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Population studies, habitat assessment and threat categorization of *Polygonatum verticillatum* (L.) Allioni in Kumaun Himalaya

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Natural populations of *Polygonatum verticillatum* in Kumaun Himalaya were surveyed for population studies, habitat assessment and threat status. This research reveals density of individuals and area occupied were low as compared to other species of the region, indicating habitat loss and heavy exploitation. Status was determined on a site-to-site basis for the entire Kumaun region. Based on species occurrence in selected areas, the species were identified as critically endangered to endangered in different areas. Frequency of *P. verticillatum* ranged between 50 and 80% at different population sites. Distribution of the species was between 50 and 80% indicating contiguous distributional range at most of the sites and random distributional range at Mukteshwer and Gagar. Density of *P. verticillatum* was highest (4.40 plant m^{-2}) in way to Kafani and lowest (2.60 plant m^{-2}) in Bhaman gupha. Total basal cover (TBC) was also found highest (0.91 cm^2 m^{-2}) in way to Kafani and lowest (0.35 cm^2 m^{-2}) in Bhaman gupha. Important value index (IVI) was found highest (51.68) in Munsyari and lowest (28.84) in Khati. Concentration of dominance (Cd) for the region showed a slight variation, with a range between 0.30 and 0.10. This may be attributed to the narrow range of distribution, habitat restriction and dominance of some species.

Key words: Population, habitat, threat, *Polygonatum verticillatum*.

INTRODUCTION

The Indian Himalayan region (IHR) is one of the most astonishing physical features on the surface of the earth. Among global mountain systems, the IHR is well known for its diverse landscapes and aesthetic, cultural and biological values (Samant and Dhar, 1997). This richness accompanied with uniqueness (endemism), sensitivity (rarity) and economic value make the biological resources of the region important from different perspectives (Dhar, 2002). The resources are used by inhabitants for various purposes such as fodder, fuel, timber, medicinal, wild edible, etc. (Samant and Dhar, 1997).

Out of 7000 endemic species of plants found in India, over 3000 grow in the Himalayan region (Chatterjee, 1980). In the last few decades, Himalayan ecosystems faced loss of forest lands due to increasing biotic pressure and exploitation for many valuable medicinal plants, which have been used for time immemorial. These plants have been mentioned in literature (Samant et al., 1997) and folk-lore, yet are no longer found in accessible habitats in large quantities. Many species have become rare in several tracts and are found only in

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inaccessible hilly areas, while a few others have been listed as endangered species.

Himalayan regions are considered as a primary source for collection of important medicinal plants. Several species including *Podophyllum hexandrum, Nardostachys jatamansi, Picrorhiza kurrooa, Aconitum* spp., *Saussurea ovallata, Saussurea lappa, Rheum* spp., *Polygonatum cirrhifolium, Polygonatum verticillatum* and *Angelica* spp. from the alpine areas are well known for their medicinal values. In India, 814 plant species have been identified as threatened; of these, over 113 taxa occur in the Indian Himalayas. Many of these medicinally important plant species are restricted to small pockets of habitat and their population size is decreasing at an alarming rate (Nayar and Shastry, 1987, 1988, 1990). Environmental degradation and loss of biodiversity as a result of excessive anthropogenic pressure, particularly in the fragile Himalaya have caused much concern among conservationists in the recent years (Kant, 1989; Saraswat and Thakur, 1998).

Kumaun region of Uttarakhand State lies between the latitudes of 28°-44' and 30°-49'N and longitudes of 78°-45' and 81°-5'E (Joshi et al., 1983) and is a hilly region containing a diverse physiographic, orographic and demographic mosaic. Its uniqueness supports rich biodiversity. A number of medicinal plant species have been reported from the Kumaun Himalaya which are facing a risk of extinction. *P. verticillatum* is one of these species. This species is widely used in traditional systems of medicine.

P. cirrhifolium (Wall) Royle belongs to the family Liliaceae, and commonly known as Mahameda (English name: Solomon's seal), and is a tall, erect, weak herb with stout, creeping rhizomes and a stem 60 to 120 cm high that is terete and grooved. Leaves occur in whorls of 3 to 6 and are linear to narrowly lanceolate, 6 to 15cm long, with margins enrolled, apex coiled and tendrils like. Flowers are white, tinged purple or green, in short stalked clusters of 2 to 4, and arise from the leaf axils. The perianth is 6-parted and somewhat reflexed (Gaur, 1999). It is found in rare, moist-shady localities of montane forests distributed in Himalaya, H.P. to Khasia hills (Gaur, 1999), specifically in temperate Himalayas at an altitude ranging between 2000 and 3000 m (Anonymous, 2006; Garg, 1996). It is an important ingredient of Astavarga (Singh, 2006); a medicine used for diseases of children, burning sensations, fever, jaundice, bleeding disorders, blood disorders and debility due to chest injuries (Anonymous, 1999, 2006). Leaves are eaten as vegetables; roots infused with milk are used as an aphrodisiac and blood purifier; and a paste is used in cuts and wounds (Gaur, 1999). It is also used in Jvara, Raktavikara, Ksaya, Daha, Raktapitta, Balaroga, Kamala, Ksata and Ksina (Anonymous, 2006). It is considered as a main constituent of 'Astavarga', a group of eight drugs, which forms an important base for a number of Ayurvedic preparations.

Keeping in mind the importance of *P. verticillatum,* this study attempted to determine population status, habitat assessment and threat categorization of this herb in the Kumaun region.

MATERIALS AND METHODS

Study area

The study was conducted in temperate regions of Kumaun. Five districts of Kumaun including Almora, Bageshwar, Champawat, Nainital and Pithoragarh were selected for population studies of the four herbs: *P. verticillatum, P. hexandrum, N. jatamansi* and *P. kurrooa* as these five districts cover temperate region of Kumaun. The study areas were surveyed extensively and a total 17 sites for *P. verticillatum* were identified on the basis of (a) habitat attributes (altitude/slope/aspect), (b) population size and (c) accessibility for data collection. A district-wide geographical description of each study area is given in Table 1.

Population studies, habitat assessment and threat categorization

In nature, *P. verticillatum* sprouts between April and May and reaches senescence by the end of October. Considering this, a phytosociological study was carried out in August-September after all species had attained maximum growth. For population studies, temperate regions of Kumaun were visited at regular intervals during three consecutive years (2007to 2010). Plots of 100 x 100 m were identified and marked on each region of *P. verticillatum*. Vegetation sampling was conducted through vertical belt transects (Michael, 1990). Since the distribution range is narrow and topography is very diverse, approximately 60 m long and 30 m wide transects were laid across each plot. Transects were divided into three stands of 20 x 10 m size as replicates and ten quadrats of 1 x 1 m size were laid randomly in each stand. Individuals of all species were counted in each quadrat. To determine status of the species, mean values of each quantitative parameter of three stands of transect were considered for further interpretation.

Data were analyzed for the population study as frequency (%F), density (D, plant m^{-2}), A/F ratio, relative frequency, relative density, relative dominance and total basal cover (TBC, cm^2m^{-2}) and calculated following Misra (1968):

$$\text{Frequency} = \frac{\text{Total number of quadrats in which species occurred}}{\text{Total number of quadrats studied}} \times 100$$

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

$$\text{Abundance} = \frac{\text{Total number of individuals of a species in all quadrats}}{\text{Total number of quadrats in which the species occurred}}$$

$$\text{A/F ratio} = \frac{\text{Abundance}}{\text{Frequency}}$$

Distribution pattern of the species was analyzed on the basis of abundance to frequency (A/F) ratio. Value of A/F < 0.025 was categorized as regular, between 0.026 to 0.050 as random and >

Table 1. Districts wise studied sites

S/N	District	Study site
	Almora	
1.	Located between 29° 36' North Latitude and 79° 30' East Longitude at an altitude of 1638 m sea level (msl).	Bhatkot, Vinayak, Balloni.
2.	**Bageshewar**	
	Located between 29°42'40" to 30°18'56" North Latitude and 79°23' to 80.9° East Longitude. The district lies at an altitude of 1646 msl.	Way to Sunderdhunga, Way to Kafni, Khati, Phurkia.
3.	**Champawat**	
	Located between 29°5'and 29°30' in Northern Latitude and 79°59' and 80°3'at the center of Eastern Longitude with an altitude of 1615 msl.	Vanasur, Debidhura, Khetikhan.
4.	**Nainital**	
	Located between29°23' North Latitude and 79°30' East Longitude at a height of 1939 msl.	Ramgarh, Mukteshwer, Gagar.
	Pithoragarh	
5.	Located between 29.4° to 30.3° North Latitude and 80° to 81° East Longitude at a height of 1645 msl.	Lilam, Thal, Munsyari, Bhaman gupha.

0.050 as contiguous types of distribution (Kershaw, 1973). Similarly, relative values of frequency, density and dominance were calculated following the methods of Misra (1968) and Kershaw (1973) as:

$$\text{Relative frequency} = \frac{\text{Percent frequency of species}}{\text{Total percent frequency of the community}} \times 100$$

$$\text{Relative density} = \frac{\text{Density of species}}{\text{Total density of the community}} \times 100$$

$$\text{Relative dominance} = \frac{\text{Total basal cover of species}}{\text{Total basal cover of the community}} \times 100$$

$$\text{Basal cover} = \frac{(\text{Cbh})^2}{4\pi}$$

Total Basal Cover (TBC) = Mean basal cover × Density

Importance Value Index (IVI) = relative frequency + relative density + relative dominance.

The concentration of dominance (CD) was computed by Simpson's Index (Simpson, 1949). For threat assessment, two criteria, that is, population estimation (density and number of mature individuals) and extent of occurrence (number of populations/plots) were used as per IUCN Red List Categories (IUCN, 1993). During the study, only flowering plants were considered as mature individuals and taken further for population estimation. Species having mature individuals <250 was considered as critically endangered, <2,500 as endangered and <10,000 as vulnerable. Similarly, species having a single population was categorized as critically endangered, <5 populations as endangered and <10 populations as vulnerable. Furthermore, status was assigned separately for each natural site as well as for the entire Kumaun region.

RESULTS

The frequency of *P. verticillatum* was found highest (80%) in Mukteshwer and Gagar and lowest (50%) in Khati and Bhaman gupha. Density was highest (4.40 plant m^{-2}) in way to Kafani and lowest (2.60 plant m^{-2}) in Bhaman gupha. Abundance was found highest (7.33) in way to Kafani and lowest (3.50) in Mukteshwer. Total basal cover (TBC) was highest (0.91 cm^2 m^{-2}) in way to Kafani and lowest (0.35 cm^2 m^{-2}) in Bhaman gupha. Important value index (IVI) was found highest (51.68) in Munsyari and lowest (28.84) in Khati. Concentration of dominance (Cd) was highest (0.30) in way to Sunderdhunga and lowest (0.10) in Mukteshwer and Gagar. Distribution pattern (R/F ratio) of the species was found contiguous in all sites except Mukteshwer and Gagar, where distribution was found to be random. As per IUCN Red List Categories, data on extent of occurrence (number of populations/plots) indicated critically endangered status of the species in most of the sites studied except Phurkia, Ramgarh and Mukteshwer, where its status was endangered. Population estimation (density and number of mature individuals) indicated critically endangered status for the species in all the sites studied, and overall status for Kumaun region was found to be vulnerable and endangered (Table 2).

Moist grassy slopes, under canopies of *Cedrus deodara*

Table 2. Population Status and Assignment of Threat Categories of *Polygonatum verticillatum* in Kumaun Himalaya

District	Sites	F	Rfr	D	Rden	A	A/F	TBC	Rdom	IVI	D	Distribution	No. of population	No. of mature individuals	Satatus
Almora	Bhatkot	70	10	2.8	10.98	4	0.06	0.41	10.59	31.57	0.12	Contiguous	1	28	CR*, CR**
	Vinayak	70	9.59	2.9	11.98	4.14	0.06	0.53	12.91	34.48	0.11	Contiguous	1	29	CR*, CR**
1638m asl															
N 29° 36'	Balloni	60	9.38	3.7	11.71	6.17	0.1	0.73	14.75	35.84	0.18	Contiguous	1	37	CR*, CR**
E79°30															
Bageshwer	Way to sunderdhunga	70	11.29	4	10.72	5.71	0.08	0.63	20.52	42.53	0.3	Contiguous	1	40	CR*, CR**
	Way to Kafni	60	9.52	4.4	12.61	7.33	0.12	0.91	21.4	43.54	0.2	Contiguous	1	44	CR*, CR**
1646 asl	Phurkia	60	10.34	4.1	14.09	6.83	0.11	0.58	17.44	41.88	0.21	Contiguous	2	41	EN*, CR**
N 29°42'40"	Khati	50	7.81	3.2	9.09	6.4	0.13	0.46	11.94	28.84	0.2	Contiguous	2	32	EN* CR**
E 79°23'															
Champawat	Vanasur	60	9.52	3.5	11.9	5.83	0.1	0.71	17.62	39.05	0.18	Contiguous	1	35	CR*, CR**
	Debidhura	70	10.77	3.9	13.36	5.57	0.08	0.5	20.36	44.48	0.22	Contiguous	1	39	CR*, CR**
1615 asl															
N 29°5'	Khetikhan	60	9.38	3	14.49	5	0.08	0.61	19.1	42.97	0.11	Contiguous	1	30	CR*, CR**
E 79°59'															
Nainital	Ramgarh	60	10	3	11.24	5	0.08	0.56	20.1	41.34	0.22	Contiguous	2	30	EN*, CR**
	Mukteshwer	80	8.7	2.8	8.89	3.5	0.04	0.58	14.17	31.75	0.1	Random	2	28	EN*, CR**
1939 asl															
N 29°23'	Gagar	80	11.27	2.9	12.24	3.63	0.05	0.55	10.17	33.68	0.1	Random	1	29	CR*, CR**
E 79°30'															
Pithoragarh	Lilam	70	10.14	3.7	17.79	5.29	0.08	0.62	22.82	50.75	0.12	Contiguous	1	37	CR*, CR**
	Thal	60	9.52	3.3	11.5	5.5	0.09	0.44	23.53	44.55	0.27	Contiguous	1	33	CR*, CR**
1645 asl	Munsyari	70	10.61	3.4	12.59	4.86	0.07	0.66	28.49	51.68	0.21	Contiguous	1	34	CR*, CR**
N 29.4°	Bhaman gupha	50	7.94	2.6	15.76	5.2	0.1	0.35	20.36	44.06	0.11	Contiguous	1	26	CR*, CR**
E 80°															
Overall status for Kumaun region															Vu*, EN**

*Based on extent of occurrence; **based on population estimation;

and *Quercus leucotrichophora* trees are the major habitats of *P. verticillatum.* In some places, it is also found under the canopies of *Myrica esculenta* and *Rhododendron arboreumn* with *Quercus leucotrichophora* and *Cedrus deodara.* Dominant associates of *P. verticillatum* at most sites were *Roscoea procera, Viola canesense, Thalictrum foliolosum, Rumex nepalensis* and *Oxalis corniculata.* Other dominant associates of the species were *Achyranthes bidentata, Paspalum scrobiculatum, Valariana wallichii* and *Polygonum* sp. The main threats to the species in most of the sites were habitat degradation, medicinal harvest, human interference and over-exploitation. Other potential threats to the species include trade and grazing (Table 3). District wise phytographs of IVI, relative frequency, relative density and relative dominance of all four species are given in Figure 1.

DISCUSSION

Population studies

Over exploitation and habitat degradation have been causing decreases in the population of *P. verticillatum*. Research reveals that some of the medicinal plants of high therapeutic value are endangered and require protection. In general, endangered and rare species generally show low levels of morphological variations, so it is important to determine population polymorphism at the biochemical and genetic levels to study these variations and develop appropriate conservation strategies.

It is indeed fascinating that two third of the world's population depend upon plant resources for their primary health care needs and a fairly large number of modern drugs have been derived from plant natural products, with many following leads provided by indigenous knowledge system. This has added to the popularity of herbal products as part of new health programs in developed countries, and combined with the traditional demand of third world nations has led to a steady increase in the market for medicinal plants worldwide.

Biodiversity conservation is a global issue, and special attention is being given to the conservation of endangered and threatened species. Most conservation programmes in India started on animal systems, however recently endangered plant species have received considerable attention. The importance of Himalayan medicinal species of endangered or threatened status and an urgent need for their conservation has recently been emphasized by many workers (Khoshoo, 1993; Bhadula et al., 1996).

Frequency of *P. verticillatum* ranged between 50 and 80% at different population sites. Distribution of the species was between 50 and 80% indicating contiguous distributional range at most of the sites and random distributional range at Mukteshwer and Gagar. Density of *P. verticillatum* was maximum (4.40 plant m^{-2}) in way to Kafani and minimum (2.60 plant m^{-2}) in Bhaman gupha. Total basal cover (TBC) was also found maximum (0.91 cm^2 m^{-2}) in way to Kafani and minimum (0.35 cm^2 m^{-2}) in Bhaman gupha. Important value index (IVI) was found maximum (51.68) in Munsyari and minimum (28.84) at Khati population. Concentration of dominance (Cd) of the region showed a slight variation. It ranged between 0.30 and 0.10. This may be attributed to narrow range of distribution, habitat restriction and dominance of some species.

Low density and relatively low dominance of the species in the present study may be due to specific microhabitat requirements of the species and over exploitation for illegal trade, etc. These factors are responsible for restricted distribution fragmented habitat and low populations of all species.

Low population density across the surveyed populations indicates poor availability of the species in the study area. However, random distribution and higher frequency of occurrence is indicative that the species have potential for better performance in these sites (habitats).

It is observed that the whole plant is used for medicinal properties (Murkherjee, 1953; Kirtikar and Basu, 1984) therefore individuals are uprooted indiscriminately. It is reported that harvesting of the whole plant is more destructive than the harvesting of fruits, seeds or leaves in isolation (Sheldon et al., 1997). Furthermore, the removal of the entire plant before seed maturation ceases the possibilities of development of future regeneration (Sheldon et al., 1997).

Threat categorization

The status of *P. verticillatum* was found critically endangered and endangered in all the sites studied (Figure 2). The principal reason for species endangerment in Himalayan medicinal plants is human interference in natural ecosystems, resulting in habitat destruction and a loss of other natural and biological factors. The use of wild plant resources and subsequent ecosystem alteration often leads to habitat fragmentation. Species susceptible to slack habitats are more fragile and have more difficulty in sustaining populations (especially small and narrowly distributed ones) and consequently this often leads to species endangerment. Habitat loss and degradation have been identified as the major factors, threatening 91% of plant species globally (IUCN, 2000). In the 2000 IUCN Red List, India is ranked sixth for having the highest number of threatened plant species.

An area-specific threat categorization of species is very important for short- or long-term management planning. Various studies have been carried out to explore and identify the threatened plants of IHR (Pangtey and Samant, 1988; Samant et al., 1993, 1996a, b, 1998a, b, 2000a; Pandey and Well, 1997; Kala et al., 1998).

Table 3. Site characteristics of selected sites of *P. verticillatum*.

District		Altitude (m)	Habitat	Dominant species	Threat
Almora	Bhatkot	2950	Grassy slope with *Quercus leucotrichophora* A. Camus *and Myrica esculenta* Buch-Ham.	*Achyranthes bidentata* Blume, *Roscoea procera* Wall., *Oxalis corniculata* Linn., *Thalictrum foliolosum* D.C.	Habitat degradation, harvested for medicine
	Vinayak	2285	Moist gentle slope with *Quercus leucotrichophora* A. Camus and *Myrica esculenta* Buch- Ham.	*Arisaema speciosum* (Wall.)Mart., *Achyranthes bidentata* Blume, *Thalictrum foliolosum* D.C., *Rumex nepalensis* Spreng.	Habitat degradation, over exploitation
	Balloni	4000	Moist shady place with *Acer, Quercus leucotrichophora* A. Camus and *Cedrus deodara* Roxb. ex D.Don.	*Roscoea procera* Wall., *Oxalis corniculata* Linn., *Polygonum nepalense* Meisn., *Paspalum scrobiculatum* Linn.	Habitat degradation
Bageshwar	Way to Sunderdhunga	3350	Shady moist grassy slope	*Oxalis corniculata* Linn., *Thalictrum foliolosum* D.C., *Paspalum scrobiculatum* Linn., *Roscoea procera* Wall.,	Habitat degradation, over exploitation
	Way to Kafni	3900	Shady moist grassy slope	*Achyranthes bidentata* Blume, *Polygonum nepalense* Meisn., *Roscoea procera* Wall., *Paspalum scrobiculatum* Linn.	Over exploitation
	Phurkia	3300	Moist shady slope with *Quercus leucotrichophora* A. Camus and *Rhododendron arboretum*	*Rumex nepalensis* Spreng., *Oxalis corniculata* Linn., *Arisaema speciosum* (Wall.) Mart., *Achyranthes bidentata* Blume	Human interference
	Khati	2300	Grassy slopes with *Quercus leucotrichophora* A. Camus	*Thalictrum foliolosum* DC., *Achyranthes bidentata* Blume, *Polygonum nepalense* Meisn., *Oxalis corniculata* Linn.	Habitat degradation
Champawat	Vanasur	1920	Grassy slope with *Cedrus deodara* Roxb. ex D.Don.	*Roscoea procera* Wall., *Arisaema speciosum* (Wall.) Mart., *Oxalis corniculata* Linn., *Achyranthes bidentata* Blume	Habitat degradation
	Debidhura	1800	Grassy slope with *Quercus leucotrichophora* A. Camus and *Cedrus deodara* Roxb. ex D.Don.	*Paspalum scrobiculatum* Linn., *Roscoea procera* Wall., *Arisaema speciosum* (Wall.) Mart., *Oxalis corniculata* Linn.,	Habitat degradation
	Khetikhan	1850	Gentle grassy slope with *Quercus leucotrichophora* A. Camus*, Myrica esculenta* Buch- Ham. and *Rhododendron arboretum*	*Viola canescens* Wall., *Galingsoga parviflora* Cav., *Asparagus curillus*, *Thalictrum foliolosum* D.C.	Human interference, Habitat degradation
Nainital	Ramgarh	2040	Grassy, shady place with *Cedrus deodara* Roxb. ex D.Don.	*Roscoea procera* Wall., *Achyranthes bidentata* Blume, *Polygonum nepalense*, *Oxalis corniculata* Linn.	Over exploitation, harvested for medicine
	Mukteshwer	2180	Grassy, shady place with *Cedrus deodara* Roxb. ex D.Don.	*Oxalis corniculata* Linn., *Rumex nepalensis* Spreng., *Paspalum scrobiculatum* Linn., *Cynodon dactylon* (Linn.)Pers.	Human interference

Table 3. Contd

Pithoragarh	Gagar	2100	Moist grassy slope with *Quercus leucotrichophora* A. Camus and *Cedrus deodara* Roxb. ex D.Don.	*Thalictrum foliolosum* D.C., *Polygonum nepalense* Meisn., *Oxalis corniculata* Linn., *Rumex nepalensis* Spreng.,	Human interference, Habitat degradation
	Lilam	1850	Moist, shady place with *Quercus leucotrichophora* A. Camus and *Cedrus deodara Roxb. ex D.Don.*	*Viola canesense* Wall., *Achyranthes bidentata* Blume, *Thalictrum foliolosum* D.C., *Polygonum nepalense* Meisn.	Over exploitation
	Thal	3150	Shady moist slope with *Quercus leucotrichophora* A. Camus	*Achyranthes bidentata Blume*, *Thalictrum foliolosum* D.C., *Paspalum scrobiculatum* Linn., *Oxalis corniculata* Linn.	Habitat degradation
	Munsyari	2150	Moist grassy slope with *Quercus leucotrichophora* A. Camus and *Cedrus deodara* Roxb. ex D.Don.	*Viola canesense* Wall., *Thalictrum foliolosum* D.C., *Rubia cordifolia* Linn., *Oxalis corniculata* Linn.	Harvested for medicine, trade
	Bhaman gupha	3000	Moist grassy slope with *Quercus leucotrichophora* A. Camus and *Cedrus deodara* Roxb. ex D.Don.	*Valeriana wallichii* D.C., *Geum alatum* Wall., *Viola canesense* Wall., *Achyranthes bidentata* Blume	Habitat degradation

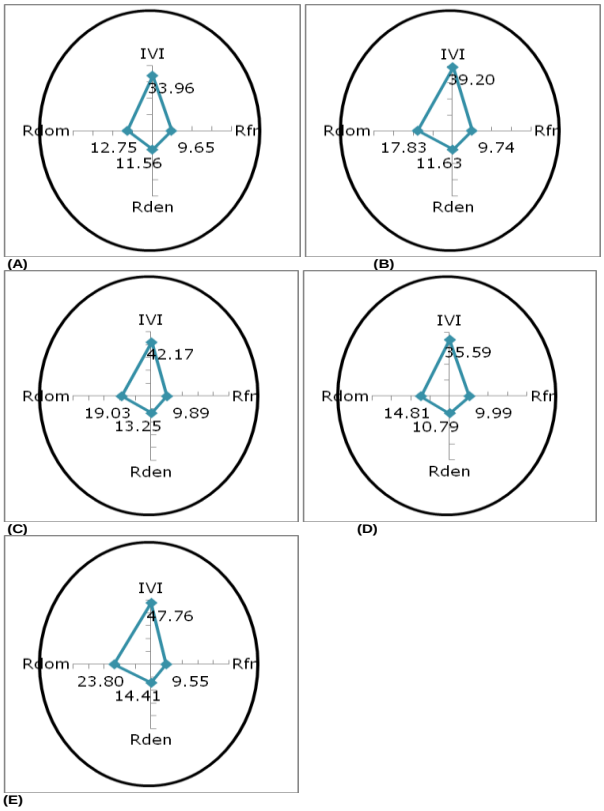

Figure 1. Phytograph of *P. verticillatum* in five districts of Kumaun (A) Almora (B) Bageshwar (C) Champawat (D) Nainital and (E) Pithoragar.

Figure 2. *P. verticillatum* in natural habitat.

Conclusions

If over-exploitation and habitat degradation of *P. verticillatum* continues, it may disappear from these areas within a few years. The patchy occurrence of critically endangered, endangered and vulnerable medicinal plants indicates that high anthropogenic pressure, over-exploitation, habitat degradation, habitat fragmentation and lack of awareness among inhabitants are the main causes of declining population of the species.

Population assessment of the species using standard ecological methods and recognition of key areas as medicinal plants conservation areas (MPCAs) for *in situ* conservation, including involvement of the Forest Department and tribal communities are suggested. Mass reproduction using conventional (vegetative and seeds) methods, establishment and maintenance of herbal gardens and medicinal plant nurseries for *ex situ* conservation, ensuring the availability of quality planting material for cultivation, and education and awareness programs for large-scale cultivation are also suggested.

The data from this study concerning population status, habitat preferences, and threat categorization for *P. verticillatum* may assist in understanding the ecology of the species and can be used in the development of a conservation plan. The study also recommends the collection of plant material in the senescence phase, which ultimately leads to sustainable utilization of the species

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