POPULATION ASSESSMENT AND DISTRIBUTION OF *POLYGONATUM CIRRHIFOLIUM* (WALL.) ROYLE AND *POLYGONATUM VERTICILLATUM* (L.) ALL. IN HIMACHAL HIMALAYAS, INDIA

SINGH, J.* – KUMAR, K. – SINGH, J. – KUMAR, R. – SHARMA, S.

ICFRE-Himalayan Forest Research Institute, Panthaghati 171013, Shimla, Himachal Pradesh, India

***Corresponding author**
e-mail: jaggy1964@gmail.com

(Received 28th Nov 2022; accepted 18th May 2023)

Abstract. *Polygonatum cirrhifolium* (Wall.) Royle and *Polygonatum verticillatum* (L.) All. are important medicinal herbs of the 'Ashtavarga group' of medicinal plants and belongs to the family Asparagaceae. The populations of these species are declining in the natural habitat due to various anthropogenic factors; hence, it is important to know existing status of the species for devising conservation and management plan. Keeping that in view, study was conducted in different geographical locations of Himachal Pradesh during June-September 2019. Nine sites falling in four districts for *P. cirrhifolium* and 23 sites falling in five districts for *P. verticillatum* were selected to assess their population status by quadrat method using random sampling and following vertical belt transects approach. The population of the *P. cirrhifolium* was recorded maximum at Kulang site ($Dm^{-2} = 7.27 \pm 10.91$, F = 23.33%), and lowest at Shakoli ($Dm^{-2} = 0.43 \pm 0.82$, F = 13.33%). The value of abundance ranged from 2.89 (Batseri) to 14.25 (Nichar). IVI was found maximum at Kulang (61.72) and the lowest at Shakoli (9.16) site. Whereas population of *P. verticillatum* was recorded maximum at Hatu ($Dm^{-2} = 8.33 \pm 3.43$, F = 60%), and lowest at Paneta Khud ($Dm^{-2} = 0.73 \pm 1.24$, F = 20.0%). The value of abundance ranged from 3.62 (Kothi) to 13.89 (Hatu). Frequency was found maximum at Baghi (66.67%) and lowest at Paneta Khud (20.0%). The Shannon diversity index and IVI was found maximum at Jamathu (0.36 and 91.02) and lowest at Paneta Khad (0.18 and 19.81). Both species were distributed in small populations with low density and frequency and were found geographically isolated.
Keywords: *conservation, demand, distribution, over-exploitation, population status*

Introduction

India is one of the twelve mega-biodiversity countries of the world, having rich vegetation with a wide variety of plants with medicinal value. The Indian subcontinent represents one of the greatest emporia of traditional medicines in the world. Even today, indigenous people living in high mountains and remote rural areas depend upon traditional medicines for treating different ailments (Singh et al., 2012). India is known for its rich reserves of plant wealth having more than 17,500 wild plant species, including 4,000 species having therapeutic properties (Sharma et al., 1997). Since ancient times medicinal plants have been the choices of medicine for health care due to their low cost, little/no side effects, and easy availability (Jain and Mudgal, 1999). Even today, 80% of the world's population relies on traditional plant medicines, as also in India by various rural and tribal communities through Indian systems of medicines and other undocumented traditional practices (Mashelkar, 2002; Khan et al., 2004; Uniyal, 2006). The flora of Himachal Pradesh revealed that there are approximately 3500 species of higher plants. Out of these about 1,500 species are reported to be of medicinal value (Chauhan, 1999). Numerous studies have been conducted on the use of medicinal plants in the north-western Himalayan region in general and the state of Himachal Pradesh in particular. From an ethnomedicinal point of view, past research work includes Uniyal and

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2104_33493362

Chauhan, 1973; Gaur and Singh, 1995; Lal et al., 1996; Chauhan, 1999; Badola and Pal, 2002; Sharma and Lal, 2005; Samant et al., 2007; Singh et al., 2008; Parkash and Aggarwal, 2010; Balkrishna et al., 2012; Singh et al., 2018a; Singh et al., 2018b; Singh et al., 2019, 2021. Moreover, some of the ethnomedicinal explorations in the Kullu District of Himachal Pradesh were carried out by various researchers (Singh, 1999; Singh and Rawat, 2000; Sharma et al., 2005; Negi and Subramani, 2006; Boktapa and Sharma, 2010; Rana and Samant, 2011; Sharma and Samant, 2014).

Genus *Polygonatum* belongs to the Asparagaceae family, which consists of 71 species of which 37 species have been reported to have therapeutic properties, owing to its wide array of health benefits the species of this genus has been used traditionally in Indian Ayurveda and Chinese Medicine system (Zhao et al., 2018). Two species of *Polygonatum* are included in Ashtaverga group of medicinal plants i.e. Mahameda (*Polygonatum cirrhifolium* (Wall.) Royle and Meda (*Polygonatum verticillatum* (L.) All.. Besides these, Kakoli (*Roscoea purpurea* Smith), KsiraKakoli (*Lilium polyphyllum* D. Don), Jivika (*Crepidium acuminatum* (D. Wear) Szlach), Rsabhaka (*Malaxis muscifera* (Lindl) Kuntze), Riddhi (*Habenaria intermedia* D. Wear), Vrddhi (*Habenaria edgeworthii* Hook.f. ex Collett) are also form part of Ashtavarga group of medicinal plants.

Polygonatum herbs are reported to be rich sources of diosgenin, steroidal saponins, polysaccharides, homoiso-flavanones, etc. (Liu et al., 2011; Khan et al., 2013; Wang et al., 2019; Upadhyay et al., 2018; Zhao et al., 2018; Pang et al., 2020).

P. cirrhifolium (Wall) Royle commonly known as Mahameda and is a tall, erect, delicate geophytic herb with sturdy, creeping rhizomes. The species is 60 to 120 cm in height with terete and grooved stem. Leaves occur in whorls of 3 to 6. Tendrils-like leaves are having linear to narrowly lanceolate shape and range from 6 to 15 cm long, with margins enrolled, apex coiled which is considered the main distinguishing feature between Meda and Mahameda plants. 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). The abundance of reports of *Polygonatum verticillatum* are existing on ethnobotanical uses (Wujisguleng et al., 2012; Nautiyal and Nautiyal, 2004), population assessment (Bhattt et al., 2014; Lohani et al., 2013); chemical constituent analysis (Suyal et al., 2019, 2021; Patra and Singh, 2018; Saboon et al., 2016); antioxidant activity and anti-cancerous activity (Suyal et al., 2019; Patra and Singh, 2018). A few reports are existing on ethnobotanical uses (Wujisguleng et al., 2012; Negi and Chauhan, 2009; Nautiyal and Nautiyal, 2004), population diversity and distribution (Suyal et al., 2020), propagation protocols (Latoo et al., 2005) and pharmacological activity (Xu et al., 2017) of *P. cirrhifolium.*

Polygonatum verticillatum commonly known as Meda is a tall, erect, rhizomatous geophytic herb found in the Himalayas up to 4000 m asl. The species is 80-150 cm in height with an angled or grooved stem. The shoot of the species comprises 1–2 scaly leaves and 4-8 whorls of green leaves. The leaves are linear or narrowly lanceolate. The fruits of *P. verticillatum* are known as berries which are globose, green when unripe, and purple–black on ripening. The above-ground shoot produced from the terminal bud dies after one growing season and leaves behind a distinct scar and the rhizome segment stretches from one scar to the next (Tybjerg and Vestergaard, 1992). The flowers of the species are hermaphrodite and pollinated by bees (Kramp et al., 2009). The flowering and fruiting period for the species is from May–October (Lohani et al., 2013). The rhizome of the plant has medicinal properties and is used in the treatment of pain, fever, burning sensation, and pulmonary tuberculosis (Amrit, 2006). It is also used as a

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2104_33493362

diuretic, and considered to remove painful urine (Ballabh et al., 2008). Other ethnobotanical uses of the plant include as an emollient, aphrodisiac, anti-inflammatory, vitiated condition of Vata and Pitta, appetizer and tonic, galactagogue (increases milk release), body weakness (Ghayur, 2004) analgesic (Khan et al., 2010). Due to the presence of phenolic compounds, it is shown to possess antioxidant, anti-inflammatory, and anticancer activities (Patra and Singh, 2018). It is also used as a substitute of *Polygonatum cirrhifolium* (Parveen et al., 2004).

The rhizome of both species is used as an ingredient for '*Chyavanprash*' and other formulations of Ayurveda. The curative property of the *P. verticillatum* and *P. cirrhifolium* is credited to their active constituents like saponins, phenol, alkaloids, phytohormones, flavonoids, antioxidants, lysine, serine, aspartic acid, diosgenin, b-sitosterol (Sagar, 2014), maleamic acid (Virk et al., 2017) etc. According to local and unofficial reports, a huge amount of plant rhizome is collected annually from the Himalayan area due to species demand in the domestic and global market and hence, depleted the species germplasm. Due to high market demand, unscientific management, destructive harvesting, and lack of cultivation practices both species are diminishing in their wild habitat. Due to a lack of literature regarding the status of these two species in Himachal Pradesh the study was undertaken to access the population of these important medicinal herbs in their natural habitat (*Fig. 1*).

(a) (b)

Figure 1. *(a) Plant of Polygonatum cirrhifolium and (b) Polygonatum verticillatum*

Materials and methods

Study area

The State of Himachal Pradesh (30°22′40″- 33°12′40″ N to 75°45′55″- 79°04′20″ E) includes parts of the Trans and Northwest Himalaya and covers 55,673 km^2: which is

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2104_33493362

9% of the IHR (Indian Himalayan Region). Like other states of the IHR, Himachal Pradesh has a representative, natural and socio-economically important biodiversity. It has a large altitudinal range (200–7109 m), with diverse habitats, species, populations, communities, and ecosystems. During the study, extensive surveys were conducted to assess the population status of *P. cirrhifolium* and *P. verticillatum* in different altitudinal zones in Himachal Pradesh. The study was conducted in 9 sites for *P. cirrhifolium* and 23 sites for *P. verticillatum* in different locations in forests and wildlife divisions of Himachal Pradesh during June-September 2019 as described in *Tables 1* and *2*.

Table 1. *Details of sites studied for population assessment of Polygonatum cirrhifolium in H.P.*

Sr. No.	Site name	Beat	Block	Range	Division	Distt.	Latitude (N)	Longitude (E)	Alt. (m)	Aspect
1.	Batseri	Batseri	Sangla	Kilba	Kinnaur	Kinnaur	31°20’28.9”	78°26’22.3”	3715	SW
2.	Cheog	Cheog	Cheog	Theog	Theog	Shimla	31°14’15.2”	77°17’45.3”	2205	E
3.	Janni	Tapri	Urni	Kalpa	Kinnaur	Kinnaur	31°31’06.5”	78°04’05.3”	2057	SW
4.	Kharogla	Sangla	Sangla	Kilba	Kinnaur	Kinnaur	31°20’44.4”	78°26’14.2”	3577	NE
5.	Kulang	Kulang	Pulga	Kasol	Parvati	Kullu	32°17’55.2”	77°11’10.1”	2249	NW
6.	Kulthach	Chhitkul	Sangla	Sangla	WL Sarahan	Kinnaur	31°20’31.6”	78°26’09.6”	3527	E
7.	Nichar	Nichar	Nichar	Nichar	Kinnaur	Kinnaur	31°55’81.5”	77°94’67.3”	2156	NE
8.	Shakoli	Kwaring	Bhaga	Kelang	Lahaul	Lahaul	32°47’19.1”	76°43’05.1”	2938	NW
9.	Tosh	Tosh	Tosh	Kasol	Parvati	Kullu	32°00’22.6”	77°26’59.7”	2400	S

Table 2. *Details of sites studied for population assessment of P. verticillatum in H.P.*

Sr. No.	Site	Beat	Block	Range	Division	Distt	Latitude (N)	Longitude (E)	Alt. (m)	Aspect
1	Baghi	Kalbog	Goach	Kotkhai	Theog	Shimla	31°15’15.2”	77°31’24.5”	2720	SW
2	Batseri	Batseri	Sangla	Kilba	Kinnaur	Kinnaur	31°20’28.9”	78°26’22.3”	3715	NW
3	Chaka-Kanda	Kalpa	Kalpa	Kalpa	Kinnaur	Kinnaur	31°32’31.6”	78°13’58.7”	3460	E
4	Churdhar	Bhairog	Pulwahal	Naura dhar	WL Shimla	Shimla	30°52’14.3”	77°28’51.9”	3530	SE
5	Dharwad	Bhandal	Shaghain	Bhandal	WL hamba	Chamba	32°45’36.7”	75°56’24.0”	2761	S
6	Hatu	Hatu	Narkanda	Kotgarh	Kotgard	Shimla	31°15’07.9”	77°29’18.2”	2851	NE
7	Hispa Bo	Chhitkul	Sangla	Sangla	WL Sarahan	Kinnaur	31°20’31.6”	78°26’09.6”	3527	E
8	Hurang	Hallan	Naggar	Naggar	Kullu	Kullu	32°04’35.5”	77°03’35.4”	3037	NW
9	Jamathu	Bhandal	Shaghain	Bhandal	Wl Chamba	Chamba	32°49’10.7”	75°56’53.3”	2981	SW
10	Jogni Dhar	Deo Thach	Thachi	Thachi	Nachan	Mandi	31°37’52.2”	77°13’51.4”	2900	N
11	Kalaban	Dodra	Kwar	Dodra-kwar	Rohru	Shimla	31°12’16.0”	77°46’03.4”	3190	SE
12	Kathnag	Bhandal	Shaghain	Bhandal	Chamba	Chamba	32°26’41.4”	76°16’45.1”	2830	NW
13	Khidki	Pawas	Jiknipul	Chopal	Chopal	Shimla	30°58’57.6”	77°31’53.4”	2981	SW
14	Kothi	Palchan	Kothi	Manali	Kullu	Kullu	32°19’28.1”	77°11’38.4”	2570	E
15	Kulta	Tosh	Tosh	Kasol	Parvati	Kullu	32°00’58.0”	77°25’58.8”	3053	SE
16	Mural-danda	Jarashayi	Berhali	Berhali	Rampur	Shimla	31°18’02.2”	77°43’26.9”	3020	E
17	Paneta Khud	Thunag	Janjheli	Seraj	Nachan	Mandi	31°29’57.1”	77°14’13.4”	2238	NW
18	Parashar	Kamand	Kataula	Kataula	Mandi	Mandi	31°45’11.4”	77°05’09.5”	2850	NW
19	Ranikot	Bhandal	Shaghain	Bhandal	Chamba	Chamba	32°51’57.1”	76°11’20.6”	2812	SW
20	Sangla-Kanda	Sangla	Sangla	Kilba	Kinnaur	Kinnaur	31°24’18.5”	78°14’26.6”	3271	NE
21	Telang	Tosh	Tosh	Kasol	Parvati	Kullu	31°58’34.5”	77°00’32.5”	2051	SW
22	Thathi Dhar	Bhandal	Shaghain	Bhandal	WL Chamba	Chamba	32°48’36.8”	75°57’07.9”	2775	SE
23	Tosh	Tosh	Tosh	Kasol	Parvati	Kullu	32°00’22.6”	77°26’59.7”	2400	S

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2104_33493362

Methodology

Population assessment of two targeted species was done in its natural zone of distribution at different location in Himachal Pradesh. Extensive surveys were conducted to select the sites in their zone of occurrence throughout the different geographical locations of Himachal Pradesh for carrying out population assessment of the targeted species. Transect walks were conducted along the important routes, throughout the targeted area to assess the density, frequency and abundance of these species in each site of the study area. This covered all slopes, aspects and altitudes. In addition, personal observations were made in the field to note any pertinent events, which helped to have a better understanding of the presence and the relative abundance based on the ecological characteristics of the species that were absent, rare, very rare, occasional, frequent, and dominant. The site details such as location name, beat, block, forest range, forest division, and district were also noted. Geo-coordinates of sites such as altitude (m), aspect, longitude and latitude were also recorded.

Selection, sampling, and population estimation

Vegetation sampling was conducted through vertical belt transects. Pockets of 100×100 m^2 were identified and marked on each region of targeted species. Approximately, a transect of 60×30 m^2 long was laid in each pocket. Transects were divided into three stands of 20 x 10 m^2 size as replicates and ten quadrats of 1.0×1.0 m^2 were laid randomly in each stand. Numbers of individuals of target species and other herb species were counted in each quadrat. The mean values of each quantitative parameter of three stands of transect were considered for further interpretation for determining the status of the species. Data were analyzed for frequency (% F), density (D, plant m^{-2}), abundance, A/F ratio, IVI following (Misra, 1968) and Shannon Wiener diversity index (H') (Shannon and Wiener, 1963).

GIS map of the occurrence sites

GIS map of the sites was prepared by using ARC-GIS (Arc Map-10.8) software. The locations were plotted against Digital Elevation Map (DEM). The data for DEM was downloaded from worldclim 2.1 website (https://www.worldclim.org/data/worldclim21.html) for 30 s and clipped for the study area (*Fig. 2*).

Data analysis and interpretation

Data was analyzed following standard methods and formulas. The data on target medicinal plants gathered was transferred to an electronic template using MS Excel spreadsheet. Data on the population status of medicinal plants in a particular site has been shown in terms of density (Plant/m^{-2}), Frequency (%), Abundance, A/F ratio and Coefficient of variance (CV) which are calculated as follows (Misra, 1968).

$$\textbf{Density (D)} = \frac{\text{Total numbers of Individuals (of a given species) in all plots}}{\text{Total numbers of plots sampled x area of plot}}$$

$$\textbf{Relative Density} = \frac{\text{Number of individuals of a species}}{\text{Number of Individuals of all species}} * 100$$

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2104_33493362

$$\textbf{Frequency}\ (\%) = \frac{\text{Total numbers of Individuals (of a given species)in all plots}}{\text{Total numbers of plots (quadrats)sampled}} * 100$$

$$\textbf{Relative Frequency} = \frac{\text{Frequency of a species}}{\text{Frequency of all species}} * 100$$

$$\textbf{Abundance}\ (\mathbf{A}) = \frac{\text{Total numbers of Individuals (of a given species) in all plots}}{\text{Total numbers of plots in which species occurred}}$$

$$\textbf{\textit{Relative}\ Abundance} = \frac{\text{Basal Area of a species}}{\text{Basal Ara of allthe species}} * 100$$

IVI = Relative Frequency + Relative Density + Relative Dominance

A/F ratio: The ratio of abundance to frequency is a relative measure of the degree of contiguousness of the distribution of any species because the same density may be the product of high frequency and low abundance or low frequency and high abundance or of intermediate values of both (Whitford, 1949). A higher A/F ratio at one place of any species than at other place denotes more contiguous distribution of that species. If the difference in the values of same species at different locations is small then conclusion can be inferred that the species has very general distribution (Whithford, 1949; Curtis and McIntosh, 1950). If, A/F ratio is less than 0.025 then it shows regular distribution pattern and if it varies from 0.025 to 0.05 then pattern is considered as random. More than 0.05 values show contiguous distribution.

$$\textbf{Coefficient of variation}\ (\mathbf{CV}) = = \frac{\text{Standard Deviations}}{\text{Mean}}$$

CV: It is the ratio of the standard deviation to the mean. The higher the CV, the greater the levels of dispersion around mean. It is a useful statistic for comparing the degree of variations from one data series to another, even if means are drastically different from one another. It is used to know the consistency of the data; by consistency, we mean the uniformity in the values of the data/distribution from the arithmetic mean of the data/distribution.

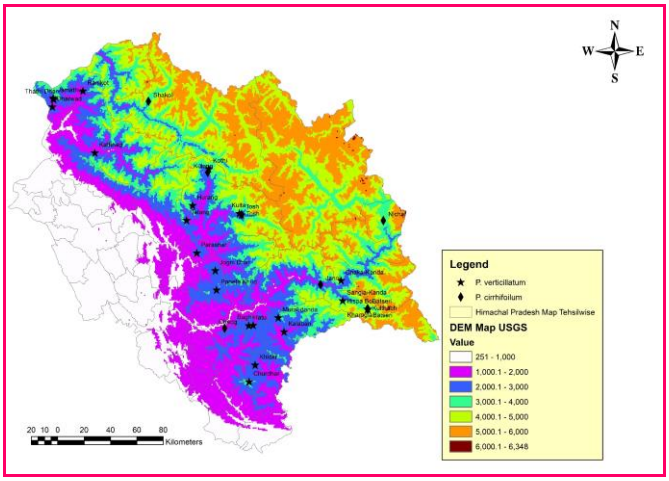

Figure 2. *GIS map of the location of occurrence of P. cirrhifolium and P. verticillatum in Himachal Pradesh plotted over DEM*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2104_33493362

Results

During the present study populations of *P. cirrhifolium* at nine locations and *P. verticillatum* at 23 locations in Himachal Pradesh were assessed. The density, frequency, and abundance of the species were recorded in each study site. There is no clear-cut distributional range of mutual exclusiveness of either of the species. Both *P. cirrhifolium* and *P. verticillatum* were found to be distributed from 2051 to 3715 m asl. During the field visits, it was observed that there were few patches of *P. cirrhifolium*, which was less as compared to *P. verticillatum*. The population of the *P. cirrhifolium* was recorded maximum at Kulang site ($Dm^{-2} = 7.27 \pm 10.91$ SD, F = 23.33%) while the lowest was reported in Shakoli ($Dm^{-2} = 0.43 \pm 0.82$ SD, F = 13.33%). The value of abundance ranged from 2.89 (Batseri) to 14.25 (Nichar). Shannon-Weiner diversity index was found maximum in the case of Kulang (0.33) while the lowest was found in Shakoli (0.11). The IVI was found maximum in the Kulang population (61.72) while the lowest was found in Shakoli (9.16; *Table 3*).

Table 3. *The population status of Polygonatum cirrhifolium at different sites in H.P.*

Sr. No.	Site	Abundance	Density (no./m^2)	Frequency (%)	A/F	CV	H'	Total number of herb species at each site	IVI	Dominant associate species in terms of density
1.	Batseri	2.89	0.87 ± 0.99	30.00	0.10	1.15	0.18	16	20.02	*Galium aparine* (9.00), *Polygonatum verticillatum* (5.86), *Geranium pratens* (2.73), *Salvia nubicola* (3.86), *Delphinium elatum* (3.13)
2.	Cheog	3.50	1.40 ± 0.86	40.00	0.09	0.62	0.22	8	26.84	*Fragaria vesca* (3.43), *Trifolium repens* (3.33), *Erigeron* (3.23), *Geranium pratense* (2.77), *Cirsium vulgare* (2.20), *Plantago ovata* (1.80)
3.	Janni	5.42	2.17 ± 3.66	40.00	0.14	1.69	0.23	15	29.85	*Oxalis corniculata* (2.47), *Trifolium repens* (1.87), *Viola serpens* (1.87), *Fragaria vesca* (1.67), *Origanum vulgare* (1.67)
4.	Kharogla	7.14	1.67 ± 3.71	23.33	0.31	2.23	0.26	13	36.91	*Geranium pratens* (2.23), *Polygonatum cirrhifolium* (1.67), *Delphinium elatum* (1.43), *Fragaria vesca* (1.20), *Salvia nemorosa* (1.00), *Viola serpens* (1.00)
5.	Kulang	3.4	7.27 ± 10.91	23.33	1.33	3.62	0.33	9	61.72	*Polygonatum verticillatum* (10.40), *Fragaria vesca* (2.10), *Bergenia Ciliata* (1.20), *Geranium pratens* (1.20), *Cirsium vulgare* (1.13)
6.	Kulthach	11.40	5.70 ± 8.54	50.00	0.23	1.50	0.24	22	33.04	*Delphinium elatum* (3.53), *Centella asiatica* (3.37), *Galium elegans* (3.20), *Polygonatum Verticillatum* (2.77), *Anaphalis triplinervis* (1.93)
7.	Nichar	14.25	5.70 ± 3.49	40.00	0.36	0.61	0.30	16	49.43	*Galium aparine* (4.67), *Trifolium repens* (3.23), *Fragaria vesca* (1.90), *Geranium pratens* (1.83), *Chenopodium album* (1.77)
8.	Shakoli	3.25	0.43 ± 0.82	13.33	0.24	1.91	0.11	8	9.16	*Fragaria vesca* (4.73), *Geranium pratens* (4.10), *Trifolium repens* (3.60), *Anemone racemose* (3.17), *Taraxcum officinale* (2.27), *Plantago ovata* (2.07)
9.	Tosh	7.62	3.30 ± 2.37	43.33	0.18	0.72	0.28	12	42.48	*Viola serpens* (3.03), *Polygonatum verticillatum* (2.67), *Fragaria vesca* (2.63), *Rumex nepalense* (2.40), *Plantago ovata* (1.93)

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2104_33493362

In the case of *P. verticillatum* the population was recorded maximum at Hatu population (Dm^{-2} = 8.33 ± 3.43 SD, F = 60%) and while the lowest was found at Paneta Khud (Dm^{-2} = 0.73 ± 1.24 SD, F = 20.0%). The value of abundance ranged from 3.62 (Kothi) to 13.89 (Hatu). Frequency was found to be maximum in the case of Baghi (66.67%) while the lowest frequency was found in Paneta Khud (20.0%). The Shannon diversity index and IVI was found maximum in the Jamathu population (0.36 and 91.02) while the lowest was found in Paneta Khad (0.18 and 19.81; *Table 4*).

Besides, different associate herb species were recorded at the studied sites. A total number of associated species in *P. cirrhifolium* site was 21 at Kulthach: 15 at Batseri; 15 at Nichar; 14 at Janni; 12 at Kharogla; 11 at Tosh; 10 at Kulang; 7 at Shakoli and 7 at Cheog While in the case of *P. verticillatum* sites, the number of associated species was 19 at Hispa Bo; 17 at Hatu; 15 at Baghi; 15 at Batseri; 14 at Chaka-kanda; 14 at Hurang; 14 at Telang; 11 at Tosh; 10 at Paneta Khud; 10 at Sangla-Kanda; 9 at Dharwad; 9 at Kathnag; 9 at Kulta; 9 at Mural-danda; 9 at Ranikot; 8 at Kothi; 7 at Churdhar; 7 at Khidki; 7 at Kalaban; 6 at Jognidhar; 6 at Thathidhar 5 at Jamathu and 4 at Parashar (*Tables 3* and *4*).

Table 4. *The population status of Polygonatum verticillatum at different sites in H.P.*

Sr. No.	Site	Abundance	Density (no./m^2)	Frequency (%)	A/F	CV	H'	Total number of herb species at each site	IVI	Dominant associate species in terms of density
1.	Baghi	12.00	8.00 ± 0.04	66.67	0.18	0.99	0.33	16	62.09	*Fragaria vesca* (5.63), *Geranium pratens* (4.03), *Viola serpens* (2.10), *Potentilla reptens* (1.73), *Valeriana jatamansi* (1.70)
2.	Batseri	5.86	1.37 ± 2.80	23.34	0.25	2.05	0.20	16	22.78	*Galium aparine* (3.00), *Geranium pratens* (1.00), *Salvia nubicola* (0.90), *Polygonatum cirrhifolium* (0.87), *Delphinium elatum* (0.83)
3.	Chaka-kanda	4.92	1.97 ± 0.03	40.00	0.12	0.87	0.31	15	52.54	*Geranium pratens* (1.00), *Napeta Racemosa* (0.27), *Bistorta affinis* (0.23), *Podophyllum hexandrum* (0.23), *Rhodiola rosea* (0.23)
4.	Churdhar	6.92	2.77 ± 0.03	40.00	0.17	1.13	0.31	8	53.41	*Fragaria vesca* (4.50), *Potentilla reptens* (1.73), *Bergenia ciliate* (1.30), *Salvia nubicola* (1.07), *Adiantum capillus* (0.73)
5.	Dharwad	9.46	3.70 ± 3.29	43.34	0.22	0.89	0.31	10	53.71	*Viola serpens* (4.63), *Bergenia Ciliata* (2.23), *Valeriana jatamansi* (1.80), *Thalictrum foliolosum* (1.23), *Salvia nubicola* (0.57)
6.	Hatu	13.89	8.33 ± 3.43	60.00	0.23	0.41	0.31	18	53.67	*Fragaria vesca* (6.97), *Selinum vaginatum* (3.80), *Valeriana jatamansi* (3.03), *Ainsliaea aptera* (1.80), *Potentilla arenaria* (1.70)
7.	Hispa Bo	7.00	3.50 ± 3.20	50.00	0.14	0.92	0.21	20	24.60	*Geranium pratens* (4.50), *Fragaria vesca* (4.27), *Anaphalis triplinervis* (2.07), *Polygonum tomentosum* (1.37), *Podophyllum hexandrum* (0.30)
8.	Hurang	7.53	3.70 ± 3.39	50.00	0.15	0.92	0.20	15	24.53	*Geranium nepalense* (5.07), *Oxalis corniculata* (4.67), *Galium aparine* (3.90), *Trifolium repens* (3.77), *Viola serpens* (3.47)
9.	Jamathu	10.15	4.40 ± 0.09	43.34	0.23	0.84	0.36	6	91.02	*Viola serpens* (3.43), *Valeriana jatamansi* (2.23), *Salvia nubicola* (1.13), *Podophyllum hexandrum* (0.33), *Trillium govanianum* (0.33)

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2104_33493362

10.	Jognidhar	6.88	1.83 ± 3.13	26.67	0.26	1.83	0.30	7	51.45	*Adiantum capillus* (0.37), *Podophyllum hexandrum* (0.30), *Fragaria vesca* (3.77), *Potentilla reptens* (1.67), *Salvia nubicola* (0.83)
11.	Kalaban	5.75	3.07 ± 2.61	53.34	0.11	0.85	0.27	8	40.03	*Fragaria vesca* (4.27), *Cirsium vulgare* (3.77), *Geranium pratens* (3.53), *Trifolium repens* (3.30), *Valeriana jatamansi* (2.60)
12.	Kathnag	7.78	4.67 ± 3.66	60.00	0.13	0.77	0.32	10	61.01	*Fragaria vesca* (4.17), *Bergenia ciliata* (2.23), *Valeriana jatamansi* (1.80), *Delphinium elatum* (1.23), *Rumex nepalense* (1.23)
13.	Khidki	6.86	3.20 ± 2.99	46.67	0.15	0.94	0.32	8	60.37	*Viola serpens* (2.00), *Rumex nepalense* (1.33), *Salvia nubicola* (1.20), *Potentilla reptens* (1.10), *Duranta repens* (0.57)
14.	Kothi	3.62	1.57 ± 1.64	43.34	0.08	1.05	0.27	9	39.87	*Viola serpens* (2.17), *Geranium pratens* (1.60), *Delphinium elatum* (1.43), *Fragaria vesca* (1.13), *Valeriana jatamansi* (0.93)
15.	Kulta	8.31	4.43 ± 3.93	53.34	0.16	0.89	0.33	10	62.07	*Viola serpens* (5.13), *Plantago ovata* (3.25), *Ainsliaea aptera* (2.33), *Chenopodium album* (2.17), *Podophyllum hexandrum* (1.44)
16.	Mural-danda	6.50	2.20 ± 2.10	33.34	0.20	0.96	0.23	10	30.20	*Centella asiatica* (2.53), *Polygonum fagopyrum* (2.13), *Anemone racemosa* (2.03), *Valeriana jatamansi* (2.00), *Ajuga bracteosa* (0.53)
17.	Paneta Khud	3.67	0.73 ± 1.24	20.00	0.18	1.70	0.18	11	19.81	*Geranium pratens* (1.80), *Potentilla reptens* (1.33), *Trifolium repens* (1.30), *Adiantum capillus* (0.93), *Fragaria vesca* (0.90)
18.	Parashar	7.23	3.13 ± 2.29	43.34	0.17	0.73	0.36	5	86.52	*Fragaria vesca* (2.70), *Valeriana jatamansi* (1.27), *Viola serpens* (1.23), *Podophyllum hexandrum* (0.37)
19.	Ranikot	9.25	3.70 ± 3.29	40.00	0.23	0.89	0.31	10	53.81	*Viola serpens* (4.63), *Bergenia ciliata* (2.23), *Valeriana jatamansi* (1.80), *Thalictrum foliolosum* (1.23), *Salvia nubicola* (0.57)
20.	Sangla-Kanda	6.40	3.30 ± 2.49	50.00	0.13	0.78	0.28	11	43.68	*Fragaria vesca* (4.27), *Geranium spp.* (2.90), *Galium aparine* (2.80), *Bergenia stracheyi* (1.77), *Polygonum tomentosum* (1.30)
21.	Telang	9.25	3.70 ± 3.39	40.00	0.23	0.92	0.20	15	24.53	*Geranium nepalense* (5.07), *Oxalis corniculata* (4.67), *Galium aparine* (3.90), *Trifolium repens* (3.77), *Viola serpens* (3.47)
22.	Thathidhar	8.91	3.27 ± 3.26	36.67	0.24	1.0	0.35	7	75.25	*Viola serpens* (2.53), *Salvia nubicola* (1.33), *Valeriana jatamansi* (1.20), *Adiantum capillus* (0.77), *Trillium govanianum* (0.53)
23.	Tosh	5.33	2.67 ± 2.91	50.00	0.11	1.09	0.26	12	38.39	*Polygonatum cirrhifolium* (3.30), *Viola serpens* (3.03), *Fragaria vesca* (2.63), *Rumex nepalense* (2.40), *Plantago major* (1.93)

Discussion

Polygonatum i.e. *P. cirrhifolium* and *P. verticillatum* are economically important and are used to cure various ailments by the local people. Owing to the demand from the herbal industry, the plants are vulnerable in their natural habitat. In many ayurvedic formulations, *P. verticillatum* is used as a substitute for *P. cirrhifolium* (Parveen et al., 2004). A few authors have worked on the population assessment of *P. cirrhifolium.* The present study has been carried out with exhaustive details of the current population status along with dominant associate species, which will help in devising effective management plans for protection and conservation in their natural zone of occurrence. During the present study, 9 sites were assessed for population status for *P. cirrihifolium*, while, population status of *P. verticillatum* was assessed at 23 sites in different parts of Himachal Pradesh. The study showed variation in the diversity of *P. cirrhifolium* and *P.*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2104_33493362

verticillatum in studied sites; however, this variation was less. The variation in the values of frequency in different parts of their zone of occurrence can be attributed to various factors *viz.*, habitat fragmentation, over-exploitation and other human interferences, site-specific habitat requirement and anthropogenic pressure (Suyal et al., 2020). The population of *P. cirrihifolium* was very scarce and this species was found in lesser regions as compared to *P. verticillatum* indicating that *P. cirrihifolium* is more vulnerable in Himachal Himalaya and needs immediate attention for its protection and conservation. The results of the present study are more or less in conformity with earlier studies in other parts of habitat of the both the species. Bhatt et al. (2014) reported that in the Kumaun region of Uttarakhand the density of *P. cirrihifolium* ranged from 0.63 to 1.90 ind/m^2 with the abundance value ranging from 1.12 to 3.20 and frequency value ranging from 50% to 76% and the author also reported similar observations for the species in Garhwal region of Uttarakhand. In the Kumaun region of Uttarakhand, the value of density ranged from 1.20 to 6.33 ind/m^2 with the frequency value ranging from 45% to 70% in the nine selected sites (Suyal et al., 2020). In the present study also the population of the *P. cirrhifolium* was recorded maximum at Kulang site (Dm^{-2} = 7.27 ± 10.91, F = 23.33%) with an abundance of 3.4 while the lowest was reported in Shakoli (Dm^{-2} = 0.43 ± 0.82, F = 13.33%). IVI was found maximum in Kulang population (61.72) and the lowest was found in Shakoli (9.16) population. It may be due to heavy biotic pressure, and unsustainable harvesting methods, consequently, the population of *P. cirrihifolium* is diminishing; hence there is an urgent need to develop its mass propagation and *ex-situ* cultivation method.

The study by Bhatt et al., 2014 found that in Kumaun region of Uttarakhand the low-value density of *P. verticillatum* ranged from 1.20 to 1.63 ind/m^2 with the abundance value ranging from 1.81 to 2.72 and frequency ranging from 50 to 70%. Lohani et al. (2013) in Kumaun region also reported low density (2.60 to 4.40 ind./m^2) of the *P. verticillatum.* Suyal et al. (2021) reported highest genetic diversity and Shannon information index in *Polygonatum verticillatum* populations growing above 2900 m asl, however, lower Genetic diversity Shannon information index was observed at lower altitude ranging from 1900 to 2400 m asl. In present study the population of *P. verticillatum* was recorded maximum at Hatu population (Dm^{-2} = 8.33 ± 3.43, F = 60%) with an abundance of 13.89 and while the lowest was found at Paneta Khud (Dm^{-2} = 0.73 ± 1.24, F = 20.0%) with abundance value of 3.67.

Both species are distributed in small populations having low density and frequency and are geographically isolated. The lesser population of both the species is also probably due to habitat degradation, unscientific and over exploitation of these species from their natural habitats. In Indian Himalayan region, reports of continuous decline of medicinal plants have been reported and this has been attributed to over-exploitation of these important species and habitat degradation (Sharma and Kala, 2018). Due to the vulnerability of the species in their natural habitat, there is an urgent need to create awareness among people about the conservation of these medicinal plants both *in-situ* and *ex-situ* so that further decline in population of these species can be stopped.

Conclusions

The present study carried out in different parts of Himachal Pradesh showed that the populations of both the species of *P. cirrhifolium* and *P. verticillatum* were found in small pockets with a low value of density, frequency and abundance in their natural

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2104_33493362

zones of occurrence. Unscientific harvesting, anthropogenic pressure, increased demands in the herbal industry and illegal extraction from their natural habitat have posed a serious threat to the existence of these medicinal plant species. There is an urgent need to develop the agrotechnology of these species and people should be encouraged to grow these medicinal plants on their agricultural land and they should also be involved in protection and conservation of these medicinal plant species in natural zone of occurrence of the species and benefits should be provided to them. This will ease the pressure on their natural habitat and will also augment the income of rural people. Medicinal Plants Conservation Areas (MPCAs) need to be identified for *in-situ* conservation of the species. Sustainable utilization and effective conservation practices are needed to protect these species. The finding of the present study will surely help in devising management plans for *in-situ* and *ex-situ* conservation for both of these medicinal plants.

Acknowledgments. The authors are thankful to Himachal Pradesh Council for Science Technology and Environment for providing financial assistance to carry out the study. The authors also extend gratitude to the field staff of the Himachal Pradesh State Forest Department and all field guides engaged during the study for helping us in identifying the locations of the species in forest areas.

REFERENCES

[1] Amrit, P. S. (2006): Ashtavarga - rare medicinal plants. – Ethnobotanical Leaflets 10: 104-108.
[2] Badola, H. K., Pal, M. (2002): Endangered medicinal plants in Himachal Pradesh. – Current Science 83(7): 797-798.
[3] Balkrishna, A., Srivastava, A., Mishra, R. K., Patel, S. P., Vashistha, R. K., Singh, A., Jadon, V., Saxena, P. (2012): Astavarga plants-threatened medicinal herbs of the North-West Himalaya. – International Journal of Medicinal and Aromatic Plants 2(4): 661-676.
[4] Ballabh, B., Chaurasia, O. P., Ahmed, Z., Singh, S. B. (2008): Traditional medicinal plants of cold desert Ladakh, used against kidney and urinary disorders. – Journal of Ethnopharmacology 118: 331-339.
[5] Bhatt, D., Kumar, R., Tewari, L. M., Joshi, G. C. (2014): *Polygonatum cirrhifolium* Royle and *Polygonatum verticillatum* (L.) Allioni: status assessment and medicinal uses in Uttarakhand, India. – Journal of Medicinal Plants Research 8(5): 253-259.
[6] Boktapa, N. R., Sharma, A. K. (2010): Wild medicinal plants used by local communities of Manali, Himachal Pradesh, India. – Ethnobotanical Leaflets 14: 259-267.
[7] Chauhan, N. S. (1999): Medicinal and Aromatic Plants of Himachal Pradesh. – Indus Publishing, New Delhi.
[8] Curtis, J. T., Mcintosh, R. P. (1950). The interrelations of certain analytic and synthetic phytosociological characters. – Ecology 31(3): 434-455.
[9] Gaur, R. D. (1999): Flora of District Garhwal North West Himalaya. – Transmedia Publishing, Srinagar Garhwal. P 715.
[10] Gaur, R. D., Singh, P. B. (1995): Ethno-medicinal plants of Mandi district, Himachal Pradesh. – B.M.E.B.R. 14(1): 1-11.
[11] Ghayur, A. (2004): Database on Medicinal Plants. – CUTS Centre for International Trade, Economics and Environment, Calcutta.
[12] Jain, S. K., Mudgal, V. (1999): A Hand Book of Ethnobotany. – Bishan Singh Mahendra Pal Singh, Dehra Dun.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2104_33493362

[13] Khan, H., Saeed, M., Khan, M. A., Dar, A., Khan, I. (2010): The antinociceptive activity of *Polygonatum verticillatum* rhizomes in pain models. – Journal of Ethnopharmacology 127(2): 521-527.
[14] Khan, H., Saeed, M., Mehmood, M. H., Rehman, N. U., Muhammad, N., Haq, I. U., Ashraf, N. E. l., Tahir, K. E. H., Gilani, A. H. (2013): Studies on tracheorelaxant and anti-inflammatory activities of rhizomes of *Polygonatum verticillatum*. – BMC Complementary and Alternative Medicine 13(1): 1-8.
[15] Khan, Z. S., Khuroo, A. A., Dar, G. H. (2004): Ethnomedicinal survey of Uri, Kashmir Himalaya. – Indian Journal of Traditional Knowledge 3(4): 351.
[16] Kramp, K., Huck, S., Niketić, M., Tomović, G., Schmitt, T. (2009): Multiple glacial refugia and complex postglacial range shifts of the obligatory woodland plant Polygonatum verticillatum (Convallariaceae). – Plant Biology 11(3): 392-404.
[17] Lal, B., Vats, S. K., Singh, R. D., Gupta, A. K. (1996): Plant Used as Ethnomedicine and Supplementary Food by Gaddis of Himachal Pradesh, India. – In: Jain, S. K. (ed.) Ethnobiology in Human Welfare. Deep Publications, New Delhi.
[18] Lattoo, S. K., Khan, S., Dhar, A. K. (2005): A new chromosome number in Polygonatum cirrhifolium Royle–an endangered liliaceous medicinal herb. – Current Science *89*(7): 1080-1081.
[19] Liu, X. X., Wan, Z. J., Shi, L., Lu, X. X. (2011): Preparation and antiherpetic activities of chemical modified polysaccharides from *Polygonatum cyrtonema* Hua. – Carbohydrate Polymer 83: 737-742.
[20] Lohani, N., Tewari, L. M., Kumar, R., Joshi, G. C., Chandra, J., Kshore, K., Kumar, S., Upreti, B. M. (2013): Population studies, habitat assessment and threat categorization of Polygonatum verticillatum (L.) Allioni in Kumaun Himalaya. – Journal of Ecology and the Natural Environment 5(5): 74-82.
[21] Mashelkar, R. A. (2002): Protecting India's traditional knowledge. – Employment News 26(50): 1.
[22] Misra, R. (1968): Ecology Work Book. – Oxford and IBM Publishing Co. Calcutta.
[23] Nautiyal, M. C., Nautiyal, B. P. (2004): Agrotechniques of High Altitude Medicinal and Aromatic Plants. – Bishen Singh Mahendra Pal Singh, Dehradun.
[24] Negi, P. S., Subramani, S. P. (2006): Ethnobotanical study in the Naggar area of Kullu Valley, Himachal Pradesh. – Journal of Economic and Taxonomic Botany 30(2): 349-358.
[25] Negi, V. M., Chauhan, N. S. (2009): Medicinal and aromatic plants wealth of a tribal district Kinnaur in Himachal Himalayas. – Indian Forester 135(6): 838-852.
[26] Pang, X., Zhao, J. Y., Wang, Y. J., Zheng, W., Zhang, J., Chen, X. J., Cen, S., Yu, L. Y., Ma, B. P. (2020): Steroidal glycosides, homoisoflavanones and cinnamic acid derivatives from *Polygonatum odoratum* and their inhibitory effects against influenza A virus. – Fitoterapia 146: 1-7.
[27] Parkash, V., Aggarwal, A. (2010) Traditional uses of ethnomedicinal plants of lower foot-hills of Himachal Pradesh. – Indian Journal of Traditional Knowledge 9(3): 519-521.
[28] Parveen, K. S., Chauhan, N. S., Brij, L. (2004): Observations on the traditional phytotherapy among the inhabitants of Parvati valley in Western Himalaya. – Indian Journal of Ethnopharmacology 92l: 167-176.
[29] Patra, A., Singh, S. K. (2018): Evaluation of phenolic composition, antioxidant, anti-inflammatory and anticancer activities of *Polygonatum verticillatum* (L.). – Journal of Integrative Medicine 16(4): 273-282.
[30] Rana, M. S., Samant, S. S. (2011): Diversity, Indigenous uses and conservation status of medicinal plants in Manali Wildlife Sanctuary, Northwestern Himalaya. – Indian Journal of Traditional Knowledge 10(3): 439-459.
[31] Saboon, B. Y., Arshad, M., Sabir, S., Amjad, M. S., Ahmed, E., Chaudhari, S. K. (2016): Pharmacology and biochemistry of *Polygonatum verticillatum*: a review. – Journal of Coastal Life Medicine 4(5): 406-415.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2104_33493362

[32] Sagar, P. K. (2014): Adulteration and substitution in endangered, ASU herbal medicinal plants of India, their legal status, scientific screening of active phytochemical constituents. – International Journal of Pharmaceutical Sciences and Research *5*(9): 4023.
[33] Samant, S. S., Pant, S., Singh, M., Lal, M., Singh, A., Sharma, A., Bhandari, S. (2007): Medicinal plants in Himachal Pradesh, North Western Himalaya, India. – International Journal of Biodiversity Science, Ecosystem Services & Management 3: 234-251.
[34] Shannon, C. E., Wiener, W. (1963). The Mathematical Theory of Communities. – University of Illinois Press, Urbana.
[35] Sharma, J. R., Mudgal, V., Hajra, P. K. (1997): Floristic Diversity - Review, Scope and Perspectives. – Mudgal, V., Hajra, P. K. (eds.) Floristic Diversity and Conservation Strategies in India. BSI, Calcutta, pp. 1: 1-45.
[36] Sharma, N., Kala, C. P. (2018). Patterns in distribution, population density and uses of medicinal plants along the altitudinal gradient in Dhauladhar mountain range of Indian Himalayas. – Current Science 114(11): 2323-2328.
[37] Sharma, P., Samant, S. S. (2014): Diversity, distribution and indigenous uses of medicinal plants in Parbati Valley of Kullu district in Himachal Pradesh, Northwestern Himalaya. – Asian Journal of Advanced Basic Sciences 2(1): 77-98.
[38] Sharma, P. K., Lal, B. (2005): Ethnobotanical notes on some medicinal and aromatic plants of Himachal Pradesh. – Indian Journal of Traditional Knowledge 4(4): 424-428.
[39] Singh, J., Rajasekaran, A. and Sharma, K. D. (2008): Traditional ethnobotanical knowledge of Kiran Pargana, Shimla district, Himachal Pradesh. – Journal of Economic and Taxonomic Botany 32(Suppl.): 253-263.
[40] Singh, J., Singh, J., Kumar, N., Jishtu, V., Sharma, S., Dhupper, R. (2018a): Ethno-medicinal plants used by indigenous people of Kanda range, Chopal forest division, Himachal Pradesh. – World Journal of Pharmacy and Pharmaceutical Sciences (1): 697-710.
[41] Singh, J., Singh., J, Jawala, P. (2021): Population assessment and distribution of *Trillium govanianum* Wall. ex D. Don in the inner Himalayas of Himachal Pradesh, India. – Medicinal Plants-International Journal of Phytomedicines and Related Industries 13(3): 467-471.
[42] Singh, J., Singh, J., Sharma, D. (2018b): Traditional wisdom to treat the most common ailments in Chopal region of Shimla district, Himachal Pradesh, India. – Plant Archives 18(2): 2759-2769.
[43] Singh, J., Singh, J., Sharma, S., Dhupper, R., Nagar, R. D. (2019): Ethnobotanical uses of medicinal and aromatic plants of Chopal forest division of Himachal Pradesh. – Medicinal Plants 11(3): 265-278.
[44] Singh, K. N., Lal, B., Todaria, N. P. (2012): Ethnobotany of Higher Plants in Spiti Cold Desert of Western Himalaya. – Nature and Science 10(5): 7-14.
[45] Singh, S. K. (1999): Ethnobotanical study of useful plants of Kullu district in Northwestern Himalaya, India. – Journal of Economic and Taxonomic Botany 23(1): 185-198.
[46] Singh, S. K., Rawat, G. S. (2000): Flora of Great Himalayan National Park, Himachal Pradesh. – Bishen Pal Mahendra Pal Singh, Dehradun.
[47] Suyal, R., Rawat, S., Rawal, R. S., Bhatt, I. D. (2019): Variability in morphology, phytochemicals, and antioxidants in *Polygonatum verticillatum* (L.) All. populations under different altitudes and habitat conditions in Western Himalaya, India. – Environmental Monitoring and Assessment 191(3): 1-18.
[48] Suyal, R., Bhatt, D., Rawal, R. S., Tewari, L. M. (2020). Status of two threatened Astavarga herbs, Polygonatum cirrhifolium and Malaxis muscifera, in west Himalaya: conservation implications. – Proceedings of the National Academy of Sciences, India Section B: Biological Sciences 90(3): 695-704.
[49] Suyal, R., Jugran, A. K., Rawal, R. S., Bhatt, I. D. (2021): Morphological, phytochemical and genetic diversity of threatened *Polygonatum verticillatum* (L.) All. populations of

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2104_33493362

different altitudes and habitat types in Himalayan region. – Physiology and Molecular Biology of Plants 27(8): 1795-1809.

[50] Tybjerg, H., Vestergaard, P. (1992): Growth dynamics in the rhizomatous herb *Polygonatum verticillatum*. – Oikos 65: 395-408.

[51] Uniyal, M. R., Chauhan, N. S. (1973): Traditionally important medicinal plants of Kangra valley in Dharmshala Forest Circle, H.P. – Journal of Research & Education in Indian Medicine 8(1): 76-85.

[52] Uniyal, S. K., Singh, K. N., Jamwal, P., Lal, B. (2006). Traditional use of medicinal plants among the tribal communities of Chhota Bhangal, Western Himalaya. – Journal of Ethnobiology and Ethnomedicine 2: 1-8.

[53] Upadhyay, S., Jeena, G. S., Shikha, Shukla, R. K. (2018): Recent advances in steroidal saponins biosynthesis and in vitro production. – Planta 248: 519-544.

[54] Virk, J. K., Bansal, P., Gupta, V., Kumar, S., Singh, R., Rawal, R. K. (2017): First report of isolation of maleamic acid from natural source *Polygonatum cirrhifolium*—A potential chemical marker for identification. – Journal of Liquid Chromatography & Related Technologies 40(20): 1031-1036.

[55] Wang, W., Dabu, X., He, J., Yang, H., Yang, S., Chen, J., Fan, W., Zhang, G., Cai, J., Ai, H., Hai, M. (2019): Polygonatone H, a new homoisoflavanone with cytotoxicity from *Polygonatum cyrtonema* Hua. – Natural Product Research 33: 1727-1733.

[56] Whitford, P. B. (1949). Distribution of woodland plants in relation to succession and clonal growth. – Ecology 30(2): 199-208.

[57] Wujisguleng, W., Liu, Y. and Long, C. (2012): Ethnobotanical review of food uses of *Polygonatum* (Convallariaceae) in China. – Acta Societatis Botanicorum Poloniae 81: 239-244.

[58] Xu, Y., Lin, W., Ye, S., Wang, H., Wang, T., Su, Y., Cai, J. (2017): Protective effects of an ancient chinese kidney-tonifying formula against H_2O_2-Induced oxidative damage to MES23. 5 cells. – Parkinson's Disease. https://doi.org/10.1155/2017/2879495.

[59] Zhao, P., Zhao, C., Li, X., Gao, Q., Huang, L., Xiao, P., Gao, W. (2018): The genus Polygonatum: A review of ethnopharmacology, phytochemistry and pharmacology – Journal of Ethnopharmacology 214: 274-291.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2104_33493362