EPIPHYLLOUS TAXA OF *RADULA* DUMORT. FROM INDIA*

RAM UDAR AND DHIRENDRA KUMAR

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

ABSTRACT

Four species of *Radula*, viz. *Radula acuminata* St., *R. protensa* Lindb., *R. assamica* St. and *R. tjibodensis* Goeb., harbouring the surface of either fern or angiospermous leaves in the tropical rain forests of eastern Himalayas and western Ghats are described. The species differ markedly in the shape of their lobules and position of gemmae. The lobule apex is acuminate in *R. acuminata* and *R. tjibodensis*, diverging almost at right angles from the axis in *R. protensa* and triangular-ligulate in *R. assamica*. However, the gemmae are ventral laminar and erect in *R. acuminata* and *R. protensa*, mostly at margin towards the lower half of lobe in *R. assamica* and all round the margin in *R. tjibodensis*. The paper provides the full taxonomic details of these epiphyllous taxa.

INTRODUCTION

Several species of *Radula* are highly selective in their habitat preferences. The most specialized are those which harbour the leaf surfaces of either ferns or broad leaved angiosperms in tropical rain forests. CASTLE (1939) instituted the section Epiphyllae for such taxa which exhibit extreme adaptive characteristics: the stem is highly reduced, lacking in distinction between cortical and medullary zones and consist of few rows of thin-walled cells. Asexual reproduction is common in most of the species by means of large discoid simple gemmae, or complex gemmae with funnel-shaped base. The latter are produced in small numbers or even singly from lobe margins (see SCHUSTER, 1980). There is the formation of a well-developed stem perigynium and SCHUSTER (1980) placed such taxa in his new subgenus Metaradula and considered them to be the most evolved phylogenetically.

The section Epiphyllae of CASTLE has twelve species which are heterogenous and form four related groups (see SCHUSTER, 1980) of equal rank (Sections) under the subgenus Metaradula Schust: Mammosae Schust., Acuminate Schust., Evansiae Schust. and Epiphyllae Castle emend. Schust based primarily on their phytogeography, presence vs absence of gemmae, stem structure and stem perigynium, etc. All the four Indian epiphyllous taxa are included under Acuminatae which has been further divided into two sub-sections, viz. Stenocalyces (with marginal gemmae inc. *R. assamica* and *R. tjibodensis*) and Acuminatae (with laminar gemmae occurring postically and oriented vertically inc. *R. acuminata* and *R. protensa*).

The epiphyllous species of *Radula* have never been investigated in Indian bryology except for a mere report by PANDE *et al.* (1957) of three species, viz. *R. javanica* Gott., *R. protensa* Lindenb. and *R. assamica* St. as occurring in India. However, in the present state of our knowledge the reported occurrence of *R. javanica* seems doubtful. The paper provides full taxonomic details of epiphyllous taxa of *Radula* commonly growing in the tropical rain forests in eastern India (Jowai, Jarain, Cherrapunji,

*Contribution from the Department of Botany, University of Lucknow, Lucknow, New Series (Bryophyta) No. 175.

Mawflang and East Siang in Arunachal Pradesh) and southern India (Gersoppa falls, Augumbe: western Ghats). Three of the Indian species *R. acuminata.*, *R. protensa* and *R. assamica*, are constantly epiphyllous. However, *R. tjibodensis* Goeb., known to be epiphyllous, has now been collected also growing as an epiphyte on bark in association with *Lopholejeunea* at Jowai. Such an occurrence of an epiphyllous taxon as an epiphyte or terricole has already been known in *R. flaccida* Lindenb. (see JONES 1977; SCHUSTER, 1980). SCHUSTER (1980) also putforth the idea that, while bulk of the species of *Radula* are epiphytic, one end group in evolution has become almost epiphyllous. He regarded Epiphyllae to be a phylogenetically advanced group.

KEY TO THE EPIPHYLLOUS TAXA OF *RADULA* IN INDIA

1. Plants with erect, laminar gemmae occurring on the ventral surface of leaf lobe 2
   2. Apex of leaf-lobules accuminate with the terminal portion directed forward .. .. *R. acuminata*
   2. Apex of leaf-lobules extended into a blunt tip and turning away from the stem .. .. *R. protensa*

1. Plants with marginal gemmae 3
   3. Gemmae restricted to the postical half of revolute margin of leaf, leaf- lobule sub-triangular ovate .. .. .. *R. assamica*
   3. Gemmae all round the margin of leaf lobe, leaf-lobule sub-quadrate with acuminate apex .. .. *R. tjibodensis*

TAXONOMIC DESCRIPTION

Radula acuminata St.

Text-fig. A1-21

Spec. Hepat., 4: 230 (1910)-*Radula yunnanensis* Chen, Feddes. Repert., 58: 39 (1955)-*Radula acuminata* St. fo. *corticola* Hatt. Bull. Tokyo Sci. Mus. 11:81 (1944).

Plants dioecious, medium sized, 1.5-2 cm long, fragile, green, epiphyllous. Stem exceptionally slender, irregularly pinnate, branches obliquely spreading, 0.05-0.06 mm in diameter, in cross-section consisting of as few as 9-11 cortical cells + 3-4 meduallary cells, all cells alike, thin-walled. Leaves imbricate, leaf lobes flat, ovate with rotundate to broadly rotundate apex,0.7-0.8 mm long, 0.5-0.7 mm wide, antical base gently arched over the stem dorsally, postical margin narrowly falcate, cuticle smooth. Cells of the leaf lobe thin-walled with feeble trigones, marginal cells 8-10 μm, medium cells 12-17 $\times$13-18 μm and basal cells 23-26 $\times$18-21 μm. Leaf lobules quadrate elongated, 0.2-0.3 $\times$0.3-0.4 mm, almost parallel with the axis, with a long insertion, base narrow, apex usually elongated to a blunt tip pointing forwards, mostly with a very strongly inflated rhizogenous sac providing conspicuous adhesive discs of short pale brown rhizoids, abaxial margin straight to slightly incurved, adaxial margin sinuate not covering the stem, keel extending at angles of 45-50° with the stem, sinus acute to subacute. Oil-body one per cell, grape cluster type, almost filling the lumen, measuring 10-13 $\times$13-15 μm. Gemmae large, discoid, consisting of numerous cells, 120-140 μm, developing from laminar lobe cells

Text-figs. A 1-21. *Radula acuminata* St. Fig. 1—Gynoecial plant with perianth and sporophyte, postical view; Fig. 2—Androecial plant, postical view; Fig. 3—Cross-section of stem; Fig. 4—A dissected leaf with ventral laminar gemmae, drawn postically; Fig. 5—Leaf cells containing oil bodies; Fig. 6—Marginal cells of leaf; Fig. 7—Median cells of leaf; Fig. 8—Basal cells of leaf; Figs. 9-11—Androecial bracts; Figs. 12, 13—Gynoecial bracts; Fig. 14—Cross-section of perianth towards the middle; Fig. 15—A portion of the same magnified; Fig. 16—Corss-section of seta; Fig. 17—Cross-section of capsule wall; Fig. 18—Epidermal layer of capsule wall; Fig. 19—Inner layer of capsule wall; Fig. 20—Spores; Fig. 21—Elater (Illustrations drawn from LWU 5423/81).

on the postical surface and oriented vertically. Androecia terminal or intercalary on branches with 4-10 (15) pairs of saccate male bracts. Bract lobe 162-216×345-367 μm, bract lobule 140-183×260-300 μm. Gynoecia terminal to lateral with one or two sub-floral innovations, innovations again becoming floriferous, bract lobe obovate spathulate with rounded or obtuse apex, 324-378×183-196 μm, bract lobule gently falcate, connate with obtuse to sub-acute apex, 216-270×162 μm. Perianth strongly elongated at maturity, slender, arising from a tubular, fleshy terete base (=stem perigynium), multistratose at base, occasionally bistratose towards middle and unistratose towards apex, 1.3-1.5 mm long, perianth mouth 0.45-0.6 mm wide with narrow base, 0.25-0.3 mm, repand. Seta massive, up to 116 μm in diameter. Capsule oval, wall bistratose, 21 μm thick, outer epidermal layer 13 μm with nodulose to confluent nodulose thickening bands on radial walls, secondary walls incompletely formed. Inner layer 8 μm thick, cells thin walled with faint nodulose thickenings. Spore tetrads tetragonal to tetrahedral. Spores globose, 18-21 μm, granulate. Elaters bispirate, 206-285 μm long, 5 μm thick with rounded extremities.

Habitat—Epiphyllous on the upper surface of leaf of *Cinnamomum* sp., fern leaflet, and other broad leaved angiosperms in association with *Cololejeunea* sp. in tropical rain forests.

Specimens examined—LWU 5423/81, 5424/81, 5425/81, 5426/81, Coll.: D. K. Singh. Loc.: Jarain (Meghalaya) in eastern Himalayas, alt. ca 1600 m. Date: April 24, 1980. Det.: Ram Udar & Dhirendra Kumar.

Other specimens examined—Radula acuminata St. 257526 (NICH). Coll.: Iwatsuki & Sharp. Loc.: Mashwai Limestone Cave near Cherrapunji, ca alt. 4500 feet. *Radula acuminata* 751/29 (G.). Loc. : Tonkin, Balansa. Date : 1887.

Characteristics of the species

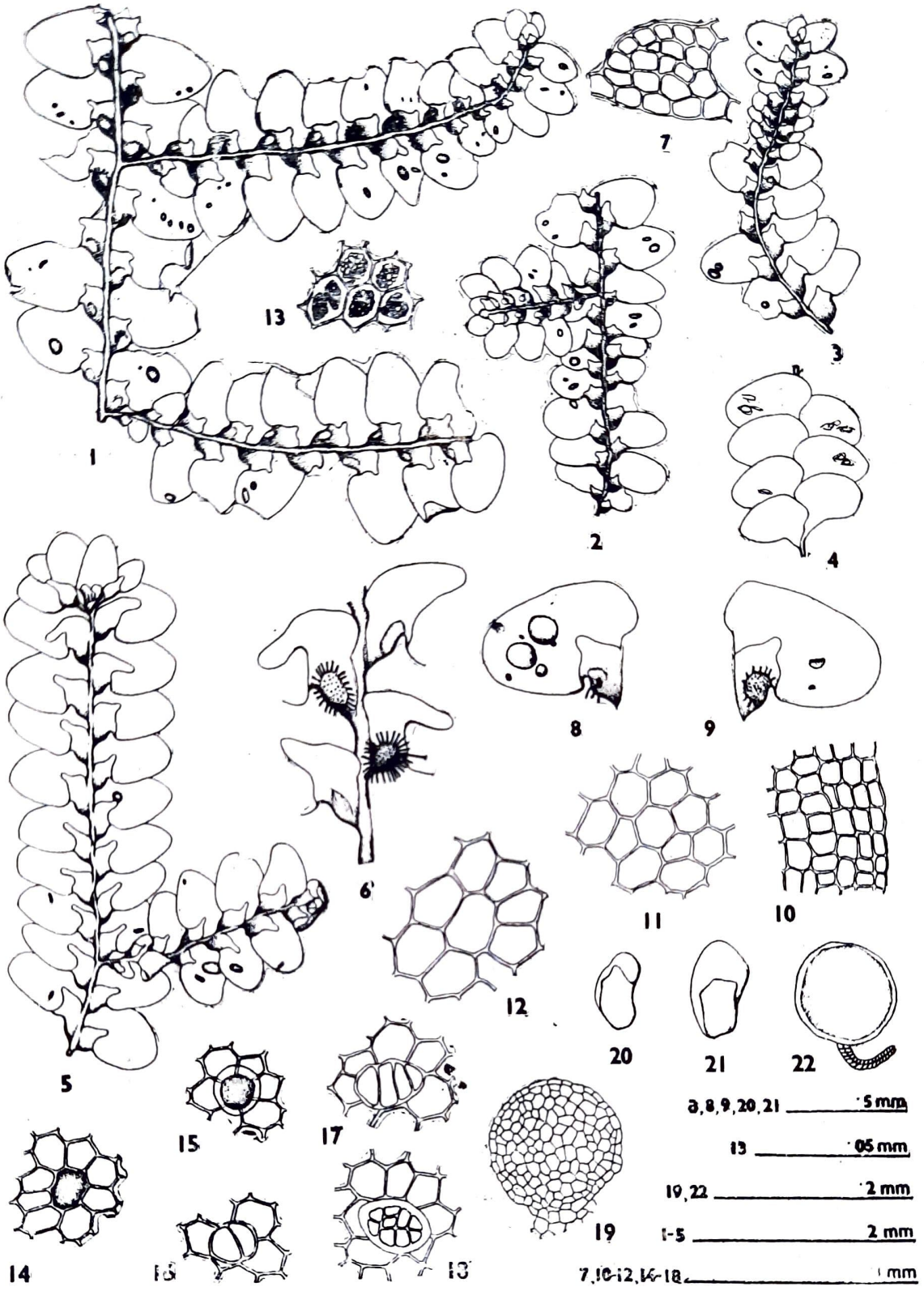
(1) The leaf lobules with acuminate apex directed forward. (2) The gemmae formed postically from the laminar cells of leaf lobe and oriented vertically on the leaf surface.

Radula protensa Lindenb.

Text-figs. B 1-22

In Meissner, Bot. Zeit. 6 : 462 (1848).

Plants dioecious, medium sized, 1-1.5 cm long, fragile, green to yellowish green, epiphyllous. Stem slender, pinnately branched, branches transversely to obliquely spreading, highly reduced, 0.05-0.04 mm, in cross-section consisting of 10-11 cortical cells + 5-6 medullary cells, all cells alike and thin-walled with minute trigones. Leaf lobes imbricate, flat, widely spreading, subtriangular—ovate, 0.8-0.9 long, 0.6-0.7 mm wide, apex mostly narrowly to rarely boardly obtuse, margin sometimes inwardly folded, antical base mostly fully covering the stem, postical margin narrowly falcate, cuticle smooth, cells of the leaf lobe thin-walled with feeble trigones, marginal cells 7-8×10-13 μm and basal cells 26-28×18-21 μm. Leaf lobules somewhat quadrate, 0.4-0.45 mm long, 0.3-0.4 mm wide, the upper half narrowly elongated and the apex abruptly drawn out into a papilla at right angles to the axis, antical margin sinuate, mostly with a strongly inflated rhizogenous sac providing conspicuous adhesive discs of short, pale brown, rhizoids, adaxial margin either partially or not covering the stem postically. Keel extending at an angle of 50-60°, mostly outwardly arched, sometimes straight, sinus acute to sub-acute. Oil bodies 1-2 per



Text-figs. B1-22. *Radula protensa* Lindenb. Fig. 1—Vegetative plant, postical view; Figs. 2, 3—Androecial plants showing terminal and intercalary position of androecial bracts; Fig. 4—A portion of the plant, dorsal view; Fig. 5—Young Gynoecial plant, postical view (drwan from the G 21574); Fig. 6—Leaf lobules, postical view (drawn magnified from G 21574); Fig. 7—Cross-section of stem; Fig. 8, 9—Dissected leaves. Fig. 10—Marginal cells of leaf; Fig. 11—Median cells of leaf; Fig. 12—Basal cells of leaf; Fig 13—Leaf cells with oil bodies; Figs—14-18. Stages in the development of gemma; Fig. 19—Discoid gemma; Figs. 20, 21, Androecial bracts; Fig. 22—An antheridium (Illustrations drawn from LWU 4784/81).

cell, grape cluster type, somewhat filling the lumen of cells, in median cells 6-15 × 4-11 μm, in marginal cells 2-4×2 μm in diameter. Gemmae discoid, large, 150-184 μm, consisting of numerous cells originating from laminar cells of lobe on the postical surface, and oriented at right angles to the lobe lamina. Androecia terminal or intercalary on branches with 4-10 (15) pairs of saccate male bracts. Antheridium solitary, axillary, globose, with a biseriate sigmoid stalk. Gynoecia and perianth unknown in Indian populations.

Habitat—Usually growing appressed on leaves of angiosperms in tropical rain forests in association with spp. of *Cololejeunea, Rectolejeunea, Rhaphidolejeunea* and *Leptolejeunea*.

Specimens examined—LWU 3764/40, 3765/40; Coll.: S. K. Pande. Loc.: Jog Falls, Karnataka in western Ghats, alt. ca. 600 m., Date 5, Jan. 1940; Det.: Ram Udar & Dhirendra Kumar. LWU 4722/81, 4773/81, 4784/81, 4785/81, Coll.: D. Kumar, A. Kumar & U. S. Awasthi ; Loc.: Agumbe, Karnataka in western Ghats; alt. ca. 791 m. Date 4, May 1981, Det.: Ram Udar & Dhirendra Kumar.

Other specimens examined—Type G 21574 *Radula protensa* Lindb., Anno. N. Kitagawa, 1970, without definite locality or date. Zollinger No. 5777.

Characteristics of the species

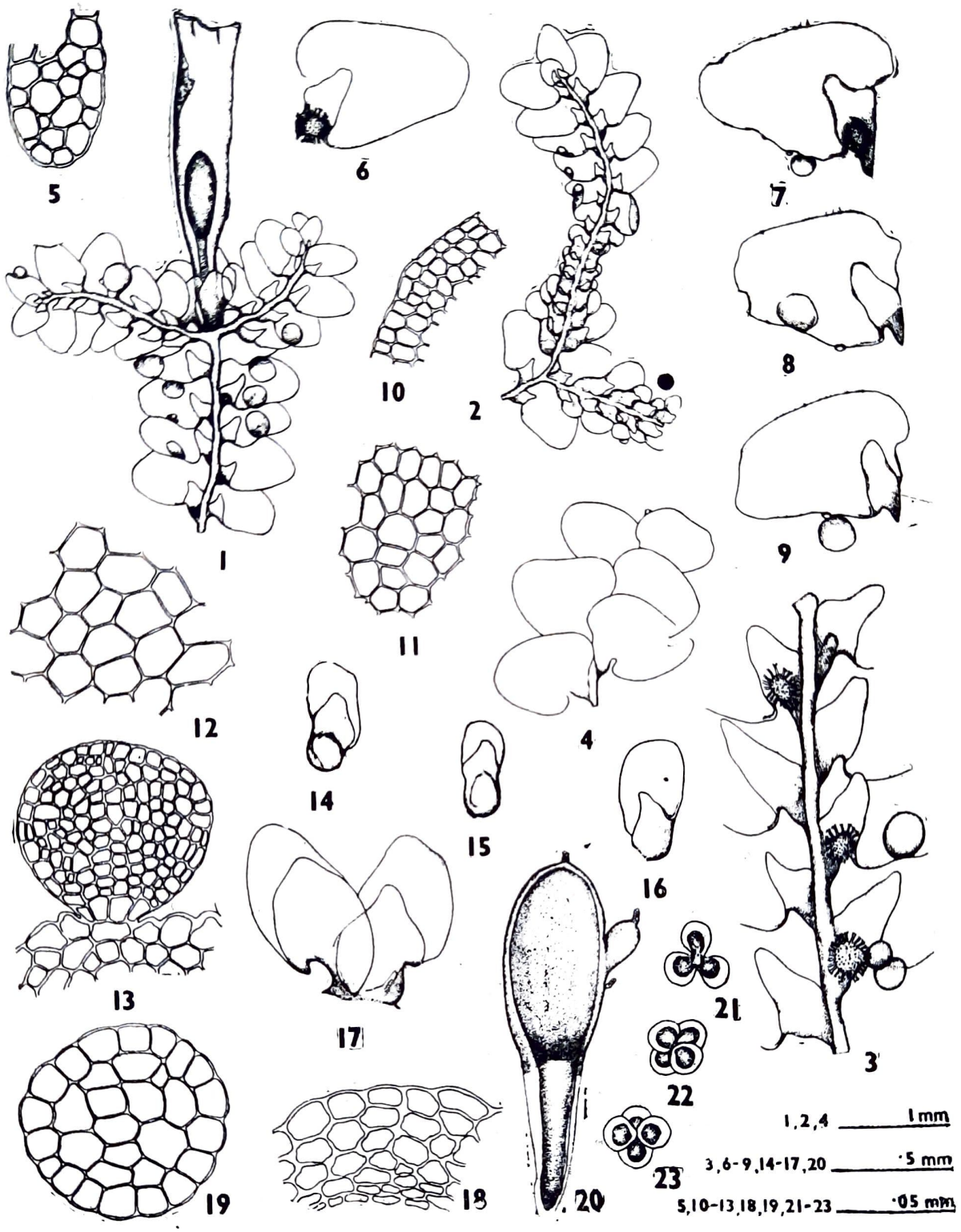
(1) Leaf-lobule with an extended blunt apex drawn out abruptly at an angle of 90° from the axis. (2) The superficial gemmae arising postically from the laminar cells of lobe and oriented vertically from the leaf surface.

Radula assamica St.

Text-figs. C1-23

Hedwigia, 23:151 (1884)-*Radula platyglossa* Chen., Acta Phytox. Sin. , 9(3) : 221 (1964).

Plants dioecious, green, 1-1.5 cm in size, yellowish in herbaria, pinnately branched, fragile, epiphyllous. Stem slender, 5-7(10) mm long, 0.06-0.07 mm in diameter, consisting of 9 cortical and 3 medullary cells, cells thin-walled. Leaves imbricate, flat, leaf lobe 1.05×0.9 mm, ovate, apex somewhat narrowed and broadly rounded, antical base either gently arching over or fully covering the stem dorsally, free portion rounded, postical margin abruptly falcate beyond the keel, cuticle smooth, cells of the lobe thin walled, marginal cells 8-10 (13) ×8-10 μm, median cells 13-15×(13) 15-18 μm, basal cells (18) 26-28×21-23 μm. Leaf lobule 0.6×0.2 mm, ligulate, sub-traingular, flat, apex extended and usually directed towards the apex of the axis, occasionally turned away and acuminate, base fused with stem for its entire length, lobule apex very often with a hyaline papilla, abaxial margin sinuate, carinal region weakly inflated, rhizoids numerous and arising in bundles from the basal portion of the lobule, keel extending at an angle of 50° from the stem, straight or slightly arched. Gemmae discoid, large 160-300 μm, consisting of numerous cells and mostly arising from the postical half of revolute margin of lobe oriented at right angles from the surface. Androecia terminal or intercalary on branches with densely imbricate 4-6(8) pairs of bracts, bracts saccate at base with subequal lobes with rounded dorsal and blunt to acute ventral apices. Bract lobe 460-540×226-261 μm, bract lobule 280-335×162-216 μm. Gynoecia terminal on leading axis with mostly two rarely one subfloral innovations which in turn becoming floriferous, female bracts smaller than vegetative leaves with somewhat arched and incurved keel, bract lobe 650-700



Text-figs. C1-23. *Radula assamica* St. Fig. 1—A portion of the female plant in the postical view; Fig. 2—A portion of the male plant in postical view; Fig. 3—Magnified view of a portion of the twig showing attachment of lobules with axis; Fig 4—A portion of the twig drawn dorsally Fig 5—Cross section of the stem; Figs 6-9—Dissected leaves; Fig. 10—Mrginal cells of leaf lobe; Fig. 11—Median cells of leaf lobe; Fig. 12—Basal cells of leaf lobe; Fig .13—A marginal gemma; Figs—14-16. Male bracts; Fig. 17—Female bracts; Fig. 18—A portion of the stem perigynium (seen in t.s.); Fig. 19—Corss-section of seta; Fig. 20—A dissected sporophyte showing shoot calyptra; Figs. 21-23—Spore tetrads. (Illustrations drawn from LWU 6800).

×432-465 μm, apex rounded, bract lobule 453-540 ×324-400 μm, apex obtuse to somewhat narrowly obtuse. Perianth 2.4-2.8 mm long, trumpet-shaped, with a narrow terete slender stout base, 3-6 stratose (=stem perigynium), flattened and broadened with a flaring mouth of 650-775 μm wide, mouth bilipped, lips faintly sinuate-crenate. Seta massive, up to 108 μm in diameter. Capsule oval-ellipsoidal, about 860 μm long, wall bistratose. Spore tetrads tetragonal to tetrahedral. Shoot calyptra extending half way across the length of capsule carrying both fertilized and unfertilized archegonia.

Habitat—Epiphyllous on the upper surface of leaves of a wide range of angiosperms in association with *Cololejeunea pseudopalgiophylla, Colura* sp. and *Radula acuminata* St., growing under highly diffused light conditions along water course.

Specimens examined—LWU 6798/183, 6799/183, 6800/183, 6801/183, 6801A, 6801 B, 6801 C and 6802/183. Coll. D. K. Singh. Loc.: Shimar forest (Yingkiyong), East Siang, Arunachal Pradesh. Alt. 750 m. Date: January 7, 1983. Det.: Ram Udar & Dhirendra Kumar.

Other specimens examined—Holotype G 8224 *Radula assamica* St. Coll.: D. Griffith. Loc. : Assam Tudor. N. 2563/f *Radula assamica* St. Det.: Pocs, T., Loc.: Vietnam boreo-oce. Montes Hoang Lienson. alt.: 1600 m. s. m. Date: 24.9.1963.

Characteristics of the species

(1) The leaf lobules somewhat ligulate to sub-traingular ovate and flat. (2) The marginal discoid gemma characteristically restricted to the postical half of the leaf lobe and oriented vertically.

Radula tjibodensis Goeb.

Text-figs. D 1—10

Nova Acta Acad. Caes. Leop.-Carol., 60(2) : 249 (1893).

Radula flavescens Steph., Spec. Hepat. 4: 203 (1910).

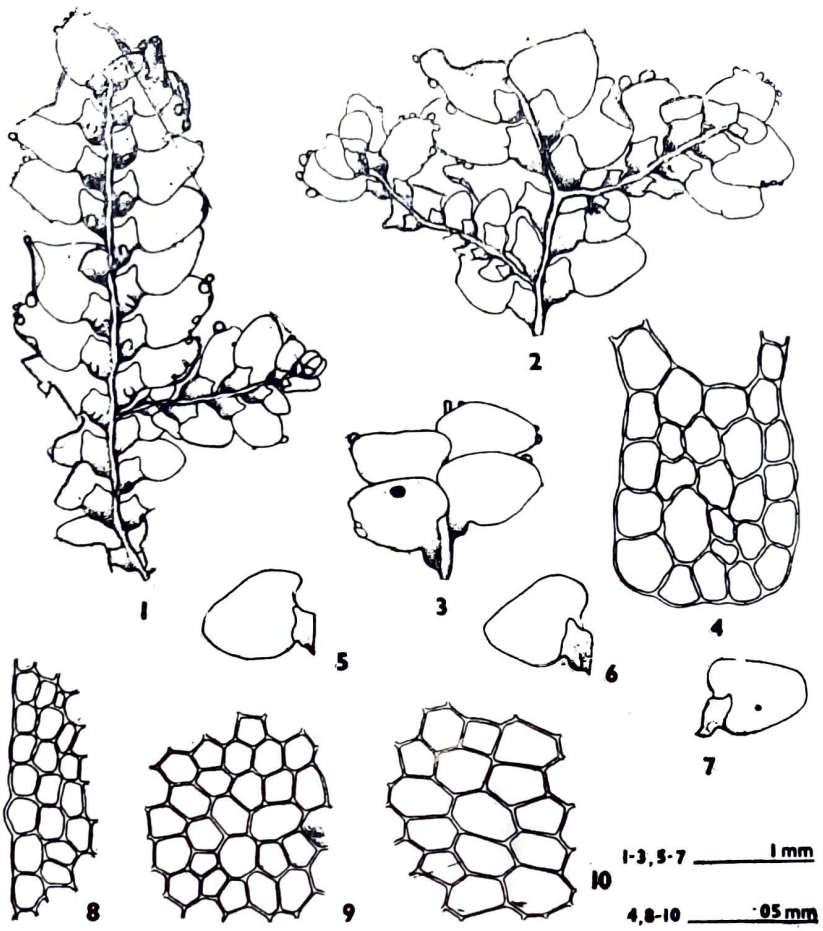
Radula tayabensis Steph., Spec. Hepat. 6: 516 (1924).

Radula reineckeana Steph. Spec. Hepat. 4: 225 (1910).

Plants green, yellowish green in herbaria, small, 1-2 cms long. Stem slender, pinnately branched, upto 0.08 mm in diameter. Cross-section of stem about 5-celled across the diameter, cortical cells somewhat brownish while medullary cells colourless, all cells thin-walled with minute trigones. Leaves 1.3-1.5 ×1.4-1.6 mm, leaf lobes moderately imbricate, widely spreading, somewhat concave, ovate to narrowly falcate with narrowly rounded apex, dorsal base rounded, fully covering the stem and occasionally arching beyond it. Leaf lobule sub-quardrate with mostly acuminate apex, front margin parallel to keel, apical margin mostly incurved, occasionally decurved, keel arched, forming an angle of 40-60° with the stem, sinus acute to broadly acute, with a distinct mamilliform convex rhizogenous sac, bearing pale brown bundle of rhizoids branched towards their tips, line of insertion straight, 3/4 of its base inserted with the stem while 1/4 free. Cells of the lobe thin-walled with minute trigones, marginal cells 10-13 ×10-13 (15) μm, median cells 13-15 ×10-13 μm, basal cells 18-21 ×(21) 26-31 μm. Gemmae 226-248 μm, both on adaxial and abaxial leaf margins, discoid, multicelled. Sexual plants not gathered.

Habitat Growing on a piece of fallen bark covered with soil in close association with *Lopholejeunea* spp.

Specimens examined--LWU 4041/79. Loc.: Jowai (Meghalaya) eastern Hima-



Text-figs. D1-10. *Radula tjibodensis* Goeb., Figs. 1-2—Portions of the gemmiparous twig in postical view; Fig. 3—A portion of the same in dorsal view ; Fig. 4—Cross-setction of stem; Figs. 5-7—Dissected leaves; Fig. 8—Marginal cells of leaf; Fig. 9—Median cells of the leaf; Fig. 10—Basal cells of leaf. (Illustrations drawn from LWU 4041/79).

layas, alt.: ca 1600 m. Coll. U. S. Awasthi & Adarsh Kumar, Date : 11 Nov. 1979 Det.: Ram Udar & Dhirendra Kumar.

Characteristics of the species

(1) The leaf-lobule with acuminate apex- produced in a mammiliform projection, on postical side bearing rhizoid initial area. (2) The discoid gemmae produced all around the leaf margin.

ACKNOWLEDGEMENTS

The authors are grateful to Drs. G. Boucquet and Patricia Geissler of Conservatoire *et* Jardin Botanique, Geneve, for providing type specimens of *Radula* spp., to Dr. S. Hattori for the specimens of *R. acuminata*, and to the Department of Science and Technology(SERC) Government of India, for financial assistance. One

of us (D. K.) also acknowledges the award of a Teacher Fellowship by the University Grants Commission, New Delhi.

REFERENCES

CASTLE, H. (1939). A revision of the genus *Radnlu*. Part II subgenus *Acroradula*. Section 1. Epiphyllae. *Ann. Bryol.*, **12** : 21-47.

JONES, E. W. (1977). African Hepatics 30. The genus *Radula* Dumortier. *J. Bryol.*, **9** : 461-504.

PANDE, S. K., SRIVASTAVA, K. P. & AHMAD, S. (1957). Epiphyllous liverworts of India and Ceylon-II. *J. Indian bot. Soc.*, **36** : 335-347.

SCHUSTER, R. M. (1980). Phylogenetic studies on Jungermanniidae II. Radulineae (Part 1). *Nova Hedwigia*, **32** : 1-57.