BRYODIVERSITY ON *PINUS WALLICHIANA* L. TREES IN NAINITAL, KUMAUN HIMALAYA, INDIA

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ABSTRACT

In Kumaun Himalaya, the temperate, evergreen blue pine forest (*Pinus wallichiana* L.) provides congenial environment for the growth and luxuriance of mosses and liverworts. Therefore, the present study was undertaken to study the bryodiversity between and within 80 *P. wallichiana* trees in Nainital, Kumaun Himalaya. In the present investigation, forty bryophyte species distributed in 23 families were recorded which were morphologically grouped into leafy liverworts (12.5%), acrocarpic mosses (25%) and pleurocarpic mosses (62.5%). The reported bryophytes showed five growth forms; tuft (23), mats (11), turf (3), pendants (2) and weft (1). The study revealed that 7 species (*Bryosedgwickia aurea* (Schwagr.) M. Fleisch., *Cryptoleptodon flexuosus* (Harv.) Ren. & Card., *Ditrichum heteromallum* (Hedw.) Britt., *Frullania muscicola* Stephani, *F. dilatata* subsp. *subdilatata* (C. Massal.) S. Hatt., *F. retusa* Mitt. and *Lindbergia koelzii* R.S. Williams) were strictly epiphytic, while the remaining species were either terrestrial and/or epilithic. The bryophyte species recorded on *P. wallichiana* showed maximum similarity (30-50%) with the species found on *Quercus spp.* of the study area. Contrary to this, minimum similarity was found between *P. wallichiana* and *Erythrina arborescens* (5%). These variations in bryodiversity may be attributed to the similarities and differences in altitude, aspect and the microclimatic nature and texture of the stems of the phorophytes.

KEYWORDS

Bryodiversity; Epiphyte; Phorophyte; Mosses; *Pinus wallichiana*; Species Composition; Growth Forms.

Introduction

Bryophytes, a group of interestingly simple and often diminutive plants, are classified into the mosses, liverworts and hornworts. They form an important component of ecosystem biodiversity which plays a significant role in species richness (Grytnes et al. 2006, Steel et al. 2004) and forest biomass in some cases (Frego 2007). They also play a prominent role in ecosystem functions, such as soil development (Zhao et al. 2009), nutrient biogeochemical cycling (Frego 2007, Turetsky 2003) water retention (Beringer et. al 2001) plant colonization (Uchida et al 2002) seed germination, seedling growth and forest regeneration (Jeschke and Kiehl 2008).

In Western Himalaya, previous studies on the diversity of bryophytes have been carried out on a variety of habitats (Srivastava 1966, Chopra and Kumar 1981, Gupta 2014). These studies included species richness, distribution pattern, biomass and net productivity etc. (Joshi 1993, Tewari and Pant 1994, Pande et al 2005, Awasthi et al 2013, Bargali et al 2014 and Porley and Hodgetts 2005). However, Pentecost (1988) opined that distribution pattern of bryophytes is primarily influenced by macroclimatic factors e.g. rainfall and temperature, and microclimatic factors e.g. light intensity.

All these studies were based on the bryophyte species composition on various phorophytes like Oaks, Chir Pine, Horse Chestnut, Maple and Thuja of the study area. Still the knowledge on species composition of bryophytes growing on the *Pinus wallichiana* L. (Blue Pine) tree stem is meager. Therefore, the present study was undertaken with the aim: 1) to investigate species composition of bryophytic vegetation associated with *P. wallichiana* and 2) to compare bryophytic vegetation of *P. wallichiana* with other tree species of this region.

Materials and Methods

Study Area

The study was conducted in 2015 at blue Pine dominated forest near Sigri village, Nainital, Kumaun Himalaya (29°27'118.90" N and 79°24'44.60" E), India. The study area is characterized by the temperate climate. The temperature ranged from -2º C (January) to 32º C (May) and rainfall varied from 2 mm (December) to 725 mm (July).

Sampling Design

80 trees of *P. wallichiana* were selected. Circumference (girth) of each tree was measured at breast height and the trees were categorized into 5 girth class categories viz., A (upto 50 cm), B (51-100 cm), C (101-150 cm), D (151-200 cm) and E (above 200cm). Bryophyte vegetation was recorded on the tree stems upto approachable height i.e., around 2 m from the ground. Quadrats (10) of 5 cm x 5 cm were laid randomly in each tree and the bryophytes from each quadrat were removed gently along with the substrate (bark) and brought to the laboratory. The plants were separated according to their growth form, habit and other distinguishing field characters. Slides of leaves and other parts were prepared in gum-chloral mounting media (Watson, 1955) and plants were identified following Gangulee (1969-1980) and Kashyap (1929 and 1932), Vohra (1977), Zander and Eckel (1993), Chopra (1975), Watson (1955) and Singh and Nath (2007). The specimens were also confirmed in Bryology laboratory, National Botanical Research Institute, Lucknow. Colour, texture and other characteristics of bark viz., pH and moisture content were also determined following Misra (1968). Voucher specimens were deposited in the Bryology Laboratory, Department of Botany, D.S.B. Campus, Kumaun University, Nainital. Species composition on *P. wallichiana* tree was compared with the other common and dominant phorophytes of Nainital.

Results

Bark Characteristics

The different physiochemical characteristics of *P. wallichiana* tree bark are given in Table 1. In general, the bark is greyish in colour and acidic in nature. Due to cracks and crevices between barks they provide better habitat for the germination of bryophyte propagules. The older barks came out easily from the surface of the tree as flakes.

Table 1: Physical Characteristics of *P. wallichiana* tree bark

Parameters	Girth Class (in cm)				
	A (0-50)	B (51-100)	C (101-150)	D (151-200)	E (above 200)
Colour	Greenish	Greyish	Greyish-Brown	Greyish	Greyish
Texture	Smooth	Rough	Rough	Rough	Rough
pH	5.8	5.9	6.2	6.3	6.1
Moisture Content (%)	49	67	89	123	114

Bryodiversity on *P. wallichiana*

In total, 40 species of bryophytes belonging to 23 families were recorded (Table 2). Among these, principal component constituting bryodiversity were mosses (35) followed by leafy liverworts (5). The maximum number of species were represented by the family Brachytheciaceae (6) followed by Thuidiaceae (4) (Fig.1).

Out of 40 species of bryophytes, 13% were leafy liverworts belonging to 3 families (Frullaniaceae, Lejeuneaceae and Plagiochilaceae), 25% were acrocarpous mosses (7 families) and 62% were pleurocarpous mosses (13 families) (Fig.2; Table 2). The reported bryophytes also showed five different growth forms i.e., tuft (23), mats (11), turf (3), pendants (2) and weft (1).

Table 2: List of bryophyte species present on the *Pinus wallichiana* tree bark.

S. No.	Bryophyte Species	Family	*M.F	*G.F	*Girth Class				
					A	B	C	D	E
1.	*Amblystegium serpens var. juratzkanum* (Schimp.) Rau & Herv.	Amblystegiaceae	**P**	Turf	+	-	-	-	-
2.	*Anomodon minor* (Hedw.) Lindb.	Thuidiaceae	**P**	Tuft	-	+	+	+	+
3.	*Atrichum obtusulum* (C. Muell.) Jaeg.	Polytrichaceae	**A**	Tuft	-	-	+	-	-
4.	*Brachymenium capitulatum* (Mitt.) Par.	Bryaceae	**A**	Tuft	+	+	+	+	+
5.	*Brachythecium buchananii* (Hook.) Jaeg.	Brachytheciaceae	**P**	Mat	-	-	+	+	+
6.	*Brachythecium falcatulum* (Broth.) Par.	Brachytheciaceae	**P**	Mat	-	+	+	+	-
7.	*Brotherella perpinnata* (Broth.) M. Fleisch.	Sematophyllaceae	**P**	Tuft	-	-	+	+	-
8.	*Bryoerythrophyllum dentatum* (Mitt.) P.C. Chen	Pottiaceae	**A**	Turf	-	+	+	+	-
9.	*Bryosedgwickia aurea* (Schwägr.) M. Fleisch.	Hypnaceae	**P**	Tuft	-	+	+	+	+
10.	*Campylopus ericoides* (Griff.) A. Jaeg.	Dicranaceae	**A**	Tuft	-	-	-	+	+
11.	*Claopodium prionophyllum* (Müll. Hal.) Broth.	Thuidiaceae	**P**	Tuft	-	-	-	+	+
12.	*Clastobryum capillaceum* (Griff.) Broth.	Sematophyllaceae	**P**	Tuft	+	+	-	-	-
13.	*Cryptoleptodon flexuosus* (Harv.) Ren. & Card.	Neckeraceae	**P**	Pendant	-	+	+	+	+
14.	*Dicranella heteromalla* (Hedw.) Schimp.	Dicranaceae	**A**	Tuft	-	+	+	+	-
15.	*Ditrichum heteromallum* (Hedw.) Britt.	Ditrichaceae	**A**	Tuft	-	-	+	+	-
16.	*Entodon laetus* (Griff.) Jaeg.	Entodontaceae	**P**	Tuft	-	+	+	+	-
17.	*Entodon pulchellus* (Griff.) Jaeg.	Entodontaceae	**P**	Tuft	-	-	+	+	+
18.	*Eurhynchium riparoides* (Hedw.) Richs.	Brachytheciaceae	**P**	Tuft	-	-	+	+	+
19.	*Fissidens bryoides var. schmidii* (C. Mull.)	Fissidentaceae	**A**	Turf	-	+	+	+	-
20.	*Frullania dilatata subsp. subdilatata* (C. Massal.) S. Hatt.	Frullaniaceae	**L.L**	Mat	+	+	-	-	-
21.	*Frullania muscicola* Stephani	Frullaniaceae	**L.L**	Mat	+	+	-	-	-
22.	*Frullania retusa* Mitt.	Frullaniaceae	**L.L**	Mat	+	+	-	-	-
23.	*Herpetineuron toccoae* (Sull. & Lesq.) Card.	Thuidiaceae	**P**	Tuft	+	+	+	+	+
24.	*Homaliodendron microdendron* (Mont.) Fleisch.	Neckeraceae	**P**	Tuft	+	-	+	+	-
25.	*Hymenostylium recurvirostre* (Hedw.) Dixon	Pottiaceae	**A**	Tuft	-	-	-	+	+
26.	*Hyophila involuta* (Hook.) A. Jaeger	Pottiaceae	**A**	Tuft	-	+	+	+	+
27.	*Lejeunea tuberculosa* Stephani	Lejeuneaceae	**L.L**	Mat	+	+	+	-	-
28.	*Leucodon secundus* (Harv.) Mitt.	Leucodontaceae	**P**	Mat	-	+	+	+	+
29.	*Lindbergia koelzii* R.S. Williams	Leskeaceae	**P**	Mat	+	+	+	+	+
30.	*Macrothamnium submacrocarpum* (A. Jaeger ex Renauld & Cardot) M. Fleisch.	Hylocomiaceae	**P**	Tuft	-	-	+	+	+
31.	*Meteorium buchananii* (Brid.) Broth.	Meteoriaceae	**P**	Pendant	-	+	+	+	-
32.	*Plagiochila gollanii* Stephani	Plagiochilaceae	**L.L**	Mat	-	+	+	-	-
33.	*Plagiomnium cuspidatum* (Hedw.) T.J. Kop.	Mniaceae	**A**	Tuft	-	-	+	+	-
34.	*Plagiothecium denticulatum* (Hedw.) Schimp.	Plagiotheciaceae	**P**	Tuft	-	+	+	+	+
35.	*Platygyrium russulum* (Mitt.) A. Jaeg.	Hypnaceae	**P**	Tuft	-	-	+	+	+
36.	*Rhynchostegiella divaricatifolia* (Ren. & Card.) Broth.	Brachytheciaceae	**P**	Tuft	-	+	+	+	+
37.	*Rhynchostegiella menadensis* (Sande Lac.) E.B.	Brachytheciaceae	**P**	Mat	-	-	+	+	+

	Bartram									
38.	*Rhynchostegium herbaceum (Mitt.) A. Jaeger*	Brachytheciaceae	**P**	Tuft	-	+	-	+	+
39.	*Thuidium assimile* (Mitt.) Jaeg.	Thuidiaceae	**P**	Weft	-	+	+	+	-
40.	*Trachypodopsis serrulata* (P. Beauv.) Fleisch.	Trachypodaceae	**P**	Mat	-	+	+	+	+

*Girth Classes; A = 0-50 cm; B = 51-100 cm; C = 101-150 cm; D = 151-200 cm; E = >200 cm
*M.F = Morphological Form; *G.F = Growth Form; P = Pleurocarpous; A = Acrocarpous and L.L = Leafy Liverworts

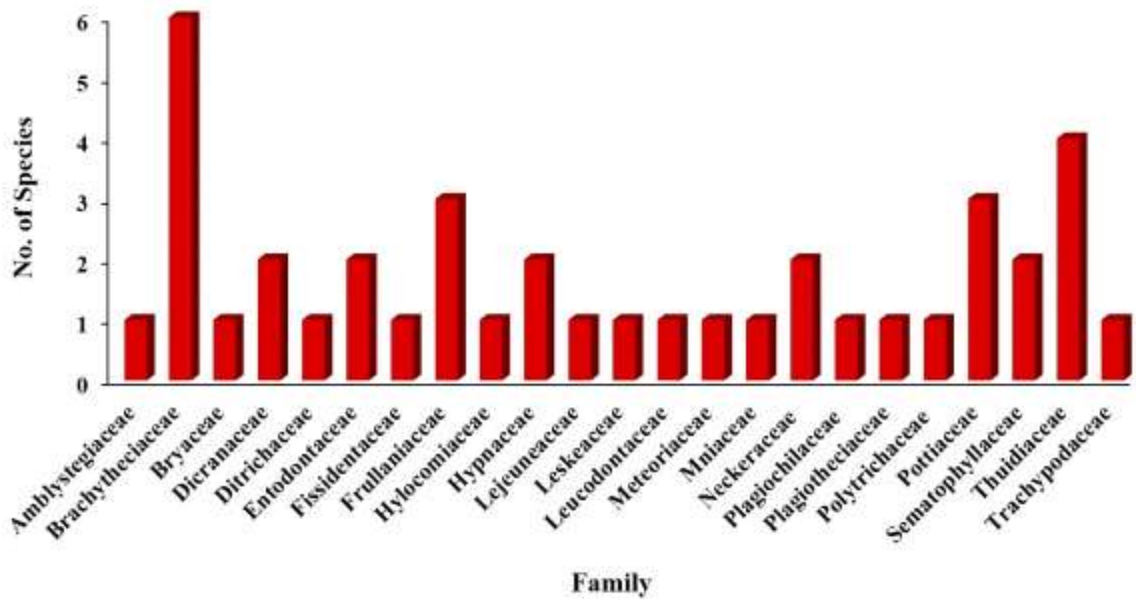

Fig.1: Family wise distribution of bryophytes on *Pinus wallichiana*

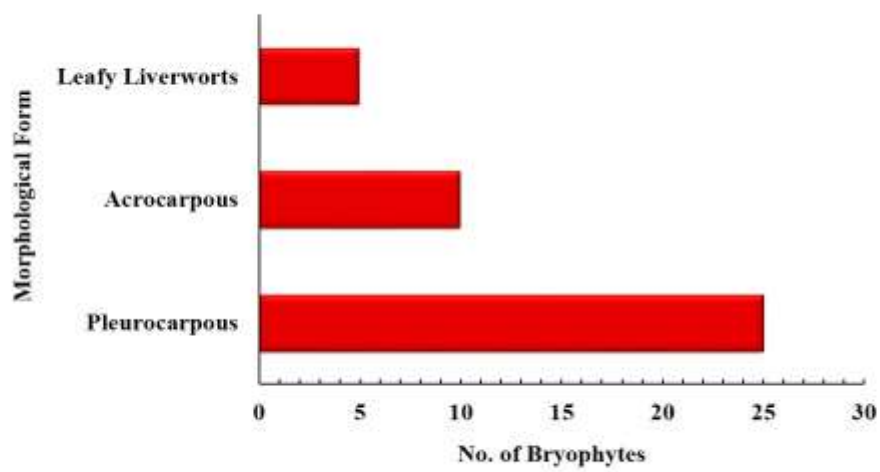

Fig.2: Distribution of bryophytes according to morphological forms.

Discussion

In the present study, 40 species of epiphytic bryophyte belonging to 23 families were recorded on *P. wallichiana.* Some other studies conducted in Kumaun Himalayan region reported 21 species of epiphytic bryophytes from *Aesculus indica* (Pande *et al.* 2005), 33 species of bryophytes from Oak species (Rawat, 2006), 17 species of epiphytic mosses from *Erythrina arborescens* (Awasthi *et al.* 2013) and 27 species of epiphytic bryophytes from *Platanus orientalis* (Bargali *et al.* 2014). The higher number of epiphytic bryophytes (40) in *P. wallichiana* than other phorophytes of the region may be due to rough texture of bark, presence of broad cracks and crevices and high moisture which helps in making substrate suitable for establishment and growth of bryophytes.

Smith (1982) suggested the possible method to study colonization and succession of epiphytes growing on phorophytes of different ages within same environmental conditions. Accordingly, in this study, species richness of bryophytes increased with increasing girth class upto girth class D and then decreased in girth class E (Fig. 3). Gustafsson and Eriksson (1995) also reported that trees with higher diameter host the richer epiphytic bryophyte flora due to changes in bark structure which is beneficial for a majority of bryophyte species. This is also due to increase in moisture content (Girth Class A, 49% to Girth Class D, 123%) and decrease in acidic nature (pH: Girth Class A=5.8 to Girth Class D=6.3) of bark from A to D girth class and then slightly decreased moisture content (114%) and increased acidic nature (pH=6.1) of bark in E girth class (Fig. 3). Species richness showed a significant positive correlation with moisture content (r=0.737) and pH (r=0.895) of tree bark. Bates (1992) also reported that the most important factor controlling the distribution of epiphytic bryophytes is the moisture content of bark surface.

Lowest number of bryophytes (10) in young trees (A girth class) and highest number of bryophytes (32) in mature trees (D girth class) indicated that smooth texture of bark with low moisture (49%) and more acidic pH (5.9) in young trees makes the substrate not suitable for the establishment of bryophytes. On the other hand, rough texture of bark with large number of cracks and crevices, high moisture content (123%) and less acidic pH (6.3) makes mature trees a good substrate for bryophyte growth and establishment. Xeric nature of bryophyte species associated with low girth class trees was also supported by their morphological adaptations like presence of water sac (*Frullania*) and concave leaves (*Amblystegium* and *Clastobryum*). Some species like *Amblystegium, Clastobryum* and *Frullania* preferred low girth class trees while some species like *Campylopus, Claopodium* and *Hymenostylium* preferred high girth class trees. However, three species viz. *Brachymenium, Herpetineuron* and *Lindbergia* exhibited broad ecological amplitude as these species were present in all girth classes.

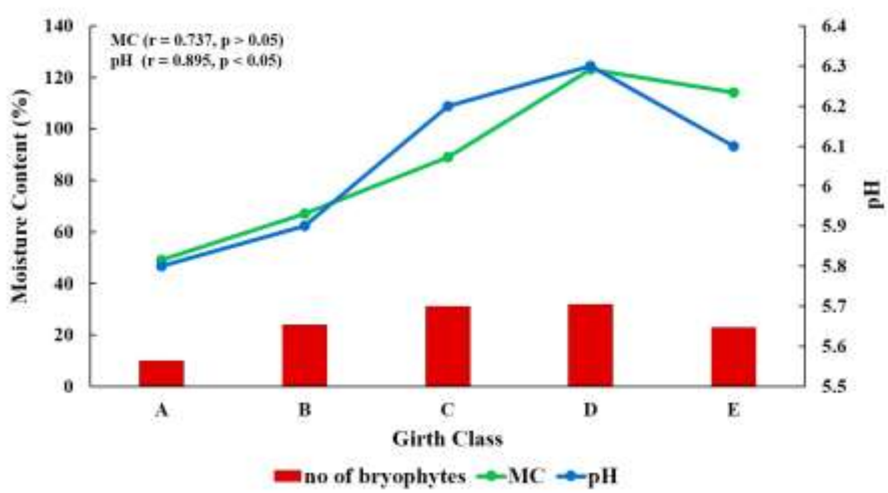

Fig. 3. Distribution of bryophyte species in relation to girth class, bark moisture content and bark pH

Comparison of the bryoflora of *P. wallichiana* with other dominant gymnosperms and angiosperms trees of this locality (Table 3) revealed that 16 species i.e., *A. serpens, A. obtusulum, B. falcatulum, B. perpinnata, C. ericoides, C. capillaceum, D. heteromalla, E. pulchellus, E. riparoides, F. bryoides* var. *schmidii, F. dilatata* subsp. *subdilatata, F. retusa, M. buchananii, P. cuspidatum, R. herbaceum* and *T. assimile* were strictly confined to the *P. wallichiana* bark and remaining 24 species were common and also present on other phorophytes. Márialigeti et al (2009) reported that epiphytic bryophytes were affected by major abiotic factors such as bark type, light, humidity etc. As bark characteristics vary among species, bryophytic species richness also vary accordingly. Among the species encountered, 8 species viz., *C. flexuosus, B. buchananii, B.*

dentatum, E. laetus, H. microdendron, L. koelzii, M. submacrocarpum and *R. divaricatifolia* exhibited broad ecological amplitude as these were present in most of the phorophytes of the locality (Table 3). Interestingly, 7 species viz. *B. aurea, C. flexuosus, D. heteromallum, F. muscicola, F. dilatata* subsp. *subdilatata, F. retusa* and *L. koelzii* were strictly epiphytic in nature. The remaining species were either epilithic (including rocks, retaining walls, stones) or ground flora species (Tewari and Pant, 1994). Index of similarity indicated maximum resemblance with *Quercus leucotrichophora* (50%) followed by *Q. floribunda* (47.5%) tree. The least similarity was recorded with *Erythrina arborescens* i.e. only 5% (Figure 4).

Table 3: Comparison of epiphytic bryoflora of *Pinus wallichiana* with other epiphytic flora of Nainital [Tewari and Pant 1994, Pande et al. 2005, Awasthi et al. 2013, Bargali et al 2014]

S.No	Bryophyte species on *Pinus wallichiana*	Phorophytes									
		PR	PO	CD	EA	AI	CT	QLE	QF	QS	QL
1.	*A. serpens*	-	-	-	-	-	-	-	-	-	-
2.	*A. minor*	-	-	-	-	-	-	+	+	+	+
3.	*A. obtusulum*	-	-	-	-	-	-	-	-	-	-
4.	*B. capitulatum*	-	+	+	-	+	-	+	+	+	-
5.	*B. buchananii*	+	-	+	-	-	+	+	+	+	+
6.	*B. falcatulum*	-	-	-	-	-	-	-	-	-	-
7.	*B. perpinnata*	-	-	-	-	-	-	-	-	-	-
8.	*B. dentatum*	-	+	-	-	+	+	+	+	+	+
9.	*B. aurea*	+	-	+	-	-	+	+	+	-	-
10.	*C. ericoides*	-	-	-	-	-	-	-	-	-	-
11.	*C. prionophyllum*	-	-	+	-	-	+	+	+	+	-
12.	*C. capillaceum*	-	-	-	-	-	-	-	-	-	-
13.	*C. flexuosus*	+	-	+	-	+	+	+	+	+	+
14.	*D. heteromalla*	-	-	-	-	-	-	-	-	-	-
15.	*D. heteromallum*	-	+	-	-	-	-	-	-	-	-
16.	*E. laetus*	-	-	-	-	+	+	+	+	+	+
17.	*E. pulchellus*	-	-	-	-	-	-	-	-	-	-
18.	*E. riparoides*	-	-	-	-	-	-	-	-	-	-
19.	*F. bryoides var. schmidii*	-	-	-	-	-	-	-	-	-	-
20.	*F. dilatata* subsp. *subdilatata*	-	-	-	-	-	-	-	-	-	-
21.	*F. muscicola*	-	+	-	-	-	-	+	+	-	-
22.	*F. retusa*	-	-	-	-	-	-	-	-	-	-
23.	*H. toccoae*	+	+	+	+	-	-	+	+	+	-
24.	*H. microdendron*	-	-	-	-	+	+	+	+	+	+
25.	*H. recurvirostrum*	-	-	-	+	-	-	-	-	-	-
26.	*H. involuta*	+	+	-	-	-	-	+	+	+	+
27.	*L. tuberculosa*	+	+	-	-	-	+	+	+	-	-
28.	*L. secundus*	+	-	+	-	-	-	+	-	-	-
29.	*L. koelzii*	+	-	-	-	+	+	+	+	+	+
30.	*M. submacrocarpum*	+	-	+	-	-	+	+	+	+	+
31.	*M. buchananii*	-	-	-	-	-	-	-	-	-	-
32.	*P. gollanii*	-	-	-	-	-	-	+	+	+	-
33.	*P. cuspidatum*	-	-	-	-	-	-	-	-	-	-
34.	*P. denticulatum*	+	+	+	-	-	-	-	-	-	-
35.	*P. russulum*	-	-	-	-	-	-	+	+	-	-
36.	*R. divaricatifolia*	-	-	-	-	+	+	+	+	+	+
37.	*R. menadensis*	-	+	-	-	-	-	-	-	-	+
38.	*R. herbaceum*	-	-	-	-	-	-	-	-	-	-
39.	*T. assimile*	-	-	-	-	-	-	-	-	-	-
40.	*T. serrulata*	+	-	+	-	-	+	+	+	+	+

Abbreviations: PR = *Pinus roxburghii;* PO = *Platanus orientalis;* CD = *Cedrus deodara*; EA= *Erythrina arborescens;* AI =

Aesculus indica; CT = *Cupressus torulosa*; QLE = *Quercus leucotrichophora*; QF = *Quercus floribunda*; QS = *Quercus semecarpifolia*; QL = *Quercus lanuginosa*

In the present study, the dominance of late successional pleurocarps indicated that, the habitat has reached at its climax vegetation and further successional change may possibly be of ferns and herbaceous vegetation. Rastorfer (1978) has reported the dominance of pleurocarpous growth habit in the wet tundra communities. Present study also reported dominance of pleurocarpous mosses (25) over acrocarpous mosses (10) indicating that bark of *P. wallichiana* provide moist habitat and climatic conditions of *P. wallichiana* forest is also moist and humid. Joshi (1993) also reported the dominance of pleurocarpous mosses in epiphytic habitats of higher altitude forests of Kumaun Himalaya. Olsen in 1917 suggested that acrocarpous mosses are pioneer species, while pleurocarpous are successional (Climax) species.

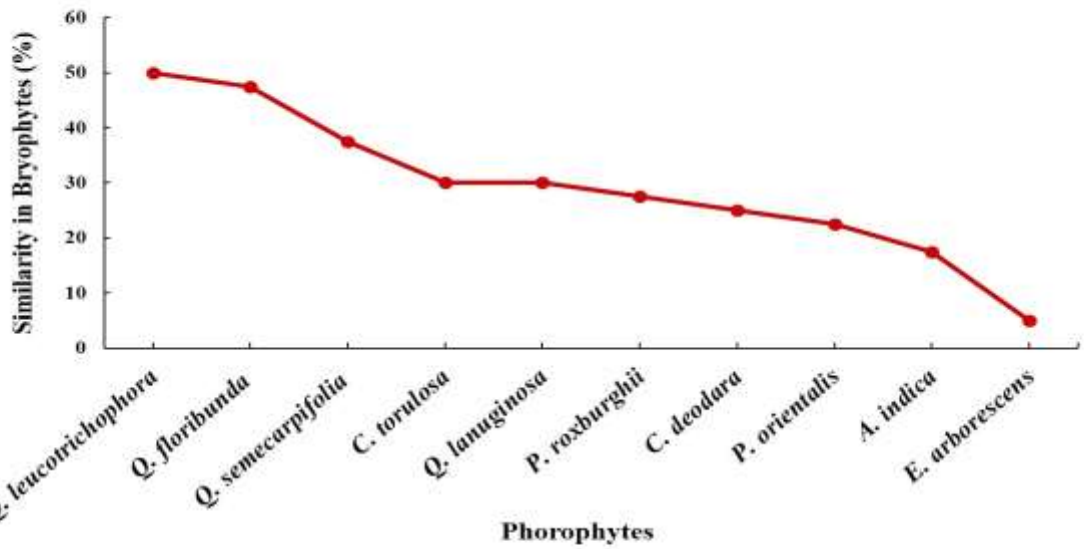

Figure 4: Similarity (%) in species composition of mosses on *P. wallichiana* trees with other epiphytic habitats of this locality (Source: Pant and Tiwari 1994; Pande et.al 2005 Awasthi et al. 2013 and Bargali et al 2014).

Conclusions

This is the first study to document epiphytic bryophyte vegetation of *P. wallichiana* from Nainital, Kumaun Himalaya, India. The number of epiphytic bryophytes recorded in the present study (40 species belonging to 23 families) was higher than other tree species of the region including different species of *Quercus*. Epiphytic bryophytes are suggested to be extremely sensitive to climatic changes and anthropogenic disturbances thus, could be used as potential indicators of forest quality and integrity. High species richness of epiphytic bryophytes in the present study indicated that *P. wallichiana* forest was less disturbed as compared to oak forest of the region. These results also indicated that bryophytes are an important component of biodiversity of forest ecosystems.

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