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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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Each microsite was observed at monthly intervals for soil moisture, soil temperature (at 15 cm depth), air temperature and light intensity; other measurements (soil texture, soil pH, organic carbon and total nitrogen) were taken once in April 1999. Soil water potential was measured in October 1999, after the rainy season.

Three soil samples were randomly collected for each microsite from 0 to 30 cm soil depth and were measured for soil moisture and soil texture and soil pH according to Misra[15], organic carbon by Walkey and Blacks titration method[16], total nitrogen by micro-Kjeldhal method[17], and soil water potential by Thermocouple Psychrometer Decagon Devices[18] (User Manual Sc.-10A).

Height and CBH of five individuals of *Coriaria* were measured with a measuring tape. For crown cover (area) of each bush, the diameter of the crown at ground level was measured at perpendicular axis, averaged and then converted to area by πr^2.

At the eroded site herb vegetation of each microsite was analysed by ten, 1 m × 1 m randomly placed quadrats (at distance of 10–15 cm from the center of the shrub) at the time of peak herbaceous cover, in the first week of September. Species were assigned to growth forms (i.e. annual and perennial). Each shoot of herb was considered an individual plant[19]. Creeping plants were counted on the basis of presence or absence of functional roots[20]. The vegetational data were analysed[21].

The index of diversity was computed by using Shannon–Wiener information index[22] as:

$$H' = \sum_{i=1}^{s} (n_i/n) \log_2 (n_i/n),$$

where s is the total number of species, n_i is the number of individuals (or biomass) of species i, and n is the total number of individuals (or biomass) of all species.

Beta-diversity was calculated[23] to illustrate the level of heterogeneity within the microsites as:

$$\beta = Sc/s,$$

where Sc is the total number of species encountered in all quadrats and s is the average number of species per quadrat.

Index of similarity (IS) was calculated[24] as:

$$IS = (2C/A + B) \times 100,$$

where A is the number of species in stand A, B is the number of species in stand B, and C is the number of common species in the two stands.

Herb biomass was measured at each microsite through five, 1 m × 1 m harvest plots. The harvested vegetation from each plot was placed in perforated polyethylene bags and brought to the laboratory and then separated by species. The samples were dried at 60°C and weighed separately.

Analysis of variance (ANOVA) was applied following Snedecor and Cochran[25], to test for significant differences in herb biomass between sites and microsites. The significance of differences was also tested for herb biomass between below-canopy and open microsites.

The soil was always more moist in the below-canopy environment than in the open, both at eroded and forest sites. At the eroded site, soil moisture (up to 30 cm soil depth) was 21 and 8.0% in below-canopy and open microsites, respectively. However, at the forest site the

Table 1. Comparison of sites and microsites for soil characters. Generally soil measurements were made once in April 1999. Air temperature, light intensity and soil temperature were measured at monthly intervals and means are shown. Soil texture and soil chemical data are on dry weight basis. Below-canopy refers to that of *Coriaria*

	Site			
	Eroded slope		Forest	
	Open	Below-canopy	Open	Below-canopy
Soil texture (%)				
Gravel and other coarse material	89.9 ± 0.29	75.4 ± 0.52	65.0 ± 0.52	54.1 ± 0.28
Sand	5.2 ± 0.25	12.1 ± 0.21	13.7 ± 0.26	19.7 ± 0.31
Silt	2.9 ± 0.27	8.5 ± 0.13	11.7 ± 0.10	14.9 ± 0.11
Clay	1.7 ± 0.02	5.9 ± 0.02	9.7 ± 0.10	11.3 ± 0.09
Water holding capacity (%)	15.7 ± 0.21	25.0 ± 0.51	35.0 ± 0.42	37.1 ± 0.52
Soil moisture (%)	8.1 ± 0.03	20.8 ± 0.06	26.8 ± 0.11	28.1 ± 0.11
Soil pH	8.0 ± 0.02	6.1 ± 0.03	6.1 ± 0.01	6.2 ± 0.01
Soil organic carbon (%)	0.62	2.40	3.25	3.50
Total soil nitrogen (%)	0.08	0.37	0.37	0.38
Soil water potential (MPa)	– 3.10	– 1.90	– 2.00	– 1.80
Soil temperature (°C)	24.6 ± 0.05	22.8 ± 0.04	20.6 ± 0.05	20.0 ± 0.41
Air temperature (units)				
Maximum	25.4 ± 0.05	22.4 ± 0.06	20.2 ± 0.05	20.0 ± 0.05
Minimum	14.4 ± 0.05	12.7 ± 0.05	12.9 ± 0.05	11.3 ± 0.05
Light intensity (Lumen m^{-2})	651.8 × 100 ± 1.72	296.5 × 100 ± 1.06	169.8 × 100 ± 0.16	82.5 × 100 ± 0.18

presence or absence of *Coriaria* did not result in significant difference in the soil moisture (28 and 26% at below-canopy and open microsites, respectively). Soil water potential was higher at under below-canopy than in open microsite. The two sites were conspicuously different in soil properties. The eroded site was covered with gravel and had little soil and the favourable forest site had good and uniform soil cover. Favourable soil conditions of the forest sites are reflected in higher percentage of soil moisture and soil water potential. Data on soil moisture, soil temperature and light intensity indicate that the eroded site was much drier and warmer in the daytime than the forest site (Table 1).

Total soil nitrogen and organic carbon (0–30 cm soil depth) was significantly higher at below-canopy microsite than in the open one (Table 1).

The crown area of *Coriaria* at the two study sites ranged from 6.97 to 8.19 m^2 $bush^{-1}$ and the height from 3.5 to 4.5 m. The circumference of *Coriaria* did not differ significantly between the two sites and ranged from 0.52 to 0.61 m^2 $bush^{-1}$ (Table 2).

Monthly sampling over one-year period indicated that in all 31 species were recorded at eroded site, out of which 22 were perennial and 9 annual. The grasses accounted for about 26%, non-leguminous forbs about 71% and leguminous forbs about 3% of the total species recorded. In the open habitat of the eroded site, species number was 23, 16 being perennial and 7 annual. The contribution of grasses, non-leguminous and leguminous forbs was about 26, 69 and 4%, respectively. In the below-canopy microsite of the eroded site, total number of species was 18 and most of them were forbs (89%).

Table 2. Crown area, height and circumference of *Coriaria nepalensis* at eroded and forest sites (each value is average of 5 individuals)

	Eroded site	Forest site
Crown area (m^2 $bush^{-1}$)	8.2 ± 0.24	7.0 ± 0.19
Height (m)	4.5 ± 0.20	3.5 ± 0.16
Circumference at breast height (m)	0.6 ± 0.19	0.5 ± 0.10

At the forest site, 39 species were recorded out of which 31 were perennial and 8 annual. The grasses accounted for about 20%, sedges about 5% and forbs 74% of the species present. In all 38 species occurred in the open and 32 in the below-canopy microsites.

On unit area basis, the below-canopy microsite was significantly more species-rich than the open microsite ($P < 0.01$), the values being 11 species m^2 and 5.3 species m^2, respectively. Contrary to this, at the forested site the open environment did not differ significantly from the below-canopy environment in terms of species richness. At the eroded site, the Shannon–Wiener index for herbs was significantly greater at the below-canopy microsite than at the open microsite, while in the forest site values were similar.

At the eroded site the beta-diversity was significantly lower at the below-canopy than the open microsite. In contrast, at the forest site both were not significantly different. The similarity index indicates that open and below-canopy microsites were dissimilar in herbaceous species composition at the eroded site and they were similar at the forest site. There were several grasses belonging to the open microsite of the eroded site such as *Arhtraxon lanceolatus*, *Apluda mutica*, *Chrysopogon sarrulatus* and *Cymbopogon distans* which also grew at the two forest microsites, resulting in more similarity between these sites than between the below-canopy microsite of the eroded site and the two forest microsites.

At the eroded site, the herb density was significantly greater in the open than below the *Coriaria* canopy. However, at the forest site herb density was similar for the two microsites. The ameliorative effect of *Coriaria* bush at the eroded site was dramatic in terms of herb biomass. At this site, the herb biomass was significantly greater ($P < 0.01$) in the below-canopy microsite than in the open microsite. However, at the forest site the herb biomass was approximately equal for the two microsites (Table 5). ANOVA results indicate that the sites (forest and eroded slope) and

Table 3. Comparison of herbaceous vegetation sampled at the time of peak herb growth between the sites and microsites within them

	Site			
	Eroded		Forest	
	Open	Below-canopy	Open	Below-canopy
Total number of species at the site	13 (23)	14 (18)	16 (38)	16 (32)
Species richness per quadrat (m^{-2})	5.3 ± 0.01	11.0 ± 0.01	11.4 ± 0.02	9.3 ± 0.02
Beta-diversity	2.5	1.3	1.4	1.7
Shannon–Wiener index	2.6	3.5	3.0	3.2
Total herb density (plant m^{-2})	445.2 ± 0.31	292.8 ± 0.08	248.2 ± 0.07	276.1 ± 0.08
Total herb biomass (g m^{-2})	175.8 ± 0.19	1208.0 ± 0.50	1232 ± 0.50	1225.1 ± 0.47

Values in parentheses indicate total number of species encountered during different seasons over one-year period.

microsites (i.e. below-canopy and open) were significantly different in relation to the amount of total biomass ($P < 0.01$; Table 6).

Our study shows a strong facilitative effect of *Coriaria* in the harsh environment of the hill slope with a severely eroded surface, consisting primarily of loose silt, gravel and stones. 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, away from *Coriaria* bushes. The facilitative act of *Coriaria*, however, is not manifested at the favourable forest site. The bush showed several ameliorative effects on the eroded site, including soil build-up and accumulation of nutrients and organic matter leading to an increase in soil water potential, which is critical to development of vegetation. On the basis of various studies carried out in deserts, dunes, Mediterranean shrublands, temperate grasslands and forests, Holmgren *et al.*[10] have reported that the nurse plant shade facilitates growth of the associated plants by improving water conditions. Joffre and Rambel[26] measured a significant delay in soil water loss under *Quercus rotundifolia* and *Q. suber* in Spanish savannas relative to soils in the open. On the basis of a study carried out in sites dominated by *Q. douglassi* in California, Callaway *et al.*[13] suggested that canopy-mediated increase in soil nutrients was the most likely mechanism of facilitative effect on the growth of understorey vegetation. An increase in nitrogen availability under the nurse canopy can also add to the facilitative effects[27,28]. The symbiotic nitrogen fixing ability may play a very important role in improving habitat quality.

At the eroded site *Coriaria* bush facilitated growth of herbs by generating organic matter, holding litters and soil at the microsites and restricting evaporation loss. By stabilizing the microenvironment, *Coriaria* bushes enable perennial herbs to establish and persist throughout the year. It is possible that the *Coriaria* also has interfering effect[28], but its facilitative effect overrode the interference effects. The herb biomass at the below-canopy microsite was eight times that at the open microsite.

At the forest site, differences between below-canopy and open microsites in regard to herbs were not significant. Facilitative effect is more in the severely dry site than in the favourable site[10,29,30]. The soil of the two habitats was similar and the potential facilitative effects of *Coriaria* such as release of nitrogen are likely masked by the negative effects of its canopy through reduced light availability to herbs. The facilitative effect of *Coriaria* bush was not seen at the forest site. Thus, it appears that *Coriaria* selects relatively favourable microsites on the eroded slope, establishes and then facilitates the colonization and growth of other species.

So conspicuous was the effect of *Coriaria* on herbs at the eroded site that the herbaceous community growing in the open had only 37% similarity with that occurring in the adjacent below-canopy microsite. In contrast, at the forest site the above two microsites had 87.5% floristic similarity.

Restoration of degraded hill slopes is one of the most challenging conservational problems in the Himalaya. The ability of *Coriaria* plants to ‘nurse’ herbs can be used to stabilize hill slopes, to regenerate them and to promote species diversity. The below-canopy environment of shrubs provided habitat for high alpha-diversity of herbs. These patches can nucleate rapid colonization of the eroded hill slopes.

Table 4. Index of similarity (based on presence and absence of species) among different microsites for herbs

	Eroded site		Forest site	
	Open	Below-canopy	Open	Below-canopy
Eroded site				
Open	100	37	55.2	55.2
Below-canopy		100	33.3	40.0
Forest site				
Open			100	87.5
Below-canopy				100

Table 5. Density (plant m^{-2}) and biomass (g dry matter m^{-2}) of herbs by growth forms for study sites and their habitats

	Eroded site				Forest site			
	Open		Below-canopy		Open		Below-canopy	
	Density	Biomass	Density	Biomass	Density	Biomass	Density	Biomass
Annual forbs	53.6 ± 2.59 (12%)	128.6 ± 7.20 (73%)	95.2 ± 0.46 (32.5%)	295.8 ± 3.11 (20.4%)	50.6 ± 0.76 (20.4%)	733.3 ± 0.47 (59.5%)	56.8 ± 0.71 (20.5%)	596.7 ± 5.25 (48.7%)
Perennials								
Grasses	346.0 ± 4.45 (77.8%)	2.3 ± 0.01 (1.3%)	34.0 ± 1.63 (11.6%)	2.2 ± 0.03 (1.7%)	156.8 ± 1.43 (63.2%)	36.6 ± 0.85 (2.9%)	162.5 ± 1.12 (58.9%)	37.4 ± 0.19 (3.1%)
Forbs	45.6 ± 0.16 (10.2%)	44.8 ± 0.33 (25.5%)	163.6 ± 0.39 (55.8%)	970.0 ± 7.11 (76.5%)	41.0 ± 0.13 (16.5%)	451.6 ± 2.11 (36.7%)	53.6 ± 0.21 (19.4%)	564.6 ± 3.13 (46.1%)
Sedges	–	–	–	–	1.8 ± 0.04 (0.7%)	10.3 ± 2.28 (2.3%)	3.2 ± 0.08 (1.2%)	26.4 ± 0.02 (2.1%)
Total	445.2	175.8	292.8	1268.0	248.2	1232.0	276.1	1225.1

Table 6. *F*-values indicating significant difference in herb biomass in canopy types (below-canopy and open) and forest types (eroded and forest sites)

Source of variation	Degree of freedom	F-value ($P < 0.01$)
Main effect		
Canopy types	1	181.2
Forest types	1	158.0
Two-way interaction		
Canopy types × forest types	1	185.8

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Clomiphene citrate and its isomers can induce ovulation in laboratory mice

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There is little doubt that clomiphene citrate has emerged as a boon to the specialized area of ovulation induction in the human female. This wonder drug, however, was discovered as an efficient antifertility, antiovulatory drug in laboratory animals. So, the adverse effects observed in clinical use of this compound have not yet been studied well. Numerous uncertainties still remain regarding the mode of action of the compound. One of the worst side effects of this compound is abortion associated with the use of this drug in clinical practice. This aspect is further complicated by the fact that clomiphene citrate is a racemic mixture of two isomers, zuclomiphene and enclomiphene, having individual opposite biological actions. The ovulation-inducing ability was studied in laboratory mice and it was observed that clomiphene citrate and its isomer enclomiphene citrate can induce ovulation and even super-ovulation only in combination with hCG. However, another isomer of clomiphene, zuclomiphene is not capable of inducing ovulation in mice. The standard protocol of ovulation induction for laboratory animals is used and ovulations are checked by oviductal flushing to observe cumulus-bound ova under stereo-microscope.

THE clinical use of clomiphene citrate (CC) had become a major therapeutic breakthrough revolutionizing the science of reproductive endocrinology. It is now often considered as an established therapeutic agent with a well-characterized mode of action in the treatment of anovulatory infertile patients. But still today numerous uncertainties remain regarding the mechanism of action of CC with respect to ovulation as well as the relative role of the other various components of the reproductive axis in this connection. Considerable knowledge gaps still exist regarding the effects of this compound in the female reproduction. This wonder drug was synthesized in 1956 by Palopoli *et al.*[1]. Then all the initial studies were done to establish it as an antifertility agent[2–4]. CC was also reported to decrease the weight of the testis and accessory sex organs in immature and mature male rats[2,5]. In 1961, Greenblatt and coworkers[6] tried to inhibit ovulation in normally ovulating women volunteers by administering this compound, but ovulation was not inhibited. On the contrary, in other trials 28 out of 36 women with oligomenorrhea or secondary amenorrhea responded favourably with CC (ref. 6). Roy *et al.*[7–11] have found that in rats

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