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Invasive weeds and climate change: past, present and future

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ABSTRACT

The invasive species is of global importance. It is recognized as one of the leading threats to biodiversity and imposes tremendous costs on agriculture, fisheries, wetlands, forestry, natural areas, and other human enterprises, including human health. The nature and distribution of invasive species has no geographical boundaries. The invasive plants (native, non-native, or alien) tend to have many similar biological attributes/traits relating to high reproduction and stress tolerance. These traits include germination of seeds without complicated requirements, rapid seedling growth, vegetative and sexual reproduction at early stage, aggressive spread by runners or rhizomes, diverse dispersal mechanisms, and the ability to tolerate a wide range of environmental conditions. Invasive species have been identified as the second biggest threat to biological diversity after habitat destruction. Will invasive weeds make ecological adaptation with climate changeϕ What impacts do these plants may have in agriculture, health and the environmentϕ

***Keywords*:** Climate, economic and environmental impact, invasive weed, pest

Biological resources are the treasure of a country. India is blessed with its own biological resources of plants, insects, microorganisms, birds and animals. Ecological diversity in India represents various habitats such as cropping lands, forests, rangelands, protected areas, agro-ecosystems, wetlands, and mountain ecosystem. Each habitat represents its own diversity of species. Alien or non-native species are becoming serious threat to the environment and economic well being locally and globally. Negative effects of invasive alien species have been identified on biological diversity, agricultural production, and human health hazards.

Invasive plant species are everywhere. They damage our crops, our industries, the environment and public health. Scientists, academics, leaders of industry and land managers are realizing that invasive species are serious environmental threats of the 21st century (Mooney and Hobbs, 2000; Yaduraju *et al*., 2000; Bhowmik, 2004). In addition, invasive species is recognized as one of the leading threats to biodiversity and imposes tremendous costs on agriculture, forestry, fisheries, wetlands, roadsides, natural areas, and other human enterprises, including human health. Invasive species take a heavy economic toll with costs estimated to be $137 billion every year in the United States (Pimentel *et al*, 2000) In 1994, the impacts of invasive plants in the United States were estimated at $13 billion per year (Westbrooks, 1998).

Many alien species such as *Parthenium hysterophorus*, *Lantana camera* and *Phalaris minor* in India and *Bromus tectorum*, *Lythrum salicaria* and *Polygonum cusp*idatum in USA are invasive in nature. These species have significant negative impacts on the ecosystems, economic systems and human health because of their high reproductive capacity, diverse dispersal mechanisms and colonization ability in new habitats, capacity to out-compete native species. Habitat disturbances and degradation, frequent introduction with high magnitude of the alien species and lack of predators or natural competitors in the new habitat are the factors that promote invasiveness of alien species.

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What are invasive weed species?

Organisms, including plant species that have been moved from their native habitat to a distant location are typically referred to as non-native, non-indigenous, exotic, or alien to the new environment. An invasive species is one that both spreads in space and has negative impacts on species already in the space that it enters.

In the United States, an "invasive species" is defined by the Executive Order in 1999 (Executive Order 13112 of February 3, 1999) as a species that is i) non-native (or alien) to the ecosystem under consideration and ii) whose introduction causes or is likely to cause economic or environmental harm or harm to human health. The Order further provides that a Federal agency may make a determination that the benefits of an action, which may lead to the introduction or spread of an invasive species, clearly outweigh the potential harm caused by the species and take steps to minimize that harm.

Invasive weeds and climate change

The climate change is real whether you agree with or not. On a global basis, the current level of CO_2 is rising and temperature is slowly rising as well. It also indicates that we can alter global ecosystems such as the atmosphere, as the carbon released from energy

use and other human activities triggers climate change. Plants are necessary for the flow of energy and carbon through ecosystems. With the exception of a few subterranean organisms, if plants did not exist, life would not exist. Plant growth, however, is dependent on four abiotic inputs: sunlight, nutrients, water and carbon dioxide. Any change in these inputs will alter all living systems.

Some evidence exists that agronomic weeds may reduce crop yields further in a higher CO_2 environment. It is also evident that rising CO_2 may be a selection factor in weed species dominance and its management strategies. Although the response of crop plants to rising atmospheric carbon dioxide concentration CO_2 has been well characterized, little is known concerning the long-term growth and/or photosynthetic response of perennial weeds. Available data indicate that sustained stimulation of photosynthesis and growth in perennial weeds could occur as atmospheric CO_2 increases, with a reduction in chemical control effectiveness and potential increases in weed/crop competition (Ziska *et al*., 2004). The basis for increased glyphosate tolerance at elevated CO_2 for these cohorts were unclear, but was not related to plant size at the time of glyphosate application. And we don't know a lot yet on the occurrence of glyphosate tolerance. Climate change with increased CO_2 and increased temperature may affect growth and development of many weed species. Evidence suggests that climate change increases risk of plant invasion (Bradley *et al*., 2010).

Invasive weeds and biodiversity

Human induced biological invasions are occurring on a global scale and are beginning to blur the regional distinctiveness of the Earth's biota. That distinctiveness, which developed over the past 180 million years as a result of the isolation of the continents (termed evolution in isolation), has maintained biodiversity. When considered as a single phenomenon, biological pollution probably has had greater impacts on the world's biota than more widely known aspects of global environmental change such as rising CO_2 concentrations, climate change, and decreasing stratospheric ozone levels (Vitousek *et al*., 1996).

Plant invasions by non-native species have become a major environmental problem (Lovich, 1996). Unlike chemical pollutants that tend to degrade over time and permit an ecosystem to recover, biological invasions tend to multiply and spread, causing over-worsening problems. Insidious effects of invasive non-native species include displacement or replacement of native plants and animals, disruptions in nutrient and fire cycles, and changes in the pattern of plant successions (Pimm and Gilpin, 1989). In general, these foreign species can pose a risk to biodiversity when they naturalize and penetrate conservation areas.

On a global scale, invasions by non-native plants, animals, fungi, and microbes are believed to be responsible for greater losses of biological diversity than any other factor except habitat loss and direct exploitation of organisms by humans. Non-native species further threaten fully two-thirds of all endangered species. Non-natives are now considered by some experts to be the second most important threat to biodiversity, after habitat destruction (Pimm and Gilpin, 1989). Native species have also been considered invasive when they spread into human-made habitats such as farms or gardens.

Nature and distribution of invasive species

The nature and distribution of invasive species has no geographical boundaries. All living organisms– bacteria, fungi, plants and other organisms-have evolved to live in specific areas on the Earth. Local climate, geology, soils, available water and other natural factors may influence plant or organism's invasion and subsequent establishment in a particular habitat. Models predict how invasive plant distributions will shift with climate change (Bradley *et al*., 2010).

1950, the number of plant introductions into the United States was estimated to be at least 180,000 (Klose, 1950). In 1975, it was estimated that at least 1,800 introduced plant species had escaped into the wild, with a large proportion establishing free-living populations (Austin, 1978). Currently, the Weed Science Society of America (2004) recognizes about 2,100 plant species as weeds in the United States and Canada, including about 65% of all weeds in the United States are non-natives, approximately 1,365 of the weeds recognized by the Weed Science Society of America are of foreign origin (Figure 1). This does not include most weeds of natural areas. Of the 6,741 plant species that are recognized as weeds somewhere in the world, only 2,063 species occur in the contiguous United States (Holm *et al*., 1979). Currently, it is estimated that there are 4,678 species of invasive plants in other countries that could still be introduced into the United States (Figure 2).

Attributes or traits of invasive weeds

Invasive woody plants tend to have small seed size, a short juvenile period, and a relatively short interval between seed crops that produce a high number of

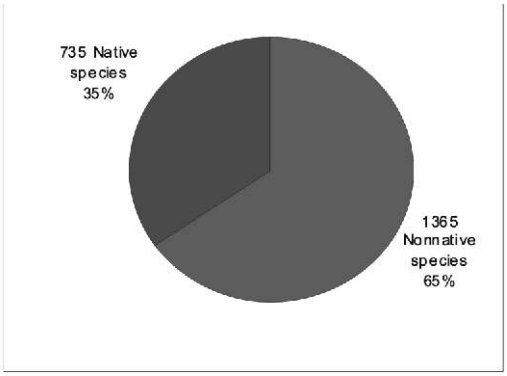

Fig. 1: Numbers of native and non native weeds in the United States.

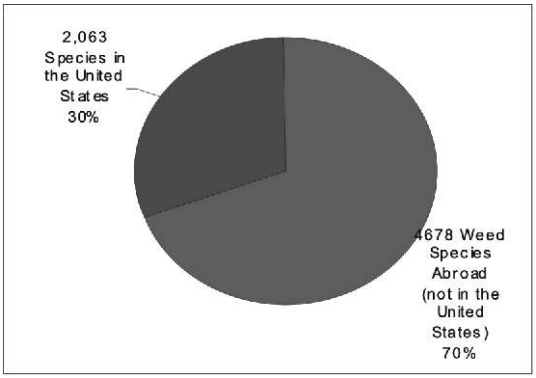

Fig. 2: Numbers of weed species in the United States and the World.

seeds (Rejmanek, 1996; Bhowmik, 2004). Invasive plants (regardless of their origin) tend to have many similar biological attributes relating to high reproductive potential and stress tolerance. Some of the common traits are as follows:

- rapid seedling growth and early maturation
- ability to reproduce by vegetative propagules as well as by seeds
- ability to reproduce at an early stage
- ability to produce viable seeds and with seed dormancy ensuring periodic germination
- diverse dispersal mechanisms and high dispersal rate
- ability to tolerate wide range of environmental conditions
- ability to tolerate high habitat disturbance

Invasiveness of plant species is dependent upon species traits, habitats, environmental stress and other biological factors. It has proven difficult to identify particular traits that are consistently associated with the tendency of plant species to invade (Reichard and Hamilton, 1997). Knowing history of past invasiveness may be the best predictor on invasiveness of a species in a new habitat. This suggests that some plant species are more invasive than others but does not explain which traits encourage invasiveness.

Pathways of introduction

Introduction means the movement, by human agency, of a species, subspecies, or lower taxa (including any part, propagule that might survive and subsequently reproduce) outside its natural range. Their movement can be either within a country or between countries. Plant invasions are important components of human-caused global environmental changes. However, Williamson and Fitter (1996) estimated that only 0.1% of all plant species that are introduced outside their native ranges by humans become invasive.

Invasive species have been introduced in a variety of ways. The means and routes by which they are introduced are called invasion "pathways". People introduce exotic plants to new areas with intent and by accident by variety of means. More than 50,000 species of plants, animals, and microbes have been introduced in the United States. Some species are introduced for use in gardening and landscaping, for erosion control, forage and other purposes. For instance, in the 1930's, the Civilian Conservation Corps planted *Pueraria lobata* (Wild.) Ohwi., introduced from Japan, throughout the Southeast to help stabilize soil in errodable areas.

Intentional introductions - Alien or foreign plants are introduced intentionally for a great variety of purposes. A large proportion of important crops are grown in areas outside their natural distribution for economic reason and as a way to feed the world population. Foreign plants can be introduced for many uses, including food use, forestry use, soil improvements, ornamental plants, cover crops and other uses. One classic example is *Festuca arundinacea* Schreb., a native European, has been planted as a pasture grass in North America. Now, it has naturalized and invaded remnant prairies, replacing the once diverse natural herbaceous community (Wittenberg and Cock, 2001). Many introduced ornamental plants invaded in natural areas in the United States. The recent intentional introduction of *Lythrum salicaria* L. is another example of a successful plant invasion. This species was introduced to the Northeastern United States and Canada in the 1800s for ornamental and medicinal uses. *Lythrum salicaria* has adapted readily to both

natural and disturbed wetlands. Various plant species also have been introduced as cover crops or for other purposes in India (Table 1).

Accidental introductions - Many of the alien agricultural weed species have been accidentally introduced as contaminants of crop seeds. Despite the Federal Seed Act, weeds continue to arrive in the USA as seed contaminants. Similar contaminations of alien plant species have been identified in many countries in the world (Lehan *et al*., 2013). Soil-inhabitating species can be introduced by shipping soil or by soil attached to plant material. Machinery and vehicles are often shipped from place to place without cleaning. Depending on their uses, they may carry soil and plant material. One of the best examples of accidental introduction is *Phalaris minor* in wheat fields of India. This accidental introduction reflects the importation of wheat from USA. Other invasive weed species such as *Bromus tectorum*, *Parthenium hysterophorus* and *Lythrum salicaria* will be highlighted at the conference.

Table 1: Intentional introduction of various weeds to India[1]

Scientific name	Common name	Introduced from	Purpose
Chromolaena odorata	Chromolina	Tropical areas	Cover crop
Eichnonia crassipes	Water hyacinth	South America	Ornamental
Lantana camera	Lantana	Many countries	Ornamental
Mikania micantha	Miconia	Malaysia	Cover crop
Opuntia strictsa	Opuntia	Australia	Hedge plant
Phaseolus labatus	Phaseolus	USA	Cover crop
Sorghum halepanse	Johnson grass	USA	Forage crop

Economic impacts

Invasive species are a major threat to the ecosystems. The differentiation of indigenous (native) and introduced (non-native) species often become difficult as only 10-15 percent of species on the earth has been fully identified. Though introduced species are often projected for their negative effects, introduced cultivated plant species contribute to 98% of human food supply equaling a monetary benefit of $5 trillion per year (Pimental, 2002). However, the threats posed by non-indigenous invasive species often outweigh the benefits of their counterparts. The annual loss caused by invasive species (plant, animals and microbes) to global agriculture ranges from $55 to $248 billion (Pimental *et al*, 2005). Invasive plant species can often turn to noxious weeds and cause considerable agricultural loss. The damage caused by weeds in global agriculture production comes to $94 billion, annually. In U.S., the agriculture weeds cause an economic damage of about $27.9 billion per year, while alien weeds inflict a damage of $37.8 billion annually in India. *Lythrum salicaria* after its introduction in Northeastern parts during the beginning of 20th. Century, has now acquired invasive proportion, and causes economic damage of $45 million annually in the United States.

According to the U.S. Congressional Office of Technology Assessment (1993), there are at least 4,500 species of foreign plants and animals that have established free-living populations in the United States since the beginning of European colonization. Of that total, at least 675 species (15%) cause severe harm. In economic terms, 79 species, or 12% of total harmful species, caused documented losses of $97 billion from 1906 to 1991.

Potential research on invasive species

We are beginning to understand invasive weeds/plants in relation to biology, ecology, invasiveness and biodiversity. However, there are many missing information/links as we attempt to predict environmental impacts of invasive plants. Integrated research needs for plant invasion with climate change are as follows:

- growth and development of invasive plants with climate change
- assessing reproductive potential of each invasive
- effects of rising CO_2 on photosynthetic capacity
- effects of rising temperature on species adaptation
- use of biogeographic information on invasive nature and distribution
- use of GPS on early detection program
- predicting plant invasion with climate change
- critical management needs for combating plant invasions with climate change

Invasive plants have made significant changes to American landscapes over the last 200 years. Similar changes have taken place around the globe. India is no exception. Economic and environmental impacts of invasive species are enormous. There are many pressing issues regarding species invasion which must

be addressed, including management strategies. Concerted efforts must be made to prevent the continued international movement of invasive plant species, and to develop programs to predict global changes. It is clear that invasive plants will continue to invade and persist in various ecosystems, and we must continue to monitor, assess, and develop management strategies for combating invasive species, and possibly to develop restoration of natural habitats. Again, we must continue to keep up with integrated current research on invasive plants with climate change, especially to rising CO_2 and temperature.

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