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The New Genus *Benitotania* (Daltoniaceae, Bryopsida) from Mt. Kinabalu

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Abstract. A new monospecific genus, *Benitotania*, is described on the basis of *B. elimbata* H. Akiyama, T. Yamag., & M. Suleiman, collected in the northern part of Sabah, Malaysia. It appears to be most closely related to *Adelothecium* and *Bryobrothera*.

Mt. Kinabalu National Park is one of the four places where diverse moss floras exist in Malesia (Tan & Iwatsuki 1999). Although quite a large number of bryophyte collections have been made there and numerous contributions have been published (Frahm et al. 1990; Iwatsuki & Noguchi 1975; Menzel 1988a,b; Noguchi & Iwatsuki 1972; Touw 1978) new taxa or new records are still being reported (Akiyama et al. 1998, 2001; Akiyama & Yamaguchi 1999). Such publications suggest that the bryophyte flora of Mt. Kinabalu is still not fully known.

In December 2001 and September 2002, the authors carried out field research in Kinabalu National Park and the Crocker Range Park. Among our collections we found curious plants that appears as a small species of *Fissidens* or *Schistochila* and therefore might be easily overlooked in the field (Figs. 1–2). The plants have the following features 1) pale green coloration with complanate leaves that are arranged in 8-ranks along the stem, 2) narrowly ovate and mucronate leaves not curled or shrunk in either dry or wet condition and easily detached from the stem, 3) single costa reaching two-thirds of leaf length, 4) leaf margins almost entire, plane, and unbordered, 4) laminal cells of stem leaves uniform in size except at apex, evenly thick-walled, hexagonal-quadrangle, minutely but distinctly verrucose throughout, 5) absence of differentiated alar regions, and 6) presence of linear pseudoparaphyllia. The marginal laminal cells are slightly narrower than the inner ones in the perichaetial leaves and thus a weak border is differentiated.

The complanate foliation, absence of a border at the leaf margin, single costa, and hexagonal-quadrangle laminal cells of the Kinabalu plants suggest a

close relationship to *Adelothecium bogotense* (Hampe) Mitten, mainly distributed in Central America, or to *Bryobrothera crenulata* (Broth. & Paris) Thér. from Seram to the South Pacific. *Adelothecium* differs from the Kinabalu plants, however, in having much larger plants and leaf sizes; broadly ovate to obovate, rounded or rounded-obtuse leaf shape; distinctly sinuate laminal cells; non-deciduous leaves; differentiated gemmiferous short branches; and longer axillary hairs (Ochyra et al. 1992). On the other hand, *Bryobrothera* differs from the Kinabalu plants in its much smaller size, elliptic to obovate or spatulate-obovate leaves, and strong costa almost reaching the leaf apex (Buck 1987, 1988; Norris & Robinson 1979). Therefore, we came to recognize our material as representing a new genus of mosses in the Daltoniaceae.

BENITOTANIA H. Akiyama, T. Yamag., & M. Suleiman, *gen. nov.*

Affinis *Adelothecio*, sed caulibus 1.0–1.5 cm longis, foliis ca 2 mm longis, anguste-ovatis, non limbatis, cellulis laminaribus sexangulis-quadratis diversa.

Plants pale green in color, complanately foliate, leaves arranged in 8-ranks. Rhizoids brown, papillose. Stems almost simple, rarely branched, reddish brown, slightly ascending. Leaves isomorphic, narrowly ovate, shortly acuminate. Laminal cells hexagonal-quadrangle, thick-walled, alar region not differentiated; costa single, reaching 3/4 of leaf length. Pseudoparaphyllia present, linear. Dioicous. Perichaetia lateral on stem. Male plants and sporophytes unknown.

TYPE SPECIES: *Benitotania elimbata* H. Akiyama, T. Yamag., & M. Suleiman

Etymology.—*Benitotania* is named after Benito C. Tan, National University of Singapore, who has

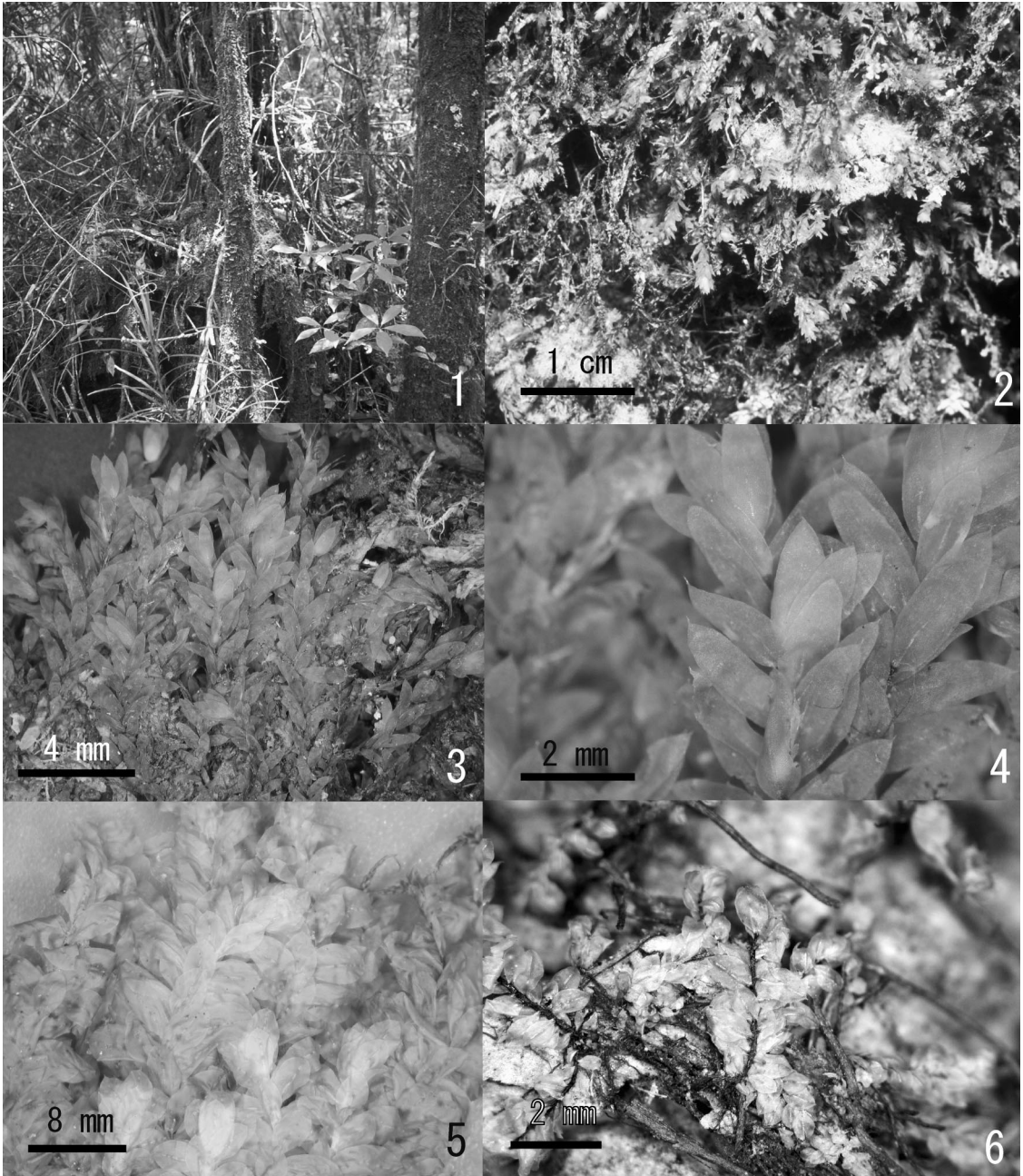


FIGURE 1–6. *Benitotania elimbata* 1–4, *Adelothecium bogotense* 5, and *Bryobrothera crenulata* 6. — 1. Photograph of type locality at Kinabalu National Park. — 2. *B. elimbata* intermingled with other bryophytes; some stems have lost their leaves in upper portions. — 3. Pure mat collected from a tree branch (holotype). — 4. Apiculate tips of stem leaves (holotype). — 5. Upper part of stems [COLOMBIA, Municipio de la Unión, ca 05°56' N, 75°17' W, 2,340–2,430 m, Churchill *et al.* 15385 (NY)]. — 6. Ascending and prostrate shoots. Naked stems can be seen due to detached leaves. [INDONESIA, West Seram, Akiyama C-15791 (HYO)].

long contributed to the clarification of the bryoflora of Asia and also first suggested the close relationship of this new genus to *Adelothecium*.

Complanate foliation; evenly thick-walled, hexagonal-quadrangle laminal cells; and absence of border of *Benitotania* might suggest resemblance to

some members of the Rhizogoniaceae. Isomorphic stem leaves arranged in 8-ranks and lateral position of perichaetia; however, indicate only a remote relationship to that family. On the other hand, 8-ranked foliation and a single, weak costa indicate a close relationship to the Daltoniaceae, especially to

Adelothecium bogotense and *Bryobrothera crenulata* that are characterized by such features. *Benitotania* seems most closely related to *Adelothecium* and *Bryobrothera* in their complanate foliation, epiphytic habit, single costa, absence of borders in stem leaves, absence of well-differentiated alar regions, small thick-walled hexagonal to quadrate laminal cells, and linear pseudoparaphyllia [Note that the observation given by Norris and Robinson (1979) that *Bryobrothera crenulata* lacks pseudoparaphyllia is incorrect].

Buck (1987) pointed out that *Adelothecium* is rather remotely related to the other members of the Hookeriales through similarites in strong single costa, isodiametric leaf cells, unbordered leaves, and filamentous pseudoparaphyllia. Later he established a new monotypic family, the Adelotheciaceae (Buck 1988), and also stated that it might be closely related to *Bryobrothera*. If we accept his view, then *Benitotania* would be included in the Adelotheciaceae along with *Adelothecium* and *Bryobrothera*. Here we adopt a more conservative position, however, and place the genus in the Daltoniaceae. For a final deposition, we will wait for the discovery of sporophytes or a molecular analysis along with related genera.

KEY TO BENITOTANIA AND RELATED GENERA

1. Plants large, usually more than 3 cm long. Propagules on specialized shoots. Stem leaves not deciduous. Leaves more than 3 mm long (dorsal leaves sometimes smaller, ca 2 mm or less). Laminal cells more or less sinuate; juxtacostal cells differentiated. Axillary hairs more than 10 cells long *Adelothecium*
1. Plants small, usually less than 1 cm long. Propagules, if present, in leaf axils. Stems easily defoliated. Leaves less than 2 mm long. Laminal cells never sinuate; juxtacostal cells not differentiated. Axillary hairs less than four cells long 2
 2. Leaves ovate, less than 1 mm long; lower part of costa tinged red, smooth; marginal cells more or less differentiated. Axillary hairs with colored basal cell. Propagules present. Perichaetial leaves unbordered *Bryobrothera*
 2. Leaves narrowly ovate, ca 2 mm long; lower part of costa green; marginal cells never differentiated; laminal cells verrucose throughout. Axillary hairs without colored basal cell. Propagules absent. Perichaetial leaves with weakly differentiated border *Benitotania*

All three of these genera are monospecific and are separated geographically—*Benitotania* occurs in northern Borneo; *Bryobrothera* in Seram (new report, as *Akiyama C-15791* HYO), northeastern Australia, New Caledonia, Solomon Islands, and Fiji (Norris & Robinson 1979); and *Adelothecium* in Central and South America (from Mexico to southeastern Brazil), Tanzania (Ochya et al. 1992), and Madagascar (Crosby 1976).

It is notable that both *Benitotania* and *Bryobrothera* have deciduous leaves. Such a phenomenon might be related to the absence of specialized branches bearing gemmae in both genera.

BENITOTANIA ELIMBATA H. Akiyama, T. Yamag., & M. Suleiman, *sp. nov.* FIGS. 1–4, 7–18

Affine *Adelothecium bogotense*, sed plantis albens viridibus, caulibus 1.0–1.5 cm longis, foliis ca 2 mm longis, anguste-ovatis, non limbatis, costis longitudine 3/4 lamina partes aequantia, cellulis laminaribus sexagulis-quadratis, aequaliter incrassatis, plane verrucatis diversa.

TYPE: MALAYSIA. SABAH. Kinabalu National Park, Silau-Silau Trail, 1,500 m elev., *Akiyama Kinabalu-2001* [HYO, holotype; BM, (BORH), Kinabalu Park Herbarium, L, NY, isotypes].

Paratypes.—MALAYSIA. SABAH. Kinabalu National Park, Bukit Tupai Trail, *Akiyama Kinabalu-1204* (HYO, BORH); Silau-Silau Trail, *Akiyama Kinabalu-1057* (HYO, BORH), 2002 (HYO, NY), *Yamaguchi 20475* (HIRO, HYO, BORH); Crocker Range, Alab Pass, *Akiyama Crocker-435* (HYO, BORH).

Plants in whitish green mats, complanately foliate, sparsely sympodially branching. Rhizoids mostly at base of stems, reddish-brown, papillose, both shorter, densely branched rhizoids and longer, rarely branched ones present. Stems reddish brown except for younger portions, ca 0.1 mm in diameter, round in transverse section; cells thick-walled, without central strand. Leaf shape and size not differentiated by position on stem. Stem leaves in eight-rows, narrowly ovate, mucronate, shortly acuminate, plane both in dry and wet conditions (sometimes slightly undulate), ca 2.0 mm long, 0.5 mm wide; laminal cells hexagonal to quadrate, evenly thickened, minutely verrucose throughout; basal cells becoming longer, distinctly porose; alar cells not differentiated; marginal cells not differentiated; costa single, narrow, 3/4 of leaf length; juxtacostal cells not differentiated from inner ones. Axillary hairs 1–2 for each leaf, 3–4 cells long; basal cells not differentiated. Dormant buds of *Bryum*-type, with short (2–5 cells long), filamentous pseudoparaphyllia. Asexual propagules absent. Dioicous? Male plants and antheridia not found. Perichaetia in leaf axils. Prefertilization perichaetial leaves much smaller than stem leaves; innermost ones ca 1.2 mm long, linear from narrowly or widely ovate base, lamina cells oblong to linear, thick-walled, somewhat porose; outer perichaetial leaves much smaller, oblong to narrowly ovate, laminal cells quadrate to rectangular, thick-walled, cells at leaf margins differentiated, linear. Archegonia ca 15 per perichaetium, without paraphyses. Sporophytes unknown.

Benitotania elimbata was found on the lower part of tree trunks, usually intermingled with other bryophytes, rarely on slender, horizontally spreading

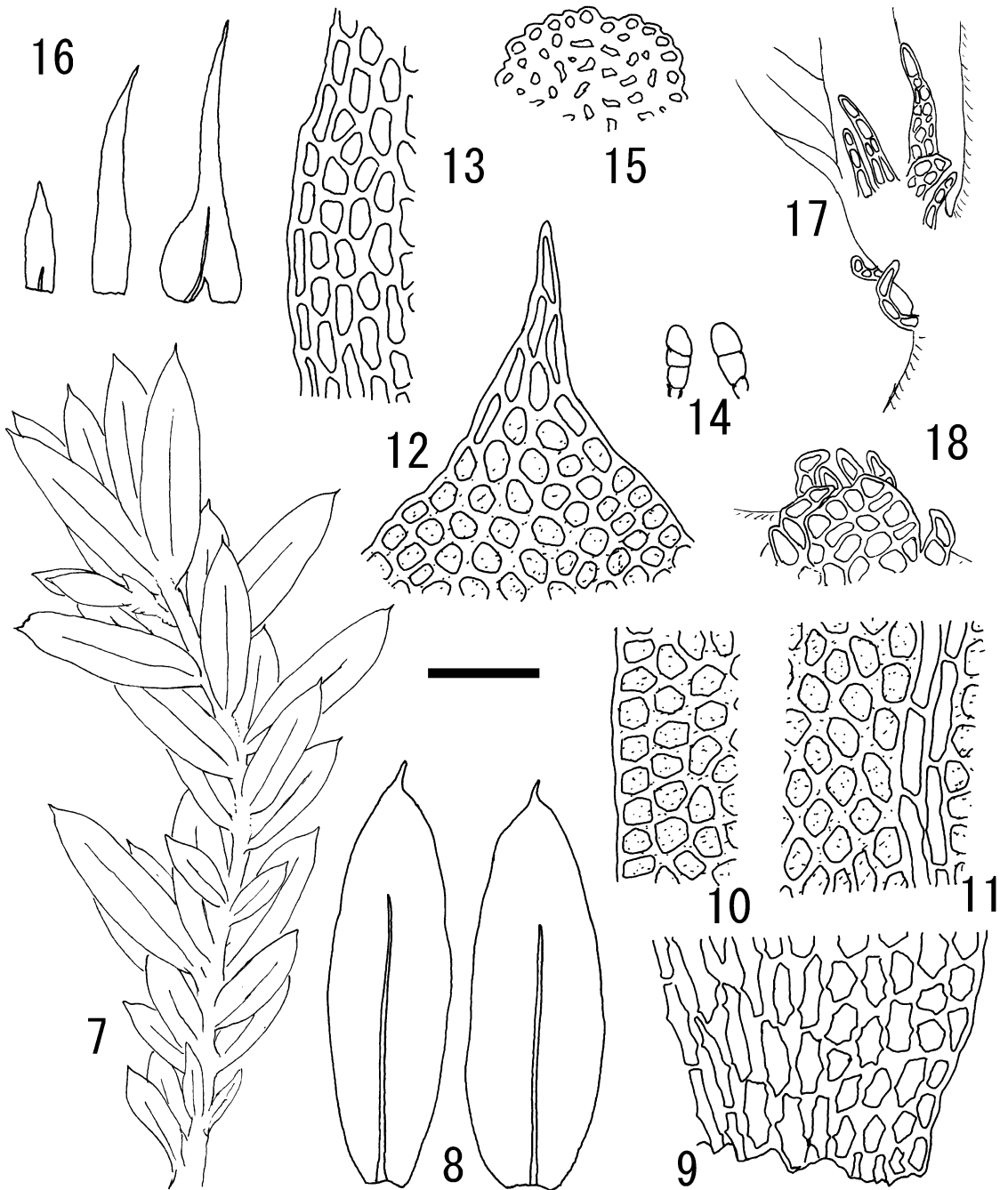


FIGURE 7–18. *Benitotania elimbata* H.Akiyama, T.Yamag, & M. Suleiman. —7. Plant. —8. Stem leaves. —9. Alar region of stem leaf. —10. Median marginal portion of stem leaf. —11. Costa and laminal cells of median part of stem leaf. —12. Apex of stem leaf. —13. Lower margin of perichaetial leaf. —14. Axillary hairs. —15. Transverse section of stem. —16. Prefertilization perichaetial leaves. —17. Pseudoparaphyllia at base of branch. —18. Pseudoparaphyllia and dormant branch bud. All from holotype. Scale bars Fig. 7; 1 mm. Figs. 8, 16; 0.5 mm. Figs. 9–15; 0.05 mm. Fig. 17; 0.1 mm.

branches of shrubs 2–4 m in height, in mossy montane forests, especially along streams. It is abundant at the type locality. Both in November 2001 and September 2002, there were a number of mature per-

ichaetia seen in the field, but no male plants and sporophytes.

This species was first found at middle elevations on Mt. Kinabalu (Silau-Silau Trail) in December,

TABLE 1. Number of different sites in 1,428 bp between *rbcL* sequences.

| Species | GenBank accession no. | | | |
|---------------------------------|-----------------------|----|----|----|
| | | 2 | 3 | 4 |
| 1 <i>Benitotania elimbata</i> | AB103351 | 33 | 33 | 43 |
| 2 <i>Adelothecium bogotense</i> | AB103352 | — | 0 | 50 |
| 3 <i>Adelothecium bogotense</i> | AB103354 | — | — | 50 |
| 4 <i>Bryobrothera crenulata</i> | AB103353 | — | — | — |

2001. On a second survey in September 2002, we found many trees on which it grew abundantly. In addition, in the course of a botanical survey of the northern part of the Crocker Range Mts. we found another locality in the vicinity of Alab Pass, where mossy montane forests are well-preserved. This makes us think *Benitotania elimbata* is not rare in the northern part of Sabah.

Relationships of Benitotania, Adelothecium, and Bryobrothera.—Phylogenetic analyses of the interrelationships of *Benitotania*, *Adelothecium*, and *Bryobrothera*, based on the chloroplast ribulose 1,5-bisphosphate carboxylase/oxygenase large subunit (*rbcL*) gene sequences, were conducted along with 22 taxa that included one species of the Hookeriaceae, one from the Daltoniaceae, and two from the Hypopterygiaceae (Appendix 1). All of the procedures were performed following Tsubota et al. (2002).

Our results indicate that the two samples of *Adelothecium bogotense* have the same sequences and

they differ at 33 sites from *Benitotania elimbata* (Table 1). *Bryobrothera crenulata* differs from *Benitotania* at 43 sites. In addition, the tree indicates that *Benitotania*, *Adelothecium*, and *Bryobrothera crenulata* form a monophyletic group (Fig. 19).

ACKNOWLEDGMENTS

We thank the Sabah Parks for permission to carry out research in the Kinabalu National Park; B. C. Tan (SINU) who first noticed the resemblance of this new genus to *Adelothecium*; and W. R. Buck (NY) who read the manuscript, provided valuable comments, and corrected the English text. This study was financially supported by a Grant-in-Aid from the Japanese Ministry of Education, Culture, Sports and Science, and Technology to HA (14596007), HT (13740490), and a UMS Research Grant 26/2000 to MS.

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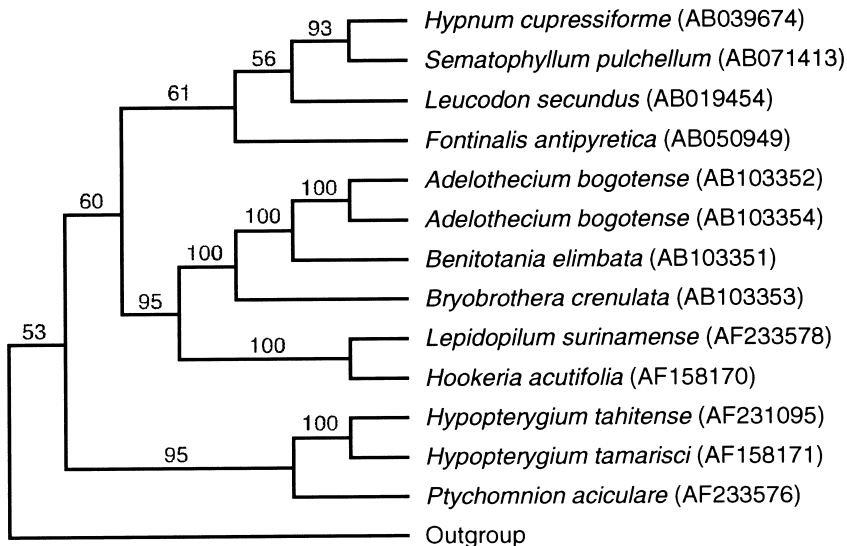


FIGURE 19. The 50% majority-rule condensed tree for the 28 bifurcating topologies by HKY85 model with high-ranking log-likelihood values that passed the Approximate unbiased test (Shimodaira 2000, 2002) based on the aligned 1,092 bp of the 25 *rbcL* gene sequences. Note that the taxa used as an outgroup are unified as “outgroup” in this tree. For the species and families investigated with the accession numbers and voucher or reference of the sequences, see Appendix 1.

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APPENDIX 1.

List of families and species investigated for *rbcL* gene sequences, along with the accession numbers, vouchers, or references of the sequences. Taxa of the outgroup were selected on the basis of a phylogenetic tree in Tsubota et al. (2002).

Hookeriaceae: *Adelothecium bogotense* (Hampe) Mitt., Colombia, *Theirs* 3702 (NY) (AB103352); *Adelothecium bogotense*, Colombia, *Churchill et al.* 15385 (NY) (AB103354); *Benitotania elimbata* H. Akiyama et al. Malaysia, *Akiyama Kinabalu-1057* (HYO) (AB103351); *Bryobrothera crenulata* (Broth. & Par.) Thér., Australia, *Streimann 57716* (NY) (AB103353); *Hookeria acutifolia* Hook. & Grev. (AF158170; De Luna et al. 2000). **Hypopterygiaceae:** *Hypopterygium tamarisci* (Sw.) Müll. Hal. (AF158171, De Luna et al. 2000); *Hypopterygium tahitense* Ångst. (AF231095, Mishler et al., only in DNA database). **Daltoniaceae:** *Lepidopilum surinamense* Müll. Hal. (AF233578, De Luna et al. 2000). **Ptychomniaceae:** *Ptychomnion aciculare* (Brid.) Mitt. (AF 233576, De Luna et al. 2000).

Outgroup taxa. **Hypnodendraceae:** *Hypnodendron menziesii* (Hook.) Paris, (AF231093, Mishler et al., only in DNA database). **Fontinalaceae:** *Fontinalis antipyretica* Hedw. (AB050949, Tsubota et al. 2001a). **Sematophyllaceae:** *Sematophyllum pulchellum* (Card.) Broth. (AB071413, Tsubota et al. 2001b). **Hypnaceae:** *Hypnum cupressiforme* Hedw. (AB039674, Tsubota et al. 2000). **Cyrtopodaceae:** *Bescherellia brevifolia* Hampe (AJ275184, Cox et al. 2000); *Bescherellia elegantissima* Duby (AF231097, De Luna et al. 2000); *Cyrtopus setosus* (Hedw.) Hook.f. (AF231096, Mishler et al., only in DNA database). **Hedwigiaceae:** *Hedwigia ciliata* (Hedw.) P. Beauv. (AF005517, Goffinet et al. 1998). **Leucodontaceae:** *Leucodon secundus* (Harv.) Mitt. (AB019454, Maeda et al. 2000). **Mniaceae:** *Plagiommium japonicum* (Lindb.) T. J. Kop. (AB050992, Tsubota et al. 2001a). **Racopilaceae:** *Racopilum convolutaceum* (Müll. Hal.) Reichardt, (AF231094, Mishler et al., only in DNA database). **Splachnaceae:** *Tayloria lingulata* (Dicks.) Lindb. (AF005515, Goffinet et al. 1998). **Orthotrichaceae:** *Ulota lutea* (Hook.f. & Wilson) Mitt. (AF005540, Goffinet et al. 1998). **Leucobryaceae:** *Leucobryum scabrum* Sande Lac. (AB029388, Tsubota et al. 1999). **Funariaceae:** *Funaria hygrometrica* Hedw. (AF005513, Goffinet et al. 1998); *Physcomitrella patens* (Hedw.) Bruch & Schimp. (X74156, Kruse et al. 1995).