The Mosses of the Ongul Islands and Adjoining Coastal Areas of the Antarctic Continent

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Abstract: Moss collections from the Ongul area include three species: *Ceratodon purpureus* (Hedw.) Brid., *Bryum argenteum* Hedw. (both cosmopolitan), and *Bryum inconnexum* Card. (endemic). The Ongul specimens of *Ceratodon purpureus* observed are characterized by the obtuse leaves with the costa diminishing below the apex. The lamina-cells tend to be somewhat larger than in usual specimens from moderate regions. The chromosome number is n=13. Ongul specimens of *Bryum argenteum* show considerable differences from its typical form: the leaves tend to be obtuse, the colorless part of leaf is indistinct or absent, and the costa is rather long ending just below the apex; monoicous, having diploid number of chromosomes, n=20. *Bryum inconnexum* shows a good deal of variability, especially in the shape of leaves, feature of leaf-margins, and the length of the costa. This species was reduced by some authors to a synonym of *B. antarcticum* Hook. f. and Wils., but such a treatment is not acceptable. *Bryum antarcticum* is quite a different species. The chromosome number of *B. inconnexum* is of diploid level, namely, n=20.

General characters seen in Antarctic mosses are summarized as: growing in compact tufts; frequent innovations; rich growth of rhizoids; tendency of the leaves to be obtuse at the apex; vegetative reproduction by means of fragmentation of stems or branches, separation of innovations, and initiation of buds ("gemmae") on the rhizoid protonema; large ability to resist low temperature and long desiccation.

The present studies are concerned with taxonomy, cytology and ecology of Antarctic mosses principally based on the materials and data acquired from the Ongul Islands and adjoining coastal areas of the Antarctic Continent.

The Ongul Islands, on which the base of the Japanese Antarctic Research Expedition was established in 1957, is located in lat. 69°00′S, long. 39°30′E, closely adjoining the Antarctic Continent. Some 70 packets of mosses from this area were investigated. They include three species: *Ceratodon purpureus* (Hedw.) Brid., *Bryum argenteum* Hedw. and *Bryum inconnexum* Card.

Ceratodon purpureus, which is a cosmopolitan moss distributed throughout the world, is the most common in this area. It is well known that this species is extremely polymorphous, and this fact is also true of the Antarctic specimens examined. The Ongul specimens of the *Ceratodon* that we observed exhibited extraordinary diversity in size of plants and in leaf characteristics such as shape of leaf, size of leaf-cells and thickness of cell-walls. The Antarctic specimens of

the *Ceratodon* considerably differ from those in the area of moderate climate, namely, they are provided with abundant rhizoids, sometimes producing flagellous innovations; the leaves are imbricated, not much divergent, rounded and obtuse at the apex, and less recurved at the margins; the costa is diminishing below the apex; the leaf-cells are tending to be somewhat larger and thicker-walled (vid. Fig. 1 in HORIKAWA and ANDO, 1961). Such a form of *Ceratodon purpureus* seems to correspond to var. *obtusifolius* Limpr. or var. *rotundifolius* Bergrr. found in the boreal regions of the Northern Hemisphere.

The samples of *Ceratodon purpureus* from the Ongul area were cytologically studied by TATUNO (1963), who noticed that they were all monoploid with n=13. This number of chromosome is just the same as that counted with the plants from Japan, Europe and North America. It is of interest that the ten samples gathered from different sites which TATUNO studied all showed male characteristics in chromosome morphology. This fact will not be an evidence strong enough to conclude that this species in Antarctic regions is lacking in female plants, but it might be true that male plants are more common than the female ones at least in the Ongul area. This reminds us that LÖVE and LÖVE (1953) pointed out that in *Bryoxiphium norvegicum*, a curious moss distributed in North America, only the female colonies had been known from the northern extremities of its range such as Iceland and Greenland. These are examples of the case that the quantitative balance of male and female plants is disturbed in peripheral parts of the range under more severe environmental conditions.

As Antarctic members of the genus *Ceratodon*, four other species have been known. Of those species, *Ceratodon minutifolius* Card., which was described from Jenny Island near Graham Land, may be included in *C. purpureus*, although it differs from the Ongul specimens in having acute leaves with a percurrent or excurrent costa (HORIKAWA and ANDO, 1963).

Bryum argenteum, well known as a world-wide weedy moss, is also frequent in the Antarctic regions. Its specimens from the Ongul area observed are all characterized by the leaves usually with the obtuse apex, sometimes acute or slightly apiculate, the rather long costa vanishing just below the apex, and by the tendency of the leaves to be chlorophyllose to the apex (Fig. 1–3a, 3b, 4a).

TATUNO (1963) studied the chromosomes of *B. argenteum* with some Ongul plants, and he found that they were of diploid level with n=20 and monoicous (synoicous), in spite of the fact that the same species in moderate regions is dioicous and its chromosome number has been reported as n=10 by several authors. When it was believed that the Ongul plants of *B. argenteum* were of diploid level, we expected that their cell size would be larger than those of monoploid ones growing in regions of moderate climate. But our studies showed that the Ongul plants of the diploid level have leaf-cells of a size scarcely different from or somewhat shorter than those of ordinary monoploid plants (Fig. 1). From these facts, the Antarctic diploid race of *B. argenteum* is considered to be of allopolyploid origin. On the strength of their chromosome number and some properties, which are considered to have been derived from the doubling of chromosome number,

such as monoicous inflorescence and distinctive features of leaves as mentioned above, the Ongul plants of *B. argenteum* may be more appropriately treated as a variety or even as a separate species. A definite conclusion, however, is reserved until more sufficient specimens from the Antarctic areas are studied.

A typical form of *B. argenteum* as characterized by the apiculate leaves being always hyaline in the upper half and with a costa vanishing considerably below the apex, was not encountered among the specimens from the Ongul area, but it was observed in some specimens among the collections from the South Victoria Land (Fig. 1-6a, 6b). It may be supposed that the Antarctic plants of *B. argenteum* maintaining such a typical form are really identical with the ordinary plants of monoploid level. Cytological studies are keenly desired with respect to the wide range of Antarctic collections.

The third species recorded from the Ongul area is *Bryum inconnexum*. *Bryum*

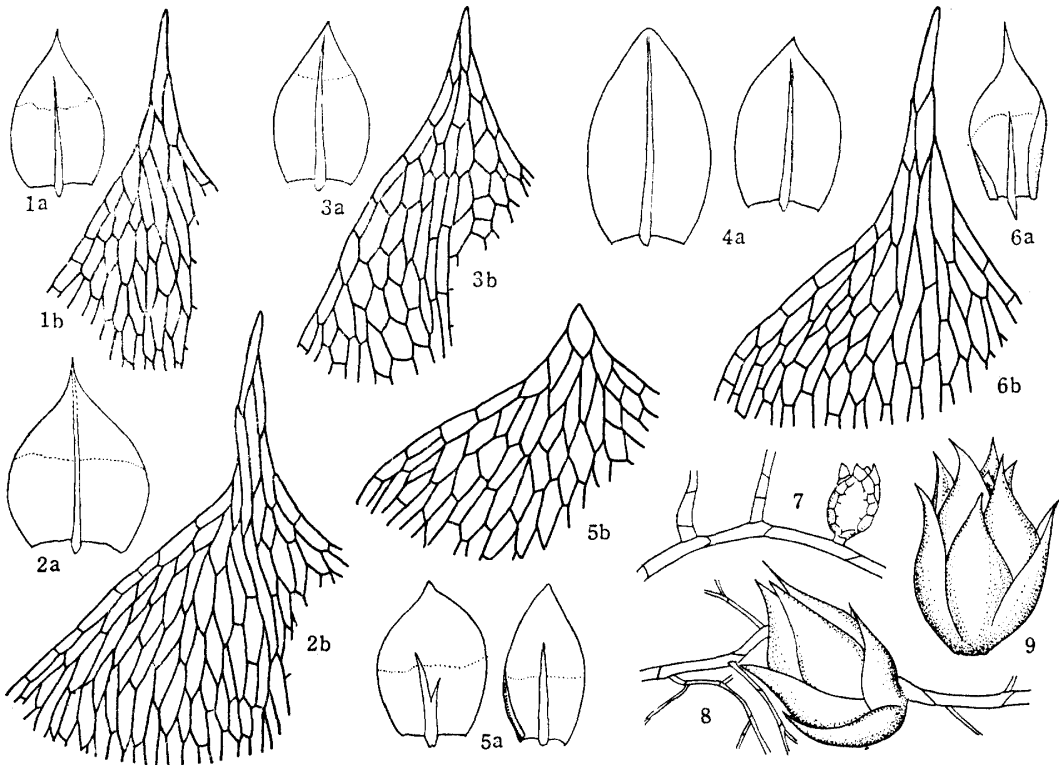

Fig. 1. Bryum argenteum *Hedw. 1, 2. Specimens from regions of moderate climate: 1. Ottawa, Canada, 2. Hiroshima, Japan; both probably n=10. 3, 4. From Ongul area; the leaves tending to be obtuse, the hyaline part of leaf indistinct or absent, the costa rather longer, n=20. 5. From Marble Point, South Victoria Land; the leaves rounded, the costa shorter and sometimes forked; an abnormal form caused by blue-green algae. 6. From Stranded Moraine, South Victoria Land; leaf characters just the same as in the typical form seen in moderate regions. a. Leaf, ×30, b. Apical portion of leaf, ×150. 7–9. Short bud-like branchlet ("gemma") produced on rhizoid protonema, ×76.*

inconnexum was first reported by CARDOT (1900) from Gerlache. This is a species endemic to the Antarctic region. Several morphological characters show a good deal of variability, not only among different plants but also in an individual plant. Especially the shape of the leaf, feature of leaf margins, whether they are plane or recurved, and the length and stoutness of the costa are quite diversified. This species, when bears inflorescences, usually shows a comose habit and the leaves are longer-acuminate, with a stronger costa usually excurrent, more frequently recurved at margins, and are more or less elongated in lamina-cells (Fig. 2; for usual forms, see Fig. 3 in HORIKAWA and ANDO, 1961).

A remarkable polymorphism of this moss has brought about a list of several puzzling species of *Bryum* from the Antarctic regions. DIXON (1918) suggested that *Bryum antarcticum* Hook. f. and Wils., which is the oldest Antarctic species of *Bryum* described from Cockburn Island (64°S, 57°W), showed an extraordinary variability and that the following species described from the Antarctic regions might be considered synonymous with *B. antarcticum*: *Bryum gerlachei* Card. (1900), *B. inconnexum* Card. (1900), *B. austro-polare* Card. (1900), *B. filicaule* Broth. (1906) and probably *B. algens* Card. (1907). This opinion was followed partly or wholly

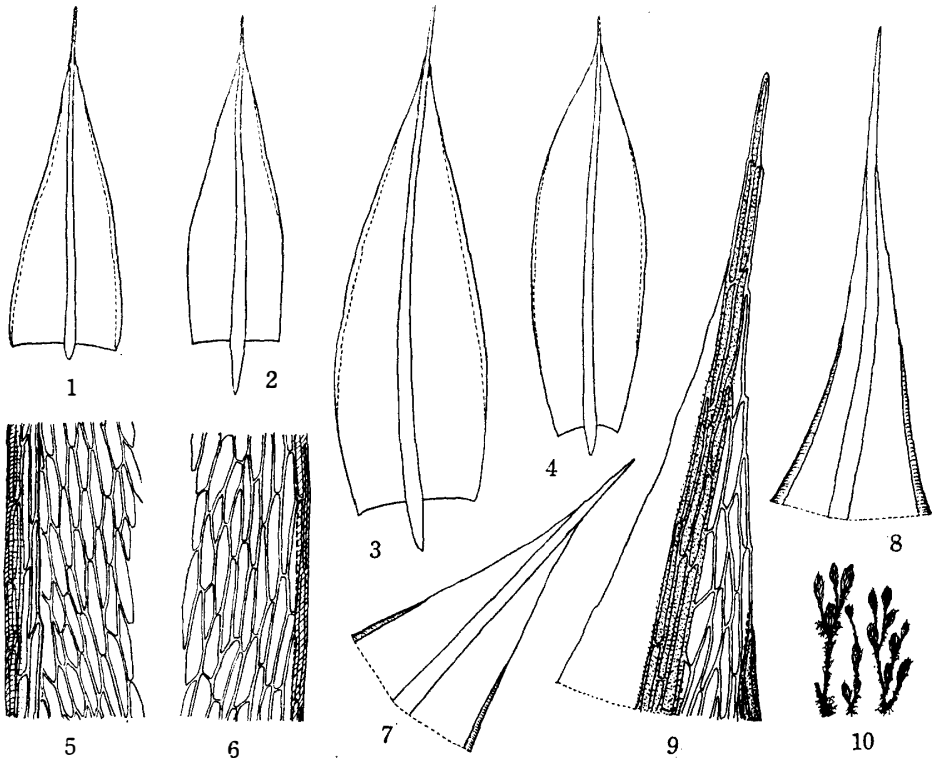

Fig. 2. Bryum inconnexum *Card. Drawn from HIRO, A. B. No. 44 (Fyfe Hills, Casey Bay, Antarctica), a comose form bearing inflorescences. 1–4. Leaves, ×28. 5, 6. Median margin of leaf, ×135. 7, 8. Apical part of leaf, ×70. 9. Ditto, ×135. 10. Plants, ×3. For usual forms, vid. Fig. 3 in HORIKAWA and ANDO (1961).*

by some subsequent authors (BARTRAM, 1938; CLIFFORD, 1957; WIJK, MARGADANT and FLORSCHÜTZ, 1959; STEERE, 1961). But, according to GREENE (in private communication), the type specimen of *B. antarcticum* is quite a different species, having wider ovate leaves with subquadrate upper lamina-cells. In the Ongul collections we could find no specimens of *B. antarcticum* defined by GREENE, but have observed its specimen from South Victoria Land determined by GREENE. Our studies have also proved *B. antarcticum* to be essentially different from the other species of *Bryum*. Even its generic position seems to be doubtful.

Bryum inconnexum and *B. austro-polare*, both of which were studied with respect to the type specimen, are undoubtedly the same, but as to the remainder, *Bryum gerlachei*, *B. filicaule* and *B. algens*, we have not seen the type specimens, so at the present stage, we are unable to give a definite judgment about their identity.

TATUNO (1963) studied the chromosomes of *B. inconnexum* and found that it was of diploid level with n=20. The sexual condition is monoicous (synoicous or autoicous).

Bryum inconnexum var. *fragile*, reported by HORIKAWA and ANDO (1961) and characterized by a minority of radicles and very brittle, blackish leaves, is only an old plant of the typical species. HORIKAWA and ANDO (1961) also described a new species, *Bryum ongulense* with a specimen from the Ongul Islands. This species was distinguished from *B. inconnexum* by reddish color of plants, flagellous growth of stems and branches, and the smaller and narrower leaves with a percurrent or excurrent costa. At present, however, we are inclined to think that it is rather an extremely modified form of *B. inconnexum*.

Generally speaking, Antarctic mosses have leaves which are usually obtuse at the apex. It has been known that, in the Arctic or Alpine regions under severe climatic conditions, the leaves of mosses tend to be more obtuse and shorter. This is likewise true of Antarctic mosses. Whether the obtuseness of leaves in Antarctic mosses is an inherent character stabilized genetically or only a modification due to environmental conditions is an interesting problem for critical studies.

Very compact tufts, frequent innovations, namely, many branches or fresh shoots from a stem, and rich growth of rhizoids are also characteristic to Antarctic mosses. These properties are considered to serve for several purposes, such as propagation, mutual combining and fixing of plant bodies, and the long preservation of water against the dryness of Antarctic climate.

Another remarkable character of Antarctic mosses is that their fruiting is quite rare. The Ongul specimens observed were all sterile, although sexual organs were occasionally observed. Reproduction of Antarctic mosses is almost exclusively vegetative. According to our observation, the processes of vegetative reproduction seen in Antarctic mosses are as follows:

The first process is fragmentation of stems or branches and separation of innovations. Separated fragments or innovations seem to be able to produce readily both rhizoids and young shoots.

The next process is the development of new plants from rhizoids or second-

ary protonemata. In *Bryum argenteum*, short bud-like branchlets are sometimes produced on rhizoid system (Fig. 1–7, 8, 9; SAVITZ-LJUBITZKAJA and SMIRNOVA, 1964). These branchlets, which are usually called "gemma" or "bulbil", are readily detached and can develop into new plants. *Bryum argenteum* has another type of gemma, which, however, we could not detect in the Ongul specimens. That is a stalked gemma bearing a few rudimentary leaves produced in the axils of leaves. *Bryum siplei* described by BARTRAM (1938) from the King Edward VII Land seems to be a form with such gemmae of *Bryum argenteum*. In a laboratory culture of an Ongul plant of *Ceratodon purpureus*, we have observed the development of young plants on the secondary protonema developed from rhizoids. Such vegetative reproduction by means of the initiation of buds on the rhizoid protonema was also observed by SAVITZ-LJUBITZKAJA and SMIRNOVA (1961, 1963) in Antarctic plants of *Bryoerythrophyllum recurvirostre* and in *Sarconeurum glaciale*, a peculiar moss endemic to Antarctica.

In the *Bryoerythrophyllum*, SAVITZ-LJUVITZKAJA and SMIRNOVA (1963) found another type of vegetative propagula, namely, bright-green leaf-like formations found among the young sexual organs which easily fall out and possibly serve the vegetative reproduction.

It is very curious and interesting that Antarctic mosses have a quite large ability to withstand low temperature, long darkness and desiccation. A remarkable example of this fact was given by Ongul mosses.

Several mosses (including *Ceratodon purpureus*, *Bryum argenteum* and *B. inconnexum*) were collected by MATSUDA in the Ongul area during the period from May, 1961 to January, 1962, and were preserved in a dark room of low temperature $-15°C$ $\sim -20°C$ for about one year, and then were sent to Hiroshima University in April, 1963. Since then, they have been preserved in a dark frozen room of the electric refrigerator of our institute. The temperature in the frozen room has been kept in the range $-3°C \sim -5°C$. At the end of July, 1966, after the five-year long deposit, they were taken out of the frozen room and cultivated under the conditions properly moistened, lighted by electric lamp and with temperature of about $+10°C$. To our surprise, most of them revived from so long dormancy and produced new fresh-green shoots or secondary protonemata. Such a wonderful vital patience shown by those small plants is indeed a question.

Ecology of Antarctic mosses seems to offer several interesting topics. According to MATSUDA (1963), the mosses on the East Ongul Island are found to occur mostly on the southwest slopes which are protected from strong prevailing winds and receive rich drifts of snow resulting in moderate moisture in summer.

On the Ongul Islands, mosses usually form open communities with the area of about 2~3 sq. m, consisting of scattered large and small cushion-like clusters 10~20 cm in diameter. At Langhovde located on the coast of the Antarctic Continent about 35 km south of the Syowa Station, MATSUDA found a well-developed dense community of mosses which spread continuously over the area of about 30× 15 m.

The moss communities on the Ongul Islands are covered by snow from au-

tumn to spring, and only in summer, namely, from January to February or to March, they become free of ice and snow. But in a certain coastal area of Antarctica, MATSUDA encountered communities exposed even in the near-winter season.

According to MATSUDA's observations made near the Syowa Station, the air temperature in summer is about +3°C, while the temperature of the surface of moss-clusters sometimes rises to over +16°C, rarely as high as +19°C; in winter, the air temperature sometimes falls to −40°C, but the temperature of mosses hidden under snow never falls below −20°C.

In the places near moss communities, there are sometimes found nests or resting places of birds such as snow petrel, and are accumulated excrements and other organic debris rich in nitrogenous substances. In summer, these nitrogenous substances are dissolved in melting snow and fertilize the habitats of mosses. Here we recall the common Antarctic mosses, *Ceratodon purpureus* and *Bryum argenteum*, both being well known as a typically nitrophilous weedy moss.

Antarctic mosses grow sometimes in competition with other plants such as lichens and blue-green algae which often invade the moss communities. The most common blue-green algae found on mosses are *Nostoc* and *Gloeocapsa*. These algae develop covering the mosses and disturb the growth of mosses, sometimes even put them to death. But, usually the mosses seem to be able to withstand the covering by blue-green algae, and their dormant buds, when favored with better conditions, become active again and develop. Abnormal forms of leaves seemingly caused by blue-green algae have been observed in some specimens. For example, a specimen of *Bryum argenteum* covered by abundant blue-green algae showed the rounded leaves with a shorter costa which is sometimes forked, rarely trifurcate (Fig. 1–5a).

In conclusion, we should like to say that we still have many problems to be explored concerning Antarctic mosses, and to solve these problems, we need continuous studies systematically planned, and further, it is highly necessary that the studies will proceed with an international co-operation program. It is also ardently desired that professional experts of mosses as well as those of other plant groups, are assigned to the Antarctic field for a few seasons or several years if possible, to make careful on-the-spot ecological, physiological and taxonomical studies.

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