EFFECT OF *LANTANA CAMARA* L. COVER ON LOCAL DEPLETION OF TREE POPULATION IN THE VINDHYAN TROPICAL DRY DECIDUOUS FOREST OF INDIA

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Abstract. The dry deciduous forest of northern India is being progressively invaded by an alien invasive woody shrub *Lantana camara* L. (Lantana). The invasion of lantana threatens the survival of many species. This study examines the demographic instability of tree species at different levels of lantana cover. Based on proportion of seedlings of a species in its total population (seedling+sapling+adult), about 39.5% and 60% of total 38 species exhibited local demographic instability at different levels of lantana cover for the first and the second census respectively. This decline in species could be attributed to altered microenvironment (light, pH and temperature) beneath the lantana bushes. The study concludes that the presence of lantana shrub as dense understorey perturbs the seedling recruitment of native tree species in the forest and this leads to differential depletion of native trees.
Key words: *declining species population, demographic instability, invasion, lantana cover*.

Introduction

Invasion of native communities by exotic species has been among the most intractable ecological problems of recent years (Sharma *et al.* 2005a). It is a global scale problem experienced by natural ecosystems and is considered as the second largest threat to global biodiversity (Drake *et al.*, 1989). Despite the recent recognition of the invasion of exotic species as a problem, there are many areas in the world where information on the demographic instability caused by invasion is lacking. In India, especially in the dry deciduous forest region, no information is available on demographic instability caused by lantana (*Lantana camara* L.). Lantana that ranked top in-terms of highest impacting invasive species (Batianoff & Butler 2003), and considered one of the worlds 100 worst invasive alien species (GISP 2003), has spread in almost all the areas in the dry deciduous region (Sharma & Raghubanshi 2006).

Tropical forests occupy 7% of the Earth's land surface (Wilson 1988) and harbour approximately two third of all biological populations (Hughes *et al.* 1997). On global basis, 52% of the total forest are tropical and over 42% of tropical forest have been classified as dry deciduous (Holdridge 1967). In India, tropical forests account for approximately 86% of the total forest land (Singh & Singh 1988) while dry forests are 38.2% of the total forest cover (MoEF, 1999). These forests are under immense pressure due to various human induced activities. Especially in Vindhyan highlands, quarrying for limestone, establishment of cement factory, thermal power stations and the construction of G B Pant Sagar reservoir have resulted in rapid population increase, causing deforestation and conversion of natural forest ecosystem into marginal croplands (Singh *et al.* 1991). In fact, during the past 20-years (1981-2001), human population doubled (1463468) in the Sonebhadra district in the Vindhyan region (Rajya

Niyojan Sansthan, 2000; Anonymous, 2003). Forests around this region are also exposed to illegal sporadic tree felling, wide spread lopping of trees for timber resources and shrubs for fuel wood and leaf for fodder (Singh & Singh 1989; Jha & Singh 1990). This rapid modification of the habitat facilitated the invasion of lantana at an accelerated rate (Sharma *et al.* 2005b), which can subsequently affect species regeneration.

Due to its strong allelopathic properties, Lantana has the potential to interrupt regeneration process of other species by decreasing germination, reducing early growth rates and selectively increasing mortality of other plant species (Sharma *et al.* 2005ab). These result in a reduction of species diversity and decline of species.

The objective of the present study was to identify the declining species population at low, medium and high lantana cover in the tropical dry deciduous forest of Vindhyan plateau, India. If the ratio of various age groups in a population is known, demography can be used to elucidate the current reproductive status and future trends of that population (Odum 1983; Smith 1996). A large population of young individuals indicates a rapidly expanding population, a more even distribution of age classes a stationary population, and a large population of old individuals a declining population (Odum 1983; Sagar & Singh 2004). We use the above demographic concept in identifying the depleting species in the areas of lantana invasion.

Material and Methods

Study area

The study area lies on the Vindhyan plateau in the Sonebhadra district of Uttar Pradesh (24º 13' to 24º19' N; 83º59' to 83º13') (Fig. 1). The elevation above the mean sea level ranges between 315 and 485 m (Singh & Singh 1992). This area has been known as “Sonaghati” (golden valley) due to the richness of its natural resources (Singh *et al*. 2002).

The climate is tropical with three seasons in a year, i.e. summer (March to mid June), rainy (mid June to September) and winter (October to February). October and March constitute the transition months between the rainy and winter seasons, and between winter and summer seasons, respectively. The average rainfall varies between 850 and 1300 mm. About 85% of the annual rainfall occurs during the rainy season from the southwest monsoon. The maximum monthly temperature varies from 20ºC in January to 46ºC in June, and the mean minimum monthly temperature reaches at 12ºC in January and at 31ºC in May.

Red coloured and fine textured sandstone (Dhandraul orthoquartzite) is the most important rock of the area. Sandstone is generally underlain by shale and limestone. The soils derived from these rocks are residual ultisols and are sandy-loam in texture (Raghubanshi 1992). These soils are part of the hyperthermic formation of typical plinthustults with ustorthents according to VII approximation of the USDA soil nomenclature (Singh *et al.* 2002). The potential natural vegetation of the region is tropical dry deciduous forest, which is locally dominated by species such as *Anogeissus latifolia, Boswellia serrata, Buchanania lanzan, Diospyros melanoxylon, Hardwickia binata, Lagerstroemia parviflora, Lannea cormendelica, Madhuca longifolia, Shorea robusta* and *Terminalia tomentosa*.

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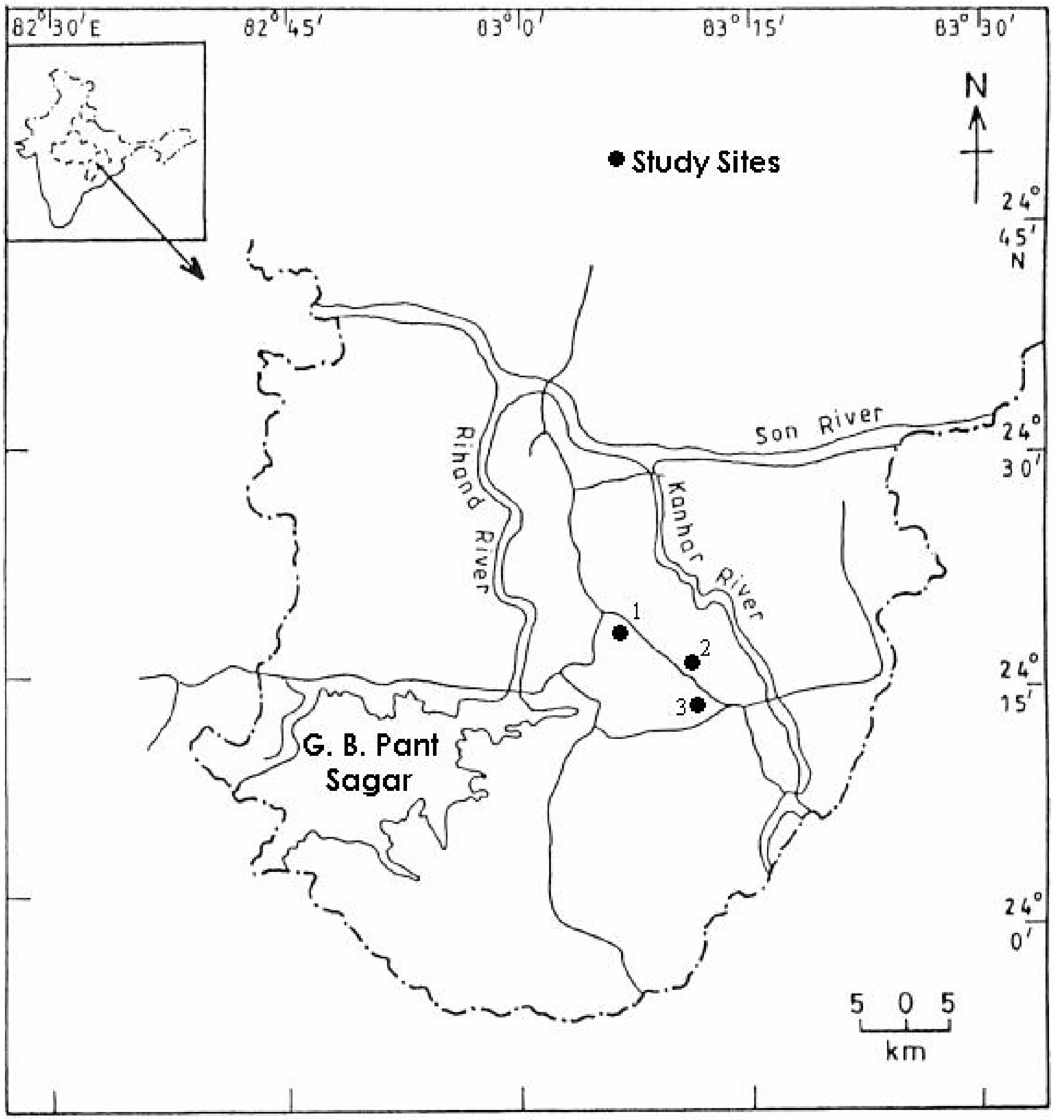

Figure 1. *Location of study sites with low, medium and high lantana cover within Vindhyan highlands, India. 1-Hathinala (low); 2- Bhaheradol (medium); 3- Rajkhar (high).*

Methods

Reconnaissance survey of the entire region was made and three sites (Baheradol, Rajkhar and Hathinala) in the region were selected at random. At these sites, which had visually different levels of lantana invasion sampling was done for the year 2002 and 2003 in the month of October. At each site, 30 quadrates each 10 x 10 m in size, were sampled randomly for vegetation analysis. A total of 90 quadrates, were sampled for vegetation analysis from the entire study area.

Lantana cover was estimated in each quadrate, using the Domin Krajina scale and was transformed into percentage cover for final analysis (Mueller-Dumbois and Ellenberg 1974). Lantana cover was taken as the percentage of the ground surface covered by the shadow of the lantana foliage, estimated as <1, 5, 10, 30, 50, 60, 75, 90, >95%, mean values of lantana cover at each site decided its presence in low, medium and high invaded sites. Later, each site was quantified into low (0%-30%), medium (31%-60%) and high (61%-100%) invasion sites on the basis of percentage cover of lantana. Data on the canopy cover were collected in each sampling unit in 2002 and 2003. Canopy covers were classified into three categories based on visual estimates of the approximate percentage of overstorey canopy cover- low canopy ; 0-30% (high light), medium canopy ; 31-60% (medium light) and high canopy ; 60-100% (low light). The sites varied in topography; the land was relatively gently sloping at Bhaheradol, undulating at Hathinala site and steep sloping at Rajkhar. These sites also differed in the physico-chemical characteristics of soil and were not related to the lantana cover.

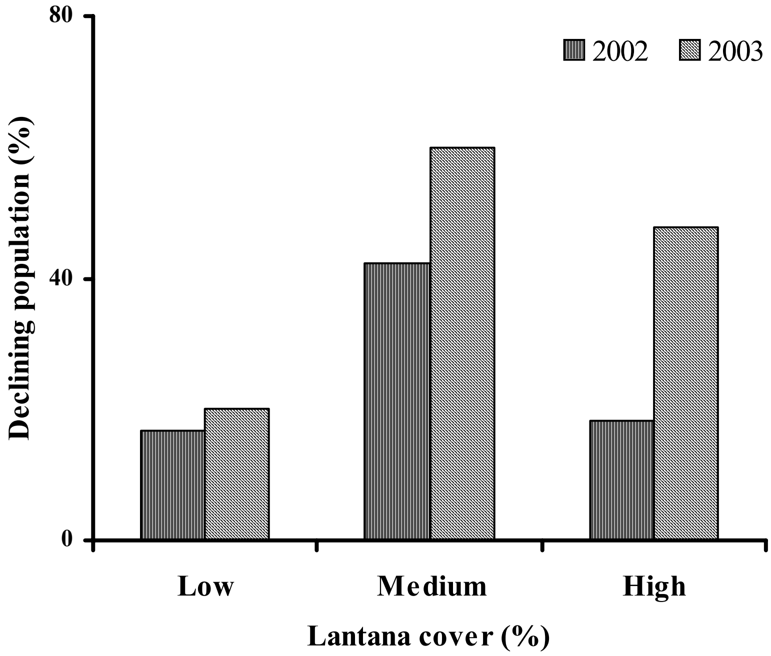

Figure 2. *Proportion of declining species at low, medium and high lantana cover within Vindhyan dry deciduous forest of India for two consecutive census (2002 and 2003).*

The diameter of each adult individual tree (≥9.6 cm diameter at breast height, dbh) was measured in each quadrate. In the centre of each 10 x 10 m quadrate, a 2 x 2 m area was marked for enumeration of saplings (individuals 3.2 cm to <9.6 cm dbh) and established seedlings (individuals <3.2 cm diameter but ≥ 30 cm height) (Sagar and Singh 2004). Seedlings shorter than 30 cm height were considered ephemeral, and the established seedlings category represented 1 to >3 yr old individuals. Stem diameter of adult and sapling individuals was measured at 1.37 m from the ground and for seedlings it was measured at 10 cm above the ground (Sagar and Singh 2004). Thus, all individuals were enumerated and measured by species.

The demographic analysis of species populations on each site was based on the proportion of seedlings of a species in its total population (seedlings + saplings +

adults). We assumed that for normal replacement, the seedling population should at least comprise more than 50% of the total population of a species. Based on this assumption we calculated the ratio of seedling population to the total population of a species. The species on each site were classified into four arbitrary categories on the basis of this ratio: <0.5 for declining species population (i.e. less than 1 established seedling per mature individual), 0.50-0.66 for relatively stable population, 0.67-0.99 for potentially expanding population (i.e. more than 2 seedlings per mature individual) and 1 for newly recruited species from neighbouring areas. A ratio of <0.25 (i.e. less than 1 established seedling per 3 mature individuals) was considered to represent severely depleting species population (Sagar & Singh 2004). Percentage decline at different lantana cover class was obtained by the ratio of number of declining species multiplied by 100 to the total number of species present in different lantana cover classes. However, percentage decline for each year was calculated by the number of declining species in each year multiplied by 100 to the total number of species present in each year.

Relationship between pH, canopy cover, temperature, lantana cover and year of sampling was analyzed by using SPSS software Version 10.0 (SPSS 1997

Result

In total, 38 species, and 28668 stems were recorded in the cumulative sampled area for both the census with 14851 and 13817 stems for the two consecutive censuses respectively (Table 1). A total of 376 adults, 1500 sapling and 12975 established seedlings were recorded in the first census while 368 adults, 2825 saplings and 10625 established seedlings were recorded in the second census. In total, 7 rare species were recorded, 2 in high and 6 in medium lantana invaded plots. *Acacia auriculiformis, Boswellia serrata, Briedelia retusa, Cassia fistula, Elaeodendron glaucum, Eriolena quinquelaris,* and *Miliusa tomentosa,* were recorded as one individual per 0.3 ha sampled area and were distinguished as rare species for both the census. *Acacia auriculiformis* and *Cassia fistula* were represented as one individual in entire 0.9 ha sampled area both the census (Table 1).

A total of 15 and 23 species exhibited demographic instability for the two consecutive censuses (Table 2), in other words, local reduction in population size. Of these, 15 species (*Acacia auriculiformis, Adina cordifolia, Boswellia serrata, Briedelia retusa, Buchanania lanzan, Cassia fistula, Elaeodendron glaucum, Emblica officinalis, Eriolena quinquelaris, Hardwickia binata, Lannea coromandelica, Miliusa tomentosa, Mitragyna parvifolia, Schleichera oleosa, Schrebera swietenioides*) showed relative declining abundances of established seedlings wherever they were present for both the census (Table 2).

Elaeodendron glaucum showed declining population at all the levels of lantana invasion both the census while large number of species with declining population occupied only one or few sites (Table 2). Thus, while 23 species showed declining population at different levels of lantana invasion both the census. The proportion of declining species population was maximum at medium lantana invasion (42 & 60 %), than at high lantana invasion (19 & 48 %) and minimal at low lantana invasion (16 & 20 %) for both the census respectively. However, the total number of species decreased with increasing lantana cover.

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ANOVA revealed that pH and temperature significantly varied with the year of sampling, but the canopy cover did not varied significantly with the year (Table 3). However, pH, canopy cover and temperature varied significantly with lantana cover (Table 3). Tukey's test revealed that pH, canopy cover and temperature showed significant differences in terms of lantana cover and year of sampling (Table 4).

Table 1. *Number of species in different growth categories (A = adult; S = sapling; ES = established seedling) at low, medium and high Lantana camara invasion in a dry tropical forest sites of northern India at temporal scale. Data are number of individuals per 0.3 ha area. Adults were enumerated in 30 quadrats of 10 x 10 m size and saplings and established seedlings were enumerated in 30 quadrats of 2 x 2 m size at each forest sites. The saplings and established seedling individuals were scaled up in same unit as adult.*

Species	**Lantana cover (%)**																	
	2002									**2003**								
	Low			**Medium**			**High**			**Low**			**Medium**			**High**		
	A	S	ES	A	S	ES	A	S	ES	A	S	ES	A	S	ES	A	S	ES
Acacia auriculiformis	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Acacia catechu Willd.	12	25	75	19	75	50	0	0	0	12	25	50	20	100	25	0	0	0
Adina cordifolia Hook.	0	0	75	0	0	0	4	0	0	0	0	75	0	0	0	4	0	0
Azadirachta indica A. Juss.	0	0	25	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0
Antidesma ghaesembilla Gaertn.	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0	0	25
Anogeissus latifolia Wall.	3	25	150	15	25	100	0	50	300	3	25	150	12	25	75	3	100	100
Bauhinia racemosa Lam.	0	0	150	0	0	0	0	0	0	0	0	150	0	0	0	0	0	0
Boswellia serrata Roxb.ex.Colebr.	3	0	400	1	0	0	0	0	0	3	0	350	1	0	0	0	0	0
Briedelia retusa Muell - Arg.	9	100	800	1	0	0	0	0	25	10	75	750	1	0	0	0	0	25
Buchanania lanzan Spreng.	10	0	50	5	25	25	3	0	0	10	0	25	4	25	0	3	0	0
Cassia fistula Linn.	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Carissa spinarum DC.	0	0	0	0	0	0	0	25	75	0	0	0	0	0	0	0	25	75
Casearia elliptica Willet.	0	0	0	0	0	0	0	0	150	0	0	0	0	0	0	0	0	150
Diospyros melanoxylon Roxb.	6	25	625	9	50	1100	2	100	950	7	0	550	10	25	1050	3	225	700
Elaeodendron glaucum Pers.	2	0	0	2	0	0	1	0	0	2	0	0	2	0	0	1	0	0
Emblica officinalis Gaerth.	6	25	50	1	0	0	0	0	25	6	25	50	1	0	0	0	0	0
Eriolaena quinquelocularis Wight.	0	0	125	1	0	0				0	0	125	1	0	0		0	0
Flacourtia indica Murr.	0	0	250	2	0	200	0	0	25	0	0	250	2	0	150	0	0	100
Gardenia latifolia Ait.	1	25	125	1	0	25	0	0	0	1	25	125	1	25	25	0	0	0
Grewia serrulata DC.	0	0	275	0	0	0	0	0	0	0	75	175	0	0	0	0	0	0
Hardwickia binnata Roxb.	5	0	0	3	25	0	0	0	0	5	0	0	3	25	0	0	0	0

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Holarrhena antidysenterica DC.	0	0	1050	1	0	150	0	0	200	0	150	875	1	0	150	0	25	75
Hymenodictyon excelsum Wall.	0	0	100	0	0	25	0	0	0	0	0	100	0	0	0	0	0	0
Lagerstroemia parviflora Roxb.	4	0	50	14	25	100	1	50	75	4	0	50	14	25	100	2	50	25
Lannea coromandelica Merr.	17	25	0	3	50	25	17	25	75	17	25	0	3	50	25	17	25	25
Madhuca longifolia MacBr.	0	0	0	0	0	0	12	0	25	0	0	0	0	0	0	10	0	25
Miliusa tomentosa Sincl.	3	25	175	3	100	450	1	0	0	3	50	125	3	200	300	1	0	0
Mitragyna Parvifolia Korth.	0	0	25	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0
Pterocarpus marsupium Roxb.	0	0	25	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0
Schleichera oleosa Oken.	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0	25	0
Schrebera swietenioides Roxb.	9	0	0	0	0	25	0	0	0	9	0	0	0	25	0	0	0	50
Semecarpus anacardium Linn.f.	2	25	300	0	25	50	0	0	25	2	75	250	0	50	25	0	0	25
Shorea robusta Gaertn.	52	75	650	39	50	450	31	75	675	48	175	550	34	175	425	28	325	300
Soymida febrifuga A. Juss	4	25	25	1	0	75	0	0	0	4	25	25	1	50	25	0	0	0
Sterculia urens Roxb.	2	50	100	0	0	50	0	0	0	2	50	100	0	25	50	0	0	0
Terminalia tomentosa Wight.	8	25	1075	12	175	275	11	75	200	7	25	1025	12	200	250	12	125	75
Zizyphus nummularia Wight & Arn.	0	0	75	0	0	50	0	0	0	0	25	75	0	0	50	0	0	0
Sikti (unidentified)	0	0	0	0	0	0	0	0	50	0	0	0	0	0	0	0	0	75

Table 2: *Species showing local population depletion (*) based on the <0.50 ratio of seedling population to total species population at low, medium and high Lantana camara invasion at temporal scale. Zeroes indicate complete absence of established seedlings. Values are ratios of established seedlings to total population (- = species not present).*

Species	**Family**	**Common names**	**Lantana cover**					
			2002			**2003**		
			Low	**Medium**	**High**	**Low**	**Medium**	**High**
Acacia auriculiformis	Mimosiaceae	Australian babool	-	0.00*	-	-	0.00*	-
Acacia catechu Willd.	Mimosiaceae	Khair	0.67	0.35*	-	0.57	0.17*	-
Adina cordifolia Hook.	Rubiaceae	Haldu/Karam	1.00	-	0.00*	1.00	-	0.00*
Azadirachta indica A. Juss.	Miliaceae	Neem	-	-	1.00	1.00	-	-
Antidesma ghaesembilla Gaertn.	Euphorbiaceae	Sahrauta	1.00	-	-	-	-	1.00
Anogeissus latifolia Wall.	Combrataceae	Dhaura/Dhau	0.84	0.71	0.86	0.84	0.67	0.49*
Bauhinia racemosa Lam.	Caesalpiniaceae	Katahul	1.00	-	-	1.00	-	-
Boswellia serrata Roxb.ex.Colebr.	Burseracaeae	Salai	0.99	0.00*	-	0.99	0.00*	-
Briedelia retusa Muell - Arg.	Euphorbiacae	Khaja	0.88	0.00*	1.00	0.90	0.00*	1.00
Buchanania lanzan Spreng.	Anacardiaceae	Piyar	0.83	0.45*	0.00*	0.71	0.00*	0.00*
Carissa spinarum DC.	Apocynaceae	Karaunda	-	-	0.75	-	-	0.75
Casearia elliptica Willet.	Flacourtiaceae	Bheri	-	-	1.00	-	-	1.00
Cassia fistula Linn.	Caesalpiniaceae	Amaltas	-	0.00*	-	-	0.00*	-
Diospyros melanoxylon Roxb.	Ebenaceae	Tendu	0.95	0.95	0.90	0.99	0.97	0.75
Elaeodendron glaucum Pers.	Celastraceae	Mamar	0.00*	0.00*	0.00*	0.00*	0.00*	0.00*

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Emblica officinalis Gaerth.	Euphorbiacae	Aonla	0.62	0.00*	1.00	0.62	0.00*	-
Eriolaena quinquelocularis Wight.	Sterculiaceae	Dheriya	1.00	0.00*	-	1.00	0.00*	-
Flacourtia indica Murr.	Flacourtiaceae	Kantaila	1.00	0.99	1.00	1.00	0.99	1.00
Gardenia latifolia Ait.	Rubiaceae	Papar	0.83	0.96	-	0.83	0.49*	-
Grewia serrulata DC.	Tiliaceae	Bichhula	1.00	-	-	0.70	-	-
Hardwickia binnata Roxb.	Caesalpiniaceae	Parsiddha	0.00*	0.00*	-	0.00*	0.00*	-
Holarrhena antidysenterica DC.	Apocynaceae	Khirana/Koraya	1.00	0.99	1.00	0.85	0.99	0.75
Hymenodictyon excelsum Wall.	Rubiaceae	Bhurkul	1.00	1.00	-	1.00	-	-
Lagerstroemia parviflora Roxb.	Lythraceae	Siddha	0.93	0.72	0.60	0.93	0.72	0.32*
Lannea coromandelica Merr.	Anacardiaceae	Gigan	0.00*	0.32*	0.64	0.00*	0.32*	0.37*
Madhuca longifolia MacBr.	Sapotaceae	Mahua	-	-	0.68			0.71
Miliusa tomentosa Sincl.	Anonaceae	Kari	0.86	0.81	0.00*	0.70	0.60	0.00*
Mitragyna Parvifolia Korth.	Rubiaceae	Gurahi	1.00	-	-	0.00*	-	-
Pterocarpus marsupium Roxb.	Fabaceae	Biya/Vijayasal	1.00	-	-	1.00	-	-
Schleichera oleosa Oken.	Sapindaceae	Kusum	-	-	1.00	-	-	0.00*
Schrebera swietenioides Roxb.	Oleaceae	Ghantha	0.00*	1.00	1.00	0.00*	0.00*	1.00
Semecarpus anacardium Linn.f.	Anacardiaceae	Bhela	0.92	1.00	1.00	0.76	0.33*	1.00
Shorea robusta Gaertn.	Dipterocarpaceae	Sal/Shakhu	0.84	0.67	0.86	0.71	0.67	0.46*
Soymida febrifuga A. Juss	Miliaceae	Rohina	0.46*	0.83	-	0.46*	0.33*	-
Sterculia urens Roxb.	Sterculiaceae	Kuruli	0.66	0.99	-	0.66	0.67	-
Terminalia tomentosa Wight.	Combrataceae	Asan/Saja	0.97	0.60	0.70	0.97	0.54	0.35*
Zizyphus nummularia Wight & Arn.	Rhamnaceae	Ber/Beri	1.00	1.00	-	0.75	1.00	-
Sikti (unidentified)			-	-	1.00	-	-	1.00

Table 3. *Summary of ANOVA for pH, Canopy cover, temperature in response to year and lantana cover.*

Source of variation	**Dependent variable**	**df**	**F**	**P**
Year	pH	1	64.04	0.000
	Canopy cover (%)	1	1.06	0.312
	Temperature (°C)	1	10.46	0.004
Lantana cover (%)	pH	2	24.06	0.000
	Canopy cover (%)	2	180.413	0.000
	Temperature (°C)	2	47.26	0.000
Year× *Lantana* cover (%)	pH	2	0.67	0.51
	Canopy cover (%)	2	0.54	0.58
	Temperature (°C)	2	0.68	0.51
Error		24		
Total		30		

Table 4. *Data on pH, temperature and canopy cover at different lantana cover for the two consecutive years.*

Lantana cover (%)	Year	
	2002	2003
	pH	
Low	6.65 ± 0.02[a]	6.86 ± 0.02[d]
Medium	6.52 ± 0.04[b]	6.72 ± 0.05[b]
High	6.38 ± 0.03[c]	6.65 ± 0.03[e]
	Temperature (°C)	
Low	33.22 ± 0.45[a]	32.61 ± 0.36[d]
Medium	30.96 ± 0.35[b]	29.73 ± 0.65[b]
High	29.53 ± 0.34[c]	27.92 ± 0.38[e]
	Canopy cover (%)	
Low	71 ± 1.87[a]	72 ± 2.55[a]
Medium	50 ± 2.24[b]	46 ± 1.87[d]
High	21 ± 3.67[c]	17 ± 3.74[e]

Values affixed with different letters were significantly different from each other at <0.05.

Discussion

Sagar and Singh (2004) reported 12 species (viz. Boswellis serrata, Carrissa spinarum, Cassia fistula, Cassia siamea, Dalbergia sissoo, Ficus benghalensis, Holoptelia integrifolia, Madhuca latifolia, Syzygium heyneanum, Terminalia tomentosa, 2 unidentified species- Papra and Rij) showing a reduction in population size at varied disturbance regimes. Study conducted at various levels of lantana cover revealed that the species with declining population differed, except for Boswellis serrata and Cassia fistula which showed declining populations at various disturbance regimes (Sagar & Singh 2004). Thirteen more species, other than those with declining population due to disturbance, showed a decline at different levels of lantana invasion for both the census. The number of declining species increased when both the phenomena (viz. disturbance and lantana invasion) were taken into consideration. Thus, we may interpret that disturbance and invasion synergistically affect the tree regeneration process in the Vindhyans. Although, Sharma et al. (2005c) emphasized that while studying invasiveness, all the available tenets must be taken into consideration to explain invasions in totality.

Species exhibited as a single individual at different lantana cover included Acacia auriculiformis, Boswellia serrata, Briedelia retusa, Cassia fistula, Emblica officinalis and Eriolena quinquelaris at medium lantana invasion and Elaeodendron glaucum and

Miliusa tomentosa at high lantana invasion (Table 1). It is obvious that the species with only one individual would be highly vulnerable, since a local population composed of only a few individuals can undergo catastrophic decline due to environmental change, genetic problem or simple random events when isolated in a limited geographic range (Cunningham & Saigo 1999). According to Barbault & Sastrapradja (1995), species with small population size are highly vulnerable and severe the environmental change the higher the rate of local loss of species population. A minimum size of population is required for long-term viability of rare and endangered species (Cunningham & Saigo 1999).

The forest supplies approximately 90% of the fuel wood and fodder needs of the local population. Exploitation of single species can cause the entire structure of the plant community to change (Spurr & Barnes 1980). Further, fuel wood collection can be a major contributor to forest degradation. These result in canopy openings, which permit lantana to flourish well and affect the tree regeneration process due to competition. Under such conditions, shading effect and allelopathic activity of lantana cause seedlings of tree species have stunted or no growth. When canopy trees are removed patches of increased light intensity (Rejmanek 1989) and nutrient resources (Davis et al. 2000) are created. Lantana is faster growing than native tree species and it captures the resources efficiently, creating substantial biomass of lantana in the inter-canopy and at the edges of the forest (personal observation). Breshears (2006) also emphasized that canopy opening (in terms of cover) affects ecosystem functioning between canopy and inter-canopy patches in terms of light irradiance. Rodger & Twine (2002) advocated that lantana invasion could be considered as a form of bush encroachment. The dense growth of lantana in the form of understorey mat prevents the light to reach the ground, resulting in marked heterogeneity in terms of irradiance and temperature. Light has long been recognized as an important plant resource (Maximov 1929; Blankenship 2002) that may interact with other plant resources to affect plant performance (Cole 2003). Below certain thresholds, however, light limitation alone can prevent seedling survival regardless of other resource levels (Tilman 1982). It is likely that seedlings of tree species are influenced by the amount of light that reaches the forest floor, and this may be probably one of the mechanisms responsible for the decline of seedlings. Sharma and Raghubanshi 2006 advocated that the growth architecture pattern of lantana is such that it prevents the light penetration to the forest floor, leading to the decline of tree seedlings.

Almost all the species with declining population (Acacia auriculiformis, Adina cordifolia, Boswellia serrata, Briedelia retusa, Buchanania lanzan, Cassia fistula, Elaeodendron glaucum, Emblica officinalis, Eriolena quinquelaris, Hardwickia binata, Miliusa tomentosa, Schrebera swietenioides) require high to moderate light for proper growth (Troup 1921). Lantana canopy certainly lowers sunlight to reach the ground level, which may affect the soil temperature. The dry forest tree species are fairly tolerant to moderately high temperatures at all the life cycle stages (Khurana and Singh 2001a). As increase in temperature triggers germination by changing the internal enzymatic kinetics and thus the biochemistry of seed cells (Khurana and Singh 2001b, Vazquez and Orozeo 1982). However, the decrease in temperature due to lantana canopy might perturb seedling recruitment. This may possibly be one of the reasons that inhibits seedling establishment of the tree species. Further, the change in pH that may be attributed to the allelopathic potential of lantana and this could have important implication for the seedling establishment.

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Lantana bushes are fire prone and can burn readily altering the fire regime to favour its persistence (Hiremath and Sundaram 2005). These lantana bushes when burned create ample heat, causing seed and seedling mortality in the area (Moore & Wein 1977). Thus, interaction of these factors with biotic pressure might inhibit both seed germination as well as seedling establishment, which may result in population loss.

There are several ways in which lantana could suppress tree recruitment selectively. As lantana forms dense bushes and when such bushes grow nearby each other they form an understorey mat like structure (personal observation). And such mat formation prevents the seeds of tree species to reach the ground; these seeds get entrapped in the lantana mat. For example, the fruit of Schrebera swietenioides is 2-3 inch long (Brandis 1978), which can be easily trapped in lantana mat. Although when few seeds reach the ground there is scarcity of light. At ground level there is accumulation of lantana litter and other broken dry debris of lantana, which could lead to allelopathic suppression for germination of seeds of tree species (Gentle & Duggin 1997).

Conclusion

This study suggests that not only many species of the tropical dry deciduous forest have small local population, but also several of them exhibit declining or even severely depleting population at different levels of lantana invasion. Such invasive species cover may create demographic instability among the tree species and reduce tree diversity and can even change the structure of the forest in the near future. As seedlings of most of the tree species of tropical dry deciduous forest are adapted to grow in relatively open conditions, because of the poor canopy cover and deciduous nature. The presence of lantana shrub as dense understorey perturbs the seedling recruitment of native tree species in the forest and this lead to differential depletion of native trees. This calls for immediate conservation activity. Further this study gives an implication and need for in-depth microcosm study in relation to lantana specific performance of declining species in the tropical dry deciduous forest.

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