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Local variation in *Agarum cribrosum* Bory (Phaeophyta) on the coasts of Hokkaido and adjacent regions*

By

Iemasa YAMADA

Introduction

Agarum cribrosum Bory which occurs in subtidal regions in the northern Pacific and in the west coast of the north Atlantic shows much variation in morphological features. POSTELS and RUPRECHT (1840) distinguished three species (*A. Gmelini*, *A. Turneri*, and *A. pertusum*) from the materials collected from Kamchatka, Alaska, Canada, and Greenland on the basis of the features of the midrib, substance of the blade, and the size of the perforation. Later, SETCHELL and GARDNER (1925) concluded that these three species should be referred to *A. cribrosum* established by Bory (1826) because the characters distinguishing them were variable. Their opinion has been accepted to the present day.

From northern Japan, Sakhalin and the Kuriles this species has been reported by several phycologists under the names of *A. Turneri* (MIYABE, 1902; OKAMURA, 1902, 1916, 1925; ZINOVA, 1938), *A. Gmelini* (OKAMURA, 1902; ZINOVA, 1929) and *A. cribrosum* (TOKIDA, 1932, 1954; MIYABE and NAGAI, 1933; OKAMURA, 1936; NAGAI, 1940; and others).

On the other hand, Y. YAMADA (1961, 1962) reported two new species of *Agarum* from Japan on the basis of the shape of the stipe and rhizoidal hapters. They are *A. oharaense* collected from Oohara, Chiba Pref. of middle Honshu, and *A. yakishiriense* from Yakishiri and Teuri Islets of western Hokkaido. According to him, *A. oharaense* has a flat stipe, often becoming partially wider, from which fimbriate hapters arise, and it seems to be intermediate between *A. fimbriatum* Harvey and *A. cribrosum*. *A. oharaense*, however, has rarely been found even in the type locality and has never been collected from any other place. *A. yakishiriense*, characterized by the flattened stipe giving off numerous slender hapters, is distributed only on the coasts of the two islets. It is interesting to note that

* Dedicated to Professor Yositeru NAKAMURA on the occasion of his academic retirement.

each of the two species, *A. oharaense* and *A. yakishiriense*, inhabits a small restricted area.

I have had many occasions to observe living plants of *Agarum* in many places around Hokkaido during an investigation of subtidal marine algae. Among these materials and many herbarium specimens previously collected by Drs. MIYABE, NAGAI, TOKIDA, Y. YAMADA and others from Hokkaido, South Sakhalin, and Kurile Islands, four local forms of *A. cribrosum* having their own distributional areas are distinguished by morphological features of the blade, stipe and rhizoidal hapters. In this paper morphological characteristics and distributional regions of these four forms are discussed.

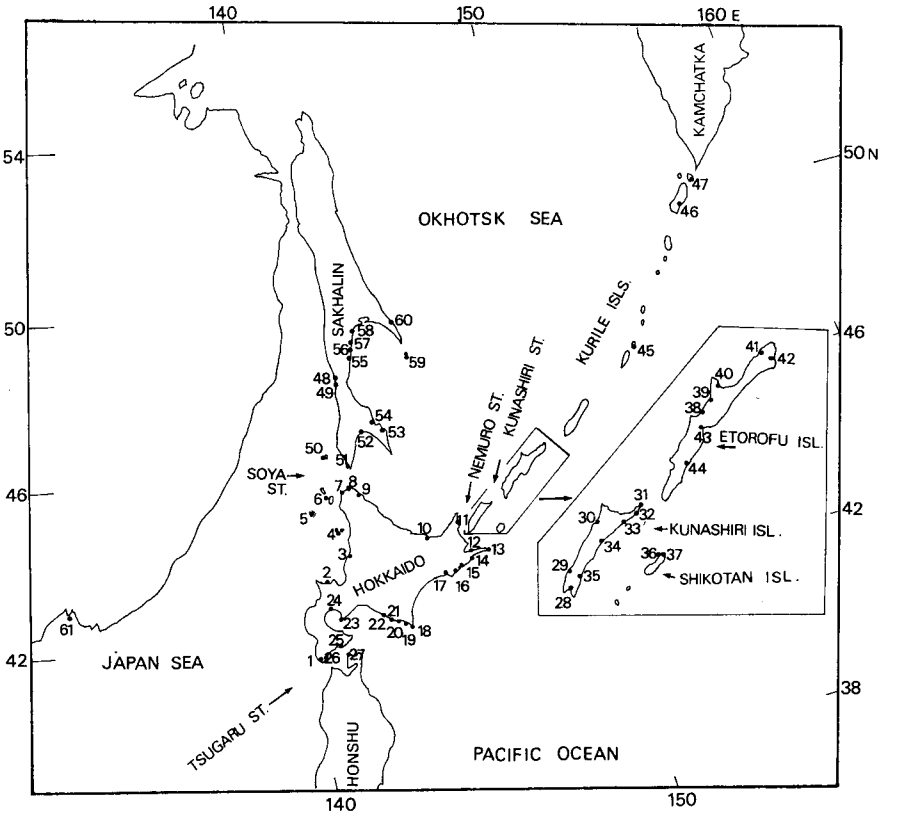

Fig. 1. Localities for the specimens used in this study. Collecters, dates and the herbaria are shown in the parenthesis.

Hokkaido (Loc. 1-26)

1. Matsumae (IMAI, 1933, SAPA); 2. Oshoro (I. YAMADA, 1961); 3. Rumoi (I. YAMADA, 1969, '70); 4. Yakishiri and Teuri Isls. (Y. YAMADA, 1960, SAP;

I. YAMADA, 1961, '64, '65, '69); 5. Musashi Bank (by the members of the Hokusei-maru ship, 1953, Herb. Fac. Fish., Hokkaido Univ.); 6. Rishiri and Rebun Isls. (MIYABE, 1891, SAPA; ISHIKAWA, 1889, SAPA; INAGAKI, 1934, SAP; I. YAMADA, 1966, '69); 7. Wakkanai (MIYABE, 1894, SAPA; I. YAMADA, 1966); 8. Cape Soya (I. YAMADA, 1961, '64); 9. Onikiribetsu (I. YAMADA, 1964); 10. Abashiri (I. YAMADA, 1961, SAP); 11. East coast of Shiretoko Peninsula (MIYABE, 1894, SAPA; NAGAI, 1931, SAPA; I. YAMADA, 1967, '68, '69); 12. Nemuro (I. YAMADA, 1970, '71); 13. Cape Nosappu (KUROGI, 1968; I. YAMADA, 1970); 14. Kiritappu (MIYABE, 1894, SAPA; KASAHARA, 1961, SAP); 15. Akkeshi (NAGAI, 1930, SAPA; Y. YAMADA, 1934, SAP; KASAHARA, 1961, SAP; I. YAMADA, 1966, '68, '69); 16. Konbumori (MIYABE, 1931, SAPA); 17. Kushiro (I. YAMADA, 1965); 18. Cape Erimo (I. YAMADA, 1966, '67, '69); 19. Samani (NAKAMURA, 1943, SAP; I. YAMADA, 1969, '70); 20. Higashi-Shizunai (I. YAMADA, 1969); 21. Niikappu (I. YAMADA, 1972); 22. Hidaka-Monbetsu (I. YAMADA, 1972); 23. Muroran (YOSHIKAWA, 1883, SAPA; MURAOKA, 1935, SAP; Y. YAMADA, 1944, SAP; TATEWAKI, 1963, SAP; I. YAMADA, 1968, '69, '72); 24. Abuta (MIYABE, 1886, SAPA); 25. Hakodate (I. YAMADA, 1972); 26. Yoshioka (FUNAHASHI, 1967).

Northern Honshu (Loc. 27).

27. Ooma of Aomori Pref. (Y. YAMADA, no date, SAP).

Kurile Islands (Loc. 28-47).

Kunashiri Isl. (28-35): 28. Tomari (NAGAI, 1936, SAPA); 29. Kotankeshi (NAGAI, 1931, SAPA); 30. Toshoro (NAGAI, 1931, SAPA); 31. Cape Atoiya (NAGAI and SHIMAMURA, 1925, SAPA); 32. Shiranuka (NAGAI and SHIMAMURA, 1925, SAPA); 33. Chinomichi (TOKIDA, 1925, SAPA); 34. Uennai (NAGAI and SHIMAMURA, 1929, SAPA); 35. Tofutsu (NAGAI, 1936, SAPA).

Shikotan Isl. (36-37): 36. Shakotan (NAGAI, 1934, SAPA); 37. Chiboi (NAGAI, 1934, SAPA); without specific locality (KAWABATA, SAP).

Etorofu Isl. (38-44): 38. Rubetsu (NAGAI, 1931, SAPA); 39. Arimoe (NAGAI, 1930, SAPA); 40. Beppi (NAGAI, 1930, SAPA); 41. Shibetoru (NAGAI, 1930, SAPA); 42. Moyoro (NAGAI, 1931, SAPA); 43. Hitokappu Bay (NAGAI, 1934, SAPA); 44. Iriribushi (NAGAI, 1934, SAPA).

Ketoi Isl. (45): 45. Minamiura (TATEWAKI and TAKAHASHI, 1920, SAPA).

Paramushiru Isl. (46): 46. Suribachi Bay (NAGAI, 1932, SAP).

Shumushu Isl. (47): 47. Tenjin-iwa and Kosekigawa (NAGAI, 1932, SAPA).

South Sakhalin (Loc. 48-60).

48. Kushunnai (MIYABE, 1906, SAPA); 49. Tomarioru (TOKIDA, 1930, SAPA); 50. Kaiba Isl. (MORIMOTO, 1937, Herb. Fac. Fish., Hokkaido Univ.); 51. Shiranushi (TOKIDA, 1927, SAPA); 52. Oodomari (TOKIDA, 1929, Herb. Fac. Fish., Hokkaido Univ.); 53. Airoppu (ISHIOKA, 1906, SAPA); 54. Ochibo (ISHIOKA, 1906, SAPA); 55. Maguntan (SAITO, 1928, Herb. Fac. Fish., Hokkaido Univ.); 56. Higashi-soya (SAITO, 1928, Herb. Fac. Fish., Hokkaido Univ.); 57. Kashipo (TOKIDA, 1931, SAPA); 58. Unetonnai (no signature, 1906, Herb. Fac. Fish., Hokkaido Univ.); 59. Robben Isl. (TOKIDA, 1930, SAP; '32, '35, Herb. Fac. Fish., Hokkaido Univ.); 60. Yoman (no signature, 1935, Herb. Fac. Fish., Hokkaido Univ.).

Vladivostok (Loc. 61)

61. Vladivostok (Specimens reported by FUNAHASHI in Bull. Jap. Phyc. Soc. **14** (3): 127-145, 1966).

Materials

Over a hundred specimens from Kuriles, South Sakhalin, and Hokkaido preserved in the herbaria of Faculty of Science (SAP), Faculty of Agriculture (SAPA) and Faculty of Fisheries of Hokkaido University were examined in this study. Several additional specimens were kindly supplied by Prof. M. KUROGI and Dr. S. FUNAHASHI. Many specimens from Hokkaido used in this study were collected by myself from 1961 to 1972. 61 localities for the materials are shown in Fig. 1.

Results

Among the plants examined three local forms of *A. cribrosum* (f. *cribrosum* f. *rugosum*, and f. *rishiriense*) and *A. yakishiriense* can be distinguished on the basis of the morphological features of the blade, stipe and rhizoidal hapters. Here, *A. yakishiriense* is regarded as a form of *A. cribrosum* as mentioned later.

Plants examined can be broadly divided into two groups by the features of the blade surface: whether they are provided with even blade or uneven blade. This evenness or unevenness of the blade results from whether or not there is an elevation formed by the periphery of a perforation. An

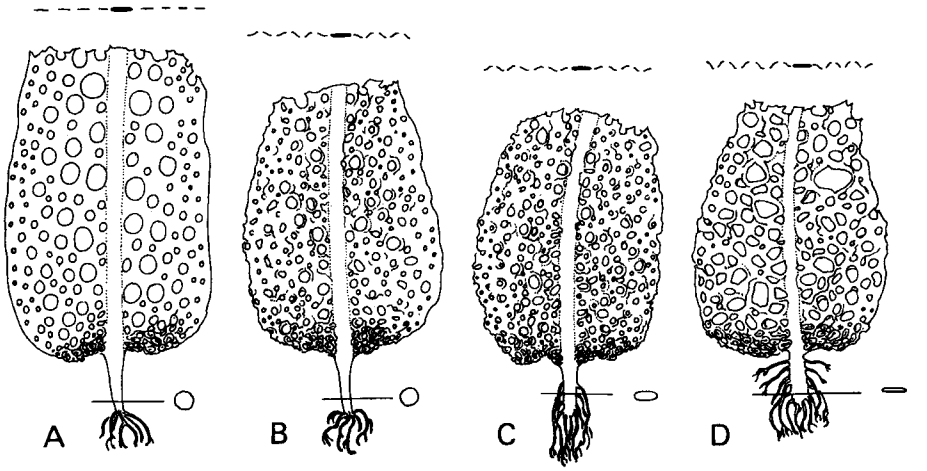

Fig. 2. Schematic representation of the habits to the four forms. A, f. *cribrosum*; B, f. *rugosum*; C, f. *rishiriense*; D, f. *yakishiriense*. Each broken line shows a cross sectional view of the blade indicating evenness or unevenness, and each cross sectional view of the stipe shows terete, compressed, or flattened.

even blade appears like a cardboad with round punch holes, while uneven blade, in the extreme case, looks like a crumpled paper with many perforations. The outline of a section of the uneven blade shows a frizzy broken line as figured by HUMPHREY (1887, Pl. 1, Fig. 4), on the contrary, that of the even blade shows a straight broken line (Fig. 2, Pl. 5 A, B).

In addition, judging from the features of the stipe and rhizoidal hapters, the even blade group comprises a single form which is regarded as *A. cribrosum* f. *cribrosum*, while in the uneven blade group three forms including *A. yakishiriense* are further distinguished. The stipe of the even blade group and most of the uneven blade group is usually flattened or compressed in the upper portion but mostly terete in the lower, and gives off relatively short and thick rhizoidal hapters from the lowest portion of the stipe (Fig. 2 A, B; Pl. 5 C, D). The plant provided with uneven blade and usual terete stipe is designated as f. *rugosum* (Pl. 5 D). On the other hand, the stipes of the plants collected from Rishiri and Rebun Islets are mostly compressed even in the lower portions and give off relatively long attenuated rhizoidal hapters, sometimes pinnately, from the margin more than halfway up the stipe (Fig. 2 C; Pl. 5 E). This form is designated as f. *rishiriense*. *A. yakishiriense*, as stated by Y. YAMADA (1962), has a broad flattened stipe with numerous slender rhizoidal hapters (Fig. 2 D; Pl. 5 F). The differences of the stipe among these three forms in the uneven blade group can be clearly shown by the correlation between their width and thickness in the lower portion of the stipe (Fig. 3).

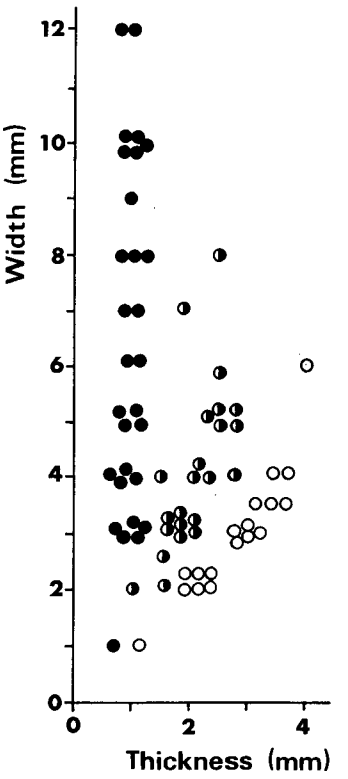

Fig. 3.
Correlation between the width and thickness in the lower portion of the stipes of the three forms referring to uneven blade group. Open circle, f. *rugosum* collected from Cape Soya; Semi-open circle, f. *rishiriense* from Rishiri Isl.; Solid circle, f. *yakishiriense* from Yakishiri Isl.

As mentioned above, the blade of *A. yakishiriense* does not differ essentially from that of other forms of the uneven blade group, and the shape of the stipe seems to be related to that of f. *rishiriense*. Therefore I conclude that *A. yakishiriense* should be regarded as a form of *A. cribrosum*.

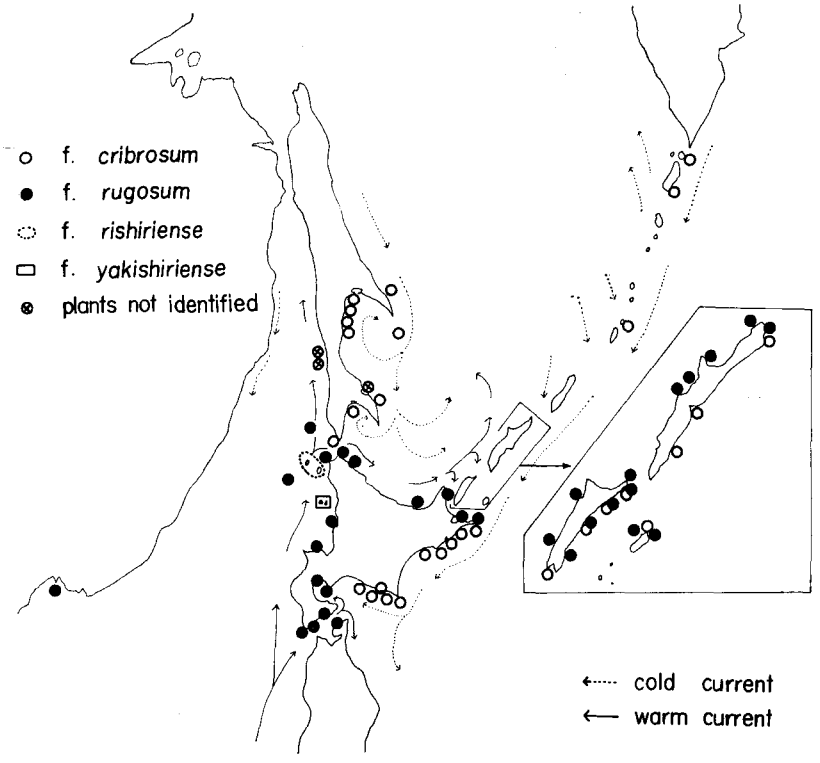

Fig. 4. Distributional map of the four forms of *Agarum cribrosum* in Hokkaido and adjacent regions, and the current system (modified after WATANABE, 1964, 1967).

These four forms may be separated on their geographical distribution from each other as shown in Fig. 4. The details of the distribution are mentioned in the following description.

Key to the forms

1. Blade even, periphery of the perforation not raised . . . f. *cribrosum*
1. Blade uneven, periphery of the perfoaration raised 2
   2. Stipe terete in the lower portion . . . . . f. *rugosum*
   2. Stipe compressed throughout . . . . . f. *rishiriense*
   2. Stipe flattened throughout . . . . . f. *yakishiriense*

Diagnosis and description of the forms

f. *cribrosum*

(Pls. 1, 5–A, C)

Stipe terete in the lower portion; rhizoidal hapters thick, coarsely branched, arising from the lowest portion of the stipe; blade even, periphery of perforations not raised excepting near the base of the blade.

Japanese name: Aname

Thallus is large, 40–80 cm high, not rarely up to 1 m or more, 30–40 cm wide. The blade is elliptical or oblong in outline, even, not so wavy, somewhat coriaceous and hard in substance, blackish brown in color. The surface of the blade is relatively smooth between perforations. The perforations are larger in size than those of the other forms especially in the central portion near the midrib. The periphery of the perforation is not raised except in the lower portion of the blade. The midrib is generally broader (1–1.5 cm) but variable (0.4–2.0 cm) in breadth. The stipe is generally compressed in the upper portion, while mostly terete in the lower one. The rhizoidal hapters are relatively short and thick, coarsely branched, arising from the lowest portion of the stipe.

In areas strongly affected by wave action, the plant usually shows a round or obtuse outline near the base of the blade, while sometimes a cordate base is found in plants from calm areas.

This form is probably identical with the plants cited below: *A. cribrosum* (pro parte) in BORY, 1826; *Fucus Agarum*, in GMELIN, 1768; *A. Gmelini* var. *planum*, in POST. and RUPR., 1840, Tab. XXI; *A. Turneri*, in HARVEY, 1851, Pl. V, Fig. 1; in MIYABE, 1902, Pl. XXVII; in OKAMURA, 1925, Pl. 225; *A. cribrosum*, in TAYLOR, 1937, Pl. 22, Fig. 1.

Distribution: Inhabiting the area affected directly by the cold current (Kurile Current, East Sakhalin Current) throughout the year.

North and Middle Kuriles; East coast of South Sakhalin; Pacific coast of Hokkaido (from Cape Nosappu to Hidaka-Monbetsu).

Although the GMELIN's plant figured as *Fucus Agarum* in his Historia Fucorum, Tab. 32 (1768) may be one of the original specimens used for his description, it is uncertain whether the type specimen (Holotype) has been designated or not. The type locality is supposed to be in Kamchatka as mentioned later.

f. *rugosum* I. YAMADA f. nov.

(Pls. 2, 5-B, D)

Stipes teres in parte infera hapterae rhizoidales crassae, ex infimo stipite exorientes; lamina inaequalis, peripheria perforationis elevata.

Stipe terete in the lower portion; rhizoidal hapters thick, coarsely branched, arising from the lowest portion of the stipe; blade uneven, periphery of the perforation raised.

Type locality: Muroran, Hokkaido.

Holotype: SAP. 031073

Japanese name: Zara-Aname (nom. nov.)

Thallus is 15–55 cm, rarely up to 1 m, 10–30 (–50) cm wide. The blade is round, elliptical or oblong in outline, uneven, occasionally wavy in the margin. The surface of the blade is slightly coarse. The perforations are relatively small and numerous over the blade. The periphery of the perforations is raised. The stipe and rhizoidal hapters are similar to those of f. *cribrosum*.

Among the plants belonging to this form, three different types are further distinguished. The first one, found on the coast from Muroran to the Tsugaru Strait, is relatively large, brown in color. The second, found on the Japan Sea coast and Okhotsk Sea coast of Hokkaido, is small, only 15–20 cm high, mostly round in outline, light brown in color. The third, found on the east coast of Shiretoko Peninsula, is similar to the first one but the blade is thinner and the perforations are small and numerous.

This form is probably identical with the plants cited below: *A. cribrosum* (pro parte) in BORY, 1826; *Fucus Agarum*, in TURNER, 1809, Tab. 75; *A. Turneri*, in HUMPHREY, 1887.

Distribution: Inhabiting the area affected by the warm current (Tsushima Current and its branches).

Okhotsk Sea side of South Kuriles; Hokkaido excepting the Pacific coast east of Hidaka Prov.

f. *rishiriense* I. YAMADA f. nov.

(Pl. 3, 5-E)

Stipes tortius fere omnes compressus; hapterae rhizoidales longae attenuataeque, e margine stipitis infra medium exorientes; lamina inaequalis, peripheria perforationis elevata.

Stipe comressed throughout; rhizoidal hapters long and attenuated, arising pinnately from the margin more than halfway up the stipe; blade uneven,

periphery of the perforations raised.
Type locality: Ooiso, Rishiri Islet.
Holotype: SAP. 031074
Japanese name: Rishiri-Aname (nom. nov.)

Thallus is 30–55 cm high, 20 cm wide. The blade is ovate or elliptical in outline, uneven and slightly coarse on the surface. The perforations are relatively small and numerous over the blade. The periphery of the perforations is raised. The lower portion of the stipe is compressed excepting the lowest. The rhizoidal hapters arise, sometimes pinnately, from the margin more than halfway up the stipe.

Distribution: Endemic on the coasts around both Rishiri and Rebun Islets of northwestern Hokkaido.

f. *yakishiriense* (Y. YAMADA) I. YAMADA,
f. comb. et stat. nov.
(Pls. 4, 5–F)

Syn. *Agarum yakishiriense* Y. YAMADA, 1962

Stipe extremely flattened; rhizoidal hapters slender, arising numerously from every portion of the stipe; blade uneven, periphery of the perforations raised.

Japanese name: Teuri-Aname

Thallus is 15–30 cm high, 15–20 cm wide. The blade is round in outline with wavy margin, scrolls are occasionally found near the base, light brown or reddish brown in color. The stipe is extremely flattened and broader, not terete even in the lower portion. Slender rhizoidal hapters arise numerously from every portion of the stipe or occasionally pinnately from the margin of the upper portion of the stipe.

Distribution: Endemic on the coasts around both Yakishiri and Teuri Islets of western Hokkaido.

Discussion

POSTELS and RUPRECHT (1840) described three species, *A. Gmelini*, *A. Turneri*, and *A. pertusum*, from materials collected in Kamchatka, Alaska, Canada, and Greenland. These three species were distinguished from each other by the breadth and prominence of the midrib, the substance of the blade, and the size of the perforation. Although their detailed observations are excellent, the characters they chose for distinguishing the species, especially the midrib, were too limited for the materials concerned as pointed out by SETCHELL and GARDNER (1925), who united these three species des-

cribed by POSTELS and RUPRECHT under the earlier name *A. cribrosum* BORY. SETCHELL and GARDNER (1925) stated that in *Agarum* from both the Atlantic and Pacific coasts of north America, there was no cleavage as broader or narrower midrib and as to coarser or finer perforations.

Concerning the selection of the type form of *A. cribrosum*, I decided it on the reason as mentioned follows. *Fucus Agarum* GMELIN (1768), the basionym of *A. cribrosum*, is difficult to be identified as to the forms concerned, because his description and figure are insufficient. However, judging from the photographs of two specimens* which are supposed to have been used for the description by GMELIN and collected from Kamchatka, these plants are very similar to the present f. *cribrosum*. Futhermore, *A. Gmelini* var. *planum* POST. et RUPR., which may be identical with f. *cribrosum* according to the description and figure by POSTELS and RUPRECHT (1840, Tab. XXI), is distributed in Kamchatka and Unalaska. One of the specimens (UBC, 26890, collected from Skan Bay of Unalaska Isl. by P. CHAMT and R. DRISKILL on July, 17, 1966), lent to me by the kindness of Prof. R F. SCAGEL and Dr. L. D. DRUEHL, is clearly identical with f. *cribrosum*. Therefore, the distribution of f. *cribrosum* in the northern Pacific from Alaska to Japan through Kamchatka and Kuriles also supports my judgment as to the type form of *A. cribrosum*.

BORY de ST-VINCENT (1826), who established the genus *Agarum*, stated in his description of *A. cribrosum* that there were two types of blades, "Les uns ont leur fronde ou lame ronde, très-ondulée ou crépée sur les bords, avec la concestance plus épaisse, et les trous qui la criblent inégaux et anguleux. Les autres ont leur fronde oblongue, moins coriace, ···, et sont perés de trous ronde tellement réguliers, quique inégaux en grandeur qu'on dirait ceux de ce gros cribles de parchemin dont on se sert dans certaines fermes pour tamiser des graines nourricières". From this description, the latter type is probably identical with the present f. *cribrosum*.

7 sheets of BORY's specimens and several other specimens of *Agarum* were kindly photographed by Dr. T. YOSHIDA with permission of Dr. BOURRELLY at the herbarium (PC) of Division of Cryptogamy, Museum

* These are preserved in the herbarium of the Museum of Leningrad. Photographs were kindly given by Dr. A. D. ZINOVA. One specimen, a fragment of blade, is appended with a label written as "CHAMISSO reportarit; *F. Clathrus ?*, *F. Agarum ?*", and the other specimen, complete plant, is written as "*Fucus Agarum* GMEL. !, GMEL. Tab. 32, *Agarum Gmelini*, M. de CHAMISSO, ab oris Kamtsch." According to personal communication by Dr. ZINOVA, the former label is written by GMELIN himself and the latter is by MERTENS. The former specimen is somewhat similar to the plant figured by GMELIN (1768, Tab. 32) but not the same.

national d'histoire naturelle, Paris. Judging from the photographs of BORY's specimens, two* of them are very similar to the present f. *cribrosum*, and other two** to f. *rugosum*.

As regards the plants referred to as f. *rugosum*, POSTELS and RUPRECHT (1840) described the raised periphery of the perforations in *A. Turneri* and in *A. pertusum*. HUMPHREY (1887) also noted and figured the raised periphery. However they did not treat it as an important character from the view point of taxonomy.

KAWASHIMA (1967) distinguished two forms of *Agarum* among the plants found in Hokkaido on the basis of the raised or no raised characters of the perforation, although their distribution was not stated. These two forms no doubt correspond to f. *rugosum* and f. *cribrosum* respectively.

These two forms are easily distinguished from each other in the adult stage, however, are not distinct in a very young plant. HUMPHREY (1887) reported in detail the manner of forming the perforations of *A. cribrosum* (as *A. Turneri*) and stated that raised periphery formed was retained for a long time.

As to the distribution of these two forms, it is probable that these are more widely distributed than stated. Photographs, offered by Dr. T. YOSHIDA, of two specimens of *A. cribrosum*, preserved in PC, collected by Farlow from the Atlantic coast of north America (Loc.: Eastport, Maine; and Cape Ann, Mass.) show that these plants are very similar to f. *cribrosum*.

It is thought that at least another form besides those enumerated in this paper may be found in some places of the north Pacific. Some of the specimens offered by Prof. SCAGEL and Dr. DRUEHL from southern Alaska (UBC, 20487, 22511 from Duke Isl. and 20421 from Baranof Isl.) have the blade scarcely perforated with terete stipe.

Concerning the Japanese plants, MIYABE (1902) first described under the name of *A. Turneri* and figured the plant collected from Rebun Islet,

* One plant of these specimens is ca. 23 cm high, 10 cm wide, elliptical in outline. This specimen is appended with two labels; A name "*Orgyia Boryi*" is found on the label of "Herbier BORY de ST-VINCENT", and the other is G. THURET's label with a note "*Agarum Turneri* POST. et RUPR. (*Laminria Agarum* var. *Asiatica* LA PYLAIE, Fl. de Terre-Neuve, p. 28). The other specimen is of a fragment of blade providing a part of midrib and appended with two labels; one is BORY's label described as "*Orgyia Boryi*", and the other is memorized as "*Laminaria Agarum*, Grónlandia, par Lyngbye, 1828" with no signature.

** One specimen is appended with two labels; one is BORY's label described as "*Orgyia Agarum* (rugosa)", and the other is THURET's label described as "*Agarum pertusum* POST. et RUPR. (*Laminaria Agarum* LA PYLAIE, Fl. de Terre-Neuve, p. 25)". The other specimen is appended with BORY's label as "*Orgyia Agarum* (rugosa)".

which looked like a plant referred to as f. *cribrosum*. However other specimens from Rebun and Rishiri Islets, determined by MIYABE, are no doubt referred to f. *rishiriense*. A plant of the even blade group has never been encountered near Rebun and Rishiri during this study. Several specimens collected by MIYABE and TOKIDA from southernmost region of Sakhalin are recognized as f. *cribrosum*, therefore MIYABE's specimen in the figure mentioned above seems to be of drifted plant from Sakhalin.

NAGAI (1940) distinguished three forms among the plants from Kuriles, referring them to *A. Turneri*, *A. Gmelini*, and a young plant respectively. According to my examination, many specimens from Kuriles by NAGAI are to be referred to either f. *cribrosum* or f. *rugosum*. Among them, the plants of f. *rugosum* are distributed on the Okhotsk Sea side of both Kunashiri and Etorofu Islands, and also on the eastern part of Shikotan Island and on some places of the Pacific side of Kunashiri, whereas the plants of f. *cribrosum* are distributed on the coast of Shikotan Isl. and on the Pacific coasts of Kunashiri and Etorofu Isls., but never found on the Okhotsk Sea side. The distribution of the two forms in this region is thought to be related to the current system that usually carries water from the Okhotsk in to the Pacific through the Nemuro and Kunashiri Straits especially in the winter season (WATANABE, 1967).

The boundary line between the distribution of the two forms, f. *cribrosum* and f. *rugosum* in Hokkaido is set at Cape Nosappu of Nemuro Peninsula in the east, while the western boundary is in a sandy coastline (about 100 km) between Hidaka-Monbetsu and Muroran. At Cape Nosappu, both of the two forms are found in a small sandy beach as washed ashore plants. They probably occur isolated from each other, as no mixed population has been found during diving work. The boundary line between Hidaka-Monbetsu and Muroran is not only the southern limit in the distribution of f. *cribrosum*, but also is that of other cold current species such as *Constantinea subulifera*. At Hidaka-Monbetsu the thalli of f. *cribrosum* are smaller than those at any other localities in the eastern Hokkaido. These facts in the distribution of the two forms suggest that the even blade group and uneven blade group are of different genetic strains.

Y. YAMADA (1962) proposed a key to the species of *Agarum* in which the plants were generally divided by the shapes of the stipe and rhizoidal hapters. According to him, *A. oharaense*, *A. yakishiriense* and *A. fimbriatum* are referred to one group characterized by the flattened stipe, and *A. cribrosum* is referred to another one characterized by the terete stipe. However it seems better to be separated by the evenness and unevenness of the blade

because the distributional pattern of the two groups appears to be affected in acccordance with the cold or warm currents.

A. yakishiriense is clearly distinguished morphologically from other forms with respect to the flattened stipe, however I think it a form of *A. cribrosum* because *A. yakishiriense* shows some characteristics of f. *rugosum* and f. *rishiriense*. F. *rishiriense* seems to be an intermediate form between f. *rugosum* and f. *yakishiriense*. Futhermore, crossing experiments between *A. yakishiriense* and other three forms of *A. cribrosum* shows that they are interfertile (NAKAHARA and I. YAMADA, 1974).

In the northwestern region of Hokkaido, f. *cribrosum*, f. *rishiriense* and f. *yakishiriense* are distributed near each other. It is ineresting that the populations f. *rishiriense* and f. *yakishiriense* are found only on the coasts of islets off Hokkaido mainland. This suggests that there must be some differences in the environmental factors controlling the distribution in this smaller area. However there are little data on the coastal waters from which to speculate the reason. The area including Rebun, Rishiri, and near Cape Soya is sometimes affected but not strongly by the cold East Sakhalin Current in winter. Some characteristic species of the cold current such as *Pelvetia wrightii, Odonthalia corymbifera* are found there; however, they have not been found at Yakishiri and Teuri Islets which are not affected directly by the cold current. This indicates that there is some difference in the sea-water temperature in this area.

It is also noticeable that the distributional regions of the plants having flattened stipe such as *A. cribrosum* f. *yakishiriense* and *A. oharaense* are restricted nearly to the southern limit of the distribution of *Agarum* in the western Pacific. On the contrary, *A. fimbriatum*, also provided with flattened stipe, is distributed in a wider range in the eastern Pacific from southern Alaska to California (DRUEHL, 1969).

VADAS (1969) reported that in the laboratory experiments, gametophytes and sporophytes of *A. cribrosum* collected from San Juan Island had optimal growth and reproductive rates under low temperature (5°C), but impaired by high light and high temperature; on the contrary optimal growth and reproduction of *A. fimbriatum* from Friday Harbor occurred at 10 to 15°C. These results suggest that physiological differences as well as morphological ones among the present four Japanese forms may be recognized.

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Summary

Four forms of *A. cribrosum* from Hokkaido, Kurile Islands and South Sakhalin are distinguished on the basis of the features of the blade, stipe and rhizoidal hapters. *A. yakishiriense* is regarded as a form of *A. cribrosum*. Their distributional patterns do not overlap. These four forms are designated as follows; f. *cribrosum* having even blade with terete stipe, inhabiting an area affected by the cold currents; f. *rugosum* having uneven blade with terete stipe, inhabiting an area affected by the warm current; f. *rishiriense* having uneven blade with compressed stipe, endemic to both Rishiri and Rebun Islets; and f. *yakishiriense* having uneven blade with flattened stipe, endemic to both Yakishiri and Teuri Islets.

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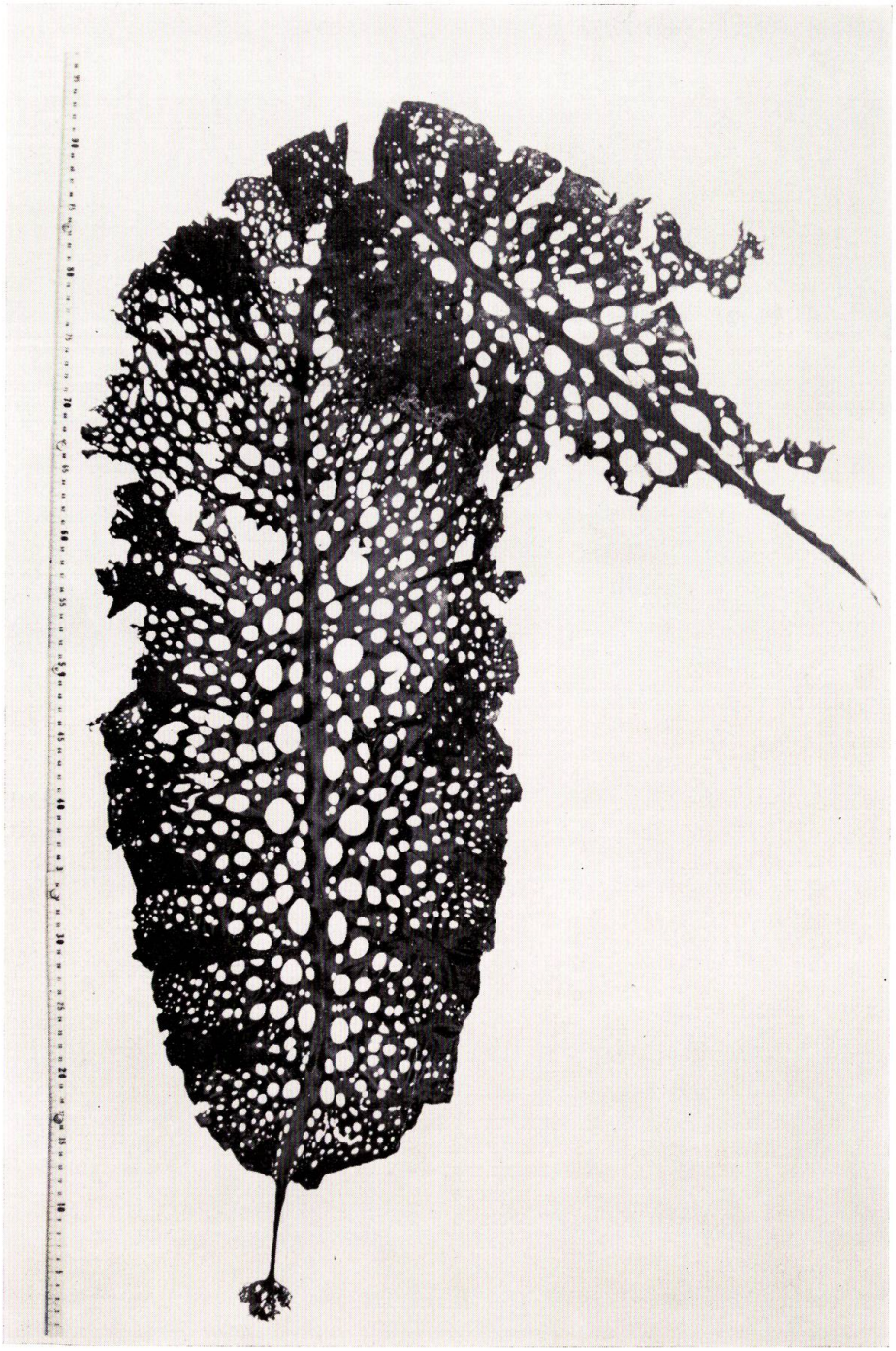
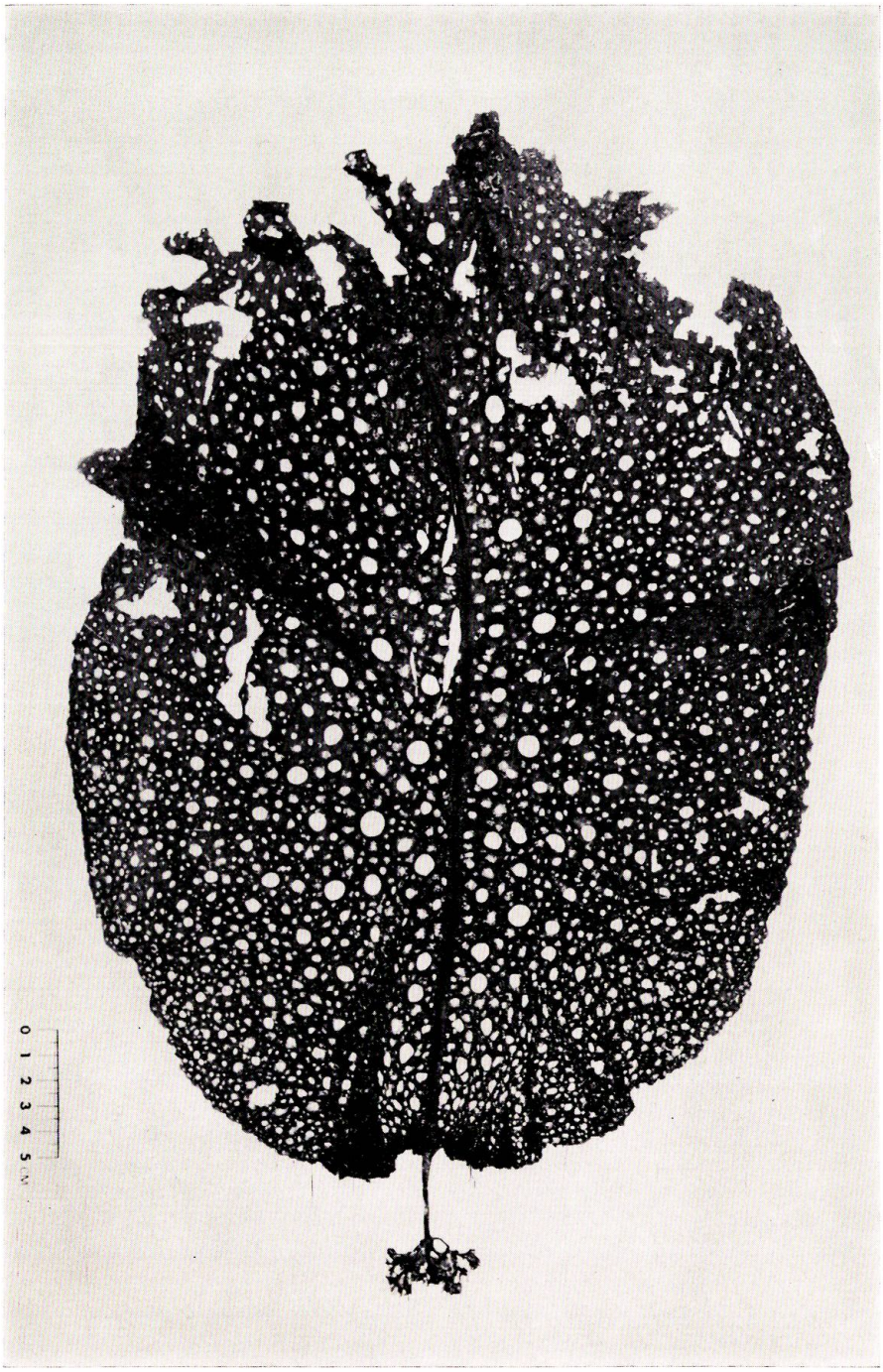
Pl. 1. *Agarum cribrosum* BORY f. *cribrosum*

SAP. 031072, collected from Cape Nosappu of Nemuro Peninsula by M. KUROGI, 1968.



Pl. 2. *Agarum cribrosum* BORY f. *rugosum* I. YAMADA f. nov. SAP. 031073 (Holotype), collected from Etomo, Muroran by I. YAMADA, April, 1971.

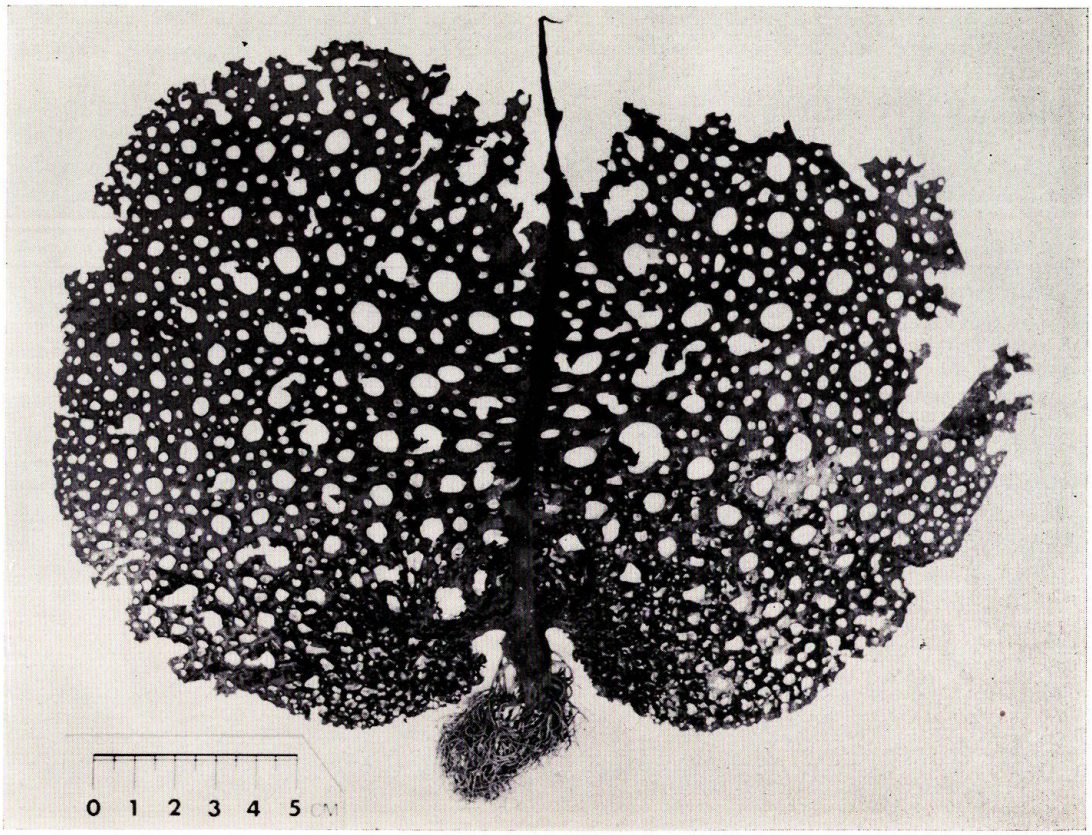

0 1 2 3 4 5 CM

Pl. 3. *Agarum cribrosum* BORY f. *rishiriense* I. YAMADA, f. nov.
SAP. 031074 (Holotype), collected from Ooiso, Rishiri Isl. by I. YAMADA, July, 1969.

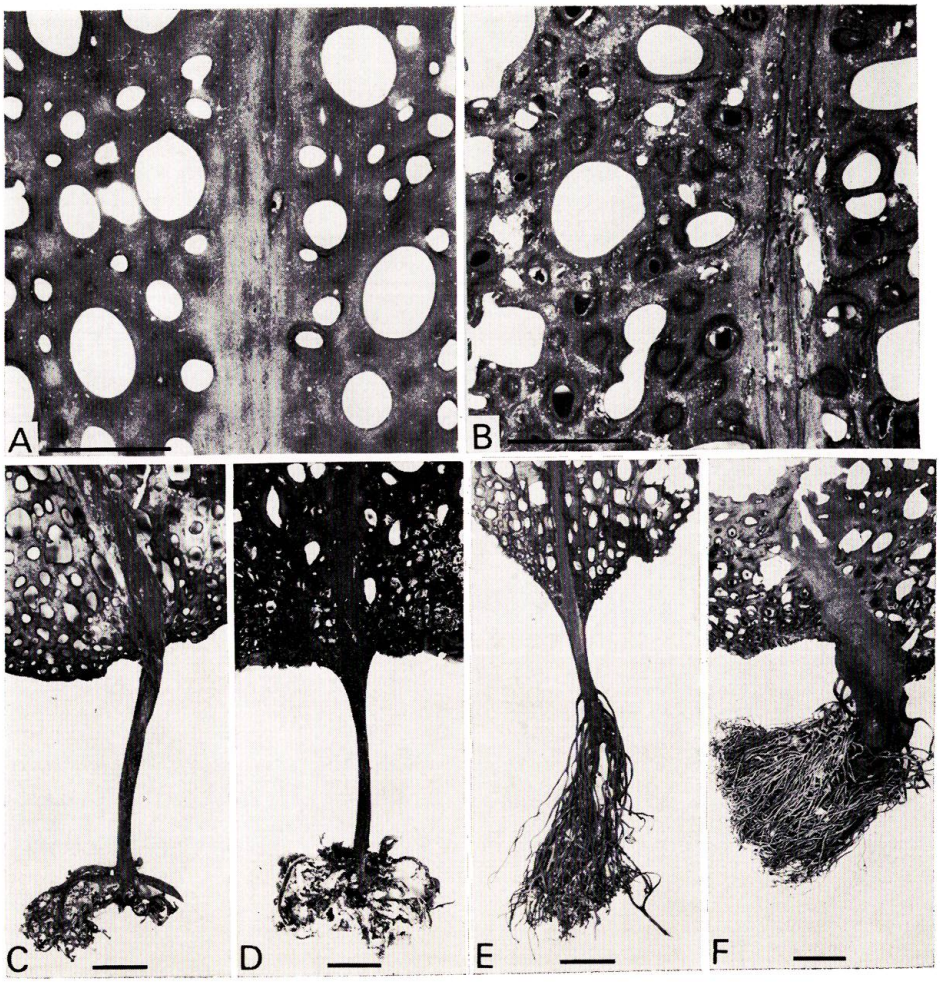
0 1 2 3 4 5

Pl. 4. *Agarum cribrosum* BORY f. *yakishiriense* (Y. YAMADA) I. YAMADA, f. comb. et stat. nov.

SAP. 028605 (Holotype), collected from Yakishiri Isl. by Y. YAMADA, Aug., 1960.


0 1 2 3 4 5 CM

Pl. 5. Differences in the blades, stipes, and rhizoidal hapters. A, Even blade in f. *cribrosum* collected from Cape Erimo; B, Uneven blade in f. *rugosum* from Muroran; C and D, Terete stipe giving off short and thick rhizoidal hapters in f. *cribrosum* from Cape Erimo (C), and in f. *rugosum* from Muroran (D); E, Compressed stipe giving off long attenuated rhizoidal hapters in f. *rishiriense* collected from Rishiri Isl.; F, Flattened stipe giving off numerous slender rhizoidal hapters in f. *yakishiriense* from Yakishiri Isl. Each of the scales shows 1 cm.


A
B
C
D
E
F