Infestation Of Weed Vegetation *Parthenium hysterophorus* L. In Tehri Garhwal Himalaya, Uttarakhand, India

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**Abstract:** *Parthenium hysterophorus* L. is a weed of global significance causing severe economic, environmental, agricultural, biodiversity, livestock, and human health problems. It is a highly noxious, invasive plant species of subtropical America and quickly spreads almost in all climatic conditions of the world. The weed has been spread almost in every part of every state of India including Uttarakhand. *P. hysterophorus* was observed to spread from sub-tropical climatic conditions to the temperate region up to 2200 m asl in Tehri Garhwal, Uttarakhand. It has severely affected the habitats of native plant species. *P. hysterophorus* is an annual herb that starts to grow during March-April and remains till last of the November-December. The infestation of *Parthenium* has been maximum during the summer and abolished during the winter season. Regular field visits and surveys were made during the growing season (2018-19) from foothills to higher ridges of the study areas. The highest density value (729000 ind ha⁻¹) for *P. hysterophorus* was recorded at the Chauras site followed by Rishikesh (554000 ind ha⁻¹) and the Badshahithaul site (417000 ind ha⁻¹) whereas, the lowest density value for this weed was recorded at the Ranichauri site (61000 ind ha⁻¹). *P. hysterophorus* was determined to be the dominating plant species in most of the survey sites based on density, basal cover, and the Importance Value Index (IVI). However, the dominance of *P. hysterophorus* in most of the study sites is a signal of probable threat to the associated species. Plant species degradation caused by high anthropogenic pressure would provide appropriate circumstances for *Parthenium* weed to invade, presenting a major threat to the ecological balance of the region. The aim of present study to investigate infestation of *Parthenium* weed with altitudes wise in Tehri Garhwal, Uttarakhand, India.

**Keywords:** *Parthenium hysterophorus* L., Distribution, Infestation, Biodiversity, Tehri Garhwal

**Introduction**

*Parthenium hysterophorus* L. (Family Asteraceae) is an invasive alien plant considered the "World's Worst Weed" (Holm *et al.*, 1977). It is native to Central America and now has been spread to over 20 nations worldwide, spanning five continents and numerous islands (Picman *et al.*, 1984; Navie *et al.*, 1996). Recent findings suggest that weed has infested African nations and even eight Chinese provinces, spreading at an alarming pace from the tropical to the subtropical regions of the world (Dogra *et al.*, 2011). The infestation level of *Parthenium* is severe in countries like Australia, South Africa, Ethiopia, India, Srilanka, and Pakistan. Nowadays, it is considered a weed of global and natural significance (Dhileepan, 2009). In India, it has entered with cereal grain imported from the USA before 1910 (Chandras and Vartak, 1970). Since then, it has become a prominent weed in practically almost every Indian state, specially Andhra Pradesh, Bihar, Haryana, Karnatak,
Madhya Pradesh, Tamil Nadu, and Uttar Pradesh, where there is a high prevalence of Parthenium infection (Sushilkumar, 2014; Manpreet Kaur et al., 2014). The infestation level of Parthenium weed studied three different parameter which are low, medium, and high levels of infestation (Sushilkumar, 2014). Uttarakhand has achieved the medium infestation level among different Indian states (Lalita and Ashok Kumar, 2018). Parthenium has invaded most of the crops and become a serious threat to agriculture production. It is a fast-growing annual herb with a deep taproot system and maybe eventually reaching a height up to 2 meters (Kaur et al., 2014). P. hysterophorus is originated because of the natural hybridization of P. bipinnatifidum and P. confertum (Nath, 1988). Parthenium can adapt to almost every agro-climatic condition and distribute itself to a variety of growing environmental conditions (Annupurna and Singh, 2003). It can produce more than 25,000 seeds per plant. The seeds are light in weight, mainly dispersed through water current, air, moving vehicle tires, machinery, livestock, fodder, grain, lesser animals, and human by their activities. Allelopathic chemicals found in Parthenium can reduce moisture and nutrients in the agricultural field and inhibit germination and growth of adjacent crops and other plants species and reduce biodiversity by the displacement of the native as well as exotic plants species (Shahir and Bajwa, 2006; Gnanavel, 2013). These studies showed that chemicals released by Parthenium weed inhibit the growth and development of wheat, sorghum, and other crop species, and the effect of Parthenium in the agricultural field in a different part of the world has been reported (Javid et al., 2011; Gnanavel, 2013; Zuberi et al., 2014; Khan et al., 2014). Parthenium weed threatens biodiversity by competing with indigenous crop plant species for resources (nutrients, moisture, sunlight, and even space). Parthenium weed completely dominated grazing land in Australia and reduced stacking rate by up to 80% and loss of beef production up to AU$ 22.0 million per year (Chippendale and Panneta, 1994).

Thus, Parthenium weed is found to affect human and animal health also. In humans, weed causes asthma, allergic, rhinitis, bronchitis, dermatitis, and hay fever were coming in contact with Parthenium leaves and inhalation of pollen grains and toxins present in weed has been reported to cause effects in milk and meat production in the livestock (Gnanavel, 2013).

Parthenium reduces 40% of several crops in Australia it is found a major threat to perennial grassland in the central states of Queensland (Kholsa and Sobti, 1997; Navie et al., 1998; 2004). The use of herbicides for the control of Parthenium is prohibited globally due to high cost and adverse effects, in severe situations weed can be controlled by application of 2, 4, D, or Atrazine (Holman, 1981). The soil seed bank is the major factor in the spreading of Parthenium. Soil can preserve its seeds for a long time for seed dormancy, seed longevity and the capability of weed to grow in favorable environmental conditions. An investigation reported the dormancy of seeds in soil was tenacious to be high seeds in Queensland and seed bank persistency reached 65-87% (Navie et al., 2004).

Parthenium is a serious problem in many rain-fed ecosystems and non-cropped situations, as well as in agricultural pastures and woodland ecosystems. However, weed is now infesting numerous forest's land and endangering biodiversity. The availability of the weed of palatable grass herbivores and national parks across the world, it’s also a concern (Sushil Kumar, 2014). Keeping in view the relevance of this invasive noxious weed in terms of suppressing native flora.
in the area. A comprehensive study was carried out to calculate the infestation and distribution of *P. hysterophorus* in the Tehri Garhwal Himalayas, Uttarakhand.

Materials and methods

The present study was undertaken in the Garhwal Himalayas region situated between Latitude 30°26′ 15″ N and between longitude 78°18′ 45″ to 80°8′ 0″ E (Atkinson, 1884). The survey elevation ranges from 370 – 2200 m asl. Physiographically, the area consists of hill slopes and valleys of Tehri Garhwal district of Uttarakhand state with sub-montane and montane forests. A total of five sites, differing in altitudes with general characteristics and species compositions, were selected for the present investigation in the district of Tehri Garhwal, Uttarakhand (Fig. 1). These sites are (i) Rishikesh (ii) Chauras, (iii) Nagni, (iv) Badshahithaul and (v) Ranichauri (Dandachali). The general characteristics with anthropogenic activities are of the study sites are presented in Table 1.

![Fig. 1: Map showing survey sites in the study area.](image)

| Study sites          | Latitude               | Longitude            | Altitude (m asl) | Habitat characteristics | Anthropogenic activities                          |
|----------------------|------------------------|----------------------|------------------|-------------------------|--------------------------------------------------|
| Rishikesh            | 30°07′25.426″N         | 78°16′47.730″E       | 370              | Forest and road sides   | Construction activities and industrialization     |
| Chauras              | 30°13′25.027″N         | 78°48′07.873″E       | 560              | Grassland and waysides  | Construction of Dam and roads                      |
| Nagani               | 30°18′39.208″N         | 78°20′40.016″E       | 1000             | Forest edges and road sides | Forest fire and grazing                            |
| Badshahithaul        | 30°23′02.837″N         | 78°25′25.633″E       | 1750             | Forest edges, road side and agricultural field margins | Forest fire, grazing, collection of fodder and fuelwood |
| Ranichauri (Dandachali) | 30°13′25.027″N     | 78°48′07.873″E       | 2200             | Forest edges, road side and agricultural field margins | Forest fire, grazing, collection of fodder and fuelwood |

The field surveys were conducted on the major road networks which were due to its core infestation of the weed in crop areas and waste lands. In every five locations, one field/area was randomly selected for data collection. Distribution and infestation were determined as
the presence and absence of *Parthenium* weed in the residential areas, along roadsides, agricultural fields, grazing lands, forest land, etc. The quadrat method was used to assess the species composition at all selected sites during 2018-2019. Herbs were measured and counted in 20 quadrats of 1 m x 1 m size at each study site. The frequency, density, and abundance values for herbs and shrub layers were calculated following by following Curtis and McIntosh (1950).

The basal area was estimated by clipping the herbaceous species with the help of scissors, at few centimeters just above the ground and the diameter of the stem emerging out of ground is measured with the of calipers or scale. Usually, 100 stems of the species were selected for the measurement of diameter, and then the average diameter for the individual species was calculated by using the formula: Basal area = 3.14 X Average diameter X Average diameter X 0.25 (Tiwari, 2005). Importance Value Index (IVI) was calculated by summing relative density, relative frequency, and relative dominance as proposed by Curtis and McIntosh (1950) and Phillips (1959). Species richness was the total number of species in a particular study site.

Shannon-Wiener Diversity Index (H) was calculated as per Shannon and Weaver (1963), employing the following formula:

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

Where, $H =$ Shannon-Wiener Diversity Index; $N_i =$ Importance Value Index of a species; $N =$ Total Importance Value Index of all the species.

**Results and Discussion**

*P. hysterophorus* is an annual herb and starts to grow during March-April at foot-hills while it started to grow in May-June or after first rain at high altitude region of Tehri Garhwal and remains till last of the November-December. The infestation of *Parthenium* has been maximum during the summer and abolished during the winter season. The highest density value (729000 ind ha$^{-1}$) for *P. hysterophorus* was recorded at the Chauras site (Fig. 2) followed by the Rishikesh site *i.e.*, 554000 ind ha$^{-1}$ whereas the lowest density value for *P. hysterophorus* was recorded at the Ranichauri site (61000 ind ha$^{-1}$) followed by Nagani (246000 ind ha$^{-1}$). Thus, it is evident from the present investigation the density and infestation of *Parthenium* are higher at a lower elevation such as Chauras and Rishikesh in comparison to higher elevations (Table 2-6). There is a great variation in the range of total basal cover (TBC) at Rishikesh 30777.78 cm$^2$ ha$^{-1}$, Chauras 43133.47 cm$^2$ ha$^{-1}$, Nagani 14052.01 cm$^2$ ha$^{-1}$, Badshahithaul 49856.73 cm$^2$ ha$^{-1}$, and Ranichauri 2624.36 cm$^2$ ha$^{-1}$ plant species at five different sites (Fig.3).

![Fig. 2 (A – H): Infestation of *Parthenium hysterophorus* at different study sites.](image)

The invasion of plant communities by hardy exotics and warned that invasive species pose a serious threat to biodiversity (Heywood, 1989; Cronk et al., 1995; Luken and Thieret, 1997 and Schmitz et al., 1997). *P. hysterophorus* is a noxious invasive weed species that have created devastation to the natural habitat around the
world by replacing native species, in their species-rich areas with single species monoculture (Mack and D’ Antonio 1998) and reducing the diversity of native (Meiners et al., 2001).

P. hysterophorus has also been found in the Kargil area of Jammu and Kashmir, as well as Port Blair in the Andaman and Nicobar Islands, demonstrating the weed's exceptional capacity to invade new environments (Yadhuraju et al., 2005). The study about the infestation of Parthenium weed in a different region of India was reported by Sushil Kumar and Varshney (2010), Sushil Kumar, (2012), Dogra et al. (2011) from Himachal Pradesh and Dolai et al., (2013) from West Bengal in the Indian continent. Similar findings have also been reported for P. hysterophorus by Fite et al. (2017), K. Dhileepan (2017), Zareen et al. (2018), Maszura et al. (2018), and Wubneh (2019) from various parts of the world.

Analysis of the Importance Value Index (IVI) of a species can be used to recognize the pattern of association of dominant species in a community (Parthasarathy and Karthikeyan, 1997). The high IVI of a species indicated its dominance and ecological success, its good power of regeneration, and greater ecological amplitude. Among the plant species, P. hysterophorus was found dominant species at most of the sites (Table 2-6). At Ranichauri high altitude site, where Eupatorium adenophorum was observed most dominant (53.98) followed by Gnaphalium sylvaticum (36.79) and P. hysterophorus (34.39) was the third dominant plant.

Based on density, basal cover, and Importance Value Index (IVI), P. hysterophorus was found to be the most dominant plant species in most of the sites, whereas the dominance of P. hysterophorus in most of the sites is an indication of possible threat to the associated species.
Table 2: Density, IVI and Diversity related parameters of plants at Rishikesh site.

| Species                | Frequency % | Density (ind ha\(^{-1}\)) | TBC (cm\(^2\) ha\(^{-1}\)) | IVI        | Shannon-Wiener Diversity Index |
|------------------------|-------------|-----------------------------|------------------------------|------------|---------------------------------|
| Achyranthus aspera     | 50          | 33000                       | 3945.50                     | 14.3847   | -0.301                          |
| Ageratum conyzoides    | 50          | 54000                       | 4234.03                     | 16.7945   | -0.394                          |
| Argeimone maxicana     | 40          | 19000                       | 1325.98                     | 8.80287   | -0.212                          |
| Artemecia cappilaris  | 50          | 18000                       | 1279.16                     | 10.0225   | -0.204                          |
| Bidens pilosa          | 30          | 26000                       | 1887.09                     | 8.73536   | -0.260                          |
| Celosia argentea       | 50          | 6000                        | 445.14                      | 7.92716   | -0.092                          |
| Conyza canadensis      | 50          | 12000                       | 190.96                      | 8.25431   | -0.154                          |
| Cynoglossum sp.        | 60          | 7000                        | 282.30                      | 9.22222   | -0.104                          |
| Desmodium sp.          | 70          | 4000                        | 180.00                      | 10.1823   | -0.068                          |
| Eupatorium adenophorum | 50          | 50000                       | 3348.90                     | 15.4443   | -0.379                          |
| Euphorbia hirta        | 70          | 35000                       | 419.66                      | 13.5395   | -0.312                          |
| Parthenium hysterophorus | 50     | 554000                     | 30777.78                    | 95.2888   | 0.712                           |
| Sida rhombifolia       | 30          | 5000                        | 541.34                      | 5.19071   | -0.080                          |
| Sonchus oleraceus      | 40          | 16000                       | 5617.95                     | 7.22755   | -0.135                          |
| Xanthium strumarium    | 40          | 10000                       | 696.89                      | 7.22755   | -0.135                          |
|                       | 730         | 849000                      | 55172.68                    | 244.127   | -2.173                          |

Table 3: Density, IVI, and Diversity related parameters of plants at Chauras site.

| Species                | Frequency % | Density (ind ha\(^{-1}\)) | TBC (cm\(^2\) ha\(^{-1}\)) | IVI        | Shannon-Wiener Diversity Index |
|------------------------|-------------|-----------------------------|------------------------------|------------|---------------------------------|
| Anisomeles indica      | 30          | 25000                       | 1620.00                     | 7.89       | -0.234                          |
| Argeimone maxicana     | 40          | 15000                       | 856.83                      | 7.44       | -0.165                          |
| Artemisia capillaris   | 60          | 146000                     | 9531.01                     | 31.22      | -0.528                          |
| Bidens pilosa          | 40          | 53000                       | 1102.82                     | 10.62      | -0.366                          |
| Boerhavia diffusa     | 50          | 26000                       | 906.05                      | 9.63       | -0.240                          |
| Cannabis sativa        | 40          | 68000                       | 2820.10                     | 13.99      | -0.415                          |
| Conyza canadensis      | 60          | 61000                       | 2190.63                     | 15.24      | -0.393                          |
| Corchorus aestuans     | 60          | 17000                       | 4654.60                     | 15.15      | -0.180                          |
| Cuscuta reflexa        | 50          | 33000                       | 748.59                      | 9.95       | -0.279                          |
| Parthenium hysterophorus | 40      | 729000                     | 43133.47                    | 116.37     | 1.175                           |
| Rumex hastatus         | 70          | 36000                       | 605.00                      | 12.59      | -0.294                          |
| Saussurea heteromalla  | 50          | 27000                       | 1024.12                     | 9.86       | -0.246                          |
| Sida cordifolia        | 70          | 35000                       | 367.94                      | 12.20      | -0.289                          |
| Stellaria media        | 30          | 19000                       | 3306.95                     | 9.65       | -0.195                          |
| Tridax procumbens      | 50          | 23000                       | 1695.74                     | 10.44      | -0.221                          |
| Triumfetta rhomboidea  | 30          | 17000                       | 1958.40                     | 7.73       | -0.180                          |
|                       | 770         | 1330000                    | 76522.25                    | 300.00     | -3.049                          |
Table 4: Density, IVI, and Diversity related parameters of plants at Nagani site.

| Species                  | Frequency % | Density (ind ha\(^{-1}\)) | TBC (cm\(^2\) ha\(^{-1}\)) | IVI  | Shannon-Wiener Diversity Index |
|--------------------------|-------------|-----------------------------|-------------------------------|------|-------------------------------|
| *Achyranthes aspera*     | 40          | 23000                       | 1360.86                       | 8.70252 | -0.221                       |
| *Ageratum conyzoides*    | 60          | 33000                       | 2154.26                       | 13.0886 | -0.279                       |
| *Ajuga bracteosa*        | 60          | 19000                       | 682.32                        | 10.1125 | -0.195                       |
| *Alternanthera sessilis* | 40          | 13000                       | 270.50                        | 6.52575 | -0.149                       |
| *Bidens pilosa*          | 40          | 35000                       | 1451.52                       | 9.72324 | -0.289                       |
| *Capsella bursa*         | 50          | 23000                       | 521.74                        | 8.90465 | -0.221                       |
| *Chenopodium album*      | 70          | 8000                        | 134.44                        | 9.86811 | -0.104                       |
| *Clinopodium umbrosum*   | 50          | 16000                       | 606.88                        | 8.4896  | -0.173                       |
| *Cyperus rotundus*       | 50          | 45000                       | 3317.76                       | 14.2126 | -0.335                       |
| *Echinochloa colona*     | 70          | 5000                        | 52.56                         | 9.53554 | -0.073                       |
| *Eupatorium adenophorum* | 50          | 37000                       | 1289.37                       | 10.9604 | -0.299                       |
| *Galinsoga parviflora*   | 50          | 18000                       | 1166.4                        | 9.37115 | -0.187                       |
| *Gomphrena celosiodes*   | 50          | 11000                       | 1914.55                       | 9.82253 | -0.132                       |
| *Origanum vulgare*       | 50          | 3000                        | 821.40                        | 7.79248 | -0.049                       |
| *Oxalis corniculata*     | 50          | 21000                       | 2419.20                       | 11.2339 | -0.208                       |
| *Parthenium hysterophorus* | 50      | 246000                      | 14052.01                      | 43.353  | -0.472                       |
| *Persicaria nepalensis*  | 50          | 6000                        | 388.80                        | 7.45272 | -0.084                       |
| *Polygonium barbatum*    | 30          | 21000                       | 3655.05                       | 10.2515 | -0.208                       |
| *Rumex hustatus*         | 60          | 33000                       | 9035.40                       | 22.081  | -0.279                       |
| *Xanthium strumarium*    | 30          | 2000                        | 230.40                        | 4.34757 | -0.035                       |
|                          | 1000        | 618000                      | 45525.48                      | 235.829 | -3.992                       |

The species diversity can be defined by the combination of two factors i.e., the number of species present to as species richness and the distribution of individuals among species, to as evenness or equitability. The number of species present is referred to as species richness. Shannon-Wiener’s index \((H')\) of diversity is one of the most popular measures of general diversity. In the present study, the maximum Shannon-Wiener’s index \((H')\) value was reported at the Chauras site (1.175) followed by the Badshahithaul site (0.099) and the minimum diversity value was recorded at the Ranichauri site (-0.405), which indicates the stress of Parthenium is very high at lower altitude and decreasing towards higher altitude regions. The highest plant diversity was recorded for the Badshahithaul site (4.352) followed by for Chauras site (3.049) while the lowest diversity indices (3.044)were recorded for the Ranichauri site (Fig. 4). The species diversity of herbaceous plants varies greatly from place to place mainly due to variation in biogeography, habitat, intensity of disturbance and anthropological interruption in a particular region (Hubbell et al., 1999; Sagar et al., 2003).
### Table 5: Density, IVI, and Diversity related parameters of plants at Badshahithaul site.

| Species                        | Frequency % | Density (ind ha\(^{-1}\)) | TBC (cm\(^2\) ha\(^{-1}\)) | IVI     | Shannon-Wiener Diversity Index |
|--------------------------------|-------------|----------------------------|----------------------------|---------|--------------------------------|
| Achyrantus aspera              | 70          | 27000                      | 323.74                     | 12.64   | -0.266                        |
| Amaranthus viridis             | 50          | 31000                      | 1722.22                    | 11.80   | -0.290                        |
| Artimesea rouxburghiana        | 50          | 30000                      | 2009.34                    | 12.01   | -0.284                        |
| Bidens pilosa                  | 40          | 45000                      | 3140.48                    | 13.35   | -0.359                        |
| Conyza canadensis              | 50          | 52000                      | 3695.35                    | 16.02   | -0.387                        |
| Cynodon dactylon               | 60          | 38000                      | 1532.46                    | 13.66   | -0.327                        |
| Datura stamonium               | 30          | 30000                      | 3248.03                    | 10.60   | -0.284                        |
| Eupatorium adenophorum         | 50          | 143000                     | 11212.34                   | 33.19   | -0.531                        |
| Galinsoga parviflora           | 50          | 27000                      | 2003.12                    | 11.70   | -0.266                        |
| Malvestrum coromandelianum     | 70          | 32000                      | 1440.00                    | 14.33   | -0.296                        |
| Parthenium hysterophorus       | 50          | 417000                     | 49856.73                   | 102.07  | 0.099                          |
| Poa fendleriana                | 40          | 25000                      | 1742.22                    | 9.85    | -0.254                        |
| Rumex hastatus                 | 40          | 21000                      | 7373.56                    | 15.49   | -0.227                        |
| Setaria viridis                | 50          | 37000                      | 588.79                     | 11.18   | -0.322                        |
| Urtia dioica                   | 30          | 45000                      | 3266.12                    | 12.12   | -0.359                        |
|                                | 730         | 1000000                    | 93154.52                   | 300.00  | -4.352                        |

### Table 6: Density, IVI and Diversity related parameters of plants at Ranichauri site.

| Species                        | Frequency % | Density (ind ha\(^{-1}\)) | TBC (cm\(^2\) ha\(^{-1}\)) | IVI     | Shannon-Wiener Diversity Index |
|--------------------------------|-------------|----------------------------|----------------------------|---------|--------------------------------|
| Anaphalis busua                | 30          | 50000                      | 2560.00                    | 31.52   | -0.366                        |
| Cynoglossum glochidatun        | 60          | 7000                       | 46.45                      | 15.81   | -0.099                        |
| Cyperus rotundus               | 30          | 18000                      | 451.58                     | 13.43   | -0.195                        |
| Echinops cornigerus            | 50          | 18000                      | 1232.10                    | 22.04   | -0.195                        |
| Eriphonum comosomos            | 20          | 47000                      | 3045.60                    | 30.96   | -0.354                        |
| Eupatorium adenophorum         | 30          | 147000                     | 2561.07                    | 53.98   | -0.530                        |
| Gnaphalium sylvaticum          | 40          | 30000                      | 4056.00                    | 36.79   | -0.272                        |
| Leucas lanata                  | 30          | 14000                      | 740.89                     | 13.97   | -0.164                        |
| Origanum vulgare               | 20          | 10000                      | 512.00                     | 9.56    | -0.129                        |
| Parthenium hysterophorus       | 30          | 61000                      | 2624.36                    | 34.39   | -0.405                        |
| Primula dentatus               | 50          | 9000                       | 517.75                     | 16.33   | -0.119                        |
| Verbascum thapsus              | 40          | 21000                      | 1391.21                    | 21.21   | -0.216                        |
|                                | 430         | 432000                     | 19739.01                   | 300.00  | -3.044                        |
The invasive species has been well established in all ecological zones and habitats, the homogenization of weed species diminishing the population of many valuable native plant species and wildlife in Chamoli and Pauri Garhwal Himalaya (Bisht et al., 2012). The high propagule pressure and dispersal rates are the two most significant features that help an invasive species to establish itself. *P. hysterophorus* meets both the requirements (Eschtruth and Battles, 2009). By human activities, most alien plant species are moved out of their natural habitat and get established in other’s native areas and persist where they are cultivated or efflorescence in many habitats like disturbed land, uncultivated land, etc. These invasive species overcome many barriers to establishment and are tenacious and consolidated in the biota of the new region (Richardson and Van Wilgen, 2004). Nowadays *P. hysterophorus* has been successfully established from tropical to subtropical regions of the world (Kohli et al., 2006). Thus, the invasion of *P. hysterophorus* is relative more in Tehri Garhwal (Uttarakhand) of India, it may be due to an increase in transportation, infrastructural development sectors, development of all-weather roads, etc. The weed has reached almost every village and city. The present investigation showed that the infestation of *Parthenium* was recorded in subtropical to temperate regions in Tehri Garhwal Himalaya, Uttarakhand. The infestation of the weed decreased with increasing altitude and the presence of weed was not recorded above 2200 m asl. The abundance and frequency of *P. hysterophorus* were significantly more between foothills and surrounding areas. The infestation level is high from 370 to 1750 m asl and gradually decreases toward higher elevation. Therefore, this study will be very helpful in the management and conservation of the local plant biodiversity of this region.

**Fig. 4. Shannon-Wiener’s index (H) of diversity at different sites in the study area.**

**Recommendations:**

*P. hysterophorus* is alien weed which is spreading almost every part of the world including India. Its high level of infestation is hazardous for biodiversity of plant and animal and human health too. In Uttarakhand, the infestation of weed has increased due to more anthropogenic...
actives from low to high altitudes areas. Due to so many harmful impact of Parthenium, its control is important. People awareness programs and integrated weed management should be applied for the management of this noxious weed. The classical biocontrol agent Zygogramma bicolorata should also be reared and released on P. hysterophorus, which is significantly controlling the weed. The biocontrol programs are cost effective and environmentally safe.

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