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Factors contributing invasion of Alien Invasive Species *prosopis juliflora* in Bundala National Park in Sri Lanka

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ABSTRACT

Bundala National Park (BNP) is a thorny shrub forest with a total extent of 6210 ha, consist of 13 habitat types; seven terrestrial types and six wetland types. Because of its precious biodiversity, Ramsar Convention considered the park as the first Ramsar site in Sri Lanka declared in 1990, and a Man and Biosphere reserve declared by UNESCO in 2005. Considering the threats, which have BNP faced, spreading of alien invasive species inside the park is considered as the most serious. Among them, *Prosopis juliflora*is considered as the most dangerous which has almost covered over 60% of the entire park. The study was conducted to evaluate the factors contributing to invasion of invasive *Prosopis juliflora* in Bundala National Park by understanding the factors enhancing invasiveness and suppressing native vegetation, allelopathic effects and mode of dispersion of *P. juliflora*. Our results strongly inferred that spreading of invasive *P. juliflora* has been imposed a significant ecological damage by suppressing native vegetation. The environmental and soil factors (salinity) enhance the *P. juliflora* growth while low sunlight and salinity are key external factors suppressing native vegetation in BNP. In addition, *P. juliflora* has allelopathic effects on native vegetation but impact is species dependent. Asian elephants and other ruminants fed on *P. juliflora* have great impact on *P. juliflora* seed dispersion throughout the BNP. The saline soil and high temperature regimes with other microclimatic conditions enhance the germination of dispersed *P. juliflora* seeds. Therefore, above factors should be taken into consideration for implementing effective management programs of *P. juliflora.*

Keywords: Bundala National Park, Invasive Alien Species, *Prosopis juliflora*, Diversity, Soil salinity

INTRODUCTION

Bundala National Park (BNP) is a wetland complex comprising of five lagoons, intertidal mudflats and salterns (MENR, 2005). The park is an important wintering ground for waders and several water birds arriving by the Central Asian migratory flyway, as the area is the destination in the southward migration of waterfowl as there is no landmass to south of Sri Lanka until Antarctica. Around 197 bird species have been recorded from the park and among them are 58 migrants (DWC, 1997).

The Park's rich biodiversity also includes 32 mammals, 48 species of reptiles and 32 species of fishes (Green and Gunawardena, 1997, Bambaradeniya *et al*., 2001). The lagoons are surrounded by slightly undulating terrain covered predominantly with lowland dry scrub forest. The topography is generally flat with high sand dunes. Being designated as Sri Lanka's first "Internationally important wetland" under the Ramsar Convention in 1990 highlighted its global significance. BNP is also the core area of the Bundala Man and Biophere Reserve, designated in 2005 under the UNESCO Man and Biospher Programe (MAB). According to Elton, (1958) and Donlan*et al.* (2003), islands have long been considered to be under intense ecological threat from the spread of invasive alien species. Sufficient evidence has emerged that IAS may now be the most significant drivers of population declines and species extinctions in island ecosystems globally (Veitch and Clout, 2002; Donlan *et al*., 2003).

In BNP, *Prosophis juliflora, Opuntia dillenii* and feral buffalo have become seriously invasive inside the park threatening the biodiversity in the park (Marambe *et al*., 2001). Among them *P. juliflora* is considered as the most serious which has already covered more than 620.6 ha, about 10% of total extent of the Bundala National Park (DWC, 2008). *P. juliflora* is a small leguminous tree (Tyagi*et al*., 2006) native to tropical America and the West Indies that has been introduced to Sri Lanka and naturalized in the dry/arid zone, more specifically in Hambantota and Puttlam districts, especially in Bundalaas a shade and erosion control tree in 1950's. Extent and pattern of agro morphological diversity of *P. juliflora* must be know to manage its biodiversity at optimum level (Singh *et al*., 2010). Lack of information on factors contributing strength of invasion hinders the adoption of proper management policy although native vegetation is completely suppressed by the invasive *P. juliflora* inside the park. The key objective of the study is to measure the ecological damage, which occurs to the native vegetation of Bundala National Park by the dispersion of invasive *P. juliflora* by following specific objectives.

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Correlation of the soil salinity for the dissemination of *P. juliflora*. Allelopathic effects of *P. juliflora*on the seed germination of native plant species, and the effect of Asian elephant for the dissemination of *P. juliflora.*

MATERIALS AND METHODS

Experimental site

Field sampling was practiced inside the Bundala National Park in Hambantota district, Sri Lanka. One transect parallel to the salinity gradient was selected from Udamalala Entrance to Malala Modara, from N 06° 09' 35.0", E 081° 10' 57.0" to N 06° 10' 00.2", E 081° 10' 04.8".

Ecological survey

All the experiments were conducted during January in 2014 to August in 2015. The field sampling (Ecological survey) was started in December 2014 just after the rainy season in Hambantota district and continued till August 2015. Along the transect, 100m^2 plots (10m by 10m) were marked with 20m intermediate distance for sampling. All plant species inside the plots were identified and number of individuals from each species was recorded.

Salinity Measurement

Soil samples from each plot were extracted using a 50mm auger for the measurement of salinity. Soil type was recorded according to the soli texture at the field. Samples were taken to the laboratory; oven dried in 35°C to a constant weight, and was sieved using a 0.5 sieve. Extractions were prepared according to the 1:5 W/V method byadding 50ml of distilled water to 10g of oven dried soil, stirred well and allowed to settle for 30 minutes. The EC of the supernatant was measured using an "Oakton 35661-11 TDS meter". EC was converted for the salinity using the soil type correction factor. Soil types were obtained according to the soil type map of BNP.

Allelopathic effects of *P. juliflora*

This study was aimed to examine the impacts of allelopathic compounds present in leaf and root extracts of *P. juliflora* and top-soils under *P. juliflora* trees on germination of seeds of six native prominent species *viz* Weera (*Drypetes sepiaria*), Palu (*Manikara hexandra*), Satin/ Buruta (*Chloroxylon sweitenia*), Kohomba (*Azadirachta indica*), Divul (*Limonia acidissima*) and Thora (*Cassia occidentalis*) found in BNP. Seeds of these species were keptin a concentration series of an aqueous leaf and root extract of *P. juliflora* (0%, 5% and 10%).Extract obtained from soil sample collected from under the canopy of *P. juliflora.* Ten grams of soil sample collected from under the canopy of *P. juliflora* were soaked in 100 ml distilled water for 24 h and, after shaking in an electric shaker for 30min, were passed through Whatman No. 1 filter paper was used as soil extract. Each sample was kept in relevant extract solution for 48 hours and observed under *in-vitro* conditions. The germination test was carried out in sterile Petri dishes using a filter paper. Four ml of each concentration of leaf, root and litter extract added to each Petri dish of respective treatments and moisture was maintained with distilled water. The control was treated with 4 ml distil water only. Four replications with 50 seeds each of receptor plants were used for each treatment. Germination count was made at two days interval until no new seed germination was observed for two consecutive counts. The seed was considered as germinated when the radicle emerged visibly**.**

Prosopis juliflora Seed Germination

The seeds were extracted from the fruits and immediately used in these experiments. Four replicates of 50 randomly selected seeds each were carried out for each treatment. The treatment factors were three salt concentrations, and three temperatures, which were applied in a randomized complete block design. For the scarification treatments, chemical (sulphuric acid) and mechanical scarification applied. Seeds were immersed in H_2SO_4 for 30, 60, 90 minutes. Mechanical scarification was accomplished by rubbing the seeds against No. 50 sandpaper. After each treatment, the seeds were promptly rinsed three times with sterile distilled water to remove acid or integument residues. The seeds were sterilized in a 1% solution of NaOCl for 10 min and then rinsed three times with sterile distilled water. The resultant seeds were transferred into germination boxes lined with a triple layer of filter paper and moistened with 5 ml of sterile distilled water. Seed germination was evaluated daily. After 40 days, the germination time was recorded and expressed in days.

Effect of Asian elephant for the dissemination of *P. juliflora*

Elephant dung samples were collected during the period of May – July by synchronizing the fruiting season of *P. juliflora.* Samples were washed through 0.5mm mesh sieve and seeds were collected for identification. Seed samples were categorized into 2 groups; native and invasive (*P. juliflora*) using collected reference seed samples.

RESULTS AND DISCUSSION

Correlation between salinity and density of *Prosopis juliflora*

Strong positive correlation between the density of *Prosopis juliflora* and salinity of the soil was observed through outtransact measured (Fig.1). In addition, strong negative correlation between the plant diversity and the level of soil salinity was noted throughout transect (data not shown).The possible underlying reasons for less native plant diversity includes the invasion by *P. juliflora* and the subsequent increased competition for resources and poor natural regeneration.

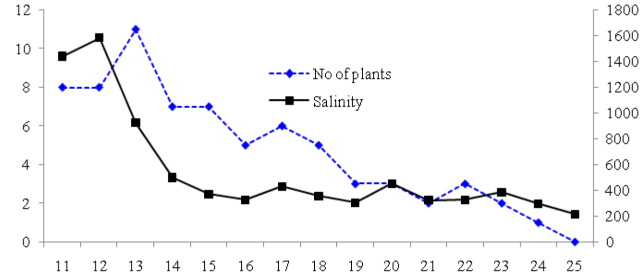

Fig. 1: Correlation between salinity and density of *Prosopis juliflora* in transect

The depressive effect of *P. juliflora* canopy in the abundance of annuals is higher than it is for perennials (El-Keblawy and Al-Rawai 2007). The seedlings of most annuals and perennials had not been seen except seedlings of *P juliflora* attributing to the allelopathic nature of *P. juliflora* and its shade effects that hinder other species' seed germination. Similar results have been reported previously that *P. juliflora* significantly reduced the number of species and density under canopy compared to outside canopy (El- Keblawy and Al-Rawai, 2007).

Effects of Leaf, Root and Soil extraction the seed germination of selected native plant species

Upon the results of soil, root, and leaf extract of *P. juliflora,* the root and soil extracts were more effective in delaying/ inhibiting the germination of test plant species except for *Azadirachta indica* and *Cassia occidentalis* which were unaffected by the extracts (Table 1). Fresh extract of soil and root significantly inhibited the germination of most test species compared with leaf extract (Table 1) inferring variability of Allelopathy in different plant parts of *P. juliflora*. Significant differences of germination rates were observed among concentrations of each extract type.

The results imply that allelopathic compounds are present in the soil and root extracts of *P. juliflora*, affecting seed germination of some native plant species. Percentage seed germination was lower on the soil collected from the *P. juliflora* stand than that on natural forest soil (data not shown). These results imply that allelopathic compounds may accumulate in the soil, adversely affecting seed germination of some plant species. However, the responses to allelopathic compounds of *P. juliflora* may vary among native coastal dry forest plant species. Plant species that are very sensitive to allelopathic compounds are at a risk of being eliminated from the dry zone ecosystems where *P. juliflora* has invaded. Species that are less sensitive to these allelopathic compounds could be recommended to grown as an attempt to restore *P. juliflora* invaded lands.

Table 1: Effect of different concentrations of aqueous extracts from soil and different parts of *Prosopis juliflora* on the final germination percentage of various test species

Species	Concentration (%)	*P. juliflora*		
		Soil Extract	Root Extract	Leaf Extract
Drypetes sepiaria	0	70[a]	73[a]	66[a]
	5	53[b]	50[b]	70[a]
	10	33.2[c]	32[c]	46.6[b]
Manikara hexandra	0	80[a]	76[a]	72[a]
	5	69[a]	69[a]	70[a]
	10	36[c]	33.2[c]	43.2[b]
Chloroxylons weitenia	0	53.2[a]	66.3[a]	63.1[a]
	5	41.6[c]	39.9[c]	48.1[b]
	10	29.2[d]	30[d]	34.3[d]
Azadirachta indica	0	100[a]	100[a]	98[a]
	5	96[a]	98[a]	98[a]
	10	82.2[a]	86.4[a]	93.2[a]
Limonia acidissima	0	72.2[a]	66.6[a]	70.4[a]
	5	67.2[a]	66.2[a]	70[a]
	10	42.2[b]	38.3[b]	62.2[a]
Cassia occidentalis	0	100[a]	98[a]	97[a]
	5	97[a]	97[a]	95[a]
	10	84[a]	86[a]	83[a]

Note: Values for each species having thesame letters within a column are not significantly different at 1% level by Duncan's multiple range test.

Germination Dynamics of *Prosopis juliflora* seeds at different treatments

Table 2: Germination rate (Days) of *P. juliflora* seeds at different concentrations of NaCl at three temperature gradients

NaCl Concentration (mM)	Temperature		
	30 °C	35 °C	40 °C
0	1.03 ± 0.01	1.02 ±0.01	1.04 ± 0.01
60	1.10 ± 0.02	1.08 ±0.01	2.33 ± 0.03
120	1.90 ± 0.03	1.82 ± 0.12	2.73 ± 0.09
240	2.99 ± 0.06	7.73 ± 0.34	4.37 ± 0.13

NaCl and Temperature

The results showed that the germination rate was inversely proportional to the NaCl concentration at all temperatures tested. Therefore, the temperature that best promotes the germination of *P. juliflora* is strongly affected by its interactions with the salt concentration of the substrate where the germination occurs (Table 2).

P. juliflora is able to germinate at higher temperature ranges. Seed germination of *P. juliflora* was considerably reduced with increasing salt concentration up to 40g/lNaCl, however, could efficiently be grown up to 36g/ lNaCl. Previous reports also confirmed that Prosopis juliflora seeds germinated with NaCl osmotic potential until −1.5 MPa (Miranda *et al.*, 2013).

Table 3: Germination rate and germination time of *Prosopis juliflora* seeds after scarification (H_2SO_4& Mechanical)

Treatment	Exposure time (min)	Germiability	Time for germination (days)
Control		8.5± 2.63 b	22.46±2.90 b
H_2SO_4	30	29± 1.73 c	6.91±0.40 b
H_2SO_4	60	85±8.39 b	2.47±0.15 a
H_2SO_4 (0)	90	86.5±5.50 b	1.99±0.07 a
Mechanical scarified		9±2.08 b	17.89±4.32 b

Means followed by different letters within columns are significantly different (Student–Newman–Keuls' test; $P \leqslant 0.05$).

H_2SO_4& Mechanical Scarification

The effects of the scarification treatments on germination rate and germination time were significant (Table 3). Mechanical scarification did not affect any germination attributes of seeds. In natural ecosystems, *P. Juliflora* seeds may be scarified by acids in the digestive tracts of ruminant animals. It has been reported that ingestion by mammals favours the germination of *Prosopis Juliflora* seeds. Rapid germination of this species may be promoted by scarification during passage through the ruminant gut. A short period for seed germination probably has a strong influence on the success of *P. Juliflora*in the Caatinga ecosystem because established seedlings can readily replace top growth and may withstand considerable environmental stress.

Effect of Asian elephant for the dissemination of *Prosopis juliflora*

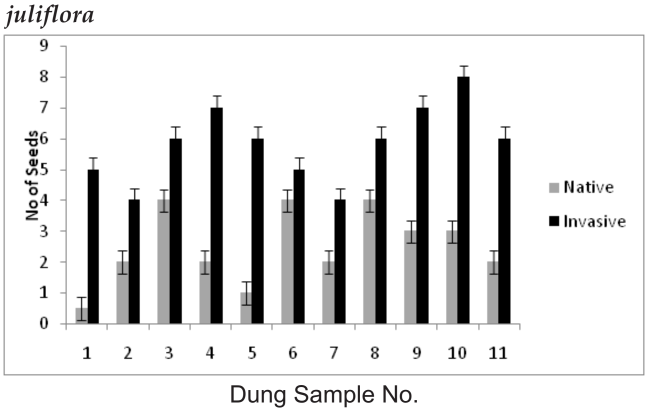

Figure 2: Number of Seeds (Native/invasive) in elephant dung samples during the period of May to July 2014. Error bars represent standard error.

The seeds of invasive *P. juliflora* were much more abundant than those of native plant seeds inferring significant contribution of this giant animal in seed dispersion (Fig.2).It is clear, as an IAS *P. juliflora* has completely adopted for the arid conditions in the BNP. Though *P. juliflora* is a prickly shrub, elephants are fed on the leaves and seedpods of the plant. The seeds in the mature seedpods have a thicker seed coat, which can't be digested in the elephants' gut. So the seeds come out with the droppings of the elephants. Thus the seed dispersion is done enhanced by the elephants.

CONCLUSIONS

Our results strongly inferred that spreading of invasive *P. juliflora* has been imposed a significant ecological damage by suppressing native vegetation. The environmental and soil factors (salinity) enhance the *P. juliflora* growth while low sunlight and salinity are key external factors suppressing native vegetation in BNP. In addition, *P. juliflora* has allelopathic effects on native vegetation but impact is species dependent. Asian elephants and other ruminants fed on *P. juliflora* have great impact on *P. juliflora* seed dispersion throughout the BNP. Therefore, above factors should be taken into consideration for implementing effective management program of *P. juliflora* in Bundala National Park.

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