

## **Bryophyte Studies in Thailand: Past, Present, and Future**

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**Abstract** – The historical development of bryophyte studies in Thailand is reviewed. Two historical periods are distinguished: the first period, 1899-1977, during which collections were made and studies were carried out by foreign botanists/bryologists in the framework of expeditions and the Flora of Thailand project; and the second one, 1977 to the present day, in which bryophyte work has been done mainly by Thai bryologists. In total, two species of hornworts, 20 of liverworts, and 63 of mosses have been described as new to science based on collections from Thailand. Of these, 48 are hitherto only known from Thailand and may be considered endemic to the country. Future work should focus more on taxonomic treatments of individual genera although further area-based research is also necessary.

**Bryophytes / hornworts / liverworts / mosses / Thailand**

### **INTRODUCTION**

Thailand, formerly known as Siam, is situated in Southeast Asia between 5-21°N and 97-106°E covering a total area of 513,115 square kilometres (Santisuk, 2007). The highest mountain in Thailand is Doi Inthanon, reaching 2,565 m asl. In the framework of the Flora of Thailand project the country has been divided into seven floristic or phytogeographical areas (Northern, North-eastern, Eastern, South-western, Central, South-eastern, Peninsular) (Smitinand, 1958). Recently, Van Welzen *et al.* (2011) proposed four phytogeographical regions including the Southern, Northern, Eastern, and Central Regions based on two databases, containing distribution data of species and of specimens, respectively. The country is covered by two main types of forest: tropical evergreen forest and tropical deciduous forest (Santisuk, 2007). In the framework of the Flora of Thailand project, the vascular plant flora of Thailand has been well-studied and has now reached a well-advanced stage of knowledge. In contrast, few studies of non-vascular plants have been conducted.

In this paper, the historical development of bryophyte studies in Thailand is reviewed.

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## HISTORICAL DEVELOPMENT OF BRYOPHYTE STUDIES IN THAILAND

### **First period: 1899-1977 – Studies by foreign botanists/bryologists in the framework of expeditions and the Flora of Thailand project**

At the beginning, the very diverse bryophyte flora of Thailand has been collected and studied by foreign botanists/bryologists. During 1899-1900, the Danish botanist E.J. Schmidt collected bryophytes on Koh Chang Island, Trat province. The collected specimens were sent to the Herbarium of the University of Copenhagen (C), Denmark, and subsequently identified by V. Brotherus in Helsinki (mosses) and F. Stephani in Leipzig (liverworts). In total, 61 species of bryophytes (44 mosses and 17 liverworts) were recognized including 19 mosses and four liverworts new to science (Brotherus, 1901; Stephani, 1902). In addition, liverworts and mosses were collected on Doi Suthep and Doi Inthanon in Chiang Mai province by C.C. Hosseus and identified by Stephani and Brotherus, respectively. Five species of liverworts, including one new species, and 15 species of mosses (three new to science) were reported (Brotherus, 1911; Stephani, 1911). An Irish medical doctor turned botanist, A.F.G. Kerr, collected 25,000 plant specimens including bryophytes throughout the country during his stay in Thailand from 1902-1932. These bryophyte specimens were held at Department of Agriculture (BK), Royal Botanic Gardens (K), and The Natural History Museum (BM) (Larsen, 1979). During 1924-1935, about 300 species of mosses were reported from Thailand by Dixon (1924, 1926, 1929, 1932, 1935). In contrast, after Stephani (1911) no liverworts were recorded for almost fifty years, until 1959, when Giesy and Richards reported two species of hornworts, three of liverworts and 40 of mosses based on collections made by P.W. Richards at the Temple of Reclining Buddha, Bangkok, at Nangrong waterfall in Nakhon Nayok province and on Chiang Dao mountain in Chiang Mai province (Giesy & Richards, 1959). Noguchi (1960) reported nine species of mosses based on his collections from Thailand, with members of Sphagnaceae studied by Hansen (1961); and 131 species of mosses were reported by Horikawa and Ando (1964) based on specimens collected by the Osaka City University biological expedition to South East Asia in 1957-1958. A compilation of the moss collection in the Forest Herbarium, Royal Forest Department, Bangkok (BKF) (now housed in the National Park, Wildlife and Plant Conservation Department), yielded a list of 168 moss species from Thailand (Tixier & Smitinand, 1966). Reed and Robinson (1967a, 1967b) reported 12 species of liverworts and 104 species of mosses from various collections made in Chanthaburi, Chiang Mai, Kanchanaburi, Khon Kaen, Loei, Nakhon Nayok, Nakhon Ratchasima, Nakhon Si Thammarat, Prachuap Khiri Khan, Saraburi, Surat Thani, and Trat provinces by workers involved in the Flora of Thailand project.

Important contributions to the knowledge of Thai liverworts were made by Japanese hepaticologists in the period 1965-1988, especially by N. Kitagawa (1967, 1968, 1969a, 1969b, 1978, 1979, 1981, 1988). As members of the Kyoto University botanical expedition to Thailand in cooperation with the Royal Forest Department of Thailand (November 1965-February 1966 and August-October 1967), Kitagawa and his colleagues, M. Tagawa, K. Iwatsuki, and N. Fukuoka, collected about 3,000 packets of bryophytes throughout the country. He reported 22 species of *Bazzania*, of which four were new species and 15 were new records (Kitagawa, 1967), furthermore three species of *Leucolejeunea* (Kitagawa, 1968), three of *Cephalozia* and seven of *Cephaloziella* (with two uncertain ones)

(Kitagawa, 1969a) were published; 46 species of *Plagiochila* including three new ones were recorded by Inoue (1974). Based on his collection from the Kyoto University botanical expedition to Thailand and Malaysia in 1967, Kitagawa (1969b) recorded three further liverwort species from Thailand, including one new to science. He also studied the liverwort specimens collected by A. Touw as a member of the Thai-Dutch botanical expedition of the Rijksherbarium, Leiden, and the Forest Herbarium, Bangkok (November 1965-February 1966), and reported 105 species and two new varieties (Kitagawa, 1978, 1979). In addition, based on the Thai-Danish expeditions during 1958-1963 and the Thai-Japanese botanical expedition during 1965-1967, 188 moss species and one variety including three new species and 33 new records were studied by Noguchi (1972, 1973). In 1980, 1,800 packets of bryophyte specimens collected by T. Shimizu, N. Kitagawa, H. Koyama, T. Santisuk, H. Toyokumi, and T. Yahara on the Thai-Japanese botanical expedition in 1979 were studied by several Japanese specialists: hornwort by J. Hasegawa; Plagiochilaceae by H. Inoue; Lejeuneaceae by M. Mizutani; remaining liverwort groups by N. Kitagawa; and mosses by A. Noguchi and Z. Iwatsuki (Shimizu *et al.*, 1980). From this collection, *Anastrophyllum* and allied genera and the members of Calypogeaceae were reported by Kitagawa (1981, 1988), with one new record of moss reported by Shin (1971) and one new species of hornwort described by Hasegawa (1979). In the course of a revision of *Radula* in Asia (Yamada, 1979), 18 species were recorded from Thailand. Of these, one species was new to science. Moreover, sporelings of a Thai liverwort (*Pleurozia acinosa* (Mitt.) Steph.) were reported by Nehira (1968).

Based on the Thai-Dutch botanical expedition in 1965-1966, 195 species of mosses, including 84 new records for Thailand, were reported by Touw (1968). Tixier (1970, 1971, 1971-1972) enumerated 516 species of mosses and 8 new species based on his collections made in Thailand during 1965-1968 as well literature reports. He also reported 56 species of liverworts from his collections made under the auspices of the South East Asia Treaty Organization (Tixier, 1973). For moss families of Thailand, Stott (1975) provided a provisional and explanatory key.

The main achievement of the first period was the report of a great number of bryophyte species from Thailand. The research was conducted by European and Japanese botanists/bryologists in the framework of the Flora of Thailand project and several major expeditions. Many of bryophyte species were new to science (see Appendix 1).

## **Second period: 1977-2013 – Studies mainly by Thai bryologists**

### *Taxonomic studies and revisions*

The first bryological studies by Thai bryologists were focused on particular groups of bryophytes. The first Thai bryologist was O. Thaithong who collaborated with S. Hattori and N. Kitagawa (Japan) in the identification of the liverwort specimens collected in Thailand during 1957-1977 in the framework of the botanical expeditions of Kyoto University, Rijksherbarium, Leiden, and Aarhus University. Based on these specimens, 34 species of *Frullania* were recognized, including two species, one variety and one forma new to science and 20 species new to Thailand (Hattori *et al.*, 1977). Other early studies by Thai bryologists included the work of Manop (1977) on mosses of the family Sematophyllaceae based on the collections held in Department of Agriculture (BK) and National Park, Wildlife and Plant Conservation (BKF), Bangkok, and of Sadakorn (1978) on the moss genus *Leucobryum*.

Recently, revisions have been presented of the Thai species of Sematophyllaceae (Pollawatn, 2008; Pollawatn *et al.*, 2008), *Fissidens* (Wongkuna *et al.*, 2009; Wongkuna, 2010), *Leucophanes* (Promma & Chantanaorrapint, 2013), division Anthocerotophyta (Chantanaorrapint, 2007, 2009), and Lejeuneaceae subfamily Ptychanthoideae (Kornochalert, 2012; Kornochalert *et al.*, 2012). The world monograph of the genus *Thysananthus* (Lejeuneaceae) by the first author recorded six species of this genus from Thailand (*T. comosus* Lindenb., *T. convolutus* Lindenb., *T. fruticosus* (Lindenb. *et* Gottsche) Schiffn., *T. gottschei* (Jack *et* Steph.) Steph., *T. retusus* (Reinw. *et al.*) B. Thiers *et* Gradst., *T. spathulistipus* (Reinw. *et al.*) Lindenb.) (Sukkharak, 2011, accepted). Lejeuneaceae is the most speciose family of bryophytes in Thailand with 135 species reported, including two species known only from Thailand (Zhu & So, 2001; Zhu & Lai, 2003; Lai *et al.*, 2008; Pócs & Bernecker, 2009; Kornochalert *et al.*, 2010; He *et al.*, 2012; Kornochalert *et al.*, 2012; He *et al.*, 2013; Lee, 2013; Pócs *et al.*, 2013; Wei & Zhu, 2013; Ye *et al.*, 2013). A rich area for the discovery of species new to science proved to be Doi Inthanon National Park in northern Thailand where three undescribed species of mosses, one of hornworts, and one of liverworts were recently discovered (Akiyama & Tsubota, 2009; Chantanaorrapint, 2009; Akiyama *et al.*, 2010; Akiyama & Goffinet, 2011; He *et al.*, 2012).

#### *Floristic studies*

Most of the work by Thai bryologists during the past thirty years was floristic, focusing on the bryophytes of particular areas within the country. The publications included a study of bryophytes of Sakaerat area, Nakhon Ratchasima province (Sornsamran, 1982, 1988); bryophytes of mangrove forest in Chanthaburi, Krabi, Phang Nga, Ranong, Satun, and Trat provinces (Thaithong, 1984); mosses of Taksin National Park and Dio Nuseu, Tak province (Pitpan, 1996); liverworts of Khun Khorn waterfall, Chiang Rai province (Chantanaorrapint, 1997); mosses of Doi Suthep-Pui (Santanachote & Rattanayun, 1999); mosses on *Pinus kesiya* and *Cupressus torulosa* on Doi Pui, Chiang Mai province (Boonpatip, 2001; Weranakrin, 2001); bryophytes on the wall of Umong temple, Chiang Mai province (Trepiyarat, 2002); bryophytes on the summit of Khao Luang, Huai Yang waterfall National Park, Prachuap Khiri Khan province (Chantanaorrapint, 2002; Chantanaorrapint *et al.*, 2004a, 2004b); epiphytic bryophytes of San Ku and terrestrial bryophytes of Huay Kog Ma, Doi Suthep-Pui National Park, Chiang Mai province (Kornochalert, 2003; Manachit, 2003); epiphytic mosses of Ru See Cave and Huay Kog-Ma, Doi Suthep-Pui National Park, Chiang Mai province (Wongkuna, 2003, 2005); bryophytes of Khun Wang community forest, Doi Inthanon, Chiang Mai province (Sukkharak, 2005); bryophytes of Na Haeo, Loei province (Sornsamran *et al.*, 2005); bryophytes of Khun Chang Khian village and the area of Sirindhorn Observatory, Doi Suthep-Pui National Park, Chiang Mai province (Kornochalert, 2006; Manachit, 2006); liverworts of Khao Nan National Park, Nakhon Si Thammarat province (Sukkharak, 2007; Sukkharak & Seelanan, 2008; Sukkharak *et al.*, 2008); coastal bryophytes of the peninsula of Thailand (Inuthai, 2007); bryophytes of the surroundings of Monthatarn fall, Doi Suthep-Pui National Park, Chiang Mai province (Bhompaa, 2007; Pholboonsri, 2007; Printarakul, 2007); bryophytes of Thong Pha Phum National Park, Kanchanaburi province (Boonkerd *et al.*, 2007a); bryophytes of Doi Inthanon National Park, Chiang Mai province (Akiyama, 2006; Tan *et al.*, 2006; Akiyama & Tsubota, 2009; Nathi, 2009; Akiyama, 2010; Akiyama *et al.*, 2010; Nathi *et al.*, 2010; Akiyama *et al.*, 2011; Akiyama & Goffinet, 2011; He *et al.*, 2012); bryophytes of the plant genetic

protection area of RSPG, Rajjaprabha dam, Surat Thani province (Chantanaorrapint & Chantanaorrapint, 2010); epiphytic bryophytes along altitudinal gradients in Southern Thailand (Chantanaorrapint, 2010; Chantanaorrapint & Frahm, 2011); bryophytes along selected streams in Ko Hong Hill, Songkhla province (Sengmee, 2011); epiphyllous bryophytes in the Naka Wildlife Sanctuary, Ranong province (Kraichak & Yaungthong, 2012); *Sphagnum* of Phu Luang Wildlife Sanctuary, Loei province (Sitthichoptham *et al.*, 2012); moss and liverwort diversity of Khao Kheow open zoo (Pearaksa, 2013; Sarawan, 2013); and the liverwort genera *Bazzania* and *Frullania* of Khao Soi Dao Wildlife Sanctuary, Chanthaburi province (Likananon, 2013; Kitlap, 2013). The recent discovery of several new species and many new records of bryophytes from northern Thailand, especially from the Doi Inthanon National Park (Tan & Ninh, 1998; Akiyama, 2006; Tan *et al.*, 2006; Boonkerd *et al.*, 2007b; Lai & Santanachote, 2007; Pollawatn *et al.*, 2008; Akiyama & Tsubota, 2009; Chantanaorrapint, 2009; Frahm *et al.*, 2009; Wongkuna *et al.*, 2009; Akiyama, 2010; Akiyama *et al.*, 2010; Ho *et al.*, 2010; Nathi *et al.*, 2010; Akiyama & Goffinet, 2011; Printarakul *et al.*, 2012, 2013), indicates that northern Thailand is an important area for bryophyte diversity investigation (He *et al.*, 2012; Wei & Zhu, 2013).

#### *Checklists of Thailand*

In their checklist of the mosses of Indochina, Tan and Iwatsuki (1993) listed 563 species of mosses from Thailand. Sornsamran and Thaithong (1995) summarized the knowledge of Thai bryophytes based on the literature published up to 1979 (24 papers) and presented a list of 279 species of liverworts and 644 of mosses. The latest moss checklist is by He (1998, internet resource) who recorded 620 species and 31 subspecific taxa. The most recent hepatic checklist is by Lai *et al.* (2008) who recorded 376 species of liverworts and 12 of hornworts. In addition, Printarakul *et al.* (2009) produced a database of bryophytes and their ecological parameters in the herbarium of Chiang Mai University (CMU).

Based on Lai *et al.* (2008) and He (internet resource) with updates, 143 species were described as new to science based on collections from Thailand. Of these, two species of hornworts, 22 of liverworts, and 62 of mosses and are still accepted as good species (Appendix 1). Forty of these are hitherto only known from Thailand and may be considered endemic to the country. Sixteen species described from Thailand (5 of liverworts, 11 of mosses) are now considered synonyms.

#### *Morphological studies*

Spore morphology has been studied of selected hornworts (Chantanaorrapint, 2007) and Marchantiopsida in Thailand (Boonkerd *et al.*, 2007b; Chekok, 2012).

#### *Chemical studies*

Chemical study on bryophytes in Thailand began relatively recently. Gas chromatography and mass spectrometry of 17 samples of *Thysananthus* from Thailand belonging to five species (*T. comosus*, *T. convolutus*, *T. fruticosus* (as *Dendrolejeunea fruticosa* (Lindenb. et Gottsche) Lacout.), *T. retusus*, *T. spathulistipus*) revealed the presence in most taxa of large quantities of sesquiterpenoids and unidentified diterpenoids (Sukkkharak *et al.*, 2011). In addition, the sesquiterpenoids occurring in *Cheilolejeunea ceylanica* (Gottsche) R.M.Schust. et Kachroo from Khao Soi Dao Wildlife Sanctuary, Chanthaburi province, were analysed (Sukkkharak & Asakawa, 2013).

### Conservation

No status survey and conservation on bryophytes in Thailand has yet been reported. However, Tan and Tan (2000) reported *Ochrobryum kurzianum* Hampe as a new ornamental moss in Singapore introduced from Thailand. Wei & Zhu (2013) suggested to place *Microlejeunea moniliata* (Mizut.) R.L. Zhu *et* Y.M. Wei in the red list of Thai bryophytes because it is only known from the type locality in northern Thailand, where it was rediscovered in 2011.

### Picture book

Frahm (2012) made a picture book of Thai bryophytes, in which the photos were taken during a fieldtrip to several national parks in central and northern Thailand together with R. Pollawatn and S. Chantanaorrapint during September to October 2006. The picture book gives an impression of the Thai bryoflora, which connects the tropics with the Himalaya.

### Future

In 2012, during the 6<sup>th</sup> Botanical Conference of Thailand at Prince of Songkla University, Songkhla province, a small group of Thai bryologists initiated the Bryological Group of Thailand. The aim of the group is to encourage the study and floristic treatment of the bryophyte flora of Thailand and promote cooperation and communication among Thai bryologists (Sukkharak, 2013). The planned future work will concentrate mainly on taxonomic treatments of individual genera. In addition, area-based studies on species diversity will also be taken into account.

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**Appendix 1. Liverworts and mosses originally described from Thailand and still accepted as good species (Lai *et al.*, 2008; Akimaya & Tsubota, 2009; Chantanaorrapint, 2009; Akiyama *et al.*, 2010; Akiyama & Goffinet, 2011; He, internet resource). \* only known from Thailand.**

**Hornworts**

- \* *Notothylas depressispora* J. Haseg.
- \* *Phaeoceros perpusillus* Chantanaorr.

**Liverworts**

- Bazzania angustistipula* N. Kitag.
- Bazzania bilobata* N. Kitag.
- Bazzania debilis* N. Kitag.
- \* *Cephaloziella crispata* N. Kitag.
- Cheilolejeunea kitagawae* W. Ye et R.L. Zhu (*Leucolejeunea paroica* N. Kitag.)
- Cololejeunea ombrophila* Tixier
- Cololejeunea ranongensis* Tixier
- Cololejeunea schmidtii* Steph.
- Cololejeunea shimizui* N. Kitag.
- Cololejeunea shimizui* N. Kitag. var. *phangngana* N. Kitag. (*Chondriolejeunea shimuzui* (N. Kitag.) Kis & Pócs var. *phangngana* (N. Kitag.) Kis et Pócs )
- Cololejeunea siamensis* Steph.
- Cylindrocolea tagawae* (N. Kitag.) R.M. Schust. (*Cephaloziella tagawae* N. Kitag.)
- \* *Drepanolejeunea laciniata* Q. He et R.L. Zhu
- Heteroscyphus inflatus* (Steph.) S.C. Srivast et A. Srivast var. *fragilissimus* (N. Kitag.) M.J. Lai et R.L. Zhu (*Chiloscyphus inflatus* Steph. var. *fragilissimus* N. Kitag.)
- \* *Kurzia touwii* N. Kitag.
- \* *Lepidozia parvula* N. Kitag.
- \* *Lophocolea kurzii* Sande Lac. var. *siamensis* N. Kitag.
- \* *Microlejeunea moniliata* (Mizut.) R.L. Zhu et Y.M. Wei (*Lejeunea moniliata* Mizut.)
- Plagiochila tagawae* Inoue
- Pycnolejeunea grandiocellata* Steph.
- Radula caduca* Yamada
- Schistochila yakushimensis* Ohnishi et Deguchi

**Mosses**

- \* *Acroporium convolutifolium* Dixon
- \* *Acroporium hamulatum* (M. Fleisch.) M. Fleisch. var. *procumbens* (M. Fleisch.) Dixon
- \* *Acroporium secundum* (Reinw. et Hornsch.) M. Fleisch. var. *siamense* Dixon
- \* *Barbula subdenticulata* Dixon
- \* *Brachythecium siamense* Dixon
- Calymperes schmidtii* Broth.
- \* *Chaetomitrium nervosum* Dixon
- Clastobryopsis imbricata* H. Akiyama *et al.*
- Distichophyllum schmidtii* Broth.
- \* *Ectropothecium diversifolium* Dixon
- Ectropothecium micro-verrucosum* Dixon
- Ectropothecium siamense* Dixon
- \* *Ectropothecium vesicularioides* Dixon
- \* *Fissidens filiformis* Z. Iwats.
- \* *Fissidens obtuso-apiculatus* Dixon
- Fissidens papillosus* Broth.
- Fissidens semperfalcatus* Dixon
- \* *Fissidens siamensis* Broth.
- Gammiella rugosa* Tixier
- \* *Hymenostomum siamense* Dixon
- \* *Hymenostyliella calcarea* (Dixon) Z. Iwats. (*Diphyscium calcareum* Dixon)

- Indopottia irieandoana* H. Akiyama  
 \* *Isopterygium perpusillum* Dixon  
 \* *Leucoloma phumiensis* Tixier  
 \* *Leucoloma siamense* Broth. (*Leucoloma beautei* Besch. ex Renauld et Cardot)  
 \* *Macromitrium brevissimum* Dixon  
 \* *Macromitrium goniorrhynchum* (Dozy et Molk.) Mitt. var. *denticulatum* Dixon  
*Macromitrium turgidum* Dixon  
 \* *Mastopoma subfiliferum* Horik. et Ando  
*Microtheciella kerrii* Dixon  
*Neckeropsis gracilis* Nog.  
*Philonotis perlaxifolia* Dixon  
 \* *Pinnatella amblyphylla* Enroth  
*Plagiothecium entodontella* Broth.  
*Pterobryopsis rubrinervis* Tixier  
 \* *Racopilum siamense* Dixon  
*Rhaphidostichum chaetomitriopsis* (Dixon) Touw (*Trichosteleum chaetomitriopsis* Dixon)  
 \* *Rhaphidostichum leptocarpoides* (Broth.) Broth. (*Trichosteleum leptocarpoides* Broth.)  
 \* *Rhaphidostichum subrevolutum* (Broth.) Broth. (*Sematophyllum subrevolutum* Broth.)  
 \* *Rhynchostegiella ovalifolia* Dixon  
 \* *Sematophyllum latifolium* Broth.  
 \* *Sematophyllum parvulum* (Broth.) Dixon (*Rhaphidostegium parvulum* Broth.)  
*Sematophyllum striatifolium* Dixon  
*Sematophyllum subconnivens* (Broth.) Dixon (*Rhaphidostegium subconnivens* Broth.)  
*Symphyodon gollanioides* Nog.  
*Symphyodon leiocarpus* Akiyama et Tsubota  
*Symphyodon scaber* (Tixier) S. He et J. Snider (*Symphyodon sutepensis* Tixier var. *scaber* Tixier)  
 \* *Symphysodon siamensis* Tixier  
*Symphysodontella siamensis* Dixon  
 \* *Taxithelium clastobryoides* Dixon  
 \* *Taxithelium epapillosum* Dixon  
 \* *Taxithelium inerme* Tixier  
 \* *Taxithelium schmidtii* Broth.  
*Taxithelium spathulifolium* Dixon  
*Tortella cyrtobasis* Dixon  
*Trachyphyllum carinatum* Dixon  
*Trichosteleum pinnatum* Dixon  
 \* *Trichosteleum trachycystis* Broth.  
 \* *Trichostomum siamense* Broth.  
 \* *Wijkia filipendula* (Dixon) H.A. Crum (*Acanthocladium filipendulum* Dixon)  
*Wijkia laxa* (Dixon) H.A. Crum (*Acanthocladium laxum* Dixon)  
*Wijkia longipila* (Broth.) H.A. Crum (*Acanthocladium longipilum* Broth.)