Effect of weeds *Lantana camara* and *Chromelina odorata* growth on the species diversity, regeneration and stem density of tree and shrub layer in BRT sanctuary

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A study was undertaken in Biligiri Rangan hills Temple wildlife sanctuary, Karnataka covering an area of 540 km^2 by laying 134 plots measuring 80 m × 5 m at 2-km intervals over the sanctuary, to understand the influence of two weeds, *Lantana camara* and *Chromelina odorata*, on species richness and stem density. All stems above 1 cm DBH were enumerated. Plots were classified based on the presence and absence of *Lantana* and *Chromelina.*

Species richness and stem density were high in the plots infested with *Lantana* compared to control and lower species richness was recorded in plots infested with *Chromelina* compared to *Lantana*. It is argued that *Lantana* may not suppress the growth of other species; it probably grows in the plots with more moisture, preferred by many other species.

STUDIES have demonstrated that invasion by exotic plants has altered population dynamics and community structure of native ecosystems[1–3]. Invasion of biological species primarily comes with the introduction of some species-curious botanists or through traders with commercial interests[4]. Further habitat disturbance due to anthropogenic or environmental reasons could lead to invasion of species[4–6]. There are few studies on influence of weeds on species diversity and regenerating potential of native flora. This paper attempts to study the impact of two weedy species *Lantana camara* and *Chromelina odorata* on the change in species diversity of native flora.

The Western Ghats in southern India is known for its rich biodiversity and in fact, it is regarded as one of the 12 mega biodiversity centres in the world. However, due to various anthropogenic disturbances, these forests have been invaded by other exotic species like *L. camara* and *C. odorata*. Both these species have invaded the hills and slopes of the Western Ghats, wastelands and other ecosystems. In this study we attempt to understand how these two species have brought changes in stem density and species diversity in four different forest types found in Biligiri Rangan hills Temple (BRT) sanctuary, Karnataka.

The BRT sanctuary covers an area of 540 km^2 and is located between 11–13°N and 77–78°E in south-east corner of Mysore district. The terrain is highly undulating with the altitude ranging from 600 to 1800 m above mean sea level. Five major vegetation types found in this area are evergreen forests, deciduous forests, scrub or thorny vegetation, shola or stunted montane forests and grasslands found mostly in the hills tops. The other details of the study are given elsewhere[7].

The entire sanctuary was divided into 134 grids at 2 km intervals. In each grid the mid point was chosen and rectangular transects, each measuring 80 m long and 5 m wide were laid and all stems above 1 cm DBH were enumerated and their girth recorded. Further, at each corner of transects a square plot of 1 m × 1 m was laid and all herbs, tree seedlings and shrubs were recorded. Methodological details are given in Murali *et al.*[8].

The plots were classified into the following categories: presence of no weeds, only *Chromelina*, only *Lantana* and presence of both weeds. Species richness and stem density were compared among these four categories of plots using *t* test and Mann–Whitney *U* test. Correlation coefficient between the number of *Lantana* stems and stem density of other species was computed.

Influence of weeds over the native species has largely been viewed as detrimental[1–3]. This study compares the influence of weeds on stem density and species richness. Table 1 indicates that the species number was significantly high in plots where *L. camara* was present. Similarly the total number of regenerating (stems between > 1 and < 10 cm DBH) stems was high in plots with *Lantana*. However, when *Lantana* was removed from the plot, there was no significant difference in stems per plot between the plots with and without *L. camara*. The species at the shrub layer were higher in plots with *L. camara*, while the understorey layer species were lower in plots without *L. camara*. Similarly, when *C. odorata* was removed from the plots of *L. camara*, the results did not vary.

Mann–Whitney *U* test also reveals the same result, indicating that the influence of *Lantana* on stem density was not by chance. Further, the correlation between the stem density of *Lantana* with the species number was very low (0.0001, $df = 132$, NS), indicating that there exists only qualitative difference and not a quantitative one. The correlation between the stem density in plots and species number was positive and significant ($r = 0.661$, $df = 132$, $P < 0.01$), indicating that the species number increases along with stem number. The correlation between stem density (without *Lantana*) and species number is also positive ($r = 0.671$, $df = 132$, $P < 0.01$), indicating that *Lantana* has no influence on the species number. Thus our study clearly indicates that infestation of *Lantana* does not really hamper biodiversity. *Lantana* simply occupies the moist habitats that most other species also prefer.

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Lantana may have come to forests in India, mainly because of degradation due to anthropogenic pressures[9], but in the Western Ghats it is not an aggressive colonizer[10].

A contrary trend was found with *Chromelina* compared to *Lantana*. Species number and stem density of size 1 to 10 cm DBH were significantly high in plots without *Chromelina* (Table 2). There was no difference in stem density of canopy species and number of understorey and canopy species. This indicates that regeneration is affected by presence of *Chromelina* and even the species richness. Further, this study indicates that *Chromelina* does hamper the diversity and species richness. Threat to native flora in South Africa due to Acacia, Hackia and Pinus has been reported[11–13]. *Chromelina* hampers the regeneration of tree species due to allelopathic effect in north-eastern India[14]. The aromatic compounds present in *Chromelina* will reduce the palatability of grasses and arrest the secondary succession of forests[15], they are highly inflammable and enhance the incidence of fire[16,17]. Though it has been conjectured that *Lantana* does affect regeneration of other native species[18,19], no quantitative data are available. BR hills also experience fire in summer, in the forest fringes where *Chromelina* is prevalent.

An analysis consisting of presence of *L. camara* and *C. odorata* individually and together revealed that (Table 3) large species were found in plots where only *Lantana* was present. The plots consisting of only *Chromelina* had lowest number of species. The number of species in > 1 and < 10 size was highest again in plots with *L. camara*, while the lowest species was recorded in plots of *Chromelina*. The number of individuals of size class 1 to 10 cm DBH was also lowest in plots with *C. odorata*, while the other plots did not vary statistically. This analysis reiterates the results obtained earlier.

Habitat-wise analysis of data on the stem density and species diversity (Table 4) indicates that the number of saplings was not significantly different in different regimes of weed infestation, except in scrub forests. In scrub forests, the seedlings per transect was high in plots infested with *Chromelina*. The stem density was highest in *L. camara*-infested plots in deciduous forests. In evergreen forests, the difference in means between plots infested with *L. camara* and those not infested was not significant. While in scrub forests the stem density was highest in *L. camara* and *Chromelina*-infested plots. Similarly, in the *L. camara*-infested plots in the shola forests stem density was higher. The total number of species was highest in plots of *L. camara* and *Chromelina*-infested plots in deciduous and scrub forests, while it is lowest in evergreen forests. In conclusion, *Lantana* may not be affecting species diversity or stem density in BR hills compared to *Chromelina*. However, more data are

Table 1. Species diversity (number of species per transect), stem density and regeneration of trees in the plots infested with *Lantana camara* and plots without *Lantana camara* infestation

Parameter	*Lantana* absent (mean ± SD; n = 78)	*Lantana* present (mean ± SD; n = 56)	t-value	Mann–Whitney U	Mann–Whitney Z
Total number of species per plot	14.75 ± 5.34	17.78 ± 6.43	2.94**	2768.5	3.72
No. of stems (> 10 cm DBH)	15.87 ± 11.42	14.36 ± 9.02	0.82	2335.5	0.96
No. of stems (> 1 and < 10 cm DBH)	55.76 ± 46.71	72.14 ± 3.59#	2.05*	2791.5	3.87
No. of species (> 10 cm DBH)	3.4 ± 2.7	3.5 ± 2.95	0.21	2251.5	0.43
No. of species (> 1 and < 10 cm DBH)	8.17 ± 5.24	10.96 ± 5.39@	3.01**	2817.5	4.04
Total stems	73.54 ± 42.36	79.74 ± 43.10	0.85	2717.5	3.4

*, **Statistical significance at $P < 0.05$ and $P < 0.01$, respectively.
#Number of stems (> 1 and < 10 cm DBH) excluding *L. camara* was 64.11; $t = 1.06$; $P > 0.05$.
@Number of shrub species (> 1 and < 10 cm DBH), excluding *L. camara* was 9.96; $t = 1.93$; $P < 0.05$.

Table 2. Species richness, stem density and regeneration of trees in the plots infested with and without *Chromelina odorata* infestation

Parameter	*Chromelina* present (mean ± SD; n = 77)	*Chromelina* absent (mean ± SD; n = 56)	t-value
Total number of species per plot	16.97 ± 6.21	13.93 ± 4.91	2.75**
No. of stems (> 10 cm DBH)	3.46 ± 3.01	3.39 ± 2.27	0.14
No. of stems (> 1 and < 10 cm DBH)	10.18 ± 5.451	7.41 ± 5.02	2.75**
No. of species (> 10 cm DBH)	15.53 ± 11.59	14.58 ± 7.47	0.47
No. of species (> 1 and < 10 cm DBH)	63.31 ± 44.47	61.00 ± 49.68	0.26
Total stems (> 1 cm DBH)	73.55 ± 41.23	82.24 ± 57.44	1.08

**Statistical significance at $P < 0.01$.

Table 3. Species richness, stem density and regeneration of trees in the plots infested with and without *Chromelina odorata* and plots infested with and without *Lantana camara*

Parameter	No weeds (mean ± SD; n = 58)	Only *Lantana* (mean ± SD; n = 35)	Only *Chromelina* (mean ± SD; n = 20)	Both present (mean ± SD; n = 21)
Total species	15.65 ± 5.40^{b}	18.94 ± 7.06^{c}	12.25 ± 4.24^{a}	15.86 ± 4.62^{b}
No. of species (> 10 cm DBH)	3.34 ± 2.92	3.80 ± 3.20	3.35 ± 1.88	3.19 ± 2.48
No. of species (> 1 and < 10 cm DBH)	8.98 ± 5.24^{b}	11.97 ± 5.37^{c}	5.95 ± 4.43^{a}	9.14 ± 4.79^{bc}
No. of stems (> 10 cm DBH)	16.60 ± 12.59	13.54 ± 9.33	13.90 ± 6.7	15.57 ± 8.22
No. of stems (> 1 and <10 cm DBH)	59.95 ± 46.22^{b}	68.08 ± 41.51^{b}	42.60 ± 45.5^{a}	79.86 ± 45.22^{b}

Letters in the row followed by the same alphabet differ significantly at $P < 0.05$.

Table 4. Species richness, stem density and regeneration of trees in plots infested with *Chromelina odorata* and *Lantana camara* in different forest types in BRT sanctuary

Forest type	No weeds (mean ± SD)	Only *Lantana* (mean ± SD)	Only *Chromelina* (mean ± SD)	Both present (mean ± SD)
Deciduous	n = 11	n = 17	n = 13	n = 11
No. of saplings	17.5 ± 6.04	18.0 ± 5.98	15.30 ± 5.51	19.50 ± 7.44
No. of stems	22.7 ± 20.72^{ab}	66.3 ± 41.23^{c}	22.38 ± 6.35^{b}	20.38 ± 6.35^{b}
Total no. of species	11.4 ± 3.11^{a}	19.2 ± 5.49^{a}	9.80 ± 2.78^{a}	14.00 ± 3.78^{a}
No. of tree species[1]	4.2 ± 2.15^{ab}	4.7 ± 3.8^{c}	3.70 ± 1.98^{a}	4.50 ± 2.31^{ab}
No. of understorey species[2]	4.5 ± 3.06^{a}	10.2 ± 4.15^{b}	3.60 ± 2.71^{a}	6.60 ± 3.25^{a}
Evergreen	n = 7	n = 3		n = 1
No. of saplings	22.3 ± 8.73	24.00 ± 3.74	NS	8.0 ± 0.0
No. of stems	56.0 ± 30.97	69.33 ± 33.41	NS	122.0 ± 0.0
Total no. of species	20.7 ± 4.2	24.70 ± 1.7	NS	11.0 ± 0.0
No. of tree species[1]	5.7 ± 1.67	7.30 ± 2.62	NS	4.0 ± 0.0
No. of understorey species[2]	10.6 ± 5.07	13.30 ± 4.19	NS	6.0 ± 0.0
Scrub	n = 24	n = 13	n = 7	n = 9
No. of saplings	5.9 ± 8.29^{ab}	3.8 ± 4.21^{a}	11.4 ± 7.75^{b}	11.7 ± 7.07^{b}
No. of stems	72.0 ± 35.64^{a}	60.5 ± 39.13^{a}	85.9 ± 57.72^{ab}	112.1 ± 38.97^{b}
Total no. of species	14.6 ± 4.97^{a}	15.2 ± 5.64^{ab}	16.9 ± 2.1^{ab}	18.8 ± 4.66^{b}
No. of tree species[1]	0.8 ± 1.26^{a}	1.3 ± 1.63^{ab}	2.7 ± 1.48^{b}	1.6 ± 1.77^{ab}
No. of understorey species[2]	11.7 ± 5.05^{a}	13.1 ± 6.48^{a}	10.3 ± 4.2^{a}	12.6 ± 4.35^{a}
Shola	n = 16	n = 2		
No. of saplings	29.5 ± 7.82^{a}	23.5 ± 5.5^{a}		
No. of stems	69.1 ± 62.68^{a}	122.0 ± 28.0^{b}		
Total no. of species	17.9 ± 4.88^{a}	33.0 ± 8.0^{b}		
No. of tree species[1]	5.6 ± 2.5^{a}	7.0 ± 0.0^{a}		
No. of understorey species[2]	7.3 ± 3.84^{a}	18.0 ± 4.0^{b}		

Letters in the row followed by the same alphabet differ significantly at $P < 0.05$.
[1]Species of stems that are > 10 cm DBH.
[2]Species of stems that are > 1 but < 10 cm DBH.

required to conclusively suggest that regeneration may be affected due to these two species.

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Facilitative effect of *Coriaria nepalensis* on species diversity and growth of herbs on severely eroded hill slopes

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In this study we examine the facilitative effect of *Coriaria nepalensis* Wall. verns. at two contrasting sites, a severely eroded hill slope consisting of loose material and a stable hill with normal soil cover (forest). The facilitative effect was measured in terms of species richness and growth of herbs associated with the nurse species. The beta-diversity was more at the open microsite than below-canopy microsite. At the eroded site, the herb density was greater in the open than below the *Coriaria* canopy. The ameliorative effect of *Coriaria* bush at the eroded site was dramatic in terms of herb biomass. Our study shows a strong facilitative effect of *Coriaria* in the harsh environment of the hill slope with severely eroded surface.

The facilitative effect is reflected in terms of significantly higher alpha-diversity and biomass of herbs growing below *Coriaria* than those growing in the open. The facilitative effect of *Coriaria*, however, is not manifested at the favourable forest site. The bush showed several ameliorative effects on the eroded site, including higher rate of soil build-up and accumulation of nutrients and organic matter leading to an increase in soil water potential. The ability of *Coriaria* plants to nurse herbs can be used to stabilize hill slopes, to regenerate them and to promote species diversity.

FACILITATION, the positive effect of one plant species on the establishment or growth of other plant species, has long been recognized as an important driving force in primary and secondary succession[1,2]. Nonetheless, competition has received far more attention in ecological research[2–6], and only recently has there been renewed interest in the topic of facilitation and the environmental conditions that make it possible[7–9]. Facilitative or 'nurse plant effect' can play a very important role in structuring plant communities in harsh environments[10]. Facilitative interactions have been demonstrated in a broad range of ecosystems. Most evidences come from ecosystems where plants are exposed to severe stress. In such situations the establishment of new plants is often restricted to the shady places under the canopy of other plants called 'nurse plants'.

Most studies of the nurse plant syndrome have focused on the interaction among just two or at most three species[11,12]. In recent years, relationships between nurse species and understorey productivity[13], or the spatial relations among all woody plants and shrubs forming nurse canopies[11] have also been investigated. However, nothing is known about the effect of nurse plants in terms of species diversity of the associated plants.

In this study we examine the facilitative effect of *Coriaria nepalensis* Wall. verns. at two contrasting sites, a severely eroded hill slope consisting of loose material and a stable hill with normal soil cover. The facilitative effect was measured in terms of species richness and growth of herbs associated with the nurse species. The 'nurse plant' *C. nepalensis* (hereafter referred to as *Coriaria)* is 2–3 m high shrub (Coriariaceae) with root nodules formed by *Frankia*. Our main objectives were (i) to find out the facilitative effect of *Coriaria* on herb species diversity and growth, and (ii) to examine to what extent its facilitative effect depends on habitat condition. We hypothesize that the positive effect of *Coriaria* on herbs should occur only in the severely harsh condition of the eroded site; in a favourable site the competitive effect may become an overriding factor.

The climate of the study area is referred to as monsoon warm temperate[14]. Annual rainfall of the area is 2347 mm and the mean monthly temperature varies from 6 to 25°C during summer and 1.7 to 4.0°C during winter. The winter is characterized by occasional snowfall. Of the total precipitations, nearly 75% occurs during the three months of monsoon, mid-June to mid-September.

The sites were located between 1900 and 2100 m altitude in Central Himalaya around Nainital town (29°22′N lat. and 79°25′E long.). The site with severe condition, referred to as eroded site was a steep hill slope (75°) covered with gravels, with little soil. At this site *Coriaria* occurred in patches, each surrounded by relatively large open areas with no woody plant cover. Thus within this site two types of microsites were recognized, i.e. below-canopy (under *Coriaria* cover) and open microsites.

The forest site was more favourable to plant growth as it had good and uniform soil cover with approximately 65% tree crown cover and had only small-scattered open patches.

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