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Systematic Study of Pteridophytes in Relation to Edaphic Factors from the Ghat Region of Pithoragarh, A Part of The Proposed Pancheshwar Dam in Uttarakhand

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Abstract : Pteridophytes are among the earliest terrestrial vascular cryptogams that instead of seeds, proliferate by the dispersion of their spores. Study of systematics includes classification, taxonomy and nomenclature. The Pancheshwar hydropower dam is being built on the Mahakali River at Pancheshwar near the confluence of the Mahakali and the Saryu River, which was the sampling site. To determine the diversity, soil nature, and established relationships between them were the main objectives. The classification and identification of the flora were done by the available literature while soil samples were analyzed in the District Agriculture Department Soil Testing Laboratory and statistical analysis by different softwares. At the species diversity point, there were seven families, 11 genera, and 19 species of pteridophytes recorded in the study area. The frequency, density, abundance, and distribution of each species were calculated, revealing significant variation. Various diversity indexes like dominance (D), Simpson index (1-D), Shannon index (H), evenness (e^H/S), and Margalef species richness were calculated, all of these indicated good diversity in the area. The physical properties of soil (water holding capacity, sand, slit, and clay) and chemical properties (nitrogen, phosphorus, potassium, organic carbon content, and pH) when statistically analysed for regression, correlation and ANOVA, showed that these factors were suitable for growth of plants.

Keywords: Pteridophytes • Himalayan flora • Soil analysis • Ecology • Biodiversity

Introduction

Pteridophytes are among the earliest terrestrial plant groupings in the world, occupying an intermediate position between the lower cryptogams and the higher vascular plants. Pteridophytes are primary terrestrial vascular cryptogams that instead of seeds, proliferate by dispersion of their spores and hence are placed into the group called treacheophyta. Most pteridophytes are homosphorous and also show successful heterospory. After flowering plants (Angiosperms), pteridophytes are the most diversified category of plants. The systematists gather and study a wide range of plants, classify them according to patterns of variation, name the species, and provide the world with diagnostic descriptions (Grytnes and Vetaas 2002), they also assist environmentalists in identifying species that comprise our biota, some of which are threatened by human activity (Thapa, 2002).

Pancheshwar hydropower dam (PHD) is being built on the Mahakali River at Pancheshwar village, about 2.5 kilometres downstream, near the confluence of the Mahakali and the Saryu River (Figure 1). The reservoir is projected to be located between latitudes 29° 7'30'N and 29° 48'N and longitudes 79° 55'E and 80° 35'E. The proposed dam has a total catchment area of approximately 12,276 km^2 that extend to two countries: Nepal (nearly 4,456 km^2) and India (an area of 9,720 km^2).The alpine area of the central Himalaya was chosen for this study primarily to determine the distribution pattern and richness of ferns and fern-allies. The main objectives of the study were to study the species diversity of the area, to analyse various soil physiochemical parameters of the soil, and to establish any relation between species and edaphic factors.

Khullar (2000) observed the fern flora from a taxonomic standpoint in the Western Himalaya. (2001) Verma and Selvan (2001) made a checklist of the ferns of Kalka and Kasauli hills in the North-West Himalaya. Pande and Pande (2002) worked on the pteridology in the Western

Himalayas, especially the Kumaun region. An excellent piece of illustrated work on fern diversity, of Kumaun Himalaya and Pteridology of the Western Himalaya with special preferences in taxonomy, was done by Pande and Pande (2002 and 2003). Pande (2004) contributed good literature on the census of Kumaun ferns (North-Western Himalaya) along with pteridophytic floristic diversity in Corbett Tiger Reserve, Uttaranchal.

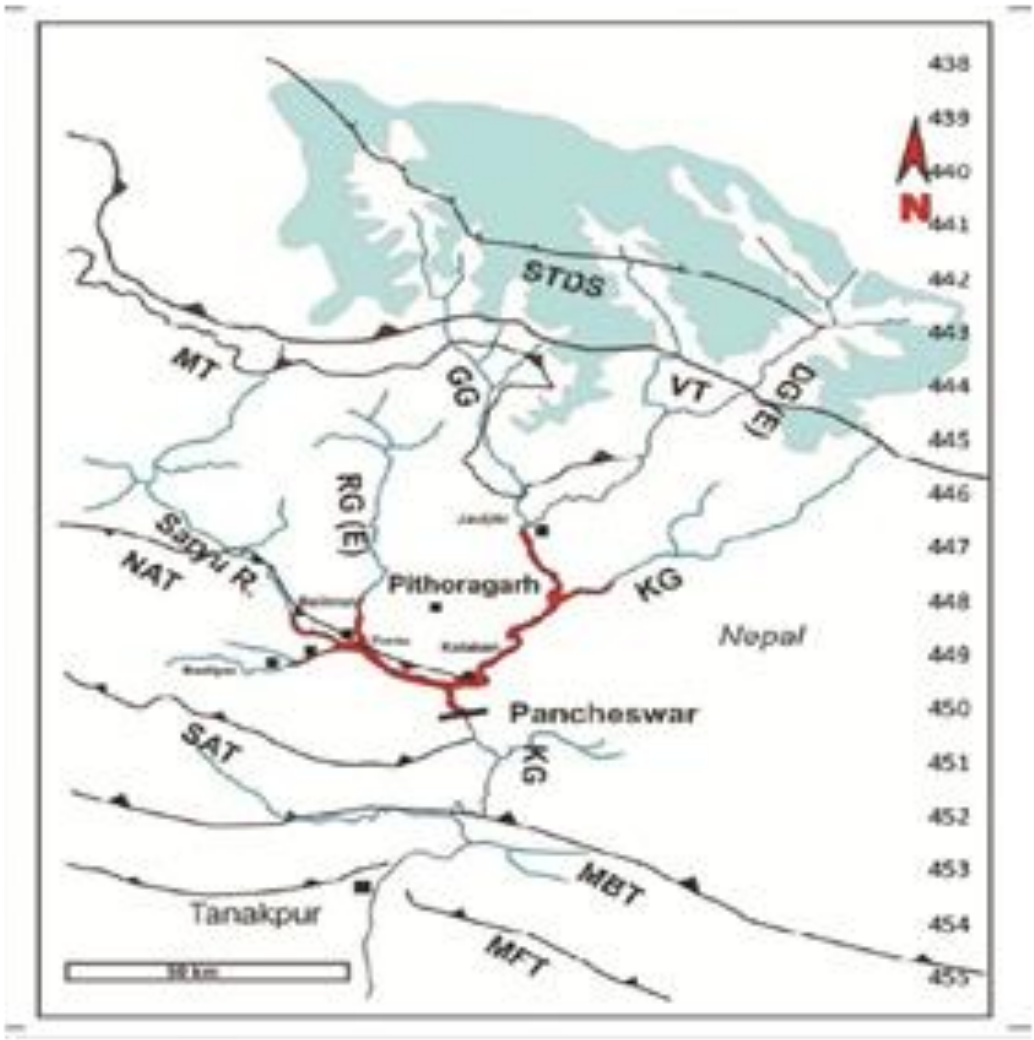

Fig. 1: Map of the study area (proposed Pancheshwar dam site).

The fern flora near Ranikhet in Kumaun (West Himalaya) was explored and illustrated by Pangtey et al. (2007). Pangtey et al. (2009) worked on pteridophytic flora of the Upper Gangetic Plain and West Himalaya and updated the fern flora list by finding some new taxa. Shah and Pande (2010), studied the Uttarkashi district for fern diversity and taxonomy. Fraser-Jenkins et al. (2017, 2018) estimated and reported the Ferns and Fern Allies of the Indian Himalaya.

Methodology

The Ghat region of the district Pithoragarh (Latitude 29.6656338 N to Longitude 80.1489584 E) was chosen as the study area because it is one of the most disaster-prone areas in Uttarakhand. Samples were collected during a period of one year by the quadrat method of 10X10 metres. The two main aspects of the study were the systematic study of pteridophytic fauna with statistical analysis and soil analysis in relation to fauna. The was basically done with the help of available literature (Khullar, 2000, Pande and Pande 2003,

Fraser-Jenkins et al 2015, 2017 and 2018). Biostatistical analysis like frequency, density, and abundance of the flora was done by various specific formulas given by MS Excel data software tools.

Various characteristics of the soil of the study area, such as physical (water holding capacity of soil and soil texture) and biochemical (nitrogen, phosphorus, potassium, organic carbon and soil pH), were determined. The parameters were analysed by the methods given below and soil analysis was done with the help of the Soil Testing Laboratory, Department of Agriculture, Pithoragarh. Soil analysis was carried out by using various specific methods, such as measuring the relative volume of sand, silt, and clay particles in a soil. The "jar separation method" was employed to determine the soil texture. Water holding capacity was measured following Piper (1944), nitrogen was estimated by the Micro Kjeldhal method (1883), phosphorus estimation by the Champman and Pant method (1962), potassium was estimated by the Richard method (1954), organic carbon calculated by the Walkley and Black method (1934), and soil pH was measured with the help of a digital pH meter. Various alpha diversity indexes such as dominance, Simpson index, Shannon index, evenness, and Margalef species richness were calculated by PAST statistical software. To establish the relationship between biotic (Pteridophyte diversity) and abiotic factors (edaphic factor), regression analysis and ANOVA analysis were done by the PAST statistical software (Hammer et al., 2001).

Results

The study area, Ghat Panar, is rich in pteridophytic species diversity (Table 1). Seven families that were recorded consisted of: Athyriaceae, Thelypteridaceae, Pteridaceae, Dryopteridaceae, Lygodiaceae, Sellaginellaceae, and Aspleniaceae. These families were represented by 11 genera and 19 species, include *Diplazium esculentum, Hypodematium crenatum var. loyali, Christella dentata, Christella appendiculata, Pronephrium penangium, Cheilanthes albomarginata, Pteris vittata, Pteris wallichiana, Pteris biaurita, Pteris aspercaulis, Adiantum incisum, Adiantum capillus-veneris, Adiantum philippense, Dryopteris cochleata, Lygodium japonicum, Lygodium flexuosum, Selaginella chrysocaulos, Selaginella subdiaphana, Asplenium dalhousiae* (Table 1). Each genus of pteridophyta was represented by one or more species. Two families had the least diversity: the Dryopteridaceae and Aspleniaceae families each had a single genus and a single species. The Pteridaceae family, which included three genera and eight species, had the most diversity. Frequency, density, abundance, and distribution A/F ratio of different species of study area Ghat Panar were calculated, showed in (Table 1). The value of frequency (F%) ranges between 33.33 and 83.33. A minimum frequency (F%) of 33.33% was calculated in *Diplaziumesculentum*, whereas a maximum of 83.33% was calculated in two species, *Peteris aspercaulis* and *Adiantum Philippense*. The value of density (D) ranges between 1.5 and 4.83. A minimum density (D) of 1.5 was calculated in *Asplenium dalhousiae*, whereas a maximum of 4.83 was calculated in *Peterisvittata*. The value of abundance ranges between 2.25 and 7.33. A minimum abundance was calculated at 2.25 in *Asplenium dalhousiae*, whereas a maximum of 7.33 was found in *Pronephrium penangium*. The value of the distribution A/F ratio ranges between 0.033 and 0.165. The minimum A/F ratio was 0.033 in *Asplenium dalhousiae*, whereas the maximum was 0.165 in *Diplaziumesculentum*. Various alpha diversity indexes (Table 2) of all species were also calculated, including dominance (D), Simpson index (1-D), Shannon index (H), evenness (e^H/S), and Margalef species richness (Table 2).

Table 1. Taxonomic status along with frequency (F%), density ((D) / 100 m^2, Abundance (A) / 100 m^2 and Distribution A/F ratio of different species at GhatPanar.

Family	Genus	Species	Frequency	Density	Abundance	Distribution Ratio
Athyriaceaes	*Diplazium*	*esculentum*	33.33	1.83	5.50	0.165
	Hypodematium	*crenatum var. loyali*	50.00	3.50	7.00	0.140
Thelypteridaceae	*Christella*	*dentata*	50.00	2.33	4.66	0.093
		appendiculata	66.67	4.16	6.25	0.093
	Pronephrium	*penangium*	50.00	3.66	7.33	0.146
Pteridaceae	*Cheilanthes*	*albomarginata*	66.67	2.50	3.75	0.056
	Pteris	*vittata*	66.67	4.83	7.25	0.108
		wallichiana	66.67	1.66	2.50	0.037
		biaurita	50.00	1.83	3.66	0.073
		aspercaulis	83.33	4.66	5.60	0.067
	Adiantum	*incisum*	66.67	3.33	5.00	0.074
		capillus-veneris	83.33	2.50	3.00	0.036
		philippense	83.33	3.50	4.20	0.050
Dryopteridaceae	*Dryopteris*	*cochleata*	66.67	1.83	2.75	0.041
Lygodiaceae	*Lygodium*	*japonicum*	50.00	1.83	3.67	0.073
		flexuosum	66.67	2.50	3.75	0.056
Sellaginellaceae	*Selaginella*	*chrysocaulos*	66.67	3.16	4.75	0.071
		subdiaphana	50.00	3.00	4.67	0.093
Aspleniaceae	*Asplenium*	*dalhousiae*	66.67	1.50	2.25	0.033

The range of dominance was between (0.1667 to 0.5636), Simpson (0.6154 to 0.8238), Shannon (0.631 to 1.593), Evenness (0.7418 to 1.161), and Margalef (0.417 to 1.477). The highest value of dominance, 0.5636 was calculated in *Diplaziumesculentum* and the lowest in (0.1667) in *Asplenium dalhousiae*. The highest value of Simpson, 0.8238 was calculated in *Adiantum Philippense* and the lowest 0.6154 in two plants *Selaginella subdiaphana* and *Christella dentata*. The highest value of Shannon 1.593 was calculated in *Adiantum capillus-veneris* and the lowest of 0.631 in *Diplaziumesculentum*. The highest value of Evenness 1.161 was calculated in *Aspleniumdalhousiae* and the lowest in 0.7418 *Adiantumincisum*. The highest value of Margalef 1.477 was calculated in *Adiantumcapillus-veneris* and the lowest at 0.417 *Diplaziumesculentum*. It was noticed that the physical and chemical constituents of the soil at the study site were highly variable in every spot.

Among the physical properties of soil (Table 3), the percentage value of water holding capacity of soil was 50–62%, sand percentage of soil was 38–48%, silt percentage of soil was 23-29%, whereas clay percentage of soil was 26-29%. The chemical properties of the soil varied as well, with the nitrogen percentage being 0.12-0.34%, the phosphorus percentage being 4.5-5.1 PPM, the potassium percentage being 132-260 PPM, the organic carbon percentage being 0.7-1.4%, and the pH of the soil being 6.0–6.9 value. After plotting species richness against soil property (Table 4), the soil property of all the sites showed a positive correlation (0.92-0.98) with the t-value (1.26 to 2.12) and P-value (0.07 to 0.25). The species richness of all the sites showed poor correlation (0.12-0.16) with the t-value (2.66 to 4.09) and P-value (0.02). This relation shows that the study area was good for the growth of pteridopytic flora.

Table 2. Alpha diversity indexes of species present at Ghat Panar.

Plant species	Taxa_S	Individuals	Dominance_D	Simpson_1-D	Shannon_H	Evenness_e^H/S	Margalef
Diplazium esculentum	2	11	0.5636	0.4364	0.631	0.9401	0.417
Hypodematium crenatum var. loyali	3	21	0.3048	0.6952	1.139	1.042	0.6569
Christella dentata	3	14	0.3846	0.6154	1.027	0.931	0.7578
Christella appendiculata	4	25	0.2433	0.7567	1.392	1.006	0.932
Pronephrium penangium	3	22	0.3203	0.6797	1.116	1.017	0.647
Cheilanthes albomarginata	4	15	0.2286	0.7714	1.423	1.037	1.108
Pteris vittata	4	29	0.234	0.766	1.416	1.03	0.8909
Pteris wallichiana	4	10	0.2	0.8	1.482	1.101	1.303
Pteris biaurita	4	18	0.2353	0.7647	1.418	1.032	1.038
Pteris aspercaulis	5	28	0.2196	0.7804	1.552	0.9443	1.2
Adiantum incisum	4	20	0.3842	0.6158	1.088	0.7418	1.001
Adiantum capillus-veneris	5	15	0.2095	0.7905	1.593	0.9835	1.477
Adiantum philippense	5	21	0.1762	0.8238	1.667	1.059	1.314
Dryopteris cochleata	4	11	0.2364	0.7636	1.4	1.014	1.251
Lygodium japonicum	3	11	0.3455	0.6545	1.086	0.9873	0.8341
Lygodium flexuosum	4	15	0.2381	0.7619	1.41	1.024	1.108
Selaginella chrysocaulos	4	19	0.2456	0.7544	1.394	1.007	1.019
Selaginella subdiaphana	3	14	0.3846	0.6154	1.027	0.931	0.7578
Asplenium dalhousiae	4	9	0.1667	0.8333	1.536	1.161	1.365

Table 3. Physiochemical parameters of the soil.

		Site 1	Site 2	Site 3
Physical properties of soil	Water holding capacity %	62	58	50
	Sand %	40	38	48
	Slit %	29	23	26
	Clay %	31	39	26
Chemical properties of soil	Nitrogen %	0.20	0.34	0.12
	Phosphorus PPM	4.5	5.1	4.9
	Potassium PPM	132	260	195
	Organic carbon %	1.4	0.9	0.7
	pH	6.0	6.5	6.9

Table 4. Relation between species richness and soil factor by Regression analysis and ANOVA.

	Soil analysis			Species richness		
Spots	AB	BC	AC	AB	BC	AC
Multiple R	0.96	0.99	0.97	0.12	0.16	0.14
R Square	0.92	0.98	0.95	0.02	0.02	0.02
Adjusted R Square	0.91	0.98	0.94	-0.04	-0.03	-0.03
Standard Error	12.36	9.85	14.56	0.73	3.01	2.78
Observations	9	9	9	19	19	19
Coefficients	10.27	-5.01	-8.30	1.94	2.70	3.49
Standard Error	12.36	3.98	6.38	0.73	1.07	0.85
t Stat	2.12	-1.26	-1.30	2.66	2.52	4.09
P-value	0.07	0.25	0.23	0.02	0.02	0.0007
Degree of freedom (df)	8	8	8	18	18	18
Sum of square (SS)	13247.31	53222.16	28559.91	112.52	158.52	134.52
Mean of square (MS)	13247.31	53222.16	28559.91	1.52	4.09	2.71
F value	86.65	547.68	134.8087	0.23	0.45	0.35
Significance F	3.42E-05	6.6E-08	7.93E-06	0.63	0.51	0.56

Discussion

On account of its environmental conditions, the Central Himalayan area has a high level of floral diversity. In our study, 07 families, 11 genera, and 19 species of pteridophytes were found near Saryu River (Ghat, District Pithoragarh), which was designated as study area. In this study we found that, this area was rich in its pteridophyten diversity, our findings were in parity with the reports of Chandra (2000), Pande and Pande (2002), Shah and Pande (2010), and Fraser Jenkins (2008, 2015, 2017, and 2018). We observed a variety of species of pteridophytes in our study area, with variation in their frequency, density, abundance, and distribution A/F ratio. Similar findings have been reported in the past. With 16 species, *Asplenium* L. has been reported, was the biggest pteridophyte genus in Karnataka (Fraser Jenkins 2017). Dryopteris and Polystichum are temperate ferns, with species extending from the far western Himalaya to eastern China and Japan through Tibet and the Chinese province of Yunnan (Khullar 1994). As per to Kholia and Punetha (2007), only Osmunda regalis is found in the middle and western Himalaya, and Osmunda japonica is just a synonym of Osmunda regalis. The indisputable family Aspleniceae consists of five species of a single genus, with very varied leaf shape and size. In the Himalayan Mountain, the rule of the latitudinal fern diversity gradient (Moran, 2008) fails. The pteridophytic flora of the area also shows variation in the various diversity indexes. Although lycophytes and ferns are abundant in humid forests, they may also be found in drier settings, where some genera can be extremely species-rich (Moran, 2008). Because frequency is a measure of a species' distribution uniformity, a low frequency implies that a species is either unevenly dispersed or scarce in a particular stand or forest (Kharkwal and Rawat, 2010). The species' high percentage frequency reflects their diverse niche preferences and capacity to spread across a vast region. Many researchers have found that the diversity value of Indian forests ranges between 0.8 and 4.90 (Kumar et al. 2006, Reddy et al. 2008, Sahu et al. 2010).

Pteridophytes have close interactions with different abiotic variables, notably environmental conditions, as a group of species and at other taxonomic levels (family, genus), that readily reflects an environment's abiotic or biotic status,

as well as ecological features like richness and diversity (Dale and Beyeler 2001, Heink and Kowarik 2010). In the middle Himalaya, for example, stable and open slopes are known to sustain high-quality meadows (Rawat, 2005). Because of its amazing range in eco-climatic conditions, soil types, and altitude, India has an unusually rich diversity of pteridophytic flora. In the current investigation, the soil was rich in nutrients for floral development. Nutrient availability, as well as environmental variables such as growing season duration, humidity, air pressure, and rainfall, impacts species dispersion and pteridophytes contributions are significantly linked to different biotic factors (Salovaara et al. 2004). Pteridophytes are not dispersed randomly locally since their development and dispersion are influenced by abiotic factors such as soil texture and fertility, ambient temperature and humidity, precipitation, and light intensity (Nobrega et al. 2011, Patil et al. 2016). The pteridophytes are also habitat-specific, and therefore the nutrients of the substrate also determine the growth of the different species of pteridophytes.

Conclusions

The studied area showed good a species diversity, while various soil factor analyses showed that this area was an environmentally favourable habitat for the given flora.

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