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STUDIES IN "COPPER MOSSES"

By Herman PERSSON¹

H. Persson: 所謂 copper moss の研究

As early as the end of the last century it was clear that the two *Mielichhoferia* species *M. elongata* Hornsch. [*M. compacta* (Hopper & Hornsch.) Kindb.] and *M. mielichhoferiana* (Funck) Limpr. (*M. nitida* Hornsch.) very often grew on deposits of copper, iron or aluminium (Limpricht, 1895, p. 213). Later Hagen (1909) added *Dryptodon atratus* (Mielichh.) Limpr. (*Grimmia atrata* Mielichh., see later) and Douin (1913) the hepatics, *Gymnocolea acutiloba* (Kaal.) K.M. [very near *G. inflata* (Huds.) Dum and sometimes brought under this species as a modification] as well as *Cephaloziella massalongii* (Spr.) K.M. and *C. phyllacantha* (Mass. & Car.) K.M. Gams and Morton (1925, p. 41, 143) called attention to the possibility that *Merceya ligulata* (Spr.) Schp. may prefer rocks containing copper ore. These four mosses and three hepatics, which have been called "copper mosses" are all very rare species.

For a survey of the "copper mosses" see my paper of 1948. At present I intend to mention what has been published later, and to deal with the analyses carried out on the soil from several herbarium specimens of *Merceya ligulata*, *Mielichhoferia mielichhoferiana*, *M. elongata*, *Dryptodon atratus* as well as from about a dozen South American *Mielichhoferia* species and the North American *Merceya latifolia* Kindb.

However, to begin with I must discuss the vascular plants, because the bryophytes have been far less studied in comparison with them. I base my statements mainly on the valuable survey reported by Rune (1953) in an important work dealing with the flora, also the cryptogamic, on serpentines and related rocks in northern Sweden. As to the older history of these interesting plants I refer the reader to Rune and limit myself to some reports appearing in the last decennium.

In Scandinavia two members of the family Caryophyllaceae are characteristic of, but not limited to, the outcrops of copper (Nordhagen, 1930, and others) and also on iron and zinc ores. One of them, *Viscaria alpina*, was found to be a good indicator of nickel ore deposits in N. Finland (Tanner, 1930). The family Caryophyllaceae is everywhere often represented on different sorts of ores containing heavy metals and it is of great interest that an affinity both to copper ores and serpentine is shown by several members of this family in other parts of the world.

Robyns (1932) described a particular vegetation connected with copper fields in the Congo. Several species were specific for copper soils there and the species name 'cupreola' was often attached to them. His observations are of special interest because e.g. in the detailed plant geographical manual by Schimper & Faber (1935), zinc, serpentine and aluminium plants are treated but it is noted only in passing that there are also reports in the literature about the influence on the

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vegetation of copper. And as for the bryophytes nothing at all is said about their relation to any kind of metallic ores.

There is a very interesting report by Prát (1934), who in Slovakia, Czechoslovakia found *Melandrium rubrum* growing abundantly on soil rich in copper as copper-hydroxycarbonate. It was sites with a maximum content of 1.8% Cu. An *Agrostis* species was also common in this copper soil and grew even in places where the copper content reached 39%. It is of utmost interest that in his cultures Prát found that the ability to endure a high concentration of copper soil is limited to plants of *Melandrium rubrum* originally taken from this copper soil and their descendants. No morphological changes could, however, be observed in this "copper-race" of the species.

As regards Rune's work, already mentioned, I quote the end of his summary: "In conclusion, it may be stated that my observations support the assumption of Robinson et al. (op. cit.) that the rather high contents of chromium and nickel are general and dominant causes of infertility. Special indications have been noted in regard to nickel. It should be emphasized that the effect of these elements on the serpentine soil depends on many other properties of this rock, e.g., the low nutrient content, absence of calcium, high magnesium content, presence of iron in reduced form, pH value, mechanical composition etc.

The 'infertility,' no doubt, explains several important characteristics of the serpentine flora, for it leaves the members of that flora largely without serious competition. Still, the problem of the effect of serpentine on plant life is too complex for a general explanation. Thus, the abundance and vigour of many serpentinicolous plants might justify the contention that serpentinicolous plants are, nevertheless, stimulated by the minor elements in question. However, conclusive proof of this is beyond the scope of a comparative ecological study, since it rather belongs to physiology and biochemistry."

Of outstanding interest is the team work by Kruckeberg, Walker and Whittaker (1954) on the ecology of serpentine soils in U.S.A. Walker, who studied the "factors affecting plant growth on serpentine soils" states a.o. in his summary: "It is concluded that plants which grow well on serpentine areas must first be tolerant of low calcium levels and, in addition, must be tolerant of one or more of the following in special situations: high concentrations of nickel and chromium, high magnesium, low levels of major nutrients, low available molybdenum, and unfavorable physical aspect of shallow soils." Kruckeberg, who studied "plant species in relation to serpentine soils" made methodical and penetrating experiments with serpentine plants to study the role of competition. I cite (p. 273): "In these experiments with competing plants, a serpentine plant occupies a serpentine environment while its potential competitors are excluded by edaphic factors. On the non-serpentine soil, in contrast, the serpentine plant is excluded by the presence of other plants, though very well able to grow on non-serpentine soil in their absence," and (summary, p. 274): "Experiments are reported showing that serpentine plants may be restricted to serpentine by intolerance of the more rigorous competition in non-serpentine plant communities. Thus, edaphic factors on the one hand, biotic or dynamic factors on the other, may produce the sharp discontinuities between serpentine and non-serpentine vegetation."

As regards the "copper mosses" in my paper of 1948 I reported the first find of *Merceya ligulata* in Macaronesia (at a hot, sulphureous spring in the Azorean island S. Miguel), I also gave an account of several localities for "copper mosses" as regards their ecology. Besides the "copper mosses" already mentioned in the literature I dealt with the N. American *Merceya latifolia* Kindb. I ended my paper in this way: "The small or scattered areas of the few *Merceya* species, which seem to be rare everywhere and often sterile, indicate a high age. Perhaps they have played a bigger role during the Tertiary—now they seem chiefly confined to the mountain chains originating from this period, when volcanic springs must have been much more numerous."

Berggren and Mårtensson (1954) commented on the ecology of *Dryptodon atratus* and *Mielichhoferia elongata* from three localities in Swedish Lapland. Their copper and pH analyses are, to my knowledge, the first ever presented in the literature. In his important work on the bryophytes of the Torne Träsk area in Swedish Lapland (Mårtensson, 1956) gives some new informations and discusses the problems. I return further on to these works as well as to others mentioned in this history.

In 1955 Schatz discussed the ecology of the "copper mosses" from a chemical point of view. I cite Mårtensson (l.c., p. 141): "Schatz...prefers the term 'sulphur mosses' to 'copper mosses'. According to his reasoning it is the occurrence of sulphur and/or sulphides in the substratum which is of primary interest. He raises the question whether the 'sulphur mosses' are able to utilize any of the energy released during the oxidation of sulphur or sulphides as we know the sulphur bacteria do in their photosynthesis. It would be very interesting if experiments should prove that this is the case."

An important work is that of Noguchi (1956). After a thorough monographic study of the genus *Merceya* (including *Merceyopsis* which according to Noguchi is hardly distinguishable from *Merceya*), resulting in the reduction of quite a lot of names to synonymy (I have profited much from these results), he gives very interesting ecological reports, including pH values from many Japanese localities of *Merceya ligulata* and *M. gedeana* (Lac.) Noguchi [*Pottia gedeana* Lac. 1872; *Anoetangium gedeana* (Lac.) Fl. 1902-1904; *Merceyopsis gedeana* (Lac.) Fl. 1915-1922] and also some brief experiments with cultures of *Merceya ligulata* with different gradients of sulphate of copper. Of utmost interest is that Noguchi states that these two *Merceya* species in Japan practically grow only on soil rich in copper or iron. Remaining localities are unknown as regards the chemical composition of their soil. The pH values of *M. ligulata* proved to be very low, on an average 3.50, *M. gedeana* had distinctly higher values, on an average 4.28. Copper analyses were not presented.

Of very great interest is Noguchi's observation of the sporulation of the two Japanese *Merceya* species. From Europe, N. and S. America as well as from Java he has not seen any sporogonia (myself I have not found any reports of the sporophytes of *M. ligulata* in the literature) but he has been lucky enough to find good sporophytes in specimens from NW. Himalaya, Formosa and Japan. But from the copper districts of Japan remarkably he has not gotten any sporogonia. He concluded: "It may be called to attention that the mosses growing on soil which contains copper hardly yield sporophytes. Judging from the above, it may

be speculated that the fertilization of both species is hardly done on the soil containing metallic, especially copper ion. Due to the scarceness of spore producing the geographical range of both species is exceedingly limited. These species seem to be declining and are scarcely living, resisting to the metallic substances in limited area, where the other plants are unable to invade."

Another important work is that by Url (1956), dealing with the resistance of several bryophytes to heavy metals and especially copper (his literature list can be recommended). Url visited one of the classical localities for "copper mosses", Schwarzwand in the valley Grossarlal in Salzburg, Austria (see the table and the text besides) and has afterwards made different analyses as well as experiments with "copper mosses" as well as other bryophytes from it. He also extended his investigations to some bryophytes from other localities. The following species are more or less fully treated: the mosses *Bryum capillare*, *Fissidens taxifolius*, *Funaria hygrometrica*, *Hookeria lucens*, *Mielichhoferia elongata*, *M. mielichhoferiana*, *Mnium affine*, *M. cuspidatum*, *M. seligeri*, *M. undulatum* and *Pohlia albicans*; and the hepatics *Calypogeia fissa*, *C. trichomanis*, *Gymnocolea acutiloba*, *Marsupella emarginata*, *Nardia scalaris* and *Porella platyphylla*.

From the summary I quote: "Für die Schwarzwandmoose, insbesondere für die bekannten 'Kupfermoose' *Mielichhoferia elongata* und *M. nitida* wurden in der Tat enorm hohe Kupferresistenzen beobachtet. Die Resistenz gegen Kupfersulfat reicht bei *Mielichhoferia elongata* bis etwa 0.1 mol, was ungefähr einer 2%igen Lösung entspricht. Die höchsten bisher aus der Literatur bekannten Resistenzen anderer Zellobjekte reichen dagegen nur etwa bis 0.001% (=5.10⁻⁵ mol). *Mnium affine* und *Madotheca platyphylla*, beides Moose von normalen Standorten, zeigen nun ebenfalls Resistenz gegen hohe CuSO₄-Konzentrationen. In diesem Falle aber sterben die Zellen in den mittleren Konzentrationen ab, es treten also Todeszonen auf," and "Die 'ökologische' Resistenz zeigt sich also nicht in der absoluten Höhe, sondern darin, dass betreffende Plasma in kritischen mittleren Konzentrationsbereich wirkliche plasmatische Resistenz zeigt. Hohe Resistenz für ein Schwermetall bedingt nicht hohe Resistenz gegen ein anderes, doch zeigen sich oft parallele Züge im Resistenzverhalten gegen Kupfer und Chrom. Auch im Chromsulfat z.B., wo ebenfalls die meisten untersuchten Moose im mittleren Konzentrationsbereich absterben, leben die beiden *Mielichhoferia*-Arten," and "Gegen Mangansulfat und Zinksulfat sind alle untersuchten Moose in allen untersuchten Konzentrationen resistent" and "Das zellphysiologische Bild der Resistenzreihen von Zink-, Mangan-, Chrom- und Vanadylsulfat ist bei Moosen und Desmidiaceen weitgehend ähnlich, ganz auffallend verschieden ist dagegen das Resistenzverhalten gegenüber Kupfersulfat. Den hohen Kupferresistenzen vieler Moose steht die absolute Empfindlichkeit der Desmidiaceen gegenüber."

At last I like to pay attention to a small but interesting work by Hattori (1955, 1, see also 1955, 2) dealing with hepatics occurring on serpentine. From the summary I cite: "Thus there are no essential serpentine-loving hepaticae so far as the present area is concerned." and: "It may be a most remarkable fact that few or no hepaticae can occur on both serpentine and limestone rocks... Generally, hepaticae are hardly tolerant to a certain degree of magnesium as well as an excess of calcium in the substrata. The injurious effect of the two rocks is not the same

physiologically.”

My own work was started some three years ago. At that time no analyses were made of the soil from the “copper moss” localities. My intention was to fill this gap and also to find out if some other species of *Merceya* and *Mielichhoferia* (more than 40 species are described from South America only; in all we know some 80), followed the same ecological scheme as the “copper moss.” I have confined myself to herbarium material, taking out samples of the soil accompanying the specimens in question. The specimens all belong to the bryophyte herbarium of Naturhistoriska Riksmuseet, Stockholm (this herbarium is kept by the Paleobotanical Department of the museum. Until a planned cryptogamic department is established the archegoniates are kept by the paleobotanical, other cryptogamic plants by the botanical department). The reason why I have used herbarium material is that my intention was to point out the possibility of exploiting the museum material to give geologists, mining engineers and ore-prospectors a chance to find new ore-deposits (besides it seems that museum material, except perhaps in some single cases, has never been exploited in this respect before). I was indeed encouraged when I handed over the material to the chemist for analysis. One of the Swedish samples collected by an “amateur bryologist” a long time ago came from a rather unknown, smaller mountain in Lappland, not known to contain any ore deposits. The chemist gave a start and rather confused, said: “We have just found copper ore there....”

It is not necessary to point out that a herbarium presents many possibilities for investigators in the future. A source of error—at least superficially seen—may be noted: sometimes it is impossible to get unmixed soil from a herbarium specimen. Especially when the tufts are big and no other soil accompanies the specimen but that interspersed among the lower parts of the tufts and when trying to separate it, the plant is always more or less intermingled with organic substance. The copper and pH values therefore tend to be too low. Yet in the greater number of cases, this circumstance has little or no importance. Besides it is problematic which is of greater importance to the mosses, the soil intermingled in the tufts or the soil beneath the tufts. It should be remembered that the lower parts of moss tufts are not alive and cannot take up nutrients from the layer beneath. Berggren and Mårtensson (l.c.) used the “substratum immediately below the moss and free from remnants of the moss....” They remarked that “material from older tufts in the herbaria proved to be too poor, and too much contaminated with organic material from the moss to give proper reproducible results.” Their pH values (they used “the well known method with sodium diethyldithiocarbamate (Welcher, 1948, p. 82)”) are between 320 and 770 p.p.m. As they refer only to three localities it is not easy to compare them with the values from my own investigations but after all (the highest value in my series is 450) they seem to be comparatively high. In this connection it is of interest to note that Mårtensson (l.c.) reported that “further analyses (...unpublished), in which the amount of copper was determined polarographically, indicate that the amount of copper...is discontinuous in the substratum. Thus four samples from one collection showed a copper content of 50.0, 70.4, 104 and 159 p.p.m.” I return to this interesting fact later on.

The copper analyses were made by the geochemist Dr. S. Landergren at the

geochemical laboratory of the Geological Survey of Sweden, Stockholm. He has kindly allowed me to publish the following account of his investigation:

"A primary distribution of elements in unweathered rocks may be changed into a secondary dispersion pattern during a number of stages in the cycle of weathering and soil forming processes. Regions where ore deposits are concealed may affect a normal pattern of geochemical distribution of elements. Such anomalies commonly result from the action of natural dispersion processes operating in and around the site of mineralization. The resulting pattern of geochemical dispersion may be developed in varying accessible material, for example, in the rocks surrounding a mineral deposit, in the overlaying soil and vegetation, and in the waters and sediments of streams draining the mineralized area. Consequently anomalies in the dispersion pattern of certain elements can be of diagnostic value and has given rise to a geochemical ore prospecting method of increasing importance.

The best studied type of a secondary dispersion is that which takes place during the formation of a residual cover. In this case the dispersion of metals from a sub-outcropping primary ore is, as V.M. Goldschmidt first pointed out (Goldschmidt, 1937), an integral part of the local weathering and soil forming processes and, furthermore, an integral part of the circulation of metals in the minor cycle soil-plan. Thus, for example, a copper ore may give rise to an anomalous enrichment of copper in the residual top soil and the vegetation. It should be emphasized, however, that local conditions (topography, streaming waters etc.) can affect the secondary dispersion pattern and make an interpretation difficult.

The best samples to be analysed in connection with studies of anomalies in the dispersion pattern of elements are those of top soil or plants (or parts of plants especially leaves, needles, flowers etc. where the evaporation is great). A number of investigations have increased our knowledge of the secondary dispersion pattern of different elements in connection with ore prospecting.

The anomalies in a secondary dispersion pattern of elements from a mineral deposit is continually fading out in all directions. If, for example, the sediment cover is too thick, say about 30 to 40 ft., it happens that the ascending solutions from the ore deposit do not reach the root-system of the covering vegetation and thus being incapable to contribute to the dispersion pattern in the system top-soil-vegetation and no significant anomalies in the distribution pattern will appear in such a region.

On the other hand, in regions where the sediment cover is very thin and the vegetation poor it would be of great interest to know if lichens or mosses could serve as useful "tools" to detect anomalies in a dispersion pattern of elements. Our knowledge in this respect is rather incomplete so far. Investigations with this object in view would, therefore, be very appreciated.

Dr. Herman Persson has started a study on the content of copper in a sampling of mosses from different localities. On his request the determinations of the copper content have been performed in the geochemical laboratory of the Geological Survey of Sweden. The results are discussed by Dr. Persson. Only a brief description of the analytical procedure will be added.

The samples to be analysed were incinerated at a moderate temperature (500-600 centigrades). The ash of each sample was mixed with two parts by

weight of purified graphite powder to which five per cent by weight of Li_2CO_3 was added. The mixture was then put into a drill hole (4 mm deep and 1.5 mm in diam.) of a purified graphite rod of 5 mm diam. This graphite rod served as negative electrode in an arc stand. As counter electrode served a graphite rod with the same diam. The spectrum was emitted by means of a direct current arc of 220 volts and 8 amps. and photographed on Ilford cromatic plates. Time of exposure was one minute. The intensity ratio of the line pair $\text{Cu-}3274 \text{ \AA}/\text{Li-}3233 \text{ \AA}$ was measured by means of a microphotometer and the ratio calculated compared with that from a standard series with copper contents 5-1000 p.p.m. Cu. The intensity ratios of the series were plotted in a calibration curve constructed on the basis of the standard series, prepared in the same way as the samples to be analysed, and the content of copper thus determined.

By means of this technique the analytical error is estimated to 10-20 per cent of the content. This precision is quite satisfying in this case, since the variation in the content of copper in the samples are at least of the same magnitude."

The lowest level as regards the method described above is at 10 p.p.m. In this connection I cite Mårtensson (l.c., p. 140): "5 p.p.m. is generally accepted as a deficiency limit in ordinary cultivated soils; amounts higher than 100 p.p.m. are certainly poisonous for vascular plants at least when the substratum is not strongly basic."

The determination of pH was made by Mr. A. Silfversparre, the chief chemist of the Swedish Tobacco Monopoly, Stockholm, who is a skilled bryologist and who has been my invaluable companion on numerous excursions in different parts of Sweden. He has used the following method: "The soils were mixed with water 1:2.5. The pH then was determined with the Beckman glass electrode in combination with saturated Calomel electrode, electrometrically."

Before I give the results of the analysis of the copper mosses I wish to report as a sort of control some analyses made with the same methods, but from mosses not on cupriferous soil, growing around Stockholm. For the purpose of comparison herbarium material was used and I have tried to choose localities which could be expected to be as free as possible from any human influence. All of them are common species with a wide distribution in the northern hemisphere and two are limestone species. Ecologically they may be characterized in this way:

Bartramia ithyphylla: mostly occurring in caves on cliffs and in crevices on perpendicular rock surfaces. It is mostly to be found on poor, sandy soil but is also, though rarely, collected on basic rocks.

B. pomiformis: grows in similar localities as the preceeding species. As to soil reaction I quote Watson (1955): "It will grow successfully on very acid soil, and although I do not know the range of soil which it will tolerate I believe it to be fairly wide, perhaps from extremely acid to near neutral."

Tortella tortuosa: Watson's (l.c.) characterization is appropriate: "most typically a plant of calcareous rock ledges....It is probably always associated with calcareous or near-neutral conditions."

Bryum alpinum: Watson (l.c.) wrote: "It grows best on moist siliceous rocks and stony ground...."

Pohlia cruda: generally in small crevices in steep slopes and cliffs. According

to Martensson (l.c.), "it seems to be rather independent of the substratum but is especially abundant in the calcareous areas." (refers to condition in Swedish Lappland).

P. nutans: Watson (l.c.) characterizes it as a calcifuge. It grows in very different habitats, mainly on decaying wood, sandy soil and peat.

Encalypta contorta: like *Tortella tortuosa*, a limestone plant, often growing on shaded limestone rocks.

Table 1. Content of copper and pH value of some mosses from the vicinity of Stockholm, Sweden.

Name	Locality	Colour of soil	Cu (ppm)	pH
<i>Bartramia</i> <i>ithy-</i> <i>phylla</i> Brid.	Sweden. Uppland, Bo parish, L: a Björknäs, c. fr., 21. VII. 1924. C.A. Tärnlund	brown	80	4.84
<i>B. pomiformis</i> Hedw.	Sweden. Södermanland, Bränn- kyrka parish, Fridhem at the lake Mälaren, c. fr., 29 V. 1919, R. Florin	grey	50	4.60
<i>Bryum alpinum</i> Brid.	Sweden. Uppland, Möja parish, St. Möja, Ramsmora, 30. V. 1925, T.S. Halle	dark brown	10	5.34
<i>Encalypta strepto-</i> <i>carpa</i> Hedw.	Sweden. Södermanland, Vårdinge parish, Sjunda, 4. IX. 1927, R. Florin	dark brown	30	6.04
D:o	Sweden. Södermanland, Utö par- ish, between the shore towards Persholmen-L. Ängsholmen in NW and the shore towards Löjskär in SE, 6. VIII. 1940, R. Florin	dark brown	20	6.17
<i>Pohlia cruda</i> (Hedw.) Lindb.	Sweden. Södermanland, Dalarö parish, c. fr., VII. 1929, A. Hülphers	yellow-brown	10	4.57
D:o	Sweden. Södermanland, V. Ha- ninge parish, Vitså, 9. X. 1927, R. Florin	yellow-brown	10	4.96
<i>P. nutans</i> (Hedw.) Lindb.	Sweden. Uppland, Ingarö parish, Kolström, 22. VII. 1923, R. Florin	yellow-green	10	3.54
<i>Tortella tortuosa</i> (Hedw.) Limpr.	Sweden. Södermanland, Nämdö parish, Nämdö Böte, c. fr., 1. IX. 1943, H. Persson	—	60	6.09
Average value			31	5.13

The Cu values must be considered as low. In several cases they are just at the lowest level. On an average they are considerably lower than the values we shall find later on with the "copper mosses" and the highest value started is 80 p.p.m. The pH values for the as could be expected limestone species are rather

high; in the other cases the values are intermediate, whereas the extremely low values so typical of the "copper mosses" are not realized.

After that I am going to deal with the classical "copper mosses" starting with *Mielichhoferia elongata*. The genus *Mielichhoferia* includes more than 80 species and is divided into 4 subgenera. *M. elongata* and its very near relative *M. mielichhoferiana* (*M. elongata* is often, a.o. by Brotherus and Mönkemeyer treated as a variety of *M. mielichhoferiana*) belong to the subgenus *Eu-Mielichhoferia* which is quite dominant. Together with some few species from Japan, N. America, Java and Hawaii they are dioicous, the bulk of the species being synoicous or paroicous. The distribution of *M. elongata* is: Alps, Pyrenees, France: Auvergne, Scotland, Scandinavia, everywhere rare. *M. mielichhoferiana* has about the same distribution (they often grow together) but is also found in Caucasia and in three localities in U.S.A. This species too is rare. Of *M. mielichhoferiana* I have only one analysis which is reported below table 5.

The Cu as well as the pH values prove to be quite different than those that

Table 2. *Mielichhoferia elongata*. Content of copper and pH value in the substratum.

Locality	Colour of soil	Cu (ppm)	pH
Sweden. Lule Lappmark, Kvikkjokk, Storholmen, 12. VII. 1867, H.J. Holmgren	reddish brown	40	2.84
Sweden. Torne Lappmark, Pâtjovare, reg. alpina, 9. VIII. 1917, E. Jäderholm	dark brown	170	2.67
Sweden. Torne Lappmark, Rakkojokk ad rupes, regio alpina, 27. VII. 1911, E. Jäderholm	yellow-brown	150	4.14
Sweden. Torne Lappmark, in rupibus ferriferis prope Vassijaure alt. ca. 4500 ft., 24. VIII. 1907, H.N. Dixon & W.E. Nicholson (same locality as <i>Dryptodon atratus</i>)	grey	210	4.12
Norway. Opland, Bisi, Eriksund, 150 m., 28 VII. 1951, I. Hagen	grey-brown	40	3.27
Norway. Opland, Lomsfjellen, Rødsheim, 30. VI. 1858, J.E. Zetterstedt	grey-brown	30	3.65
Switzerland. Wallis, Penninische Alpen, auf beschatteten und feuchten eisen- oder kupferhaltigen Felsen bei Zinal, 1600-1900 m.s.m., in grosser Menge mit <i>Andreaea petrophila</i> , <i>Hymenostylium</i> etc., 16. VII. 1924, J. Amann (Bauer, Musci europ. et amer. exsiccati n. 1774)	brown	270	3.88
Austria. Salzburg, Hohe Tauern, Talkschieferfelsen der Grube Schwarzwand in d. Gross-Aalthal ca 1600 m., 29. VII. 1894, Kern	dark brown	450	2.38
Austria. Tirol, Stilfserjoch, Südabhang der Dreispaochenspitze an Schieferfelsen 2000 m., 9. VII. 1909, C. Trautmann	grey-brown	50	4.23
Average value		156	3.46

are reported in table 1. The Cu values vary between 30 and 450 p.p.m. (in 5 times of 9 they are 150 or more) and on an average the value is 156 i.e. 5 times greater than for the "ordinary mosses." It is of great interest to note that in the two cases, where the labels do not say anything about ore deposits etc. such high Cu values as 150 resp. 170 were stated.

Of the other "European" *Mielichhoferia* species *M. mielichhoferiana* which very often accompanies *M. elongata* and the other "copper mosses" only one specimen was analysed, namely "Norway. Filefjeld, Maristuen, 19, VII. 1892, C. Johanson". The Cu value proved to be 60 and the pH 3.20.

The pH values are extremely low, they vary between 2.38 (!) and 4.23 (three times they are lower than 3), on an average they are 3.46 which is practically the same value (3.5) which was found and stated by Noguchi as regards the "copper moss" *Merceya ligulata*. The pH value of the "ordinary" mosses in table 1 was on an average 5.13.

The next "copper moss" to be treated is *Dryptodon atratus*. The nomenclature of this species is yet a problem. When Bridel introduced the genus *Dryptodon* he did not refer this species to it, but placed it in the genus *Grimmia*. Jensen (1939) used *Dryptodon* as a monotypic genus embracing only *D. atratus*. Hagen (1909) referred the species to a separate monotypic subgenus *Streptocolea* under *Grimmia*. If a monotypic genus is necessary for the species, which often is believed and is also the opinion of the author, the name *Streptocolea* has priority. Yet it sounds too hepaticological and I should prefer to follow Jensen. Indeed, a certain convention seems to exist already for a monotypical *Dryptodon* including *D. atratus* [I refer to the excellent exposition by Mårtensson (1956) which I have followed].

The distribution, rather similar to that of *Mielichhoferia elongata* follows: Alps, Pyrenees, Scotland, Wales, Scandinavia, Japan, everywhere rare. Like the two *Mielichhoferia* species it is a rock moss.

The Cu values are rather low, on an average 61.7 whereas *Mielichhoferia elongata* which often accompanies *Dryptodon* attained an average value of 156. Yet, in comparison with the "ordinary mosses" the value is about twice as great. It is noteworthy that in the Laktavagge locality in the Swedish Lappland not only *Dryptodon* but also *Mielichhoferia elongata* grow in masses. Mårtensson & Berggren (l.c.) analysed the substratum immediately below the *Mielichhoferia elongata* from that locality. The Cu values varied from 510 to 770 p.p.m. It is of interest to compare these values with the value (90) in the table above from the same locality. A striking example how greatly the Cu values may vary in the same locality. I have visited this locality myself and seen the two species growing there. They are distributed over a rather wide area.

The pH values are like those for *Mielichhoferia elongata* very low, from 2.82 to 4.33, on an average 3.79, a little higher than in the *Mielichhoferia*.

Now I am going to consider *Merceya ligulata*. To begin with I wish to discuss the genus *Merceya*. Since Noguchi has reduced *Merceyopsis* to a synonym of *Merceya*, the subfamily Merceyoideae of the Pottiaceae consists of one single genus, *Merceya*. A lot of species have been described but Noguchi reduces them to four: *Merceya ligulata* (Europe; Azores; Caucasus; Asia Minor; Himalaya; China; Yunnan; Java; Japan; Formosa; U.S.A.: Arizona, Tennessee; Guatemala;

Table 3. *Dryptodon atratus*, content of copper and pH value in the substratum.

Locality	Colour of soil	Cu (ppm)	pH
Sweden. Torne Lappmark, Låktavagge ca. 1000m., c. fr., 16. VIII. 1944, O. Gjaerevoll & H. Persson	grey-brown	90	3.68
Sweden. Torne Lappmark, Låktatjåkko, VII. 1944, A. Hülphers (same locality as the preceeding or very near it. Same locality as <i>Mielichhoferia elongata</i> (see under this)	yellow-brown	40	4.33
Norway. Sör-Trøndelag, Røldal, Kjønerget in Valdalen, 1300 m., c. fr., 15. VIII. 1873, N. Wulfsberg	grey-brown	60	3.88
Norway. Nord-Trøndelag, Borgund, Lårdal, Maristuen on vein of copper, c. fr., 30. VII. 1900, H.N. Dixon & W.E. Nicholson. Same locality as <i>Mielichhoferia</i> <i>elongata</i> (see under this)	brown	30	3.70
France. The Pyrenees, Bagnères de Bigorre, nasse schwer zu erreichende Felsen am lac Bleu, c. fr., 15. VII. 1847, W.P. Schimper	black-brown	70	2.82
Austria. Steiermark, Hochgolling bei Schladming, 3. IX. 1891, J. Glowacki	yellow-brown	80	4.33
Average value		61.7	3.79

Ecuador), *M. gedean* (Himalaya; Philippines; Japan; Formosa; Korea; Bolivia), *M. difficilis* Herz. & Thér. (Peru), and *M. latifolia* Kindb. (Western U.S.A.; Canada: British Columbia). In table 2 I deal with *Merceya ligulata*; an analysis of soil from a locality of *M. latifolia* is reported further on, as well as a doubtful collection from Mexico.

Merceya ligulata, contrary to *Dryptodon atratus* and the two *Mielichhoferia* species, sometimes grows on rocks, sometimes at sulphureous springs.

The Cu values vary between 10 and 420, and average 94.5. The classical Schwarzwand copper mine locality in Austria was represented by three different specimens, the pH values of which were 70, 250 and 420. This is one more good example of how the pH value may fluctuate in the same locality. In this connection it is worth while to give an account of the copper analysis made by Url (l.c.) in the Schwarzwand locality: "Das verwiterte Schiefergestein, auf dem *Mielichhoferia nitida* mit *Marsupella emarginata* wuchs hat einen sehr geringen Kupfergehalt. Er beträgt weniger als 0.01%. Wesentlich grösseren Kupfergehalt zeigte dagegen der eisenreiche Schlamm des Bächleins, welches dem alten Kupferstollen entsprang und auf welchem, vom Wasser überrieselt, die *Pohlia*-art (*Pohlia* species in edit. The author's remark) wuchs. Er enthält 0.93% Kupfer. Die schlammig-erdige Unterlage vom Rande des Bächleins, auf *Mielichhoferia elongata* wuchs, enthält 0.43% Kupfer. Der Kupfergehalt des zersetzten Gesteins, auf dem *Alicularia scalaris* wächst, beträgt 0.30%. Sehr wenig Kupfer enthält hingegen die Unterlage von *Gymnocolea acutiloba*. Es fanden sich nur Spuren von Kupfer, weniger also 0.01%. Gerade *Gymnocolea acutiloba* ist aber als eine Pflanze

Table 4. *Merceya ligulata*, content of copper and pH value in the substratum.

Locality	Colour of soil	Cu (ppm)	pH
West-Java. Bei Garoet am Vulkan Papandajan an heissen Quellen auf vulkanischer Asche, 1700 m., 28. VII. 1898, M. Fleischer n. 123 (as <i>Scopelophila sulfatarae</i> Fl. v. <i>termalis</i> Fl.)	whitish grey	30	4.12
West-Java. Am Vulkan Papandajan bei Garoet an schwefelhaltigen Quellen, 1400 m., 28. VII. 1898, M. Fleischer n. 158 (as <i>Scopelophila sulfatarae</i> Fl.)	grey-brown	20	3.37
India. East Punjab, below Simla, toward the South East, 4500-5000 ft., c. fr., XII. 1903, H.S. Hein n. 215 (as <i>M. Duthiei</i>)	brown-grey	50	3.44
Turkey. Distr. Trapezunt, in ditione vici Eseli prope oppidum Goerele (Eluhu), in fauce silvatico rami occidentalis vallis Tschemlikdschi Deressi, ad rupes madidas, substrato tophaceo-vulcanio cupro infiltrato, ca. 900 m.s.m. VII. H. Handel-Mazzetti n. 1683 (as <i>Scopelophila acutiusecula</i>)	—	10	—
U.S.S.R. Caucasia, Imeratia, Opotsheti, 31. V. 1877, V.F. Brotherus	grey-brown	70	4.53
France. Départm. de L'Arlège, Zentralpyrenäen, auf Schiefer bei den Eisenquellen von Couflens, 690 m.s.m., 23. VII. 1923, P. Culman (E. Bauer, Musci europaei exs. n. 1604)	yellow-red	90	2.96
France. Dép. de la Haute Savoie, Gorge de L'Arve bei den Kupfer und Silberminen von Sainte Marie au Fouilly auf Felsen (schistes de Nouilles) mit beiden <i>Mielichhoferia</i> , <i>Grimmia atrata</i> , <i>Coscinodon pulvinatus</i> , <i>Grimmia calvescens</i> , <i>Rhacomitrium aciculare</i> , <i>Gymnocolea inflata</i> u.a., 18. VII. 1928, P. Culman (Bauer, Musci europ. et amer. exs. n. 2051)	yellow	10	2.96
Switzerland. Ticino, prope Isona, ad rupes siliciosas irrorata, 740 m., IX. 1934, M. Jäggli (Verdoorn, Musci selecti et critici n. 143)	grey-brown	20	3.90
Austria. Salzburg, Kupfergrube "Schwarzwand" bei Hüttschlag im Gr. Arltale in den Spalten und Höhlungen verwitterter Schieferfelsen, etwa 1600 m.s.m., 31. VII. 1910, J. Baumgartner et V. Schiffner (Bauer, Musci europ. exs. n. 845)	brown	250	2.50
Austria. Salzburg, Schwarzwand im Grossalthal, 1600 m., 27. VIII. 1880, J. Breidler	white-grey	70	3.54
Austria. Salzburg, Kupfergrube, Schwarzwand im Gross-Arltale, an feuchtem, verwitternden Schiefergestein, ca. 1600 m., 9. IX. 1904, J. Baumgartner	brown	420	3.05
Average value		94.5	3.44

bekannt, die ausschliesslich oder fast ausnahmslos auf kupferhaltigen Untergrund wächst." These variable values speak for themselves and stress the necessity of total chemical analyses.

It is not surprising that the Cu values of the sulphureous spring localities are low, for (cf. Noguchi) such springs often seem to be rich in iron. It is astonishing that examples from two localities, where according to the labels copper is represented, show so extremely low a value as 10 p.p.m. Although it is not possible to explain it surely, yet we must remember that copper ores often are intermingled in beds of other ores or of rocks without any metals at all.

One more station for this species is in Mexico: Sonora, on moist rock ledge in canyon 26 miles southwest of Cumpas, 21. IX. 1939, D. Richards, F. Drouet & W. A. Lockhart n. 729. The Cu value proved to be 110 and the pH 4.04. After having made an analysis this specimen was studied by Noguchi together with the whole *Merceoideae* collection of our museum. The specimen from Mexico, he has stated, does not belong to *Merceya ligulata*.

The analysis of a specimen of the N. American *Merceya latifolia* Kindb. from U.S.A., Montana, Great Falls, 6. X. 1899, R. S. Williams is of great interest. Here a high Cu value namely 320 p.p.m. is correlated with a very high pH value 7.63. This is the highest value obtained among all the analyses presented here and represents on the whole a very high value. Mr. Silfversparre has kindly analysed this sample for carbonates. The soil was treated with 2-n HCl and the solution was analysed. The silicates were not analysed. Analytical result (in % of dry soil):

$\text{CaCO}_3 = 27.34\%$ (that means 10.95% Ca)

$\text{MgCO}_3 = 0.56\%$ („ „ 0.14% Mg)

$\text{Fe}_2\text{O}_3 + \text{Al}_2\text{O}_3 \} = 2.51\%$
in solution

Insoluble } = 52.93%
silicates }

This is the only case when I have found a high Cu value combined with a high pH value. I will treat this case in a discussion later on. As regards this Montana locality I quote from my paper of 1948: "As to the Great falls region the well known springs there are numerous and of different kinds (Fisher, 1909)."

At the end I give a table of the analyses of 14 *Mielichhoferia* species from Africa, Australia but mainly of South America. As copper often is found in the Andes, I thought the study of species from this mountain range would be of some special interest.

The Cu as well as the pH values are rather surprising. The highest Cu value is only 70 but most of the values are only 10-20. The average value is only 28.7, even lower than that of the "ordinary mosses" (33.8). The pH varies from 4.29-5.05, an average of 4.64; not in a single case is there a value as low as that typical of the "copper mosses". The average pH value is lower than for the "ordinary mosses" (5.13) but much greater than those of the "copper mosses" (3.46, 3.79, 3.44). I will return again, in the discussion, to these examples.

In summary, and before starting the discussion, the principal results of the foregoing analyses are presented in the following table (table 6).

Table 5. *Mielichhoferia* species, content of copper and pH value in the substratum.

Name	Locality	Colour of soil	Cu (ppm)	pH
<i>M. angustata</i> Broth.	Bolivia. Auf Hochgebirgstriften im oberen Slaveta, ca. 4200 m., V. 1911, Th. Herzog n. 4767	—	30	—
<i>M. basilaris</i> Br. & Schp.	Cameroon, ad rupes 8000 ft., VI. 1891, J.K. Jungner n. 169	grey-brown	20	4.60
<i>M. hymenodonta</i> Dix.	Celebes. Rante Lemo, 1500 m., VI., 1929, S. Kjellberg n. 103M. (Typus)	grey-brown	20	4.53
<i>M. lindigii</i> Hpe.	Colombia. Lipaquira in areal, 2600 m., VII, 1863, Herb. Lindig.	black-brown	20	4.60
<i>M. microstoma</i> Hpe.	Colombia. Bogota Guadalupe, VIII. 1863, Herb. Lindig.	dark grey	20	4.67
<i>M. multiflora</i> Bartr.	Chile. Prov. de Nubla, Cordillera de Chillan, 2200 m., 15. IV. 1929, H. Roivainen	dark grey	50	4.79
<i>M. pulvinata</i> C.M.	Hawaii, Maui, Puu Nianiau, Haleakala, with <i>Anoetangium haleakalae</i> (C.M.) Par., VII. 1919, C.M. Forbes n. 1571 M.	dark brown	10	4.91
<i>M. secundifolia</i> Herz.	Bolivia. Im Hochtal von Viloco, ca. 4500 m., XI. 1911, Th. Herzog n. 3167	grey-brown	70	4.29
<i>M. sericea</i> C.M.	Bolivia. Am Chacaltaya bei La Paz, 4800 m., III. 1908, O. Buchtien	grey-brown	10	4.74
<i>M. skottsbergii</i> Card.	Argentina. Fuegia, Slogget Bay, 16. VII. 1909, C. Skottsberg n. 492 (Typus)	yellow-brown	50	4.29
<i>M. subcampylocarpa</i> Broth.	Bolivia. Begraste Felsen im Pinagebiet, VIII. 1911, Th. Herzog n. 2600 (Typus)	reddish brown	60	5.05
<i>M. subglobosa</i> R.S.W.	Bolivia. Hochtal Viloco, 4700 m., XI. 1911, Th. Herzog n. 3169	yellow-brown	20	4.62
<i>M. submacrodonia</i> Broth.	Bolivia. An der Waldgrenze über Tablas, ca. 3400 m., V. 1911, Th. Herzog n. 2877 (Typus)	dark brown	10	4.48
<i>M. subpohlioidea</i> Broth.	Argentina. Prov. Jujuy, Moreno (in "puna") in fissuris rupium loco subumbroso, 3500 m.s.m., 24. X. 1901, R.E. Fries n. 56	grey-brown	10	4.76
Average value			28.7	4.64

Table 6. A summary of the analyses reported in the foregoing pages.

	Name and locality	Number of proofs	Average value of:	
			Cu (p.p.m.)	pH
Classical "copper mosses"	"Ordinary mosses" from the Stockholm region (table 1)	9	33.8 10-80	5.13 3.54-6.17
	<i>Mielichhoferia elongata</i> (table 2)	9	156 30-450	3.46 2.38-4.23
	do. from 2 localities in Swedish Lapland (after Berggren & Mårtensson)	3*	554 335-640	—
	<i>Dryptodon atratus</i> (table 3)	6	61.7 30-90	3.79 2.82-4.33
	do. from a locality in Swedish Lapland (after Berggren & Mårtensson)	2*	625 575-675	—
	<i>Merceya ligulata</i> (table 4)	11	94.5 10-420	3.44 2.50-4.53
	do. from Japanese localities (after Noguchi)	25**	—	3.50 2.4-4.3
	<i>Merceya geddeana</i> from Japanese localities (after Noguchi)	7**	—	4.28 3.4-5.8
	14 <i>Mielichhoferia</i> species from Africa, Asia, S. America (mostly) and Hawaii (table 5)	14	28.7 10-70	4.64 4.29-5.05

* The tests were taken of the substratum "immediately below the moss and free from remnants of the moss."

** "The pH values of the soil in the habitats of *M. ligulata* were also examined."

Discussion

As earlier copper and pH analyses were made only on soil from single stations for species (yet Noguchi reports pH value from a great number of Japanese localities for *Merceya*) it may be of interest to say something about the results.

To begin with the three "copper mosses" studied very often present Cu values higher than ordinary and in many cases the values are very high. *Mielichhoferia elongata* leads with an average copper value of 156, *Merceya ligulata* follows with 94.5 and *Dryptodon* presents the value of 61.3. Yet it is observed that the material is rather limited in order to say anything definite about their relative placing. Besides *Merceya* like the two other mosses is not only a rock moss but also often grows at sulphureous springs.

It is interesting that sometimes the analyses of samples of copper mosses from localities, at which there has been no mention of any occurrence of copper or other heavy metals, show a percentage of copper considerably higher than that found in ordinary localities. This suggests possibilities for cooperation between bryologists and ore-prospectors of various kinds. All known stations for "copper mosses", where analysis shows an increased copper value ought to be investigated geologically and probably it would be worth while to study even those localities at which there

was no high Cu value. Neither should it be forgotten that Noguchi stated that in many cases *Merceya ligulata* is growing on soil rich in iron or as in one case antimony.

For the first time other *Mielichhoferia* species than the two classical "copper mosses" *M. elongata* and *M. mielichhoferiana* have been analysed. 14 species from different parts of the world outside of Europe were chosen. Though most of them have grown in the S. American Andes so rich in i.a. copper ores the rather surprising result was that practically all the specimens apparently had grown on soil with a low, and often very low, copper content. None of the analyses gave a value higher than 70 p.p.m.; in four cases the value was only 10. The average value was 28.7, lower than the value presented by the "ordinary mosses" from the Stockholm region (33.8)! The average pH value was 4.64, considerably higher than that of the "copper mosses" but lower than that of the "ordinary mosses" (5.13). Certainly it is not possible to exclude the possibility that at least some of these species are real "copper mosses", total analyses are necessary in this case as in others.

The "copper mosses" present very low, quite often extremely low pH values. In no less than 7, they are lower than 3. The lowest value obtained is 2.38. My results agree well with those obtained by Mårtensson and Berggren, and by Noguchi and others which we know well from the study of similar phanerogams. It is rather striking that with *Merceya ligulata*, from different parts of the world besides Japan, I obtained an average value of 3.44, whereas Noguchi on Japanese material got the value 3.50.

There is no doubt that the "copper mosses" need a low pH, and therefore it is a question whether the *Mielichhoferia* species presented in table 5 merit the name of "copper mosses". Certainly, besides pH, only the content of copper has been studied but the conspicuously low Cu values for the 14 species combined with the ordinary pH values can not be neglected. Yet, I stress what is said about *Merceya geddeana*, which presents a distinctly higher pH value than *M. ligulata* but grows in similar localities.

As regards the collection of *Merceya latifolia* which presented the unique combination of very high Cu content and very high pH value, the species must be studied more closely and from other localities. It is quite possible that it shows another pattern than that of the "copper mosses". Recall that Noguchi found that specimens of *Merceya geddeana*, though found in similar districts—rich in copper or iron—as *M. ligulata*, presented a much higher pH value than the latter, a value of the same order as for the "ordinary mosses". No doubt, there are many different combinations possible of these factors.

How to explain the occurrence of the "copper mosses"? As the low, often extremely low, pH value seems to be constant (It is of interest that the "copper mosses" are not found on serpentines though the soil there is very poor and poisonous for most plants. In spite of that the pH values of the serpentines is generally high, between 6–7), one could suppose that this low value was the dominant factor, but if that is so, they ought to be found in many localities without any ore deposits where pH is sufficiently low. The fact that they are so rare everywhere and that they so very often are growing on ore deposits is contradictory to this explanation.

Noguchi's observation that the Japanese species of *Merceya* grow well in cultures with a pH value of 7, without any copper at all, as well as his statement that he could not find any fructifying specimens from the copper districts in Japan (see the introduction)—according to Noguchi the specimens of *Merceya ligulata* from Europe, Java, N. and S. America are sterile—seems to be evidence for his explanation.

This is also the view of Kruckeberg i.a. as regards the serpentine plants, that the "copper mosses" are restricted to their rare localities because only there can they compete with other mosses. A combination of low pH and some chemical factor is typical of these localities. This factor, which must be poisonous for most mosses and in some degree also for "copper mosses" (see Noguchi's statements above), should be studied more thoroughly. It is probable that it is the metallic factor which plays the dominant role. Careful analyses are necessary and much stress is to be laid upon the trace metals.

No doubt it will be worthwhile to analyse all "copper moss" specimens in the herbaria. There should be, not only results of interest for ecology but also for locating new ore deposits. As far as I know there have been no previous attempts—at least not as regards the cryptogamic plants—to use herbarium specimens in this manner. Such studies may be extended also to other species, which have a distribution defying the usual explanations of the distribution of plants.

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MUSCI JAPONICI, V.

The genus *Distichophyllum*

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野口 彰: 日本の藓類, V. ツガゴケ属

Morphological notes

Plants of the genus *Distichophyllum* are tender and soft, especially in water, and usually form depressed mats of considerable extent. Stems are blackish, procumbent or ascending from a rhizoid-bearing base, simple or sparingly branched. They are rounded or elliptical in cross section and consist of uniformly hexagonal cells with delicate, brown walls. In many species the cells are large and lax in the center of the stem, but toward the periphery they become smaller gradually. The epidermal layer is formed by much smaller cells, but is scarcely differentiated from the inner tissue. Occasionally, for example, in *D. carinatum* the stem consists of delicate isodiametrical cells throughout the entire area of the section. In the species of this genus the central strand is entirely lacking.

In certain species, such as *D. cuspidatum* and *carinatum* the foliation is not complanate, and the leaves are uniform both in shape and size. Such leaves are usually carinate, especially those of *D. carinatum*. While, in majority of species, the leaves are complanate or concave, and differentiated into dorsal or ventral ones appressed to the stem and lateral ones which are widely spread from stem. This feature accounts for the generic name. The lateral leaves usually differ from dorsal or ventral ones both in shape and size, being asymmetrical, narrower and longer than those of the latter. The distinction between the leaves is much better marked in *D. osterwaldii* than in other species of the genus. The costa is single, reaching over half way up and is flexuose above. In many species it is slender, being formed merely by several uniform cells in the lower part, and vanishing in a chain of single linear cells at the apex. Leaf cells are large with delicate walls, and usually hexagonal varying to quadrate hexagonal or rectangular. In many species, they become smaller toward the margin and apex, and larger toward the base. Among our species, *D. collenchymatosum*, *obtusifolium*, *carinatum* and *cuspidatum* have large cells in the upper half of the leaf. Therefore the cells in the apex and midmargin are hardly distinguishable, both in shape and size, from those in the median part of leaf. Usually the marginal borders are well developed all around the leaf, but they vary in width in different species. In *D. osterwaldii*, however, the border is well developed on the lower half of leaf, becomes narrower upwards and vanishes far beneath the leaf apex. Archegonia are borne on the stem, accompanying a few antheridia and few or no paraphyses. A few bracts surround the sex organs. The seta is moderately long, smooth or covered with dense papillae on the surface. The theca is inclined to horizontal, usually oblong with a distinct

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neck, and mamilllose on the surface. The exothecial cells are hexagonal with delicate walls, which are characterized by trigones. The outer peristome teeth are linear-lanceolate, and their upper part is pale, with dense papillae, the lower part is yellow and densely striated. The peristome teeth show a zigzag line on the outer surface, but are furrowed along the median line on the inner surface. This

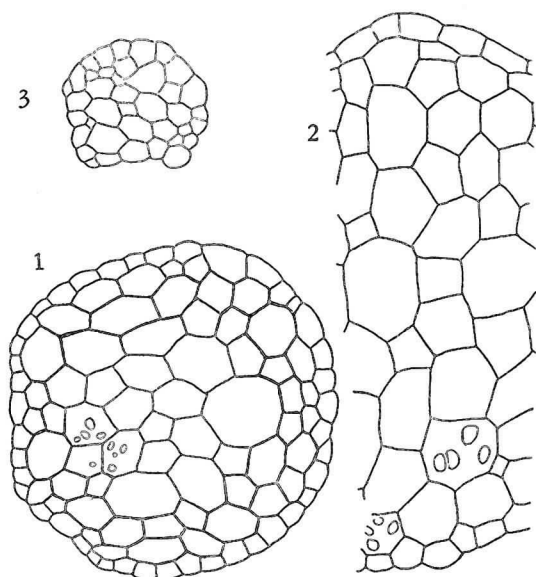


Fig. 1. Cross-sections of stems, $\times 166$.

1. *D. maibarae*. 2. *D. collenchymatosum*.
3. *D. carinatum*.

furrow is derived from the independent thickenings of peristomial halves. However, the manner of development of teeth is of the diplolepideous type. The deposits of thickenings of the outer teeth occur on both cells between the outer and inner peristomial layers, as is the case with the ordinary diplolepideous mosses. But the two bands of deposits increase the thickenings independently and they do not coalesce with each other, thus a span remains even in a fully developed tooth. The inner peristome is pale; its segments are long as the outer teeth; cilia are absent or very short. The calyptra is long conical or horn shaped, copiously fringed at base, and its surface is naked or scabrous, and occasionally bears several erect cilia. Antheridia are gemmiform,

in autoicous inflorescences which are located beneath the archegonia. The bracts are few in number, accompanying several antheridia and paraphyses, but not occasionally the latter are absent.

Notes on distribution

The genus *Distichophyllum* is widely distributed in tropical and subtropical regions. Some eight species of the genus are recognized in Japan and adjacent regions. The majority of the species grow on damp rocks or soil, not rarely on dripping-rocks, but a few are sometimes found on damp logs or tree trunks. The plants usually form depressed mats of considerable extent. The species, *D. mittenii*, *jungermannioides*, *cuspidatum*, *osterwaldii*, widely distributed in tropical regions, are found in Formosa and in the southern part of the Loo Choo archipelago, but seem to be confined to limited areas. *D. maibarae* is widely dispersed in the warmer part of Japan, but seems not to be beyond the geographically northernmost line for tropical mosses, which the author proposed in 1951. This species is also found not rarely in the Loo Choo archipelago. As this species is closely allied to *D. montagneanum* found in Java and Nilghir, further collections may narrow the gap between the two species. *D. obtusifolium* which has hitherto been considered an endemic species in Amami-oshima Island in the Loo Choo archipelago, extends northward

to Yakushima Island on the south of Kyushu, and southward to Okinawa Island, but seems to be restricted to the Loo Choo archipelago, between Kyushu and Formosa. A handsome species, *D. collenchymatosum* has a wide range in the southwestern part of Japan, but was also found in an isolated station in Niigata Pref., facing the Japan Sea in central Japan, and this may be a northernmost station for the species. This species extends southward as far as China and Hong Kong through Okinawa island. It is a notable fact that *D. carinatum* was unexpectedly found in central Japan. This species has been found on dripping-limestone in a ravine near Salzburg, Austria. In Japan it grows in a similar habitat. The station in Japan at which this species was collected is of a stratum of Palaeozoic age. As already mentioned by N. Takaki, such rare mosses in Japan as *Myurella gracilis*, *Seligeria pusilla*, *Mnium hymenophylloides*, *Timmia megapolitana*, have already been found there. *D. carinatum* has peculiar morphological features, and no related form found in the neighbouring regions, thus this species, like the above mentioned ones, may be a relic.

Classification

Key to the species of *Distichophyllum*.

- 1 { Leaves oblong or oblong-linear, with a distinct point at apex 2
- 1 { Leaves spatulate or oblong-spatulate, the apex rounded obtuse or with minute point .. 5
- 2 { Leaves oblong-linear, with a subulate acumen at apex..... *cuspidatum*
- 2 { Leaves oblong, the apex shortly acuminate or with a short point..... 3
- 3 { Leaves conduplicate and bending inward, leaf margins broadly revolute..... *carinatum*
- 3 { Leaves slightly carinate, leaf margins plane 4
- 4 { Marginal border of leaves stout and coloured in yellow. Leaf cells more than 30μ in the middle of leaf. Calyptra smooth on the surface..... *collenchymatosum*
- 4 { Marginal border narrow and almost pale. Leaf cells less than 30μ . Calyptra bearing erect hairs *maibarae*
- 5 { Upper leaf margins not bordered *osterwaldii*
- 5 { Leaf margins bordered throughout..... 6
- 6 { Leaves bearing a distinct acumen. Costa reaching half way *jungermannioides*
- 6 { Leaf apices rounded obtuse or bearing a minute point. Costa reaching near leaf apex.. 7
- 7 { Cells large in the middle of leaf, much smaller towards leaf apex and margins .. *mittenii*
- 7 { Leaf cells large, hardly smaller towards leaf apex and margins *obtusifolium*

Distichophyllum maibarae Besch. in Journ. Bot. 13: 41 (1899); Horik. in Bot. Mag. Tokyo 48: 715 (1934). (Fig. 2)

Syn. *D. gonoi* Card. in Bull. Soc. Bot. Genève, 2 ser. 3: 278 (1911)—syn. nov.

Musci Japonici Exsic. ser. 8, no. 360 (1954) & ser. 10, no. 464 (1956).

When Bescherelle published this species, he gave a brief description only. Therefore, a more detailed account of it is added.

Plants small, pale green in dense mats; stems procumbent, about 10 mm. long, occasionally more, about 0.25 mm. broad, blackish, simple or sparingly branched, densely and complanately leaved, about 3 mm. broad with leaves. Leaves contracted and undulate when dry; dorsal and ventral leaves oblong, apex rounded but with short apicules, or acuminate, symmetrical; lateral ones oblong but slightly spatulate and longer than dorsal ones, asymmetrical, $1.5 \times 0.7 \sim 2 \times 0.8$ mm.; margin entire, frequently with obscure and minute teeth on the upper part. Costa slender,

slightly flexuose above, ending far beneath the leaf apex. Leaf cells quadrate hexagonal, walls delicate but indistinctly collenchymatous, median cells $20 \times 15 \sim 30 \times 20 \mu$, smaller toward leaf apex and margins, at leaf apex $15 \times 12 \sim 20 \times 17 \mu$, hexagonal, rapidly much larger toward leaf base, near the insertion $40 \times 25 \sim 55 \times 27 \mu$, hexagonal with delicate walls. Marginal border narrow, slightly yellowish or pale, consisting of one or two rows of linear flexuose cells on the apical, two on the middle, and two or three on the basal parts, respectively. Sporogonium on stem, perichaetial bracts few in number; inner ones widely ovate with a moderately long acumen, concave, ecostate, about 1 mm. long, the cells lax, with indistinct marginal border. Paraphyses few, occasionally none. Seta curved when dry, brown, smooth on the surface, about 5~8 mm. long, 0.12 mm. broad. Theca inclined, oblong with a distinct neck, brown. $0.5 \times 0.3 \sim 0.65 \times 0.4$ mm., mamillate on the surface, strongly constricted beneath the mouth and above the neck when dry. Operculum long and erectly rostrate from a conical base, smooth on the surface, about 0.6 mm. high. Outer peristome teeth lanceolate, about 0.25 mm. long, and in other respects similar to those in other species of the genus. Spores globose, almost smooth

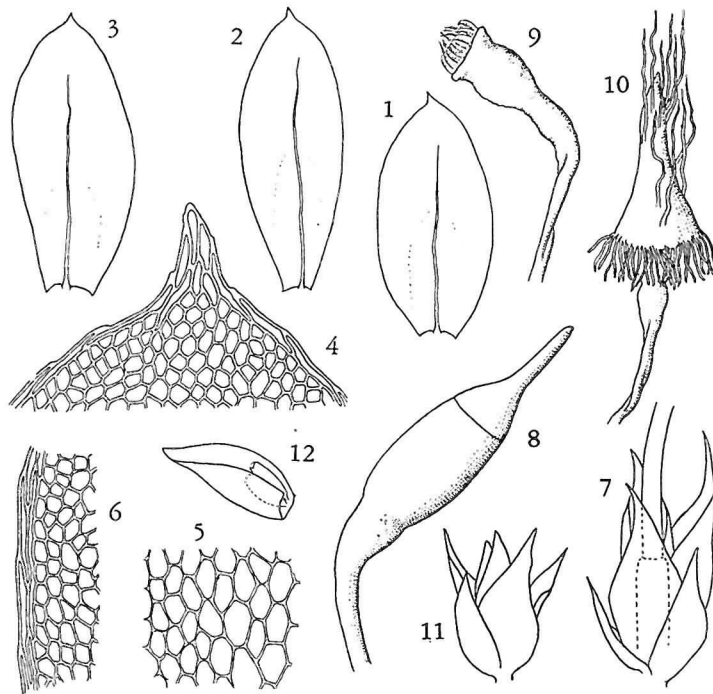


Fig. 2. *D. maibarae* Besch. 1. Dorsal leaf, $\times 19$. 2, 3. Lateral leaves, $\times 19$. 4. Apical part of leaf, $\times 166$. 5. Cells from middle of leaf, $\times 166$. 6. Mid margin of leaf, $\times 166$. 7. Perichaetial bracts, $\times 29$. 8. Capsule, $\times 29$. 9. Deoperculate capsule when dry, $\times 29$. 10. Capsule bearing calyptra when dry, $\times 29$. 11. Male bracts, $\times 29$. 12. Innermost male bract bearing antheridia, $\times 29$.

on the surface, 8.5~11 μ in diam. Calyptra horn-shaped, finely fringed at base, about 1 mm. long, slightly yellowish, but blackish at apex, with several erect hairs. Each hair consists of one row of linear cells on the upper, three rows on the basal part, respectively. Inflorescence autoicous. Antheridia grow beneath the archegonia, with few bracts; inner bracts wide ovate, acute at apex, and cymbiform, ecostate, about 0.6 mm. long. Paraphyses few or none, antheridia few.

Hab. **Loo Choo.** Okinawa: Mt. Genga (S. Sakaguchi), Kitameijiyama (T. Amano), Yonahadake (T. Amano); Amami-oshima (J. B. Ferrie, Y. Koyama). **Kyushu.** Kagoshima Pref.: Yakushima, Kosugidani~Hananoego (T. Shin), Gongendani (T. Shin); Kagoshima-shi (T. Shin); Mt. Takakuma (A. Noguchi, T. Amakawa, T. Sugino); Mt. Kirishima (T. Shin); Koshikizima (T. Shin). Kumamoto Pref.: Ashikita-gun, Kugino (H. Kaneda); Hitoyoshi-shi (K. Maebara). Fukuoka Pref.: Korasan (T. Sugino, H. Shikata, T. Osada); Sora-gun, Yuyama (T. Osada); Minamihata-mura (T. Osada); Tsushima Isl. (T. Amakawa). **Shikoku.** Kochi Pref.: Nana-tsubuchi (M. Gono, no. 467-type of *D. gonoi*); Ochi-machi (M. Kamimura); Aki-gun, Ioki (H. Inoue). **Honshu.** Hiroshima Pref.; Hiroshima-shi (A. Nog.). Shimane Pref.: Gakuenzi (A. Nog.). Kyoto Pref.: Ohara (T. Nakajima). Shiga Pref.: Otsu-shi (K. Yamamoto). Wakayama Pref.: Mt. Koyasan (Y. Numaziri), Nachi (M. Kurita, T. Nakaj.). Mie Pref.: Tadoyama (M. Midutani), Akame (N. Takaki). Aichi Pref.: Miyadiyama (N. Tak.); Nukadagun, Toyotomi-mura (N. Tak.), Miwa-mura (N. Tak.). Tokyo Pref.: Irima-gun, Umezonomura (U. Mizushima). Niigata Pref.: Kitakanbara-gun, Kanehachiyama (Y. Ikegami); Karibagun, Geiha-mura (Y. Ikeg.). Tochigi Pref.: Shiobara (M. Nakadi), Kogashiyama (M. Nakamura).

Bescherelle did not mention the nature of the inflorescence of this species. Brotherus, however, later described it as dioicous in the first edition of Engler and Prantl's *Natürlichen Pflanzenfamilien*. Thence the dioicous inflorescence has been considered as a specific character that separates this species from its alliance.

In numerous fertile specimens collected in Japan, including those from near the type locality of *D. maibarae*, the inflorescence is always autoicous. The author has not seen any dioicous plants referred to *D. maibarae*. The autoicous species, *D. gonoi* is similar to *D. maibarae*, except for the nature of the inflorescence. Unfortunately the author has not examined the original specimen of *D. maibarae*, but Bescherelle's original description of the species, though it is brief, seems to agree well with *D. gonoi*. There is a specimen from the Amami-oshima Island, in the Loo Choo archipelago, determined by Thériot as *D. maibarae* in the author's herbarium. The specimen has an autoicous inflorescence and agrees well with the original specimen of *D. gonoi*. Indeed *D. maibarae* was a puzzling species to the author. In fact he could not distinguish *gonoi* from *maibarae*. At present the author considers that both species are identical.

Bescherelle compared this species with *D. nigricaulis*, and Cardot compared *D. gonoi* with the same species, but the author believes that its closest ally is *D. montagneanum* which Horikawa² reported from Isl. Okinawa and Isl. Iriomote. The former is slightly divided from the latter by the narrow marginal border, but the author is not sure whether this is a stable difference between them or not.

Distichophyllum collenchymatosum Card. in Bull. Soc. Bot. Genève, 2 ser. 3: 278 (1911); Nog. in Journ. Sci. Hiroshima Univ. B. 2. 3: 149 (1938). (Fig. 3)

² Bot. Mag. Tokyo 49: 220 (1935).

Syn. *D. gracilicaule* (non Fleisch.) Sak. in Bot. Mag. Tokyo 47: 337 (1933).

D. sinense Dixon in Hong Kong Natur. suppl. 2: 22 (1933)—syn. nov.

D. tutigae Ihsiba in Trans. Sapporo Nat. Hist. Soc. 13: 395 (1934)—syn. nov.

D. sikokuense Dixon in Rev. Bryol. n. ser. 13: 14 (1942)—syn. nov.

D. acutifolium Dixon, l. c. 15 (1942)—syn. nov.

Musci Japonici Exsic. ser. 5, no. 212 (1951), labelled as *D. gonoi*.

Lateral and dorsal leaves slightly differentiated: the dorsal ones oblong or widely lingulate with a distinct but rather short acumen, usually 2.2×1.2 mm. in size; the lateral ones mostly lingulate, slightly asymmetrical and somewhat longer than the former. Costa yellow and reaches $\frac{3}{4}$ the length of the leaf or more. Leaf margins slightly but broadly recurved almost their entire length. Leaf cells hexagonal with usually collenchymatous walls, $30 \times 28 \sim 40 \times 35 \mu$ in the middle, and toward both leaf apex and margins slightly smaller; in the leaf apex $27 \times 20 \sim 32 \times 22 \mu$. Marginal borders broad and distinct, yellow; on both the median and upper parts of two rows of linear but somewhat broader cells than those of the other species. Sporogonia occur on the stems. Perichaetial bracts few in number; the inner ones narrowly oblong with an acute apex, ecostate, about 0.8×0.27 mm.; the outer ones larger and concave, and with slightly differentiated border of one row; paraphyses not found. Setae brown, smooth and longer than in other species, measuring 15–20 mm. The latter feature and the broader marginal border characterize the species. Thecae inclined or horizontal, oblong with a distinct neck, and mamillate on the surface. Size is variable, but usually 1×0.5 mm. Opercula rostrate from a rounded conical base and about 0.6 mm. in height. Outer peristome teeth usually 0.35 mm. long, and like the inner teeth the same those of the other species. Calyptrae usually about 2 mm. long, with a blackish and somewhat scabrous apex. Antheridia occur beneath the archegonia, and gemmiform with few bracts around them; inner bracts broadly ovate with an acute apex, and cymbiform, measuring about 0.4 mm long. No paraphyses were found.

Hab. **Hong Kong** (Ah. Nin, Nov. 13, 1931—Orig. specimen of *D. sinense*). **Loo Choo**. Okinawa: Gengadake (S. Sakaguchi), Hanechi-mura (T. Amano), Nago-machi (T. Amano). **Kyushu**. Kagoshima Pref. Yakushima (T. Doi, July 27, 1932—det. by Sakurai as *D. gracilicaule*; T. Shin, N. Takaki, T. Amakawa, S. Hattori, Y. Ikegami), Tashiro-mura (T. Shin), Mt. Takakuma (T. Amak.). Miyazaki Pref.: Aoidake (A. Noguchi), Sanno-mura (I. Taki), Nichinan-shi (A. Nog.), Sakatani-mura (A. Nog.), Kitago-mura (A. Nog.). Kumamoto Pref.: Mt. Ichifusa (A. Nog.). Fukuoka Pref.: Mt. Inugatake (Y. Araki), Sora-gun, Nogochi (Y. Kuwahara). **Shikoku**. Ehime Pref.: Asahi-mura (Ch. Watanabe-Sasaoka's no. 5799—type of *D. sikokuense*, Oct. 12, 1930). **Honshu**. Hiroshima Pref.: Miyazima (I. Kashimura, Feb. 7, 1927—Sasaoka's no. 3249—type of *D. acutifolium*, A. Nog.). Mie Pref.: Kamagatake (Y. Tsuchiga, no. 770—type of *D. tutigae*). Wakayama Pref.: Mt. Odaigahara, Osugidani (N. Tak.), Aichi Pref.: Miyadiyama (N. Tak.); Gumma Pref.: Mt. Tanigawadake (H. Inoue). Niigata Pref.: Minamikanbara-gun, Nagasawa-mura (Y. Ikeg.).

A considerable number of specimens of this species have been collected from Japan, but a majority of them are sterile. Specimens from both Mt. Aoidake and Mt. Ichifusa are autoicous and fertile, bearing rather old sporogonia. The type specimen of *D. sikokuense* possesses long setae, measuring 20 mm. or more. This specimen, like the other fertile ones, seems to be dioicous. Thus the inflorescence may be heteroicous.

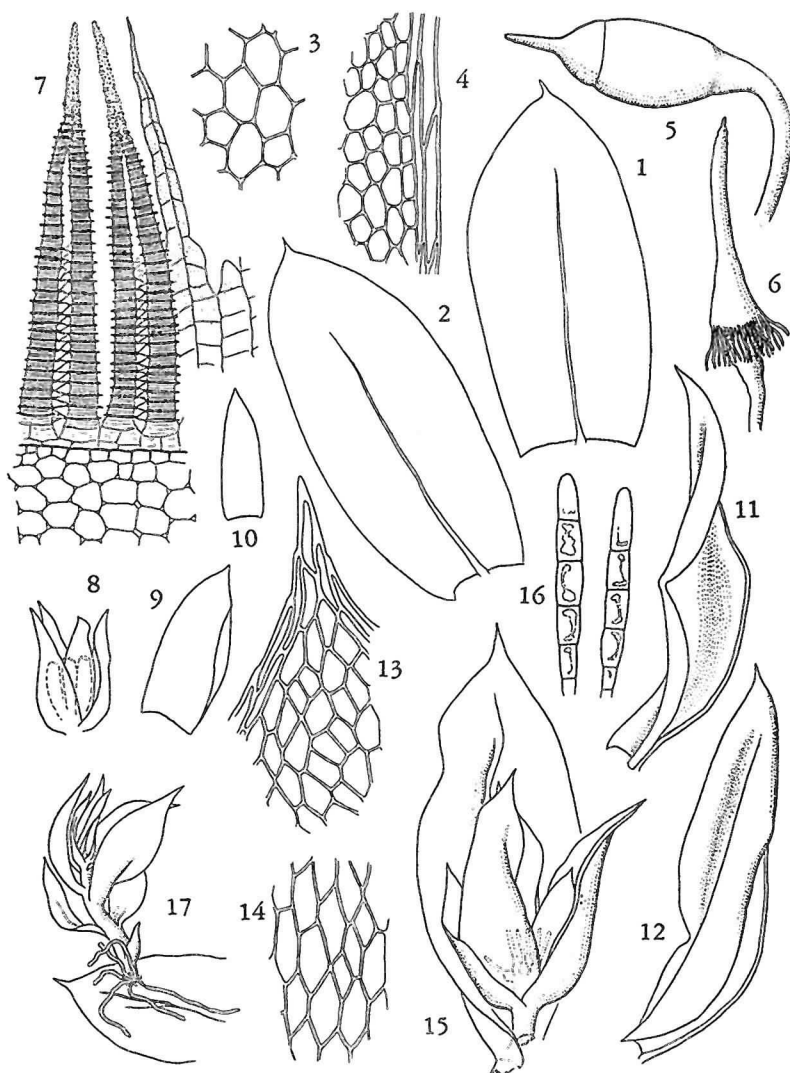


Fig. 3. *D. collenchymatosum* Card. (1~10.) and *D. carinatum* (11~17). 1. Dorsal leaf, $\times 19$. 2. Lateral leaf, $\times 19$. 3. Cells from middle of leaf, $\times 166$. 4. Mid-margin of leaf, $\times 166$. 5. Capsule, $\times 19$. 6. Capsule bearing calyptra, $\times 19$. 7. Peristome, $\times 166$. 8. Male bract, $\times 29$. 9. Outer perichaetial bract, $\times 19$. 10. Inner perichaetial bract, $\times 19$. 11, 12. Leaves. $\times 42$. 13. Apical part of leaf, $\times 236$. 14. Cells from middle of leaf, $\times 236$. 15. Female bract and a stem leaf, $\times 42$. 16. Gemmae, $\times 166$. 17. Juvenile plant occurring on a stem leaf, $\times 58$.

In 1942, Dixon published two new species of *Distichophyllum* from Japan, the one *D. acutifolium* being sterile, and the other *D. sikokuense*, mentioned above. He emphasized the peculiarities of these species, but did not compare them with *D. collenchymatosum*. Having observed the type specimens of these three species, no essential difference was found among them. Another species, *D. sinense*, which he published from China and Hong Kong in 1933, also is not separable from *D. collenchymatosum*. *D. tutigae*, established by Ihsiba in 1934 is also identical with the present species.

As stated previously the present species was found in Niigata Pref., a disjunct station for it. Although the plants from this specimen are smaller than those from southern regions of Japan, there is no other essential difference between them.

Distichophyllum jungermannioides (C. Müll.) Bosch et Lac. Bryol. jav. 2: 22 (1861); Fleisch. Musc. Fl. Buit. 3: 977 (1908); Horik. in Journ. Jap. Bot. 11: 504 (1935); Herz. et Nog. in Journ. Hattori Bot. Lab. 14: 65 (1955).

This species has several characteristic features. The concave leaves broadly spatulate, with rounded but shortly cuspidate apex. Costa short, reaching scarcely half way up; inflorescence dioicous. This species has been known from two stations only in Isl. Botel Tobago in the region of the present subject.

Distichophyllum carinatum Dix. et Nichol. in Rev. Bryol. 36: 24 (1909); Moenk. Laubm. Eur. 672 (1927); Takaki in Journ. Jap. Bot. 26: 239 (1951) (Fig. 3).

This curious species was found at Zinkenbach, near Salzburg in the Alps by H. N. Dixon and W. E. Nicholson. The plants minute and green; stems covered with crowded but not complanate leaves; therefore the difference between lateral and dorsal leaves is not found. The leaves small, measuring 1~1.3 mm. in length, broadly ovate, not being broadly rounded at apex, but shortly acuminate. This species is best characterized by its conduplicate and incurved leaves (therefore the costa is bending inward), and its widely recurved margins on the entire length. These features are well demonstrated in both Dixon's and Takaki's figures. Leaf cells almost uniform both in shape and size in the entire area of leaf, excluding the margins. Cell shape hexagonal with delicate and non collenchymatous walls. The cells $30 \times 15 \sim 40 \times 17 \mu$ in the upper half of leaf, but toward the base slightly larger. The margins entirely bordered with two rows of linear, pale cells. Archegonia on stems, gemiform with few bracts. The bracts broadly ovate and acuminate at apex, reaching 0.75 mm. length and ecostate, with margins rather indistinctly bordered by one of linear cells. Several archegonia found but no paraphyses. Sporogonia unknown. Gemmae spindle shaped, about 0.1 mm. long. Occasionally, juvenile plants bearing several leaves, and attaching an old leaf on stem by means of rhizoids are found. These presumably might be developed from gemmae. As stated above, gametophytes are peculiar, but this affinity to other members of the genus is not certain.

The present species has been known only from the type locality for a long time. Takaki's collection of it from the Japanese South Alps is a remarkable extension of its geographical range. No stable difference between the plants from Europe and Japan could be found. Concerning the ecology of this species, Dixon

and Nicholson mentioned that the limestone cliffs were for the most part moist and dripping and covered with rich moss vegetation customary in such spots. . . . In one spot where the mosses were densely growing over an almost perpendicular rock face in a trickle of water, In Japan too it grows on dripping-limestone cliffs in ravines at an elevation of about 1300 m. and 1450 m. above sea level.

Hab. **Honshu**. Nagano Pref.: foot of Mt. Akaishi (N. Takaki), Miwa-mura, Shiroyadani (N. Tak.).

Distichophyllum cuspidatum Doz. et Molk. Musc. frond. ined. Archip. Ind. 101 (1846); Bryol. jav. 19 (1861); Fleisch. Musc. Fl. Buit. 3: 987 (1908); Nog. in Journ. Jap. Bot. 13: 788 (1937); Bartr. in Philipp. Journ. Sci. 68: 258 (1939). (Fig. 5)

Stems are aggregated on logs or trunk of trees. Leaves on stem are hardly complanate, thus the difference between lateral and dorsal leaves is not seen. Leaf shape is characteristic almost linear or narrowly lingulate, and almost rounded at apex with a long and sharp acumen, and somewhat carinate. The costa extends nearly to the base of the acumen. Leaf cells are slightly collenchymatous, rectangular or quadrate-rectangular, measuring $20 \times 15 \sim 30 \times 20 \mu$ in the middle, towards the margin and apex they become slightly smaller, measuring $15 \times 12 \sim 22 \times 15 \mu$ near the margin. The cells become hexagonal upwards, and are rectangular and larger, $40 \times 17 \sim 65 \times 20 \mu$. Margins are entire, slightly revolute near the base, and broadly bordered all around with 2~3 (2 in the middle, 3 in the lower) rows of linear, thickwalled and yellow cells. Marginal border is rigid, therefore the leaves are hardly contracted nor undulate when dry. No sporogonia have been found in Formosa.

Hab. **Formosa**: Mt. Arisan (A. Nog.); Isl. Botel Tobago (T. Kano).

Distichophyllum mittenii Bosch et Lac. Bryol. jav. 2: 25 (1861); Fleisch. Musc. Fl. Buit. 3: 987 (1908); Nog. in Journ. Jap. Bot. 13: 788 (1937); Bartr. in Philipp. Journ. Sci. 68: 261 (1939); Horik. in Asahina's Nippon Inkwas yokubutu Dukan 953, pl. 459 (1939); Herz. et Nog. in Journ. Hattori Bot. Lab. 14: 65 (1955). (Fig. 4)

Plants robust, reaching 7 mm. broad with leaves. Leaves constricted when dry, both lateral and dorsal leaves symmetrical, spatulate-lingulate from a much narrowed base, with rounded and broad apices, but the former longer than the latter. A minute apicule occurs at the tips of leaves, but occasionally it is absent. The costa slender, flexuose, and yellowish, reaching $2/3$ the length of the leaf in dorsal leaves, but reaching near the leaf apex in lateral leaves. Leaf cells large in the wide area surrounding the costa, measuring $65 \times 35 \sim 75 \times 45 \mu$. and regularly hexagonal with delicate and non collenchymatous walls. They decrease rapidly in size toward the leaf apex and margins; near the apex only $10 \sim 20 \mu$ in diameter. This feature, along with the leaf form and narrow marginal border, characterizes the present species. Marginal borders narrow and slightly yellow, the lower half usually of two rows of linear cells, but the upper of one layer. The seta slender and densely covered with high papillae. The upper region of the calyptra blackish and scabrous.

Hab. **Formosa**: Shinchiku Count., Mt. Rito (T. Hirotsu); Isl. Botel Tobago (T. Kano), without definite locality (G. H. Schwabe).

Distichophyllum obtusifolium Thér. in Monde d. Plantes 22 (1907).

Syn. *D. undulatum* (non Doz. et Molk.) Sak. in Bot. Mag. Tokyo 47: 337 (1933);

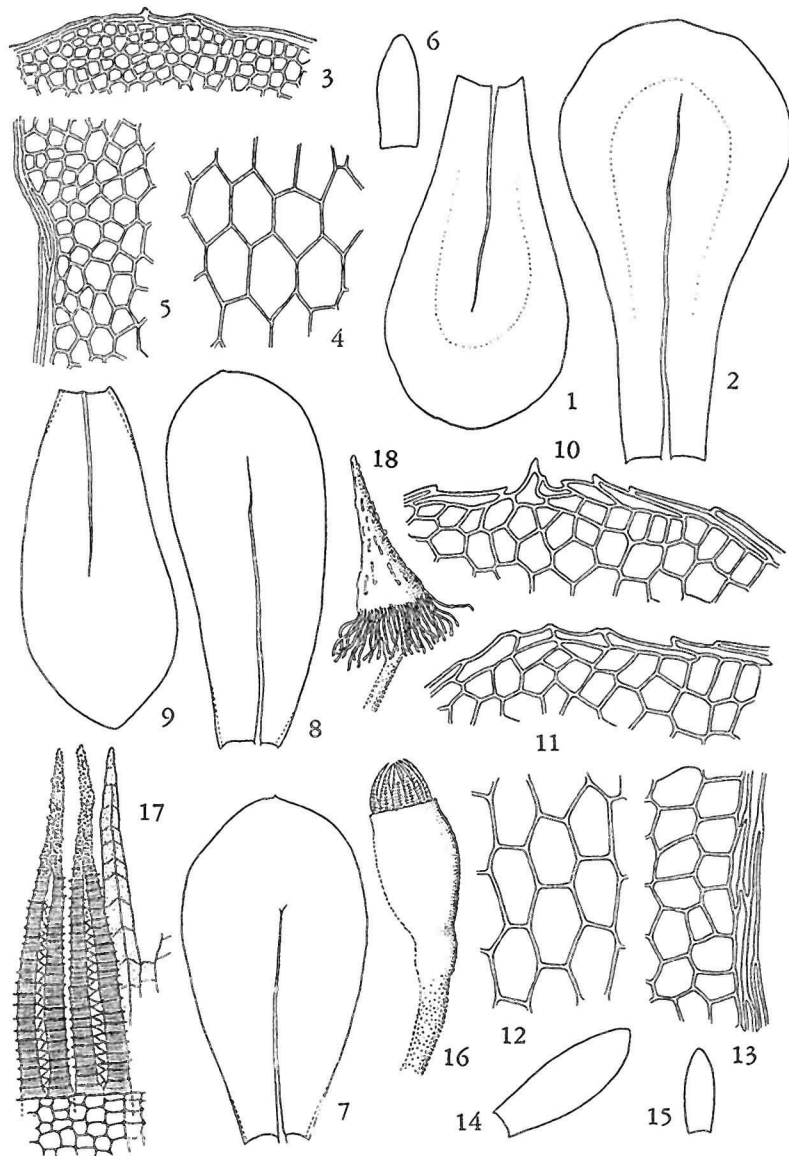


Fig. 4. *D. mittenii* Bosch et Lac. (1~6) and *D. obtusifolium* Thér. (7~19). 1. Dorsal leaf, $\times 19$. 2. Lateral leaf, $\times 19$. 3. Apical part of leaf, $\times 166$. 4. Cells from middle of leaf, $\times 166$. 5. Mid-margin of leaf, $\times 166$. 6. Inner perichaetial bract, $\times 166$. 7. Dorsal leaf, $\times 19$. 8, 9. Lateral leaves, $\times 19$. 10, 11. Apical parts of leaf, $\times 166$. 12. Cells from middle of leaf, $\times 166$. 13. Mid-margin of leaf, $\times 166$. 14. Outer perichaetial bract, $\times 19$. 15. Inner perichaetial bract, $\times 19$. 16. Deoperculate capsule, $\times 29$. 17. Peristome, $\times 166$. 18. Capsule bearing calyptra when dry, $\times 19$.

Horik. in Asahina's Nippon Inkwas yokubutu Dukan 953, pl. 459 (1939). (Fig. 4)

Thériot's original description is so brief that a more detailed account is added.

Plants robust, yellowish green in dense tufts. Stems procumbent, attaining about 3 cm. in length, about 4 mm. wide with leaves, simple or sparingly branched, densely and complanately leaved. Leaves constricted when dry. Dorsal leaves symmetrical, obovate, being much narrower on the basal part, the apices rounded obtuse, but with a minute apicule, about 2×1.2 mm.; lateral leaves oblong obovate or somewhat oblong spatulate, asymmetrical, about 2.5×1 mm.; margins slightly recurved on the inferior part, minutely denticulate at the apex; costa yellowish, slender, from $1/2$ to $2/3$ the length of the leaf; costa of lateral leaves usually longer than that of dorsal ones. Leaf cells very lax in the entire leaf, thinwalled, median cells quadrate hexagonal, hardly collenchymatous, $53 \times 32 \sim 65 \times 42 \mu$, toward leaf apex and margins gradually but slightly smaller, at leaf apex $32 \times 25 \sim 40 \mu$, toward leaf base rectangular, much larger, $85 \times 42 \sim 120 \times 35 \mu$; marginal border narrow, yellowish, consisting of two rows of linear cells for the most part, but a single row of somewhat broader linear cells at the leaf apex. Sporogonia on stem, perichaetial bracts oblong, apex obtuse, ecostate, inner ones about 0.7×0.2 mm. Seta about 5 mm. long, reddish brown, about 0.17 mm. broad, scabrous throughout. Theca inclined, oblong with a distinct neck, about 0.8×0.4 mm., reddish brown, mamillate on the surface, constricted beneath the mouth and above the neck when dry. Outer peristome teeth about 0.3 mm. long. Spores globose, almost smooth on the surface, $8 \sim 11 \mu$ in diam. Calyptra about 1.5 mm. long, not scabrous but with longitudinal ridges.

Hab. **Loo Choo:** Okinawa, Yonahadake (T. Amano); Amami-oshima, Naze (J. B. Ferrie, Nov. 1899-type). **Kyushu:** Yakushima, Kosugidani (Y. Doi, det. by Sakurai as *D. undulatum*; S. Hattori, Y. Kuwahara, Y. Nishihara).

The present species is so closely allied to *D. mittenii* that it is hardly distinguishable from the latter by its external appearance and leaf shape. Thériot stated that the calyptra of the former is smooth on the surface, which separates it from *D. mittenii*. Having examined the type specimen of *D. obtusifolium*, the calyptra is smooth on the surface, instead of scabrous as in *D. mittenii*, but when it is fully examined, it bears several longitudinal but short ridges on the surface. These low ridges consist of a cell projected from calyptra surface, and the upper ones are usually shorter than the lower. Moreover, this species is distinguished from the latter by its different leaf areolation: the leaf cells of *D. mittenii* are large in the median area but become rapidly very much smaller toward both leaf apex and margins, being only $10 \sim 20 \mu$, while the cells of the leaf apex and margin of *D. obtusifolium* are somewhat smaller than the median ones, but not so much.

Having compared with *D. tortile* and *D. undulatum*, the latter is hardly separated from *D. mittenii*, Thériot stated that the leaf of *D. obtusifolium* has a rounded apex but no apiculus. The leaf apices of this species are rounded obtuse, but not occasionally, have a minute point, which is frequently overlooked when under examined low magnification. This species differs from *D. tortile* by its rounded leaf apex, and from *D. undulatum* by the same characteristics that separate *D. mittenii*, respectively.

Distichophyllum osterwaldii Fleisch. Musc. Fl. Buit. 3: 994 (1908); Horik. in Bot. Mag. Tokyo 48: 715 (1934) & Asahina's Nippon Inkwas yokubutu Dukan 955, pl. 460 (1939); Bartr. in Philipp. Journ. Sci. 68: 260 (1939). (Fig. 5)

Plant robust, being 8 mm. broad with leaves. Leaves lax, strongly undulate and crispate when dry, and distinctly dimorphous. Dorsal leaves obovate-oblong or lingulate-spatulate with rounded apex, non apiculate, somewhat asymmetrical; costa reaching $3/4$ the length of the leaf. Lateral leaves long lingulate or spatulate-lingulate, asymmetrical; the lax and widely spreading leaf characterizes the species. Costa of lateral leaves nearly reaches the apex. Leaf cells lax, hexagonal, hardly collenchymatous, about $30 \times 27 \sim 45 \times 30 \mu$ in the middle of leaf, toward margins

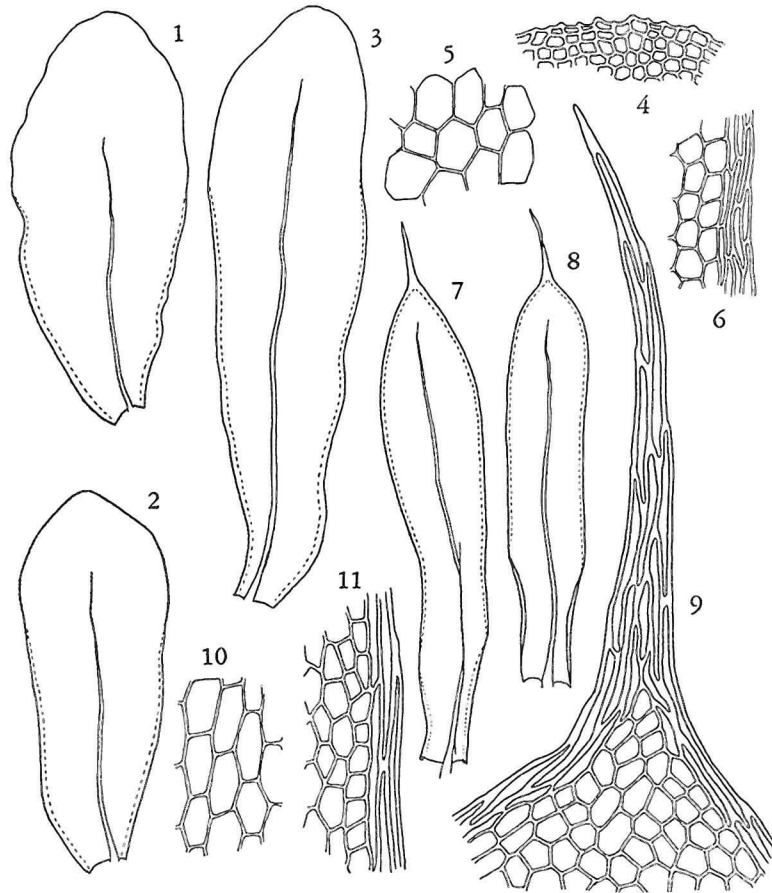


Fig. 5. *D. osterwaldii* Fleisch. (1~6) and *D. cuspidatum* Doz. et Molk. (7~11). 1, 2. Dorsal leaves, $\times 19$. 3. Lateral leaf, $\times 19$. 4. Apical part of leaf, $\times 166$. 5. Cells from middle of leaf, $\times 166$. 6. Mid-margin of leaf, $\times 166$. 7, 8. Stem leaves, $\times 29$. 9. Apical part of leaf, $\times 236$. 10. Cells from middle of leaf, $\times 236$. 11. Mid-margin of leaf, $\times 236$.

slightly smaller, but toward leaf apex rapidly and much smaller, only measuring about $10\sim12\ \mu$ in diameter. This characteristic feature of marginal border is not seen in other species: the broad and yellow coloured border of linear and rather thickwalled cells does not extend the entire length of leaf. The border consists of 4~5 rows of cells in the lower half, but gradually decreases in width, and vanishes far beneath the leaf apex.

Hab. **Loo Choo**: Isl. Iriomote (Y. Horikawa).

Y. Horikawa³ reported *D. nigricaula* Mitt. from the south-western region of the Loo Choo archipelago, but the author has not examined the specimens.

Corrigendum

Macromitrium sarawaketense Noguchi, nom. nov.

Syn. *Macromitrium clemensiae* Nog. in Journ. Hattori Bot.
Lab. **10**: 16 (1953). Not *M. clemensiae* Bartr. in Philipp. Journ.
Sci. **61**: 242 (1936).

³ Bot. Mag. Tokyo, 49: 220 (1935).

GERMINATION OF SPORES AND REGENERATION OF LEAVES OF *MERCEYA LIGULATA* AND *M. GEDEANA*

By A. NOGUCHI¹ and H. FURUTA²

野口 彰・古田 洋: *Merceya ligulata* 及び *M. gedean* の胞子発芽と茎葉再生

The senior author has reported that *Merceya ligulata* grows well on soil, containing Cu- or Fe-ion and on sulphureous soil, so that the species has a remarkable, disjunct distribution. The sporophyte of this species is rarely found. The senior author has examined a few plants, bearing thecae from north-western Himalaya and the Andes, South America, and numerous fertile plants from the Tarutama hot spring in Japan. The other species, *M. gedean* is found in Himalaya, Java, Philippines, Formosa, Japan and South America. He has also reported that this is a remarkable, copper-favoring species. This species like the preceding one yields sporophytes rarely in Japan. He has examined the sporophytes of this species on rocks covered with limonite in Chichibu district, central Japan, but never found them on soil, containing copper. It is of much interests whether metallic ions have any physiological role on the life of *Merceya* or not. Several writers have already speculated about this. Such authors as Hegi and Persson have evaluated the role of hydrogen iron concentration. Recently, however, Schatz has estimated the more important role of sulphur.

In order to clarify the mechanism of reproduction in these two species, the authors have undertaken experiments on the regeneration of leaves and germination of spores in the laboratory. At the same time they have carried on several experiments to clarify the possible role that Cu-, Fe-ion and sulphur may have in the life of these mosses.

Here the authors wish to express their thanks to Assist. Prof. S. Ishikawa of Kumamoto University and to Dr. S. Hattori of Hattori Botanical Laboratory for their suggestions afforded to the present study. Thanks are also due to Mr. S. Imae and Mr. I. Miyata who helped the authors in various ways.

Material and methods

In order to examine the regeneration of leaves of *M. ligulata*, plants were collected from Sasaguri-machi, Fukuoka Pref., Kyushu, where pyrrhotite was dug before, and the Tarutama hot spring, Kumamoto Pref., Kyushu. The material used for the germination of spores was collected from the latter station alone. As for *M. gedean*, the material for the regeneration of leaves and stem were collected

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from Saijo-shi, Shikoku, where the plant grows on soil moistened by the rainwater from copper roof, and for the germination of spores from Nakatsugawa, Chichibu, Saitama Pref., central Japan, where the plant grows on rock covered with limonite. All cultures were kept in sterilized Petri dishes, measuring 12 cm. in diameter, near the window at room temperature. The detached leaves (avoiding the very young and very old ones) were placed on the surface of porous plates submerged in the nutrient solution in closed Petri dishes (the solution was poured into the dishes, keeping the upper surface of plates over the solution). The porous plates were made with felsitic soil, whose pH values are 6.8~7.0. The spores were scattered on the 1% agar nutrient media mounted on slides which were kept on damp filter paper in closed dishes. As culture medium Benecke's solution was used. In order to examine the growth of stem, they were washed in neutral water to remove as much of the soil as possible, and placed on a *Sphagnum* mat in Petri dishes; preceding the experiments the *Sphagnum* was sterilized and washed in neutral water for about twenty-four hours. To give nutrient solutions of different pH value, 1/5 mol of the phosphate buffer mixtures were prepared. All these cultures were illuminated by day light coming through the window, avoiding any direct rays of the sun.

Regeneration of leaves

1. *M. ligulata*. The leaves of this species consist of large rectangular and hyaline cells in the inferior part and of much smaller quadrate chlorophyllous cells

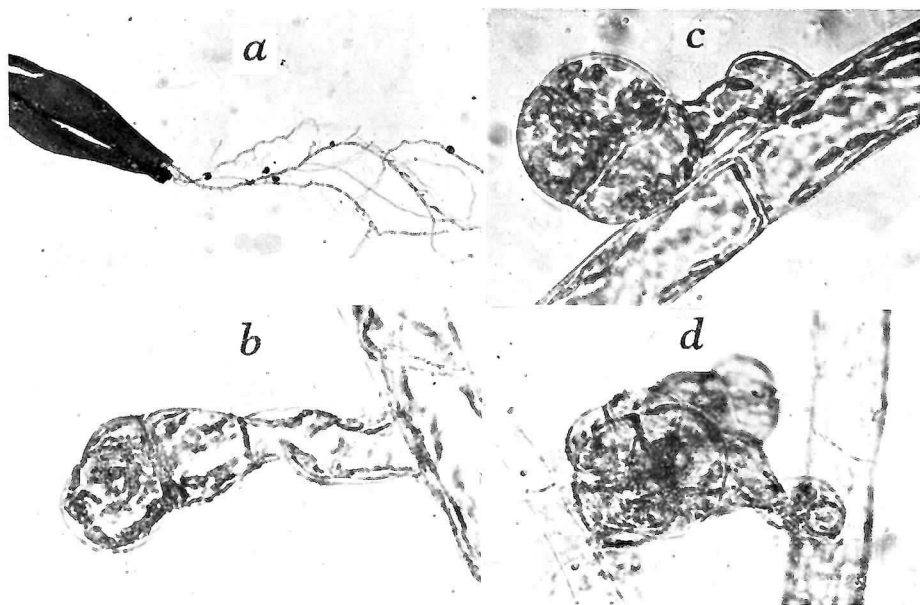


Fig. 1. Regeneration of a leaf in *Merceya ligulata*. a, protonemata produced from the basal part of a leaf; the black spots show the buds of leafy plant. b~d, gemmae of leafy plants developed on protonemata.

above. The freshly detached leaves were placed on the surface of porous plates, keeping the entire length of a leaf in contact with the medium. Within a few days after treatment a mamillate projection was produced from some of the basal cells. No filaments were formed from any upper small cells. When the leaves were mutilated into several sections and cultured, still no formation of filaments from the upper small cells was observed. In every case the filaments arose from the basal cells, and they showed almost 100% of regeneration within a month on the nutrient substratum, bearing a pH value of 3. Preceding the regeneration, the leaf cells producing protuberance were filled with well formed chloroplast. Afterwards, this protuberance gave rise to a long main filament with several branches (Figs.

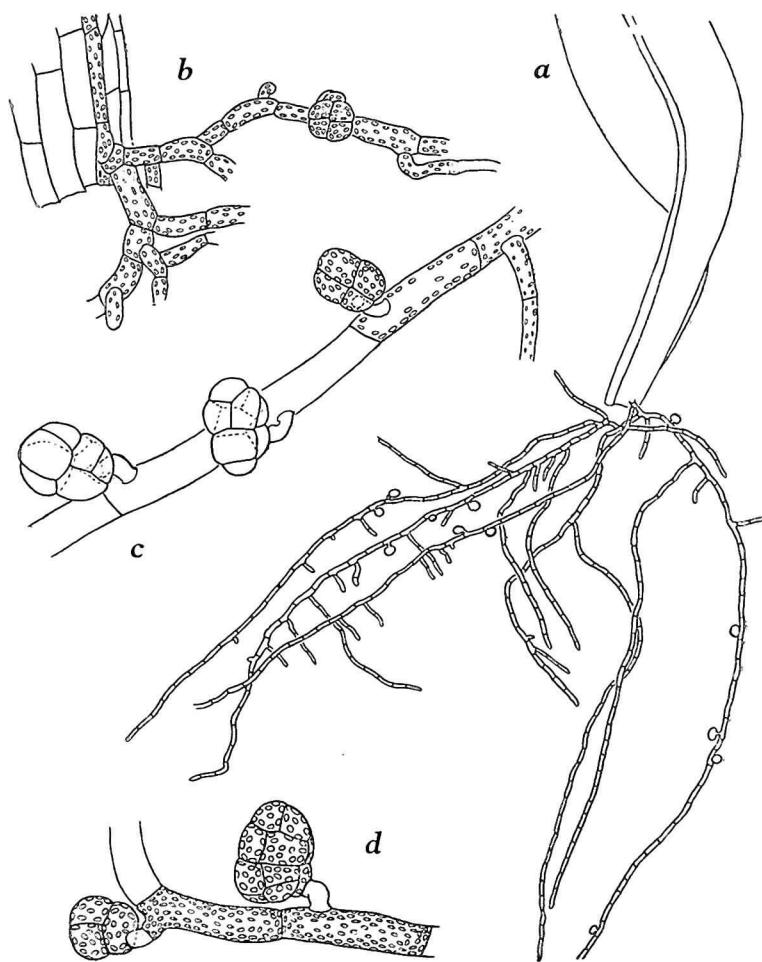


Fig. 2. Regeneration of leaves in *Merceya ligulata*. a, protonemata produced from the basal part of a leaf, $\times 29$. b, ditto, $\times 166$. c, d, protonemata bearing buds of leafy plants, $\times 236$.

1-a, 2-a). Some branches grew more rapidly and differentiated into a main filament, thus many fasciculate main filaments were successively formed. The short branches were narrower than the main filaments. The cells of the filaments are rather short, with cross walls at right angles to the long axis. Within about two months after treatment buds of the leafy plant were formed on the main filament, whose number is indefinite. On some filaments the buds are solitary, while on some seven were observed. The first cell of the bud arises as a small protuberance just anterior to the transverse walls of the main filaments, and is followed by the first segmentation. The first cell thus formed, is cylindrical and somewhat curved in shape, and at first it bears numerous chloroplasts, but subsequently turns to a brownish colour. This cell, afterwards, plays the part of a bridge connecting the leafy plant with a filamentous cell. Soon after the appearance of the first cell of a bud, a chain of two or three cells was formed by successive segmentation. Through the activities of the apical cell of the chain a leafy plant is formed. The apical cell is much larger than the rest of the chain and is subsequently segmented in three planes (Fig. 1-b). Thus, a globose or obovoid cell-mass which correspond to the basal part of a juvenile plant was formed, but no further development was observed in the cultures (Figs 1-c, d, 2-c, d). It might be caused by the absence in the medium of some inorganic substances which are indispensable for the growth of the plant.

As mentioned above, the leaves detached completely from the stem regenerated well on the nutrient medium, while the entire leaves with a small fragment of stem attached produced no filaments. But in the latter case many filaments developed from the stem fragment. It was also observed that the filaments are readily produced from the wounded basal part of the leaf.

2. *M. gedeania*. The material collected from Saijo-shi, Shikoku, on the 25th of April was treated on the 3rd of May, and the cultures were continued for three months. The culture methods were the same as those for the preceding species. The leaves of this species consist of small, quadrate and chlorophyllous cells for the most part, but only the basal part of the leaves is occupied by larger, rectangular, hyaline cells. The leaves of this species regenerate more easily than those of *M. ligulata*. The leaves produce numerous filaments within four or five days after treatment. The manner of regeneration is similar to that in the preceding species, but the regeneration is not restricted to the basal cells of the leaf. Filaments arise from each of the distal, middle and proximal regions of the leaves, but more frequently in the latter region (Fig. 3-a). Within ten days, the filaments arising from the proximal large cells of the leaves, being $10\sim12\mu$ in width, attain twice the length of the leaf, and bear few branches. The cells of the filament are slender and contain few chloroplasts. The branches formed on the upper part of the filament arise just anterior to the transverse walls and consist of shorter and broader cells than those of the filament. The branches consist of one to three short cells in a chain, in which numerous and well formed chloroplasts are observed. This seems to correspond to a bud of the leafy plant. Afterwards, each cell of this short branch produces a rhizoid like filament. On the other hand, the distal and middle but juxta-costal cells of the leaves produce different filaments. These have no branches and are usually narrower and shorter than those from proximal cells. The

cells forming the filament are very long and colourless, and their cross walls are usually oblique. At the tip of the filament, a chain of two or three, chlorophyllous cells is formed, and it connects obliquely or at right angles with the filament (Fig. 3-b). The chain is frequently dropped from the filament. The cells of a chain are much shorter and broader than those of the filament, whose walls are erect. After fifty or sixty days, a long rhizoid like filament showing negative phototropism occurred from each cell of the chain (Fig. 3-c, d).

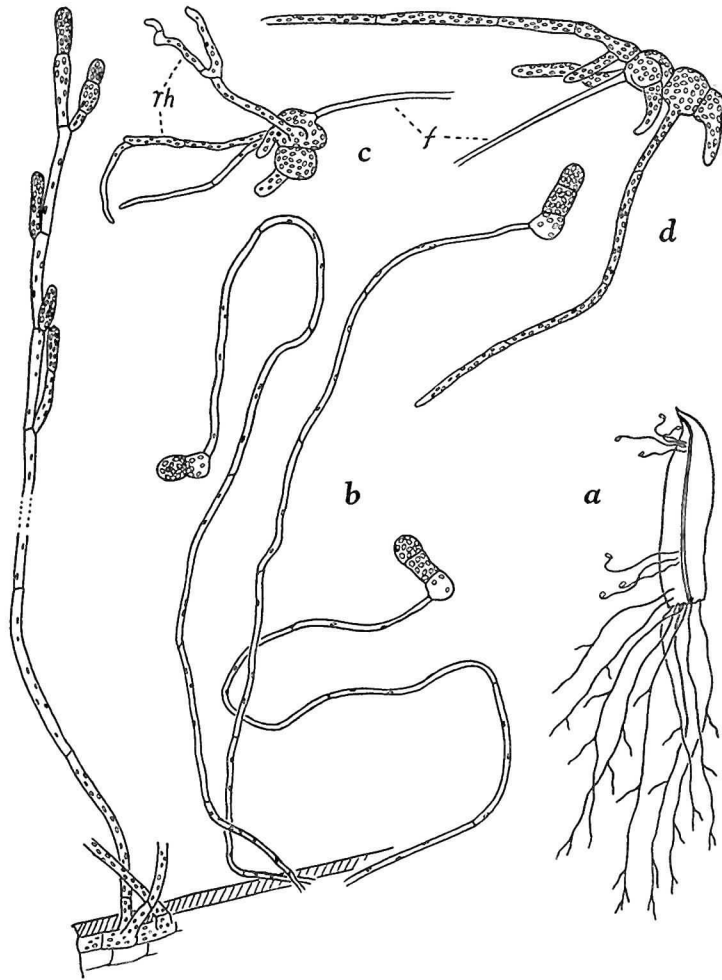


Fig. 3. Regeneration of leaves in *Merceya gedana*. *a*, two kinds of protonemata produced from a leaf, $\times 19$. *b*, two kinds of protonemata, showing buds of leafy plants, $\times 166$. *c*, *d*, buds of leafy plants, *rh*.....rhizoids, *f*.....filaments of protonemata, $\times 166$.

Regeneration of both juvenile and dry leaves

The stems of *M. ligulata* elongate in April in Kyushu. The juvenile leaves in natural habitats, like the leaves on innovations formed on the stems in cultures, were cultured as described above. In no case, did the leaves regenerate. However, several protonemata were produced from the stem fragment attached to an entire leaf. But no protonemata from an entire innovation of the stem was found.

As to the regeneration of plants kept dry during some periods, the following observations were made. The plants of *M. ligulata* from the Tarutama hot spring were kept in dry Petri dishes for about three months. As was the case in the preceding experiments, the detached leaves from treated plants were laid on the surface of porous plates in Petri dishes filled with Benecke's solution, whose pH value was 3. In this case, 60% of the leaves regenerated, but this was lower than the percentage of regeneration of stem fragments. The leaves of *M. gedeana* kept dry for about three months were treated as well, but in this culture the pH value of the solution was 4. In this case, the leaves regenerated rarely, although the stem fragments did well.

Germination of spores

1. *M. ligulata*. The authors got spores from the Tarutama hot spring on the 26th of November. The spores were kept dry, and the cultures were prepared in both December and May at room temperature. The spores of this species vary in size from 10 to 15 μ in diameter and have a rough exospore. The spores were placed both on porous plates submerged in nutrient solution, and on agar, both bearing a pH value of 3 to 4. The spores germinated in about ten days on the agar. At first they swelled by absorbing solution, and the endospore appeared as a large protuberance through the rupture of the exospore. The protuberance developed into a filament of several chlorophyllous cells in a chain, with perpendicular cross walls. In the experiments carried on both in winter and late spring no further development was observed. The percentage of germination on Benecke's agar is smaller than that on porous plates.

2. *M. gedeana*. The experiments on spore germination of this species were carried on in the same manner as with the foregoing species, but the percentage of germination in the former is higher than that in the latter. The filaments from the spores placed on porous plates developed into three-cell stages only during the winter, but this might have been caused by lower temperature in the room. On the contrary, the spores placed on Benecke's agar with a pH of 4 during the period from June to August germinated well and formed an extensive protonemata (Fig. 7-d). The percentage of germination in both seasons is almost alike and about 90%.

Correlation between the growth of entire plants and copper

1. *M. ligulata*. This has been considered as a copper-tolerant species. In order to clarify the subject, the culture experiments of entire plants in Benecke's solution, containing various gradients of sulphate of copper were performed during the period from May to June. The methods were mentioned on the foregoing page. The stems kept in a damp chamber produce one or two (usually one) from their

tips, within a few days. The correlation between the frequency at which the innovations were formed from each stem and the gradient of CuSO_4 concentration and of pH values of the solution are listed below. The results were tabulated on the 15th day after treatment.

The correlation between the growth rate of innovation and the different gradient of CuSO_4 in the culture solution was judged from the number of juvenile leaves

Table 1. Correlation between frequency of innovation-forming on stems and different concentration of CuSO_4 in *Merceya ligulata*.

	Control	CuSO_4 0.1%	CuSO_4 0.3%	CuSO_4 0.5%
pH3	100%	23%	0	0
pH6	81%	0	0	0

occurring on each innovation. The results on the 15th day after treatment are shown in the following figure.

2. *M. gedean*. Concerning the ecology of the present species little has been known. The senior author mentioned in a preceding paper that this is an extremely cop-

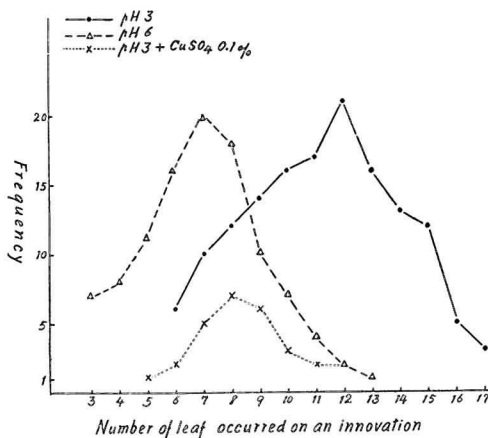


Fig. 4. Correlation between growth of stem and pH values of the medium in *Merceya ligulata*.

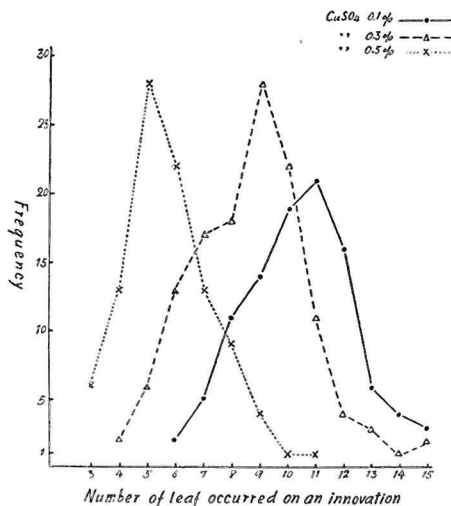


Fig. 5. Correlation between growth of stem and different concentration of CuSO_4 in medium bearing a pH value of 4 in *Merceya gedean*.

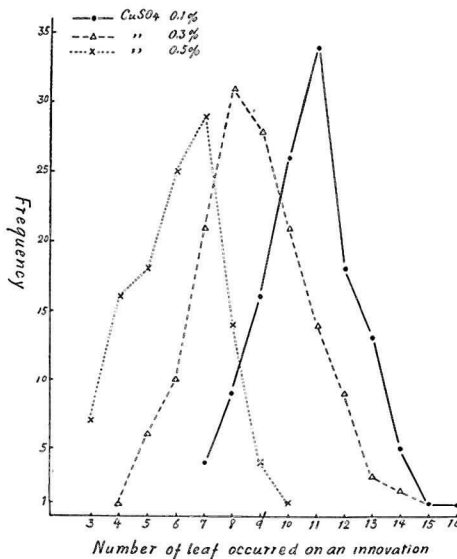


Fig. 6. Correlation between growth of stem and different concentration of CuSO_4 in medium bearing a pH value of 6 in *Merceya gedean*.

Table 2. Correlation between frequency of innovation-forming on stems and different concentration of CuSO_4 in *Merceya gedana*.

	Control	CuSO_4 0.1%	CuSO_4 0.3%	CuSO_4 0.5%
pH4	100%	95%	85%	80%
pH6	100%	95%	87%	82%

of juvenile leaves as before. The results obtained on the 11th day are shown in the following figures.

Correlation between regeneration, germination and metallic ions

1. *M. ligulata*. In order to examine the correlation between the regeneration of leaves and CuSO_4 or FeCl_3 , freshly detached leaves were cultured on porous plates in Petri dishes. The treated plates were kept in Benecke's solution containing various gradients of CuSO_4 or FeCl_3 concentration. After about a month the leaves on the plates, in groups of 100~200 in number, were examined under the microscope. The results obtained in early winter are as follows. In this case, a leaf bearing numerous filaments was numbered as one.

Table 3. Correlation between regeneration of leaves and different concentration of CuSO_4 and FeCl_3 in *Merceya ligulata*.

	Control	CuSO_4 0.1%	CuSO_4 0.3%	CuSO_4 0.5%	CuSO_4 0.8%	FeCl_3 0.1%	FeCl_3 0.3%	FeCl_3 0.5%	FeCl_3 0.8%
pH3	90%	0	0	0	0	0	0	0	0
pH7	25%	/	/	/	/	/	/	/	/

For germination, the spores of this species were gathered at the Tarutama hot spring on the 26th of November in 1955 and kept dry until the experiments were begun. The spores were scattered on Benecke's agar mounted on a slide glass. The medium was prepared with a gradient of CuSO_4 or FeCl_3 concentration. The slides were kept on damp filter paper in Petri dishes and the germination was examined under microscope. These experiments were begun the 13th of May, and 500~1500 spores were examined in each section of the culture. The rate of germination on the 10th day after treatment is shown in the following table.

Table 4. Correlation between germination of spores and different concentration of CuSO_4 and FeCl_3 in *Merceya ligulata*.

	Control	CuSO_4 0.1%	CuSO_4 0.3%	CuSO_4 0.5%	CuSO_4 0.8%	FeCl_3 0.1%	FeCl_3 0.3%	FeCl_3 0.5%	FeCl_3 0.8%
pH3	37%	0	0	0	0	21%	46%	15%	5%
pH7	8%	/	/	/	/	/	/	/	/

In the above culture, the majority of the germinated spores produced a one-celled tube, but in some (e.g. FeCl_3 0.1%) form a moderately long one of about three

per-favoring species in Japan. The authors carried on the experiments for this species in the same manner as those for *M. ligulata*. The rate of innovation formation is much higher than that for the latter species. The results on the 11th day after treatment are tabulated as follows.

The growth rate of innovations in connection with various gradients of CuSO_4 concentration was also judged from the number

cells. Those treated in 0.5% concentration of FeCl_3 produce a small mamilla only. It was noted that the spores on the nutrient medium containing 0.3% concentration of FeCl_3 had a higher percentage of germination than others and formed a long filament of seven to eight cells.

2. *M. gedeana*. The leaves were collected from Saijo-shi in late April. Experiments on the regeneration of fresh leaves were begun in early May and carried on as before. The results obtained on the 21st day after treatment are shown in the following table.

Table 5. Correlation between regeneration of leaves and different concentration of CuSO_4 and FeCl_3 in *Merceya gedeana*.

	Control	CuSO_4 0.1%	CuSO_4 0.3%	CuSO_4 0.5%	CuSO_4 0.8%	FeCl_3 0.1%	FeCl_3 0.3%	FeCl_3 0.5%	FeCl_3 0.8%
pH4	96%	92%	74%	56%	46%	48%	62%	44%	35%
pH7	64%	/	/	/	/	/	/	/	/

The spores on this species from Nakatsugawa, Chichibu, Saitama Pref. on the 20th of November in 1955 and kept dry until the experiments were begun. Then they were scattered on Benecke's agar in the same manner as those of *M. ligulata*. The experiments were performed during the months of June and July, and 500~1500 spores were examined in each section of culture. The spores scattered on Benecke's agar without such metallic ions as copper or iron germinated within four or five days after treatment. The endospores emerge as a large protuberance through the rupture of the exospores and later they develop into a long filament (Fig. 7-a, b). On about the 5th day several spores cut off a moderately long cell, but the majority of the spores produced a protuberance only. The cells of the filaments were rather shortly cylindrical with erect cross walls and contained well formed chloroplasts. After about ten days lateral branches arose from a cell of filament just anterior to cross walls of the main filament. Thus a protonemal system was formed (Fig. 7-d), whereas in some spores the filament remained a long cell, or rarely in a mamilla stage only. Though the majority of the spores placed on Benecke's agar containing both metallic ions, copper or iron showed a variable percentage of germination in connection with the different gradient of the above metallic substances, they died away after the formation of a large or a long protuberance. The spores on medium containing 0.3% concentration of CuSO_4 , however, exhibit a more advanced development: the spores produced a tube of one cell, and some of them formed a long tube of three cells in a chain, but died after about twenty days. The results of the germination experiments (they were done in late June) obtained on the 12th day after treatment, in connection with different gradient of metallic substances in the culture solution are shown in the following table.

Table 6. Correlation between germination of spores and different concentration of CuSO_4 and FeCl_3 in *Merceya gedeana*.

	Control	CuSO_4 0.1%	CuSO_4 0.3%	CuSO_4 0.5%	CuSO_4 0.8%	FeCl_3 0.1%	FeCl_3 0.3%	FeCl_3 0.5%	FeCl_3 0.8%
pH4	88%	42%	40%	35%	31%	30%	16%	11%	6%

Discussion

After the publication by Heald (1898), the regeneration of detached leaves have been observed by several writers such as Boas, Marchal, Meyer, Gemmell, Bopp and others. Their reports indicate that the regeneration rate is not so high, for example, in Meyer and Ford's observation on *Physcomitrium turbinatum* (1942), thirty-two out of fifty leaves produced protonemata in the nutrient medium. While both species of *Merceya* show high rates of regeneration, of about almost 100%. In *Merceya ligulata* the difference in rates of regeneration of leaves was not found between material collected on substrata containing copper and one brought from sulphureous hot spring. It might also be noted that the leaves of *M. ligulata* kept

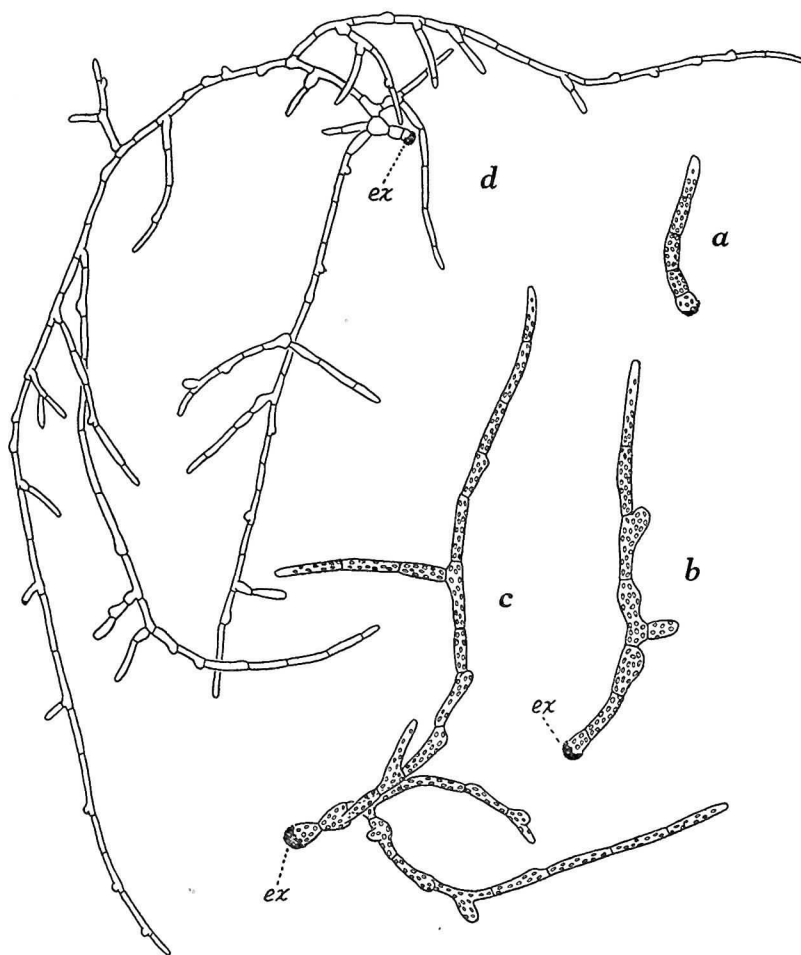


Fig. 7. Germinations of spores in *Merceya gedeana*. ex...exo-spores. a, filament on the 7th day, b, on the 12th day, c, 20th day after treatment, respectively, $\times 166$. d, protonemata on the 40th day after treatment, $\times 87$.

in dry condition for three months showed high rates of regeneration. These facts indicate that both species of *Merceya* are able to form a vast colony in habitats by means of asexual reproduction. In many species of mosses the cells producing protonemata seem not to be restricted to any definite part of leaves. This is the same with the case of *M. gedecana*. On the other hand, in *M. ligulata* such cells are restricted to the lowermost part of the leaves. In *M. gedecana* the basal cells of leaves readily produce protonemata bearing few, short, and chlorophyllous branches. The superior cells of the leaves, however, produce more slender and unbranched filaments, on the tip of which a chain of large chlorophyllous cells arises. These chlorophyllous cells seem to be a bud of a leafy plant. It seems to be unknown in other mosses that two kinds of protonema are produced from a single leaf.

Heald and Meyer stated that the entire leaves attached to stems produce hardly any protonemata. According to the authors' observations the leaves with a fragment of a stem also produce no protonemata, while the fragment of stem readily produced them. The wounded parts of a leaf, as already pointed out by Meyer, Gemmell, and others, easily produced protonemata. These facts seem to indicate that wounding of the leaves induces the production of protonemata. E. G. Pringsheim wrote that the formation of a leafy plant occurs readily in alkaline medium. In *M. ligulata* the initial cells masses were formed in the media bearing a pH value of 3, and in *M. gedecana* of 4 to 6, respectively, but no leafy plants were observed. This may have been due to the absence of some other nutrient substances.

As already mentioned, both species are restricted to stations correlated with the occurrence of such metallic substances as copper, iron and others, or with sulphur. Therefore, it might be of interest to determine the correlation between the growth of plant, likewise the germination of spores, and metallic substances. It seems that no culture experiments of this subject had ever been made. The spores of *M. ligulata* did not germinate on the medium containing more than 0.1% concentration of CuSO_4 , but they germinated well in those media containing FeCl_3 . The entire stems and detached leaves of *M. gedecana* regenerated well in the medium containing a considerable amount of copper or iron, but the spores did not germinate so well as the stems and leaves. This seems to indicate that a single cell like the spore is affected by a high concentration of metallic substances. But it may be worth mentioning that the spores and detached leaves of *M. gedecana* germinated better on the medium containing 0.3% concentration of FeCl_3 than the other sections. The reason for this is not clear.

In *M. ligulata* the stems grew well in the nutrient solution bearing a pH value of 3, which agrees with that of the soil on which this species grows, but does not agree in its pH of 6. As mentioned in Table 1, stems grow a little in the solution, containing 0.1% concentration of CuSO_4 , of which pH value is 3. On the contrary, no regeneration of leaf was found in the medium containing the same degree of CuSO_4 with the foregoing one, but its pH value was 6. Unsuitable pH value in the medium for the growth of the plant, as well as copper seem to serve to control the growth of the stem. While in *M. gedecana*, the stems are well developed in both media, bearing a pH range of 4 to 6 (Table 2). This agrees with the fact that this species grows on soil with a wide range of pH value. *M. gedecana* exhibits also

a high degree of resistance to copper. As Tables 2 and 5 show, it grows well in such solutions with a concentration of CuSO_4 , as high as 0.5% or more.

In *M. ligulata*, as stated above, the regeneration of leaves is affected by pH value, while in *M. geddeana* its effect is not so marked. The leaves of the former also did not regenerate in such solutions containing Cu- or Fe-ions, though the pH value of the media is suitable for regeneration. On the contrary, the leaves of the latter possess a strong resistance to copper and iron. It is a notable fact that 35% of the leaves of *M. geddeana* regenerate on a medium, bearing such a high concentration of CuSO_4 as 0.8%. This serves to emphasize that this species grows well on soil containing copper such as the other mosses are unable to invade. The regenerating ability of leaves on media containing iron like the germination of spores, is smaller than that in media containing copper (Tables 5 & 6). This suggests that *M. geddeana* is more frequently found on soil containing copper than on soil containing iron in Japan.

Lastly, there is still the question of the correlation between the presence of sulphur and the growth of plants or the germination of spores. Owing to high temperature during summer, the results obtained by the authors' experiments on this subject are questionable and therefore its consideration is postponed.

Summary

1. The stems and leaves of both *M. ligulata* and *M. geddeana* regenerate readily, especially when wounded. The leaves bearing a fragment of stem yield little protonema. The cells producing protonema in *M. ligulata* are restricted to the basal part, while in *M. geddeana* they are not confined to any definite part of the leaf. The reproduction of both species is mainly by the regeneration of stems and leaves.

2. Few juvenile or old leaves regenerate, while the juvenile stem produces protonemata from the wounded part.

3. Stems of both species grow well in the pH range, agreeing with that of soil on which the species grow, and the regenerating rate of stems is higher than that of leaves. But, in *M. ligulata* the growth of stems is affected by pH value, and also is inhibited by Cu-ion, whereas in *M. geddeana* it is hardly inhibited by metallic ions.

4. The regeneration of leaves in *M. ligulata* is reduced by Cu- and Fe-ions, while that in *M. geddeana* is slight in the presence of these metallic ions.

5. The spores of both species germinate on nutrient medium, but their growth is poor. The spores of *M. ligulata* show less germination and growth on nutrient medium, and they have no tolerance for copper, but have a considerable one for iron. Those of *M. geddeana*, on the other hand, have a good deal of tolerance for both copper and iron, especially for the former.

6. The geographical range of *M. ligulata* seems to be affected by pH values, so far as the authors' experiments would seem to indicate. That of *M. geddeana* seems to be affected by the presence of Cu- or Fe-ions in the soil. These two species are probably relics, being limited to such special soils as described above.

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ON THE BRYOPHYTE FLORA OF THE TSUSHIMA ISLANDS

By Tairoku AMAKAWA¹ and Takemasa OSADA²

尼川大録・長田武正: 対馬の蘚苔類フロラについて

The Tsushima Islands lie at Lat. $34^{\circ}5'-42'N$ and Long. $129^{\circ}10'-30'E$, at a distance of 52 km. from the southern coast of Korea and 82 km. from the northern edge of the main island of Kyushu (S. Japan). The Tsushima Islands, on the whole, are about 72 km. long in N-S, and 12-16 km. wide, covering about 435 sq. km., the group consists of two main islands, the northern island being twice as large as the southern one. The islands are mountainous, sloping into the sea very steeply for the most part. But the mountains or hills are not so high. The highest, Mt. Yatate, rises only 645 m., and both Mt. Ariake and Mt. Tatera 558 m., Mt. Shiratake 519m. and Mt. Mitake 490 m. above sea level. The islands are composed of Mesozoic (or Tertiary?) stratified rocks with some eruptions of Quartz and Granite porphyry at Izuhara, Mt. Shiratake, Mt. Tatera and other localities.

The climate is oceanic and mild under the influence of the Tsushima Current, a branch of the Brack Current. The annual average temperature is $14\sim15^{\circ}C$, the maximum $32\sim34^{\circ}C$, the minimum $-3\sim-7^{\circ}C$ at Izuhara. The annual rainfall is 2000~2700 mm. at Izuhara.



The Tsushima Islands

The Tsushima Islands are considered to be a relic of the land which had once connected Japan and Korea, and the animals and plants of the islands are a mixture of those of the two areas. For example, the birds like *Dryocopus richardi* and *Phasianus torquatus* are thought to establish an affinity between Tsushima and Korea, while the mammals are more closely related to those of Japan Proper.

As for the flora, Wilford collected on the islands in 1860, Gotze in 1883, Warburg in 1887, Faurie in 1901. Yabe (1903-04), Nakai (1928) and K. Nakashima (1942) studied the flora of Tsushima. Nakai (1928), after investigating the woody plants of the islands, stated that the Japanese element is more important than the Korean one, comprising such species as the bamboos, *Citrus* and *Aleurites* which hardly migrate from one land to another unless there is a land-connection, and concluded that Tsushima was separated first from Korea and after-

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wards from Japan.

However, only a few species of Bryophytes are recorded in Tsushima. Cardot (1907) described *Syrrhopodon tsushimae* for the first time. Horikawa (1939) recorded 6 species of Hepaticae. Recently Horikawa (1954-55) added some 15 bryophytes to the known flora of the islands in his 'distributional studies'. The authors visited the islands for two weeks in the spring of 1956, and collected about 600 packets of bryophytes from Izuhara, Mt. Ariake, Mt. Shiratake, Mt. Tatera and Mt. Mitake. Among these there are 225 species of bryophytes. Adding 6 species³ which were not collected by them but are known already from Tsushima, there are 231 species of Bryophytes including 94 species of Hepaticae (comprising 49 genera and 23 families), and 137 species of Musci (comprising 91 genera and 37 families). Among them, 2 species⁴ are new to Science and 202 species are new to Tsushima.

List of Bryophytes of the Tsushima Islands⁵

Hepaticae

- Calobryaceae: *Calobryum rotundifolium* (Mitt.) Schffn.
 Ptilidiaceae: *Blepharostoma minus* Horik.
 Lepidoziaceae: *Bazzania albicans* Staph., *B. japonica* (S. Lac.) Lindb. (det. Hattori), *B. pompeana* S. Lac., *Lepidozia vitrea* Steph., *Microlepidozia makinoana* (Steph.) Hatt.
 Calypogeiaceae: *Calypogeia arguta* Mont. et Nees, *C. tosana* Steph.
 Cephaloziaceae: *Cephalozia media* Lindb., *C. nipponica* Hatt., *C. otaruensis* Steph., *Odontoschisma denudatum* (Nees) Dum.
 Harpenthaceae: *Heteroscyphus bescherelei* (Steph.) Hatt., *H. planus* (Mitt.) Schffn., *Lophocolea heterophylla* (Schrad.) Dum., *Lophocolea minor* Nees, *Saccogyna curiosissima* Horik.
 Jungermanniaceae: *Jamesoniella autumnalis* (D. C.) Steph., *Jungermannia lanceolata* L., *Nardia grandistipula* Steph., *Plectocolea infusca* Mitt., *P. ovicalyx* (Steph.) Hatt.⁶, *P. rubripunctata* Hatt.
 Plagiochilaceae: *Plagiochila japonica* S. Lac., *P. ovalifolia* Mitt., **P. yokogurensis* Steph.
 Scapaniaceae: *Diplophyllum serrulatum* (K. Muell.) Steph., *Scapania stephanii* K. Muell.
 Radulaceae: *Radula japonica* Gott., *R. kojana* Steph., *R. oyamensis* Steph.
 Porellaceae: *Porella japonica* (S. Lac.) Mitt., **P. perrottetiana* (Mont.) Hatt., *P. ulophylla* (Steph.) Hatt., *P. vernicosa* Lindb.
 Frullaniaceae: *Frullania amplicrania* Steph., *F. aoshimensis* Horik **F. densiloba* Steph., *F. diversitexta* Steph., *F. fauriana* Steph., *F. hampeana* Nees, *F. kagoshimensis* Steph., **F. makinoana* Steph., **F. moniliata* subsp.

³ *Frullania usamiensis*, *Brothera leana*, *Syrrhopodon tsushimae*, *Eriopus mollis*, *Pyloisia chrysophylla* var. *brevifolia* and *P. nana*. ⁴ *Riccardia tsushimensis* and *Fissidens verruculosus*.

⁵ An asterisk(*) marks the species which have previously been recorded from the islands. ⁶ The present species agrees with the description and figures of *Eucalyx ovicalyx* Horik. (in Journ. Hiroshima Univ. 1: 57, f. 2, 1931), which, however, seems to be different from the type specimen of Stephani.

obscura Verd., *F. muscicola* Steph., *F. osumiensis* (Hatt.) Hatt., *F. pedicellata* Steph., *F. squarrosa* (R.B.N.) Dum., **F. truncatifolia* Steph., **F. usamiensis* Steph., *Jubula hatchinsiae* subsp. *japonica* (Steph.) Horik. et Ando.

Lejeuneaceae: *Archilejeunea kiushiana* (Horik.) Hatt., **Brachiolejeunea sandvicensis* (Gott.) Evans, *Cololejeunea spinosa* (Horik.) Hatt., *Drepanolejeunea japonica* Horik., **D. tenuis* (R.B.N.) Schffn., *Euosmolejeunea auriculata* Steph., *Harpalejeunea intermedia* Evans, *Lejeunea flava* (Sw.) Nees, *L. japonica* Mitt., *L. planiloba* Evans, *L. rotundistipula* (Steph.) Hatt., *L. vaginata* Steph., *Lep- tocolea japonica* Schffn., *L. magnistyla* Horik., *Leptolejeunea subacuta* Steph., **Microlejeunea punctiformis* (Tayl.) Spr., *Ptychocoleus nipponicus* Hatt., **Pty- chanthus striatus* (L. et L.) Nees, **Pycnolejeunea imbricata* (Nees) Steph., *P. ob- tusilobula* Hatt., **Spruceanthus semirepandus* (Nees) Verd., *Taeniolejeunea ocelloi- des* (Horik.) Hatt., *T. pseudofloccosa* (Horik.) Hatt., *Tuyamaella molischii* (Schffn.) Hatt.

Pallaviciniaceae: *Pallavicinia longispina* Steph.

Makinoaceae: *Makinoa crispata* (Steph.) Miyake.

Pellieae: *Pellia fabbrioniana* Raddi.

Metzgeriaceae: *Metzgeria fruticulosa* (Dicks.) Evans.

Riccardiaceae: *Riccardia decrescens* (Steph.) Hatt. (det. Mizutani), *R. miyake- ana* Schffn. (det. Mizut.), *R. pellioides* Horik. (det. Mizut.)⁷, *R. planiflora* (Steph.) Hatt. (det. Mizut.), *R. tsushimensis* Mizut. et Hatt. msc. (det. Mizut.).

Marchantiaceae: **Dumortiera hirsuta* subsp. *tatunoi* Horik., *Wiesnerella denudata* (Mitt.) Steph.

Conocephalaceae: **Conocephalum conicum* (L.) Dum.

Rebouliaaceae: *Reboulia hemisphaerica* (L.) Raddi.

Ricciaceae: *Riccia glauca* L.

Anthocerotaceae: *Anthoceros nagasakiensis* Steph., *Megaceros tosanus* Steph.

Musci

Fissidentaceae: *Fissidens cristatus* Wils., *F. gymnogynus* Besch., *F. japonicus* Doz. et Molk., *F. lateralis* Broth., *F. nagasakinus* Besch., *F. taxi- folius* var. *acutifolius* Nog. (det. Noguchi), *F. verruculosus* Shin. msc. (det. Nog.).

Dicranaceae: **Brothera leana* (Sull.) C. Muell., *Campylopus viridulus* Card., *Dicranum scoparium* Hedw., *D. nipponense* Besch., *Ditrichum mayebarae* Sak., *Leucoloma okamurae* Broth., *Onchophorus crispifolius* (Mitt.) Lindb., *Trematodon drepanellus* Besch.

Leucobryaceae: *Leucobryum neilgherrense* C. Muell. (det. Nog.), *L. scabrum* S. Lac.

Calympereaceae: **Syrrophodon tsushimae* Card.

Pottiaceae: *Anoetangium dichroum* Card., *Barbula* sp., *Hyophila pro- pagulifera* Broth., *Tortella japonica* (Besch.) Broth., *T. tortuosa* Limpr., *Weisia controversa* Hedw. (= *W. viridula* Hedw.), *Weisiopsis cardoti* Broth.

Grimmiaceae: *Grimmia pilifera* Pal.-Beauv., *Ptychomitrium dentatum*

⁷ The second record of *R. pellioides*, which hitherto was known only from Mitaki (type locality), vicinity of Hiroshima.

(mitt.) Jaeg., *P. linealifolium* Reim., *Rhacomitrium canescens* var. *ericoides* (Web.) B.S.G.

Erpodiaceae: *Glyphomitrium humillimum* (Mitt.) Card., **Venturiella sinensis* (Vent.) C. Muell.

Funariaceae: *Funaria hygrometrica* Hedw.

Bryaceae: *Brachymenium exile* (Doz. et Molk.) B.S.G. (det. H. Ochi), *Bryum argenteum* var. *lanatum* (Pal.-Beauv.) B.S.G. (det. Ochi), *B. cyclophyllum* (Schw.) B.S.G. (det. Ochi), *B. nagasakense* Broth., (det. Ochi), *B. ramosum* (Hook.) Mitt. (det. Ochi), *Pohlia scabridens* Mitt. (det. Ochi).

Mniaceae: *Mnium cuspidatum* Hedw., *M. laevinerve* Card., *M. maximowiczii* Lindb., *M. microphyllum* Doz. et Molk., *M. punctatum* Hedw., *M. succulentum* Mitt., *M. trichomanes* Mitt., *M. vesicatum* Besch.

Rhizogoniaceae: *Rhizogonium dozyanum* S. Lac., *R. spiniforme* Bruch.

Bartramiaceae: *Bartramia pomiformis* Hedw., *Philonotis socia* Mitt.

Hedwigiaceae: *Hedwigia ciliata* (Hedw.) Pal.-Beauv. (= *H. albicans*).

Orthotrichaceae: *Macromitrium comatum* Mitt., *M. gymnostomum* Sull. et Lesq., *M. incurvum* (Lindb.) Par., *Schlotheimia japonica* Besch. et Card.

Cryphaeaceae: *Pilotrichopsis dentata* (Mitt.) Besch.

Leucodontaceae: *Leucodon nipponicus* Nog.

Pterobryaceae: **Pterobryum arbuscula* Mitt.

Trachypodaceae: *Trachypus humilis* Lindb. (det. Nog.).

Myuriaceae: *Myuriopsis sinica* (Mitt.) Nog.

Meteoriaceae: *Barbella asperifolia* Card., **Chrysocladium retrorsum* (Mitt.) Fleisch., *Meterorium helminthocladum* (C. Muell.) Fleisch., *M. helminthocladulum* (Card.) Broth., *Pseudobarbella kiushiuensis* (Broth.) Nog.

Neckeraceae: *Neckera flexiramea* Card., *N. humilis* Mitt., *N. nakajimae* (Ihshiba) Nog., *N. tosaensis* Broth., *Neckeropsis nitidula* (Mitt.) Fleisch., **Homaliodendron scalpellifolium* (Mitt.) Fleisch., *Thamnum plicatulum* S. Lac., *T. sandei* Besch.

Lempophyllaceae: *Isothecium subdiversiforme* Broth., *Tripterocladium robustulum* Broth.

Hookeriaceae: *Distichophyllum maibarae* Besch., **Eriopus mollis* Card., *Hookeria nipponensis* (Besch.) Broth.

Hypopterygiaceae: *Cyathophorella kyusyuensis* Horik. et Nog.

Theliaceae: *Fauriella tenuis* (Mitt.) Card.

Thuidiaceae: *Anomodon giraldii* C. Muell., **Claopodium assurgens* (Sull. et Lesq.) Card., *Haplocladium subulaceum* var. *subulatum* (Card.) Ther. (det. Nog.), *Haplohymenium longinerve* Broth., *H. triste* (Cesati) Kindb. (= *H. microphyllum* Broth. et Par.), *H. sieboldii* Doz. et Molk., *H. stenoglossum* (Card.) Broth. (det. Nog.), *Herpetineuron toccoe* (Sull. et Lesq.) Card., *Heterocladium gracillimum* Nog. (det. Nog.), *Pseudoleskeopsis orbiculata* (Mitt.) Broth., *Thuidium cymbifolium* Doz. et Molk., *T. toyamae* Nog.

Amblystegiaceae: *Campylium* sp., *Platyhypnidium rusciforme* (Neck.) Fleisch.

Brachytheciaceae: *Brachythecium buchanani* (Hook.) Jaeg., *B. plumosum* (Sw.) B.S.G., *B. populeum* (Hedw.) B.S.G., *Bryhnia novae-angliae* (Sull. et Lesq.) Grout, *B. sublaevifolia* Broth. et Par. (det. Takaki), *Eurhynchium hians* (Hedw.)

S. Lac. (det. Takaki), *E. polystictum* (Mitt.) Takaki (det. Takaki), *Homalothecium laevisetum* S. Lac., *Myuroclada concinna* (Wils.) Besch., *Okamuraea brachydictyon* (Card.) Nog., *O. hakoniensis* (Mitt.) Broth., *Rhynchostegium pallidifolium* (Mitt.) Jaeg.

Fabroniaceae: *Fabronia matsumurae* Besch., *Schwetschkeopsis japonica* (Besch.) Broth.

Entodontaceae: *Entodon attenuatus* Mitt. (det. Nog.), *E. challengerii* (Par.) Card., *E. drummondii* (B.S.G.) Jaeg., *Erythrodontium leptothallum* (C. Muell.) Nog., *Sakuraia conchophylla* (Card.) Nog.

Sematophyllaceae: *Acroporium nipponense* Sak. (det. Nog.), *Brotherella henoni* (Duby.) Fleisch., *B. yokohamae* (Broth.) Broth., *Sematophyllum* sp.

Plagitheciaceae: *Plagithecium silvaticum* (Bridel) B.S.G. (det. Nog.)

Hypnaceae: *Dolichotheca perrobusta* (Broth.) Broth., *?Homomallium adnatum* (Hedw.) Broth., *Hypnum circinatulum* Schimp., *H. oldhamii* (Mitt.) Jaeg., *H. plumaeforme* Wils., *Isopterygium albescens* (Schw.) Jae., *I. textorii* S. Lac., *I. tosaense* Broth., **Pylaisia chrysophylla* var. *brevifolia* Card., **P. nana* Mitt., *Taxiphyllum hisauchii* (Okam.) Sak., *T. taxirameum* (Mitt.) Fleisch., *Vesicularia apiculata* Broth.

Hylocomiaceae: *Hylocomium cavifolium* Fleisch.

Diphysciaceae: *Diphyscium fulvifolium* Mitt.

Polytrichaceae: *Atrichum undulatum* Hedw., *Pogonatum inflexum* (Lindb.) Jaeg., **P. spinulosum* Mitt., *Polytrichum attenuatum* Menz.

Phytogeographical Considerations

It is natural that the Holarctic and the Asiatic-Holarctic elements occupy a large proportion of Tsushima. At the same time, tropical and subtropical species, particularly of Hepaticae, are moderately numerous under the influence of the warm current. Of our 231 species, 108 are also distributed in the Holarctic regions (excluding Japan), and 94 also occur in the Palaeotropical regions. It is of more interest to correlate the flora with those of Korea and Japan and with the geological history of Tsushima, but the authors cannot go into a detailed discussion here because our knowledge of the bryophytic flora of Korea is so poor at present.

1) **Holarctic element.** One cannot expect the occurrence of subarctic-subalpine species because of the lack of high mountains in our area. The authors found only the following lowland species of the Holarctic element: *Cephalozia media*, *Odontschisma denudatum*, *Lophocolea heterophylla*, *Jamesoniella autumnalis*, *Conocephalum conicum*, *Riccia glauca*, *Fissidens cristatus*, *Mnium punctatum*, *Bartramia pomiformis*, *Brachythecium populeum*, *Atrichum undulatum*, *Polytrichum attenuatum*.

More bryophytes which are now thought to be limited to the Holarctic regions of Asia, or the temperate regions of the Far East, would probably be found with additional exploration. In our area, *Radula japonica*, *Porella ulophylla*, *Ptychomitrium dentatum*, *Glyphomitrium humillimum*, *Mnium succulentum*, *Rhizogonium dozyanum*, *Myuriopsis sinica*, *Meteorium helminthocladulum*, *Thamnum sandei*, *Haplomenium longinerve* belong to such an element. *Blepharostoma minus*⁸,

⁸ Cf. Horikawa (1951).

*Nardia grandistipula*⁹, *Okamuraea brachydictyon*¹⁰ are known from very restricted regions—Japan and Korea—around the Japan Sea. Some others, such as *Plagiochila yokogurensis*, *Diplophyllum serrulatum*, *Euosmolejeunea auriculata*, *Mnium maximowiczii*, *Homalothecium laevisetum*, *Okamuraea hakoniensis*, *Hypnum plumaeforme*, *Pogonatum inflexum* were recorded from Liukiu and Formosa, areas south of the Holarctic.

The authors failed to find some of the most common cosmopolitan species, so-called 'Unkrautmoose' (Herzog 1931), such as *Marchantia polymorpha*, *Ceratodon purpureus*, in spite of their careful search. Also some of the most common Holarctic and Asiatic-Holarctic members in the following were not found: *Trichocolea tomentella*, *Nowellia curvifolia*, *Marchantia paleacea*, *Conocephalum supradecompositum*, *Ditrichum pallidum*, *Dicranodontium denudatum*. The lack of these common species may be understood to be a feature of the island flora as some authors have already pointed out.¹¹

2) **Tropical element.** Fifty one species of Hepaticae and 43 species of Musci of Tsushima are common with those of Palaeotropical regions. Some of the Tropical element is widely distributed northwards to Korea. These are as follows: *Porella perrottetiana*¹², *Frullania moniliata* subsp. *obscura*, *Brachilejeunea sandvicensis*, *Microlejeunea punctiformis*, *Wiesnerella denudata* and *Claopodium assurgens*. Some do not reach Korea. They are *Frullania hampeana*, *Drepanolejeunea tenuis*, *Pycnolejeunea imbricata*, *Ptychathus striatus*, *Spruceanthus semirepandus*, *Taeniolejeunea pseudofloccosa*¹³, *Brachymenium exile*, *Bryum ramosum*, *Rhyzogonium spiniforme*, *Meteorium helminthocladum*, *Homaliodendron scalpellifolium*, *Thuidium cimbifolium*, *Isopterygium albescens*. Such subtropical species as *Frullania densiloba*, *Drepanolejeunea japonica*, *Leptocolea magnistyla*, *Taeniolejeunea ocelloides*, *Megaceros tosanus*, *Fissidens japonicus*, *Pohlia scabridens*, *Neckera flexiramea*, which are found in Formosa, Liukiu and Southern Japan, also reach the islands. The northern limit of these tropical and subtropical species roughly coincides with the average January isotherm of 4°C in Japan (Cf. Hattori 1951 and Noguchi 1951), and the average in January at Izuhara is 4.7° C.

These tropical and subtropical species occur mostly in the moist primeval forest near the summit of mountains (above 400 m. alt.) in our area. *Pytychanthus striatus*, *Chrysocladium retrorsum*, *Neckera flexiramea*, *Barbella asperifolia*, *Pseudobarbella kiushiuensis* grow pendulously on trees and represent the subtropical aspect of Tsushima. Three epiphyllous liverworts, namely *Tuyamaella molischii*, *Leptocolea japonica* and *Leptolejeunea subacuta*, which occur on the leaves of evergreens (mostly of *Camellia japonica*) are another indicator of the subtropical nature of the islands.

3) **Correlation to the flora of Korea and to that of Japan.** About one third of our species are common with the Korean flora. All these species are

⁹ The present species was reported from Daglet Isl. (Korea) by Iwamasa (1953) as *Alicularia comata*.

¹⁰ The present species is known in Japan Proper, Isl. Quelpaert and Korea (Fusan), Cf. Noguchi (1953).

¹¹ Cf. Hattori (1947), for example.

¹² Cf. Iwamasa (1953).

¹³ Benedix (1953) reported the present species from Sumatra, Borneo and Java recently.

widely distributed also in Japan, and there is no species restricted to Tsushima and Korea. However, all our species (excluding 2 new species) occur also in Japan, and the endemic species of Tsushima and Japan amount to one third of our species. These endemic species are as follows: *Bazzania pompeana*, *Cephalozia nipponica*, *Scapania stephanii*, *Radula oyamensis*, *Frullania kagoshimensis*, *Pycnolejeunea obtusilobula*, *Riccardia pellioides*, *Anthoceros nagasakiensis*, *Fissidens lateralis*, *Ptychomitrium linearifolium*, *Barbella asperifolia*, *Pseudobarbella kiushiuensis*, *Eurhynchium polystichum*, *Sakuraia conchophylla*, *Hypnum circinatulum*. Many of these are widely distributed in S. W. Japan or throughout Japan. Though some of these endemic species may be found in Korea in the future, the authors think that the bryophytic flora of Tsushima has its closest affinity to that of Japan.

In this occasion the authors wish to express their gratitude to Dr. S. Hattori and Dr. A. Noguchi who gave them valuable criticism and also to Dr. N. Takaki, Mr. H. Ochi and Mr. M. Mizutani for the identification of some species.

Summary

In the spring of 1956 the authors visited the Tsushima Islands to investigate its bryophytic flora. They recognized 223 species of bryophytes on the islands. Tropical and sub-tropical species are moderately numerous because of the influence of the Tsushima Current. One third of the species are known also in Korea, but there is no species which is restricted to Tsushima and Korea. All our species also occur in Japan, and one third of them are restricted to Tsushima and Japan. The bryophytic flora of Tsushima is most similar to that of Japan rather than that of Korea.

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AN OBSERVATION ON THE ECOLOGICAL DISTRIBUTION OF PENDULOUS BRYOPHYTES IN THE TSUSHIMA ISLANDS

By Takemasa OSADA and Tairoku AMAKAWA

長田武正・尼川大録： 対馬に於ける懸垂苔類生態分布の一観察

In the field, bryologists often see that the bryophytic flora on different sides of a mountain are quite different. In the Tsushima Islands the authors came across a remarkable example of this fact.

In these islands the bryophytic flora on the lowland is quite sparse and abundant bryophytic vegetation occurs only near the summit of the mountains. Everywhere at an altitude of 400 m. above sea level, a dendroid moss, *Pterobryum arbuscula*, appears, and only above this altitude can we see a rich bryophytic vegetation, including many tropical and subtropical species. But below this altitude, in spite of well preserved primeval forests, the authors failed to find them. Among them there are some pendulous bryophytes such as *Pilotrichopsis dentata*, *Neckera flexiramea*, *Barbella asperifolia*, *Pseudobarbella kiushiuensis* and *Ptychanthus striatus*, and some epiphyllous liverworts such as *Tuyamaella molischii*, *Leptocolea japonica* and *Leptolejeunea subacuta*.

On Mt. Shiratake (519 m. high), the authors first found that those pendulous species are very rich on the ENE slope of the mountain, but not so on the WNW slope. On Mt. Tatera the contrast is even more remarkable. The ridge of this mountain lies about N70°E. On the NWN slope above 400 m. alt., all the tree trunks are so densely covered with bryophytes as to resemble the rich epiphytic moss community which is widespread in Southern Kyushu. This community reaches the summit, but on the SES slope we saw no pendulous bryophytes. In fact, only 10 or 20 meters below the summit, they disappear entirely.

As a cause of this remarkable distribution, a difference of light intensity may be surmised, but apparently the forests on both sides are quite similar, and do not exhibit any difference except the bryophytes on the tree trunks. The forest consists of such dominant evergreen trees as *Quercus acuta*, *Castanopsis cuspidata* and *Camellia japonica*, and a few deciduous ones. In the forest the lower stratum consists of *Carex* spp. and some orchids on the floor densely covered with fallen leaves. Here and there one can see some trunks completely covered with brown mats of *Haplohymenium longinerve* which, around the trunks, show no difference of grows due to exposure. This fact seems to

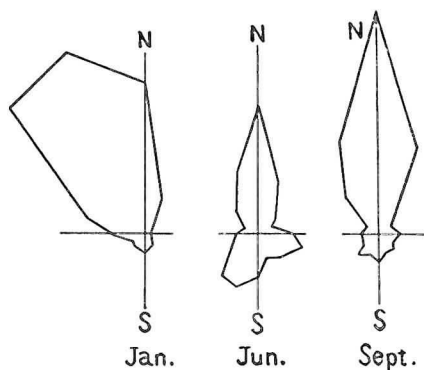


Fig. 1. Diagram showing the frequency of wind direction at Izuhara.

indicate that under the forest canopy only dispersed light comes through the dense crown of broad leaved evergreens and no direct solar illumination. The light intensity on both slope, as far as the interior layer of the community is concerned, apparently differs little.

Thus the authors come to conclude that such conspicuous local distribution is primarily due to the moisture carried by wind up the mountain slope. The climatic data recorded at Izuhara Meteorological Station (Table 1 & Fig. 1) seems to support this conclusion. Usually the wind in the islands blows from N-NW all the year round. It blows over the warm current which washes the coast of the islands, and ascends the N-W slope of these mountains, and produces sufficient moisture to maintain the mosses, particularly from November to February when humidity becomes minimum; but not so on the other side of the mountains, because the descending current of wind and solar radiation warm the internal air of the forests and reduce its humidity.

Table 1. Meteorological data at Izuhara (averaging 1896-1955).

Data	Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	(Annual)
Average Temperature (°C)		4.7	5.0	8.1	12.7	16.6	20.1	24.4	25.7	22.2	17.0	12.0	7.0	14.6
Precipitation (mm)		76.5	93.5	130.0	207.6	191.2	351.4	313.7	236.4	323.6	133.4	88.3	81.0	1855.5
Average Humidity (%)		65.2	66.2	68.7	73.2	75.7	82.2	84.7	82.5	79.4	72.7	70.5	66.8	74.0
Prominent Wind		NW	NW	N	N	N	N	N, SW	N	N	N	N	NW	

The ridge of Mt. Ariake (558 m. high) lies nearly N-S. Its eastern side is covered with a beautiful forest from foot to summit, and the bryophytic flora is not so sparse. *Neckera tosaensis* most common here, and *Pterobryum arbuscula* appears at an altitude of about 400 m. These species do not seem to be so dependent on the air humidity. The authors could find no pendulous mosses, but only a fragment of *Neckera flexiramea* creeping on the bark, and a small form of *Chrysocladium retrorsum* twining on bark and twigs near the summit. The western side of this mountain is destitute of such forest, and on its broad grassy slope we found only small deciduous shrubs and pines (*Pinus thunbergii*) scattered here and there. It would be impossible for pendulous bryophytes to grow there. Instead, one of us found the rare moss, *Sakuraia conchophylla*, on the bark of pines. He assumed, judging from its habitat, that this species needs sunlight in addition to high humidity from the ascending current of air.

In Southern Japan, stations for these pendulous bryophytes are not rare. From an ecological point of view, their habitats may be classified into two groups. One is a moist valley with sufficient humidity from its running streams. In such cases the habitat is not necessarily so high, (sometimes 100-200 m. or lower), as in the

cases of Inohae valley¹ near Nichinan in Miyazaki Pref. The other type is a mountain slope or summit as in the case seen in Tsushima and Wari'iwa² of Miyazaki Pref. In the latter case those species occur only above the altitude of which the ascending air current produces sufficient humidity to maintain plant life, and their habitat and abundance seem to be influenced by wind directions.

The authors wish to express their deep gratitude to Dr. S. Hattori and Dr. T. Hosokawa for their guidance and suggestions.

Summary

In the Tsushima Islands, the authors observed that the two sides of the mountains have quite different epiphytic bryophyte floras. Particularly the pendulous bryophytes show a remarkably limited distribution. Its cause may be due to a wind which ascends the slope of the mountain and carries along the necessary moisture for pendulous bryophytes. The habitats of those bryophytes may be classified into two groups from an ecological point of view.

¹ Cf. Iwatsuki & Hattori in Journ. Hattori Bot. Lab. 15: 105-133 (1955); 16: 83-102 (1956). ² Cf. Iwatsuki & Hattori, l.c. 16: 106-116 (1956).

STUDIES ON SPORE GERMINATION OF HEPATICAE

1. *Trichocoleopsis sacculata* (Mitt.) Okam.

By Hiroshi INOUE¹

井上 浩: 苔類胞子の発芽 1. ピロードゴケ

Trichocoleopsis belongs to the family Ptilidiaceae which includes *Herberta*, *Anthelia*, *Blepharostoma*, *Trichocolea*, *Neotrichocolea*, *Ptilidium*, and others (Dr. Evans (1939) listed 17 genera in this family), and seems to be a critical family containing phylogenetically distinct genera. Of these genera, *Trichocolea*, *Neotrichocolea* (formerly included in *Mastigophora*, *Ptilidium* and *Trichocoleopsis*) and *Trichocoleopsis* are closely related to each other, and the late Dr. T. Nakai (1943) established the family Trichocoleaceae for them instead of merging them in the family Ptilidiaceae. Dr. K. Müller (1954) separated this critical family into 5 families, and established the family Trichocoleaceae including *Trichocolea* and *Trichocoleopsis*.

Trichocoleopsis includes only one species, *T. sacculata*, which is known only from south-east Asia (Japan, Korea, Liukiu, Formosa, China, Burma). In Japan the sporophytes appear during April or May. The plants used for this study were collected in Mt. Kumotori (ca. 2000 m, on humus over rocks) in the Chichibu-mountains, Saitama Pref. These plants had some very young sporophytes, and were cultured in the laboratory for two weeks until spores were collected from them on 10 May. The spores were sown two days after being collected. The media for germination were: (1) Knop's agar, (2) Knop's solution, (3) unglazed plate soaked in Knop's solution, (4) sterilized soil moistened by Knop's solution. The best result was obtained with Knop's solution in which the spore germinated in four days and developed comparatively rapidly. In any cases the process of germination was hardly modified.

Germination

The spores are pale green, spherical, about 40μ in diameter, with a granular coat, and many chloroplasts were observed in the endospore (fig. 1). The spores do not require any rest period before germination (those sown on 13 May germinated on 18 May), and lose the ability to germinate in a few days (those sown a week after being collected did not germinate). On germination the spore coat swells and the endospore divides into two cells of equal size. The chloroplasts assemble at the median portion of the endospore and spread along new wall after the cell-division. Cell-division continues until there are 6-8 cells in the exospore. At the 5-8 celled stage of the exospore, rhizoid formation takes place (fig. 2). Rhizoid formation follows expansion of some portion of the exospore until it ruptures to liberate the rhizoid (fig. 3). Near the apical portion of the rhizoid chloroplasts are observed, and later they disappear. The number of rhizoid is usually 2-3, sometimes 1 or 4, and rhizoid formation is limited to half of the spore (figs. 5-6).

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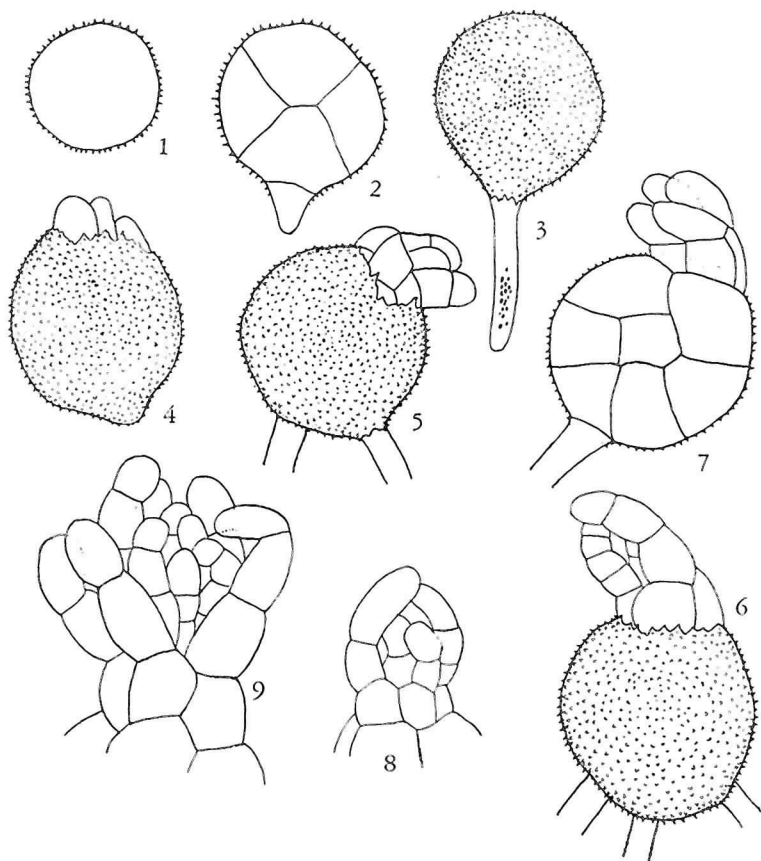
Slightly smaller cells are produced in the exospore opposite the developing rhizoid. At the 16–20 celled stage the portion opposite the rhizoid raises and ruptures to liberate the primary leaves (fig. 4–8). In some cases, primary leaves are formed before the rhizoids, but in this case the expansion of the exospore of primary leaf formation is larger than that of rhizoid formation (fig. 4). The primary leaves are always 4, short lineate and composed of 3–5 cells (fig. 8).

The cells of the primary leaf have many chloroplasts and 17–23 oil-bodies, each ellipsoidal, from $1-3\mu$ long, and without globules. The secondary leaves contain the oil-bodies and develop from the primary leaves which they resemble. The exospore remains throughout this development.

This detailed description of the development of leaves and underleaves will be published later.

Discussion

Our knowledge of the germination of leafy Hepaticae up to 1954 was summarized by Dr. M. Fulford (1954), who recognized 10 types. Of the Ptilidiaceae there were



Figs. 1–9. Various stages in spore germination in *T. sacculata*, $\times 360$. For explanation see text.

Trichocolea tomentella (Goebel 1951), *Blepharostoma trichophyllum* (Goebel 1915, M. Fulford 1955), and *Lepidolaena clavigera* (Goebel 1915). According to Dr. M. Fulford, the first two species are of the *Nardia*-type and the latter is of the *Frullania*-type.

Dr. Nakai (1943) and Dr. K. Müller (1954) included *Trichocolea* and *Trichocoleopsis* in the family Trichocoleaceae. However, the spore germination, as described above, is very different in the two genera, and it seems not to be proper to place them in a single family. Morphologically *Trichocoleopsis* is closely related to *Mastigophora* and *Lepidolaena*, especially to *Ptilidium* as mentioned by Dr. S. Okamura (1911) and Dr. S. Hattori (1947), but there are no data on the sporeling of *Ptilidium* and *Mastigophora*. As cited above, *Lepidolaena* is of the *Frullania*-type which includes some members of *Frullania*, *Porella* and *Lepidolaena*, and is the one most similar to that of *Trichocoleopsis*. But, according to Dr. M. Fulford, in the *Frullania*-type 50 or more cells are formed within the exospore and the primary leaves are plane and orbicular to broadly ovate in outline.

The characteristic points of the sporeling of *Trichocoleopsis sacculata* are as follows: the protonema develops in the exospore to about 20 cells, the primary leaves are always 4, and linear, and the following leaves are similar in shape. Thus I can distinguish the type of germination in *Trichocoleopsis sacculata* from the other type, and I wish to propose the *Trichocoleopsis*-type as a new type of sporeling. The family Ptilidiaceae poses many phylogenetic problems, and more data of sporeling are needed.

It is of interest that the oil-bodies are formed in the cells of the primary leaves. The oil-bodies are far smaller than those of mature leaves, and the globules are not recognized (in the mature leaves each cell has 20-30 oil-bodies with about 20 globules). According to my data on *Jungermannia lanceolata* and *Scapania stephanii* (unpublished), the oil-bodies are not in the cells of the protonema, but are in the primary leaves and stem (in *Jungermannia lanceolata* the oil-bodies are observed very rarely in some cells of the protonema), and they differ from those of mature plants. A detailed account of the oil-bodies will also be published later.

I wish to express my hearty thanks to Dr. S. Hattori for his very helpful suggestions.

Summary

The developmental pattern of the sporeling of *Trichocoleopsis sacculata* is described as a new type. Germination takes place in the exospore and in it the protonema develops to about 20 cells. The 4 primary leaves are linear and of 3-5 cells. The 1-4 rhizoids are limited to half of the spore circumference. The following leaves are similar to the primary leaves. Oil-bodies in the primary leaves are different from those of mature plant. A suggestion for non-inclusion of *Trichocolea* and *Trichocoleopsis* in a single family is given. The pattern is constant in spite of certain environmental variables.

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Errata

N. TAKAKI's Researches on the Brachytheciaceae of Japan and its adjacent areas, I~II

高木 典雄：日本及び近接地域産ヒツジゴケ科群類の研究 I~II 正誤

No.	Page	Line	For	Read
14	7	17	(1932)	(1931)
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"	23	6 from bottom	Nat. 379	Nat. ser. 7, Bot. 17: 379
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"	15	11	<i>robusta</i>	<i>robustum</i>
"	16	25	<i>laevisetum</i>	<i>laevisetum</i>
"	22	4	(Bruch.)	(Bruch.)
"	24	9 from bottom	U. S.	U. F.
"	25	3	U. S.	U. F.
"	39	Explanation of Fig. 20	13-14	13-24
"	"	"		Add: 23. Capsule ($\times 21$). 21. Portion of seta ($\times 35$).
"	43	20	(1909)	(1908)
"	44	17	(1909)	(1908)
"	57	Explanation of Fig. 26		Add: 24, 25. Capsules ($\times 12$).

BRYOLOGICAL MISCELLANIES, IV-VI

By Zennoske IWATSUKI¹

岩月善之助：蘚苔類雜記 4-6

4. Two additional genera for the known Japanese moss flora

A. *Physcomitrella californica* Crum et Anderson in The Bryologist 58: 4 (1955). (Fig. 1, a-g)

Recently, Mr. M. Mizutani kindly gave me a specimen of a moss belonging to the Funariaceae. It was one which I did not recognize but finally identified as *Physcomitrella californica*. This moss was found on muddy soil in a green house in which carnations had been cultivated, at Akashi, Central Japan. Only two genera, *Funaria* and *Physcomitrium*, among ten in the Funariaceae, had been reported from Japan before. Therefore the genus *Physcomitrella* is an addition to the known Japanese moss flora. It is distinct in having cleistocarpous thecae, though its phylloids are similar to those of *Physcomitrium*. The present species was recently separated from *P. patens* as new because of its broader phylloids with shorter costa, and its stouter beaks on the thecae. Only one other collection besides the type specimen was known from America in the past. Our materials compare well with the type material and with Crum and Anderson's description of it, with the exception of the diameter of the spores (30-32 μ).

Recently, I received a letter from Dr. Leo F. Koch who collected the type, and he had kindly sent my specimen to Drs. Crum and Anderson for comparison with it. He wrote to me that, "Although there is a definite difference in the spore sizes of the two collections, the gametophores are very similar. Dr. Crum believes they probably are the same species in spite of this difference of spore size. His idea is that when we discover additional material of the species, we may find that this variation of size of spore is not significant."

In Japan, *P. californica* is not abundant, and often is associated with *Physcomitrium* spp. and *Nanomitrium tenerum* (Bruch) Lindb. It sporulated every winter of the last 3 years in the same green house. However, it probably was introduced there with nursery stock from America or another country.

Coll. M. Mizutani, July 28, 1955; in Herb. Hattori Bot. Lab. no. 29598.

B. *Brachyodontium trichodes* (Weber f.) Bruch in Paris, Index Bryol. (Ed. 2) 1: 124 (1904). (Fig. 1, h-q).

In the summer of 1955, I collected this minute, rare moss in the alpine zone of Mt. Tateyama, central Japan. It was found on the vertical surface of an acid rock on the fairly sunny slope of a snow valley, at ca. 2400 m. above sea level. Formerly Dr. N. Takaki reported *Seligeria pusilla*, a genus related to *Brachyodontium*, from Shiroiwa as a calciphilous moss. *B. trichodes* usually grows on acid rocks at higher altitudes also in Europe and N. America, and is easily distinguished from *Seligeria*

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in having plicate, cylindrical thecae, a well developed annulus and short, truncate peristome teeth.

Coll. Z. Iwatsuki, Aug. 19, 1955; in Herb. Hattori Bot. Lab. no. 28734.

5. Distribution of three rare species in southern Japan

A. *Macromitrium holomitrioides* Noguchi in Jour. Sci. Hiroshima Univ. Ser. B, Div. 2, 3: 1, pl. 13 (1938).

Hab. On tree trunk, along stream, ca. 150 m. alt. above sea level, Inohae Valley, Miyazaki Pref. (Coll. Z. Iwatsuki, Feb. 21, 1956, in Herb. Hattori Bot. Lab. no. 29646).

The present species is another addition to the known Japanese moss flora, as previously been recorded only from Formosa.

B. *Diphyscium ryukyense* Noguchi in Jour. Jap. Bot. 11: 272 (1953); N. Takaki in Jour. Jap. Bot. 25: 188 (1950).

Hab. On sandstone rocks in shade, on the floor of a broad-leaved forest near the sea coast, ca. 50 m. alt., Udo, Nichinan, Miyazaki Pref. (Coll. Z. Iwatsuki, Feb. 25, 1956; in Herb. Hattori Bot. Lab. nos. 29151, 29648); among conglomerate in shade, beneath a evergreen forest, Mt. Ogasa, Shizuoka Pref. (Coll. N. Takaki, March 18, 1956; in Herb. N. Takaki, no. 16998).

The above cited locality is the northernmost station of the present species. Previously, it was reported only once from a locality in Ryūkyū. At Udo, it is present in fairly large tufts on sandstone in shady places in the forest, and it often occurs with *Distichophyllum maibarae* Besch. This record constitutes an extension of the known range of *D. ryukyense*.

C. *Lopidium javanicum* Hampe in Linn. p. 672 (1874); Horikawa in Bot. Mag. Tokyo 48: 607 (1934); Noguchi in Jour. Hattori Bot. Lab. 7: 1 (1952).

Hab. On trunk of tree, ca. 300 m. above sea level, Suzukawa, Isl. Yakushima (Coll. K. Mayehara no. 1533, July 30, 1951; in Herb. Hattori Bot. Lab. no. 23876).

This moss has not been rediscovered in Japan, since Dr. Y. Horikawa reported it from Kii (Honshū) and Ryūkyū. Dr. A. Noguchi, in his monograph of Hypopterygiaceae in Japan, reported only one station for it in Formosa. So, this second locality in Japan, partly fills the gap in the known distribution of this fine moss.

6. Notes of Japanese *Syrrhopodon*

A. *Syrrhopodon yakushimensis* Takaki et Iwatsuki, spec. nov. (Fig. 2, a-j)

Sterilis. Planta mediocris, ± mollis, opaca, lutescenti-viridis, inferne fusca. Caulis adscendens, 1.2~2.0 mm. longus, nigrescens, tenuis, ad 0.2 mm. latus, basi paulum radiculosus, simplex vel parce ramosus, laxiuscule foliosus. Folia sicca circinata vel crispata, madida erecto-patentia, apice ± arcuato-inflexa, e basi vaginante

Fig. 1. a-g. *Physcomitrella californica* Crum et Anderson. h-q. *Brachyodontium trichodes* (Weber f.) Bruch. a. Plants (×1.5). b. Do. (×7). c. Upper phylloid (×35). d. Lower phylloid (×35). e. Areolation of upper-phylloid-margin (×150). f. Calyptra (×35). g. Spore (×500). h. Plant (×15). i. Do. (×35). j-k. Phylloids (×50). l. Apical part of phylloid (×350). m. Areolation of lower part of phylloid (×350). n. Calyptra (×70). o. Operculum (×70). p. Annulus (×230). q. Spores (×500).

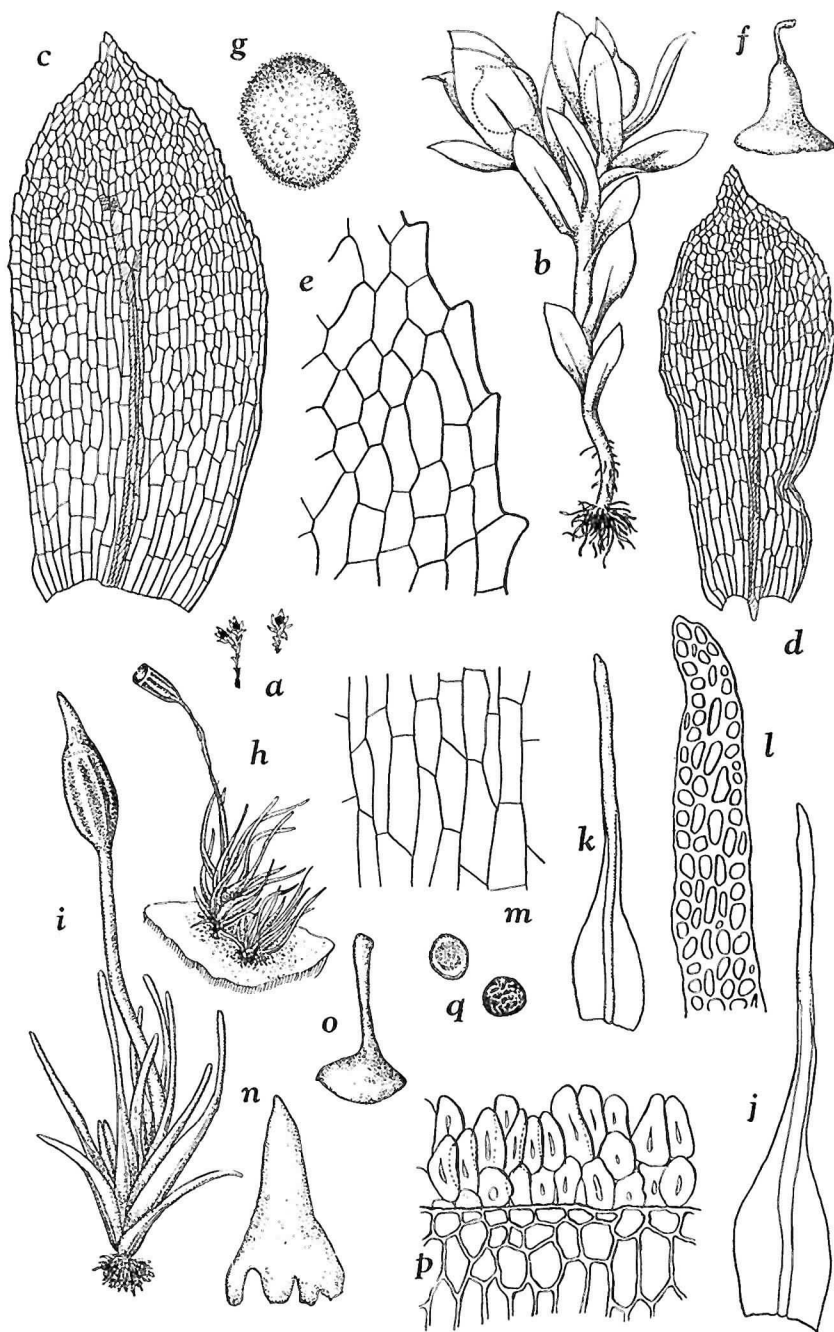


Fig. 1.

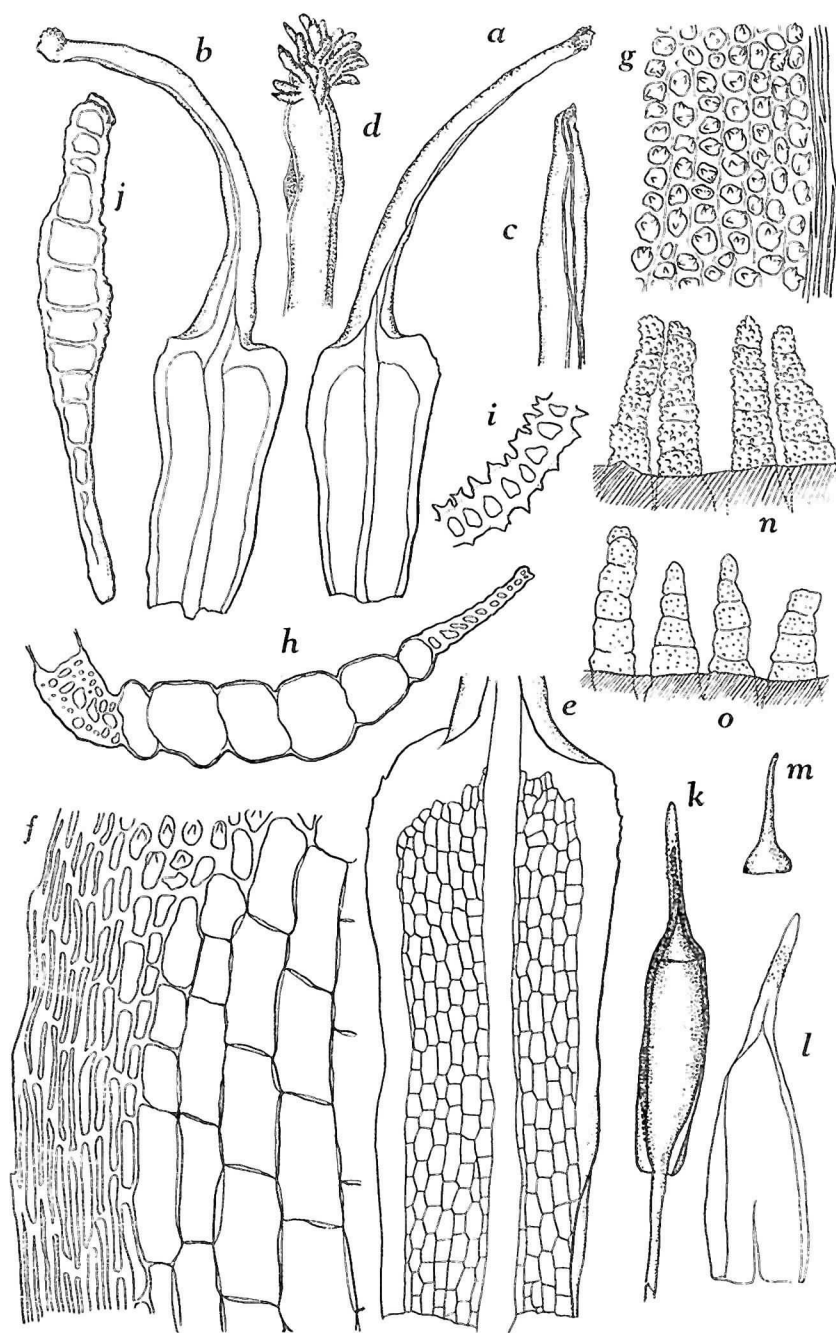


Fig. 2.

sensim versus in laminam lanceolatam attenuata, marginibus valde involutis, $2.5 \times 0.3 \sim 3.3 \times 0.5$ mm. (vagina ca. 1.0 mm. longa), apice obtusa (propagulifera) vel acuta, propagulis fusiformibus, ca. 0.15 mm. longis, papillois; folia anguste limbata, limbo distincto, continuo, e cellulis anguste linearibus, pellucidis composito, ipso vaginae valido, 6~10 cellulas anguste lineares lutescentes lato, superiore minutissime serriato. Costa valida, continua, laevis, ad basin $40 \sim 60 \mu$ lata, saepe rubiginosa. Cellulae laminae obscurae, quadrato-hexagonae vel quadratae, parietibus valde incrassatis, lumine $8 \sim 10 \sim 14 \mu$ in diam., alte papilloso, papillis plerumque stelliformibus, cancellina e cellulis laxis rectangularibus vel quadratis hyalinis, $30 \times 20 \sim 80 \times 30 \mu$, parietibus tenuissimis composita. Caetera ignota.

Hab. On bark of tree, at Odakumi, Isl. Yakushima, Kyushu (Coll. H. Hasegawa and M. Fukuhara, April 14, 1950; in Herb. N. Takaki no. 8525-Holotype and in Herb. Hattori Bot. Lab. no. 29647-Isotype).

This species is easily distinguished from others by means of its phylloids which are widely incurved above the sheath, and its minutely serrate sheath.

B. **Sporophyte of *Syrrhopodon tosaensis* Card.** (in Bull. Herb. Boiss. 7: 716, 1907).

S. tosaensis has a known distribution in southern Japan, Ryūkyū and Formosa. It is rare in Japan, and its sporophyte was unknown. This specimen collected in Inohae, southern Kyūshū, bore many sporophytes, and some details of the plant are as follows.

Dioicous (?); seta terminal, erect, elongate and smooth, 7~9 mm. long, brown above, yellowish-brown below, fragile. Perichaetial phylloids about like those of axis. Theca erect, regular, cylindrical, chestnut-colored, 0.8~1 mm. long; peristome teeth 16, lanceolate, papillose (sometimes smooth or finely papillose); operculum long rostrate; calyptra cucullate, descending to base of theca, the apex rough. Male plant not found.

Comparing it with the sporophyte of *S. tushimae* Card. which also is found in southern Japan, the present species is distinguishable in having a calyptra which extends to the base of the theca.

I wish to express my appreciation to Drs. S. Hattori, A. Noguchi and N. Takaki for their constant guidance of my work. I am also indebted to Dr. Leo F. Koch for his helpful suggestions.

Fig. 2. a-j. *Syrrhopodon yakushimensis* Takaki et Iwatsuki k-o. *Syrrhopodon tosaensis* Card. a-b. Phylloids ($\times 30$). c. Apical part of phylloid ($\times 70$). d. Do. bearing propagula ($\times 70$). e. Base of phylloid ($\times 70$). f. Areolation of upper phylloid-base ($\times 350$). g. Areolation of upper phylloid-margin ($\times 350$). h. Cross-section of phylloid-base ($\times 350$). i. Cross-section of median part of phylloid ($\times 350$). j. Propagulum ($\times 350$). k. Theca ($\times 30$). l. Calyptra ($\times 30$). m. Operculum ($\times 30$). n-o. Peristome ($\times 350$).

COLOLEJEUNEA HASKARLIANA AND ITS ALLIED SPECIES IN JAPAN

By Tsutomu KODAMA¹

見玉 務: 日本産ウニバコージョーゴケとその近縁種

Five species of the section *Venustae* of subgenus *Lasiolejeunea* Benedix have been reported from Japan. They are *Cololejeunea spinosa* (Horikawa) Pande et Misra, *C. venusta* (Sde. Lac.) Schiffn., *C. nakajimae* Hatt., *C. yamanakana* Kamimura and *C. kodamae* Kamimura. But the specific characteristics described by the original authors are inadequate and need to be supplemented.

The writer examined Japanese material, and placed them in the following taxa: *C. haskarliana* var. *haskarliana*, *C. haskarliana* var. *spinosa*, *C. haskarliana* var. *nakajimae*, *C. kodamae* and *C. yamanakana*.

I wish to express my sincere thanks to Dr. S. Hattori for his kind guidance, Dr. W. Meijer for his sending Malayan material of *Cololejeunea*, and to Messrs. Y. Ikegami, T. Amakawa and H. Inoue for their help in many ways.

Key to species and varieties.

- A. Stylus large, consisting of more than 3 cells, rarely inconspicuous, each cell of the ventral lobe with a spinose papilla. *C. yamanakana*
- AA. Stylus inconspicuous.
 - B. Each cells of the ventral lobe lacking papillae.
 - C. Leaves acuminate, or rarely acute, at the apex, papillae on the dorsal leaf-surface shorter, 10-14 μ long, occurring on bark and leaves of trees. *C. haskarliana* var. *nakajimae*
 - CC. Leaves rotundate to subacute at the apex, papillae on the dorsal leaf-surface longer, 17-23 μ long.
 - D. Dorsal lobe 350-450 μ long, 200-330 μ wide, rotundate at the apex, ventral lobe abruptly inflated at the basal part, apical teeth frequently crossing one another. *C. haskarliana* var. *haskarliana*
 - DD. Dorsal lobe 270-400 μ long, 180-270 μ wide, usually subacute at the apex, ventral lobe not abruptly inflated at the basal part, apical teeth not crossing. *C. haskarliana* var. *spinosa*
- BB. Cells along keelar region of the ventral lobe with subconical papillae, usually on bark or rocks. *C. kodamae*

Cololejeunea haskarliana (Gott.) Benedix var. *haskarliana* (Fig. 1)

Lejeunea haskarliana Gott. Syn. Hep. 346 (1844).

Lejeunea venusta S. Lac. Syn. Hep. Jav. 64 (1856).

Cololejeunea venusta Schiffn. Nat. Pfl-Fam. 1-3, 122 (1895).

Plants scattered or in small, shallow patches, pale green; leafy shoot 800-900 μ wide. Stems prostrate, about 70 μ thick, irregularly branched; branches rather few

¹ Osaka Municipal Museum of Natural History, also Hattori Botanical Laboratory.

² Fedd. Repert. 134: 56 (1953).

to many, widely spreading, much like the main shoot; subfloral innovation 1. Leaves distant to imbricate. Keel usually quite short, but variable in length due to usually reduced ventral lobes; on leaves with well-developed ventral lobes the keel convex, 180-200 μ long, strongly denticulate due to projecting cells. Dorsal lobe spreading, ovate, more or less falcate, 350-450 μ long, 200-330 μ wide, 2-2.4 times as long as the well-developed ventral lobe, plane or slightly convex dorsally; apex obtuse; the dorsal surface densely spinose; papillae spinose; margin with spinose, projecting cells. Well-developed ventral lobe ovate, 175-200 μ long, 115-125 μ wide, smooth

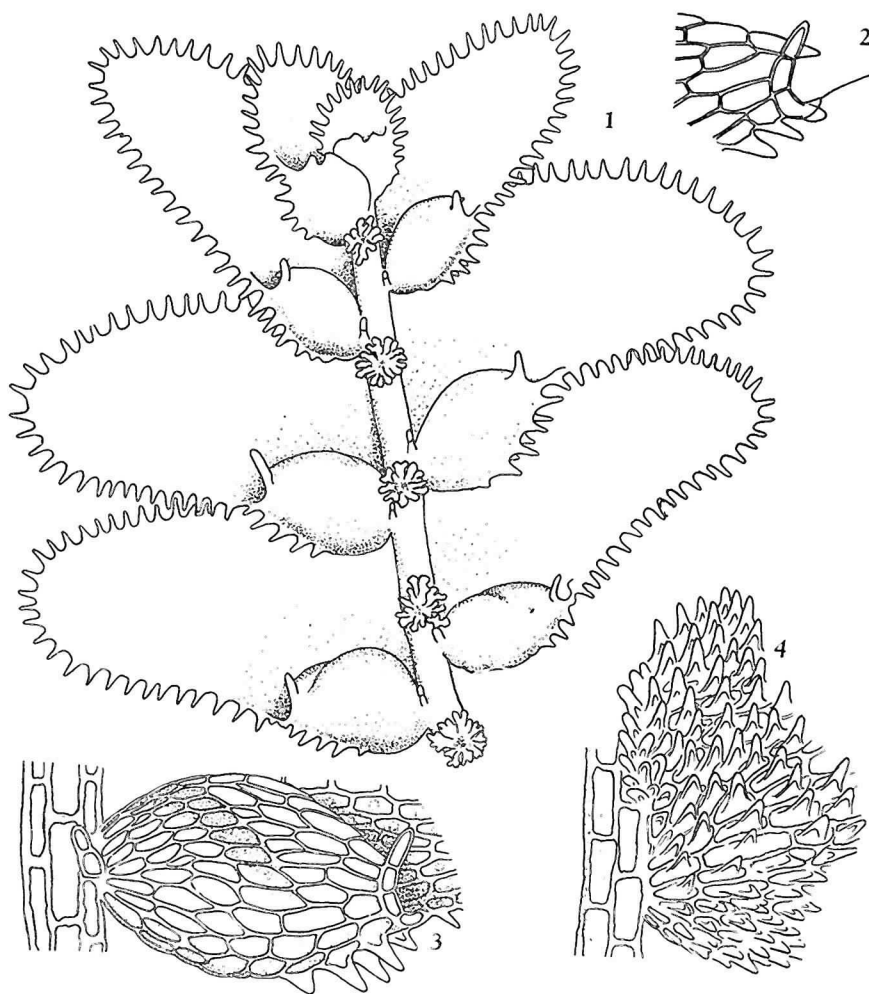


Fig. 1. *Cololejeunea haskarliana* var. *haskarliana*

1. Upper part of sterile shoot ($\times 253$). 2-3. Ventral leaf-lobes, ventral view ($\times 456$). 4. Basal part of leaf, dorsal view ($\times 456$). All drawn by T. Kodama from the specimen T. Amano 6760.

(lacking papillae), abruptly inflated at the basal part, narrower at the apex; apex with 2 teeth, the distal tooth more or less reduced and hidden within the proximal one, or well-developed distal tooth frequently crossing the proximal one. Stylus 1 or 2 cells, inconspicuous. Cells of middle of the dorsal lobe, $16 \times 18 \mu$, of margin $9 \times 10 \mu$, of base $16 \times 20 \mu$, constituted mostly of thickened wall, every cell with a single spine-like dorsal papilla, papillae $18 \times 22 \mu$ long, trigones wanting; paracysts wanting; vitta indistinct, composed of 2-5 cells in one row, each cell about 33μ long, about 16μ wide, cells with weak papillae. Underleaves wanting. (The description is based on a sterile specimen from Liukiu collected by T. Amano).

Range: Malay Archip., Formosa, Liukius.

***Cololejeunea haskarliana* var. *spinosa* (Horik.) Kodama, comb. nov. (Fig. 2)**

Cololejeunea remusta (non S. Lac.) Evans in Proc. Acad. Sci. 8: 146 (1906).

Physocolea spinosa Horik. in Journ. Sci. Hiroshima Univ. Ser. B, Div. 2, 1: 71 (1931).

Cololejeunea spinosa Pande et Misra in Journ. Ind. Bot. Soc. 15: 166 (1936); Hatt. in Bull. Tokyo Sci. Mus. 11: 102 (1944); Journ. Hattori Bot. Lab. 8: 38 (1952).

Quite similar to var. *haskarliana*; leafy shoot 650-830 μ wide. Stems about 60-65 μ thick, irregularly branched. Leaves distant to imbricate. Well-developed keels convex, 180-200 μ long, strongly denticulate due to projecting cells. Dorsal lobe spreading, ovate, not or slightly convex dorsally; apex subacute, or rarely acute, the dorsal surface densely spinose. Well-developed ventral lobe ovate, about 220-240 μ long, 120-150 μ wide, smooth (lacking papillae), more or less inflated along the keel; apex with 2 teeth, the distal tooth usually reduced and minute in size, 1-celled, the proximal one long, and straight, composed of 2 cells; hyaline cell on the inner surface at base of the proximal tooth; margin strongly spinose due to projecting cells. Stylus very inconspicuous, 1-celled, often disappearing. Cells of middle of the dorsal lobe about $13 \times 16 \mu$, of margin about $10 \times 13 \mu$, of base $16 \times 18 \mu$, each cell with a single spine-like dorsal papilla, 17-23 μ long; trigones wanting; vitta indistinct, composed of 2-5 cells in one row, each cell 22-26 μ long, 16 μ wide. Gemmae discoid, rare. Underleaves wanting. Plants bisexual. Male inflorescence on short lateral or elongate branch, not proliferating. Male bracts 3-6, similar to the cauline leaves; ventral lobe a little larger in proportion to the dorsal one than in the cauline leaves; antheridium 1. Female inflorescence on more or less elongate branch. Female bracts smaller or larger than stem leaves, rather firmly folding the perianth, erect-spreading, more or less complicately 2-lobed; the dorsal surface as the leaves; dorsal lobe 270-350 μ long, 180-250 μ wide; ventral lobe ovate or ovate-triangular, with dense papillae, margin spinose due to projecting cells. Perianth obovoid, 400-600 μ long, 250-450 μ wide, bluntly 5-keeled in the upper half or more when young, strongly inflated and practically without keels when matured, rounded to truncate at the apex, surface greatly roughened due to projecting cells, mouth beakless, or slightly beaked.

Fig. 2. *Cololejeunea haskarliana* var. *spinosa*

1. Upper part of fertile plant with male and female organs ($\times 253$).
 - 2-4. Leaves ($\times 456$).
 5. Young leaf ($\times 456$).
 6. Basal part of leaf, dorsal view ($\times 456$).
 7. Upper part of young plant ($\times 253$).
- Figs. 1-4, 6 from T. Kodama 7872; figs. 5, 7 from S. Hattori 10754. All drawn by T. Kodama.

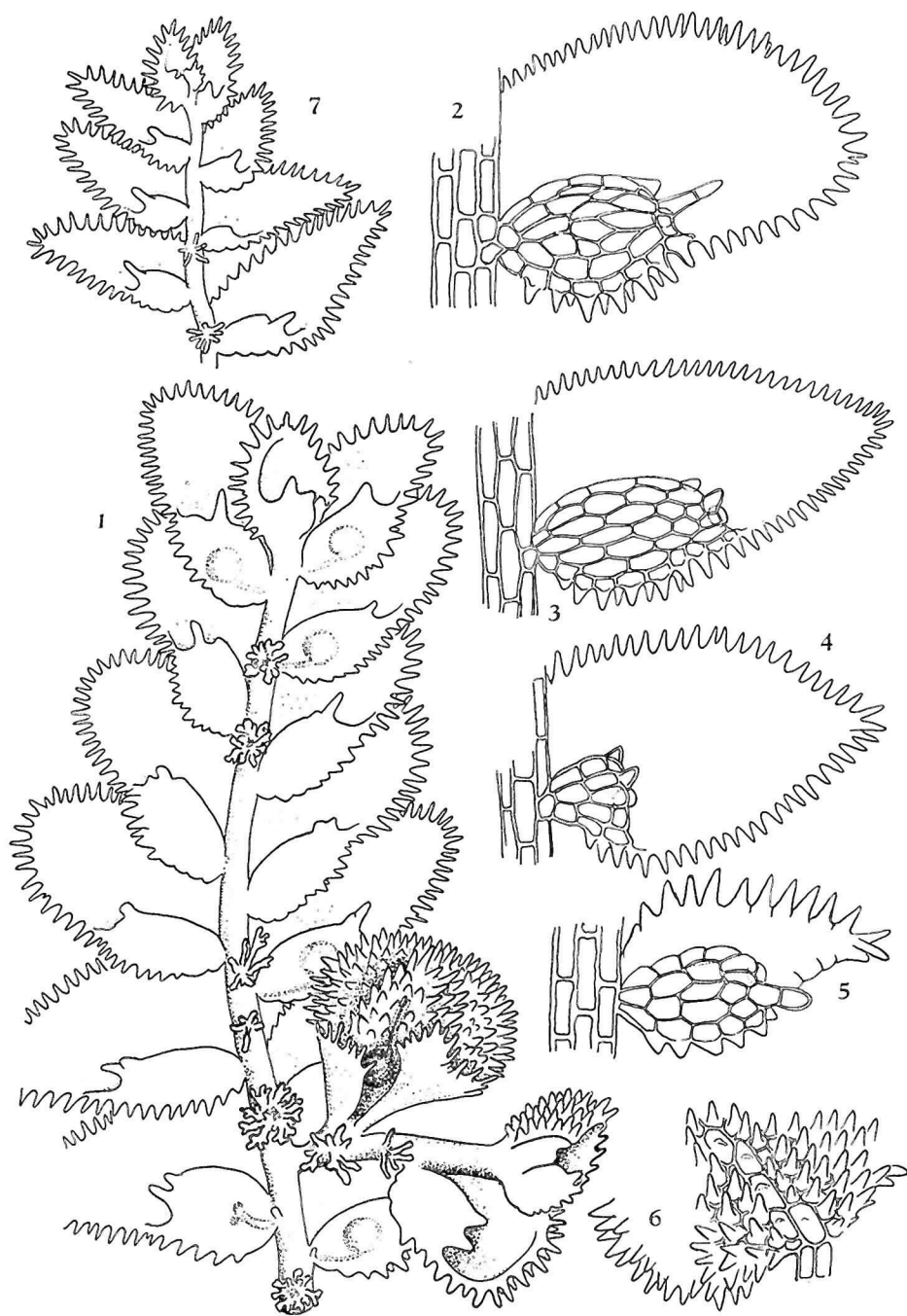


Fig. 2.

Specim. Exam. **Honshū.** Pref. **Niigata:** Kanazu, 40 m. on *Hymenophyllum*, Y. Ikegami 1894. Pref. **Chiba:** Mt. Kiyosumi, on *Hymenophyllum*, S. Asano. Pref. **Shizuoka:** Jōrendaki, on *Hymenophyllum*, T. Ichikawa; Kamikawazu, on *Hymenophyllum*, S. Kurata. Pref. **Aichi:** Miwa, on leaves of *Aucuba japonica* and *Hymenophyllum*, K. Torii. Pref. **Mie:** Gegū, 40 m, on thallus of *Conocepharum conicum*, T. Kodama, 2964; Akame, on *Hymenophyllum*, M. Yamanaka 352; Binnoyama, on *Hymenophyllum*, T. K. 2819; Owashi, 100 m., on leaves of *Alpinia japonica* etc., T.K. 10401; Mifune, on *Hymenophyllum*, K. Seto 4470. Pref. **Wakayama:** Komoridani, on *Hymenophyllum*, K. Seto 5964; Dorokyō, on ferns, T.K. 91; Kitayama, on ferns, T.K. 826; Nachi, 200 m, on *Hymenophyllum* etc., T.K. 7872. Pref. **Nara:** Mt. Kasuga, 200 m., on leaves of *Carex*, *Hymenophyllum*, T.K. 4933, on mosses, T. K. 5390; Murōji, 300 m., on *Hymenophyllum*, K.S. Pref. **Osaka:** Amami, 350 m., on *Hymenophyllum*, T.K. 3460. Pref. **Hyōgo:** Tomisu, on *Hymenophyllum*, E. Tatebe; Mt. Funakoshi, 400 m., on *Hymenophyllum*, T.K. 4485. **Shikoku.** Pref. **Tokushima:** Kawakami, on leaves of *Abies firma*, T. Hinode. Pref. **Kōchi:** on ferns, *Bladhia villosa* etc., K. Seto; Ogawa, on leaves of *Damnacanthus indicus*, *Ircx latifolia*, T. Yoshinaga, as *Cololejeunea venusta*; Higashikawa, on *Hymenophyllum*, T. Yoshinaga; Kitagawa, on ferns, H. Inoue 388. **Kyūshū.** Pref. **Oita:** Shinyabakei, on *Hymenophyllum*, Ono 1374. Pref. **Kumamoto:** Nishinomura, on *Hymenophyllum*, K. Mayebara 822; Mt. Ichifusa, 800 m., on *Carex*, K.M. 2618; Ichibu, 100 m., on thallus of *Conocepharum conicum*, K.M. 2895. Pref. **Miyazaki:** Mt. Osuzu, on *Hymenophyllum*, T. Amakawa 727; Sakatani, 500 m., on ferns, S. Hattori 10780; Obi, on ferns, S.H. 10015. Pref. **Kagoshima:** Isl. Yakushima, on ferns, K.M. 7084; Mt. Takakuma, 600–700 m., on *Hymenophyllum*, T.A. 1706; Kagoshima, on *Hymenophyllum*, T. Shin 3310.

Range: Japan (Honshū, Shikoku, Kyūshū).

Judging from Horikawa's description of *Physocolea spinosa*, the type seems to be a weak plant with minute ventral lobes. Such minute ventral lobes normally are present on a weak or rudimentary shoot. Horikawa described this plant as unisexual, but bisexual plants are common.

This variety appears similar, and is closely allied, to var. *haskarlana*. But it differs in smaller size, usually subacute leaves, not so convex surface of ventral lobe and its geographical range. The present variety is known from southwestern Japan, Lat. 30–38°N., whereas var. *haskarlana* is in tropical Asia and its northernmost station is in the Liukiu Islands, Lat. about 28°N.

Cololejeunea haskarlana var. *nakajimae* (Hatt.) Kodama, comb. nov.

(Fig. 3:1–6)

Cololejeunea nakajimae Hatt. in Journ. Hattori Bot. Lab. 10: 57 (1953).

Plant similar to *C. kodamae*; with a leafy shoot 600–800 μ wide. Stems about 40 μ thick, branches as in var. *spinosa*. Leaves distant, or somewhat imbricate.

Fig. 3. *Cololejeunea haskarlana* var. *nakajimae* (1–5) and *C. kodamae* (7–11)

1. Fertile shoot with male and female organs ($\times 106$). 2. Middle part of sterile shoot ($\times 106$). 3. Ventral leaf-lobe ($\times 500$). 4. Basal part of leaf, showing stylus ($\times 405$). 5. Basal part of leaf, dorsal view ($\times 380$). 6. Gemma ($\times 600$). 7. Female shoot with young perianth ($\times 152$). 8. Apical part of ventral lobe, showing hyline cell (h) ($\times 500$). 9. Leaf, ventral view ($\times 326$). 10. Antical margine of leaf ($\times 326$). 11. Male shoot ($\times 152$). Fig. 1 was drawn from specim. T. K. 9864; 2–6 from T. K. 9764; 7–8 from T. K. 7349; 9–11 from T. K. 7545. All drawn by T. Kodama.

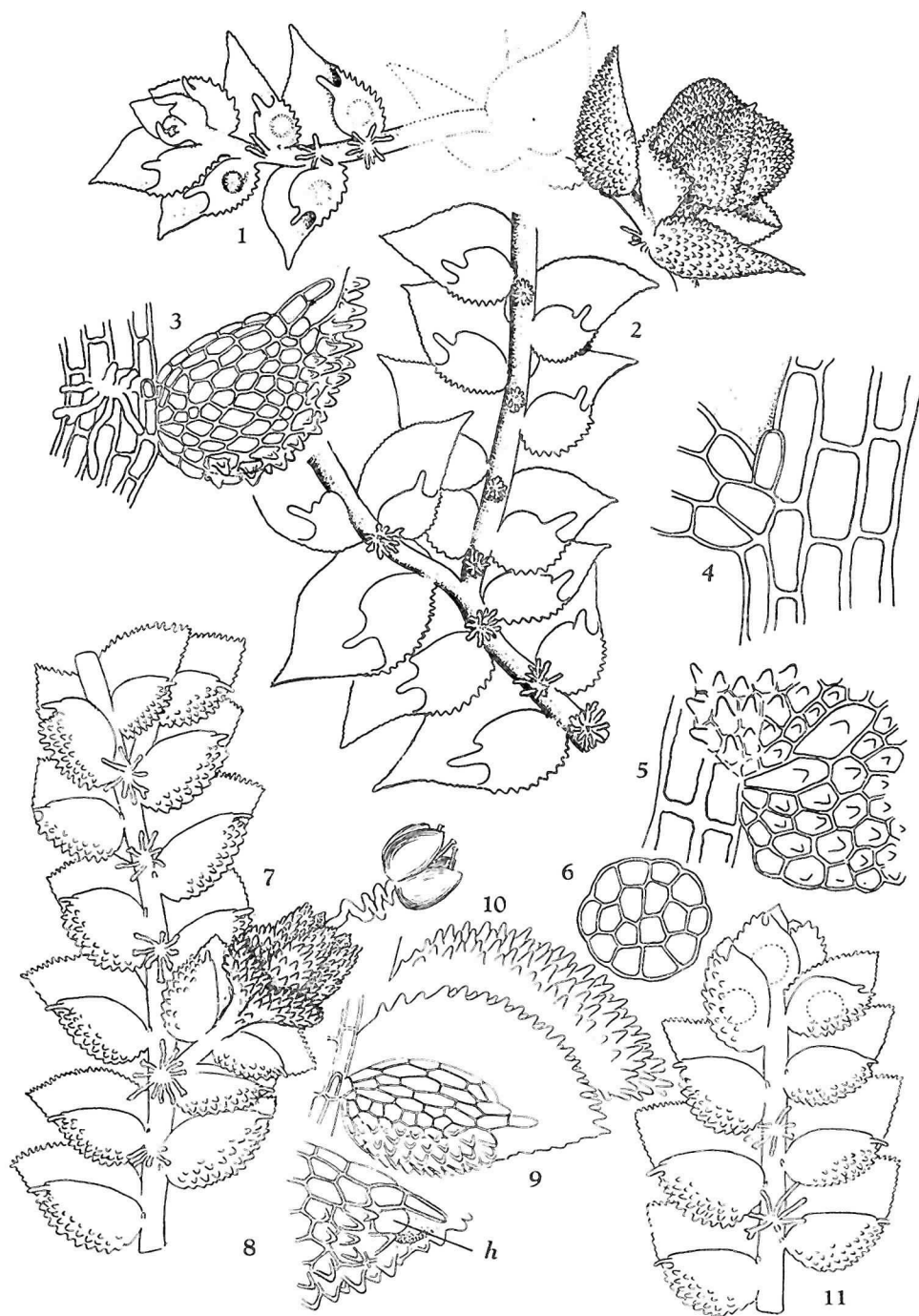


Fig. 3.

Keel similar to that in var. *spinosa*, about $200\ \mu$ long, denticulate due to projecting cells. Dorsal lobe ovate, more or less falcate, $280\text{--}330\ \mu$ long, $150\text{--}210\ \mu$ wide, 1.6–2 times as long as ventral lobe, flat or slightly convex dorsally; apex acuminate or rarely acute; the dorsal surface shortly spinose with conical papillae. Ventral lobe ovate, $220\text{--}240\ \mu$ long, about $150\ \mu$ wide, surface smooth (papillae lacking); apex with 2 teeth as in var. *spinosa*, distal tooth usually reduced and hardly visible; margin denticulate due to projecting cells except near the base. Stylus composed of 1 or 2 cells, inconspicuous. Cells of the middle part of the dorsal lobe about $13\times 16\ \mu$, of the margin about $8\times 10\ \mu$, nearly every cell with a conical papilla, papillae $10\text{--}14\ \mu$ long; trigones wanting; vitta rather indistinct, composed of 2–4 cells in one low, each cell $20\text{--}22\ \mu$ long, $16\ \mu$ wide. Gemmae discoid, normally 16-celled, $50\ \mu$ in diameter, organs for attachment uncertain. Plants bisexual. Male and female organs similar to those of var. *spinosa*.

Specim. exam. Honshū. Pref. Niigata: Nakasato, 80 m., on bark of *Rhododendron*, Y. Ikegami 9035; Sugidani, 350 m., on tree trunk, Ch. Sato 3269; Tsuchidaru, 900 m., on bark, Y.I. 18055; Mt. Kurohime, 1000 m., on leaves and branches of *Cephalotaxus*, Y.I. 26722; Isl. Sado, 250 m., on bark, K. Homma 1765; Seisui-tōge, 350 m., on bark, K.H. 913 b. Pref. Shiga: Mt. Hira, 950 m., on shrub, T. Kodama 9861, on leaves and branches of *Cephalotaxus*, T.K. 9764, on trunk of *Fagus crenata*, T.K. 9872. Pref. Kyōto: Daihizan, 300 m., on leaves and branches of *Cephalotaxus*, T. Nakajima 262-typus, 500 m., on branches of *Deutzia*, T. Kokama 10897.

Range: Japan (Honshū).

The present variety differs from var. *spinosa* in its smaller size, distinctly acuminate leaves, shorter papillae on the antical surface of the dorsal lobe and in its occurrence in more northern, snowy areas of Japan, Lat. $35\text{--}38^{\circ}\text{N}$.

Cololejeunea kadamae Kaminura in Fedd. Report. 58: 55 (1954). (Fig. 3:7–11)

Cololejeunea venusta (non S. Lac.) auct.—quoad plant. Japan.

Plants in small shallow patches, green or rather dark green; leafy shoot $350\text{--}550\ \mu$ wide. Stems prostrate, about $30\text{--}35\ \mu$ thick, irregularly branched; branches similar to *C. haskarliana*. Leaves imbricate. Keel distinctly convex, $180\text{--}200\ \mu$ long, denticulate due to projecting cells. Dorsal lobe spreading, ovate, little or not at all falcate, $150\text{--}280\ \mu$ long, $100\text{--}200\ \mu$ wide, 1.5–1.9 times as long as the ventral lobe, more or less convex dorsally; apex acute; the dorsal surface shortly spinose with conical papillae; margin denticulate due to projecting cells. Ventral lobe ovate, $90\text{--}120\ \mu$ long, $70\text{--}80\ \mu$ wide, strongly inflated, with papillae along keelar region; apex with 2 teeth; the distal tooth 1-celled, and smaller, the proximal one, larger, and composed of 2 cells, both acute and curved; hyaline cell on inner surface at base of the proximal tooth. Stylus inconspicuous, composed of 1-cell, often disappearing. Cells of middle of the dorsal lobe about $9\times 11\ \mu$, of margin about $8\times 10\ \mu$, of base $12\times 14\ \mu$, each cell with a conical papilla, papillae $7\text{--}10\ \mu$ long; cell walls usually thick; trigones wanting; vitta indistinct, composed of 2–4 cells in one low, each cell $16\text{--}18\ \mu$ long, about $10\ \mu$ wide, with low papillae dorsally, Gemmae discoid, normally 16-celled, about $50\text{--}60\ \mu$ in diameter, organs for attachment uncertain. Plants bisexual. Male and female organs similar to those of *C. haskarliana*, but smaller in size; female bract $200\text{--}250\ \mu$ long, $70\text{--}90\ \mu$ wide; perianth about $200\text{--}300\ \mu$ long, $210\text{--}300\ \mu$ wide.

Specim exam. **Hokkaidō**: Isl. Rebun, 200 m., on trunk of *Abies sachalinensis*, D. Shimizu 53428; Mt. Apoi, 810 m. on ledge of serpentine, D. Shimizu 54656, sub *C. nakajimae*.

Honshū. Pref. **Fukushima**: Eda, 350 m., on bark of *Abies firma*, Y. Ikegami 34379. Pref. **Niigata**: Isl. Sado, on boulder, K. Homma 2647. Pref. **Shizuoka**: Funabara Onsen, 300 m., on *Hymenophyllum*, T. Haneda 1388. Pref. **Shiga**: Mt. Hiei, 600 m. on rock, T. Kodama 6410; Miidera, on rock, M. Hutoh. Pref. **Kyōto**: Mt. Daihizan, 450 m., on tree base, T.K. 10839; Kyōto, on tree base, T.K. 6297, on tree base, T.K. 10661. Pref. **Ōsaka**: Minō, 100-150 m., on tree base, T.K. 3468; Mt. Inunaki, 250 m., on tree base, T.K. 7333; Iwafune, 100-150 m., on tree base, T.K. 10279; Yamanakadani, 200 m., on tree base, T.K. 8649. Pref. **Nara**: Mt. Kasuga, 300 m., on tree base, T.K. 5380, on boulder, T.K. 7314; Imoyama, 150 m., on fallen wood, T.K. 10502; Mt. Odaigahara, 600 m., on *Hymenophyllum*, T.K. 4680 (the type of *C. kodamae*); Mt. Sanjō, 850 m., on *Hymenophyllum*, T.K. 8729; Kawakami, 400-500 m., on *Hymenophyllum*, T.K. 9094. Pref. **Mie**: Akame, 500 m., on tree base, T.K. 6133; Gegū, 300 m., on tree base, T.K. 5465; Nakajima, 100 m., on rock, T.K. 5636; Takiharanomiya, 110 m., decaying wood, T.K. 10294; Mt. Yakiyama, 550 m., fallen wood, T.K. 7900. Pref. **Wakayama**: Isl. Tomogashima, 20 m., on rock, T.K. 7535. Pref. **Hyōgo**: Mt. Funakoshi, on *Hymenophyllum*, Y. Tatebe 91; Mt. Koganegadake, 600 m., on tree base, T.K. 7773. Pref. **Shimane**: Senjōkei, on rock, T. Amakawa 1425.

Shikoku. Pref. **Kōchi**: Amatsubo, 400 m., on *Hymenophyllum*, M. Kamimura.

Kyūshū. Pref. **Miyazaki**: Toimisaki, fallen wood, S. Hattori 10575; Hinokage, 600 m., on bark, Y. Kuwahara 1647; Kadogawa, 30 m., rock, T. Amakawa 318; Mt. Ōgue, 700 m., on tree trunk, T.A. 1111; Tōgō, on fern, T.A. 579. Pref. **Kumamoto**: Mt. Ichifusa, 900 m., decaying wood, K. Mayebara 2470; Hitoyoshi, 450 m., on *Hymenophyllum*, K.M. 2840.

Range: Japan (Hokkaidō, Honshū, Shikoku, Kyūshū).

C. kodamae resembles to *C. haskarliana* var. *nakajimae* in its size, acute leaves, and short conical papillae, but is distinct from the latter in the presence of papillae along the keelar region of the ventral lobe. However, such characters may be caused by environmental conditions, because (1) minute and acute leaves are usually found in both corticolous and rupicolous plants, while the large and obtuse leaves are found in epiphyllous ones; (2) *C. kodamae* is usually found on rough substrata (bark, rocks); on the contrary, *C. haskarliana* is found on smooth substrata (living leaves of trees, shrubs and ferns); (3) *C. kodamae* is to the north of *C. haskarliana* var. *spinosa* in its geographical range; (4) the presence of papillae on the surface of the ventral lobe is usually limited to the keelar region where it adheres not closely to the substratum.

Thus, these characteristics may vary according to the difference of ecological conditions, and *C. kodamae* may be conspecific with *C. haskarliana*. At present, however, the writer regards *C. kodamae* as a separate species. In the future, perhaps, experimental evidence may lead to a different conclusion.

Cololejeunea yamanakana Kamimura; emend Kodama (Fig. 4)

Cololejeunea yamanakana Kamimura, Contr. Fl. Hepat. Shikoku. 93 (1952).

Cololejeunea hattorii Ikegami, nom. nud. ex. Hattori in Journ. Hattori Bot. Lab. 8: 37 (1952).

Plants scattered, or in small, shallow patches, pale green to green; leafy shoot 350-400 μ wide. Stems 35-40 μ thick, branches similar to *C. haskarliana*. Leaves imbricate. Keel distinctly convex, 180-200 μ long, spinose due to projecting cells.

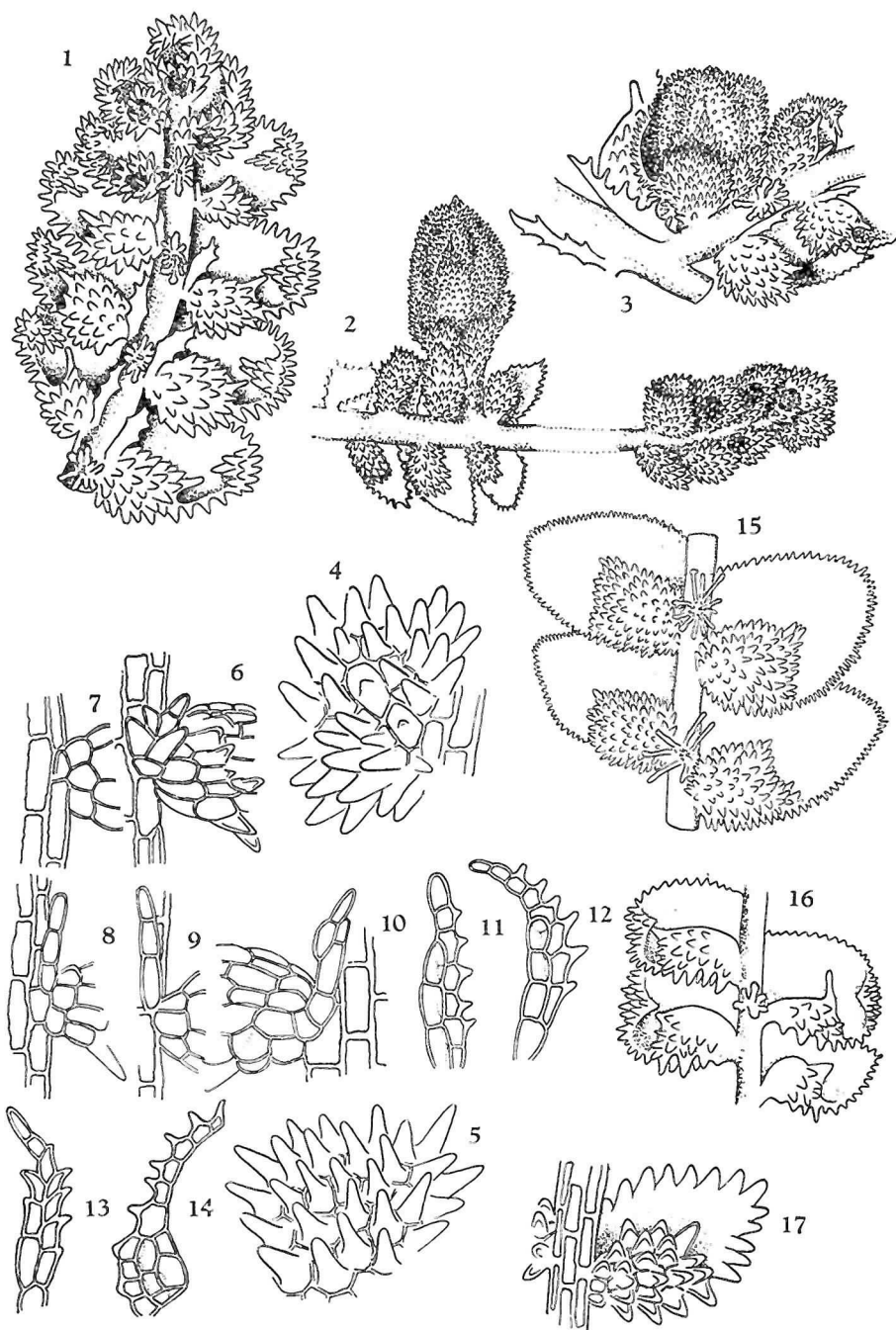


Fig. 4.

Dorsal lobe erect to spreading, ovate, not or only slightly falcate, dorsally convex, densely spinose on the dorsal surface, $180\text{--}250\ \mu$ long, $100\text{--}200\ \mu$ wide, 1.2–1.8 times as long as the ventral lobe, apex acute to \pm acuminate, ventrally secund; margin densely spinose due to projecting cells. Ventral lobes varying in form: well-developed ventral lobes ovate, $100\text{--}120\ \mu$ long, about $80\ \mu$ wide, densely spinose on the surface, more or less inflated along the keel; apex with 2 teeth, the distal tooth indistinct, very small, the proximal one composed of 1–2 cells. Stylus filiform to foliaceous, varying widely in size, entire to denticulate due to projecting cells, 1–9 cells long, 1, or near base 3, cells wide. Cells of the middle of the dorsal lobe $10\times 12\ \mu$, of the margin $8\times 10\ \mu$, every cell with a dorsal papilla, papillae spinose, large, $14\text{--}23\ \mu$ long, with thick wall at its tip; trigones wanting; cells of the ventral lobe with papillae similar to those of the dorsal lobe (sometimes disappearing along the free margin). Gemmae unknown. Underleaves wanting. Plants bisexual. Male and female organs closely resembling those of *C. haskarlana*; perianth obovoid, sometimes oblong when immature or exposed to unfavorable conditions, $350\text{--}450\ \mu$ long, $250\text{--}350\ \mu$ wide, 5-keeled in the upper half, rounded at apex, beakless or with a short beak, densely spinose like the dorsal surface of the leaf except at the base.

Specimen. exam. **Honshū.** Pref. **Niigata:** Mt. Kurohime, 900 m., calcicola, Y. Ikegami 9781 (the type of *C. hattorii*), Y.K. 9832, 26687. Pref. **Chiba:** Mt. Mitsuishi, on *Hymenophyllum*, H. Inoue, 5314. Pref. **Shizuoka:** Mt. Amagi, 500 m., on tree trunk, T. Kodama 6884; Iwashina, 220 m., on *Hymenophyllum*, T. Haneda 1266. Pref. **Nara:** Mt. Ōdaigahara, 800 m., on *Hymenophyllum*, T.K. 9564; Tōnomine, 460 m., on leaves of *Tracherospermum asiaticum*, T.K. 7441. Pref. **Wakayama:** Mt. Kōya, 600 m., on *Hymenophyllum*. Pref. **Okayama:** Katsuyama, on *Porella perrottetiana*, Ch. Igi 1462.

Kyūshū. Pref. **Kumamoto:** Hitoyoshi, 100 m., on pleurocarpous mosses, K. Mayebara; Kōnose, 100 m., on pleurocarpous mosses, K.M. 3331; Isshōchi, 80 m., on *Hymenophyllum*, K.M. 2912; Hitoyoshi, 100 m., on pleurocarpous mosses, K.M. 3411. (K.M. 3321, 2912, 3411 are a form; plants are reduced in size, with inconspicuous styli).

Range: Japan (Honshū, Shikoku, Kyūshū).

According to Kamimura's original description, *C. yamanakana* was distinguished from *C. ornata* Evans, an American species, by larger styli, more distinctly spinose papillae and oblong perianths. However, the writer considers that these characteristics possibly may be caused by differences of substrata and other habitat conditions. *C. yamanakana* was originally described as epiphyllous. Epiphyllous or corticolous

Fig. 4. *Cololejeunea yamanakana*

1. Male shoot ($\times 190$). 2. Fertile shoot with male and female organs—a form; plants growing on pleurocarpous mosses, reduced in size, with inconspicuous styli ($\times 190$). 3. Female shoot with perianth ($\times 190$). 4. Basal parts of leaf, dorsal view ($\times 405$). 5. Papillae on the antical surface of leaves ($\times 446$). 6–14. Basal parts of leaf, showing styli variable in size ($\times 446$). 15. Middle part of sterile shoot—a form, with inconspicuous styli ($\times 190$). 16. Middle part of sterile shoot—a form; plants reduced in size, with inconspicuous styli ($\times 190$). Figs. 1, 3 were drawn from the specimen K. Mayebara 1005; 4–5 from T. K. 6484; 2, 16–17 from K. M. 1978; 6–14 from H. Inoue 5314; 15 from K. M. 3321. All drawn by T. Kodama.

plants show such characteristics as Kamimura describes. However, on such substrata as rocks and pleurocarpous mosses, they are reduced in size, with short papillae and weak styli, often far smaller and filiform, and almost like those of *C. ornata*. Thus, *C. yamanakana* possibly may be regarded as a geographical variant of *C. ornata*.

Errata

N. TAKAKI's Researches on the Brachytheciaceae of Japan and its adjacent areas, III

高木典雄: 日本及び近接地域産ヒツゴケ科酢類の研究 III 正誤

No.	Page	Line	For	Read
16	8	Explanation of Fig. 33		Add: 26. Basal angle of stem-leaf ($\times 155$).
"	17	12	in habit, have	in habit and have
"	23	11	are, however, show	show, however,
"	24	6 from bottom	(Mitt.) Takaki comb. nov.	(Mitt.) Par.
"	"	between 5 and 6 from bottom		Insert: <i>Eurhynchium polystictum</i> (Mitt.) Par., Ind. 446 (1894).
"	"	1 from bottom	Syn. nov.	Omit!
"	26	16	erectpatent	erect-patent
"	"	18	Seta	Capsules
"	27	11	<i>Eurhynchium</i>	<i>Oxyrrhynchium</i>
"	"	2 from bottom	1157	1156
"	34	5	foliade	foliate
"	35	7	braechlets	branchlets
"	59	22	correspond	corresponds
"	66	25	Labmoose	Laubmoose
"	67	1 from bottom (right column)	<i>acroporiodes</i>	<i>acroporioides</i>
"	68	19 from bottom (left column)	<i>littolare</i>	<i>littorale</i>
"	70	5 (left column)	<i>macrostegium</i>	macrostegium
"	"	12 (right column)	III	II
"	"	20 (right column)	II	I
"	71	1 from bottom (left column)	51	50

351. *Anastrophyllum yakushimense* Horikawa (Jungermanniaceae) ヤクシマアミバゴケ 鹿児島大隅半島, ほよし岳 (シャ・ジャンボの幹, 枝上). 352. *Bazzania albicans* Steph. (Lepidoziaceae) シロムチゴケ 愛知県犬山 (半陰, 土上). 353. *Calyptogeiopsis granditexta* Steph. (Calyptogeiaceae) 北海道大雪山国立公園, 黒岳 (湿, 土上). 354. *Cephalozia hamatiloba* Steph. (Cephaloziaaceae) シマヤバネゴケ 鹿児島県屋久島小杉谷 (湿, 花崗岩上). 355. *C. otariensis* Steph. var. *acrogyna* Amakawa オーギヤマトヤバネゴケ 熊本県人吉市附近 (湿岩上). 356. *Chiloscyphus polyanthus* (L.) Cda. (Lophocoleaceae) フジウロコゴケ 北海道石狩国安足間 (流水中). 357. *Cololejeunea (Leptocolea) longilobula* (Horikawa) Hatt. comb. nov. Syn. *Leptocolea longilobula* Horikawa (Lejeuneaceae) ナガシタバヨージュゴケ 宮崎県南那珂郡北郷村 (水にひたる砂岩上). 358. *C. (subgen. Taeniolejeunea) verdoornii* (Hatt.) Hatt. comb. nov. Syn. *Taeniolejeunea verdoornii* Hatt. イボヨージュゴケ 産地同上 (スジヒトツバの葉上). 359. *Dendroceros japonicus* Steph. (Anthocerotaceae) キノボリツノゴケ 産地同上 (枝上). 360. *Drepanolejeunea tenuis* (R. Bl. N.) Schiffn. (Lejeuneaceae) ヒメサンカクゴケ 福岡県英彦山 (杉樹皮上). 361. *Euosmolejeunea nipponica* (Hatt.) Hatt. ヤマトクサリゴケ 宮崎県南那珂郡北郷村 (砂岩壁上). 362. *Frullania delaveyi* Steph. Syn. *Fr. bidentula* Steph., syn. nov. (Frullaniaceae) ツルギヤスデゴケ 長野県木曾駒岳 (針葉樹幹上). 363. *Fr. moniliata* subsp. *obscura* Verd. エダウチヤスデゴケ 大分県祖母山 (ミズナラ樹幹上). 364. *Fr. taradakensis* Steph. タラダケヤスデゴケ 長崎県多良岳 (樹幹上). 365. *Fr. truncatifolia* Steph. アカチャボヤスデゴケ 北海道石狩国愛別 (ヤチダモ樹皮上). 366. *Gymnocolea montana* (Horik.) Hatt. (Lophoziaaceae) ヤマイチョーウロコゴケ 北海道大雪山国立公園黒岳 (土上). 367. *Gymnomitrium faurianum* (Steph.) Herz. (Marsupellaceae) サキジロゴケ 北海道大雪山国立公園, 黒岳〜北海岳 (岩壁). 368. *Heteroscyphus planus* (Mitt.) Schiffn. (Lophocoleaceae) ツクシウロコゴケ 大分県佐賀関 (やや乾, 崖上). 369. *Lejeunea boninensis* Horik. (Lejeuneaceae) オガサワラクサリゴケ 宮崎県日南市鶴戸 (やや乾, 砂岩上). 370. *L. rotundistipula* (Steph.) Hatt. Syn. *Microlejeunea rotundistipula* Steph. ヒメコミミゴケ 宮崎県南那珂郡北郷村 (砂岩〜コヤコケシノブ上). 371. *Lopholejeunea yoshinagana* (Hatt.) Hatt. ヨシナガクロウロコゴケ 宮崎県東臼杵郡行藤山 (岩上). 372. *Macrodiplophyllum plicatum* (Lindb.) Perss. (Scapaniaceae) フタエウロコゴケ 北海道大雪山国立公園, 黒岳 (陰, 岩上). 373. *Marsupella apertifolia* Steph. (Marsupellaceae) ヒロハミゾゴケ 産地同上 (水中). 374. *M. tubulosa* Steph. タカネミゾゴケ 愛知県犬山 (半陰, 土上). 375. *Metzgeria conjugata* Lindb. var. *japonica* Hatt. (Metzgeriaceae) エゾフタマタゴケ 山梨県蘆安村 (岩上). 376. *Neotrichocolea bisseti* (Mitt.) Hatt. (Trichocoleaceae) サワラゴケ 宮崎県鞍岡村白岩山 (湿岩上). 377. *Nipponolejeunea subalpina* (Horik.) Hatt. (Lejeuneaceae) ヒメケンゲリゴケ 長野県木曾駒岳 (樹皮上). 378. *Pallavicinia longispina* Steph. (Pallaviciniaceae) クモノスゴケ 愛媛県西条市外. 379. *Phaeoceros laevis* (L.) Proskauer (Anthocerotaceae) ナメリツノゴケ 宮崎県日南市男鈴山 (湿, 頁岩上). 380. *Plagiochila (Chiastocaulon) dendroides* Lindenb. (Plagiochilaceae) ムチハネゴケ 鹿児島県大隅半島ほよし岳 (樹幹基部). 381. *Pl. fruticosum* Mitt. トサハネゴケ 産地同上. 382. *Pl. shinii* Hatt. (msc.) 鹿児島県紫尾山 (樹幹基部〜岩上). 383. *Plectocolea flagellata* Hatt. (Jungermanniaceae) ムチホーキゴケ 鹿児島県屋久島花ノ江川 (湿砂上). 384. *Pl. infusca* Mitt. オーホーキゴケ 宮崎県東臼杵郡北方村 (花崗岩壁). 385. *Pleurozia purpurea* (Lightf.) Pears. (Pleuroziaceae) ミズゴケモドキ 群馬県水ノ上町谷川岳 (岩上の腐植). 386. *Porella tosaana* (Steph.) Hatt. (Porellaceae) トサクラマゴケモドキ 宮崎県南那珂郡北郷村 (半陰, 砂岩上). 387. *Ptilidium ciliare* (L.) Hmpe. (Ptilidiaceae) ケテガタゴケ 北海道大雪山国立公園, 黒岳 (腐植土上). 388. *Ptychanthus striatus* (L. et L.) Nees (Lejeuneaceae) カタヒバモドキ 宮崎県南那珂郡北郷村 (シラカシの枝上). 389. *Radula acuminata* Steph. (Radulaceae) ヨージュケビラゴケ 産地同上 (スジヒトツバの葉上). 390. *R. boryana* (Web.) Hampe ミミケビラゴケ 岡山県新見市, 姫坂鐘乳洞 (石灰岩上). 391. *R. cavifolia* Hampe オーシタバケビラゴケ 鹿児島県屋久島花ノ江川 (イスツゲの枝上). 392. *R. kojana* Steph. コーヤケビラゴケ 宮崎県日南市鶴戸 (半陰乾, 砂岩上). 393. *Riccardia miyakeana* Schiffn. (Riccardiaceae) ミヤケテングサゴケ 熊本県人吉市附近 (湿岩上). 394. *R. multifida* (L.) Gray クシノハスジゴケ 北海道石狩国安足間 (トドマツ植林下の腐植土上). 395. *R. sinuata* (Dicks.) Trev. ナミガタスジゴケ 宮崎県日南市小布瀬滝 (水の滴下する頁岩上). 396. *Riccia glauca* L. (Ricciaceae) ハタケゴケ 長崎県対馬厳原 (石垣上). 397. *Scapania ornithopodioides* (With.) Pears. (Scapaniaceae) ムカシヒシヤクゴケ 高知県長岡郡梶ヶ森 (林床). 398. *Sc. undulata* (L.) Dum. ムラサキヒシヤクゴケ 福島県南会津郡燧岳 (小流中). 399. *Solenostoma cyclops* (Hatt.) Hatt. comb. nov. Syn. *Jungermannia cyclops* Hatt. (Jungermanniaceae) マルバツボミゴケ 鹿児島県屋久島花ノ江川 (湿, 花崗岩上). 400. *S. decurrens* (Steph.) Hatt. comb. nov. Syn. *Jungermannia decurrens* Steph. (nec Nees) フォーリツボミゴケ 産地同上 (湿砂上).

501. *Aulacomnium heterostichum* (Hedw.) B. et S. (Aulacomniaceae) ナガミチョーテンゴケ 北海道雌阿寒岳 (樹陰, 倒木). 502. *Barbella pendula* (Sull.) Fl. (Meteoriaceae) イトゴケ 宮崎県日南市おび楠原 (陰, 灌木の小枝より垂下). 503. *Barbula gigantea* Funck (Pottiaceae) オーフトゴゴケ 埼玉県秩父, 白岩山 (陰, 石灰岩壁). 504. *Bryoxiphium savatieri* (Husn.) Mitt. (Bryoxiphiaceae) エビゴケ 長野県木曽駒岳 (花崗岩壁の垂直面). 505. *Bryum capillare* Hedw. var. *nagasakiense* (Broth.) Ochi (Bryaceae) ナガサキハリガネゴケ 鳥取市 (コンクリート上). 506. *Bryum caespiticium* Hedw. ホソハリガネゴケ 熊本県球磨郡免田町 (河畔の石上). 507. *Bryum coronatum* Schwaegr. ナガハリガネゴケ 熊本県葦北郡吉尾村 (地上). 508. *Bryum pallescens* Schlecht. チョボハリガネゴケ 新潟県東蒲原郡阿用村 (岩石地の地上). 509. *Buxbaumia aphylla* Hedw. (Buxbaumiaceae) キセルゴケ 長野県御嶽 (登山道側の土手). 510. *Cratoneuron filicinum* (Hedw.) Roth (Amblystegiaceae) ミヅシダゴケ 長野県上伊那郡美和村 (草原内湿地). 511. *Ctenidium homalophyllum* Broth. et Yas. (Hypnaceae) 熊本県球磨郡一勝地村 (岩上). 512. *Dendrocypthophorum paradoxum* (Broth.) Dix. (Hypopterygiaceae) フチナシクジャゴケ 鹿児島出水市定の段 (杉林内の頁岩). 513. *Dolichomitria cymbifolia* (Lindb.) Broth. var. *subintegerrima* Okam. (Lembophyllaceae) ハナシエボシゴケ 熊本県人吉市 (腐木上). 514. *Duthiella pellucens* Card. et Thér. (Trachypodaceae) ツヤノコギリゴケ 宮崎県日南市酒谷 (湿った頁岩壁). 515. *Eriopus mollis* Card. (Hookeriaceae) ケムシゴケ 鹿児島出水市紫尾山々腹 (森下細流中の湿った頁岩). 516. *Erythrodontium leptothallum* (Müll.) Nog. fo. *tereticaule* (Müll.) Nog. (Entodontaceae) ネジレベニハゴケ 大阪府八尾市恩智 (石垣上). 517. *Fabronia matsumurae* Besch. (Fabroniaceae) コゴメゴケ 福岡市内 (エノキ樹幹). 518. *Fissidens gymnogynus* Besch. (Fissidentaceae) ヒメホーオーゴケ 宮崎県南那珂郡北郷村 (頁岩壁上). 519. *Fissidens saxatilis* Tuz. et Nog. 熊本県球磨郡一勝地村 (岩上). 520. *Floribundaria floribunda* (Doz. et Molk.) Fl. (Meteoriaceae) シノブイトゴケ 産地同前 (灌木の根もと). 521. *Fontinalis hypnoides* Hartm. (Fontinalaceae) カワゴケ 鳥取県八頭郡沖の山中腹 (水中の石). 522. *Funaria hygrometrica* Hedw. (Funariaceae) ヒョータンゴケ 宮崎県南那珂郡北郷村 (炭焼がま跡の土上). 523. *Grimmia doniana* Smith (Grimmiaceae) タカネギボシゴケ 富山県立山浄土山〜ざら峠 (雪溪の流紋岩上). 524. *Habrodon leucotrichus* (Mitt.) Perss. (Fabroniaceae) ミヤマイトツルゴケ 長野県木曽駒岳 (シラベ優占林, 樹幹上). 525. *Haplocladium subulaceum* (Mitt.) Broth. var. *amblystegioides* (Broth. et Par.) Thér. (Thuidiaceae) ニワゴケ 宮崎県南那珂郡北郷村 (溪側, イスビワの枝上). 526. *Haplohymenium longinerve* (Broth.) Broth. (') ナガスデイトゴケ 鹿児島県開聞岳頂上 (イヌツゲ樹皮上). 527. *Hyophila stenophylla* Card. (Pottiaceae) ホソバハマキゴケ 熊本県球磨郡川村 (岩上). 528. *Isopterygium textori* Lac. (Hypnaceae) アカイチイゴケ 熊本県球磨郡一武村 (土上). 529. *Isotheicum subdiversiforme* Broth. (Lembophyllaceae) ヒメコクサゴケ 宮崎県日南市酒谷 (モミ, ツガの根もと). 530. *Leucodon nipponicus* Nog. (Leucodontaceae) ニッポンイタチゴケ 熊本県球磨郡神瀬村 (樹幹上). 531. *Merceya gedana* (Lac.) Nog. (Pottiaceae) ホンモンシゴケ 東京都芝増上寺境内 (青銅製燈籠の石合上及び附近の礫上). 532. *Mnium speciosum* Mitt. (Mniaceae) カシワパチョーテンゴケ 長野県八ヶ岳 (湿, 腐植上). 533. *Mnium subglobosum* B. et S. マルハパチョーテンゴケ 長野県木曽駒岳 (腐植上). 534. *Oncophorus wahlenbergii* Brid. (Dicranaceae) エゾノコブゴケ 産地同前 (花崗岩上). 535. *Philonotis socia* Mitt. (Bartramiaceae) ツクシサワゴケ 熊本県球磨郡神瀬村 (土手上). 536. *Polytrichum attenuatum* Menz. (Polytrichaceae) オースギゴケ 産地同前 (岩上). 537. *Polytrichum sphaerothecium* (Besch.) Broth. タカネスギゴケ 福岡県安達太郎山, 鉄山 (安山岩壁). 538. *Pseudoleskeopsis orbiculata* Mitt. (Leskeaceae) アサイトゴケ 熊本県球磨郡西村 (湿岩上). 539. *Rhacomitrium anomodontoides* Card. (Grimmiaceae) ナガエノスナゴケ 熊本県人吉市 (岩上). 540. *Rhacopilum aristatum* Mitt. (Rhacopilaceae) ホゴケ 宮崎県南那珂郡北郷村 (陰湿, 頁岩壁). 541. *Syrrhopodon japonicus* (Besch.) Broth. (Calymperaceae) カタシロゴケ 宮崎県南那珂郡北郷村 (タブノキ幹〜基部). 542. *Syrrhopodon tosaensis* Card. イサワゴケ 産地同前. 543. *Taxiphyllum taxirameum* (Mitt.) Fl. (Hypnaceae) キャラハゴケ 熊本県人吉市 (土上). 544. *Thamnum alopecurum* (Hedw.) B. et S. (Neckeraceae) キツネノオゴケ 長野県上伊那郡白岩谷 (陰湿, 石灰岩上). 545. *Timmia megapolitana* Hedw. (Timmiaceae) ミヤマクサスギゴケ 埼玉県秩父十文字峠 (石灰岩壁下の土上). 546. *Trachypus bicolor* Reinw. et Hornsch. (Trachypodaceae) サラザラゴケ 鹿児島県大隅半島ほよし岳頂上 (湿, 花崗岩上). 547. *Trematodon drepanellus* Besch. (Dicranaceae) ナガダイゴケ 愛媛県西条市加茂川岸 (砂土上). 548. *Trichostomum crispulum* Bruch (Pottiaceae) テヂミクチヒゴケ 熊本県葦北郡大野村 (岩上). 549. *Ulotia reptans* Mitt. (Orthotrichaceae) ハイキンモーゴケ 長野県木曽駒岳 (シラベ優占林, 樹皮上). 550. *Vesicularia apiculata* Broth. (Hypnaceae) セイナソフクロゴケ 熊本県人吉市 (湿岩上).

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