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Cover: Common Silverline *Spindasis vulcanus vulcanus* in poster colours adapted from photograph by Kalpesh Tayade. © Pooja R. Patil.



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COMMUNICATION

A preliminary survey of moss flora of Chail Wildlife Sanctuary, Himachal Pradesh, India

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Abstract: The present study aims to account for the moss flora of Chail Wildlife Sanctuary, district Solan, Himachal Pradesh (HP). Frequent field visits were made in different seasons to collect moss samples. Ecological data like temperature, humidity, and habitat preferences were also recorded at the time of collection. A total of 31 moss species belonging to 22 genera and 15 families were recorded so far. The family Pottiaceae (7 spp.) was the most dominant one, followed by Brachytheciaceae (4 spp.), Polytrichaceae, Fissidentaceae, and Entodontaceae with (3 spp.) each. In the acrocarpous mosses, family Pottiaceae was highly dominant, whereas, among the pleurocarpous mosses family, Brachytheciaceae was dominant. Among the genera, *Atrichum* P. Beauv. (Acrocarpous), *Fissidens* Hedw. (Acrocarpous), and *Entodon* C. Muell. (Pleurocarpous) were dominantly present, represented by three species each. This study provides baseline data of moss diversity and their ecological attributes in Chail Wildlife Sanctuary, which may prove beneficial in establishing policies for future exploration of bryodiversity with proper management and conservation in the sanctuary area.

Keywords: Acrocarpous, Bryodiversity, Bryophytes, Pleurocarpous, western Himalaya.

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Author contributions: MS surveyed the study area, collected the plant material, prepared the slides for identification and written up the whole manuscript. SSK helped with the identification of the plant material. AR designed and supervised the whole experiment throughout. All authors read and approved the final manuscript.

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INTRODUCTION

Bryophytes constitute a vast group of land plants, only second after angiosperms. Approximately 20,000 species of bryophytes (Mosses, liverworts, and hornworts) are reported worldwide (Ismail et al. 2020). In India, the bryophytes are represented by 2,562 taxa (1,636 mosses, 887 liverworts and 39 hornworts (<http://www.bsienvi.nic.in/Database/Bryophytes>). Bryophytes can colonize a wide variety of habitats, including rocks, tree bark, wood, forest floors, and riverbank. Mosses constitute an important group of bryophytes with more species richness and wide geographic distribution than liverworts and hornworts. Moss flora of western Himalaya has been extensively studied by several authors such as Chopra & Kumar (1981), Vohra (1983); Tewari & Pant (1994), Joshi et al. (2001); Kumar & Singh (2002), Kapila & Kumar (2003), Saxena et al. (2006), Nath et al. (2008), Sahu & Asthana (2012), Alam (2013), Alam et al. (2013), Asthana & Sahu (2013), Riaz et al. (2015), and Sahu & Asthana (2015). In Himachal Pradesh (HP), several authors (Sharma & Choyal 2011) have documented the moss flora at the local scale. However, to the best of our knowledge, no study has explored the moss flora of a protected area in HP so far. Therefore, the present study aims to document the moss flora of Chail Wildlife Sanctuary supplemented with their habitat and ecological attributes.

MATERIAL AND METHODS

Study area

Chail wildlife sanctuary is situated in the Solan district of Himachal Pradesh (Figure 1), covering an area of ~110 km². The majority of the sanctuary area comes under the Kandaghat sub-division of Solan district, however, some part of it also falls under the jurisdiction of the Shimla wildlife division. It lies between 30.891 latitude & 77.138 longitude at an altitude range of 701–2,405 m. The study area experiences sub-tropical to temperate climatic conditions with temperatures ranging from 40°C in summer to -4°C in winters. The annual rainfall amounts to about 1,250 mm, most of which is procured during the monsoon season between July to September. The area receives occasional snowfall during winters.

Sampling and collection

The frequent field visits were made in different seasons to collect moss samples from the sanctuary. Samples were systematically collected from different

parts of the sanctuary to cover various aspects, topography, and forest types. The moss plants were collected from different habitats such as rocks, tree barks, trunks, and soil surfaces. The specimens were scraped out carefully with the edge of a knife and immediately placed in polybags. While collecting the samples, several field parameters such as habitat, host, geographic coordinates, surrounding vegetation, and substrate conditions were recorded. In addition, at each sampling site, soil, temperature and moisture data were also gathered. The collected moss samples were transferred to the laboratory and air-dried at room conditions. The dried material was then soaked in luke warm water for 5–10 minutes. The specimens are deposited in the herbarium of the Department of Botany, Punjab University, Chandigarh and a voucher number for each specimen was obtained. The geographical map of the study area was prepared using ArcGIS software version 10.8.

Identification and taxonomic treatment

For identification, anatomical studies were performed by soaking the plant material in luke warm water for 5–10 minutes to regain the turbidity and the permanent slides were prepared using 30% glycerine and DPX (Dibutyl phthalate Polystyrene Xylene) solvent. The selected mounts were observed and photographed under a microscope. Photographs of dry and wet plant material were also taken. The specimens were identified with the help of previously published floras such as Gangulee (1969–1980), Chopra (1975), Chopra & Kumar (1981), and Kumar (1980). The families are arranged according to Goffinet & Buck (2004) system of classification.

RESULTS AND DISCUSSION

In the present study, 31 species of mosses belonging to 22 genera and 15 families were recorded so far. The family Pottiaceae accounts for the highest number of species (7), followed by Brachytheciaceae (4 spp.) and Polytrichaceae, Entodontaceae, & Fissidentaceae with (4 spp.) each. Rest of the recorded families were represented by one species each (Figure 2). All the recorded families along with their respective species and their habitat preferences are depicted in Table 1. Among the recorded families, nine are acrocarpous and six are pleurocarpous. The coloured pictures of all the collected taxa are provided in photo Images 1–31. A detailed description of recorded families with diagnostic

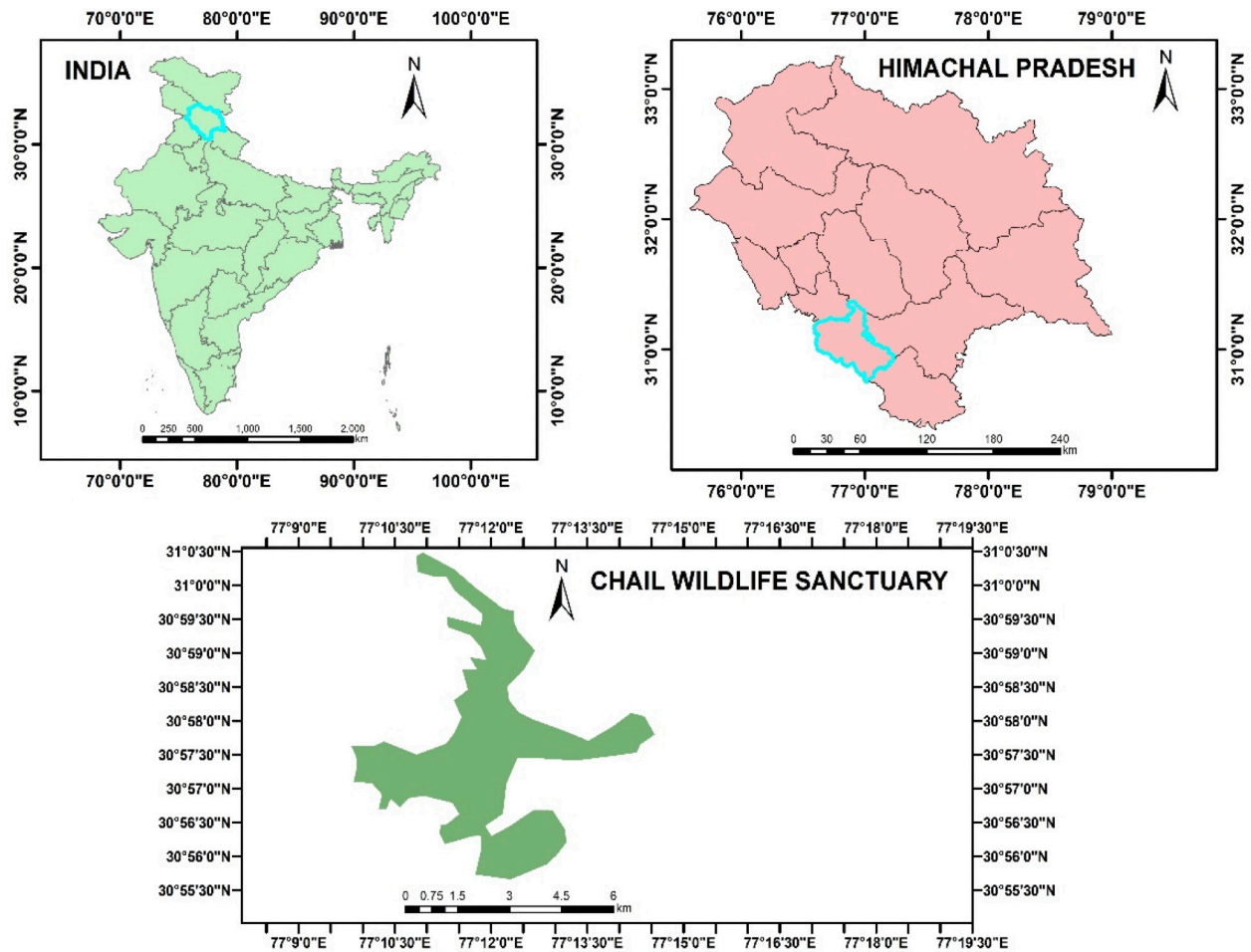


Figure 1. Location map of study area.

features is discussed below:

1. Polytrichaceae: Polytrichaceae includes 25 genera, of which four are commonly found in the Western Himalaya (Alam 2013). In the present study, only one genus, i.e., *Atrichum* (3 species, i.e., *Atrichum undulatum* (Hedw.) P. Beauv., *A. flavisetum* Mitt. and *A. obtusulum* (Müll. Hal.) A. Jaeger) was recorded. All three species are terricolous in habitat. Plants are usually small with an erect, unbranched stem. The characteristic feature of *Atrichum*, i.e., leaf lamina bisect with teeth and lamellae restricted to nerve portion only, helped in easy identification. The peristome teeth in the studied taxa are of nematodontous type.

2. Dicranaceae: Dicranaceae includes a total of 70 genera, of which 18 are present in the western Himalaya (Alam 2013). In our study area, this family is represented by only one taxon, i.e., *Dicranella divaricata* (Mitt.) A. Jaeger. This species is terricolous in its habitat. Plants are small, erect with the tomentose and usually branched stem. Leaves broader at the base and long distinctive

apex, leaf cells subquadrate or elongated in the apical region and alar cells are usually well differentiated. The sporophytic stage was not observed.

3. Fissidentaceae: This family comprises five genera, of which only one is reported from the western Himalaya (Alam 2013), i.e., *Fissidens*; this genus is also reported from the study area with three species viz. *Fissidens bryoides* Hedw., *F. crispulus* Brid. and *F. involutus* Wilson ex Mitt. *Fissidens bryoides* was recorded on the tree trunk and *F. crispulus* & *F. involutus* were found to be terrestrial. The plant body of *Fissidens* sp. is erect and ranges between 1–5 mm in height. This most distinctive taxon among mosses was easily recognizable by its distichous leaves and each leaf with lamina vaginata, lamina dorsalis and lamina apicalis. The sporophytic stage was not observed.

4. Ditrichaceae: Ditrichaceae includes 32 genera worldwide, of which only four are found in the western Himalaya (Alam 2013). In the present study, only one taxon, i.e., *Ditrichum tortipes* (Mitt.) Kuntze was

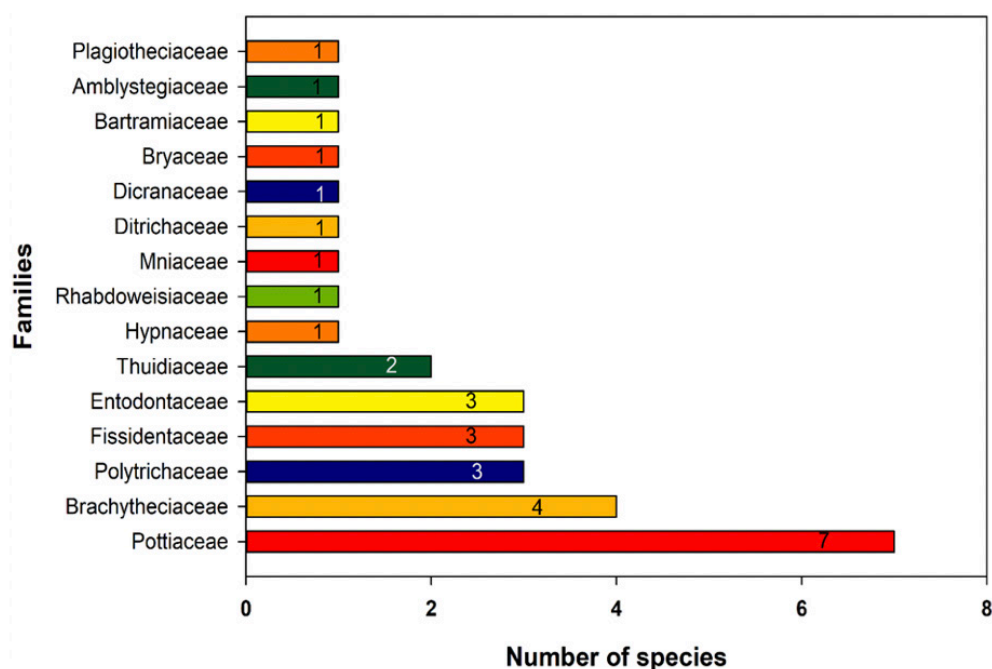


Figure 2. Family-wise number of species reported from the study area.

observed. The plants were found growing in loose tufts. Stem usually unbranched, with slightly dentate apex. The shape of the leaf, the deeper color of percurrent costa, leaves linear to almost square in shape with areolation helped distinction. The sporophytic stage was not observed.

5. Rhabdoweisiaceae: Rhabdoweisiaceae includes two genera, of which only one is found in the western Himalaya (Alam 2013). In the area under present study, only taxon, i.e., *Rhabdoweisia crenulata* (Mitt.) H. Jameson. was recorded. Like the other members of this acrocarpous family, plants are small and found growing in dense cushions. The long lingulate leaves with irregularly serrated margins, short, quadrate to elongated thin-walled areolation with undifferentiated alar cells, helped separation from other species. The sporophytic stage was not observed.

6. Pottiaceae: Pottiaceae includes 112 genera, of which 32 genera are found in the western Himalaya (Alam 2013). In present study, five genera i.e., *Anoetangium* (2 species, *A. stracheyanum* Mitt. and *A. bicolor* Renaud & Cardot), *Molendoa* [1 species, *M. roylei* (Mitt.) Broth.], *Hymenostylium* [1 species, *H. recurvirostrum* (Hedw.) Dixon], *Hyophila* [2 species, *H. involuta* (Hook.) A. Jaeger. and *H. rosea* R.S. Williams] and *Hyogonium* [1 species, *H. arcuatum* (Griff.) Wijk & Margad.] were recorded. *Anoetangium strachyanum* and *Hymenostylium recurvirostre* were epiphytic and others were terrestrial. All members of the family

Pottiaceae are acrocarpic and grow in loose tufts. The plant body is erect, small and caespitose. The stem is well developed with a central hydroid strand. The most important identifying feature of this family is the multi papillose laminal cells. Leaves are of variable shape ovoid to lanceolate, broad at the apex and tapered at the base with entire or sometimes serrated margins. *Hyophila involuta* have serrated margins, while *Hyophila rosea* have smooth margins. *Anoetangium bicolor* can be easily identified by the presence of prominent costa, which extends beyond the tip. Peristome teeth are absent in all of the reported taxa.

7. Bartramiaceae: Bartramiaceae includes 11 genera, of which seven are found in the western Himalaya (Alam 2013). In the present study area, only one taxon, i.e., *Philonotis fontana* (Hedw.) Brid. is reported. Bartramiaceae is commonly called as a family of apple mosses because of the apple-like shape of the capsules. The plants grow in extensive tufts. Stems mostly tomentose, with whorls of subfloral innovations, leaves lanceolate and acuminate with single costa ending below the tip, laminal cells rectangular at the base, elongated in mid leaf with cell ends extended as mamillae which offer an additional feature of distinction. Capsules were found to be erect or slightly inclined with diplolepidous peristome teeth.

8. Mniaceae: Mniaceae includes 12 genera, of which seven are found in the western Himalaya (Alam 2013). In the present study area, only one taxon,

Table 1. A list of recorded moss species with habitat preferences and herbarium specimen numbers.

Genus	Species	Family	Habitat	Herbarium specimen number (PAN)
<i>Atrichum</i> P. Beauv.	<i>A. undulatum</i> (Hedw.) P. Beauv.	Polytrichaceae	RP, TR	6323
	<i>A. flavisetum</i> Mitt.		TR	6324
	<i>A. obtusulum</i> (Müll. Hal.) A. Jaeger		TR	6325
<i>Dicranella</i> Schimp.	<i>D. divaricata</i> (Mitt.) A. Jaeger	Dicranaceae	TR	6330
<i>Fissidens</i> Hedw.	<i>F. bryoides</i> Hedw.	Fissidentaceae	SX	6333
	<i>F. crispulus</i> Brid.		TR	6335
	<i>F. involutus</i> Wilson ex Mitt.		CT, RP, TR	6336
<i>Ditrichum</i> Hampe	<i>D. tortipes</i> (Mitt.) Kuntze	Ditrichaceae	TR	6341
<i>Rhabdoweisia</i> Bruch & Schimp.	<i>R. crenulata</i> (Mitt.) H. Jameson	Rhabdoweisiaceae	RP	6343
<i>Anoetangium</i> Schwägr.	<i>A. stracheyanum</i> Mitt.	Pottiaceae	CT, RP, TR, SX	6346
	<i>A. bicolor</i> Renauld & Cardot		TR	6348
<i>Molendoa</i> Lindb.	<i>M. roylei</i> (Mitt.) Broth.		TR	6349
<i>Hymenostylium</i> Brid.	<i>H. recurvirostrum</i> (Hedw.) Dixon		CT, RP, SX	6351
<i>Hyophila</i> Brid.	<i>H. involuta</i> (Hook.) A. Jaeger		RP, TR, SX	6358
	<i>H. rosea</i> R.S. Williams		RP, TR	6359
<i>Hydrogonium</i> (Müll. Hal.) A. Jaeger	<i>H. arcuatum</i> (Griff.) Wijk & Margad.		TR	6366
<i>Philonotis</i> Brid.	<i>P. fontana</i> (Hedw.) Brid.	Bartramiaceae	RP, TR	6370
<i>Plagiomnium</i> T. J. Kop.	<i>P. cuspidatum</i> (Hedw.) T.J. Kop	Mniaceae	TR	6375
<i>Ptychostomum</i> Hornsch.	<i>P. capillare</i> (Hedw.) D.T. Holyoak & N. Pedersen	Bryaceae	RP, TR	6384
<i>Cratoneuron</i> (Sull.) Spruce	<i>C. filicinum</i> (Hedw.) Spruce	Amblystegiaceae	TR	6386
<i>Thuidium</i> Schimp.	<i>T. glaucinum</i> (Mitt.) Bosch & Sande Lac.	Thuidiaceae	TR	6392
<i>Herpetineuron</i> (Müll. Hal.) Cardot	<i>H. toccocae</i> (Sull. & Lesq.) Cardot		SX	6410
<i>Brachythecium</i> Schimp.	<i>B. buchananii</i> (Hook.) A. Jaeger	Brachytheciaceae	CT, RP, TR, SX	6394
	<i>B. populeum</i> (Hedw.) Schimp.		TR	6396
<i>Rhynchostegium</i> Schimp.	<i>R. planiusculum</i> (Mitt.) A. Jaeger		TR	6401
<i>Oxyrrhynchium</i> (Schimp.) Warnst.	<i>O. vagans</i> (A. Jaeger) Ignatov & Huttunen		RP, TR	6402
<i>Pseudotaxiphyllum</i>	<i>P. elegans</i> (Brid.) Z. Iwats.	Plagiotheciaceae	TR	6407
<i>Entodon</i> Müll. Hal.	<i>E. flavescens</i> (Hook.) A. Jaeger	Entodontaceae	RP	6403
	<i>E. myurus</i> (Hook.) Hampe		TR, SX	6404
	<i>E. rubicundus</i> (Mitt.) A. Jaeger		RP, TR, SX	6405
<i>Hypnum</i> Hedw.	<i>H. cupressiforme</i> Hedw.	Hypnaceae	RP	6409

RP—Rupicolous | TR—Terricolous | SX—Saxicolous | CT—Corticolous.

i.e., *Plagiomnium cuspidatum* (Hedw.) T.J. Kop. was observed. The species is characterized by large leaves, spatulate to oval in shape often present in rosette at stem apex, with sharp uniseriate teeth on the margins. The plants were found growing in loose tufts. The sporophytic stage was not observed.

9. Bryaceae: Bryaceae includes 33 genera, of which only six are reported from the western Himalaya (Alam 2013). In the present study, only one taxon, i.e.,

Ptychostomum capillare (Hedw.) D.T. Holyoak & N. Pedersen was recorded. The plants are terrestrial as well as epiphytic found growing in dense tufts under damp and shady conditions. Leaves ovate-lanceolate in shape with smooth margins, serrated at the tip and hexagonally elongated areolations helped recognition of this taxon. The sporophytic stage was not observed.

10. Amblystegiaceae: Amblystegiaceae includes 44 genera, of which only two are found in the western

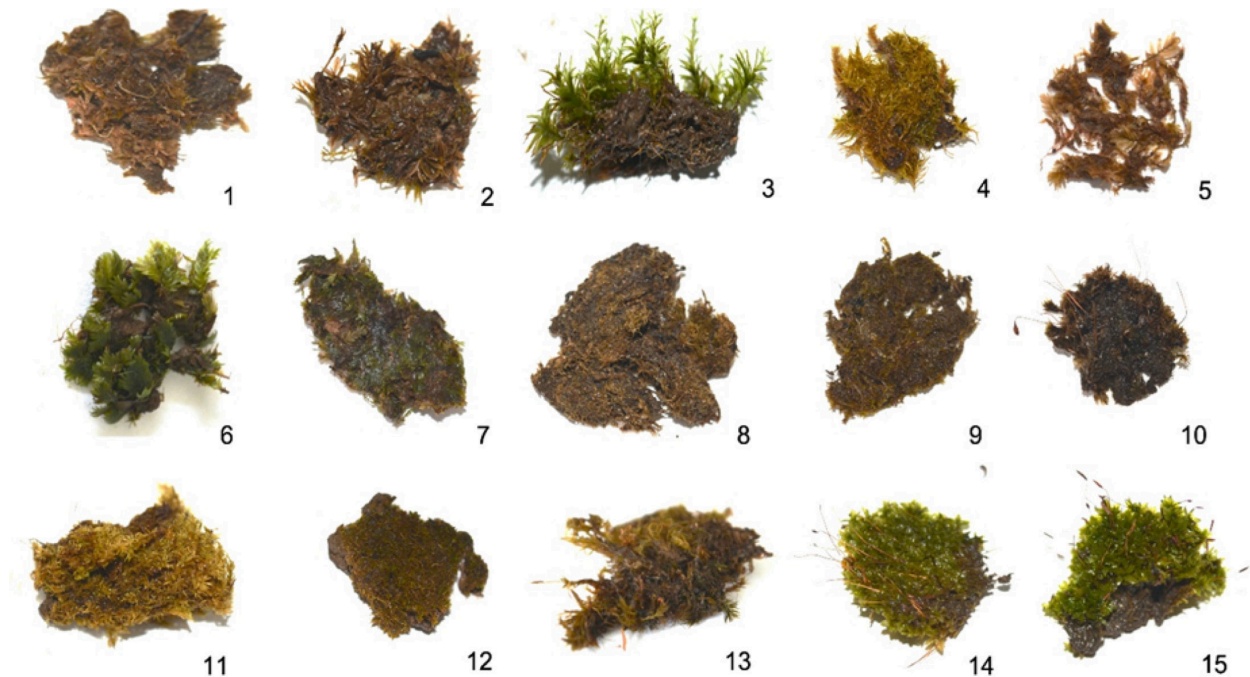


Image 1–15. 1—*Atrichum undulatum* (Hedw.) P.Beauv. | 2—*A. flavisetum* Mitt. | 3—*A. obtusulum* (Mull.Hal.) A.Jaeger | 4—*Dicranella divaricata* (Mitt.) A.Jaeger | 5—*Fissidens bryoides* Hedw. | 6—*F. crispulus* Brid. | 7—*F. involutus* Wilson ex Mitt. | 8—*Ditrichum tortipes* (Mitt.) Kuntze | 9—*Rhabdoweisia crenulata* (Mitt.) H.Jameson | 10—*Anoetangium stracheyanum* Mitt. | 11—*A. bicolor* Renauld & Cardot | 12—*Molendooa roylei* (Mitt.) Broth. | 13—*Hymenostylium recurvirostrum* (Hedw.) Dixon | 14—*Hyophila involuta* (Hook.) A. Jaeger | 15—*H. rosea* R.S.Williams. © Meenal Sharma

Himalaya (Alam 2013). In the present study, only one taxon, i.e., *Cratoneuron filicinum* (Hedw.) Spurge was recorded. The stem leaves are broader than the branch leaves, lanceolate, acuminate, areolations elongated in the apical region and rhomboidal in the lower half. Peristome teeth are diplolepidous, hypnoid type.

11. Thuidiaceae: Thuidiaceae includes 25 genera, of which five are found in the western Himalaya (Alam 2013). In the present study, two taxa, viz., *Thuidium glaucinum* (Mitt.) Bosch. & Sande Lac. and *Herpetineuron toccoae* (Sull. & Lesq.) Cardot were recorded. In both these taxa, plants are yellowish-green growing in dense mats. Stem stoloniferous, branched pinnately with or without paraphyllia, dimorphic leaves viz. small leaves which are scale-like, large leaves ovate with broad apex, single costa usually ending below the leaf apex, laminal cells small, papillose helped distinction. The absence of paraphyllia and the tortuous costa of the leaves are the most characteristic features of the *Herpetineuron*. The sporophytic stage was not observed.

12. Brachytheciaceae: Brachytheciaceae includes 51 genera, of which 10 are reported from the western Himalaya (Alam 2013). In the present study, two taxa viz. *Brachythecium* [2 species, *B. buchananii* (Hook.) A. Jaeger & *B. populeum* (Hedw.) Schimp.] and *Rhynchostegium* [2 species, *R. planiusculum* (Mitt.) A.

Jaeger and *Oxyrrhynchium vagans* (A. Jaeger) Ignatov & Huttunen] were observed. These are the most common mosses among the plerocarpous, which are found on soil, tree trunks, and rocks. Plants are small, glossy, stem prostrate, irregularly branched. Stem leaves and branch leaves are well distinguished; branch leaves are relatively smaller, narrower, with more serrated margins and longer costa. Laminal cells linear, elongate, rhomboidal, costa reaching halfway to the apex of leaves of these taxa helped distinction. The capsules are slightly inclined in the case of *B. buchananii* and horizontal in *R. planiusculum*. Peristomes are hypnoid type.

13. Plagiotheciaceae: Plagiotheciaceae includes five genera worldwide, of which three are found in western Himalaya (Alam 2013). In the present study only one taxon, i.e., *Psuedotaxiphyllum elegans* (Brid.) Z. Iwats. was recorded. *P. elegans* is terricolous in habitat and is easily recognized by its glossy leaves with whitish tinges, apparently arranged in two rows. Irregularly and pinnately branched stems, ovate to ovate-lanceolate leaves with short and double costa. The sporophytic stage was not observed.

14. Entodontaceae: Entodontaceae includes 13 genera worldwide, of which four are found in the western Himalaya (Alam 2013). In the area under study, only one genus, i.e., *Entodon* [3 species, *E. flavescens*

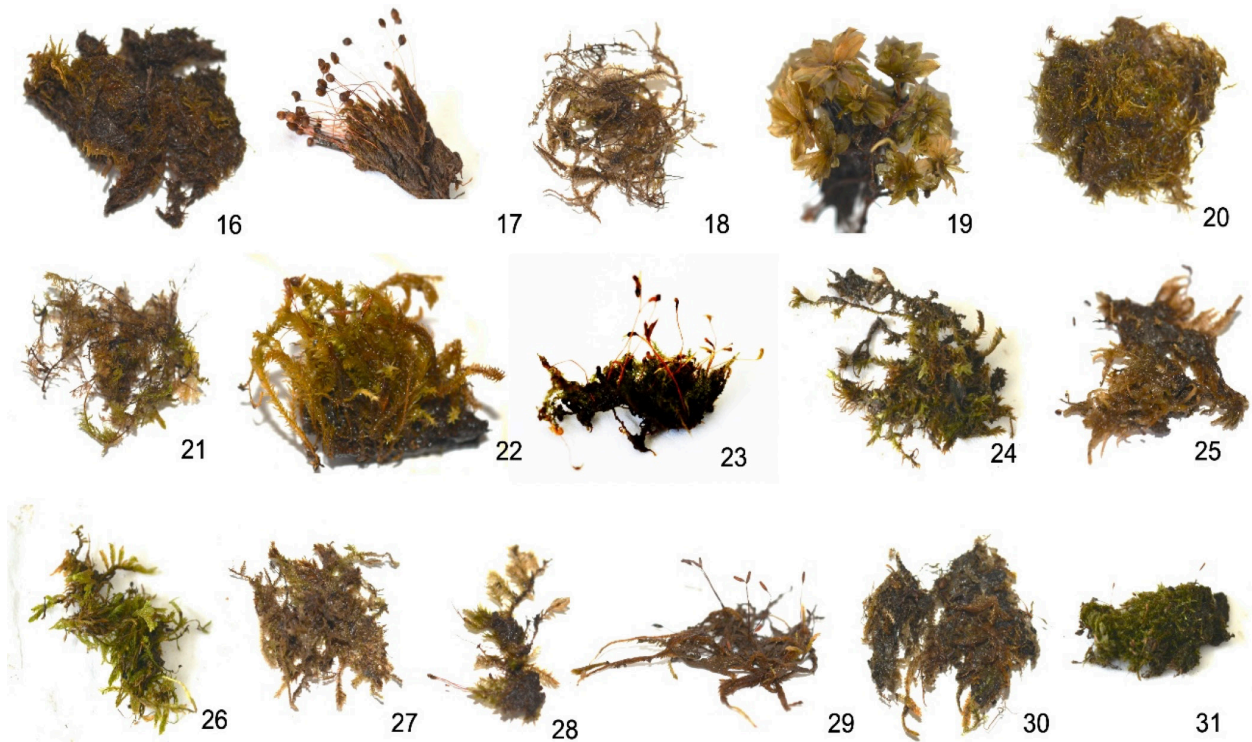


Image 16–31. 16—*Hydrogonium arcuatum* (Griff.) Wijk & Margad. | 17—*Philonotis fontana* (Hedw.) Brid. | 18—*Plagiomnium cuspidatum* (Hedw.) T.J.Kop | 19—*Ptychostomum capillare* (Hedw.) D.T.Holyoak & N.Pedersen | 20—*Cratoneuron filicinum* (Hedw.) Spruce | 21—*Thuidium glaucinum* (Mitt.) Bosch & Sande Lac. | 22—*Herpatineuron toccoeae* (Sull. & Lesq.) Cardot | 23—*Brachythecium buchananii* (Hook.) A.Jaeger | 24—*B. populeum* (Hedw.) Schimp. | 25—*Rhynchostegium populeum* (Hedw.) Schimp. | 26—*Oxyrrhynchium vagans* (A.Jaeger) Ignatov & Huttunen | 27—*Pseudotaxiphyllum elegans* (Brid.) Z.Iwats. | 28—*Entodon flavescens* (Hook.) A.Jaeger | 29—*E. myurus* (Hook.) Hampe | 30—*E. rubicundus* (Mitt.) A.Jaeger | 31—*Hypnum cupressiforme* Hedw. © Meenal Sharma

(Hook.) A. Jaeger, *E. myurus* (Hook.) Hampe, and *E. rubicundus* (Mitt.) A. Jaeger] were recorded. *Entodon flavescens* & *E. myurus* are terricolous and *E. rubicundus* is saxicolous in habitat. Plants thin, glossy, and found growing in mats. Branch leaves are smaller than stem leaves. Leaves lanceolate to ovate in shape. Laminal cells elongated rhomboidal, differentiated alar cells, double, short or absent costa is the most characteristic feature of the recorded taxa. Capsules are erect and cylindrical in shape. Peristome teeth are two-rowed.

15. Hypnaceae: Hypnaceae includes 60 genera, of which 15 are found in the western Himalaya (Alam 2013). In the area under study, only one taxon, i.e., *Hypnum cupressiforme* Hedw. was recorded. These green-glossy plants were found to be saxicolous in habitat. Leaves are ovate to lanceolate with smooth margins. The costa is indistinct. Areolations linear, differentiated at angles helped distinction. Capsule mostly erect. Peristome teeth are observed to be hypnoid type.

The number of reported species (31 spp.) in our study is comparatively less than other studies in the Himalayan region. In a similar study conducted at

Kedarnath Wildlife Sanctuary, Bahuguna et al. (2016) reported 113 species of mosses belonging to 65 genera. The lesser number of moss species in our study could be attributed to the small geographical area of the sanctuary. Alam (2013) provided an updated list of moss flora of western Himalaya, comprising three states, namely, Jammu & Kashmir, Uttarakhand, and Himachal Pradesh. He reported a total of 745 species of mosses across the three Himalayan states.

In the present study, acrocarpous mosses were found in greater numbers. The plerocarpic mosses were mostly observed as epiphytes or saxicolous. The relatively lower occurrence of plerocarpic mosses than the acrocarpous mosses appears to be due to the lack of shade and moisture availability in the epiphytic and saxicolous conditions.

Among the acrocarpous mosses, Pottiaceae (7 species) is most commonly found, followed by Polytrichaceae (3 spp.) and Fissidentaceae (3 spp.), suggesting that it can exploit more diverse habitats and can also withstand relatively more bryologically xeric conditions. Among the plerocarpous mosses,

Brachytheciaceae (4 spp.) and Entodontaceae (3 spp.) are more dominant. Among genera, the most dominating are *Atrichum*, *Fissidens* and *Entodon*, each represented with three species. As evident from the table 1, the substrate preference of most of the taxa is terricolous, a few are found to be epiphytic and some of them were present in both types of habitats. It is further observed that the acrocarpous mosses are better adapted to the arid and exposed habitats, whereas the pluerocarpous mosses are scarce in such environmental conditions. In short, 19 acrocarpous (63.3%) and 11 pluerocarpous (36.6%) mosses were collected from the site, which indicates the dominance of the acrocarpous mosses.

CONCLUSION

Although bryophytes are the second largest group of plants after angiosperms, detailed information about their number and distribution is still scarce. The present study provides a preliminary assessment of the moss flora of the Chail Wildlife Sanctuary with a total of 31 moss species. The most dominating family was found to be Pottiaceae (7 species). Acrocarpous mosses dominate the study area compared to pleurocarpous mosses, suggesting that the former possesses varied ecological adaptability than the latter. The habitat preferences data provided can be used in niche modelling and conservation programs. Regional and local plant inventories of mosses, especially in protected areas, can be an important tool for national database preparation and keeping a record of species for future management and conservation practices. Therefore, this study will undoubtedly act as baseline information for futuristic researchers. Further studies are recommended to understand the relationships between moss flora, associated tree species, and substrate conditions.

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