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Invasion of *Prosopis juliflora* in native arid grazing lands: competition and dominance

Suresh Kumar and Manish Mathur
Division of Integrated Land Use Management & Farming System,
Central Arid Zone Research Institute, Jodhpur, 342003 Rajasthan, India.
Corresponding author email: sk_ecology@yahoo.co.in, ravi_mm2099@yahoo.com
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Abstract

Explaining and predicting invasion is a multidimensional process involving many variables. To predict invasion by a particular species in any area, knowledge of component species, competition amongst them and disturbance is essential. Such relationship has been studied in grazinglands of Jamnagar district of arid coastal Gujarat. The relative importance values of species growing in sites having varying density and cover of *Prosopis juliflora* were plotted as Dominance Diversity curve (DD curve). Dominance diversity curves were logarithmic at all sites having *P. juliflora* compared to log normal curve at sites without it. One tenth of abundance of *P. juliflora* in this study emerged as a threshold beyond which it drastically changed dominance diversity relations. Actual relative abundance (RA) of species in sites with and without *P. juliflora* was compared to assess competition effect. Study revealed that *P. juliflora* has adversely affected abundance of climax species *Acacia senegal* in both types of habitats. Canopy cover analysis was carried out through Relative mixture response (Rm). Occurrence of this plant on both types of protected sites severely affected cover of *Maytenus emarginata*.

Key words: - Actual Relative Abundance, DD curves, GIS and RS, Grassland, Grazing land, Invasive species, Relative Mixture Response, Weed

Introduction

Ecological invasion is considered as the second most serious threat to natural habitats, after fragmentation and habitat losses (Kelly *et al.,* 2003). From the ecological point of view, a successful invasion not only controls the flow of resources in a habitat but also affects the associates in various ways. Thus, the impacts of invasive species are both, ecological and economical (Alin, 2011).

In order to understand such impacts, a study was carried out to assess invasiveness of *Prospois juliflora* in semi arid part of Gujarat. A hypothesis was developed for the prediction of invasiveness of *P. juliflora* with the help of dominance diversity curves. Further, the hypothesis was verified with various ecological parameters related with cover and competition on the basis of data recorded from two types of protected habitats. Results are discussed to understand the basic knowledge of competitive edge of *P. juliflora* in native grazing lands.

Material and Methods

Study site: The study was carried out in the Jamnagar district (latitude $21^0 47'$ to $22^0 58'$ longitude $68^0 57'$ to $70^0 40'$) in the northwestern part of the Gujarat state of India. Its terrain is uneven, marked at places by hill ranges with the 'Great Rann' to the north and east and extensive range of sand dunes along the coast in the north and the west. The area faces water scarcity with stony/rocky gravely surface. The torrential nature of rainfall generates 40-50 per cent as runoff which quickly recedes through well-integrated drainage system to sea. Climate of the district is arid with the mean moisture index of –67.5. Monsoon normally sets in the first week of July. The average annual rainfall varies from 338 mm at Dwarka (Okha) in northwestern part to 666.5 mm at Dhrol in southeastern part of the district. The average number of rainy days (*i.e.,* days with 2.5 mm rainfall or more in a year) in the district varies from 13.6 at Dwarka to 28.1 at Jam Jodhpur. In summer, the temperature rises up to 40.3^0C. During winter period the mean air temperature varies between 10.6-28.8^0C. Relative humidity ranges from 62 to 82 percent.

Sampling design: Using the Survey of India (S.O.I) topographical sheets and satellite data of IRS 1C LISS III, both at 1:50000 scales combined with ground truth, grasslands with and without *P. juliflora,* forest, croplands and other categories were mapped.

Finalized mapped data was processed in GIS using ARC/INFO package to generate cartographic output including area of each mapped category. From these mapped units (Fig. 1), 37 grasslands representing protected sites (equivalent to reserve forest) called 'reserve vidis' and open sites called 'unreserved vidis', protected forests and unprotected open grazinglands were selected for detailed sampling. 'Vidi' is a local name of site for maintaining natural grasses, shrubs and trees in silvipastoral system of vegetation. Data were collected in ten 10 x 10 m quadrat abutting each other. In each quadrat, occurrence and density of woody perennials was recorded. Further, data was analyzed for relative frequency, relative density, relative abundance and relative importance value (Curtis and McIntosh, 1950). Canopy cover of ligneous plant was assessed by measuring canopy along 2 diagonals / diameters (d) and calculated as cover with the following formula: Cover = Đ $(d1+d2)^2/4$.

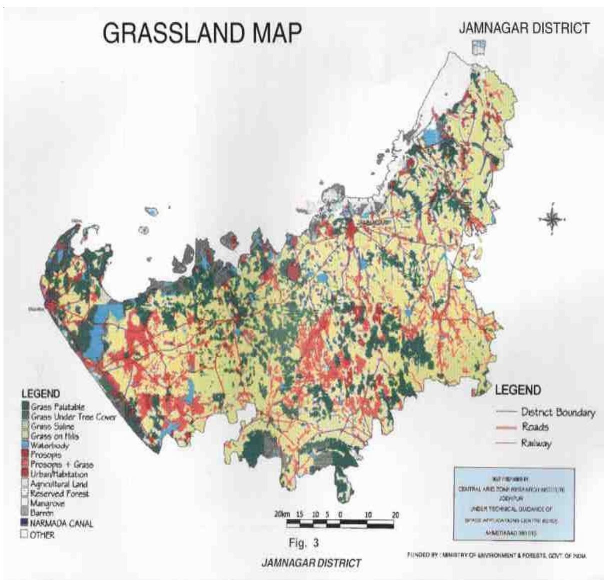

Fig. 1. GIS Map of Grassland in Jamnagar District

Statistical analysis: Dominance diversity curves were drawn after Whittaker (1965). Dominance diversity (DD) curves graphically illustrate the status of environmental stability (Stenseth, 1979). Actual Relative abundance (RA) of some selected species in protected site invaded by *P. juliflora* was assessed according to Goldberg (1994) by using following formula.

Actual RA in mixture $RAa_{mix} = A_{mix}/ÓP_{xmix}$

Where

A_{mix} = Performance of species a in mixture

P_{mix} = performance of all species in mixture

Canopy cover was used in assessing Relative Mixture Response (R_m) of selected species in a plant community (Jolliffe *et al.*, 1984)

$R_m = Y_{mono} – Y_{mix}/_{Ymono}$

Where

$Y_{mono =}$ Species cover in situations without *P. juliflora*

$Y_{mix =}$ Species cover in situation with *P. juliflora*

Trends of all the above parameters were compared in sites with and without invasion of *P. juliflora*.

Results and Discussion

Dominance Diversity Relations: Status of a habitat can be judged by three types of DD curves. Lognormal curve of a community indicates stable environment and logarithmic unstable system. Broken stick distribution reflects an ideally uniform pattern of distribution and logarithmic models showed uneven division of resources say from competition. The lognormal distribution results from multiplicity of interaction in more complex community. Thus, if sites having *P. juliflora* showed logarithmic distribution (Fig. 2), it was most likely due to uneven division of resources (mainly soil moisture) resulting from competition with other species. In reserve forest, similar trend was also observed. Further, it was examined whether the location of *P. juliflora* on dominance diversity curve had bearing on type of the curve. It revealed that when RIV of *P. juliflora* is below 10, the curves are lognormal. Thus, when invasion of *P. juliflora* assumed greater proportion, so that its abundance is over 1/10th of total community, and then its DD curve is logarithmic, resources were perhaps being used in an uneven way. One tenth of abundance of *P. juliflora* in this study emerged as a threshold above which it drastically changed dominance diversity relations (Fig. 2). The hypothesis was tested by assessing competition effect.

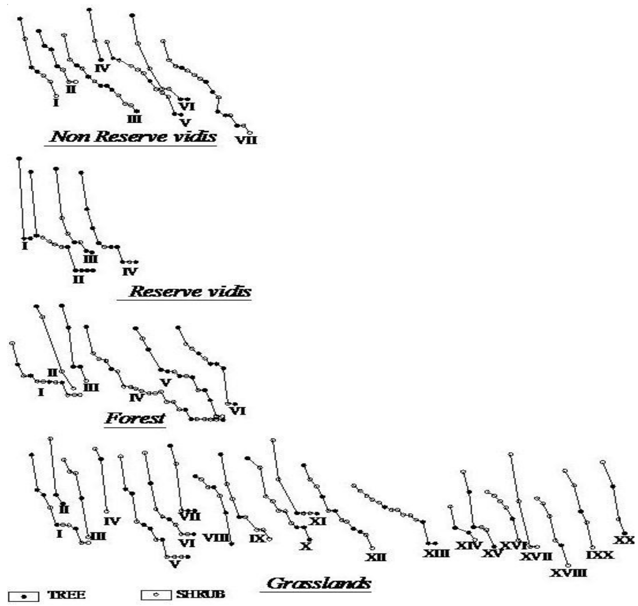

Fig 2. Dominance diversity curves of woody perennials

Assessment of competition effect: Actual relative abundance of species (RA) in sites with and without *P. juliflora* was compared (Table 1) to assess the competition effect in reserve vidis. *Acacia senegal* and *Ziziphus nummularia* had lower relative abundance at sites with *P. juliflora* than without *P. juliflora* whereas *Maytenus emarginata* had higher abundance, in the presence of *P. juliflora*. In reserve forest too, *A. senegal* showed same response but *Z. nummularia* and *Cassia auriculata* behaved otherwise. Thus *P. juliflora* has adversely affected abundance of climax species *A. senegal* in both reserve vidis and reserve forest.

Table 1. Competition effect as estimated by Actual Relative Abundance of species in mixture

Habitat	Species	RA in mixture with *P. juliflora*	RA in mixture without *P. juliflora*
Reserve vidis	*A. senegal*	1.10	1.53
	M. emarginata	0.127	0.064
	Z. nummularia	0.028	0.148
Forest	*A. senegal*	0.05	0.25
	Z. nummularia	0.10	0.017
	C. auriculata	0.20	0.098

Relative mixture response (*Rm*) index progressively declined to one; it shows increasing impact of one species (invaded species) on other species (native species). A perusal of Table 2 indicated that *A. senegal* was more affected in reserve vidis than in forest. *Z. nummularia* was not affected, while *M. emarginata* was severely affected in terms of its low canopy in reserve vidis. Interestingly abundance of *M. emarginata* was same in sites with and without *P. juliflora* but canopy of *M. emarginata* was less at sites of presence of *P. juliflora*. This might be due to the facts that shrubby nature of *P. juliflora* and *M. emarginata* were observed in the same niche. Hence, in the protected sites, occurrence of *P. juliflora* adversely affected the abundance of *A. senegal* and canopy cover of *M. emarginata*.

Table 2. Relative Mixture Response in canopy cover of different species in situations with *P. juliflora*

	Habitats	
Species	**Reserve vidis**	**Forest**
A. senegal	0.295	0.868
M. emarginata	-0.49	-
Z. nummularia	0.798	0.46
C. auriculata	-	0.942

Prevention and 'Early Detection and Rapid Response' (EDRR) practices are the most effective strategies for managing the invasive plants species for long-terms and in large-scales. Successful management of invasive species will require active attempts to prevent new introductions, vigilant detection of nascent population and persistent efforts to eradicate invaders. Rejmanek (2000) described five groups of complementary approaches related with predictions of invasive plants. These approaches include (i) Stochastic approaches, (ii) Empirical taxon- specific, (iii) Evaluation of the biological character of the invaded species at various habitats, (iv) Evaluation of environmental compatibility and (v) Experimental approaches to find out the intrinsic and extrinsic factors underling invasion success. Heger and Trepl (2003) reviewed various models for predicting biological invasions and according to them key-lock method was most suitable to examine single cases of invasion. This model incorporated the relationships between characteristics of invading species and on those of the ecosystems invaded. Lbanez *et al.,* (2009) have pointed out various drawbacks in early detection methods associated with historical and local conditions only. They emphasized that landscape structure, habitat types and canopy closure are the better parameters for developing multivariate forecast method for invasive plant distributions. However, inter-specific competition is considered as one of the most important processes determining the likelihood of plant invasion. Vila and Weiner (2004) discussed about the hypothesis relating to competitiveness between native and invasive species, and according to this hypothesis invasive plants are often more competitive than native ones. They tested this hypothesis with the help of evidence from pair-wise competition experiments. Various competitions indices are useful tools for quantifying the effect of competition between pairs of species. These indices can quantify the proportional decrease in plant performance due to competition, and compare effects of competition on different species or under different environmental conditions. Hence we have employed these competition indices to elucidate these impacts in grazing lands of Jamnagar district.

Of 48 different indices to assess plant competition (Weigelt and Jolliffe, 2003), it was found those proposed by Goldberg (1994) and Jolliffe *et al.* (1984) to be most nearly applicable to assess competitive impacts by *P. juliflora* invasion. Again in order to rule out confounding by anthropogenic factors, we selected only protected habitats *i.e.*, forest and reserve vidis where *P. juliflora* has invaded to observe its competitive advantage or disadvantage.

Open grazing lands invaded by *P. juliflora* and over utilized by human and livestock for over five decades showed adverse affects on the composition in favors of sub climax and lower order successional species. Protected grazing lands invaded by *P. juliflora* found unvaried in their composition. Entry of *P. juliflora* into protected grazing lands and forests caused a decline in successional status as exemplified by adverse impacts on abundance of climax species *A. senegal* and cover of *M. emarginata*.

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