

A taxonomic revision of Thuidiaceae (Bryophyta) in Africa and the East African islands

by

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Submitted in partial fulfilment of the requirements for the degree

Magister Scientiae

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Supervisor: Prof. Dr. A. E. van Wyk

Co-supervisor: Dr. J. van Rooy



Thuidium assimile, upper stem branches (Sim 7447, Zwaartkop, KwaZulu-Natal, South Africa, 1915). Scale bar = 1 mm.

Dedication

I dedicate this thesis to my family and everyone who understands, appreciates or seeks to understand the significance of the bryophytes in our environment.

Declaration

I, Nonkululo Phephu, declare that the dissertation that I hereby submit for the degree Magister Scientiae at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

Signature:



Date: 23 May 2013

TABLE OF CONTENTS

ABSTRACT	vii
INDEX TO SCIENTIFIC NAMES	ix
LIST OF FIGURES, TABLES AND PLATES	xiii
1. INTRODUCTION	1
1.1 Background.....	1
1.2 Motivation and problem statement.....	1
1.3 Hypotheses.....	2
1.4 Objectives.....	3
1.5 Layout of thesis.....	3
2. HISTORIC OVERVIEW OF THE THUIDIACEAE	5
3. MATERIALS AND METHODS	22
3.1 Geographical scope.....	22
3.2 Materials.....	23
3.3 Methods.....	23
3.3.1 Morphological studies.....	23
3.3.2 Ancestral character state reconstruction.....	25
3.3.3 Mapping methods.....	25
3.4. Systematic treatment of taxa.....	26
3.5 Terminology.....	26
3.6 Author abbreviation.....	26
4. CIRCUMSCRIPTION AND CHARACTER STATE RECONSTRUCTION OF THE THUIDIACEAE IN AFRICA	27

4.1 Introduction	27
4.2 Results	28
4.3 Discussion	36
4.4 Conclusions	37
5. TAXONOMIC SIGNIFICANCE OF CHARACTERS	38
5.1 Introduction	38
5.2 Structural characters	39
5.2.1 Gametophyte	39
5.2.2 Sporophyte	41
6. TAXONOMIC TREATMENT	57
6.1 Family Thuidiaceae	57
6.2 Key to the genera and species, description of taxa and additional notes	61
7. GENERAL DISCUSSION AND CONCLUSIONS	151
7.1 Discussion	151
7.2 Conclusions	152
SUMMARY	154
ACKNOWLEDGEMENTS	155
CURRICULUM VITAE	156
REFERENCES	157
APPENDIX: New combinations and a key to the species of <i>Pelekium</i> (Thuidiaceae) in sub-Saharan Africa and the East African Islands	163

ABSTRACT

A taxonomic revision of Thuidiaceae (Bryophyta) in Africa and the East African islands

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A taxonomic revision of the family Thuidiaceae Schimp. for Africa and the east African Islands is presented. Three genera, namely, *Pelekium* Mitt., *Thuidiopsis* (Broth.) M. Fleisch. and *Thuidium* Bruch & Schimp., and 16 species are accepted and revised for the region. The nomenclature, keys to genera and species, descriptions, illustrations and distribution maps are included.

Thuidiaceae is one of over 40 families that belong to the Hypnales which is known to contain the most diversity among pleurocarpous mosses. Members of the Thuidiaceae are characterised by gametophytes with attractive, regularly 2- or 3-pinnate branching, presence of paraphyllia on surfaces of stems and branches, dimorphic stem and branch leaves, longitudinally plicate leaves with a single costa, papillose leaf cells, and a hypnoid peristome.

Abietinella Müll. Hal., *Haplocladium* (Müll. Hal.) Müll. Hal., *Hylocomiopsis* Cardot and *Raiiella* Reimers are excluded from African Thuidiaceae. *Thuidium involvens* var. *thomeanum* Broth. is raised to species status under *Pelekium*, as *Pelekium thomeanum* (Broth.) Phephu. *Thuidium pseudoinvolvens* (Müll. Hal.) A. Jaeger is also transferred to *Pelekium* and the new combination *Pelekium pseudoinvolvens* (Müll. Hal.) Phephu is proposed.

Key words: Africa, anatomy, characters, distribution, ecology, morphology, *Pelekium*, *Thuidiopsis*, *Thuidium*.

INDEX TO SCIENTIFIC NAMES

Currently accepted names in *bold italics*, synonyms in *light italics*.

Taxa	Page
<i>Cyrto-hypnum byssoideum</i> (Besch.) W. R. Buck & H.A. Crum = <i>Pelekium investe</i> (Mitt.) A. Touw	79
<i>Cyrto-hypnum chenagonii</i> (Müll. Hal. ex Renauld & Cardot) W. R. Buck & H.A. Crum = <i>Pelekium chenagonii</i> (Müll. Hal. ex Renauld & Cardot) A. Touw	67
<i>Cyrto-hypnum gratum</i> (P. Beauv.) W.R. Buck & H.A. Crum = <i>Pelekium gratum</i> (P. Beauv.) A. Touw	73
<i>Cyrto-hypnum investe</i> (Mitt.) W. R. Buck & H.A. Crum = <i>Pelekium investe</i> (Mitt.) A. Touw	79
<i>Cyrto-hypnum involvens</i> subsp. <i>thomeanum</i> (Broth.) W.R. Buck & H.A. Crum = <i>Pelekium thomeanum</i> (Broth.) Phephu	91
<i>Cyrto-hypnum minusculum</i> (Mitt.) W.R. Buck & H.A. Crum = <i>Pelekium minusculum</i> (Mitt.) A. Touw	82
<i>Cyrto-hypnum montei</i> Hedenäs = <i>Thuidiopsis sparsa</i> (Hook. f. & Wilson) Broth.	106
<i>Cyrto-hypnum ramusculosum</i> (Mitt.) W.R. Buck & H.A. Crum = <i>Pelekium ramusculosum</i> (Mitt.) A. Touw	88
<i>Cyrto-hypnum squarrosulum</i> (Renauld & Cardot) W.R. Buck & H.A. Crum = <i>Pelekium minusculum</i> (Mitt.) A. Touw	82
<i>Cyrto-hypnum tenuissimum</i> (Welw. & Duby) W.R. Buck & H.A. Crum = <i>Pelekium investe</i> (Mitt.) A. Touw	79
<i>Cyrto-hypnum varians</i> (Welw. & Duby) W.R. Buck & H.A. Crum = <i>Pelekium varians</i> (Welw. & Duby) A. Touw	94
<i>Hypnum chloropsis</i> Müll. Hal. = <i>Pelekium gratum</i> (P. Beauv.) A. Touw	73
<i>Hypnum ferricola</i> Müll. Hal. = <i>Pelekium gratum</i> (P. Beauv.) A. Touw	73
<i>Hypnum gratum</i> P. Beauv. = <i>Pelekium gratum</i> (P. Beauv.) A. Touw	73
<i>Hypnum investe</i> Mitt. = <i>Pelekium investe</i> (Mitt.) A. Touw	79
<i>Hypnum mascarenicum</i> Müll. Hal. = <i>Thuidium tamariscinum</i> (Hedw.) Schimp.	122
<i>Hypnum nabambissense</i> Müll. Hal. = <i>Pelekium gratum</i> (P. Beauv.) A. Touw	73
<i>Hypnum promontorii</i> Müll. Hal. = <i>Thuidium assimile</i> (Mitt.) A. Jaeger	117
<i>Hypnum pseudoinvolvens</i> Müll. Hal. = <i>Pelekium pseudoinvolvens</i> (Müll. Hal.) Phephu	85
<i>Hypnum sigmatella</i> Müll. Hal. = <i>Pelekium varians</i> (Welw. & Duby) A. Touw	94
<i>Hypnum sparsum</i> Hook. f. & Wilson = <i>Thuidiopsis sparsa</i> (Hook. f. & Wilson) Broth.	106
<i>Hypnum tamariscellum</i> Müll. Hal. = <i>Pelekium versicolor</i> (Müll. Hal.) A. Touw	100
<i>Hypnum tamariscinum</i> Hedw. = <i>Thuidium tamariscinum</i> (Hedw.) Schimp.	122

<i>Hypnum versicolor</i> Hornsch. ex Müll. Hal. = <i>Pelekium versicolor</i> (Müll. Hal.) A. Touw	100
<i>Leskea assimilis</i> Mitt. = <i>Thuidium assimile</i> (Mitt.) A. Jaeger	117
<i>Leskea contortula</i> Mitt. = <i>Pelekium contortulum</i> (Mitt.) A. Touw	70
<i>Leskea investis</i> (Mitt.) Mitt. = <i>Pelekium investe</i> (Mitt.) A. Touw	79
<i>Leskea minuscula</i> Mitt. = <i>Pelekium minusculum</i> (Mitt.) A. Touw	82
<i>Leskea nigeriana</i> Mitten = <i>Pelekium thomeanum</i> (Broth.) Phephu	91
<i>Leskea ramusculosa</i> Mitten = <i>Pelekium ramusculosum</i> (Mitt.) A. Touw	88
<i>Leskea subfalcatata</i> Mitt. = <i>Pelekium thomeanum</i> (Broth.) Phephu	91
<i>Leskea tamariscella</i> (Müll. Hal.) Mitt. = <i>Pelekium versicolor</i> (Müll. Hal.) A. Touw	100
<i>Lorentzia velata</i> (Mitt) W.R. Buck & H.A. Crum = <i>Pelekium velatum</i> Mitt.	97
<i>Pelekium chenagonii</i> (Müll. Hal. ex Renault & Cardot) A. Touw	67
<i>Pelekium contortulum</i> (Mitt.) A. Touw	70
<i>Pelekium gratum</i> (P. Beauv.) A. Touw	73
<i>Pelekium intricatum</i> (A. Jaeger) A. Touw	77
<i>Pelekium investe</i> (Mitt.) A. Touw	79
<i>Pelekium minusculum</i> (Mitt.) A. Touw	82
<i>Pelekium pseudoinvolvens</i> (Müll. Hal.) Phephu	85
<i>Pelekium ramusculosum</i> (Mitt.) A. Touw	88
<i>Pelekium thomeanum</i> (Broth.) Phephu	91
<i>Pelekium varians</i> (Welw. & Duby) A. Touw	94
<i>Pelekium velatum</i> Mitt.	97
<i>Pelekium versicolor</i> (Müll. Hal.) A. Touw	100
<i>Thuidiopsis furfurosa</i> var <i>sparsa</i> (Hook. f. & Wilson) Wijk & Margad. = <i>Thuidiopsis sparsa</i> (Hook. f. & Wilson) Broth.	106
<i>Thuidiopsis sparsa</i> (Hook. f. & Wilson) Broth.	106
<i>Thuidium aculeoserratum</i> Renault & Cardot	114
<i>Thuidium angolense</i> Welw. & Duby = <i>Pelekium ramusculosum</i> (Mitt.) A. Touw	88
<i>Thuidium assimile</i> (Mitt.) A. Jaeger	117
<i>Thuidium borbonicum</i> Besch. = <i>Pelekium versicolor</i> (Müll. Hal.) A. Touw	100
<i>Thuidium borbonicum</i> f. <i>breviseta</i> Thériot = <i>Pelekium versicolor</i> (Müll. Hal.) A. Touw	100
<i>Thuidium byssoideum</i> Besch. = <i>Pelekium investe</i> (Mitt.) A. Touw	79
<i>Thuidium tamariscellum</i> (Müll. Hal.) Bosch & Sande Lac. = <i>Thuidium tamariscinum</i> (Hedw.) Schimp.	122
<i>Thuidium chenagonii</i> fo. <i>laxifolia</i> Cardot = <i>Pelekium varians</i> (Welw. & Duby) A. Touw	94
<i>Thuidium chenagonii</i> Müll. Hal. ex Renault & Cardot = <i>Pelekium chenagonii</i> (Müll. Hal. ex Renault &	

Cardot) A. Touw	67
<i>Thuidium chenagonii</i> var. <i>campyloneuron</i> Renauld & Paris = <i>Pelekium chenagonii</i> (Müll. Hal. ex Renauld & Cardot) A. Touw	67
<i>Thuidium chloropsis</i> (Müll. Hal.) Paris = <i>Pelekium gratum</i> (P. Beauv.) A. Touw	73
<i>Thuidium contortulum</i> (Mitt.) A. Jaeger = <i>Pelekium contortulum</i> (Mitt.) A. Touw	70
<i>Thuidium contortulum</i> var. <i>mussooriense</i> Vohra = <i>Pelekium versicolor</i> (Müll. Hal.) A. Touw	100
<i>Thuidium ferricola</i> (Müll. Hal.) A. Jaeger = <i>Pelekium gratum</i> (P. Beauv.) A. Touw	73
<i>Thuidium furfurosum</i> var <i>sparsum</i> (Hook. f. & Wilson) Sainsbury = <i>Thuidiopsis sparsa</i> (Hook. f. & Wilson) Broth.	106
<i>Thuidium gratum</i> (P. Beauv.) A. Jaeger = <i>Pelekium gratum</i> (P. Beauv.) A. Touw	73
<i>Thuidium gratum</i> subsp. <i>grammifolium</i> (P. Beauv.) A. Touw = <i>Pelekium gratum</i> (P. Beauv.) A. Touw	73
<i>Thuidium gratum</i> subsp. <i>subscissum</i> (Müll. Hal. ex Besch.) A. Touw = <i>Pelekium gratum</i> (P. Beauv.) A. Touw	73
<i>Thuidium integricalyx</i> Müll. Hal. = <i>Pelekium chenagonii</i> (Müll. Hal. ex Renauld & Cardot) A. Touw	67
<i>Thuidium intricatum</i> A. Jaeger = <i>Pelekium intricatum</i> (A. Jaeger) A. Touw	77
<i>Thuidium investe</i> (Mitt.) A. Jaeger = <i>Pelekium investe</i> (Mitt.) A. Touw	79
<i>Thuidium involvens</i> subsp. <i>thomeanum</i> (Broth.) A. Touw = <i>Pelekium thomeanum</i> (Broth.) Phephu	91
<i>Thuidium involvens</i> var. <i>thomeanum</i> Broth. = <i>Pelekium thomeanum</i> (Broth.) Phephu	91
<i>Thuidium konkourae</i> Paris & Broth. = <i>Pelekium varians</i> (Welw. & Duby) A. Touw	94
<i>Thuidium laevipes</i> Mitt. = <i>Pelekium varians</i> (Welw. & Duby) A. Touw	94
<i>Thuidium mascarenicum</i> (Müll. Hal.) A. Jaeger = <i>Thuidium tamariscinum</i> (Hedw.) Schimp.	122
<i>Thuidium matarumense</i> Besch. = <i>Thuidium assimile</i> (Mitt.) A. Jaeger	117
<i>Thuidium minusculum</i> (Mitt.) A. Jaeger & Sauerb. = <i>Pelekium minusculum</i> (Mitt.) A. Touw	82
<i>Thuidium nabambissense</i> (Müll. Hal.) A. Jaeger = <i>Pelekium gratum</i> (P. Beauv.) A. Touw	73
<i>Thuidium nigerianum</i> (Mitt.) Paris = <i>Pelekium thomeanum</i> (Broth.) Phephu	91
<i>Thuidium pallidisetum</i> Dixon = <i>Pelekium investe</i> (Mitt.) A. Touw	79
<i>Thuidium perbyssaceum</i> Müll. Hal. ex Broth = <i>Pelekium investe</i> (Mitt.) A. Touw	79
<i>Thuidium promontorii</i> (Müll. Hal.) Paris = <i>Thuidium assimile</i> (Mitt.) A. Jaeger	117
<i>Thuidium pseudoinvolvens</i> (Müll. Hal.) A. Jaeger = <i>Pelekium pseudoinvolvens</i> (Müll. Hal.) Phephu	85
<i>Thuidium pycnangiellum</i> Müll. Hal. ex Broth. = <i>Pelekium chenagonii</i> (Müll. Hal. ex Renauld & Cardot) A. Touw	67
<i>Thuidium ramusculosum</i> (Mitt.) A. Jaeger = <i>Pelekium ramusculosum</i> (Mitt.) A. Touw	88
<i>Thuidium sigmatella</i> (Müll. Hal.) A. Jaeger = <i>Pelekium varians</i> (Welw. & Duby) A. Touw	94
<i>Thuidium sparsum</i> (Hook. f. & Wilson) Reichardt = <i>Thuidiopsis sparsa</i> (Hook. f. & Wilson) Broth.	106

<i>Thuidium spurio-involvens</i> Broth. & Paris = <i>Pelekium varians</i> (Welw. & Duby) A. Touw	94
<i>Thuidium strangulatum</i> P. de la Varde = <i>Pelekium investe</i> (Mitt.) A. Touw	79
<i>Thuidium subfalcatum</i> (Mitt.) Paris = <i>Pelekium thomeanum</i> (Broth.) Phephu	91
<i>Thuidium sublaevipes</i> Dixon = <i>Pelekium ramusculosum</i> (Mitt.) A. Touw	88
<i>Thuidium subpellucens</i> Dixon = <i>Pelekium versicolor</i> (Müll. Hal.) A. Touw	100
<i>Thuidium subserratum</i> Renauld & Cardot = <i>Thuidium assimile</i> (Mitt.) A. Jaeger	117
<i>Thuidium subscissum</i> Müll. Hal. ex Besch. = <i>Pelekium gratum</i> (P. Beauv.) A. Touw	73
<i>Thuidium tamariscellum</i> (Müll. Hal.) Bosch & Sande Lac. = <i>Pelekium versicolor</i> (Müll. Hal.) Touw	100
<i>Thuidium tamariscinum</i> (Hedw.) Schimp.	122
<i>Thuidium tenuisetum</i> Renauld & Cardot = <i>Pelekium varians</i> (Welw. & Duby) A. Touw	94
<i>Thuidium tenuissimum</i> Welw. & Duby = <i>Pelekium investe</i> (Mitt.) A. Touw	79
<i>Thuidium torrentium</i> Müll. Hal. = <i>Pelekium versicolor</i> (Müll. Hal.) A. Touw	100
<i>Thuidium trachynotum</i> Renauld & Paris = <i>Pelekium ramusculosum</i> (Mitt.) A. Touw	88
<i>Thuidium varians</i> Welw. & Duby = <i>Pelekium varians</i> (Welw. & Duby) A. Touw	94

LIST OF FIGURES, TABLES AND MAPS

Figures:

Character charts: 5.1 = stem size, 5.2 = branching pattern, 5.3 = paraphyllia branching, 5.4 = paraphyllia terminal cell morphology, 5.5 = stem leaf attachment, 5.6 = stem leaf plication, 5.7 = stem leaf apex, 5.8 = stem leaf margin, 5.9 = stem leaf margin ornamentation, 5.10 = stem leaf costa end, 5.11 = stem leaf median cell shape, 5.12 = stem leaf median cell ornamentation, 5.13 = stem leaf terminal cell, 5.14 = stem leaf basal cell colouration, 5.15 = stem leaf basal cell porosity, 5.16 = stem leaf alar cells, 5.17 = branch leaf terminal cell, 5.18 = breeding system, 5.19 = inner perichaetial leaf shoulder, 5.20 = seta ornamentation, 5.21 = calyptra ornamentation, 5.22 = operculum shape, 5.23 = capsule orientation, 5.24 = endostome cilia, 5.25 = spore size.

Trees: 4.1 = phylogeny tree of Thuidiaceae, 4.2 = phylogeny tree of Thuidiaceae groups, 4.3 = phylogeny tree of Thuidiaceae-Leskeaceae clade, 4.4 = phylogeny tree of Thuidiaceae and new Leskeaceae clades, 4.5 = optimisation tree of stem leaf shape, 4.6 = optimisation tree of stem leaf cell ornamentation, 4.7 = optimisation tree of stem pinnation, 4.8 = optimisation tree of branch leaf terminal cell, 4.9 = optimisation tree of stem leaf margin.

Images: 6.1 = *Pelekium chenagonii*, 6.2 = *P. contortulum*, 6.3 = *P. gratum*, 6.4 = *P. intricatum*, 6.5 = *P. investe*, 6.6 = *P. minusculum*, 6.7 = *P. pseudoinvolvens*, 6.8 = *P. ramusculosum*, 6.9 = *P. thomeanum*, 6.10 = *P. varians*, 6.11 = *P. velatum*, 6.12 = *P. versicolor*. 6.13 = *Thuidiopsis sparsa*. 6.14 = *Thuidium aculeoserratum*, 6.15 = *T. assimile*, 6.16 = *T. tamariscinum*.

Tables:

2.1 = Summary of selected literature outlining the studied regions, 2.2 = Summary of how the previous authors classified the taxa in Thuidiaceae and selected taxa of closely related families, 2.3 = Nomenclature of African Thuidiaceae taxa, 5.1 = Character scores.

Distribution maps:

3.1 = Map of Africa and the East African Islands, 6.1 = *Pelekium chenagonii*, 6.2 = *P. contortulum*, 6.3 = *P. gratum*, 6.4 = *P. intricatum*, 6.5 = *P. investe*, 6.6 = *P. minusculum*, 6.7 = *P.*

pseudoinvolvens, 6.8 = *P. ramusculosum*, 6.9 = *P. thomeanum*, 6.10 = *P. varians*, 6.11 = *P. velatum*, 6.12 = *P. versicolor*. 6.13 = *Thuidiopsis sparsa*. 6.14 = *Thuidium aculeoserratum*, 6.15 = *T. assimile*, 6.16 = *T. tamariscinum*.

CHAPTER 1

INTRODUCTION

1.1 Background

Thuidiaceae, commonly known as fern mosses, is a family of pleurocarpous mosses characterised by attractive, regularly 2- or 3-pinnate branched stems; dimorphic stem and branch leaves, deltoid-triangular, often longitudinally plicate with a single costa; ornamented leaf cells (uni- to pluripapillose); presence of paraphyllia on surfaces of stems and branches; monoicy or dioicy; perfect, hypnoid peristomes; often asymmetrical capsules, collenchymatous exothecial cells; occasionally papillose setae; and sometimes ciliate inner perichaetial leaf margins (Buck & Crum 2010; Martin 2003; Touw 1976, 2001a).

Thuidiaceae is known to occur in temperate and tropical regions of the World (Schiaivone *et al.* 2007). The region under study is Africa and the East African Islands, namely Madagascar, Pemba, Zanzibar, Seychelles, Comoros, Mayotte, Mauritius and Réunion. Members of the family are found in shady and open forest areas on various substrates and under both moist and dry conditions, at altitudes between 250 and 2000 m.

Thuidiaceae consists of about 9 genera and about 130 species, distributed worldwide (Buck & Crum 2010). In Africa and the East African Islands three genera are recognized (*Pelekium* Mitt., *Thuidiopsis* (Broth.) M. Fleisch. and *Thuidium* Bruch & Schimp.) and 16 species, six of which are endemic to the region (O'Shea 2004), namely *Pelekium chenagonii* (Müll. Hal. ex Renauld & Cardot) A. Touw, *P. ramusculosum* (Mitt.) A. Touw, *P. varians* (Welw. & Duby) A. Touw, *Thuidium aculeoserratum* Renauld & Cardot, *Thuidium involvens* var. *thomeanum* Broth., here transferred to *Pelekium* as *Pelekium thomeanum* (Broth.) Phephu. and *Thuidium pseudoinvolvens* (Müll. Hal.) A. Jaeger, here transferred to *Pelekium* as *Pelekium pseudoinvolvens* (Müll. Hal.) Phephu.

1.2 Motivation and problem statement

Difficulties have been experienced with regard to identification within the family Thuidiaceae and the delimitation of the taxa. According to Touw & Falter-Van den Haak (1989), the species of this family have a reputation for being taxonomically problematic. Many taxa remain poorly

understood and definition of some regional taxa (e.g. American and Asian) is still misunderstood. Even the relationships within and among other pleurocarpous mosses are still controversial (García-Avila *et al.* 2009). Re-circumscription of the family seems inevitable as most authors who have worked with Thuidiaceae have drawn attention to this longstanding taxonomic problem. This nomenclatural confusion could be unravelled, once all the regional problems are solved, by establishing a reliable, phylogenetic hypothesis of Thuidiaceae among other pleurocarpous mosses, the redefinition of groupings and a new classification (Touw 1976 & García-Avila *et al.* 2009).

These taxonomic difficulties result from the fact that the members of Thuidiaceae are morphologically very similar to one another. Many characters are almost indistinguishable and there is much infraspecific variation among the taxa. The differences between species are very small or difficult to observe and sometimes unexpectedly variable (Touw & Falter-Van den Haak 1989). For example, one can find the following variation in plants of the same species: leaf cell ornamentation can be smooth, uni- or pluripapillose; stem branching can be uni- to bipinnate or bi- to tripinnate; paraphyllia branching can be simple to weakly branched; paraphyllia length can vary from short to long and perichaetial margins can be entire or ciliate. The difficulties seem to be worsened by application of characters that are unsuitable and of little value or an imbalance of weight that is put on characters. Consequently there has been continual changing in the scope of the taxa.

1.3 Hypotheses

García-Avila *et al.* (2009) expressed the need for the name Thuidiaceae to be reserved for the 'Thuidioid group' that was recognised by Touw (2001a). This homogeneous group is represented by *Thuidium*, *Thuidiopsis* and *Pelekium* in Africa. García-Avila *et al.*'s recent molecular work to resolve uncertainties in classification of the group was used as hypothesis to test for the validity of generic circumscription in the study area, based mainly on evidence from morphology and DNA.

In this regard we tested whether the re-circumscription of the family, involving the exclusion of some genera (*Abietinella* Müll. Hal., *Haplocladium* (Müll. Hal.) Müll. Hal., *Hylocomiopsis* Cardot) and *Rauiella* Reimers) from African Thuidiaceae, is supported or falsified. It is also hypothesized that a detailed comparative study of morphology and anatomy is

likely to provide consistent characters that can be used to classify the African Thuidiaceae, both at species and generic levels.

In his review of the family, Touw (2001a) realigned the species of *Thuidium* subgenus *Microthuidium*, which led to the transfer of almost all the monoicous species to *Pelekium*. The transfer of *Thuidium involvens* subsp. *thomeanum*, as previously suggested by O'Shea (2006), and consequently the transfer of *T. pseudoinvolvens* also to *Pelekium* are here proposed.

This study will also contribute towards the fourth fascicle of the *Flora of southern Africa (FSA): Bryophyta*, which will include the two genera and four species of the southern African region.

1.4 Objectives

The principal objectives of this study are:

- To discriminate species;
- To classify related species into a group of higher ranking;
- To use morphological and molecular data to test the re-circumscription of the Thuidiaceae in Africa.
- To propose required nomenclatural adjustment;
- To compile a comprehensive taxonomic account of the African Thuidiaceae.

1.5 Layout of thesis

This thesis is composed of seven chapters. The introduction gives an overview of the family, outlines its taxonomic problems, possible solutions and the objectives and expected outcomes of the study. The historic overview (Chapter 2) looks into the history of the Thuidiaceae, from a broader, worldwide view down to local (African) level. It also involves a summary of the previously studied regions, existing classifications and the current nomenclature. The materials and methods section (Chapter 3) includes the geographical scope of the study. It details all the materials and methods used in morphological, molecular and systematic treatments, as well as the terminology used. Following this the re-circumscription of the Thuidiaceae in Africa is introduced in Chapter 4. The results are presented in the form of phylogenetic trees and discussed. Then conclusions are drawn. This is followed, in Chapter 5 by the presentation and

discussion of gametophytic and sporophytic characters that were selected for taxonomic purposes. The taxonomic significance of evidence from geography and ecology is also discussed. Chapter 6 contains the taxonomic treatment of the taxa, beginning with the description of the family, followed by keys to the genera and species. Thereafter there are descriptions of the genera and species. These include additional notes, maps and illustrations for each species. In Chapter 7, there is general discussion of the work done and final conclusions are made. A summary of each chapter is also presented. The dissertation concludes with a general summary, Acknowledgements, short Curriculum Vitae and References.

CHAPTER 2

HISTORIC OVERVIEW OF THE THUIDIACEAE

The detailed historic account of the classification of Thuidiaceae at world level is comprehensively outlined in Buck & Crum (1990) and Touw (2001a). The taxonomy of Thuidiaceae has been revised for most regions of the world with the Asian centre of diversity appearing as the best studied region. Touw (1976) revised seven genera and 22 species for sub-Saharan Africa, which has been very helpful in this revision. The studied regions, the classification of the Thuidiaceae by various authors and the current nomenclature are presented in Tables 2.1, 2.2 and 2.3 respectively.

TABLE 2.1.—Summary of selected literature on Thuidiaceae, outlining some recently studied regions

Region	Author
Sub-Saharan Africa	Touw (1976)
Japan and adjacent areas	Watanabe (1972)
Himalayas	Watanabe (1977)
Australasia and adjacent regions	Touw & Falter-Van den Haak (1989)
Asia	Touw 1993
E. Malaysia – Seram & Ambon	Watanabe & Akiyama (1991)
Malaysia	Touw (1993)
Yunnan	Zeng (1991)
China	Fang & Koponen (2001), Koponen & Touw (2003), Peng-Chen, Crosby & He (1999)
Tropical Asia, W. Pacific & Hawaii	Touw (2001)
Kenya	Chuah-Petiot (2003)
Subantarctic Marion Island	Ochyra, Smith & Gremmen (2003)
N.W. Argentina	Schiavone & Suárez (2007)
Quebec-Labrador	Faubert (2008)

TABLE 2.2.—Summary of how previous authors classified the taxa in Thuidiaceae and selected taxa of closely related families. Currently accepted taxa of African Thuidiaceae (including their synonyms) in *bold italics*.

Author	Family	Subfamily	Groups	Genera
Fleischer (1923)	Thuidiaceae	Heterocladioideae		<i>Heretocladum</i> and <i>Leptopterigynandrum</i>
		Anomodontaceae		<i>Anomodon</i> , <i>Claopodium</i> , <i>Haplocladium</i> , <i>Haplohymenium</i> , <i>Herpetineuron</i> and <i>Miyabea</i>
		Euthuidioideae		<i>Abietinella</i> , <i>Boulaya</i> , <i>Cyrto-hypnum</i> , <i>Lorentzia</i> , <i>Raiiella</i> , <i>Thuidiopsis</i> and <i>Thuidium</i> (subg. <i>Thuidiella</i> & subg. <i>Euthuidium</i>)
		Heloidioideae		<i>Actinothuidium</i> , <i>Helodium</i> , <i>Hylocomiopsis</i> and <i>Tetrastichum</i>
Grout (1928– 1940)	Leskeaceae	Thuidioideae		<i>Claopodium</i> , <i>Helodium</i> , <i>Heterocladium</i> and <i>Thuidium</i>
		Leskeaeae		<i>Leskea</i> , <i>Lindbergia</i> , <i>Pseudoleskea</i> and <i>Pterigynandrum</i>
		Thelieae		<i>Myurella</i> and <i>Thelia</i>
		Anomodontaeae		<i>Anomodon</i> and <i>Herpetineuron</i>
Sim (1926)	Leskeaceae	Thuideae		<i>Thuidium</i> , <i>Haplocladium</i> , <i>Raiiella</i> , <i>Thuidiella</i> and <i>Euthuidium</i>

Author	Family	Subfamily	Groups	Genera
Watanabe (1972)	Thuidiaceae	Thuidioideae		<i>Abietinella</i> , <i>Actinothuidium</i> , <i>Bryonoguchi</i> , <i>Boulaya</i> , <i>Claopodium</i> , <i>Haplocladium</i> , <i>Helodium</i> , <i>Hylocomiopsis</i> , <i>Pelekium</i> , <i>Raiiella</i> and <i>Thuidium</i>
				<i>Anomodon</i> , <i>Haplocladium</i> , <i>Herpetineuron</i> and <i>Miyabea</i>
		Anomodontaceae		<i>Heterocladium</i> and <i>Leptopterygynandrum</i>
		Heterocladiodeae		
Touw (1976)	Thuidiaceae	Thuidioideae	Thuidium subg. <i>Thuidium</i>	<i>Thuidium</i> (dioicous)
			Thuidiella/ <i>Thuidium</i> subg. Microthuidium	<i>Thuidium</i> (monoicous) and <i>Raiiella</i>
Crum & Anderson (1981)	Thuidiaceae			<i>Haplocladium</i> , <i>Helodium</i> , <i>Heterocladium</i> , <i>Myurella</i> , <i>Pseudoleskea</i> , <i>Pseudoleskeela</i> and <i>Thuidium</i>
Walther (1983)	Thuidiaceae	Anomodontoideae		<i>Anomodon</i> , <i>Herpetineuron</i> and <i>Miyabea</i>
		Thuidioideae		<i>Abietinella</i> , <i>Boulaya</i> , <i>Claopodium</i> , <i>Cyrto-</i> <i>hypnum</i> , <i>Haplocladium</i> , <i>Lorentzia</i> , <i>Raiiella</i> and <i>Thuidium</i>
		Helodioideae		<i>Actinothuidium</i> , <i>Bryonoguchia</i> , <i>Helodium</i> and <i>Hylocomiopsis</i>

Author	Family	Subfamily	Groups	Genera
Vitt (1984)	Leskeaceae	Euthuidioideae Heloidioideae		<i>Hylocomiopsis</i>
	Thuidiaceae			<i>Abietinella, Actinothuidium, Bryonoguchia, Claopodium, Cyrtohypnum, Haplocladium, Helodium, Lorentzia, Pseudoleskeela, Pseudoleskeopsis, Raiiella</i> and <i>Thuidium</i>
Buck & Vitt (1986)	Thuidiaceae	Euthuidioideae Heloidioideae		<i>Thuidium, Thuidiopsis</i> and <i>Pelekium</i>
Touw & Falter-van den Haak (1989)	Thuidiaceae			<i>Thuidium</i>
Buck & Crum (1990)	Thuidiaceae	Thuidioideae Cyrtohynoideae Hylocomiaceae		<i>Thuidium, Abietinella, Bryonoguchia</i> and <i>Thuidiopsis</i> <i>Cyrto-hypnum, Lorentzia, Boulaya</i> and <i>Raiiella</i> <i>Hylocomiopsis</i> and <i>Actinothuidium</i>
	Helodiaceae			<i>Helodium, Bryohaplocladium, Claopodium</i> , etc.
	Leskeaceae			<i>Claopodium, Haplocladium, Pseudoleskela, Pseudoleskeopsis</i> and <i>Leptopterigynandrum</i>
	Pterigynandraceae			<i>Pterigynandrum, Habrodon</i> and <i>Iwatsukiella</i>
Touw (2001a) & García-Avila <i>et al.</i> (2009)	Thuidiaceae		Thuidioid Heloidioid	<i>Thuidium, Pelekium, Thuidiopsis, Aequatoriella, Bryochenea, Indotheidium</i> and <i>Orthothuidium</i> <i>Actinothuidium, Hylocomiopsis, Helodium, Bryonoguchia</i> and

Author	Family	Subfamily	Groups	Genera
				<i>Echinophyllum</i>
			Combined	<i>Boulaya</i> , <i>Abietinella</i> , <i>Haplocladium</i> and <i>Raiiella</i>
Phephu (present study)	Thuidiaceae			<i>Thuidium</i>, <i>Pelekium</i> and <i>Thuidiopsis</i>
	Leskeaceae			<i>Abietinella</i> , <i>Haplocladium</i> , <i>Raiiella</i> and <i>Hylocomiopsis</i>

TABLE 2.3.— Summary of the nomenclature of the African Thuidiaceae taxa showing the date, taxa, publication, type collector and number, herbaria and type country of the original names and synonyms.

Taxa	Date of publication	Original Publication	Type collector & number	Herbaria	Type country	Current identity
<i>Thuidium aculeoserratum</i> Renauld & Cardot	1894	Renauld, F. & J. Cardot. 1894. <i>Bull. Soc. Roy. Bot. Belgique</i> 32 (1): 101–121.	Besson 334	PC holotype, BR, FH	Madagascar	<i>Thuidium aculeoserratum</i> Renauld & Cardot
<i>Thuidium angolense</i> Welw. & Duby	1871	Duby, J. -E. 1871. <i>Mém. Soc. Phys. Hist. Nat. Genève</i> 21: 425–444.	Welwitsch 23	G holotype, BM, PC	Angola	<i>Pelekium ramusculosum</i> (Mitt.) A. Touw
<i>Leskea assimilis</i> Mitt.	1859	Mitten, W. 1859. <i>J. Proc. Linn. Soc. Bot. Suppl.</i> 1: 133.	Strachey & Winterbotto m 92 = 74B	NY, BM isotypes, H	Himalayas	<i>Thuidium assimile</i> (Mitt.) A. Jaeger
<i>Thuidium assimile</i> (Mitt.) A. Jaeger	1878	Jaeger, A. & Sauerbeck. 1878. <i>Ber. Thätigk. St. Gallischen Naturwiss. Ges.</i> 1876/77: 211– 454.				
<i>Thuidium borbonicum</i> Besch.	1880	Bescherelle, E. 1880A. <i>Ann. Sci. Nat. Bot. sér.</i> 6, 10: 233–332.	de l'Isle 175	BM holotype, PC	Réunion	<i>Pelekium versicolor</i> (Müll. Hal.) A. Touw
<i>Thuidium borbonicum</i> fo. <i>breviseta</i> Thér.	1925	Thériot, M.H.I. 1922. <i>Recueil. Publ. Soc. Havraise Études Diverses</i> 1925: 25.	Perrier de la Bathie s.n.	PC?	Madagascar	
<i>Thuidium byssoideum</i> Besch.	1885	Bescherelle, E. 1885. <i>Ann. Sci. Nat. Bot. sér.</i> 7, 2: 82–98.	Marie s.n.	BM isotype!	Mayotte	<i>Pelekium investe</i> (Mitt.) Touw
<i>Cyrto-hypnum byssoideum</i> (Besch.) W.R. Buck & H.A. Crum	1990	Buck, W.R. & Crum, H.A. 1990. <i>Contr. Univ. Michigan Herb.</i> 17: 55–69.	Marie 56	BM holotype, PC	Mayotte	<i>Pelekium investe</i> (Mitt.) Touw

Taxa	Date of publication	Original Publication	Type collector & number	Herbaria	Type country	Current identity
<i>Thuidium chenagonii</i> Müll. Hal. ex Renauld & Cardot	1895	Renauld, F. & Cardot, J. 1895. <i>Bull. Soc. Roy. Bot. Belgique</i> 33 (2): 129.	Croll s.n. ex parte	PC holotype, FI, G, H	Madagacsar	<i>Pelekium chenagonii</i> (Müll. Hal. ex Renauld & Cardot) Touw
<i>Thuidium chenagonii</i> var. <i>campyloneuron</i> Renauld & Paris	1900	Paris, E.G. 1900. <i>Rev. Bryol.</i> 27: 89.				
<i>Cyrto-hypnum chenagonii</i> (Müll. Hal. ex Renauld & Cardot) W.R. Buck & H.A. Crum	1990	Buck, W.R. & Crum, H.A. 1990. <i>Contr. Univ. Michigan Herb.</i> 17: 65.				
<i>Pelekium chenagonii</i> (Müll. Hal. ex Renauld & Cardot) A. Touw	2001	Touw, A. 2001. <i>J. Hattori Bot. Lab.</i> 90: 167–209.				
<i>Thuidium chenagonii</i> fo. <i>laxifolia</i> Cardot	1915	Cardot, J. 1898–1915. In Grandidier, A. & Cardot, J. <i>Hist. Phys. Madagascar Mouses</i> 39: 1–562.	Drouhard s.n.	PC holotype, Bizot	Madagascar	<i>Pelekium varians</i> (Welw. & Duby) A. Touw
<i>Hypnum chloropsis</i> Müll. Hal.	1886	Müller, C. 1886. <i>Flora</i> 69: 499–525.	Moenkemeyer 6	B holotype, H, JE, S-PA	Gabon	<i>Pelekium gratum</i> (P. Beauv.) A. Touw
<i>Thuidium chloropsis</i> (Müll. Hal.) Paris	1898	Paris, E. G. 1894–1898. <i>Index Bryol.</i> 1278.				
<i>Leskea contortula</i> Mitt.	1859	Mitten, W. 1859. <i>J. Proc. Linn. Soc. Bot. Suppl.</i> 2: 1–171.	Hooker 1124	NY holotype, BM isotype!	Himalayas	<i>Pelekium contortulum</i> (Mitt.) A. Touw

Taxa	Date of publication	Original Publication	Type collector & number	Herbaria	Type country	Current identity
<i>Thuidium contortulum</i> (Mitt.) A. Jaeger	1878	Jaeger, A. & Sauerbeck. 1878. <i>Ber. Thätigk. St. Gallischen Naturwiss. Ges.</i> 1876–77: 211–454.		FH isotype!		
<i>Pelekium contortulum</i> (Mitt.) A. Touw	2001	Touw, A. 2001. <i>J. Hattori Bot. Lab.</i> 90: 167–209.				
<i>Hypnum ferricola</i> Müll. Hal.	1875	Müll. Hal. 1875. <i>Linnaea</i> 39:325–474.	Schweinfurth, s.n.	BM lecto, NY	Sudan	<i>Pelekium gratum</i> (P. Beauv.) A. Touw
<i>Thuidium ferricola</i> (Müll. Hal.) A. Jaeger	1878	Jaeger, A. & Sauerbeck. 1878. <i>Ber. Thätigk. Gallischen Naturwiss. Ges.</i> 1876/77: 211–454.				
<i>Thuidiopsis furfurosa</i> var <i>sparsa</i> (Hook. f. & Wilson) Wijk & Margad.	1961	Wijk, R. v. d. & W. D. 1961. <i>Taxon</i> 10: 26.	Bolton s.n	BM holotype!, L isotype, NY	New Zealand	<i>Thuidiopsis sparsa</i> (Hook. f. & Wilson) Broth.
<i>Thuidium furfurosum</i> var <i>sparsum</i> (Hook. f. & Wilson) Sainsbury	1952	Sainsbury, G.O.K. 1952. <i>Rev. Bryol. Lichénol.</i> 21: 223.				
<i>Hypnum gratum</i> P. Beauv.	1805	Palisot de Beauvois, A. M. F. J. 1805. <i>Prodr. Aethéogam.</i> : 64.	Palisotypet de Beauvois, s.n.	G holotype, H isotype BM isotype!	Nigeria	<i>Pelekium gratum</i> (P. Beauv.) A. Touw
<i>Thuidium gratum</i> (P. Beauv.) A. Jaeger	1878	Jaeger, A. 1878. <i>Ber. Thätigk. St. Gallischen Naturwiss. Ges.</i> 1876/77: 211–454.				

Taxa	Date of publication	Original Publication	Type collector & number	Herbaria	Type country	Current identity
<i>Cyrto-hypnum gratum</i> (P. Beauv.) W.R. Buck & H.A. Crum	1990	Buck, W.R. & Crum, H. A. 1990. <i>Contrib. Univ. Michigan Herb.</i> 7: 65.				
<i>Pelekium gratum</i> (P. Beauv.) A. Touw	2001	Touw, A. 2001. <i>J. Hattori Bot. Lab.</i> 90: 167–209.				
<i>Thuidium gratum</i> subsp. <i>gratum</i> (P. Beauv.) A. Touw	1976	Touw, A. 1976. <i>Lindbergia</i> 3: 135–195.				
<i>Thuidium gratum</i> subsp. <i>subscissum</i> (Müll. Hal. ex Besch.) A. Touw	1976	Touw, A. 1976. <i>Lindbergia</i> 3: 135–195.	Boivin s.n.	PC lecto	Nosy Bé	<i>Pelekium gratum</i> (P. Beauv.) A. Touw
<i>Cyrto-hypnum gratum</i> subsp. <i>subscissum</i> (Müll. Hal. ex Besch.) W.R. Buck & H.A. Crum	1990	Buck, W.R. & H.A. Crum. 1990. <i>Contr. Univ. Michigan Herb.</i> 17: 65.				
<i>Thuidium integricalyx</i> Müll. Hal.	1895	Müller, C. 1895. In Renauld, F.F.G. <i>Bull. Soc. Roy. Bot. Belgique.</i> 33 (2): 129.	Saurez, Chenagon s.n.	PC holotype, BM, BR, MAN CH, W	Madagascar	<i>Pelekium chenagonii</i> (Müll. Hal. ex Renauld & Cardot) A. Touw
<i>Thuidium intricatum</i> A. Jaeger	1878	Jaeger, A. 1878. <i>Ber. Thätigk.St. Gallischen Naturwiss. Ges.</i> 1876–77: 211–454.	Mann s.n.	NY holotype, BM isotype!, H, K	Cameroon	<i>Pelekium intricatum</i> (A.Jaeger) Touw
<i>Pelekium intricatum</i> (A. Jaeger) A. Touw	2001	Touw, A. 2001. <i>J. Hattori Bot. Lab.</i> 90: 167–209.				

Taxa	Date of publication	Original Publication	Type collector & number	Herbaria	Type country	Current identity
<i>Hypnum investe</i> Mitt.	1856	Mitten, W. 1856. <i>Hooker's J. Bot. & Kew Gard. Misc.</i> 8: 353–357.	Parish 15	NY holotype, BM isotype	Moulmein	<i>Pelekium investe</i> (Mitt.) Touw
<i>Leskea investis</i> (Mitt.) Mitt.	1859	Mitten, W. 1859. <i>J. Proc. Linn. Soc. Bot. Suppl.</i> 1: 135.				
<i>Thuidium investe</i> (Mitt.) Jaeg.	1878	Jaeger, A. & F. Sauerbeck. 1878. <i>Ber. Thätigk. Gallischen Naturwiss. Ges.</i> 1876–77: 211–454.				
<i>Cyrto-hypnum investe</i> (Mitt.) W.R. Buck & H.A. Crum	1990	Buck, W.R. & Crum, H.A. 1990. <i>Contrib. Univ. Michigan Herb.</i> 17: 55–69.				
<i>Pelekium investe</i> (Mitt.) A. Touw	2001	Touw, A. 2001. <i>J. Hattori Bot. Lab.</i> 90: 167–209.				
<i>Thuidium involvens</i> var. <i>thomeanum</i> Broth.	1890	Brotherus, V.F. 1890. <i>Bol. Soc. Brot.</i> 8: 173–190.	Quintus 133a	H holotype, NY	Sao Tomé	<i>Pelekium thomeanum</i> (Broth.) Phephu
<i>Thuidium involvens</i> subsp. <i>thomeanum</i> (Broth.) A. Touw	1976	Touw, A. 1976. <i>Lindbergia</i> 3: 135–195.	Quintus s.n.			
<i>Cyrto-hypnum involvens</i> subsp. <i>thomeanum</i> (Broth.) W.R. Buck & H.A. Crum	1990	Buck, W.R. & Crum, H.A. 1990. <i>Contr. Univ. Michigan Herb.</i> 17: 65.				
<i>Thuidium konkourae</i> Paris & Broth.	1907	Paris, E.G. 1907. <i>Rev. Bryol.</i> 34: 93–99.	Pobegiun s.n.	PC holotype, H	Guinea	<i>Pelekium varians</i> (Welw. & Duby) A. Touw

Taxa	Date of publication	Original Publication	Type collector & number	Herbaria	Type country	Current identity
<i>Thuidium laevipes</i> Mitt.	1886	Mitten, W. 1886. <i>J. Linn. Soc. Bot.</i> 22: 298–329.	Hannington s.n.	Unknown	Tanzania	<i>Pelekium varians</i> (Welw. & Duby) A. Touw
<i>Hypnum mascarenicum</i> Müll. Hal.	1851	Müller, C. 1851. <i>Syn. Musc. Frond.</i> 2: 485.	Bory de Saint-Vincent s.n.	B	Réunion	<i>Thuidium tamariscinum</i> (Hedw.) Schimp.
<i>Thuidium mascarenicum</i> (Müll. Hal.) A. Jaeger	1878	Jaeger, A., & Sauerbeck, F. 1878. <i>Ber. Thätigk. St. Gallischen Naturwiss. Ges.</i> 1876–77: 211–454.				
<i>Thuidium matarumense</i> Besch.	1880	Bescherelle, E. 1880. <i>Ann. Sci. Nat. Bot. sér. 6, 10:</i> 233–332.	Valentin s.n.	BM lectotype!, PC isotype	Réunion	<i>Thuidium assimile</i> (Mitt.) A. Jaeger
<i>Leskea minuscula</i> Mitt.	1859	Mitten, W. 1859. <i>J. Proc. Linn. Soc. Bot. Suppl.</i> 1: 133.	Hooker & Thomson 1092	BM, NY. lectotype	Khasia	<i>Pelekium minusculum</i> (Mitt.) A. Touw
			Hooker & Thomson 1071	NY lecto, BM isotype!		
<i>Thuidium minusculum</i> (Mitt.) A. Jaeger	1878	Jaeger, A., & F. Sauerbeck. 1878. <i>Ber. Thätigk. St. Gallischen Naturwiss. Ges.</i> 1876–77: 211–454.	Hooker & Thomson 1072a	BM syntype!		

Taxa	Date of publication	Original Publication	Type collector & number	Herbaria	Type country	Current identity
<i>Cyrto-hypnum minusculum</i> (Mitt.) W.R. Buck & H.A. Crum	1990	Buck, W.R. & Crum, H.A. 1990. <i>Contrib. Univ. Michigan Herb.</i> 17: 55–69.				
<i>Pelekium minusculum</i> (Mitt.) A. Touw	2001	Touw, A. 2001. <i>J. Hattori Bot. Lab.</i> 90: 167–209.				
<i>Cyrto-hypnum montei</i> Hedenäs	1992	Hedenäs, L. 1992. <i>Bryophyt. Biblioth.</i> 44: 71. f. 19.	Barreto s.n.	MADS holotype, not seen	MADEIRA	<i>Thuidiopsis sparsa</i> (Hook.f. & Wilson) Broth.
<i>Hypnum nabambissense</i> Müll. Hal.	1875	Müller, C. 1875. <i>Linnaea</i> 39: 325–474.	Schweinfurth, s.n.	B holotype, BM lectotype & isotype!, K, NY	Sudan	<i>Pelekium gratum</i> (P. Beauv.) A. Touw
<i>Thuidium nabambissense</i> (Müll. Hal.) A. Jaeger	1878	Jaeger, A., & F. Sauerbeck. 1878. <i>Ber. Thätigk. St. Gallischen Naturwiss. Ges.</i> 1876–77: 211–454.				
<i>Leskea nigeriana</i> Mitt.	1860	Mitten, W. 1860. <i>Trans. Linn. Soc. London</i> 23: 51–58.	Vogel s.n.	NY holotype, BM, H, K	Nigeria	<i>Pelekium involvens</i> (Broth.) Phephu
<i>Thuidium nigerianum</i> (Mitt.) Paris	1898	Paris, E. G. 1894–1898. <i>Index Bryol. Suppl.</i> 1286.				
<i>Thuidium pallidisetum</i> Dixon	1918	Dixon, H.N. 1918. <i>Smithsonian Misc. Collect</i> 69, 8: 1–10.	Dummer 719	US, BM holotype!, BOL, PRE cotype!	Uganda	<i>Pelekium chenagonii</i> (Müll. Hal. ex Renauld & Cardot) A. Touw
<i>Thuidium perbyssaceum</i> Müll. Hal. ex Broth.	1897	Müller, C. 1897. <i>Bot. Jahrb. Syst.</i> 24: 283.	Dusén 267	H lectotype, BM isotype!, BOL, FI, G, K, L, NY	Cameroon	<i>Pelekium investe</i> (Mitt.) A. Touw

Taxa	Date of publication	Original Publication	Type collector & number	Herbaria	Type country	Current identity
<i>Hypnum promontorii</i> Müll. Hal.	1899	Müller, C. 1899. <i>Hedwigia</i> 38: 52–155.	Ecklon & Zeyher s.n.	B holotype, G lectotype, H	South Africa	<i>Thuidium assimile</i> (Mitt.) A. Jaeger
<i>Thuidium promontorii</i> (Müll. Hal.) Paris	1900	Paris, E.G. 1900. <i>Index Bryol. Suppl.</i> 321.				
<i>Hypnum pseudoinvolvens</i> Müll. Hal.	1876	Müller, C. 1876. <i>Linnaea</i> 40: 225–300.	Hildebrandt 1835	G lectotype, BM isoelectotype!, K, NY B holotype lost G lecto, BM, K, NY	Johanna	<i>Pelekium pseudoinvolvens</i> (Müll. Hal.) Phephu
<i>Thuidium pseudoinvolvens</i> (Müll. Hal.) A. Jaeger	1878	Jaeger, A., & Sauerbeck, F. 1878. <i>Ber. Thätigk. St. Gallischen Naturwiss. Ges.</i> 1876–77: 211–454.				
<i>Thuidium pycnangiellum</i> Müll. Hal. ex Broth.	1897	Müller, C. ex Brotherus, V.F. 1897. <i>Bot. Jahrb. Syst.</i> 24: 232–347.	Dusén 225 ex parte	H, FI, NY, PC, S-PA, UPS, W, G, BM lectotype! G, NY, S-PA	Cameroon, Buea Rumpi Mts	<i>Pelekium chenagonii</i> (Müll. Hal. ex Renauld & Cardot) A. Touw
<i>Leskea ramusculosa</i> Mitt.	1863	Mitten, W. 1863. <i>J. Linn. Soc. Bot.</i> 7: 147–169.	Mann s.n.	NY holotype, K, BM isotype!	Fernando Póo	<i>Pelekium ramusculosum</i> (Mitt.) A. Touw
<i>Thuidium ramusculosum</i> (Mitt.) A. Jaeger	1878	Jaeger, A., & F. Sauerbeck. 1878. <i>Ber. Thätigk. St. Gallischen Naturwiss. Ges.</i> 1876–77: 211–454.				

Taxa	Date of publication	Original Publication	Type collector & number	Herbaria	Type country	Current identity
<i>Cyrto-hypnum ramusculosum</i> (Mitt.) W.R. Buck & H.A. Crum	1990	Buck, W.R. & Crum, H. A. 1990. <i>Contrib. Univ. Michigan Herb.</i> 17: 55–69.				<i>Pelekium ramusculosum</i> (Mitt.) A. Touw
<i>Pelekium ramusculosum</i> (Mitt.) A. Touw	2001	Touw, A. 2001. <i>J. Hattori Bot. Lab.</i> 90: 167–209.				
<i>Hypnum sigmatella</i> Müll. Hal.	1875	Müller, C. 1875. <i>Linnaea</i> 39: 325–474.	Schweinfurt h s.n.	NY lectotype	Sudan	<i>Pelekium varians</i> (Welw. & Duby) A. Touw
<i>Thuidium sigmatella</i> (Müll. Hal.) A. Jaeger	1878	Jaeger, A. 1878. <i>Ber. Thätigk. St. Gallischen Naturwiss. Ges.</i> 1876–77: 211–454.				
<i>Hypnum sparsum</i> Hook. f. & Wilson	1854	Hooker, J.D. & Wilson, W.M. 1854. <i>Flor. Nov.-Zel.</i> 2: 190. 89 f. 5.	Botton s.n.	BM holotype, L isotype, NY	New Zealand	<i>Thuidiopsis sparsa</i> (Hook. f. & Wilson) Broth.
<i>Thuidium sparsum</i> (Hook. F. & Wilson) A. Jaeger	1870	Jaeger, A. 1870. 1878. <i>Ber. Thätigk. St. Gallischen Naturwiss. Ges.</i> 1876–77: 211–454.				
<i>Thuidiopsis sparsa</i> (Hook. f. & Wilson) Broth.	1925	Brotherus, V. F. 1925. <i>Nat. Pflanzenfam.</i> (ed 2). 11: 323.				
<i>Thuidium spurio-involvens</i> Broth. & Paris, Fouta	1908	Paris, E.G. 1908. <i>Rev. Bryol.</i> 35: 4	<i>Pobeguin s.n.</i>	H holotype, PC, S-PA	Guinea	
<i>Cyrto-hypnum squarrosulum</i> (Renaud & Cardot) W.R. Buck & H.A. Crum	1990	Buck, W.R. & Crum, H.A. 1990. <i>Contrib. Univ. Michigan Herb.</i> 17: 67.	Stevens 159 Stevens 160	PC lecto, S isotype PC lectotype	Sikkim	<i>Pelekium minusculum</i> (Mitt.) A. Touw

Taxa	Date of publication	Original Publication	Type collector & number	Herbaria	Type country	Current identity
<i>Thuidium strangulatum</i> P. de la Varde	1939	Potier de la Varde, R.A.L. 1939. <i>Rev. Bryol. Lichénol.</i> 11: 165–186.	Eckendorf s.n.	PC holotype, BR	Central African Republic	<i>Pelekium investe</i> (Mitt.) Touw
<i>Leskea subfalcata</i> Mitt.	1860	Mitten, W. 1860. <i>Trans. Linn. Soc. London</i> 23: 51–58.	Barter 1424	NY holotype, K, BM isotype!	Nigeria	<i>Pelekium involvens</i> (Broth.) Phephu
<i>Thuidium subfalcatum</i> (Mitt.) Paris	1898	Paris, E. G. 1894–1898. <i>Index Bryol.</i> 1292.				
<i>Thuidium sublaevipes</i> Dixon	1920	Dixon, H.N. 1920. <i>Trans. R. Soc. South Africa</i> 8: 178–224.	Wager 295 Henderson 358	BM lectotype!, PRE isotype! ! BM syntype!, H, PC	South Africa	<i>Pelekium ramusculosum</i> (Mitt.) A. Touw
<i>Thuidium subserratum</i> Renauld & Cardot	1894	Renauld, F.F.G & Cardot, J. 1894. <i>Bull. Soc. Roy. Bot. Belgique</i> 32(1): 110.	Humblot s.n.	PC holotype, BR, FH, FI, NY, S-PA	Grande Comore	<i>Thuidium assimile</i> (Mitt.) A. Jaeger
<i>Thuidium subscissum</i> Müll. Hal. ex Besch.	1880	Müller, C. In Bescherelle, E. 1880. <i>Ann. Sci. Nat. Bot. sér.</i> 6, 10: 233–332.	Boivin s.n. Marie s.n.	PC lectotype BM, FI, PC	Nosy Bé	<i>Pelekium gratum</i> (P. Beauv.) A. Touw
<i>Hypnum tamariscellum</i> Müll. Hal.	1854	Müller, C. 1854. <i>Bot. Zeitung (Berlin)</i> 12: 573.	Schmid s.n.	JE lectotype	India Nilgiris	<i>Pelekium versicolor</i> (Müll. Hal.) A. Touw
<i>Thuidium tamariscellum</i> (Müll. Hal.) Bosch & Sande Lac.	1865	Bosch, R & Sand Lacoste, C. 1865. <i>Bryol. Jav.</i> II: 20				

Taxa	Date of publication	Original Publication	Type collector & number	Herbaria	Type country	Current identity
<i>Hypnum tamariscinum</i> Hedw.	1801	Hedwig, J. 1801. <i>Sp. Musc. Frond.</i> 261–262, pl. 67, f. 1–5.	Unknown		European	<i>Thuidium tamariscinum</i> (Hedw.) Schimp.
<i>Thuidium tamariscinum</i> (Hedw.) Schimp.	1852	Schimper, W.P. 1852. <i>Bryol. Eur.</i> 5 (fasc. 49–51 Mon. 7. 2, 3.).	Balbo 85	BM!	Tanzania	<i>Pelekium ramusculosum</i> (Mitt.) A. Touw
<i>Thuidium tenuisetum</i> Renauld & Cardot	1905	Renauld, F.F.G. & Cardot. J. 1905. <i>Bull. Soc. Roy. Bot. Belgique</i> 41 (1): 7–122.	Gillet s.n.	PC holotype, S-PA	DRC	<i>Pelekium varians</i> (Welw. & Duby) A. Touw
<i>Thuidium tenuissimum</i> Welw. & Duby	1871	Duby, J. -E. 1871. <i>Mém. Soc. Phys. Genève</i> 21: 425–444.	Welwitsch 51	G holotype, BM isotype!, L, PC	Angola	<i>Pelekium investe</i> (Mitt.) A. Touw
<i>Cyrto-hypnum tenuissimum</i> (Welw. & Duby) W.R. Buck & H.A. Crum	1990	Buck, W.R. & Crum, H. A. 1990. <i>Contrib. Univ. Michigan Herb.</i> 17: 55–69.				
<i>Thuidium torrentium</i> Müll. Hal.	1899	Müller, C. 1899. <i>Hedwigia</i> 38: 52–155.	Mac Owen s.n.	Not seen	South Africa	<i>Pelekium versicolor</i> (Müll. Hal.) A. Touw
<i>Thuidium trachynotum</i> Renauld & Paris	1902	Renauld, F.F.G. & Paris, E.G. 1902. <i>Rev. Bryol.</i> 29: 76–86.	Galinon s.n.	PC holotype, FL, L, S-PA	Madagascar	<i>Pelekium ramusculosum</i> (Mitt.) A. Touw
<i>Thuidium varians</i> Welw. & Duby	1871	Welwitsch, F.M.J. & Duby, J. -E. 1871. <i>Mém. Soc. Phys. Genève</i> 21: 425–444.	Welwitsch 101	G holotype, BM isotype!, H	Angola	<i>Pelekium varians</i> (Welw. & Duby) A. Touw

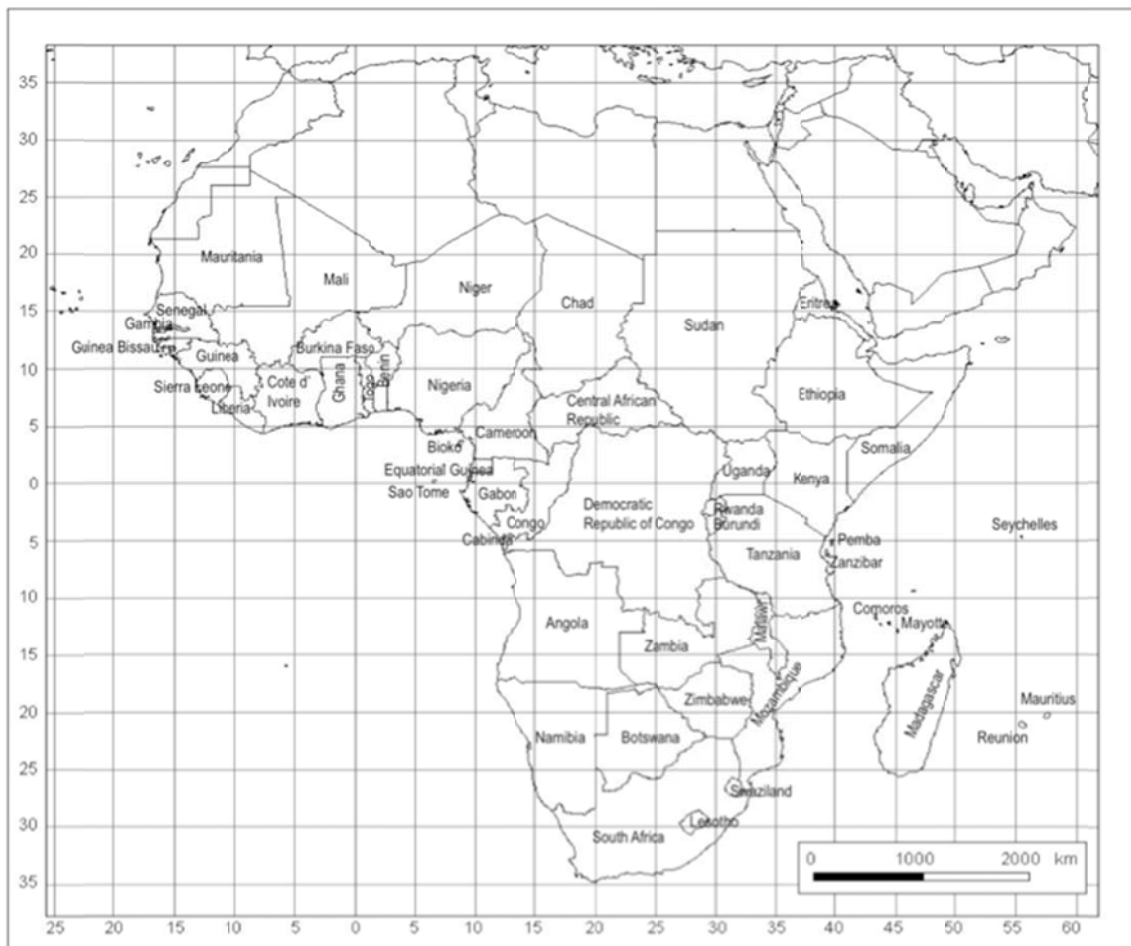
Taxa	Date of publication	Original Publication	Type collector & number	Herbaria	Type country	Current identity
<i>Cyrto-hypnum varians</i> (Welw. & Duby) W.R. Buck & H.A. Crum	1990	Buck, W.R. & Crum, H.A. 1990. <i>Contrib. Univ. Michigan Herb.</i> 17: 55–69.				<i>Pelekium varians</i> (Welw. & Duby) A. Touw
<i>Pelekium varians</i> (Welw. & Duby) A. Touw	2001	Touw, A. 2001. <i>J. Hattori Bot. Lab.</i> 90: 167–209.				
<i>Pelekium velatum</i> Mitt.	1868	Mitten, W. 1868. <i>J. Linn. Soc. Bot.</i> 10: 166–195.	Powell 14	NY lectotype, BM isotype, EGR, FH, H, L, MO, S	Samoa	<i>Pelekium velatum</i> Mitt.
<i>Lorentzia velata</i> (Mitt) W.R. Buck & H.A. Crum	1990	Buck, W.R. & Crum, H.A. 1990. <i>Contrib. Univ. Michigan Herb.</i> 17: 69.	Moley 15	NY lectotype	Borneo	
<i>Hypnum versicolor</i> Hornsch. ex Müll. Hal.	1851	Hornschuch, C. F. 1851. <i>Syn. Musc. Frond.</i> 2: 494.	Mundt & Marie s.n. Ecklon 1832	B, S-PA, H BM syntype!, H, S-PA	South Africa	<i>Pelekium versicolor</i> (Müll. Hal.) A. Touw
<i>Thuidium versicolor</i> (Müll. Hal.) A. Jaeger	1878	Jaeger, A. 1878. <i>Ber. Thätigk. Gall. Naturwiss. Ges.</i> 1876–77: 211–454.				<i>Pelekium versicolor</i> (Müll. Hal.) A. Touw
<i>Pelekium versicolor</i> (Müll. Hal.) A. Touw	2001	Touw, A. 2001. <i>J. Hattori Bot. Lab.</i> 90: 167–209.				

CHAPTER 3

MATERIALS AND METHODS

3.1 Geographical scope

Thuidiaceae mosses occur in temperate and tropical regions of the world. The study area for the present taxonomic revision covers Africa, omitting the northernmost countries where these fern mosses are not found. It also includes the East African Islands, Madagascar, Pemba, Zanzibar, Seychelles Comoros, Mayotte, Mauritius and Réunion. The Thuidiaceae taxa known to occur in the study area are considered in this thesis. The study area is presented in Map 3.1.



MAP 3.1.— Map of Africa and the East African Islands. Study area reflected by countries for which names are supplied.

3.2 Materials

This study was conducted at the Pretoria National Herbarium (PRE) and the University of Pretoria. The specimens examined were obtained from BM, EGR, FH, G, L, NY, PRE and TNS (abbreviation of herbaria according to Holmgren *et al.* 1990). Numerous specimens of members of the family occurring outside Africa were also examined, only for comparison of regional forms. I was able to examine type material of 13 species; the two that I did not see had been seen by Touw (1976), whose taxonomic judgement has been accepted. I was unable to access the type material of *Pelekium velatum* Mitt. but this species is confirmed to be growing in Africa and is very distinct among other *Pelekium* species. The material used in this study is cited at the end of each taxon description. It is presented as voucher name and number, as they appear on specimen labels, and listed under the country of origin.

The various images of morphology and anatomy were taken with a microscope camera, using an ACT-1 Version 2 programme at the University of Pretoria and a Leica DC150 digital camera at PRE. The photos were edited using Corel Photo-Paint X4 and Microsoft Office Picture Manager 2007. A Scanning Electron Microscope (SEM) was used to study stem, leaf and spore surfaces. The SEM model used was Joel JSM – 840 while the software programme used was Orion 6.60.4, both housed at the University of Pretoria.

3.3 Methods

3.3.1 Morphological studies

The specimens were examined in dry and moistened conditions for morphology using a Bausch & Lomb light microscope. Anatomical examination was done under moist condition using a Nikon Labophot compound microscope. Slides were prepared using standard bryophyte preparation methods employing Hoyer's Mounting Medium. Attempts were made to hydrate the material to see if the SEM images would show the ornamentation better. Material was hydrated by soaking in absolute alcohol for five minutes, then in water overnight. The fixative was prepared by mixing 1.5 ml 50% pure glutaraldehyde, 15 ml of 0.15 M NaPO₄ buffer and up to 30 ml double-distilled water, enough to cover the material. Two ml of the fixative was added to each sample and left for 15 minutes, then it was sucked out. Two ml of a mixture of 50% buffer and 50% double-distilled water was added to each sample. The samples were left for 15 minutes. This was repeated three times. The material was then dehydrated by soaking for 15 minutes in

each of a series of alcohol dilutions: 30%, 50%, 70%, and 3 times in absolute alcohol. However, the hydration of the material did not show better surface ornamentation.

Microscopic examination remained necessary for all the material because of character overlapping and variability. Only a few African species can be identified to species level by naked eye, e.g. *Thuidium assimille* (Mitt.) A. Jaeger, *P. chenagonii* (Müll. Hal. ex Renauld. & Cardot.) A. Touw and *P. varians* (Welw. & Duby) A. Touw. A multi-character analysis was therefore used to describe the taxa. The grouping of taxa here is based on similarities of the taxonomic characters. The descriptions are in the format of the *Flora of southern Africa (FSA): Bryophyta* and the references follow the style of *Bothalia*.

All measurements were taken three times and the average recorded. Plant size was measured in millimetres (mm) and microscopic characters in micrometres (μm). Angular shape includes rhombic and hexagonal. The description of the costa ending below, at or above the ‘apex’ refers to the apical tip of the leaf. Stem and branch leaf descriptions are based on fully grown leaves taken from about half way up the stem or branch. ‘Median leaf cells’ refer to those at about 1/3 of the leaf length from the leaf apex. ‘Laminal cell measurements’ relate to the cell wall only. The description of ‘perichaetial leaves’ is based on only fully grown inner leaves.

Distinction of ‘paraphyllia’ and ‘pseudoparaphyllia’ is as understood by Norris (*pers comm.* 2010), i.e. the paraphyllia are scattered all over and cover the stem surface, whereas the pseudoparaphyllia are associated with the bud. Both may be filamentous (filiform) or foliose. Although the pseudoparaphyllia are often included as a diagnostic character of this family by some authors, in this study only the paraphyllia, found scattered on the stem will be considered. Consequently the descriptions in this study will focus only on the uniseriate, filiform paraphyllia. The pluriseriate, foliose ones are excluded as they seem to be almost uniform throughout the family. The number and length of cells of paraphyllia is relative to the total length of paraphyllia where longer paraphyllia have a larger number of cells or longer cells and vice versa.

Stem leaves have been given priority in the descriptions, rather than branch leaves, because features of the latter are similar for most of the species, i.e. there is no significant difference between species, unless otherwise stated. Morphology of distal costa and axillary hairs has been treated with low priority because no significant features were observed and the numbers of axillary hair cells are never stable for one species. Description of axillary hair is

based on my own observations. Where the material was too old to observe these structures, the description is taken from and cites to reliable literature. Unless smooth, ornamentation of the leaf cells is as understood by Touw & Falter-Van den Haak (1989). They stated that all cells are mamillate and bear either one papillum (on top of the mamillae in middle or apical part) or more papillae (scattered over the mamillae). Therefore morphology of the papillae will be given priority over that of the mamillae. The sexual state for most species was easily obtained by observation. This information rarely had to be found in reliable literature or non-African material. Ecological data (habitat, substrate and altitude) was obtained from specimen labels and literature.

3.3.2 Ancestral character state reconstruction

This chapter is based on molecular work done by García-Avila *et al.* (2009). In an attempt to resolve uncertainties in classification of the group and re-circumscribe the African Thuidiaceae, morphological and anatomical characters of selected Thuidiaceae and closely related families were studied and reconstructed onto her phylogenetic trees, using parsimony. Character optimization was done by polarizing 40 morphological characters using the Mesquite program. The relationships of the African species of *Haplocladium*, *Abietinella* and *Rauiella* with other members of the Thuidiaceae were investigated. The phylogeny trees of Thuidiaceae s.l. and closely related families in Figures 4.1 to 4.9 were adapted from García-Avila *et al.* (2009). The black, white and grey shadings of clades represent the character states and apply only to the optimization trees in Figure 4.5 to Figure 4.9. The purple and green shadings of clades in all the trees represent the families/groups. The matrices of the trees are available from Compton Herbarium, South African National Biodiversity Institute in Kirstenbosch.

3.3.3 Mapping methods

The template distribution map (Fig. 3.1) was obtained from Hester Steyn of PRE. The country names were inserted using MS PowerPoint 2007. The species distribution was mapped using Corel Draw software. Localities of species that are reported to occur, but of which PRE has no voucher specimens, were also mapped. Countries of occurrence are shaded in grey and known precise localities are indicated by a dot. The distribution in the islands is represented by shading and a dot, regardless of known precise locality, because of small scale of the islands. World

distribution of species in the E and W of the northern and southern Hemisphere of Africa are indicated on the corners of the maps by black triangles.

3.4 Systematic treatment of taxa

The genera recognized are the traditional Thuidioid genera, namely *Thuidium*, *Thuidiopsis* and *Pelekium*, as recognized by Touw (2001a), García-Avila *et al.* (2009) and Hedenäs (1998). The current names of the taxa are as accepted in TROPICOS, botanical information system at the Missouri Botanical Garden. The treatment of each species begins with the accepted name, in bold, followed by the basionym, information of the type specimen, the synonyms and type material involved, the full description of the species, notes, illustrations and a map. The nomenclature of African Thuidiaceae is also presented in Table 2.3 and includes the information on the date of publication, original publication source, the type material, the herbarium in which the type is housed and the region where the type was collected.

The arrangement of genera and species is alphabetical. The descriptions and images were based on African material, unless stated otherwise. Material of species reported to be synonyms and of those from other continents was also examined, mainly for comparison. The descriptions were prepared following the pattern in the *Flora of southern Africa (FSA): Bryophyta*. An identification key for each genus and species is provided.

3.5 Terminology

Terminology follows the bryology literature. The herbarium acronyms are according to the *Index herbariorum* (Holmgren *et al.* 1990). The abbreviation ‘CH’ followed by a number on some vouchers stands for Cryptogam Herbarium and was assigned in PRE. The material examined is housed in PRE except otherwise stated.

3.6 Author Abbreviations

Author abbreviations follow TROPICOS.

CHAPTER 4

CIRCUMSCRIPTION AND CHARACTER STATE RECONSTRUCTION OF THE THUIDIACEAE IN AFRICA

4.1 Introduction

The evidence for a re-circumscription of the Thuidiaceae in Africa and the East African Islands is presented in this chapter. Members of the Thuidiaceae in Africa are morphologically very similar and exhibit considerable infraspecific variability. As a result the delimitation of genera and species has been problematic. The exclusion of several genera from Thuidiaceae has been suggested by previous studies and a relationship rather with Leskeaceae proposed. García-Avila *et al.* (2009) attempted to resolve phylogenetic relationship of Thuidiaceae using molecular markers, chloroplast genes *rbcL* and *rps4*, and *rps4-trnS* intergenic spacer. They sampled the genera that at some point have been considered to be closely related to Thuidiaceae, covering the morphological variation of the three informal groups of Thuidiaceae, namely Thuidioid, Helodioid and Combined groups that were recognised by Touw (2001a). In an effort to resolve uncertainties in classification of the group and re-circumscribe the African Thuidiaceae, in this study the morphological and anatomical characters of selected Thuidiaceae and closely related families were studied and reconstructed onto the phylogenetic trees using parsimony.

The species of *Abietinella*, *Haplocladium*, *Raiiella* and *Hylocomiopsis* have historically often been placed or suggested to belong to other closely related families (e.g. Leskeaceae and Hylocomiaceae) and their position in the Thuidiaceae has always been doubtful, hence the exclusion of the African species of these genera in the current study. Their unique taxonomy differs from other Thuidiaceae species and include a character combination of prorate leaf cells, paraphyllia pluriseriate at insertion, absence of central strand (in *Hylocomiopsis*), 1-pinnate ramification and often differentiated alar cells. *Pelekium minutulum* (Hedw.) A. Touw is also excluded from the African Thuidiaceae because of very poor material from Africa and poor label data.

4.2 Results

The trees showing the phylogenetic and character state relationships of Thuidiaceae are presented here.

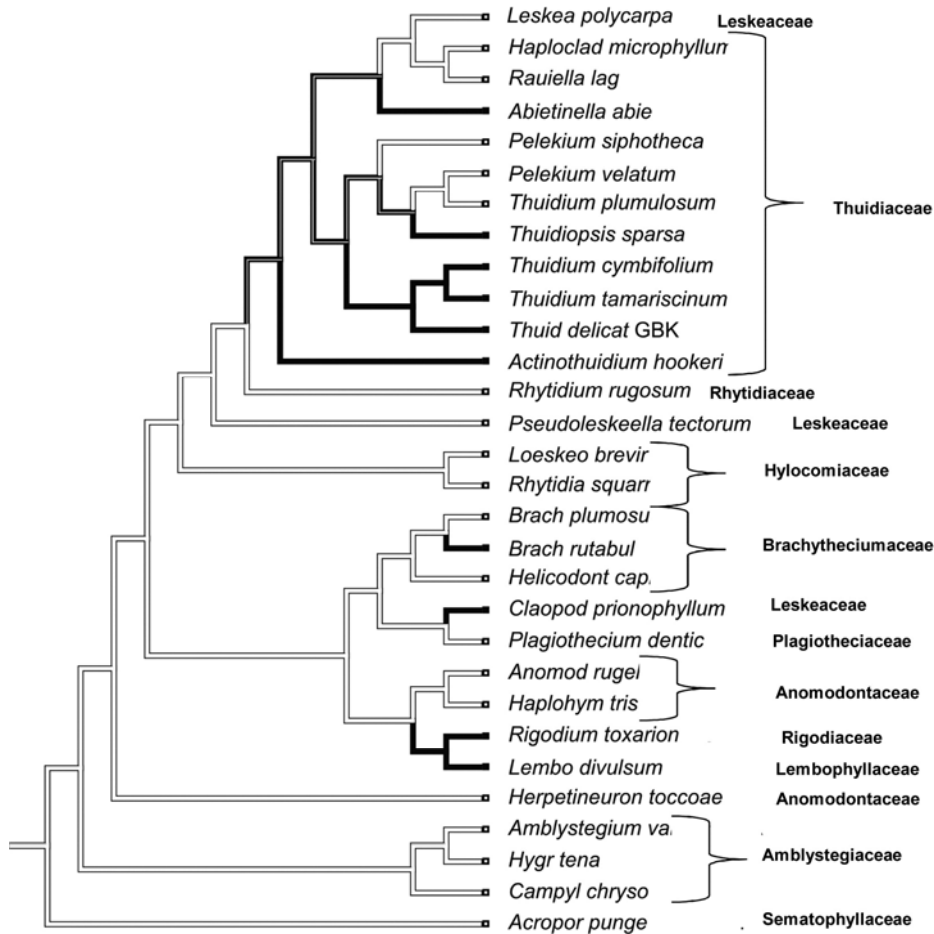


FIGURE 4.1.—Phylogeny tree of Thuidiaceae s.l. and closely related families (adapted from García-Avila *et al.* 2009).

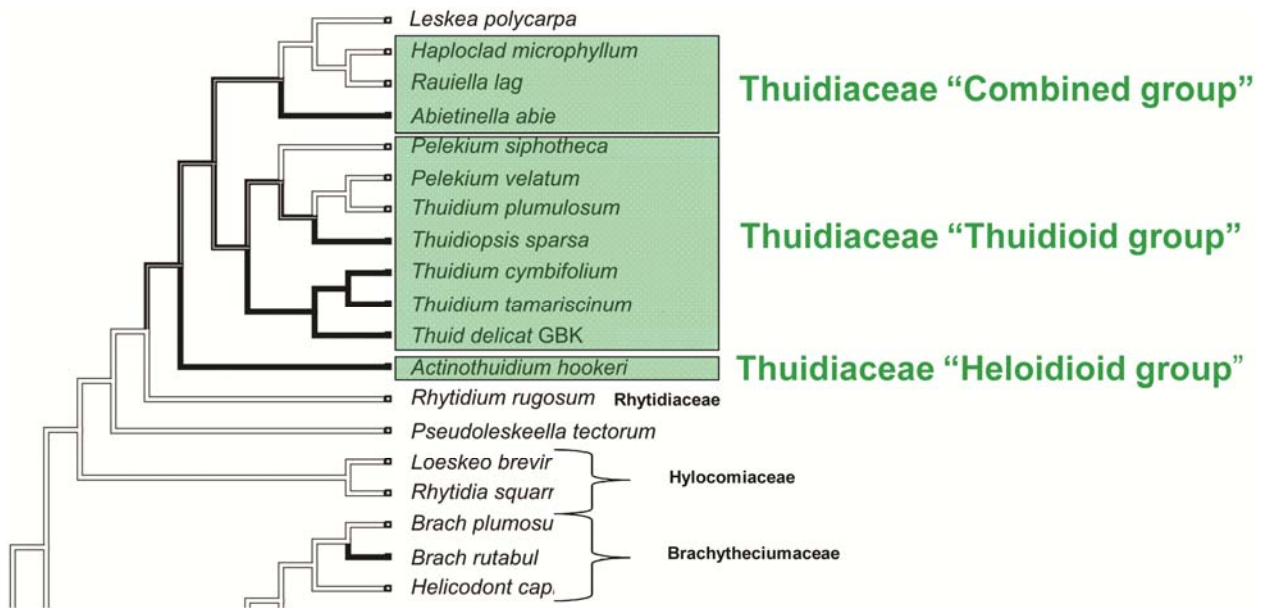


FIGURE 4.2.—Phylogeny tree of Thuidiaceae showing the Combined, Thuidioid and Heloidioid groups as recognized by Touw (2001a); (adapted from García-Avila *et al.* 2009).

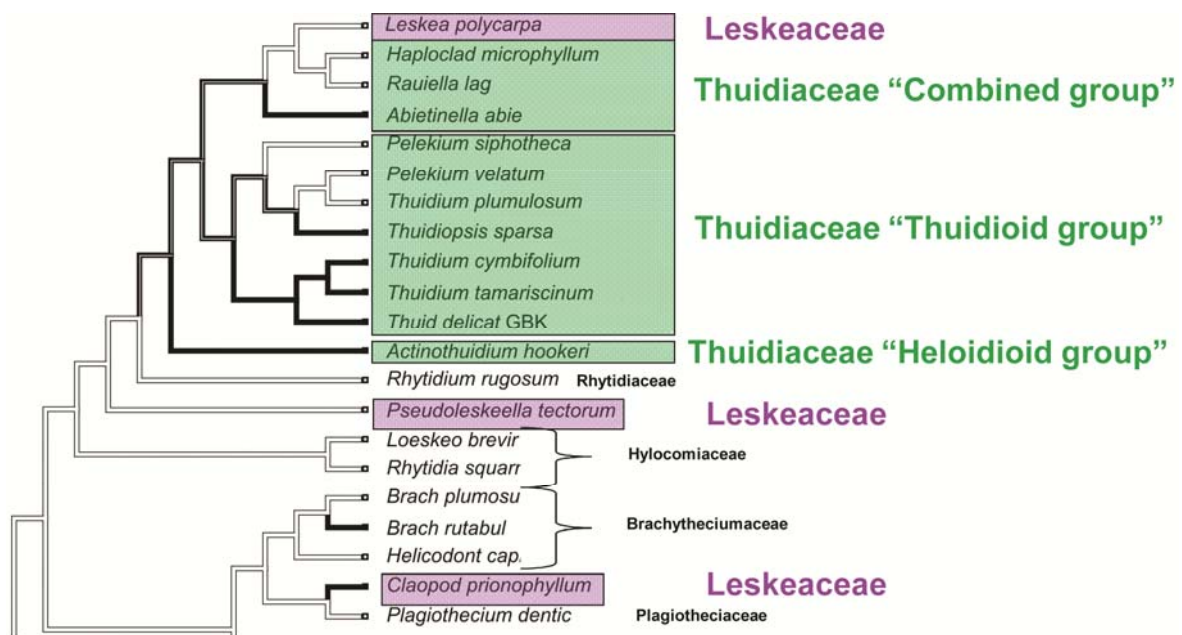


FIGURE 4.3.—Phylogeny tree showing non-monophyly of the Combined, Thuidioid and Heloidioid group as recognized by Touw (2001a), shaded in green and Leskeaceae clades, shaded in purple; (adapted from García-Avila *et al.* 2009).

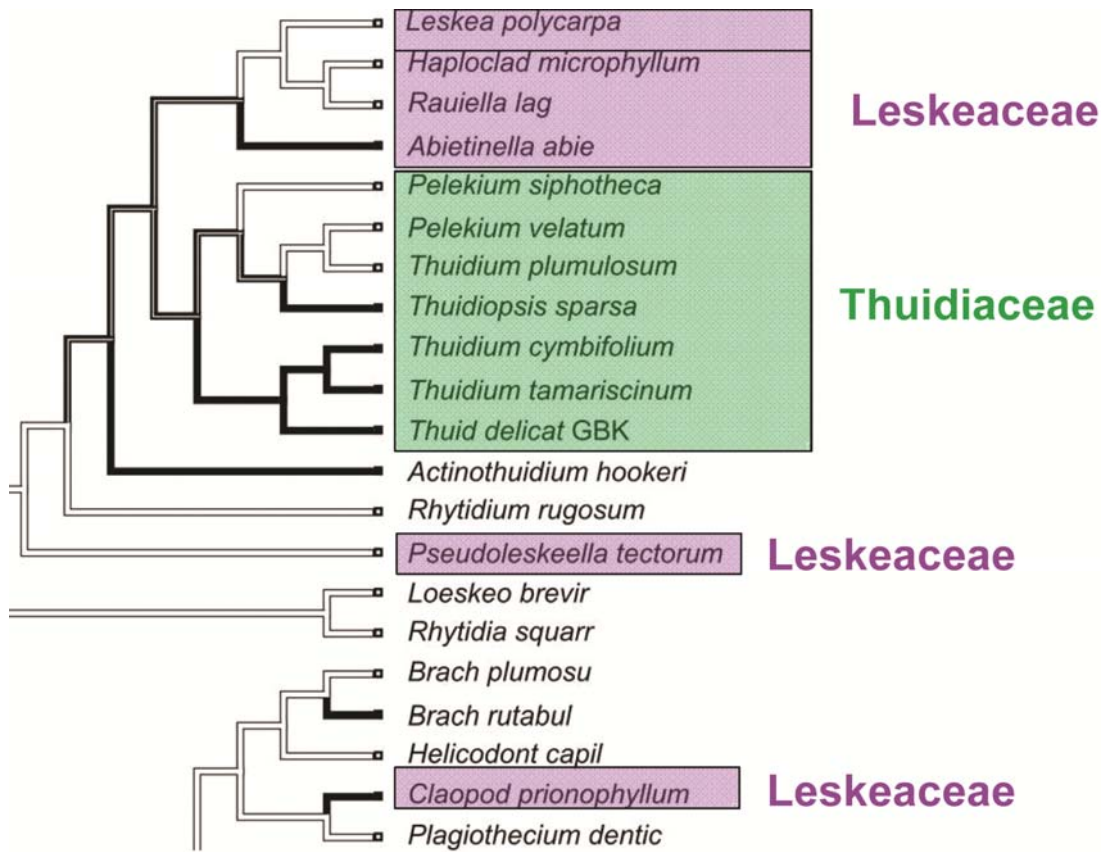


FIGURE 4.4.—Phylogeny tree showing the clades of Thuidiaceae, shaded in green and newly proposed Leskeaceae, shaded in purple (adapted from García-Avila *et al.* 2009).

Stem leaf shape

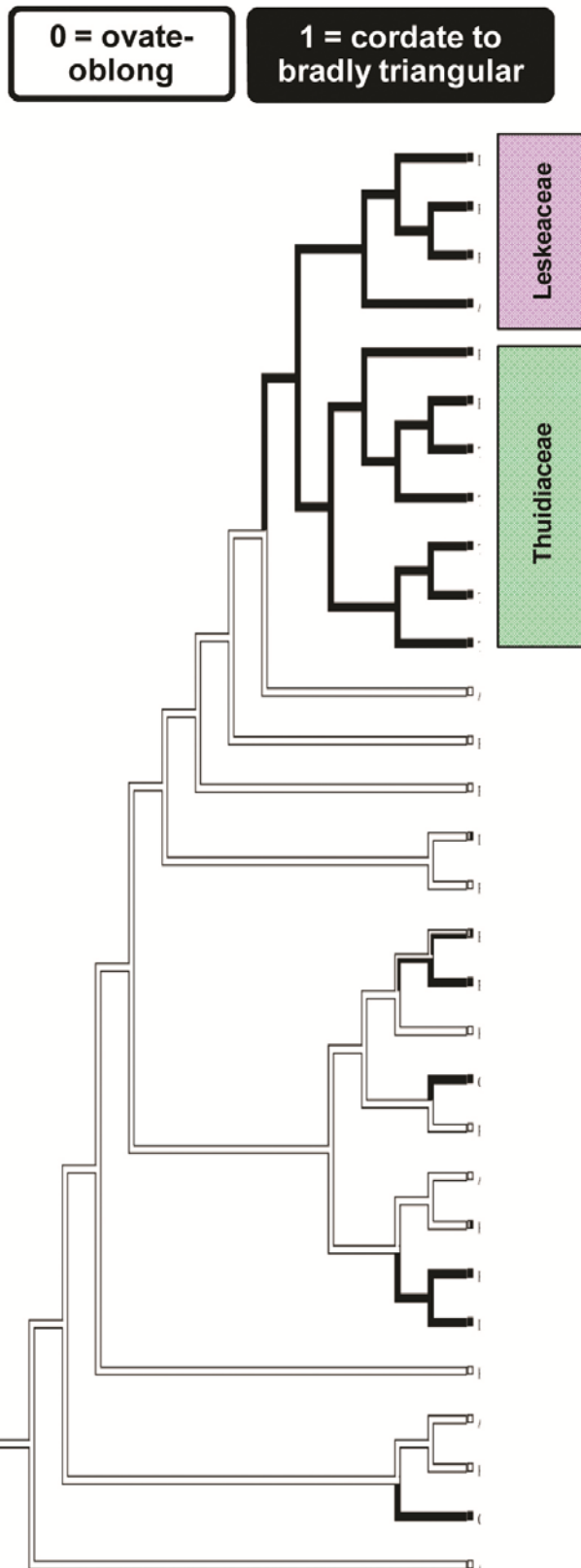


FIGURE 4.5.—Optimisation tree of Thuidiaceae and Leskeaceae clades (adapted from García-Avila *et al.* 2009). Black clades represent cordate or broadly triangular leaves, white clades represent ovate-oblong leaves.

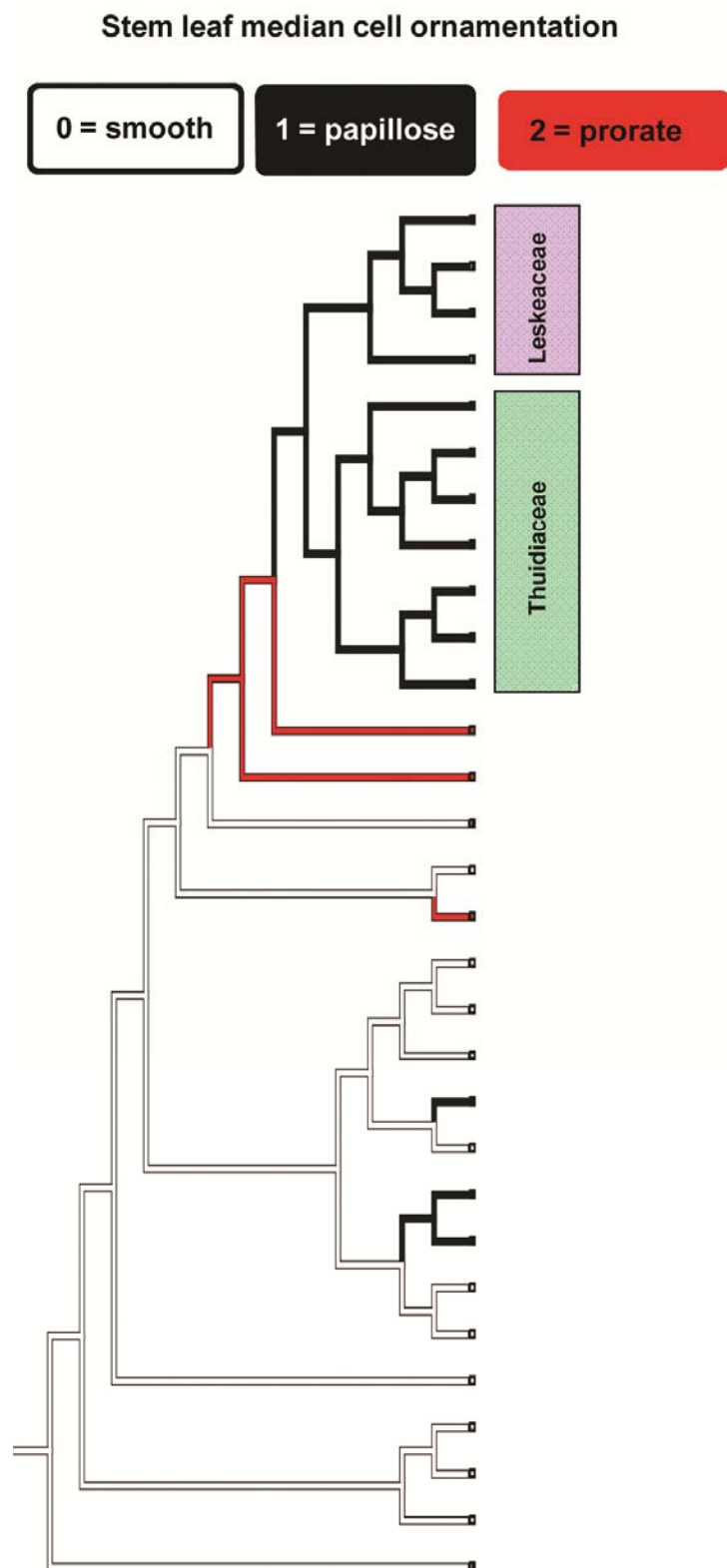


FIGURE 4.6.—Optimisation tree of Thuidiaceae and Leskeaceae (adapted from García-Avila *et al.* 2009). Black clades represent papillose stem leaf median cells, white clades represent smooth and red represent prorate stem leaf median cells.

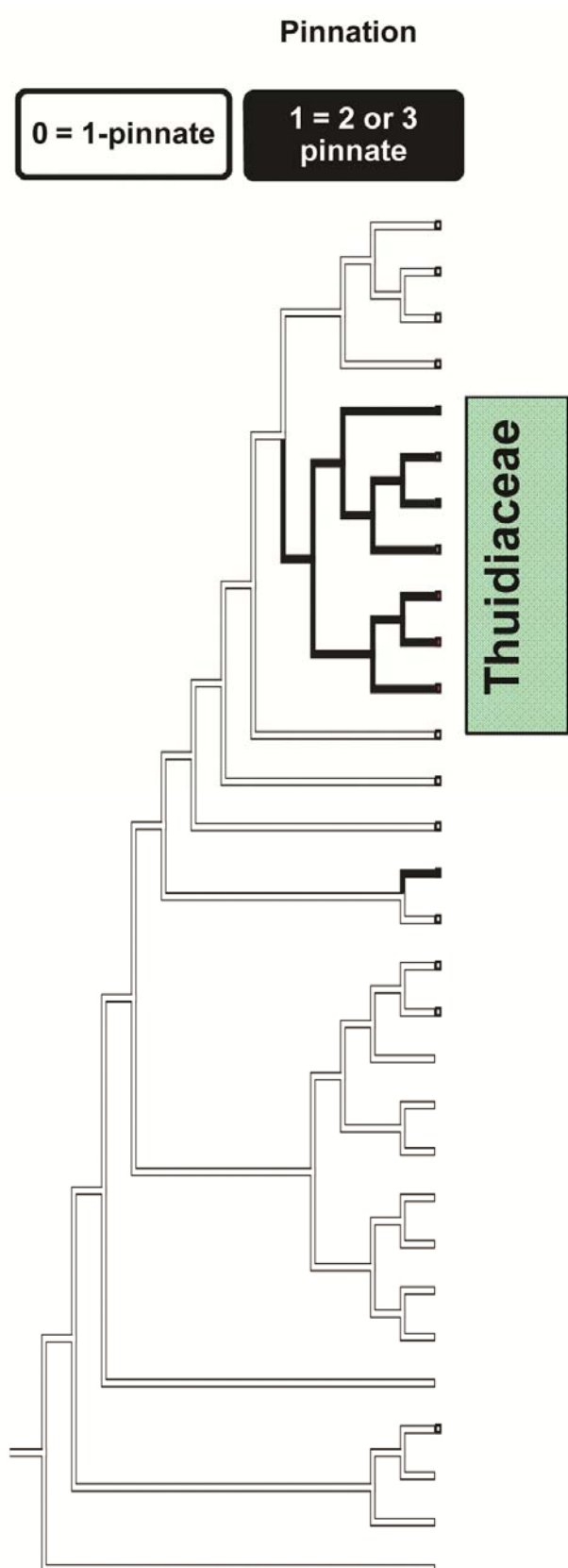


FIGURE 4.7.—Optimisation tree of Thuidiaceae (adapted from García-Avila *et al.* 2009). Black clades represent 2- or 3-pinnate stems, white clades represent 1-pinnate stems.

Branch leaf terminal cell shape

0 = acute, occ.
obtuse

1 = truncate

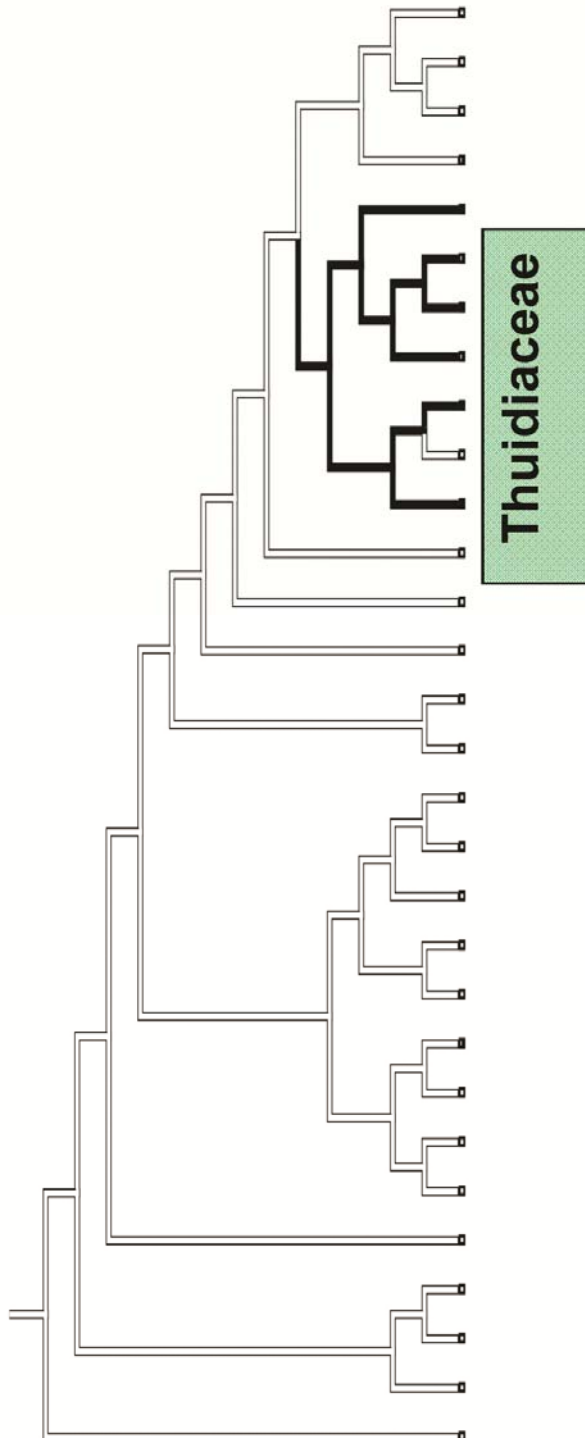


FIGURE 4.8.—Optimisation tree of Thuidiaceae (adapted from García-Avila *et al.* 2009). Black clades represent truncate branch leaf terminal cells, white clades represent acute, occasionally obtuse branch leaf terminal cells.

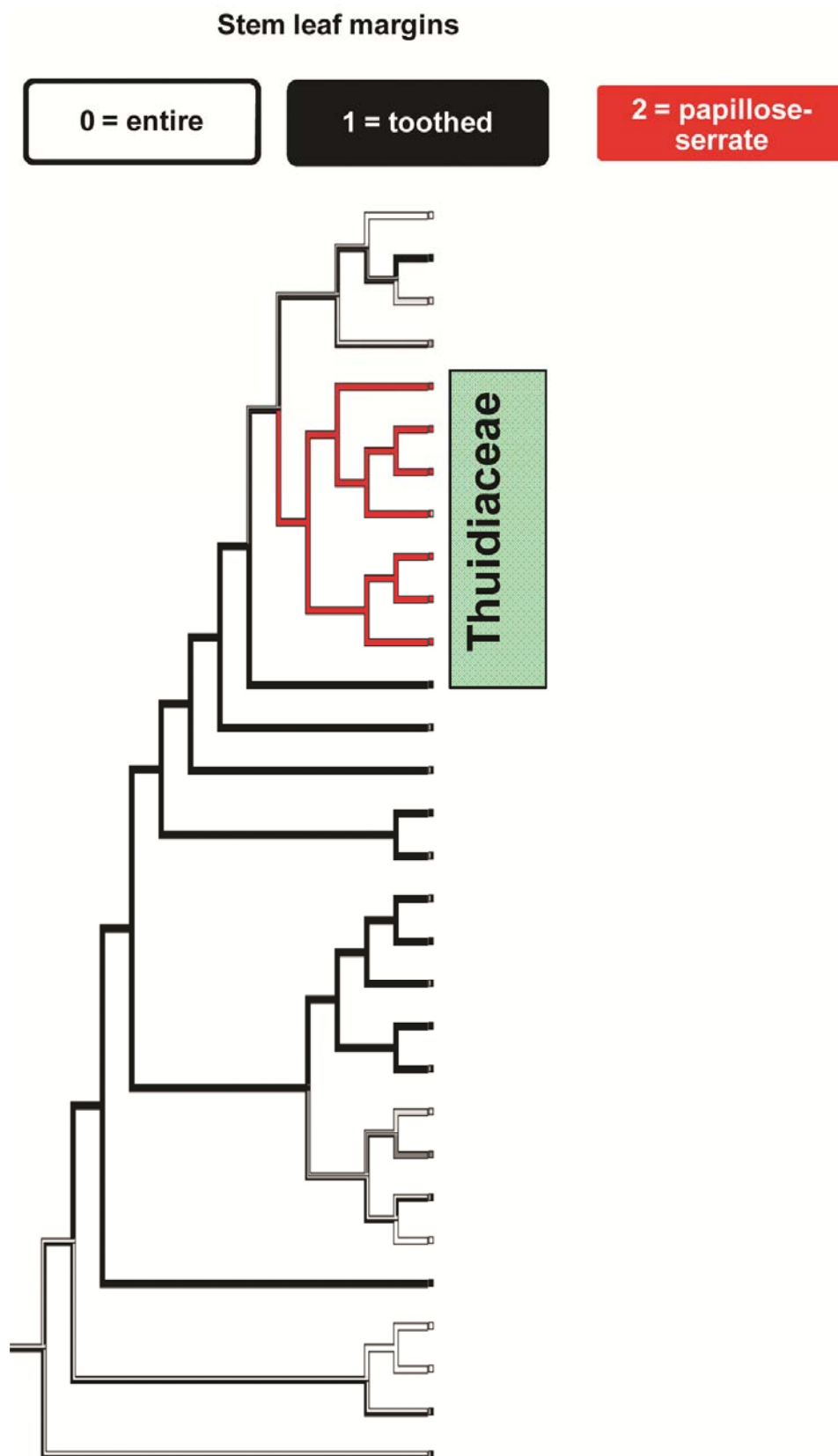


FIGURE 4.9.—Optimisation tree of Thuidiaceae (adapted from García-Avila *et al.* 2009). Black clades represent toothed stem leaf margins, white represent entire and red clades represent papillose-serrate stem leaf margins.

4.3 Discussion

The reconstruction of different character states on phylogenetic trees produced similar results to those obtained by García-Avila *et al.* (2009) when they studied the phylogenetic relationships of Thuidiaceae. They determined that Thuidiaceae and Leskeaceae are not monophyletic (Figure 4.1 and 4.4). Among various characters shared by both families, Leskeaceae (now including Thuidiaceae “Combined group”) and Thuidiaceae clade are strongly supported by cordate to broadly triangular stem leaves (Figure 4.5) and papillose median stem leaf cells (Figure 4.6). Thuidiaceae clade is supported by 2- or 3-pinnate stems (Figure 4.7), truncate terminal cells of branch leaves (Figure 4.8), and papillose-serrate leaf margins (Figure 4.9).

They proposed recognizing the Combined group (involving *Abietinella*, *Haplocladium*, *Rauarella*) as members of the Leskeaceae clade (Figure 4.2, 4.3 and 4.4). We agree with their proposal because when we plotted various character states of these genera, a group distinct from Thuidiaceae, that shares more characters with Leskeaceae, was formed. The relationship of the Combined group with *Leskea* (Leskeaceae) is therefore confirmed.

Abietinella Müll. Hal. in Africa is represented by *A. abietina* (Hedw.) M. Fleisch. The stems are 1-pinnate, paraphyllia basally multistratose with apical cell acute and differentiated alar cells.

Haplocladium (Müll. Hal.) Müll. Hal. in Africa is represented by *H. angustifolium* (Hampe & Müll. Hal.) Broth. and *Haplocladium jacquemontii* (Müll. Hal.) Broth. The species are characterized by 1- pinnate branching, prorate median leaf cells, and simple, smooth, basally multi-stratose paraphyllia with acute apical cell. According to O’Shea (2006)’s note under *Haplocladium jacquemontii* (Müll. Hal.) Broth., this taxon is not a *Haplocladium* but a *Pseudoleskea* Bruch & Schimp., and is synonymised with *Pseudoleskea dispersa* Müll. Hal. as *Haplocladium dispersum* (Müll. Hal.) Reimers, a combination not recorded in *Index Muscorum* or TROPICOS. In recent literature *Haplocladium* is classified under Leskeaceae (Crosby *et al.* 1999).

Rauarella Reimers in Africa is represented by *R. subfilamentosa* (Besch.) Wijk & Margad. The species is endemic to Africa and is characterized by wiry, dull olive green plants,

stems 1-pinnately branched, leaf margins crenate by bulging cell walls, paraphyllia basally multi-stratose with acute or truncate apical cell, and smooth seta.

Hylocomiopsis Cardot had also been classified under Thuidiaceae and Touw (2001a) put it under his Heloidiod group. In Africa the genus is represented by *H. cylindricarpa* Thér. This species is endemic to Africa. The plant lacks a central strand and endostome cilia and has large (40–50 µm wide), green, multicellular spores. It has already been excluded from Thuidiaceae and being placed in other families closely related to Thuidiaceae by previous authors. The genus has been placed in Leskeaceae because of its specialized sporophyte or Hylocomiaceae because of axillary hairs, paraphyllia, leaf cell ornamentation and ramification (Martin 2003). Recently the genus has been placed in Leskeaceae (Buck 1993, Crosby *et al.* 1999, Goffinet & Shaw 2009 and Kis 1985).

4.4 Conclusions

The relationship between the Combined group and *Leskea* (Leskeaceae) is confirmed. The exclusion of *Haplocladium*, *Rauarella*, *Abietinella*, including *Hylocomiopsis* from Thuidiaceae is confirmed by morphological and anatomical data. Thuidiaceae in the narrow sense is supported by three synapomorphies, namely, 2- or 3-pinnate stems, truncate terminal cells of branch leaves and papillose-serrate leaf margins. *Pelekium minutulum* is also excluded from this study until its locality problem is resolved.

CHAPTER 5

TAXONOMIC SIGNIFICANCE OF CHARACTERS

5.1 Introduction

The family Thuidiaceae is characterized by a combination of several characters shared by all genera (Touw 2001b). Characters considered diagnostic for the family vary from author to author. In this study no single character was found to best circumscribe the family, genera or species but this group is best defined by a set of characters at all these three levels.

According to Touw & Falter-van den Haak (1989) the stable gametophytic characters that are the most differentiating are the relative number of pseudoparaphyllia; direction of the base of stem leaves; ornamentation of the abaxial face of the costa, ornamentation of leaf cells; spore size and seta ornamentation. Some of the characters they thought were of little value are the colour and shape of the plant; distribution of paraphyllia; plication of stem leaves; direction of the apex of branch leaves when dry; ornamentation of inner perichaetial leaves; capsule orientation and number and size of the endostomial cilia. However some of these characters are among the ones that I consider taxonomically useful, namely plant size; ramification of the plant and the shape of stem leaves.

Buck & Crum (1990) selected seta ornamentation, position of leaf cell papillae, papillosity of paraphyllia cells, and morphology (cell number) of axillary hairs as useful characters. They noted that following strict sporophytic definition results in some plants with extreme gametophytic similarities falling under different families. In this study the morphology of the axillary hairs was investigated, based on observations and the cited literature. These hairs were best found in stem or branch apical shoots and the number and colour of basal and distal cells were examined. These features were found to be very variable and therefore axillary hair morphology is not considered a strong character.

According to Hedenäs (1997), gametophytic characters had more significance than those of sporophytes as the differences are believed to have evolved as adaptations to habitat. The species he included had homogeneous sporophytes and only a few characters of the sporophyte were important his study.

Touw (*pers comm.* 2010) noted that plant size is associated with characters of paraphyllia and leaves (tall plants have larger, more elaborate paraphyllia) and that more often than not the intermediate cells of paraphyllia are, in fact, associated with median leaf cells. Touw (2001a) found breeding system to be another important generic character.

Martin (2003) drew attention to branching pattern, paraphyllia on the stem and particularly stem and branch leaf papillae. He believed that these allow many of the sub-Saharan African species to be identified, even without sporophytes and in a few cases, seta ornamentation required.

Characters that I found to be useful in characterizing the species of the African Thuidiaceae are listed, discussed and plotted in various graphs below. The gametophytic characters are valuable at species level, while the sporophytic characters are valuable at generic level. Characters that were found to be less useful than others are the ones that are more or less uniform throughout the family. Table 1 covers characters and characters states, with scores. The second bars in Figures 5.3 and 5.6 represent the other character states. A gap in a graph means that the species did not have data.

5.2 Structural characters

5.2.1 Gametophyte

Plant size: Large, medium and small plants have stems 70–130 mm, 40–60 mm and < 40 mm long respectively. The plant size was a valuable character at generic level.

Branching pattern: Ramification varies between 1-, 2- and 3-pinnate and a combination with less or more ramified forms, e.g. (1–)2-pinnate and (2–)3-pinnate. Ramification is valuable at species level when used together with shape, cell ornamentation of the stem leaves and plant size. See Figure 5.2.

Paraphyllia: These are often lacking on branches and older stems, otherwise few to abundant, simple or moderately to strongly branched, short, 1–5 cells long (Figure 6.12B) or long, ≥ 5 cells long (Figure 6.14B). Cells may be short or long; quadrate, quadrate-rhombic or oblong-rectangular and smooth or weakly or coarsely papillose. The terminal cell may be acute, obtuse

or truncate. Paraphyllia branching and length were valuable at generic level and the latter at species level. See Figures 5.3 and 5.4.

Stem leaves: Attachment is by either a decurrent or sessile base. Most taxa have a short, decurrent leaf base. Plication of the leaf may be weak to strong, or almost none (plane). All large plants have strongly plicate stem leaves. This character was valuable at generic level. Apex also shows variation and may be narrowly or broadly acute, shortly or narrowly long acuminate to filiform ending in a long awn. Margins in median leaves may be plane or recurved and entire, papillose-serrate or rarely crenate by bulging cell walls (e.g. in *T. sparsa*). The margin is almost never uniform for the entire leaf length. Costa varies from percurrent, ending below the apex with tip often distinct, especially when laminal cells are short; disappearing in apex, the tip often indistinct when laminal cells are long; to excurrent, ending beyond the apex in a long awn. Median cells show no absolute uniformity in one leaf. The cells are short to elongate and mostly mixed in shape and variously angulated. However they have a dominant shape combination, this being one of the three main shape combinations: with cells often short, isodiametrical-quadraterounded; cells variously angulated, hexagonal-rhombic or cells of elongate, rectangular-oblong-elliptical shapes. Median cell ornamentation (all mixed with smooth cells) may be mostly unipapillose (papillae more or less central), bipapillose or pluripapillose (more than 2 papillae scattered over the mamillae). The cell ornamentation was valuable at species level. Terminal cell shape varies from acute or obtuse (often smooth, sometimes papillose) to truncate (papillose). Basal cells are either the same size as adjacent cells or larger; tinted or the same colour as adjacent cells and with cell walls porose (pitted) or not. Alar cells are often not or weakly differentiated. See Figures 5.5. to 5.16.

Branch leaves: Terminal cell may be acute or obtuse (smooth or papillose) or truncate (papillose). This character was valuable at species level when used with paraphyllia terminal cell and stem leaf median cell ornamentation. The rest of the characters are not taxonomically significant and are more or less the same as in stem leaves with few exceptions e.g. branch leaf smaller and narrower, laminal cells shorter, crowded and thicker-walled. See Figure 5.17.

5.2.2 Sporophyte

Breeding system: Monoicous or dioicous. The sexual condition was a useful character at generic level. See Figure 5.18.

Perichaetia mature inner leaves: Margin shoulders are either ciliate or eciliate. This character was valuable at species level. See Figure 5.19.

Seta: Ornamentation is either rough at neck only; papillose throughout; hispid throughout or smooth. The seta morphology was valuable at species level. See Figure 5.20.

Peristome: The features showed uniformity throughout the family, except for size.

Endostome cilia are present, vestigial or absent. See Figure 5.24.

Operculum: The shape may be conical or rostrate. See Figure 5.22.

Calyptra: The shape is cucullate throughout the family. The surface may be naked or hispid. See Figure 5.21.

Spores: The ornamentation appeared to be the same throughout the family. The youngest spores are smooth to weakly papillose, later becoming more papillose with age but mixed with spores that have patches where papillae have fallen off. See Figure 5.25.

TABLE 5.1.—Characters and character states, with scores.

1. Stem size (length): 1 = 70–130 mm 2 = 40–69 mm 3 = <40 mm	15. Stem leaf terminal cell morphology: 1 = non-truncate (acute/obtuse) 2 = truncate
2. Branching pattern: 1 = 1-pinnate 2 = 2-pinnate 3 = 3-pinnate	16. Stem leaf basal cells colouration: 1 = not tinted 2 = tinted (reddish brown or yellowish brown)
3. Paraphyllia branching: 1 = not branched 2 = branched	17. Stem leaf basal cell porosity: 1 = porose 2 = eporose
4. if branched 1 = weakly branched 2 = strongly branched	18. Stem leaf alar cells: 1 = differentiated 2 = not differentiated
5. Paraphyllia terminal cell morphology 1 = acute 2 = truncate	19. Branch leaf terminal cell morphology: 1 = acute, occasionally obtuse 2 = truncate
6. Leaf attachment: 1 = decurrent 2 = not decurrent	20. Breeding system: 1 = monoicous 2 = dioicous
7. Plication: 1 = plain 2 = plicate	21. Inner perichaetial leaf shoulder margins: 1 = ciliate 2 = eciliate (entire or serrate)
8. If plicate: 1 = weakly plicate 2 = strongly plicate	22. Seta ornamentation: 1 = Smooth 2 = ornamented
9. Stem leaf apex: 1 = acute 2 = short to long acuminate 3 = filiform	23. If ornamented: 1 = papillose above 2 = Papillose throughout 3 = hispid throughout
10. Stem leaf margins: 1 = plain 2 = recurved	24. Calyptra ornamentation: 1 = smooth/naked 2 = hispid

TABLE 5.1 (Cont.).—Characters and character states, with scores.

11. Stem leaf margins ornamentation: 1 = entire 2 = papillose-serrate 3 = crenulate by bulging cell walls	3 = with paraphyses and/archegonia at lower portion
12. Stem leaf costa end: 1 = percurrent 2 = excurrent 3 = disappearing in apex	25. Operculum shape: 1 = conical 2 = rostrate
13. Stem leaf median cell shape: 1 = short, isodiametrical-quadrate-rounded 2 = variously angulated hexagonal-rhombic 3 = elongate, rectangular-oblong-elliptical-linear	26. Capsule orientation: 1 = inclined to horizontal to pendulous 2 = erect
14. Stem leaf median cell ornamentation: 1 = smooth 2 = unipapillose 3 = Bipapillose 4 = Pluripapillose	27. Endostome cilia: 1 = present 2 = vestigial 3 = absent
	28. Spore size: 1 = $\leq 13.0 \mu\text{m}$ 2 = $> 13.0 \mu\text{m}$

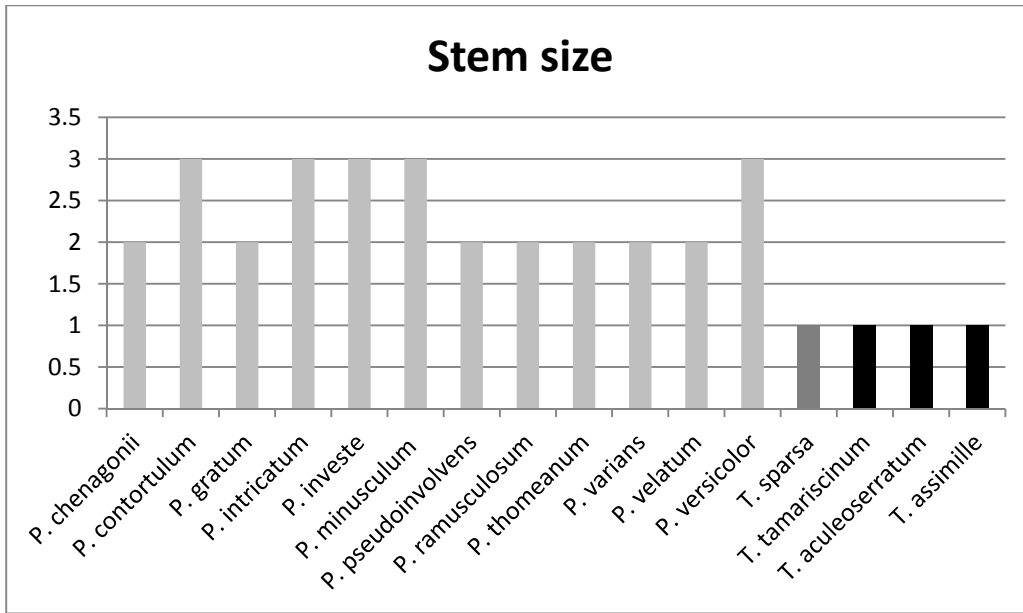


FIGURE 5.1.—Stem size for character 1. Pale grey = *Pelekium*; dark grey = *Thuidiopsis*; black = *Thuidium*.

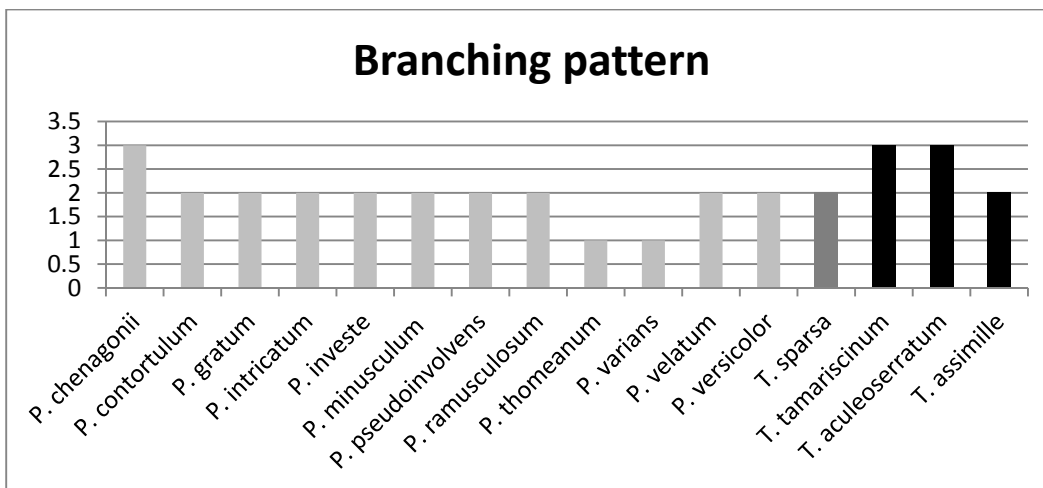


FIGURE 5.2.—Branching pattern for character 2. Pale grey = *Pelekium*; dark grey = *Thuidiopsis*; black = *Thuidium*.

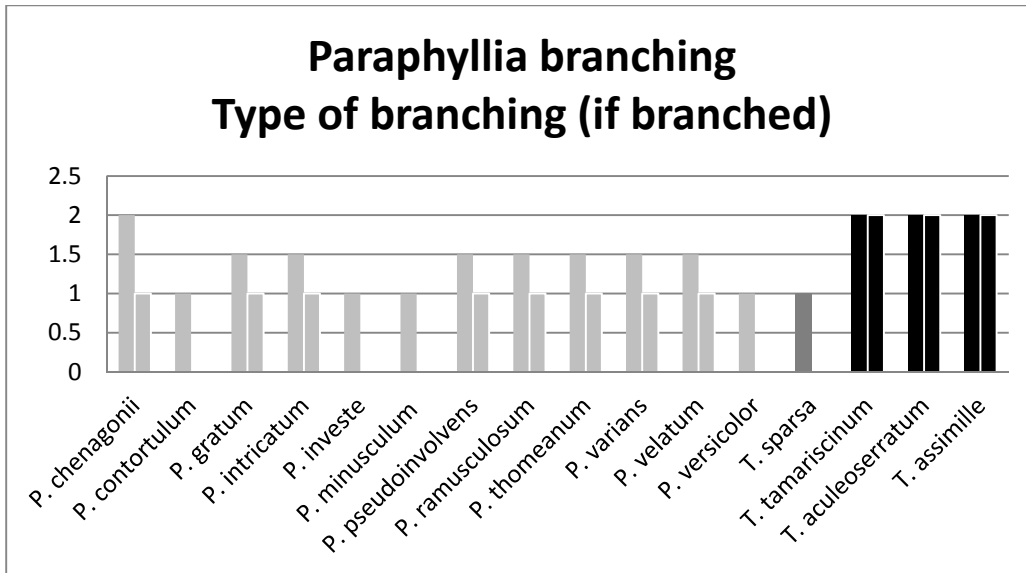


FIGURE 5.3.—Paraphyllia branching and types of branching for character 3 & 4. Pale grey = *Pelekium*; dark grey = *Thuidiopsis*; black = *Thuidium*; bordered bars = type of branching.

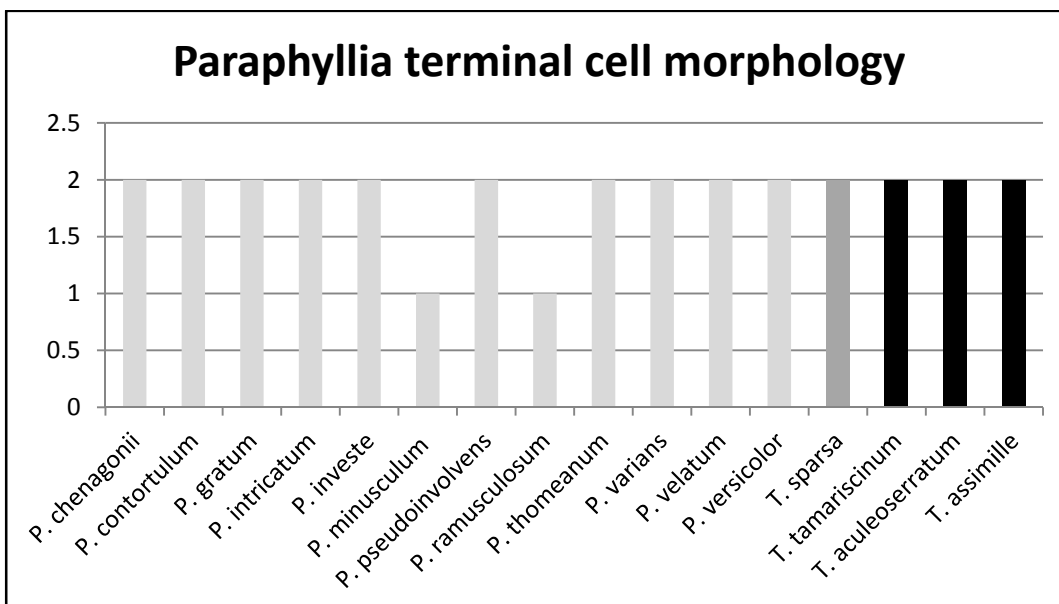


FIGURE 5.4.—Paraphyllia terminal cell ornamentation for character 5. Pale grey = *Pelekium*; dark grey = *Thuidiopsis*; black = *Thuidium*.

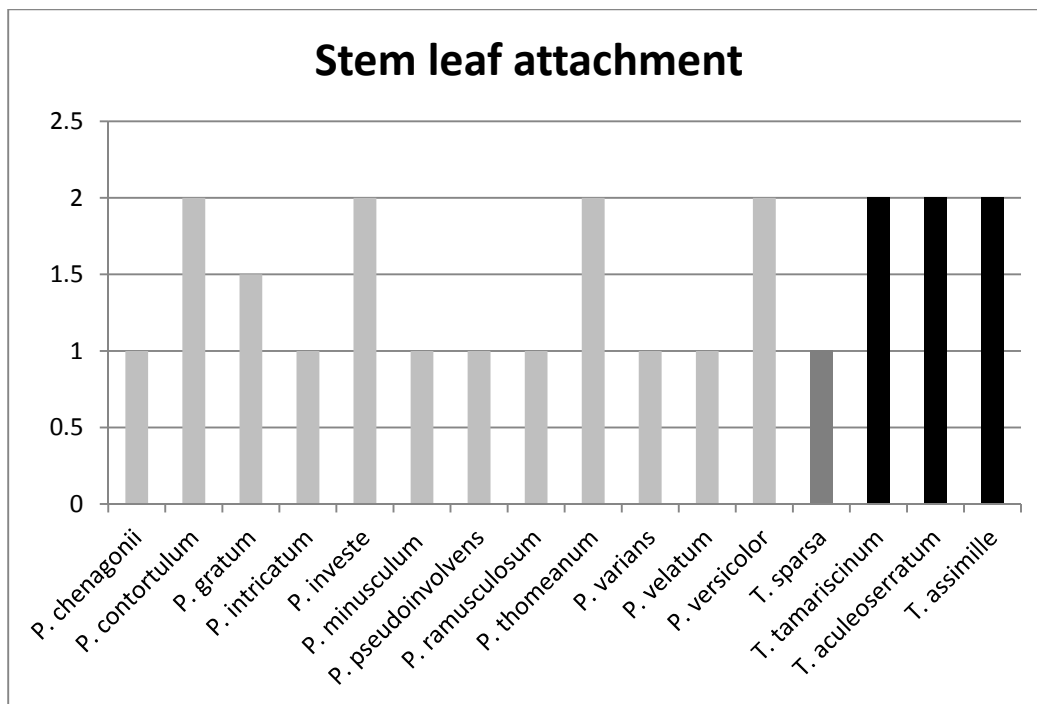


FIGURE 5.5.—Stem leaf attachment for character 6. Pale grey = *Pelekium*; dark grey = *Thuidiopsis*; black = *Thuidium*.

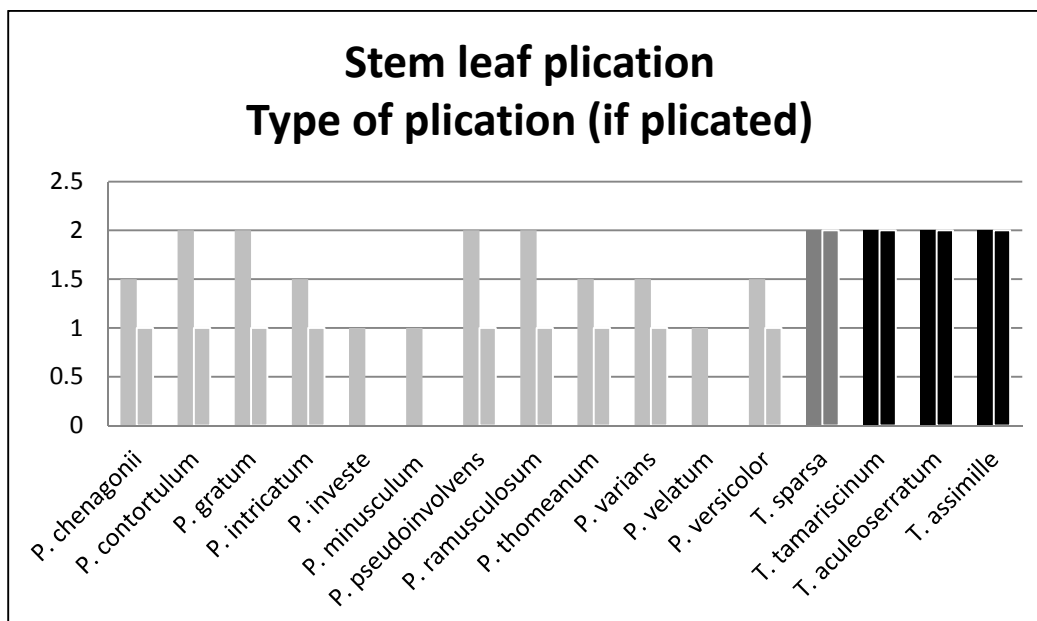


FIGURE 5.6.—Stem leaf plication and types of plication for character 7 & 8. Pale grey = *Pelekium*; dark grey = *Thuidiopsis*; black = *Thuidium*.

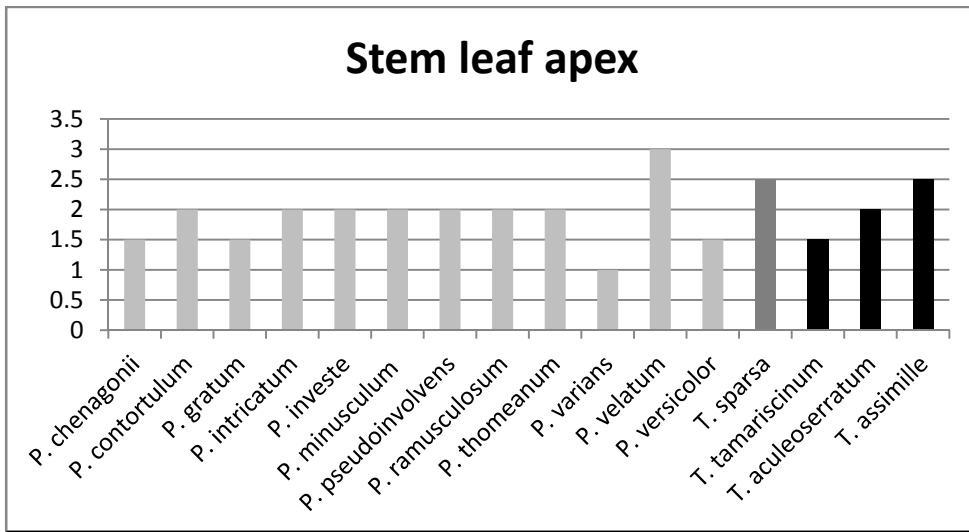


FIGURE 5.7.—Stem leaf apex for character 9. Pale grey = *Pelekium*; dark grey = *Thuidiopsis*; black = *Thuidium*.

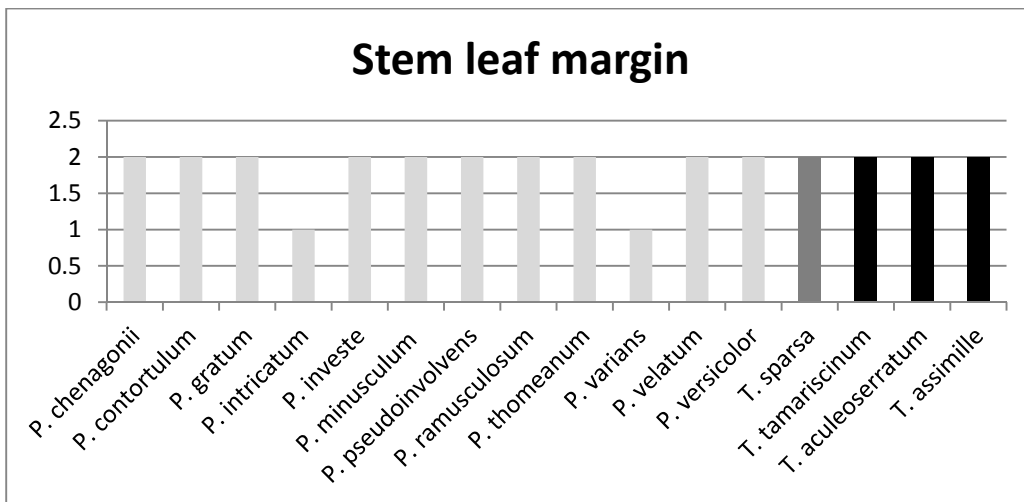


FIGURE 5.8.—Stem leaf margin for character 10. Pale grey = *Pelekium*; dark grey = *Thuidiopsis*; black = *Thuidium*.

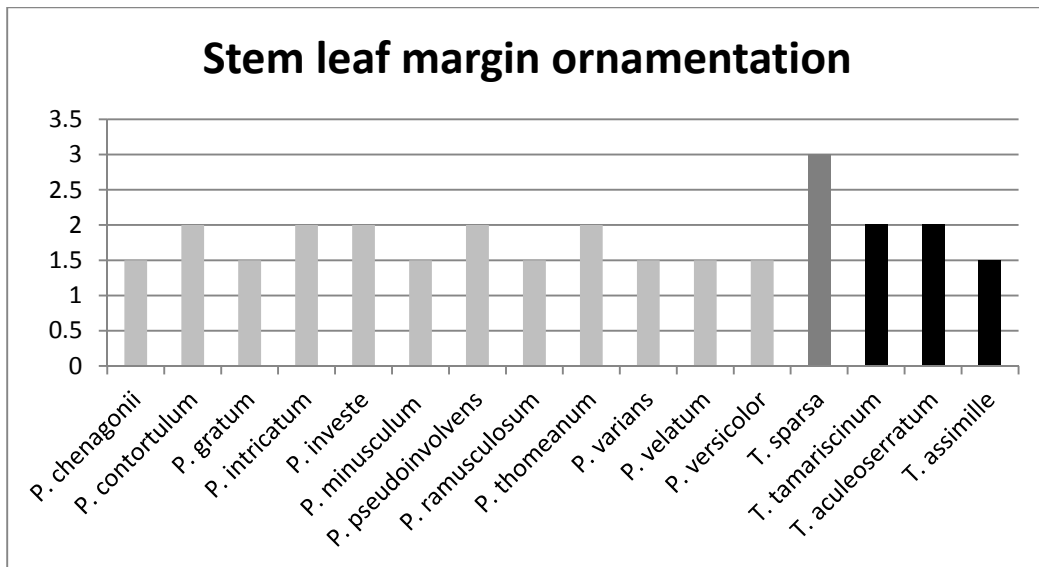


FIGURE 5.9.—Stem leaf margin ornamentation for character 11. Pale grey = *Pelekium*; dark grey = *Thuidiopsis*; black = *Thuidium*.

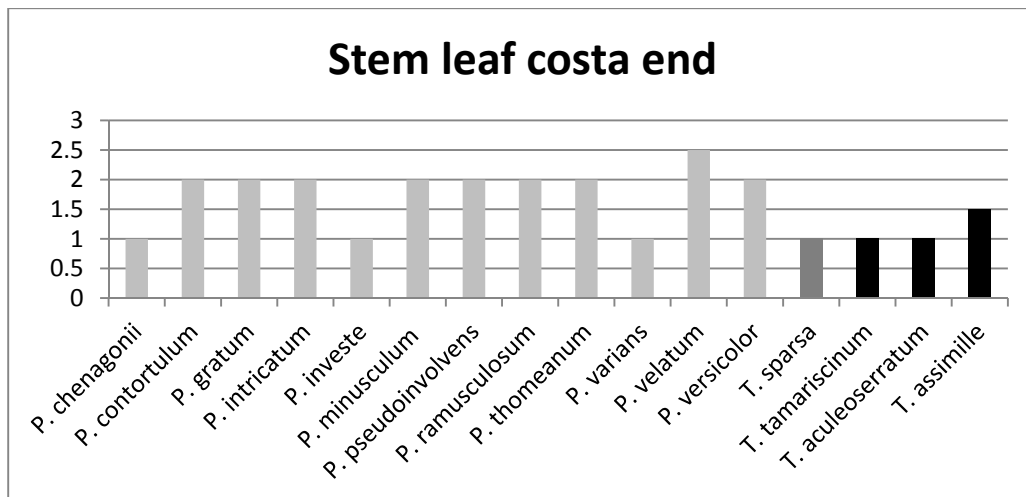


FIGURE 5.10.—Stem leaf costa end for character 12. Pale grey = *Pelekium*; dark grey = *Thuidiopsis*; black = *Thuidium*.

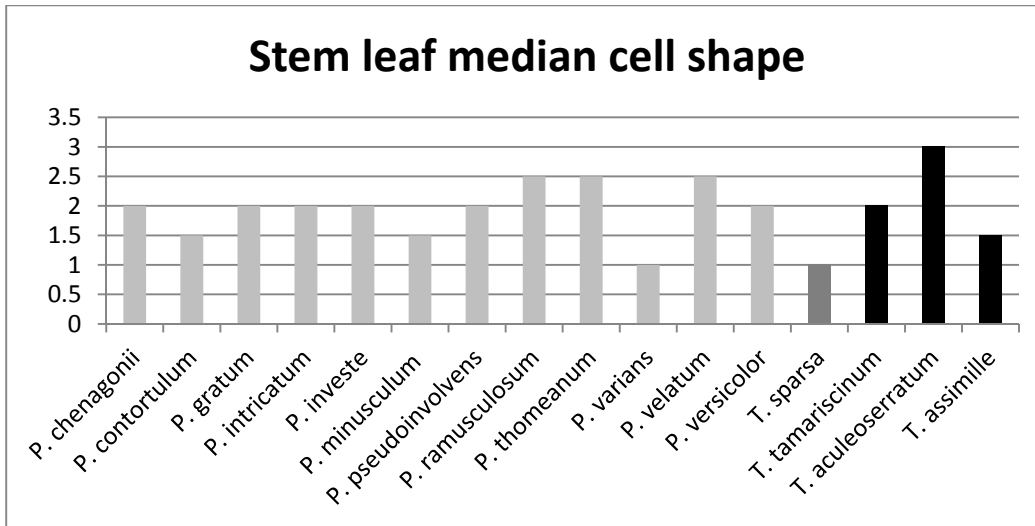


FIGURE 5.11.—Stem leaf median cell shape for character 13. Pale grey = *Pelekium*; dark grey = *Thuidiopsis*; black = *Thuidium*.

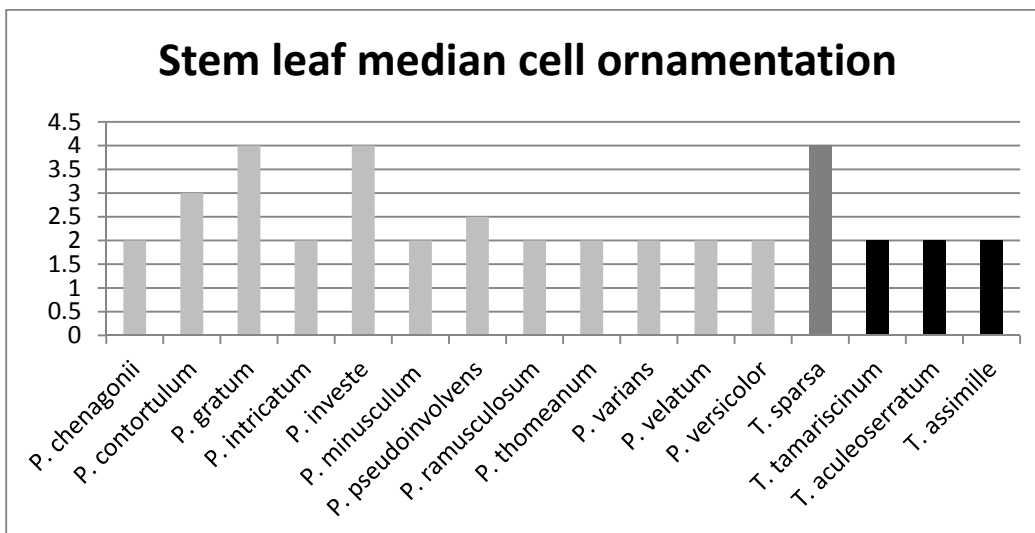


FIGURE 5.12.—Stem leaf median cell ornamentation for character 14. Pale grey = *Pelekium*; dark grey = *Thuidiopsis*; black = *Thuidium*.

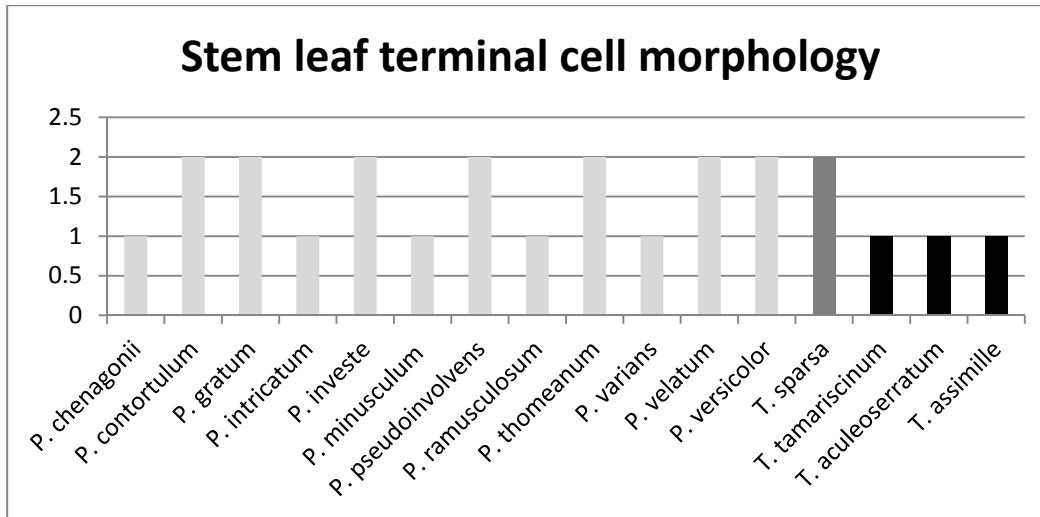


FIGURE 5.13.— Stem leaf terminal cell morphology for character 15. Pale grey = *Pelekium*; dark grey = *Thuidiopsis*; black = *Thuidium*.

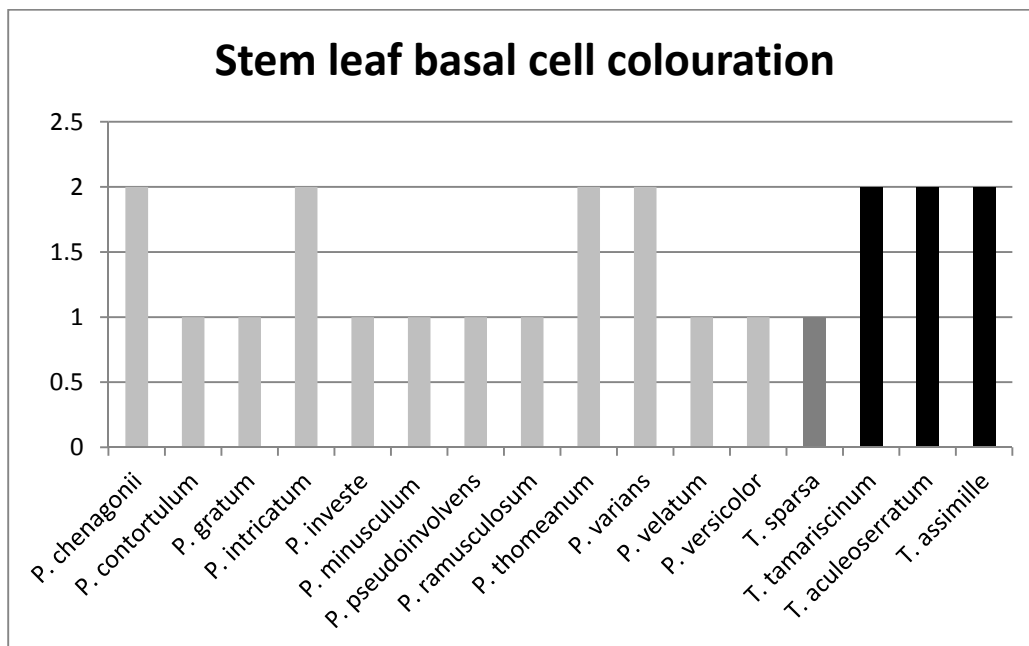


FIGURE 5.14.— Stem leaf basal cell colouration for character 16. Pale grey = *Pelekium*; dark grey = *Thuidiopsis*; black = *Thuidium*.

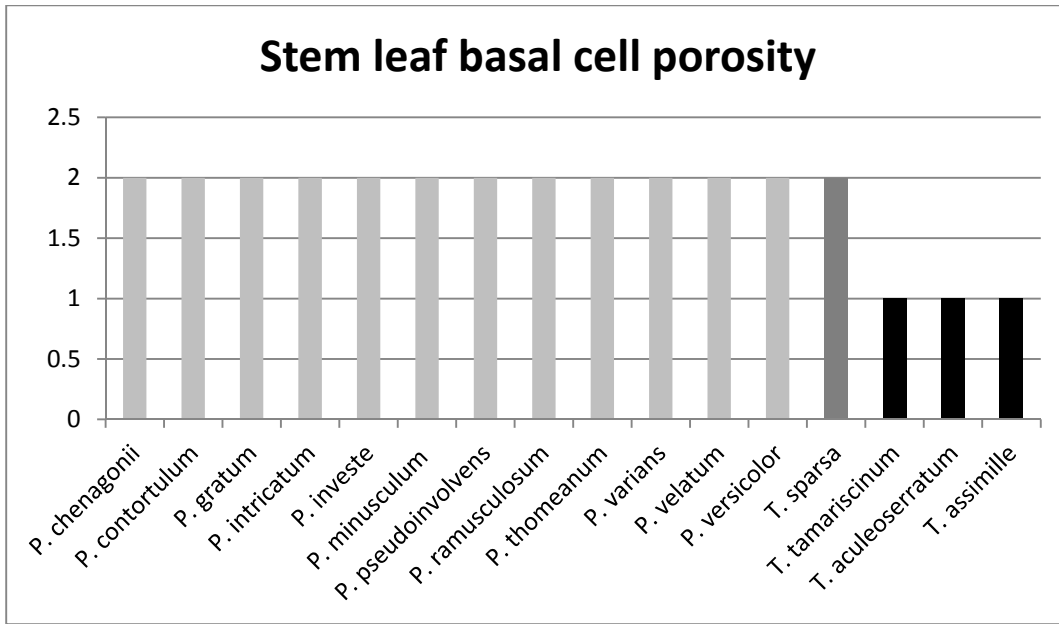


FIGURE 5.15.— Stem leaf basal cell porosity for character 17. Pale grey = *Pelekium*; dark grey = *Thuidiopsis*; black = *Thuidium*.

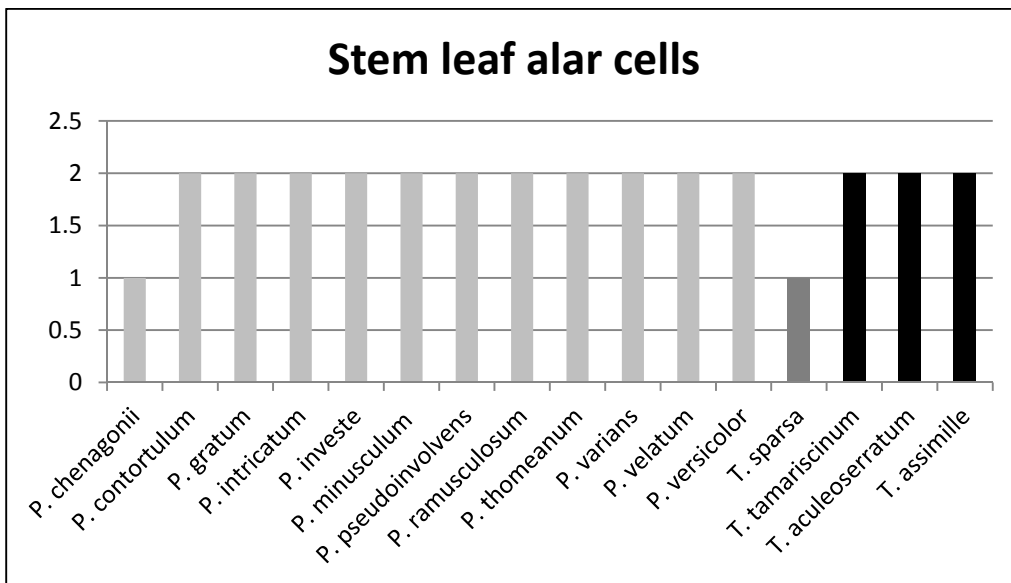


FIGURE 5.16.— Stem leaf alar cells for character 18. Pale grey = *Pelekium*; dark grey = *Thuidiopsis*; black = *Thuidium*.

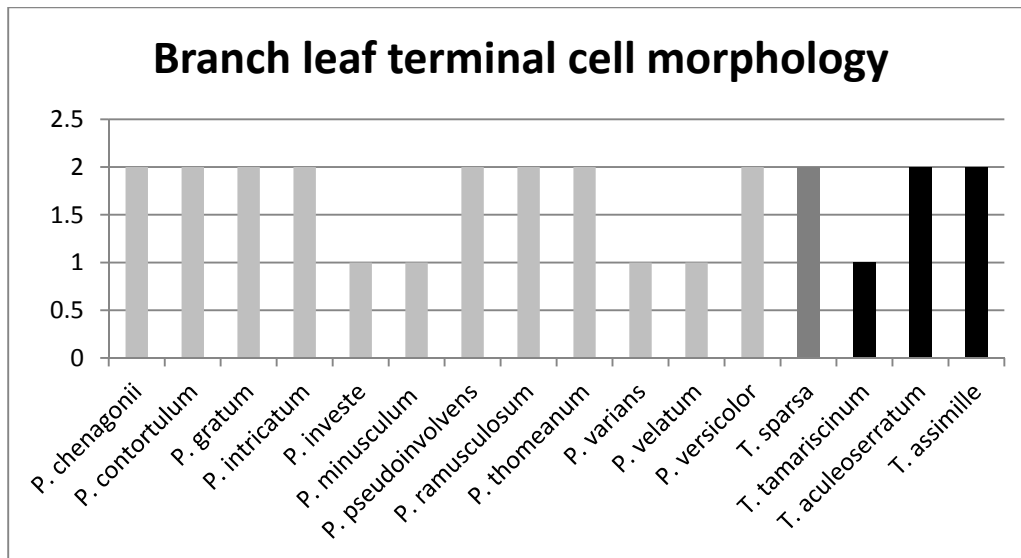


FIGURE 5.17.—Branch leaf terminal cell morphology for character 19. Pale grey = *Pelekium*; dark grey = *Thuidiopsis*; black = *Thuidium*.

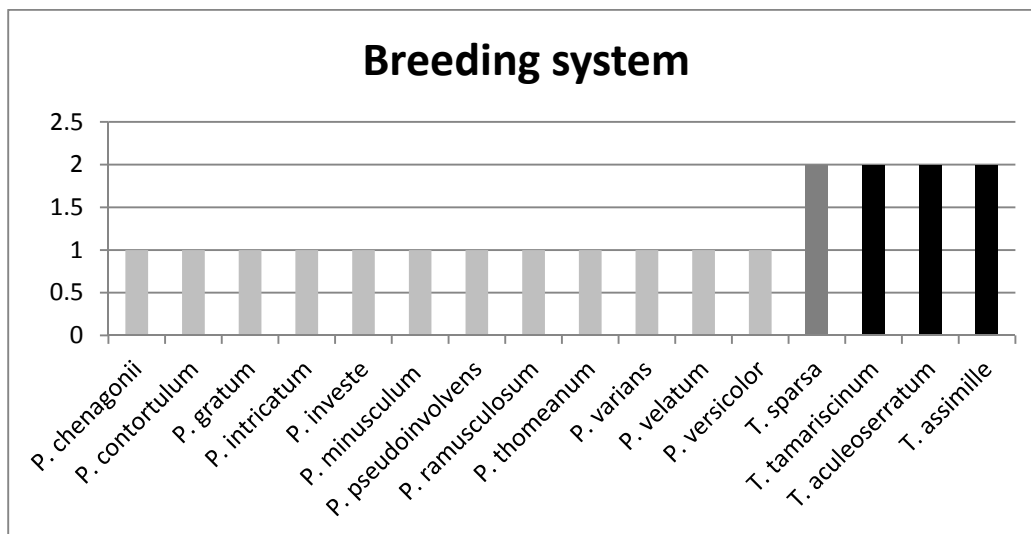


FIGURE 5.18.—Breeding system for character 20. Pale grey = *Pelekium*; dark grey = *Thuidiopsis*; black = *Thuidium*.

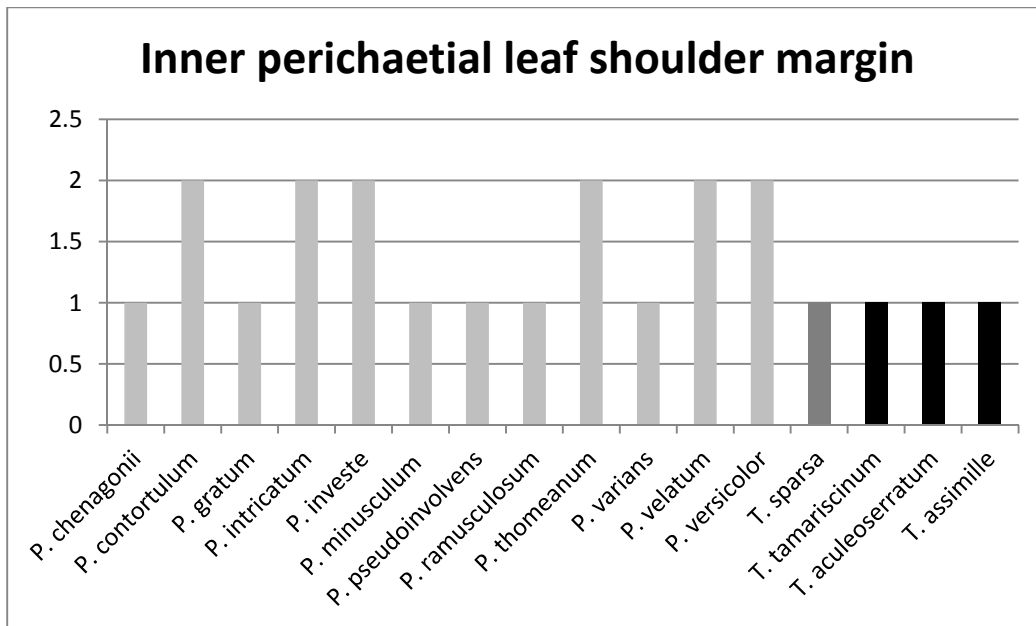


FIGURE 5.19.—Inner perichaetial leaf shoulder margin for character 21. Pale grey = *Pelekium*; dark grey = *Thuidiopsis*; black = *Thuidium*.

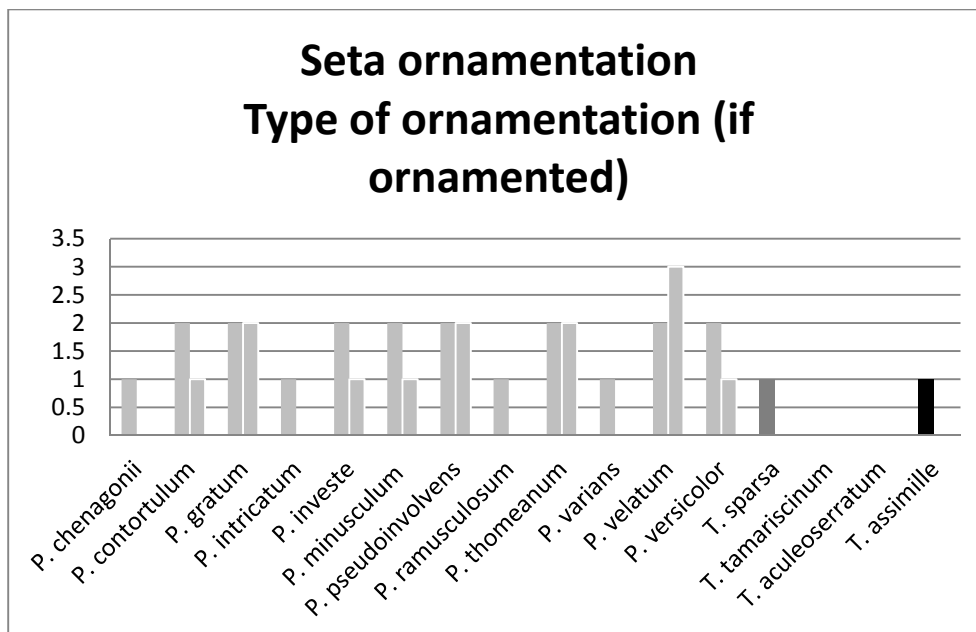


FIGURE 5.20.—Seta ornamentation and type of ornamentation for character 22 & 23. Pale grey = *Pelekium*; dark grey = *Thuidiopsis*; black = *Thuidium*; bordered bars = type of ornamentation.

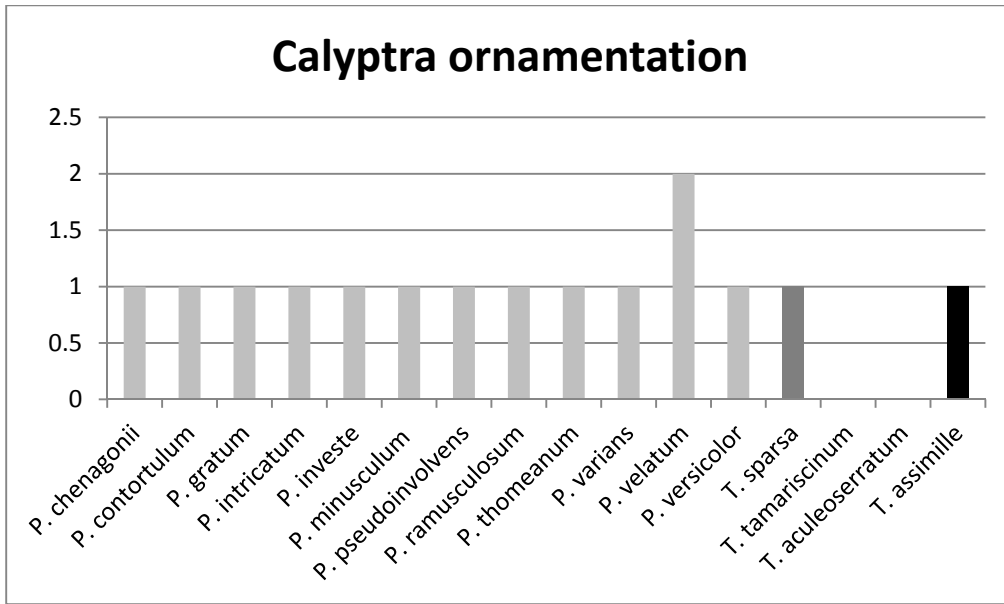


FIGURE 5.21.—Calyptra ornamentation for character 24. Pale grey = *Pelekium*; dark grey = *Thuidiopsis*; black = *Thuidium*.

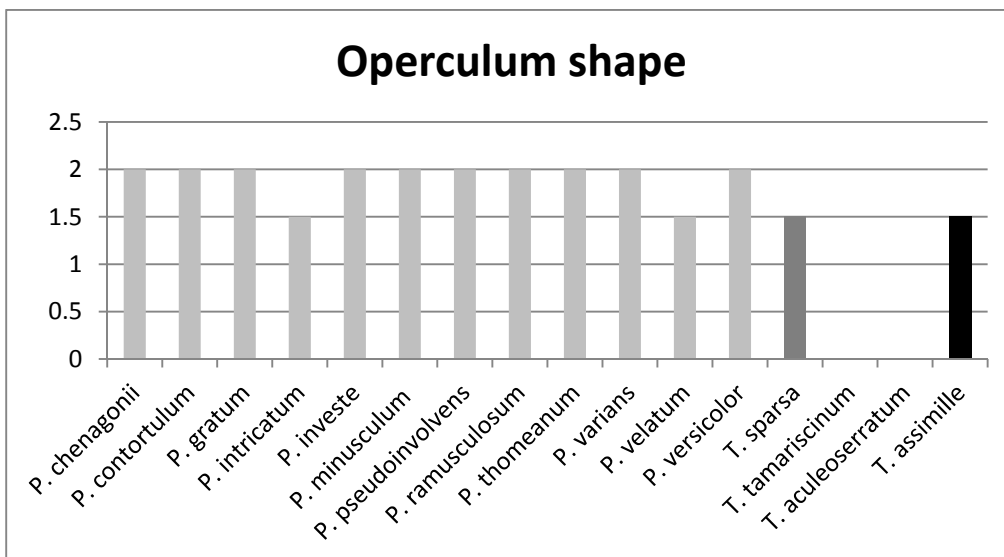


FIGURE 5.22.—Operculum shape for character 25. Pale grey = *Pelekium*; dark grey = *Thuidiopsis*; black = *Thuidium*.

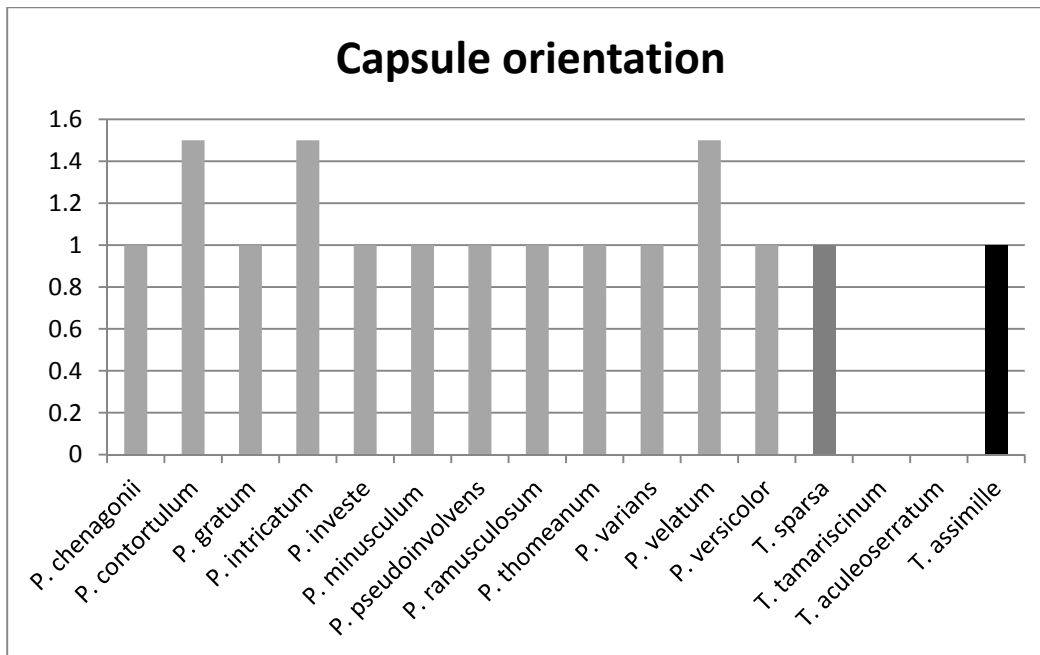


FIGURE 5.23.—Capsule orientation for character 27. Pale grey = *Pelekium*; dark grey = *Thuidiopsis*; black = *Thuidium*.

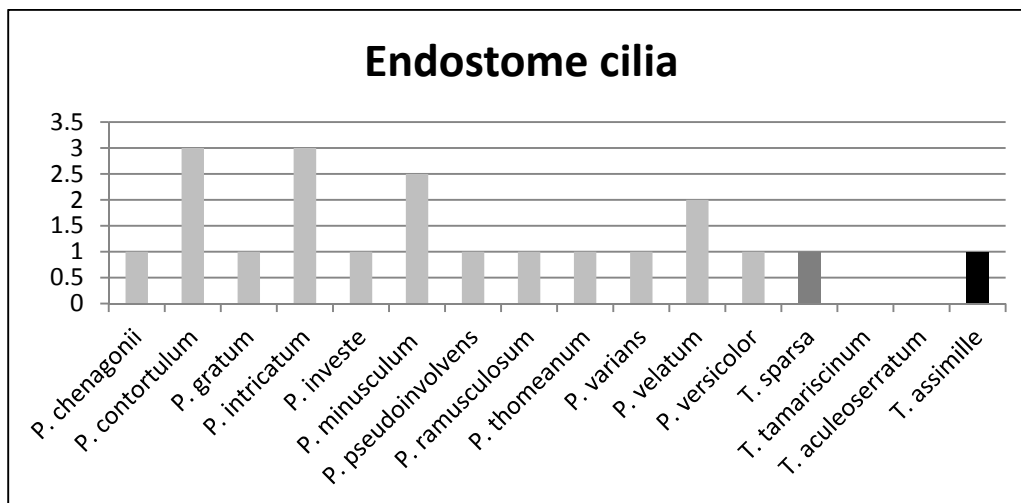


FIGURE 5.24.—Endostome cilia for character 27. Pale grey = *Pelekium*; dark grey = *Thuidiopsis*; black = *Thuidium*.



FIGURE 5.25.—Spore size for character 28. Pale grey = *Pelekium*; dark grey = *Thuidiopsis*; black = *Thuidium*.

CHAPTER 6

TAXONOMIC TREATMENT¹

6.1 FAMILY THUIDIACEAE

Thuidiaceae Schimp.

Classification: Class Bryopsida; Subclass Bryideae; Order Hypnales

Type genus: *Thuidium* Bruch & Schimp.

Common name: Tamarisk-mosses

Plants small and very slender, medium to large and robust; more or less rigid, forming loose to somewhat dense mats, tufts, cushions or wefts; dorsiventrally flattened, spreading, suberect or ascending; rooting mostly at stem base but also occasionally at apex, or where stem is in contact with substrate; when fresh older parts light to dark sordid green, bright green upwards and young parts yellowish green, with age older parts dark brown, upwards orange-brown, terminal parts yellow; shoots often yellow; usually dull because of the paraphyllia and papillose leaves cells. Axillary hairs with 1–3 basal cells, 1(2) distal cells. *Stems* arching, prostrate or creeping with often stoloniform apices; distinctly regularly 2- or 3-pinnately branched, often beautifully frondose; often rather densely tomentose. Central strand present, small. *Paraphyllia* present; few to abundant, scattered to dense; simple or weakly to strongly branched; uniseriate; cells rounded or short to long rectangular, smooth especially below or papillose; terminal cell rounded, acute or truncate. Branches often arcuate or homomallous; shoots complanate; paraphyllia fewer, scattered, often scarce to absent in branchlets. *Leaves* weakly to mostly strongly dimorphic, in size (stem leaves being the widest) and shape; usually longitudinally weakly to strongly plicate; relatively decurrent; often asymmetrical; ovate to narrowly lanceolate, deltoid, or lingulate. *Stem leaves* distant or crowded; larger, appressed to erect-spreading; mainly cordate, or ovate, triangular or ovate-triangular, triangular-lanceolate, lanceolate-subulate or subulate, from a cordate, occasionally decurrent base; apex acute, short to long acuminate or subulate ending in a long awn; margins plane distally to recurved below to insertion; entire to papillose-serrulate; often bearing papylloid appendages at base; costa single; strong or occasionally weak;

¹ For new combinations see Appendix.

extending beyond the middle of the leaf, ending mostly below (percurrent), in or above (excurrent) apex, tip distinct or indistinct; cells linear, elongate, smooth or papillose; often bearing paraphylloid appendages at base; projecting on back, often distally prominent and rough at back (abaxially) with papillae, ending in one or several small spines; laminal cells differentiated to weakly so; more or less mamillate, smooth or uni- to pluripapillose; papillae on back or on both surfaces but strongly developed on abaxial (back) side; papillae low and indistinct to prominent, long, curved and oblique, mostly central, scattered or upper on cell wall; thin to thick walled, walls straight or pitted; terminal cell truncate or acute, smooth or papillose; same length as lower cells or longer; upper cells usually elongated or same as adjacent cells, smooth or uni- to pluripapillose, often smooth or papillose; median cells oblong, rounded, oval, isodiametrical, hexagonal, rectangular, and irregularly angulated or a combination of two or more shapes; basal cells weakly or not differentiated or becoming elongated and weakly papillose to smooth downwards; alar cells mostly weakly to not differentiated, if weakly differentiated cells shorter, oblate and more crowded than adjacent cells; cells at insertion larger, elongated, rectangular, smooth to weakly papillose, usually hyaline, in robust species often pitted and reddish or yellowish brown. *Branch leaves* smaller and narrower; ovate from a rounded base, broadly to somewhat narrowly ovate or ovate-short lanceolate; mostly plane or less plicate than stem leaves; concave; often crowded or distant; leaves of ultimate branches even smaller, mostly ovate or ovate oblong, occasionally oblong, lanceolate or lingulate; apex mostly acute, short acuminate becoming obtuse-rounded distally and in branchlet leaves; margin entire to weakly or strongly papillose-crenulated, plane to recurved below or only at insertion; costa often ending below apex, cells as in stem, shorter; ornamentation on distal part same or stronger than in stem leaves; laminal cells rounded, oblong, irregularly angulated, short rectangular or isodiametrical; smooth or uni- to pluripapillose, papillae low to mostly prominent; terminal cell sharply or bluntly acute or truncate, smooth or papillose; same length as adjacent cells or longer; median cells same shape, usually shorter than stem leaf cells; ornamentation usually more prominent.

Monoicous or dioicous. All monoicous species are with gametoecea of both sexes often in close proximity on the stem. *Perigonia* 0.5–1.5 mm long; bud-shaped; lateral; leaves ovate to short ovate-lanceolate, concave; apex acuminate; costa mostly weak or absent; margins eciliate, plane to strongly recurved, entire to papillose-serrulate; median leaf cells oblong to short-linear, walls thin or incrassate, smooth; antheridia to 500 µm long. *Perichaetia* buds situated at about middle or basal part of stem, lateral; long, polyphyllous, imbricate, rigidly or mostly loosely

tubular; mature inner leaves usually differentiated, large, plane to plicate, long ovate-lanceolate, ovoid, cylindrical to lanceolate; base sheathing; apex gradually ending in a straight, flexuose or twisted short to long caudate, aristate or filiform awn; margins denticulate or serrulate, at shoulder ciliate, serrate, or entire; costa mostly ill-defined, weak or strong; widest at base; reaches up in acumen; median leaf cells oblong to linear; smooth or weakly papillose; thin walled to incrassate; outer leaves shorter, cordate, triangular, cells shorter; paraphyses to 950 μm long; archegonia to 600 μm long. *Seta* elongate, 20–70 mm long; often straight and twisted upwards, smooth, hispid or papillose throughout at neck; orange-red or yellowish brown; neck obconical, pustulose or often wrinkled when dry. *Capsule* exerted, asymmetrical, ovoid, ellipsoid, oval-oblong to cylindrical, inclined, horizontal, sub-erect to sub- or pendulous, usually weakly curved; usually contracted below the wide mouth when dry; often swollen at neck; smooth, long-pedicillate, oval, oblong, cylindrical, slightly curved or curved, rather straight, lightly drooping and horizontal; with an annulus. *Peristome* showy, hypnoid, double, occasionally specialised and more or less reduced, particularly in epiphytes; exostome teeth 16, long; not grouped; not deeply cleft; not perforated; thin, membranous, and transversely barred; exteriorly with a fine longitudinal dividing line between the transverse bars; lanceolate-subulate, bordered, cross-striate below, distally becoming papillose, reddish or orange, yellowish to yellowish brown, ventral lamellae high; endostome well developed; shorter than exostome; with a basal membranous ring; cilia well developed, long, smooth or lightly papillose, paraphyllate, in groups of 1–3 or occasionally 4 of same length; basal membrane wide, folded, low to high, 1/3 of endostome length or shorter; processes as high as teeth, 16, keeled, narrowly perforated lanceolate-subulate, sometimes perforated, broad. *Exothecial cells* isodiametrical to elongate-rectangular, cell walls incrassate, collenchymatous; smooth. *Operculum* short to long rostrate to rounded conical, rostellate or gradually acuminate, obliquely beaked from an arched conical base. *Calyptra* symmetrical, splitting down one side; typically cucullate, occasionally mitrate (in *P. velatum*) or companulate, usually naked and smooth or mamilliose or hispid/spinose in *P. velatum*, base often bordered by a ring of annulus-like yellowish 2-celled row of cells, apex obtuse, mucronate or apiculate. *Spores* spherical or sub-spherical; smooth or papillose; mostly 8–18 μm ; yellowish brown.

Ecology: Plants grow in closed or open forest situations on diverse substrates, including rocky soil, rocks, humus, tree bases, exposed roots, trunks and decaying logs. They can be found in moist and humid or dry places, both shady and exposed. Their altitudinal range is from 250 m to

2000 m. Most dioicous plants grow mainly in cool climates and in almost mesic environments (Touw 2001a).

According to Touw (2001a), monoicous genera are mostly tropical and include many epiphytes. He considered that the large internal diversity within the monoicous genera is caused by adaptations to their epiphytic or tropical lowland habitats. Epiphytic adaptations include reduction or weakness of regular branching, which becomes prominent in unfavourable conditions; erect capsule; insertion of the peristome below the mouth; modification or reduction of exostome ornamentation; paler colour and reduced or absent endostome (Buck & Crum 1990). According to these authors, one should expect gametophytic adaptations to habitat. Also they noted that the sporophyte can be influenced by environment because of its function. They pointed out that the morphological adaptations should be observed when primarily terrestrial organisms adopt epiphytic lifestyle.

Distribution: Members of the family Thuidiaceae grow in temperate and tropical regions of the world (Martin 2003).

6.2 KEY TO THE GENERA AND SPECIES, DESCRIPTION OF TAXA AND ADDITIONAL NOTES

Key to genera of Thuidiaceae

1. Plants medium to large (stems 40–130 mm long); paraphyllia simple or moderately to strongly branched; dioicous; seta smooth **2**
 - Plants small to medium (stems <70 mm long); paraphyllia simple to moderately branched; monoicous; seta smooth or ornamented **1. *Pelekium***
2. Paraphyllia strongly branched; paraphyllia base uniseriate; calyptra without hairs **3. *Thuidium***
 - Paraphyllia mostly simple to moderately branched; paraphyllia base uni- to pluriseriate; calyptra with hairs **2. *Thuidiopsis***

1. *Pelekium* Mitt.

Pelekium Mitt. in Mitten, Trans. Linn. Soc. London 10: 176 (1868).

Type species: *P. velatum* Mitt. The typification of *Pelekium* is according to Buck & Crum (1990).

Plants small to medium (<70 mm), thin, less rigid; forming loose to dense mats; light to dark green, often with tinges of yellow or light green distally. *Stems* loosely spreading; 1–2-pinnate. *Paraphyllia* few, scattered to dense; mostly simple to weakly branched; uniseriate; short to long, 2–7 cells long; cells isodiametrical, hexagonal or rectangular, weakly papillose; terminal cell truncate or acute, papillose or smooth. Pseudoparaphyllia foliose, simple or branched; cells papillose. Axillary hairs consist of one brown basal and about two hyaline distally. Branches remote or closely set; loosely spreading; paraphyllia few to absent in ultimate branches. *Leaves* dimorphic or primary branch leaves weakly differentiated; often biplicate or weakly so; often short decurrent. *Stem leaves* 0.4–0.7 mm long; broadly triangular to ovate, cordate, cordate-triangular, ovate-triangular or triangular, mostly carinate; apex acute or short to long acuminate; margins often recurved below, plane above; papillose-serrulate; costa weak to mostly strong; ending in or below apex, 4/5 of leaf length; laminal cells isodiametrical-quadrangle-rounded, variously angulated hexagonal-rhombic or elongated rectangular-oblong-elliptical; thin or thick walled; smooth, uni- to pluripapillose, on both surfaces, papillae weak to strong, within periphery of cell wall. *Branch leaves* 0.15–0.5 mm long; smaller than stem leaves; loosely placed; ovate to oblong-ovate, ovate to oblong-ovate; concave; apex obtuse, acute or short acuminate; margins mostly plane to recurved; entire to papillose-crenulate; costa weak to strong; 3/4 of leaf length, ending below apex; abaxially cristate by longitudinal rows of cells similar to the laminal cells; laminal cells isodiametrical-quadrangle-rounded or variously angulated and hexagonal-rhombic; terminal cell truncate or acute, pluripapillose.

Monoicous. *Perigonia* 0.5–1 mm long. *Perichaetia* elongated, mature inner leaves ovate-triangular to –lanceolate, or oblong lanceolate; costa extending into acumen, percurrent or excurrent; apex short to mostly long acuminate; margins plane; entire, serrate to ciliate. *Seta* 8–20 mm long; roughened (papillose) throughout or at neck or occasionally smooth. *Capsule* 0.7–2.5 mm long; inclined or pendent, curved or not, rarely erect or suberect; short to long ovoid or ovoid-cylindrical; inclined to horizontal. *Exothecial cells* isodiametrical-quadrangle-rounded or variously angulated hexagonal-rhombic; cell walls incrassate, collenchymatous; smooth. *Peristome* double; exostome teeth cross striate below, papillose upwards, reddish to orange,

yellowish to yellowish brown; segments not or narrowly perforated, endostome membrane high, processes reduced, short or rudimentary, narrow, weakly perforated or not, segments keeled, cilia 1–3(4), most cilia in 2-s or 3-s. *Annulus* in 2 or 3 rows. *Operculum* conic or short to long rostrate, oblique. *Calyptra* cucullate, naked, smooth, companulate, subcylindrical, lobate, spinulose or unique mitrate and hispid in *P. velatum*, apex mucronate or apiculate. *Spores* spherical, smooth to lightly papillose.

Ecology: Plants grow in lowland forests, lower montane forests; on soil, logs, tree bases, rocks; in moist to semi-dry situations; at up to 3000 m. Epiphytic adaptations mentioned by Buck & Crum (1990) that include reduction or weakness of regular branching which becomes prominent in unfavourable conditions and the reduced or absent endostome were observed in some of the species e.g. *P. velatum*, *P. intricatum*, *P. minusculum* and *P. contortulum*.

Distribution: *Pelekium* is mostly tropical (Buck & Crum 2010) and has a circumtropical to temperate distribution and has been reported from tropical Africa, Eurasia, the Pacifics, Australia and the Americas.

Notes: Representing a heterogeneous group in the family, with majority of species, *Pelekium* also consists of most microscopic discrepancies. Touw (1976) already identified most comparatively small differences between species of this genus, which I also observed.

While revising the African members of Thuidiaceae, two African endemics currently recognised in the genus *Thuidium* Bruch & Schimp., *T. involvens* subsp. *thomeanum* (Broth.) A. Touw and *T. pseudoinvolvens* (Müll. Hal.) A. Jaeger were found to display characters typical of the genus *Pelekium*. When Touw (2001a) transferred almost all monoicous species previously treated in *Thuidium* subg. *Microthuidium* to the genus *Pelekium* Mitt., he did not transfer these two taxa, as well as a number of other (mainly South American) species, either because he had not yet examined type specimens or because he was not convinced that they were 'good' taxa (Touw *pers comm.* 2010). I have examined the African taxa in detail and decided to move them to *Pelekium* (Appendix).

The four African specimens from BM that were misidentified as *P. minutulum* have unipapillose, thin-walled laminal cells, short-acuminate stem leaf apices, and short, simple paraphyllia of up to 6 cells long. I re-identified these specimens as *P. versicolor*. I also re-

identified two South African specimens labeled as *P. minutulum* as *P. versicolor*. Only one *P. minutulum* specimen was correctly identified but because it had incomplete locality data its legitimacy is yet to be resolved. Therefore, there is no valid record of *P. minutulum* in Africa hence this species is excluded from this study. *Pelekium minutulum* is predominant in N. and rarely in C. and S. America, West Indies, Europe, Quebec, Bolivia, Ecuador, Spain and Costa Rica.

Pelekium is distinguished from the other two genera of Thuidiaceae in Africa, *Thuidium* and *Thuidiopsis*, by its small size, simple or weakly branched paraphyllia, plane or weakly plicate stem leaves, occasionally ornamented seta and monoicous sexual state. This is the largest and the most morphologically and ecologically diverse genus of African Thuidiaceae. A key to the 12 species of *Pelekium* recognized in Africa, now including *P. thomeanum* and *P. pseudoinvolvens*, is given below.

Key to the species of *Pelekium* Mitt. in Africa

1. Plants mostly minute to small (stems \leq 50 mm long); paraphyllia simple, short (usually \leq 7 cells long)..... **8**
 - Plants medium-sized (stems $>$ 50 mm long); paraphyllia simple to weakly branched, short or long (usually \geq 8 cells long)..... **2**
2. Terminal cells of paraphyllia and stem leaves predominantly acute..... ***P. ramusculosum***
 - Paraphyllia and stem leaf terminal cell mostly truncate..... **3**
3. Stem leaves mostly not plicate; margins plane; apex broadly acute..... ***P. varians***
 - Stem leaves plane to weakly plicate; margins recurved below, plane above; apex acute, acuminate or apiculate..... **4**
4. Stem leaf apex long apiculate; seta strongly hispid..... ***P. velatum***
 - Stem leaf apex acute or acuminate; seta smooth or roughened throughout..... **5**
5. Stems 2- or 3-pinnately branched; laminal cells uni- or bipapillose; perichaetial leaf shoulders ciliate; seta smooth..... ***P. chenagonii***
 - Stems 1- or 2-pinnately branched; laminal cells uni- to pluripapillose; perichaetial leaf shoulders ciliate or eciliate; seta roughened throughout..... **6**
6. Stems 1- or 2-pinnately branched; laminal cells mostly unipapillose, mixed with bi- to pluripapillose ones; perichaetial leaf shoulders eciliate..... ***P. thomeanum***
 - Stems 2-pinnately branched; laminal cells bi- to pluripapillose; perichaetial leaf shoulders ciliate..... **7**
7. Paraphyllia few, mostly simple (see Figure 6.13B); stem leaves plane to weakly plicate..... ***P. pseudoinvolvens***
 - Paraphyllia abundant (see Figure 6.14B), mostly weakly branched; stem leaves mostly plane..... ***P. gratum***
8. Plants wiry; stems irregularly branched; paraphyllia almost absent; stem leaf cells thin-walled..... ***P. investe***
 - Plants not wiry; stems regularly branched; paraphyllia abundant; stem leaf cells thick-walled..... **9**
9. Stems 2-pinnately branched; paraphyllia simple, short; laminal cells with 1–3 papillae; perichaetial leaf shoulders eciliate; seta rough at neck..... ***P. versicolor***
 - Stems 1-, 2-, or 3-pinnately branched; paraphyllia simple to weakly branched; laminal cells with 1 or 2 papillae; perichaetial leaf shoulders ciliate or not; seta smooth or rough at neck..... **10**

10. Stems (1–)2(–3)-pinnately branched; paraphyllia abundant; perichaetial leaf shoulder eciliate; seta rough at neck.....***P. contortulum***
- Stems (1–)2-pinnately branched; paraphyllia few perichaetial leaf shoulders ciliate or not; seta smooth or rough at neck.....**11**
11. Paraphyllia simple to weakly branched; stem leaves plane to weakly plicate; laminal cells uni- or bipapillose; perichaetial leaf shoulders eciliate; seta smooth.....***P. intricatum***
- Paraphyllia simple; stem leaves plane; laminal cells unipapillose; perichaetial leaf shoulders ciliate; seta rough at neck.....***P. minusculum***

1.1 *Pelekium chenagonii* (Müll. Hal. ex Renauld & Cardot) A. Touw in Touw, J. Hattori Bot. Lab. 90: 203 (2001a).

Basionym: *Thuidium chenagonii* Müll. Hal. ex Renauld & Cardot in Renauld & Cardot, Bull. Soc. Roy. Bot. Belgique. 33 (2): 129 (1895).

Other combinations: *Cyrto-hypnum chenagonii* (Müll. Hal. ex Renauld & Cardot) W.R. Buck & H.A. Crum in Buck & Crum Contr. Univ. Michigan Herb. 17: 65 (1990). Type: MADAGASCAR, Diego Saurez, *Chenagon s.n.* [PC holotype, BM, BR, MANCH, W, fide Touw (1976)].

Thuidium chenagonii var. *campyloneuron* Renauld & Paris in Paris, Rev. Bryol. 27: 89 (1900). Type: MADAGASCAR, Soarano, *Croll s.n. ex parte* [PC holotype, FI, G, H, fide Touw (1976)].

Thuidium pycnangiellum Müll. Hal. ex Broth. in Müller ex Brotherus, Bot. Jahrb. Syst. 24: 283 (1897). Syntype: CAMEROON, Bueam, *Dusén 225, ex parte* [BM !, H lectotype, FI, NY, PC, S-PA, UPS, W, fide Touw (1976)]; Cameroon, Rumpi Mts, Jumbo, *Dusén 225, ex parte* [G, NY, S-PA, fide Touw (1976)].

Thuidium pallidisetum Dixon in Dixon, (Smithsonian Misc. Collect 69 (8): 7 (1918). Type: UGANDA, Mt Elgon, *Dummer –Maclennan Exp.* [PRE !]; UGANDA, Kipayo, *Dummer 719/CH 8859* [BM holotype !, US, BOL, PRE, fide Touw (1976)].

Plants medium-sized; loose mats; dark green, pale, green, yellowish, to brown green. *Stems* up to 60–80 mm long; more or less arching; (2)3-pinnately branched. *Paraphyllia* plenty; moderately branched; often bistratose at base or irregularly; short to long, up to 15 cells long; cells rectangular to oblong, strongly papillose; terminal cell truncate, occasionally acute. Axillary hairs consist of 1 or 2 brown basal and 2 hyaline apical cells. Branches 5–8 mm long; pointing to apex; closely set; paraphyllia dense basally, becoming naked upwards and on branchlets. *Leaves* dimorphic; plane to biplicate; short-decurrent. *Stem leaves* 0.4–0.7 × 0.4–0.6 mm; distant to closely set; broadly ovate, cordate or triangular, base usually very broad; plicate; base appendiculate; when dry erect-patent, strongly incurved with twisted apex; when wet erect-patent; apex gradually to abruptly acuminate or acute; often second; margins plane above, recurved below; entire or weakly papillose-crenulate; costa strong; percurrent, ends in apex, tip distinct; abaxially strongly prominent; cells linear and papillose; appendiculate at base; laminal cells 5–12 × 3.5–6 µm; terminal cell acute or obtuse, occasionally truncate, smooth to weakly

pluripapillose; upper cells subquadrate or irregularly angulated; unipapillose, papillae low; median cells variously shaped, hexagonal-rhombic or elliptical; unipapillose, some cells bipapillose, papillae sharp, centered; marginal cells smooth to weakly unipapillose, sometimes oblate; basal cells larger; smooth to occasionally pluripapillose; often reddish brown; alar cells moderately differentiated; cells smaller; papillae prominent. *Branch leaves* up to 0.6 mm long; crowded; when dry crisped, twisted, incurved; when wet spreading to patent-erect; ovate; apex acute or obtuse to acuminate or broadly so; margins plane above, recurved below; papillate-crenulate; costa percurrent, tip distinct; abaxially prominent; cells papillose; terminal cell truncate, occasionally acute; laminal cells same as in stem; 5–7 µm wide; unipapillose, papillae strong.

Monoicous. *Perigonia* 0.5–0.8 mm; leaves ovate or oblong lanceolate, concave, plane or weakly biplicate; apex acute, straight or secund; margins entire; cells rhomboidal or elliptical, smooth, basal cells larger, becoming hyaline downwards and costally, walls thin to incrassate. *Perichaetia* 2.8–3.5 mm long; mature inner leaves oblong-lanceolate; apex gradually or abruptly narrowing to a long straight or flexuose subula; margins entire to weakly serrate, shoulders ciliate; costa strong, excurrent; cells linear-rhomboidal, smooth, walls thin to incrassate, often sinuose, below becoming elongate, often hyaline. *Seta* 10–16 mm long; smooth; reddish below to pale orange upwards. *Capsule* 1.0 mm long; ovoid-elliptic; weakly curved, inclined, horizontal to subpendulous; neck constricted; brownish. *Exothecial cells* short hexagonal; smooth; walls incrassate, collenchymatous. *Peristome* perfect; exostome teeth oblong-lanceolate; cross-striated and trabeculate below, upwards papillose, hyaline and nodulose or trabeculate; endostome membrane $\frac{1}{2}$ the endostome length; processes alternating the exostome teeth, folded, narrowly perforated; cilia in groups of 1–3, free or partly united. *Operculum* 0.8–1.0 mm long; rostrate, from a convex base. *Calyptra* 2.0–3.2 mm long; cucullate; smooth; apex obtuse-truncate; yellowish white. *Spores* 8–15 µm wide; spherical; papillose. See Figure 6.1.

Diagnostic characters: This species is recognized by regularly 3-pinnately branched stems, branched paraphyllia with truncate terminal cell, acute stem leaf terminal cell, mainly unipapillose median stem leaf cells, truncate branch leaf terminal cell, ciliate perichaetial leaf shoulder margin and smooth seta.

Ecology: *Pelekium chenagonii* is an epiphytic and terricolous afro-montane species and is widespread in forests (mixed evergreen, afro-montane vegetation zone, mountain rain forest, thick forest) under cliff, in river valley; on humus, fallen branch, litter covered and decaying

wood of forest bottom, on tree trunk, tree base, rocks, stone, lava blocks, soil, ground; in full light partial to deep shade; in damp or moist environments; at 600–2200 (2750) m.

Distribution: *Pelekium chenagonii* is endemic to Africa and widespread in tropical Africa (Ochyra & Pócs 1982). It occurs in Bioko, Burundi, Cameroon, Central African Republic, Comoros, Guinea, Gabon, Cote d'Ivoire, Democratic Republic of Congo, Kenya, Madagascar, Malawi, Mozambique, Nigeria, Réunion, Rwanda, Sierra Leone, Tanzania, Uganda, Zambia and Zimbabwe. See Map 6.1.

Specimens studied: CAMEROON: *Dusén 225* (BM); *voucher 1081* (BM); *Pócs 9150/AP*. DEMOCRATIC REPUBLIC OF CONGO: *Bequaert 5712* (BM); *Henrickx 4987* (PRE); *Müller Z361, Z364, Z410* (L). KENYA: *Mücke 95* (PRE). MADAGASCAR: *Chenagon s.n.* (BM); *Touw & Snoek 25097* (L). MALAWI: *Touw M7543a* (L). MOZAMBIQUE: *De Torre 6300* (PRE). RÉUNION: *Mildbraed 9133* (BM). TANZANIA: *Greenway & Kanuri 13.532* (PRE); *Rojkowski 385* (BM). UGANDA: *Dummer 719a/ CH8859* (BM, PRE), *720/ CH8856 & 720/CH8860*; *Dummer-Maclennan Expedition CH8858*; *Edwards 17, 18* (BM); *Jones 527*(BM); *Lind 36* (BM); *Thomas Th 2901*(BM); ZIMBABWE: *Müller 2540* (PRE).

Notes: *Pelekium chenagonii* has a neat and pretty regular 3-pinnate branching (Fig. 5.2) and looks pale green, stem leaves with a falcate apex, very broad stem leaf base. The paraphyllia are almost always branched (Fig. 5.3) and stem leaves more plicate than in other *Pelekium* species. *Pelekium chenagonii* is reportedly a slender form of, and looks very close to *T. plumulosum*, a species of South-eastern hemisphere. The material labeled *Recd. 188* (BM) is identified as *T. plumosum* and believed not to be collected from Africa by Touw (1976:181); therefore it was excluded in this study. The specimen of Dummer 719 (PRE) is a mixed collection of *P. varians* and *P. chenagonii*. *Pelekium chenagonii* grows in association with other species such as *Podocarpus latifolius*, *Leucosidea sericea*, *Entodon cameruniae* and *Trichostomum lorifolium*.

1.2 *Pelekium contortulum* (Mitt.) A. Touw in Touw, J. Hattori Bot. Lab. 90: 203 (2001a).
Basionym: *Leskea contortula* Mitt. in Mitten, J. Proc. Linn. Soc., Bot., Suppl. 2: 134 (1859).
Other combination: *Thuidium contortulum* (Mitt.) A. Jaeger in Jaeger, Ber. Thätigk. St.
Gallischen Naturwiss. Ges. 1877–77: 256 (1878). Type: SIKKIM, *Hooker 1124* [NY holotype;
MB, FH, isotype !].

Thuidium trachelocarpum Dix. & P. de la Varde in P. de la Varde, in Ann. Cryptog. Exot. 1: 44.
4 f. 1. (1928). Type: South India, *Foreau 715* [BM lectotype; H isotype].

Thuidium benguetense Broth. ex E.B.Bartr. in Philipp. J. Sci. 68: 291 (1939). Type:
PHILLIPINES, Elmer 8566 (FH lectotype; L, S, US, W, isotype; BM, H, isotype, no. 8566a),
PHILLIPINES, McGregor BS8689 [FH, H, MO, NY, syntypes].

Thuidium brevisetum E.B.Bartr. in Rev. Bryol. Lichénol. 30: 201 (1962). Type: PAPUA NEW
GUINEA, Robbins 2723 [FH holotype; B, L, isotype].

Plants small; yellowish green, sordid green, yellowish or rusty brown. *Stems* about 30 mm long; thin, slender; proliferous, straight or flexuose; creeping, arching or ascending; regularly or mostly irregularly (1–)2(–3)-pinnately branched; often strongly tomentose. *Paraphyllia* crowded, or few to sometimes absent; simple; sometimes bistratose at base; short, up to 5 cells long; cells oblong-rectangular, smooth to strongly papillose; terminal cell truncate or rounded, occasionally acute, pluripapillose. Axillary hairs of 1(2) basal cells and 1 distal cell. Branches 4–5 mm long; ascending, flexuose; closely set, strongly ramified; when dry terete; when wet weakly compressed; paraphyllia absent or nearly so. *Leaves* differentiated. *Stem leaves* up to 0.5 mm × 0.3 mm; ovate-triangular to broadly triangular; remote or closely set; when dry folded and incurved or falcate-secund from a patent base; when wet patent; fairly plicate; paraphyllate at base; apex acute to short-acuminate, gradually short-acuminate, straight or flexuose; margins recurved below, plane upwards; papillose-crenulate; costa strong; smooth; percurrent, disappearing in apex, tip indistinct; paraphyllate at base; terminal cell truncate-rounded; smooth or minutely pluripapillose; upper cells elongate, smooth; medium cells 5–8 µm wide; isodiametrical, oblong or irregularly 4–6-angulated; uni- to pluripapillose, mostly bipapillose, papillae central or upper on cell wall, more prominent on lower surface; walls incrassate; basal cells weakly differentiated; larger and longer than adjacent cells; smooth to pluripapillose; alar cells not differentiated. *Branch leaves* up to 0.3 mm long; ovate to ovate-oblong; weakly

complanate; asymmetrical; weakly plicate; when dry widely patent, strongly incurved and catenulate; when wet straight and concave; apex broadly acute, blunt or rounded to shortly acuminate; margins irregularly plane or recurved; papillose-crenulate; costa up to 0.7–0.8 the leaf length; rough at back; terminal cell truncate; median cells 6–8 μm wide; isodiametrical or irregularly angulated; thin walled; uni- to pluripapillose, up to four low to prominent papillae; ornamentation on both surfaces; basal cells weakly differentiated; larger; alar cells not differentiated.

Monoicous. *Perigonia* leaves ovate-lanceolate; weakly plicate; apex acute to setaceous; margins entire, bordered by short- to long-rectangular cells; costa weak; laminal cells rhomboidal to linear-rhomboidal, smooth. *Perichaetial* 1.2–2 mm long; mature inner leaves ovate-lanceolate; spreading; apex flexuose or straight, apiculate or subulate; margins serrulate, shoulder eciliate; costa fairly strong, ends in acumen or excurrent. *Seta* 15–17 mm long; straight or flexuose; distinctly rough at neck, smooth below; reddish or brownish. *Capsule* 1–1.5 mm long; ovoid to cylindrical, curved, constricted below orifice when dry; horizontal, suberect to weakly inclined; pale brown; stomatal near base. *Exothecial cells* quadrate or isodiametrical; thin walled or moderately incrassate, collenchymatous; smooth. *Peristome* perfect; exostome yellowish to hyaline above, reddish, orange or brownish below; ventral lamellae high; endostome as long as exostome, basal membrane 1/3 of exostome height; endostome cilia absent. *Operculum* up to 1mm long; narrowly rostrate, long subulate. *Calyptra* 0.7–1(2.2) mm long; narrowly cylindrical, cucullate; naked; brownish at base. *Spores* 13–30 μm wide, minutely papillose. See Figure 6.2.

Diagnostic characters: This species is characterized by irregular bipinnately branched stems, simple paraphyllia, truncate terminal cell of paraphyllia, stem and branch leaves, bipapillose stem leaf median cells, eciliate perichaetial leaf shoulder margins, seta rough at neck, stomatal capsule base and lack of endostome cilia.

Ecology : *Pelekium contortulum* is an epiphytic mountain species growing in open, isolated, upper montane or swamp forests; on tree trunks or bark, branches, twigs, occasionally on decaying wood and rocks; at 1160 m.

Distribution: *Pelekium contortulum* is a tropical eastern species occurring in Uganda and Tanzania. Elsewhere it occurs in Philippines, New Guinea, Pakistan, Himalayas, China, India, Malaysia and Japan. See Map 6.2.

Specimens studied: TANZANIA: *Pócs & Jones 6376/F* (L). UGANDA: *Lye B389* (L). SIKKIM: *Hooker 1124* (FH, BM). BALI: *Kofman 28*(NY). N. THAILAND: *Robbins 3595*(NY). CHINA: *Redfearn, Magill, Crosby, Wu, Lou & Wang 33854, 33882, 34237, 34253* (NY).

Notes: Sporophyte not seen on examined material; description according to Touw (2001b). *Pelekium contortulum* is another small species that resembles *P. versicolor*. It is known as a plastic species with considerable variation and plants at the extremes bearing little resemblance to each other. It differs from *P. versicolor* by ornamentation of branch leaf cells, spore size, lack of endostome cilia and endostomial capsule (Touw 2001b).

1.3 *Pelekium gratum* (P. Beauv.) A. Touw in Touw, J. Hattori Bot. Lab. 90: 203 (2001a).

Basionym: *Hypnum gratum* P. Beauv. in Palisot de Beauvois, Prodr. Aethéogam. 64. (1805).

Other combinations: *Thuidium gratum* (P. Beauv.) A. Jaeger, in Jaeger, Ber. Thätigk. St.

Gallischen Naturwiss. Gen. 1876–77: 256 (1878).

Cyrto-hypnum gratum (P. Beauv.) W.R. Buck & H.A. Crum in Buck & Crum, Contr. Univ.

Michigan Herb. 17: 65 (1990).

Thuidium gratum ssp. *gratum* (P. Beauv.) A. Touw in Touw, J. Hattori Bot. Lab. 90: 203

(2001a). Type: NIGERIA, Oware et Benin, *Beauvois s.n.* [BM isotype !, G holotype, H isotype, fide Touw (1976)].

Thuidium gratum subsp. *subscissum* (Müll. Hal. ex Besch.) A. Touw in Touw, J. Hattori Bot.

Lab. 90: 203 (2001a).

Cyrto-hypnum gratum subsp. *subscissum* (Müll. Hal. Ex Besch.) W.R. Buck & H.A. Crum in

Buck & Crum, Contr. Univ. Michigan Herb. 17: 65 (1990). Type: NOSY BÉ, *Boivin s.n.* [PC lectotype, fide Touw (1976), BM, FI]

Hypnum nabambissense Müll. Hal. in Müller, Linnaea 39: 470 (1875).

Thuidium nabambissense (Müll. Hal.) A. Jaeger in Jaeger, Ber. Thätigk. Gall. Naturwiss. Ges.

1878–77: 256 (1878). Type: SUDAN, Niamniam, Nabambisso, Mbanga, *Schweinfurth s.n.* [BM isotype & lectotype !].

Hypnum ferricola Müll. Hal. in Müller, Linnaea 39: 329–471 (1875).

Thuidium ferricola (Müll. Hal.) A. Jaeger in Jaeger, Ber. Thätigk. Gallischen Naturwiss. Ges.

1878–77: 256 (1878). Type: SUDAN, Dar Fertit, ad flumen Dschih in solo ferruginoso,

Schweinfurth s.n. [B holotype lost, BM lectotype fide Touw, NY].

Hypnum chloropsis Müll. Hal. in Müller, Flora 69: 525 (1886).

Thuidium chloropsis (Müll. Hal.) Paris in Paris, Index Bryologicus. 1278 (1897). Type:

GABON, Lebrville, ad saxa, *Moenkemeyer 6* [G holotype, H, JE, S-PA, fide Touw (1976)].

Plants minute to medium, forming horizontal mats or wefts; pale, yellow-green, dark-green or brown-green. *Stems* 40–150 mm long; delicate, slender, wiry, flexuose, prostrate, arching or creeping; regularly, remotely to densely bipinnately branched. Axillary hairs of 1 brown basal and 1 or 2 hyaline apical cells. *Paraphyllia* abundant, crowded to remote; short to long, 4–10(17)

cells long; simple to mostly moderately branched; cells short-hexagonal or isodiametrical, coarsely papillose; terminal cell rounded-truncate, mostly short, papillose. Branches up to 6 mm long; closely set; spreading out, ascending to complanate, loose imbricate; paraphyllia dense on basal part, scattered to almost naked upwards and on branchlets naked. *Leaves* dimorphic; plane to weakly plicate both wet and dry. *Stem leaves* up to 0.3–0.6 mm by 0.2–0.4 mm; lanceolate, broadly cordate-triangular, ovate or deltoid, base wide; when dry appressed to weakly spreading or patent, concave with flexuose apex and appressed to erecto-patent base; patent-erect when wet; mostly remote set; short decurrent or not decurrent; occasionally paraphyllate basally; apex acute or ends in a tapering mostly abruptly, or gradually short or long narrow acumen or hair tip; margin plane upwards, recurved irregularly or only below, papillose-crenulate, occasionally entire, bordered by 1 or 2 rows of short, oblate cells; costa strong; percurrent, or fading in apex, tip distinct or indistinct; abaxially prominent, ends in a spine or a projecting short pluripapillose cell, more or less verrucose by projecting cell apices and papillae; base often short-appendiculate; laminal cells 6–12 $\mu\text{m} \times 5\text{--}7 \mu\text{m}$; fairly thin-walled; terminal cell mostly short, rounded-truncate; upper cells longer and smooth or same as adjacent cells, downwards becoming isodiametrical, rectangular or hexagonal; smooth to pluripapillose, papillae low to prominent; median cells 6–8 μm wide; rhomboid-hexagonal; pluripapillose, up to four prominent papillae scattered over cell wall; walls thin to weakly incrassate; basal cells larger, rectangular to hexagonal, smooth to pluripapillose; alar cells not differentiated. *Branch leaves* 0.2–0.3(0.35) mm long; narrow-lanceolate or -ovate; when dry crisped, appressed to spreading loosely catenulate with incurved apex; when wet patent erect, spreading, concave; often asymmetrical; lanceolate to ovate; plane to weakly plicate; apex broad, abruptly narrowed to rounded, acute or short-acuminate; costa strong, often hyaline; percurrent, ends below apex, tip distinct; cells prorate; abaxially cristate, prominent and strongly papillose distally; margins often plane on one side and recurved on the other; papillose-crenulate, irregularly toothed; bordered by short, oblate cells; terminal cell short, rounded-truncate; laminal cells 5–7 μm wide; short, isodiametrical; crowded; pluripapillose, papillae low, often indistinct; walls incrassate.

Monoicous. Sporophyte almost always present. *Perigonia* inner leaves 0.5–1 mm long; sub-triangular or broadly lanceolate, concave or plane; apex gradually or abruptly acute to long acuminate; margins plane, entire, shoulders ciliate or not; cells linear rhomboidal or rectangular, smooth or weakly papillose, thin-walled; costa weak, percurrent. *Perichaetial* 1.5–2 mm long; mature inner leaves lanceolate, cordate or ovate; apex gradually to mostly abruptly subulate to a long awn, erect to flexuose; costa strong, excurrent; margins plane to weakly recurved, entire to

serrate, shoulders ciliate; median cells elongate hexagonal to linear, smooth to weakly papillose. *Seta* up to 15 mm long; strongly papillose throughout; reddish brown. *Capsule* 0.6–1.5 mm long; inclined to horizontal to pendulous or subpendulous; ovoid to sub-cylindrical; pale yellowish to reddish brown. *Exothecial cells* short-hexagonal or -rhombic; smooth; walls incrassate, collenchymatous. *Peristome* perfect; exostome teeth oblong-lanceolate, cross-striated and short-trabeculate below, becoming papillose and trabeculate upwards, yellowish below, hyaline above; endostome shorter than or equal to exostome; membrane less than $\frac{1}{2}$ the length of processes; processes alternating the exostome teeth, partly folded, papillose, narrowly perforated above; endostome cilia in groups of 1–3, longer than or as long as the processes, free to more or less united. *Operculum* 1 mm long; long rostrate. *Calyptra* up to 2 mm long; narrowly cucullate; naked, smooth; straw-coloured, apex obtuse. *Spores* 10–20 μ m wide; smooth to weakly papillose. See Figure 6.3.

Diagnostic characters: *Pelekium gratum* is easily recognized by its delicate, wiry habit, regularly bipinnately branched stems, simple to weakly branched paraphyllia with short, isodiametrical, coarsely papillose cells, rounded-truncate terminal cell of paraphyllia, stem and branch leaves, pluripapillose stem leaf median cells, ciliate perichaetial leaf shoulder margins and seta strongly papillose throughout.

Ecology: This is a lowland rain forests species and grows on forest floor in open forests, dense forests, secondary lowland forest, closed evergreen forest, or often in gully; on rotting logs, tree trunk, tree bases, tree roots, or variety of solid substrates like soil, rocks (laterite, laval rocks, limestone, concrete); in moist or near water source, in light to full shade; from sea level to higher elevation, at 0 (30–)370–1600 m.

Distribution: *Pelekium gratum* is the most widespread of all *Pelekium* species and predominant in West African countries (Ochyra & Pócs 1986). It grows in West, Central and East tropical Africa and islands and very common in Angola, Annobón Island, Benin, Bioko, Burkina Faso, Burundi, Central African Republic, Cameroon, Comoros, Congo, Côte d’Ivoire, Democratic Republic of Congo, Equatorial Guinea, Gabon, Ghana, Guinea Bissau, Guinea, Liberia, Madagascar, Mali, Malawi, Mayotte, Nigeria, Senegal, Seychelles, Sierra Leone, Sudan, Tanzania, Togo and Uganda. Elsewhere it occurs in tropical parts of continental Asia, Malaysia, Melanesia, Tonga, Samoa, Sri Lanka and Australia. See Map 6.3.

Specimens studied: ANGOLA: *Gossweiler 4633, Pearson 2309, Welwitsch 143* (BM). CAMEROON: *Argent AR874, AR881, Dusén 65, Zenker 1202b, 1926, 2362, 2448d, 3930*, (BM). CÔTE D'IVOIRE: *Porembski 439, 520* (L). DEMOCRATIC REPUBLIC OF CONGO: *Babet 123, Vanderyst s.n., 279* (PRE); *Bequaert 1024, 1539 Overlaet 568, Philippe 364, 402, Vermeulen 409* (BM); *Müller Z363, Z419* (L). GABON: *Balázs 4764* (BM); *Dorr & Barnett 4259* (L). GHANA: *Cummis s.n., Johnson s.n., 22* (BM). GUINEA: *Pobeguin s.n.* (BM); *Porembski 188* (L). GUINEA BISSAU: *Maclaud s.n.* (BM). KENYA: *Jones 632* (BM). MADAGASCAR: *Marie s.n., 9, 76, 78, 92a, Hildebrandt 2062* (BM). MALAWI: *Lillie 2561*(BM). MAYOTTE: *Marie s.n., 39, Marie 170* (BM). NIGERIA: *Barter 919, Beauvois s.n., Saxby 1, Moenkemeyer s.n.* (BM). SIERRA LEONE: *Thomas 2002, 2126, 373, 4417* (BM); *Marmo s.n.* SUDAN: *Schweinfurth s.n.* (BM). TANZANIA: *Leighton CH8952*. UGANDA: *Dummer 4336, Jones 613* (BM). AUSTRALIA: *Streimann 42428, 46476* (L). INDONESIA: *Touw & Snoek 22576* (L). MALAYSIA: *Klazenga 2067* (L). PAPUA NEW GUINEA: *Hovenkamp 91/9* (L). PHILLIPPINES: *Tan 92-237* (L). N. THAILAND: *Schäfer-Verwimp & Verwimp 16123* (L). JAPAN: *Sugimura 3613*

Notes: *Pelekium gratum* is characterized by a combination of pluripapillose (1–4) stem laminal cells, prominent papillae, acute stem leaf apex; simple, short- to long-branched paraphyllia with short and isodiametrical, pluripapillose cells, densely papillose seta, and ciliate inner perichaetial leaf margins. Paraphyllia look almost like those of *Rauiella subfilamentosa*. Australian and Philippines plants are smaller and their stem leaves have broader base. *Pelekium gratum* often grows in association with leafy liverworts, *Porotrichum elongate*, *Philonotis* sp, *Calymperes rhyariophyllum*, *Rhacopilum orthocarpoides* and *Elaeis guineensis*.

1.4 *Pelekium intricatum* (A. Jaeger) A. Touw in Touw, J. Hattori Bot. Lab. 90: 203 (2001a).

Basionym: *Leskea intricata* Mitten in Mitten, J. Proc. Linn. Soc. Bot. 7: 161 (1864).

Other combinations: *Thuidium intricatum* A. Jaeger in Jaeger, Ber. Thätigk. St. Gallischen Naturwiss. Ges. 1876–77: 251(1878).

Cyrto-hypnum intricatum (A. Jaeger) W.R. Buck & H.A. Crum in Buck & Crum (1990). Type: CAMERRON, Mt Cameroon, *Mann s.n.* [BM isotype !, NY holotype, H, BM, K, fide Touw (1976)].

Plants minute to small; light green, yellow green to brownish green, delicate mats. *Stems* creeping to arching, 20–45 mm long; irregularly 1 or 2-pinnately branched. *Paraphyllia* very few; short to mostly long, 3–7 cells long; simple to weakly branched; sometimes bistratose at base; cells quadrate or short-rectangular, mostly short, smooth or weakly papillose; terminal cell truncate. Branches up to 6 mm long; often flexuose, pointing in same direction; delicate; distant; paraphyllia few to naked at branchlets. *Leaves* sometimes short-decurrent; differentiated. *Stem leaves* 0.35–0.55 mm long by 0.3 mm; cordate-triangular or broadly lanceolate-triangular; distant; asymmetrical; mostly plane, sometimes weakly plicate; when dry strongly incurved, appressed; when wet patent, suberect; apex mostly abruptly short- or long- acuminate; second; margins mostly plane, plane only above or on one side, recurved downwards or on one side; papillose-crenulate; often bordered by a row of oblate sharply papillose cells; costa strong, percurrent, disappearing in apex, tip often distinct; abaxially more or less prominent; paraphyllate at base; terminal cell acute, occasionally truncate, often long, smooth or papillose; upper cells short- to long- hexagonal, smooth to papillose; median cells 6–12 mm by 6 µm; short-hexagonal; mostly unipapillose, rarely bipapillose, papillae distinct, sharp, large, central; walls thin to incrassate; basal cells larger; rectangular; smooth or papillose; often yellowish brown; alar cells not differentiated. *Branch leaves* distant; up to 0.45 mm long; when dry crisped, incurved; when wet patent-erect or spreading; ovate-lanceolate; weakly plicate; often asymmetrical; apex acute to short-acuminate; margins plane throughout, or only upwards and recurved basally; papillose-crenulate; costa strong; ends below apex, tip distinct; abaxially prominently coarsely papillose; laminal cells 6–9 µm wide; isodiametrical or quadrate; uni- or bipapillose, papillae often low; terminal cell truncate, occasionally acute or obtuse.

Monoicous. *Perigonia* 0.5 mm long; leaves ovate-lanceolate, apex acute to short-acuminate, margins plane, or recurved, entire to serrate; costa weak, percurrent; cells linear-rhomboidal or long-hexagonal, smooth to unipapillose, walls thin. *Perichaetia* up to 2 mm long; mature inner

leaves ovate-lanceolate, plane or concave, apex gradually subulate; costa weak to strong, percurrent; margins plane, entire to serrulate, shoulders eciliate, cells linear-rhomboidal or -rectangular, smooth, walls incrassate to thin. *Seta* 8–10 mm long; smooth; orange-brown. *Capsule* 1.0–1.7 mm long; elliptical to short cylindrical; suberect to inclined, curved to almost straight; brownish. *Exothecial cells* short- to long- hexagonal; smooth; walls incrassate, minutely collenchymatous. *Peristome* teeth filiform, solid, nodulose, papillose; cilia absent; operculum 0.5 mm long; conical-rostrate. *Calyptra* up to 2.5 mm long; cucullate; thin, slender, smooth. *Spores* 10–17 µm wide; papillose. See Figure 6.4.

Diagnostic characters: This species is characterized by irregularly 1- or 2-pinnately branched stems, simple to weakly branched paraphyllia with occasional bistratose base and truncate terminal cell, acute stem leaf terminal cell, unipapillose stem leaf median cells, truncate branch leaf terminal cell, eciliate perichaetial leaf shoulder margins, smooth seta and lack of endostome cilia.

Ecology : *Pelekium intricatum* is epiphytic and restricted to mountains and grows in forests; on tree trunk; at (610) 1000–2740 m.

Distribution: *Pelekium intricatum* occurs in Bioko, Burundi, Cameroon, Democratic Republic of Congo, Madagascar, Rwanda, Sierra Leone and Uganda. See Map 6.4.

Specimens examined: CAMEROON: *Dusén* 225 (BM); *Dusén s.n.* (NY); *Mann s.n.* SIERRA LEONE: *Scott Elliot s.n.* (BM). DEMOCRATIC REPUBLIC OF CONGO: *Bequaert 118, 6365* (BM); *Müller Z147* (L).

Notes: *Pelekium intricatum* is often mistaken for *P. versicolor* when sterile while in fact the former has irregular ramification with often abruptly long-acuminate apices of stem leaves, stem leaf margins plane and less prominent median cell papillae. *Pelekium intricatum* is similar to *P. minusculum* by acute terminal stem leaf cell (Figure 6.4E). It is the only species among the small-sized *Pelekium* that has branched paraphyllia (Figure 6.4B) and smooth seta. *P. intricatum* also lacks cilia (Figure 6.4N).

1.5. *Pelekium investe* (Mitt.) A. Touw in Touw, J. Hattori Bot. Lab. 90: 203 (2001a).

Basionym: *Hypnum investe* Mitt. in Mitten, Hooker's J. Bot. Kew Gard. Misc. 8: 355 (1856).

Other combinations: *Leskea investis* (Mitt.) Mitt. in Mitten, J. Proc. Linn. Soc., Bot., Suppl. 135 (1859).

Thuidium investe (Mitt.) A. Jaeger in Jaeger, Ber. Thätigk. St. Gallischen Naturwiss. Ges. 1876–77: 252 (1878).

Cyrto-hypnum investe (Mitt.) W.R. Buck & H.A. Crum in Buck & Crum, Contr. Univ. Michigan Herb. 17: 66 (1990). Type: BURMA, Tenasserim, on rocks, Moulmein, *Parish 15* [NY holotype, fide Touw (1976), BM isotype, fide Touw (2001b)].

Thuidium byssoideum Besch. in Bescherele, Ann. Sci. Nat., Bot., sér. 7, 2: 95 (1885).

Cyrto-hypnum byssoideum (Besch.) W.R. Buck & H.A. Crum in Buck & Crum, Contr. Univ. Michigan Herb. 17: 66 (1990). Type: MAYOTTE, *Marie s.n.* [BM isotype !].

Thuidium tenuissimum Welw. & Duby in Duby, Mém. Soc. Phys. Genève 21: 442, t, 5, f, 2 (1871).

Cyrto-hypnum tenuissimum (Welw. & Duby) W.R. Buck & H.A. Crum in Buck & Crum, Contr. Univ. Michigan Herb. 17: 66 (1990). Type: ANGOLA, Distr. Pungo, Adongo, ad terram madidam juxta rivulos in ipso praesidio loco dicto 'Barraco Grande de Catete', *Welwitsch 51* [BM isotype !, G holotype, BM, L, PC, fide Touw (1976)].

Thuidium perbyssaceum Müll. Hal. ex Broth. in Müller, Bot. Jahrb. Syst. 24: 283 (1897). Type: CAMEROON, Ekundu N'dene, *Dusén 267* [BM isotype !].

Thuidium strangulatum P. de la Varde in Potier de la Varde, Rev. Bryol. Lichénol. 11: 176. 1, 5 (1939). Type: CENTRAL AFRICAN REPUBLIC, Oubangui, Subdiv. de Bocaranga, sources de la Kali, ravin très peu boise, *Eckendorf s.n.* [PC holotype, BR, fide Touw (1976)].

Plants small very delicate; forming intricate low wefts of diffuse, dense interwoven tufts or open fronds; yellowish green to brownish green, sordid green or blackish green. *Stems* about 30 mm long; thin, very slender, inconspicuous, flexuose, creeping, arching or repent; irregularly 2-pinnately branched. *Paraphyllia* very few to mostly absent, scattered; simple; short, 1–3 cells long; cells mostly smooth; terminal cell mostly truncate or conical; pluripapillose or smooth. Axillary hairs of 2 or 3 basal cells and 1 distal cell. Branches 3–5 mm long; complanate; mostly

ascending-parallel; often remote. *Leaves* not decurrent. *Stem leaves* 0.2–0.45 mm by 0.1–0.25 mm; narrowly ovate, triangular or deltoid; distant; erecto-patent, spreading to patent both wet and dry, slightly concave when wet, plane; apex gradually or abruptly acuminate, occasionally ending in a hair tip of 2 or 3 cells; acumen narrow, broader in shorter leaves; weakly recurved or second; margins plane or weakly recurved; weakly papillose-crenulate below, sub-entire upwards; costa weak; percurrent; terminal cell truncate or rounded; pluripapillose; median cells 5–8 μm wide; hexagonal, or rhomboidal; smooth to pluripapillose, 1–4 mostly low or prominent papillae; thin walled; basal cells larger; smooth; alar cells not differentiated. *Branch leaves* up to 0.2 mm long; ovate to ovate-oblong; mostly weakly complanate, loosely catenulate, densely or remotely set; asymmetrical; concave, slightly to strongly incurved with incurved apex both wet and dry; when dry appressed; apex narrowly or broadly obtuse, blunt, or broadly acute; margins plane; coarsely papillose-crenulate; costa to 0.6 the leaf length; abaxially strongly prominent; ends in a projecting cell; laminal cells weakly differentiated; terminal cell conical; pluripapillose; median cells 5–8 μm wide; isodiametrical or quadrate; more or less opaque by projecting papillae, pluripapillose, with 1–4 low indistinct to prominent papillae; mostly thin walled.

Monoicous. *Perigonia* leaves about 1 mm long; ovate-lanceolate; apex caudate; costa strong, ending in a subula; margins plane, entire; weakly bordered by rectangular cells; cells linear-rhombic, smooth, walls incrassate. *Perichaetia* up to 1.5 mm long; mature inner leaves ovate-lanceolate; apex gradually or abruptly contracted to a flexuose subula or long acuminate, recurved to squarrose-recurved; margins plane, entire to crenulate, shoulders eciliate; costa weak, more or less ecostate, ending in subula; cells linear-rhomboidal, or -rectangular, smooth, walls incrassate. *Seta* (4.5)6–12 mm long; reddish brown; strongly papillose throughout, sometimes only in upper part. *Capsule* 1–1.8 mm long; ovoid, obovoid to cylindrical, curved; inclined, horizontal to pendulous; constricted below orifice when dry; yellowish brown. *Exothecial cells* hexagonal-rhombic; smooth; incrassate, collenchymatous. *Peristome* perfect; exostome teeth longer than or as long as endostome; oblong-lanceolate; yellowish, cross-striated and trabeculate below, becoming nodulose and papillose upwards, hyaline at apex; endostome almost as long as exostome; membrane $\frac{1}{2}$ the processes height; processes alternating exostome, weakly folded, perforated, yellowish; endostome cilia in groups of 2–3, free, shorter than to as long as processes. *Operculum* 0.6–1 mm long; abruptly long rostrate; asymmetrical. *Calyptra* 1.3–1.5 mm long; narrow, cucullate; smooth. *Spores* 11–15 μm wide; weakly papillose. See Figure 6.5.

Diagnostic characters: *Pelekium investe* has a delicate habit with very slender, irregularly, bipinnately branched stems, few to absent, simple paraphyllia with truncate terminal cell, truncate stem leaf terminal cell, thin-walled, pluripapillose stem leaf median cells, conical branch leaf terminal cell, eciliate perichaetial leaf shoulder margins and seta strongly papillose throughout.

Ecology: *Pelekium investe* is a rain forest, lowland forest bottom species of evergreen forests, terrestrial, clayey soil or near streams; on rocks (limestone, sandstone, soil-covered, preferably weathered), clay soil, and tree bases; in deep shade to moderately open situation; in humid; at 30–1800m.

Distribution: This is a Tropical west and central African species and occurs in Angola, Bioko, Cameroon, Central African Republic, Comoros, Democratic Republic of Congo, Equatorial Guinea, Gabon, Guinea, Madagascar, Mayotte, Nigeria, Sierra Leone and Togo. Elsewhere it occurs in Tropical Asia, Australia, Society Islands, Malaysia, Peninsula, Java, Panay, New Guinea, India, Burma, Indonesia, Philippines and Sri Lanka. See Map 6.5.

Specimens studied: ANGOLA: *Welwitsch 196* (BM). CAMEROON: *Argent AR.514, AR.823* (BM); *Dusén 267* (PRE); CENTRAL AFRICAN REPUBLIC: *Tisserant 2203* (BM). DEMOCRATIC REPUBLIC OF CONGO: *Bequaret 7769* (BM). GUINEA: *Pobeyan s.n.* (BM). MAYOTTE: *Marie s.n.* (BM). NIGERIA: *Browne 2* (BM). SIERRA LEONE: *Thomas 2120* (BM). INDONESIA: *Touw & M. Snoek 22548, 24296* (L). JAVA: *Moller s.n.* (NY). PHILLIPINES: *Curevas 137, Robinson 17212, Williams 856, 1844* (NY). SERAM: *Akiyama 10855* (NY). SOCIETY ISLANDS: *Sloover 21.125, 21.168, Whittier 2353, 2554, 2938, 2557, 2936, 2959* (NY).

Notes: *Pelekium investe* is the smallest and most delicate plant among African members of *Pelekium*, with a character combination of thin, inconspicuous, naked stems, ascending branches, very weakly papillose laminal cells, collenchymatous exothelial cells, and rough seta. The species seems to be variable. Touw (1976)'s *T. tenuissimum* has entire perichaetial leaf shoulder margins and seta strongly papillose throughout and *T. byssoides* with ciliate perichaetial leaf shoulder margins and distally rough seta. According to a note on voucher Williams 1844 (NY) from Philippines, *P. investe* is described as having a smooth seta yet this material has a seta more or less rough in upper part. The African material also has seta rough in upper part.

1.6 *Pelekium minusculum* (Mitt.) A. Touw in Touw, J. Hattori Bot. Lab. 90: 204 (2001b).

Basionym: *Leskea minuscula* Mitt. in Mitten, Musci Indiae Orientalis. J. Proc. Linn. Soc. Bot. Suppl. 1: 134 (1859).

Thuidium minusculum (Mitt.) A. Jaeger in Jaeger, Ber. Thätigk. Gall. Naturwiss. Ges. 1876/77: 211–454 (1878).

Cyrto-hypnum minusculum (Mitt.) W.R. Buck & H.A. Crum in Buck & Crum. Contrib. Univ. Michigan Herb. 17: 55–69 (1990). Type: KHASIA, Nimkbou, *Hooker & Thomson 1071* [BM isotype !].

Thuidium squarrosulum Renauld & Cardot in Renauld & Cardot, Bull. Soc. Roy. Bot., Belgique 38 (1):31 (1900).

Cyrtohypnum squarrosulum (Renauld & Cardot) W.R. Buck & H.A. Crum in Buck & Crum, Contrib. Univ. Michigan Herb. 17:67(1990). Type: SIKKIM, Darjeeling, Stevens 159 [PC lectotype, S isotype, both fide Touw (2001b)].

Plants small; whitish green, pale yellowish green or pale sordid green. *Stems* about 25 mm long; creeping; flexuose or arching; mostly regularly or irregularly (1)2-pinnately branched.

Paraphyllia few, rarely crowded; simple; short, 1–4 cells long; cells smooth or unipapillose; terminal cell acute, smooth, occasionally truncate. Axillary hairs 2-celled, distal cell yellowish-brown. Branches 4(–6) mm long; spreading-ascending, flexuose or straight; naked or nearly so.

Leaves weakly dimorphic; decurrent. *Stem leaves* up to 0.5 mm long; broadly ovate, deltoid to short-lanceolate or semi-orbicular; plain; closely set, variously oriented; when dry mostly incurved from a patent base; when wet widely patent to recurved; apex abruptly contracted to a narrow acumen, occasionally ending in a row of 2 cells; recurved; margins strongly recurved below, plane or slightly incurved upwards; minutely papillose-crenulate or almost entire; costa weak, narrow; percurrent, disappearing and indistinct just below the apex; abaxial face weakly prominent; terminal cell acute, sometimes rounded or truncate; hyaline; pluripapillose; upper cells papillae often very low and rounded; median cells 4–8 μm wide; rounded, isodiametrical to irregularly short-elliptic or -angulated; weakly unipapillose, ornamentation on both faces similar but less pronounced on adaxial face; thin walled or moderately incrassate; basal cells larger; papillae taller and conical; alar cells not differentiated. *Branch leaves* 0.2–0.3 mm long; ovate; strongly concave, closely set; when dry erect-strongly incurved and folded; when wet widely patent and not folded; apex mostly broadly acute to short-acuminate, occasionally rounded; margin plane; minutely crenulate; costa 0.7–0.9 the leaf length; abaxial face weakly prominent,

distal abaxial epidermal cells linear, smooth or prorulate-spinulose; terminal cell acute, sometimes truncate; mostly pluripapillose; median cells 5–8 μm wide, isodiametrical, angulated; abaxial face rough, unipapillose, papillae low and rounded, or indistinct, acute and curved; adaxial face weakly ornamented; moderately incrassate. Basal cells same as adjacent cells; alar cells not differentiated.

Monoicous. *Perigonia* not seen. *Perichaetial* up to 1.3 mm long; mature inner leaves narrowly triangular to ovate-oblong; apex gradually or rather abruptly contracted to a relatively short, acute or filiform acumen; margins plane or recurved, serrulate above, sub-entire below, mostly coarsely papillose-dentate; shoulder sparingly ciliate; costa percurrent, becoming indistinct in the acumen. *Seta* 2.7–5 mm long; thin; smooth below, papillose at neck; yellowish brown; straight or flexuose. *Capsule* up to 1.8 mm long; weakly inclined to horizontal; yellowish, pale or greyish brown; ovate-cylindrical; weakly to strongly curved; weakly or not constricted below the orifice. *Peristome* perfect; endostome as long as exostome, basal membrane about half the exostome height; processes fragile; endostome cilia short to mostly vestigial or lacking, occasionally to 1/5 of exostome height, irregular, single or in groups of 3, longer ones occasionally filiform; exostome orange-brown at base, becoming whitish upwards, ventral lamellae high. *Operculum* up to 0.7 mm long; gradually rostellate or short-rostrate. *Calyptra* about 2 mm long; narrowly cucullate; smooth, naked. *Spores* 20–30 μm ; coarsely papillose. See Figure 6.6.

Diagnostic characters: This species is recognized by bipinnately branched stems, short, simple paraphyllia, acute terminal cell of paraphyllia, stem and branch leaves, unipapillose stem leaf median cells, ciliate perichaetial leaf shoulder margins, seta papillose at neck and vestigial to lacking endostome cilia.

Ecology: *Pelekium minusculum* is an epiphytic mountain species growing on tree bark or trunk; at (600–)1400–2100 m.

Distribution: *Pelekium minusculum* is known to occur in Tanzania and Malawi. Elsewhere it is known from the eastern Himalayas, eastern India, China, Thailand, Vietnam and Java. See Map 6.6.

Specimens studied: TANZANIA: *Pócs & Crosby 6854/X*, mixed with *P. contortulum* (L).
KHASIA: *Hooker & Thomson 1071, 1072a, 1092* (BM). BHUTAN: *Griffith s.n, 96* (NY).
NEPAL: *Hooker s.n.* (NY).

Notes: Distinguishing characters include acute terminal cell of paraphyllia, stem and branch leaves (Figure 6.6B, E and I respectively). *Pelekium minusculum* resembles *P. haplohymenium* in terms of pale colour, mostly acute paraphyllia, short-acuminate stem leaves, less inclined capsule, reduced endostome and large coarsely papillose spores (Touw 2001b). It closely resembles *P. contortulum* and *P. versicolor*. The second of the only African specimens, collected from Malawi, Zomba Plateau by Mlungusi R., A.C. Crundwell 271 (herb. Crundwell) was not found.

1.7 *Pelekium pseudoinvolvens* (Müll. Hal.) Phephu in Phephu, Van Rooy & Van Wyk, *Phytotaxa* 84 (2): 60–64 (2013).

Basionym: *Hypnum pseudoinvolvens* Müll. Hal. in Müller, *Linnaea* 40: 285 (1876).

Other combination: *Thuidium pseudoinvolvens* A. Jaeger in Jaeger, *Ber. Thätigk. St. Gallischen Naturwiss. Ges.* 1876–77: 254 (1878). Type: COMOROS. Johanna: Anjouan, ad truncos arborum, 800 m, *Hildebrandt 1835* [B holotype, lost; G lectotype; K, NY isoelectotypes, fide Touw (1976); BM isoelectotype!].

Plants medium-sized; yellow- or dark-green. *Stems* prostrate; about 55 mm long; 2-pinnately branched. *Paraphyllia* few, scattered to dense; mostly short, or long, up to 11 cells long; mostly simple to moderately branched; cells mostly rectangular, smooth to papillose; terminal cell truncate, papillose. Axillary hairs of 1 hyaline basal and 2 brown apical cells. Branches up to 5 mm long; remote; sparingly pinnate; branchlets remote and irregular; paraphyllia few basally to absent upwards, branchlets naked. *Leaves* dimorphic. *Stem leaves* distant; 0.4–0.6 mm long, 0.2–0.3 mm wide; triangular to subtriangular; plain to weakly plicate; when dry incurved, weakly spreading, appressed with long, incurved, flexuose or twisted apex; when wet erect spreading, concave; basally paraphyllate; short decurrent; apex gradually narrowly short- to long-acuminate; margins irregularly plane or recurved; papillate-crenulate; bordered by a row of shorter or oblate; costa strong; percurrent, ends in apex, tip indistinct; abaxially prominent when dry, weakly so when moist; laminal cells weakly differentiated; terminal cell truncate, occasionally acute papillose or smooth; upper cells short to elongated, pluripapillose to smooth; median cells 10–17 by 6 µm; short to long, often inflated; variously angulated hexagonal-rhomboidal; pluripapillose, with 1–3 low or sharp, small papillae over cell wall; thin- to thick-walled; basal cells larger, longer, smooth to pluripapillose; papillae low and blunt; alar cells not differentiated. *Branch leaves* up to 0.45 mm long; lanceolate; asymmetrical; when dry with spreading base and strongly incurved-twisted apex; when wet spreading to complanate; apex acute to short-acuminate; margins mostly plane to occasionally recurved; papillate-crenulate; costa percurrent, tip distinct; abaxially prominent when dry, weakly or not when moist; terminal cell truncate and often larger than adjacent cells; laminal cells up to 6 µm wide; short, variously angulated or hexagonal; pluripapillose, papillae low, blunt, indistinct; crowded; walls incrassate basal cells larger, longer, pluripapillose to smooth.

Monoicous. *Perigonia* 0.5–1 mm long; linear-lanceolate; apex mostly gradually filiform; margins plane or recurved, entire, serrate or papillose-crenulate; costa weak, percurrent; cells

elongate-hexagonal or -rhombic, smooth to mostly papillose, thin-walled. *Perichaetia* up to 1 mm long; mature inner leaves oblong-lanceolate; apex mostly gradually to abruptly subulate, erect or flexuose; margins plane, entire or weakly serrate, shoulders ciliate, cells linear-rhomboidal or rectangular, smooth or weakly unipapillose. *Seta* 6–8 mm long; strongly papillose throughout; brown. *Capsule* 0.5–0.7 mm long; ovoid; subpendulous; dark brown. *Exothecial cells* isodiametrical, quadrate or rounded; smooth; walls incrassate, collenchymatous. *Peristome* perfect; exostome teeth oblong-lanceolate, cross-striated and short-trabeculate below, becoming papillose, trabeculate and hyaline upwards; endostome shorter than exostome; membrane $\frac{1}{2}$ the length of processes; processes alternating with exostome teeth, weakly folded, narrowly perforated upwards; endostome cilia in groups of 2 or 3, free. *Operculum* 1 mm long, short-rostrate; dark brown. *Calyptra* cucullate; smooth; apex acute, gradually mucronate. *Spores* 7–15 μm wide. See Figure 6.7.

Diagnostic characters: The species is recognized by the remotely 2-pinnately branched stems, short or long, simple to weakly branched paraphyllia with a truncate terminal cell, plane to weakly plicate stem leaves with gradually short to long-acuminate apex, truncate terminal laminal cell and uni- to bipapillose median cells, truncate branch leaf terminal cell, strongly roughened seta and ciliate inner perichaetial leaf shoulders.

Ecology: *Pelekium pseudoinvolvens* is an epiphytic, lowland rain forest species growing on dead wood or tree trunks, at 450–800 m.

Distribution: It is endemic to Africa and has an East African islands distribution (Comoros, Mauritius, Madagascar and Mayotte). It is also reported to occur in Tanzania (O’Shea 2006). See Map 6.7.

Specimens studied: MADAGASCAR: *Marie s.n.* (BM). COMOROS: *Hildebrandt 1835* (BM). Mayotte: *Marie 64, 85, 103, s.n.* (BM). MAURITIUS: *Robillard s.n.* (BM).

Notes: After having studied the tropical Asian members of *Pelekium*, Touw (pers comm. 2010) questioned if *P. pseudoinvolvens* is really different from *P. gratum* (P. Beauv.) A. Touw. Although *P. pseudoinvolvens* is closely related to and sympatric with *P. gratum*, it differs from it in the weak, remotely bi-pinnate branching, stem paraphyllia less dense, paraphyllia cells longer and less papillose, often plane stem leaves with median and especially apical laminal cells

elongated with thinner walls, papillae often less prominent, calyptra apex gradually mucronate, and exostome teeth broader and taller. These two species are similar in size, median cell ornamentation, inner perichaetial leaf shoulder margin and seta ornamentation. For consistency in the family, *P. pseudoinvolvens*, like the other small thuidioid species, should be classified under *Pelekium* as circumscribed by Touw (2001a), where it is closely related to species like *P. gratum*.

1.8 *Pelekium ramusculosum* (Mitt.) A. Touw in Touw, J. Hattori Bot. Lab. 90: 203 (2001a).

Basionym: *Leskea ramusculosa* Mitt. in Mitten, J. Linn. Soc. Bot. 7: 161(1864).

Other combinations: *Thuidium ramusculosum* A. Jaeger in Jaeger, Ber. Thätigk. St. Gallischen Naturwiss. Ges. 1876/77: 254 (1878).

Cyrto-hypnum ramusculosum (Mitt.) W.R. Buck & H.A. Crum in Buck & Crum, Contr. Univ. Michigan Herb. 17: 66 (1990). Type: FERNANDO POO, Clarence Peak, *Mann s.n.* [NY holotype, K, fide Touw (1976); BM isotype !]

Thuidium angolense Welw. & Duby in Duby, Mém. Soc. Phys. Hist. Nat. Genève 21: 441 (1871). Type: ANGOLA, Huilla, Monino, *Welwitsch 23* [G holotype, BM, PC, fide Touw (1976)].

Thuidium trachynotum Renaud & Paris in Renaud & Paris, Rev. Bryol. 29: 83 (1902b). Type: MADAGASCAR, Betafo Dist., Mania R., near Ambilamby, *Galison s.n.* [PC holotype, FI, L, S-PA, fide Touw (1976)].

Thuidium sublaevipes Dixon in Dixon, Trans. R. Soc. South Africa 8: 216, f. 16 (1920). Type: SOUTH AFRICA, Mpumalanga, Kaapschehoop, *Wager 295* [PRE isolectotype !; BM lectotype !]; South Africa, Eastern Cape, Tyumie, *Henderson 358* [BM syntype !, H, PC, fide Touw (1976)].

Plants medium-sized; yellowish green or brown-green; forming low, flat, loose mats. *Stems* 60 – 70 mm long; very slender; arching to sinuose-straggling, tapering basally; irregularly, remotely (1) 2-pinnately branched. *Paraphyllia* plenty, dense; simple to moderately branched, up to 8 cells long; cells short; sometimes bistratose at base; cells rectangular, elongate, papillose or smooth; terminal cell acute, long conical, or truncate. Axillary hairs with one brown cell basally and 1 or 2 hyaline cells apically. Branches remote; 2–6 mm long; paraphyllia dense basally to absent upwards and in branchlets. *Leaves* dimorphic; base short-decurrent or not. *Stem leaves* 0.5–1 mm by 0.5–0.7 mm; broadly ovate, widely cordate or cordate-triangular; distant; weakly plicate; base often paraphyllate; when dry strongly incurved, appressed, chain-like, very concave, scoop-shaped, crisped, to spreading, often with reflexed apex; when wet patent-erect, often falcate; apex gradually to mostly abruptly acuminate, straight or falcate; margins recurved below, plane above; entire to prominently papillose-crenulate; costa strong; percurrent, ends in apex, tip distinct; cells linear, smooth, papillose or spinose; abaxially prominent; appendiculate at base;

terminal cell acute, occasionally truncate or obtuse; smooth or papillose; upper cells subquadrate, oblong, rhomboidal, often elongated; smooth to papillose; median cells 5–10 by 3.5–6 μm ; rhomboidal, elongated; uni- to occasionally bipapillose, papillae low to prominent, central; walls mostly thin. Basal cells becoming longer downwards, rectangular, smooth to unipapillose; alar cells not differentiated. *Branch leaves* 0.2–0.65 mm long; lanceolate, concave; sparse; weakly plicate; asymmetrical; when dry crisped, concave below and twisted above, strongly incurved; when wet patent-erect, concave, spreading to weakly incurved; apex acute, acute-rounded to short acuminate; margins plane to occasionally recurved; strongly papillose-crenulate; costa strong; percurrent, ends below apex, tip distinct; abaxially prominent; cells linear; papillose-projecting; terminal cell truncate, rarely acute; laminal cells as in stem; 5–7 μm wide; unipapillose, papillae curved; walls mostly thin.

Monoicous. *Perigonia* leaves 0.8–1 mm; broadly lanceolate; concave; apex acute; margins plane, entire, bordered by shorter cells; costa weak; cells long rhomboidal, smooth, walls thin. *Perichaetia* up to 2.5 mm long; mature inner leaves oblong-lanceolate; apex gradually narrowed to a straight or flexuose subula or short hair-point; base linear to widely lanceolate, convolute; margins denticulate, spinose-toothed, shoulder short-ciliate; cells linear; walls straight or flexuose, sometimes pitted; costa weak. *Seta* up to 15 mm long; smooth; light yellow above, red-brown below. *Capsule* 1.5–2.0 mm long; elliptic to cylindrical, narrow; when dry curved, inclined or horizontal, suberect with distinct constricted neck; asymmetrical; brownish. *Exothecial cells* short to long rhomboidal, walls incrassate, collenchymatous, straight or occasionally wavy and pitted. *Peristome* perfect; exostome teeth oblong-lanceolate, cross-striated and short-trabeculate below, papillose, trabeculate and hyaline upwards; endostome shorter than exostome; endostome cilia in groups of 1–3. *Operculum* 0.5–0.8 mm long; short rostrate, apex mucronate. *Calyptra* 2 mm long; smooth. *Spores* 10–15 μm wide; strongly papillose. See Figure 6.8.

Diagnostic characters: *Pelekium ramusculosum* is recognized by irregularly bipinnately branched stems, simple to moderately branched paraphyllia with acute terminal cell and occasional bistratose base, acute stem leaf terminal cell, unipapillose stem leaf median cells, truncate branch leaf terminal cell, ciliate paraphyllia and smooth seta.

Ecology: *Pelekium ramusculosum* is an epiphytic afro-montane species and grows in forests (forest reserve, mountain forests, open forest, mixed evergreen forest, afro-montane vegetation

zone), along road and waterfalls; on forest floor, on tree bark, tree boles, fallen and decaying tree trunk, rotting log, or tree stumps, on rocks, or terrestrial intermixed among other mosses; in wet, moist or dry situations; in shaded places; at 914–1200(3300) m.

Distribution: This is an uncommon montane species (Ochyra & Sharp 1899) and is endemic to Africa. It is known from Angola, Bioko, Cameroon, Equatorial Guinea, Fernando Póo, Kenya, Madagascar, Malawi, Mozambique, Rwanda, South Africa, Tanzania, Uganda, Zambia and Zimbabwe. See Map 6.8.

Specimens studied: FERNANDO POO: *Mann s.n.* (PRE, BM). MALAWI: *Lillie 2588, O'Shea M7251a* (BM). SOUTH AFRICA: *Esterhuysen 21629, Marshall & Crosby 7663, 13, 407, Lambert 3, Rehmann 644b, 645, NH645, 612, Sim PRE-CH8915, PRE-CH 8929, Wager 325* (BM), *Wager 295* (BM, PRE), *Wager 737/PRE-CH613, 737/PRE-CH12140, 741, TM1384C, Van Rooy 4242, 4245, Von Breitenbach PRE-CH 13519*, TANZANIA: *Balbo 85* (BM); *Balbo 10, 24, 77, 80, 87* (BM). *Pócs, Ochyra & Bednarek-Ochyra 88149/A*; UGANDA: *Budd 29* (BM). ZAMBIA: *Phiri 1270*. ZIMBABWE: *Eyles 4665, Müller 2594*, (BM).

Notes: *Pelekium ramusculosum* is easily distinguished by its stems that appear to be slender because of remote branching and acute terminal cell of paraphyllia, stem and branch leaves (Fig. 5.4, 5.13 and 5.17). Although close to *P. varians*, *P. ramusculosum* is distinguished by a stronger habit, slender stems, less complanate branches, more incurved-crisped dry leaves, longer seta, and twice larger and longer capsule. *Pelekium ramusculosum* is associated species with species such as *Hagenia abyssinica* and *Hypnum* sp.

1.9 *Pelekium thomeanum* (Broth.) Phephu in Phephu, Van Rooy & Van Wyk, *Phytotaxa* 84 (2): 60–64 (2013).

Basionym: *Thuidium involvens* var. *thomeanum* Broth., in Brotherus, *Bol. Soc. Brot.* 8:183 (1890).

Other combinations: *Thuidium involvens* subsp. *thomeanum* (Broth.) A.Touw in Touw, *Lindbergia* 3: 168 (1976).

Cyrto-hypnum involvens subsp. *thomeanum* (Broth.) W.R. Buck & H.A. Crum, in Buck & Crum, *Contr. Univ. Michigan Herb.* 17: 65 (1990). Type: SAO TOMÉ: Queluz, *Quintas 1333a* [H holotype, fide Touw (1976)].

Leskea subfalcata Mitt. in Mitten, *Trans. Linn. Soc. London.* 23:53 (1860).

Thuidium subfalcatum (Mitt.) Paris in Paris, *Index Bryologicus* 1292 (1898). Type: NIGERIA, Niger R., Onitscha, *Barter 1424* [BM isotype !; NY holotype, K, fide Touw (1976)].

Leskea nigeriana Mitt. in Mitten *Trans. Linn. Soc. London* 53 (1860).

Thuidium nigerianum (Mitt.) Paris in Paris, *Index Bryologicus* 1286 (1898). Type: NIGERIA, Niger R., *Vogel s.n.* [NY holotype, BM, H, K, fide Touw (1976)].

Plants medium-sized, pale green to yellowish green or brownish. *Stems* to 60 mm long, arching, 1- or 2-pinnately branched. *Paraphyllia* many, simple to very weakly branched, short, mixed with long ones, to 15 cells long; cells oblong-rectangular or isodiametrical, sparingly papillose; terminal cell truncate, papillose. *Axillary hairs* with 1 brown basal and 1 or 2 hyaline apical cells. *Branches* to 5 mm long, closely to remotely set; paraphyllia very few to lacking on branchlets. *Leaves* dimorphic, strongly incurved. *Stem leaves* 0.5–10 mm long, 0.25–0.6 mm wide, narrowly to broadly cordate-triangular, with patent base, plain to weakly plicate, closely set; when dry crisped, curved, concave, when wet spreading to widely patent. *Apex* gradually or abruptly short- to mostly long-acuminate, often twisted when dry. *Costa* strong, percurrent, ending in apex, tip indistinct, abaxially prominent, often grooved; cells smooth to very weakly papillose. *Margins* recurved to rarely plane below, plane upwards, papillate-crenulate. *Terminal laminal cell* truncate. *Median cells* 7–12 × 5–10 μm, short- to elongate-rhomboidal or -hexagonal, mainly unipapillose, some cells bi- to pluripapillose especially towards base; papillae weak or prominent, mostly central on lumen; cell walls thick or thin. *Basal cells* longer, larger, sometimes yellowish and smooth at insertion. *Alar cells* not differentiated. *Branch leaves* to 0.75 mm long, broadly rounded at base to narrowly ovate, asymmetrical, when dry strongly incurved,

crisped, chain-like, with twisted apex and patent base, when wet spreading, complanate. *Apex* abruptly acute to short-acuminate. *Margins* recurved below, plane upwards, papillate-crenulate. *Costa* strong, abaxially weakly prominent, occasionally protruding in a distal spine. *Terminal laminal cell* truncate. *Laminal cells* to 6 µm wide, isodiametrical, mostly unipapillose, pluripapillose towards base, papillae low, indistinct.

Monoicous. *Perigonia* about 0.9 mm long; leaves ovate to broadly lanceolate; apex acute to abruptly long-acuminate; costa strong to weak; entire to weakly serrate; cells isodiametrical, smooth, thick-walled; cells at insertion yellowish brown. *Perichaetial inner leaves* to 2 mm long; apex abruptly filiform, ending in subula; costa strong, filling subula; margins entire to serrulate, shoulders eciliate. *Setae* to 17 mm long, strongly roughened throughout, reddish. *Capsules* 0.6–1.5 mm long, ovoid to elliptic, weakly curved, horizontal to pendulous, constricted at neck, reddish brown. *Exothecial cells* quadrate, smooth; walls incrassate, collenchymatous. *Peristome* perfect; exostome teeth oblong-lanceolate, cross-striate below, papillose and trabeculate upwards, yellowish brown below, hyaline upwards; endostome membrane $\frac{1}{2}$ the length of exostome; processes keeled (or carinate), narrowly perforate; endostome cilia in groups of 3, free. *Operculum* 1.0 mm long, long-rostrate. *Calyptrae* 1.5–1.7 mm long, cucullate, apex obtuse, smooth. *Spores* about 10–13 µm in diameter, papillose. See Figure 6.9.

Diagnostic characters: The species is recognized by 1-pinnately branched stems, simple to weakly branched, short or long paraphyllia with a truncate terminal cell, plain to weakly plicate stem leaves with gradually or abruptly acuminate short to long-acuminate apex, truncate terminal cell and unipapillose median cells, truncate branch leaf terminal cell, strongly roughened seta and eciliate inner perichaetial leaf shoulders.

Ecology: *Pelekium thomeanum* is a lowland, forest bottom species (Ochyra & Pócs 1982), growing in the rain forest zone or high forests, on tree bases, decaying wood, or occasionally terrestrial on soil and rocks, at 270–900 m, in light to dense shade.

Distribution: *Pelekium thomeanum* is endemic to Africa and occurs in Angola, Cameroon, Central African Republic, Côte d'Ivoire, Congo, Equatorial Guinea (Río Muni), Democratic Republic of Congo, Gabon, Ghana, Nigeria, Togo, and São Tomé. The lowland tropical American variant of *P. involvens*, namely *P. involvens* var. *involvens*, is known from Florida, Mexico, Ecuador, Bolivia, Venezuela and Brazil.

Specimens of *Pelekium thomeanum* examined: DEMOCRATIC REPUBLIC OF CONGO: Müller Z331 (L). CAMEROON: *Argent AR.522* (BM); *Dusen s.n.* (NY); *Sjostedt s.n.* (NY); *Staudt 711* (BM); *Zenker 2008b* (BM). NIGERIA: *Barter 1424*; (BM). ANGOLA: *Junio 174* (BM). TANZANIA: *Pócs & Pócs 6236/H* (EGR).

Specimens of *Pelekium involvens* examined:—DOMINICAN REPUBLIC: *Allard 16142*, *16168*, *16209a*, *17923a*, *17958*, (NY); *Buck 4966*, *4969*, *5066*, *5118* (NY); *Reese 15051*, *15496*, *15560* (NY).

Notes: Brotherus (1890) created an African variety ‘*thomeanum*’ of the American *Thuidium involvens* based on a *Quintus 1333a* specimen collected in São Tomé. Touw (1976) changed that variety to subspecies rank as *Thuidium involvens* subsp. *thomeanum*. Although Touw (1976) regarded the American and African taxa as forms of a single species with many plants showing intermediate characters, he ranked the African taxon as a subspecies because of its geographical isolation. He recently suggested that more American material be examined to decide the rank at which ‘*thomeanum*’ should be recognized (Touw *pers comm.*, 2010). In his notes, O’Shea (2006) suggested that the subspecies, like *P. involvens*, presumably belongs to *Pelekium*. We found that *Thuidium involvens* subsp. *thomeanum* resembles other medium- and small-sized species of *Pelekium* like *P. varians* (Welw. & Duby) A. Touw, *P. chenagonii* (Müll. Hal. ex Renauld & Cardot) A. Touw, *P. ramusculosum* (Mitt.) A. Touw and *P. velatum* Mitt. It resembles *P. varians* in many respects especially in the 1-pinnate branching. It is similar to *P. velatum* on account of eciliate perichaetial leaf shoulder margins and small spores.

The American *P. involvens* var. *involvens* and var. *thomeanum* are similar in respect to the 1-pinnately branching, strongly incurved stem leaves with long-acuminate apex, eciliate inner perichaetial leaf shoulder margins, and rough setae of equal lengths.

However the African plants differ from the American *P. involvens* in the latter having slightly shorter stems, shorter and unbranched paraphyllia, smaller stem and branch leaves, blunt branch leaf apex, plane stem leaves with entire margins and pluripapillose laminal cells, a slightly longer capsule, narrower and more curved when dry, and smaller spores.

Two BM *P. thomeanum* specimens with voucher numbers 133 and 321, BM963137 and BM963135 respectively, have no collector details except that they were collected in

‘Nigeria/Cameroon’. The species often grows in association with *P. gratum*.

1.10 *Pelekium varians* (Welw. & Duby) A. Touw in Touw, J. Hattori Bot. Lab. 90: 203 (2001a).

Basionym: *Thuidium varians* Welw. & Duby in Welwitsch & Duby, Mém. Soc. Phys. Genève 21: 440 (1871).

Other combination: *Cyrto-hypnum varians* (Welw. & Duby) W.R. Buck & H.A. Crum in Buck & Crum, Contr. Univ. Michigan Herb. 17: 68 (1990). Type: ANGOLA, Pungo Andoro, Barrancos de Catete, *Welwitsch 101* [G holotype, H, fide Touw (1976)]; BM isotype !].

Hypnum sigmatella Müll. Hal. in Müller, Linnaea. 329–473 (1875).

Thuidium sigmatella (Müll. Hal.) A. Jaeger in Jaeger, Ber. Thätigk. Gall. Naturwiss. Ges. 255 (1878). Type: SUDAN, *Schweinfurth s.n.* [NY lectotype, fide Touw (1976)].

Thuidium laevipes Mitt. in Mitten, J. Linn. Soc. Bot. 22: 318 (1886). Type: TANZANIA, *Hannington s.n.* [Herbarium unknown].

Thuidium tenuisetum Renauld & Cardot in Renauld & Cardot, Bull. Soc. Roy. Bot. Belgique 39, 2: 89 (1905). Type: DEMOCRATIC REPUBLIC OF CONGO, Kisantu, *Gillet s.n.* [PC holotype, fide Touw (1976)]; S-PA, fide Touw (1976)].

Thuidium konkourae Paris & Broth. in Paris, Rev. Bryol. 34: 97 (1907). Type: GUINEA, Fouta Djallon, Konkouré super, *Pobeguain s.n.* [PC holotype, fide Touw (1976)]; H, fide Touw (1976)].

Thuidium spurio-involvens Broth. & Paris in Paris. Rev. Bryol. 35: 4 (1908). Type: GUINEA, Fouta Djallon, in valle fluminis Bafing, *Pobeguain s.n.* [H holotype, PC, S-PA, fide Touw (1976)].

Thuidium chenagonii Müll. Hal. ex Renauld & Cardot fo. *laxifolia* Cardot in Cardot. In Grandidier & Cardot. Hist. Phys. Madagascar Mouses 39: 1–562 (1915). Type: MADAGASCAR, *Drouhard s.n.* [PC holotype, BIZOT, fide Touw (1976)].

Plants medium-sized; pale yellow-green, olive green to light green, laxly matted, prostrate. *Stems* 60–120 mm long; arching, simple or branched; 1(2)-pinnately branched. *Paraphyllia* dense to mostly few; simple or weakly branched; mostly short mixed with long ones, up to 8 cells long; cells mostly rectangular-oblong or isodiametrical, papillose; terminal cell truncate,

pluripapillose. Axillary hairs of 1 brown basal and 1(2) hyaline apical cell. Branches simple, scattered, mostly strongly complanate; paraphyllia scattered, few to absent. *Leaves* weakly dimorphic; decurrent. *Stem leaves* up to 0.5–1.0 mm by 0.4–0.7 mm, distant to closely set, larger below; broadly ovate, cordate or triangular; sometimes asymmetrical; when dry recurved appressed, very concave, strongly incurved-twisted from a wide patent base; when wet widely patent, plane to weakly 1-plicate, incurved, occasionally regulose; apex gradually rounded-acute, acumen broad, often falcate.; margins plane throughout or only upwards and recurved below, crenate by bulging cell walls to smooth especially below; costa strong; percurrent, ends below apex, tip distinct; abaxially strongly prominent, smooth to weakly ornamented; terminal cell acute to occasionally obtuse or truncate, pluripapillose; upper cells not differentiated; median cells 7–12 by 5–8 μm , isodiametrical, quadrate or rounded; unipapillose, on back only, papillae low to prominent, central; marginal cells smaller and shorter, inner cells longer and larger; walls incrassate; basal cells longer, oblong to rectangular; smooth to pluripapillose, yellowish; alar cells not differentiated. *Branch leaves* 0.5–0.9 mm long; narrowly ovate to triangular-ovate or ovate lanceolate, oval oblong; laxly set; crowded, appressed; when dry strongly incurved-twisted from a patent base; when wet spreading, complanate, patent and incurved, occasionally regulose; asymmetrical; apex bluntly acute, sub-acute, obtuse to slightly acuminate, acumen broad, incurved or twisted; margins mostly plane; serrulate at apex, papillate-crenulate or crenulate by bulging cell walls to smooth especially downwards; costa strong; percurrent, ends below apex, tip distinct; abaxially prominent; cells smooth; terminal cell conical or truncate; laminal cells same as in stem leaves; 5–7 μm wide; unipapillose, papillae low, indistinct; dense.

Monoicous. *Perigonia* about 0.5 mm; inner leaves ovate-lanceolate, concave; apex acute; costa weak; margins entire, bordered by a row of quadrate to rectangular cells; upper cells hexagonal, smooth to unipapillose; median cells long, fusiform to oblong-hexagonal, smooth becoming unipapillose marginally, thin- to thick-walled; basal cells elongate, hyaline, yellowish or brownish at insertion, smooth, thin-walled. *Perichaetia* 3.5–3.8 mm long; mature inner leaves ovate-lanceolate to oblong-lanceolate, plane to weakly plicate; apex gradually to abruptly narrowed to a straight or flexuose subula; costa strong, excurrent; shoulder margins ciliate; upper cells linear-rhomboidal, sometimes sinuose, thick-walled; cells linear-rhomboidal to rectangular, smooth, thick-walled; basal cells enlarger, rectangular, smooth, thin- to thick-walled. *Seta* orange or yellowish brown; 10–24 mm long; smooth. *Capsule* 1.0–1.5 mm long; ovoid to elliptic; inclined to horizontal; yellowish brown; when dry constricted at neck, oval when moist; neck distinct. *Exothecial cells* hexagonal-rhombic; smooth; walls incrassate, collenchymatous.

Peristome perfect; exostome teeth lanceolate, cross-striated and short-trabeculate below, upwards hyaline, papillose and nodulose, trabeculate at apex; endostome processes alternating exostome teeth, folded, narrowly perforated, papillose distally; membrane $\frac{1}{2}$ the height of processes; cilia in groups of 2–3, partly united, nodulose to trabeculate. *Operculum* up to 1 mm long; short-rostrate. *Calyptra* up to 2.5(–2.7) mm long; cucullate; smooth; apex mucronate. *Spores* 10–15 μm wide; papillose; yellowish. See 7.10.

Diagnostic characters: *Pelekium varians* is characterized by simple to bipinnately branched stems, simple to weakly branched paraphyllia with truncate terminal cell, plane stem leaves with acute terminal cell, unipapillose median cells and plane margins, conical branch leaf terminal cell, ciliate perichaetial leaf shoulder margins and smooth seta.

Ecology: This lowland rain forest, epiphytic species grows in forested reserves, riverines; it is terrestrial along stream, river valley, waterfalls, on hills and rocky side of footpaths; on boulder, acid gneiss, decaying log, dead wood, tree trunks and tree bases; in shade; in dry or humid areas; from near sea level to moderately higher elevations of 300–1500 m.

Distribution: *Pelekium varians* is endemic to Africa and is widespread throughout tropical Africa (Ochyra & Sharp 1988). It occurs in Angola, Bioko, Burundi, Cameroon, Central African Republic, Comoros, Cote d’Ivoire, Democratic Republic of Congo, Gabon, Ghana, Guinea, Kenya, Madagascar, Malawi, Mozambique, Nigeria, Rwanda, Sierra Leone, South Africa, Sudan, Swaziland, Tanzania, Togo, Uganda and Zambia. See Map 6.10.

Specimens studied: ANGOLA: *Welwitsch 101, 102* (BM); *Gossweiler 4515, 4667* (BM); *Mungo? 30.1.50* (BM). CENTRAL AFRICAN REPUBLIC: *Assel 390*. DEMOCRATIC REPUBLIC OF CONGO: *Bequaert 5613*; *Müller Z362, Z358* (L); *Vanderyst 431, 19* (BM). GHANA: *Hall & Jones 1274* (BM); *Irvine 413, 420* (BM). MOZAMBIQUE: *Gerstner 220* (BM). SIERRA LEONE: *Marmo s.n., Small 903* (PRE); *Thomas 2969*(BM). SOUTH AFRICA: *Gerstner 215* (BM), *Magill 5295* (PRE). SWAZILAND: *Wager 1168* (BM). TANZANIA: *Holst 2281, 4310, 4306* (BM); *Pócs 88193/R* (PRE); *Stuhlmann s.n., 1075* (BM, online). UGANDA: *Chandler 1636, 1903* (BM); *Dummer 512, 719b, 720, 720b, 828, 993* (PRE); *512, 720, 826, 828, 993, 3990, 4013* (BM); *Snowden 2b* (BM); *Thomas 2792* (BM).

Notes: *Pelekium varians* is characterized by the distinctly 1-pinnate ramification (Figure 6.10A), distinct broad stem leaf apex (Figure 6.10D) with short laminal cells (Figure 6.10E), and leaf margins mostly plane (Figure 6.10E). The dry material of *P. varians* looks very similar to *P. ramusculosum*. The specimen of *Dummer 719* is a mixed collection of *P. varians* and *P. chenagonii*. *P. varians* grows in association with other species e.g. *Vesicularia sphaerocarpa*, *Cupressus* trees and *Pelekium chenagonii*.

1.11 *Pelekium velatum* Mitt. in Mitten, J. Linn. Soc. Bot. 10: 176 (1867).

Basionym: *Thuidium velatum* Par. in Index. 1294 (1897). Type: AMERICAN SAMOA INSEL, Tutuila, *Powell s.n.* (MO, BM, Herb. Univ. of Michigan). Not seen.

Plants minute to small; rough to touch, delicate; dull, yellow green to light green, whitish and look shinny especially in branches. *Stems* 80–140 mm long; prostrate; bipinnately branched. *Paraphyllia* plenty, dense; simple to moderately branched; long, up to 9 cells long; cells short-hexagonal to -rectangular, isodiametrical; strongly pluripapillose; terminal cell truncate. Branches up to 4 mm long; horizontally spreading and complanate; few paraphyllia basally, branchlets naked and rather remote. *Leaves* dimorphic; decurrent. *Stem leaves* up to 0.6(–0.7) mm long; broadly ovate, triangular, triangular-ovate, cordate; distant; base appendiculate; when dry patent, appressed with awn twisted and growing away from stem; when wet patent-erect; apex subulate, tapering gradually or abruptly acuminate or filiform; margins plane or recurved; papillae-crenulate to entire, often bordered with a row of short oblate cells; costa excurrent, ends in or above apex, tip indistinct; abaxially papillose; laminal cells weakly differentiated; terminal cell truncate to occasionally acute; mostly elongated, pluripapillose; median cells 10–20 μm by 4–6 μm ; elongated, oblong-hexagonal to rectangular or long hexagonal; uni- to bipapillose, some cells pluripapillose, papillae usually low and simple; thin walled; basal cells larger; often smooth, to papillose; alar cells not differentiated. *Branch leaves* complanate; up to 0.4 mm long; asymmetrical; ovate; when dry strongly crisped, widely spreading with strongly incurved and twisted apex; when wet patent-erect, widely spreading; apex acuminate, broadly acute, obtuse or rounded, strongly cristate; margins plane; papillose-crenulate; costa percurrent, ends in or below apex, tip distinct; abaxially prominent; cells inflated, pluripapillose; laminal cells 8 μm wide; isodiametrical, oblong or short rectangular; unipapillose, papillae prominent; terminal cell conical or truncate.

Monoicous. *Perigonia* not seen. *Perichaetia* up to 1.5 mm long; mature inner leaves lanceolate, weakly ornamented; when dry patent-erect; apex straight, gradually aristate-acuminate, serrate; costa excurrent; margins entire or spinulose-serrulate, eciliate. *Seta* 10–15 mm long; densely hispid or spinose throughout, spines up to 70 μm , 1–3-celled; reddish brown below, becomes lighter upwards. *Capsule* 1–1.3 mm long, short-ovoid, bulging; asymmetrical; horizontal, cernuous to vertical; often strongly contracted below orifice; neck well defined, rough at neck; dark reddish brown. *Exothecial cells* rounded to polygonal; smooth; walls incrassate, collenchymatous. *Peristome* perfect; exostome teeth oblong-lanceolate, cross-striated and short-trabeculate below, becoming papillose and trabeculate upwards; endostome cilia

vestigial, in groups of 2 or 3. *Operculum* 1–1.2 mm long; abruptly long rostrate from a conical base, apex pellucid; pale yellow. *Calyptra* 1.5–2.5 mm long; distinctly companulate, bell-shaped, strongly hispid, base deeply laciniate into about 22 segments, deeply plicate, apex obtuse with protruding brown spiny tip. *Spores* 9–12 µm wide; subspherical; finely papillose. See Figure 6.11.

Diagnostic characters: *Pelekium velatum* is recognized by bipinnately branched stems, simple to moderately branched paraphyllia with coarsely papillose, isodiametrical cells and truncate terminal cell, subulate stem leaf apex, truncate stem leaf terminal cell and uni- to bipapillose median cells, conical branch leaf terminal cell, eciliate perichaetial leaf shoulder margins, seta densely hispid throughout, reduced endostome cilia and bell-shaped, strongly hispid calyptra with laciniate base.

Ecology: *Pelekium velatum* is a lowland forest bottom moss; grows on mountains, lowland rainforest to lower montane forests, along river, streamlets and foothills; on decaying log, tree roots, tree trunk, tree bases, rocks (limestone); in wet, shady places; at 10–300(–1800) m.

Distribution: This is a Tropical East African species known to occur in Burundi, Tanzania and Democratic Republic of Congo. Elsewhere *P. velatum* is circumtropical and widespread in Indomalaysia (Indonesia, Sumatra, Malaysia, Philippines, American Samoa, Thailand, Vietnam, Papua Guinea, Borneo, Japan and Sri-Lanka) Australia. See Map 6.11.

Notes: I did not manage to trace the type material of *P. velatum* but this species is confirmed to be growing in Africa. I have examined the material from Tanzania. *Pelekium velatum* is unique among other *Pelekium* species mainly by its filiform stem leaf apex, entirely spinulose seta (Figure 6.11K), reduced endostome cilia (Figure 6.11M) and distinctly companulate, bell-shaped, strongly hispid calyptra (Figure 6.11O and P). *Pelekium velatum* shares a combination of characters with small-sized species (e.g. size and paraphyllia morphology), medium-sized (e.g. inner perichaetial margins) and large-sized (stem leaf apex) species. The immediate species that are taxonomically closely related to *P. velatum* are *P. gratum*, *P. pseudoinvolvens* and *P. thomeanum*. It shares the acute branch leaf terminal cell with *P. varians* (Figure 6.11.H). The Sumatra plants are larger and have longer seta and perichaetial leaves, both up to ± 20 mm long.

Specimens studied: TANZANIA: *Pócs & Pócs 6188/AU, 6236/H* (EGR). INDONESIA: *Touw & Snoek 24316* (L). MALAYSIA: *Klazenga 2070* (L). JAPAN: *Higuchi 32318*. SUMATRA: *Touw & Snoek S25289* (L).

1.12 *Pelekium versicolor* (Müll. Hal.) A. Touw in Touw, J. Hattori Bot. Lab. 90: 205 (2001a).
Basionym: *Hypnum versicolor* Hornsch. ex Müll. Hal. in Müller, Syn. Musc. Frond. 2: 494
(1851).

Other combinations: *Thuidium versicolor* Jaeger in Jaeger, Ber. Thätigk. St. Gallischen
Naturwiss. Ges. 1876–77: 249 (1878).

Cyrto-hypnum versicolor (Müll. Hal.) W.R. Buck & H.A. Crum in Buck & Crum, Contr. Univ.
Michigan Herb. 17: 68 (1990). Type: SOUTH AFRICA, Krakakamma, *Ecklon 1832* [BM
syntype !, H, S-PA, fide Touw (1976)]; SOUTH AFRICA, Hangklip, *Mundt & Marie s.n.* [S-PA,
lectotype, H, fide Touw (1976)].

Thuidium borbonicum Besch. in Bescherele, Ann. Sci. Nat. Bot. sér. 6, 10: 289 (1880). Type:
RÉUNION, Hellbourg, *de l'Isle 175* [BM holotype, PC, fide Touw (1976)].

Thuidium borbonicum fo. *breviseta* Thér. in Thériot, Recueil Publ. Soc. Havraise Études
Diverses 1925: 25 (1925). Type: Madagascar, Mt Tsaratanana, *Perrier de la Bathie s.n.* [PC?].

Hypnum tamariscellum Müll. Hal. in Müller Bot. Zeitung (Berlin) 12: 573 (1854).

Thuidium tamariscellum (Müll. Hal.) Bosch & Sande Lac. in Bosch & Sande Lacoste, Bryol.
Jav. II: 20 (1865). Type: INDIA, Nilgiris, *Schmid s.n.* [JE lectotype, fide Touw (2001b)]

Thuidium torrentium Müll. Hal. in Müller, Hedwigia 38: 149 (1899). Type: *Mc Owen s.n.*
[Herbarium unknown].

Plants minute to small, very slender, yellowish green, light to dark green, or brownish yellow, straggling low masses, rooting occasionally. *Stems* 30–50 mm; flexuose, arching, ascending, creeping or procumbent; regularly (1)2-pinnately branched, apices tapering. *Paraphyllia* often dense to scattered, fairly short, up to 5(–7) cells long; simple; cells oblong-rectangular, mostly smooth to papillose; terminal cell truncate, occasionally acute or obtuse. Axillary hairs of 1 brown basal cell and 1–3 hyaline distal cells, sometimes all cells brown. Branches remote to closely set; up to 2.5(–4) mm long; terete, flexuose, with 4–7 branchlets on both sides; apices tapering; paraphyllia dense, few to absent, scattered; branchlets naked. *Leaves* dimorphic; mostly not decurrent; plane or weakly to strongly plicate both wet and dry. *Stem leaves* to 0.25(–0.6) mm by 0.2(–0.35) mm; broadly ovate, sub-triangular or deltoid or cordate triangular, strongly incurved to flexuose from a patent or squarrose base; mostly plane, larger leaves plicate; closely

set; when dry weakly spreading to appressed with incurved apex; when wet spreading, keeled, patent and straight to weakly curved; apex abruptly or gradually acute or constricted to a narrow triangular acumen, mucicous or ending in a row of 2 short cells; margins recurved below, plane upwards; entire to papillose-serrulate or denticulate; terminal cell truncate, pluripapillose; costa strong; percurrent, disappears in apex; abaxial face strongly prominent, rough by projecting cell ends; appendiculate at base; median cells 9–15 μm by 10 μm ; mostly slightly longer than wide, hexagonal or rhomboid; uni- to pluripapillose, papillae low to high, acute, central or drawn up; adaxial face less prominent; walls thin to incrassate; basal cells elongate; weakly papillose to smooth; alar cells not differentiated. *Branch leaves* 0.4 mm long; ovate to ovate-triangular or narrowly ovate; when dry spreading, chain-like, with incurved apex, from an erecto-patent base; when wet spreading or erecto-patent to patent and weakly concave, suberect; apex mostly bluntly acute, acute to sharply short-acuminate; margins recurved below, plane above; strongly papillose-serrulate, or crenulated; costa strong; percurrent, ends in apex; to 0.7–0.9 of leaf length; abaxially prominent; terminal cell truncate; pluripapillose; median cells 4–8 (–10) μm wide; isodiametrical, roundish; coarsely uni- or bipapillose, papillae prominent, tall, oblique, acute, curved; ornamentation prominent on both faces; thin-walled; basal cells up to 15 μm long; dense and very bristle with papillae when dry.

Monoicous. *Perigonia* leaves ovate; concave; apex mostly abruptly acuminate; margins entire, plane or recurved; bordered by shorter cells; costa weak, percurrent; cells linear-rhomboidal, often vermiculate, smooth but unipapillose at apex, thin-walled; basal cells brownish. *Perichaetia* about 1.5(–2.2) mm long; mature inner leaves ovate-lanceolate to oblong-lanceolate; plane or concave; apex gradually acuminate to subulate, flexuose; margins serrate, weakly crenulate to subentire, shoulder eciliate, cells 25 μm long, rectangular to linear-rhomboidal, smooth or unipapillose, thin-walled to incrassate; costa weak to strong, ends in a subula. *Seta* up to 15(–20) mm long; rough at neck, smooth basally, occasionally smooth throughout; orange-brown or reddish below, pale above. *Capsule* 1.5–2 mm long; ovoid, obovoid, elliptical, or sub-cylindrical; asymmetrical; mostly curved; constricted below orifice, with wide mouth when young; inclined to horizontal, subnutant; tomentose at base; brown. *Exothecial cells* short- to long- hexagonal; smooth, incrassate, collenchymatous. *Peristome* perfect; almost always present; exostome teeth longer than or as long as endostome; oblong-lanceolate; yellowish, cross-striated and trabeculate below, becoming hyaline, nodulose and papillose towards apex; endostome membrane less than $\frac{1}{2}$ the processes height; processes alternating exostome, weakly folded, perforated, yellowish to hyaline above; endostome cilia in

groups of 2 or 3, mostly united, varying in length to as long as processes. *Operculum* 2 mm long; narrowly obliquely rostrate. *Calyptra* 1.4–2 mm long; cucullate, narrow; smooth, naked; apex long-apiculate. *Spores* 7–17µm wide; papillose to almost smooth. See Figure 6.12.

Diagnostic characters: This species is recognized by bipinnately branched stems, short, simple paraphyllia, truncate terminal cell of paraphyllia, stem and branch leaves, unipapillose stem leaf median cells, eciliate perichaetial leaf shoulder margins, seta rough at neck and capsule stomatal at base.

Ecology: *Pelekium versicolor* is an epiphytic, mountain moss growing in bottom layer of forest, rain forest, lowland forest; primeral upper montane forest, mountain rain forest, terrestrial in caves, near streams and along rivers; on tree trunk, decaying tree, tree stumps, rocks (limestone), damp stones; in shade and prefers wet, humid places; at (100–)900–4000 m.

Distribution: *Pelekium versicolor* is an East African species occurring in Cameroon, Democratic Republic of Congo, Ethiopia, Kenya, Lesotho, Madagascar, Malawi, Réunion, Rwanda, South Africa, Tanzania, Uganda, Zambia and Zimbabwe. Elsewhere it is of tropical South and Southeast Asian and West Indomalaysian distribution (Sumatra, Philippines, Borneo, Java, Taiwan, Ryukyus, Thailand, India, Vietnam, Japan, China, and Sri Lanka). See Map 6.12.

Specimens studied: DEMOCRATIC REPUBLIC OF CONGO: *Berquert* 789, 784, 777 (BM); *Hendrickx* 4960. KENYA: *Hedberg* 16, 286 (BM). MADAGASCAR: *Touw & Snoek* 25125. RÉUNION: *Arts* REU64/15, REU100/68, REU57/46, REU53/30 (L); *Bourbon* (*Schimper*) 177, *Bourbon s.n.*, *Retenil s.n.* (BM). SOUTH AFRICA: *Arts* RSA24/14; *Arts* RSA21/14 (L); *Bosman* 1599; *Breutel s.n.* (BM); *Cheeseman s.n.* (BM); *Cholnoky* 335, 350, 351; *Doidge* 26; *Farquhar* 23; *Glen* 2376; *Haygarth* 8, 15620; *Hedderson* 15372; *Henderson* 335 (BM); *Jacot-Guillarmond* 6131, 6132; *Junond* 4005, 4005a; *Kut* 11 (BM); *Mac Lea* 644b, 645 (BM), 2952; *Mac Lea* 645; *Mac Owen s.n.*; *Magill* 4850, 5580, 6565, 5532, 5110; *Marshall & Crosby* 7904, 7550, 7954, 7760; *Martin* 7800; *Noel* 6; *Oliver* 6790; *Pegler* CH8890; *Perold* 4210; *Phephu* 85, 63, 65, 113; *Rehmann* 644, 359, 359b, 359c (BM); *Schelpe* 7515, 7528, CH13517; *Sim* 8556, 7239, 10325 (BM); 71, 7377, 7167, CH8939, CH8891; *Wager s.n.*, 255b (BM), CH606, 168, 7752, 11620, 744, 711; 1115, 95; *Smook & Phelan* 835; *Smook* 1746; *Van Rooy* 1278, 1280, 2180, 1157, 1445, 924, 1275, 4227, 4119, 838, 923, 4227; *Von Breitenbach* 188, 304, 331, 191, 274, 433; *Vorster* 248, 1492, 1491, 1819; *Wood* 262 (BM); *Ecklon s.n.* (BM); *Zantovska* 154;

TANZANIA: *Balbo* 72 (BM); *Leighton* 9, 18, 19 (BM); *Leighton* CH8904; *Pocs, Ochyra & Bednarek-Ochyra* 88122/0 (L). UGANDA: *Dummer* 4099 (BM); *Lind* 93 (BM); *Scott Elliot* 280 (BM). ZIMBABWE: *Eyles* 4669 (BM); *Farquhar* 23 (PRE, BM); *Long* 12480; (BM); *Müller* 2619; *Perold* 4210, 4783; *Priestly & Scott* 90, 93 (BM); *Sim* 8893 (BM); *Rolpes* 706 (BM); *Vahrmeijer* CH13033; *Wager* 128. INDONESIA: *A Touw & Snoek* 23365 (L). SUMATRA: *Touw & Snoek* 25364.

Notes: *Pelekium versicolor* is a very variable species, represented in different forms and when sterile often mistaken with other closely related species e.g. *P. intricatum* and *P. contortulum*. Variation can be seen on density of paraphyllia (dense to almost naked), stem leaf shape; laminal cell shape and ornamentation and seta ornamentation (smooth throughout or rough at neck). *Pelekium versicolor* is characterized by leaf cells mostly coarsely unipapillose, papillae prominent, paraphyllia short and simple, perichaetial leaf margins eciliate, calyptras long apiculate and seta rough at neck.

The synonyms *Leskea sparsifolia* Mitt. and *Thuidium sparsifolia* (Mitt.) A. Jaeger. are according to Touw (2001b). The BM type specimens *Maud & Budd* 36a, *Budd* 42a and 31, para, from Uganda, and *Becquaert* 73, lecto, from DRC labelled *Pseudoleskea falcifolia* = *Thuidium sparsifolia*, identified by M. Krieger in 2002 are not *P. versicolor*. The specimens are clearly once-pinnate, much larger and could belong to Leskeaceae. The two Réunion specimens of *Thuidium tenellum* Schimp. BM000962930 & 31, *Bourbon (Schimper)* 177 and *Bourbon s.n.* have not been considered as type specimen here since no original description citing them was found. The specimen *Thomas* 2899 named by HND as *Thuidium parvicaulifolium*, ined, BM000962955, collected in Uganda is in fact *P. versicolor*. Six BM specimens misidentified as *P. minutulum* are in fact *P. versicolor* and only one with no locality had a correct identity of *P. minutulum* which is excluded in this study because the locality details are lacking. *Pelekium versicolor* grows in association with *Trichocladus* sp., *Neckera* sp., *Racopilum paelongium* and *Eustichia longirostris*.

2. *Thuidiopsis* (Broth.) M. Fleisch.

Thuidiopsis (Broth.) M. Fleisch. in Fleischer, Flore de Buitenzorg 4 (1923).

Type species: *T. furfurosa* (J.D.Hook. & Wilson) M.Fleisch., lectotype, selected by Reimers (1937).

Plants very variable; medium- to tall-sized; forming small to large, compact or loose wefts; dull, yellowish green or dark green, aging yellowish brown. *Stems* prostrate or ascending, straight or weakly flexuose, up to 250 mm long, apices often stoloniform, branching generally more open. Central strand present. *Paraphyllia*, uniseriate, predominantly short, abundant to occasionally lacking, up to 15 cells long, simple; cells short rectangular, smooth basally, pluripapillose apically, terminal cell truncate. Axillary hairs 3-celled, with 1 or 2 distal cells. Branches up to 150 mm long, about equal in length, widely spreading, pinnate. *Stem leaves* broadly rounded, cordate-triangular; up to 2 mm × 1 mm; incurved or secund, widely patent at base when wet and dry, mostly deeply plicate below, becoming plane upwards; apex gradually or abruptly to a narrowly triangular or subulate acumen, slightly erect, patent or flexuose; margins moderately to strongly broadly recurved below, narrowly recurved to plain upwards; appendiculate at base; costa strong, abaxially prominent, smooth or rough by prorate cell; laminal cells 5–12 µm wide; differentiated, variously shaped; terminal cell elongated acute or truncate; upper cells elongated, smooth to weakly ornamented; median cells isodiametrical; uni- to pluripapillose, papillae sharp; walls weakly to strongly incrassate. *Branch leaves* up to 0.5 mm long; ovate-triangular when dry strongly incurved, when wet patent with weakly incurved acumen; apex narrowly short acuminate, acute or obtuse; terminal cell truncate, pluripapillose, sometimes hyaline; costa abaxially weakly prominent; cells 5–10 µm wide; isodiametrical; with 2 or 3 distal papillae; walls thin or moderately incrassate.

Dioicous. *Perichaetia* ovate-lanceolate; apex gradually narrowing to flexuose acumen or subula; margins plane, shoulder strongly ciliate; costa thin, weak, laminal cell linear, prorate or smooth. *Seta* reddish orange; smooth. Capsule orange-brown; inclined to subpendulous, subcylindrical or narrowly ellipsoid, weakly to strongly curved. *Calyptra* cucullate and smooth to sparingly papillose.

Ecology: It grows in wet and dry forests and grasslands.

Distribution: *Thuidopsis* is a Southern Hemisphere genus distributed in South America, Australia, New Zealand, southern Pacific, S. Malaysia, tropical Asia and western Pacific and may extend into Northern Hemisphere. In Africa it occurs in the Comoros.

Notes: A detailed account of *Thuidopsis* is outlined in Touw (2001b). It is similar to large species of *Thuidium* by stature, paraphyllia terminal cell shape, stem leaf placement, stem leaf margins, branch leaf terminal cell shape, breeding system, inner perichaetial leaf shoulder margin, and seta ornamentation.

2.1. *Thuidiopsis sparsa* (Hook. f. & Wilson) Broth. in Brotherus, Nat. Nat. Pflanzenfam. (ed. 2).11: 1–542. (1925).

Basionym: *Hypnum sparsum* Hook. f. & Wilson in Hooker & Wilson, Flor. Nov.-Zel. 2: 109. 89 f. 5 (1854).

Other combination: *Thuidium sparsum* (Hook. f. & Wilson) Reichardt in Reichardt, Fungi, Hepaticae et Musci frondosi. In E. Fenzl, Reise der Osterreichischen Fregatte Novara um die Erde. Bot. Theil. 1: 131–196 (1870).

Thuidium furfurosum var *sparsum* (Hook. F. & Wilson) Sainsbury, in Sainsbury, Rev. Bryol. Lichenol. 21: 223 (1952).

Thuidiopsis furfurosa var. *sparsa* (Hook. f. & Wilson) Wijk & Margad. in Wijk & Margadant, Taxon 10: 26 (1961). Type: NEW ZEALAND, North Island, Whangarei, *Bolton s.n.* [BM holotype !; NY, L isotype, fide Touw (2001b)].

Cyrto-hypnum montei Hedenäs in Hedenäs, Bryophyt. Biblioth. 44 (1992). Type: MADEIRA, "Quinta do Rocha Machado – Monte," *Barreto s.n.* [MADS holotype, not seen].

Thuidium subserratum Renauld & Cardot. Bull. Soc. Belgique 32 (1): 110 (1894). Type: GRANDE COMORE, *Humblot s.n.* [PC holotype, BR, FH, FI, NY, S isotype, fide Touw (2001b)].

Plants medium to large; loose or compact, intricate wefts or mats, occasionally thread-like elongate fronds; pale green or yellowish green; wiry, coarse and rigid. *Stems* spreading, ascending, prostrate, occasionally creeping; about 60–120 mm long; (1)2-pinnately branched. *Paraphyllia* plenty; simple; mostly short or long, 7(–12) cells long; cells short, oblate, oblong, or quadrate; coarsely papillose; terminal cell mostly truncate or rounded; uniseriate or multiseriate at base. Axillary hairs 2- or 3-celled, 1(2) brown basal and 1 hyaline distal cell. Branches up to 10 mm long; generally more open ramification, occasionally dense, often less strictly pinnate, making the plant look wiry; unequal in length, horizontally spreading or ascending, 7(–12) mostly distant branchlets on both sides; paraphyllia restricted to the basal half of main branch to absent in branchlets. *Leaves* dimorphic; plane to deeply plicate. *Stem leaves* 1(–1.5) mm × 0.8(–1.0) mm; cordate, deltoid, triangular-ovate or broadly triangular; distant to closely set; short decurrent; strongly incurved, often from a patent base when dry; widely patent at base both wet and dry; apex gradually or mostly abruptly contracted, narrowly acuminate to subulate, occasionally ending in a short uniseriate hair tip of up to 5 cells; straight to mostly flexuose and

often secund when dry; margins plane to mostly strongly recurved below, plane above; entire to weakly papillose-serrulate; occasionally short-appendiculate at base; marginal cells oblate; costa weak or strong; percurrent, ends below or disappears in apex, tip indistinct; yellowish at base; paraphyllate at base; laminal cells crowded; terminal cell truncate or acute, pluripapillose; upper cells longer; less strongly ornamented to smooth; median cells 5–12 μm wide; rounded or isodiametrical; pluripapillose, or rarely mixed with a few unipapillose cells; walls moderately incrassate, occasionally strongly incrassate or collenchymatous; basal cells elongated, enlarged; smooth to pluripapillose; alar cells weakly differentiated to form a group of oblate crowded cells. *Branch leaves* 0.3 mm long; broadly ovate or oblong-ovate; when dry appressed to strongly incurved, imbricate, from a patent base; when wet erecto-patent; deeply concave; apex mostly broadly or narrowly acute, occasionally weakly acuminate, obtuse or rounded; margin plane; entire to weakly papillose-crenulate; costa reaching $\frac{3}{4}$ the leaf length; median cells rounded or isodiametrical; bi- to pluripapillose, upwards occasionally unipapillose to smooth; terminal cell truncate or acute.

Dioicous. *Perigonia* up 1.5 mm long; leaves obovate or ovate-lanceolate; apex short to long acuminate; costa strong, disappearing in apex; margins entire, occasionally recurved at apex or shoulders; terminal cell acute or truncate; upper cells and median cells rectangular, elliptical or linear-rhomboidal, pluripapillose, walls incrassate, sometimes flexuose and pitted; basal cells elongate-rectangular, inflated, smooth, yellowish brown at insertion, walls thin to thick. *Perichaetia* up to 2.5 mm long; mature inner leaves triangular-lanceolate or oblong-lanceolate; plain or weakly plicate; apex acuminate to forming a long fine hair point, often flexuose; costa strong, disappearing in apex to long excurrent; margins entire, ciliate at shoulders, cilia top cell often truncate; upper and median cells linear-vermiculate, pluripapillose, walls incrassate, often pitted; basal cells larger, smooth, walls thin to thick; occasionally yellowish brown at insertion. Sporophyte in Africa not seen; material examined from Touw & Snoek 25705, W. Australia (L). *Seta* 15–18 mm long, smooth, deep red, orange-brown or red-brownish; twisted. *Capsule* up to 3 mm long mostly inclined, horizontal to sub-pendulous; constricted below mouth when dry; with neck; deep red. *Exothecial cells* quadrate, rounded to irregularly short-angulated; smooth; walls incrassate, collenchymatous. *Peristome* perfect; exostome pale yellowish to orange-brown; exostome longer than endostome; cilia in groups of 2 or 3. *Operculum* up to 2 mm long, conical to rostrate. *Calyptra* cucullate, smooth, sparingly papillose, basal part often sparingly fringed at base. *Spores* 6–16 μm wide, smooth or minutely papillose. See figure 6.13.

Diagnostic characters: This species is recognized by bipinnately branched stems, simple, paraphyllia with short, quadrate cells, truncate terminal cell of paraphyllia, stem and branch leaves, very broad base of stem leaves, isodiametrical and pluripapillose stem leaf median cells, ciliate perichaetial leaf shoulder margins, smooth seta, and long paraphysal hairs fringing at the base of the calyptra.

Ecology: *Thuidiopsis sparsa* is a Gondwanan species with austral distribution; its habitats are known to range from subtropical rain forest to dry sclerophyll forest, shrub communities, open forest communities, mountains, valleys, grassland; on rocks, tree roots, tree bases, rotting logs, boulders, granite and litter; in humid, wet and damp areas or in immediate vicinity of watercourses; in sheltered or well-lit places; at 600–1850 m.

Distribution: In Africa it is known only from the Comoros islands. The specimen examined was a collected by J.N. Hildebrandt (No. 1827E) in 'Insel Johanna, Comoren', on 6/9/1875, and has been housed in Helsinki under the name of *Thuidium subserratum*. It is a widespread and common species of southern South America, Australasia, New Zealand, Malaysia, West and southern Pacific islands, New Caledonia, Fiji, India?, Chile, Kermadecs, Cook Island, Tristan da Cunha and the drier parts of Indonesia. It also occurs almost certainly and introduced in Madeira (Touw *pers comm.* 2010). See Map 6.13.

Specimens of *T. sparsa* studied: COMOROS: *Hildebrandt 1827e* (H). NEW ZEALAND: *Bolton s.n.* (BM). *Buck 52834* (NY); *Ratkowsky & Ratkowsky B 100A, B 115, B 112A* (NY). JAPAN: *Higuchi 31518*. CHILE: *Ireland & Bellolio 33136, 33149, 33152, 31840, 31227, 35428, 35592, 35158, 35396, 33545* (NY).

Specimens of *T. sparsa* var. *hastatum* studied: AUSTRALIA: *Touw & Snoek 25705, 25567* (L).

Notes: *Thuidiopsis sparsa* is similar to *Thuidium* by its tall, robust habit and sexuality (Fig. 5.1 and 5.18). The genus is frequently treated as a synonym of *Thuidium* (Buck & Crum 1990); according to them it differs from *Thuidium* by having simple paraphyllia (Fig. 5.3), leaf cells ornamented on both faces, strongly incurved stem leaves, 3-celled axillary hairs with two brown basal and one hyaline apical and long paraphysal hairs at base of calyptra. African specimen examined resemble the Australian material with both being medium to large statured and having

distinctly imbricate branch leaves making a plant look like a *Haplocladium* species. Japanese plants seen are smaller and wiry. Chilean specimens examined are represented by very small plants but with stem branching resembling *Haplocladium*. The Australian *T. sparsa* var. *hastata* is more robust and resembles the African *Abietinella abietina*. Another common species of *Thuidiopsis* is *T. furfurosa* which differs from *T. sparsa* by being more robust with fluffier appearance (Meagher & Fuhrer 2003).

3. *Thuidium* Bruch & Schimp.

Thuidium Bruch & Schimp. in Bruch & Schimper, Bryol. Eur. 5: 157 (fasc. 49–51. Mon. 1.)

Type (lectotype) species: *T. tamariscinum* (Hedw.) Schimp. Typification of *Thuidium* is accepted according to discussion by Buck & Crum (1990).

Plants loose wefts, tufts or cushion, medium to large, tall, very vigorous, robust, more or less rigid; dull green or yellowish brown; prostrate, elongate horizontal fronds and rooting at base, spreading or suberect. *Stems* up to 150 mm long; prostrate, creeping or ascending, regularly, complanately and densely 2 or 3-pinnately branched, attractively frondose; central strand present, ill defined. Axillary hairs 3-celled with 1 brown basal cell and 2 hyaline apical cells. *Paraphyllia* numerous on main stem, strongly branched and uniseriate, about 20–25 cells long, cells quadrate to rectangular, mostly papillose, terminal cell mostly truncate or rounded. Branch paraphyllia few to often absent in ultimate pinnate, shorter, often unbranched, scattered, often basal. *Leaves* dimorphic or weakly so, erecto-patent, never secund, decurrent. *Stem leaves* triangular, deltoid, ovate-triangular or lanceolate-subulate from a cordate base; strongly plicate; apex gradually to abruptly ending in a short or subulate acumen, or piliferous; margins often recurved below, plane upwards, entire, toothed or papillose-crenulate; paraphyllate basally; costa strong; percurrent, disappearing in apex or excurrent; ridge rough, ends in one to several spines, abaxial face flat or prominent; paraphyllate basally; laminal cells not differentiated; terminal cell truncate, rounded or acute; upper cells often longer and less ornamented than adjacent cells; median cells isodiametrical, oblong, roundish or oval-hexagonal, 4–10 µm wide; mostly uni- or - pluripapillose, abaxial face smooth or papillose, adaxial face smooth or weakly to strongly papillose near margins; walls incrassate, sometimes sinuose, often pitted. Basal cells often pitted, longer, larger; alar cells not differentiated. *Branch leaves* erect, concave, ovate, ovate-lanceolate or broadly ovate-oblong, concave; apex triangular, acute, occasionally obtuse; margins plane or recurved, papillose-crenulate, or serrulate; costa shorter and weaker, to 0.7 the leaf length, abaxial face weakly prominent, smooth or weakly papillose below and strongly upwards, occasionally ending in a spine; terminal cell acute or truncate; median cells 4–12 µm wide, isodiametrical, rounded to oblong-hexagonal; adaxial face ornamentation stronger; thick-walled.

Dioicous. *Perigonia* 1–2 mm long; lateral on stem; leaves ovate or lanceolate; concave; plane or weakly plicate; apex acute to long acuminate; margins plane to incurved, entire to serrate especially at apex, often bordered by a row of shorter cells; costa strong to weak, disappearing at ½ the length of leaf; upper and median cells elongate-rectangular, linear-

vermiculate or -rhomboidal, smooth or papillose, papillae central or upper on cell wall, walls thin to incrassate, straight or pitted; basal cells elongate-rectangular, smooth, thin- to thick-walled, sometimes pitted, reddish brown at insertion. *Perichaetia* up to 5.5 mm long; mature inner leaves lanceolate to ovate-lanceolate, apex long acuminate to setaceous, straight or flexuose; margins plane, entire to serrate, shoulder ciliate, occasionally not. *Seta* long, smooth. *Capsule* inclined to horizontal, curved, cylindrical or oval-oblong, usually narrowed below the mouth when dry, sometimes with short distinct neck. *Peristome* teeth lanceolate-subulate, bordered, striate, with close lamellae; endostome smooth or finely papillose, reddish or orange; basal membrane wide and plaited; processes as high as teeth, lanceolate, folded, perforated; cilia 2-4, shortly paraphyllate, seldom rudimentary or absent. *Operculum* obliquely beaked from an arched conical base. *Calyptra* elongate cucullate, naked, smooth to spinose, often fails to split or splits irregularly; apex obtuse, mucronate or apiculate. *Spores* 12–15 µm wide; spherical; papillose; yellowish brown.

Ecology: *Thuidium* is a mountain forest genus found on tree trunks and logs or rotting wood, rocks, litter, humus and soil, among boulders, on mountain summits, valleys, cliffs, road banks as well as in plantations, closed and open wood forests or scrub, near river, streamside, waterfall, river tribinary or ravine; in high rainfall, misty, humid, damp to well drained sites; in full or partial shade; at 450–3000 m.

Distribution: The genus is subcosmopolitan in distribution. *Thuidium aculeoserratum* is endemic to Africa and is found in Madagascar and Réunion. *Thuidium assimille* is a pan-tropical species occurring in temperate and boreal parts of the Northern hemisphere and tropical mountains of South and East Africa, New Guinea, Central and South America (Touw 2001b). In Africa, *T. tamariscinum* grows in Ethiopia, Réunion, Tanzania, and Uganda.

Notes: The genus name refers to the resemblance of the fronds with branches of cedar (*Thuja*). *Thuidium* is the largest dioicous genus with 20–25 species worldwide. This is the prettiest and most attractive genus of the family. African *Thuidium* is narrowed down to large dioicous species. It is known for having small differences and large overlapping variability between species making it hard to define species. Touw (1976) classified this group as *Thuidium* subgenus *Thuidium* represented by large, frondose, 2 or 3-pinnate, dioicous species.

The morphological and anatomical examination of the African Thuidiaceae clearly validates the new re-grouping of the African taxa. The true *Thuidium* species can now be characterized by a character combination of a tall, robust habit, 2- or 3-pinnately branched stems, abundant, strongly branched paraphyllia, often strongly plicate stem leaves, often pitted, reddish brown basal laminal cells, basally appendiculate leaves, dioicous breeding, ciliate perichaetial shoulder margins and smooth setae.

Key to the African species of *Thuidium*

1 Paraphyllia and laminal terminal cell mainly acute; stem leaf apex broadly acute.....

.....**3.3. *T. tamariscinum***

- Paraphyllia and laminal terminal cell mainly truncate; stem leaf apex narrowly acuminate to filiform.....2

2 Stem leaf apex acuminate to short awn of up to 3 cells; paraphyllia cells elongated; stem leaf margins coarsely papillose-serrate.....**3.1. *T. aculeoserratum***

- Stem leaf apex mostly ends in a long filiform hair point of up to about 10 cells; paraphyllia cells mostly short; stem leaf margins mostly entire to weakly papillose-crenulate.....

.....**3.2. *T. assimile***

3.1. *Thuidium aculeoserratum* Renaud & Cardot. Bull. Soc. Roy. Bot. Belgique 32(1): 109 (1894).

Type: MADAGASCAR, Betsileo, in silvis inter Vinanitelo et Ikongo, *Besson 334* [PC holotype, BR, FH, fide Touw (1976)].

Plants large, robust; forming horizontal, yellowish green to brown green thick mats. *Stems* 50–100 mm long; flexuose; creeping, prostrate; 3-pinnately branched, becoming shortly 1 or 2-pinnate at apex; base often short-branched. *Paraphyllia* abundant, dense; strongly branched, with short to long branches, up to about 20 cells long; cells short to mostly long, papillose; terminal cell truncate. Axillary hairs consist of 1(2) brown basal cell and 2 or 3 hyaline distal cells. Branches 10–14 mm long, closely to sparsely set, ascending, narrowing towards apex, branchlets thin and closely set, paraphyllia dense becoming sparse in ultimate branchlets, apically tapering, apices occasionally rooting. *Leaves* weakly dimorphic; from a cordate base. *Stem leaves* broadly ovate, deltoid or lanceolate; 1–1.25 mm long, 0.5 mm wide; irregularly strongly plicate; when dry appressed; when wet patent-erect, spreading; apex gradually to abruptly short-acuminate or ending in a short awn of a row of up 1 or 2(3) hyaline, elongate, smooth cells; erect or flexuose. margins plane to weakly incurved below, plane upwards; coarsely papillose- or spine-like-serrate throughout leaf length; marginal cells subquadrate, rectangular or oblong, longer than short; costa strong; percurrent, $\frac{3}{4}$ of leaf length, tip distinct; prominent, strongly spinulose ventrally; appendiculate ventro-basally; laminal cells weakly or not differentiated; terminal cell acute, often longer than adjacent cells smooth; median cells 0.1 mm long; mostly elongated rectangular-oblong- or linear-elliptical; unipapillose, occasionally bipapillose, dorsally becoming smooth, papillae low, small, mostly central or upper on cell wall; walls thin to incrassate, pitted or not, often sinuose; basal cells enlarged, elongated, linear; smooth to weakly unipapillose; yellowish or reddish brown; alar cells not differentiated. *Branch leaves* 1–1.5 mm, 0.25 mm wide; ovate; crowded, closely set; when dry appressed; when wet erect-patent, incurved; plicate; apex gradually broadly or narrowly acute to short-acuminate, sub-obtuse in ultimate branch leaves; margins plane to recurved below, plane upwards; serrate or weakly papillose-crenulate; marginal cells elongated; costa strong; percurrent, ending below apex, tip distinct; cells papillose; terminal cell truncate, occasionally acute; often papillose; median cells $7\text{--}15 \times 3.5\text{--}7 \mu\text{m}$; short isodiametrical, quadrate or rounded; flexuose; smooth to mostly unipapillose to occasionally bipapillose, papillae prominent, sharp, ventrally curving towards apex, central; walls incrassate; basal cells same as median cells; alar cells not differentiated.

Dioicous. *Perigonia* up to 1 mm long; leaves ovate or lanceolate; concave; apex acute to short acuminate; costa weak, disappearing at $\frac{1}{2}$ the length of leaf; margins plane to incurved at shoulders, entire, roughly serrate at apex, bordered by a row of shorter cells; upper and median cells linear-vermiculate or -rhomboidal, papillose, papillae central or upper on cell wall; basal cells elongate-rectangular, smooth, thin- to thick-walled, sometimes pitted, reddish brown at insertion. *Perichaetia* up to 2.5 mm long; mature inner leaves lanceolate or oblong; sheathing; apex gradually subulate, setaceous, ending in a piliferous point of up to 5(–6) cells, flexuose; margins entire to irregularly coarsely serrate, shoulder ciliate; median cells linear-rhomboidal, smooth, walls thick, pitted; basal cells rectangular or sub-hexagonal, almost inflated, smooth, thin- to thick-walled. Sporophyte not seen. See Figure 6.14.

Diagnostic characters: This species is recognized by tripinnately branched stems, dense, strongly branched paraphyllia with truncate terminal cell, strongly plicate stem leaves with short to long awned apex, coarsely serrate margins, acute terminal cell and unipapillose, pitted and sinuose laminal cells, truncate branch leaf terminal cell and ciliate perichaetial leaf shoulder margins.

Ecology: *Thuidium aculeoserratum* is a mountain forest species found on ground layer and tree trunk; in shade; at up to 1700 m.

Distribution: *Thuidium aculeoserratum* is endemic to Africa and is found in Madagascar and Réunion only. See Map 6.14.

Specimens studied: MADAGASCAR: *Crosby & Crosby 7138; Hildebrandt 2075* (BM).

Notes: Touw (1976) states that *T. aculeoserratum* is an intermediate between *T. assimille* and *T. tamariscinum* in many respects. I found this to be true because *T. aculeoserratum* combines the characters of both species. *Thuidium aculeoserratum* can be distinguished from *T. assimille* by a distinct tripinnately branched stem; less neat branching; much shorter stem leaf apex; denser, thinner and longer-branched stem paraphyllia. It can be separated from both *Thuidium* species by leaf margins and back of costa more coarsely serrate throughout the leaf length. All the African voucher specimens labeled as *T. aculeoserratum* in BM have been found to be *T. assimille* except for one, *Hildebrandt 2075* (BM). These specimens have less filiform stem leaf apex, less apparent tripinnate branching and far less coarsely serrate leaf margins compared to the type

material which has these characters apparent. The four BM specimen (Madagascar, Central Madagascar, S. Betsiléo, Wald von Ankafina, *Hildebrandt 2075*), filed as types of *Hypnum struthiopteris* Müll. Hal. are under an invalid name and I have not recognized them as types. Frahm (2009) listed *T. aculeoserratum* among the low number of species common in the Mascarenes where it occurs on the Réunion.

3.2. *Thuidium assimile* (Mitt.) A. Jaeger in Jaeger, Ber. Thätigk. St. Gallischen Naturwiss. Ges. 211–454 (1878).

Basionym: *Leskea assimilis* Mitt. J. Proc. Linn. Soc. Bot. Suppl. 1: 133 (1859). Type:

HIMALAYAE OCCID. reg. temp., Kumaon, Kathi, *R. Strachey & J.E. Winterbottom 92 = 74B* [NY holotype, BM, H isotype, fide Touw (2001b)].

Hypnum promontorii (subsect. *Tamariscella*) Müll. Hal. Hedw. 38: 150 (1899).

Thuidium promontorii (Müll. Hal.) Paris Id., Suppl. Prim. 321 (1900). Type: SOUTH AFRICA, Cape of Good Hope, *Ecklon & Zeyher s.n.* [B holotype, lost; G lectotype, H isotype, fide Touw (2001b)].

Thuidium matarumense Besch. in Besherville, Ann. Sci. Nat. Bot. sér. 6, 10: 290 (1880A). Type: RÉUNION, Cilaos, Hauts du Matarum, *Valentin s.n.* [BM lectotype !, PC isotype, fide Touw (2001b)].

Plants large, robust; sordid green, yellowish green to reddish or yellowish brown, tinged with rusty red; erect or creeping open fronds forming mats. *Stems* procumbent, arching; 30–100(–200) mm long; deep reddish brown; regularly 2(3)-pinnately branched, becoming 1-pinnate at apex; older stems occasionally leafless or branchless. *Paraphyllia* abundant, dense; strongly short-branched; short to long, up to about 25 cells long; cells mostly short, isodiametrical quadrate to short-rectangular, smooth to coarsely pluripapillose; terminal cell truncate, occasionally rounded or acute, mostly uni- or pluripapillose or smooth; reddish brown basally. Axillary hairs consists of 1 brown basal cell and 1–3 hyaline distal cells. Branches up to (5–)20 cm long, very closely to sparsely set, falcate, pointing towards stem apex, sometimes on one side of the rooting stem, apical branches shorter; paraphyllia sparse, plenty basally, becoming naked upwards and on distal branchlets. *Leaves* dimorphic, from a cordate to short-decurrent base. *Stem leaves* broadly lanceolate, ovate, triangular-ovate, cordate to deltoid-ovate; up to 2 mm by up to 1 mm; deeply 2–4 longitudinally plicate; when dry julaceous, concave, incurved, appressed with twisted apex; when wet patent-erect to spreading; apex short or long acuminate to mostly piliferous, ending in a very long fine filiform awn of 3–10, smooth to weakly papillose, elongated, often hyaline cells; erect, flexuose or twisted, often broken; margins recurved below, plane upwards; papillose-crenulate below, finely papillose-serrate to mostly entire upwards; costa strong; occasionally grooved dorsally; percurrent, disappearing in apex, tip distinct often when laminal cells are short or indistinct; cells papillose on ventral face; occasionally flexuose; reddish brown, pitted basally;

appenditulate ventro-basally; terminal cell acute, mostly elongated, smooth; upper cells irregularly angulated, mostly elongate, oblong to linear-rhomboidal; smooth to unipapillose; walls incrassate, straight or vermiculate, often pitted; median cells variously angulated, short to long, hexagonal or rhomboidal; $10\text{--}32 \times 3.5\text{--}7 \mu\text{m}$; dorsally smooth in middle, becoming strongly unipapillose to occasionally bipapillose, ornamented towards margins and on ventral face, papillae central or upper on cell wall, short, mostly prominent, straight or curved; walls weakly to mostly strongly incrassate, pitted; basal cells elongated; rectangular to linear; reddish brown; smooth to mostly bipapillose; walls incrassate, pitted, straight or sinuose; alar cells not differentiated. *Branch leaves* cordate, ovate to broadly ovate; 0.4–0.75mm long; weakly asymmetrical; plicate; when dry julaceous, concave, strongly incurved from erecto-patent base; when wet patent-spreading; very rough with papillae; apex acute; margin plane; coarsely papillose-crenulate; marginal cells weakly differentiated, short, isodiametrical, smooth to unipapillose, papillae low; costa strong; percurrent, 0.7 the leaf length, tip distinct; ventrally prominent, papillose, papillae curving towards apex; terminal cell mostly truncate, occasionally acute; occasionally hyaline; pluripapillose; median cells isodiametrical, quadrate or rounded; $7\text{--}15 \times 3.5\text{--}7 \mu\text{m}$; papillae distinct, ventrally curving towards apex; thin-walled to incrassate, pitted; basal cells elongate-rectangular; alar cells not differentiated.

Dioicous. *Perigonia* up to 2 mm long; leaves ovate to lanceolate; concave, plane or weakly plicate; apex acuminate to setaceous, straight or flexuose; margins plane, entire, serrate at apex, shoulder bordered by shorter cells; costa very weak, disappearing at $\frac{1}{2}$ length of the leaf; upper and median cells linear-vermiculate or linear-rhomboidal, smooth, walls incrassate, pitted; basal cells elongate-rectangular, smooth, thin- to thick-walled, sometimes pitted, reddish brown at insertion. *Perichaetia* 2.5–5.5 mm long; mature inner leaves lanceolate or oblong; sheathing; strongly plicate; apex gradually subulate, setaceous, ending in a piliferous point of up to 5(–6) cells, flexuose; margins irregularly coarsely serrate, shoulder ciliate or not; median cells linear or linear-rhomboidal, vermiculate, smooth, thick-walled or pitted; basal laminal cells rectangular or sub-hexagonal, almost inflated, smooth, thin- to thick-walled. *Seta* (20)30–40 mm long, smooth, deep red or orange-brown below, yellowish brown above, twisted. *Capsule* 1.5–3.0(4.0) mm long, about 1.3 mm wide, asymmetrical, cylindrical, curved, constricted at neck, inclined to horizontal, pale brown to orange-brown. *Exothecial cells* short, irregularly angulated, hexagonal or rhomboidal, walls smooth, strongly incrassate, not collenchymous. *Peristome* double; exostome teeth linear-lanceolate, trabeculate, yellowish-brown and cross-striated, becoming lighter to hyaline and papillose towards apex; endostome almost as long as exostome, cilia

nodulose to trabeculate, in groups of 1–3, partly united, basal membrane almost $\frac{1}{2}$ of exostome height, processes folded, medially perforated. *Operculum* 0.6–1.6 mm, obliquely long-rostrate or conical. *Calyptra* cucullate, smooth, apex mucronate. *Spores* spherical, 12–15 μm wide, papillose, yellowish brown. See Figure 6.15a and 15b.

Diagnostic characters: This species is recognized by regular bipinnately branched stems, dense, strongly short-branched paraphyllia with isodiametrical cells and truncate terminal cell, filiform stem leaf apex, acute terminal cell, unipapillose median cells and reddish brown, pitted basal cells, truncate branch leaf terminal cell, ciliate perichaetial leaf shoulder margins, smooth seta, none-collenchymatous exothecial cell walls.

Ecology: *Thuidium assimile* is an afro-montane moss growing on mountain summits, valleys, cliffs, slopes as well as a forest bottom species growing in plantations, closed and open wood forests or scrub, near river, streamside, waterfall, river tributary or ravine; on rock (gravel, sandstone, quartzite, limestone), litter, humus, sandy soil, tree trunk, bark, branches or log; in full to partial shade; in high rainfall, misty, humid, damp to well drained sites; at (450–)1000–3500 m. This species often grows in association with other species such as *Leucosidea* sp., *Podocarpus latifolius*, *Buddleja* sp., *Protea* sp., *Erica arborea*, Lichen species, *Hymenophyllaceae* species, *Frullania* sp., *Betulina* sp. and *Erica arborea*.

Distribution: *Thuidium assimile* is a Pan-tropical species occurring in temperate and boreal parts of the Northern hemisphere and tropical mountains of South and East Africa, New Guinea, Central and South America (Touw 2001b). In Africa it grows in mountain and coastal bushes of Comoros, Kenya, Lesotho, Madagascar, Malawi, Réunion, South Africa, Tanzania, Uganda and Zimbabwe. See Map 6.15.

Specimens studied: KENYA: *Allan 1043; Leighton 61 (BM); Marshall & Crosby 13,333b; Nekesa s.n.; Hedberg 1974, 2419a (BM)*. LESOTHO: *Deal & Killick 121a; Dieterlen 591, 591a, 591b; Getliffe & Mzamane 331; Jacot-Guillarmod & Killick 4406b; Magill 4335; Magill 4447; Schmitz 7868; Wilson 9*. MADAGASCAR: *Perrie s.n.* RÉUNION: *Arts REU 18/40 (L); Marshall & Crosby 8995; Valentin s.n. (BM)*.

SOUTH AFRICA: *Anderson PRE-CH 12949; Burrows 5977(L); Burt 13141; Burt-Davy 15354; Cholnoky 6, 92; Cooper 1049 (BM); Cooper 3395 (BM); Davidson & Mogg 33009;*

Esterhuysen 21629; *Garabedian* 3006; *Garabedien* 49742; *Haygarth* 8086, 12; *Henderson* 187, 98 (BM); *Hilliard & Jacobz* 4724; *Jacot-Guillarmod* 4170; *Lambert* 3; *Glen* 3018; *Leighton* PRE-CH 6010; *Liebenberg* 7581, 7651; *Mac Lea* 646 (BM); *Magill* 5620, 5652; 5610, 5597; 5764, 5812, 4868; *Marshall & Crosby* 9212; *Mogg* PRE-CH 6009, PRE-CH 6018; *Nicholas & Van der Berg* 1315; *Owen* 65; *Rennie & Lambert* 15; *Rolpes* 167 (BM); *Schelpe* 2124, 2129; 7577a, 7576 (PRE); *Schelpe* 2129 (BM); *Sim* 7385, PRE-CH 8881; 7234; 8558, PRE-CH 6015, 7477, PRE-CH 6003, 8022; *Sim* 8558 (BM); *Smook* 11436A, 4019; *Smook & Phelan* 843; *Stirton* 9008; *Strey* 7760; *Sweeney* 25260; *Tyler* 12526; *Tyson* 1429, PRE-CH 8877 (PRE); *Tyson* 1429, 1280b (BM); *Van der Bijl* 12, 501; *Van der Schijff* 5598; *Van Rooy* 1370, 1438, 1498, 4186, 4168, 4212; 1446; 4224; *Van Rooy & Perold* 3799 (L); *Young* 7395; *Venter* 11,348; *Vorster* 447a, 114, 1216; *W. Mitten deter. II.* 1886 (BM); *Wager* 20407 (BM); *Wager* 7751; *Young* 3002. TANZANIA: *Pócs, Ochyra & Bednarek-Ochyra* 88123/F, 88150/F, 88123/F (L). COSTA RICA: *Fondus s.n.* (NY); *Marshall & Crosby* 2671 (NY); *Maxon* 499, 499a (NY). GUATEMALA: *Standley* PC, 90602, 84265, 80922, 77498, 81879, 84749, 84457, 85230, 47463 (NY); *Sterymark* 35606, 50190, 33375a (NY); *Standley* PG 86586, 85861 (NY); *Croat* 41756, 40977, 40976, 41248 (NY); *Vogel* 9030 (NY); *Richards* 2989 (NY). HONDURUS: *Yuncker, Dawson & Youse* 6614 (NY). PANAMA: *D'Arcy & Davidse* 10311b (NY). SPAIN: *Touw & Snoek* 25550 (L). SWITZERLAND: *Touw & Snoek* 25711(L). TIBET: *Meihe & K. Koch* 94-469-58, 99-156-23.3 (L).

Additional specimens studied (*Thuidium delicatulum*): USA: *Redfearn* 28631 (NY); *Touw* 14345 (L).

Notes: Commonly known as the “delicate fern moss” or “Philibert’s tamarisk-moss”, *T. assimile* is known to belong to the same complex of ill-defined taxa that include the northern hemisphere *T. delicatulum*, East Asian *T. kanende*, and Australian *T. laeviusculum* (Touw 2001b). All the African material examined had the characters listed in this description including some characters known to belong to other species within this complex. *Thuidium assimile* differs from the other two African dioicous *Thuidium* species by bipinnately branched stems, shorter paraphyllia with short, less prominently papillose cells, leaf margins less coarsely toothed, stem laminal cells elongated and often more flexuose and pitted and stem leaf apex ending in a long filiform awn of up to 10 often hyaline cells.

I saw no strong difference between *T. assimile* and *T. delicatulum* as they both share major character states. *Thuidium delicatulum* is a species of northern hemisphere and is not known from southern South America, Africa and Australasia (Ochyra *et al.* 2003). In North America this species is poorly known as the species cannot be distinguished from the closely-related *T. philibertii* (a synonym of *T. assimile*) (Ochyra *et al.* 2003). This species is also confused with closely related *T. recognitum* (Faubert 2008). The material of *T. delicatulum* that I examined shared major characters with *T. assimile*. According to Ochyra *et al.* (2003), *T. delicatulum* occurs in Marion Islands and its migration from the northern hemisphere to this island is probably via Africa by oceanic southern Africa or migration that might have occurred as a result of long distance dispersal from Andean stations using the prevailing westerlies or by man. Since these two species have proven to be conspecific, Africa therefore seems as an intermediate station between Europe and Marion Island and subsequently the migration might have occurred by oceanic southern Africa.

3.3. *Thuidium tamariscinum* (Hedw.) Schimp. Bruch, in Schimper, *Bryologia Europaea* 5: 163 (1852).

Basionym: *Hypnum tamariscinum* Hedw. in Hedwig, *Sp. Musc. Frond.* 261–262, pl. 67, f. 1–5 (1801). Type: MEXICO, Mirador, *Sartorius*, *F.* no date (NY, not seen).

Hypnum mascarenicum Müll. Hal. in Müller, *Syn. Musc. Frond.* 2:485 (1851).

Thuidium mascarenicum (Müll. Hal.) A. Jaeger in Jaeger & Sauerbeck. *Gen. Sp. Musc.* 2: 314 (1878). Type: RÉUNION, *Bery de Saint Vencent s.n.* [B, fide Touw (1976)].

Plant large, robust; forming dull, dark green, yellowish brown or reddish brown mats. *Stems* creeping; 50–160 mm long; 3-pinnately branched. *Paraphyllia* abundant, dense; strongly branched; very long, up to about 25 cells long; cells short to long, oblong-rectangular, sharply pluripapillose; terminal cell truncate, papillose, basal cells reddish brown. Axillary hairs consist of 1 brown basal cell and 1–3 hyaline apical cells. Branches up to 20 mm long; closely set, falcate, pointing towards stem apex, sometimes to one side of the rooting stem. *Leaves* dimorphic, from a cordate base, plicate. *Stem leaves* deltoid, obcordate, cordate or triangular from a short-decurrent base; 5–20 × 9–12 mm; closely, imbricate to sparsely set; occasionally asymmetrical; regulose-plicate; when dry deeply concave, appressed; when wet keeled, curved, erecto-patent; apex abruptly or gradually narrowly to mostly broadly acute to short acuminate; erect or flexuose, when dry pointing away from stem; margins recurved below to just below apex, plane upwards, irregularly distinctly, coarsely serrate at apex, papillose-crenulate downwards; marginal cells weakly differentiated; costa strong; grooved; percurrent, ends below apex, tip distinct; prominently papillose on the upper part, below smooth to weakly papillose; paraphyllate ventro-basally; terminal cell distinctly acute, smooth; laminal cells weakly or not differentiated; upper cells longer, walls incrassate, pitted, sinuose; median cells mostly short, variously angulated, hexagonal, or rhomboid; 10–32 × 3.5–7 µm; mostly uni- to bipapillose, papillae sharp, curving upwards, central to occasionally upper on cell wall; basal cells elongated, enlarged; smooth to bipapillose; reddish brown to brownish orange; pitted; alar cells not differentiated. *Branch leaves* differentiated; 1–1.2 mm × 0.9 mm; broadly lanceolate; concave; closely set; when dry appressed; when wet keeled, curved, erect-patent; apex acute to short-acuminate; margin papillose-crenulate; costa strong, percurrent; laminal cells sharply papillose ventrally; median cells as in stem leaves, 7–15 × 3.5–7 µm; weakly differentiated; mostly unipapillose, papillae central or upper on cell wall, prominent and curving upwards at back;

terminal cell distinctly acute, smooth, occasionally unipapillose, often hyaline; alar cells not differentiated.

Dioicous. *Perigonia* up to 1.5 mm long; leaves lanceolate or oblong, concave or not; apex narrowly to broadly short acuminate; costa strong; margins entire below, coarsely serrate above; upper and median cells linear-vermiculate or -rhomboidal, coarsely unipapillose, papillae central or upper on cell wall; basal cells elongate-rectangular to almost inflated, smooth, thin- to thick-walled, sometimes pitted, reddish brown at insertion. *Perichaetia* as in *T. assimille*. *Sporophyte* not seen. See Figure 6.16.

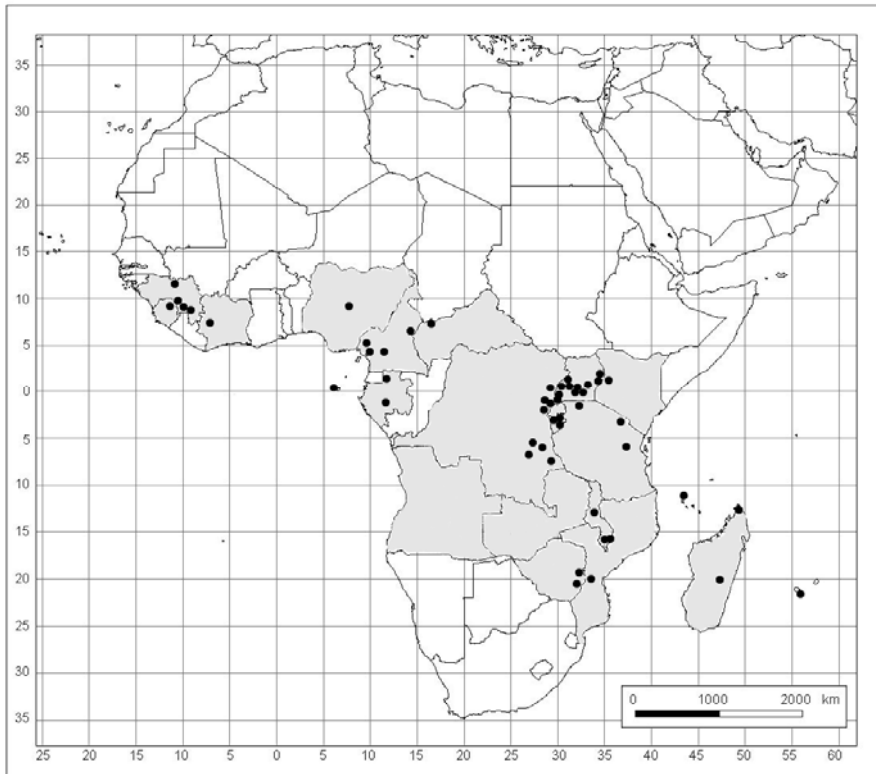
Diagnostic characters: This species is commonly known as a ‘tamarisk-leaved feather moss’ (Jewell 1964), and is recognized by its tripinnately branched stems, dense, strongly branched paraphyllia with coarsely papillose cells and truncate terminal cell, broad, coarsely serrate stem leaf apex, acute terminal cell of stem and branch leaves and unipapillose stem leaf median cells.

Ecology: *Thuidium tamariscinum* grows in mountains, lowlands, forest, among boulders, road banks; on boulders, soil, and rooting wood; at 1100–25000 m; in shade.

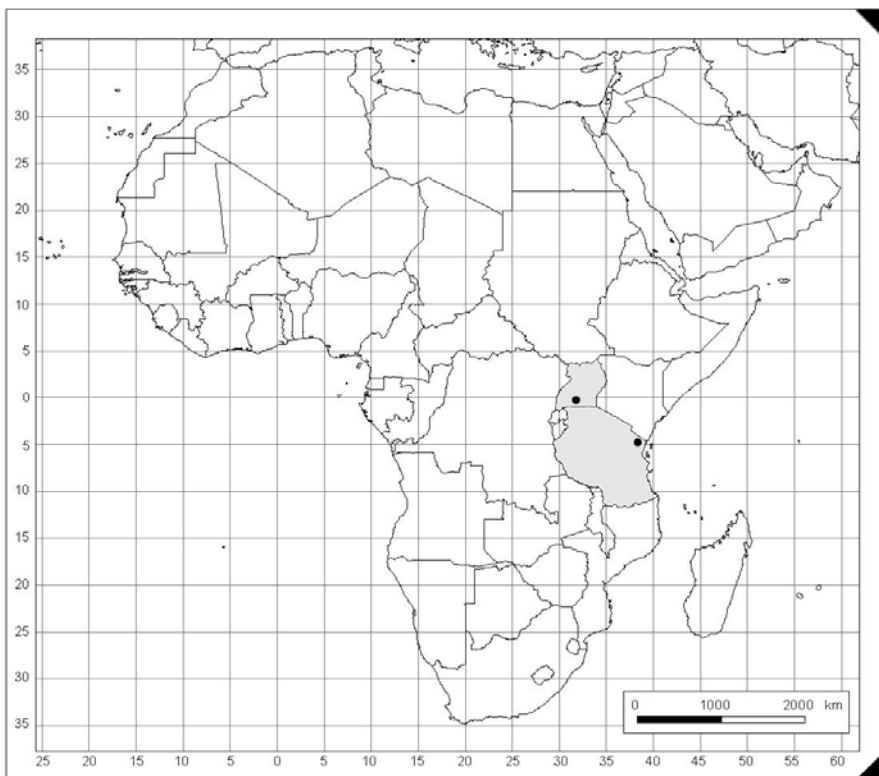
Distribution: *Thuidium tamariscinum* has been reported from Ethiopia, Réunion, Tanzania, and Uganda. Elsewhere it is widespread in temperate, tropical and boreal parts of the world, in America, Europe, Asia, Brazil, Colombia, El Salvador, and Acores. See Map 6.16.

Specimens studied: RÉUNION: *Arts REU51/25, 61/36* (L); *Lépervanche s.n.* (BM); *Marshall & Crosby 8327, 8827*. AZORES: *Persson date 5/1937* (NY). JAPAN: *Iwatsuki & Smith 1298* (NY); *Smith J-579, J-584, J-393, J-355, J-335, J-199, J-257, J-579* (NY); *Watanabe 800* (NY).

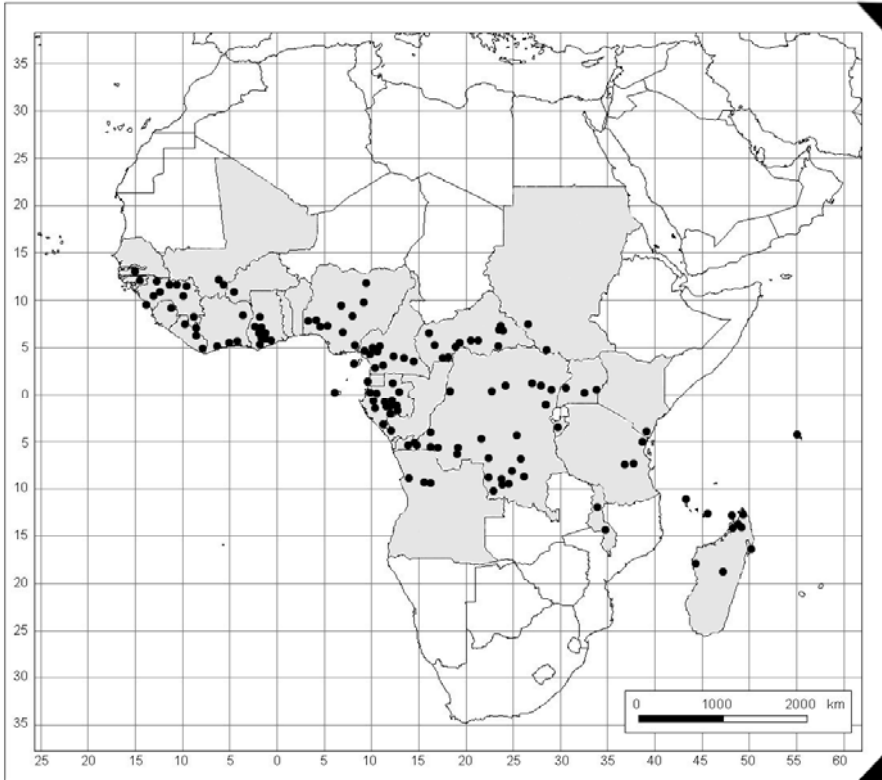
Notes: This species is distinguished from the other two dioicous species of *Thuidium* by acute and smooth terminal cell of stem and branch leaves; distinctly serrulate margins; more distinct costa tip; broad acumen of stem leaf; very long paraphyllia; and short, not differentiated, unipapillose stem leaf cells.



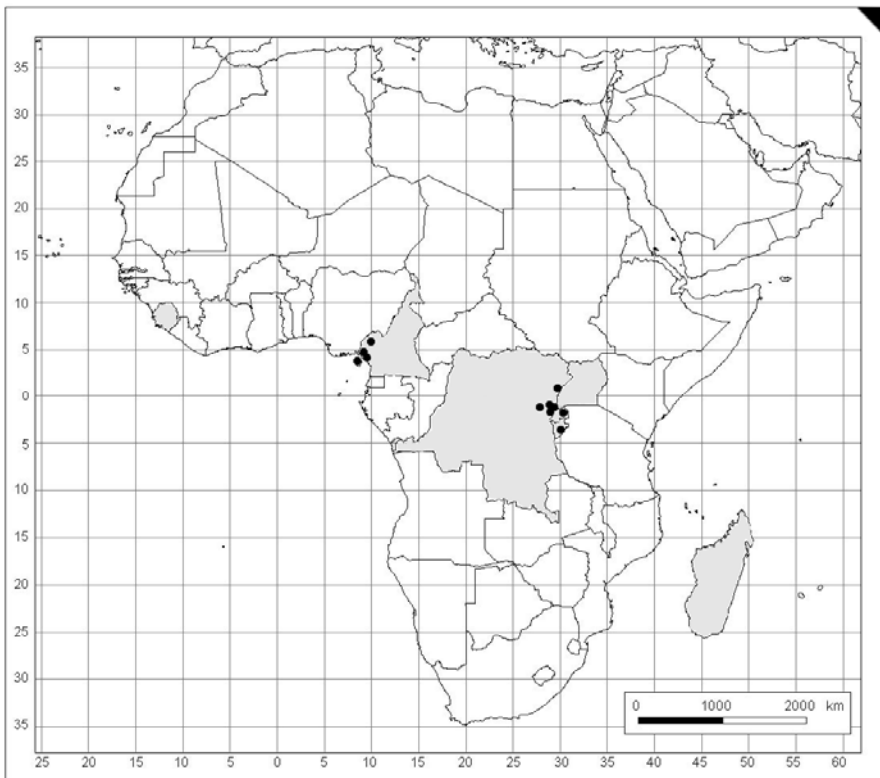
MAP 6.1.— Known distribution of *Pelekium chenagonii* (Müll. Hal. ex Renauld & Cardot) A. Touw.



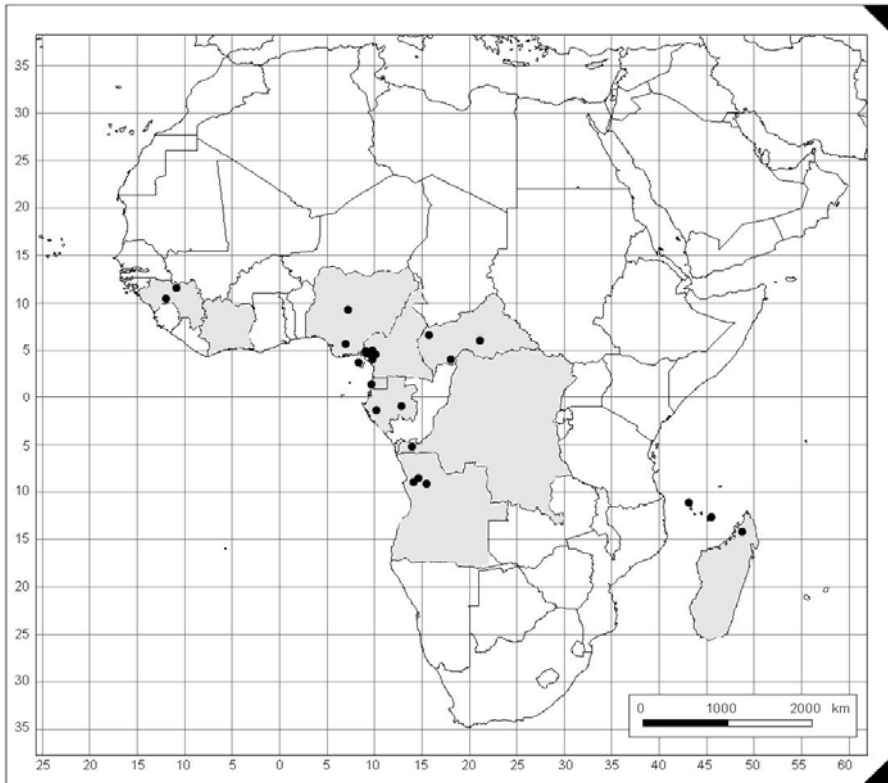
MAP 6.2.— Known distribution of *Pelekium contortulum* (Mitt.) A. Touw.



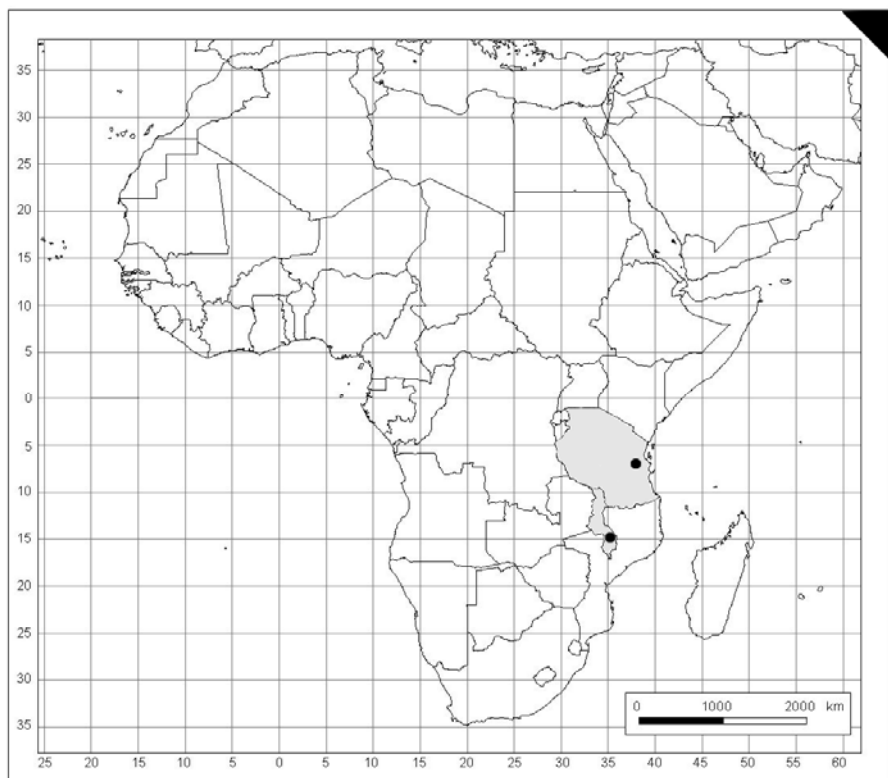
MAP 6.3.— Known distribution of *Pelekium gratum* (P. Beauv.) A. Touw.



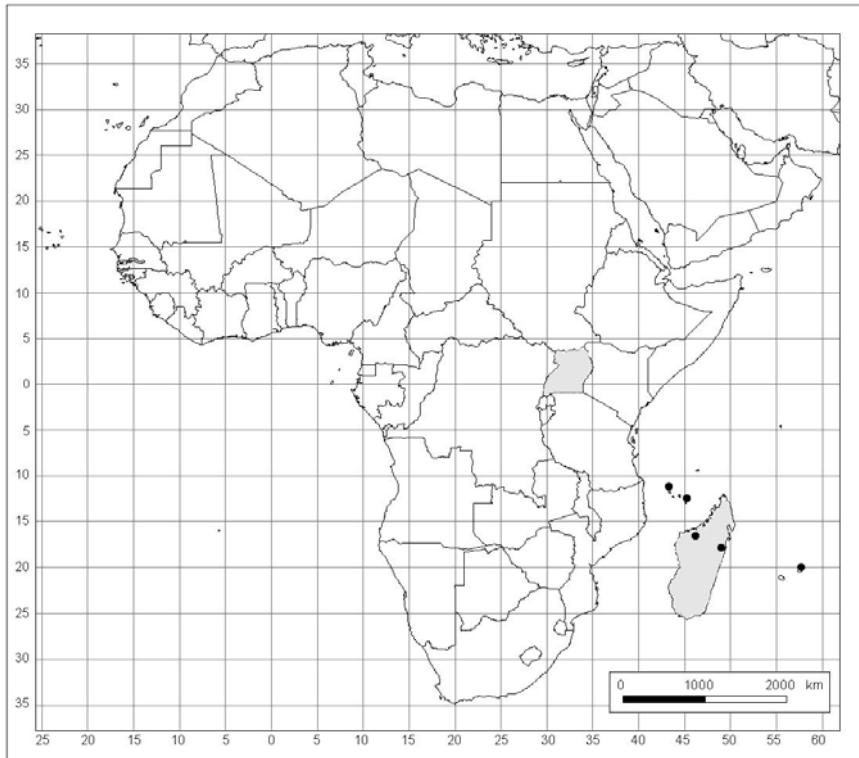
MAP 6.4.— Known distribution of *Pelekium intricatum* (A. Jaeger) A. Touw.



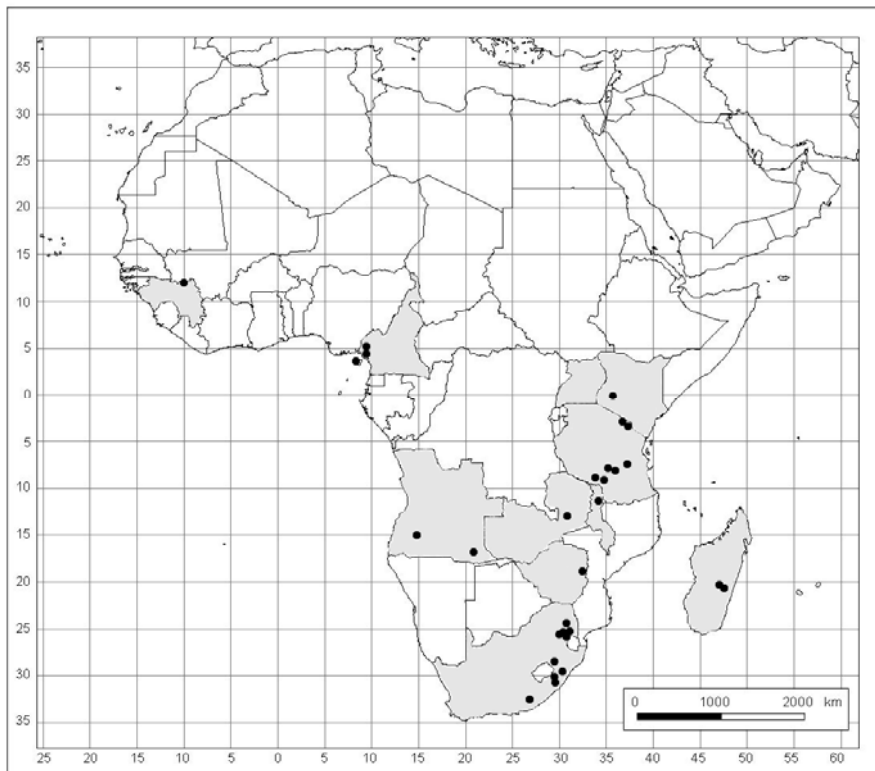
MAP 6.5.— Known distribution of *Pelekium investe* (Mitt.) A. Touw.



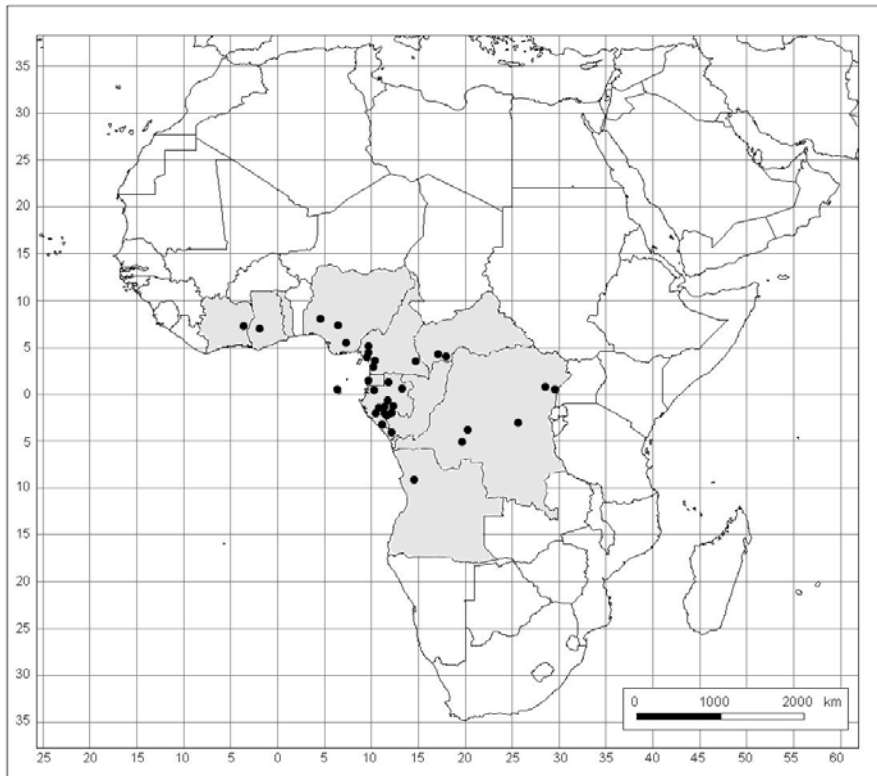
MAP 6.6.— Known distribution of *Pelekium minusculum* (Mitt.) A. Touw.



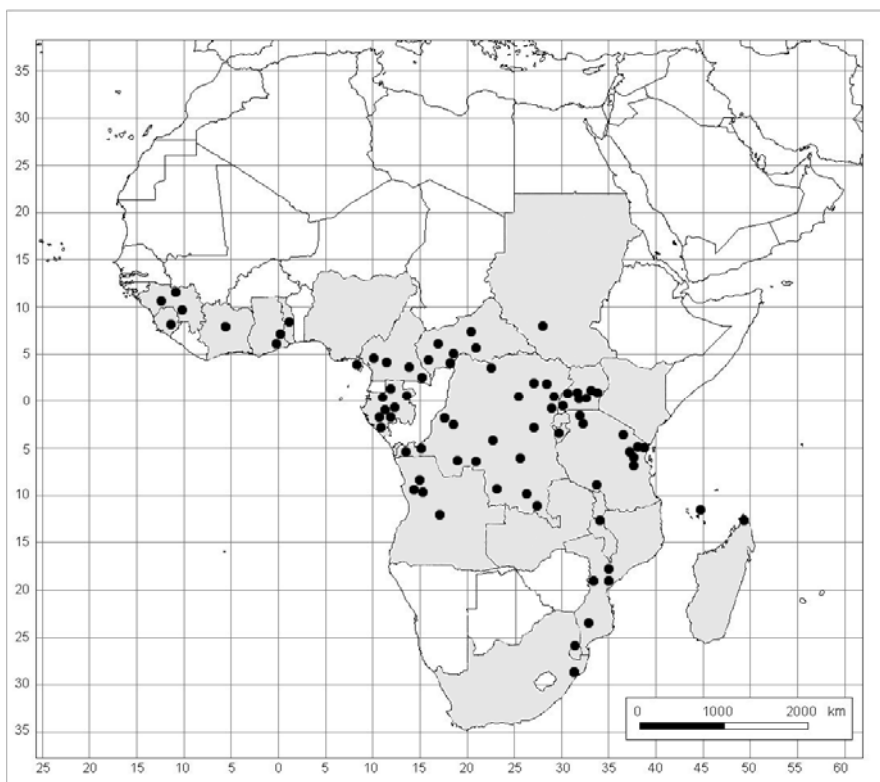
MAP 6.7. — Known distribution of *Pelekium pseudoinvolvens* (Müll. Hal.) Phephu.



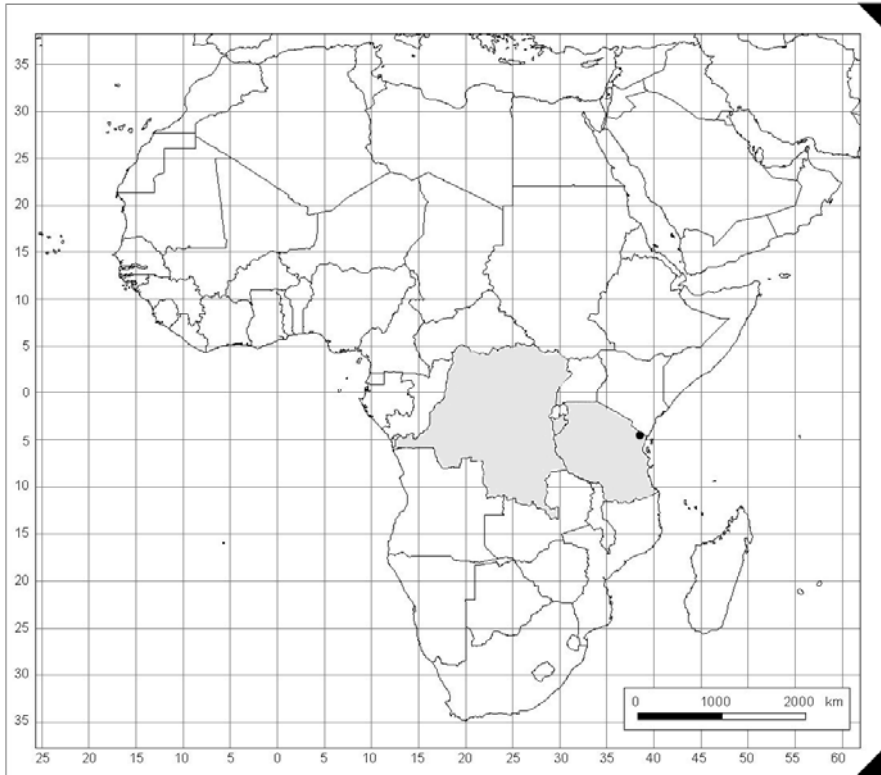
MAP 6.8.— Known distribution of *Pelekium ramusculosum* (Mitt.) A. Touw.



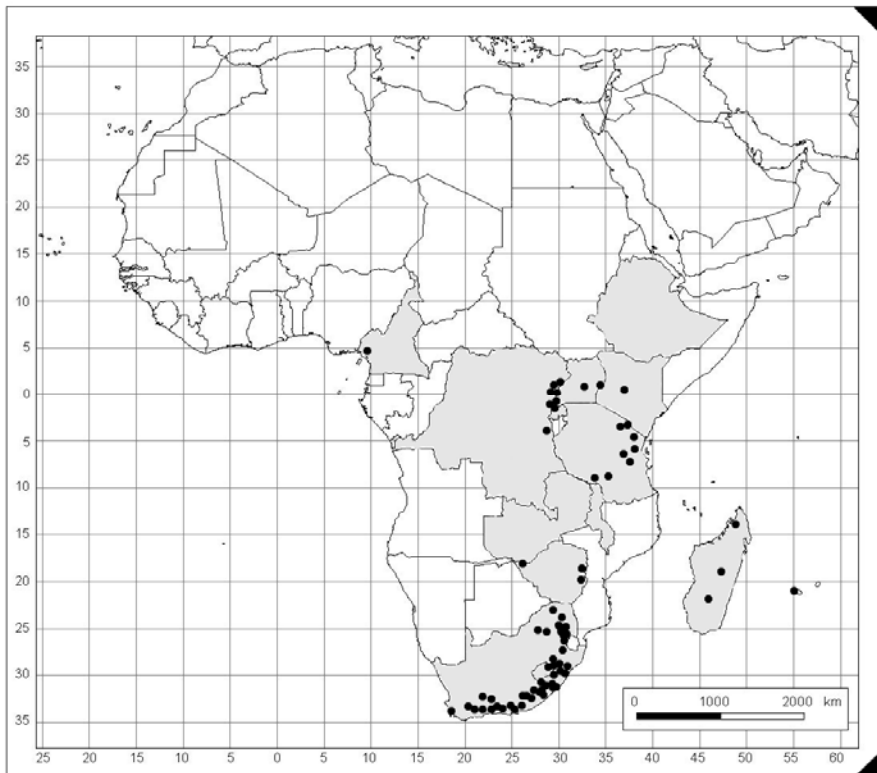
MAP 6.9.— Known distribution of *Pelekium thomeanum* (Broth.) Phephu.



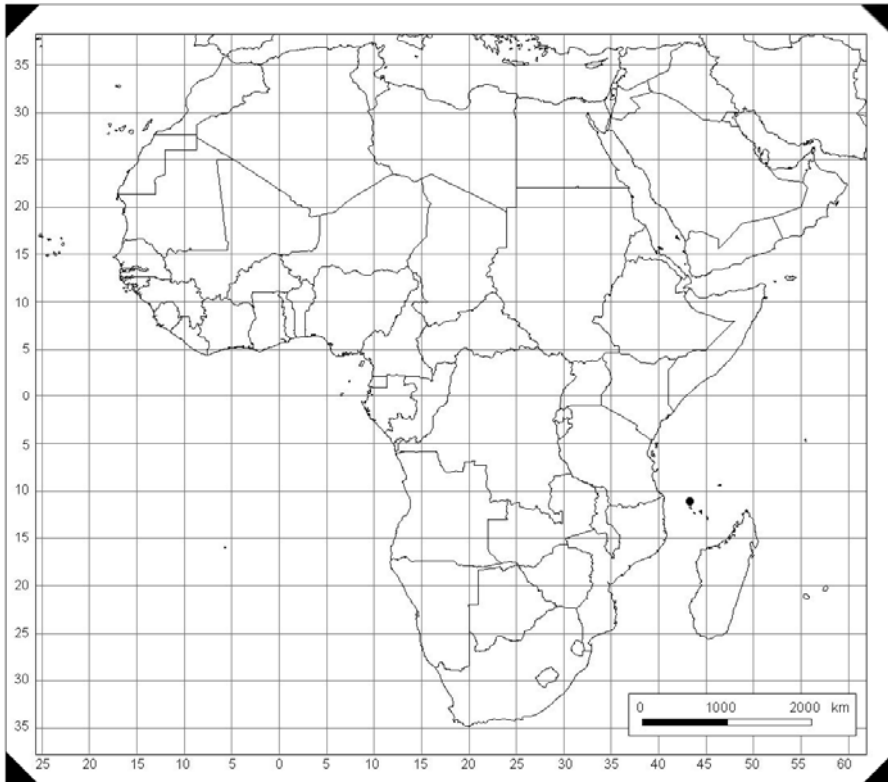
MAP 6.10.— Known distribution of *Pelekium varians* (Welw. & Duby) A. Touw.



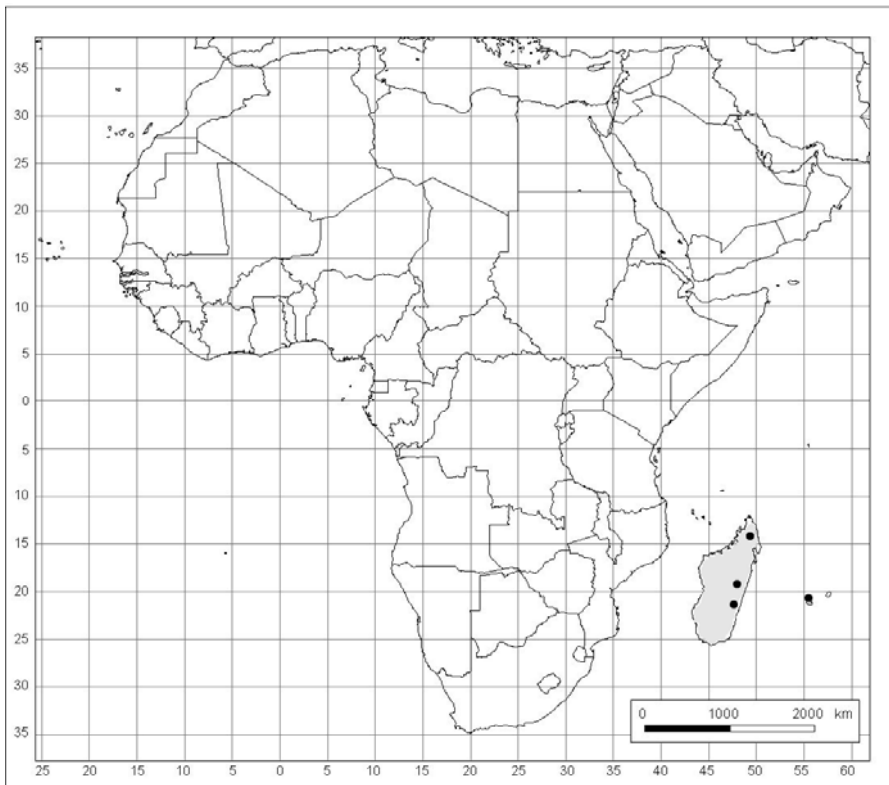
MAP 6.11. — Known distribution of *Pelekium velatum* Mitt.



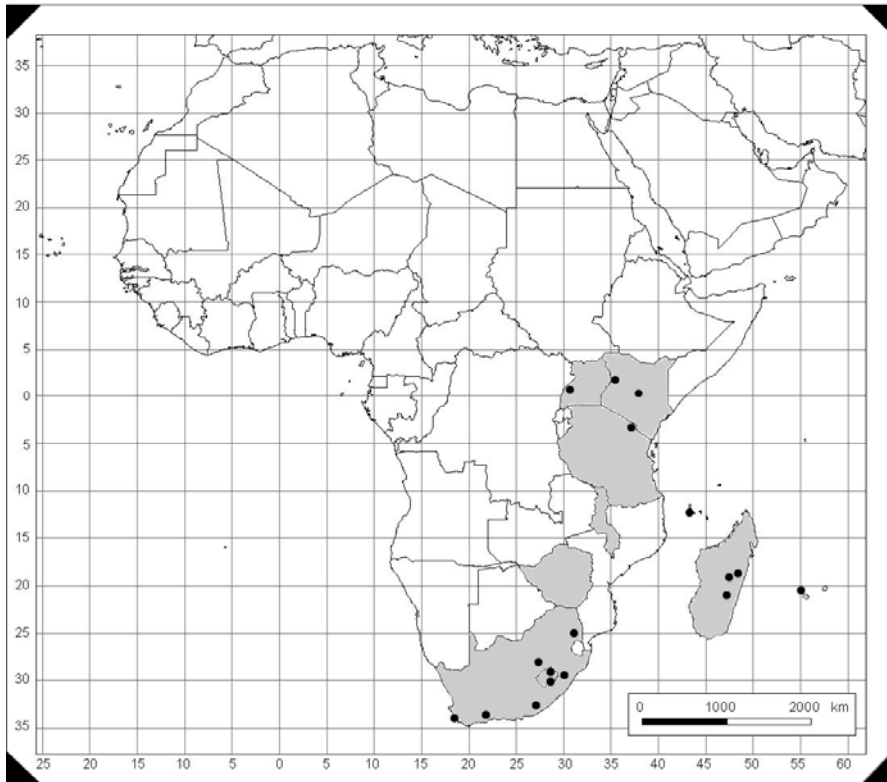
MAP 6.12. — Known distribution of *Pelekium versicolor* (Müll. Hal.) A. Touw.



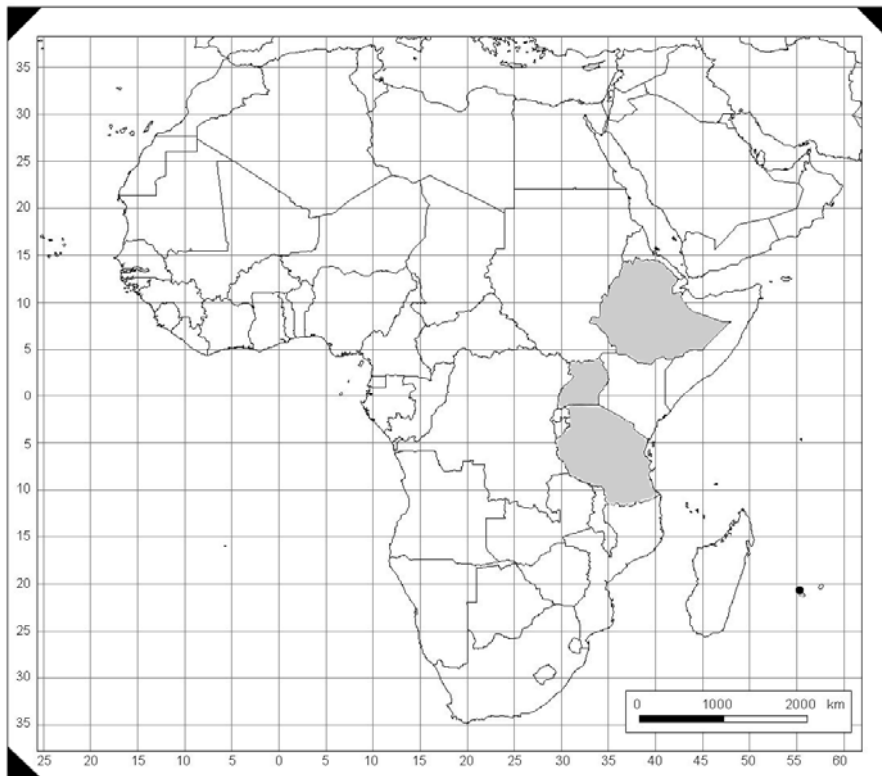
MAP 6.13.—Known distribution of *Thuidiopsis sparsa* (Hook. f. & Wilson) Broth.



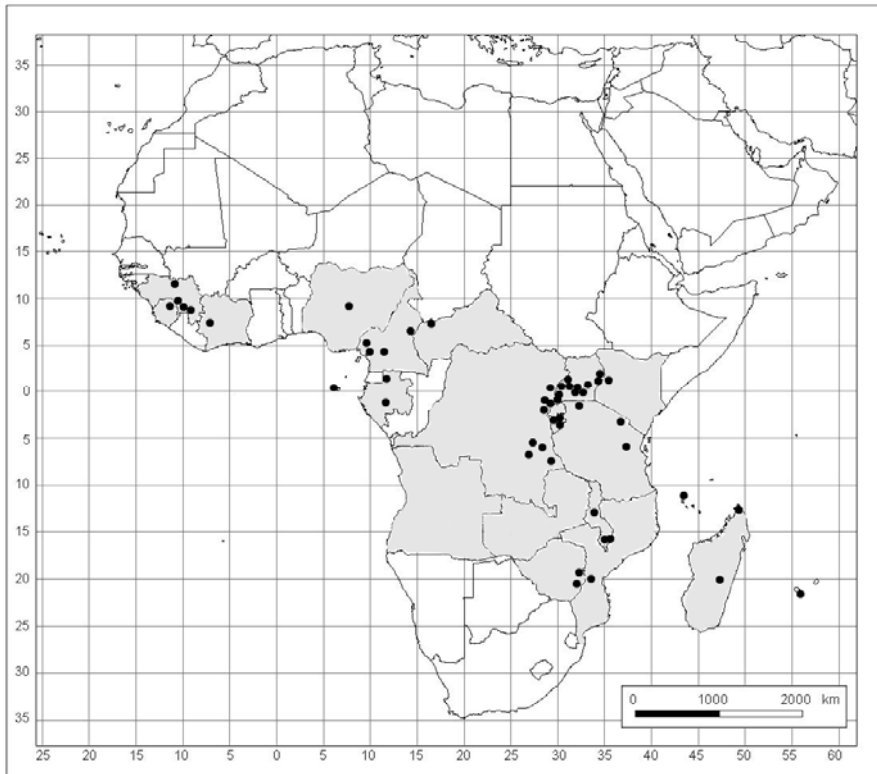
MAP 6.14.—Known distribution of *Thuidium aculeoserratum* Renaud & Cardot.



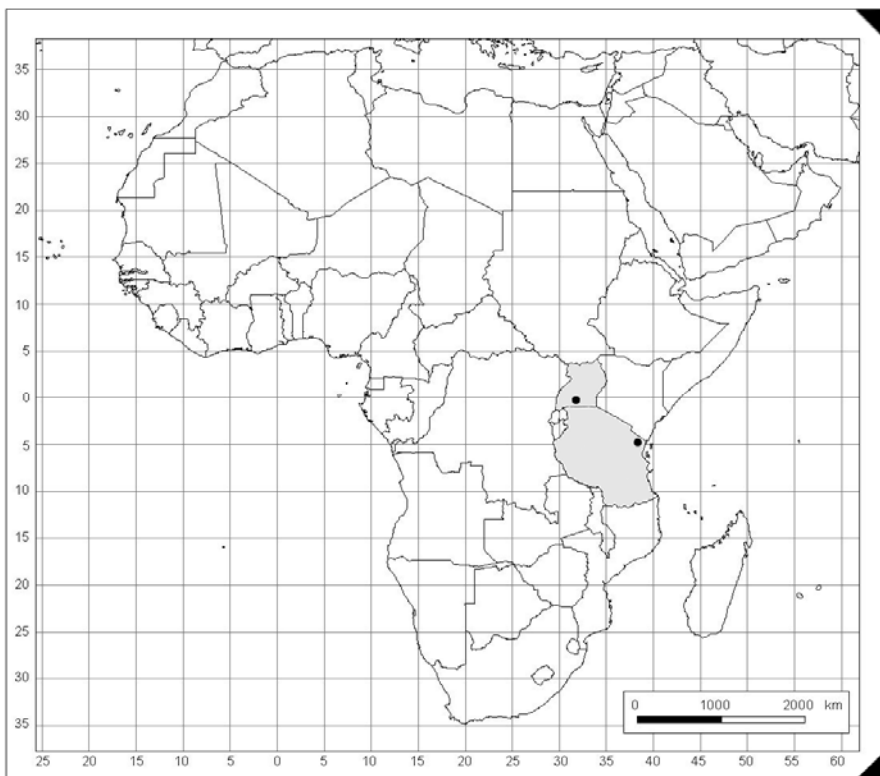
MAP 6.15.—Known distribution of *Thuidium assimile* (Mitt.) A. Jaeger.



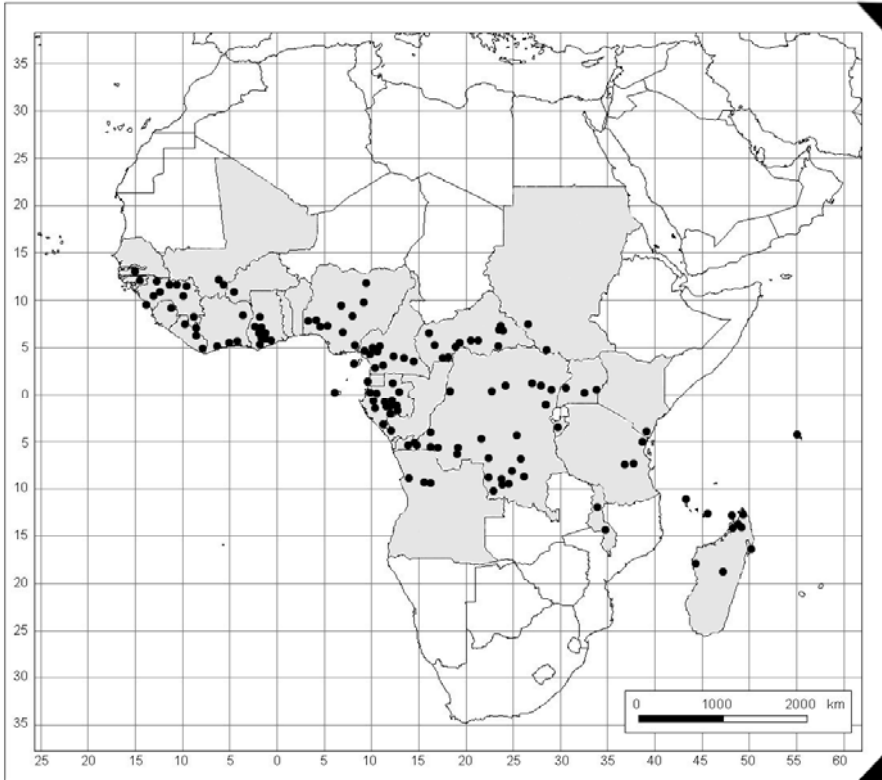
MAP 6.17.—Known distribution of *Thuidium tamariscinum* (Hedw.) Schimp.



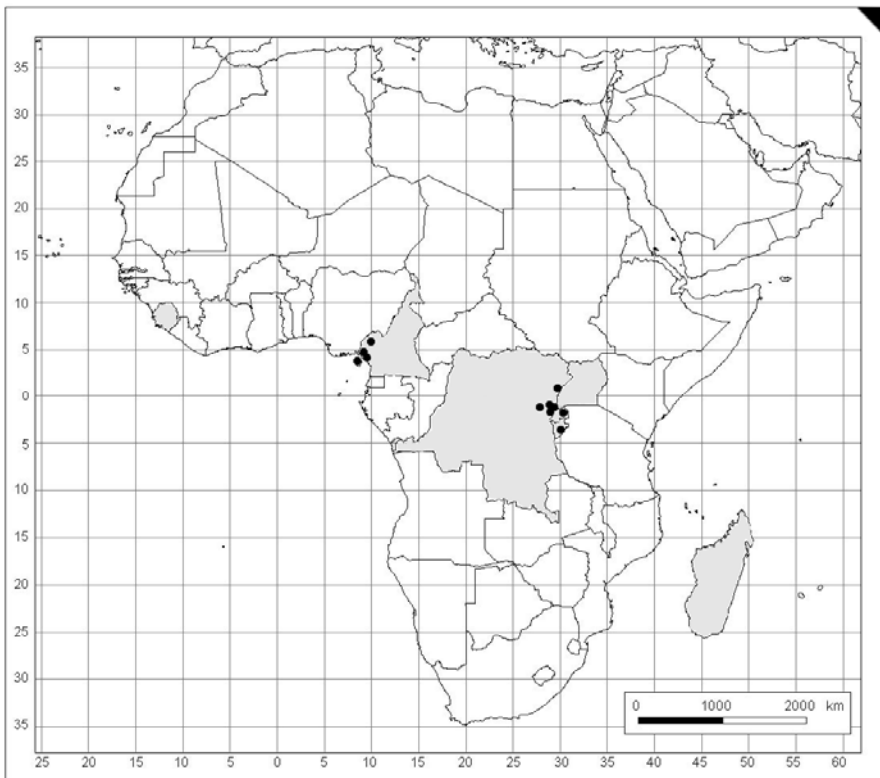
MAP 6.1.— Known distribution of *Pelekium chenagonii* (Müll. Hal. ex Renauld & Cardot) A. Touw.



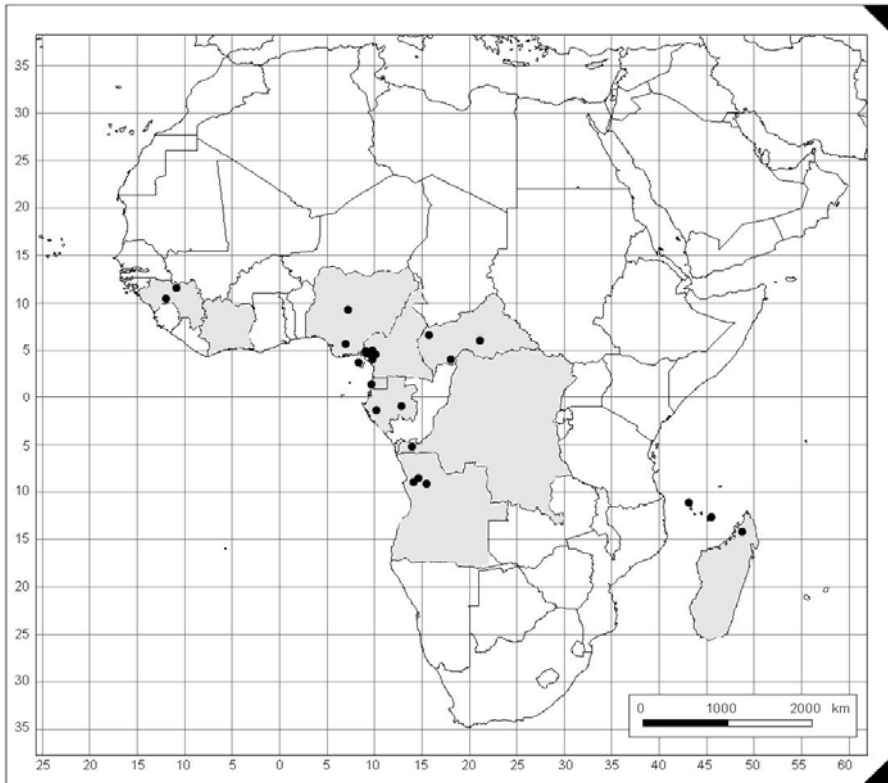
MAP 6.2.— Known distribution of *Pelekium contortulum* (Mitt.) A. Touw.



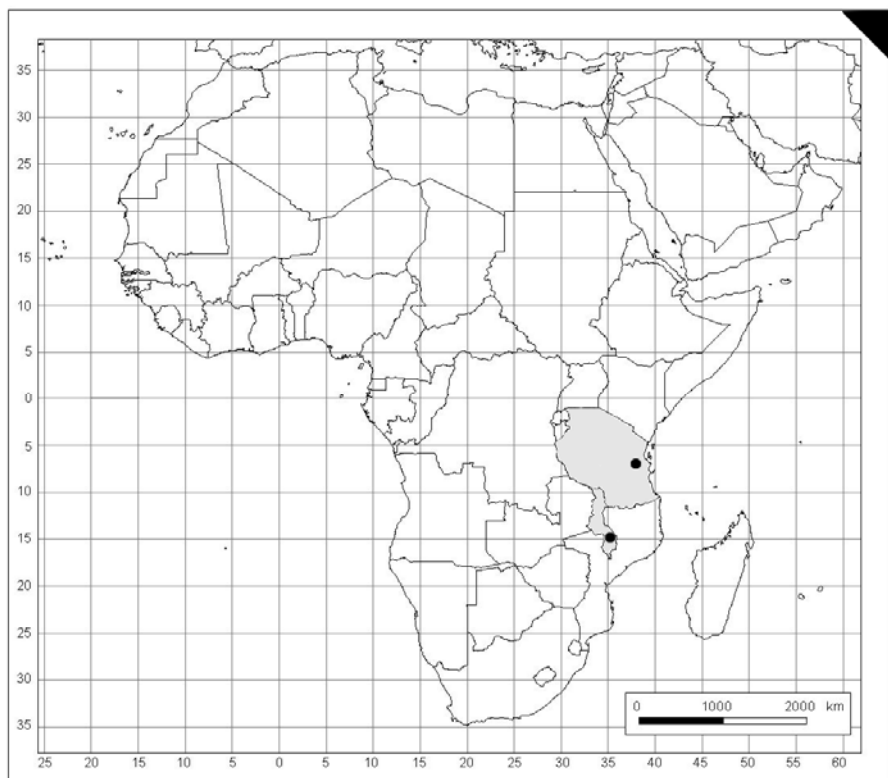
MAP 6.3.— Known distribution of *Pelekium gratum* (P. Beauv.) A. Touw.



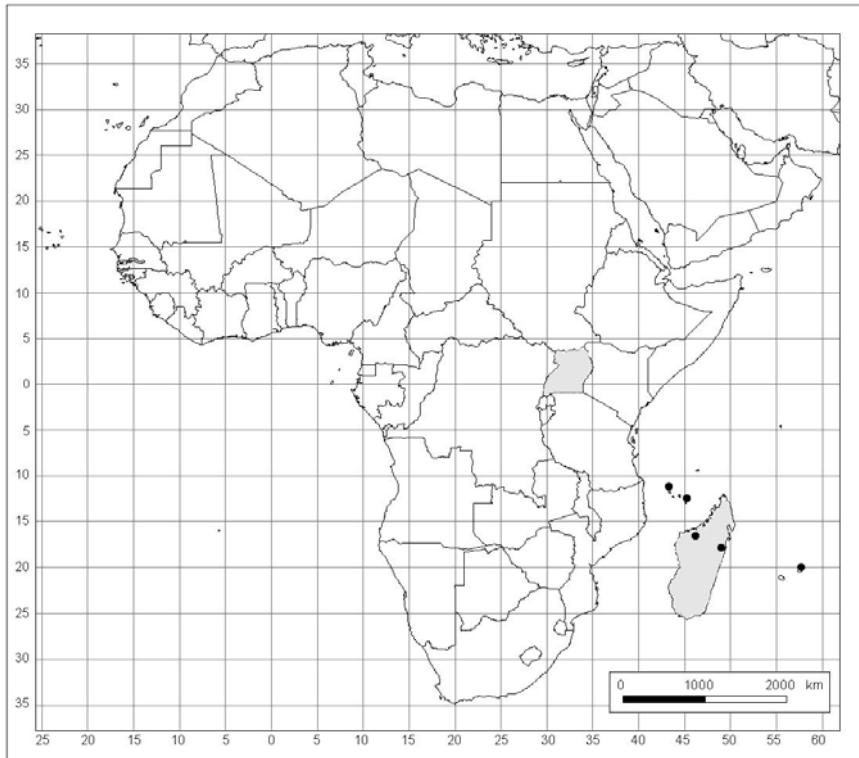
MAP 6.4.— Known distribution of *Pelekium intricatum* (A. Jaeger) A. Touw.



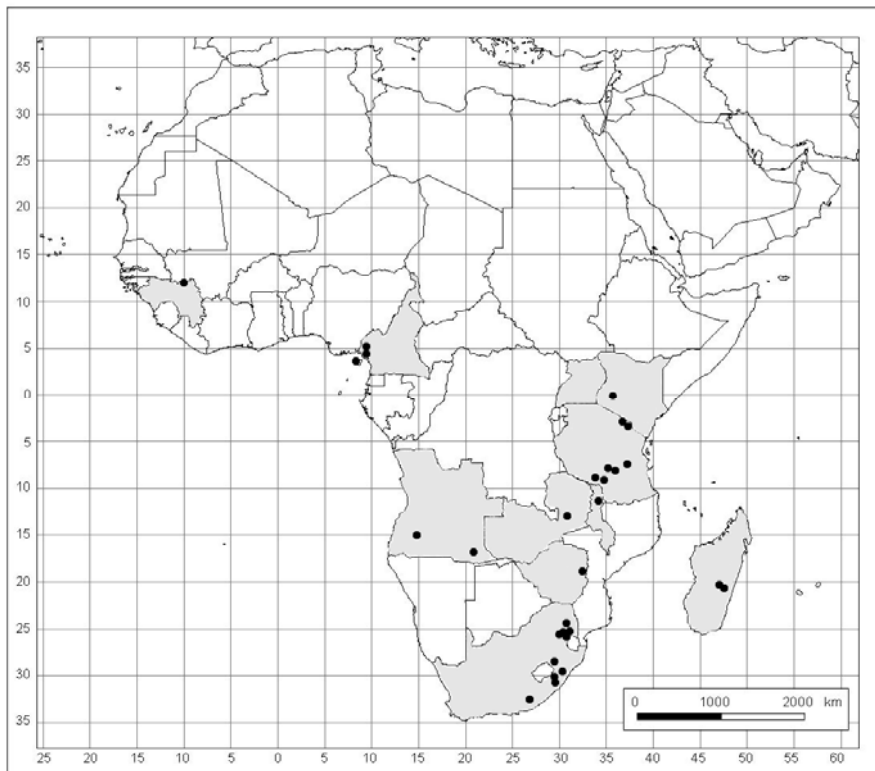
MAP 6.5.— Known distribution of *Pelekium investe* (Mitt.) A. Touw.



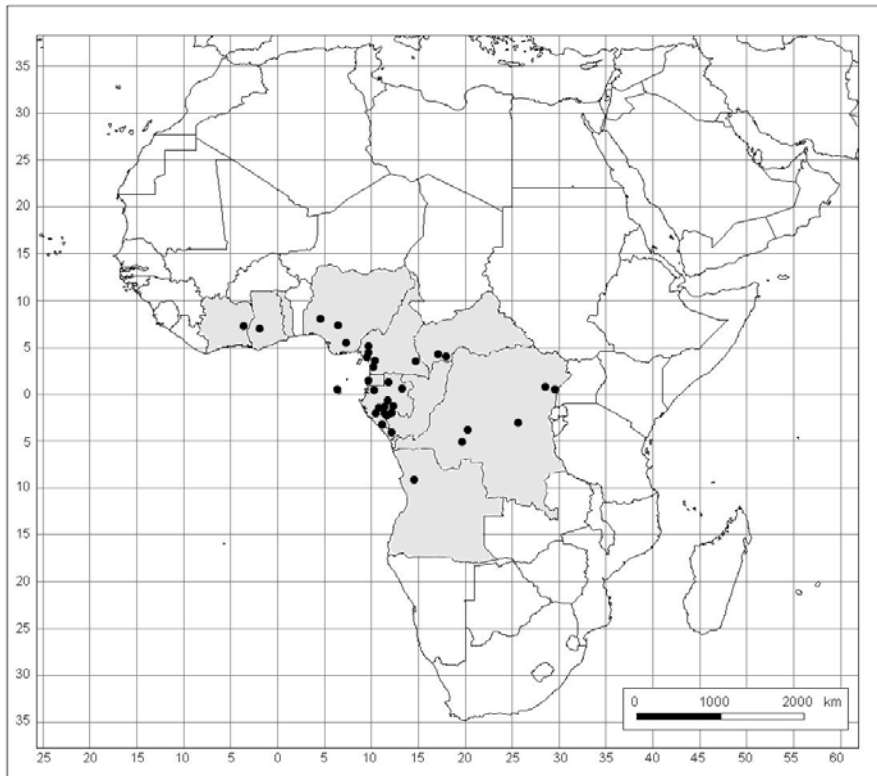
MAP 6.6.— Known distribution of *Pelekium minusculum* (Mitt.) A. Touw.



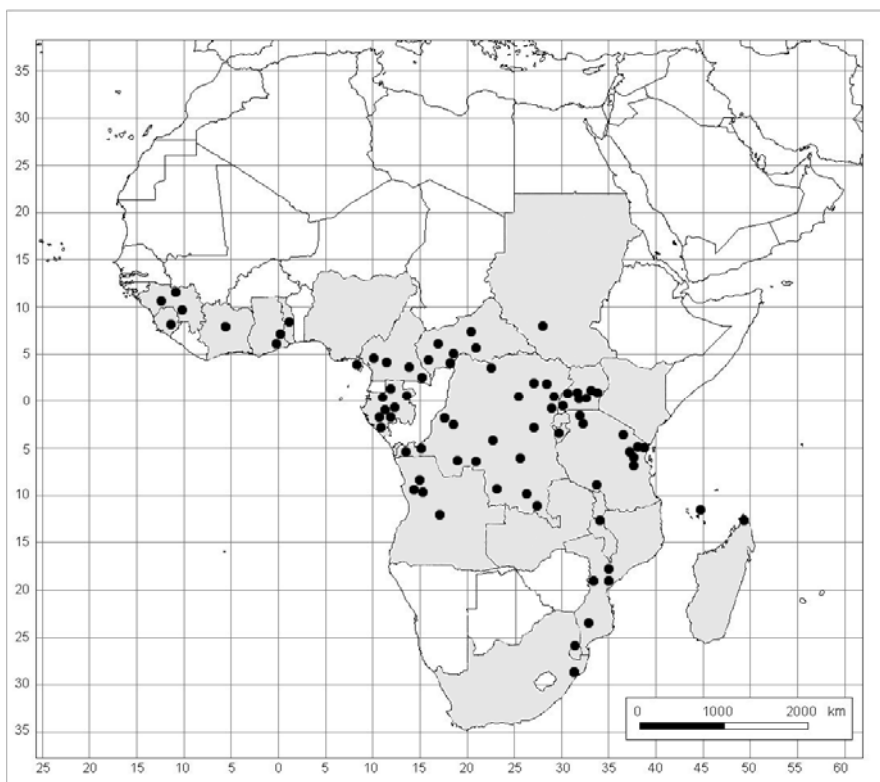
MAP 6.7. — Known distribution of *Pelekium pseudoinvolvens* (Müll. Hal.) Phephu.



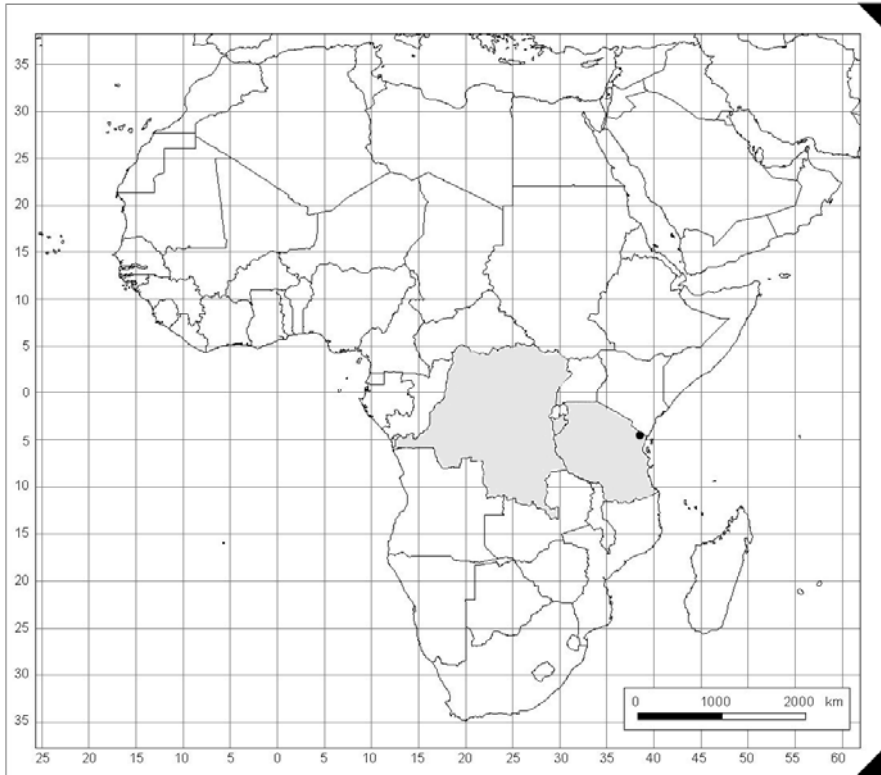
MAP 6.8.— Known distribution of *Pelekium ramusculosum* (Mitt.) A. Touw.



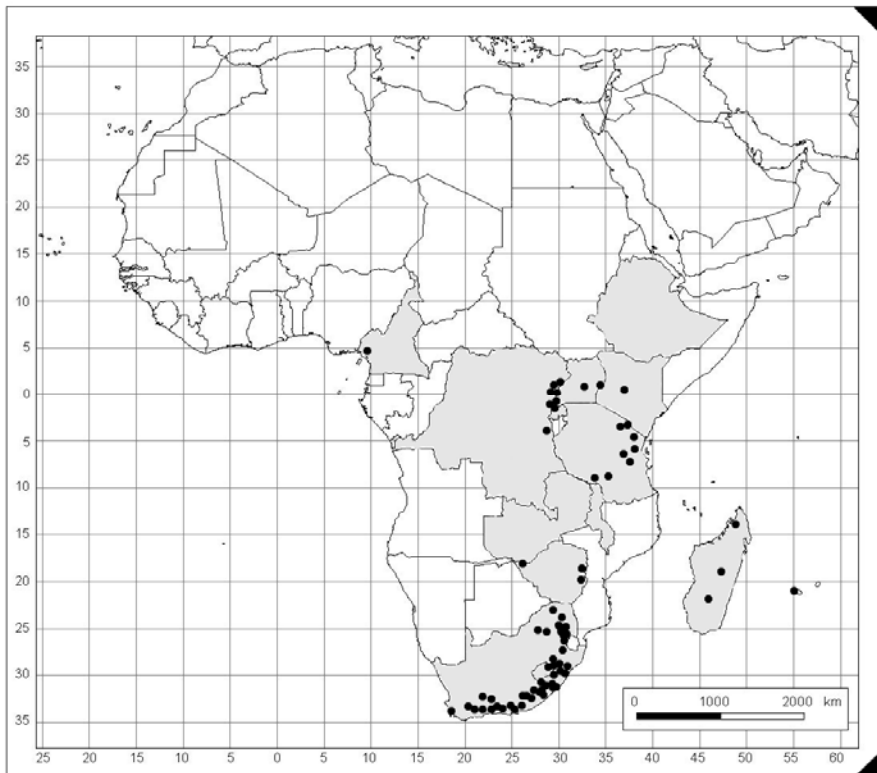
MAP 6.9.— Known distribution of *Pelekium thomeanum* (Broth.) Phephu.



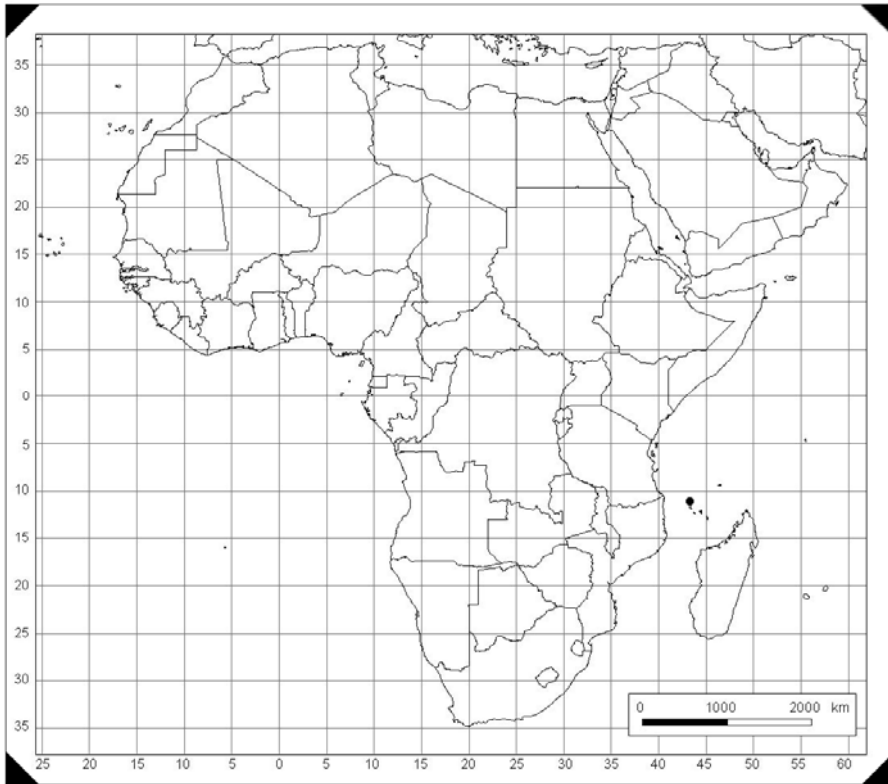
MAP 6.10.— Known distribution of *Pelekium varians* (Welw. & Duby) A. Touw.



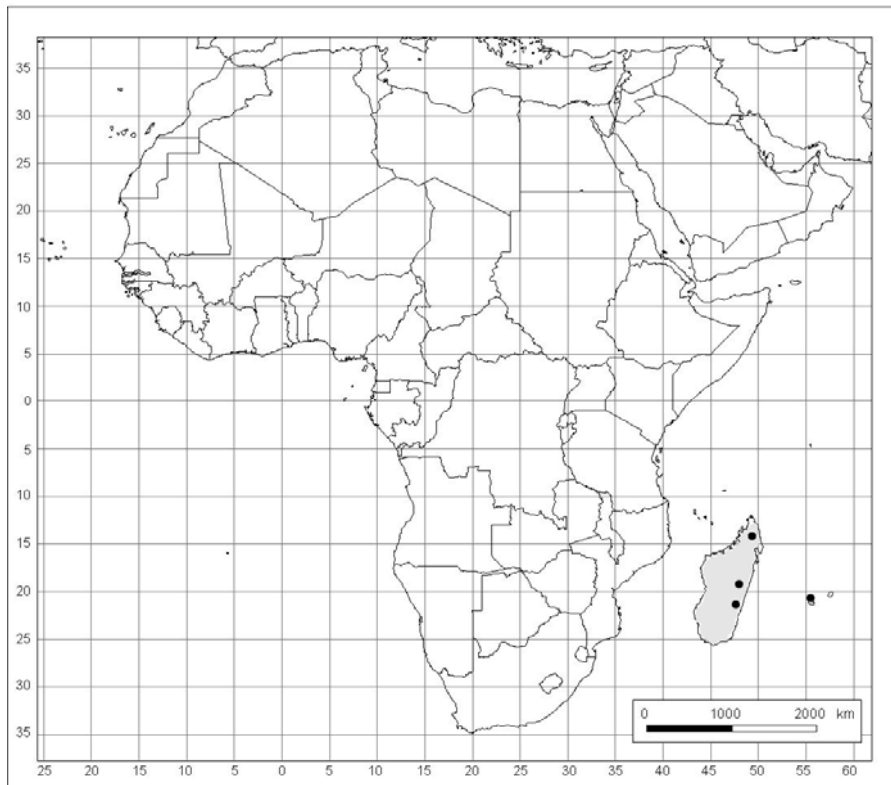
MAP 6.11. — Known distribution of *Pelekium velatum* Mitt.



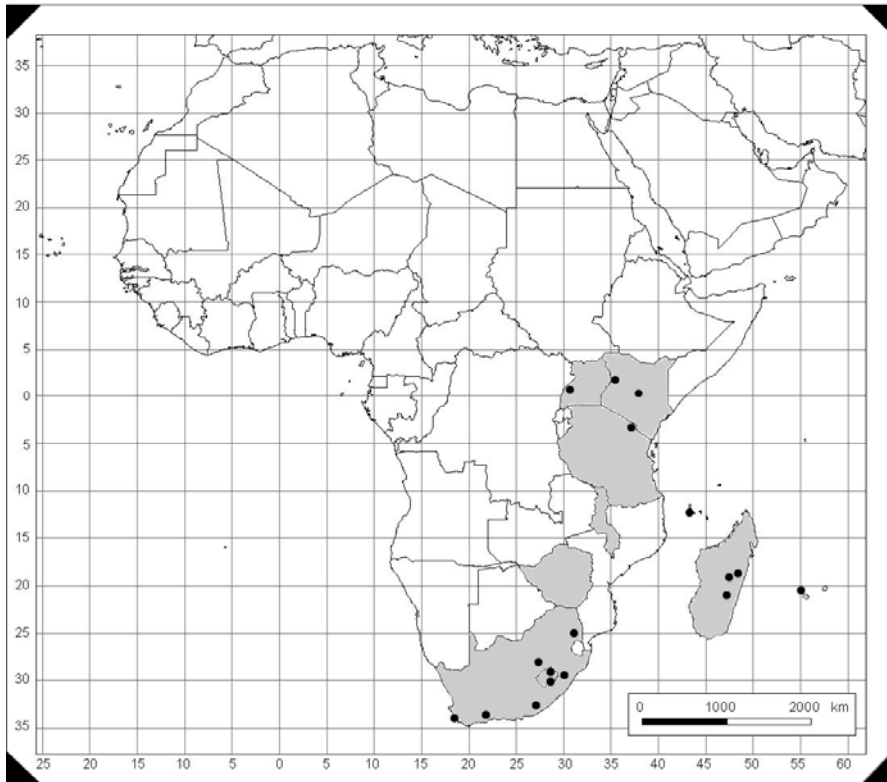
MAP 6.12. — Known distribution of *Pelekium versicolor* (Müll. Hal.) A. Touw.



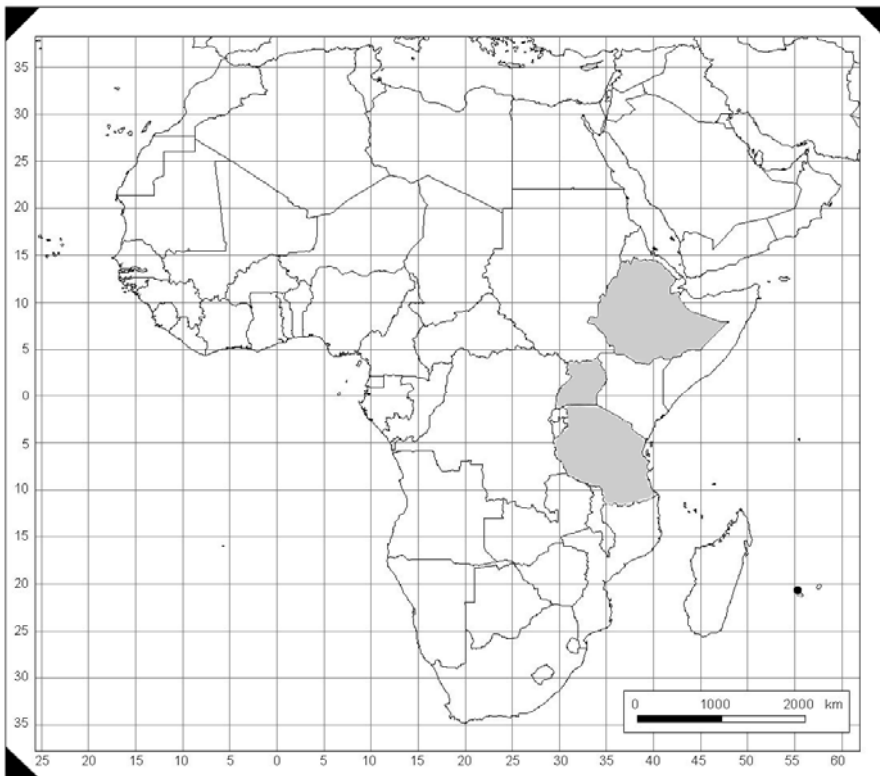
MAP 6.13.—Known distribution of *Thuidiopsis sparsa* (Hook. f. & Wilson) Broth.



MAP 6.14.—Known distribution of *Thuidium aculeoserratum* Renaud & Cardot.



MAP 6.15.—Known distribution of *Thuidium assimile* (Mitt.) A. Jaeger.



MAP 6.17.—Known distribution of *Thuidium tamariscinum* (Hedw.) Schimp.

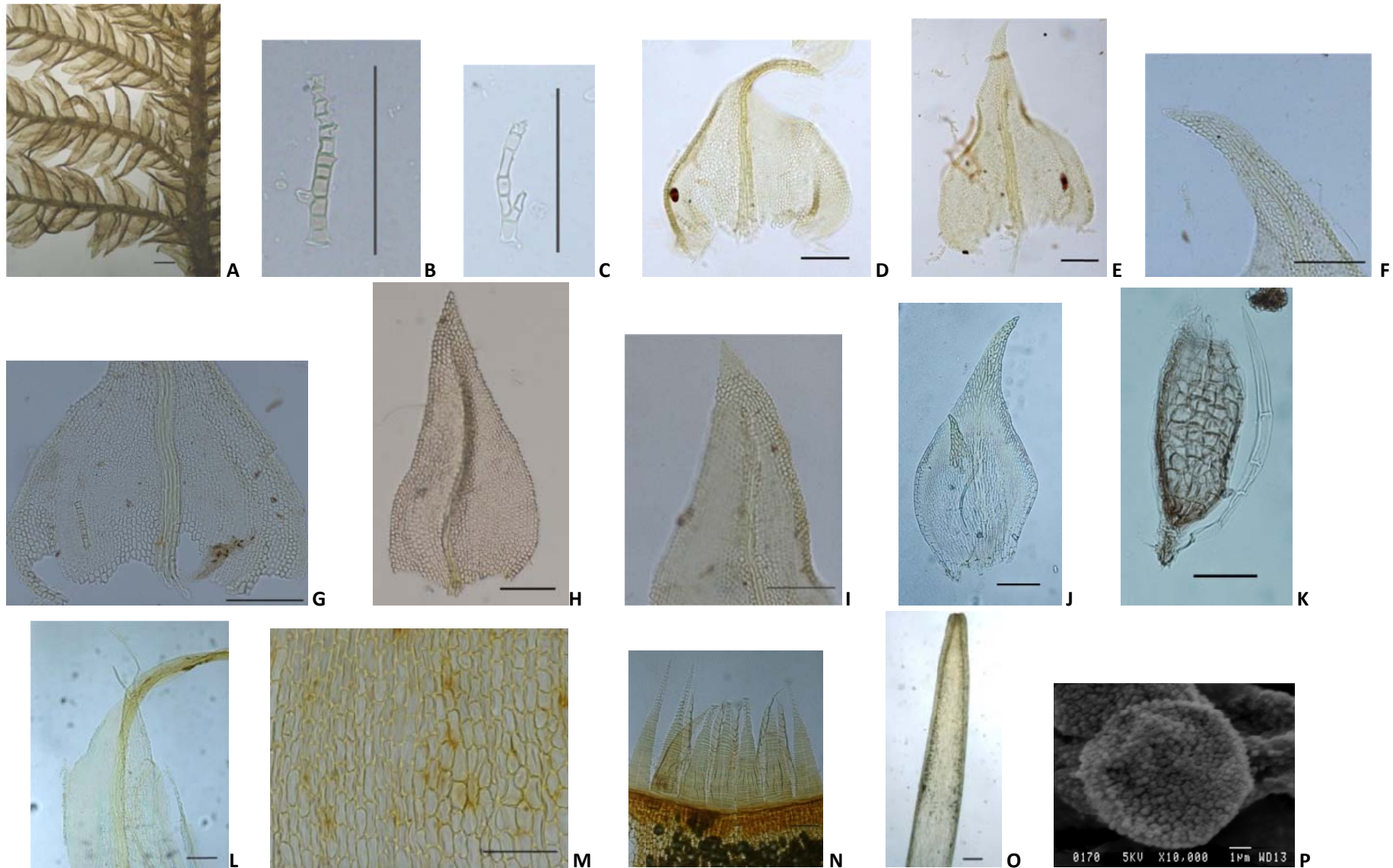


FIGURE 6.1.—*Pelekium chenagonii* (Müll. Hal. ex Renauld & Cardot) A. Touw: A. branch; B & C. paraphyllia; D & E. stem leaves; F. stem leaf apex; G. stem leaf margin & laminal cells; H. branch leaf; I. branch leaf apex; J. perigonium leaf; K. antheridium; L. perichaetial leaf shoulder; M. exothecial cells; N. peristome teeth; O. calyptra; P. spore. Vouchers: Müller Z361 (L) A,B,C, E, G, H, I, J; De Torre 6300 (BM) D, K, L, M, N, O, Q; Rojkowski 385 (BM) P. Scale: A–O = 0.1 mm.

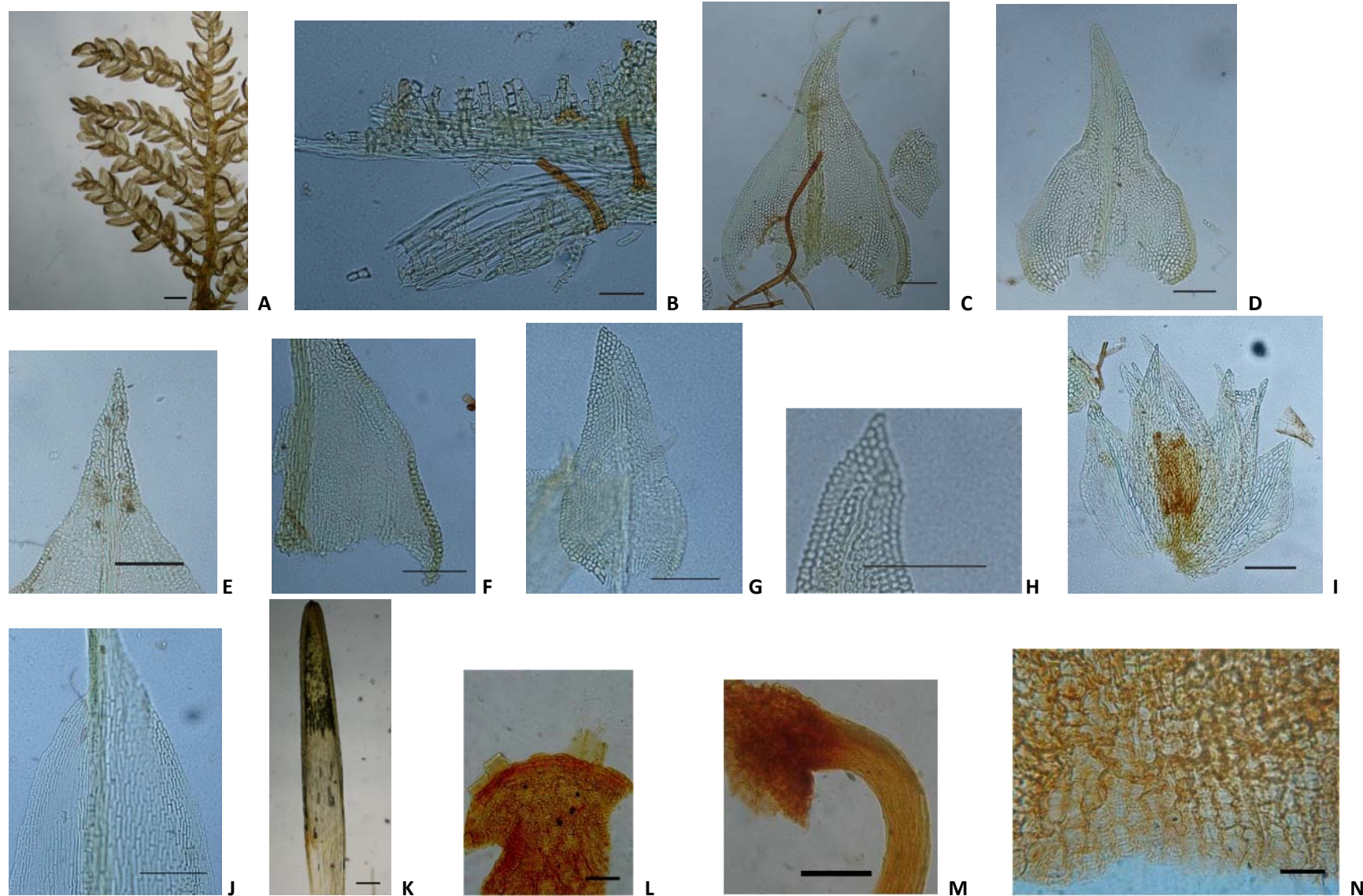


FIGURE 6.2.—*Pelekium contortulum* (Mitt.) A. Touw: A. branch; B. paraphyllia; C & D. stem leaves; E. stem leaf apex; F. stem leaf base, margin & laminal cells; G. branch leaf; H. branch leaf apex; I. perigonium; J. perichaetial leaf. K. seta; L. peristome teeth; M. upper part of seta; N. exothecial cells. Vouchers: *Lye B389* (L) B, C, D, E & F; *Pócs & Jones 6376/F* (L) A, G, H, I, L, M & N; *Kofman 28* (NY) J & K. Scale: A–K = 0.1 mm.

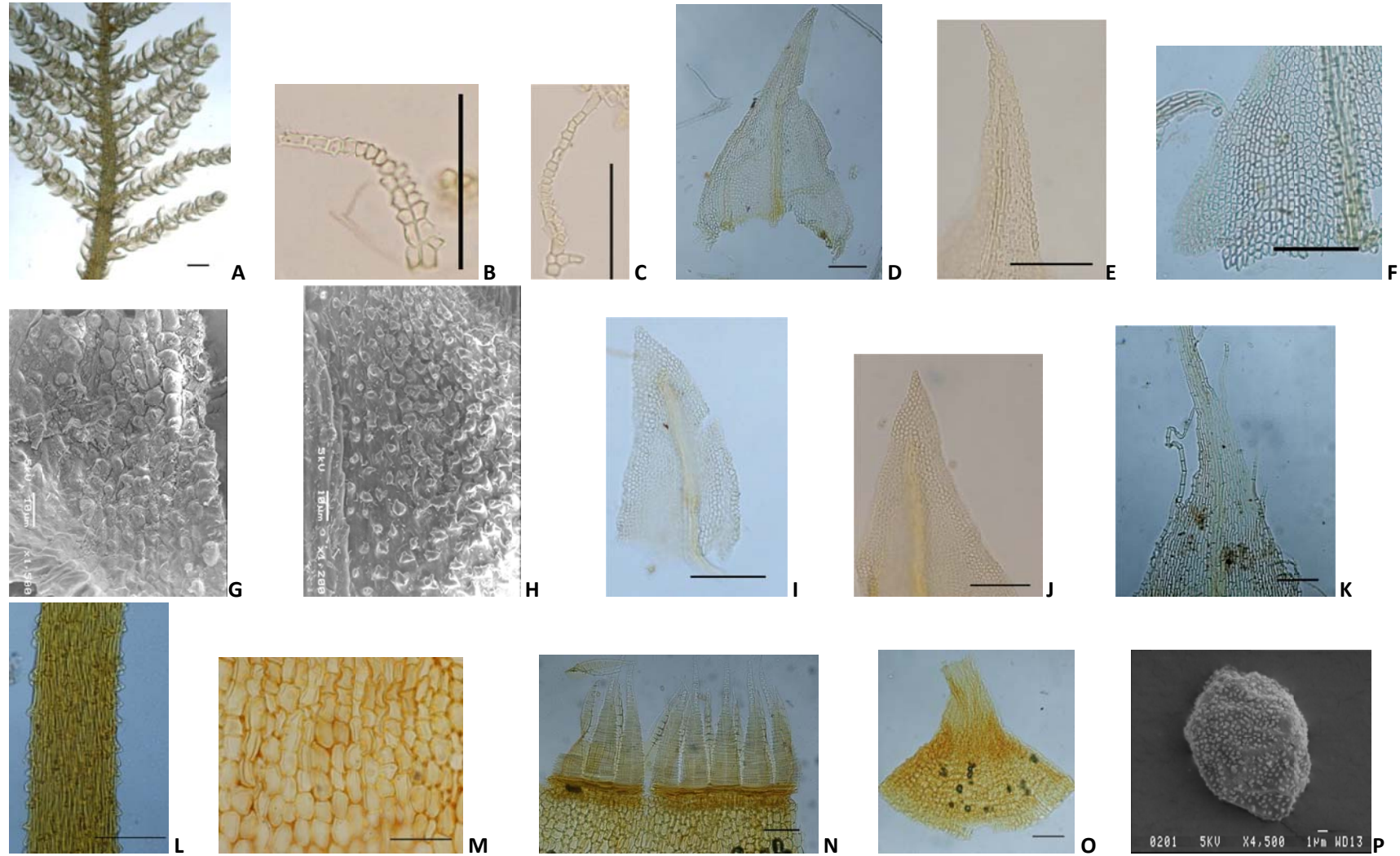


FIGURE 6.3.—*Pelekium gratum* (P. Beauv.) A. Touw: A. branch; B & C. paraphyllia; D. stem leaf; E. stem leaf apex; F. stem leaf margin & median cells; G. stem leaf lower surface; H. stem leaf upper surface; I. branch leaf; J. branch leaf apex; K. perichaetial leaf shoulder; L. seta; M. exothecial cells. N. peristome teeth; O. operculum; P. spore. Vouchers: *Lillie 2561* (BM) A, D, G, H, I, L & M; *Porembski 188* (L) B, C, E & F; *Leighton CH8952* (PRE) J, K, N, O, P & Q. Scale: A – N = 0.1 mm.

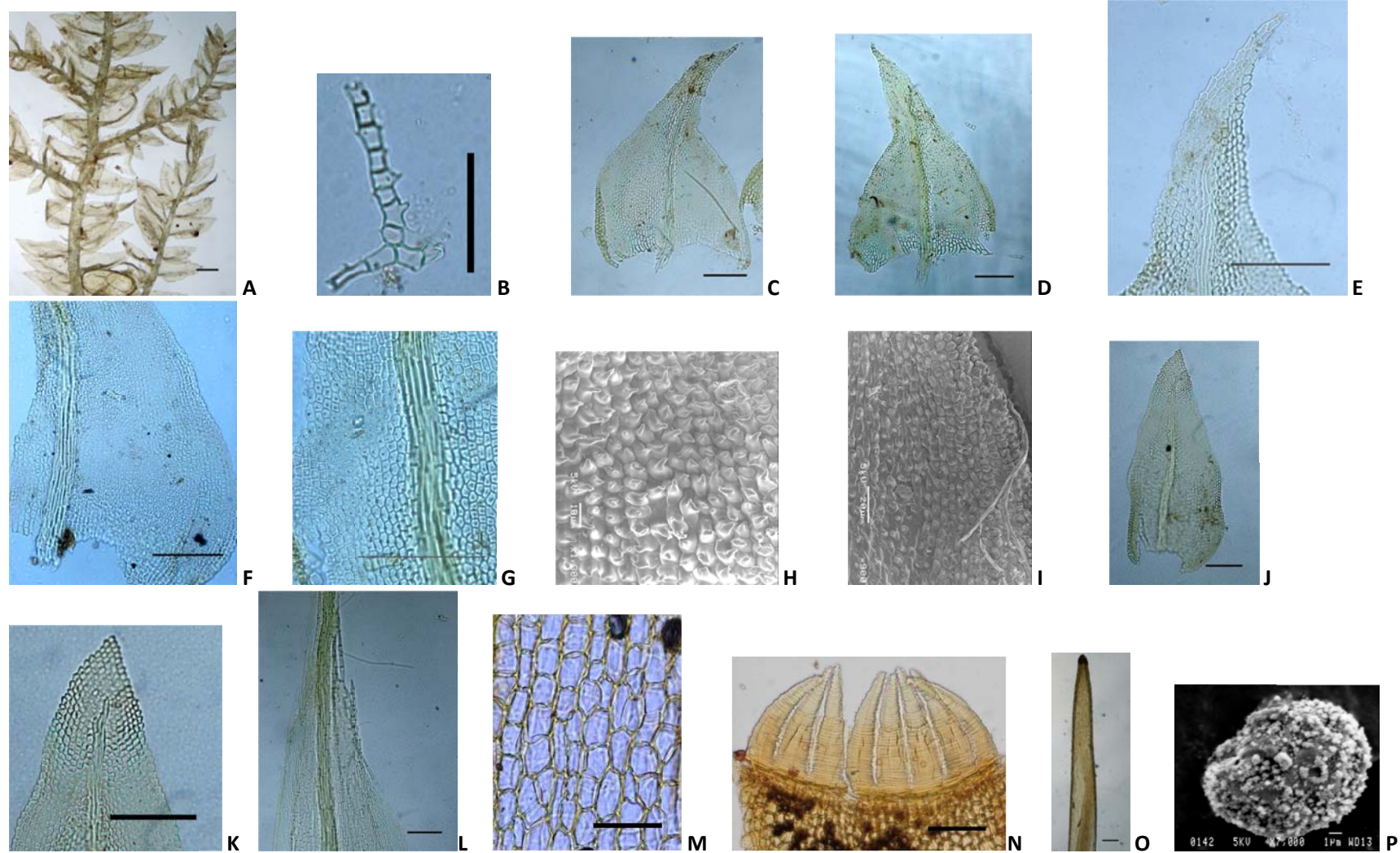


FIGURE 6.4.—*Pelekium intricatum* (A. Jaeger) A. Touw: A. branch; B. paraphyllia; C & D. stem leaves; E. stem leaf apex; F. stem leaf margin & median cells; G. stem leaf median cells; H. stem leaf lower surface; I. stem leaf upper surface; J. branch leaf; K. branch leaf apex; L. perichaetial leaf shoulder; M. exothecial cells; N. peristome teeth; O. calyptra; P. spore. Vouchers: *Dusen s.n.* (NY) A, B, C, D, E, F, J, K, H, I & P; *Müller Z147* (L) G, L, M, N & O. Scale: A–G & J–O = 0.1 mm.

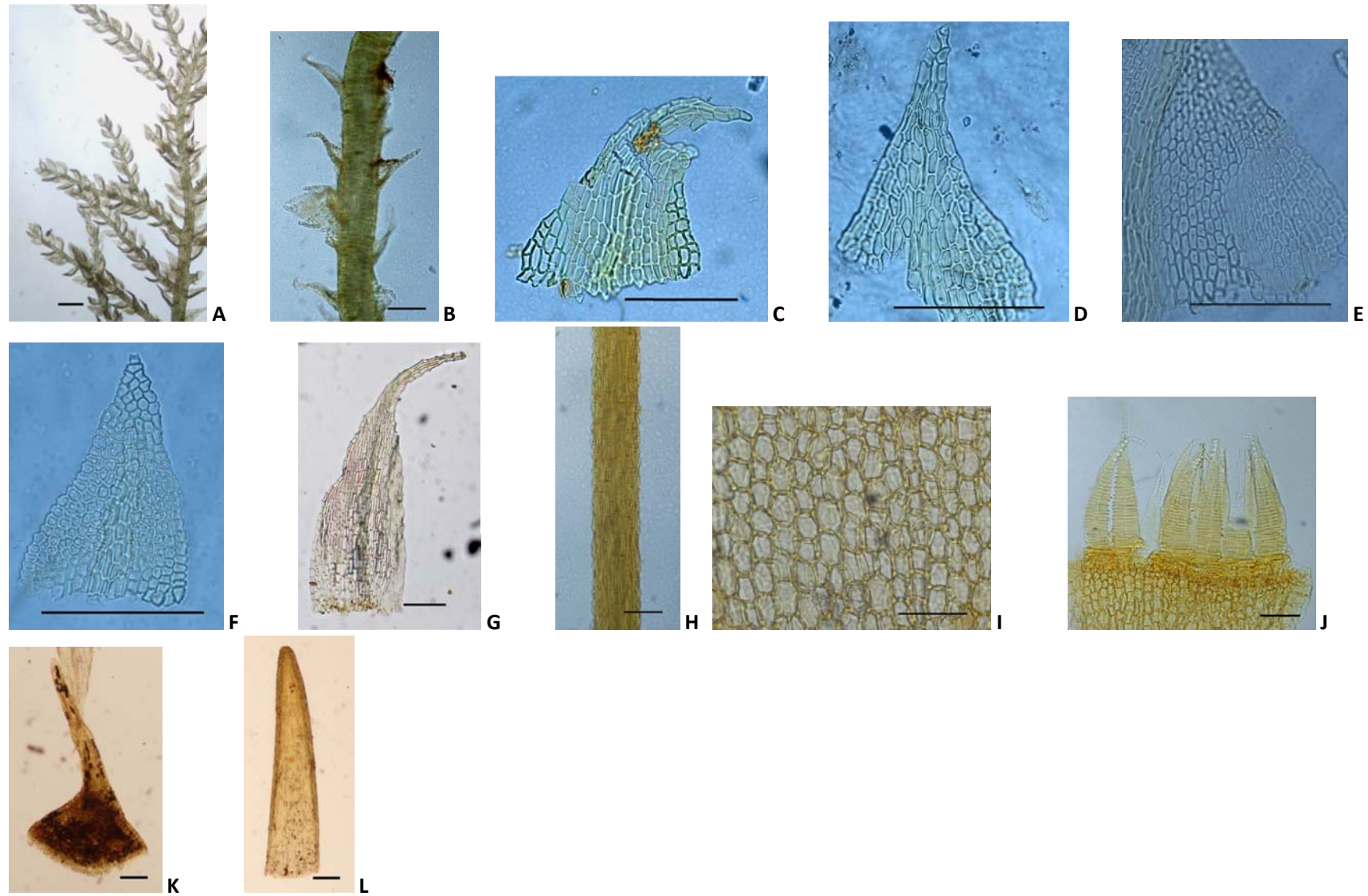


FIGURE 6.5.—*Pelekium investe* (Mitt.) A. Touw: A. branch; B. stem; C & D. stem leaves; E. Stem leaf margin & laminal cells; F. branch leaf; G. perichaetial leaf; H. seta; I. exothecial cells; J. peristome teeth; K. operculum; L. calyptra. Vouchers: *Pobeyan s.n.* (BM) A; *Tisserant 2203* (BM) B, C, D & E; *Williams 1844* (NY) G, H, I, J & K & L; *Argent AR.514* (BM) F. Scale: A–L = 0.1 mm.

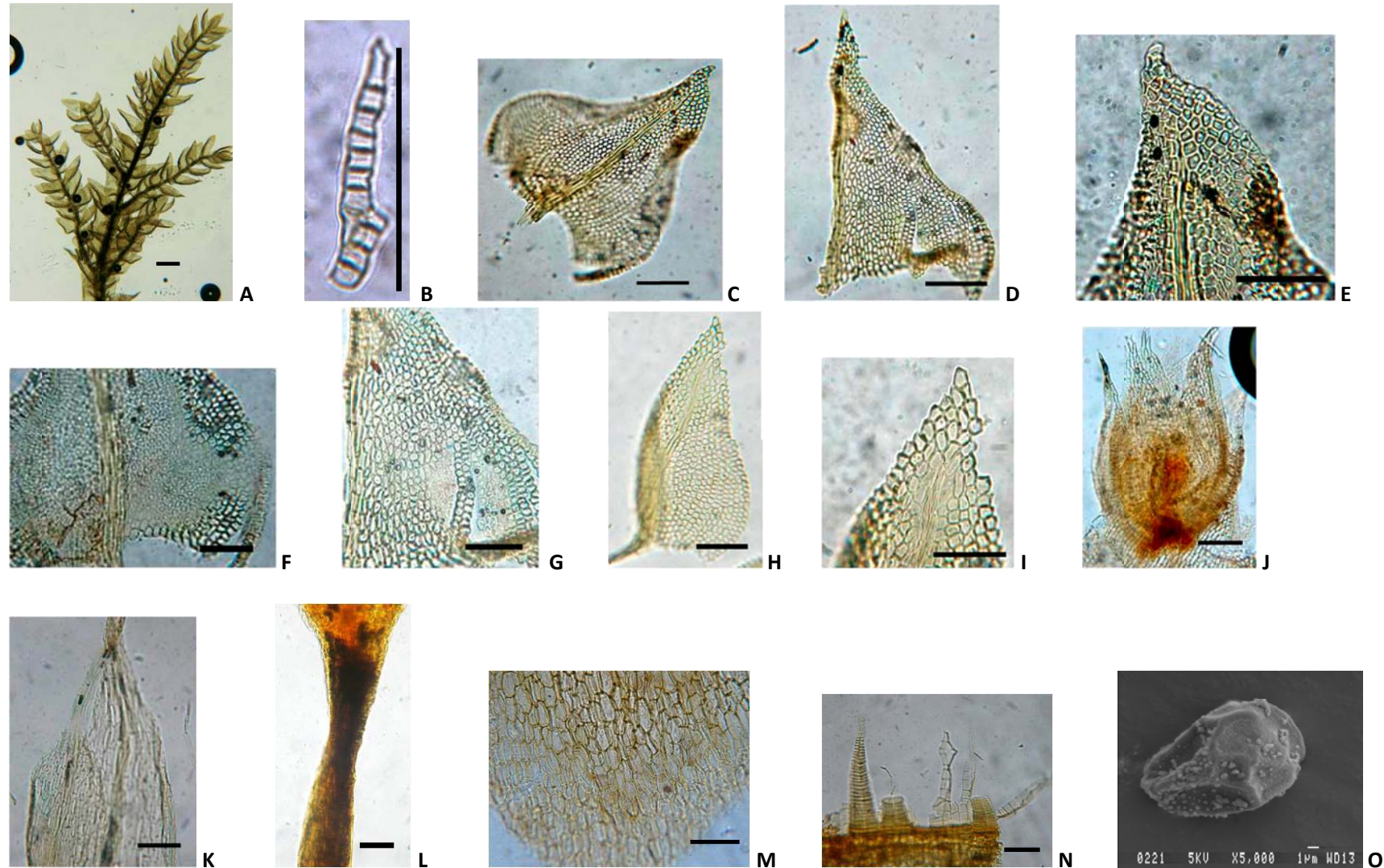


FIGURE 6.6.—*Pelekium minusculum* (Mitt.) A. Touw: A. branch; B. paraphyllia; C & D. stem leaves; E. stem leaf apex; F. stem leaf base & laminal cells; G. stem leaf margin & median laminal cells; H. branch leaf; I. branch leaf apex; J. perigonium; K. perichaetial leaf shoulder; L. seta; M. exothecial cells. N. peristome teeth; O. spore. Vouchers: *Griffith s.n* (NY) K, L, M, N & O; *Pócs & Crosby 6854/X* (L) A, B, C, D, E, F, G, H, I & J. Scale: A–N = 0.1 mm.

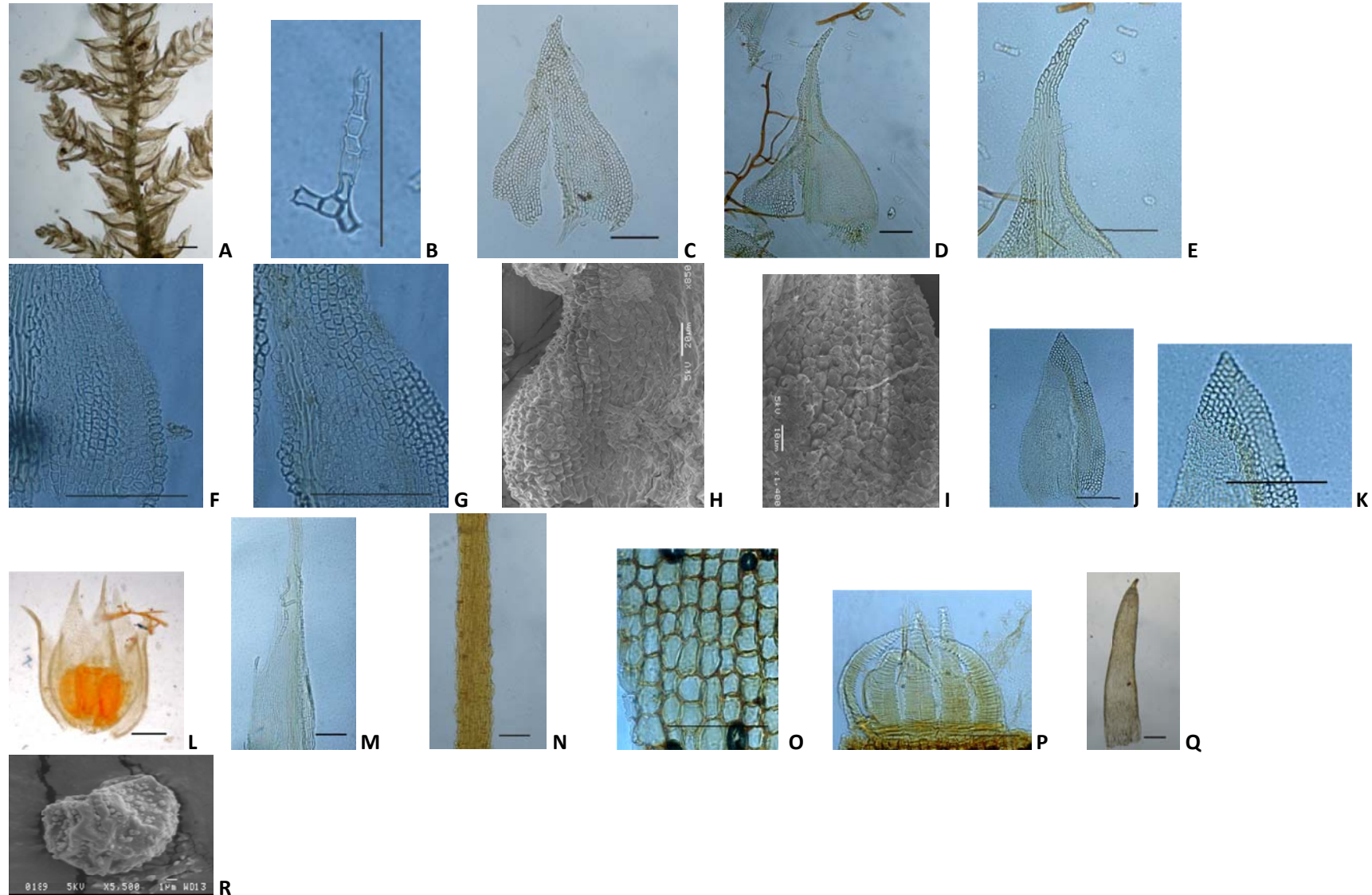


FIGURE 6.7.—*Pelekium pseudoinvolvens* (Müll. Hal.) Phephu: A. branch; B. paraphyllium; C & D. stem leaves; E. stem leaf apex; F & G. stem leaf margin & median cells; H. stem leaf lower surface; I. stem leaf upper surface; J. branch leaf; K. branch leaf apex; L. perigonium; M. perichaetial leaf shoulder; N. seta; O. exothecial cells; P. peristome teeth; Q. calyptra; R. spore. Vouchers: *Marie s.n.* (BM) A, H, I, L, N, O, P, Q & R; *Marie 103* (BM) B, D, E & F; *Marie 85* (BM) C, G, J & K. Scale: A–Q = 0.1 mm.

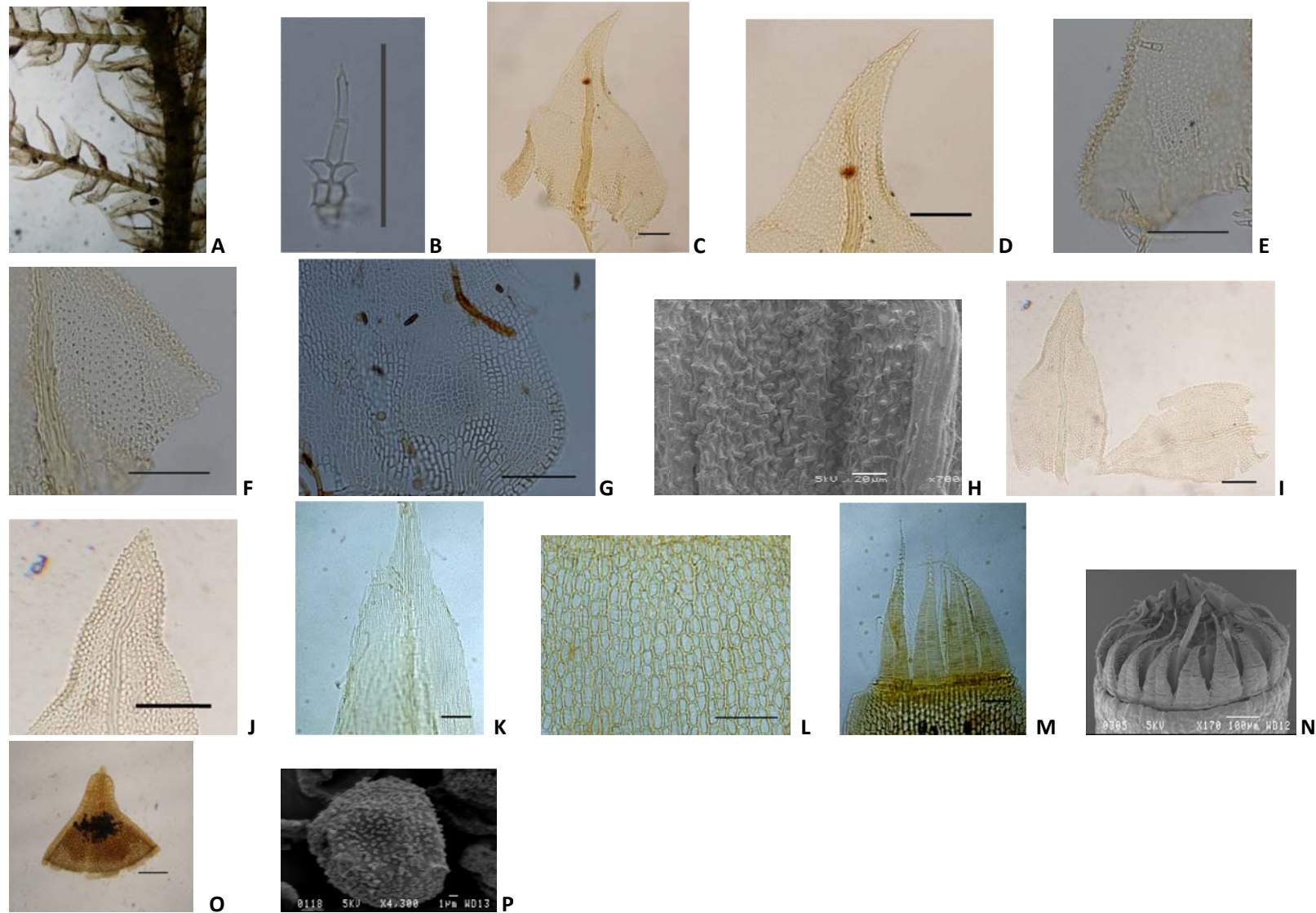


FIGURE 6.8.—*Pelekium ramusculosum* (Mitt.) A. Touw: A. branch; B. paraphyllium; C. stem leaf; D. stem leaf apex; E. stem leaf margin; F. stem leaf median cells & costa; G. stem leaf basal cells; H. stem leaf lower surface; I. branch leaves; J. branch leaf apex; K. perichaetial leaf shoulder; L. exothecial cells; M & N. peristome teeth; O. operculum; P. spore. Vouchers: *Sim PRE-CH8915* (PRE) A, B, C, D, E, F, G, I & J; *Phiri 1270* (PRE) K, L & O; *Van Rooy 4242* (PRE) I, M, N & P. Scale: A–G & I–M & O = 0.1 mm.

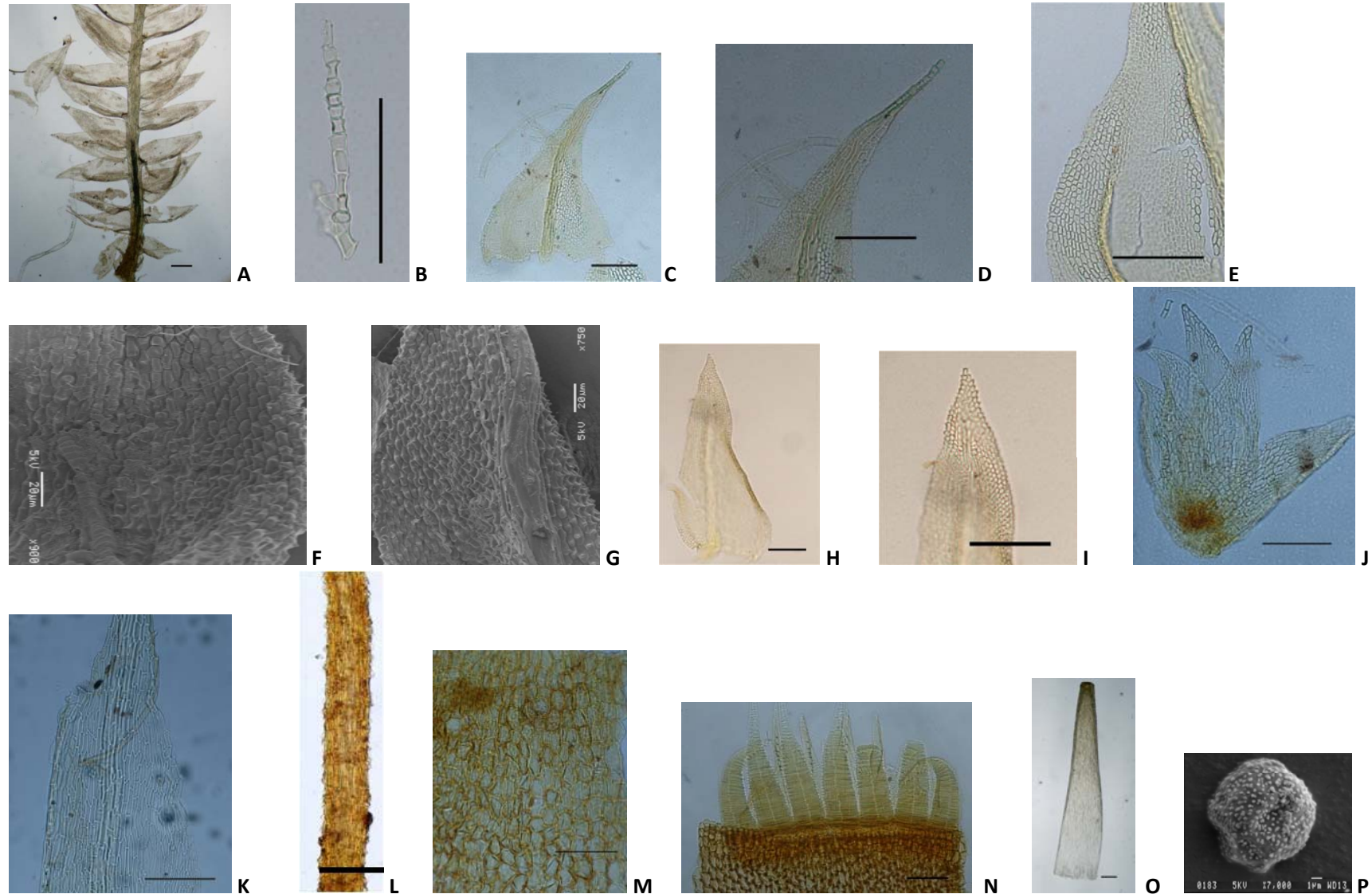


FIGURE 6.9.—*Pelekium thomeanum* (Broth.) Phephu: A. branch; B. paraphyllium; C. stem leaf; D. stem leaf apex; E. stem leaf margin and laminal cells; F. stem leaf lower surface; G. stem leaf upper surface; H. branch leaf; I. branch leaf apex; J. perigonium; K. perichaetial leaf shoulder; L. seta; M. exothecial cells; N. peristome teeth; O. calyptra; P. spore Vouchers: *Pocs & Pocs 6236/H* (EGR) B, C, D, F & G; *Dusen s.n.* (NY) A, J, K, L & M; *Müller Z331* (L) E, H, I, J, K, N, O & P. Scale: A–E & H–O = 0.1 mm.

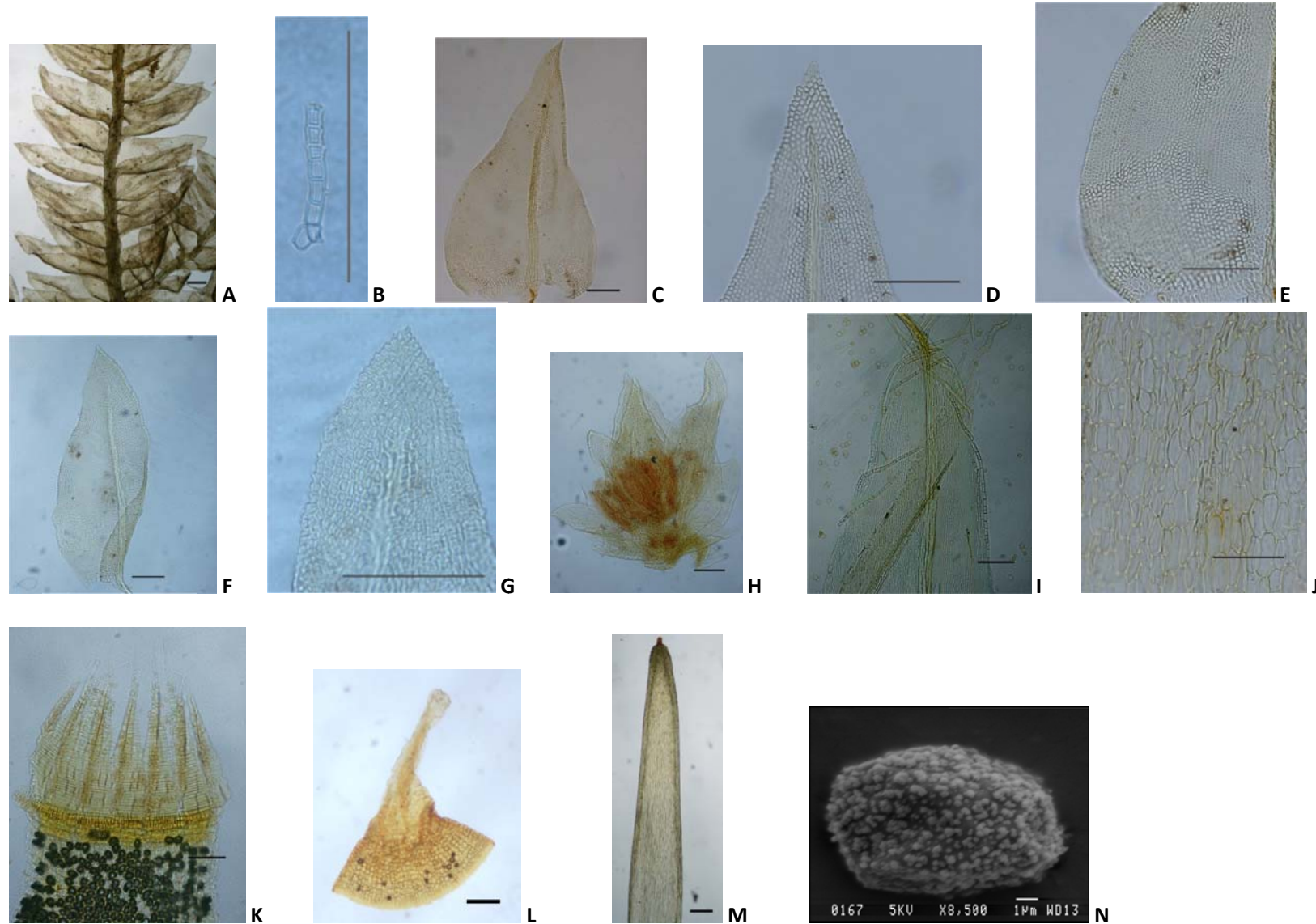


FIGURE 6.10.—*Pelekium varians* (Welw. & Duby) A. Touw: A. branch; B. paraphyllium; C. stem leaf; D. stem leaf apex; E. stem leaf margin and laminal cells; F. branch leaf; G. branch leaf apex; H. perigonium; I. perichaetial leaf shoulder; J. exothecial cells; K. peristome teeth; L. operculum; M. calyptras; N. spore. Vouchers: *Dümmer* 512 (PRE) J, K, L, M, N; *Dümmer* 993 (PRE) C & F; *Irvine* 413 (BM) A, B, D, E, G, H & I. Scale: A–M = 0.1 mm.

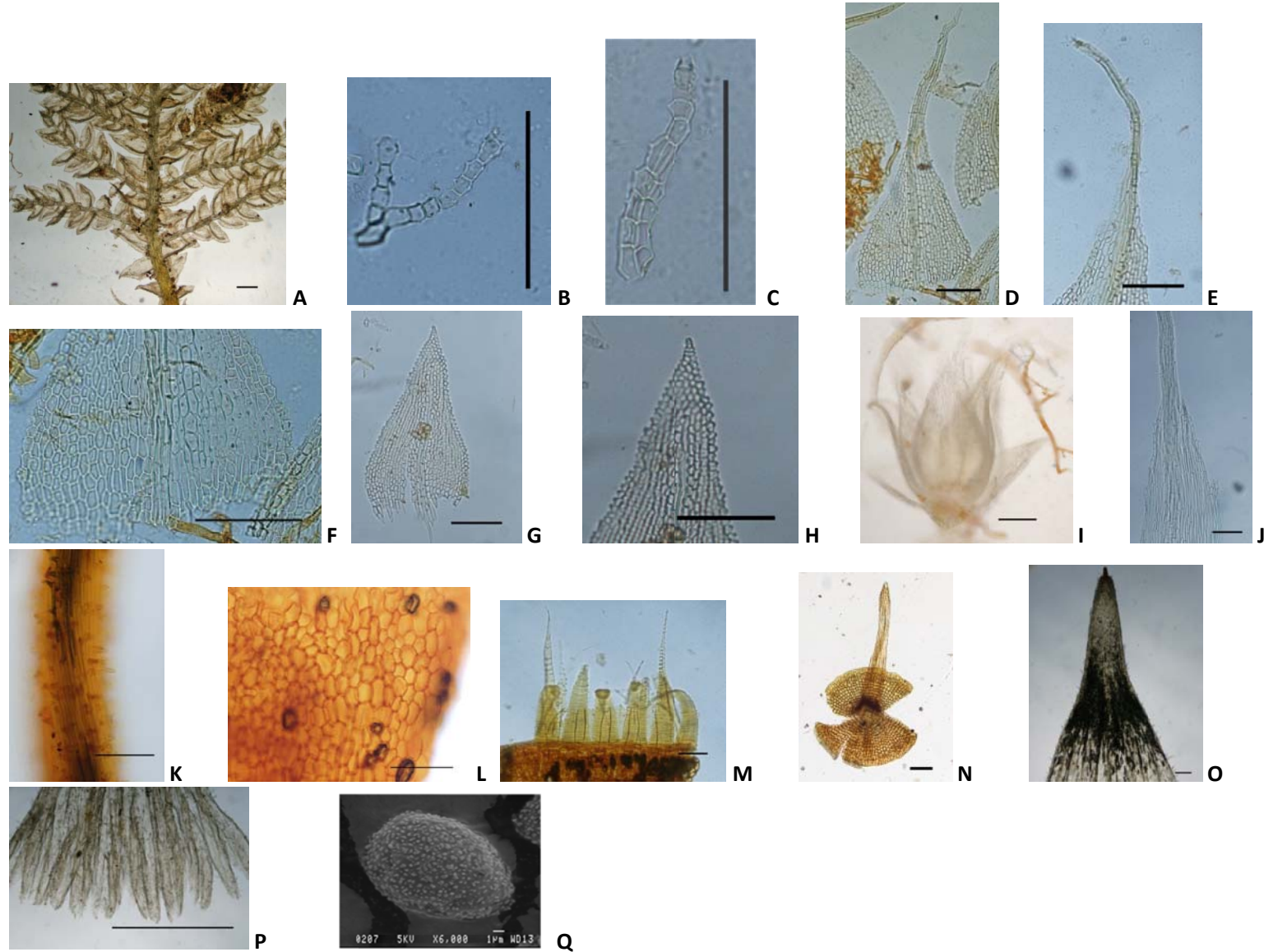


FIGURE 6.11.—*Pelekium velatum* Mitt.: A. branch; B & C. paraphyllia; D. stem leaves; E. stem leaf apex; F. stem leaf margin & laminal cells; G. branch leaf; H. branch leaf apex; I. perigonium; J. perichaetial leaf shoulder; K. seta; L. exothecial cells; M. peristome teeth; N. operculum; O & P. calyptra; Q. spore. Vouchers: *Pócs & Pócs 6188/AU* (EGR) A, B, C, D, E, F, H, I, J & L; *Pócs & Pócs 6236/H* (EGR) G, K, M, N, O, P & Q. Scale: A–P = 0.1 mm.

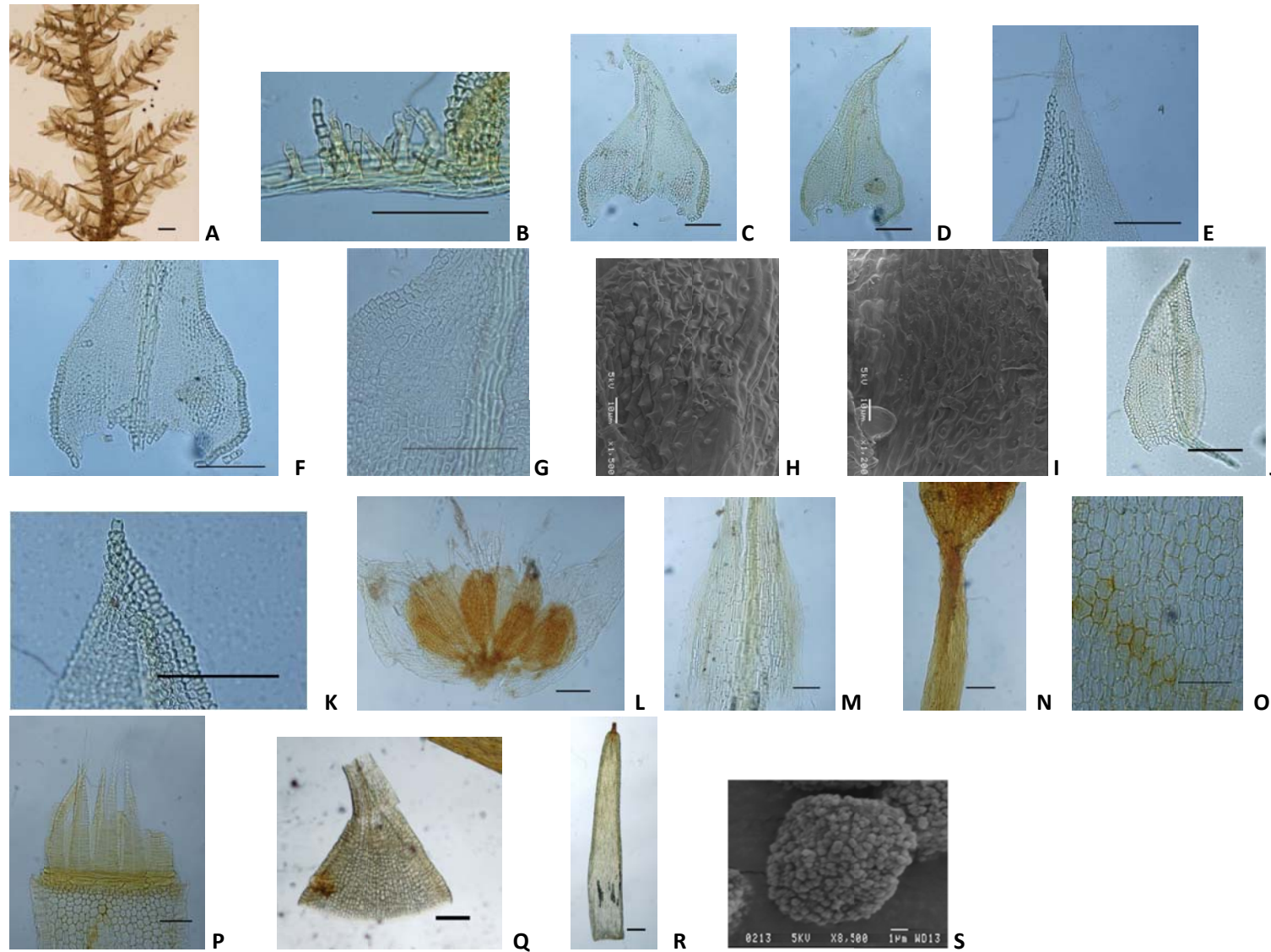


FIGURE 6.12.—*Pelekium versicolor* (Müll. Hal.) A. Touw: A. branch; B. paraphyllia; C & D. stem leaves; E. stem leaf apex; F. stem leaf base; G. stem leaf median laminal cells; H. stem leaf lower surface; I. stem leaf upper surface; J. branch leaf; K. branch leaf apex; L. perigonium; M. perichaetial leaf shoulder; N = upper part of seta; O. exothecial cells; P. peristome teeth; Q. operculum; R. calyptra; S. spore. Vouchers: *Martin 7800* (PRE) A, B, C, D, E, F, G, J & K; *Cholnoky 335* (PRE) R; *Farquhar 23* (PRE) M, N, O, P, Q & S); *Perold 4210* (PRE) H, I & R. Scale: A–G & J–R = 0.1 mm.

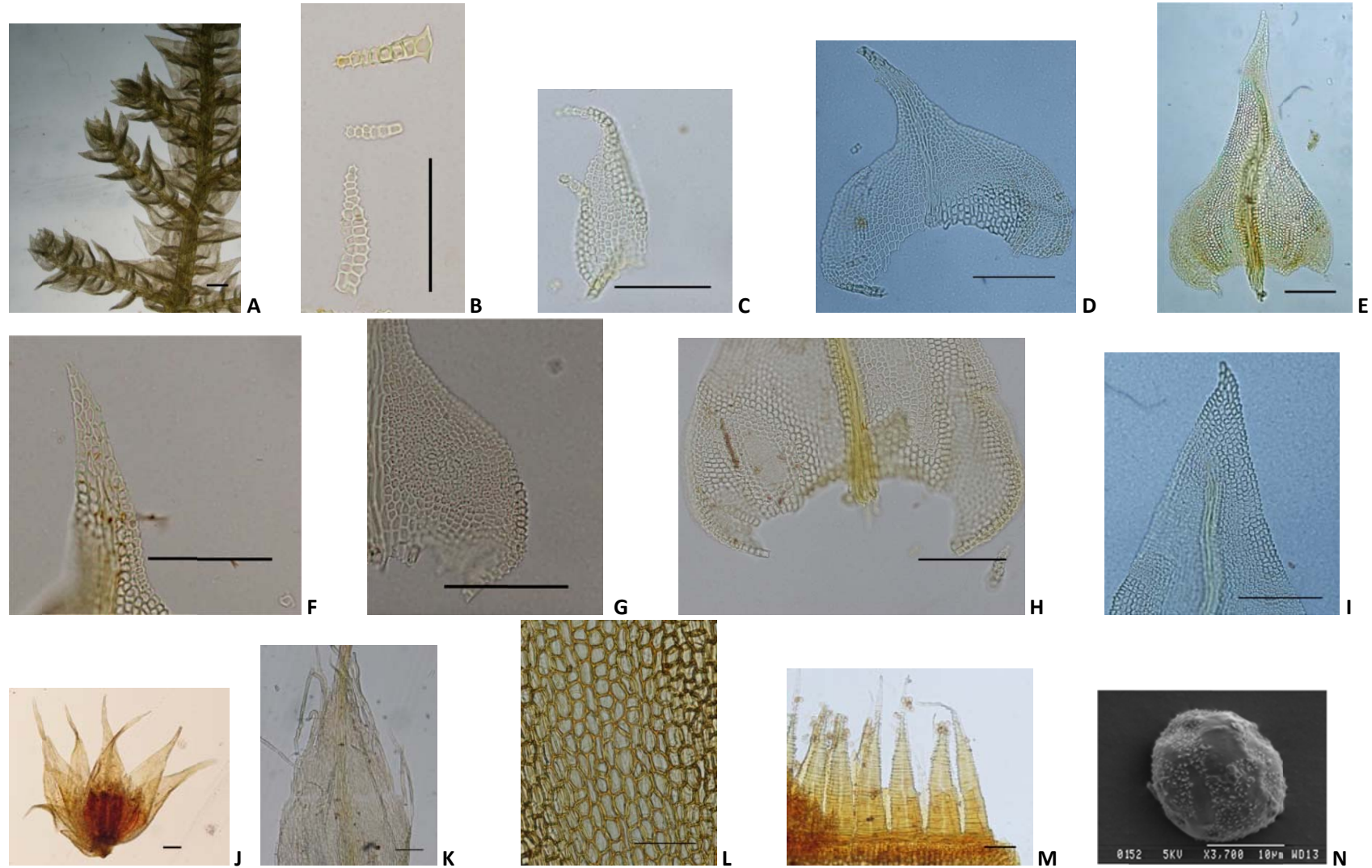


FIGURE 6.13.—*Thuidiopsis sparsa* (Hook. f. & Wilson) Broth.: A. branch; B. paraphyllum; C. pseudoparaphyllum; D & E. stem leaves; F. stem leaf apex; G. stem leaf margin & laminal cells; H. stem leaf basal cells; I. branch leaf apex; J. perigonium; K. perichaetial leaf. L. exothecial cells; M. peristome teeth; N. spore. Vouchers: *Hildebrandt 1827e* (H) A, B, C, E, G, I, J & K; *Higuchi 31518* (PRE) D, F & H; *Touw & Snoek 25705* (L) L, M & N. Scale: A–M = 0.1 mm.

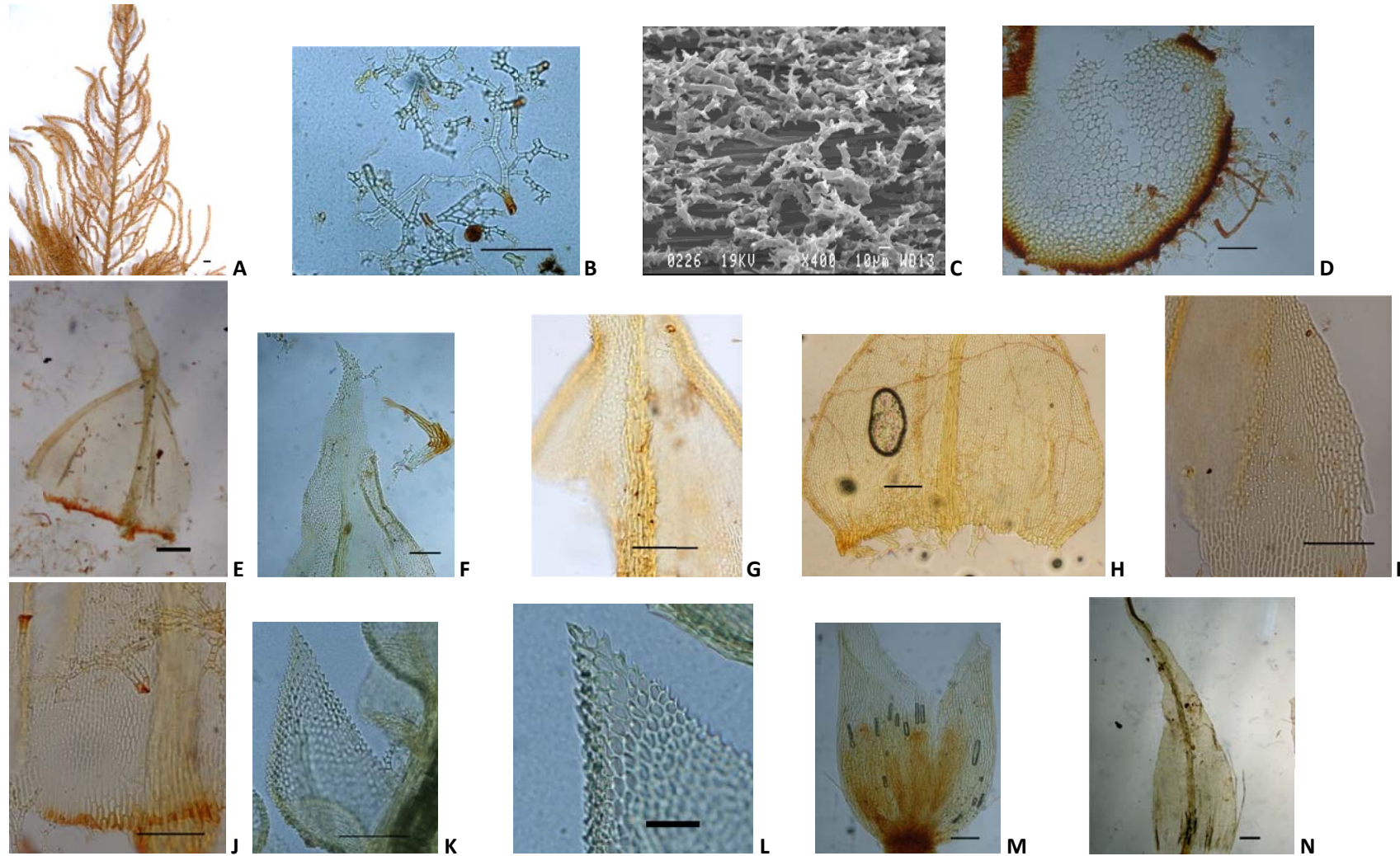


FIGURE 6.14.—*Thuidium aculeoserratum* Renauld & Cardot: A. branches; B & C. paraphyllia; D. cross section of stem; E. stem leaf F. stem leaf apex; G. stem leaf lower surface of costa; H. stem leaf base & margin; I. stem leaf median cells; J. basal cells; K. branch leaf; L. branch leaf apex; M. perigonium; N. perichaetial leaf. Vouchers: *Crosby & Crosby 7138* (PRE) B, C, G, I, J, K, L & M; *Hildebrandt 2075* (BM) A, D, F, H & N. Scale: A–B & C–N = 0.1 mm.

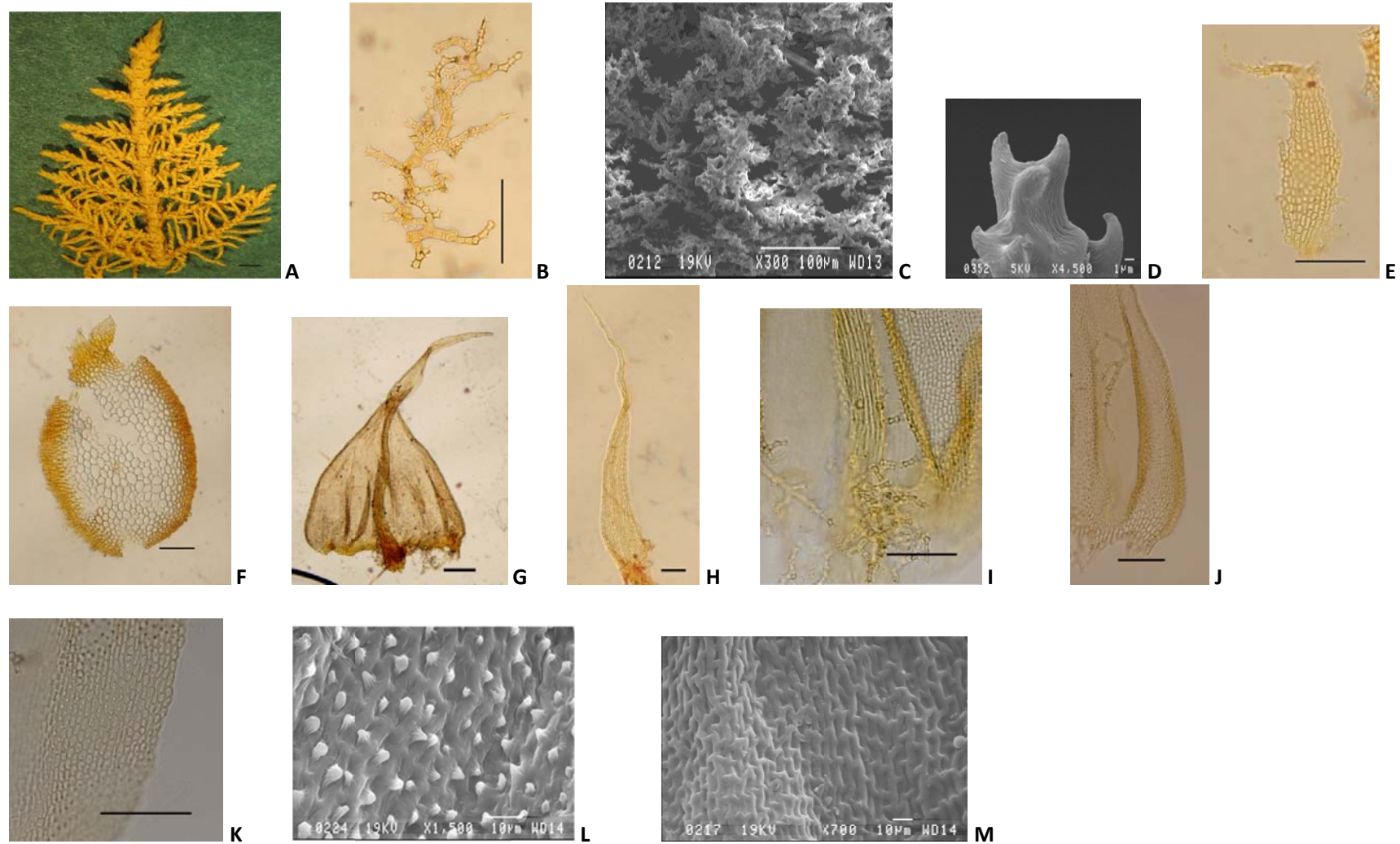


FIGURE 6.15a.—*Thuidium assimile* (Mitt.) A. Jaeger: A. branches; B & C. stem paraphyllia; D. paraphyllia terminal cell. E. pseudoparaphyllium; F. cross section of stem; G. stem leaf; H. stem leaf apex; I. stem leaf basal part of costa; J. stem leaf margin; K. stem leaf median cells; L. stem leaf lower surface; M. stem upper surface. Scale: A = 1 mm; B, E–K = 0.1 mm.

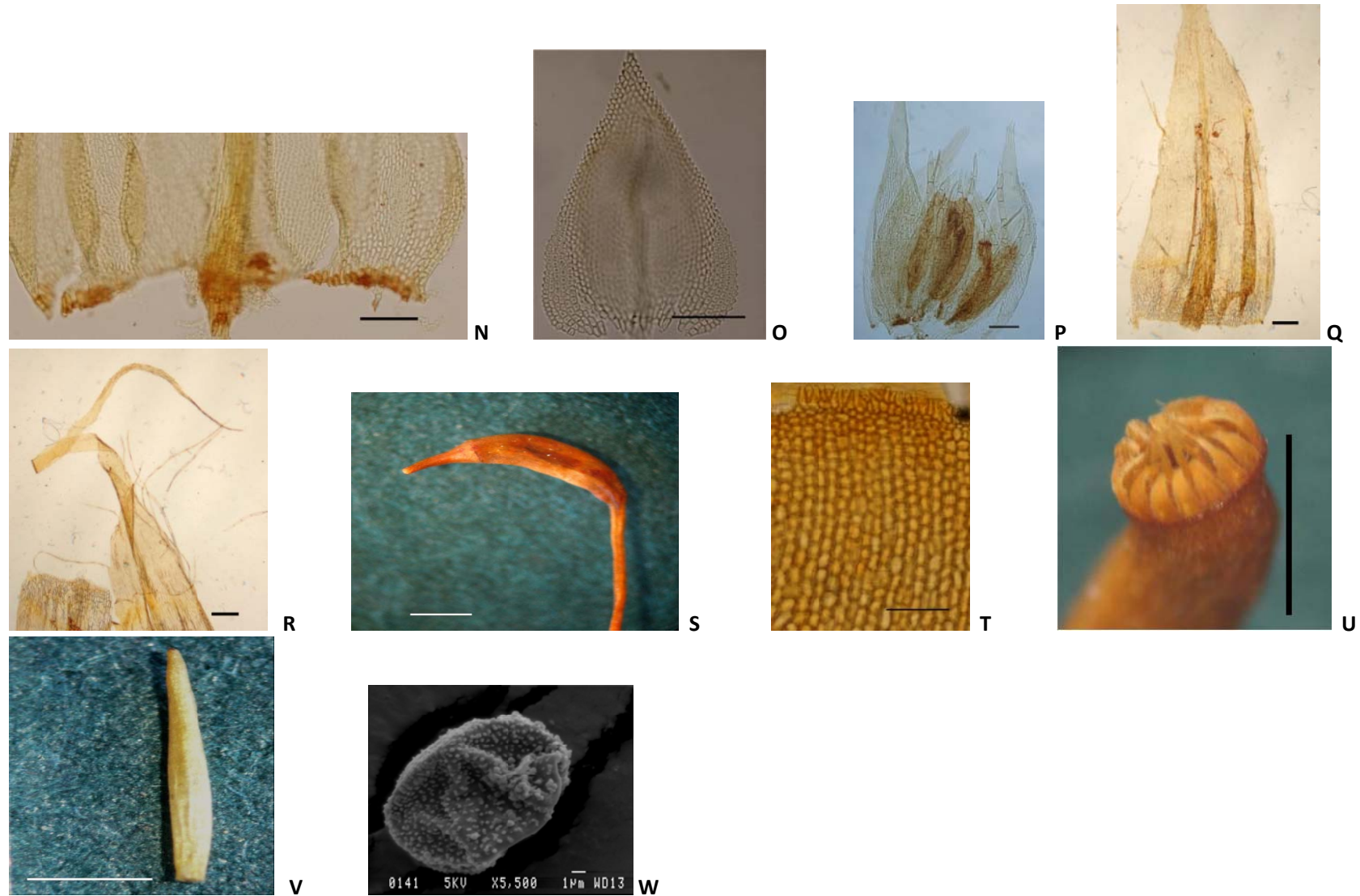


FIGURE 6.15b.—*Thuidium assimile* (Mitt.) A. Jaeger: N. stem leaf basal cells; O. branch leaf; P. perigonium; Q. perichaetial leaf shoulder; R. perichaetial leaf apex; S. capsule with operculum; T. exothecial cells; U. peristome teeth; V. calyptras; W. spore. Vouchers: *Van Rooy 4224* (PRE) B, E, F, G, I, J, K, N, P & Q; *Pócs, Ochyra & Bednarek-Ochyra 88123/F* (L) L & M; *Sim 8558* (PRE) A, C, D & H. Scale: N–R & T = 0.1 mm; S, U & V = 1 mm.

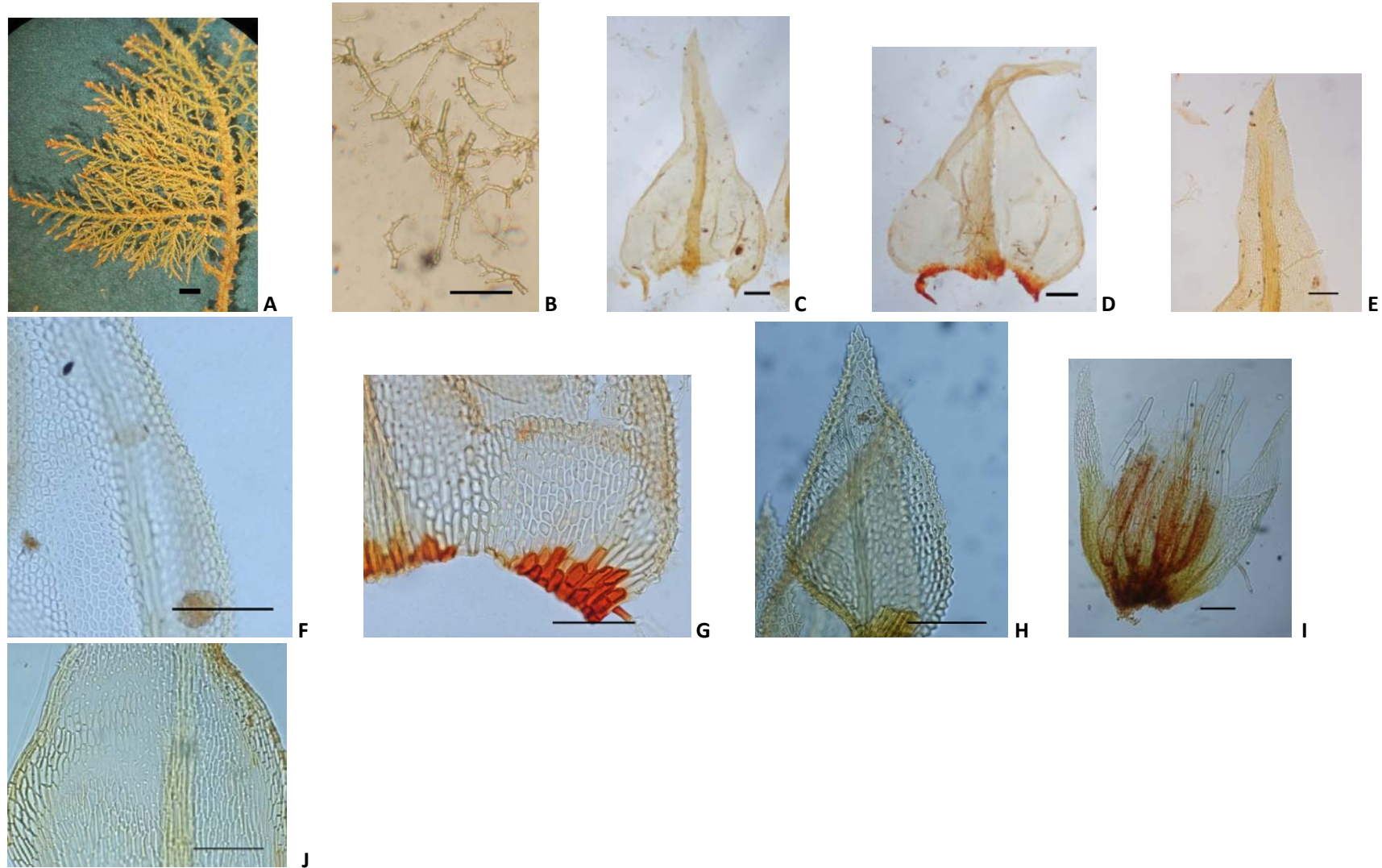


FIGURE 6.16.—*Thuidium tamariscinum* (Hedw.) Schimp.: A. branch; B. paraphyllia; C & D. stem leaves; E. stem leaf apex; F. stem leaf margin & median laminal cells; G. stem leaf basal cells; H. branch leaf. I. perigonium; J. perigonium leaf. Vouchers: *Marshall & Crosby 8327* (PRE) A, B, C, D, E, F, G, H & J; *Arts REU51/25* (L) I. Scale: A = 1 mm; G–J = 0.1 mm.

7. GENERAL DISCUSSION AND CONCLUSIONS

7.1 Discussion

Morphological and molecular data was used to test the re-circumscription of the Thuidiaceae as proposed by Touw (2001a) and García-Avila *et al.* (2009). The primary hypothesis of this study was supported by the results. Re-circumscription of the Thuidiaceae involving the exclusion of some genera, namely *Abietinella*, *Haplocladium*, *Hylocomiopsis* and *Rauarella* from African Thuidiaceae is supported. Also the transfer of *Thuidium involvens* subsp. *thomeanum* and *T. pseudoinvolvens* to *Pelekium* and a new status for *Thuidium involvens* subsp. *thomeanum* is supported.

The detailed comparative study of morphology and anatomy provided consistent characters used to classify the African Thuidiaceae, both at generic and species level. The taxonomic difficulties experienced with regard to identification within the family and delimitation of the taxa were addressed. The definition of African taxa is now better understood and this is contributing improvements to the existing global nomenclatural confusion of the Thuidiaceae. Our observations confirmed that the African Thuidiaceae consists of *Thuidium* and *Pelekium* species and they both belong to the thuidioid group. We therefore support the grouping proposed by the two above-mentioned authors. We also affirm this study as successful in providing a better taxonomic perspective and stable scope of the family in the region.

The objectives of this study generated these outcomes: species can be clearly discriminated; the classification of related species into a group of higher ranking has been achieved; morphological and molecular data were successfully used to re-circumscribe the Thuidiaceae in Africa; all monoicous species were transferred to *Pelekium*, including the transfer of *T. pseudoinvolvens* and *T. involvens* subsp. *thomeanum*, and the transfer of the latter to new status; this work also contributes towards the compilation of a comprehensive account of Thuidiaceae in Africa.

The nomenclatural confusion at generic level in Thuidiaceae still exists and will do so until all the regional problems are resolved. Also a reliable phylogenetic hypothesis of Thuidiaceae, among other pleurocarpus mosses, will have to be launched, groupings will have to be redefined and

a clear classification will have to be put in place. The relationships within Thuidiaceae and among other pleurocarpus mosses are still controversial, many taxa remain poorly understood on a global scale and definition of some regional (e.g. American and Asian) taxa is still misunderstood. A comprehensive taxonomic revision and phylogenetic study of Thuidiaceae, at a global level, is therefore necessary.

This study has successfully addressed the uncertainties in African members of the group.

7.2 Conclusions

- The demarcation of Thuidiaceae was resolved for Africa.
- Three genera (*Pelekium*, *Thiudiopsis* and *Thuidium*) and 16 species are recognized for the African Thuidiaceae.
- Phylogenetic analysis of Thuidiaceae with closely related families agreed with the morphological data used to re-circumscribe the family.
- Several stable taxonomic characters were established for the African Thuidiaceae.
- At family level the most valuable diagnostic characters are the 2- or 3-pinnate stems, uni- to pluripapillose laminal cells, truncate terminal cells of branch leaves and papillose-serrate leaf margins.
- At generic level the most valuable taxonomic characters include plant size, paraphyllia branching and length, stem leaf plication, sexual condition and seta morphology.
- At species level diagnostic characters include the stem branching pattern, paraphyllia branching and length, stem leaf median cell ornamentation, branch leaf terminal cell morphology, inner perichaetial leaf shoulder margin and seta morphology.
- It is now possible to identify most African material of Thuidiaceae (even sterile) to species level.
- The main habitats of the group are temperate and tropical regions of the world, shady and open forest areas on various substrates and under both moist and dry conditions, at altitudes between 250 and 2000 m.

- The main distribution of the group in Africa is the South-eastern region of the continent.
- Six species, namely *Pelekium chenagonii*, *P. ramusculosum*, *P. thomeanum*, *P. pseudoinvolvens*, *P. varians* and *Thuidium aculeoserratum* are endemic to Africa.
- The widespread African species show an affinity to Asia which is the centre of diversity for Thuidiaceae.

SUMMARY

There have been longstanding taxonomic questions reported with regard to identification of the family Thuidiaceae and delimitation of the taxa in Africa. These problems were addressed because of the family's reputation for being taxonomically difficult.

Various morphological, anatomical and phylogenetic methods were used to circumscribe the family for the African region.

The results of the phylogenetic-morphological analysis of Thuidiaceae led to the exclusion of some genera from the African Thuidiaceae, viz. *Haplocladium*, *Abietinella*, *Rauarella* and *Hylocomiopsis*.

The accepted Thuidiaceae nomenclature for the African region was outlined. A set of stable characters, which are best used in combination, was established and used in defining the species.

Three genera (*Pelekium*, *Thuidiopsis* and *Thuidium*) and 16 species are recognized in African Thuidiaceae and are described and discussed. Illustrations and distribution maps are included.

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I would like to thank my supervisors, Dr J. van Rooy and Prof. A. E. van Wyk for giving me this opportunity to work on such a taxonomically challenging bryophyte family. I also thank Dr A. Touw (L), who had a lifelong interest in Thuidiaceae, for his patience in sharing his expertise, loan arrangements and permission to extract the DNA from their herbarium material; Dr D. García-Avila (UMSNH) for sharing her recent Thuidiaceae findings, phylogenetic tree and matrices; Dr A. Magee (Compton Herbarium) for hosting my laboratory visit and assisting in constructing morphological-phylogenetic trees, and for discussions; Prof. Masa Higuchi (TNS) for gift specimens; Dr B. Buck and Dr B. Thiers (NY) for hosting my visit to their herbarium, loan arrangements and permission to extract the DNA from their herbarium material; Prof. T. V. Jacobs (UNISA) for Latin translations. I wish to thank the following staff from PRE: Mrs S. Smithies for English editing, Mr. A. Mothapo for the administration of the loans, Ms H. Steyn and Mrs B. Hölscher for providing me with a template map of Africa and Corel Draw software respectively, used to map the various taxa. I also would like to thank the following herbaria for allowing me to examine their specimens: BM, EGR, FH, G, L, NY, PRE and TNS.

CURRICULUM VITAE

Nonkululo Phephu was born on 6th April 1975 in Bizana, Eastern Cape. She attended primary and secondary school (1982–1990) at Mzamba Junior Secondary School and passed Matric in 1993 at Nongeke High School, both schools in Bizana. She studied towards a BSc degree at Walter Sisulu University in Umtata (1996–1999) and BSc Honours at the University of Johannesburg in 2005. She joined SANBI as an intern for the Bryophyte Section of the National Herbarium in Pretoria. Her position progressed from contract, then to permanent technical position and later to a researcher position where she is currently responsible for bryophyte identification and taxonomic research on the southern African liverworts.

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APPENDIX

Phephu, N., Van Rooy, J & Van Wyk, A.E. 2013. New combinations and a key to the species of *Pelekium* (Thuidiaceae) in sub-Saharan Africa and the East African Islands. *Phytotaxa* 84 (2): 60–64.



New combinations and a key to the species of *Pelekium* (Thuidiaceae) in sub-Saharan Africa and the East African Islands

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Abstract

Two taxa currently recognised in *Thuidium* are transferred to *Pelekium* to complete the relocation of monoicous species from *Thuidium* subg. *Microthuidium* to *Pelekium*. The new combinations are: *Pelekium thomeanum* (Broth.) Phephu *stat. et comb. nov.* (basionym *Thuidium involvens* (Hedw.) Mitt. var. *thomeanum* Broth.), now recognised as a species distinct from *P. involvens* (Hedw.) A. Touw, and *P. pseudoinvolvens* (Müll. Hal.) Phephu *comb. nov.* A full taxonomic treatment, including descriptions and notes on the distribution and ecology of these two species is presented, followed by a key to the African species of *Pelekium*.

Key words: Africa, classification, nomenclature, *Thuidium*, taxonomy

Introduction

While revising the African members of Thuidiaceae, two African endemics currently recognised in the genus *Thuidium* Bruch & Schimp., *T. involvens* (Hedw.) Mitt. subsp. *thomeanum* Touw and *T. pseudoinvolvens* (Müll. Hal.) A. Jaeger, were found to display characters typical of the genus *Pelekium*. When Touw (2001) transferred almost all monoicous species previously treated in *Thuidium* subg. *Microthuidium* to the genus *Pelekium* Mitt., he did not transfer these two taxa, as well as a number of other (mainly South American) species, either because he had not yet examined type specimens or because he was not convinced that they were 'good' taxa (Touw, pers comm., 2010). We have now examined the African taxa in detail and decided to move them to *Pelekium* as well.

Pelekium is distinguished from the other two genera of Thuidiaceae in Africa, *Thuidium* and *Thuidiopsis*, by its small size, simple or weakly branched paraphyllia, plane or weakly plicate stem leaves, occasionally ornamented seta and monoicous sexual state. This is the largest and the most morphologically and ecologically diverse genus of African Thuidiaceae. A key to the 12 species of *Pelekium* recognized in Africa, now including *P. thomeanum* and *P. pseudoinvolvens*, is given below.

Taxonomic treatment

Pelekium thomeanum (Broth.) Phephu *stat. et comb. nov.*

Basionym:—*Thuidium involvens* (Hedw.) Mitt. var. *thomeanum* Broth. (1890: 183).

Other combinations:—*Thuidium involvens* subsp. *thomeanum* (Broth.) A. Touw (1976: 168).

Cyrto-hypnum involvens subsp. *thomeanum* (Broth.) W.R.Buck & H.A.Crum (1990: 65).

Type:— SAO TOMÉ. Queluz: 270 m, *Quintas 1333a* (holotype H, fide Touw (1976)).

Description:—*Plants* medium-sized, pale green to yellowish green or brownish. *Stems* to 60 mm long, arching, 1 or 2-pinnately branched. *Paraphyllia* many, simple to very weakly branched, short, mixed with long ones, to 15 cells long; cells oblong-rectangular or isodiametrical, sparingly papillose; terminal cell truncate, papillose. *Axillary hairs* with 1 brown basal and 1 or 2 hyaline apical cells. *Branches* to 5 mm long, closely to remotely set; paraphyllia very few to lacking on branchlets. *Leaves* dimorphic, strongly incurved. *Stem leaves* 0.5–10 mm long, 0.25–0.6 mm wide, narrowly to broadly cordate-triangular, with patent base, plain to weakly plicate, closely set; when dry crisped, curved, concave, when wet spreading to widely patent. *Apex* gradually or abruptly short- to mostly long-acuminate, often twisted when dry. *Costa* strong, percurrent, ending in apex, tip indistinct, abaxially prominent, often grooved; cells smooth to very weakly papillose. *Margins* recurved to rarely plane below, plane upwards, papillate-crenulate. *Terminal laminal cell* truncate. *Median cells* 7–12 × 5–10 µm, short- to elongate-rhomboidal or -hexagonal, mainly unipapillose, some cells bi- to pluripapillose especially towards base; papillae weak or prominent, mostly central on lumen; cell walls thick or thin. *Basal cells* longer, larger, sometimes yellowish and smooth at insertion. *Alar cells* not differentiated. *Branch leaves* to 0.75 mm long, broadly rounded at base to narrowly ovate, asymmetrical, when dry strongly incurved, crisped, chain-like, with twisted apex and patent base, when wet spreading, complanate. *Apex* abruptly acute to short-acuminate. *Margins* recurved below, plane upwards, papillate-crenulate. *Costa* strong, abaxially weakly prominent, occasionally protruding in a distal spine. *Terminal laminal cell* truncate. *Laminal cells* to 6 µm wide, isodiametrical, mostly unipapillose, pluripapillose towards base, papillae low, indistinct.

Autoicous. *Perigonia* about 0.9 mm long; leaves ovate to broadly lanceolate; apex acute to abruptly long-acuminate; costa strong to weak; entire to weakly serrate; cells isodiametrical, smooth, thick-walled; cells at insertion yellowish brown. *Perichaetial inner leaves* to 2 mm long; apex abruptly filiform, ending in subula; costa strong, filling subula; margins entire to serrulate, shoulders eciliate. *Setae* to 17 mm long, strongly roughened throughout, reddish. *Capsules* 0.6–1.5 mm long, ovoid to elliptic, weakly curved, horizontal to pendulous, constricted at neck, reddish brown. *Exothecial cells* quadrate, smooth; walls incrassate, collenchymatous. *Peristome* perfect; exostome teeth oblong-lanceolate, cross-striate below, papillose and trabeculate upwards, yellowish brown below, hyaline upwards; endostome membrane ½ the length of exostome; processes keeled (or carinate), narrowly perforate; endostome cilia in groups of 3, free. *Operculum* 1.0 mm long, long-rostrate. *Calyptrae* 1.5–1.7 mm long, cucullate, apex obtuse, smooth. *Spores* about 10–13 µm in diameter, papillose.

Diagnostic characters:—The species is recognised by 1-pinnately branched stems, simple to weakly branched, short or long paraphyllia with a truncate terminal cell, plain to weakly plicate stem leaves with gradually or abruptly acuminate short to long-acuminate apex, truncate terminal cell and unipapillose median cells, truncate branch leaf terminal cell, strongly roughened seta and eciliate inner perichaetial leaf shoulders.

Ecology and distribution:—*Pelekium thomeanum* is a lowland, forest bottom species growing in the rain forest zone or high forests, on tree bases, decaying wood, or occasionally terrestrial on soil and rocks, at 270–900 m, in light to dense shade. *P. thomeanum* is endemic to Africa and occurs in Angola, Cameroon, Central African Republic, Côte d'Ivoire, Congo, Equatorial Guinea (Río Muni), Democratic Republic of Congo, Gabon, Ghana, Nigeria, Togo, and São Tomé. The lowland tropical American variant of *P. involvens*, namely *P. involvens* var. *involvens*, is known from Florida, Mexico, Ecuador, Bolivia, Venezuela and Brazil.

Specimens of *P. thomeanum* examined:—DEMOCRATIC REPUBLIC OF CONGO: Müller Z331 (L). CAMEROON: *Argent AR.522* (BM); *Dusen s.n.* (NY); *Sjostedt s.n.* (NY); *Staudt 711* (BM); *Zenker 2008b* (BM). NIGERIA: *Barter 1424*; (BM). ANGOLA: *Junio 174* (BM). TANZANIA: *Pócs & Pócs 6236/H* (EGR).

Specimens of *P. involvens* examined:—DOMINICAN REPUBLIC: *Allard 16142, 16168, 16209a, 17923a, 17958*, (NY); *Buck 4966, 4969, 5066, 5118* (NY); *Reese 15051, 15496, 15560* (NY).

Notes:—Brotherus (1890) created an African variety ‘*thomeanum*’ of the American *Thuidium involvens* based on a *Quintus 1333a* specimen collected in São Tomé. Touw (1976) changed that variety to subspecies rank as *Thuidium involvens* subsp. *thomeanum*. Although Touw (1976) regarded the American and African taxa as forms of a single species with many plants showing intermediate characters, he ranked the African taxon as a subspecies because of its geographical isolation. He recently suggested that more American material be examined to decide the rank at which ‘*thomeanum*’ should be recognized (Touw, pers comm., 2010). In his notes, O’Shea (2006) suggested that the subspecies, like *P. involvens*, presumably belongs to *Pelekium*. We found that *Thuidium involvens* subsp. *thomeanum* resembles other medium- and small-sized species of *Pelekium* like *P. varians* (Welw. & Duby) Touw, *P. chenagonii* (Müll. Hal. ex Renauld & Cardot) Touw, *P. ramusculosum* (Mitt.) Touw and *P. velatum* Mitt. It resembles *P. varians* in many respects especially in the 1-pinnate branching. It is similar to *P. velatum* on account of eciliate perichaetial leaf shoulder margins and small spores.

The American *P. involvens* var. *involvens* and var. *thomeanum* are similar in respect to the 1-pinnately branching, strongly incurved stem leaves with long-acuminate apex, eciliate inner perichaetial leaf shoulder margins, and rough setae of equal lengths.

However the African plants differ from the American *P. involvens* in the latter having slightly shorter stems, shorter and unbranched paraphyllia, smaller stem and branch leaves, blunt branch leaf apex, plane stem leaves with entire margins and pluripapillose laminal cells, a slightly longer capsule, narrower and more curved when dry, and smaller spores.

Pelekium pseudoinvolvens (Müll. Hal.) Phephu *comb. nov.*

Basionym:—*Hypnum pseudoinvolvens* Müll. Hal. (1876: 285).

Other combination:—*Thuidium pseudoinvolvens* A. Jaeger (1878: 254).

Type:—COMOROS. Johanna: Anjouan, ad truncos arborum, 800 m, *Hildebrandt 1835* (holotype B, lost; lectotype G, isolectotypes K, NY, fide Touw (1976); BM!).

Description:—*Plants* medium-sized; yellow- or dark-green. *Stems* prostrate, about 55 mm long; 2-pinnately branched. *Paraphyllia* few, scattered to dense, mostly short, or long, to 11 cells long, mostly simple to moderately branched; cells mostly rectangular, smooth to papillose; terminal cell truncate, papillose. *Axillary hairs* of 1 hyaline basal and 2 brown apical cells. *Branches* to 5 mm long, remote, sparingly pinnate; branchlets remote and irregular; paraphyllia few basally to absent upwards, lacking on branchlets. *Leaves* dimorphic. *Stem leaves* distant, 0.4–0.6 mm long, 0.2–0.3 mm wide, triangular to subtriangular, plane to weakly plicate; when dry incurved, weakly spreading, appressed with long, incurved, flexuose or twisted apex; when wet erect spreading, concave, basally paraphyllate, short decurrent. *Apex* gradually narrowly short- to long-acuminate. *Costa* strong; percurrent, ending in apex, tip indistinct, abaxially prominent when dry, weakly so when moist. *Margins* irregularly plane or recurved, papillate-crenulate, bordered by a row of shorter or oblate cells. *Terminal laminal cell* truncate, occasionally acute papillose or smooth. *Upper cells* short to elongate, pluripapillose to smooth. *Median cells* 10–17 × 6 µm, short to long, variously angled hexagonal-rhomboidal, pluripapillose, 1 or 2 or rarely 3 papillae over lumina, papillae low or sharp, small, thin- to thick-walled. *Basal cells* larger, longer, smooth to pluripapillose; papillae low and blunt. *Alar cells* not differentiated. *Branch leaves* to 0.45 mm long, lanceolate, asymmetrical, when dry with spreading base and strongly incurved-twisted apex, when wet spreading to complanate. *Apex* acute to short-acuminate. *Margins* mostly plane to occasionally recurved, papillate-crenulate. *Costa* percurrent, tip distinct; abaxially prominent when dry, weakly or not when moist. *Terminal laminal cell* truncate and often larger than adjacent cells. *Laminal cells* to 6 µm wide; short, variously angled or hexagonal, pluripapillose, papillae low, blunt, indistinct, crowded; walls incrassate. *Basal cells* larger, longer, pluripapillose to smooth.

Autoicous. Perigonia 0.5–1.0 mm long; leaves linear-lanceolate; apex mostly gradually filiform; margins plane or recurved, entire, serrate or papillose-crenulate; costa weak, percurrent; cells elongate-hexagonal or

-rhombic, smooth to mostly papillose, thin-walled. *Perichaetial inner leaves* to 1 mm long, oblong-lanceolate; apex mostly gradually to abruptly subulate, erect or flexuose; margins plane, entire or weakly serrate, shoulders ciliate; cells linear-rhomboidal or rectangular, smooth or weakly unipapillose. *Setae* 6–8 mm long; strongly roughened throughout, brown. *Capsules* 0.5–0.7 mm long, ovoid, subpendulous, dark brown. *Exothecial cells* isodiametrical, quadrate or rounded, smooth; walls incrassate, collenchymatous. *Peristome* perfect; exostome teeth oblong-lanceolate, cross-striate and short-trabeculate below, becoming papillose, trabeculate and hyaline upwards; endostome shorter than exostome; membrane $\frac{1}{2}$ the length of processes; processes weakly keeled, narrowly perforate upwards; endostome cilia in groups of 2 or 3, free. *Operculum* 1 mm long, short-rostrate, dark brown. *Calyptra* cucullate, smooth; apex acute, gradually mucronate. *Spores* 7–15 μm in diameter, papillose.

Diagnostic characters:—The species is recognised by the remotely 2-pinnately branched stems, short or long, simple to weakly branched paraphyllia with a truncate terminal cell, plane to weakly plicate stem leaves with gradually short to long-acuminate apex, truncate terminal laminal cell and uni- to bipapillose median cells, truncate branch leaf terminal cell, strongly roughened seta and ciliate inner perichaetial leaf shoulders.

Ecology and distribution:—*Pelekium pseudoinvolvens* is an epiphytic, lowland rain forest species growing on dead wood or tree trunks, at 450–800 m. It is endemic to Africa and has an East African islands distribution (Comoro, Mauritius, Madagascar and Mayotte). It is also reported to occur in Tanzania (O’Shea, 2006).

Notes:—After having studied the tropical Asian members of *Pelekium*, Touw (pers comm., 2010) questioned if *P. pseudoinvolvens* is really different from *P. gratum* (P. Beauv.) Touw. Although *P. pseudoinvolvens* is closely related to and sympatric with *P. gratum*, it differs from it in the weak, remotely bi-pinnate branching, stem paraphyllia less dense, paraphyllia cells longer and less papillose, often plane stem leaves with median and especially apical laminal cells elongated with thinner walls, papillae often less prominent, calyptra apex gradually mucronate, and exostome teeth broader and taller. These two species are similar in size, median cell ornamentation, inner perichaetial leaf shoulder margin and seta ornamentation. For consistency in the family, *P. pseudoinvolvens*, like the other small thuidioid species, should be classified under *Pelekium* as circumscribed by Touw (2001), where it is closely related to species like *P. gratum*.

Specimens examined:—MADAGASCAR: *Marie s.n.* (BM). COMOROS: *Hildebrandt 1835* (BM). MAYOTTE: *Marie 64, 85, 103, s.n.* (BM). MAURITIUS: *Robillard s.n.* (BM).

Key to the species of *Pelekium* Mitt. in Africa

1. Plants mostly minute to small (stems ≤ 50 mm long); paraphyllia simple, short (usually ≤ 7 cells long) 8
- Plants medium-sized (stems > 50 mm long); paraphyllia simple to weakly branched, short or long (usually ≥ 8 cells long) 2
2. Terminal cells of paraphyllia and stem leaves predominantly acute *P. ramusculosum*
- Paraphyllia and stem leaf terminal cell mostly truncate 3
3. Stem leaves mostly not plicate; margins plane; apex broadly acute *P. varians*
- Stem leaves plane to weakly plicate; margins recurved below, plane above; apex acute, acuminate or apiculate 4
4. Stem leaf apex long apiculate; seta strongly hispid *P. velatum*
- Stem leaf apex acute or acuminate; seta smooth or roughened throughout 5
5. Stems 2- or 3-pinnately branched; laminal cells uni- or bipapillose; perichaetial leaf shoulders ciliate; seta smooth ..
..... *P. chenagonii*
- Stems 1- or 2-pinnately branched; laminal cells uni- to pluripapillose; perichaetial leaf shoulders ciliate or eciliate; seta roughened throughout 6
6. Stems 1- or 2-pinnately branched; laminal cells mostly unipapillose, mixed with bi- to pluripapillose ones; perichaetial leaf shoulders eciliate *P. thomeanum*
- Stems 2-pinnately branched; laminal cells bi- to pluripapillose; perichaetial leaf shoulders ciliate 7
7. Paraphyllia few, mostly simple; stem leaves plane to weakly plicate *P. pseudoinvolvens*
- Paraphyllia abundant, mostly weakly branched; stem leaves mostly plane *P. gratum*
8. Plants wiry; stems irregularly branched; paraphyllia almost absent; stem leaf cells thin-walled *P. investe*

- Plants not wiry; stems regularly branched; paraphyllia abundant; stem leaf cells thick-walled 9
- 9. Stems 2-pinnately branched; paraphyllia simple, short; laminal cells with 1–3 papillae; perichaetial leaf shoulders eciliate; seta rough at neck *P. versicolor*
- Stems 1-, 2-, or 3-pinnately branched; paraphyllia simple to weakly branched; laminal cells with 1 or 2 papillae; perichaetial leaf shoulders ciliate or not; seta smooth or rough at neck 10
- 10. Stems (1–)2(–3)-pinnately branched; paraphyllia abundant; perichaetial leaf shoulder eciliate; seta rough at neck.....
..... *P. contortulum*
- Stems (1–)2-pinnately branched; paraphyllia few perichaetial leaf shoulders ciliate or not; seta smooth or rough at neck 11
- 11. Paraphyllia simple to weakly branched; stem leaves plane to weakly plicate; laminal cells uni- or bipapillose; perichaetial leaf shoulders eciliate; seta smooth *P. intricatum*
- Paraphyllia simple; stem leaves plane; laminal cells unipapillose; perichaetial leaf shoulders ciliate; seta rough at neck *P. minusculum*

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