



Assessment of ecological parameters of crofton weed along the road-side forests of Kumaun Himalaya

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ABSTRACT

Present study deals with certain ecological attributes of crofton weed (*Eupatorium adenophorum* Spreng), an abnoxious invasive weed invading the road-side forests mixed with oaks and conifer. The average density of *E. adenophorum* shared 22.4 - 65.8% of total herb density which was almost higher in forest below the roadside. The biomass of *E. adenophorum* accounted for 84.0 - 99.8% of total herbaceous biomass in different forest sites. Study reveals the dominated impact of this species, which altered the composition, diversity and growth of herbs in forests, and also can change the habitat and disturb the ecology of native plants in the region. Therefore, needs of was felt to sustain the habitat of native species.

Key words: Forest, Roadside, Herbs, *Eupatorium adenophorum*, Species diversity, Biomass.

Forests are essential for the survival of people as they provide various benefits to society and environment. Recent degradation of forest ecosystems showed that biological diversity, species composition and regeneration pattern have changed significantly influencing the productivity and sustainability of the forest ecosystem. The invasive species has been considered as one the severe threat to biological diversity and other natural resources after habitat destruction (Heywood 1995).

Invasive species like *Lantana camara*, has replaced natural forest of sal, pine and oak by forming pure stands or mixing up with understory forest vegetation. (Bhatt *et al.* 1994) and have had a deleterious impact on biological diversity and ecosystem processes (Mack *et al.* 2000). Invasion potential of species enables it to be successful invader and colonizer of the novel environments, whether introduced deliberately or accidentally (Dogra *et al.* 2009). Biological invasions by non-indigenous plants have become major global threats that alter landscapes, reduce biodiversity, and endanger national economies.

Eupatorium adenophorum Spreng. also called as Crofton weed and locally called as 'banmara' (killer of forest) commonly growing as herb (occasionally as subshrub) has been considered a serious threat to biodiversity and agricultural productivity due to its rapid growth (Ma and Bai 2004). Once invades an area, it develops into a single pre-dominant plant

community in a short period. Roadsides and wastelands were found most sensitive to *E. adenophorum* invasion as seed is carried by the wind or water, via sand and gravel used in road construction, and colonises disturbed areas readily. Once it is established, it further alter the soil community, inhibit native plants, which promote further invasion (Hao *et al.* 2010).

The objectives of the study were: to analysis of oak-conifer forests along the road sides, and to find out the extent of *E. adenophorum* invasion along the road side oak- conifer forest upto 0-50 m distance on both (above and below) the sides of road.

MATERIALS AND METHODS

The study sites were situated at Nainital (29°23 N - 79°27E, 29.38°N- 79.45°E), Uttarakhand of the outer Himalaya. Climate of Nainital is temperate and monsoon type. An average annual rainfall was 1247 mm in 2013-2014. Maximum rainfall was during June (763.0 mm). The mean minimum temperature ranged from 0.2 °C (February) to 16.3 °C (July) and the mean maximum day temperature varied from 15.2 °C (January) to 26.8 °C (May).

Herb species were analysed by placing 1 x 1 m quadrats in different forests along both the sides of road. Quadrats were placed in each forest at distance of 0-10 m, 10.1-20, 20.1-30, 30.1-40, and 40.1-50 m, above and below the road side towards inner side of forest. The vegetational data were quantitatively analyzed for density according to the formula given by Curtis and Mc Intosh (1950).

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$$\text{Density} = \frac{\text{Total number of individuals in all quadrats}}{\text{Total number of quadrats studied}}$$

For herbs, provenience value (PV) index was calculated by summing up the values of relative frequency and relative density (Phillips 1959, Curtis 1959).

$$\text{Provenience value (PV)} = \text{RF} + \text{RD}$$

Species diversity was calculated using Shannon-wiener information index (Shannon and Wiener, 1949) as:

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

Where, N_i is density of individual species and N the total density of all species in that forest.

For biomass estimation of herbaceous species, plants from 25 quadrats (1 x 1 m) were harvested and dry weight (after oven drying at 80 °C till constant weight) was determined.

RESULTS AND DISCUSSION

Forest site-1 (Khurpatal)

Cypress forest (above the road side): Total 10-14 herb species were present in 0-50 m distance from the road. The density of herbs ranged 41.2 - 63.7 ind./m² of which *E. adenophorum* showed maximum density 30.2 - 39.2 ind./m² and PV 69.8 - 104.2 (Table 1 and 2). Total herb species diversity (H') was 1.33 - 2.10 (Table 1). Total biomass of herb species was 726.0 g/m² of which total above ground biomass was 482.1 g/m² and total below ground biomass was 244.0 g/m². The biomass of *E. adenophorum* was 725.4 g/m², which shared around 99.8% of total herbaceous biomass. Biomass of other herb species was 0.7 g/m² which shared around only 0.2% of total herbaceous biomass above road side (Table 7).

Mixed-pine forest (below the road side): Total 7-13 herb species were present in 0-40 m distance from the road. *E. adenophorum* was not present from 40.1-50 m distance. Total density of herbs ranged 47.9 - 86.7 ind/m² of which *E. adenophorum* showed maximum density 30.3 - 45.8 ind/m² and PV 71.01 - 92.67 (Table 1 and 2). Total herb species diversity (H') was 1.63-2.45 (Table 1). Total biomass of herb species was 704.33 g/m². The biomass of *E. adenophorum* was 701 g/m² which shared around 99.5% of total herbaceous biomass. Biomass of other herb species was 3.33 g/m² which shared around only 0.5% of total herbaceous biomass below road side (Table 7).

Forest site-2 (Hanumangarh)

Cypress forest (above the road side): Total 18 herb species were present in 0 - 40 m distance from the road. Crofton weed was not present from 40.1 - 50 m distance. Total density of herbs ranged 57 - 112.9 ind./m² of which it showed maximum density 12.1 - 53.9 ind./m² and PV 35.51 - 61.25 (Table 3 and 4). Total herb species diversity (H') was 2.68-3.01 (Table 3). Total biomass of study site was 730.43 g/m². The biomass of *E. adenophorum* was 727.84 g/m² and which shared around 99.6% of total herbaceous biomass. Biomass of other herb species was 2.59 g/m² which shared around only 0.4% of total herbaceous biomass above road side (Table 7).

Cypress forest (below the road side): Total 11-26 herbs were present in 0-50 m distance from the road. Total density of herbs ranged 89.8 - 234.7 ind./m² of which *E. adenophorum* showed maximum density 17.3 - 60.1 ind./m² and PV 30.64 - 61.25 (Table 3 and 4). Total herb species diversity (H') was 2.79 - 3.49 (Table 3). Total biomass of study site was 640.96 g/m². The biomass of *E. adenophorum* 630.04 g/m², which shared around 98.3% of total herbaceous biomass. Biomass of other herb species was 10.92 g/m², which shared around only 1.7% of total herbaceous biomass below road side (Table 7).

Forest site-3 (Bhowali)

Oak forest (above the road side): Total 12- 14 herb species were present in 0-50 m distance from the road. The density of herbs ranged 17.8 - 41.9 ind./m² of which *E. adenophorum* showed 2.5 - 19.3 density ind/m² and PV was 17.6 -78.14 (Table 5 and 6). Total herb species diversity (H') was 2.27 - 3.27 (Table 5). Total biomass of study site was 176.6 g/m². The biomass of *E. adenophorum* was 160.8 g/m² and which shared around 91% of total herbaceous biomass. Biomass of other herb species was 15.8 g/m² which shared around 9% only of total herbaceous biomass above road side (Table 7).

Oak forest (below the road side): Total 6-10 herb species were present in in 0-40 m distance from the road. *E. adenophorum* was not present in 40.1 - 50 m distance. The density of herbs ranged 39.8 - 86.4 ind/m² of which *E. adenophorum* showed density 10.9-17.4 ind./m² and PV 36.09 - 48.77 (Table 5 and 6). Total herb species diversity (H') was 0.0 - 2.98 (Table 5). Total biomass of study site was 135.68 g/m². The biomass of *E. adenophorum* was 113.68 g/m², which shared around 84% of total herbaceous biomass. Biomass of other herb species was 21.73 g/m², which shared around only 16% of total herbaceous biomass below road side (Table 7).

Table 1. Density and species diversity of herbaceous vegetation in Khurpatal forest site- 1

Species name/ distance (m)	Density (ind./m ²)					Species diversity				
	0-10	10.1-20	20.1-30	30.1-40	40.1-50	0-10	10.1-20	20.1-30	30.1-40	40.1-50
Cypress forest (above the road side)										
<i>Anthraxon</i> sp.	0.9	1.5	2.2	-	1.6	0.09	0.17	0.23	-	0.17
<i>Agrimonia pilosa</i>	-	1.5	0.5	1.5	-	-	0.17	0.08	0.13	-
<i>Conyza canadensis</i>	-	-	-	2.4	-	-	-	-	0.18	-
<i>Cynodon dactylon</i>	1.1	0.2	0.1	0.9	-	0.11	0.04	0.02	0.09	-
<i>Eupatorium adenophorum</i>	30.2	27.9	32.1	39.2	33.9	0.49	0.40	0.28	0.43	0.30
<i>Erigeron annua</i>	15.4	0.6	0.7	8.2	0.7	0.51	0.09	0.10	0.38	0.09
<i>Gallium aparina</i>	-	-	-	4.2	-	-	-	-	0.26	-
<i>Geranium wallichianum</i>	0.7	0.2	2.8	0.3	4.9	0.08	0.04	0.26	0.04	0.35
<i>Lindenbergia indica</i>	2.8	2.0	1.4	2.1	0.3	0.21	0.21	0.17	0.16	0.05
<i>Lytharus</i> sp.	0.1	0.1	-	-	0.2	0.01	0.02	-	-	0.03
<i>Oxalis latifolia</i>	2.1	3.3	0.8	1.8	0.2	0.17	0.28	0.11	0.14	0.03
<i>Prunella vulgaris</i>	1.1	0.5	-	-	-	0.11	0.07	-	-	-
<i>Rubia cordifolia</i>	-	0.7	0.4	-	0.2	-	0.10	0.06	-	0.03
<i>Rumex hastatus</i>	0.8	0.1	0.1	0.4	-	0.08	0.02	0.02	0.06	-
<i>Strobilanthus atropurpurem</i>	1.8	3.4	-	2.7	1.1	0.16	0.29	-	0.19	0.13
<i>Senecio nudicaulis</i>	0.1	-	-	-	-	0.01	-	-	-	-
<i>Thalictrum foliolosum</i>	0.6	0.8	0.1	-	1.3	0.07	0.11	0.02	-	0.15
Total	57.7	42.8	41.2	63.7	44.4	2.10	2.01	1.35	2.06	1.33
Mixed pine forest (below the road side)										
<i>Anthraxon</i> sp.	-	0.3	-	2.6	0.3	-	0.03	-	0.23	0.03
<i>Agrimonia pilosa</i>	4.3	-	9.3	1.7	-	0.21	-	0.36	0.17	-
<i>Conyza canadensis</i>	9.7	-	1.7	-	-	0.35	-	0.12	-	-
<i>Cynodon dactylon</i>	3.4	4.3	2.3	-	1.3	0.18	0.26	0.15	-	0.11
<i>Eupatorium adenophorum</i>	45.8	39.2	44.9	30.3	38.6	0.49	0.42	0.47	0.42	0.47
<i>Erigeron annua</i>	-	-	1.8	-	1.2	-	-	0.12	-	0.10
<i>Gallium aparina</i>	1.8	7.7	3.4	-	0.2	0.12	0.37	0.19	-	0.02
<i>Geranium wallichianum</i>	6.5	-	0.9	10.5	0.3	0.28	-	0.07	0.48	0.03
<i>Lindenbergia indica</i>	2.2	1.9	8.5	1.0	1.3	0.13	0.15	0.34	0.12	0.11
<i>Oxalis latifolia</i>	3.1	1.9	3.2	-	7.2	0.17	0.15	0.18	-	0.34
<i>Rubia cordifolia</i>	-	0.2	0.6	-	-	-	0.02	0.05	-	-
<i>Rumex hastatus</i>	0.3	0.2	-	-	1.5	0.03	0.02	-	-	0.12
<i>Strobilanthus atropurpurem</i>	0.2	7.2	2.7	1.4	15.0	0.02	0.35	0.16	0.15	0.48
<i>Senecio nudicaulis</i>	0.5	-	-	-	-	0.04	-	-	-	-
<i>Stellaria media</i>	4.6	0.3	-	-	2.3	0.22	0.03	-	-	0.16
<i>Thalictrum foliolosum</i>	-	-	0.1	0.4	-	-	-	0.01	0.06	-
<i>Viola odorta</i>	4.3	-	1.3	-	0.3	0.21	-	0.10	-	0.03
Total	86.7	63.2	80.7	47.9	69.5	2.45	1.80	2.32	1.63	2.00

Table 2. PV (provenience value) of herbaceous vegetation in pine Cypress forest site- 1

Species name/ distance (m)	PV(above the road side)					PV(below the road side)				
	0-10	10.1-20	20.1-30	30.1-40	40.1-50	0-10	10.1-20	20.1-30	30.1-40	40.1-50
<i>Anthraxon</i> sp.	5.07	10.48	21.13	-	11.71	-	3.04	-	20.13	2.93
<i>Agrimonia pilosa</i>	-	12.81	3.85	9.17	-	14.05	-	22.64	15.31	-
<i>Conyza canadensis</i>	-	-	-	10.59	-	20.28	-	6.87	-	-
<i>Cynodon dactylon</i>	8.92	2.79	2.87	5.96	-	11.19	22.19	10.79	-	6.87
<i>Eupatorium adenophorum</i>	69.88	88.44	104.23	84.27	103.38	71.01	87.67	71.51	92.67	80.54
<i>Erigeron annua</i>	44.23	6.05	4.33	24.24	4.28	-	-	8.58	-	4.23
<i>Gallium aparina</i>	-	-	-	20.23	-	5.71	22.44	12.15	-	2.79
<i>Geranium wallichianum</i>	8.23	5.12	22.59	2.74	35.36	22.04	-	7.46	51.33	2.93
<i>Lindenbergia indica</i>	18.89	18.63	19.19	14.66	6.08	11.63	10.70	20.06	5.03	9.37
<i>Lytharus</i> sp.	1.93	2.56	-	-	5.86	14.48	15.83	13.49	-	25.36
<i>Oxalis latifolia</i>	12.41	17.01	9.84	7.37	5.86	-	-	-	-	-
<i>Prunella vulgaris</i>	5.42	3.49	-	-	-	-	-	-	-	-
<i>Rubia cordifolia</i>	-	6.29	6.23	-	3.15	-	2.88	3.92	-	-
<i>Rumex hastatus</i>	4.90	2.56	2.87	2.90	-	3.98	2.88	-	-	9.66
<i>Strobilanthus atropurpurem</i>	11.89	19.57	17.87	17.87	7.88	2.05	29.34	12.87	11.75	41.58
<i>Senecio nudicaulis</i>	1.93	-	-	-	-	2.39	-	-	-	-
<i>Stellaria media</i>	6.30	4.19	2.87	-	16.44	8.94	3.04	-	-	10.81
<i>Thalictrum foliolosum</i>	-	-	-	-	-	-	-	1.71	3.78	-
<i>Viola odorta</i>	6.30	4.19	2.87	-	16.44	12.23	-	7.96	-	2.93
Total	200	200	200	200	200	200	200	200	200	200

Table 3. Density and species diversity of herbaceous vegetation in pine-Cypress forest in Hanumangarh forest site- 2

Species name/distance (m)	Density (ind/m ²)					Species diversity				
	0-10	10.1-20	20.1-30	30.1-40	40.1-50	0-10	10.1-20	20.1-30	30.1-40	40.1-50
Pine-Cypress forest (above the road side)										
<i>Acorus calamus</i>	3.4	8.6	6.0	22.3	-	0.15	0.30	0.34	0.51	-
<i>Agrimonia pilosa</i>	0.7	1.1	-	1.1	-	0.04	0.07	-	0.08	-
<i>Ajuga parvifolia</i>	7.1	-	-	-	-	0.25	-	-	-	-
<i>Anthraxon sp.</i>	1.1	2.2	-	11.8	-	0.06	0.12	-	0.40	-
<i>Bidens biternata</i>	1.0	1.6	1.7	-	-	0.06	0.09	0.15	-	-
<i>Climantis pitcheri</i>	-	0.2	-	-	-	-	0.18	-	-	-
<i>Cyperus rotundus</i>	2.8	-	-	3.3	-	0.13	-	-	0.19	-
<i>Erigeron bonariensis</i>	5.0	-	-	0.4	-	0.20	-	-	0.04	-
<i>Eupatorium adenophorum</i>	53.9	45.2	12.1	24.7	-	0.51	0.52	0.47	0.52	-
<i>Gallium aparina</i>	2.2	-	-	-	-	0.11	-	-	-	-
<i>Geranium wallichianum</i>	1.5	1.4	1.7	1.7	-	0.08	0.08	0.15	0.12	-
<i>Justicia smilax</i>	2.9	2.0	7.6	-	-	0.14	0.11	0.39	-	-
<i>Lapidagathis sp.</i>	0.4	4.7	1.1	-	-	0.03	0.20	0.11	-	-
<i>Lytharus sp.</i>	1.4	2.3	2.0	0.8	-	0.08	0.12	0.17	0.07	-
<i>Micromeria sp.</i>	2.9	-	-	-	-	0.14	-	-	-	-
<i>Oxalis latifolia</i>	2.4	6.9	1.9	5.4	-	0.12	0.26	0.16	0.26	-
<i>Prunella vulgaris</i>	-	4.6	4.9	0.2	-	-	0.20	0.30	0.02	-
<i>Rubia cordifolia</i>	-	0.5	2.4	2.2	-	-	0.04	0.19	0.14	-
<i>Senecio nudicaulis</i>	-	1.7	2.3	-	-	-	0.10	0.19	-	-
<i>Siegesbeckia orientalis</i>	-	-	0.2	-	-	-	-	0.03	-	-
<i>Stellaria media</i>	15.2	12.7	6.2	-	-	0.39	0.37	0.35	-	-
<i>Strobilanthus atropurpurem</i>	8.5	6.6	6.9	6.5	-	0.28	0.25	0.37	0.29	-
<i>Thalictrum foliolosum</i>	0.5	-	-	0.5	-	0.03	-	-	0.04	-
Total	112.9	102.3	57.0	80	-	2.80	3.01	3.37	2.68	-
Pine-Cypress forest (below the road side)										
<i>Acorus calamus</i>	6.5	3.4	14.8	22.3	6.9	0.14	0.15	0.37	0.50	0.28
<i>Acyrenthes bidentata</i>	0.2	-	-	-	1.5	0.01	-	-	-	0.10
<i>Agrimonia pilosa</i>	1.8	0.7	2.5	-	0.9	0.05	0.04	0.12	-	0.07
<i>Ajuga parviflora</i>	8.1	7.1	-	1.3	0.4	0.17	0.25	-	0.09	0.03
<i>Anthraxon sp.</i>	5.5	1.1	2.4	13.8	11.4	0.13	0.06	0.11	0.41	0.37
<i>Bidens biternata</i>	2.2	1.0	3.2	-	7.8	0.06	0.06	0.14	-	0.30
<i>Cynodon dactylon</i>	38.3	-	-	-	3.5	0.43	-	-	-	0.18
<i>Cyperus rotundus</i>	1.2	2.8	-	3.9	-	0.04	0.13	-	0.20	-
<i>Erigeron bonariensis</i>	8.3	5.0	9.4	2.7	-	0.17	0.20	0.29	0.15	-
<i>Eupatorium adenophorum</i>	60.1	53.9	39.3	24.7	17.3	0.50	0.51	0.53	0.51	0.45
<i>Gallium aparina</i>	-	2.2	1.1	2.4	-	-	0.11	0.06	0.14	-
<i>Geranium wallichianum</i>	1.5	1.5	0.4	1.7	7.4	0.05	0.08	0.03	0.11	0.29
<i>Hetropogon contontus</i>	0.6	-	-	-	-	0.02	-	-	-	-
<i>Justicia simplex</i>	16.4	2.9	3.2	-	4.2	0.27	0.14	0.14	-	0.20
<i>Lapidagathis cristata</i>	0.3	0.4	0.7	-	-	0.01	0.03	0.01	-	-
<i>Lindenbengia indica</i>	0.1	-	0.1	-	-	0.01	-	0.04	-	-
<i>Lytharus sp.</i>	0.6	1.4	2.2	0.8	0.2	0.02	0.08	0.11	0.06	0.02
<i>Micromeria sp.</i>	5.5	2.9	0.9	-	-	0.13	0.14	0.05	-	-
<i>Oxalis latifolia</i>	13.7	2.4	10.7	9.7	8.7	0.24	0.12	0.31	0.35	0.32
<i>Prunella vulgaris</i>	3	-	1.9	-	3.1	0.08	-	0.11	-	0.17
<i>Rubia cordifolia</i>	0.3	-	1.5	-	1.9	0.01	-	0.08	-	0.12
<i>Senecio nudicaulis</i>	0.4	-	0.9	-	-	0.02	-	0.05	-	-
<i>Siegesbeckia orientalis</i>	1.2	-	0.5	-	13.5	0.04	-	0.03	-	0.41
<i>Stellaria media</i>	26.6	15.2	13.9	-	-	0.36	0.39	0.36	-	-
<i>Strobilanthus atropurpurem</i>	31.2	8.5	9.0	6.5	0.8	0.39	0.28	0.28	0.27	0.06
<i>Thalictrum foliolosum</i>	0.5	0.5	-	-	1.6	0.02	0.03	-	-	0.10
<i>Vitis himalayana</i>	0.6	-	-	-	0.2	0.02	-	-	-	0.02
Total	234.7	112.9	118.6	89.8	91.3	3.39	2.80	3.22	2.79	3.49

Forests in Himalaya are playing a significant role in socio-economic and environmental development. But recently they are degrading by various disturbances such as biotic, infrastructural expansion and also by many invasive plant species in natural forest habitats. *Lantana camara*, *Eupatorium*

adenophorum and *Parthenium hysterophorus* are most troublesome plants commonly occupied every possible habitat (Singh and Vashistha 2014). This rapid and increasing rate of invasive potential and its establishment have very little prospect of reversing (Muniappan *et al.* 2009, Sharma and Raghubanshi 2011).

Table 4. PV (provenience value) of herbaceous vegetation in pine-Cypress forest in Hanumangarh forest site- 2

Species name/ distance (m)	PV(above the road side)					PV(below the road side)				
	0-10	10.1-20	20.1-30	30.1-40	40.1-50	0-10	10.1-20	20.1-30	30.1-40	40.1-50
<i>Acorus calamus</i>	8.42	17.38	19.10	39.10	-	6.77	8.42	21.65	35.55	14.05
<i>Acyrenthes bidentata</i>						1.09	-	-	-	2.94
<i>Agrimonia pilosa</i>	6.03	3.64	-	5.21	-	5.77	6.03	8.53	-	4.88
<i>Ajuga parvifolia</i>	8.99	-	-	-	-	7.45	8.99	-	6.80	1.74
<i>Anthraxon</i> sp.	2.33	3.43	-	26.12	-	7.34	2.33	7.53	27.87	22.88
<i>Bidens biternata</i>	4.94	7.97	10.13	-	-	6.94	4.94	10.04	-	16.34
<i>Climantis pitcheri</i>	-	1.48	-	-	-	-	-	-	-	-
<i>Cynodon dactylon</i>	-	-	-	-	-	23.32	-	-	-	12.92
<i>Cyperus rotundus</i>	10.59	-	-	13.69	-	1.51	10.59	-	15.06	-
<i>Erigeron bonariensis</i>	9.83	-	-	2.42	-	7.54	9.83	12.51	4.79	-
<i>Eupatorium adenophorum</i>	61.25	57.00	35.51	49.76	-	35.61	61.25	42.31	45.36	30.64
<i>Gallium aparina</i>	7.35	-	-	-	-	-	7.35	3.68	8.03	-
<i>Geranium wallichianum</i>	5.38	9.06	12.98	9.79	-	4.64	5.38	3.09	9.04	15.90
<i>Hetropogon contortus</i>	-	-	-	-	-	1.26	-	-	-	-
<i>Justicia smilax</i>	6.62	5.80	23.33	-	-	13.99	6.62	8.20	-	9.80
<i>Lapidagathis</i> sp.	1.71	12.29	4.79	-	-	2.13	1.71	1.00	-	-
<i>Lindenbengia indica</i>						1.04	-	3.34	-	-
<i>Lytharus</i> sp.	5.29	11.22	13.51	8.68	-	3.26	5.29	8.28	8.03	1.52
<i>Micromeria</i> sp.	5.27	-	-	-	-	4.34	5.27	3.51	-	-
<i>Oxalis latifolia</i>	14.29	15.72	6.19	14.37	-	13.84	14.29	17.28	19.73	18.62
<i>Prunella vulgaris</i>	-	10.91	14.31	2.17	-	4.28	-	5.27	-	7.29
<i>Rubia cordifolia</i>	-	1.77	7.07	4.64	-	2.13	-	4.02	-	5.98
<i>Senecio nudicaulis</i>	-	6.79	11.18	-	-	1.17	-	2.59	-	-
<i>Siegesbeckia orientalis</i>	-	1.78	1.78	-	-	3.51	-	4.09	-	21.28
<i>Stellaria media</i>	21.57	20.11	15.16	-	-	14.33	21.57	18.14	-	-
<i>Strobilanthes atropurpurem</i>	18.34	15.43	24.96	21.50	-	23.29	18.34	14.93	19.74	4.77
<i>Thalictrum foliolosum</i>	1.79	-	-	2.54	-	1.21	1.79	-	-	5.65
<i>Vitis himalayana</i>	-	-	-	-	-	2.26	-	-	-	2.82
<i>Total</i>	200	200	200	200	200	200	200	200	200	200

In present study, density of herbaceous layer ranged from 41.2 ind./m² to 234.7 ind./m² for conifer forest and 17.8 - 86.4 ind./m² in oak forest. The values were higher than 67.2 ind./m² during summer season for oak - pine mixed forest in Kumaun Himalaya by Joshi *et al.* (2012) and 20.3 - 34 ind./m² for banj oak forest by Kharkwal *et al.* (2010).

The species diversity of herb layer in present study ranged 1.33 - 3.49, which was on lower side than 2.11 - 3.56 reported for oak-pine mixed forest in Kumaun Himalaya by Joshi *et al.* (2012), and 3.3 - 5.1 for Uttaranchal forests by Kumar and Ram (2005), and supporting the study that once *E. adenophorum* weed invaded barren land, it was able to restrain tree seedling growth as well as the regeneration of other species of grass (Sun *et al.* 2004).

Density of *E. adenophorum* ranged from 2.5 ind./m² to 60.1 ind./m² in present study. Average density of *E. adenophorum* in forest below the road side ranged 11.24 to 39.76 ind./m², which was higher almost in all sites than forest above road site that ranged 7.84 to 32.66 ind./m².

Density of *E. adenophorum* was higher in Cypress forest *i.e.* 30.1 - 65.4% followed by mixed pine forest 57.1% and lowest in mixed oak forest 23.2 - 26.8%. On the basis of density and PV, *E. adenophorum* was the dominant species of herbaceous layer in mixed conifer forest and shared 30 - 65.4% of total herbaceous density, when we moved upto 50 m above and below the road side. While in oak forest, it was not the dominant herb species and shared only 23.2 - 26.8%. Habitats with high diversity and complexity possessed strong resistance to the *E. adenophorum* invasion, while disturbed habitats favoured invasion (Hao *et al.* 2010).

Total herbaceous biomass ranged from 135.68 - 730.43 g/m², which was higher than 8.8-227 g/m² for banj oak forest (Kharkwal *et al.* 2010). Biomass of *E. adenophorum* shared 84 - 99.8% of total herbaceous biomass.

The values of density, PV, diversity and biomass of *E. adenophorum* indicated that it has highly reduced available habitat for the growth of other herbaceous species and dominated the ground layer

Table 5. Density and species diversity of herbaceous vegetation in oak forest in Bhowali forest site- 3

Species name/distance (m)	Density (ind/m ²)					Species diversity				
	0-10	10.1-20	20.1-30	30.1-40	40.1-50	0-10	10.1-20	20.1-30	30.1-40	40.1-50
Oak forest (above the road side)										
<i>Acorus calamus</i>	-	-	4.4	7.5	2.2	-	-	0.35	0.47	0.31
<i>Agrimonia pilosa</i>	0.2	0.3	0.9	0.2	0.7	0.04	0.1	0.12	0.04	0.15
<i>Ajuga parvifolia</i>	-	2.1	-	0.6	-	-	0.36	-	0.1	-
<i>Anthraxon</i> sp.	0.8	0.9	7.5	9.5	3.1	0.11	0.22	0.45	0.5	0.38
<i>Clematis pitcher</i>	-	-	1.2	2.1	1	-	-	0.15	0.24	0.19
<i>Conyza canadensis</i>	5.3	-	-	-	-	0.38	-	-	-	-
<i>Cyperus rotundus</i>	-	-	0.7	-	0.2	-	-	0.1	-	0.06
<i>Erigeron annua</i>	10	2.5	5.4	-	5.7	0.49	0.4	0.39	-	0.49
<i>Eupatorium adenophorum</i>	19.3	9.1	4.8	2.5	3.5	0.51	0.49	0.36	0.26	0.4
<i>Gallium aparina</i>	0.3	0.2	2.6	1.2	0.2	0.05	0.07	0.25	0.16	0.06
<i>Gentian</i> sp.	-	-	-	0.1	-	-	-	-	0.02	-
<i>Geranium wallichianum</i>	2	0.5	0.9	-	0.5	0.21	0.14	0.12	-	0.11
<i>Lindenbergia indica</i>	2.7	1.6	7.1	8.3	2.4	0.25	0.31	0.44	0.48	0.33
<i>Lytharus</i> sp.	0.1	-	0.7	0.4	0.6	0.02	-	0.1	0.07	0.13
<i>Micromeria</i> sp.	-	-	-	0.9	-	-	-	-	0.13	-
<i>Prunella vulgaris</i>	0.3	0.2	-	0.3	-	0.05	0.07	-	0.06	-
<i>Rubia cordifolia</i>	0.2	-	-	-	-	0.04	-	-	-	-
<i>Rumex hastatus</i>	-	-	-	-	-	-	-	-	-	-
<i>Senecio nudicaulis</i>	0.4	0.1	-	-	0.6	0.06	0.04	-	-	0.13
<i>Stellaria media</i>	0.2	0.2	-	-	0.2	0.04	0.07	-	-	0.06
<i>Strobilanthus atropurpurem</i>	0.1	0.1	3.8	3	3.6	0.02	0.04	0.32	0.3	0.41
<i>Thalictrum foliolosum</i>	-	-	0.9	-	-	-	-	0.12	-	-
Total	41.9	17.8	40.9	36.6	24.5	2.27	2.31	3.27	2.83	3.21
Oak forest (below the road side)										
<i>Acorus calamus</i>	1.2	0.3	1.6	2.8	-	0.09	0.33	0.18	0.26	-
<i>Agrimonia pilosa</i>	0.1	3.1	3.6	8.4	-	0.01	0.19	0.3	0.47	-
<i>Anthraxon</i> sp.	31.2	4.3	2.4	1.4	-	0.41	0.24	0.23	0.17	-
<i>Cyperus rotundus</i>	1.3	7	4.8	4.7	-	0.09	0.32	0.35	0.36	-
<i>Erigeron annua</i>	10.9	1.9	2.6	3.6	-	0.37	0.14	0.25	0.31	-
<i>Eupatorium adenophorum</i>	17.4	14.7	13.2	10.9	-	0.47	0.47	0.52	0.51	-
<i>Gallium aparina</i>	4.6	-	-	-	-	0.22	-	-	-	-
<i>Geranium wallichianum</i>	0.8	6.5	2.3	0.7	-	0.06	0.31	0.23	0.1	-
<i>Lindenbergia indica</i>	21.8	15.4	8.2	4.5	-	0.5	0.47	0.46	0.36	-
<i>Oxalis letifolia</i>	13.6	19.8	0.6	1.1	-	0.42	0.51	0.09	0.14	-
<i>Strobilanthus atropurpurem</i>	1.5	-	-	-	-	0.1	-	-	-	-
<i>Thalictrum foliolosum</i>	-	-	3.4	1.7	-	-	-	0.29	0.19	-
Total	104.4	73	42.7	39.8	0	2.74	2.98	2.9	2.87	0

Table 6. PV (provenience value) of herbaceous vegetation in oak forest in Bhowali forest site- 3

Species name/distance (m)	PV (above the road side)					PV (below the road side)				
	0-10	10.1-20	20.1-30	30.1-40	40.1-50	0-10	10.1-20	20.1-30	30.1-40	40.1-50
<i>Acorus calamus</i>	-	-	20.09	34.34	20.09	6.65	2	9.1	14.05	-
<i>Agrimonia pilosa</i>	2.98	7.09	10.2	3.62	6.56	1.87	16.94	19.15	36.9	-
<i>Ajuga parvifolia</i>	-	19.91	-	6.25	-	-	-	-	-	-
<i>Anthraxon</i> sp.	9.41	15.87	30.34	41.34	21.91	25.8	17	16.33	7.03	-
<i>Clematis pitcher</i>	-	-	12.27	13.43	9.64	-	-	-	-	-
<i>Conyza canadensis</i>	32.65	-	-	-	-	-	-	-	-	-
<i>Cyperus rotundus</i>	-	-	4.38	-	4.52	5.01	20.7	25.53	29.35	-
<i>Erigeron annua</i>	33.87	27.56	19.86	-	30.67	30.16	7.36	11.43	16.06	-
<i>Eupatorium adenophorum</i>	71.05	78.14	21.07	17.6	29.1	37.68	36.01	48.77	43.18	-
<i>Gallium aparina</i>	3.22	3.83	14.36	9.43	2.67	12.34	-	-	-	-
<i>Gentian</i> sp.	-	-	-	1.81	-	-	-	-	-	-
<i>Geranium wallichianum</i>	12.27	10.92	6.2	-	5.74	2.68	23.19	14.31	7.02	-
<i>Lindenbergia indica</i>	11.44	19.8	28.03	36.52	20.91	39.27	36.97	37.06	20.08	-
<i>Lytharus</i> sp.	2.74	-	3.04	5.71	8	-	-	-	-	-
<i>Micromeria</i> sp.	-	-	-	5.54	-	-	-	-	-	-
<i>Prunella vulgaris</i>	3.22	3.83	-	3.9	-	-	-	-	-	-
<i>Rubia cordifolia</i>	5.48	-	-	-	-	-	-	-	-	-
<i>Rumex hastatus</i>	-	-	-	-	-	-	-	-	-	-
<i>Oxalis letifolia</i>	-	-	-	-	-	29.78	39.82	3.19	9.78	-
<i>Senecio nudicaulis</i>	5.95	3.26	-	-	6.15	-	-	-	-	-
<i>Stellaria media</i>	2.98	6.53	-	-	2.67	-	-	-	-	-
<i>Strobilanthus atropurpurem</i>	2.74	3.26	21.29	20.5	31.36	8.75	-	-	-	-
<i>Thalictrum foliolosum</i>	-	-	8.87	-	-	-	-	15.11	16.55	-
Total	200	200	200	199.99	199.99	199.99	199.99	199.9	200	-

Table 7. Biomass of herb species

Component	Forest site-1		Forest site-2		Forest site-3	
	Above	Below	Above	Below	Above	Below
TAG biomass(g/m ²)	482.1 (481.4)	465.8 (463.6)	499.8 (498.0)	407.0 (400.4)	119.5 (115.2)	89.4 (75.4)
TBG biomass (g/m ²)	244.0 (244.0)	238.6 (237.4)	230.6 (229.8)	234.0 (234.0)	57.1 (45.6)	46.3 (38.5)
Total (g/m ²)	726.1 (725.4)	704.3 (704.0)	730.4 (727.8)	641.0 (641.0)	176.6 (160.8)	135.7 (113.9)

Values in parentheses are indicating biomass shared by *Crofton* weed

of forest. It was concluded that prevention and early detection of *E. adenophorum* is vital in protecting forest environments from non-indigenous and possibly invasive species as these species would have effective reproduction and dispersal mechanism, superior competitive ability and are capable of displacing native species.

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