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An assessment of bryophyte diversity of Nagar Nigam areas at Haldwani in Kumaun region of northwest Himalaya

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Abstract

The present paper deals with an exploration of bryophytic species and communities growing on diverse habitats and localities in and around Nagar Nigam areas of Haldwani(Nainital). In all, 61 bryophyte species belonging to the 26 families including, 25 liverworts, 2 hornworts, and 34 species of mosses were recognized. As liverworts, 16 thalloid, and 9 leafy liverworts were recorded. *Riccia* species were turned out to be the dominant hepatics. Amongst mosses, 19 species were documented as dominant acrocarps followed by the 14 species of pleurocarps. Interestingly, the majority of liverworts and mosses were observed as gemmiferous. The present bryo-exploratory study aims to document and assess in time the current status of the existing bryodiversity. The naturally occurring bryophyte incorporated substrates are being frequently replaced by the excessive use of cementing material. In such man-made habitats, hardy, calcicole, bryophyte species and communities are found as the dominant colonizers.

Keywords: Acrocarpous, bryodiversity, calcicole, gemmiferous, hepatics, pleurocarpous

Introduction

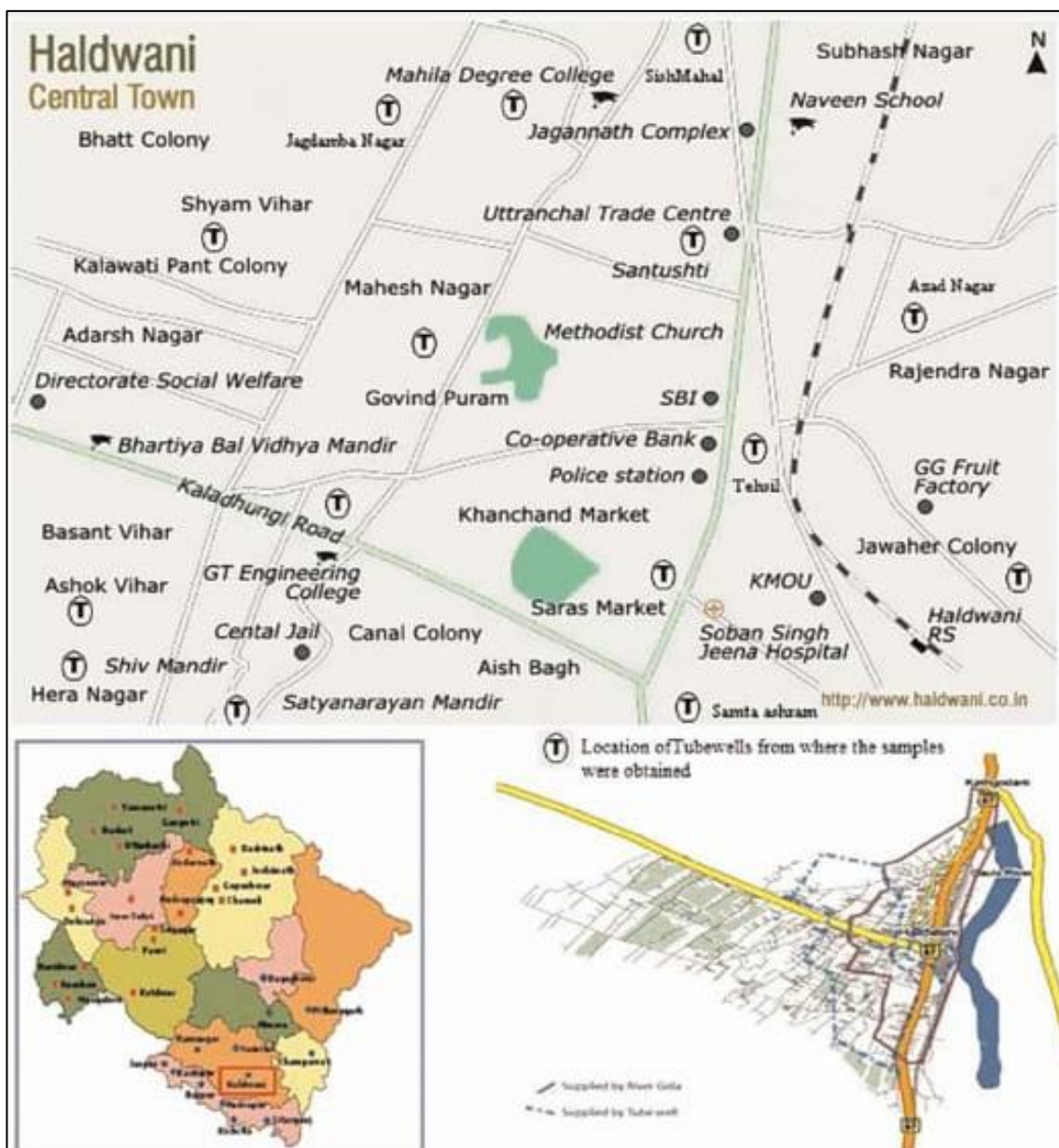
Bryophytes- a potentially bioactive green group of naturally occurring, surface-dwelling plants, constitute an important part of the Himalayan biodiversity. These poikilohydrous plants impart lush green cover on or over the variety of moisture-retaining substrates. Unfortunately, in spite of the rich bioactive potential of both liverworts and mosses, no proper attention has given in the exploration and screening of their complex bioactive composition. This may be due to their small size and difficulties in their identification. Very little/ fragmentary exploratory work is known from the Kumaon region of the North-West Himalaya. Some earlier survey and collection are known through the studies on Himalayan bryophytes made by Kashyap, 1929-1932^[12]; Chopra, 1961^[5]; Parihar 1962^[16]; Bischler *et al.*, 1994^[3]; Udar, 1976^[23]; Gangulee, 1961, 1971, 1972, 1980^[8]; Chopra and Kumar 1981^[7]; Kumar, 1985^[11]; Kanwal, 1977^[10]; Pant and Tewari, 1983^[14]; Tewari and Pant, 1982^[21], 1994^[22]; Vohra 1983^[25]; Lal, 2005^[13]; Pande *et al.*, 2005^[15]; Vashitha *et al.*, 2007^[24]; Vohra and Aziz, 2008^[26]; Tewari, 2010^[20]; Asthana and Sahu 2013^[1]; Sahu and Asthana, 2015^[17]; Singh *et al.*, 2016^[18]; Chaturvedi *et al.*, 2018^[4]; Bhandari *et al.*, 2019^[2]. The present bryoexploratory work was undertaken to document or explore the regional unexplored existing natural bryophytic wealth in and around Nagar Nigam areas of Haldwani which is under the constant grip of rapid urbanization. This study will form the firm bases for future investigations particularly, on the screening of the bioactive potential of these eco-sensitive plants.

Materials and Methods

The study site, Haldwani Nagar Nigam area is located in District Nainital, starching between 29.2183°N latitude and 79.5130°E longitude at an altitudinal range of 424-500m (Fig 1). Both liverworts and mosses collected from the diverse habitats/localities were brought to the laboratory in the sealed polyethylene bags along with some notable amount of their underlying substrates. The collected bryophyte samples were identified by observing gametophytic characters, such as thallus structure, the arrangement of leaf lobes, the structure of leaves, as well as types of vegetative propagules, and sporophytic structures including foot, seta, capsule, spores, elaters, calyptras, and structure of peristome teeth. Temporary slides were prepared by using 30% glycerine. Hardy, thalloid liverworts specimens were preserved in FAA and delicate thalli in 70% alcohol. Permanent slides were prepared by using a gum chloral mounting medium (Watson, 1955^[28]). With the help of available literature monographs, books, recent publications together with the expert advice, the bryo-specimens were identified. Field

and microphotographs of the interesting forms were also taken. The voucher specimens of both liverworts and mosses were

deposited in the Herbarium of Botany Department, I.P.G.P.G.G.C.C, Haldwani, (Nainital).



*Source: google map

Fig 1: Map showing the study areas of Haldwani Nagar Nigam (Uttarakhand).

Observations

Categorization of liverworts, hornworts and mosses is based on the classification given by Goffinet et.al (2009) [9], Stotler et.al

(2009) [6] and Renzaglia et.al.(2009) [19]. Familywise listing of the plants with habitat details is being mentioned.(Table1)

Table 1: List of Bryophytes recorded from Nagar Nigam areas of Haldwani.

A.	Thalloid liverworts				
1	<i>Riccia billardieri</i> Mont. & Nees ex Gottsche.	Ricciaceae	Haldwani, Katghariya, 424-500m	Incomplete rosettes	On cultivated soil
2	<i>Riccia crispatula</i> Mitt.	Ricciaceae	Nawabi Road, Haldwani, 424-500m	Complete rosettes,	On garden soil.
3	<i>Riccia cruciata</i> Kash.	Ricciaceae	Nawabi road, Katgharia, Fatehpur, Lamachaur, Malli Bamouri, Kathgodam, 424-500m	Thick rosette	On moist soil of fallow rice fields.
4	<i>Riccia crystallina</i> L.	Ricciaceae	Fatehpur, on way to kaladhungi. 424-500m	Thick rosette,	On shady moist soil.
5	<i>Riccia discolor</i> Lehm. & Lindenb.	Ricciaceae	Nawabi Road, on way to Ranibagh, Fatehpur, on way to Kaladhungi, 424-500m	Thick rosette,	On moist sloppy sites, and the garden soil.
6	<i>Riccia frostii</i> Austin	Ricciaceae	Nawabi Road, Katgharia, Fatehpur, Lamachaur, 424-500m	Thick rosette,	On moist soil of fallow rice fields.
7	<i>Riccia gangetica</i> Ahmad	Ricciaceae	Laldath, 424-500m	Complete rosettes	On cultivated soil.

8	<i>Riccia hirta</i> (Austin) Underw.	Ricciaceae	Nawabi road, Katgharia, Fatehpur, Lamachaur, on way to Kaladungi. 424-500m	Thick rosette,	On shady moist retaining walls.
9	<i>Riccia pathankotensis</i> Kash.	Ricciaceae	Uchapul. 424-500m	Rosettes in dense patches,	On exposed slopes.
10	<i>Riccia plana</i> Taylor	Ricciaceae	Laldath, 424-500m	Forms intermixed overlapping rosette	On cultivated crop fields.
11	<i>Marchantia polymorpha</i> L.	Marchantiaceae	Nawabi road, Katgharia, Fatehpur, on way to Kaladungi. 424-500m	Thick patches	On moist sloppy muddy gules, wall & nalies.
12	<i>Marchantia papillata</i> Raddi	Marchantiaceae	Nawabi road, Katgharia, Donariya Fatehpur, on way to Kaladungi. 424-500m	Thick patches,	Along moist muddy gules, wall & nalies.
13	<i>Cyathodium tuberosum</i> Kash.	Cyathodiaceae	Nawabi road, Katgharia, Fatehpur, Lamachaur, on way to kaladungi. 424-500m	Thick patches or layer,	On shady moist walls and bricks.
14	<i>Targionia hypophylla</i> L.	Cyathodiaceae	Nawabi road, Katgharia, Fatehpur, Lamachaur, Kusumkhera, on way to kaladungi. 424-500m	Forming overlapping small patch	Humus capped stony walls.
15	<i>Asterella wallichiana</i> (lehm.) Grolle	Aytoniaceae	Nawabi road, Katgharia, Fatehpur, Lamachaur, on way to kaladungi. 424-500m	Thick patches,	On shady moist cemented walls.
16	<i>Plagiochasma appendiculatum</i> Lehm. & Lindenb.	Aytoniaceae	Nawabi road, Katgharia, Fatehpur, 424-500m	Large thick patches, walls.	Common on retaining walls.
B. Leafy Liverworts					
17	<i>Cololejeunia himalayensis</i> (Pande & R.N.Mishra) R.M.Schust.	Lejeuneceae	On way to Kaladungi, (424-500m)	Thick Patch	Epiphytic on the mango tree bark.
18	<i>Lejeunea tuberculosa</i> steph.	Lejeuneceae	On way to Rani bagh. (424-500m)	Yellowish, green patches,	Epiphytic on the mango tree bark
19	<i>Radula complanata</i> (L.) Dum.	Radulaceae	On way to Katghariya (424-500m)	Forms low patches,	On the bark of jackfruit and mango trees.
20	<i>Plagiochila denticulata</i> Mitt.	Plagiochiaceae	Damuwadhunga (424-500m)	Form patches,	On the moist walls.
21	<i>Frullania squarrosa</i> Gottsche	Frullaniaceae	Katghariya, on way to Ranibagh (424-500m)	Extensive mats,	Epiphytic on mango tree bark
22	<i>Frullania muscicola</i> Steph.	Frullaniaceae	Damuwadhunga. (424-500m)	Extensive mats	Epiphytic on Sal tree trunk.
23	<i>Chiloscyphus polyanthos</i> (L.) Corda	Herpenthaceae	On way to Rani bagh. (424-500m)	Lose prostrate mats,	On the moist stony wall.
24	<i>Lophocolea bidenta</i> (L.) Dum.	Herpenthaceae	Kathgodam (424-500m)	Intermixing patch	On humus capped moist soil.
25	<i>Jungermannia gollanii</i> Steph.	Jungermanniaceae	On way to Ranibagh. (424-500m)	Intermixed ramifying layer,	Epiphytic on the mango tree bark.
C. Hornworts					
26	<i>Anthoceros erectus</i> Kash.	Anthocerotaceae	Katghariya, on way to Ranibagh. (424-500m)	Dense cluster,	On damp soil of gules.
27	<i>Notothylas levieri</i> Schiff.	Notothylaceae	Old ITI, Talli Bamouri, Malli Bamouri, Dhar Bithoria (424-500m)	Light-yellow green rosette,	On trampled soil, as well as on animal hoop prints.
D. Mosses					
28	<i>Fissidens bryoides</i> Hedw.	Fissidentaceae	Katghariya, on way to Ranibagh. (424-500m)	Small patches,	Epiphytic on the mango tree trunk.
29	<i>Fissidens ceylonensis</i> Doz. & Molke	Fissidentaceae	Damuwadhunga (424-500m)	Small patches,	On the bark of sal tree trunk.
30	<i>Fissidens minutus</i> Thwaites & Mitt.	Fissidentaceae	Kusumkhera, Uchapul, (424-500m)	Small patches,	Epiphytic on the mango tree trunk.
31	<i>Fissidens polysetulus</i> Gang.	Fissidentaceae	Fatehpur, (424-500m)	Small patches,	Epiphytic on mango tree trunk.
32	<i>Fissidens strictus</i> C.Muell.	Fissidentaceae	Katghariya, on way to Ranibagh. (424-500m)	Small patches,	Epiphytic on mango tree trunk.
33	<i>Fissidens sylvaticus</i> Griff.	Fissidentaceae	Katghariya, on way to Ranibagh. (424-500m)	form tufts	On termite mound soil.
34	<i>Fissidens taxifolius</i> Hedw.	Fissidentaceae	Katghariya, on way to Ranibagh. (424-500m)	Small patches,	On calcareous soil.
35	<i>Brothera leana</i> (Sull.) C.Muell.	Dicranaceae	Katghariya, Fatehpur, on way to Ranibagh. (424-500m)	Cushion,	On the rotten tree trunk of jackfruit.
36	<i>Anoetangium thomsonii</i> Mitt.	Pottiaceae	Katghariya, Fatehpur, on way to Ranibagh. (424-500m)	Densely tufted,	On the Cemented wall.
37	<i>Didymodon recurvus</i> (Griff.) Broth.	Pottiaceae	Katghariya, Fatehpur, on way to Ranibagh. (424-500m)	Densely tufted,	On the moist retaining wall.
38	<i>Hydrogonium amplexifolium</i> (Mitt) chen	Pottiaceae	Katghariya, Fatehpur, on way to Ranibagh. (424-500m)	Densely tufted	On moist soil of retaining walls.
39	<i>Hyophila involuta</i> (Hook.) Jaeg.	Pottiaceae	Common in all the study sites.	Densely tufted	Common on cemented walls, bricks, and brickworks.

40	<i>Entosthodon wallichii</i> Mitt.	Funariaceae	Katghariya, Fatehpur, on way to Ranibagh. (424-500m)	densely tufted	Epiphytic on mango tree bark.
41	<i>Funaria hygrometrica</i> Hedw.	Funariaceae	Adarsh Nagar, Katghariya, Fatehpur, on way to Ranibagh. (424-500m)	loosely to closely tufted,	Pioneer of a newly constructed retaining wall.
42	<i>Physcomitium cyathicarpum</i> Mitt.	Funariaceae	Common on cultivated soil in all the study sites.(424-500m)	wide patches,	Abundant on cultivated soil.
43	<i>Bryum argenteum</i> Hedw.	Bryaceae	Common on all the study sites. (424-500m)	Densely tufted,	On moist walls, Countors of the footpath.
44	<i>Bryum bicolor</i> Dicks.	Bryaceae	On way to Ranibagh, Haldwani, (424-500m)	Densely tufted,	On slopy soil.
45	<i>Bryum capillare</i> L.	Bryaceae	Haldwani, Kathgodam, Fatehpur, (424-500m)	Densely tufted,	On humus capped soil, roof tops.
46	<i>Bryum rubens</i> Mitt.	Bryaceae	Nawabi road, Thar Bithoria,(424-500m)	Thin turf,	Near the areas of seepage.
47	<i>Pohlia annotina</i> (Hedw.)Lindb.	Bryaceae	Katghariya, Fatehpur, on way to kaladungi.. (424-500m)	Shiny tufts	Moist sides of cemented gules.
48	<i>Brachythecium buchananii</i> (Hook.) A.Jaeg.	Brachytheciaceae	Katghariya, on way to kaladungi, (424-500m)	Glossy plants in dense mats,	On the mango tree trunk.
49	<i>Brachythecium pulmosum</i> (Hedw.) B.S.G.	Brachytheciaceae	Damuwadhunga, on way to Ranibagh. (424-500m)	Glossy plants in dense mats,	Epiphytic on Sal tree trunk.
50	<i>Rhynchostegium vagans</i> Jaeg.	Brachytheciaceae	Fatehpur, Dhar Bithoria, on way to Kaladungi, Katghariya. (424-500m)	Glossy plants in lax tufts,	On shaded side of muddy gules.
51	<i>Entodon plicatus</i> C. Muell.	Entodontaceae	Haldwani,Lamachaur, (424-500m)	Glossy plants forming tufts,	On the moist stony wall.
52	<i>Erythrodonium julaceum</i> (Schieo.)Par.	Entodontaceae	Laldath, Fatehpur, Kusumkhera, Haldwani, (424-500m)	Dense tufts.	Epiphytic on mango tree bark.
53	<i>Trachyphyllum inflexum</i> (Harv.) A. Gepp.	Pterigynandraceae	Damuwadhunga, on way to Ranibagh. (424-500m)	Extensive thin mats	Epiphytic on sal tree trunk.
54	<i>Plagiothecium denticulatum</i> (Hedw.) B.S.G	Plagiotheciaceae	Katghariya, Fatehpur. (424-500m)	Shiny flattened tufts,	On moist muddy gules.
55	<i>Stereophyllum tavoyense</i> (Hook.) Jaeg.	Plagiotheciaceae	Haldwani, old ITI, Fatehpur, on way to kaladungi(424-500m)..	Flat mats,	Epiphyte on mango tree bark.
56	<i>Isopterygium distichaceum</i> (Mitt.) Jaeg.	Hypnaceae	Damuwadhunga. (424-500m)	Flat mats,	On the walls of muddy gules.
57	<i>Taxiphyllum taxirameum</i> (Mitt.) M.Fleisch	Hypnaceae	On way to Ranibagh. (424-500m)	Extensive but low tufts,	On moist soil.
58	<i>Gymnostomiella vernicosa</i> (Hook.) Fleisch	Splachanaceae	Nawabi Road, Adarsh Nagar, on way to kaladungi, (424-500m)	Small patches or thick tufts,	On moist shaded sides of retaining walls.
59	<i>Erpodium maniferae</i> C.Muell	Erpodiaceae	Haldwani, Kathgodam, Lamachaur, on way to Rani bagh. (424-500m)	Loose mats,	Constant epiphyte of the mango tree trunk.
60	<i>Thuidium tamariscellum</i> (C.Muell.) Bosch.	Thuidiaceae	Damuwadhunga. (424-500m)	Intermixed perennial patches,	Epiphytic on the Sal tree base.
61	<i>Neckeropsis exserta</i> (Schwaegr.) Broth.	Neckeraceae	Damuwadhunga. (424-500m)	Pendant	Epiphytic on the Sal tree trunk.

Results and Discussion

During the present study, In all, 61 bryophytes species belonging to 26 families were recognized based on the collection made from the different habitats and localities of Haldwani Nagar Nigam areas. Out of the total 61 bryospecies, 16 thalloid, 9 leafy liverworts, 2 hornworts, and 34 mosses were included (Fig 2). Amongst thalloid liverworts, both winter and rainy season species of *Riccia* (*viz.*, *R. cruciata*, *R. hirta*, *R. frostii*, *R. crystalliana*, and *R. discolor*) were found dominant followed by the species of *Asterella*, *Marchantia* and *Plagiochasma*. Profusely gemmiferous patches of *Marchantia papillata* and *M. polymorpha* were found colonizing on moist muddy sloppy walls as well as along damp, old cemented gules and nallies. *Plagiochasma appendiculatum*, one of the most common and hardy thalloid liverwort of this region is known to grow almost on a variety of substrates. During the rainy season, characteristic patches of rotten fish-like smell emitting thalloid liverwort *Asterella wallichiana* were notable on moist cementing materials of retaining walls, gules, and nallies. It is worth to highlight that during rainy season, the yellowish-green, pungent smell emitting male thalli of *Cyathodium*

tuberosum were found spreading almost on the moist, damp, and low light receiving habitats.

The characteristic occurrence of a non-columellate species of *Notothylus* (*N. levierei*) was noticeable particularly on shady damp trampled soil as well as the areas of animal hoops prints on cultivated fields.

Out of 34 mosses, belonging to 14 families, fissidentaceae is turned out to be the dominant moss family followed by pottiaceae as co-dominant. The most widely spreading gemmiferous pottiaceous moss, *Semibarbula orientalis* along with *Hyophila involuta* was found as constant associates. Another noteworthy observation was the frequent occurrence of a silver moss *B. argenteum*, in the area of high trampling activities all along the footpath regions. This nitrophilous, gemmiferous moss together with other associates *viz.*, *Semibarbula*, *Hyophila*, and *Funaria hygrometrica* was observed to form the green line by following the contours of brickworks on the shady, moist, damp footpath areas. It is important to highlight that during the winter season, the cultivated, as well as fallow fields of the Bhabhar region, support the luxuriant growth of an epimeral moss *Physcomitrium cyathicarpum*. Unfortunately, with each

passing year, the population and spread of this moss *P.cyathicarpum* are reducing due to the rapid urbanization, resulting in shrinkage of the agricultural land habitats. Frequent uses of weedicides, fungicides, herbicides, insecticides together with excessive use of chemical fertilizers, all are putting adverse effects on the spread and growth of this acrocarpous moss.

The bryophyte incorporated natural habitats mainly as croplands, nalies, gules, and cultivated fields, mango orchards of this area are under the influence of urbanization.

Consequently, the bryophytic spread and luxuriance can only be seen in certain man-made substrates such as cementing materials and brickworks with the colonization of the hardy liverworts and moss species. The present study will provide baseline data for future scientific investigations of these eco-sensitive organisms. This study will also provide an urgent need to document and conserved these bioactively potential plants of our regional biodiversity, which is under the constant pressure of anthropogenic activities.

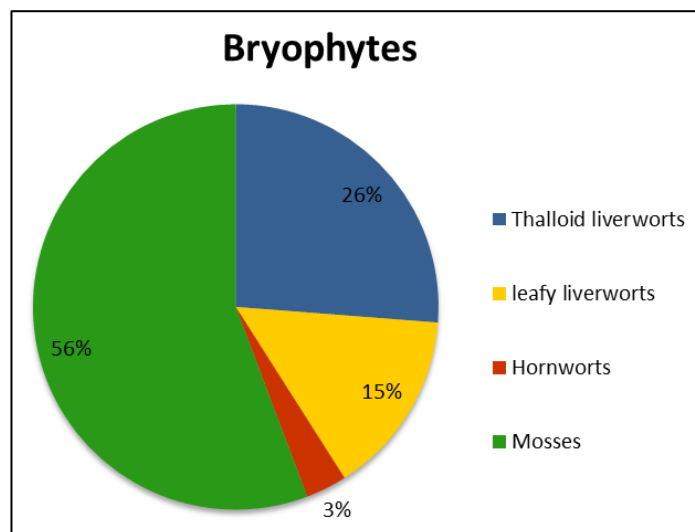


Fig 2: Pie chart showing the present status of the bryophytic vegetation Nagar Nigam areas of Haldwani.



Fig 1: *Riccia hirta* colonization on the cemented wall.



Fig 3: Fertile patch of *Plagiochasma appendiculatum* on the retaining walls.



Fig 2: Gemmiferous (arrow) patch of *Marchantia polymorpha* on moist muddy substrates.



Fig 4: Yellowish-green male thalli of *Cyathodium tuberosum* forming thin layer on the shady, moist side of retaining walls.



Fig 5: *Notothylus liverii* with horizontal sporogonia (arrow) growing in association with *Riccia* and *Semibabula* on the trampled field.



Fig 8: Dominant moss community of *Semibarbula orientalis*, *Hydrogonium amplexifolium*, *Didymodon recurvus* and *Hyophila involuta* on cementing material of retaining walls.



Fig 6: *Fissidens taxifolius* on calcareous habitat.



Fig 9: Common moss, *Hyophila involuta* on cemented walls, bricks, and brickworks.



Fig 7: Copiously fruiting population of an ephemeral moss, *Physcomitrium cyathicarpum* on cultivated soil.

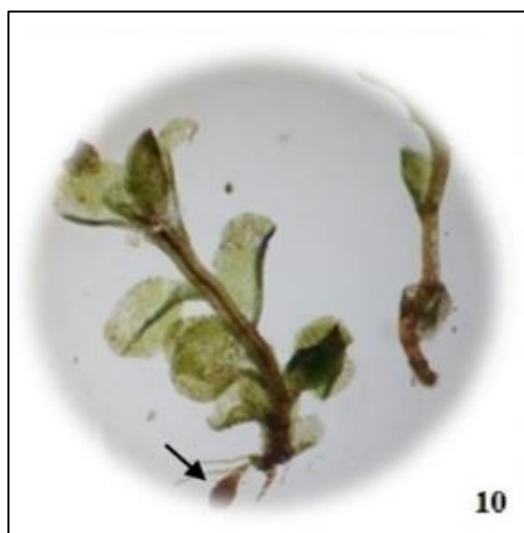


Fig 10: Splachnaceae, gemmiferous (arrow) moss, *Gymnostomiella vernicosa* shoots.



Fig 11: Silver moss, *Bryum argenteum* thriving on counters of the brickworks.



Fig 12: *Erpodium mangiferae*- a constant epiphytic moss of Mango tree bark.

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