	Poaceae	Annual herb	Jan.-March
4.	*Cannabis sativa* L.	Cannabinaceae	Perenial herb/bushy shrub	Jan.-Dec.
5.	*Chenopodium album* L.	Chenopodiaceae	Annual herb	Aug.-Jan.
6.	*Campanula gracilis*	Companulaceae	Annual herb	Jan.-March
7.	*Convolvulus arvensis* L.	Convolvulaceae	A twinning annual herb	Nov.-April
8.	*Gnaphilium purpureum* L.	Asteraceae	Annual herb	Nov.-April
9.	*Lathyrous aphaca* L.	Fabaceae	Annual herb	Jan.-March
10.	*L. odoratus* L.	Fabaceae	Annual herb	Jan.-March
11.	*Parthenium hysterophorous* L.	Asteracee	Perennial herb/shrub	Aug.-Jan.
12.	*Phalaris minor* Retz.	Poaceae	Annual herb	Nov.-March
13.	*Scoparia dulsis* L.	Scrophulariaceae	Herb/shrub	Sept.-March
14.	*Silene conoidea* L.	Caryphyllaceae	Annual herb	Oct.-March
15.	*Sonchus oleraceous* L.	Asteraceae	Annual herb	Dec.-March
16.	*Vaccaria pyramidata* Medik.	Caryophyllaceae	Annual herb	Jan.-April
17.	*Verbascum chinense* (L.) Santapau	Scrophulariaceae	Annual herb	Feb.-May
B.	**Sugarcane field**			
1.	*Alternanthera sessilis* (L.) DC.	Amaranthaceae	Perennial herb	Aug-Sept.
2.	*Biophytum sensitivum* DC. Prodr.	Oxaladaceae	Annual herb	Aug.-Oct.
3.	*Caesulia axillaris* Roxb.	Asteraceae	Annual/binneal herb	Feb.-March
4.	*Dicanthium annulatum* Stapf.	Poaceae	Perennial herb	Aug.-Jan.
5.	*Gnaphalium luteoalbum* Hook.f.	Asteraceae	Annual herb	Dec.-March
6.	*Ipomea hedracea* (L.) Jacq.	Convolvulaceae	Annual twinning herb	Aug.-Sept.
7.	*Ipomea nil* (L.) Roth.	Convolvulaceae	Annual twinning herb	Aug.-Nov.
8.	*Ipomea pes-tigridis* L.	Convolvulaceae	Annual twinning herb	Aug.-Jan.
9.	*Vicoa vestita* Benth. ex Hook.f.	Asteraceae	Annual herb	Feb.-April
C.	**Paddy field**			
1.	*Caesulia axillaris* Roxb.	Asteraceae	Annual/binneal herb	Feb.-March
2.	*Sphaeranthus indicus* L.	Asteraceae	Annual/binneal herb	Nov.-April

To study the dominance of a family in the area, number of species from each family has been counted and presented in a graph (Figure-1), which shows that the Amaranthaceae, Cannabinaceae, Chenopodiaceae, Companulaceae, Oxaladaceae, Primulaceae and Scrophulariaceae were represented by only a single species whereas Caryophyllaceae (2 species), Poaceae (3 species), Convolvulaceae (4 species) and the dominant family is Asteraceae with 9 species.

In wheat field, we have also count the number of alien plants of different species randomly and observed that the most dominant alien plant species is Phalaris minor Retz. and the second most is the *Avena sterilis* L. (Fig. 2). The presence of several alien plant species like *Parthenium hysterophorous L., Phalaris minor* Retz. and *Avena sterilis* L., which were very rare in the past (Srivastava, 1986) are now dominant in the agricultural field.

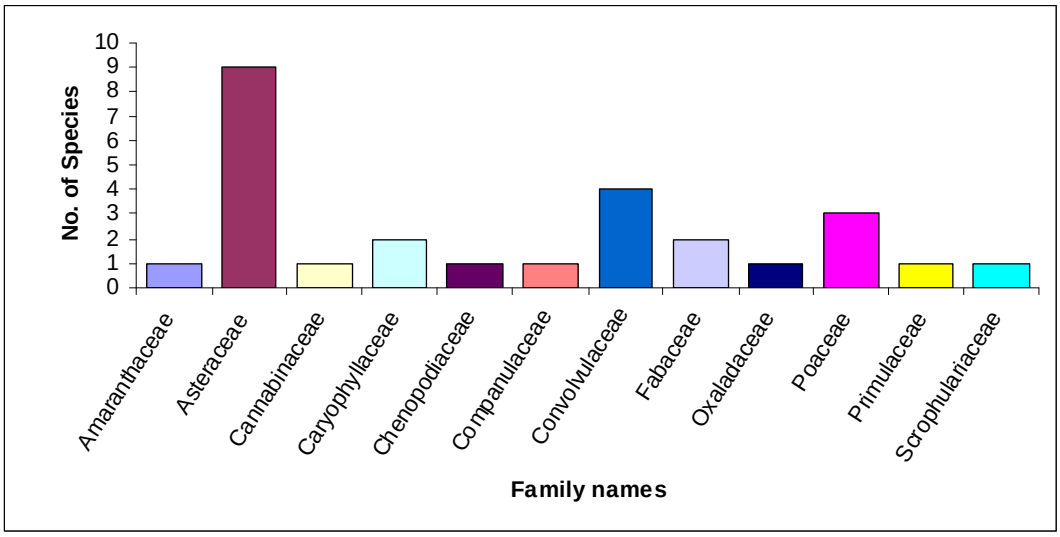

Fig. 1 : Showing dominance of Family

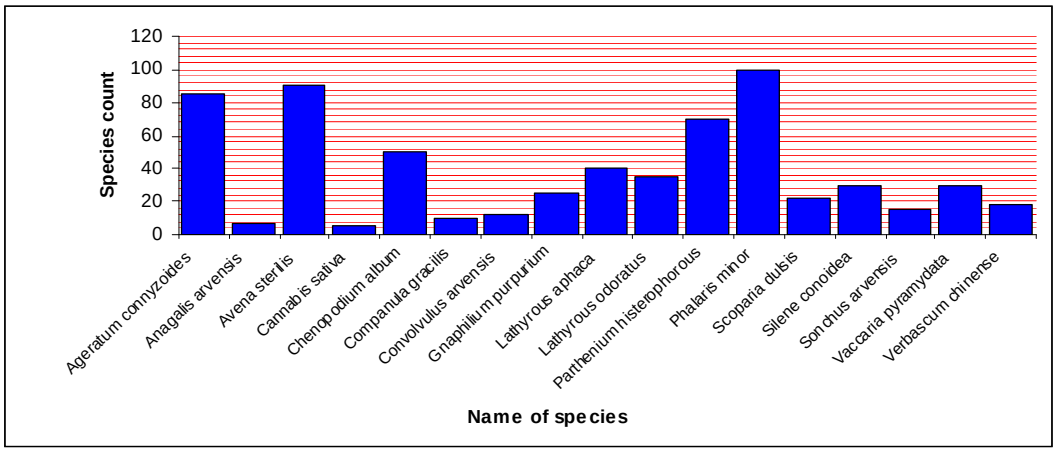

Fig. 2 : Showing dominance of different species in wheat field.

Conclusion

A national strategy to manage invasive alien plants is needed to consider a broad range of management actions simultaneously. For example, it should aim to eradicate invasive alien plants that are confined to small areas or just beginning to become invasive. Currently, it is more essential to understand why these species become invasive.

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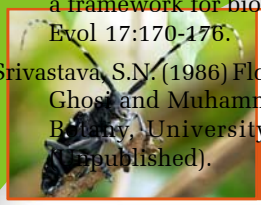

Plate-1: **A-C**. **A**. Photograph showing *Ageratum connyzoides* L. in wheat field; **B**. *Lathyrous aphaca* L.in wheat field; **C**. *Cannabis sativa* L. in wheat field.

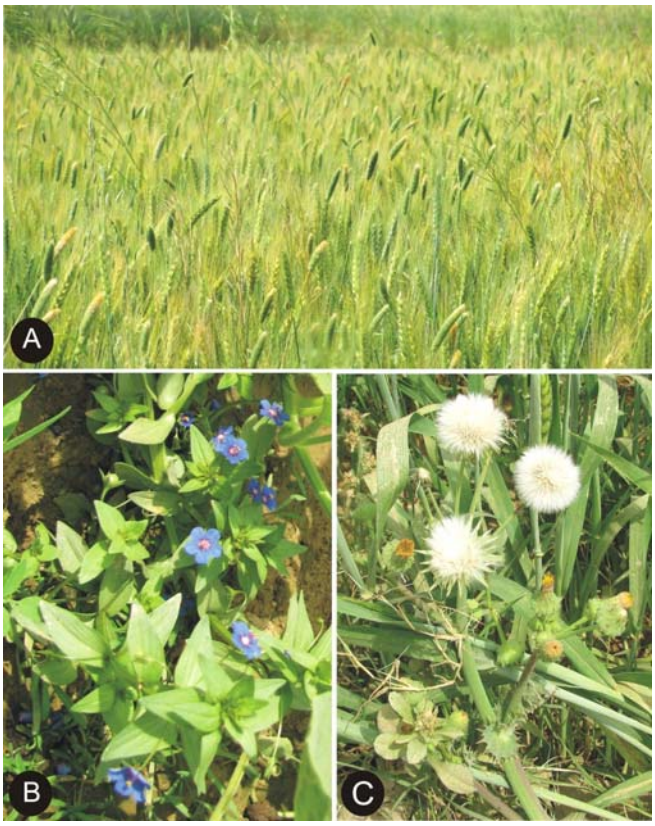

Plate-2. A-C. **A**. Photograph showing the dominance of *Phalaris minor* Retz. in wheat field; **B**. *Anagalis arvensis* L. in wheat field; **C**. *Sonchus oleraceous* L. in wheat field.

Invasive Alien Species and its Impact on Soil, Water and Environment

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International Union for Conservation of Nature and Natural Resources (IUCN) defines Invasive Alien Species as an alien species which becomes established in natural or semi-natural ecosystems or habitat, an agent of change, and threatens native biological diversity. These invasive species are widely distributed in all kinds of ecosystems throughout the world, and include all categories of living organisms. Invasive species are good at exploiting bare soil and empty niches. Invasive species are generally non-natives that infest natural ecosystems, including forest, rangelands, and pastures. One way to avoid invasive species is to choose the ones that are native to the area. Natives often are adapted to a specific environmental niche, and have natural controls that keep them in balance. Invasive species, on the other hand, are tolerant against environmental extremes and possess greater flexibility for survival in wide range of conditions with high water, light and nutrient use efficiencies. Some of the invasive species also exhibit fire resistance besides better competitive ability and allelopathy.

Causes of invasion

Land disturbance particularly by grazing, mining, urban development etc. which causes removal of vegetation and disturbs soil generally promote invasive alien species. Absence of predators and parasites in new found habitat that otherwise kept invasive alien species under control in native habitat also help in advancing invasive alien species. Land development such as fragmentation, corridors through undisturbed vegetation help enabling the spread of invasive species. Global change such as elevated CO_2 level due to greenhouse effect, climate change also promotes invasive alien species. The present era of globalisation and open market economy has accelerated the influx of invasive alien species. Many of these invasive species have caused catastrophic ecological impacts (Liebhold *et al.* 1995, Simberloff *et al.* 2000). Any invasion undergoes three distinct phases: arrival, establishment and spread (Dobson & May 1986; Williamson 1996). Corresponding to each of these three phases, there exist approaches to managing invasions by three distinct modes: quarantine, eradication and containment (Liebhold *et al.* 1995).

Global action against invasive alien species

In 1996, concern that invasive species might be one of the most significant "negative externalities" of globalization brought 78 countries and numerous international and intergovernmental organizations together at the "Trondheim Conference." This meeting, sponsored by Norway and the United Nations, was the first global effort to assess the impact of invasive species on the environment. Participants concluded that:

- The impact of invasive species is "immense, insidious, increasing, and irreversible." In other words, every country has been impacted by invasive species, the patterns and trends follow that of globalization, and as long as we engage in international trade, travel, and transport we'll need to manage this problem;
- Aside from climate change, invasive

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species are the most significant threat to the environment worldwide. Developing countries will be severely impacted, particularly Small Island Developing States (SIDS); and

- A global plan and strategy is urgently needed to address the problem.

In 1997, three international organizations came together with a commitment to share their expertise and other resources in order to address the scientific and technical aspects of the problems identified in Trondheim. The World Conservation Union (IUCN), CAB International (CABI), and the Scientific Committee on Problems of the Environment (SCOPE) formed the Global Invasive Species Programme (GISP). GISP is a coalition of scientific and technical experts

Invasive species of India

Invasive alien species of plants/animals/ microorganisms are as equally ancient as human civilization, and are ongoing chronologically indistinguishable by man. However, biological invasions have lately become one of the major global issues of concern since June 1992 soon after the UNCED's Earth Summit held in Rio de Janeiro, Brazil. It was estimated that about 40% of the species in the Indian flora are alien, of which 25% are invasive in nature. *Parthenium hysterophorus*, first report in 1951 from Maharashtra was introduced from Tropical America and presently has stretched throughout the length and breadth of India. *Lantana camara* was introduced in 1809-10 from Tropical and subtropical America has reached in submontane regions of the outer Himalaya to southernmost part of India. Eichhornia crassipes was introduced in 1914-16 from Brazil has extended large area of water bodies of India. *Mikania micrantha* is rather neotropical origin but has extended natural forests, plantations, agricultural systems in northeast and southwest India.

Impacts of invasive species on biodiversity

- Loss of biodiversity due to capture of habitat by IAS
- Extinction of native animal species by predation
- Loss of biodiversity due to increased fire incidence following exotic grass invasion
- Reduced abundance of threatened and endangered species

Impacts of invasive species on soil and water

- Increased soil erosion
- Increased incidence of flooding in some situation
- Increased water use, reduction in water table
- Changes in soil chemistry, e.g., salt accumulation
- Changes in soil microorganisms, e.g., reduced mycorrhizal association with mustards
- Loss in productivity

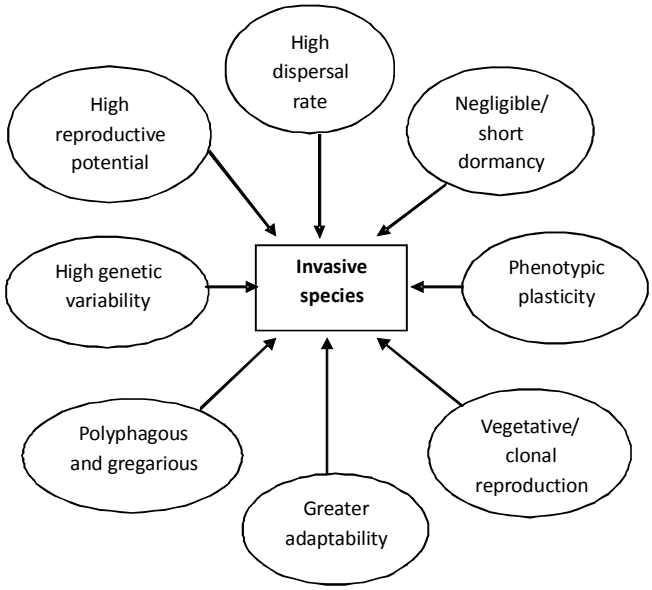
Impacts of invasive species on environment

Some environmental issues are well documented and flagged as the impacts of alien invasive species. The movement of people, commodities and their conveyances through international trade has augmented the danger of transmit of these unwanted organisms. Although many non-native species has been proved to provide great benefits to society, many others after establishment cause significant and often irreparable damage to the native ecosystems beside negative economic consequences in the new found habitat. Invasive species can also cause dramatic ecological changes due to landscape transformations that reduce the adaptability and competitiveness of more desired native species. Such transformation can be caused by the disproportionate use of resources by invasive

species like increased ability to capture light, use water, uptake nutrients.

Mechanism of Invasiveness

Invasive species including micro-organisms, plants and animals act as key threat to the functioning of agro-ecosystem although the mechanism is not fully understood. One main reason is that exotic species are too abundant and dominant even in poorly fertile soil and disruptive to the other native species reducing their variability. Majority of the studies have focused on invasive plants and animals, although few have considered the effects of invasive microbes, or interactions of invasive plant and animal species with microbial communities.



Invasive plants, animals and soil micro-organisms have profound effects on the abundance of native species, their diversity and ecosystem functioning. Invasive micro-organisms of decomposer group most likely have little impact, because of limited specificity and great functional redundancy (van der Putten *et al*. 2007). However, invasive plants and animals can have major effects on microbial decomposition in soil. Another study, however, shown that aggressive invasion of a nutrient-demanding, rapidly decomposable, and invasive plant exert large impacts on soil microbial decomposers (Kao-Kniffin and Balser, 2008). The study of microbial ecology and biological invasion has shown that some plant species accumulate pathogens quickly and maintain low densities as a result of the accumulation of species-specific pathogens, whereas others accumulate species-specific pathogens more slowly and do not experience negative feedback until plant densities reach high levels (Klironomos, 2002) indicating differential abilities of plants have to influence their abundance by changing the structure of their soil communities, and that this is an important regulator of plant community structure.

Modus operandi to check invasive species

Avoid using known invasive species: This is first and foremost principal of avoiding invasive species. For this, a list of invasive species may be widely circulated through media for awareness of general public.

Minimising landscape disturbance: Invasive species thrive well on bare soil and disturbed ground where the native plant/animal/microbial community has been displaced. Protection of healthy native species is the key to control invasive species.

Judicious use of inputs: Many studies have shown that high nitrogen levels provide an advantage to invasive species that are better adapted to using plentiful nutrients for rapid growth and establishment as compared to native species. Soil test based nutrient application in conjunction with manure is important; slow release of nutrient from manures favours native species.

Regular monitoring of land use plan: All land use plans need to be monitored regularly and invasive species need to be checked for their removal. Scouting at regular interval helps in

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preventing spread of invasive species. Particularly, seeding need to be checked either by uprooting or by adopting other measures like spot application of herbicide, if necessary. Removal of invasive species when the population is low helps native species to occupy the empty niche.

Future safeguard plan and research needs

- Build capacity in terms of human resource development and technology transfer to address invasive alien species.
- Promote community participation through awareness generation and involvement in efforts to address IAS through promotion of Public-Private Partnership (PPP) approach.
- In line with USDA Invasive Species Information Centre, National Invasive Species Information Centre may be formed for dissemination of knowledge.
- Early warning system against invasive alien microbial species
- Spatial stochastic modelling to map introduction and spread risks of invasive alien species.
- Hazard analysis and critical control point planning to prevent unintentional introduction of invasive alien species.
- Integrating DNA bar-coding into detection and surveillance programs for invasive alien species.
- Exploiting Alee dynamics in the management of invasions.
- Risk analysis of invasive alien species.

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Biotics and mesobiotics as invasive alien species

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International Union for Conservation of Nature and Natural Resources (IUCN) defines Alien Invasive Species as an alien species which becomes established in natural or semi natural ecosystems or habitat, an agent of change, and threatens native biological diversity. These invasives are widely distributed in all kinds of ecosystems throughout the world, and include all categories of living organisms such as animals, plants, fungi and microorganisms. While a small percentage of organisms transported to new environments become invasive, the negative impacts can be extensive and over time, these additions become substantial. A species introduction is usually vectored by human transportation and trade. If a species' new habitat is similar enough to its native range, it may survive and reproduce. For a species to become invasive, it must successfully out-compete native organisms, spread through its new environment, increase in population density and harm ecosystems in its introduced range. To summarize, for an alien species to become invasive, it must **arrive, survive and thrive**.

Common characteristics of IAS include rapid reproduction and growth, high dispersal ability, phenotypic plasticity (ability to adapt physiologically to new conditions), and ability to survive on various food types and in a wide range of environmental conditions. A good predictor of invasiveness is whether a species has successfully or unsuccessfully invaded elsewhere. Ecosystems that have been invaded by alien species may not have the natural predators and competitors present in its native environment that would normally control their populations. Native ecosystems that have undergone human-induced disturbance are often more prone to alien invasions because there is less competition from native species.

The threat to biodiversity due to invasive alien species is considered second only to that of habitat destruction. Invasive species cause loss of biodiversity including species extinctions, and changes in hydrology and ecosystem function. Differences between native and exotic plant species in their requirements and modes of resource acquisition and consumption may cause a change in soil structure, its profile, decomposition, nutrient content of soil, moisture availability, etc. Invasive species are thus a serious hindrance to conservation and sustainable use of biodiversity, with significant undesirable impacts on the goods and services provided by ecosystems. Biological invasions now operate on a global scale and will undergo rapid increase in this century due to interaction with other changes such as increasing globalization of markets, rise in global trade, travel and tourism. Increasing travel, trade, and tourism associated with globalization and expansion of the human population have facilitated intentional and unintentional movement of species beyond natural biogeographical barriers, and many of these alien species have become invasive. Invasive alien species (IAS) are considered to be one of the main direct drivers of biodiversity loss at the global level. It is clear that IAS can produce substantial environmental and economic damage, and their negative effects are exacerbated by climate change, pollution, habitat loss and human-induced disturbance. Increasing domination by a few invasive species increases global homogenization of biodiversity, reducing local diversity and distinctiveness. IAS can change the community structure and species composition of native ecosystems directly by out-competing indigenous species for resources. IAS may also have important

indirect effects through changes in nutrient cycling, ecosystem function and ecological relationships between native species. IAS can also cause cascading effects with other organisms when one species affects another via intermediate species, a shared natural enemy or a shared resource. These chain reactions can be difficult to identify and predict. Furthermore, aggregate effect of multiple invasive species can have large and complex impacts in an ecosystem. Invasive species may also alter the evolutionary pathway of native species by competitive exclusion, niche displacement, hybridization predation, and ultimately extinction. IAS themselves may also evolve due to interactions with native species and with their new environment. IAS can directly affect human health. Infectious diseases are often IAS imported by travelers or vectored by exotic species of birds, rodents and insects. IAS also have indirect health effects on humans as a result of the use of pesticides and herbicides, which infiltrate water and soil. Several plants from lower groups as algae, fungi and virus are also reported as invasive alien species. Some of the important ones are described here.

Ophiostoma ulmi

Ophiostoma ulmi is an Ascomycetous wilt pathogen of *Ulmus* spp. Dutch elm disease (DED) is a fungal disease of elm trees which is spread by the elm bark beetle. Although believed to be originally native to Asia, it has been accidentally introduced into America and Europe, where it has devastated native populations of elms which had not had the opportunity to evolve resistance to the disease. The name Dutch elm disease refers to the identification of the disease in the 1920s in the Netherlands; the disease is not specific to the Dutch Elm hybrid.

The causative agents of DED are ascomycetous microfungi. Three species are now recognized: *O. ulmi*, which afflicted Europe in 1910, reaching North America on imported timber in 1928, *O. himal-ulmi*, a species endemic to the western Himalaya, and the extremely virulent species, *O. novo-ulmi*, which was first described in Europe and North America in the 1940s and has devastated elms in both areas since the late 1960s. The origin of *O. novo-ulmi* remains unknown but may have arisen as a hybrid between *O. ulmi* and *O. himal-ulmi*. The new species was widely believed to have originated in China, but a comprehensive survey there in 1986 found no trace of it, although elm bark beetles were very common.

The disease is spread in North America by two species of bark beetles (Family: Curculionidae, Subfamily: Scolytinae): the native elm bark beetle, *Hylurgopinus rufipes*, and the European Elm Bark Beetle, *Scolytus multistriatus*. In Europe, while the aforementioned *S. multistriatus* again acts as vector for infection, it is much less effective than the Large Elm Bark Beetle *S. scolytus*. In an attempt to block the fungus from spreading further, the tree reacts to the presence of the fungus by plugging its own xylem tissue with gum and tyloses, bladder-like extensions of the xylem cell wall. As the xylem (one of the two types of vascular tissue produced by the vascular cambium, the other being the phloem), delivers water and nutrients to the rest of the plant, these plugs prevent them from traveling up the trunk of the tree, eventually killing it. The first symptom of infection is usually an upper branch of the tree with leaves starting to wither and yellow in summer, months before the normal autumnal leaf shedding. This progressively spreads to the rest of the tree, with further dieback of branches. Eventually, the roots die, starved of nutrients from the leaves. Often, not all the roots die: the roots may put up small suckers. These may grow up for some years into small elm trees.

The fungus produces long-necked ostiole, black perithecia, which contain neither paraphyses nor periphyses. These perithecia have lost the ability to actively discharge and contain deliquescing asci. Ascospores mass at the top of the ostiole and form a sticky drop. The conidia are

also sticky and are produced on appressed conidiophores, forming a coremium or synnema. Both of perithecia and coremia develop within the beetle galleries of the insect vector and stick to the insects as they feed and develop. The spores and conidia are transmitted with the mycangia, specialized pits within the roofs of the beetles mouths. A yeast-like mitospore may also be produced within the host's vasculature, this is named *Sporothrix*.

DED primarily spread 3 ways: 1) by beetle vectors which carry the fungus from tree to tree (the beetle doesn't kill the tree, the fungus it carries does). 2) through direct contact of an infected tree's roots with a neighboring healthy tree. 3) by pruning of a healthy tree with saws which have been used to take down diseased trees. This third method of spread is common and not recognized by many tree pruning and removal services. Arborists at Kansas State University claim that cleaning blades with a 10% solution of a household bleach will prevent this type of spread. Owners of healthy trees should be vigilant about the companies they hire to prune healthy trees. Blades need to be disinfected between use to remove dead trees and use to prune healthy trees.

Dutch Elm Disease (DED)

Control measures: The first fungicide used for preventive treatment of Dutch elm disease was Lignasan BLP (carbendazim phosphate), which was introduced in the 1970s. This had to be injected into the base of the tree using specialized equipment, and was never especially effective. It is still sold under the name "Elm Fungicide". Arbotect (thiabendazole hypophosphite) became available some years later, and it has been proven effective. Arbotect must be injected every 2 to 3 years to provide ongoing control; the disease generally cannot be eradicated once a tree is infected.

Alamo (propiconazole) has become available more recently and shows some promise, though several university studies show it to be less effective than Arbotect treatments. Alamo is primarily recommended for treatment of Oak Wilt.

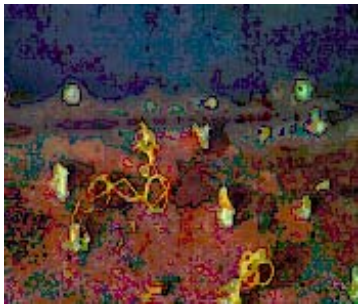
Cryphonectria parasitica

Cryphonectria parasitica is a fungus that attacks primarily *Castanea* spp. but also has been known to cause damage to various *Quercus* spp. along with other species of hardwood trees. American chestnut, *C. dentata*, was a dominant over storey species in United States forests, but now they have been completely replaced within the ecosystem. *C. dentata* still exists in the forests but only within the under storey as sprout shoots from the root system of chestnuts killed by the blight years ago. Chestnut blight only infects the above-ground parts of trees, causing cankers that enlarge, girdle and kill branches and trunks.

C. parasitica forms yellowish or orange fruiting bodies (pycnidia) about the size of a pin head on the older portion of cankers. Spores may exude from the pycnidia as orange, curled horns during moist weather. Stem cankers are either swollen or sunken, and the sunken type may be grown over with bark. The bark covering swollen cankers is usually loose at the ends of the canker. Trees die back above the canker and may sprout below it and *C. parasitica* branches are killed when a canker girdles the stem disrupting phloem transport and cambial growth. As the pathogen cannot enter the root system, genets survive and new sprouts are produced from the root collar. The epidemic is perpetuated when the sprouts become infected. An intracellular hyperparasite of *C.*

parasitica can alter the interaction between chestnuts and blight. *C. parasitica* infection occurs most commonly at branch points, where movement creates small wounds that allow the pathogen to enter the tree. Individuals less than 50cm in height are only rarely infected and disease incidence increases with plant size, presumably because of an increase in the number of potential wound entry sites.

Chestnut blight



Cryphonectria parasitica

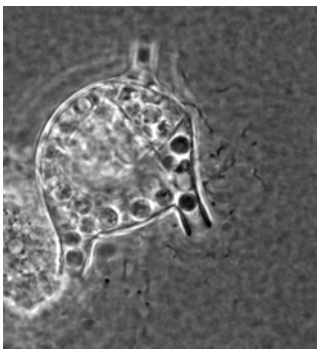
Control measures: A virus that attacks this fungus appears to be the best hope for the future of *Castanea* spp., and current research is focused primarily on this virus and variants of it for biological control.

Batrachochytrium dendrobatidis

Chytrid fungi were long thought to be predominantly free-living saprophytes, with a few species capable of infecting only invertebrates and vascular plants. However, in 1999 a new species - *Batrachochytrium dendrobatidis* was described infecting amphibians and causing the often fatal disease, chytridiomycosis. Since that discovery, B. *dendrobatidis* has been identified in association with amphibian population declines on every amphibian-inhabited continent.

From the site of its introduction, *B. dendrobatidis* spreads through water courses and amphibian-to-amphibian contact, and possibly by other mechanisms not yet fully understood. In Central America, where the spread of *B. dendrobatidis* has been extensively studied, its rate of progression has been calculated at 28-100km/yr.

Where *B. dendrobatidis* thrives, generally moist cool habitats, 50% of amphibian species and 80% of individuals can be expected to disappear within 1 year. Currently it cannot be stopped in the wild and a minority of species seem able to survive with a *B. dendrobatidis* infection as larvae or as adults and these animals likely serve as a reservoir and vectors for future outbreaks. Notable among resistant species are worldwide invasive pest species including marine toads, American bullfrogs and African clawed frogs.



Chytrid frog fungi

Chytrid iomycosis in frog

Control Measure: Main preventative management strategies for the Chytrid fungus *Batrachochytrium dendro-batidis* are:

Improving Diagnostics and Knowledge of Epidemiology: Diagnostics is an important part of any disease control management programme. If frogs develop symptoms characteristic of amphibian chytridiomycosis or there is a high mortality rate in two to three week old metamorphs they may be infected with *B. dendrobatidis*. However, diagnostic tests are required to confirm the presence of the fungus, and usually consist of histological examination (using a light microscope) of an unstained piece of skin (taken from fresh,

fixed or frozen specimens). Polyclonal antibodies were produced for diagnosing chytridiomycosis in amphibians. Antisera were produced that reacted strongly with all forms of *B. dendrobatidis*. Cross-reactivity occurred with (only) some fungi in the Chytridiomycota. It has been suggested that this immunoperoxidase stain is a useful screening method for *B. dendrobatidis* when combined with morphological investigation and symptom identification.The development of diagnostic tests such as enzyme-linked immunosorbent assays or in situ hybridisation are appropriate areas for future research

Developing Trade and Quarantine Regulations: Regulations regarding quarantine, testing, treatment and movement of amphibians need to be introduced on an international scale to prevent the proliferation of *B. dendrobatidis*. In 2001 the World Organisation for Animal Health (also known as *Office Internationale des Epizootes*) placed amphibian chytridiomycosis on the Wildlife Diseases List.. To comply with the intentions of *Office Internationale des Epizootes* listing, amphibians, when moved between countries, should be placed in a different container on arrival; all water, soil, plants, and litter in contact with the amphibian during transport should be adequately disinfected by using techniques capable of killing *B. dendrobatidis*. Water in contact with amphibians should be regarded as contaminated for up to at least 7 weeks after the last contact with the amphibian. All water, moist soil, and wet fomites (A fomite is defined as an inanimate object that serves to transmit an infectious agent from person to person) in contact with an amphibian imported into a country, or moved between locations within a country (eg: between captive amphibian colonies), should be regarded as infectious. Storage of infected materials for a period of time should not be used as a means of ensuring water is not contagious. All water and wet soil in contact with an amphibian should be disinfected before discharge into the wastewater system or the natural environment. Enclosures previously used by amphibians should be disinfected before introducing new amphibians. Any other wet objects that have been in contact with amphibians should either be disposed of or disinfected.

Raising Awareness: National and international structures for the rapid dissemination of information between scientists, politicians, and the public may be crucial in combating the threat of globally emergent pathogens. However, large geographic areas (e.g., Africa and much of Asia) have not yet been surveyed for declining amphibian populations or for the occurrence of these pathogens. Raising awareness of this threat should be one of the highest priorities for the immediate future Amphibians carrying *B. dendrobatidis* have been detected in the pet trade in Europe, the USA. Organisations associated with the pet trade and stakeholders should be targeted with the aim of reducing reservoirs of *B. dendrobatidis* in captive amphibians and stopping release of captive amphibians into the wild. Amphibian owners should be informed about the risks of releasing captive amphibians into the wild. Pet shops should be persuaded to regularly quarantine amphibians and materials in contact with amphibians and observe quarantine procedures before accepting new amphibians.

Chemical: The most effective products for field use were Path-XTM and the quaternary ammonium compound 128. Bleach, Didecyl dimethyl ammonium chloride or sodium hypochlorite at a concentration greater than 1% for 1 min are effective treatment procedures. Antifungals used for amphibians or fish may prove useful in treating *B. dendrobatidis*. Benzalkonium chloride is a disinfectant that has been used at 2 mg/l to successfully treat a similar superficial mycotic dermatitis in amphibians caused by *Basidiobolus ranarum*. Oral itraconazole has also been used to treat *Basidiobolus ranarum* infections. Other possible antifungal treatments include oral

Ketoconazole (10mg/kg once a day) or copper sulphate baths (500mg/l dip 2 minutes daily to effect).

Physical: One of the most effective strategies of disinfection is thermal sterilisation. *B. dendrobatidis* is sensitive to heat and 100% mortality is achieved by heating to 37°C for 4 hours, heating to 47°C for 30 mins) or heating to 60°C for 5 mins.

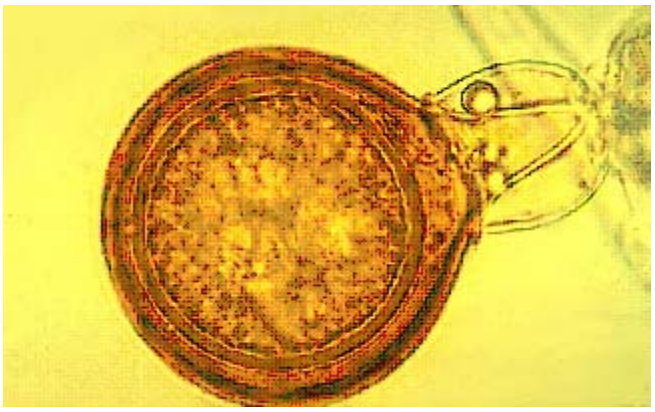
Appropriately applied thermal manipulations of amphibians and their enclosures may prove to be a safe and effective way of eliminating the fungus from captive amphibian populations and preventing spread of the pathogen when animals are translocated or released.

Phytophthora cinnamomi

Phytophthora cinnamomi is a destructive and widespread soil-borne pathogen that infects woody plants causing root rot and cankering. It needs moist soil conditions and warm temperatures to thrive, but is particularly damaging to susceptible plants (e.g. drought stressed plants in the summer). *P. cinnamomi* poses a threat to forestry, ornamental and fruit industries, and infects over 900 woody perennial species. Diagnostic techniques are expensive and require expert identification.

P. cinnamomi spreads both by chlamydospores as well as water-propelled zoospores. The presence of the macro-fungus is only determinable by soil or root laboratory analysis, although its effects upon the vegetation it destroys is readily evident. Infection often results in the death of the plant, with earlier symptoms including wilting, yellowing and retention of dried foliage and darkening of young feeder roots and occasionally the larger roots. The plant is unable to adequately absorb enough water from the soil because its roots are damaged and consequently may die. The invasion by pathogen causes water deficiency symptoms which can result in tree death, following a slow or abrupt decline. Primary symptoms caused by this pathogen in temperate oaks (*Q. rubra* and *Q. robur*) include fine root lesions which may extend into larger roots, collar and trunks causing bleeding cankers. The initial lesions at root or collar level develop upwards in the trunk and the disease expression is typically a bleeding trunk canker, therefore named 'ink disease'. Since *P. cinnamomi* essentially develops in inner cortical tissues and not in the wood, oaks keep track of past infections in the form of necroses at the cambium level (scars).

Phytophthora cinnamomi



Control measure: To control *P. cinnamomi* resistant stocks should be used.

Sanitation of tools, machinery and boots is probably the most effective means by which the spread of *P. cinnamomi* can be limited. Plants should, wherever possible, be grown in soil mixes which have been correctly steam-air pasteurised (30 minutes at 60°C). If it is not possible to pasteurize mixes make sure that the mix components are disease free. Keep the whole nursery area clean and free of dead plant material and refuse. Burning the infected plant or disposal in garbage are the most satisfactory methods of disposal. Infested potting soil should be carefully disposed.

Phosphite is a known inhibitor of *P. cinnamomi* growth and seed germination.

Metalaxyl (RidomilR) is highly soluble, moves readily in soil and is absorbed readily by roots. It may be applied as a granular, a drench or injected into the irrigation water. A single application of metalaxyl will provide 3 months of control. The other fungicide is phosetyl-AI (AlietteR) or potassium phosphonate which breaks down into the active ingredient phosphorous acid. They appear to be superior to metalaxyl when applied to mature trees in California This fungicide is translocated both upward and downward in the plant, although the upward movement is much stronger. Applications of calcium as calcium carbonate, calcium nitrate and calcium sulfate have also been shown repeatedly to reduce P.cinnamomi. Several commercial biocontrol products available with *Trichoderma* or *Gliocladium* as the active biocontrol agent are also used against this pathogen.

Aphanomyces astaci

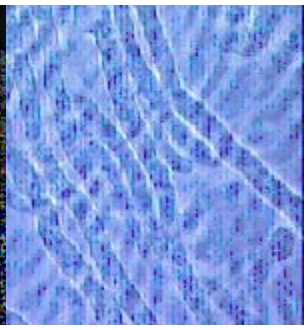
Aphanomyces astaci is commonly referred to as crayfish plague. It is a specialised parasitic fungus that infects only crayfish species. This fungus is endemic of North America and it is carried by North American species, i.e. signal crayfish *Pacifastacus leniusculus, Procambarus clarkii* and *Orconectes limosus*. The parasitic fungus *A. astaci* was introduced into Europe by imports of North American species of crayfish. Native European crayfish populations are not resistant to the fungus. It has since devastated native crayfish stocks throughout the continent. The origin and native range of *A. astaci* is assumed to be North America, based on the fact that North American crayfish species have developed defense mechanisms against the crayfish plague and display a normal host-parasite relationship, in contrast to European, Asian and Australian freshwater crayfish species which are highly susceptible. This is evidence of co-evolution of the crayfish plague and the North American crayfish species on the North American continent.

A. astaci are not visible to eye. Non-septate, branching hyphae, ca. 7-10 μm in diameter with rounded hyphal tips can be seen in the cuticle of infected crayfish with light microscope. *A. astaci* is, as mentioned, a parasite of freshwater crayfish and reproduces asexually through formation of mobile zoospores. Infection of the host commences with the encystment of the zoospore in the cuticle of the crayfish. Both susceptible and more resistant crayfish are infected this way, but the subsequent host defence response determines whether the host is killed or a stable host-parasite relationship is established. After settling on the crayfish cuticle the zoospore discards the flagellae and encysts. Germination proceeds, a germ tube penetrates the cuticle and hyphae ramify the cuticle. In resistant species, encapsulation/melanisation of the growing tip of the hyphae inhibits further invasion. In susceptible species, hyphae penetrate into deeper tissues and organs. This may also happen in individuals of resistant species weakened by other infections, injuries or stress. The final phase of the infection is sporulation and release of zoospores, which occurs just prior to or soon after death, when hyphae grow outwards and give rise to sporangia. The primary spores are extruded through the hyphal tip and cluster around the sporangial orifice to form a typical “spore ball”. These primary spores then discharge as secondary zoospores, develop flagella and swim off in the hunt for a new host. The zoospores remain viable only for a few days, after which they either encyst in a favourable site and germinate, or, if the encystment site is not suitable, develop into a new zoospore. This process of repeated zoospore emergence can occur up to three times before the zoospore finally dies.

Humans are the overall most important vector for the dispersal and spread, by the illegal/uncontrolled spread of plague-carrying crayfish species, first and foremost the signal crayfish. Once introduced to a water body the crayfish plague will spread downstream through water transport of

spores, while upstream spread mainly occurs through movement of infected crayfish. Fish is not a suitable host for the crayfish plague, but zoospores encysted on a fish can be transported quite a distance before they develop into new swimming zoospores hunting for another host. The rate of spread depends on factors such as crayfish density, flow rates and the presence of barriers to crayfish movements.

Symptoms of crayfish plague



Mycel ium of A. astaci

Control measure: The crayfish plague cannot live without a suitable host and only the North American crayfish species have been shown to be naturally adapted hosts. The European crayfish species are susceptible and will eventually die after being infected with the crayfish plague. Thus, if there are no American crayfish species present in an infected watercourse, it is supposed that the crayfish plague will disappear after killing all the susceptible native crayfish, and the crayfish population can be re-established. The only effective way of preventing further spread and maintenance of the crayfish plague is to stop the spread of American, plague-carrying crayfish species. In all countries in the region it is forbidden to stock crayfish in natural waters (permission needed), and in most of the countries there is a strict ban on the import of live crayfish.

Viable crayfish plague spores can also be spread from an infected watercourse to new water bodies by contaminated water, boats or equipment. Not taking water from one locality to another and disinfection or drying of the gear are effective methods to avoid such spread. This requires good and targeted information which can be a great challenge.

Plasmodium relictum

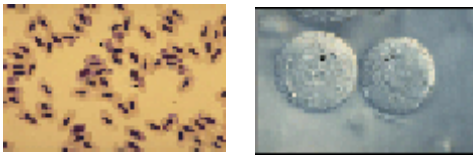
The protozoa, *Plasmodium relictum*, are one of the causative parasites of avian malaria and may be lethal to species which have not evolved resistance to the disease (e.g. penguins). It may be devastating to highly susceptible avifauna that has evolved in the absence of this organism, such as native Hawaiian birds. The parasite cannot be transmitted directly from one bird to another, but requires a mosquito to move from one bird to another. In Hawaii, the mosquito that transmits Plasmodium relictum is the common house mosquito, *Culex quinquefasciatus*. Passerine birds are the most common victims of avian malaria.

The clinical signs of disease are caused by the tissue phase, causing tissue damage. There may not be enough destruction within the red blood cells to cause clinical anemia. The clinical signs in penguins are paleness, anoxia, dyspnea, inappetence, regurgitation, and death. The gross pathology reveals a much enlarged spleen, swollen liver, and congested and extremely edematous lungs. Impression smears from these tissues often reveals schizonts. Schizonts are present in several tissues throughout the body. Histologically, the lungs have acute severe interstitial pneumonia with schizonts present. Post mortem blood samples from major vessels or the heart can be extremely useful in the diagnosis, even up to 48 hours after death.

This organism is an intracellular parasite that acquires most of its essential nutrients directly from the host cells. It undergoes sexual and asexual reproduction at different stages in both the vertebrate (bird) and invertebrate (mosquito) hosts. Sporozoites are the infectious stage of the *Plasmodium* protozoan parasite and are

transmitted to a vertebrate host through blood feeding by a mosquito. The disease to the host is caused by the parasite protozoan attacking red blood cells to continue its development. Fully developed erythrocytic schizonts cause rupturing of the red blood cells to release merozoites (to continue the blood cycle in the host) and gametocytes (capable of initiating sexual development if ingested by a mosquito). It is the merozoites with accompanying toxins that cause the chills and fever of malaria Exponential growth every 36 hours while in circulating blood cells.

This disease causing agent is carried and transmitted by a mosquito vector. The mosquito takes a blood meal from the reservoir host and ingests micro and macro gametocytes. These develop into oocysts in the gut of the mosquito. The oocysts then produce numerous sporozoites, which migrate to the salivary gland of the mosquito. These are infectious agents of malaria and are injected into the blood stream of the bird when the mosquito is taking its next blood meal. The cycle through the mosquito takes approximately 13 days.



Plasmod ium rel ictum

Control measures: Because *P. relictum* presence is linked to mosquito populations malaria is very hard to eradicate. To effectively eliminate malaria from a habitat either the vector (mosquito) must be eliminated or prevented from feeding on the bird. This is difficult particularly in remote areas in the wet forests of Hawaii where wallows from feral pigs and hollowed out logs of the native apuu ferns provide ample areas of standing water where the mosquito breeds. One effective procedure is to reduce the number of potential water catchments containers in order to reduce the mosquito breeding sites available.

Caulerpa taxifolia

This is a species of seaweed, an alga of the genus *Caulerpa*. Native to the Indian Ocean, it has been commonly used as ornamentation in aquarium installations around the world. The alga has a stem which spreads horizontally just above the seafloor, and out of this stem grow vertical fern-like pinnae, whose blades are flat like yew, hence the species name "*taxifolia*" (the genus of yew is "taxus"). The alga produces a large amount of a single chemical that is toxic to fish and other would-be predators. This is in contrast to other plants which produce a variety of toxins, but in reduced amounts.

A specific strain of this alga was found to thrive in cold aquarium environments by the staff at the Wilhelma Zoo in Stuttgart, Germany in 1980. At the zoo aquarium, selective breeding under exposure to chemicals and ultra-violet light made the *Caulpera* even hardier, and when it eventually found its way into the Mediterranean, it created an invasive species panic because of fears that it threatened to alter the entire ecosystem by crowding out other seaweed while being inedible to animals.

It appears that, in 1984, this seaweed was accidentally released into coastal waters of the Mediterranean Sea just below the Oceanographic Museum of Monaco. It was claimed that *Caulerpa* had grown to cover 7400 acres. A belief arose that it was preventing other plants from growing, leading to the nickname "Killer Algae". The plant began to spread between ports along the Mediterranean coast. *C. taxifolia* has been discovered off the coasts of Australia and the United States, though none of those encroachments have been anywhere near the scale of what is happening in the Mediterranean.

The aquarium strain reproduces asexually, that is, vegetatively: the viscous, elastic white fluid inside the stem was found under the microscope to contain only male gametes. Rate of growth can be as fast as a centimeter per day. If any small part is severed from the rest of the alga, this small part will regrow into another alga. Anchors of ships and fishing nets can serve as carriers of *Caulerpa*. Thus this alga has been found to jump from the coast of one port city to the coast of another port city. The natural strain reproduces sexually and has both male and female individuals. Gametes are expelled from each sex and meet to form a zygote which then goes through two larval stages before becoming an adult.

Caulerpa taxifol ia: a killer alga

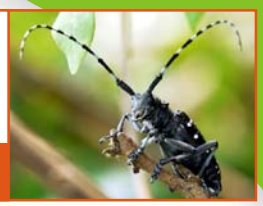
Control measures: Researchers at the University of Nice in France have been studying a tiny aquatic slug which is known to be a natural predator of *C. taxifolia*. Called Elysia subornata, it was found off the coast of Florida, in waters warmer than those in the Mediterranean. This slug is believed to feed exclusively on *C. taxifolia*, by sticking its proboscis into the stem and sucking out the white viscous liquid inside the stem: this causes the algae to become limp, discolored, and dead. As the slug does so, it absorbs the algae's poison. The slug has an enzyme which neutralizes the noxious effect of the poison, and at the same time the poison protects the slug from being eaten by fish. This slug cannot survive in the cooler waters of the Mediterranean, however, and so is unable to check the growth of the killer weed.

Undaria pinnatifida

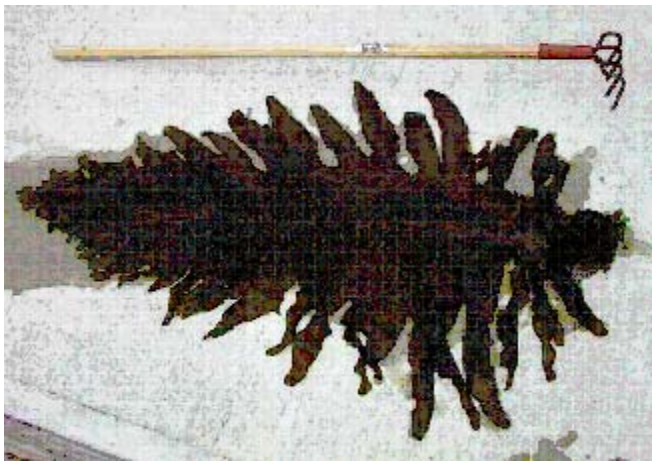
This is a large, brown alga of commercial interest that has recently been introduced to European shores and has subsequently been found on the English South coast. As in the case of *Sargassum muticum*, it has the potential to displace other native species on infralittoral rocky reefs and it is crucial, therefore, that the spread and consequences of the arrival of *U. pinnatifida* on native European communities are understood.

U. pinnatifida or wakame is large brown kelp with a branched holdfast giving rise to a stipe. Just above the holdfast, the stipe has very wavy edges, giving it a corrugated appearance. The stipe gives rise to a blade that is broad, flattened and lanceolate. It has a distinct midrib. The margins of the blade are wavy. Plants can reach an overall length of one to three metres. *U. pinnatifida* is an annual species with two separate life stages. It tolerates a wide salinity and temperature range. Its morphological and reproductive characteristics make it a very successful invasive species. U. pinnatifida possesses a heteromorphic life cycle with alternation of generations between a diploid sporophyte and a haploid gametophyte. It may be confused with Alaria esculenta but the corrugated stipe is distinctive.

It is an annual species with two separate life stages. The macroscopic stage (the sporophyte), is usually present through the late winter to early summer months. A microscopic stage (the gametophyte), is present during the colder months. The sporophyte is golden-brown in colour, with a lighter coloured stipe. It has a strap-like midrib



reaching the full length of the thallus, 1-3 cm wide. The edges of the midrib are expanded as a thin membranous pinnatifid blade. The pinnnae are 50-80 cm long. The blade is dotted with white cryptostomata and dark gland cells and terminates well short of the base. The naked basal section of the midrib forms the stipe. As sporophytes mature, two thickened fluted sporophylls develop, one along each edge of the stipe. They bend laterally around the stipe with folds becoming interleaved. The gametophyte is microscopic.



Undaria pinnatifida:A apron-ribbon vegetable

Control measures: *Undaria* has a microscopic phase in its life cycle, and it is thought that eradication of this species is unlikely to succeed. The approach to Undaria management would thus be to slow its spread and reduce the chances of it reaching new locations. In addition to natural dispersal the role of human mediated vectors; ballast water, attachment to hulls, marine equipment etc plays a major role in the spread of alga. Vector management and awareness would go a long way in slowing its spread. In the long-term, it is hoped that eventually there could be systems to treat vessel hulls with UV light or high-pressure, heated water to kill harmful spores and bacteria quickly and efficiently.

Banana Bunchy Top Virus

Banana bunchy top virus (BBTV) is one of the most serious diseases of banana. Once established, it is extremely difficult to eradicate or manage. BBTV is widespread in Southeast Asia, the Philippines, Taiwan, most of the South Pacific islands, and parts of India and Africa. BBTV does not occur in Central or South America. In Hawaii, BBTV was first observed in 1989 and is now widely established on Oahu. In 1995 it was discovered in the Kona area of the island of Hawaii, and in 1997 it was found on the island of Kauai. The virus is spread from plant to plant by aphids and from place to place by people transporting planting materials obtained from infected plants. There is no cure for BBTV. Some banana varieties, like the Cavendis types, are more readily infected with the virus, but no variety of bananas is resistant. Banana plants that show symptoms rarely bear fruit, and because they are reservoirs of the virus, they must be destroyed. BBTV is a serious threat to Hawaii's banana industry and to the productivity of banana plantings in home gardens.

The initial symptoms of banana bunchy top virus consist of dark green streaks in the veins of lower portions of the leaf midrib and the leaf stem (petiole).The streaks also occur, but are less prominent, in the veins of the leaf blade (lamina). This symptom is sometimes referred to as “Morse code streaking” because the streaks are irregular and resemble a series of “dots" and “dashes.” Rubbing away the waxy white coating that covers the petiole or midrib makes it easier to see the streaking. Also, dark green, hook-like extensions of the leaf lamina veins can be seen in the narrow, light-green zone between the midrib and the lamina. The short hooks point down along the midrib toward the petiole. They can best be seen by back-lighting the leaf against the sky. On mature plants infected with BBTV, new leaves emerge with difficulty, are narrower than normal, are wavy rather than flat, and have yellow (chlorotic) leaf margins. They appear to be “bunched” at the top

of the plant, the symptom for which this disease is named. Severely infected banana plants usually will not fruit, but if fruit is produced, the banana hands and fingers are likely to be distorted and twisted. The keikis (suckers) that develop after a "mother" plant has been infected with BBTV are usually severely stunted, with leaves that do not expand normally and remain bunched at the top of the pseudostem. These leaves are stiff and erect, are shorter and narrower than normal leaves, and have chlorotic edges. Keikis with these symptoms will not produce fruit.

Banana bunchy top virus is spread by the banana aphid, which acquires the virus after at least four (but usually about 18) hours of feeding on an infected plant. The aphid can retain the virus through its adult life, for a period of 15-20 days. During this time, the aphid can transmit the virus to a healthy banana plant by feeding on it, possibly for as little as 15 minutes but more typically for about two hours. Disease symptoms usually appear about a month after infection

Banana bunchy top d isease

Control measures: The most important factors in controlling banana bunchy top virus are killing the aphid vector (disease carrier) and rogueing (removing and destroying) infected banana plants. By killing the aphids on the banana plant, dispersal of virus-carrying aphids to nearby, healthy banana plants is avoided. Since the only host of BBTV is banana, rogueing infected trees reduces spread of the virus by reducing the opportunity for aphids to aquire the virus or for people to obtain and transport infected suckers or planting material.

Rinderpest virus

Rinderpest virus is a species of morbillivirus causing cattle plague, a highly fatal viral disease of domestic cattle, buffaloes and yaks. It also affects sheep, goats, some breeds of pigs and a large variety of wildlife species. Although humans are not susceptible to Rinderpest, famine devastates human population's dependant on cattle and buffalo for their food and livelihood. Mass vaccinations over the last century have greatly reduced outbreaks of Rinderpest. The Global Rinderpest Eradication Program (GREP), which was established in 1987 by the United Nation's FAO to develop strategies of control in high risk countries, will lead to the total eradication of the Rinderpest virus by 2010.

Control measures : There is no treatment for rinderpest once an animal is infected. Prevention involves following sanitary practices in case of infection: isolation of sick animals, slaughtering, destruction of slaughtered animals, disinfection and maintaining protected free zones. Vaccination and annual revaccination is recommended. Surveillance is important in identifying infections and preventing spread

What need to be done?

Invasive alien species (IAS) is a global issue that requires international cooperation and actions. Preventing international movement of IAS and rapid detection at borders are less costly than control and eradication. Preventing the entry of IAS is carried out through inspections of international shipments, customs checks and proper quarantine regulations. Prevention requires collaboration among governments, economic sectors and non-governmental and international organizations.

Plant Health Vs Invasive Alien Soil Microbes

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Nature is a home to innumerable organisms, a place where they interact in a coordinated fashion and form a complex environment. A variety of invasive alien and native microbes are associated with plants and they exert different qualitative and quantitative impact on plant health and production. Plant-associated microbes play important role in agricultural, food safety, security and in the maintenance of balanced ecosystem. Some of these diverse microbes, which include viruses, bacteria, fungi, and nematodes cause various plant diseases while others prevent diseases or enhance plant growth. Plant health is an important key for productivity, their roots are embedded in soil, an active zone of invasive alien and native microbes. Such Invasive alien and native microbes have had profound impact on plant health and production. This complex association has been shown to cause distinct biological changes in both, the host and the pathogen. Some microbes cause diseases whereas others prevent diseases or enhance plant growth. Microbes also interact with each other on or within plants with the result of more or less severe disease. Within each microbe group, the diversity of species that interacts with plants is tremendous.

Here we intend to emphasize the role of invasive alien microbes and interaction with native soil plant parasitic nematode which become a major threat to plant health not only to agro forestry and horticultural plants but various other crops like cereals, pulses, spices, vegetables and other cash crops like sugarcane, cotton etc. In general microorganisms are important in agriculture in order to promote the circulation of plant nutrients, reduce the need for chemical fertilizers and chemical pesticides. Phytonematodes in soil are exposed to variety of microbes especially to fungal and bacterial antagonists. Bacteria are more abundantly present in soil and some of them have shown more potential for lowering the plant parasitic nematode population in soil. The major objective of phytonematode management to improve soil health and gain economic benefits. Soil health is the capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality and promote plant health. A healthy soil possesses high biodiversity and provides relief by pests or pathogens and most importantly, improving plant health. The management effect depends on the interaction among "host plant-nematode target - soil-microbes-environment". Thus, phytonematode management can be achieved through simultaneously promoting the health of plant, facilitating the antagonistic activity or rhizosphere colonization of the microbial antagonists, while antagonizing nematode. Aside from stable virulence of microbial diversity towards target nematode, some other features of microbial strains must also be met before use of invasive alien and native microbes for plant parasitic nematode management (Gupta and Pandey, 2009):

i. Microbial strains should be non-pathogenic to non-target organisms including human, livestock's, birds, and other terrestrial and aquatic organisms.

ii. Microbial strains should be good colonizers of the host root rhizosphere,

establishing and reproducing in the soil.

iii. Biologically competitive with other soil microorganism.

iv. Adaptable to variable environmental conditions.

v. Compatible with other pathogen control methods.

vi. Compatible with other cultural practices and commercialization methodology.

vii. Conducive to plant growth and soil health.

No matter how well suited a nematode antagonist is to a target nematode *in vitro*, rational management decision can be made only by analyzing the interactions naturally occurring among "host plant - nematode target - soil microbial environment". The most important bacterial antagonists used for the management of nematode in variety of agricultural crops are *Pasteuria, Pseudomonas, Bacillus* etc. Such bacteria unquestionable play an important role in decreasing nematode population below the economic threshold level and these microbes are found to be deleterious to large number of phytonematode population especially in presence of organic materials or under anaerobic conditions. Such bacteria affect plant parasitic nematode population by a variety of mode of action like parasitizing, producing toxins, antibiotics or enzymes; interfering with nematode plant host recognition, competing for nutrients, inducing systemic resistance of plants, and promoting plant growth / health etc. in soil ecosystem. Various types of bacteria are involved in decreasing the nematode population in soil. On the basis of their mode of action these bacteria may be considered as obligate parasite, opportunistic, rhizospheric, cry protein forming, endophytic, symbiotic etc. parasitizes to variety of nematode and others are indirectly involved to reduce the nematode infestation to plants.

Parasitic bacteria- *Pasteuria* is an obligate nematode parasitic endospore forming bacteria, which has great potential to control different genera of plant parasitic nematodes on variety of crops. *P. penetrans* is highly diverse in nature and has been reported all around the world on variety of phytonematodes. This bacterium has been reported in 51 countries on 323 nematodes species belonging to 116 genera, including both plant parasitic nematodes and free living nematode species. Majority of plant parasitic nematode are parasitized by these bacteria. Different species of *Pasteuria* vary in their parasitism which may be due to their host range and morphological differences. The major species of *Pasteuria* are as follows.

- *P. penetrans* (Thorne) Sayre & Starr, 1985
- *P. thornei* Starr & Sayre, 1988
- *P. nishizawae* Sayre, Wergin, Schmidt & Starr, 1988

Opportunistic parasitic bacteria: Some of the bacteria other than obligate parasite live saprophytically and target nematode as one of the food source for their growth and proliferation. Such types of bacteria are known as opportunistic bacteria like *Brevibacillus laterosporus, Bacillus laterosporus* etc. Various isolates of *B. laterosporus* have been reported to kill number of nematode species. During infection of nematode by the opportunistic bacteria hydrolytic enzymes play a critical role for degradation of the nematode cuticle. Most of the work on this group of bacteria is in progress using free living nematode as a target to develop potential agent for nematode management.

Rhizobacteria: The term Rhizobacteria has been accepted to describe the rhizosphere bacteria which exhibit root colonization. The root colonization is a process, whereby bacteria survive inoculation to seed or in to soil, multiply in the spermosphere in response to seed exudates which

are rich in carbohydrates and amino acids. Rhizobacteria especially plant growth promoting rhizobacteria (PGPR) are a group of root-colonizing bacteria in the root rhizosphere of many plant species that exhibit useful effects on plants. To date, many mechanisms have been proposed for growth promotion by PGPR strains. PGPR are associated with plant roots, and either directly or indirectly stimulates plant growth. Plant exudates in the rhizosphere, such as amino acids and sugars, provide a rich source of energy and nutrients for bacteria, resulting in bacterial populations greater in this area than outside the rhizosphere. Therefore rhizobacteria are considered as efficient rhizosphere competetors in the rhizosphere which displace the native microorganisms. The most common and best characterized and at the same time physiologically most active auxin in plants is indole - 3 - acetic acid (IAA), which is known to stimulate both rapid increase in cell elongation and long-term cell division and differentiation responses in plants. More than 80% of bacteria isolated from the rhizosphere can produce the plant growth regulator IAA. One study indicated that as many as 90% of the microorganisms found in the rhizosphere are capable of releasing cytokinins when cultured *in vitro*. As cytokinins move from roots to shoots, root exposure to cytokinins could affect plant growth and development. Increases in yield and N, P and K content of grains obtained after exogenous application of cytokinins in rice field trials support the hypothesis that bacterially supplied cytokinins to the soil can improve the growth and yield of treated plants. Therefore indirectly these bacteria induce resistance against plant parasitic nematode by inducing maximum growth and yield of the crop.

Aerobic endospore forming bacteria mainly *Bacillus* spp. and *Pseudomonas* spp. are among the dominant population in the root rhizosphere which antagonize the phytonematode population. Similarly *Pseudomonas* spp. also exhibit nematode suppressive effect against variety of nematode species through production of antibiotic, induction of systemic resistance. Several genera of other rhizobacteria have shown the antagonistic activities against plant parasitic nematodes are *Actinomycetes, Agrobacterium, Arthobactor, Alcaligenes, Aureobacterium, Azotobacter, Beijerinckia, Burkholderia, Chromobacterium, Clavibacter, Clostridium, Comamonas, Corynebacterium, Curtobacterium, Desulforibtio, Enterobacter, Flavobacterium, Gluconobacter, Hydrogenophaga, Klebsiella, Methylobacterium, Phyllobacterium, Phingobacterium, Rhizobium, Serratia, Stenotrotrophomonas, Variovorax* etc. in the ecosystem. The different ways by which rhizobacteria antagonize the plant parasitic nematode populations are:

- Disrupts the nematode-host recognition and regulate the nematode behavior.
- They compete with nematode for nutrients for their living.
- Rhizobacteria promote plant growth and therefore nematode could not attack the healthy roots easily.
- Antibiotics produced by the rhizobacteria directly or indirectly induce resistance and hence reduce nematode population

Resistance induced by rhizobacteria (ISR) has been reported to be active against nematode pests. Rhizobacteria can induce systemic resistance by depositing callose, accumulating phenols and cell wall thickening. When the plant is attacked by the pathogen or pest, rhizobacteria promote the synthesis of some defence chemicals viz. PR proteins, increase the chitinase and peroxidase activity and also helps in synthesing phytoalexins and other important secondary metabolite. Bacterial determinants of ISR include lipopolysaccharides (LPSs), siderophores and salicylic acid (SA). *Streptomyces avermitilis* produces macrocyclic lactones called avermectins which are potent antihelminthic and insecticidal

compounds. One such avermectin named abamectin is reported to be successful in controlling *Meloidogyne incognita* root-knot nematode infection. Various rhizobacteria produces the several metabolic by products which directly or indirectly reduces nematode population at large around the root rhizosphere. Amonifying bacteria during decomposition of nitrogenous organic materials reduces nematode population in soil. *Pseudomonas* reduces nematode population at significant level by production of antibiotic such as 2, 4 diacetylphloroglucinol (DAPG).

However, the use of crop rotations and mulches as a method to increase levels of rhizoflora antagonistic to plant-parasitic nematodes have considerable success. Reasons cited for poor performance include varying levels of nematode sensitivity to decomposition products from antagonistic plant residues and the poor rhizosphere competence of some rhizobacterial antagonists. One way to introduce selected beneficial bacteria into the field is through bacterization of receptive plant tissue. The recipient plant is inoculated in tissue culture, obviating the need for rhizobacteria that are rhizosphere competent, but instead requiring them to be end root competent (endophytic). Rhizobacteria applied to seeds or planting material are seldom long lasting, limiting the usefulness of bacterial inoculants to those that control nematodes attacking seedlings. Some of bacteria based products like Bio Yield™, Gustafson LLC based on *Paenobacillus macerans* and *Bacillus amyloliquefaciens* are available in market for the management of variety of plant parasitic nematode. Other product Deny based on *Burkholderia cepaci* found very active to reduce egg hatching and juvenile mobility in soil. BioNem is also used to manage the root-knot nematode infestation in vegetable crops in Israel based on *Bacillus firmus*. Wheat mash as an organic amendment, in combination with the 200-ml culture of the actinomycete, Streptomyces costaricanus sp. nov. (ATCC 55274), gave a higher shoot weight and responses than their individual use.

Factors influences the root colonization by rhizobacteria

The colonization of plant roots by rhizobacteria is affected by number of biotic and abiotic factors like host plant species, soil pH, soil temperature, soil types and other soil microbes.

Host plant

Rhizobacteria obtain nutrients from the roots and root exudates have direct impact for their growth and development. Sometimes the root exudates have adverse effect on rhizobacteria but at the same time rhizobacteria are found to be capable of utilizing root exudates for their multiplication. Therefore plant species, cultivars and growth stage of the plant can affect the root colonization by rhizobacteria.

Soil microflora

Plant root colonization by introduced strains of rhizobacteria is greatly restricted in natural soil indicating that the soil microflora has profuse effect on the process of colonization. Microbial interaction like competition, mutualism, and antagonism has been reported in the root colonizing bacteria.

Abiotic factors

Abiotic conditions in root rhizosphere also have considerable influence on the growth, development and distribution of root colonizing bacteria. These are soil pH, soil temperature, soil types, soil texture etc. on root colonization. For the establishment of rhizobacteria to manage phytonematode population, it is imperative to consider following :

- Establishment of efficient techniques for isolation of rhizospheric bacteria
- Development of suitable and least time consuming *in vitro* screening techniques

for efficient rhizobacteria against phytonematodes.

- Manipulation of rhizobacteria which should be resistant to different biotic and abiotic factors.
- Rhizobacteria should posses rhizospheric competence potentiality.
- Development of formulation techniques for application to planting materials / sites towards management of phytonematode population.

Cry protein producing bacteria

Bacillus thuringiensis (Bt), an aerobic gram positive bacterium, remains the focus of research on biopesticides. This bacteria produces crystal protein a pore forming toxin, which is known to be toxic to a narrow range of insect species all around the world and leaving vertebrate, benificial organism unaffected . Some Cry proteins are also toxic to other invertebrates such as nematodes, mites and protozoans. It was found that six Cry proteins viz Cry5, Cry6, Cry12, Cry13, Cry14 and Cry21 are toxic to variety of nematodes. The purified thermostable exotoxin was reported to be toxic to *Meloidogyne* eggs and larvae *in vitro* at 1:10 concentration whereas with Panagrellus redivivus, a LC 50 was obtained with 175ng/ml of a solution containing 10.7% active Thuringienisn-A.

Endophytic bacteria

Endophytic bacteria are those bacteria which reside inside the living tissues without doing substantive harm or gaining benefit other than securing residency. These bacteria enhance plant growth and reduce the disease severity caused by variety of plant pathogens. Instead of different ecological niches, root rhizobacteria and endophytic bacteria showed almost same mechanism for plant growth promotion and inhibition of phytopathogens. Both compete for ecological niche, substrate, produce inhibitory chemicals and induce systemic resistance in the host plant. It has been suggested that introducing bacterial endophytes at an early stage during plant development, may be one method to circumvent their poor competitiveness. It has been reported that bacterial lipopolysaccharides of Rhizobium etli strain G12 act as inducer of systemic resistance in potato towards infection by the cyst nematode *Globodera pallida*. Bacterial endophytes which act as biocontrol agents can be divide in two groups:

- Extensive colonizers of the internal plant tissues which suppress the pathogens by niche occupation, antibiosis, or both.
- Primarily colonizers which occupy the root cortex where they elicit plant defense/resistance mechanisms.

Bacterial uptake of nutrients would then reduce the nutrients available to the nematode and may, therefore, interfere with nematode development and reduce egg production. Nutrient competition is a potential mechanism for suppression of plant-parasitic nematodes by endophytic bacteria.

Apart from their nitrogen fixing capabilities, some rhizobia also benefit economically important crops by protecting them from various soil-borne plant pathogens including root-knot nematodes. The control mechanisms include suppression of juvenile survival. *Microbacterium esteramaticum* and *Kocuria varians* have been reported to possess activity against root-lesion nematode (*Pratylenchus penetrans*); they suppress the nematode population without yield reduction.

Mutualistic Endophytes

Mutualistic endophytes are considered as good source for developing nematode control agents because of the following facts.

- Both the organisms inhabit the same niche and are present in cortex.
- Control activity of these endophytes is towards nematodes as well as in insects.

- Can be cultured in fermentors.
- They are good colonizers of the root.
- Easy to apply to tissue culture plantlets and suckers.
- Moderate cost factor due to level of inoculums needed.

Conclusion

Rhizosphere is complex environment where several invasive alien and native microbes interact with each other. The major microbial diversity are used to combat with major pathogens including plant parasitic nematode of important crops are bacteria (PGPR, parasitic, endophytic, opportunistic, cry protein forming) and fungi (nematophagus, egg parasitic, female and cyst parasitic, endophytes). Studies conducted at CIMAP, Lucknow so far indicate that various invasive alien microbes may play a significant role in limiting the infestation of nematodes to various agro forestry and horticultural crops.

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22 MAY 2009

INVASIVE ALIEN SPECIES

Invasive Alien Plant Pathogens: A Threat to Agriculture

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"Alien Microbes" are basically non -native or exotic microbial species or subspecies that occur outside their natural adapted range and dispersal potential. It may include any part of the organism capable of surviving in the new ecological niche and subsequently reproduce and does no harm to the invaded ecosystem either economically or environmental point of view. Many alien species support our farming and forestry systems in a big way. However, some of the alien species become invasive when they are introduced deliberately or unintentionally outside their natural habitats into new areas where they express the capability to establish, invade and out-compete native species. Therefore, "invasive alien microbe (or IAM)" can be described as those microbial species which are non-native or alien to a particular ecosystem and whose introduction in the new ecological territory causes or is likely to cause economic or environmental harm, or harm to human health. In other words IAM are those microbes that produce fertile offsprings in large numbers at a considerable distance from their original ecosystem, compete with native species, destabilize the ecosystem, cause economical loss and get naturalized over there. The movement of microbes across habitats and ecosystem is a natural process chiefly due to human actions including agricultural activities. The ecosystems are inherently dynamic, losing some species, gaining others. It is the constantly accelerating rate of invasion that looms large over the world economy today. The invasive species generally have dramatic and negative effect on the other species and even entire ecosystem to the extent that it includes the extinction of species or sometimes even the hydrology and nutrition cycles of entire ecosystems have changed. Or we can say that the negative effect of the invasive alien species is visible whereas positive effects are not readily visible. We are more concerned about the negative effects as they have a greater impact on economy, environment and health. The frequency of invasion by alien species including plants, animals and microbes recorded in six countries namely the US, UK, Australia, South Africa, Brazil and India can be judged by the number 1,20,000 which is quite high and has significant impact on the economy and environment. The invasion potentiality leading to an increase in species richness is welcome but extinction of native species resulting in decrease of species richness is not welcome.

Plant pathogens comprise just one subset of the many types of invasive species of concern, but this subset is very important economically and politically. Crops are susceptible to a large number of diseases caused by fungi, oomycetes, viruses, bacteria, phytoplasmas, and nematodes. Losses due to plant diseases have been estimated to be Billions of US dollars globally per year. Taking example of the US, not all pathogens of a given crop are present currently. Perusal of any Compendium of Plant Disease published by the American Phytopathological Society (APS) will quickly show that there are several serious pathogens that have not yet arrived or have not become established in this country. Other important plant pathogens are found in only limited areas within the country, such that most

of the crop is not affected. One example is soybean rust, caused by the fungus *Phakopsora pachyrhizi*. Yield reductions of 10 to 30% on a regional basis are typical in areas where the Asiatic strain is found, and yield reductions of over 90% (relative to attainable yields) have been reported for individual fields. The pathogen has been in Puerto Rico for some time, but the strain is less aggressive than the Asiatic one. However, the Asiatic strain is now prevelant in South America. Obviously, one can assume that not all exotic plant pathogens will become established and spread if introduced into the country. Differences in climate, cropping practices, and local microbial competitors and antagonists all will influence what happens when the pathogen or diseased plant is introduced into a given area. For every chestnut blight, there are probably several "failed" establishments, or establishments with minor economic consequences. Nevertheless, it has been argued that a large fraction of the pathogens of U.S. crops were introduced in modern times from other locations and that roughly 65% of crop losses are attributable to introduced pathogens. Similarly, citrus canker is another good example of an invasive plant pathogen that has caused economic damage. The disease was discovered near Miami in 1995, likely due to an accidental introduction 2 years earlier. Canker has now spread to about 1000 square miles of southern Florida. The eradication effort has cost over $200 million and the disease is still spreading because tree destruction programs have been successfully challenged in court. Other recent examples of plant pathogen introductions include Karnal bunt of wheat and plum pox of stone fruits. The Karnal bunt case is interesting because the disease has virtually no impact on crop production, yet is important because of international trade restrictions on wheat from areas where the disease occurs. Some species of the Erysiphales have long been known to cause biological invasions. The introduction and spread of the North American grape powdery mildew pathogen, *Erysiphe necator* (syn. *Uncinula necator*) in Europe in the 19th century is a good example for invasions caused by powdery mildew fungi. *Podosphaera mors-uvae* (syn. *Sphaerotheca mors-uvae*) has invaded Europe and Asia from North America in a similar way at the beginning of the 20th century where it caused a serious plant disease called 'American gooseberry mildew'. Recently, some other powdery mildew species previously not recorded in Europe have also appeared in some European countries. For example, *Microsphaera azaleae* (syn. *Erysiphe azaleae*), known to infect Rhododendron spp. in North America, was detected on rhododendrons in Germany; *Uncinula kusanoi* (syn. *Erysiphe kusanoi*), an Asian pathogen of Celtis trees, was identified on *Celtis australis* in Serbia; and *Microsphaera symphoricarpi* (syn. *Erysiphe symphoricarpi*), known only from North America until the 1990s, is now present on snowberry (*Symphoricarpos albus*) bushes in some European countries.

The threat possessed by the invasive alien microbes in Indian agriculture is reduced crop and livestock yield. The Bengal famine of 1943 is one amongst the several famines that occurred in India and caused by the invasive fungus *Cochliobolus miyabeanus* (formerly *Helminthosporium oryzae*), from Japan in about 1919 affecting the crop resulting in major rice losses. Nearly, 2 million people died and several millions were affected. So far at least 17 major alien plant pathogens have been recorded in India and some are posing serious threat by causing severe crop losses ranging from 70 to 100% with an average of 20% crop losses which is still a significant loss looking at the huge amount of people suffering from malnutrition in India. Banana Bunchy Top Virus is another classical example of microbial invasion causing sever economic losses in India. The Bunchy top virus is believed to have been introduced in India through infected suckers brought from Sri Lanka to Kerala. It was first observed in India in 1940 and by 1943 it had spread to few areas in Kottayam, and now has affected an area of about 3000 square

miles in Kerala. Subsequently, it spread to Tamil Nadu, Orissa, West Bengal, and Assam. Domestic quarantine measures were followed to keep the disease from spreading to other areas by putting restrictions on the movement of the planting material from these states to other states. Another, important invasive crop pathogen of India is the potato late blight pathogen *Phytophthora infestans* of European origin. The disease was first observed in Nilgiris in 1970s and in Darjeeling in 1983. The pathogen is believed to arrive in India with the potatoes initially imported by the Europeans and the disease spread to other places in the hills and plains subsequently. It is a common problem in all the potato growing areas of India causing nearly 70% loss to the potato growers every year once the disease appear with common epiphytotic in Punjab areas. Among the bacterial diseases, bacterial blight of rice caused by *Xanthomonas campestris* pv. *oryzae* is another exotic pathogen of rice migrated to India from Phillipines reported for the first time in 1951 in India. The disease broke out in epidemic form in Shahabad district of Bihar in 1963 and with the introduction of the variety Taichung Native 1, the disease spread in a severe form in 1966 throughout India. Losses due to bacterial blight can reach upto 50%. The other important invasive plant pathogens in India are coffee rust cause by *Hemileia vastatrix* migrated from Sri lanka, flag smut of wheat cause by *Urocystis tritici* migrated from Australia, downy mildew of grapes cause by *Plasmopara viticola* migrated from Europe, downy mildew of maize cause by *Sclerospora phillipinensis* migrated from South East Asia, onion smut cause by Urocystis cepulae migrated from Europe, blast of rice cause by *Pyricularia oryzae* migrated from South East Asia, black shank of tobacco cause by *Phytophthora parasitica* var. *nicotianae* migrated from Dutchland, wart of potato cause by *Synchytrium endobioticum* migrated from the Netherlands, powdery mildew of cucurbits cause by *Erysiphe cichoracearum* migrated from Sri Lanka, powdery mildew of rubber cause by *Oidium* hevae migrated from Malayasia, peanut stripe virus from China, cotton leaf curl virus from Pakistan, and golden nematode of potato cause by *Heterodera rostochinensis* migrated from Europe.

Historically, stem rust of wheat has been the most destructive disease of wheat and barley and has inflicted very heavy losses worldwide. Since the 1950s, resistance genes bred into wheat varieties have held truly devastating stem rust epidemics in check. However, one unusually potent race was detected in Uganda in 1999 (named Ug99), has overcome many of those resistance genes and is marching east through southern Asia. Ug99 first appeared in Ugandan wheat in 1999 and spread to Kenya and Ethiopia during the next few years and has crossed the Red sea as there are reports of its occurrence in Iran at a relatively faster pace than what was expected. Looking into its spreading pattern in a smaller time span, it may arrive in India at any future wheat growing season.

Weeds also pose serious ecological problems; invasive weeds in natural areas are capable of altering ecosystem processes and displacing native plant and animal species. They may also support populations of non-native animals and microbes and hybridize with native species, subsequently altering gene pools. In addition, weeds serve as reservoirs for plant pathogens that impact crops. This source can serve as the initial inoculum for epidemics in crops and can exacerbate existing problems by providing multiple hosts for reproduction. The survival of *Phytophthora capsici* on weed hosts is an example of a difficult-to-control pathogen that can utilize a weed host in the absence of a suitable crop, complicating attempts to utilize cultural control measures for this serious vegetable pathogen. Similarly, the use of plant pathogens to suppress weeds is considered as one of the alternative weed control options for areas or production systems where the use of chemical herbicides is not permitted or feasible or where existing production practices lead to

Table 1: Alien plant pathogens introduced into India

Pathogens	***Disease***	***Introduced from***	***Year***
Hemileia vastatrix	Leaf rust of coffee	Sri Lanka	1879
Phytophthora infestans	Late blight of potato	UK	1883
Urocystis tritici	Flag Smut of wheat	Australia	1906
Erisphe cichoracearum	Powdery mildew of cucurbits	Sri Lanka	1910
Plasmopara viticola	Downy mildew of grapes	Europe	1910
Sclerospora phillipinensis	Downy mildew of Maize	Java	1912
Pyricularia oryzae	Paddy Blast	SE Asia	1918
Xanthomona campestris pv. *campestris*	Black rot of crucifers	Java	1929
Oidium heavea	Powdery mildew rubber	Malaya	1938
Phytophthora nicotianae	Black shank of tobacco	Holland	1938
Virus	Bunchy top of banana	Sri Lanka	1940
Virus	Hairy root of apple	England	1940
Synchytrium endobioticum	Wart of potato	Netherlands	1953
Urocystis cepulae	Onion Smut	Europe	1958
Xanthomona campestris pv. *oryzae*	Bacterial leaf blight of paddy	Phillipines	1959
Globodera rostochiensis	Golden nematode of potato	Europe	1961

(***Source:*** Singh, R.S. and Kaur, J. 2002. Alien plant pathogens in India. In: Biological Invasions, Ed. D. Pimentel, CRC Press, LLC, pp. 159-170.)

uncontrolled weed monoculture. But there lies a potential threat that the introduced pathogen of the weed may infect some other related crop species and cause epidemic at a later stage. Generally, pathogens intended as classical biocontrol agents are subjected to rigorous safety and host-specificity testing under the oversight of the Technical Advisory Group (TAG) on Biological Control of Weeds. Among the most successful is the control of *Acacia saligna* by the rust fungus *Uromycladium tepperianum* introduced into South Africa from Australia. Another widely acclaimed example of success is the use of *Puccinia chondrillina* from the Mediterranean to control *Chondrilla juncea* (rush skeleton) in Australia. Another successful weed biocontrol program has involved the use of a foliar smut fungus, *Entyloma ageratinae* from Jamaica, to control *Hamakua pamakani* (*Ageratina riparia*) in Hawaiian forests and rangelands.

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22 MAY 2009

INVASIVE ALIEN SPECIES

Among the 100 World's Worst Invasive Alien Species the following microbes figure in the list due to the extent of damage they caused:

Aphanomyces astaci (fungus)

Aphanomyces astaci is commonly referred to as crayfish plague. It is a specialised parasitic fungus that infects only crayfish species. This fungus is endemic of North America and it is carried by North American species, i.e. signal crayfish *Pacifastacus leniusculus*, *Procambarus clarkii* and *Orconectes limosus*. The parasitic fungus *A. astaci* was introduced into Europe by imports of North American species of crayfish. Native European crayfish populations are not resistant to the fungus. Since then it has devastated native crayfish stocks throughout the continent.

Common Names: crayfish plague, Wasserschimmel

Banana bunchy top virus (BBTV) (virus)

Banana bunchy top virus (BBTV) is a deadly pathogen which affects many areas of the world-wide banana industry. Infected banana plants produce increasingly smaller leaves on shorter petioles giving the plants a bunched appearance. Fruits may be distorted and plants become sterile before the whole mat (rhizome) eventually dies. The international spread of BBTV is primarily through infected planting materials.

Common Names: abaca bunchy top virus, banana bunchy top disease (BBTD), BBTV, bunchy top, bunchy top virus, *laufeti'iti'i*

Batrachochytrium dendrobatidis (fungus)

Batrachochytrium dendrobatidis is a non-hyphal parasitic chytrid fungus that has been associated with population declines in endemic amphibian species in upland montane rain forests in Australia and Panama. It causes cutaneous mycosis (fungal infection of the skin), or more specifically chytridiomycosis, in wild and captive amphibians. First described in 1998, the fungus is the only chytrid known to parasitise vertebrates. *B. dendrobatidis* can remain viable in the environment (especially aquatic environments) for weeks on its own, and may persist in latent infections.

Common names: chytrid frog fungi, chytridiomycosis, chytridiomycosis, Chytrid-Pilz, frog chytrid fungus

Ophiostoma ulmi sensu lato (fungus)

Dutch Elm disease (DED) is a wilt disease caused by a pathogenic fungus disseminated by specialised bark beetles. There have been two destructive pandemics of the disease in Europe and North America during the last century, caused by the successive introduction of two fungal pathogens: *Ophiostoma ulmi* and *Ophiostoma novo-ulmi*, the latter much more aggressive. The vector is represented by bark beetles, various different species of scolyts living on elm trees. These beetles breed under the bark of dying elm trees. The young adults fly from the DED infected pupal chambers to feed on healthy elm trees. As a consequence, spores of the fungus carried on the bodies of these beetles are deposited on healthy plant tissue. *O. ulmi sensu lato* can also spread via root grafts.

Common names: dutch elm disease, Schlauchpilz

Phytophthora cinnamomi (fungus)

Phytophthora cinnamomi is a widespread soil-borne pathogen that infects woody plants causing root rot and cankering. It needs moist soil conditions and warm temperatures to thrive, but is particularly damaging to susceptible plants (e.g. drought stressed plants in the summer). *P. cinnamomi* poses a threat to forestry, ornamental and fruit industries, and infects over 900 woody perennial species. Diagnostic techniques are expensive and require expert identification. Prevention and chemical use are typically used to lessen the impact of *P. cinnamomi*.

Common names: cinnamon fungus, green fruit rot, heart rot, jarrah dieback, phytophthora crown and root rot, Phytophthora Faeule der Scheinzypresse, phytophthora root rot, seedling blight, stem canker, wildflower dieback

Plasmodium relictum (protozoa)

The protozoa, *Plasmodium relictum*, is one of the causative parasites of avian malaria and may be lethal to species which have not evolved resistance to the disease (e.g. penguins). It may be devastating to highly susceptible avifauna that has evolved in the absence of this organism, such as native Hawaiian birds. The parasite cannot be transmitted directly from one bird to another, but requires a mosquito to move from one bird to another. In Hawaii, the mosquito that transmits *P. relictum* is the common house mosquito, *Culex quinquefasciatus*. Passerine birds are the most common victims of avian malaria.

Common names: avian malaria, paludisme des oiseaux, Vogelmalaria

Rinderpest virus (virus)

Rinderpest virus is a species of morbillivirus causing cattle plague, a highly fatal viral disease of domestic cattle, buffaloes and yaks. It also affects sheep, goats, some breeds of pigs and a large variety of wildlife species. Although humans are not susceptible to Rinderpest, famine devastates human population dependant on cattle and buffalo for their food and livelihood. Mass vaccinations over the last century have greatly reduced outbreaks of Rinderpest. The Global Rinderpest Eradication Program (GREP), which was established in 1987 by the United Nation's FAO to develop strategies of control in high risk countries, will lead to the total eradication of the Rinderpest virus by 2010.

Common names: cattle plague

Looking into the seriousness of the damages caused by the invasive plant pathogens, an ad hoc committee of American Phytopathological Society (APS) was formed in 1999 to address the issue of emerging plant diseases and threatening pathogens. The major activities of the APS ad hoc Committee are to develop a strategy for identifying threatening plant pathogens, prepare a list of newly emerging threatening nonindigenous plant pathogens, and develop a plan for rating the plant pathogens and preparing a "final" list. The committee members rated the pathogens on a 0-to-3 scale: 0, no threat at all if introduced; 1, small threat (could have some economic impact if not controlled); 2, moderate to large threat; and 3, must be kept out at all costs. Average scores were calculated and suggested pathogens with low scores were eliminated. In addition, to combat invasive alien microbes, researches have to be accomplished through a multifaceted approach integrating the disciplines of molecular biology, genomics, population ecology, epidemiology, meteorology, climatology, and microbiology. For dealing with recently introduced or invasive pathogens on a particular locality one need to utilize novel techniques for rapid and accurate assessment of pathogen presence and abundance in the field; quantitative information on distribution of clones, migration of new strains, degree and rates of out-crossing, and sources of resistance to the introduced/invasive pathogens, elucidation of important genetic traits that impact disease development; and increased understanding of factors influencing disease epidemics and generate improved disease forecasting models. Consortium of these techniques along with other new techniques will certainly be able to handle the threat possessed by alien phytopathogens for safety of agricultural crops leading to food safety globally.

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22 MAY 2009

INVASIVE ALIEN SPECIES

Some Invasive Alien Fish Fauna of Northern India

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The organic evolution is a slow process and a series of partial or complete and irreversible transformations of the genetic composition of population based on altered interactions with their environments. Darwin described the evolution as "descent with modification".

According to Darwin a species tends to adopt itself when it encounters altered environment. The dispersal of diversified animal life on this planet earth has taken several billion years. The time of origin of this planet is assumed to be about 5 to 6 billion years ago and present form of biodiversity has taken several billion years to reach today's scenario. The most astonishing evolution has been that of ever invading humans. According to paleontologists humans came into existence few million years ago and in this short span of time they have conquered almost all the niches on earth. Mankind is burdened with the care of the unfit and their genes. The ever growing needs of man have resulted into several experiments with nature. One such experiment is to introduce exotic or alien species to a new environment or to a new geographical area. Such experiments may lead to failure also. The impact of new guest some times (or very often) results in the competition or struggle with local flora and fauna.

The classical example is that of "Jalkumbhi" (*Eichornia crassipes*), which is a weed present in almost all the ponds of India. This was not a native of Indian continent till eighteenth century. During British Raj wife of an British officer brought few plants of "Jalkumbhi" as an ornamental plant in an earthen pot and within a span of two hundred years it has invaded all the stagnant water bodies and also spread in flowing waters.

Another example of invasive species is of Congress grass (*Parthenium hysterophorus)*, which was accidentally introduced in India as a weed with imported wheat grains. Today *Parthenium* is the fastest invading weed on our land. The spread of *Parthenium* is aided by characteristics of their leaves which are somewhat poisonous to most animals.

The growing demand of food has directed man to introduce several fish varieties to new locations, which was not possible without human interference. Some experiments of this kind have been successful but many have created disastrous effect on local fish fauna. The varieties of fish introduced in India include Carps, Cichlids and Catfishes etc.

Carps

1. ***Cyprinus carpio*** (Common Carp)

Phylum: Chordata
Group: Pisces
Class: Osteichthyes
Order: Cypriniformes
Family: Cyprinidae
Genus: *Cyprinus*
Species: *carpio*

Description: Body compressed laterally, moderately elongate, covered with large cycloid scales. Snout blunt, mouth large, inferior. Two pairs of short barbles. Colour: dark on back, golden on sides.

Habitat: *C. carpio* prefers water bodies with stagnant and slow flowing water.

Food: It is a Euryphagous species; consumes zooplankton, vegetable and animal detritus. The food habits change with the age. The young fish feed on plankton, Adults feed more on molluscks, worms, crustaceons, larvae of insects etc. *C. carpio*

is a food competitor with regard to other benthos-feeding fish.

Alien verities in India: The common carp has three recognized phenotype differentiable according to the pattern of scaling-

1. The Scale carp, *C. carpio* var. *communis* with moderately large regularly arranged scales in rows throughout the body. Based on morphometric characters and scaling patterns the scale carp is further distinguished in India into different races/varieties:
   (a.) The Chinese stock or big belly carp: This variety is cultivated in China, Japan, Thailand and Malaysia. It was introduced in Cuttack (India) from Bangkok in 1967. It proliferates freely in the planes of India, wherein it attains maturity within six months. It has two distinct breeding periods in February to March/April and June to July. However it is found to contain eggs throughout the year. Now a days this variety is cultivated throughout the country along with other major carps.
   (b.) The Prussian stock of scale carps. It resembles wild carp in general body colour.
2. The Mirror carp with body unevenly scaled. A few in number large and bright and leaving a large area of body naked. This specie is extensively variable. The Mirror carp was first introduced into the waters of Ceylon from Prussia in 1914, from Ceylon it was brought to the Nilgiris in 1939 stocked in Ooty lake. In 1974 this variety was introduced in Kumaon hills at an altitude of 1524 m from Nilgiries and by the end of 1954 it was introduced in Nainital lake. It has also been reported in planes. It is available in Assam, Bihar, Delhi, Himanchal Pradesh, J & k, Tamilnadu, UP and Uttaranchal etc.
3. The Leather carp, *C. carpio* var. *nudes* with body almost completely naked or devoid of scales except for a single row of degenerated scales.

2. ***Hypophthalmicthys molitrix*** (Silver Carp)

Phylum: Chordata
Group: Pisces
Class: Actinopterygii
Order: Cypriniformes
Family: Cyprinidae
Genus: *Hypophthalmichthys*
Species: *molitrix*

Description: The silver carp is also called the flying carp for its tendency to leap from the water. They can leap 10 ft in the air.

Habitat: It is a type of fresh water cyprinid fish cultivated in China. It has been introduced to, or spread into via connected waterways, at least 88 countries around the world.

Food: The silver carp is a filter feeder with a remarkable filtration apparatus. It mainly feeds on phytoplankton along with they also consume zooplankton and detritus. Silver carp have no stomach and are thought to feed more or less constantly.

Alien verities in India: In India the first ever consignment of 360 fingerlings of Silver carp was brought from Japan in 1959 to Central Inland Fisheries Research Institute at Cuttack (Orrisa). These fishes were first induced breed in 1962. The progenies so obtained became mature in ponds when they were only 11 months old. Later on the fries of Silver carp were sent to different locations in India. It has an adverse affect on the growth of Catla if cultured in large numbers along with Catla young ones. There is only one variety of silver carp found as invasive in India-

Big Head Carp: There is one more species in the *Hypophthalmichthys* genus, the big head (*H. nobilis*). The genus *Aristichthys* is also sometimes used for big head carp, but this genus was based on fallacious theory and should no longer be used.

The big head carp differs from the silver carp in its behavior (it does not leap from the water) and also in its diet. Big head has round abdomen with posterior ventral part of abdomen keeled whereas in Silver carp the abdomen is slightly compressed. Big head was brought incidentally along with Silver carp fry in the year 1959. These are also filter feeders, but they filter larger particles than silver carp and in general consume a greater proportion of zooplankton in the diet than silver carp, which consume more phytoplankton. In at least some parts of the United States, big head and silver carp hybridize in the wild and produce fertile offspring.

Cichlids

Alien varieties in India: There are two verities of alien cichlids found as invasive in India-

1. Oreochromis mossambicus

Phylum: Chordata
Group: Pisces
Class: Actinopterygii
Order: Perciformes
Family: Cichlidae
Genus: *Oreochromis*
Species: *mossambicus*

Description: This is one among "100 of the World's worst invasive alien species". The Mozambique tilapia is laterally compressed, and has a deep body with long dorsal fins. The front part of the dorsal fin is the most inconvenient to handle because it has spines on it. The main coloration is yellow, though coloration is unreliable due to the many different colors of cichlid fish and the many different feeding strategies.

Habitat: *O. mossambicus*, is the Mozambique tilapia. According to Science in Africa, the Mozambique occurs naturally above in the Limpopo River.

In India the first consignment of Tilapia was brought by The Central Marine Fisheries Research Institute in 1952 from Bangkok and second by Madras Fisheries Department in the same year from Ceylon.

Food: The Mozambique tilapia are omnivores that consume detrital material, vegetation with various ranges from diatoms to macro algae to rooted plants, invertebrates, and small fry. Diets vary depending on location. *O. mossambicus* co-occurs with a number of other non-native tilapia species in many of the states that have this Tilapia in them. They were released for the control of mosquitoes but became a nuisance. They are considered filter feeders because they can literally filter plankton out of the water. This can be done by the mucous secreted by the tilapias that trap the plankton. Digestion of the plankton is started by the grinding of the food between two pharyngeal plates.

2. **Oreochromis nilotica**

Phylum: Chordata
Group: Pisces
Class: Actinopterygii
Order: Perciformes
Family: Cichlidae
Tribe: Tilapia
Genus: *Oreochromis*
Species: *nilotica*

Oreochromis nilotica is an important food fish of the Nile and other rivers of Africa and Asia Minor. The Mozambique tilapia is being threatened by the Nile tilapia. Both fish species show similar feeding, breeding, growth and behavioural patterns. They are allopatric in distribution where complete separation has not yet occurred. When the transition of one species into the others habitat occurs the threat of hybrids can occur being in the same species. Never having occurred together in earlier years, both the Nile and the Mozambique had no strategies to evolve from producing hybrids. Thus they created hybrid offspring through mating.

Cat Fishes

Phylum: Chordata
Group: Pisces
Class: Actinopterygii
Order: Siluriformes
Family: Claridae
Genus: *Clarias*
Species: *lazera*
Origin: Thailand, Sumatra

Descrtiption: *C. lazera* (Thai Mangur): This catfish has the ability to wipe out local ponds and "walk" away on land to find a new target area. The Clarias, or Walking Catfish is a large fish from the family Claridae. It has an elongated body with very long-based dorsal and anal fins. Eight barbels outline the mouth. The Clarias catfish can display a large variety of colors including tan, gray, and brown.

C. lazera catfish are illegal in India due to the fact that they can be released by foolish owners into local ponds and take over with their predatory lifestyle and ability to wipe out an entire food chain and then move on to the next pond to continue. A Clarias catfish can attack, kill and eat fish close to its same size. The walking catfish, has an elongate body that is broader at the head, tapering toward the tail. It is readily recognizable as a catfish with four pairs of barbels (whiskers) and fleshy, papillated lips. Color is drab but variable among individuals: olive to dark brown or purple to black on the dorsal surface; pale to white on the ventral surface; and blue-green on the sides.

Habitat: Walking catfish can be found in a variety of habitats, but they are most commonly encountered in muddy or swampy water of high turbidity.

Food: Clarias is a voracious feeder feeding almost on any thing. It can also negatively impact native amphibian populations by preying on tadpoles. The ability of walking catfish to exploit isolated, ephemeral water bodies allows them to access tadpole prey stocks that other fish cannot reach.

Conclusion

The impact of introduction of the above mentioned fish species on local fish population has been tremendous. Although the introduction of silver carp has been successful to some extent but all other introductions have failed disastrously. Bighead and Thai Mangur which were accidentally introduced are playing havoc with local carps and slowly capturing the waters.

Tilapia is a mouth breeder. The male takes the time to excavate a nest, the female then lays her eggs. After the eggs are laid the male fertilizes them. The female then takes the eggs and stores them in her mouth until the fry hatch. According to an article in science in Africa the Mozambique is being endangered by the Nile Tilapia. In all other parts of the world the Mozambique is being identified as a nuisance. *O. mossambicus* has been nominated by the Invasive Species Specialist Group (ISSG) as among "100 of the World's worst" invasive alien species. *O. mossambicus* pose threats to local native populations through competition for food and nesting space interaction may reduce the biodiversity of the native fishery due to reduction of food availability and by the native fish being eaten as prey for example the larval stages. Never having occurred together in earlier years, both the Nile and the Mozambique had no strategies to evolve from producing hybrids. Thus they created hybrid offspring through mating. Recently Tilapia has escaped captivity and fingerlings have been reported from river Yamuna which is not a good sign as it has an edge over local fish fauna in showing parental care of young ones and one day it may become another "Jalkumbhi".

INTERNATIONAL DAY FOR BIOLOGICAL DIVERSITY

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INVASIVE ALIEN SPECIES

Using Potentially Invasive Alien Species Eisenia Foetida for Vermiculture: A Threat to Local Biodiversity

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Vermiculture in India is a recently promoted practice of employing '*earthworms*' for production of '*Vermicompost*' a manure said to be useful for farming and doing wonders to farm produce both qualitatively and quantitatively. It is also claimed to improve soil health and projected by marketers of the '*worm-technology*' as a cosmetic '*soil-conditioner*'.

Any species when introduced in a new habitat should be able to live in harmony with other species without disturbing or threatening other species of the niche. If the introduced species breeds faster than their local counterparts, competes for food with other species and harms or threatens any other species, then it is potentially Invasive-Alien-Species.

A number of reports exist in literature on transmission by earthworms of a variety of plant, animals and human pathogens. In animal husbandry, the epigeic earthworms are a threat as they are carrier of many diseases of poultry, piggery and duck farming including Foot-and-mouth disease of cattle. The coelomic fluid of *Eisenia foetida* has been found to be toxic to vertebrates. The birds and other predators that prey on earthworms are known to be killed. Heavy metals deposits have been found in kidneys of birds killed after predation on earthworms. Chemical changes which occur in the ingested material during passage through alimentary canal of earthworms render various metals more available to plants. Mineralization of earthworm body will release such concentrated heavy metals into the environment and food chain. This phenomenon of bioaccumulation and biomagnification of heavy metals and bioavailability after mineralization into food chain makes them a threat to biodiversity. Similarly, pesticide residues, radio-active materials and hazardous chemicals have been found to be stored in earthworm body for long durations and magnifying their half-life and increasing risks.

In 1982, during the conference '*Earthworm Ecology From Darwin to Vermiculture*', in England, it has been reported that the bait market in North America has found that neither *Eisenia foetida* nor *Eudrilus euginae* are desirable as fish-bait. *E.a foetida* has typical garlic-like unpleasant odour making it unsuitable as fish-bait and being smaller in size does not stay on fishing-hooks and remain as active as other species. The worm casting does not qualify as a field fertilizer because it contains less N, P & K than mandatory requirement in North America. The buy-back worm scam have opened up several cases of defraud in Ontario, Canada.

The *E. foetida* and other exotic species of earthworms have every potential to become an Invasive-Alien-species and it is essential to check their spread and resulting damage to biodiversity. The present Indian legislative measures should be strengthened to control these activities and check the entry of such '*Biological weapons*'.

Earthworms in nature remain in soil in the upper crust of humus and contribute in recycling and redistributing the nutrient maintaining equilibrium and retain soil characteristics. Native

earthworms play an important role in maintaining characteristics of ground water aquifers. As during percolation of water to aquifers, their presence in sub-soil region acts as a natural sieve for trapping hazardous substances from water like heavy metals Cadmium [Cd], Arsenic [As], etc. and retain these harmful heavy metals in their body. The tolerance level of earthworms to these hazardous metals is much higher to mammals and these metals are stored in their body in combination with metallothioneins inside the glandular epithelial cells of epidermis and intestine for long durations. Thus, by acting as a natural sieve, earthworms help in maintaining water quality of ground water aquifers.

The notion that farmlands are having little or no population of sub soil fauna or earthworms is based on the fact that continuous cultivation and ploughing is responsible more for the loss than chemicals only. Ploughing or mechanical tillage damages the natural habitat of earthworms and up to 50% population could be reduced in a single operation. The amount of organic matter present in the soil is also a controlling factor for earthworm population.

Vermiculture is a technique, in which worms are reared away from their natural habitat, in artificially promoted conditions for producing humus like substance. In this process, first step involves using pesticides to protect earthworms from their natural enemies and predator insects like ants, cockroaches etc. Then, exotic species of earthworms *Eisenia foetida*, *Perionyx excavatus, Lumbricus terrestris*, *Eudrilus euginae* etc. are introduced in artificially created pits, windrows, bins etc. The food available to indigenous species of earthworms is provided to these worms in favourable conditions. This creates stress conditions for local fauna, flora disturbing biodiversity and threatening local worm population and fauna of their existence. It has been reported that lumbricids (members of the family Lumbricidae to which these worms belong) have a better ability to adapt to new environments than any other Oligochaetes, and that once introduced into an area 'frequently cause the disappearance of the endemic earthworm fauna'. No lumbricid species has been known to have colonized tropical lowlands anywhere and when introduced in large numbers, has never survived. This practice of vermiculture, if practiced on a large scale is bound to create pressure on local biodiversity and cause irreparable damage to nature. The exotic or foreign species of animals have created havoc to local biodiversity. Like loss of seeds of our indigenous varieties of staples and food grains, local fish population has been greatly affected by introduced species of culturable/cultivable fishes. The native honey bee population is greatly affected by introduction of Italian species of honey bee. We are already facing the problems with exotic weeds like *Parthenium, Lantana*, *Phalaris, Ipomea* and *Mimosa* etc. It is reported that in United States of America more than 100 species of animals and plants have been categorized as 'Invasive-Alien-species'. UNEP has recognized this phenomenon as second biggest threat to biodiversity after loss of habitat. The tendency to look on foreign country for remedy for all our maladies has threatened our culture and biodiversity. Attempts should have been undertaken for improving performance of our native species of animals by adopting better rearing conditions and breeding technology.

In agriculture, use of earthworms was envisaged by Europeans in new settlements in temperate climate. In the snow capped temperate regions, the process of bacterial decomposition is either very slow or absent. As the sub-soil fauna is also very thin, natural recycling of nutrients is affected. In temperate forests, leaf litter under the tree remains for a long time. Earthworms when introduced in new world caused quick disappearance of leaf litter under the trees. This introduction of European species of earthworms in North America has caused rapid decline in population of some forest plants and threatened their existence.

In India, the concept of vermiculture is alien to our practice of agriculture, since, 1960s with the onset of Green revolution, modern practices of agriculture were adopted. These practices were adopted without proper care and infrastructure and rarely followed the prescribed recommendations and dosing of agrochemicals. Improper use of agrochemicals in excessive doses and without proper safety measures have led to loss of biodiversity and resulted in decreasing fertility of the soil. This has created warning bells to policy makers. In mid 1980s certain vested interests have propelled the vermiculture technology claiming as a remedy for all the maladies. Till now, as earthworms being silent creatures in their natural habitat, lacking any biting or cutting appendages and toxin release mechanism are not considered as a threat in any way among Indian masses.

All these claims that vermiculture is eco-friendly though appear very soothing in this 'chemically induced atmosphere' are far form truth and can not be substantiated by facts either in practice or in reasoning. The enormous literature being published by vested interests lacks any substantial facts based on scientific research undertaken by accredited laboratories with GLP norms. More of it is based on hearsay or whims and vested interests rather than basic scientific observations acceptable to scientific community.

Vermiculture being labour intensive and requires a lot of efforts is not easy to practice in rural India. With increasing cost of labour and other inputs it is bound to increase the input cost of agriculture. Tall claims made by promoters of high Nitrogen contents in vemicompost were never substantiated with scientific evidences. Earthworms belong to group of ammonotelic animals, secrete ammonia as excretory product. This ammonia being in gaseous state readily escapes into atmosphere, when they are reared in open. Thus, earthworms are responsible for depleting nitrogen content from surrounding. The worm casts produced by vermiculture have very little shelf life and more or less useless to be used as manure in farmlands. In sub soil habitat, this ammonia is available to root zone 'rhizosphere' and helps in plant nutrition.

The emphasis being given to 'organic agriculture' or 'sustainable agriculture' or farming with natural resources or low-inputs' has nothing to do with vermiculture as this is neither 'natural' nor eco-friendly as it poses threat to biodiversity and nature. In Uttar Pradesh, non-standard practices of vermiculture employing exotic species have cropped up from all nooks and corners without proper check and control measures. This is bound to create disturbances in faunal biodiversity as all these worms have higher metabolic rates and having high rate of reproduction. The malpractices using these worms have gone up to the extent of repaying debts to public sector organizations amounting to several lakhs of rupees. Several cases of fraudulent activities involving vermiculture up to the tunes of several million dollars have been reported from USA & Canada.

Native species of earthworms in their natural habitat are helpful to farmers and mankind. They contribute in recycling of nutrients in the soil. By their movements and physical activity, they maintain soil aeration and porosity and maintain equilibrium. Every attempt should be made to retain this equilibrium in nature. Mulching, green manuring, application of Farm Yard Manure, reduction in use of agro-chemicals and pesticides are some of the steps which will help in sustaining sub-soil fauna and maintaining eco-system of farmland essential for successful organic agriculture.

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INVASIVE ALIEN SPECIES

Eco-Restoration of a Degraded Land :A Case Study

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I joined TERI in July 1986 after taking retirement from U.P. Forest Department. I decided that my first priority was to rehabilitate the field site of TERI. This site is located at Gual Pahari in the State of Haryana on the Aravalli hills at 77°12'E longitude and 28°35'N latitude. The altitude of highest point is 255m.There is an abandoned agriculture land. The area receives an annual average rainfall of about 500mm. The Aravalli range of hills is the oldest mountain range of India. It came into existence at the close of the DHARWAR ERA. The Aravallis themselves are now no more than the stumps of a once lofty range. They reach their maximum height at Mount Abu (1722m) in the South-West, sink to low hills in the Jodhpur-Jaipur saddle and rise again to the North-East. These cover the present day States of Rajasthan, Uttar Pradesh, Haryana and the Union territory of Delhi. The last spur of the Aravallis reaches as far as the Ridge of Delhi. The main profession of the residents of these areas has been keeping cows for dairy products since the times of Lord Krishna. Lord SRI KRISHNA was born on July 21, 3228 B.C. (8th day of Bhadrapad Krishna Paksh) and died at age of 125 years on February 18, 3102 BC at 2pm. This long practice of unregulated grazing is responsible for heavy soil erosion and the formation of Ravines. The site has three prominent features.

Stratum I :

Top most area: Part of this area consists of rock out crops but was then largely a flat area with active sheet erosion and with little vegetation. The whole surface looked white due to heavy accumulation of salts. There was, a masonry well, at the site, which had not been used for many years. I had the water of the well tested. The pH of the water was 8.6and was unfit for irrigation. The springs of the well had dried up. The well was cleaned up manually through local professionals. After removing the debris to about 2m depth the springs became active. The water discharge was however very low. A pump was installed the water was collected in an overhead tank and measured quantity of H_2SO_4 was added to bring down the pH to 6.5.The whole area of the intended Nursery was frequently flooded with this water. 0.2% H2SO4 was also used to neutralise the salts from the Nursery site. The operation continued for several months till some natural vegetation reappeared. The nursery area was planted with light crowned species like *Peltoferum feruginum,* Neem, Aonla, *Cassia siamea*, etc. at spacing of 8m*5m to provide shade and reduce surface evaporation. Seed sowing in the nursery was started in September 1986. In the adjoining area in 1987, *Dendrocalamus strictus* in combination with *Acacia nilotica*, and *Casuarina equisetifolia*, were planted. Inland variety of *C. equisetifolia* was used; Frankia infection was added for establishment and growth. The spacing for bamboo was kept at 6m*5m and for trees at 3m*2.5m. Bamboo seeds were obtained from Mirzapur in U.P. This bamboo has the characteristic of tolerating drought, is almost solid and has a flowering cycle of 26years. Prior to planting the upper layer of the soil was tested. The pH of the soil was 8.4 and Organic Carbon varied from 0.19% to 0.36%.. Natural weeds that came up in the area were not removed. Weeds consist of plants that tolerate the climatic conditions. Weeds die out in time and provide bio-mass that adds organic matter to the soil and improves the fertility. *Cassia tora* was the first plant to appear at the site along with some grasses. It was followed by *Indigoferra trita*. There was no water available for irrigation. The lack of water forced the plants to send down the tap- root.

There was some mortality in *Casuarina* trees but bamboo and babool tolerated the drought and the adverse edaphic conditions satisfactorily. The plantation got established by 1990.

Problems: Initially grazing by live stock was a serious problem. This was controlled by strengthening the barbed wire fencing. A bore-well was dug at this site and a diesel pump set was installed for providing irrigation. Initial depth of the bore-well was 25m. During the first summer season the level of the bore-well went down by 6m. The boring was deepened by about 6m and the pump assembly was accordingly shifted down. After another dry season the water level went down further and the bore-well was abandoned. By this time the bamboo and trees were about five years old and did not need any irrigation.

Solar Pump: During 1989 TERI received some Solar pump systems as a donation from a foreign country. One such system was set up at Gwalpahari. The solar panels used *amorphous Silica*. The system provided a steady source of irrigation. The discharge was low but it was available for about 5 to 6 hours continuously during sunny days. The system worked without any trouble for about 18 months. After this time the Alternator and the submersible pump started malfunctioning. The alternator was locally repaired but the pump was completely worn out. The pump was replaced by a spare one, which was supplied by the manufacturers. It became clear that the pumping system involved very high cost of maintenance and was not economically viable in the long run.

The problem of damage by Rats: After the establishment of bamboo and trees the rats appeared and started cutting the roots of babool trees. Such trees would lodge on the ground. The damage was caused during the night. Every morning some trees were found lodged on the ground. I did not want to use any rat poisons. I got the trees firmed up and rammed the soil around the root system. After about one year some snakes were seen at the site. One worker was bitten by a snake. He was sent to the hospital and became, alright, after treatment. I however ordered the staff not to kill any snakes. The rat population started declining and damage to trees almost stopped. After about one year I saw some peacocks on the site. One day a snake was found dangling in the beak of a peacock. The rat damage as well as the snake fear had disappeared. It appeared that, a biological equilibrium was established The trees and bamboo were shedding large quantity of leaf litter and the site was recovering fast. The organic carbon level in 1994-95 had increased to 0.86% and pH had gone down to 7.84. After bamboo clumps had established, I selected, six clumps, that produced 30 new culms each year. These were then cloned through culm cuttings and were planted in a statistically designed experiment. The early indications appeared to show that these clumps may provide, the future genetic material, for increasing productivity of the site.

Stratum II:

Ravine land: This consists of badly eroded slopes. The site had very little natural vegetation that consisted of tufts of Munj grass (*Erianthus munja*), scattered trees of khejari (*Prosopis cinararia*), Kairi (*Dichroostachys cinerea*), Reonj (*Acaci lleucophloe*) and Chamror (*Eheretia laevis*). The common shrubs were *Croton bonplandianum*, I*ndigofera trita, Tephrosia villosa, Leptadenia spartium, Randia tetrasperma, Calotropis procera* etc. The plants were scattered and badly damaged due primarily to biotic pressure. This area was under active soil erosion. Gully plugging and planting of tufts of Munj grass was carried out. The site was very variable. At most places the soil depth was very shallow. In such portions direct seed sowing was done. The matching of site to the species was most essential. The work was started in 1989. Prosopis juliflora, Acacia nilotica , Kanju (*Holoptelia integrifolia*), Kathsagon (*Haplo-phragma adenophyllum*), Roira (*Tecomella*

undulata) etc. were the principal species sown and planted in this area. By 1992, the area was, reasonably covered with vegetation. Some species started sprouting naturally either from root suckers or from seed brought by insects and birds.

Stratum III:

Water-logged site: This site got water-logged annually during the rainy season. After drying up of water the site showed heavy salinity and alkalinity. During winter months it became a frost hole. The site contained some grasses like *Typha elephantina* in the lowermost area and *Imperata cylindrica* and *Saccharum spontanium* in the upper portion. After water receded, in November 1989 Jamun (wild variety) and Arjun were planted. The planting was gradually extended as water receded. The root system was established by the next rainy season. During the next rainy season the plants were submerged under water and only the leading shoots could be seen outside the water. During the summer months the accumulation of salts caused some mortality. During subsequent winter months planting were resumed mostly with Jamun as Arjun did not show good growth. I found an interesting adaptation by Jamun plants. After the plants had established in three years they started developing dome shaped crowns. They adopted this shape only in area where salt formation was severe. The area soon got completely shaded. With very little evaporation from the site the salt formation almost stopped and the process of natural restoration of the site was set in motion.

Imperata cylindrica areas : In the area where *Imperata cylindrica* had a foothold neither Jamun nor Arjun showed satisfactory growth. After trying out several species I found that Kanji (*Pongamia pinnata*), not only grew well on such sites but it suppressed *Imperata*. Gradually *Imperata* completely disappeared from this area.

Populus euphratica: During the winter of 1991, in a portion of the remaining area, trial planting of *Populus euphratica* was started. Root -suckers, sets and Entire transplants were used. The planting material was obtained from Pakistan where this species grows in the flood plains of river Sindh and covers large tracts. Only six cuttings (three male and three female), were initially obtained. These were multiplied in the nursery. This variety tolerates the conditions of water logging as well as drought. It also tolerates occasional frost, which also is a characteristic of this site. The species spreads fast through root suckers. I found the plants sprouting through root suckers as far away as 10m from the mother plant. Trees older than five year old , were felled and were tested for their paper pulp quality. The wood was found to be suitable for making paper pulp

Neem Kala Siris and Bamboo: Neem (*Azadirachata indica*) and Kala siris (*Albizzia lebbek*) were planted in 1988 on a suitable site in combination with *Dendrocalamus longispathus*. Neem trees were heavily attacked by fungi and repeatedly died back. I had to use Bavistin, a systemic fungicide to control this attack. After about six years, the Neem trees picked up growth. Kala siris was badly attacked by some borers during spring. The trees started oozing out a gum. The insects got drowned in this gum and were killed. The insect attack again started in the next season but the trees reacted again and the attack was controlled. After two seasons the trees started growing healthy and there was no further attack.

Irrigation of forest plantations: Surface irrigation; flooding or sprinkler; in the growing season, increases growth of trees. However in semi arid climate it induces surface rooting and inhibits the growth of tap- roots. The trees lodge after growing well for some years. The evaporation of the surface water also induces salts to come up on the surface. I tried a novel system of irrigation. I planted Babool trees at a spacing of 3m*2m. Sprinkler irrigation lines were aid in the middle of 3m rows but the sprinkler nozzles were fixed

35 cms below ground. The objective was to provide water far from the root system to force, the roots to spread and 30cm below ground for the roots to go deeper. The trees grew healthy with strong taproots. The installation of the irrigation system and the running costs are no doubt high, but the system produces better growth. The system avoids lodging of trees as well as formation of salts. After establishment the system can be shifted. More trials with this system are needed to work out its practical feasibility.

I left TERI in 1994-95. By this time a man-made forest had been raised over 25 hectares. A sustained annual yield of about 15 tons of grass, bamboo and wood was expected from this asset. Income from the forest produce showed gradual increase over the years.

Financial Year	*Forest Produce*	*Quantity*	*Sale Price*
1988-89	Munj grass	Lump sum	Rs 2500.00
1989-90	Munj grass	Lump sum	Rs 5000.00
1990-91	Munj grass	Lump sum	Rs 10000.00
1991-92	Munj grass	Lump sum	Rs 15000.00
1992-93	Munj grass	Lump sum	Rs 20000.00
	Bamboo culms	2000 culms (approx 3tons)	Rs 8000.00
1993-94	Wood (thinning)	5.0 tons	Rs 1500.00
	Bamboo culms (appox 3.5 tons)	2000 culms used internally	
	Munj grass	Lump sum	Rs 25000.00
1994-95	Wood(thinning)	50 tons	Rs 15000.00
	Munj grass	Lump sum	Rs 29000.00

The above table indicates that the income showed steady increase. The centre was expected to become self supporting in due course. This could also become, a training ground for rehabilitating similar sites. At present it is like an oasis as the surrounding areas are devoid of almost all tree vegetation. It needs to be professionally and scientifically managed following the well -known principles of forestry.

Conclusion

The degradation of hill -sides is invariably caused by mismanagement of the ecosystem over several centuries. Use of appropriate technology and patience, has restored the site. This has shown the way, how it can be done. The sites are variable and there were many problems. The typical site includes the ridge top with active sheet erosion; the ravine land with active gullies as well as water-logged site with heavy salt formation during summer and severe frost during winter months besides water logging during the rainy season. It took about 8 years to start the process of natural restoration. The top portion used Babool and Male bamboo as the principal species. The water- logged site was rehabilitated using Jamun and *Populus euphratica* as the main species. The ravine land used many species like Neem, Kala siris, Kanju, Kathsagon, Khejari etc. The rehabilitated site will need proper management all the time as new problems will keep arising.

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INVASIVE ALIEN SPECIES

Livestock Development and Conservatin of Genetic Resources

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Livestock and Development:

India has limited land, but has a very large population of humans and livestock. The pressure on land is far in, excess of what the land can bear, with the result that, at one end, plant life is over used to the extent of desertification and at the other end, livestock does not get adequate feed. Livestock with a low nutrition level does not produce optimum output, and consequently larger numbers of livestock are kept for milk and work. In order to ensure adequate food-grain production and green fodder for livestock, productivity of land has to go up. Concurrently, productivity of livestock will go up. If healthy, well-fed animals are used with improved equipments and processes. India can get increased output from lesser number of livestock, thus reducing burden on land. The gravity of the situation can be gauge from the fact that India, with about 2 & of land area in the world, is maintaining nearly 17% of the world's human population and about 20% of the livestock. Livestock-Man ratio is 1:2 in India, and is less in all countries. The situation is grave which calls for urgent measures for rectifying this imbalance.

Among the animal species, 'Livestock contributes directly to Man's sustenance and progress. Man and Livestock are both dependent on land sustenance. Increases in population industrialization, urbanization etc. are putting pressure on the limited land area available, giving less and less pasture land for animals. In order to provide adequate food grains at a reasonable level of nutrition and to feed the increasing human population, agricultural production has to be increased, which required additional land for agricultures as well as more intensive agricultural production in the same area. Concurrently, demand for products of livestock and/or increased output from the existing livestock. A variety of factors have thus disturbed the balance in the Man-Livestock-Land relationship. In order to restore this balance, productivity of both livestock and land has to go up so that more output could be obtained for the increasing human population from the same population of livestock and available land area. At the same time while livestock should not over-graze and denigrate land, available land should provide adequate feed for livestock.

Livestock Sector has been neglected and given much less attention than it deserves, in terms of investment and application of technology and management, which has resulted in many-sided inter-active ill effects. This is in spite of its vital importance to economic and social development. Research work carried out during the last two decades show that such neglect has led to many-sided economic losses and other tangible and intangible ill effects. Livestock is treated as part of agriculture. Agriculture provides food in the form of grain, fruits, vegetables, oilseeds, sugarcane etc. Livestock gives milk and meat directly as food, helps in the production of food-grain, supplying dung as organic manure and muscle power of draught animals (DA's) for land preparation and other agricultural operations. Therefore, there is an organic relationship between agriculture and livestock.

Conservation of Livestock Genetic Resources:

The purpose of human civilization and animal domestication over thousands of years, the isolation of animals and natural barriers led to the formation of many species/breeds/lines with

special adaptation for species purposes all over the world. Very few species of livestock and birds have been domesticated by man, however, within these few species, there are many breeds each having the special features and adaptations developed over thousands of years of domes-tication in different environmental niches. India also possesses abundant and diverse forms of livestock genetic resources providing ample scope for tapping this genetic diversity for improvement of the livestock. This large biodiversity was the farmers and also contributed significantly through different products to the large human population of the country.

India has 27 cattle, 8 buffalo, 42 sheep, 22 goat, 8 house and 7 camel breeds. 18 breeds of indigenous diverse germplasm such as pashmina goat, yak and mithun. India has contributed historically to the world animal population in different ways viz. The Red Indian Jungle fowl is the progenitor of the modem commercial layer and broiler breeds of ducks in the world. Jamnapari was the male parent of Anglo-Nubian goats, Sindhi, Sahiwal, Ongole, Kankrej and Gir have contributed to the dairy and meat breeds of the world. However, the established breeds of livestock make up only 18 per cent of the total livestock population, while the remaining animals especially in cattle and buffaloes have not been characterized and are termed non-descript/desi.

The number of animals in each pure breed among the different livestock and poultry is steadily declining over the past few decades, although the livestock strength in total has not altered much. Two basic reasons afforded for this are (i) use of exotic breeds mainly in cattle, sheep and poultry, and (ii) mechanization in agriculture. Before one thinks of conservation of the different breeds which are declining in numbers or facing extinction, one has to realize the fact that these indigenous animals and fowls have existed in particular ecological systems over many centuries of years.

They have adapted themselves to particular agro-climatic conditions and management practices, which have endowed them with abilities of (i) heat tolerance, (ii) disease resistance, (iii) subsistence on sparse feeding resources and poor nutrition and (iv) existing under extreme conditions of climate. The local fowls are hardy, disease resistant, heat tolerant and good brooders. Any attempts to improve the domestic animals have simultaneously paced some of the indigenous germplasm at risk. Introduction of exotic breeds and extensive artificial insemination practices have resulted in crossbred animals which have lost some of the innate and advantageous attributes of their ancestors. Moreover, the crossbreeds generated need better management including nutrition and health coverage which are additional burdens on the common man, whose own economic situation has not improved much over the same period. Added to this, the conversion of land for commercial crop productivity as well as~ for housing of the ever increasing human population has limited the natural grazing land earlier available for the domesticated livestock.

All these factors acting together has resulted in the decline of the indigenous livestock and poultry resources. Among cattle breeds, Hariana, Rathi and Nagori in the North, Malvi and Nimari in Central India and Hallikar and Amrithmahal in Karnataka have reduced in numbers drastically, mainly due to mechanization of agriculture. The fate of many other breeds is not known simply due to the fact that there is no information is available on them.

Toda buffaloes in the Nilgries of Tamilnadu, with a population of less than 50,000 and Bhadawari buffaloes (yielding 10-13 % butterfat) in the Tarai region of Uttar Pradesh with a number of less than 5,000 are in a similar predicament.

In sheep the migratory nature of this species along with the indiscriminate use of rams of one breed to improve the performance of the other

breeds has also resulted extreme decline on their population for eg, Malpura and Sonadi, urbanization and land coming under commercial agriculture has again been the main cause for the decline in the population of different sheep breeds.

Although some of the established breeds of livestock such as Tharparkar cattle, Murrah buffaloes, Bannur and Nellore sheep, Jamnapari goats, etc., exist in large numbers at present, inadequate programmes to improve genetically and maintain these animals can also decline in their numbers with the possibility of facing extinction over the next several decades. Ultimately, India will be left with nameless varieties of animals and fowls with no distinct or characteristic features.

Animal genetic diversity is a part of earth's natural heritage. The loss of unique breed is an irreplaceable reduction in the natural profusion of life forms. Breeds with unique physiological or other traits are always of great interest. Many indigenous breeds have special adaptive traits mentioned earlier. Man has depended on domestic animals for his material (food, fiber and finance), cultural and scientific needs. Scientific study of animals will also contribute to a greater understanding of man himself and nature. It is likely that many animal products will be needed by man for a long time yet. Also, as man's condition changes (standard of living technology and fashion), his needs may alter greatly. Therefore, it is wise to converse and ensure the continued availability of the genetic resources in our domestic animals.

Methods of Conservation and Future Strategies:

The objective in conservation and improvement should stress not only on economic traits but also at the reproductive efficiency and survivability in a given eco-system. Policies for genetic conservation and those for genetic improvement (selection programmes for commercial exploitation) have opposing objectives. Commercial livestock system are likely to result in genetic uniformity, wherein further improvement is not possible. These two policies can be made compatible and genetic loss resulting from selection programmes can be minimized. The technique advocated to maintain genetic variability include the use of high ration of males to females breeding stock, and the application of random breeding system. These are intended to minimize genetic drift and inbreeding, which are the feature of small, close population and to prevent genetic slippage in populations subject to artificial selection pressures. Indigenous germplasm imminent danger may be preserved in the form of (i) live animals, (ii) cryogenic of germplasm or (iii) Storage of DNA.

Maintenance of the breeds in small numbers as nucleus breeding herds especially in the Government livestock, farms, research institutes and with breeders at field level in the respective breeding tracts could be considered immediately. Other methods of conservation are cryo-preservation of gametes or embryos, embryo preservation, multiplication and transfer and in vitro fertilization. Other newer methods like embryonic stem cell, micromanipulation of embryos, sex identification and strangeness have opened up newer avenues, but these have to be made cost effective.

- There is a need of evaluation of indigenous animal genetic resources along with strategies for their conservation & sustainable management.
- Conservation is positive, embracing preservation, maintenance, sustainable utilization, management & enhancement of the natural resources of the environment.
- The gene resource of farm animals consists of genetic variation between & within the breeds of the various species. The extinction of breeds thus results in the reduction of genetic variation within a species.

Livestock / Poultry Breeds at the risk of extinction :

Species	*Breeds*	*Population*	*Present Status*
Buffalo	Wild Asiatic	<2000	Decreasing
	Bhadawari	<20000	Decreasing
	Toda	<5000	Decreasing
Cattle	Shiwal	<10000	Decreasing
	Red Sindhi	<5000	Decreasing
	Punganur	<1000	Almost Extinct
	Vechure	<500	Near Extinction
	Ponwar	<15,000	Decreasing
	Krishna Valley	<15,000	Decreasing
Sheep	Breeds of J & K	Few hundreds of each Breed	Nearly Extinct
	Nilgiri	<2000	Endangered
	Hissardala	<500	Rare
	Pugal	<10,000	Endangered
Camel	Bacterian	<100	Critical
Poultry	All indigenous poultry except Aseel and Kadaknath	Few thousands each	Nearly Extinct
Goat	Jamunapari	<10,000	Endangered
	Beetal	>10,000	Endangered
	Changthangi	Around 8000	Endangered

Upgradation, modernization and better management of the Livestock System will enable us to tap the full potential of livestock by way of increased agricultural production, rural transport capability, employment earnings and pace of rural development. In addition, it would help to reduce wastages, pollution, soil degradation, desertification, suffering of animals, etc. The rate of return for incremental investment may be as much as 100%. One of the main reasons for neglect is lack of awareness among leaders, public at large. In fact, livestock and adjunct equipments are the main instruments of production of about 60 million small and marginal farmers. Because of its low productivity, these poor farmers are eking out only subsistence level earnings, which is mainly responsible for the persisting poverty in the country in spite of massive investments on agricultural and rural development during the last four decades. Therefore, from every point of view, including poverty alleviation and upliftment of the disadvantages sectors, it is essential to assign a higher priority to livestock in planning the economic agenda for the country's development.

The massive demand of milk from the urban population has compelled the Government to

launch the Operation Flood Programme through the NDDB., Repeated breeding results in ill health, infertility and susceptibility to diseases in cattle. Indian cattle breed, such as Amrit Mahal, Hallikar, Ongole and Kangayan are well known, little has been done in recent years towards their development. In fact, Indian cattle are really a draught variety, with milk being given a byproduct status. It is apprehended that the overwhelming enthusiasm for milk production has led to the neglect of the draught characteristics in the breeding programme. According to Dr. D.S. Balain former Head of the Animal Genetic Resources, the Ongole breed of cattle has already disappeared in India and is reportedly found only in Brazil, where it was imported from India (Source - Seminar Journal). Dual purpose breeding retaining the draught characteristic has to be encouraged.

Poor feed and nutrition is a major factor affecting the quality of livestock. In spite of the research and development and extension programmes, there has been no significant increase in feed resources. A large proportion of feed resources are of poor quality pastures, crop residues, straw, etc., which are low in protein and energy. India has 20% of the world's livestock population, but has hardly 2.5% of the world's land area. About 12m hectares land area is classified as grazing land, which is inadequate for the 400 million livestock. Increase in human population, urbanization and industrialization has resulted in serious shrinkage of grazing land, causing pressure on remaining pastures and forests. According to estimates from satellite pictures, India is losing forests at the rate 1.3 million hectares a year. Overgrazing mostly by sheep and goats damages vegetation. Sheep and goats are being encouraged on the assumption that it would not affect environment and pasture. Shortage of pasture land on the other hand has affected the fertility and productivity of livestock. A large population of livestock is thus not sustainable under the existing resource constraints.

Therefore, it is recommended that high priority is given to increase production of fodder and the development of grassland, pasture and the animal feed industry in the development programmes of the country. Export of oil cakes and raw materials that go into the production of animal feeds should be reduced, if not stopped. Agro-forestry practices, intercropping, growing leguminous fodders, and increasing area for fodder cultivation on marginal land. Improving quality of straw with alkali/water treatment, use of agro waste from food processing, supplying concentrates to farmers, stall feeding, etc., are some of the measures whereby livestock can be kept in a better fed condition.

Bullocks constitute 88% of work animals, supplying the bulk of motive power for agriculture, buffaloes 9%, mainly in Andhra Pradesh, Haryana, Punjab, Orissa, & Kerala. Buffaloes are kept more for milk than for work; buffalo power in the country has not been tapped much for draught purposes. The available census of buffaloes shows depressed sex ratio of male to female. About 8 million male calves are killed at birth, which can be raised for work. Cows account for hardly 2% of work animals. Mechanization of ploughing and the use of mechanized transport system in rural areas have not reduced the number of DA's. The number of DA's required in agriculture depends on the type of soil, the cropping pattern, duration of season for ploughing and sowing and the extent of use of lift irrigation. The number of bullocks employed is closely related to the number of cultivators and to the average size of holdings.

A : **Percentage of milk obtained from bovines in India**

Particulars	%
Indigenous Cow	: 57
Cross breed Cows	: 5
Buffaloes	: 38

B : **Contribution of buffaloes and cows to the total milk production**

	%
Buffaloes	: 56
Cows	: 44

C : **Milk Production Trends in India 1970-1992**

	1970	1992
	(in million tons)	
Cow	16.40	31.00
Buffalo	13.80	30.00
Goat	0.61	2.00
	30.81	63.00

Animal Welfare:

The importance of the welfare of livestock may be viewed from different perspectives - economic, ecological, social, cultural and emotional or affective. Livestock have contributed a great deal to human civilization. Humans and domestic animals are mutually dependent and human progress depends on the utilization of animal and natural resources in a balanced way. Human self-interest alone could provide sufficient impetus for proper animal care. Therefore measures are necessary to foster the care and welfare of livestock.

Livestock has been Considered as an economic resource providing food and work and other products useful to Man. However, animals are sentient beings, like humans, and experience pleasure and pain. Any civilized society that uses animals for its own purchases ought to take this factor into consideration. Ideally, Man ought to use animals without causing pain or injury to them. In practice, Man has not been fair to animals; he has been cruel to them right from the beginning of civilization and even now, some societies and cultures, like the Indian Society, consider animals as partners in progress and even revere them. There are other societies that consider them as created for Man's use, and hence they do not have humanistic feelings towards them. Therefore in any discussion of Livestock for Sustainable Development, the animal welfare issue should be discussed from economic, ecological, cultural and spiritual points of view. It must be noted that animals were the first inheritors of the Earth, and Man came later. Further, Man needs animals, while animals, in fact, can do without Man. But such theoretical and sentimental considerations have not made Man humane in his treatment of animals. He has been ruthlessly exploiting them and continues to do so. This is done by the educated and effluent sections as well as by the poor and ignorant.

Promoting growth and increased domestic as well as international competitiveness of the livestock sector would assume greater dimension on the adoption of improved technologies and the improvement of domestic production and marketing efficiency for ensuring profitability. These activities must be combined with a firm commitment on environmental conservation in order to ensure sustainability of the livestock production in the country.

The future strategies of livestock production have to be based on a mixed model approach of (i) reduction in livestock population numbers and (ii) vertical genetic improvement of livestock. The possible solution to overcome the population number could be that the population growth will continue at the current levels of 1.2% in the large ruminants and at around 7% in small ruminants and 20% in poultry with the net result of heavy burden on feed resources leading to land degradation, loss of grass cover and environmental pollution. The current achievements cannot sustain the kind of growth rates achieved so far in the livestock sector. Consequently, desi mongrels and unproductive stock would drop in their number and products. Therefore, a significant change is needed in the policy frame and its mode of implementation to reduce the number.

Other possible approach would be that genetic improvement is achieved along with reduction of

total feed burden through two major strategic ways viz (i) the genetic improvement in livestock has to be linked with new technologies viz molecular genetic approach in selection of bulls and bull mothers which can be based on associated markers or QTLs in particular for linked loci and structural genes responsible for economic traits and (ii) development of transgenic animals using Embryo Transfer Technologies, etc.

The expected improvement is possible only with participation of personnel at all levels and under proper direction. Without proper direction to the livestock production systems in the country, new technologies which have been developed over the last forty years will become self defeating and cause great economic loss. Vertical genetic improvement will have to be linked with reduction in animal numbers, especially in cattle. The reduction in cattle numbers has to be made mandatory by the policy frame and time bound actions. Otherwise, all feed resources will get exhausted. Reduction in population numbers will automatically lead to a reduction in feed burden and thus conserves the feed resources. Probably, this will become the main mantra and tantra of the twenty first century.

All the aforesaid constraints are to be viewed seriously and addressed in the next two decades, which can make India to become leading nation and world power in livestock production. The livestock sector occupies an important posit in the overall economy of the country. The share of livestock products to the overall agricultural GDP has been substantially increasing over the years. The share of this sector which was 8.9% in 195051 has increased to about 23% in 1990-91 on constant price basis. On the contrary the share of the crop sector to the agricultural GDP sowed a decline from 81 % to 72% during the same period (George, 1996) which only reflects the important role being played by the livestock sector in the Indian economy in terms of income, employment, equity and foreign exchange earnings. For achieving further growth or even to sustain the present level of this sector, one of the areas which needs focusing is the animal feed resource management. For providing the support to the targeted levels of production in the livestock sector, it is of crucial importance not only to have adequate feed resources but also to provide quality feeds to the animals.

Conclusion & Recommendations:

Identification and listing of all available animal genetic resources with breed description and / characterization to understand their unique qualities and contributions.

Prioritizing the breed for characterization and conservation based on their population structure, economic utility and genetic diversity.

In situ and Ex-Situ conservation methods.

Creation of Data base on indigenous animal genetic resources and development of technology for collection and freezing of genetic material.

Documentation and creation of mass awareness through breed survival trusts, breeding societies, animal welfare bodies and similar other endeavors.

Systematic surveys for all breeds for a comprehensive inventory. Livestock census should be on breed basis for a pure breed population picture and effective breeding programme.

Relevant ecological and socioeconomic issues should be identified which affect conservation of livestock.

Training and HRD Programmes should be in a large way to support conservation issues.

R & D with training programmes on developing new techniques in Bio technology for the economic generation of biological material and its conservation for posterity.

Livestock conservation) should be among major extension activity of animal husbandry in State A.H. Department.

Publication of Literatures, Monographs, Maps and watch list should be encouraged and rewarded.

There is also strong need of 'sustainable Animal Husbandry' to protect it from environmental pollution and also to reduce environmental pollution coming out of it. Sustainable Development should be focused primarily on sustainable agriculture and sustainable Animal Husbandry for environmental conservation, social equality and equity with economic efficiency & also for poverty alleviation.

then, bacteria have been given great deal of prominence and till the beginning of this century they were considered the sole agent responsible for disappearance of organic matter in soil. Soil microorganisms play an important role in increasing soil fertility and recycling of nutrients within in soil. Different microorganisms including filamentous fungi, yeast, mycorrhiza, bacteria, cynobacteria and actinomycetes have a role to play in this regard.

Recently many workers have studied the role of fungi in relation to soil fertility and reported that their activities are not differed from those of bacteria. Fungi are also important contributors to the ammonification, nitrogen transformation, cellulose decomposition and humification processes. The problem of decomposition of cellulosic materials is thus bound up not only with the study of the chemical constituents of the organic materials, but also with the microorganism's dynamics in soil during decomposition. The following are the genera of fungi which are most commonly encountered in soils and which can be isolated by conventional methods - *Acrostalagmus, Aspergillus, Botrytis, Cephalosporium, Gliocladium, Monilia, Penicillium, Scopulariopsis, Spicaria, Trichoderma, Trichothecium* and *Verticillium*. A number of fungi associated with the decomposition of rice residues are *Alternaria, Cladosporium, Pullularia, Cylindrocarpon* and *Fusarium* (*fungi imperfecti*); *Absidia, Cunninghamella, Mortierella, Mucor, Rhizopus, Zygorynchus and Pythium* (*Phycomycetes*); *Chaetomium* (*Ascomycetes*) and *Rhizoctonia* (*Mycelia Sterilia*). The potential of crop residues of major cereals, pulses, oilseeds and commercial crops for recycling of valuable plant nutrients for sustained crop production is enormous.

Decomposition of rice residue in a rice-wheat ecosystem has crucial impact on germination, growth and development of succeeding crop wheat and it is a major source of organic carbon in this cropping system. In addition, its residue contains bacterial and fungal compounds and residues of micro and macro fauna. A large amount of rice residues left after harvesting in soil is metabolized by bacteria, actinomycetes, fungi, protozoa, nematodes, micro and macro arthropods, enchytraeids and certain worms. The decomposition of residues is accompanied by development of *phylloplane mycoflora*, colonization by saprophytic microorganisms, combination and ingestion by invertebrates resulting in incorporation of organic matter into soil and increase in the surface area. The microbial colonization and utilization of comminuted litter results in chemical degradation and utilization of tissues and production of complex phenolic polymers (humic acids) and formation of stable organo-mineral complexes.

Residue decomposition and nutrient cycling are important for maintaining soil health. Fungi play an important role in residue decomposition. However, information on their role in rice residue decomposition process is scanty in literature. An attempt has been made to review the literature on role of fungi in decomposition of rice residue in rice-wheat cropping system and other crops.

Soil contains five major groups of microorganism, *viz.*, bacteria, actinomycetes, fungi, algae and other members of animal kingdom such as nematodes, earthworms, and arthropods. Among all the organisms, fungi play an important role in recycling of mineral nutrient from plant tissue bulk to plant tissue via herbivore, carnivore and saprophagous food chain. The fungi normally grow under semi solid fermentation conditions and it is by virtue of their ability to ramify through a solid substrate, they colonize very quickly (Hudson, 1971).

Decomposition process in context to diverse fungal community:

Nandi *et al.* (1996) observed two steps in the composting process of conversion of rice straw into

high humic substance content and reported that in the first step lignin decomposing fungi *Phanerochaete chrysosporium*, *Polyporus versicolor* and *Ganoderma lucidum* were involved while in the second step of humification general decomposing fungi were prevalent. Kuhad and Johri (1992) studied the colonization pattern and mechanism of action of white rot basidiomycetes fungus *Cyathus* sp. on rice straw and reported that fungal hyphae penetrated into the vascular bundles and their lateral branches penetrated the walls of adjoining cells thereby promoting decomposition. The highest decomposition of rice straw was obtained when it was inoculated with mixture of *Aspergillus, Helicomyces, Chaetomium* and *Streptomyces* (Limtong *et al.*, 1993). In a study, cellulolytic fungi *Chaetomium cellulolyticum*, *Rhizoctonia betaticola*, *Chaetomium globosum* and *Myrothecium verrucaria* were used to find out SCP production from wheat straw and it was found that *Chaetomium cellulolyticum* and *Chaetomium globosum* gave the highest percentage of protein, total protein and biomass, respectively (19.30 per cent, 15-03 per cent and 0.19g/g, respectively) while the highest carboxymethyl cellulose (CMC) activity was fund in the case of *Rhizoctonia bataticola* (24.0 units/ml) followed by *Chaetomium cellulolyticum* (15.0 units/ml). Dhillon *et al.* (1980) studied bioconversion of the delignified rice straw by eight fungi, *viz.*, *Myrothecium verrucaria, Curvularia lunata, Sclerotium rolfsii, Fusarium equiseti, Helminthosporium maydis, Helminthosporium tetramera, Chaetomium globosum* and *Chaetomium cellulolyticum* and reported that *Chaetomium cellulolyticum* showed highest percentage of crude protein (32.1 per cent) of SCP per g of substrate followed by another species of the same genera *Chaetomium globosum* (30 per cent) per g of the substrate. In another study *Chaetomium thermophile* was found to produce maximum SCP when grown on delignified wheat straw with inoculation of cellulolytic microorganisms' fermentation temperature and decomposition of rice straw increased rapidly compared to other treatments. During decomposition of straw proportions of mannose, galactose, fructose, mannose and ribose increased consistently with time whereas the proportion of cellulosic glucose became consistently smaller. The chemical agent and biological agent combined treatment was the most effective on the decomposition of rice straw.

Role of Fungi in decomposition: Among the potential groups of residue decomposing organisms, fungi are the most active ones. Although they have immense role in rice residue decomposition, there are very few studies on their structural and functional role during decomposition. Fungi have successive phases of colonization, exploitation and exhaustion of organic substrates during decomposition. Initially, the residue is colonized by weak parasites, which invade living tissues and pave the way for saprophytes. Later on the ground saprophytes colonize residue in successive and overlapping layers. Each fungus that colonizes the residue after the microhabitat paves the way for the next colonizers. Litter quality variables, such as total nitrogen, total phosphorus, total carbon, tissue nutrient concentrations explain most of the succession patterns and differences in the micro fungal assemblages of peat and plant litter.

Fungal Succession: The succession of fungi on different crop residue is scarcely understood in the tropics. The colonization and succession of fungi on various leaf litter and observed a specific pattern that resembled the one proposed by Hudson (1968). He reported that primary colonizers were deuteromycetes and ascomycetes. Somewhat similar successional pattern was observed on *Chemopodium album* by Mehrotra and Aneja (1979). Hudson (1968) from his detailed study on succession and colonization of fungi classified the fungi as-

1. Living parasites (Ascomycetes and fungi imperfecti *viz. Leptoshaeria sacchari*,

Gnomonia errabunda, *Readeriella mirafilis*.

2. Senescent (Common primary saprophytes -Ascomycetes and fungi imperfecti - *Cladosporium herbarum, Epicoccum nigrum, Nigrospora* sp., *Curvularia* sp. and restricted primary and saprophytes- Ascomycetes and fungi imperfecti - *Leptoshaeria microscopiea, Fusarium bacillare, Piggotia substellata*)

3. Secondary saprophytes (Ascomycetes, Basidiomycetes, Soil inhabitant Mucorales, Penicillia).

The fungi including phyllosphere colonizers (*Alternaria alternata, Epicoccum nigrum*) and other common decomposing fungi (species of *Cylindrocarpon, Fusarium, Mucor* and *Phoma*) on sorghum residue. *Trichoderma, Fusarium* and *Penicillium* were identified as early decomposers of pineapple leaf litter. Rosenbroack *et al.,* (1995) found in initial phase of decomposition, the colonization of zymogenic mycoflora of genus *Mucor, Alternaria,* and *Epicoccum* on the litter. This flora was positively replaced by autochthonous species principally of the genus *Fusarium*. In Canada, in a study at different stages of decomposition approximately ten thousand micro fungal communities were isolated representing 292 species of filamentous micro fungi including 41 Ascomycetes, 21 Zygomycetes and 222 mitosporic fungi. The most commonly isolated species were *Trichoderma viride*, *Rhinocladiella atrovirens*, *Penicillium pinophilum*, and *Mortierella ramanniana*. Dominance of Dematiaceous, Hyphomycetes and Coelomycetes were observed in early decomposing stage whereas Basidiomycetes reached a peak after six month but were absent from nitrogen rich pineapple needle. In later stage of decomposition soil fungi *Penicillium, Trichoderma, Absidia,* and *Mucor* species were the most common (Santro *et al.*, 2002).

Factors affecting Fungal Colonization on Residue:

Primary fungal colonizer and successive invaders are governed by interacting factor of soil, climate and residue. The climatic and fungal ecological factors such as moisture, temperature, pH, depth, aeration and organic nutrients play important role in the dynamics of soil mycoflora. Moisture is one of the factors that regulates the growth and activities of fungi of decomposing fungi. During winter months, low temperature and moisture create an environment not conducive to fungal growth. The improved moisture during rainy season along with optimum temperature favours fungal growth. In rice -wheat ecosystems crops are grown in different seasons and the population and activity of fungi varies with a change in temperature and moisture. Increased temperature due to climatic change may increase the turn over of soil organic matter and hence reduce soil organic carbon. The response of soil pH changes to the addition of organic matter, depend upon the type of plant materials and pH in initial stages.

Another factor that influences the fungal colonization is the C:N ratio of the organic residue. Majority of the fungi show optimum growth within a narrow C:N ratio. A C:N ratio of 60 was found most effective for fungal colonization and succession. The microbial community structure (measured as phospholipids fatty acid, PLFA profile) affected by initial C:N ratio, with lower fungal/bacterial ratios is low compared to high C:N treatment after 12 months of composting (Hemicellulose: 50-80 per cent, cellulose: 40-60 per cent), while high initial C:N ratio resulted in 10-20 percent degradation of both hemicelluloses and cellulose. The decomposition rates and nutrient release pattern is influenced by the litter quality especially in initial N concentration and initial C:N ratio. Dynamics of microbial biomass is closely related to N-mineralization.

Carbon use efficiency by soil microorganism during rice decomposition in a paddy soil under aerobic and anaerobic (flooded) conditions at different temperatures (5, 15 and 250C) in relation to nutrient availability in rice cropping was studied by many workers and concluded that flooding had tendency to reduce 'C' mineralization and enhance methane (CH4) production while a decrease in temperature lowers methane (CH4) production markedly. Microbial activities were similar under flood and non flooded conditions even though anaerobes decomposed less straw than aerobes. Significant amount of decomposition occurred under flooded condition but less straw was mineralized compared to aerobic condition. Rapid decomposition of rice straw takes place under aerobic condition and marked increase in C in humic substance than under anaerobic conditions. *Aspergillus* and *Penicillium* were the most dominant fungal species. Addition of mussorie rock phosphate was found to cause rapid loss in weight and decrease in C:N ratio owing to marked increase in fungal activities.

Mucor hiemalis and *Truncatella truncata* were significantly more abundant in the control (untreated litter) but their population decrease due to UV-B radiation indicating thereby their sensitivity to UV-B radiation while *Penicillium brevicompactum* was equally abundant in UV-B and control treatment. *Alternaria alternata*, *Aspergillus* spp. *Cheatomium herbarum*, *Penicillium* spp., *Trichoderma* spp., *Cephalosporium* spp. and filamentous yeast were the most dominant species on litter during rainy season, their population decreased towards the end of season. Sources of carbon affect the predominance of various saprophytic fungi. *Rhodotorula graminis* and *Fusarium oxysporum* stimulate higher proportion of sucrose while in *Morteirella* isolates and FPC 341 (an unidentified isolate) were lower. *Aspergillus flavus* and *Fusarium oxysporum* had higher metabolic activities on glucose containing disaccharide cellobiose than on glucose strongly suggests preferential uptake of cellobiose compared to glucose and suggesting the potential ability to use the cellulose by those fungi.

Alien Saprophytic Fungi and Decomposition:

In the context of climatic change and ever increasing global temperature, the alien saprophytic fungi are ecologically more fit in the environment and they are dominating the native fungi of regular occurrence due to the virtue of tolerance of higher temperature and other ever changing ecological situations. The occurrence of exotic fungi in ornamental and garden setting has been known for many years. The fragile caps of *Leucocoprinus* species (notably *L. denudatus* and *L. birnbaumii*) are frequently encountered in green houses. Other several exotic or alien fungi *viz. Smitiomyces mexicanus, Laccaria fraterna, Stropharia aurantiaca, Psilocybe cyanesens, Volvariella gloiocephala, Agrocybe praecox, Psilocybe percevalli* and *P. magnivelaris* have been reported all over the world including India from different decomposed substrates. These fungi have proved their role in the decomposition process as well as in the maintenances of the fungal diversity.

Residue Decomposition in Rice-Wheat Ecosystem:

In rice-wheat cropping system wheat is grown just after harvest of rice and disposal of large amount of rice residue is a serious problem. One of the ways of rice residue disposal is in situ microbial decomposition. Microbial decomposition of residue is very important in this aspect. However, information on this is not available in literature, hence reports for the decomposition of other crop species is reviewed. Looking into the colonization pattern of fungi on crop residue, it was observed that phycomycetous fungi were the pioneer colonizer but deuteromycetes such as *Trichoderma, Penicillium, Aspergillus* and *Alternaria* were predominant throughout decomposition processes. Abdel and El Said (2000) isolated 23 species of 11 genera of xylem

decomposing filamentous fungi from decomposing rice straw, 16 species of 7 genera from wheat straw and 20 species of 8 genera from sugarcane bagasse. Among these species *Aspergillus flavus, A. niger, Penicillium chrysogenum, P. corylophilum, P. funiculotum, P. oxalicum,* and *Trichoderma harzianum* were the most prevalent species.

Incorporation of crop residue, like wheat or rice straw decreases the bulk density and increases the organic matter, cation exchange capacity, hydraulic conductivity, water holding capacity of the soil and also increases the grain and straw yield of rice. An increasing trend in wheat yield and organic carbon in soil with the incorporation of crop residue was observed. Rice yield also increased when wheat residue was incorporated with green manure. Physiological efficiency was higher when rice straw was incorporated in wheat and when wheat straw plus green manure were incorporated in rice. The long term application of rice residue increased carbon accumulation in soil. Soil carbon increases with the application of wheat straw and FYM in rice-wheat cropping system. Regular wheat straw application results in rise of grain yield by 0.31-0.5 t/ha for winter rye and by 0.23-0.52 t/ha for spring wheat. Straw application ensures soil sanitation from root pathogens, which also favours a rise in grain yield.

The residual effects of straw, FYM and mineral fertilization was observed to enhance the organic carbon content and consequently the content of decomposable carbon. Jenkyn *et al*. (2000) studied the effects of incorporation of different amount of straw on growth, diseases and yield of consecutive crops of winter wheat. *Lantana* residue improves the nutrient status of soil and yield in rice-wheat cropping system. Grandy *et al* (2002) studied the organic amendment and crop rotation effects on the recovery of soil organic matter. Thus, it is seen that decomposing fungi play some very important role in improving soil health and crop productivity. Useful alien decomposing fungi can be utilized in this context for rapid decomposition of crop residues looking into their strong adaptability in different environments and rapid decomposition ability.

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Invasive Alien Species vs Local Plant Biodiversity (FOMEAG Cafeteria: Conservation of endangered plant and Habitats)

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Biodiversity is the variability among the living organisms i.e.plants,animals and microbs from all sources . Plant biodiversity is a natural boon for the biological system on this planet i.e. they govern all the biofunctiuons, distribution and climatic link of the different habitats of this world. Local plant biodiversity(LPB) is important in the world because of their species composition, specificity of species , habitats and local climate-link. Introduction /Invasion of alien species is not a new phenomenon but it occur since long by the natural process as well as by the activities of human beings for their greed and not for their basic need.

The threat to biodiversity/Local biodiversity due to invasive alien species is considered second only to that of habitat destruction. Invasive species cause loss of biodiversity including species extinction, and changes in hydrology and ecosystem function. Invasive species are thus a serious hindrance to conservation and sustainable use of biodiversity, with significant undesirable impacts on the goods and services provided by ecosystems. For effective management of invasive species,knowledge about ecology, morphology, phenology, reproductive biology, physiology and phytochemistry is essential.

There is an urgent need to develop a new integrated design and model to conserve our natural biodiversity-climate links in the state, country and at global level including with consideration of invasive alien species. Different regions or parts of the state and country have specific regions with "region specific biodiversity" which directly linked with economy, health, wealth and status of common people of that specific region. In these specific areas plants are naturally localized. Now, it is essential to know their value, utility and impact of invasive alien species for the native biodiversity and biodiversity-climate links. These area specific biodiversity regions should be developed and named as "FOMEAG CAFETERIA"

The Integrated model of "FOMEAG CAFETERIA" would serve to conserve our natural biodiversity, biodiversity-climate links and provide an array studies on invasive alien species for future line of action through this bio-functional model.

FOMEAG (FO = Food/ Forest/ Fodder/ Forage + ME = Medicine + AG = Arborteum Garden / Aquatic Garden/ Agricultural Garden) Cafeteria are the important for the sustainability of life and have basic regulatory role in biodiversity and biodiversity - climate links. It can be implemented in different system in these ways:

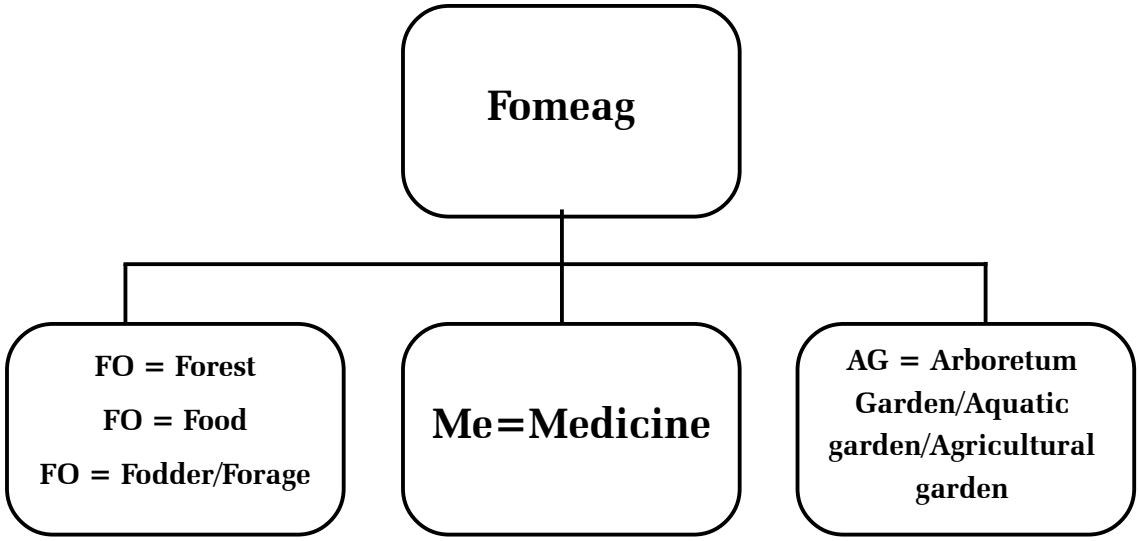

Fig: *Fomeag Cafeteria : A sustainable biofunctional model for conservation of biodiversity, biodiversity - climate links and studies on invasive alien species.*

Fomeag Cafeteria provides information, knowledge links among the local people, farmer, women, students, teachers, scientists, forest officers, agricultural scientists, planners, NGO's, Govt. officials and policy makers . Fomeag cafeteria strategy will provide great role in sustainable utilization and conservation of plant biodiversity.

Strategy for sustainable utilization and conservation of biodiversity/ Plant biodiversity through FOMEAG CAFETERIA

A. Ban on an indiscriminate and voracious utilization/ collection, ensuring proper use through Fomeag cafeteria with the help of local administration .
   - Non professional should not be allowed to harvest wild plants.
   - Knowledge about invasive alien plants (IAS)
   - Fixation of harvest limit of whole plants and plant parts.
   - Proper storage and commercialization of plant parts available in sizable quantity.

B. Planning and control for sustainability through Fomeag cafeteria :Production and care of lands on roads and rail sides and documentation of plant species by core group:
   - Identification of species with respect to their utility potential.
   - Assessment of productivity and carrying capacity of the site.
   - Judicious benefit sharing between local people and government agencies.

C. Strategy for conservation of plant biodiversity of Uttar Pradesh:
   - Awareness of invasive alien species, medicinal, nutraceutical and other value of local plants through village panchayat by the village panchyat officers, school teachers, kisan mitra (Farmer's friend), block development officer ,sub divisional magistrate and District magistrate along with forest department.
   - Through audio visual of diseases *vs*. useful plants.

– through campaigning by school and colleges during vacation

D. Place (land/ water reservoir/ forest /public site) for conservation of local region specific plants.

– Waste and vacant land of gramsabha.

– Premises of monuments, temple, fort, abandoned places, cementeries,colleges and universities campus.

1. Road side
2. Rail track side
3. Canal and damp side
4. Natural ponds, lakes and water resevoir.

"Fomeag cafateria" is a new integrated designed model for the conservation of biodiversity, biodivesity - climate links in the state and country which will provide knowdge about plants utility, invasive plants, collection, culture and utilization in a sustainable manner as per need of state and and the country. It would be a new mile-stone and vision to the nature's health, biodivesity climate links, utilization and conservation of biodiversity and provides a new impetus in revolutioning the econamic development of the contury and help in establishing the nation as developed nation.

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INTERNATIONAL DAY FOR BIOLOGICAL DIVERSITY

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INVASIVE ALIEN SPECIES

Invasive Alien Weeds: A threat to Agriculture and Biodiversity

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The significant threat from alien weed species is being increasingly recognized in agricultural and non-agricultural lands. In India, over 60 weed species have been introduced from other parts of the world and found their route in plant materials/ seeds of economically important crops. Few examples of invasive alien weed aspecies which have a significant impact on agri-ecosystem and also on human health are *Argemone mexicana, Lantana camara, Ageratum* spp., *Chromolaena odorata, Cuscuta campestris, Eichhornia crassipes, Ipomoea carnea, Mikania micrantha, Mimosa* spp., *Parthenium hysterophours* and *Salvinia molesta*. Threats posed by these alien weeds to the agriculture and bio-diversity are discussed and management strategies are highlighted in this paper.

Ageratum conyzoides

Ageratum conyzoides, an alien obnoxious weed is a native of tropical America. It out competes the native associated vegetation for nutrients. moisture and light thereby suppressing them. The invasion by Ageratum spp is leading to shrinkage of grazing area for animals, reduction in productivity of grasslands by 90 per cent. Growth of newly planted trees in forests and interferes in successions of natural forests besides threatening to the biodiversity. The weed provides shelter for wild animals. Farmers working in Ageratum infested fields suffer from nausea, giddiness, headache and skin and eye irritation. Similarly cases of poisoning in farm animals have also been reported. In crops like maize, *A. conyzoides* interferes in the harvesting and establishment of crops in rotation.

Management : Mechanical and manual weeding is limited due to its allergic effects and strong foul smell which often results in giddiness, vomiting, fever and headache. Puddled rice-wheat rotation will have lower weed infestation than maize- wheat system. Seeding of Cassia tora before the onset of monsoons has been found effective in minimizing this weed in waste lands.

Alachlor at 1.5 kg/ha applied pre-emergence with one hand weeding was found very effective in controlling Ageratum conyzoides in maize. One application of atrazine at 1.5 kg/ha (PE) during May or October in pasture lands or glyphosate at 1.5 kg/ha in May-June and or September-October before flowering will help in controlling this weed.

Chromolaena odorata

Chromolaena odorata R. M. King and is a perennial scrambling shrub of New-tropical origin (South and Central America). It was first deliberately introduced to India as an ornamental into the Royal Botanic Gardens in Calcutta in 1845. Where agricultural and human activity prevent forest regeneration. *C. odorata* persists as a typical plant of forest edges and paths, abandoned fields and pastures, building sites, and along roads railways and streams. The weed constitutes a potential fire hazard particularly during the dry seasons. It is rapidly reducing the grazing areas besides being poisonous to cattle.

Management: Hand pulling, digging with spade and slassing with sickle are the common practice for controlling the weed. However, they are labour intensive and costly and also give short-term control. Crops like *Tephrosia purpurea*

planted as a cover crop in coconut plantations, *Pueraria phaseoloides* in rubber plantations and *Leucaena leucocephala* in pastures are reported to contain the establishment of this weed.

Cuscuta campertris

Cuscuta campertris, commonly known as "dodder" is an invasive obnoxious parasite weed that attaches itself to the stems and leaves of a wide variety of host plant species. It draws nutrients from the host plant for sustenance and provides a dense barrier that drastically retards growth and vigour of the host plant and reduces grain yield by 35-100 per cent. Cuscuta parasitizes legumes, clovers, niger, linseed, onion, sugar beet and many other crops. The yield reductions due to Cuscuta are repored to the tune of 70 per cent in chillies, 31-34 per cent in green gram and black gram, 60-65 per cent in niger and 60-70 per cent in alfalfa. Cuscuta infestation is also known to reduce the quality besides enhancing the cost of harvesting in agricultural crops.

Management: Cuscuta is one of very few weeds that can be controlled completely by rotating host crop with non-host crop. The shade from dense crop foliage suppresses Cuscuta effectively to control it almost completely. Several soil and foliage applied herbicides such as paraquat, 2,4-D, glyphosate, trifluralin, pendimethalin, ethofumesate, etc, are known to achieve moderate to good control of Cuscuta most of which are either not available to the farmers or they can't be used selectively in rice-fallow cropping system. Extreme sensitivity of crop seedlings to foliage applied herbicides prohibit their use as post-emergence, treatment in host crops.

Lanlana camara

Lantana camara is an invasive weed affecting pastures and native forest in over 60 countries world wide. A native of tropical America, it was introduced into Netherlands by Dutch explores from Brazil in the late 1600s, before its spread to other countries as an ornamental. Lantana invades both the natural forest and agricultural ecosystems. In disturbed native forests. It can become the dominant under-storey species, disrupting succession and decreasing biodiversity. Lantana is widely reported to be poisonous to cattle, buffalo, sheep, goats and horses. In India, Lantana poisoning in grazing animals have also been reported from Himachal Pradesh, Uttaranchal, Uttar Pradesh and Maharashtra.

Management: Lantana can not withstand frequent soil disturbance. This is the reason that our cultivated areas under crops and orchards have so far been free from this weed A three phase integrated strategy developed for its management could be practiced.

Phase 1: Cut the Lantana bushes up to 5-8 cm above the ground level between August and October months.

Phase II: Spray glyphosate(0.75-1%) solution on regenerated foliage during September to November months.

Phase III: Plant competitive species such as guinea grass (*Panicum maximum*) or Siratro NB-37 Setaria or any fast growing fodder tree like robinia or poplar tree as per the land suitability

Parthenium hysterophorus

Parthenium hysterophorus is currently considered one of the seven most dreaded weeds of the world. It is suspected to have sneaked into India along with wheat imported from the USA under PL-480 scheme some time in early fifties. The weed has high reproductive capacity, with light weight seeds which disseminate fast by wind, rain and traffic activity. Lack of seed dormancy also enables the weed to complete 3-4 life cycles in a year.

The presence of chemicals like parthenin, hysterin, hymenin and abborsin the weed exerts

strong allelopathic effects on different crops grown in association in terms of poor germination and crop growth. The weed also affects nodulation in legumes due to inhibition of activity of nitrogen fixing bacteria. Direct contact with plant causes contact dermatitis in human being. Even the presence of pollen in the air is allergic to some and may result in diseases like fever and asthma.

Management: Post-emergence application (before flowering) of glyphosate (0.5%), 2, 4-D, (0.5%) or metribuzin (0.3%-0.5%) provides effective control of Parthenium. Biological control of Parthenium using Zygogramma bicolorata, a Mexican beetle has been found very promising. Growing competitive crops (fodder sorghum, sunflower and maize) are self perpetuating. Competitive plant species like *Cassia sericea, C. tora, Tagetus erecta*, and *Abutilon indicum* in non-crop areas is recommended for control of the weed.

Water hyacinth

Water hyacinth (*Eichhornia crassipes* Solms-Laubach) originating from South America, is ranked among the top ten worst weeds world wide. It is one of the most successful colonizers in the plant kingdom with beautiful lavender blue flowers which produces seed prolifically, an important factor contributing to its distribution. In India, the plant was first introduced in Bengal, most probably in early 1780s. The explosive growth rate of the weed is due to a large extent, to the eutrophicatiion in water bodies. In additions, the absence of natural enemies of the plant contributes to the rapid colonization of the weed. Water hyacinth is a big menace severely affecting navigation , fishing, recreational use of aquatic bodies and hydroelectric generation. It causes human health hazards by harboring harmful insects and vectors of diseases like malaria, encephalitis, filariasis etc. and by providing a safe hide out for wild animals like crocodiles and snakes. By increasing the evapo- transpiration losses of water, the weed is responsible for drying up of innumerable water tanks and ponds which are the mainstay of agriculture in rainfed areas.

Management: Manual removal of water hyacinth using mechanical mowers, dredgers or manual extraction methods, is probably the most widely practiced method of control in developing countries. Several herbicides have been found promising in controlling the weed. A single application of 2, 4-D at 4 kg/ ha is found to give better control than two split applications of 2 kg each. However, control with glyphosate at 2.20 kg/ ha was more effective with least effect on water quality and fish mortality.

Three exotic bio-control agents, two *coleopteran weevils viz. Neochetina bruchi* and *N. eichhorniae* and one mite *viz Orthogalumna terebrantis* were introduced in India in 1982. About 3000 weevil would be required in one hectare for control of this weed.

Ipomoea carnea

Ipomoea carnea a native of South America has spread fast in India during the last three decades and has become an obnoxious weed in diverse eco-systems. It is a highly invasive plant, which does not allow the establishment of other vegetation, posing a great threat to biodiversity.

Management : Because of semi-woody and deep rooted nature of this weed, manual removal is not practicable. Cutting this weed using knife/ sickle leads to re-growth and hence is not effective. Foliar application of 2, 4-D Na salt (0.2%) soap oil (1 ml/1 of water) is quite effective in drying up the plants.

Mikania micrantha

Mikania micrantha H.B.K. (Asteraceae), a perennial fast growing weed of Neotropical origin is a major menace in natural forests, forest plantations and agricultural systems in northeast and southwest India. The apparent negative impact of the weed includes reduction in yield of subsistence and cash crops, loss of native bio-diversity and prevention of forest regeneration.

Among commercial crops, tea, coffee, pineapple, banana and ginger are under serious threat.

Management: Of the herbicides tested for the control of mikania, triclopyr @ 500 ml/ ha, glyphosate @205-5 1 ha and diuron @ 1-1.5 kg/ha gave good control if applied before flowering/seed stetting stage of the weed (August-September). However, the treatments last only for 9-12 months since their application during monsoon season, Therefore, integrated approach involving mechanical, chemical and biological methods is required to manage control this weed.

Conclusion

Threats posed by the invasive alien weed species are enormous in dimensions and intensity. Measures and guiding principles for dealing with invasive alien weeds are broadly known including the prevention of their entry, early detection, control and management practices, restoration effort, research support, information management and public awareness. However, their fruitful integration is required to address the emerging threat posed by invasive alien species to the agriculture and native biodiversity in India.

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