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Effect of a Nitrogen-Fixing Actinorhizal Shrub on Herbaceous Vegetation in a Mixed Conifer Forest of Central Himalaya

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ABSTRACT

In this study, we examined the effect of a nitrogen-fixing shrub *Coriaria nepalensis* Wall on herb species composition, diversity and biomass. The effect was measured in terms of species richness, diversity and biomass of herb species in three sites varying in *Coriaria* density viz. site 1 (low *Coriaria* density; 20 ind. ha^{-1}), site-2 (medium *Coriaria* density; 120 ind. ha^{-1}) and site-3 (high *Coriaria* density 190 ind. ha^{-1}). Species richness was minimum at Site-1 (16 species), and maximum at site-2 (27 species). *G. aparine* dominated site-1 and *Arthraxon sp* dominated site-2 and 3. The individual herb density ranged between 0.40 - 42.40 m^{-2}, and total herb density ranged between 138- 170.4 m^{-2} and was maximum at site-2. Value for species richness (27) and Shannon Index (3.72) was highest for medium *Coriaria* density site and lowest for low *Coriaria* density site. Simpson Index ranged between 0.11 and 0.14 and was lowest for site-2 (medium *Coriaria* density) indicating that at this the dominance was shared by many species. Along the gradient of *Coriaria* density, maximum biomass was recorded at site-3 with highest *Coriaria* density and lowest at site-2 with medium *Coriaria* density. This may be due to the symbiotic nitrogen fixing ability of *Coriaria* that improve the habitat quality. The facilitative effect of *C. nepalensis* in terms of soil amelioration and herb growth can be used to regenerate degraded forest ecosystems.

Key words: Biomass, *Coriaria,* density, diversity, facilitation, species richness.

INTRODUCTION

The herbaceous layer plays an important role in forest ecosystem; it contains the highest number of species and affect nutrient cycling (Gilliam, 2007; Jhariya *et al*., 2013, Parihaar *et al*., 2014). This layer is also responsible for approximately 12% of the Gross Photosynthetic Production (GPP) of a forest ecosystem (Bargali and Bargali, 2000; Muller, 2003). Herbaceous vegetation also affect regeneration of trees therefore, has important implications for the regeneration of trees (Chandra *et al*., 1989; Kittur *et al*., 2014; Rana *et al*., 2015). Species that have impacts on the distribution, amount and composition of resources in the environment either through their own physical structures or the artifacts they created are increasingly recognized as ecosystem engineers (Jones *et al*., 1994; Bargali *et al*., 2014, 2015). As reviewed extensively by Jones *et al*., (1994), ecosystem engineers are a taxonomically diverse group, with representatives including vertebrates, invertebrates, algae, nonvascular plants and higher plants (especially woody species).

Low nitrogen supply is a limiting factor for plant growth in most terrestrial ecosystems. N-fixing plants therefore, have the potential to facilitate surrounding vegetation by increasing soil N levels. *Coriaria nepalensis* Wall. is a common native shrub/under tree species of the Central Himalayan region between 1200 to 2500m elevations and is a successful colonizer of landslide-affected or freshly exposed rocky and eroded slopes. It is a nitrogen-fixing actinorhizal plant that forms root nodules with actinomycete *Frankia* (Bargali *et al.*, 2003). The biological N-fixation in this species meets the relatively heavy demand for nitrogen in nutrient-poor degraded soils and can play key roles as ecosystem engineer by altering the physical environment beneath its canopy as well as characteristic of plant populations, communities and ecosystems (Shachak *et al.*, 2008). It can also facilitate growth of associate plants therefore; can change the composition and structure of the forest.

In the present study, we examined whether herb species composition, diversity and biomass differed with increasing density of an actinorhizal shrub *Coriaria nepalensis* Wall in a mixed conifer forest of Central Himalaya, India.

MATERIALS AND METHODS

The study area Nainital is located between 29°36’56"-29°36’79" N latitude and 79°46’03"-79°46’19" E longitude between 1600- 1850m above mean sea level in the Central Himalaya. This Site experienced a heavy land slide that occurred about 75-80 years ago (based on information collected from local inhabitants). For detailed study the area was divided into three sub sites (each with 1 ha area) varying in *Coriaria* colonisation in terms of density viz. site-1(low *Coriaria* density; 20 ind. ha^{-1}), site-2 (medium *Coriaria* density; 120 ind. ha^{-1}) and site-3 (high *Coriaria* density; 190 ind. ha^{-1}). The study area was dominated by conifers like *Pinus roxburghii* and *Cupressus torulosa* (Fig. 1).

The climate of Nainital is characterized by long-cold often snowy winter and short summer. It is temperate and monsoon type (Singh and Singh, 1992) and the year has four distinct seasons viz., monsoon (July to September), post-monsoon (October to November), winter (December to January) and summer (April to mid-June). Climatic data for 2012-2014 were obtained from the State Observatory at Nainital. The annual average rainfall was 1853 mm, 60% of which was occur in the rainy season and the mean daily temperature ranged from -2.0°C to 30.5°C (Source: ARIES, Nainital) (Fig. 2).

Composite soil samples were collected from each site, packed in polyethylene bags and brought to the laboratory for analysis of physical and chemical characters. After removing all fine roots, one part of each sample was weighed and oven dried to determine the gravimetric moisture content. Air dried soil samples sieved through 2 mm mesh screen were analysed for various physical (texture, moisture content, bulk density, porosity, water holding capacity) and chemical (soil pH) properties of the soil.

The phytosociological analysis of herb species was conducted by placing 30 quadrats of 1m x 1m size at each site. The size and number of samples was determined following Saxena and Singh, (1980).Grasses were studied through tiller analysis. Each tiller of grass was considered as an individual plant and creeping plants were counted on the basis of presence of functional roots (Saxena and Singh, 1980)). The vegetational data were quantitatively analysed for abundance, density and frequency (Curtis and Mc Intosh, 1950). The Provenance value (PV) of herbs was determined as the sum of the relative frequency and relative density (Curtis, 1959). The ratio of abundance to frequency indicates regular distribution if < 0.025, random distribution between 0.025 to 0.05 and contagious distribution if >0.05 (Cottam and Curtis, 1956). Similarity between pairs of stands was calculated following (Muller – Dombois and Ellenberg, 1974) using species richness in different sites:

$$\text{Index of similarity (IS)} = \frac{2C}{A+B} \text{ X } 100$$

where, C is the common species in comparison sites; A the total number of species in site A and B the total number of species in site B.

Species diversity for each site was determined with the Shannon and Wiener, (1963) index:

$$H' = -\sum_{i=1}^{S} \left(\frac{Ni}{N}\right) \log_2\left(\frac{Ni}{N}\right)$$

where, Ni is the density of species i and N is the total density of all species in that stand.

Concentration of dominance was measured by Simpson's index (Simpson, 1949),

$$C = \sum_{i=1}^{S} \left(\frac{Ni}{N}\right)^2$$

where, Ni and N were the same as described for the Shannon-Wiener information function. The calculations of diversity index and concentration of dominance were made separately for herbs. Species richness was determined following Whittaker, (1972) by the total number of species in a given community and the equitability was calculated by Pielou, (1966). Dominance diversity curves (Whittaker, 1975) were employed to interpret the community organization in terms of resource share or niche space.

RESULTS AND DISCUSSION

A total of 31 species distributed in 16 families were recorded from the study site. Family asteraceae had the maximum number of species (19.3% of the total species) while 12 families were represented by a single species each (Table 1). Site-1 had 16 species and 10 families, site-2 had 27 species and 18 families and site-3 had 22 species and 13 families. Site-2 had the highest number of unique species (07) while site-1 had no unique species (Table 2). Twelve species were common to all the sites and accounted for 38.7% of the total

Fig. 1a: Tree layer vegetation

Fig. 1b: Herb layer vegetation

species. *G. aparine* dominated site-1 and *Arthraxon sp* dominated site-2 and 3.On the basis of dominant and co-dominant species, site-1 represented *G. aparine- C. versicolor* community site-2 and site-3 represented *Arthraxon -C. rotundus* community. On the basis of percent similarity site-1 and site-2 were 34.88% similar, site-1 and site-3 were 36.84% similar and site-2 and site-3 were 34.69% similar in species composition.

The individual herb density ranged between 0.40 and 42.40 m^{-2}, and total herb density ranged between 138 and 170.4 m^{-2}. The values are comparable with those reported earlier by Chandra *et al.,* 2010 for forest of Garhwal Himalaya. At site-1 the total herb density was 159.2 m^{-2} and the individual herb density ranged from 0.8 herbs m^{-2} for *J. procumbens* to 42 herbs m^{-2} for *G. aprine.* A/F ratio varied between 0.03 and 0.29. Nine species (*G.nepalense*, *J. procumbens , A. bidentata, O. corniculata, E. adenophorum, A. annua, C. rotundus,C. dactylon* and *P. gerardiana*) showed the random distribution and remaining species showed the contagious distribution.

Table 1: Provenence value of herbaceous species as affected by *Coriaria* density

Species	Family	*Coriaria* density		
		Low	Medium	High
Achyranthes bidentata Blume	Amaranthaceae	9.22	11.93	18.83
Ajuga bracteosa Wall.ex Benth.	Lamiaceae	-	1.98	2.66
Artemisia annua Linn.	Asteraceae	12.84	5.74	2.08
Arthraxon sp Thunb.	Poaceae	14.39	35.49	36.85
Bidens pilosa L.	Asteraceae	14.78	13.10	13.23
Cardamine impatiens Linn.	Brassicaceae	-	-	9.95
Cerastium vulgatum L.	Rosaceae	-	2.22	-
Clematis buchananiana D.C	Ranunculaceae	-	1.98	2.08
Craniotome versicolor Reichb	Lamiaceae	32.21	22.45	17.33
Cynodon dactylon(L.) Pers.	Poaceae	5.49	1.98	-
Cyperus rotundus L.	Cyperaceae	18.97	26.55	24.92
Dioscorea deltoidea Kunth.	Dioscoreaceae	-	3.39	-
Erigeron bellidiodes L.	Asteraceae	-	1.98	10.24
Eupatorium adenophorum Spreng	Asteraceae	8.96	12.85	7.97
Fragaria vesca Linn.	Rosaceae	-	3.50	-
Galium aparine L.	Rubiaceae	39.54	3.39	2.08
Galium elegans Wall. ex Roxb.	Rubiaceae	7.10	4.80	-
Geranium nepalense Sweet	Geraniaceae	14.45	3.39	2.37
Gerbera gossypina (Royle) Beauv.	Asteraceae	-	1.75	2.66
Justicia procumbens L. var *simplex* (D.Don)	Acanthaceae	2.12	7.36	5.89
Lapidagathis cristata Nees	Acanthaceae	2.87	5.85	6.23
Micromeria biflora (Buch.-Ham.ex D.Don) Benth.	Lamiaceae	4.48	1.98	2.66
Oenothera rosea Ait.	Onagraceae	-	1.75	-
Origanum vulgare L.	Lamiaceae	-	-	14.30
Oxalis corniculata L.	Oxalidaceae	8.11	13.10	2.08
Potentilla gerardiana Lindl.ex Lehm.	Rosaceae	4.48	-	2.37
Rubia cordifolia L.	Rubiaceae	-	-	6.47
Selaginella sp.	Selaginellaceae	-	6.21	-
Tridax procumbens L.	Asteraceae	-	1.75	6.81
Veronica beccabunga L.	*Plantaginaceae*	-	3.50	-
Viola canescens Wall.ex Roxb.	Violaceae	-	1.75	-

At site-2 the total herb density was170.40 $m^{-2}$and the individual herb density ranged from0.40 m^{-2} for *V. canescens, T. procumbens, G.gossypina, and O.rosea* to 42.40 m^{-2} for *Arthraxon sp.* A/Fratio varied between 0.10 and 2.00, all the species showed the contagious distribution. At site-3 the total

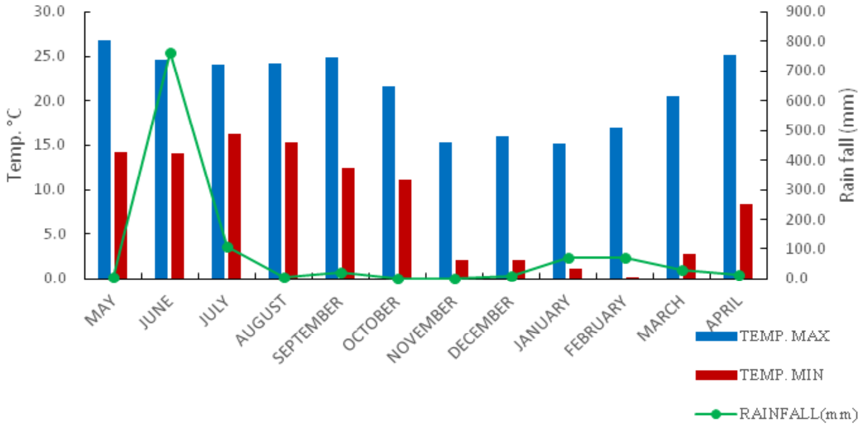

Fig. 2: Metrological data of the study site 2012-2014 (Source: ARIES, Nainital)

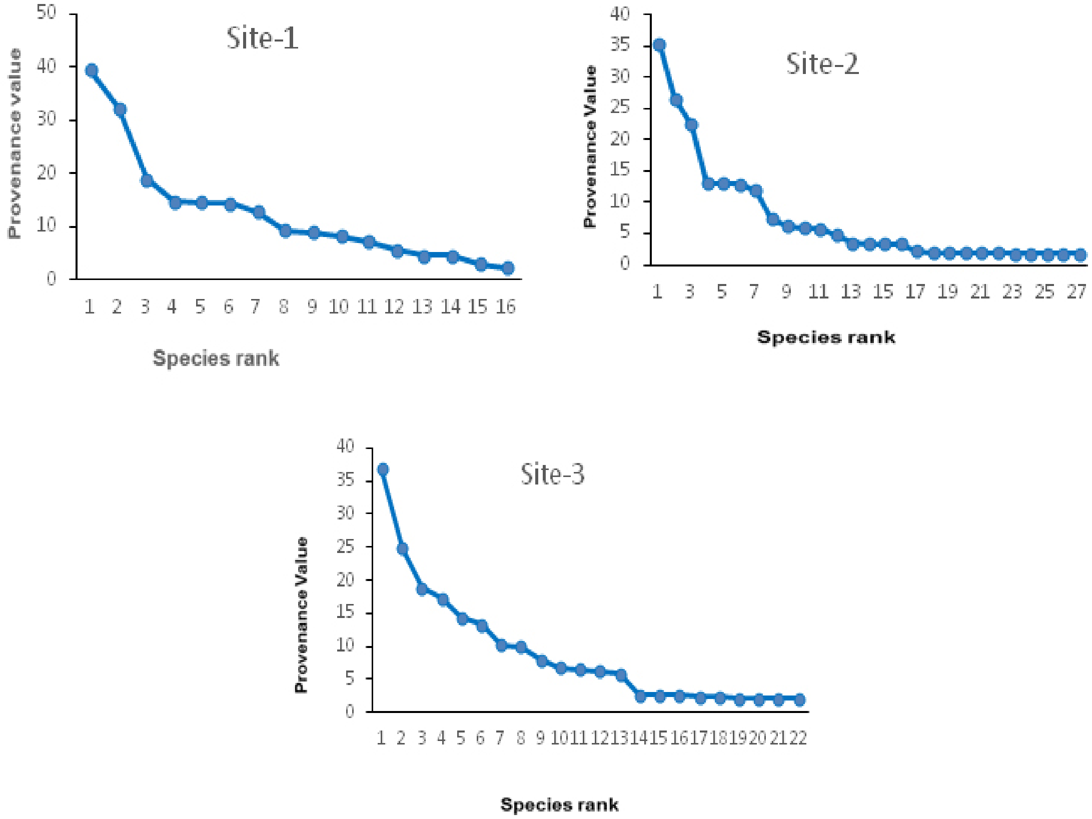

Fig. 3: Dominance diversity curves of herb species across the three study sites

Table 2: Biomass (gm^{-2}) of different component of herbs species in mixed conifer forest as affected by *Coriaria* density

Species	Biomass	*Coriaria* density		
		Low	Medium	High
Achyranthes	D	4.40	10.00	11.20
bidentata	AGB	3.61	8.40	26.99
	BGB	2.99	8.30	30.46
	Total	6.60	16.70	57.45
Ajuga	D	-	0.80	1.20
bracteosa	AGB		0.19	0.26
	BGB		0.19	0.25
	Total		0.38	0.51
Artemisia	D	7.60	7.20	0.40
annua	AGB	9.88	2.30	0.48
	BGB	18.77	0.50	0.99
	Total	28.65	2.80	1.47
Arthraxon sp.	D	15.20	42.40	33.60
	AGB	13.38	157.72	108.19
	BGB	4.41	21.62	17.14
	Total	17.79	179.34	125.33
Bidens	D	18.40	12.00	8.40
pilosa	AGB	0.92	0.84	4.87
	BGB	0.36	0.36	1.59
	Total	1.28	1.20	6.46
Cardamine	D	-	-	8.80
impatiens	AGB			10.56
	BGB			7.48
	Total			18.04
Cerastium	D	-	1.20	-
vulgatum	AGB		0.61	
	BGB		0.41	
	Total		1.02	
Clematis	D	-	0.80	0.40
buchananiana	AGB		0.03	1.64
	BGB		0.03	0.96
	Total		0.06	2.60
Craniotome	D	25.60	17.60	11.60
versicolor	AGB	102.4	21.29	17.75
	BGB	106.88	19.89	23.89
	Total	209.28	41.18	41.64
Cynodon	D	3.60	0.80	
dactylon	AGB	5.45	0.04	
	BGB	1.44	0.12	
	Total	6.89	0.16	
Cyperus	D	14.80	22.00	19.60
rotundus	AGB	6.07	24.20	39.00
	BGB	6.66	10.12	6.82
	Total	12.73	34.32	45.82
Dioscorea	D	-	3.30	-
deltoidea	AGB		3.52	
	BGB		3.52	
	Total		7.04	
Erigeron	D	-	0.80	9.20
bellidiodes	AGB		1.54	40.11
	BGB		0.37	10.21
	Total		1.91	50.32
Eupatorium	D	4.00	6.40	3.60
adenophorum	AGB	57.44	9.98	32.65
	BGB	19.84	1.60	5.51
	Total	77.28	11.58	38.16
Fragaria	D	-	0.80	-
vesca	AGB		0.06	
	BGB		0.02	
	Total		0.08	
Galium	D	42.40	3.20	0.40
aparine	AGB	30.10	0.03	0.02
	BGB	5.80	0.03	0.01
	Total	35.90	0.06	0.03
Galium	D	3.60	5.60	-
elegans	AGB	30.10	1.34	
	BGB	5.80	0.61	
	Total	35.90	1.95	
Geranium	D	7.60	3.20	0.80
nepalense	AGB	2.43	0.22	0.30
	BGB	0.73	0.22	0.11
	Total	3.16	0.44	0.41
Gerbera	D	-	0.40	1.20
gossypina	AGB		0.01	1.69
	BGB		0.004	14.81
	Total		0.014	16.50
Justicia	D	0.80	4.80	3.20
procumbens	AGB	0.29	2.69	1.63
	BGB	0.76	2.59	1.69
	Total	1.05	5.28	3.32
Lapidagathis	D	2.00	4.80	1.20
cristata	AGB	0.72	1.00	0.80
	BGB	0.40	0.67	0.46
	Total	1.12	1.67	1.26
Micromeria	D	2.00	0.80	1.20
biflora	AGB	0.40	0.02	1.07
	BGB	0.08	0.01	0.12
	Total	0.48	0.03	1.19
Oenothera	D	-	0.40	-
rosea	AGB		0.10	
	BGB		0.04	
	Total		0.14	
Origanum	D	-	-	14.80

vulgare	AGB			34.04
	BGB			6.05
	Total			40.09
Oxalis	D	5.20	12.00	0.40
corniculata	AGB	0.73	3.00	0.08
	BGB	0.16	1.56	0.004
	Total	0.89	4.56	0.084
Potentilla	D	2.00	-	0.80
gerardiana	AGB	0.12		1.01
	BGB	0.10		0.68
	Total	0.22		1.69
Rubia	D	-	-	4.00
cordifolia	AGB			6.40
	BGB			1.08
	Total			7.48
Selaginella sp	D	-	8.00	-
	AGB		0.24	
	BGB		0.24	
	Total		0.48	
Tridax	D	-	0.40	2.00
procumbens	AGB		0.01	0.20
	BGB		0.01	0.10
	Total		0.02	0.30
Veronica	D	-	0.40	-
beccabunga	AGB		0.01	
	BGB		0.03	
	Total		0.04	
Viola	D	-	0.40	-
canescens	AGB		0.004	
	BGB		0.004	
	Total		0.008	

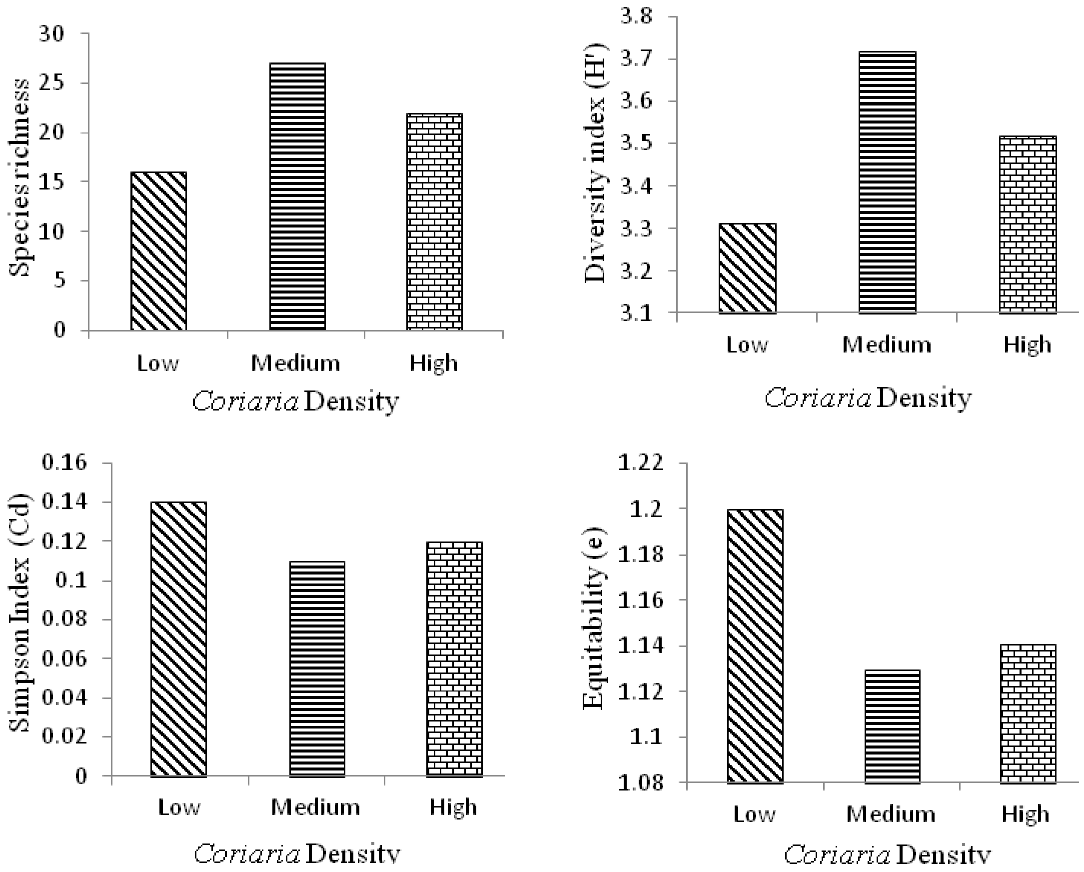

Fig. 4: Herbaceous species diversity at three sites varying in *Coriaria* density

herb density was138.0 herbs $m^{-2}$and the individual herb density ranged from0.40 m^{-2} for *G.aparine, A. annua, C.buchananiana, R. cordifolia* and 33.6 m^{-2} for *Arthraxon sp*., A/F ratio varied between0.03 and 0.93. *L. cristata* showed random distribution while remaining species showed contagious distribution. In the present study, maximum number of herb species were contagiously distributed as reported for other Himalyan forest by Singh and Singh, (1992); Pande, (2012); Bargali *et al.,*(2013).

Dominance diversity curves (on the basis of PV) have been drawn to interpret the community organization in term of resource share and niche space (Fig 3). At each site, two or three species indicated dominance while rest of the species showed relatively greater equitable share of resources.

Analysis of variance indicated that the differences in species richness, Shannon index, Simpson index, evenness due to *Coriaria* density were significant (Table 4). Values for species richness (27) and Shannon Index (3.72) were highest for medium *Coriaria* density site and lowest for low *Coriaria* density site (Fig 4). Simpson Index ranged between 0.11 and 0.14 and lowest for site-2 (medium *Coriaria* density) indicating that at this the dominance was shared by many species (Fig 4). Equitability also followed the same trend.

Herb layer biomass

At site-1 total herb biomass was 439.22 gm^{-2} of which 264.04 gm^{-2} was above ground and 175.18 gm^{-2} was below ground (Table 4).*C. versicolor* contributed the highest biomass (102.4 gm^{-2}) while *P. girardiana* contributed lowest biomass (0.12 gm^{-2}). At site-2 herb layer biomass was 312.57 gm^{-2} of which 239.39 gm^{-2} was above ground and 73.06 gm^{-2} was below ground. Maximum biomass was contributed by *Arthraxon sp.* (157.72 gm^{-2}) and minimum biomass was contributed by *G. gossypina* and *V. canescens* (0.01 gm^{-2}). Total herb layer biomass at site-3 was 443.65 gm^{-2}, of which 329.74 gm^{-2} was above ground and 130.41 gm^{-2} was below ground (Table 4). Among species, maximum biomass was contributed by *Arthraxon sp.* (108.19 gm^{-2}) and minimum biomass was contributed *G. aparine* (0.02 gm^{-2}). Along the gradient of *Coriaria* density, maximum biomass was recorded at site-3 with highest *Coriaria* density and lowest at site-2 with medium *Coriaria* density (Table 4). This may be due to the symbiotic nitrogen fixing ability of *Coriaria* that improve the habitat quality.

CONCLUSION

The herb layer vegetation is a major component for any forest ecosystem. It is critical to many system ecological processes by altering nutrient cycles, protecting erosion and contributing to the communities diversity and are considered as good ecological indicators of forest health. In the present study, the species richness and density of herbaceous species were remarkably high in site with medium *Coriaria* density while biomass was maximum in high Coriaria density site indicating that *Coriaria* provide favourable microsites on degraded forests and facilitate the colonization and growth of herb species. This nursing behavior of *Coriaria* can be used to restore degraded forest ecosystems of Central Himalaya.

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