Effect of Global Warming on Invasion of Alien Plants in Asia

Rm.Kathiresan
Department of Agronomy, Faculty of Agriculture, Annamalai University
Annamalainagar, Tamilnadu, India – 608 002
rm.kathiresan@sify.com

Abstract: The world Meteorological Day celebrated on March, 2005 chose the theme "Weather, Climate, Water and Sustainable development". Increasing "Green house gases" and Global warming is expected to trigger suppression of native bio-diversity by invasive alien weeds in Asia. Alteration in the precipitation and evaporation pattern coupled with frequent inundation and drought, increasing temperature regimes and sea-level rises that are regarded as consequences of global warming would alter the nature of vegetation and agriculture in Asia. More number of wet years (annual rainfall excess by ten per cent or more resulting in frequent inundation or flooding) between 1991 to 2000 compared to the preceding ten years resulted in invasion of rice fields of Cauvery river delta in India by alien invasive weeds Leptochloa chinensis Nees and Marsilea quadrifolia (L.) by virtue of their amphibious adaptation to alternating flooded and dry situations. Increasing temperature regimes are also observed to favor invasive potential of alien weeds in monsoon Asia. Under upland conditions, increasing temperature above 35°C favored the germination and establishment of Trianthema portulacastrum L, an invasive weed originated in Tropical Africa. Germination of noxious carrot grass Parthenium hysterophorus L is observed to be triggered by a combination of higher temperature and moderate available soil moisture. Mean monthly maximum temperatures above 30°C linked to available soil moisture between 40 and 60 per cent favored the weed's germination and establishment. With increasing temperature and fluctuating precipitation, the weed may pose a severe threat assisted by globalized trade and agriculture. Similarly, the rate of increase in root bio-mass of invasive alien weed Prosopis julijlora Swartz (DC) under increasing temperatures is observed to be higher, increasing it's persistence potential and invasive behavior. The interaction between the invasive potential of these alien weeds and climate change along with some of the management aspects are discussed.

Introduction:

Unabated use of forest fuel and deforestation have contributed largely for global warming and the ultimate climate change. The climatic change due to global warming in the last century has been greater than at any other time during the last millennium. The concentration of carbon dioxide is 33 per cent higher than it was before the industrial revolution. The sea level has been rising at the rate of 2mm a year since the beginning of 20th century. Droughts and floods have become more common (The Hindu, 2005). The year 1990 was the hottest in last century with all other five of the warmest years in the century falling with in the last 22 years. Scientists agree that the planet's temperature has risen by 0.5 degree Celsius since 1900 and will continue to increase at an increasing rate. This sort of a climate change either directly or indirectly induces changes in land use. Land use changes involve conversion from one type of land cover to another along with changes in management practices. These include fertilization, type of land preparation and changes in availability of surface water and river flow. Because of change in the land use pattern, the terrestrial biosphere of the 21st century would probably be further impoverished in species richness. The biosphere will be generally more weedier (Walker and Steffen, 1997).

Climate Change and green invaders:

Because of globalization of economies and subsequent movement of people and materials, invasion by alien species is going to be the second important factor causing loss of biodiversity next to land use pattern. Changes in atmospheric composition and climate are regarded as long term factors influencing weed invasion, increasing in relative importance over time.

Increasing temperature regimes and invasive behaviour of weeds:

Introduced from Central America as a drought tolerant species suitable for afforestation in arid and semi arid zones of India in 1877, *Prosopis juliflora* has invaded nearly 5.55 million hectares of land contributing for 1.8% of geographical area of the country. Remote sensing data has predicted the expansion of the species in Gujarat State of India at the rate of 25km^2 per year. Reports predict that by the year 2020, more than 56 percent of the area in Banni with rich bio-diversity and grassland ecosystem would be under *Prosopis*. The most potential invasive feature of the species is typical greater assimilate partioning towards root, leading to extraordinary enlargement in the root mass with rich food reserves, aiding rapid and robust regeneration after mechanical lopping or after revival of ecological stress conditions such as drought or inundation. Studies at Annamalai University has shown that the root enlargement in *Prosopis* species is greatly influenced by the temperature regime of the locality. The

annual increase in root bio-mass is greater in areas where the mean annual temperature is higher than that in areas of lesser mean annual temperature (Table.1)

Table.1. Temperature regimes and root biomass enlargement in *Prosopis*

Mean Annual	Mean Annual Increase in	Mean Annual Increase in	
Temperature °C	Root biomass (kg)	Shoot biomass(kg)	
28	1.9	42	
30	4.4	47	
32	6.2	56	

Increase in shoot biomass due to increasing temperature, though observed is not as significant as the increase in root biomass. The increase in root biomass largely contributes for the weed's ability to tolerate climatic extremes such as peak summer associated with high temperature and water scarcity and peak monsoon winter with water inundation and flooding. This adaptation favors the weed to predominate over other native flora that are susceptible to any one of the two extremes.

Similar alien weed of wide occurrence in Asia is *Parthenium hysterophours*. This weed, originated in Gulf of Mexico and Central South America has invaded India, Pakistan and Srilanka through cereal and grass seed shipments from U.S.A during 1950s. The weed has been predicted to increase it's invasivity due to ecological niches provided by frequent flooding and higher CO₂ resulting from global warming (Adkins et al. 2005). These weeds are observed to posses periodicity of germination and phenology to evade environmental stress conditions (Kathiresan et al.2005). Prevailing maximum temperatures between 30-34°C linked to available soil moisture status of 40 to 60 per cent favour germination and flowering, where as temperatures above 35°C (co -inciding with summer) or excessive soil moisture (co-inciding with monsoon winter) above 80 per cent is detrimental. The weed has adapted to complete two generations with in one year, programming it's phenology between these climatic extremes (Table.2)

Table 2: Phyto-eco-sociology of parthenium in veeranum ayacut region (Average values for 2000 & 2001)

Months	Parthenium Important Value percentage	Available soil moisture (Percentage)	Mean Monthly Max Temperature (°C)	
January	-	-	28.65	
February	76	55	32.00	
March	81	42	32.40	
April	84	32	34.35	
May	11	29	37.55	
June	-	25	36.25	
July	-	29	36.00	
August	-	40	34.65	
September	48	42	33.75	
October	51	58	31.65	
November	32	81	29.80	
December	-	86	28.05	

A major weed that has been invading irrigated upland agro eco-systems in several tropical Asian countries is *Trianthema portulacastrum*. This weed is reported to have been originated from tropical Africa and has invaded several continents viz., Australia, Africa and Asia (Rawson and Bath, 1984). A survey conducted in different irrigated upland crops of Veeranum Ayacut in Tamilnadu, India indicate that

T. portulacastrum predominates as the dominant species in all the three crops viz., sugarcane, sunflower and gingelly with Important Value Index percentages of 28.73, 26.83 and 25.99, respectively. This weed tops the list of 15 weed species recorded in all these crops in different locations. (Kathiresan, 2004). One of the most important character responsible for it's invasiveness is thermal induction of seed germination with soil temperature around 35° C favouring synchronized and mass germination of seeds, covering the soil as a green carpet. In a field study conducted at Annamalai University, it was observed that, increasing soil temperature with the summer months of June and July triggered the mass germination of seeds of this weed suppressing the native species (Table 3). The seeds of this weed undergo dormancy during winter and thermo-induction to break the dormancy require soil temperatures above 35° C (Sundari and Kathiresan 2001).

Table 3. Thermo - induction of seed germination in Trianthema portulacastrum

Month	Seedling emergence m ⁻² , 15 days after land preparation at the beginning of the month	Mean Monthly Max Temperature(°C)
January	8.5	28.5
February	11.6	30.4
March	16.7	33.1
April	23.4	34.2
May	32.9	36.9
June	85.6	37.3
July	102.4	36.2
August	126.8	35.0
September	20.5	33.9
October	-	31.2
November	-	28.7
December	-	28.1

Rainfall pattern and weed invasion

Global warming directly reflects on rising sea levels due to melting of ice caps and natural expansion of sea water as it becomes warmer. Consequently, areas adjoining the coast and wetlands could be frequently flooded and the distribution pattern of monsoon rains gets altered with more intense downpours, storms and hurricanes. The meteorological data available at the Annamalai University, in tail end of Cauvery river delta region of Tamilnadu state, India, shows that the average annual rainfall during the period of 1991 to 2000 has increased by 129 mm compared to that during 1981 to 1990. The record also reveals that the annual evaporation has reduced by 255 mm from the period between 1981 to 1990 & 1991 to 2000. Further, wet years (years with excess average annual rainfall by more than ten per cent) are also more frequent between 1991 to 2000 than 1980 to 1990. (Table 4). Phytosociological survey of floristic composition of weeds in this region reveals the recent invasion of these rice fields by alien invasive weeds *Leptochloa chinensis* and *Marsilea quadrifolia* (Table 5). These two weed species dominated over the native weeds such as Echinochloa sp. and others by virtue of their amphibious adaptation to alternating flooded and residual soil moisture conditions prevalent during recent years in this region (Yaduraju and Kathiresan, 2003; Kathiresan, 2005).

Table 4. Rainfall and evaporation pattern in the Cauvery river delta region of India

Vacu	Average annual	Annual	Rainfall defecit /	
Year	rainfall (mm)	evaporation (mm)	excess percentage	
1981	1192.0	2701.0	-14.86	
1982	926.8	2482.0	-33.8	
1983	1148.6	2336.0	-18.0	
1984	1479.6	1861.5	5.69	
1985	1985.2	1971.0	41.8	
1986	1257.5	1971.0	-10.18	
1987	1438.7	2080.5	2.76	
1988	1132.6	2007.5	-19.10	
1989	1448.3	2153.5	3.45	
1990	1543.0	1971.0	10.21	
Average	1355.2	2153.5		
1991	1196.4	1934.5	-14.54	
1992	1257.3	2007.5	-10.19	
1993	2024.1	1934.5	44.58	
1994	1349.8	1971.0	-3.59	
1995	1124.8	1861.5	-19.66	
1996	1701.5	1825.0	21.54	
1997	1636.0	1861.5	16.85	
1998	1560.1	1861.5	11.44	
1999	1434.0	1861.5	2.43	
2000	1555.0	1861.5	11.07	
Average	1483.9	1898.0		
2001	1343.2	1788.5	-4.06	
2002	1281.0	2007.5	-8.50	
2003	938.7	1825.0	-32.95	
2004	1699.5	1745.1	21.26	
2005	1745.1	1733.3	24.51	
Average	1401.5	1819.88		

Leptochloa chinensis owes it's invasive behaviour to longer life span that extends in to the relay crop of mung bean after transplanted rice. These two crops differ widely in the soil conditions with transplanted rice surviving in inundated water, where as mung bean thrives in residual soil moisture below 30 per cent. Leptochloa shows adaptation to both the extremes of climate, with in the same generation. Marsilea quadrifolia is tolerant to most of the grass killer herbicides used like butachlor. Further, frequent floods do favour it's perpetuation.

Wetlands are more prone to weed invasions in part, because they serve as landscape sinks that accumulate materials resulting from both terrestrial and wetland disturbances (excess water, debris, nutrients, sediments, salts and other contaminants). Opportunities that make wetland more prone to weed invasions are that the riparian habitats are subjected to flood pulses and inflows from surface water. Habitats fed by surface water are low in species richness and the inhabitants are low in quality with coefficient of conservatism scoring less than five. (Kercher and Zedler, 2004). Studies in wisconsin show that wetlands with a history of hydrological disturbance show more widespread invasions (Zedler and Kercher, 2004). Despite the emphasis on increased influxes as causing disturbance, it has also been observed that some invasives are abundant where the regions have reduced flood flows. Both increased

and decreased run off will alter wetland water regimes and the floristic composition could be invaded by the floating weeds, like *Eichhornia crassipes* under inundation and *Ipomoea aquatica* under semi or complete dry situations of water sheds in Southern India.

Table 5. Floristic composition of weeds in rice fields irrigated by channels in Cauvery river delta (IVI %), India

Weed species	Channel I		Channel	Channel II		Channel III	
	1992	2002	1992	2002	1992	2002	
Echinochloa colonum	25.56	5.45	28.48	4.42	27.52	5.34	
Leptochloa chinensis	22.74	28.81	24.81	29.79	23.64	29.50	
Cyperus rotundus	17.23	9.13	22.28	7.61	17.01	3.60	
Echinochloa crusgalli	8.33	3.44	6.00	2.96	5.80	3.00	
Sphenoclea zeylanica	2.02	4.60	0.68	4.47	1.68	5.08	
Marsilea quadrifolia	1.46	19.10	0.63	20.98	0.46	21.97	

PREDICTING WEED INVASION IN RESPONSE TO GLOBAL WARMING

Range extension and invasion of plant community by both an exotic invader and a native species though differs in several aspects, have one attribute in common. In both the cases plants invade new territory through efficient reproduction and dispersal. The long-haul mechanisms of dispersal including dispersal by wind and vertebrates deserve special attention in predicting large-scale migration of invasive species. For some, these natural agents are likely to be superseded by human activities. Water hyacinth (Eichhornia crassipes) native of Brazil, was first traced in history, as to have been gifted as a compliment to visitors of cotton Expo in New Orleans state of USA in late 1870s. At present, the weed has invaded all continents except temperate Europe. However, dispersal is only the first phase ensuring entry of an invader but to pass through successive phases of establishment, expansion and explosion, the species need to successfully germinate, grow and reproduce. The possibility of a new species establishing itself is resisted by the existing vegetation and favoured by the type and frequency of disturbances in that particular habitat. In general, the disturbances of established vegetation by fire, flood and grazing mammals render it more vulnerable for invasion. This indicates that climate changes in future that would suppress native vegetation would increase the probability for open niches in the ecosystem favouring invasion by alien weeds. An alien species getting naturalized involves escaping from cultivation and establishing self sustaining populations in the wild. This critical step before the species becoming invasive was studied for different introduced species in Australia and New Zealand by Williams et al. 2004. Results indicated the difference in naturalization rates for the same species in these two countries. This emphasizes the importance of role of climate and climate matching in predicting invasive species. Though, weed invasion has been observed to be influenced by the cultural practices at the field scale, in the larger context, regional weed invasions have been observed to be mainly influenced by climatic factors. Global warming with the causal and consequent effect of elevated carbon dioxide levels, increased temperature regimes, changes in precipitation pattern might influence the invasive potential of different weed species in various parts of the globe under differing situations. Accordingly, any programme for prediction and prevention of weed invasion should consider the climatic factor as one of the vital component.

Several systems have been developed to help predicting invasion for the purpose of plant quarantine. All these systems involve applying a series of questions to be answered from the view point of a suspected weed species. Based on the answer, either the weed is eliminated from the list of suspected invader or is kept under observation, monitoring and/or preventive programme. In certain cases the invasive weeds are also classified as "highly invasive", "moderately invasive" and "possibly/potentially invasive". These systems satisfactorily predict whether an individual species will/will not become invasive. In addition to the Invasive potential A (rhizomatous, climbing, small and readily dispersed seed) and Damage potential B (competitive, toxic etc), Geography potential C (the magnitude of range of geography or ecologies to be invaded) and Entry potential D (mode of entry either deliberate or accidental) are also considered, to arrive at a product of A X B X C X D, for finally ranking the suspected weed's invasive nature (Parker 2001), In this new approach, inclusion of Geographic potential and Entry potential based on

the major predictive character of weediness elsewhere imparts better scope for predicting the invasive alien species. It would be more appropriate to include climate matching and adaptive features of weed species along with Geographic potential to confer more precision to the predictive models.

Management

Managing the alien invaders include several key components, such as Weed Risk Analysis involving pre-entry as well as post entry assessment, modeling for matching climate change and invasive behaviour of weeds, prevention by raising awareness etc. But a simple but vital clue is to continue to practice traditional farming leads and techniques. Raising a green manuring legume in the summer in rice fields that would be ploughed in situ at the time of preparing fields for rice has significant impact on suppressing *Leptochloa* in rice. Similarly allowing pigs to burrow in the puddled field at the time of land prepation for rice helps suppressing perennials such as nut sedge and *Marsilea*. Plantation of Avenue Trees Such as Tamarind (*Tamarindus indica* L) largely keeps the road sides and social sites free from *Parthenium* infestation

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