Manual of Liverworts & Hornworts of Himachal Pradesh, India

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Front Cover : *Asterella wallichiana* (Lehm. & Lindenb.) Grolle., *Aneura pinguis* (L.) Dumort., *Ptychanthus striatus* (Lehm. & Lindenb.) Nees., *Marchantia papillata* Raddi subsp. grossibarba Bischl.

Back Cover : *Phaeoceros laevis* (L.) Prosk.

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PREFACE

Kashyap (1929) and Kashyap and Chopra's (1932) landmark publication on liverworts of Western Himalaya and the Punjab plain included 87 species from Himachal Pradesh. For long these two volumes remained the only floristic treatise on the liverworts and hornworts in India and served as excellent first-hand identification manual for these plants, for the beginners as well as the experienced bryologists, of not only this region but the country as a whole. With the changing concepts in the taxonomy of a number of families and genera over the period of time, however, only 35 species of these remain nomenclaturally valid today. Advances in bryological research since Kasyap's time has considerably enhanced our knowledge of the Indian liverworts and hornworts in general and those of Himachal Pradesh in particular and we now have much enlarged inventory of these plants recorded to be occurring in the State. But, apart from our recent publication on the liverworts and hornworts of the Great Himalayan national park – a World Heritage (Natural) site, in the Kullu district dealing with 104 taxa, there is no detailed flora that readily helps in identification of these plants. This Manual is, therefore, an attempt to fill this significant void.

The manual deals with 142 species, subspecies, varieties and forma belonging to 51 genera and 35 families of liverworts and 10 species belonging to five genera and two families of hornworts so far recorded from the State of Himachal Pradesh. It provides a brief account of different vegetation types met within the State with associated major liverwort and hornwort taxa; methodology for the collection, preservation and preparation of samples of liverworts and hornworts for study; salient morphological features of traditionally recognised orders of liverworts and hornworts; a conspectus of the taxa recorded from the State; identification key to the genera and isolated species followed by detailed description for each genus, keys to the species and the infraspecific taxa under a genus, their nomenclature, including basionyms and synonyms if any, and distribution within the State and the country, and is supported by two maps and 42 figures comprising illustrations and colour as well as black & white photographs featuring habit and key characters

of the taxa. At the end, a glossary of technical terms has also been provided for the benefit of different section of its users. The manual provides comprehensive baseline information on the diversity and distribution of liverworts and hornworts in Himachal Pradesh and it is hoped that it will serve as a useful guide for the students of botany for identification of these plants within the State and elsewhere.

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Introduction

The liverworts, or the Marchantiophyta, and hornworts, or the Anthocerotophyta, represent an interesting yet small group of nonvascular, flowerless, spore-producing land plants. They are autotrophic (except *Cryptothallus* – a non-photosynthetic, parasitic liverwort) in nature and have heteromorphic life cycle dominated by ecologically persistent and photosynthetically independent gametophytic, or the haploid phase. The sporophyte, or the diploid phase, is comparatively short-lived and fully (in case of liverworts) or partially (in case of hornworts) dependent on the gametophyte. In case of hornworts the gametophytes are always thallose, whereas in liverworts it may either be flattened and thalloid or foliose with the plant body differentiated into stem or '*caulis*' and leaves or '*phyllid*'. However, the leaves in leafy liverworts are always arranged in rows and not spirally like that in mosses.

The liverworts and hornworts occur worldwide, though most commonly in the tropical regions. They may be terricolous (*Solenostoma, Marchantia, Dumortiera, Notothylas, Phaeoceros, Anthoceros,* etc.), or corticolous growing on tree trunks (*Frullania, Porella, Plagiochila, Lejeunea,* etc.), or foliicolous growing on upper surface of leaves (*Cololejeunea, Drepanolejeunea, Leptolejeunea,* etc.). Sometimes they are aquatic as well, both floating (*Riccia fluitans* and *Ricciocarpus natans*) and benthic (species of *Riella*). They grow up to 5000 m above the mean sea level in the Himalaya, showing their best manifestation between 1000-3000 m altitudes.

Traditionally they are known as plants of little importance, although they have numerous economic values. They play an important role in terrestrial ecosystem, such as modification of habitat, nutrient cycling and the maintenance of nutrient status of the soil and primary production. In short, they 'make the habitat habitable' for other group of plants. Besides, high concentration of flavonoids and terpenoids in large number of liverworts make them natural antibiotics, fungicides and pesticides. A number of them, like species of *Chiloscyphus, Conocephalum, Plagiochasma, Reboulia, Diplopyllum, Jamesoniella, Scapania,* etc., have considerable pharmaceutical potential. They, however, still remain a little known group of plants in India, not only because of cryptic nature of plants which easily escape the attention of untrained eyes in the field, but also the lack of general interest among the students of botany leading to taxonomic impediments.

The taxonomic and floristic studies on Indian liverworts began with the publication of Lehman and Lindenberg (1832) on some liverworts of India and Nepal, followed subsequently by some valuable contribution by a number of European botanists. Mitten's (1861) '*Hepaticae Indiae Orientalis*' is perhaps the first extensive list of liverworts of this subcontinent. He listed 39 genera and 205 species of hepatics which also includes 16 species from the Western Himalaya. Stephani (1900–1924) while dealing with hepatic flora of the world in his '*Species Hepaticarum*' described many species from India, including a few from the Western Himalaya. Prof. Kashyap was the first Indian hepaticologist who made notable contribution in this field and his monumental work *'Liverworts of the Western Himalayas and the Panjab Plain',* published in two volumes (Kashyap, 1929; Kashyap & Chopra, 1932), deals with 161 species of liverworts and hornworts, including four new genera and 51 new species instituted by him. Since then, Indian Hepaticology has made notable progress (see Chopra, 1943; Pande, 1958; Parihar 1961–1962; Srivastava, 1964; Kachroo, 1969, 1970a,b, 1973; Srivastava & Udar, 1975, 1975a, 1976; Udar, 1976; Kachroo *et al.*, 1977; Asthana & Srivastava, 1991; Sharma & Srivastava, 1993; Srivastava, 1994; Parihar *et al.*, 1994; Srivastava & Dixit, 1996; Singh, 1997, 2002; Srivastava & Srivastava, 2002; Asthana & Srivastava, 2003; Manju *et al.*, 2005; Chaudhary *et al.*, 2005; Rawat & Srivastava, 2007; Singh & Nath, 2007; Manju *et al.*, 2008; Singh *et al.*, 2008; Singh & Singh, 2009, 2010; Daniels, 2010; Singh *et al.*, 2010; Dey & Singh, 2012; Singh & Barbhuiya, 2012) with considerable contributions from European, Japanese and Chinese bryologists as well.

According to Singh (2001) the liverworts and hornworts of the country comprised *ca* 850 species, belonging to 140 genera and 52 families, of which 38 species belonged to hornworts and the rest to the liverworts. Subsequent to this publication (Singh, 2001), nearly 100 species have been added to the Indian liverwort flora from different schools of Bryology within and outside the country (see also Sanjappa & Singh, 2008, 2009, 2010; Singh & Singh, 2011; Singh *et al.*, 2012, 2013; Singh & Dash, 2014). The Himalayas, Western Ghats and the Andaman & Nicobar Islands, with abundant precipitation and high humidity, are the major centers of liverwort and hornwort diversity in India as compared to the large plains stretching over greater part of the country. Presently, it is estimated that the Western Himalaya (Jammu & Kashmir, Himachal Pradesh and Uttarakhand) harbours about 250 taxa of liverworts and hornworts, including the three globally threatened liverworts, viz. *Aitchisoniella* Kashyap, *Stephensoneilla* Kashyap and *Sewardiella* Kashyap.

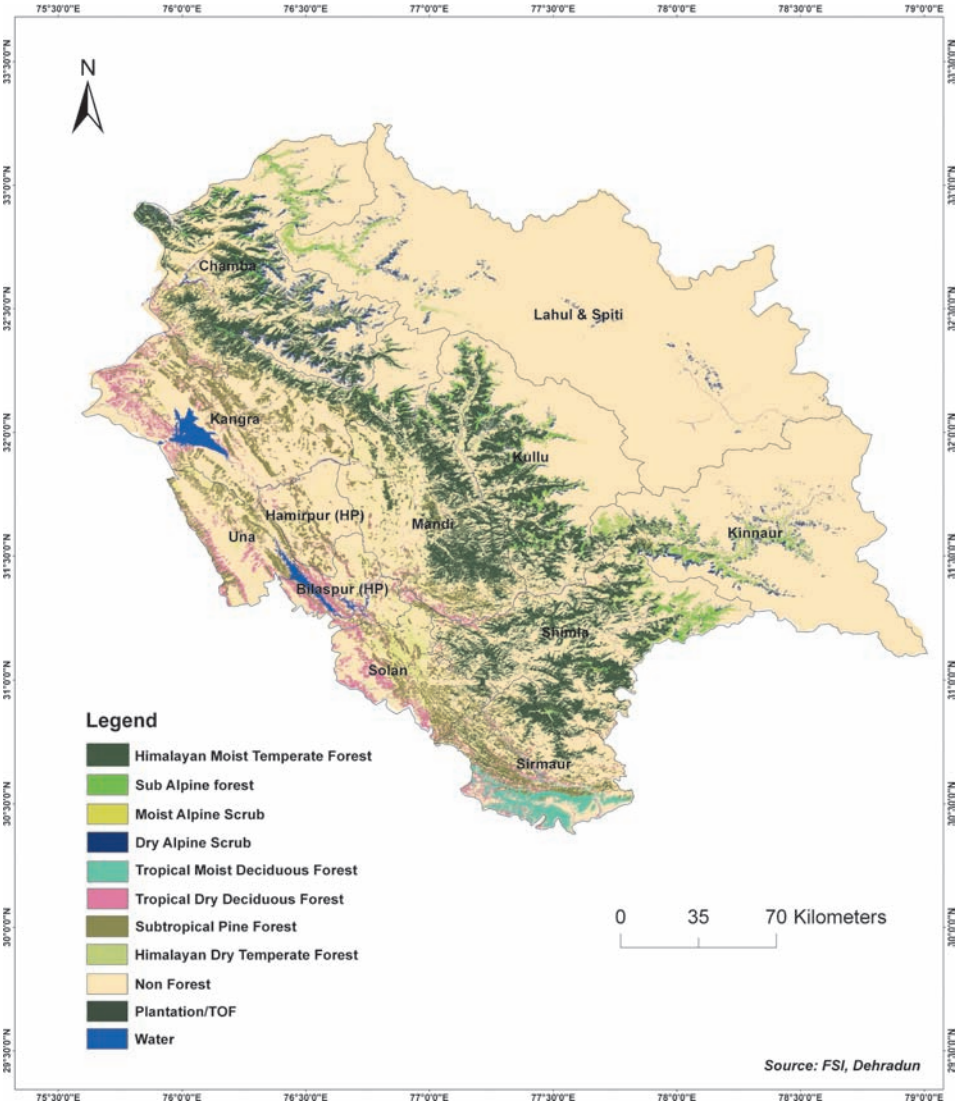
The State of Himachal Pradesh is a green pearl nestled in the Western Himalayan mountain ranges with the majestic, perpetually snow-clad peaks presenting breathtaking panoramic view. Sprawling over an area of *ca* 55,673 sq. km along the Indus – Sutlej river systems, it is located between 30° 22' 40"– 33°12' 20" N latitudes 75° 45' 55"–79° 04' 20" E longitudes. It is surrounded by Jammu & Kashmir in North, Punjab in the West and South-west, Haryana and Uttarakhand in the South-east and the China in the East (Map. 1). The State presents a deeply dissected topography and complex geological structure with the altitudes ranging from 350–6,975 m above mean sea level. It harbours a rich temperate flora in subtropical latitudes.

Map 1. Map of Himachal Pradesh

The Himachal Pradesh supports 38 forest subtypes referable to Champion and Seth's (1968) classification belonging to eight major forest types, viz. (i) tropical moist deciduous, (ii) tropical dry deciduous, (iii) subtropical Pine, (iv) Himalayan moist temperate, (v) Himalayan dry temperate, (vi) subalpine

forests, (vii) moist alpine scrubs, and (viii) dry alpine scrubs (Anon., 2011) (Map. 2). Chowdhery (1999), however, broadly divided the vegetation of the State into five types, viz. (i) tropical, (ii) subtropical, (iii) temperate, (iv) subalpine and (v) Alpine.

Tropical vegetation is mainly referable to two subtypes, (i) tropical moist deciduous and (ii) tropical dry deciduous forests. These are distributed in the



Map 2. Forest type map of Himachal Pradesh

lower altitudes occupying Shivalik hills or lower montane zone ascending up to 1000 m and predominated by *Shorea robusta* (Sal). Other associated tree species include *Anogeissus latifolia*, *Aegle marmelos*, *Albizia procera*, *Buchanania lanzan*, *Bauhinia* spp., *Bombax ceiba*, *Ehretia laevis*, *Terminalia alata*, *T. tomentosa*, *Toona ciliata*, *Mangifera indica*, *Phyllanthus emblica*, *Syzygium cumini*, *Dalbergia sissoo*, *Lannea coromandelica*, *Mallotus philippensis*, etc. The thorny elements in these forests are represented by species of *Acacia*, *Balanites*, *Capparis*, *Carissa*, *Ziziphus*, etc. The common liverworts associated with such vegetation are *Marchantia papillata* subsp. *grossibarba*, *M. paleacea*, *Asterella wallichiana*, *Mannia indica*, *Plagiochasma appendiculatum*, *Riccia pathankotensis*, *R. discolor*, *Aneura pinguis*, etc.

Subtropical vegetation in the state is chiefly represented by subtropical Pine forests formed by *Pinus roxburghii* (Chir Pine) dominating the altitudes from 1000-1800 m. However, patches of both, subtropical evergreen and subtropical dry deciduous forests are visible throughout hilly tarrain from Chamba to Sirmaur. Common lignaeous species in this zone include *Olea cuspidata*, *Pistacia* spp., *Rhus* spp., *Zanthoxylum armatum*, *Nyctanthes arbor-tristis*, *Murraya koenigii*, etc. This zone provides considerable congenial conditions for luxurious growth of thallose liverworts and hornworts. The species like *Dumortiera hirsuta*, *Conocephalum conicum*, *Targionia hypophylla*, *T. indica*, *Cryptomitrium himalayense*, *Asterella khasiana*, *A. mussuriensis* subsp. *mussuriensis*, *Athalamia pinguis*, *Blasia pusilla*, *Pellia endiviifolia*, *Anthoceros erectus*, *Phaeoceros himalayensis*, *P. laevis*, *Notothylas himalayensis* can be seen commonly growing here. Among the leafy liverworts, the species like *Porella plumosa, P. caespitans, P. chinensis, P. obtusata* subsp. *macroloba, Frullania* spp., *Ptychanthus striatus* are commonly found here.

Temperate forests are the most dominating vegetation type occurring throughout the State with nearly 45 per cent of the forests referable to this category. These are broadly divided into Himalayan moist temperate forest, and Himalayan dry temperate forests. Various subcategories of moist temperate forests are observed along altitudinal gradient based on dominant species such as Ban oak (*Quercus leucotrichophora*) between 1800-2300 m, Moru oak (*Quercus dilatata*) between 2000-2500 m, moist deodar (*Cedrus deodara*) forests between 1700-2500 m, conifer and western mixed conifer forests (*Abies spectabilis*, *Abies pindrow, Picea smithiana*, etc.) between 2200-2800 m, Kharsu oak (*Quercus semecarpifolia*) between 2400-3300 m and moist deciduous (broad-leaved) forests (*Acer* spp., *Alnus nitida, Ulmus wallichiana, Aesculus indica, Betula alnoides, Celtis australis, Ilex dipyrena, Euonymus* spp., *Prunus cornuta, Lyonia ovalifolia, Rhododendron*

arboreum, etc.) between 2200-3200 m (Chowdhery, 1999). Similarly, western Himalayan dry temperate vegetation of Himachal Pradesh is formed by dry chilgoza pine (*Pinus gerardiana* - 2000-3500 m) forests, dry deodar (*Cedrus deodara* – 2100-3200 m) forests and mixed forests of conifers and broad-leaved species (*Quercus-Ilex-Pinus gerardiana* – 2000-2400 m). In these forests, the liverworts like *Cyathodium tuberosum*, *C. aureonitans, Targionia hypophylla, T. indica*, *Reboulia hemisphaerica, Wiesnerella denudata*, *Aneura pinguis*, *Fossombronia kashyapii*, *Blasia pusilla*, *Calycularia crispula*, *Pellia endiviifolia*, *Riccardia levieri*, *Metzgeria consanguinea*, *M. lindbergii*, *Frullania ericoides*, *F. muscicola*, *F. retusa* var. *retusa*, *Chiloscyphus* spp., *Lophocolea minor*, *Plagiochila* spp., *Porella* spp., *Heteroscyphus* spp., *Radula complanata, R. grandifolia, R. lindbergiana, Metacalypogiea alternifolia*, *Solenostoma infusca*, *Scapania ferruginea*, *S. verrucosa*, *Trocholejeunea sandvicensis*, etc. and hornworts *Anthoceros bharadwajii*, *Phaeoceros himalayensis*, *P. laevis*, etc. are common.

Subalpine forests of conifers and broad-leaved species occupy altitudinal zone of 2800-3300m. Dominant conifer species include *Cedrus deodara, Pinus wallichiana, Picea smithiana*, *Pinus gerardiana*, *Abies pindrow* and *A. spectabilis*, whereas broad-leaved species are represented by *Quercus semecarpifolia*, *Acer* spp., *Alnus nidita*, *Corylus jacquemontii*, *Betula alnoides, B. utilis*, *Sorbus* spp., etc. Conifererous forests are either of pure type dominated by a single species or of western mixed confer type. High altitude fir (*Abies spectabilis*) forests are seen along Tos nullah in Parvati Valley. Conifers and broad-leaved species sometimes get intermixed forming mixed forests such as 'Birch-Fir' forest at Jalori pass in Kullu district, where dense growth of *Betula utilis* and *Quercus semecarpifolia* is intermixed with *Abies spectabilis* (Dhaliwal & Sharma, 1999). These are sometimes associated with broad-leaved species which occupy the gap areas or gullies on slopes. The commonly occurring liverworts in this zone are *Blepharostoma trichophyllum*, *Syzygiella autumnalis*, *Scapania ferruginea*, *Geocalyx graveolens*, *Plagiochila elegans*, *P. nepalensis*, *P. retusa*, *Radula grandifolia, R. obscura*, *Porella campylophylla* var. *campylophylla*, *P. chinensis* var. *chinensis*, *P. platyphylla*, *Frullania ericoides*, *Calycularia crispula*, *Blasia pusilla*, *Apometzgeria pubescens*, *Asterella khasyana*, *Cryptomitrium himalayense*, *Plagiochasma pterospermum*, *Sauteria spongiosa*, *Marchantia paleacea*, *M. papillata* subsp. *grossibarba*, *Riccia beyrichiana*, etc., with only *Phaeoceros laevis* occasionally representing the hornworts.

Alpine vegetation of the state can be subcategorized into (i) alpine forests, (ii) alpine scrubs, (iii) alpine meadows and (iv) cold deserts. Extended from 3000

to 3600 m, alpine forests are formed by blue pine (*Pinus wallichiana*), bhojpatra (*Betula utilis*) and *Rhododendron campanulatum*. Such vegetation is common in Lahaul-Spiti and Kinnaur. Open dry forests of Junipers are also visible in Lahaul valley. Alpine scrubs (both, moist and dry type) are mainly found on dry arid stony-scree slopes, rocks, ledges, dominating slopes above tree line up to 4200 m. Shrubby elements such as *Rhododendron anthopogon* subsp. *hypenanthum*, *R. lepidotum*, *Berberis* spp., *Caragana* spp., *Cassiope fastigiata*, *Cotoneaster* spp., *Devendraea* spp., *Hippophae rhamnoides*, *H. tibetana*, *Juniperus* spp., *Lonicera* spp., *Rosa webbiana*, *R. macrophylla*, *Salix* spp. along with perennials like *Artemisia* spp. are important representatives of such vegetation. The alpine meadows occupying the zone between tree line and snow line extend from 3300-4500 m and are dominated by grasses and sedges along with herbaceous species of *Primula, Aconitum, Androsace, Aster, Anemone, Bistorta, Erigeron, Juncus, Persicaria, Aconogonon, Elsholtzia, Impatiens, Caltha, Iris, Allium, Pedicularis, Potentilla, Gentiana, Rheum, Geranium, Nepeta, Corydalis*, etc. Northern region of the state, which includes Lahaul-Spiti and northern Kinnaur, falls in rain shadow area of Trans Himalayan belt characterized by arctic cold desert vegetation comprising of saxicolous and scree flora adapted to drier climate. In addition to dry scrubs formed by species of *Caragana, Hippophae, Berberis, Artemisia*, the vegetations here is chiefly of cushinoid and mat or tuft forming species, like *Arenaria bryophylla, A. festucoides, Acantholimon lycopodioides, Thylacospermum caespitosum*, *Astragalus* spp. and scree plants such as *Androsace* spp., *Corydalis crassifolia, Rhodiola* spp., *Saxifraga* spp., *Draba* spp., *Rheum* spp., *Chorispora sabulosa*, *Christolea crassifolia*, *Desideria himalayensis*, *Waldheimia* spp. This zone is not suitable for the growth and development of liverworts and hornworts and support fewer species, like *Marchantia polymorpha*, *Preissia quadrata*, *Sauteria spongiosa*, *Asterella leptophylla*, *Reboulia hemisphaerica*, *Riccia cavernosa*, *Apometzgeria pubescens*, *Blepharostoma trichophyllum*, *Lophozia inscisa*, *Chiloscyphus inflatus*, *Porella chinensis* var. *chinensis*, *Scapania purpurea*, etc., occurring in comparatively moister situations in Chandrabhaga valley, especially in Lahaul and Pangi area.

Kashyap (1914a, 1914b, 1915, 1916, 1917a 1917b, 1919a, 1919b, 1920, 1921, 1923) dealt with several aspects of liverworts from Western Himalaya in general and Himachal Pradesh in particular. His treatise (Kashyap, 1929; Kashyap & Chopra, 1932) on the liverworts of Western Himalaya and the Punjab plains included 87 species from Himachal Pradesh. For long, these two volumes remained the only floristic treatise on the liverworts and hornworts and the first hand identification manual for the beginners of not only this region but also the country as a whole.

However, due to changing concepts in the taxonomy of a number of families and genera over the period of time, only 35, out of 87 species dealt by Kashyap (1929) and Kashyap & Chopra (1932) from Himachal Pradesh, are nomenclaturally accepted today. Besides, a number of taxa have since been added to the liverwort and hornwort flora of the State (Singh & Singh, 2009, 2010).

In the present state of our knowledge the State is represented by 152 species (including infraspecific taxa) belonging 51 genera and 35 families of liverworts and 10 species belonging to five genera and two families of hornworts. Though the area has been explored intensively in recent years, yet a well documented illustrated account or a comprehensive annotated checklist of the taxa occurring in the State is still awaited.

The manual provides a brief methodology for the collection, preservation and preparation of samples of liverworts and hornworts for study; salient morphological features of different orders of liverworts and hornworts; identification keys for the genera and species occurring in Himachal Pradesh supported by illustrations/ photographs and the references to the literature cited in the text. In the end a glossary of technical terms has also been provided for the benefit of different section of its users.

Herbarium Methodology

Collection

For the collection of bryophyte materials in fields, a sharp sheath knife with non metallic handle (for scraping the specimens from various habitat type, such as soil, rock faces or crevices), and a good doublet or triplet hand lens of about 10 to 20 x having a field of about one centimetre or more, is required. It is important to learn the use of such lens in the field as it allows one to be effectively selective in making collections. Because of their small size of the plants and the multitude of habitats in which they grow, one requires a keen eye to locate them in the field.

While collecting the specimens, a part of the population should always be left, especially if the species is not common, to allow its natural growth. However, the specimens should be adequate enough to establish record. The specimens are of maximum value only when they are collected as whole plants bearing both androecia and gynoecia. Tufted terrestrial specimens should be separated into thin slabs and as much substratum material should be removed as possible. In case of small plants with somewhat scattered individuals, it is always helpful to remove a few plants from the substrate and keep them in separate packets.

Preservation

The collected material should be kept inside small craft paper bag or brown paper sacks or envelops. The data can be written directly on such bags / packets with pencil or permanent ink. Alternatively, pre-numbered bags / packets can also be used and simultaneously the field data is recorded by that number in the field book. Each collection should be separately packaged in the field for subsequent study. Plastic bags should normally be avoided for the collection of herbarium specimens of bryophytes to avoid their molding and decay. Collections in the paper bags / packets can be air dried without transfer. While drying the specimens, care should be taken to apply very little pressure to save them from getting distorted.

The collections should be preserved in herbarium packets, folded from a standard 8.5–9" × 11" brown sheet, with a finished size of 5.5–6" × 4". As the bryophytes in general have a very high content or flavonoids and turpenoids, which make them natural antibiotic, fungicide and pesticide, poisoning of the specimens is normally not required. The storage of specimens without poisoning has another advantage too. Bryophyte propagules (both spores as well as vegetative

regenerants) have very long viability. As such even herbarium materials can sometimes be used for propagation of bryophyte species.

Name of the species and other collection data should be written on the labels, which can be printed directly on the packet or printed separately and pasted on the packet. The labels may be plain or have the map of the area of study. The minimum data for the specimen should include: scientific name with authority; family name; state, country and location (with coordinates, altitudes, etc.); vegetation type; life-form; substrate; collector name; date of collection; field or collection number and the name(s) of the identifier. The geographic coordinates of the locality greatly helps in relocating and monitoring the species.

Often rare species are found in admixture, with just a few plants. It will, therefore, be useful to sort out such individuals of a species and keep them in separate small packets made of tissue paper or lens tissue, which should then be kept in the larger herbarium packet. Similarly, fertile plants of a species should be singled out and wrapped in individual, small packets.

Properly identified and curated specimens can be stored in trays in steel/wooden herbarium cabinets. Placing some fumigant or pest strips in each tray will save the specimens from any pest attack. Usually a natural system of classification is followed for arranging the specimens whereby related families and genera are located near to one another. Smaller herbaria and the amateurs may conveniently store the packets alphabetically by family or genera and genera/species similarly arranged within family/genus. The herbarium packets can also be stored in shoe boxes or other card board boxes on shelves or in metal cabinets. In many herbaria sometimes the packets are glued to standard herbarium sheet, which are in turn placed in folders in large drawers or pigeon holes. Such practice however, is not recommended for maintaining the collections.

Preparation of material for study

The collected material can be studied fresh or dried first to work over leisurely at a later date. In the latter case, the specimens should normally be soaked in the warm water to allow them to regain their shape. As bryophytes generally grow in mixed population, therefore the material available for the study should be carefully examined and similar plants within the population should be isolated with the help of binocular microscope. Of these, best-developed plants bearing perianth and sporophytes should be selected for the study of morphological as well as anatomical details. For the study of morphological and anatomical features, the sections or dissected parts of the plants should be placed on a glass slide and

mounted in 30 per cent aqueous glycerin and covered by cover-slip. Wait for a moment before covering your object with cover-slip to allow it to fully settle down on the surface of the slide. The material is now ready for study under the microscope. The illustrations of the key morphological features can be prepared with the help of drawing or photo-micrographic attachment as desired.

Measurements

In case of thalloid plants, the breadth should be measured immediately below the dichotomy and the length of a thallus can be taken from the centre of the rosettes to the extreme margin of the lobes. Whereas, in case of leafy plants, the breadth including axis and leaves, should be measured at middle portion of the mature plants. The length of leaves and underleaves should be measured at their longest, including lobes and teeth, along their longitudinal axis, while their breadth is measured at their widest perpendicularly across the longitudinal axis. While recording the dimensions of the cells, the first figure should represent its measurement along the longitudinal axis of the structure to which it belonged and second representing the same along the perpendicular axis. The measurements of the spores should be taken at minimum and maximum diameter including the width of wings, or equatorial crassitudo and the flange (in case of hornworts). In each case the measurements should be taken as an average of at least twenty counts with the help of either eyepiece occulometer and stage micrometer, or standard image analysis software.

Identification

For the identification of bryophytes a proper understanding of the structure or morphology of various groups is necessary. Accordingly, cross-sections and dissections are to be made as per the requirement of the *Identification Key,* which should invariably be derived from both gametophytic and sporophytic features. However, as the dominant generation in bryophytes as a whole is a haploid gametophyte, the variations in its structure is normally and conveniently (as in many case sporophytes are very rare) utilised to segregate families, genera and species. Identification of the liverworts and hornworts can be done by using protologues, monographs and floristic accounts. In case of critical taxa, however, the comparison of key morphological characters of the plants at hand with those of the type / authentic specimens of allied taxa will be necessary.

Key Morphological Features of Liverworts and Hornworts

While hornworts are characterized by the uniformity in the morphological features of their plant body, which is always thalloid and mostly ecostate with or without mucilage canals, the liverworts exhibit three different kinds of gametophytic structures. The most widely occurring gametophyte morphology in liverworts is the foliose organization having the plant body differentiated into stem and two or three rows of leaves that characterizes all the taxa of order Jungermanniales and few, like species of genus *Fossombronia*, *Apotreubia, Treubia, Noterclada, Phyllothallia* (the last three not found in India) of Metzgeriales. The rest of the members of order Metzgeriales show simple thalloid organization with unspecialized thallus usually with thickened median region, or the midrib, with two lateral wings. The gametophyte in the Marchantiales, on the other hand, presents a complex thallus organization with usually dorsiventrally differentiated plant body with dorsal air-pores, photosynthetic and storage zones, ventral scales and tuberculate rhizoids.

Morphologiacal features of Jungermanniales (foliose forms)

- The gametophyte is leafy, with two lateral rows of leaves and often with one ventral row of leaf, i.e. underleaves or amphigastria.
- Branching pattern is very important parameter in the taxonomy of the Jungermanniales. The branching is of two basic types, viz. terminal (or exogenous) which arise from a cortical cell and the branch rudiment is developed very close to the shoot apex, and the intercalary (or endogenous) which arise from the stem medulla wherein the ruptured cortex forms a sheath or collar around the branch base and the branch rudiment usually arises far from the shoot apex.
- Stem in cross-section may have identical cells or differentiated into 1-3 (-5) layers of thick-walled cortical cells and thin-walled medullary cells.
- The leaves are unistratose, rarely more than one-layered thick (members of Haplomitriales and some species of *Frullania*) towards base, simple or complicate bilobed with smaller ventral lobe, or the leaf lobule (except *Scapania* in which ventral lobe is larger than the dorsal one), and larger dorsal lobe, or the leaf lobe; the leaf lobe may be undivided or 1-4 (-5)-lobed; incubously or

succubously or transversely inserted, they may be entire or minutely toothed or lascinately toothed or lobed to the base.

- Leaf cells are mostly more or less isodiametric throughout the leaf, although marginal cells may sometimes be somewhat smaller or larger, and basal cells may be somewhat elongated.
- Trigones in between the cells may be concave, convex or strongly bulging; intermediate thickenings between the corner of the cells may or may not be present. Cuticle of cells may be smooth, or variously ornamented.
- Oil-bodies in liverworts are intracellular organelles containing lipophilic globules which can be best observed in fresh, living materials. These are sometimes very characteristic and constant for a species. These may be simple or compound and vary in number and shapes.
- Leaf lobule (ventral leaf lobe) present in several families like Frullaniaceae, Lejeuneaceae, Porellaceae, Radulaceae, Scapaniaceae, etc., in various forms, provides important taxonomic criteria for the identification of taxa at genus and species level.
- Underleaves (a modified leaf which are usually smaller in size than normal leaf and present on underside of plant) present in many families, Pseudolepicoleaceae, Geocalycaceae, Lophocoleaceae, Calypogeiaceae, Porellaceae Lepidoziaceae, Frullaniaceae, Lejeuneaceae (absent in sub-family Cololejeuneoidae), may be entire, bilobed – 5-lobed or toothed.
- Rhizoids, usually present on the ventral surface of the stem, are always unicellular in liverworts and generally originate either singly and irregularly, or in fascicles from the basal part or insertion line of the underleaves, or from the specialised rhizoidal disc, or base of leaf lobule. In some rare cases they are produced from the margin (*Acrobolbus ciliatus*) or from the underside of the leaves (certain species of *Solenostoma*).
- Asexual reproduction takes place by means of death and decay of older plants, fragmentation of plant parts, innovations and different types of gemmae which may vary from 1 – many-celled in various form, simple to discoid or sometimes filamentous (in *Lophocolea minor*).
- Plants may be dioicous or monoicous; in the latter condition they may be of three type: (i) autoicous, with antheridia and archegonia borne on the axis on the same plant or on a separate branches on the same plant; (ii) paroicous, with antheridia mostly in the axil of bracts below the female bracts and archegonia

or in cavities adjacent to archegonia and (iii) synoecious, with antheridia and archegonia intermingled in same receptacle.

- Androecia are mostly intercalary, with the Antheridia protected by male bracts, which are often smaller in size and different in shape from the normal leaves.
- Archegonia and developing sporophytes may be surrounded by a perianth, a perigynium, or a marsupium.
- Sporophytes are simple and acrogynous, differentiated into foot, seta and capsule.
- The seta may be smooth or articulated, slender with 1–3 rows across the diameter of a few (6–10) cells in transverse section, or massive having many rows across the diameter with numerous cells in transverse section.
- The capsule is globose, clavate to cylindrical; dehisces by 4 longitudinal valves; capsule wall usually 2-layered (6–8-layered in the primitive genera); cells of outer layer generally with nodular thickenings usually on both sides of radial walls and often on the transverse walls; cells of inner layer generally with complete or incomplete, transverse – semiannular thickening bands.
- Spores are apolar, usually unicellular, small, mostly 6-30 μm in size, minutely papillose – vermiculose, spinose or tuberculate, sometimes (in family Frullaniaceae and Lejeuneaceae) with radially arranged clusters of spines forming islands.
- Elaters are free or attached to the top and to the base of the capsule wall in some genera like *Frullania*.

Morphologiacal features of Metzgeriales (simple thalloid forms)

- The gametophytes are mostly thalloid, simple or rarely superficially leafy or intermediate between thalloid and leafy form (*Fossombronia*).
- The thallus often with a central midrib, which is lacking in few genera, like *Aneura* and *Riccardia*.
- Branching is irregular, pinnate or pseudo-dichotomous.
- The intermediate forms or superficially leafy plant bodies are formed by bilaterally arranged leaf-like lobes on the axis.
- Rhizoids, when present, are unicellular, smooth, scattered on the ventral surface of the thallus aligned with the midrib.

- Scales, when present, are much prominent near apices (*Blasia, Calycularia*).
- Cilia or hairs are sometimes present at the margin and, rarely on dorsal and/or ventral surface of the thallus and provide important tool for identification of species in case of the genus *Metzgeria*.
- Asexual reproduction takes place by means of death and decay of older plant parts, adventitious branches *(Blasia, Metzgeria, Pellia)*, tubers (*Sewardiella, Fossombronia*) and 2 – several-celled simple or discoid gemmae (in case of *Blasia*, simple discoid gemmae are produced in specialised flask-shaped receptacles present at the apical notch of the thallus, while stellate gemmae are borne on the dorsal surface of the thallus near apices).
- Antheridia are scattered, or clustered on dorsal surface of midrib of main thallus, or on lateral or ventral, sometimes modified branches, shielded by scale-like lamellae or branched lamina.
- Archegonia are protected by a leaf-like scale or by tissues of the thallus (perigynium or involucre).
- The sporophyte is differentiated into small bulbous foot, thick and elongated seta and spherical to clavate capsule.
- Seta usually massive, many cells thick across the diameter, or 4 cells across with 12–16 epidermal and 4 inner cells in case of genus*Riccardia* and the members of Metzgeriaceae.
- The capsule may be globose to cylindrical to ellipsoidal, dehiscing irregularly (in *Fossombronia*) or mostly along 4 longitudinal valves; wall 2–3 (–4)-layered; epidermal cells with nodular thickenings on radial walls, or without thickenings (in *Fossombronia*); inner cells generally with complete or incomplete semiannular bands on radial and tangential walls, or with nodular or irregular thickenings, or both (in *Fossombronia*).
- Spores are usually apolar (or cryptopolar in Fossombroniaceae), free or in tetrads, unicellular, pigmented or several-celled and green (in *Pellia*). The exine ornamentation of spores varies from smooth – finely verruculose or echinate (Aneuraceae and Metzgeriaceae), papillose or vermiculose (*Blasia*), granulate (*Pellia*), echinate (*Calycularia*) or lamellate (*Fossombronia*), reticulate (*Sewardiella*) and provides tangible diagnostic features in the taxonomy of this order.
- Elaters are free, or attached with the base or apex of the capsules forming basal or apical elaterophores with 2–3 (-4) spiral thickening band.

Morphologiacal features of Marchantiales (complex thalloid forms)

- The gametophytes are always thalloid, generally dichotomously branched.
- The thallus structure is relatively complex, differentiated into photosynthetic zone and storage zones.
- Epidermal pores are simple, semi barrel or barrel-shaped, or stellate (members of family Cleveaceae) and provide a tangible diagnostic character for identification at the family and genus level.
- Air chambers may be in 1 – several layers with straight (most of the taxa) or oblique partition walls (members of family Aytoniaceae), empty or filled with chlorophyllose filaments.
- Ventral scales well developed, usually in 2 rows (4–6 rows in *Marchantia* and members of Cleveaceae), with or without appendages of various shapes, or highly reduced and scattered on the under surface of thallus and receptacles (members of Cyathodiaceae and Monosoleniaceae).
- Rhizoids are present throughout ventral surface, usually along midrib or scattered, of 2 types, i.e. smooth-walled and tuberculate with peg-like invaginations, which are not found in any other bryophytes.
- Asexual reproduction takes place by means of death and decay of older plants, adventitious branches *(Riccia, Marchantia, Dumortiera, Targionia, Reboulia,* etc.), tubers (*Stephensoniella, Aitchisoniella, Cyathodium*) and multicellular stalked discoid gemmae (*Marchantia*). The gemmae in the *Marchantia* are borne in a well-defined, cupular gemma cups (a characteristic of the genus). In case of *Lunularia* and *Conocephalum japonicum* (not recorded from the State), however, the gemmae are borne in semi-lunar or crescen-shaped gemma cups and along the margin of the thallus respectively.
- Antheridia are embedded in the thallus (Ricciaceae, Cleveaceae, Exormothecaceae), or arranged in specialised discs (Targioniaceae, Cyathodiaceae, Aytoniaceae, etc.) or produced in sessile – subsessile, circular receptacles (*Monosolenium, Dumortiera, Wiesnerella*), or borne on stalked receptacles or antheridiophores (*Marchantia, Preissia*).
- Archegonia are borne on stalked archegoniophores (except the members of family Cyathodiaceae, Targioniaceae where they are enclosed within the bivalved involucres), whereas in Ricciaceae the archegonia are embedded in the thallus.

- The sporophyte is enclosed in a calyptra or tubular outgrowth of the gametophyte (pseudoperianth) and differentiated into reduced foot, short seta and globose capsule.
- Capsule dehisces irregularly in most of the members or by separation of operculum (Aytoniaceae, Targioniaceae and Cyathodiaceae), or by decomposition (Ricciaceae). The capsule wall is unistratose, rarely weakly chlorophyllose in basal part, without thickenings (Aytoniaceae, Ricciaceae) or with transverse – annular thickenings.
- The spores are usually polar, occasionally apolar, large, free or united, with or without a wing or perispore, unicellular, (appear multicellular only in *Conocephalum* because of precocious or *in vivo* germination). The sporoderm is variously ornamented and provide the most important taxonomic parameter for identification.
- Elaters are well developed with 2–3 (-4)-spiral thickenings or sometimes with annular thickening bands, rarely without thickenings. They are septate and chlorophyllose in *Monosolenium,* but, totally absent in members of Ricciaceae.

Morphological features of Anthocerotales

- The gametophytes are thalloid, forming an irregularly dichotomous rosette, usually with endogenous *Nostoc* colonies.
- Thallus internally compact (*Hattorioceros, Megaceros*, *Notothylas* and *Phaeoceros*) or spongy (*Anthoceros* and *Folioceros*); when spongy, with 1-3 layers of mucilagenous chambers.
- Epidermal cells usually with a single (except in *Megaceros* and some species of *Notothylas)* large, plate-like chloroplast having a central pyrenoid region (many scattered pyrenoids present in *Megaceros* and some species of *Notothylas).*
- Rhizoids are simple smooth-walled, unicellular, scattered throughout ventral surface.
- Asexual reproduction takes place by means of death and decay of older plants, adventitious branches, tubers (*Phaeoceros himalayensis, Notothylas pandei*). Gemmae usually unknown, except in few species of the genus *Folioceros*.
- Antheridia are developed endogenously and are embedded in the dorsal surface of the thallus in cavities – the antheridial chambers. The cells of the

jacket layer may be arranged in 4 tiers with the upper tier comprising 8 cells (*Anthoceros* and *Folioceros*), or arranged irregularly.

- Archegonia are embedded and histologically continuous with thallus tissue. Sometimes, however, the archegonial neck projects well above the thallus surface (like *Anthoceros erectus*).
- Involucres erect (most genera) or horizontal (*Notothylas*), cylindrical – oblong-cylindrical, slightly broader towards base, smooth-crenulate at mouth, sometimes smoothly ridged or lamellate, spongy or compact, up to 14 cells or thicker, pierced at mouth by growing sporophyte.
- The sporophyte is differentiated into bulbous foot, horn-shaped or needle-like capsule which is usually indeterminately long, cylindrical – ellipsoidal with subacute – obtuse apex.
- Seta is replaced by a intercalary meristematic zone.
- Capsules dehiscent or rarely cliestocarpous, usually bivalved rarely 4-valved (*Notothylas orbicularis, N. indica*); wall (2 –) 4–6-layered with the cells, other than those of the epidermis, having chloroplast; epidermal layer usually stomatiferous (except in *Megaceros* and *Notothylas*); cells of epidermal layer usually with uniformly thickened radial and end walls, while cells of inner lining layer with or without, irregular, thin, dark bands on the tangential and radial walls.
- Columella persistent (except for some species of *Notothylas*), with surface cells having no thickening bands (except in some species of *Notothylas* and *Dendroceros*).
- Spores are polar with the sporoderm smooth to spiny, minutely papillate, baculate, vermiculate, striate or perfectly reticulate over distal surface; often with thick equatorial crassitudo (an important feature not found in other bryophytes) in the species of *Phaeoceros* and *Notothylas*.
- Pseudoelaters 1–4 (–5)-celled, short and stout, sometimes plate-like (in the species of *Notothylas*), stumpy and thin walled (*Anthoceros* and *Phaeoceros*) to vermiform longish, thin-walled (*Hattorioceros*) to thick-walled with a central narrow dark lumen (*Folioceros*), or unispirally thickened with rounded – tapering ends (*Megaceros*).

Conspectus of Liverworts and Hornworts for Himachal Pradesh

The families and genera are listed alphabetically within the orders without any consideration of their phylogenetic relationship.

Number in parentheses is the numbers of species reported from Himachal Pradesh

Anthocerotophyta (hornworts) (2)

Anthocerotales (10)

Anthocerotaceae : *Anthoceros* (2)

Dendrocerotales (1)

Dendrocerotaceae: *Megaceros* (1)

Notothyladales (7)

Notothyladaceae: *Hattorioceros* (1), *Notothylas* (3), *Phaeoceros* (3)

Marchantiophyta (liverwworts) (142)

Jungermanniales (87)

Adelanthaceae: *Syzygiella* (3)

Antheliaceae: *Anthelia* (1)

Calypogeiceae: *Metacalypogeia* (1)

Cephaloziaceae: *Cephalozia* (1)

Delavayellaceae: *Liochlaena* (1)

Frullaniaceae: *Frullania* (8)

Geocalycaceae: *Geocalyx* (1)

Jungermanniaceae: *Leiocolea* (1)

Solenostomataceae: *Solenostoma* (8)

Lophocoleaceae: *Chiloscyphus* (3), *Heteroscyphus* (4), *Lophocolea* (3)

Lejeuneaceae: *Lejeunea* (3), *Lopholelejeunea* (1), *Ptychanthus* (1), *Trocholejeunea* (2), *Tuzibeanthus* (1)

Lepidoziceae: *Bazzania* (1)

Plagiochilaceae: *Plagiochila* (13)

Porellaceae: *Porella* (14)

Pseudolepicoleaceae: *Blepharostoma* (1)

Radulaceae: *Radula* (5)

Scapaniaceae: *Lophozia* (1), *Scapania* (9)

Marchantiales (40)

Aytoniaceae: *Asterella* (5), *Cryptomitrium* (1), *Mannia* (4), *Plagiochasma* (4), *Reboulia* (1)

Cleveaceae: *Athalamia* (2), *Sauteria* (1)

Conocephalaceae: *Conocephalum* (1)

Cyathodiacaeae: *Cyathodium* (2)

Dumortieraceae: *Dumortiera* (1)

Exormothecaceae: *Stephensoniella* (1), *Aitchisoniella* (1)

Marchantiaceae: *Marchantia* (3), *Preissia* (1)

Monosoleniaceae: *Monosolenium* (1)

Ricciaceae: *Riccia* (8)

Targioniaceae: *Targionia* (2)

Wiesnerellaceae: *Wiesnerella* (1)

Metzgeriales (15)

Allisoniaceae: *Calycularia* (1)

Aneuraceae: *Aneura* (1), *Riccardia* (2)

Blasiaceae: *Blasia* (1)

Fossombroniaceae: *Fossombronia* (2)

Petalophyllaceae: *Sewardiella* (1)

Metzgeriaceae: *Apometzgeria* (1), *Metzgeria* (4)

Pelliaceae: *Pellia* (2)

Key to Genera and Isolated Species

Anthocerotophyta

1a. Capsule nearly horizontal, marginal in position on thallus, almost entirely enclosed within the involucre at maturity; capsule wall without stomata; pseudoelaters present or absent, short and stumpy, with or without week transverse, spiral or annular thickenings ..... ***Notothylas***

1b. Capsule erect, dorsal in position on thallus, almost entirely projecting out of the involucre at maturity; capsule wall with or without stomata; pseudoelaters up to 4-celled or short and stumpy, with or without sinuate or unispiral thickening 2

2a. Thallus spongy, with schizogenous cavities; spores dark brown to black; ..... ***Anthoceros***

2b. Thallus compact, without schizogenous cavities; spores yellow or light coloured 3

3a. Thallus margin laciniately fringed, epidermal cells with more than two chloroplasts pseudoelaters with unispiral thickening band ..... ***Megaceros tjibodensis***

3b. Thallus margin not laciniately fringed, epidermal cells always with single chloroplasts pseudoelaters without unispiral thickening band 4

4a. Sporoderm spinose, papillose or vermiculose ..... ***Phaeoceros***

4b. Sporoderm canaliculated or striate ..... ***Hattorioceros striatisporus***

Marchantiophyta

1. Jungermanniales

1a. Leaves differentiated into lobe and lobule 16

1b. Leaves not differentiated into lobe and lobule, simple 2

2a. Underleaves present 3

2b. Underleaves absent 10

3a. Leaves deeply 3–5-lobed; lobes ciliate ..... ***Blepharostoma trichophyllum***

3b. Leaves not as above 4

4a. Underleaves deeply bilobed 5

4b. Underleaves entire or shallowly 2–4-lobed 9

Notothylas levieri Schiffin.

Octokepos khasyanum Griff. = **Asterella khasyana** (Griff.) Pande, K.P.Srivast. & Sultan Khan

Omphalanthus infuscatus Steph. = **Trocholejeunea infuscata** (Mitt.) Verd.

Porella niitakensa (Horik.) S.Hatt. = **Porella gracillima** Mitt. subsp. **urogea** (C. Massal.) S.Hatt.

Pellia calycina (Taylor) Nees = **Pellia endiviifolia** (Dicks.) Dumort.

Pellia endiviifolia (Dicks.) Dumort.

Pellia epiphylla (L.) Corda

Pellia fabroniana Raddi. = **Pellia endiviifolia** (Dicks.) Dumort.

Phaeoceros carolinianus (Michx.) Prosk.

Phaeoceros communis (Steph.) Schiffn. & Pande = **Phaeoceros carolinianus** (Michx.) Prosk.

Phaeoceros himalayensis (Kashyap) Prosk. ex Bapna & Vyas

Phaeoceros laevis (L.) Prosk.

Phaeoceros laevis (L.) Prosk. f. *carolinianus* (Michx.) R.M.Schust. = **Phaeoceros carolinianus** (Michx.) Prosk.

Phaeoceros laevis (L.) Prosk. subsp. *carolinianus* (Michx.) Prosk. = **Phaeoceros carolinianus** (Michx.) Prosk.

Phaeoceros laevis (L.) Prosk. subsp. *laevis* (L.) Prosk. = **Phaeoceros laevis** (L.) Prosk.

Phaeoceros striatisporus J.Haseg. = **Hattorioceros striatisporus** (J.Haseg.) J.Haseg.

Phragmicoma sandvicensis Gottsche = **Trocholejeunea sandvicensis** (Gottsche) Mizut.

Plagiochasma appediculatum Lehm. & Lindenb.

Plagiochasma articulalum Kashyap = **Plagiochasma pterospermum** C. Massal.

Plagiochasma australe Nees = **Plagiochasma rupestre** (J.R.Forst. & G.Forst.) Steph.

Plagiochasma bicornutum Steph. = **Plagiochasma pterospermum** C. Massal.

Plagiochasma bisetulum Steph. = **Reboulia hemisphaerica** (L.) Raddi

Plagiochasma cardoti Steph. = **Plagiochasma appediculatum** Lehm. & Lindenb.

Plagiochasma grandisquamum Steph. = **Plagiochasma rupestre** (J.R.Forst. & G.Forst.) Steph.

Plagiochasma intermedium Lindenb. & Gottsche

Plagiochasma nepalense Lehm. & Bisch.) Steph. = **Plagiochasma rupestre** (J.R.Forst. & G.Forst.) Steph.

Plagiochasma pinguis (Falc.) Steph. = **Athalamia pinguis** Falc.

Plagiochasma polycarpon (Griff.) Steph. = **Plagiochasma appediculatum** Lehm. & Lindenb.

Plagiochasma pterospermum C.Massal.

Plagiochasma quadricornutum Steph. = **Plagiochasma pterospermum** C. Massal.

Plagiochasma rupestre (J.R. Forst. & G.Forst.) Steph.

Plagiochasma sessilicephalum Horik. = **Plagiochasma pterospermum** C. Massal.

Plagiochasma simlensis Kashyap = **Plagiochasma rupestre** (J.R.Forst. & G.Forst.) Steph.

Plagiochila acanthophylla Gottsche = **Plagiochila sciophila** Nees

Plagiochila accedens Steph. = **Plagiochila korthalsiana** Molk.

Plagiochila aequiloba Mont & Nees = **Scapania aequiloba** (Schwägr.) Dumort.

Plagiochila alata Inoue = **Plagiochila durelii** Schiffn.

Plagiochila ambagiosa Mitt. = **Plagiochila uniformis** Mitt.

Plagiochila beccariana Schiffn. = **Plagiochila korthalsiana** Molk.

Plagiochila bhutanensis Schiffn. = **Plagiochila durelii** Schiffn.

Plagiochila birmensis Steph. = **Plagiochila parvifolia** Lindenb.

Plagiochila boniensis Inoue = **Plagiochila fordiana** Steph.

Plagiochila brevifolia Steph. = **Plagiochila nepalensis** Lindenb.

Plagiochila cadens Inoue = **Plagiochila sciophila** Nees

Plagiochila campanulata Steph. = **Plagiochila ovalifolia** Mitt.

Plagiochila cavifolia Steph. = **Plagiochila duthiana** Steph.

Plagiochila ciliata Gottsche = **Plagiochila sciophila** Nees

Plagiochila consimilis Steph. = **Plagiochila elegans** Mitt.

Plagiochila decidua Inoue & Grolle = **Plagiochila sciophila** Nees

Plagiochila decolyana Schiffn. ex Steph. = **Plagiochila nepalensis** Lindenb.

Plagiochila dichotomoramosa Inoue = **Plagiochila fordiana** Steph.

Plagiochila didyma Inoue = **Plagiochila parvifolia** Lindenb.

Plagiochila douleana Steph. ex Dugas = **Plagiochila uniformis** Mitt

Plagiochila durelii Schiffn.

Plagiochila duthiana Steph.

Plagiochila elegans Mitt.

Plagiochila fauriana Steph. = **Plagiochila ovalifolia** Mitt.

Plagiochila ferruginea Steph. = **Plagiochila durelii** Schiffn.

Plagiochila flavovirens Steph. = **Plagiochila sciophila** Nees

Plagiochila fordiana Steph.

Plagiochila gollanii Steph. = **Plagiochila nepalensis** Lindenb.

Plagiochila gollanii Steph. var. *triquerta* Herzog = **Plagiochila nepalensis** Lindenb.

Plagiochila grata Steph. = **Plagiochila nepalensis** Lindenb.

Plagiochila harae Inoue = **Plagiochila durelii** Schiffn.

Plagiochila hartlessiana Steph. = **Plagiochila elegans** Mitt.

Plagiochila hattorii Inoue = **Plagiochila parvifolia** Lindenb.

Plagiochila himalayensis Steph. = **Plagiochila duthiana** Steph.

Plagiochila japonica Sande Lac. = **Plagiochila sciophila** Nees

Plagiochila korthalsiana Molk.

Plagiochila madurensis Steph. = **Plagiochila elegans** Mitt.

Plagiochila makinoana S.Hatt. = **Plagiochila nepalensis** Lindenb.

Plagiochila minima Horik. = **Plagiochila sciophila** Nees

Plagiochila minutistipula Herzog = **Plagiochila sciophila** Nees

Plagiochila mundaliensis Steph.

Plagiochila nana Steph. = **Plagiochila durelii** Schiffn.

Plagiochila nepalensis Lindenb.

Plagiochila orbicularis S.Hatt. = **Plagiochila ovalifolia** Mitt.

Plagiochila orientalis Taylor = **Plagiochila sciophila** Nees

Plagiochila ovalifolia Mitt.

Plagiochila parvifolia Lindenb.

Plagiochila phalangea Taylor = **Plagiochila parvifolia** Lindenb.

Plagiochila pluridentata Steph. = **Plagiochila elegans** Mitt.

Plagiochila pseudorientalis Inoue = **Plagiochila nepalensis** Lindenb.

Plagiochila pseudoventricosa Inoue = **Plagiochila parvifolia** Lindenb.

Plagiochila remotistipula Steph. = **Plagiochila nepalensis** Lindenb.

Plagiochila retusa Mitt.

Plagiochila richteri Steph. ex S.C.Srivast. & R.Dixit

Plagiochila sciophila Nees

Plagiochila simlana Steph. = **Plagiochila uniformis** Mitt.

Plagiochila subacanthophylla Herzog = **Plagiochila sciophila** Nees

Plagiochila thomsonii Steph. = **Plagiochila durelii** Schiffn.

Plagiochila toshoguna Steph. = **Plagiochila ovalifolia** Mitt.

Plagiochila trabeculata Steph. var. *bifida* S.Hatt. = **Plagiochila fordiana** Steph.

Plagiochila treubii Schiffn. = **Plagiochila parvifolia** Lindenb.

Plagiochila uniformis Mitt.

Plagiochila ventricosa Steph. = **Plagiochila parvifolia** Lindenb.

Plagiochila vygensis Steph. = **Plagiochila sciophila** Nees

Plagiochila wiltensii Steph. = **Plagiochila korthalsiana** Molk.

Plagiochila yokogurensis Steph. = **Plagiochila parvifolia** Lindenb.

Plectocolea infusca Mitt. = **Solenostoma infuscum** (Mitt.) J.Hentschel

Porella appendiculata (Steph.) S.Hatt. = **Porella densifolia** (Steph.) S.Hatt. subsp. **appendiculata** (Steph.) S.Hatt.

Porella appendiculata (Steph.) P.C.Chen. = **Porella densifolia** (Steph.) S.Hatt. subsp. **appendiculata** (Steph.) S.Hatt.

Porella caespitans (Steph.) S.Hatt.

Porella campylophylla (Lehm. & Lindenb.) Trevis.

Porella campylophylla (Lehm. & Lindenb.) Trevis. f. *pariharii* S.Hatt. = **Porella campylophylla** (Lehm. & Lindenb.) Trevis.

Porella chinensis (Steph.) S.Hatt.

Porella chinensis (Steph.) S.Hatt. f. *frullanioides* (Steph.) S.Hatt. = **Porella chinensis** (Steph.) S.Hatt.

Porella chinensis (Steph.) S.Hatt. var. *decurrens* (Steph.) S.Hatt. = **Porella decurrens** (Steph.) S.Hatt.

Porella chinensis (Steph.) S.Hatt. var. *gambleana* Steph.) S.Hatt. = **Porella chinensis** (Steph.) S.Hatt.

Porella decurrens (Steph.) S.Hatt.

Porella densifolia (Steph.) S.Hatt. subsp. **appendiculata** (Steph.) S.Hatt.

Porella frullanioides (Steph.) S.Hatt. = **Porella chinensis** (Steph.) S.Hatt.

Porella fulva (Steph.) Grolle = **Porella obtusata** (Taylor) Trevis. var. **macroloba** (Steph.) S.Hatt. & Zhang

Porella gracillima Mitt.

Porella gracillima Mitt. subsp. **urogea** (C.Massal.) S.Hatt.

Porella gracillima Mitt. var. *urogea* (C.Massal.) S.Hatt. = **Porella gracillima** Mitt. subsp. **urogea** (C. Massal.) S.Hatt.

Porella hattorii Udar & Shaheen

Porella heterophylla (Steph.) S.Hatt. = **Porella japonica** (Sande Lac.) Mitt.

Porella japonica (Sande Lac.) Mitt.

Porella japonica (Sande Lac.) Mitt. f. *gracilis* S.Hatt. = **Porella japonica** (Sande Lac.) Mitt.

Porella japonica (Sande Lac.) Mitt. f. *paucispina* S.Hatt. = **Porella japonica** (Sande Lac.) Mitt.

Porella japonica (Sande Lac.) Mitt. f. *pusilla* (Steph.) Pócs = **Porella japonica** (Sande Lac.) Mitt.

Porella japonica (Sande Lac.) Mitt. var. *pusilla* (Steph.) Kamim. = **Porella japonica** (Sande Lac.) Mitt.

Porella macroloba (Steph.) P.C.Chen = **Porella obtusata** (Taylor) Trevis. var. **macroloba** (Steph.) S.Hatt. & Zhang

Porella madagascariensis (Nees & Mont.) Trevis.

Porella madagascariensis (Nees & Mont.) Trevis. f. *integristipula* Pócs = **Porella plumosa** Inoue

Porella nilgheriensis (Mont.) Trevis. = **Porella madagascariensis** (Nees & Mont.) Trevis.

Porella nilgheriensis (Mont.) Trevis. var. *parva* Pócs = **Porella japonica** (Sande Lac.) Mitt.

Porella obtusata (Taylor) Trevis. f. *macroloba* (Steph.) S.Hatt. = **Porella obtusata** (Taylor) Trevis. var. **macroloba** (Steph.) S.Hatt. & Zhang

Porella obtusata (Taylor) Trevis. var. **macroloba** (Steph.) S.Hatt. & Zhang

Porella parvistipula (Steph.) S.Hatt. f. *parvidenticulata* S.Hatt. = **Porella japonica** (Sande Lac.) Mitt.

Porella platyphylla (L.) Pfeiff.

Porella plumosa Inoue

Porella plumosa Inoue var. *gollani* (Steph.) Pócs = **Porella campylophylla** (Lehm. & Lindenb.) Trevis.

Porella plumosa Inoue var. *pallida* (W.E. Nicholson.) Pócs, = **Porella japonica** (Sande Lac.) Mitt.

Porella ptychantha (Mitt.) S.Hatt. = **Porella campylophylla** (Lehm. & Lindenb.) Trevis.

Porella pusilla (Steph.) S.Hatt. = **Porella japonica** (Sande Lac.) Mitt.

Porella setigera (Steph.) S.Hatt. f. *circinans* (W.E. Nicholson) S.Hatt. = **Porella caespitans** (Steph.) S.Hatt.

Porella setigera (Steph.) S.Hatt. var. *pearsoniana* (C. Massal.) S.Hatt. f. *circinans* (W.E. Nicholson) S.Hatt. = **Porella caespitans** (Steph.) S.Hatt.

Porella shikokiana H.Hara = **Porella obtusata** (Taylor) Trevis. var. **macroloba** (Steph.) S.Hatt. & Zhang

Porella urogea (C. Massal.) P.C.Chen = **Porella gracillima** Mitt. subsp. **urogea** (C. Massal.) S.Hatt.

Porella variabilis (Kashyap) Kachroo

Preissia commutata Nees = **Preissia quadrata** (Scop.) Nees

Preissia quadrata (Scop.) Nees

Ptilidium trichophyllum Mitt. = **Blepharostoma trichophyllum** (L.) Dumort.

Ptychanthus chinensis Steph. = **Tuzibeanthus chinensis** (Steph.) Mizut.

Ptychanthus japonicus Steph. = **Trocholejeunea sandvicensis** (Gottsche) Mizut.

Ptychanthus striatus (Lehm. & Lindenb.) Nees

Radula aequiloba Dumort. = **Scapania aequiloba** (Schwägr.) Dumort.

Radula alpestris Lindb. ex Berggren = **Radula complanata** (L.) Dumort.

Radula commutata Gottsche = **Radula lindbergiana** Gottsche

Radula complanata (L.) Dumort.

Radula complanata (L.) Dumort. var. *propagulifera* Nees = **Radula lindbergiana** Gottsche

Radula douleana Steph. = **Radula grandifolia** Steph.

Radula grandifolia Steph.

Radula hallii Austin = **Radula complanata** (L.) Dumort.

Radula hyalina Steph. = **Radula complanata** (L.) Dumort.

Radula indica Steph. = **Radula tabularis** Steph.

Radula lindbergiana Gottsche

Radula notarisii Steph. = **Radula complanata** (L.) Dumort.

Radula obscura Mitt.

Radula rara Steph. = **Radula tabularis** Steph.

Radula tabularis Steph.

Rebouillia hemisphaerica (L.) Raddi = **Reboulia hemisphaerica** (L.) Raddi

Reboulia hemisphaerica (L.) Raddi

Reboulia javanica Nees = **Reboulia hemisphaerica** (L.) Raddi

Reboulia longiceps Sande Lac. = **Reboulia hemisphaerica** (L.) Raddi

Reboulia microcephala (Taylor) Nees = **Reboulia hemisphaerica** (L.) Raddi

Reboulia sullvanti Lehm. = **Reboulia hemisphaerica** (L.) Raddi

Riccardia crenulata Schiffn. = **Riccardia tenuicostata** Schiffn.

Riccardia indica (Steph. ex Kashyap) Pande & K.P. Srivast. = **Aneura pinguis** (L.) Dumort.

Riccardia levieri Schiffn.

Riccardia pinguis (L.) Gray = **Aneura pinguis** (L.) Dumort.

Riccardia tenuicostata Schiffn.

Riccia bengalensis Khan = **Riccia billardieri** Mont. & Nees

Riccia beyrichiana Hampe

Riccia billardieri Mont. & Nees

Riccia bulbifera Steph. = **Riccia billardieri** Mont. & Nees

Riccia canaliculata Hoffm. = **Riccia fluitans** L.

Riccia canaliculata Hoffm. var. *fluitans* Schiffn. = **Riccia fluitans** L.

Riccia cavernosa Hoffm.

Riccia crystallina auct. non L. sensu Kashyap 1929. = **R. cavernosa** Hoffm.

Riccia discolor Lehm. & Lindenb.

Riccia duplex Lorh. (Dubia)

Riccia epicarpa Wallr. = **Riccia sorocarpa** Bisch.

Riccia fluitans L.

Riccia gangetica Ahmad ex L.Söderstr., A.Hagborg & von Konrat

Riccia glauca L. var. *ciliaris* Warnst. = **Riccia beyrichiana** Hampe

Riccia glauca L. var. *subinermis* Warnst. = **Riccia beyrichiana** Hampe

Riccia gollani Levier = **Riccia discolor** Lehm. & Lindenb.

Riccia himalayensis Kashyap = **Riccia discolor** Lehm. & Lindenb.

Riccia intermedia E.Jones = **Riccia discolor** Lehm. & Lindenb.

Riccia media Klinggr. = **Riccia fluitans** L.

Riccia minima L. = **Riccia sorocarpa** Bisch.

Riccia pathankotensis Kashyap

Riccia pimodii Kachroo = **Riccia billardieri** Mont. & Nees

Riccia raddiana J.B.Jack & Levier ex Steph. = **Riccia sorocarpa** Bisch.

Riccia robusta Kashyap = **Riccia cavernosa** Hoffm.

Rriccia sorocarpa Bisch.

Ricciella crystallina Warnst. = **Riccia crystallina** L.

Ricciella fluitans A.Braun = **Riccia fluitans** L.

Ricciella rautanenii Steph. = **Riccia crystallina** L.

Rupinia appendiculata (Lehm. & Lindenb.) Trevis. = **Plagiochasma appediculatum** Lehm. & Lindenb.

Rupinia intermedium Trevis. = **Plagiochasma intermedium** Lindenb. & Gottsche

Rupinia nepalensis (Lehm. & Bisch.) Trevis. = **Plagiochasma rupestre** (J.R.Forst. & G.Forst.) Steph.

Saccogyna graveolens Lindb. = **Geocalyx graveolens** (Schrad.) Nees

Sauchia spongiosa Kashyap = **Sauteria spongiosa** (Kashyap) S.Hatt.

Sauteria spongiosa (Kashyap) S.Hatt.

Scapania aequiloba (Schwägr.) Dumort.

Scapania andreana Steph. = **Scapania ferruginea** (Lehm. & Lindenb.) Gottsche

Scapania angusta Mitt. ex Müll Frib.

Scapania ferruginea (Lehm. & Lindenb.) Gottsche

Scapania glaucocephala (Taylor) Austin

Scapania nepalensis Nees = **Scapania ferruginea** (Lehm. & Lindenb.) Gottsche

Diplophyllum orientale (Steph.) Steph. = **Scapania orientalis** Steph.

Scapania parva Steph.

Scapania purpurea Kashyap

Scapania udarii S.C.Srivast. & Anshu Srivast.

Scapania verrucifera Mass. = **Scapania parva** Steph.

Scapania verrucosa Heeg.

Scopulina epiphylla Dumort. = **Pellia epiphylla** (L.) Corda

Sewardiella tuberifera Kashyap

Sindonisce fragrans Corda = **Mannia fragrans** (Balb.) Frye & L.Clark

Solenostoma breviflorum Kashyap

Solenostoma crenulatum Mitt. = **Solenostoma gracillimum** (Sm.) R.M.Schust.

Solenostoma glaucum (Amakawa) Váňa & D.G.Long

Solenostoma gracillimum (Sm.) R.M.Schust.

Solenostoma indrodayanum (S.K.Singh & D.K.Singh) Váňa & D.G.Long

Solenostoma infuscum (Mitt.) J.Hentschel

Solenostoma polyrhizoides (Grolle ex Amakawa) Váňa & D.G.Long

Solenostoma purpuratum (Mitt.) Steph.

Solenostoma subrubrum (Schiffn. ex Steph.) Váňa & D.G.Long

Stephensoniella brevipedunculata Kashyap

Synhymenium aureonitens Griff. = **Cyathodium aureonitens** (Griff.) Mitt.

Syzygiella autumnalis (DC.) K. Feldberg, Váňa, Hentschel & J. Heinrichs (Fig. 40 A-B).

Syzygiella elongella (Taylor) K. Feldberg, Váňa, Hentschel & J. Heinrichs

Syzygiella nipponica (S.Hatt.) K. Feldberg, Váňa, Hentschel & J. Heinrichs

Targionia hypophylla L.

Targionia indica Udar & Gupta

Taxilejeunea discreta (Lindenb.) R.M. Schust. = **Lejeunea discreta** Lindenb.

Trocholejeunea bidenticulata P.C.Wu = **Trocholejeunea infuscata** (Mitt.) Verd.

Trocholejeunea infuscata (Mitt.) Verd.

Trocholejeunea levieri (Steph.) Schiffn. = **Trocholejeunea infuscata** (Mitt.) Verd.

Trocholejeunea sandvicensis (Gottsche) Mizut.

Tuzibeanthus chinensis (Steph.) Mizut.

Tuzibeanthus porelloides S.Hatt. = **Tuzibeanthus chinensis** (Steph.) Mizut.

Wiesnerella denudata (Mitt.) Steph.

Wiesnerella javanica Schiffn. = **Wiesnerella denudata** (Mitt.) Steph.

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