

# Exploration of liverwort diversity on *Cinchona* plantation in Dodabetta, Nilgiri Hills, India

S.C. Srivastava and Praveen Kumar Verma

*Botany Department, Lucknow University, Lucknow -226 007*

Srivastava S.C. & Verma P.K. 2004. Exploration of liverwort diversity on *Cinchona* plantation in Dodabetta, Nilgiri Hills, India. *Geophytology* 32 (1&2) : 1-18.

The epiphytic diversity of Hepaticae occurring on *Cinchona* plantation spread in an area of over 3 sq. km in Dodabetta, Nilgiri hills (Tamil Nadu), has been discussed. The bark of phorophyte provides a suitable substrate to the liverworts because of rugged surface. Samples gathered from basal and middle stem (trunk) of the host trees including the twigs provide a changed physical environment in all the three regions of the stem. The basal region contains those species which are facultative epiphytes such as *Lophocolea muricata* while the other two regions show obligate epiphytes like *Metzeria pandei*. A total of 13 species belonging to Jungermanniales and a single species of Metzgeriales have been described.

**Key-words**—Liverwort, *Cinchona*, Nilgiri Biosphere Reserve.

## INTRODUCTION

IN recent years much work has been done on epiphytic bryophytes as well as on relationship between cryptogamic epiphytes and host trees (the phorophytes) in United States, Canada, eastern Europe and Japan (Culberson, 1955; Iwatsuki, 1960; LeBlanc, 1959, 1963; Hale, 1952, 1955; Phillips, 1959; Shacklette, 1961; Schuster, 1959; Engle, 1960; Hoffman and Kazmeierski, 1969; Denison, 1973; Slack, 1971, 1976; Stringer and Stringer, 1974; Barkman 1958; Pike *et al.*, 1975) except India where no adequate attention has been given on this aspect of bryology (see Udar, 1976) in spite of rich forest cover in different bryologically rich territories of the country (Kachroo, 1993; Srivastava, 1994, 1998). Both Angiospermous and Gymnospermous phorophytes are well known to host epiphytic forms in India which have been described sporadically and reviewed from time to time (see Srivastava, 1998). In a recent contribution Srivastava *et al* (1994) have studied the bryophytes (liverworts) on tea plantations in a tea garden in Darjeeling (West Bengal) hosting half a dozen species including *Plagiochila luthiana* St., *Plagiochila forficata* Schiffn., *Porella campylophylla* var. *ligulifera* (Tayl.) Hatt., *Frullania neurota* Tayl., *Lejeunea flava* (Sw.) Nees and *Microlejeunea punctiformis* (Tayl.) Spr.

During a plant collection trip to Nilgiri hills in Ootacamund some liverworts growing as epiphyte on *Cinchona* plantations in Dodabetta (alt. ca. 2600 m.), an area which constitutes a part of one of the oldest Biosphere Reserve of the country (Nilgiri Biosphere Reserve) were collected. The liverworts found in this region show somewhat specific preference over the bark of *Cinchona officinalis* (Rubiaceae), a cultivar, which is always planted on sloppy mountains and requires annual precipitation of nearly 2200 mm and prefers cool and humid conditions. The phorophyte under consideration is an evergreen shrub and is a native of Andian highland of South America with opposite, simple, entire leaves and small flowers. The bark contains 30 important alkaloids with medicinally rich source of anti malarial drug quinine (Jain, 1994).

A critical investigation of the hepatic vegetation of the area under study revealed a total of 14 species forming conspicuous corticolous population with dominance of the largest order Jungermanniales (13 species) and a sole representative of Metzgeriales (one species). These include: *Lophocolea muricata* Nees (Geocalycaceae), *Plagiochila ghatiensis* St. (Plagiochilaceae), *Porella acutifolia* (Lehm. *et* Lindenb.) Trev. (Porellaceae), *Frullania tamarisci* (L.) Dum. (Jubulaceae), *Microlejeunea ulicina* Evans, *Cheilolejeunea imbricata* (Nees) Hatt.,

*Cheilolejeunea udarii* Srivastava *et al*, *Lejeunea flava* (Sw.) Nees, *Lejeunea wightii* Lindenb., *Lejeunea discreta* Lindenb., *Lopholejeunea sikkimensis* St. (Lejeuneaceae), *Radula madagascariensis* Gott., *Radula nilgiriensis* Udar *et* Kumar and *Metzgeria pandei* Srivastava *et* Udar (Metzgeriaceae).

### MATERIAL AND METHOD

Plant specimens were collected in October 2000 and March 2001 from the bark of *Cinchona officinalis* in Dodabetta, Nilgiri, Tamil Nadu, South India and are preserved in LWU (Lucknow University Hepatic Herbarium). Dried herbarium specimens were treated with tap water for nearly 3 hours to revive them to their original shape, however, fresh plants provide features of their natural colours. External morphology has been studied under a stereoscopic binocular microscope. Hand cut sections were mounted in 50% aqueous glycerine and internal structures were investigated under a compound microscope. The selection of phorophyte was made in about 3 km area of *Cinchonia* plantations. Random selection technique was applied, but no specific sampling methods were used. The plants were collected from the basal part (about 50 cm from base), middle part (1-2 metre) and branches or twigs of phorophytes.

### Key to genera and species of Hepaticae (Liverwort) on *Cinchona* bark

1. Plants thalloid without any differentiation in the assimilatory (photosynthetic) and storage zone .....Metzgeriales
  - Thalli with a sharp distinction between a narrow costa and unistratose wing, sex organs always on specialized ventral shoots (Metzgeriaceae) *Metzgeria*
  - Thallus wing 20-24 cells wide on either side of midrib, hairs occasionally present on ventral surface of the wing.....*M. pandei*
2. Plants always leafy (foliose) in organization, developing from a tetrahedral apical cell..... (Jungermanniales) -2
2. Leaves in two alternate rows on the axis without underleaves.....3
2. Leaves in three rows (two dorso-lateral and one ventral row of amphigastria) on the axis..... 4
3. Leaves simple and dentate, vegetative branches lateral intercalary, postical intercalary or even terminal and always *Frullania*-type..... Plagiochilaceae
  - Stem usually with one layer of cortical cells, leaves and female bracts usually dentate, leaf insertion extended to dorsal mid line of stem .....*Plagiochila*
  - Plants generally small, up to nearly 20 mm or so, with flagelliform branches, leaves bi to tridentate *P. ghatiensis*
3. Leaves complicate bilobed, rhizoids always arising from leaf-lobule, branching *Radula*-type..... (Radulaceae) *Radula* 5
4. Leaves and underleaves bifid
  - Branching intercalary, underleaf free or connate with dorso-lateral leaves, rhizoids usually in fascicles on underleaf-base..... Geocalyceae
  - Male and female inflorescence terminal on main shoot or on equally vigorous lateral shoots, female bracts and bracteoles larger or as large as the leaves and underleaves..... *Lophocolea*
  - Leaf, underleaf, bracts, bracteoles and perianth with 2-4 celled spinate projections all over the plant surface.....*L. muricata*
4. Leaves complicate bilobed, underleaves entire or bifid.....6
5. Plants gemmiparous, gemmae marginal on leaf.....

### PLATE 1

**Figures 1-4.** *Metzgeria pandei* Srivastava *et* Udar 1. Plant (ventral view). 2. Cross section of the thallus. 3. Median cells of the wing. 4. Dorsal epidermal cells of midrib. **Figures 5-10.** *Lophocolea muricata* (Lehm.) Nees. 5. Male Plant (Dorsal view). 6.

Male plant (ventral view). 7. Leaf. 8,9. Underleaves. 10. Median cells of Leaf. **Figures 11-17.** *Plagiochila ghatiensis* St. 11. Plant (dorsal view). 12. Cross section of axis. 13-16. Leaves. 17. Median cells of leaf.

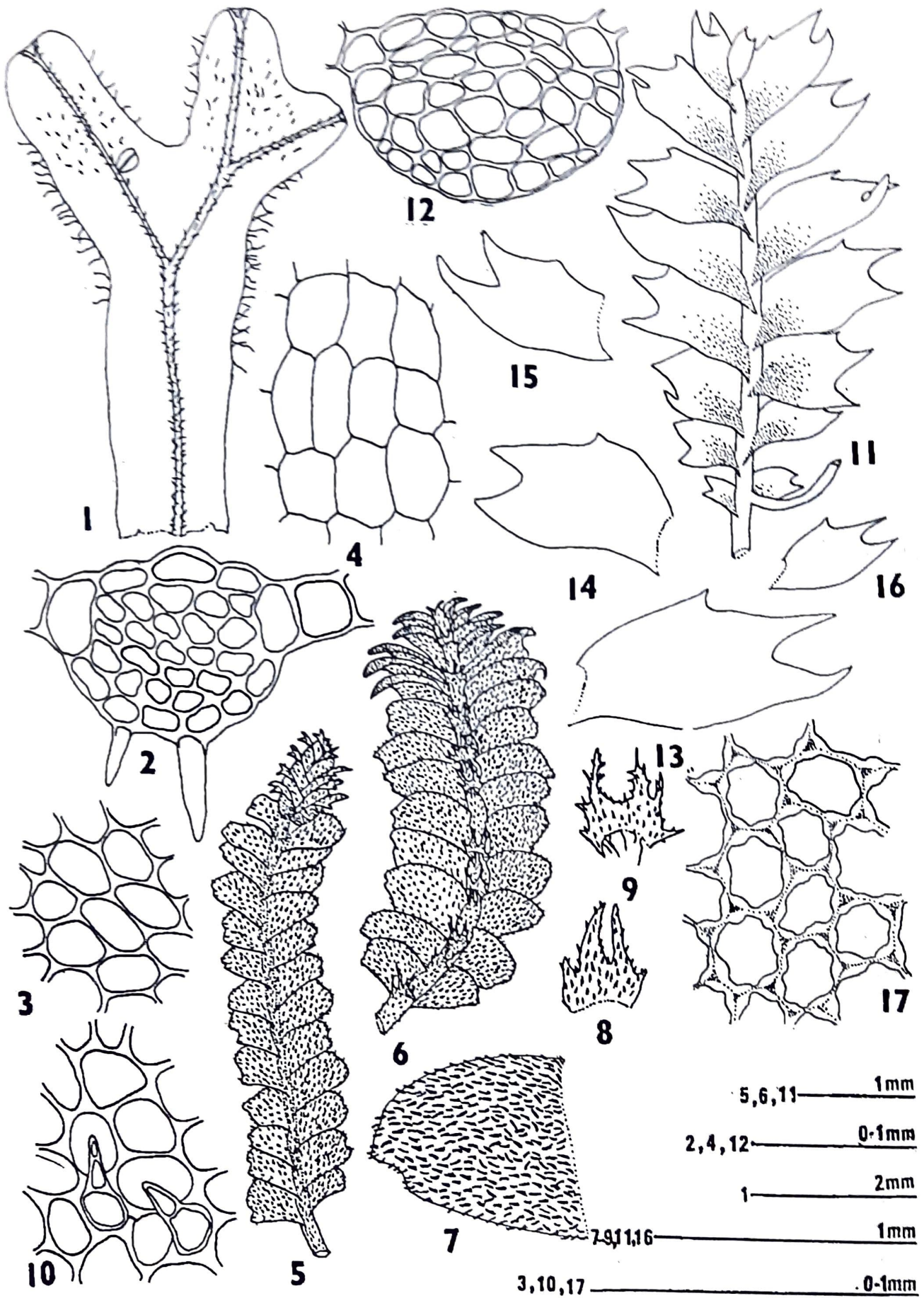


PLATE 1

- lobe and leaf-lobule, lobule  $\frac{1}{2}$  of the lobe length  
.....*R. nilgiriensis*
5. Plants non-gemmiparous, leaf lobule-rectangular,  
2/3 of leaf-lobe length and narrowly falcate.....  
.....*R. madagascariensis*
6. Leaf-lobules and underleaves more or less  
identical in shape and size.....  
.....(Porellaceae) *Porella*
- Leaf-lobe densely imbricate, with acute apex,  
leaf lobule and underleaves obtuse, some-  
times with 2-3 dentitions at apex.....  
.....*P. acutifolia*
6. Leaf-lobules and underleaves never identical, leaf  
-lobules inflated.....7
7. Plants reddish-brown to black or deep green, leaf,  
lobule parallel to stem, usually not attached to it,  
generally inflated or linear, perianth trigonous,  
dorsiventrally flattened....Jubulaceae (*Frullania*)
- Plants mostly dark-brown, without subfloral  
innovations, leaf-lobules saccate with 2-3(4)  
celled stylus, ocelli in one or two rows with  
leaf cells thick-walled, underleaf bifid.....  
.....*F. tamarisci*
7. Plants generally green or plae-green, leaf lobule  
parallel to posterior margin of leaf-lobe and  
broadly attached to stem at an angle with distinct  
keel.....Lejeuneaceae-8
8. Underleaves always entire, branching *Frullania*-  
type, seta with 16 peripheral and 4 (or rarely  
more) inner cells, perianth pluriplicate (4-to  
multiplicate).....Ptychanthoideae
- Leaf cells with radiate trigones, subfloral  
innovation absent.....*Lopholejeunea*
  - Leaf-lobe obtuse, underleaves almost  
orbicular, slightly wider than long, female bract  
dentate, bracteole entire, perianth 5-keeled  
with prominent dentitions over surface.....  
.....*L. sikkimensis*
8. Underleaves always bifid (except *Leucolej-*  
*eunea*) branching *Lejeunea*-type, seta with 12  
peripheral and 4 inner cells, perianth typically 5-  
keeled.....*Lejeuneoideae*-9
9. Plants relatively very small (2-7 mm. long), stem  
with only 3 medullary cells, leaf-lobules large (3/4  
of the lobe length).....*Microlejeunea*
- Leaf-lobes ovate, with sub-rounded apex  
.....*M. ulicina*
9. Plants medium-large (9-25 mm long), leaf-lobule  
generally inflated.....10
10. Plants large, up to 35 mm long, leaf-lobules with  
1-3 celled apical tooth, lobule forming sharp keel  
with leaf lobe.....*Cheilolejeunea*-11
10. Plants generally medium in size (up to 18 mm),  
leaf-lobule always with one-celled apical tooth,  
leaf-cells and stem cells thin walled.....  
.....*Lejeunea*-12
11. Second tooth of lobule large, uniseriate, 2-4  
celled and acute, leaf lobule 2/3 of the lobe.....  
.....*Cheilolejeunea imbricata*
11. Second tooth of lobule short, triangular, 1-3  
celled, leaf-lobule  $\frac{1}{2}$  of the leaf-lobe length.....  
.....*C. udarii*
12. Leaves widely spreading, leaf-lobule 1/3 of the  
leaf-lobe length, monoecious.....*L. flava*
12. Leaf-lobules  $\frac{1}{2}$  of the leaf-lobe length, dioecious.  
..... 13
13. The cells below the first tooth of the leaf-lobule  
larger than other neighbouring cells.....*L. discreta*
13. The cells below the first tooth of the leaf-lobule  
similar to other neighbouring cells..... *L. wightii*

## OBSERVATIONS

*Metzgeria pandei* Srivastava et Udari in: *New Botanist* Vol. II(1): 1-57 (1975). (Plate-1, figs. 1-4; Plate-5, figs. 1, 2)

## PLATE 2

Figures 1-7. *Frullania tamarisci* (L.) Sde. Lac. 1. Plant (ventral view). 2-3. Leaves. 4-6. Underleaves. 7. Median cells of Leaf. Figures 8-13. *Porella acutifolia* (Lehm. & Lindenb) Trev. 8. Plant (ventral view). 9,10. Leaves. 11,12. Underleaves. 13. Median cells of Leaf-lobe. Fig-

ures 14-26. *Lopholejeunea sikkimensis* St. 14. Plant (ventral view). 15. Female plant (ventral view). 16-18. Leaves. 19,20. Underleaves. 21. Median cells of Leaf-lobe. 22,23. Female bract. 24. Female bracteole. 28. Perianth. 26. Cross Section of Perianth.

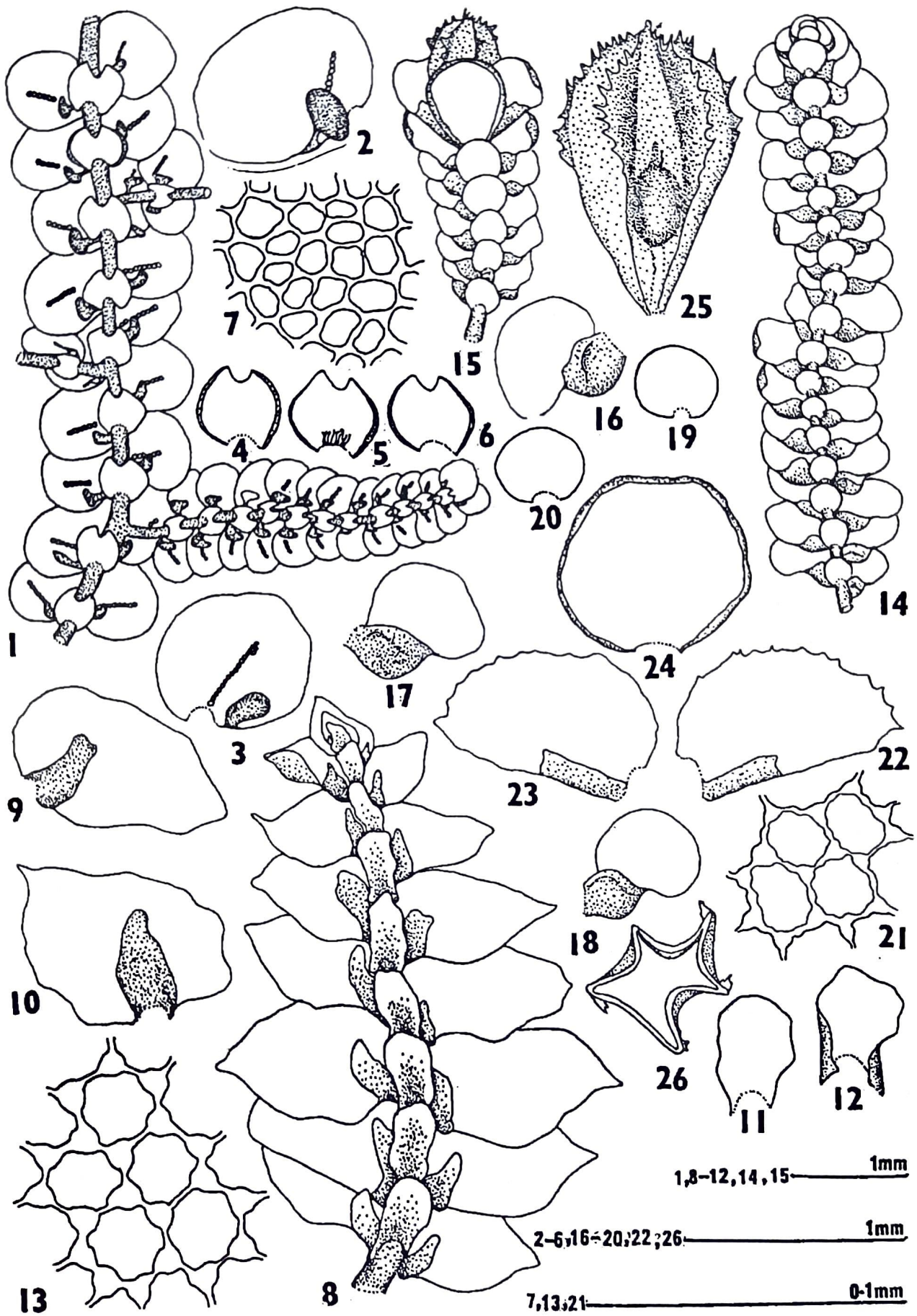


PLATE 2

Thallus prostrate, green up to 12.0 mm long, 2.5-3.0 mm wide, apices wide, obtuse, dichotomously branched, Gemmae absent, wing 17-25 cells wide on either side of midrib, marginal cells 45-54  $\mu\text{m}$ , thin walled, without trigones, hairs long disposed singly at the margins, also scattered ventrally on the wings towards the apical shoot, besides midrib, midrib cells 3/5, with 15-20 smaller polygonal, thick-walled inner cells, Sterile.

Type loc.: Kodaikanal (Palni hills) (Srivastava and Udar, 1975)

Range: Endemic to India

Distribution in India: South India: Tamil Nadu- Nilgiri hills, Ootacamund, (Dodabetta, Government Botanical Garden; Palni hills, Kodaikanal, Shembagnur (Srivastava and Udar, 1975)

Associates: *Radula nilgiriensis*, *Lopholejeunea sikkimensis* and *Frullania tamarisci*

Specimen examined: LWU 52/62 (Holotype). *Metzgeria pandei* Srivastava et Udar; Loc.: South India: Tamil Nadu-Palni Hills, Kodaikanal (Bryant Park), alt. ca. 1970 m; Date: Oct. 18, 1962; Legit.: R. Udar and V. Chandra; Det.: S.C. Srivastava and R. Udar.

LWU 12493/2000, 12499/2000 *Metzgeria pandei* Srivastava et Udar; Loc.: South India: Tamil Nadu- Nilgiri hills, (Dodabetta); alt. ca. 2600 m; Date: Oct. 8, 2000; Legit., S.C. Srivastava and Party; Det.: S.C. Srivastava and P.K. Verma.

*Metzgeria pandei* is closely related to *Metzgeria indica* in distribution of hairs on ventral surface of thallus wings and number of rows of cells over the dorsal and ventral epidermal cells of the midrib, but differs in the presence of dorsal gemmae and relatively wide wing in *M. indica* (up to 34 cells wide on either side of the wing). This species has been collected for the first time since its original discovery (Srivastava & Udar, 1975) and is very well spread over the Nilgiri

hills in Tamil Nadu. Earlier it was reported from Kodaikanal (Palni hills) and is stated to be endemic to India. Presently this species has been very frequently observed in peninsular India.

*Lophocolea muricata* (Lehm.) Nees in: Gott. et al Syn. Hep. 169(1845). (Plate-1, figs. 5-10; Plate-5, fig.3)

Plants prostrate, light green, up to 20.0 mm long, 0.8-1.1 mm wide, with lateral branching. Leaves sub-imbriate, sub-transversally inserted, succubous, alternate, ovate, 0.6-0.92 mm long, 0.41-0.88 mm wide, bifid, lobes sub-acute, antical margin straight, postical margin arched, leaves covered with 1-3 celled acute spine; median cells thin walled with triradiate trigones, 11.2-19.8  $\mu\text{m}$  x 11.0-19.2  $\mu\text{m}$ . Underleaves narrowly and laterally connate with adjoining leaves only at the base, bisbifid, 0.22-0.39 x 0.18-0.28 mm, lobes acute, sinus wide, rhizoids arising from base.

Dioecious. Male inflorescence terminal or on lateral branches, spicate, bract in 5-6 pairs, apex usually bifid, bract-lobe and bract-lobule covered with spines. Female plant not seen.

Type Loc.: Cape of Good Hope (Schuster, 1980)

Range: Australia, Indonesia, India, Fiji Isls, NewZeland, Tasmania, New Guinea.

Distribution in India: South India: Tamil Nadu: Nilgiri hills- Dodabetta, Avalanche, Ootacamund, Naduvattam, Palni hills, Kodaikanal, Shembagnur (see also, Srivastava and Srivastava, 2002).

Associates: *Radula nilgiriensis*, *Porella acutifolia*, and *Lopholejeunea sikkimensis*

Specimens examined: LWU 12509/2000: South India: Tamil Nadu-Nilgiri hill (Dodabetta); alt. ca. 2600 m; Date : Oct. 8, 2000; Legit.: S.C. Srivastava and party; Det.: S.C. Srivastava and P.K. Verma.

Male plants of *Lophocolea muricata* has been observed for the first time in a recent collection from

### PLATE 3



**Figures 1-6.** *Lejeunea flava* (Sw.) Nees. 1. Plant (ventral view). 2. Female plant (ventral view). 3,4. Leaves. 5. Underleaf. 6. Median cells of Leaf-lobe. 7-12. *Lejeunea wightii* Lindenb. 7. Plant (ventral view). 8,9. Leaves. 10,11. Underleaves. 12. Median cells of Leaf-lobe. **Figures 13-19.** *Lejeunea discreta* Lindenb.

13. Plant (ventral view). 14-16. Leaves. 17,18. Underleaves. 19. Median cells of Leaf-lobe. **Figures 20-27.** *Microlejeunea ulicina* Evans. 20. Plant (ventral view). 21. Female plant (ventral view). 22-24. Underleaves. 25,26. Underleaves. 27 Median cells of Leaf-lobe.

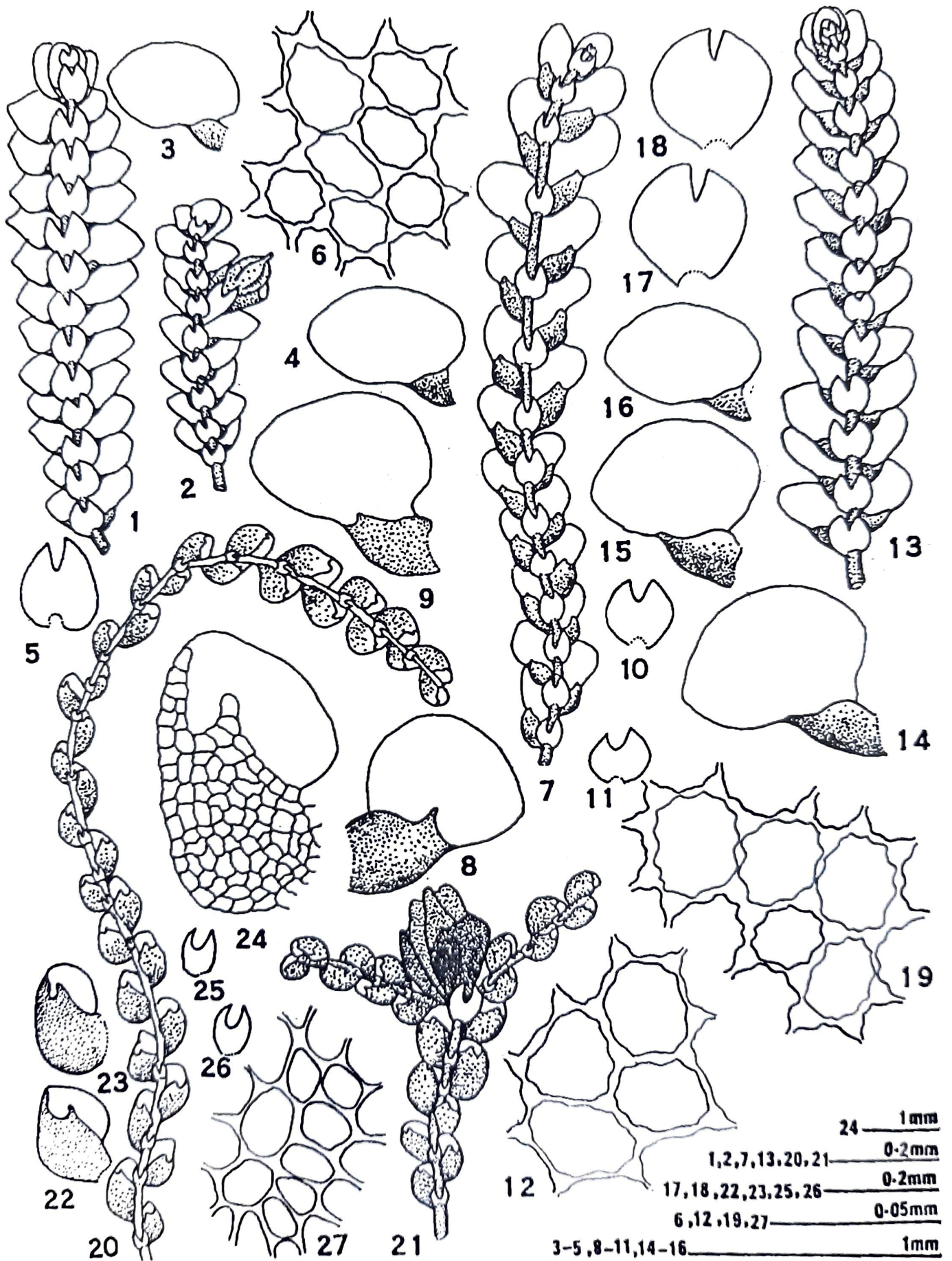


PLATE 3

India. However, female plants grow on other angiospermic phorophyte. This species is uncommon.

*Plagiochila ghatiensis* St. in: *Species Hep.* VI: 158 (1918). (Plate-1, figs. 11-17; Plate-5, fig.4).

Plants erect to suberect, small, up to 10.0 mm long, 1.60 mm wide, branching *Frullania*-type, often becoming flagelliform, Leaves small distant to sub-imbricate, sub-transverse to obliquely inserted, succubous, oblong, 1.01-1.08 mm long, 0.45-0.52 mm wide, dorsal margin decurrent at base, marginal teeth 2-3, small, leaf cells trigonous, median cells 16-27  $\mu\text{m}$  x 10-18  $\mu\text{m}$ , rhizoids restricted on lower axis. Plants sterile.

Type Loc.: Kodaikanal, (Bonner, 1962)

Range: India, China.

Distribution in India: South India: Tamil Nadu- Nilgiri hills, Ootacamund, Dodabetta; Palni hills, Kodaikanal, Shembagnur.

Associates: *Radula nilgiriensis*

Specimen examined: LWU 12507/2000 *Plagiochila ghatiensis* St.: Loc.: South India: Tamil Nadu- Nilgiri hills (Dodabetta), alt. ca. 2600 m, Date: Oct. 8, 2000. Legit.: S.C. Srivastava and Party. Det.: S.C. Srivastava & P.K. Verma.

This species was earlier reported from Kodaikanal (Stephani, 1918). It has now been recorded from Nilgiri mountains. The plants collected are sterile with frequent flagelliferous branches.

*Porella acutifolia* (Lehm & Lindenb) Trev.

in: *Mem. Real. Istit. Lombardos Sc. Lett ser.* 3, 4: 408 (1877). (Plate-2, figs. 8-13; Plate-5, fig.5)

Plants green prostrate, up to 35 mm long, large, bipinnately branched, Leaves densely imbricate, incubous, obliquely inserted, leaf-lobe usually oblong, ovate, 1.20-1.40 mm long, 1.19-1.28 mm wide, entire, apex acute some time with 1-3 sub-apical teeth, cells trigonous, median cells 21-32  $\mu\text{m}$  x 16-27  $\mu\text{m}$ ,

leaf-lobules lanceolate, entire, 0.40-0.49 mm long, 0.28-0.33 mm wide, apex obtuse, slightly notched or acute, base decurrent. Underleaves imbricate, sinuately inserted, triangular-ovate, entire, 0.48-0.56 mm long, 0.44-0.048 mm wide, rarely with acuminate long decurrent base, reproductive structure not seen.

Type Loc.: Annamalai Hills (Tamil Nadu) (see Shaheen, 1983).

Range: Sri Lanka (Ceylon) Indonesia, Sumatra, Java, Indo-China, Celebes, Burma, Philippines, New Guinea, Hawaii, Ryukyu Islands, Japan, Nepal (Shaheen, 1983).

Distribution in India: South India: Nilgiri Hills- Ootacamund, Avalanche, Kalhatty slope, Dodabetta; Kerala- Devicolom; Karnataka- Kudremukh.

Associates: *Lophocolea muricata* and *Lopholejeunea sikkimensis*.

Specimens examined: LWU 12504/2000, *Porella acutifolia* (Lehm. & Lindenb.) Trev. Loc.: South India: Tamil Nadu- Nilgiri hills, (Dodabetta), alt. ca. 2600 m; Date: Oct. 8, 2000; Legit.: S.C. Srivastava and Party; Det.: S.C. Srivastava & P.K. Verma.

*Porella acutifolia* is sterile, growing only on *Cinchona* plantation. The species is very rare and not collected from any other phorophytes in Dodabetta.

*Frullania tamarisci* (L.) Sde. Lac.

in: *Miquel, Ann. Mus. Lugd. Batavi.* 1:313(1836) (Plate-2, figs. 1-7; Plate-5, fig.6)

Plants prostrate, reddish brown, upto 32.0 mm long, 1.2 mm wide, branching *Frullania*-type. Leaves imbricate, incubous, obliquely inserted, lobe ovate, 0.45-0.52 mm long, 0.38-0.42 mm wide, apex rounded, cells thickened, trigonous, indistinct, median cells 10-16  $\mu\text{m}$  x 8-13  $\mu\text{m}$ , leaf-lobule saccate, sub-parallel with the stem, galeate, uniform, 0.17-0.24 mm x 0.20-0.24 mm, Ocelli in a single row. Underleaves sinuately inserted, bifid, reproductive structures not seen.

#### PLATE 4

Figures 1-5. *Cheilolejeunea imbricata* (Nees) Hatt. 1. Plant (ventral view). 2. Leaf. 3,4. Underleaves. 5. Median cells. Figures 6-12. *Cheilolejeunea udarii* Asthana et al. 6. Plant (ventral view). 7-9. Leaves. 10,11. Underleaves. 12. Median cells of Leaf-lobe. Figures

13-16. *Radula madagascariensis* Gott. 13. Plant (ventral view). 14,15. Leaves. 16. Median cells of Leaf-lobe. 17-20. *Radula nilgiriensis* Udar et Kumar. 17. Plant (ventral view). 18,19. Leaves. 20. Median cells.



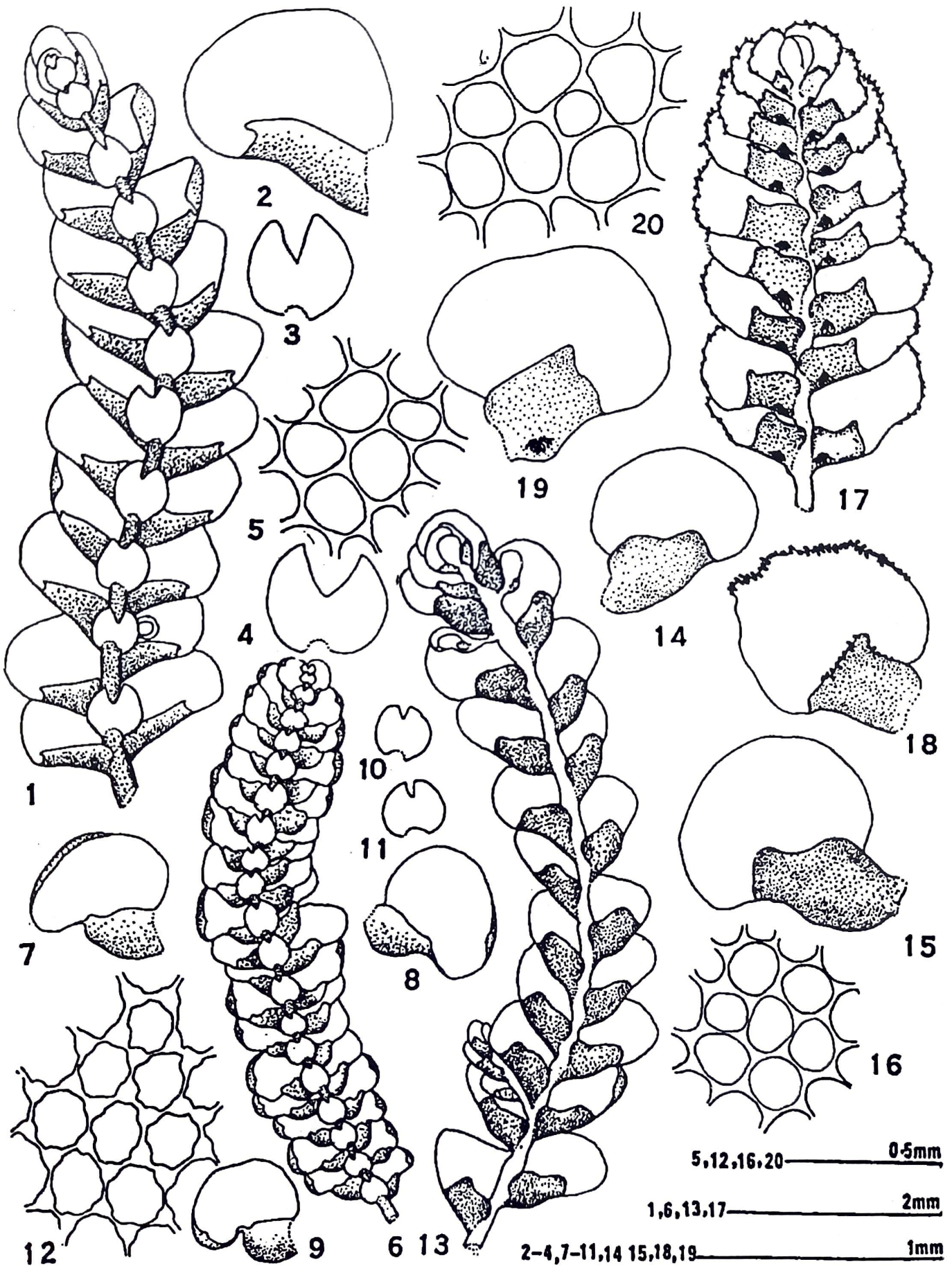


PLATE 4

Type Loc.: Europe (Macvicar, 1912)

Range: India, Sri Lanka (Ceylon), Europe

Distribution in India: South India: Tamil Nadu-Nilgiri hills, Ootacamund, Avalanche, Upper Bhavani, Dodabetta, Pykara, Palni hills, Kodaikanal; Kerala-Idukki, Wynad.

Associates: *Metzgeria pandei*, *Radula nilgiriensis*, *Lopholejeunea sikkimensis* and *Cheilolejeunea imbricata*.

Specimen examined: LWU 12493/2000, 12499/2000, 12502/2000, 12503/2000, 12513/2000, *Frullania tamarisci* (L.) Sde. Lac.; Loc.: South India: Tamil Nadu-Nilgiri hills, (Dodabetta); alt. ca. 2600 m; Date: Oct. 8, 2000; Legit.: S.C. Srivastava & Party; Det.: S.C. Srivastava & P.K. Verma.

*Frullania tamarisci* is similar to *F. densiloba* (newly reported from India) (Srivastava and Alam, 2002), both being ocellate in nature. However, it differs in characters related to size of leaf, leaf-lobule shape, and underleaves. The species is most frequently occurring as a terrestrial and epiphytic population in Dodabetta.

*Lopholejeunea sikkimensis* St. in: *Species Hep. V*: 87(1912). (Plate-2, figs. 14-26; Plate-5, fig.7).

Plants prostrate, greenish-brown, upto 21.0 mm long, 2.0 mm wide, Leaves imbricate, incubous, widely spreading, lobe ovate, 0.55-0.77 mm long, 0.48-0.68 mm wide, margin entire, cells with radiate trigones, median cells 18-35  $\mu\text{m}$  x 15-28  $\mu\text{m}$ , leaf-lobules saccate,  $\frac{1}{2}$  of the lobe length 0.25-0.31 mm x 0.17-0.21 mm, with indistinct tooth. Underleaves wider than long, 0.30-0.35 mm long, 0.43-0.49 mm wide, margin entire, apex rounded. Monoecious, Male inflorescence usually on lateral branches, without subfloral innovation, bracts-lobe ovate or obovate 0.70-0.77 mm long, 0.35-0.38 mm wide, margin entire to dentate, acute, bract-lobule, rectangular, bracteole almost orbicular 0.66-0.73 mm long, 0.77-0.80 mm wide, revolute, Perianth obovate, 5-keeled, keel dentate.

Type Loc.: Sikkim (Stephani, 1912)

Range: India, Nepal

Distribution in India: Eastern Himalaya: West Bengal-Darjeeling (L.B.G.)- Manipur; Meghalaya; Shillong; Sikkim: Nathula Road; Western Himalaya: Uttaranchal; Central India: Madhya Pradesh-Pachmarhi; South India: Tamil Nadu-Nilgiri hills-Naduvattam, Dodabetta, Government Botanical Garden, Pykara; Kerala-Lakkidi (See Awasthi *et al* 2001).

Associates: *Metzgeria pandei*; *Radula nilgiriensis*, *Frullania tamarisci*, *Porella acutifolia* and *Lophocolea muricata*.

Specimens examined: LWU 12493/2000, 12494/2000, 12504/2000; *Lopholejeunea sikkimensis*; Loc.: South India: Tamil Nadu-Nilgiri hills (Dodabetta), alt. ca. 2600 m; Date: Oct. 8, 2000, Legit.: S.C. Srivastava & Party. Det.: S.C. Srivastava and P.K. Verma.

*L. sikkimensis* shows great range of plasticity in structure specially female bract. The species is widely distributed in various parts of country. In Nilgiri hills the plants grow on a wide range of diversified habitats (see also, Awasthi *et al*, 2001)

*Lejeunea flava* (Sw.) Nees in: *Naturg. Eur. Leberm.* 3: 277(1838); *Journ. Hatt. Bot. Lab.* 11: 22-23 (1954). (Plate-3, figs. 1-6; Plate-5, fig.9)

Plants prostrate, light yellowish green, up to 13 mm long, irregularly branched by *Lejeunea*-type branching. Leaves imbricate, obliquely inserted, widely spreading, lobe ovate, sub-acute, 0.5-0.65 mm long, 0.48-0.5 mm wide, dorsal margin arched, postical margin less arched, margin entire, cells thin walled with minute trigones, intermediate nodular thickening present, median cells 11-15  $\mu\text{m}$  x 14-22  $\mu\text{m}$ , leaf-lobule uniformly inflated,  $\frac{1}{2}$  of the lobe length, apical cell obtuse with single celled tooth. Underleaves large, sub-imbricate, sinuately inserted, ovate-orbicular, 0.48-

## PLATE 5

Figures 1-9. 1. *Metzgeria pandei* Srivastava *et* Udar (x 8). 2. Same (magnified view x 13). 3. *Lophocolea muricata* (Lehm.) Nees (x 18). 4. *Plagiochila ghatiensis* St. (x18). *Porella acutifolia* (Lehm. &

Lindenb.) Tarev. (x18). *Frullania tamarisci* (L.) Sde. Lac. (x18). *Lopholejeunea sikkimensis* St. (x10). 8. *Lejeunea discreta* Lindenb. (x18). 9. *Lejeunea flava* (Sw.) Nees (x16).

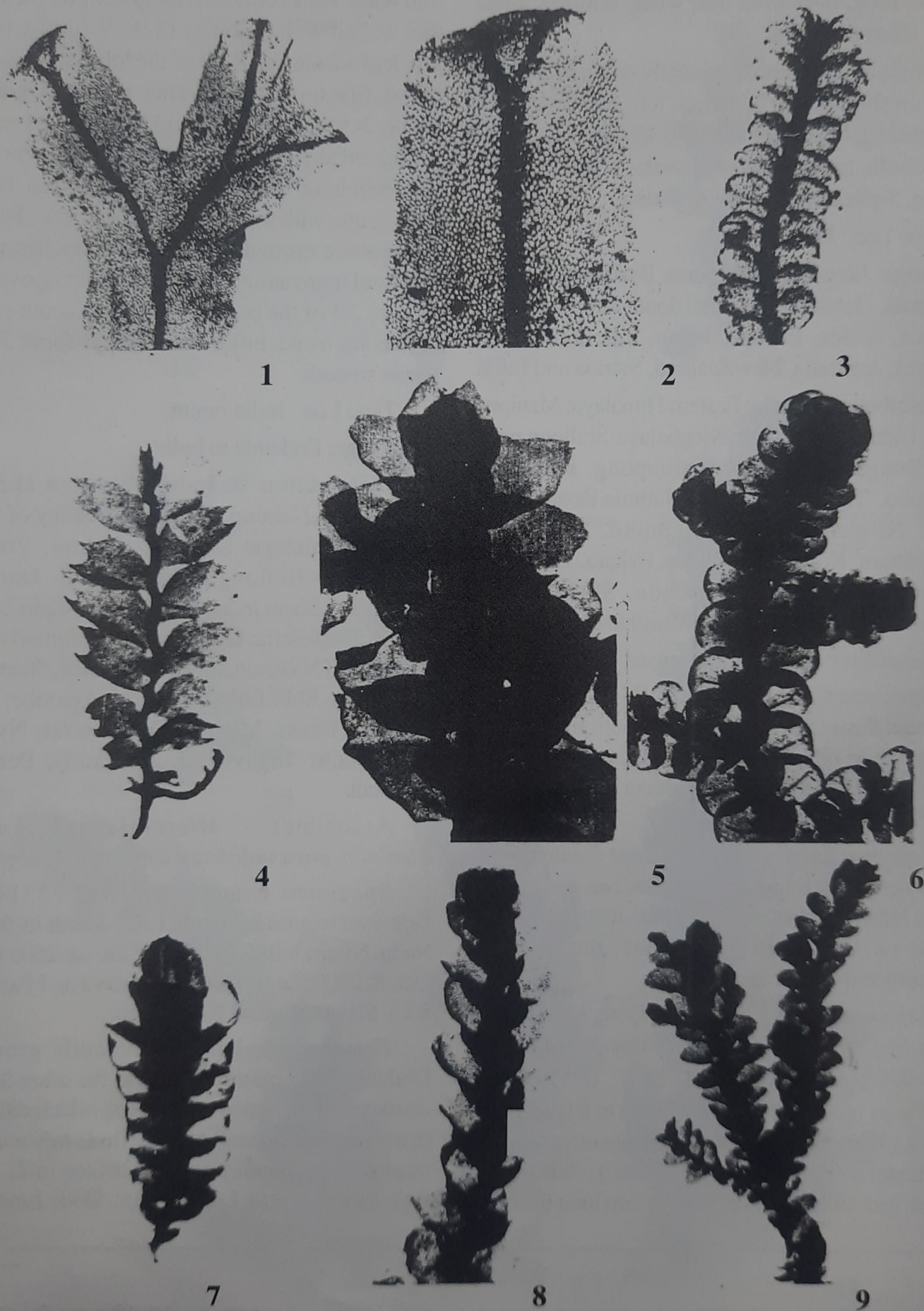


PLATE 5

0.51 mm long, 0.41-0.45 mm wide, bilobed, sinus narrow, lobes triangular.

Female inflorescence frequently on main shoot as well as on short lateral branches, terminal bract-lobe ovate-oblong, 0.62-0.69 x 0.38-0.43 mm, sub-acute, bract-lobule, large, bracteole ovate, bifid; Perianth obovate, 5-plicate, sporophyte young.

Type Loc.: Jamaica

Range: Jamaica, West Indies, Bermuda, Mexico, Guatemala, Honduras, Panama, South America, North America, Africa, Europe, Japan, Indonesia (Java, Sumatra), Australia, New Zealand, Samoa and India.

Distribution in India: Eastern Himalaya: Manipur-Jowai, Ukhrul, Vishnupur; Meghalaya-Shillong peak; West Bengal-Darjeeling, Kalimpong, Kurseong, Mongpoo, Tiger hill; Sikkim-Nathula Road, South India: Nilgiri hills, Ootacamund, Dodabetta, Naduvattam, Kotagiri, Coonoor, Pykara, Palni hills, Perumalmalai, Silver cascade, Shembagnur, Periakulam, Berizam; Kerala-Murukkady.

Associates: *Radula nilgiriensis*

Specimen examined: LWU 12499/2001, *Lejeunea flava* (Sw.) Nees, Loc.: South India: Tamil Nadu- Nilgiri hills (Dodabetta), alt. ca. 2600 m; Date Oct. 8, 2000; Legit.: S.C. Srivastava and Party; Det.: S.C. Srivastava and P.K. Verma.

*Lejeunea flava* is one of the most dominant species among South Indian Lejeuneaceae, specially in Nilgiri hills. The plant is monoecious, though plants not found on *Cinchona* plantations, but on other phorophyte it occurs abundantly:

*Lejeunea wightii* Lindenb. in: Gott., Lindenb. and Nees *Syn. Hep.* 379(1845). (Plate-3, figs. 7-12; Plate-6, figs. 10, 11)

Plants prostrate, small, green up to 6.0 mm long, 0.45-0.49 mm wide, branching *Lejeunea*-type. Leaves imbricate, incubous, widely spreading, obliquely inserted, leaf-lobe ovate, 0.28-0.50 mm long 0.21-0.41

mm wide, apex rounded, margin entire, median cells thin walled with trigones, 18.9-29.7  $\mu\text{m}$  x 16.2-24.3  $\mu\text{m}$ , leaf-lobule small 1/3 of the lobe length, ovate, inflated, first tooth with hyaline papilla. Underleaves small, 2-3 times of stem width, sub-transversely inserted, bifid 1/2 of the length, ovate-orbicular, 0.13-0.28 mm long, 0.11-0.24 mm wide, lobes triangular, apex acute, with a wide sinus. Dioecious, Female inflorescence normally on lateral branches with one subfloral innovation, bract-lobes oblong-ovate, bract lobules 2/3 of the bract length, apex acute-subacute, bracteoles ovate, bifid. Perianth pyriform, 5-plicate, plicae smooth.

Type Loc.: India orient.

Range: Endemic to India

Distribution in India: Western Himalaya: Uttaranchal-Nainital, Chaubatia, Valley of flowers; Eastern Himalaya: Manipur- Ukhrul, Vishnupur; Meghalaya-Shillong; West Bengal- Darjeeling, Kalimpong; South India: Tamil Nadu-Nilgiri hills, Avalanche, Dodabetta, Coonoor, Ootacamund (G.B.G., Rly. Track.) Naduvattam, Perumalmalai, Shembagnur; Karnataka-Abbi falls, Mercara, Agumbe; Kerala-Achilatti forest, Munnar, Perriavurrai, Nymakad, Devicolam, Vagavurrai, Thekkady, Peermade, Ponnudi.

Associates: *Microlejeunea ulicina*, *Cheilolejeunea imbricata* and *Radula nilgiriensis*.

Specimen examined: LWU 12514/2000, *Lejeunea wightii* Lindenb. Loc.: South India, Tamil Nadu, Nilgiri hills (Dodabetta); alt. ca. 2600 m; Date: Oct. 8, 2000. Legit.: S.C. Srivastava and Party; Det.: S.C. Srivastava and P.K. Verma.

*Lejeunea wightii* is abundantly growing in Dodabetta and closely related to the other South Indian species, *Lejeunea tuberculosa*, which differs only in mammilose perianth surface (in *L. tuberculosa*) as opposed to smooth perianth surface in *L. wightii*, *Lejeunea discreta* Lindenb. in: Gott. Lindenb. &

## PLATE 6

Figures 10-18. 10. *Lejeunea wightii* Lindenb. (x16). 11. Female plant of *Lejeunea wightii* Lindenb. (x16). 12. *Microlejeunea ulicina* Evans (x30). 13. Female plant of *Microlejeunea ulicina* (x30). 14. *Cheilolejeunea*

*imbricata* (Nees) Hatt. (x15). 15. *Cheilolejeunea udarii* Asthana et al (x 15). 16. *Radula madagascariensis* Gott. (x6). 17. *Radula nilgiriensis* Udar et Kumar (x8). 18. Same, showing branching (x10).

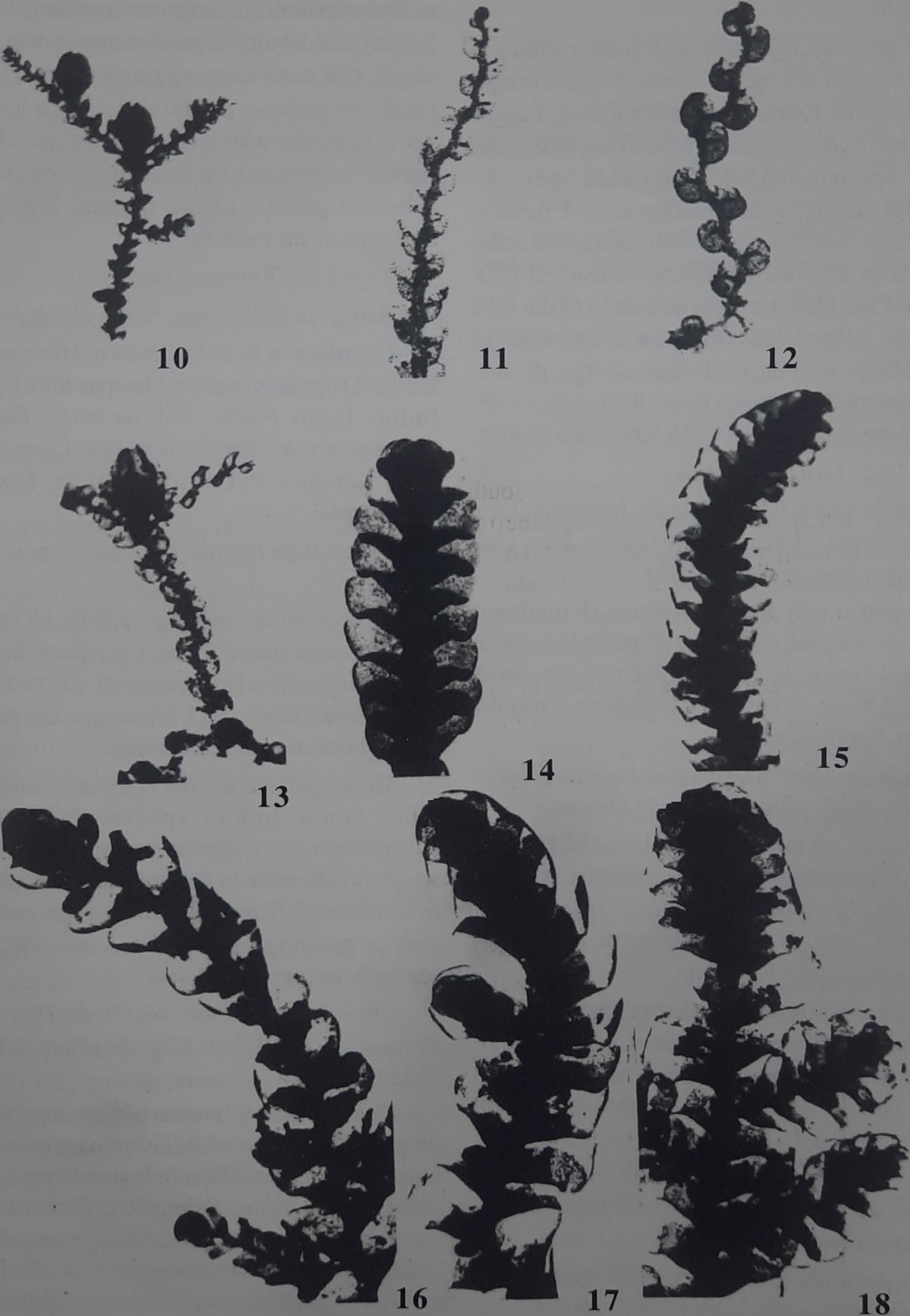


PLATE 6

Nees, *Syn. Hep.* 361(1848). (Plate-3, figs. 13-19; Plate-5, fig.8)

Plants, prostrate, light yellowish-green, medium in size, up to 8.0 mm in length, 1.0 mm in width, irregularly branched by *Lejeunea*-type branching. Leaves sub-imbricate, obliquely inserted, incubous, lobe ovate, 0.63-0.73 mm long, 0.45-0.52 mm wide, apex sub-acute, margin entire, antical margin arched, postical margin straight, cells thin walled with intermediate nodular thickenings, trigones prominent, median cell 18.0-24.0  $\mu\text{m}$  x 13.0-18.0  $\mu\text{m}$ , leaf-lobule  $\frac{1}{2}$  of the lobe length, large, inflated, cells below the first tooth larger than neighbouring cells. Underleaves large, distant, sinuately inserted, 3-4 times wider than stem, ovate, bifid,  $\frac{1}{2}$  of the length, sinus wide, lobe acute at apex.

Type Loc.: Java (Indonesia)

Range: Sri Lanka (Ceylon), India, Indonesia (Java, Sumatra), Burma, Molucca, New Guinea, New Caledonia, Japan (see, agarwal, 1986)

Distribution in India: Western Himalaya: Uttaranchal- Nainital, Chaubatia; Eastern Himalaya: West Bengal-Darjeeling, Rimbic; Sikkim-Sukia, South India: Tamil Nadu- Nilgiri hills, Dodabetta, Emerald, Wellington, Naduvattam.

Associates: *Cheilolejeunea imbricata*, *Radula nilgiriensis* and *Lopholejeunea sikkiminsis*.

Specimen examined: LWU 12514/2000, *Lejeunea discreta* Lindenb.; Loc.: South India: Tamil Nadu-Nilgiri hills (Dodabetta), alt. ca. 2600 m; Date: Oct. 8, 2000; Legit.: S.C. Srivastava and Party; Det.: S.C. Srivastava and P.K. Verma.

*Lejeunea discreta* grows very commonly in Dodabetta and other areas besides *Cinchona* plantation with association of other native species *Lejeunea perrottetii*. But most of them are vegetative.

*Microlejeunea ulicina* Evans in: *Mem. Torrey Bot. Club.* 8: 165, (1902). (Plate-3, figs. 20-27; Plate-5, figs. 12, 13)

Plants prostrate, green, very small, upto 12 mm long, 2.5-3.0 mm wide, branching *Lejeunea*-type. Leaves distant, incubous, obliquely inserted, sub-erect spreading, lobe sub-ovate, apex rounded, 0.13-0.19

mm long, 0.12-0.19 mm wide, leaf-lobe cells thin walled with indistinct trigones, median cells 5-9  $\mu\text{m}$  x 5-8  $\mu\text{m}$ , leaf-lobules large, about more than  $\frac{2}{3}$  of lobe length, first tooth long and single celled. Underleave, small, orbicular-ovate, bifid  $\frac{1}{2}$  of their length, sinus small, triangular with acute-subacute apex, Dioecious, Female inflorescence on lateral branches, perianth pyriform, 5-plicate, plicae smooth, bracts oblong, bracteole ovate and bifid.

Type Loc.: Kenmore Kerry county, Ireland

Range: India, Europe, Japan, North America.

Distribution in India: Eastern Himalaya: West-Bengal-Darjeeling; Sikkim; Manipur-Kanchipur, South India: Tamil Nadu- Nilgiri hills, Dodabetta, Naduvattam, Avalanche, Kutukuli, Coonoor, (Laws fall), Kotagiri, Pykara; Palni hills, Kodaikanal, Shembagnur.

Associates: *Radula nilgiriensis* and *Lejeunea wightii*.

Specimen examined: LWU 12512/2000. *Microlejeunea ulicina* Evans, Loc.: South India: Tamil Nadu, Nilgiri hills (Dodabetta); alt. ca. 2600 m; Date: Oct. 8, 2000; Legit.: S.C. Srivastava and party. Det.: S.C. Srivastava and P.K. Verma.

*Microlejeunea ulicina* is closely related to another south Indian species *Microlejeunea punctiformis* (Tayl.) Spruce on the basis of leaf-lobe which is sub-acute in *M. punctiformis* and rounded in *M. ulicina* differentiates the two species. The species is growing on *Cinchona* as well as other phorophytes, specially *Eucalyptus*.

*Cheilolejeunea imbricata* (Nees) Hatt. in: *Misc. Bryol. Lichenol.* 1(14): 1(1957). (Plate-4, figs. 1-5; Plate-6, fig. 14).

Plants prostrate, brownish-green, up to 28.0 mm long, 1.28-1.67 mm wide, *Lejeunea*-type branching. Leaves imbricate, obliquely inserted, incubous, lobe oblong 0.80-0.89 mm long, 0.70-0.77 mm wide, apex rounded, margin entire, antical margin arched, postical margin straight, cells trigonous, median cells 10-18  $\mu\text{m}$  x 10-16  $\mu\text{m}$  leaf-lobule inflated, rectangular, tooth indistinct, second tooth acute, falcate, 2-3 celled long, underleaves distant, sub-transversely inserted, double

of the stem width, orbicular-ovate, 0.30-0.35 mm long, 0.38-0.42 mm wide, bifid, ½ of the length, reproductive structure not seen.

Type Loc.: India orient.

Range: India, Japan, Bonin Is., Ryukyu, Taiwan (Formosa), Burma, Indonesia (Sumatra, Java), New Guinea, Thailand, Philippines, Japan (Kyushu, Shikoku, Honshu) (see Agarwal, 1986).

Distribution in India: Eastern Himalaya: Meghalaya- Shillong, Elephant falls; Sikkim- Nathula Road; South India: Tamil Nadu- Nilgiri hills, Ootacamund (G.B.G), Dodabetta, Kalhatty slope, Pykara, Naduvattam, Kotagiri; Kerala-Lakkidi; Karnataka- Agumbe.

Associates: *Frullania tamarisci* and *Radula nilgiriensis*.

Specimen examined: LWU 12513/2000, 12516/2000, *Cheilolejeunea imbricata* (Nees) Hatt., Loc.: South India: Tamil Nadu- Nilgiri hills (Dodabetta), alt. ca.: 2600 m; Date: Oct. 8, 2000 Legit.: S.C. Srivastava and party; Det.: S.C. Srivastava and P.K. Verma LWU. 13463/2001, *Cheilolejeunea imbricata* (Nees) Hatt., Loc.: South India: Tamil Nadu- Nilgiri hills (Dodabetta); alt. ca. 2600 m; Date: 29, March 2001; Legit.: P.K. Verma and A. Alam; Det.: S.C. Srivastava & P.K. Verma.

This species is frequently growing vegetatively on *Cinchona* as well as other trees and represents the most dominant species of *Cheilolejeunea* in Nilgiri hills.

*Cheilolejeunea udarii* Srivastava *et al* in: *Lindbergia* 20: 125-143 (1995). (Plate-4, figs. 6-12; Plate-5, fig. 15)

Plants prostrate, greenish brown, up to 16 mm long 0.50-1.0 mm wide, pinnately branched, branching *Lejeunea*- type. Leaves imbricate, obliquely inserted, incubous, leaf-lobe convex, ovate, triangular, 0.46-0.53 mm long, 0.30-0.50 mm wide, apex obtuse, pointed, margin entire, antical margin arched, postical margin straight, only incurved at middle, cells thick walled with trigones, median cells 15-23  $\mu\text{m}$  x 12-18  $\mu\text{m}$  leaf-lobule large more than 2/3 of lobe length, 0.16-0.33 mm long, 0.9-0.20 mm wide, inflated constricted at apex, first tooth indistinct, second

tooth 1-2 celled. Underleaves distant, sub-transversely inserted, 2-3 times wide as the stem, orbicular, bilobed, ½ of the length, margin entire. Monoecious. Male inflorescence terminal on main shoot or on lateral branches, saccate, 2-6 pairs of bract, female inflorescence terminal on main axis, with 1-2 subfloral innovation. Female bracts 0.41-0.58 mm long, 0.30-0.38 mm wide, apex obtuse to acute, margin entire, bracteole large, ovate. 0.44-0.69 mm long, 0.32-0.39 mm wide, bilobed, perianth obovate, three plicate.

Type Loc.: Tamil Nadu (Nilgiri-Dodabetta peak). (Srivastava *et al*; 1995).

Range: Endemic to India

Distribution in India: South India: Tamil Nadu- Nilgiri hills, Dodabetta, Ootacamund, G.B.G., Pykara,

Associates: Growing with association of mosses

Specimen examined: LWU 12512/2000. *Cheilolejeunea udarii* Srivastava *et al*; Loc.: South India: Tamil Nadu- Nilgiri hills (Dodabetta); alt. ca. 2600 m; Date: Oct. 8, 2000; Legit.: S.C. Srivastava and party; Det.: S.C. Srivastava and P.K. Verma.

*Cheilolejeunea udarii* is endemic to Nilgiri hills with remarkable 3 keeled perianth. The species occurs only on *Chinchona* in Dodabetta, however, it is known to occur elsewhere on other phorophytes also.

*Radula madagascariensis* Gott. in: *Abhandler. naturwissensch. Verein in Bremen* 7: 349 (1882). (Plate-4, figs. 13-16; Plate-6, fig. 16)

Plants prostrate, light brown to green, up to 18 mm long; 2.6 mm wide, branching *Radula*-type. Leaves imbricate, widely spreading, incubous, obliquely inserted, leaf-lobes ovate, 0.70-0.77 mm long, 0.45-0.59 mm wide, often falcate, with broadly rounded apex, cells thin walled, trigonous, 13-18  $\mu\text{m}$  x 10-18  $\mu\text{m}$ , leaf-lobules rectangulate to subrectangulate, saccate, 0.31-0.38 mm long 0.24-0.31 mm wide, apex obtuse, Under-leaves absent, rhizoids in tufts, arising from leaf-lobules base.

Type Loc.: Madagascar, Ambaranavarauata (Yamada, 1979)

Range: Burma, Sri Lanka (Ceylon), Indonesia (Java, Sumatra), Mauritius, Reunion, Tanzania. (Yamada, 1979), India (Kumar, 1983)

Distribution in India: Eastern Himalaya: Meghalaya-Shillong, Elephant fall, Jowai; West Bengal-Darjeeling, Tonglu, Llyod Botanical Garden, Tiger hill; South India: Tamil Nadu-Nilgiri hills (Dodabetta).

Associates: *Metzgeria pandei*

Specimen examined: LWU 12499/2000, *Radula madagascariensis* Gott. Loc.: South India: Tamil Nadu- Nilgiri hills (Dodabetta); alt. ca 2600 m; Date: Oct. 8, 2000; Legit.: S.C. Srivastava and Party; Det.: S.C. Srivastava and P.K. Verma.

*Radula madagascariensis* is commonly found in Dodabetta in Peninsular India growing vegetatively on variety of habitats.

*Radula nilgiriensis* Udar et Kumar in: *J. Indian bot. Soc.* **61**: 177-182 (1982). (Plate-4, figs. 17-20; Plate-6, Figs. 17, 18)

Plants prostrate, brown to green, up to 20 mm long 2.0 mm wide, irregularly branched by *Radula*-type of branching. Leaves imbricate, incubous, widely spreading, obliquely inserted, leaf-lobe ovate with rounded apex, 0.50-0.73 mm long, 36.0-0.60 mm wide, margin entire, gemmae present at margin of leaf-lobes and also on leaf-lobule, gemmae discoid, irregular, leaf cells thick walled with inconspicuous trigones, median cells 9-14  $\mu\text{m}$  x 13-18  $\mu\text{m}$ , leaf-lobule rectangulate, apex apiculate, obtuse, 0.29-0.35 mm long 0.21-0.25 mm wide, covering  $\frac{1}{2}$  of the stem rhizoids in tufts. Reproductive structure not seen.

Type Loc.: Avalanche (Ootacamund, Nilgiri hills) (Udar and Kumar, 1982)

Range: Endemic to India

Distribution in India: South India: Tamil Nadu- Nilgiri hills, Ootacamund, (G.B.G.), Dodabetta, Kotagiri, Avalanche, Pykara, Coonoor,

Associates: *Frullania tamarisci*, *Lopholejeunea sikkimensis*, *Cheilolejeunea imbricata*, and *Microlejeunea ulicina*

Specimen examined: LWU. 12493/2000, 12514/2000 *Radula nilgiriensis* Udar et Kumar, Loc.: South India, Tamil Nadu-Nilgiri hills (Dodabetta); alt. ca. 2600 m; Date: Oct. 8, 2000; Legit.: S.C. Srivastava and party; Det.: S.C. Srivastava and P.K. Verma.

*Radula nilgiriensis* is a frequently occurring spe-

cies after *Frullania tamarisci*. The species has characteristic marginal gemmae, which help in asexual reproduction.

## DISCUSSION

Topographically, Dodabetta is situated in the middle of Nilgiri hills in the Nilgiri district of Tamil Nadu with sub-tropical broad-leaved plantations consisting of different shrubby species (such as Coffee, Tea, *Cinchona*, Rubber plant, etc.) intermixed with some of the woody species (like *Eucalyptus*, *Thuja*, *Accacia*, etc.). The shrubby species are cultivated under the network of naturally growing trees, which not only help in lowering to some extent the temperature and light intensity but also tend to increase humidity required for the growth and development of hepatic vegetation.

The vertical distribution of liverworts on *Cinchona* plantation in Dodabetta shows a wide range of diversity including a total of 14 species, majority of which are obligate as well as facultative epiphytes except a few which also prefer other habitats and phorophytes for their luxuriant preponderance. Out of these, 13 species belong to Jungermanniales and one to Metzgeriales. None of them are host specific. Three regions of the phorophyte including the tree trunk (up to 2 m height), the twigs and the branches thoroughly explored for the hepatic vegetation show remarkable distribution of different taxa. Besides, the age of host tree with respect to bark factor is quite characteristic as the younger plants of *Cinchona* have smooth bark surface as compared to the older trees which possess rugged (cracked) bark with relatively good anchoring surface for the rhizoids of leafy liverworts (see Hoffman and Kazmierski, 1969; LeBlanc, 1959). The older parts of the trunk not only provide more time for establishment of bryo-vegetation but also provide time for change in bark characteristic (see Billings and Drew, 1938 and Quartermann, 1949). The bark pH is also known to play a key role in host-specificity and a range of 4.0 to 6.6 pH is generally well suited for many cryptogamic epiphytes including liverworts (Hale, 1955). *Cinchona* shows acidophyllous bark (pH 5.6) hosting species of *Frullania tamarisci*, *Radula nilgiriensis*, *Plagiochila ghatiensis*, *Porella*



*acutifolia*, *Lophocolea muricata*, *Lejeunea flava* and *Metzgeria pandei*. The trunk base of *Cinchona* has high relative humidity as compared to the upper trunk and the microclimatic conditions at base up to a metre or so is suitable for hygrophylous species (*Lophocolea muricata* and *Porella acutifolia*). The middle region of the trunk receives diffused sun light causing more or less mesic condition rather suitable for *Metzgeria pandei*, *Cheilolejeunea udarii*, *Cheilolejeunea imbricata* and *Frullania tamarisci*. Similarly the vertical surface of the upper tree trunk is directly exposed to sunlight and shows maximum differentiation of *Plagiochila*, *P. ghatiensis* which prefers slightly xeric conditions.

*Porella acutifolia*, *Cheilolejeunea udarii* and *Plagiochila ghatiensis* are rare on other habitats or phorophytes in Dodabetta region except on *Cinchona*. *Plagiochila ghatiensis* was originally described from India orientalis (Kodaikanal: Stephani, 1918) and has been re-collected for the first time from Dodabetta showing its range extension. Similarly *Metzgeria pandei*, yet another species from Kodaikanal (Srivastava and Udar, 1975) has also been re-discovered from Dodabetta since its original report. Interestingly the male plants of *Lophocolea muricata* has also been collected for the first time from India. *Radula madagascariensis*- commonly found in Eastern Himalaya, has been documented from Peninsular India also. The frequency of *Radula nilgiriensis* and *Frullania tamarisci* is maximum in this area of Nilgiri hills followed by *Lejeunea flava* and *Microlejeunea ulicina*.

### ACKNOWLEDGEMENT

Financial support from Department of Environment and Forest Govt. of India, New Delhi is greatly acknowledged.

### REFERENCES

- Agarwal, A 1986. Studies in Indian Lejeuneoideae Ph. D. Thesis, Department of Botany, University of Lucknow, Lucknow.
- Awasthi, US, Srivastava, SC and Sharma, D 2001. *Lopholejeunea* (Spruce) Schiffn. in India. *Geophytology* 29(1 & 2): 35-60.
- Barkman, JJ 1958. *Phytosociology and Ecology of Cryptogamic Epiphytes* Van Groenou and Co., Assen, Netherlands.
- Billings, WD and Drew, WB 1938. Bark factors affecting the distribution of corticolous bryophytic communities. *Ammer. Midl. Natur.* 20: 302-333.
- Bonner, CEB 1962. *Index Hepaticarum*. Part I. *Plagiochila* (Dum.) Dum. J. Cramer Weinheim (Germany).
- Culberson, WL 1955. The corticolous communities of lichens and bryophytes in upland forests. *Ecol. Monogr.* 26: 215-231.
- Denison, WC 1973. Life in tall trees, *Sci Amer.* 228: 74-80.
- Engle, MJ 1960. Corticolous Bryophytes on *Pinus* in Florida. *The Bryologist* 63(4): 238-240.
- Hale, ME 1952. Vertical distribution of cryptogams in a virgin forest in Wisconsin. *Ecology* 33: 398-406.
- Hale, ME 1955. Phytosociology of corticolous cryptogams in the upland forests of southern Wisconsin. *Ecology* 36: 45-63.
- Hoffman, GR and Kazmierski, RG 1969. An ecologic study of epiphytic bryophytes and lichens on *Pseudotsuga menziesii* on the Olympic Peninsula, Washington, I. A description of the Vegetations. *The Bryologist* 72: 1-48.
- Iwatsuki, Z 1960. The epiphytic bryophyte communities in Japan. *Jour. Hattori Bot. Lab.* 22: 159-352.
- Jain, SK 1994. *Medicinal Plants*, pages 53-54, National Book Trust, India.
- Kachroo, P 1993. Himalayan Biodiversity Conservation- *An overview in Himalayan Biodiversity Conservation Strategies* (Ed. U. Dhar) Gyanodaya Publication, Nainital.
- Kumar, D 1983. Monographic Studies on Indian Radulaceae. Ph.D. Thesis, Department of Botany, University of Lucknow, Lucknow.
- LeBlanc, F 1959. Ecologie et phytosociologie des epiphytes corticales du sud du uebe. Dissertation Universite de Montreal.
- LeBlanc, F 1963. Quatient depiphytisme des arbres du sud du Quebec. *Rev. Can. Biol.* 22: 19-25.
- Macvicar, SM 1912. *The Student's Handbook of British Hepatics* (2nd Ed.), 1-464, Eastbourne.
- Phillips, A 1959. Bark bryophyte unions in Southern Ireland. *The Bryologist* 62(1): 17-23.
- Pike, LH, Denison, WC, Diani, M; Tracy, DM, Sherwood, MA and Rhoades, FM 1975. Floristic survey of epiphytic Lichens and Bryophytes growing on old-growth conifers in western origin. *The Bryologist.* 78: 389-402.
- Quarterman, E 1949. Ecology of cedar glades. III Corticolous bryophytes. *The Bryologist* 52: 153-165.
- Schuster, RM 1959. Epiphyllous Hepaticae in the Southern Appalachians. *The Bryologist* 62(1): 52-54.
- Schuster, RM 1980. *The Hepaticae and Anthocerotae of North America*. East of the Hundredth Meridian IV. Columbia Univ. Press. New York.
- Shaheen, F 1983. Monographic Studies on Indian Porellaceae. Ph.D. Thesis, Department of Botany, University of Lucknow, Lucknow.
- Shacklette, HT 1961. Substrate Relationships of some Bryophyte communities on Latouche Island, Alaska. *The Bryologist* 64 (1): 1-15.

- Slack, NG 1971. Species diversity and community structure in bryophytes. Ph.D. Thesis. State University of New York, Albany New York State Museum and Science Service Albany, N.Y.
- Slack, NG 1976. Host specificity of bryophytic epiphytes in Eastern North America. *Jour. Hattori Bot. Lab.* **41**: 96-107.
- Srivastava, A and Srivastava, SC 2002. *Indian Geocalycaceae*, Bishan Singh Mahendra Pal Singh, Dehradun, pp. 1-246.
- Srivastava, SC and Alam, A 2002. A collection of *Frullania* from Nilgiri with *F. densiloba* St.- As a new Record for India, *J. Bombay nat. Hist. Soci.* **99**(2) : 232-239.
- Srivastava, G, Srivastava, SC and Asthana, AK 1995. The genus *Cheilolejeunea* in India. *Lindbergia* **20**: 125-143.
- Srivastava, SC 1994. Bryophyta: Morphology, Systematics Reproductive Biology In: *Botany in India- History and Progress* (Ed. B.M. Johri) Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi, pp. 387-436.
- Srivastava, SC, Srivastava, A and Dixit, R 1994. Epiphytic liverworts on tea-plantations in Darjeeling. *Geophytology*. **24**: 63-72.
- Srivastava, SC 1998. Distribution of Hepaticae and Anthocerotae in India. In: *Topics in Bryology* (Ed. R.N. Chopra) Allied Publisher Ltd. pp. 53-85.
- Srivastava, SC and Udari, R. (1975). Taxonomy of Indian Metzgeriaceae- A monographic study. *New Botanist* **2**: 1-57.
- Stephani, F 1912. *Species Hepaticarum V.* Geneve.
- Stephani, F 1918. *Species Hepaticarum VI.* Geneve.
- Stringer, PW and Stringer, MHL 1974. A quantitative study of corticolous bryophytes in the vicinity of Winnipeg, Manitoba. *The Bryologist* **77**: 551-560.
- Udari, R 1976. *Bryology in India*. Chronica Botanica Co., New Delhi.
- Udari, R and Kumar, D 1982. The genus *Radula* Dum. in India. *J. Indian bot. Soc.* **61**: 177-182.
- Yamada, K 1979. A Revision of Asian Taxa of *Radula* Dum. *Journ. Hattori Bot. Lab.* **45**: 201-322.