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*Full Length Research Paper*

# The management of alien species in India

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**Alien species, after becoming locally dominant, invade natural communities and become Invasive Alien Species (IAS). The impacts of exotic plants on community structure and ecosystem processes are poorly understood in India. A total 173 species in 117 genera are invasive alien plants, representing 1 % of the Indian flora. The agricultural economy in India is vulnerable to threat from exotic pests/ diseases. In India, 116 alien insect species mainly belong to the order Coleoptera and Lepidoptera. Over 300 alien fish species including 291 ornamental species, 31 aquaculture species and 2 larvicidal fishes are recorded. Examining the ecology and genetic make-up of the IAS is important for developing management strategies. Monitoring of invasion can be done through species inventory, phyto-sociological methods, mapping using ground-based methods, and remotely-sensed images. The Government of India in 2003 has approved the notification of a new plant quarantine order harmonizing India's regulatory framework with the International plant protection convention and internationally accepted standards and the tenets of the SPS agreement of the World Trade Organization. Community based approaches, for alien species management, can best be complemented with biological control. Brief description of alien species and their present management strategies in India are discussed in this communication along with a note on strengthening the said strategy.**

**Key words:** Anthropogenic activities, threat to biodiversity, prevention, detection, eradication.

## INTRODUCTION

An alien species (AS), also known as exotic, introduced, non-indigenous or non-native, is one that is introduced by us from one geographic region to another, intentionally or accidentally or through human agency for social or personal gain. AS pose a serious threat to native biodiversity and after becoming locally dominant invade natural communities and are referred as Invasive Alien Species (IAS). IAS constitute the second most serious threat to biodiversity habitat destruction (Pimentel, 2000) and comprises the introduced plants, animals and organisms; the establishment and spread of which threatens ecosystems, habitats, and other species (CBD, 2001). The world's worst 100 IAS include microorganisms, macro fungi, plants, invertebrates, amphibians, fishes, birds, reptiles, and mammals (Lowe et al., 2000). The global extent and rapid increase in IAS is homogenizing the world's flora and fauna (Mooney and Hobbs, 2000) and such bio-invasion may be regarded as a form of biological pollution and significant component on global change and one of the major causes of species extinction (Drake et al., 1999). During the last decade, AS including IAS were identified as the major influencing factors in India's natural resource management (Diwakar, 2003). IAS makes endemic species defenseless, uncompetitive, and may result in world's ecosystem dominated by few ultra-competitive, "super species" (Mandal and Nandi, 2009). Bio-invasion affects the global ecosystem (Chen and Kang, 2003) including ecosystems of India, and may lead to huge economic loss (Drake et al., 1999). IAS change the hydrology and ecosystem function, soil structure and profile, nutrient content and moisture availability of soil, decomposition, and global environment including biodiversity. Besides, IAS affects the species composition and their spatial distribution, and availability of natural resources. Complex impact of IAS involves ecological, social, and economic issues (Poulsen, 2001). Exotic plant invasion is occurring at an unprecedented rate due to our activities (Chapin et al., 2000). Bio-invasion management requires identification of morphological and reproductive traits which are associated with invasiveness (Reichard and Hamilton, 1997). IAS often exhibits morphological, physiological

and demographic plasticity to flourish in a variety of habitats (Meekins and McCarthy, 2001). Plasticity is a feature for predicting invasive character (Rejm´anek and Richardson, 1996).

In the year 2003, seventy percent of imported logs were found to carry pests from 36 countries and regions (Pan, 2003). At least 10% of the world's vascular plants (300,000) have the potential to invade other ecosystems (Singh et al., 2006). International trade constitutes the primary cause of IAS introduction (Koo and Mattson, 2004) along with tourism, fisheries, agriculture, and forestry activities (FAO, 2001). Globally as many as 80% of the endangered species are threatened and at risk due to AS (Armstrong, 1995). However, all non-indigenous species are not harmful. Most species used in agriculture, forestry, and fisheries are alien species.

## ALIEN SPECIES IN INDIA

India occupies only 2.4% of the world's land area and contributes about 8% to the world's species diversity. The described number of species on earth is estimated to be 1.75 million, of which more than have been described in India. Nearly 60% of India's bio-wealth is contributed by the fungi and insects (Khoshoo, 1996). As mega diversity country, India harbors 45,000 wild plant species and about 90,000 animal species in less than 50% geographical region surveyed so far (MoEF, 2008). In India, 18,000 plant species, 30 mammal species, 4 bird species, and over 300 fish species are alien (Pimentel et al., 2001). About 40% of the Indian flora is alien, of which 25% are IAS (Raghubanshi et al., 2005).

### Exotic pests/ diseases with potential of bio-weapon

The agricultural economy in India is vulnerable to threat from many potential bio-weapons including exotic pests/ diseases. A list of such pests and diseases is given in Table 1, along with the pests intercepted in quarantine (Table 2). The accumulated loss due to White Spot Syndrome Virus (WSSV) in Indian shrimp farming was about Rs. 40000 millions during the last one decade (Vijayan and Rao, 2009). The pathogenic fungus, *Aphanomyces invadans* causing epizootic ulcerative syndrome is already established in many states of India and caused an estimated loss of 42.5 million US$ during 1992 to 1995 (Lilley et al., 2002).

### Alien plants

The alien plants are cultivated for food /forage /timber /ornamental and other economic purposes. Invasive alien plants are generalists and found in forests, crop lands, waste lands, plantations, gardens, and road sides. *Mikania micrantha, Prosopis juliflora, Cabomba caroliniana,* and *Salvinia molesta* are worth mentioning aliens. Invasive alien weeds are *Lantana camera*, *Chromolaena odorata*, *Eichhornia crassipes, Opuntia dillenii, Mimosa pudica, Lippia geminate*, and *Jaropha gossipifolia* (Viraktamath, 2002). *Parthenium hysterophorus, Phalaris minor* (Diwakar, 2003), *Eupatorium glandulosum, Ulex europaeus, Acacia mearnsii, Cytisus scoparius*, *Opuntia vulgaris, Prosopis chilensis, Euphorbia royleana* (Srivastava and Singh, 2009) are also invasive. Weeds cause an estimated 30% loss in crop production (Singh, 1996) which worth about US$90 billion per year. *L. camara* is toxic to cattle and cost towards its control was US$70 per hectare (Singh et al., 1996). The economic loss from *Lantana* is estimated to be US$924 million per year. In India, about 50 alien diseases of livestock and wildlife including foot and mouth disease cause significant loss (Khera and Sharma, 1967). Nearly 50,000 cases of foot and mouth disease were reported with treatment costs of about US$ 17,000 in a period of 8 months in 1996 (Singh, 1996).

Two prominent invasive alien plants in India are *Eupatorium odoratum* and *L. camara* amongst the World's worst invasive. These weeds originated in the Neotropical region and were introduced into India through the Calcutta Botanical Garden during the last century (Muniappan and Viraktamath, 1993). Other highly invasive Neotropical plants established in India are *M. micrantha*, and *P. hysterophorus. Mimosa invisa* has rapidly expanded its range in the Western Ghats (Ramkrishnan et al., 1996). A comprehensive inventory of the invasive alien flora in the state of Uttar Pradesh, India revealed 152 species from 109 genera and 44 families (Singh et al., 2010).

### Alien insects

In India, 116 alien insect species include mainly the coleopterans and lepidopterans. During per-independence era, only 2 to 3 species were introduced, but during 2000 to 2008, the number was 14 (Doddabasappa et al., 2010). Twenty eight native Indian species are found in other bio geographical zones (MoEF, 2008). To date, 40 insect species have been introduced through timber imports and 35 as accidental introduction. Insect invaders also belong to the orders Hemiptera, Diptera, and Hymenoptra. Few examples are *Lupros tristis* in the rubber plantations of Kerala, *Bemisia tabaci, Monomorium pharaonis, Ludwigia peruviana*, and *Gymnocoronis spilanthoides* (Doddabasappa et al., 2010). in addition to *Eriosoma lanigerum, Quadraspidiotus perniciousus, Orthezia insignis, Icerya purchasi, Phthorimaea operculella, Plutellc xylostella, Pineus pini, Heteropsylla cubana, Liriomyza trifolii, Hypothenemus hampei, Aleurodicus disperses, Bemisia argentifolii, Leptocybe invasa* (Sujay et al., 2010). Codling moth, *Cydia pomonella* and potato tubermoth,

**Table 1.** Major threats from devastating exotic plant pests/ diseases (Khetrapal and Gupta 2007).

| |
|---|
| **Bacterial and fungal pathogens** |
| Bacterial wilt and ring rot of potato (Clavibacter *michiganenis sepedonicus)* |
| Fire blight of apple and pear *(Erwinia amylovora)* |
| Black pod of cocoa *(Phytophthora megakarya)* |
| Powdery rust of coffee *(Hemileia coffeicola)* |
| Sudden death of oak *(Phytophthora ramorum)* |
| South American leaf blight of rubber *(Microcyclus ulei)* |
| Vascular wilt of oil palm *(Fusarium oxysporum)* |
| Soybean downy mildew *(Peronospora manshurica)* |
| Blue mold of tobacco *(P. hyocyami tabacina)* |
| Tropical rust of maize *(Physopella zeae)* |
| **Virus, viroid and phytoplasma** |
| Barley stripe mosaic virus |
| Coconut cadang (viroid) |
| Palm lethal yellowing (phytoplasma) |
| **Nematodes** |
| Pine wood nematodes *(Bursaphelenchus xylophilus)* |
| Red ring nematode of coconut *(Rhadinaphelenchus cocophilus)* |
| **Insects** |
| Mediterranean fruit fly (*Ceratitis capitata*) |
| Cotton boll weevil *(Anthonomus grandis)* |
| Russian wheat aphid *(Diuraphis noxia)* |

**Table 2.** Examples of different categories of pests intercepted in quarantine (Khetrapal and Gupta 2007).

| Categories of pest intercepted | Pest/ host/ source country |
|---|---|
| Unknown in India | *Peronospora manschurica*/ Soybean/ USA |
| | *Uromyces betae*/ sugarbeet/ USA and Italy |
| | *Fusarium nivale*/ wheat/ UK |
| | *Cowpea mottle virus*/ Cowpea/ Philippines |
| | *Tomato black ring virus*/ French bean/ CIAT (Columbia) |
| | *Heterdera schactii* Sugarbeet/ Denmark |
| | *Anthonomus grandis*/ Cotton/ USA |
| | *Quadrastichodella eucalypti*/ Eucalyptus/ Australia |
| Known to occur but the race/biotype/strain intercepted is not known to occur | *Helminthosporium maydis* / race T/ Sorghum/ USA |
| | Pea seed -borne mosaic mosaic virus/ Broadbean |
| | *Burholderia solanacearum*/ biovar 3/ Groundnut/ Australia |

*Phthorimaea operculella* are also alien species (Diwakar, 2003). Insects which are threatening the eucalyptus plantations are *Tracymela sloanei, Ophelimus eucalypti, Aprostocetus sp., Epichrysocharis burwelli, Nambouria xanthops, Ophelimus maskelli, Quadrastichodella nova, Leptoybe invassa, Moona spermophaga, Coryphodema tritis, Gonipterus scutellatus, Thaumastocoris australicus, Leprosamilga, Selitrrichod globules, Glycaspis brimblecombei, Eucalyptolyma maideni and Phoracantha semipunctata (*Ramanagouda et al., 2010). Other invasive pests are *Heteropsylla cubana, liriomyza trifolii Hypothenemus hampei, Aleurodiscus disperses,* and,

*Aceria guerreronis* (Viraktamath, 2002).

### Alien mites

The coconut mite, *Aceria guerreronis* was first observed in Kerala in 1998 (Sathiamma et al., 1998).

### Alien molluscs

Giant African snail, *Achatina fulica,* a voracious plant eater is found in many parts of india (Vijayan and Rao, 2009). *Mytilopsis sallei* and *Ficopomatus enigmaticus* are pests of the Indian seas (Gaonkar et al., 2010).

### Alien fishes

Alien fish species were brought for the aquaculture, aquarium trade, therapeutic value, research and bio-control by private aqua culturists, entrepreneurs and aqua-industrialists for immediate gains causing their indiscriminate spread with adverse ecological consequences (Lakra et al., 2008). Alien fish species imported intentionally or illegally include 291 ornamental species, 31 aquaculture species and 2 larvicidal fishes. Invasive ornamental fish in peninsular India are *Cecilia reticulate, Xiphophorus maculates, Xiphophorus helleri, Trichogaster trichopterus, Pterygoplichthys multiradiatus, Osphronemus goramy, Amphilophus trimaculatum, Pygocentrus nattereri, and Ca hypophthalmus, Piaractus brachypomus, Pygocentrus mattereri, Pterygoplichthys spp, P. reticulata, and Astronotus ocellatus. Rassius auratus* (Knight, 2010), *Carassius carassius, Cyprinus carpio, Pangasianodon.* The common b larvicidal fishes are *P. reticulata* and *Gambusia affinis* (Singh and Lakra, 2011). Parthenogenetic artemia is also found (CMFRI-DBT, 2009).

### Alien mammals

*Mustela ermine, Myocastor coypus, Sus scrofa, Sciurus carolineus Canis lupus* are mentionable. The rat in India alone costs loss of an estimated $25 billion annually (Vijayan and Rao, 2009).

## MANAGEMENT

Monitoring is required to determine location/ early detection of problematic species. Monitoring can be done through qualitative approach like species inventory, and quantitative approach using phyto-sociological methods and mapping using ground-based methods. Forest invasive species so far recorded are 61 plant species including 12 fungi species and 14 insect species having national distribution, and 36 species with regional distribution (Forest Invasive Species ICFRE Publication, 2005). An effective planning for early detection and reporting of infestations of new and naturalized weeds by plant detection network in each State is primarily needed. CAB International for Global invasive species program (GISP) proposes 3 major management options, prevention, early detection, and eradication (Wittenberg and Cock, 2001) for alien species management.

Prevention of introductions is mostly a cost-effective option. Interception based on regulations along with inspections and fees, treatment of contaminated material, prohibition of commodities following international rules, besides import risk assessment are the prevention options. Early detection focuses on a concern species. Species-specific surveys are designed and adapted for a specific situation considering the ecology of target species. Site-specific surveys can identify invaders near high-risk areas or in biodiversity rich areas. When prevention fails, eradication is the only option. Eradication aims to reduce the density of IAS below the acceptable threshold level.

## STRATEGIES

Examining the ecology and genetic make-up of the IAS is required for developing suitable management strategies. Lee (2002) emphasizes the utility of genomic approaches for determining invasion mechanisms through analysis of gene expression, gene interactions and genomic rearrangements that are associated with invasion events. The measures involving early detection with contingency plans for eradication/ containment of invasive species can be efficiently implemented and would have a higher cost/ benefit outcome. In India, economic costs towards management of IAS are yet to be done in details. Three imperatives are evident at this juncture, namely: developing policies with sound biological rationales ensuring the effective biodiversity conservation affect; accelerating the implementation action on the ground urgently; and ensuring the legislative frameworks which are adequate to support the policies (Walton, 2008). Current control methods are expensive, lengthy, and risky because total eradication is required to prevent reestablishment. Effective site-eradication procedures require multi-year treatments, continued monitoring, and follow-up treatments. All infestations on adjacent lands should be treated to prevent reinvasion. Infestations along railway tracks and roads are rarely treated for eradication, fostering widespread immigration to adjacent lands. The national integrated pest management (IPM) program is the mechanism to prevent and control the threat posed by IAS within the country. State governments, non-governmental organizations, private sector organizations, research institutions and farmer

self-help groups are all increasingly involved in the surveillance and detection of pests and diseases. International cooperation has helped in dealing with migratory locust, a pest of great concern for the Asian region. India maintains active coordination with FAO and with neighboring countries for surveillance, early detection and control measures for locust. Research and preventive control measures under way include study of the rodent characteristics, damage capacity, pathways associated with the pest and an environmentally friendly control strategy. The traditional knowledge of the local agrarian community of the region is also utilized.

The task of research, future prevention and control measures for white woolly aphid is being handled by the Ministry of Agriculture in coordination with other central government departments, concerned state governments, the Indian Council of Agricultural Research, other research institutions and agriculture universities, private sector organizations and sugar factories. The severity of the white woolly aphid infestation, recorded in 2002 in over 200,000 ha of sugarcane, has subsequently reduced substantially. However, almost 75,000 ha of the crop were still infested in 2003 and the matter continues to be of concern. An action plan for pest risk analysis was drawn up to take effect from December 2003 for establishing a national pest risk analysis unit. The plan includes organizing PRA training, establishing working groups and holding a workshop attended by national and international experts to prioritize crops and commodities for pest risk analysis. Some 36 commodities were selected for which a pest database is under development.

## CONTROL

Mechanical control is highly target- specific and labor-intensive. Chemical control is often very effective as a short term solution. Classical biological control is highly cost-effective, permanent, self sustaining, ecologically safe and is appropriate for use in conservation areas, because of its environmental friendly nature and prohibition of pesticide use in such areas. Introducing a natural enemy (for example, water hyacinth weevil *Eochetina* spp. for *Eicchornia*) for eradication of invasive species is a current focus of interest. Control projects for invasive species offer a logical, long-term solution, but none has been seriously attempted in India. The support of all stakeholders must be ensured during the entire program (Doddabasappa et al., 2010). Many exotic sawflies and wood wasps (Hymenoptera: Symphyta) have been reduced to insignificant pest status through introduction of parasitoids, or pathogens as shown from Canada (Langor et al., 2000). Comparison of the pre-1960 faunal survey data for the Indian seas with that for the post-1960 period showed that 205 non-indigenous taxa were introduced in the post-1960 period. Shipping activity is considered as a plausible major vector for many introductions (Subba, 2005). In India, plant protection is the joint responsibility of both the Central and State Governments. India has a multi-agency, multi-departmental, multidisciplinary, and multi-program approach for pest management, including management of IAS. There is no single national –level agency to coordinate management of IAS. India lacks a regional policy although it needs it at a regional and national level. An initial assessment, including a survey serves as a base for comparison as the program progresses (Sunding et al., 2000). All plants leaving and entering a nursery should be checked for sign of infestation (Verma, 2009). In India, the bio-control agent (*Teleonemia scrupulosa*) released for *Lantana* control failed since it could not cope with the vigorous re-growth of *Lantana* at the onset of monsoon rains or the control agent itself suffered heavy mortality during winter (Sharma, 1998). Thus, the need for concerted research on suitable and environment-friendly control measures is clear. A set of strategic national plans and guidelines have been developed for the import of alien aquatic organisms to sustain the effort made for regulating the culture of alien species in the country (Lakra et al., 2006). Development of a national strategy should be the first step in managing IAS.

## LEGAL AND INSTITUTIONAL NEEDS

A legal and institutional approach to the country's bio-security threat is a prerequisite to long-term success against invasive species. Unauthorized introduction of wild and domesticated animals and plants into new areas, between states and within the country should be reviewed and monitored by concerned Government departments. Techniques to be developed to make rapid assessment of the status and movement of invaders and of their impacts on ecosystem. The Government of India has approved the notification of a new (Plant Quarantine Order, 2003) in harmonizing India's regulatory framework with the International plant protection convention and internationally accepted standards and the tenets of the SPS agreement of the World Trade Organization. Other supporting and managerial steps are also being taken to improve to international standards, the entire gamut of the country's quarantine activity and phyto-sanitary border controls, including import and export inspections, on-field surveillance for pests and vectors, treatment standards and processes, and certification methodology. Efforts are also continuing to improve the export certification process and standards (Shah, 2008).

The 2003 new order for plant quarantine in India makes pest risk analysis a precondition for imports and prohibit import of commodities contaminated with weeds and/or alien species. Import of packaging untreated material of plant origin is restricted. A permit requirement is now enforced on imports of seeds, including flower seeds;

propagating material and mushroom spawn cultures. Declarations are also specified in for the import of 144 agricultural commodities. There are now 130 of such entry points, whereby previously, it was only 59. The new order also rationalizes the structure of certification fees and inspection charges.

## DEVELOPING SUSTAINABLE SOLUTIONS

Some new initiatives in India may start to turn the tide against the invading plants. In the Himalayan and the Western Ghats regions of the country, ecologists from the Jawaharal Nehru University have been leading some promising projects which are developing landscape management plans with local communities (Ramakrishnan et al., 2001). Ramakrishnan et al. (2001) have identified the close parallelism between ecologically significant keystone species and the socially/ culturally/ religiously valued keystone species. An approach based upon this connection enables local communities to identify themselves with a value system that they are able to understand and appreciate, and hence participate in rehabilitation activity that could check biological invasion. These community based approaches can best be complemented with technologies such as biological control, which can provide a long term sustainable component to an overall management plan.

During quarantine processing, pests intercepted are not known to occur in India. These interceptions, especially of pests and their variability not yet reported in India signify the importance of the quarantine in preventing the destruction of destructive exotic pests.

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