

Audouinella kurogii, a new marine red alga (Acrochaetiaceae) from eastern Hokkaido

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A new species of Acrochaetiaceae is described from the eastern coast of Hokkaido. It is characterized by a single large endophytic basal cell, oppositely branched "erect" filaments lying parallel to the host surface, a single stellate plastid per cell, a thick but transparent cell wall, and simple carposporophyte development after transverse division of the fertilized carpogonium.

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Despite the large number of species of Acrochaetiaceae which have been described to date, new taxa continue to be reported. Owing to their small size, acrochaetioid algae can be easily overlooked, and only microscopic examination will reveal the presence of endophytic, endozoic, or small epiphytic species, which are easily camouflaged by florideophycean and other hosts. The species reported in this paper was first noticed during microscopic examination of the host plant, *Constantinea rosamarina*.

Description

*Audouinella kurogii*¹⁾ Y. P. LEE et LINDSTROM, sp. nov.

Thallus in parte endophyticus, e cellula basali unica et 4-6 filamentis erectis compositus; cellula basalis in strato corticali hospitis immersa, obpyriformis usque ampuliformis, 18-35 μm lata et 25-27 μm longa;

filamenta erecta e cellula basali orientia et ad planum paginae hospitis parallele evoluta, in longitudine 300-600 μm , secus axem totum opposite ramosa; cellulae filamentorum erectorum obovoideae usque breviclaviformes cum pariete cellulae aliquantum crasso (usque ad 5 μm), in parte inferiori 8-10 μm latae et 12-15 μm longae, oblongae vel triangulares in forma, in parte superiori ca 5 μm latae et 5-7 μm longae; plastidia cum pyrenoide centrali stellata, unica pro cellula una; planta monoecia; spermatangia lateralialia aut terminalialia, globosa, 2-3 μm in diametro; carpogonia terminalialia in axe principali ramisque, 4-5 μm lata et 6-7 μm longa cum trichogyne papillata usque spatulata; carposporophyta valde simplicia e cellula una rare eis duabus a divisione transversali carpogonii fertilis oriundis et plerumque carposporangiis tribus; carposporangia obpyriformia usque oblonga, 9-11 μm lata et 18-22 μm longa; monosporangia globosa, ca 5 μm in diametro. Tetrasporo-

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1) This alga is named in honor of Professor Munenao KUROGI in appreciation for his sincere interest in our studies. In addition, we feel it is particularly appropriate to name this species after him because of his contributions to the study and the commercial cultivation of seaweeds in the cold current area of Japan where this plant is found.

phyton ignotum.

Thallus partially endophytic, composed of a single basal cell and 4-6 erect filaments; basal cells immersed in the cortical layer of the host, obpyriform to ampulliform, 18-35 μm wide by 25-27 μm long; erect filaments arising from the basal cell and developing parallel to the plane of the host surface, 300-600 μm in length, oppositely branched along the entire axis; cells of erect filaments obovoid to short club-shaped with a rather thick cell wall (to 5 μm), 8-10 μm wide by 12-15 μm long in the lower part, and oblong or triangular in shape, about 5 μm wide by 5-7 μm long in the upper part of the filament; plastids stellate with a central pyrenoid, one per cell; plants monoecious; spermatangia lateral or terminal, globose, 2-3 μm in diameter; carpogonia terminal on the main axis and branches, 4-5 μm wide by 6-7 μm long with papillate to spatulate trichogynes; carposporophytes very simple, composed of one or rarely two cells derived from a transverse division of the fertilized carpogonium and usually three carposporangia; carposporangia obpyriform to oblong, 9-11 μm wide by 18-22 μm long; monosporangia globose, about 5 μm in diameter. Tetrasporophyte unknown.

Japanese name: Hane-beninoito (M. KUROGI)

Holotype: Collected at Nosappu Misaki, Nemuro Province, on 7 June 1978. Type collection is deposited as SAP-034552 in

the Hokkaido University Faculty of Science Herbarium.

Habitat: This species is recorded only from the type locality, Nosappu Misaki (Lat. 43°23'N, Long. 145°49'E), Nemuro Province, Hokkaido, Japan. Plants were found on the host species *Constantinea rosamarina* (GMELIN) POSTELS et RUPRECHT at a depth of about 5 meters below zero tide level.

Vegetative Structure: Plants grow on the blade of *Constantinea rosamarina* by inserting the basal cell into the cortical layer of the host. Germinating spores presumed to be monospores were observed penetrating between the cortical cells of the host (Fig. 1); they appear more or less stellate from above and cuneate from the side. They give rise to erect filaments in the opposite direction during their penetration of the host (Fig. 2). Consequently, the original spore itself is transformed into the basal cell, which settles in the host tissue one and a half times the basal cell length beneath the surface.

Basal cells are obpyriform. In some plants, the cell becomes irregularly furrowed longitudinally in the upper half, making it ampulliform in side view (Fig. A) and giving it a somewhat stellate appearance when seen from above (Fig. B). The plastid of the basal cell is stellate, lying along the top of the cell with arms extending almost to the base of the cell. Each basal cell gives rise to 4-6 erect fila-

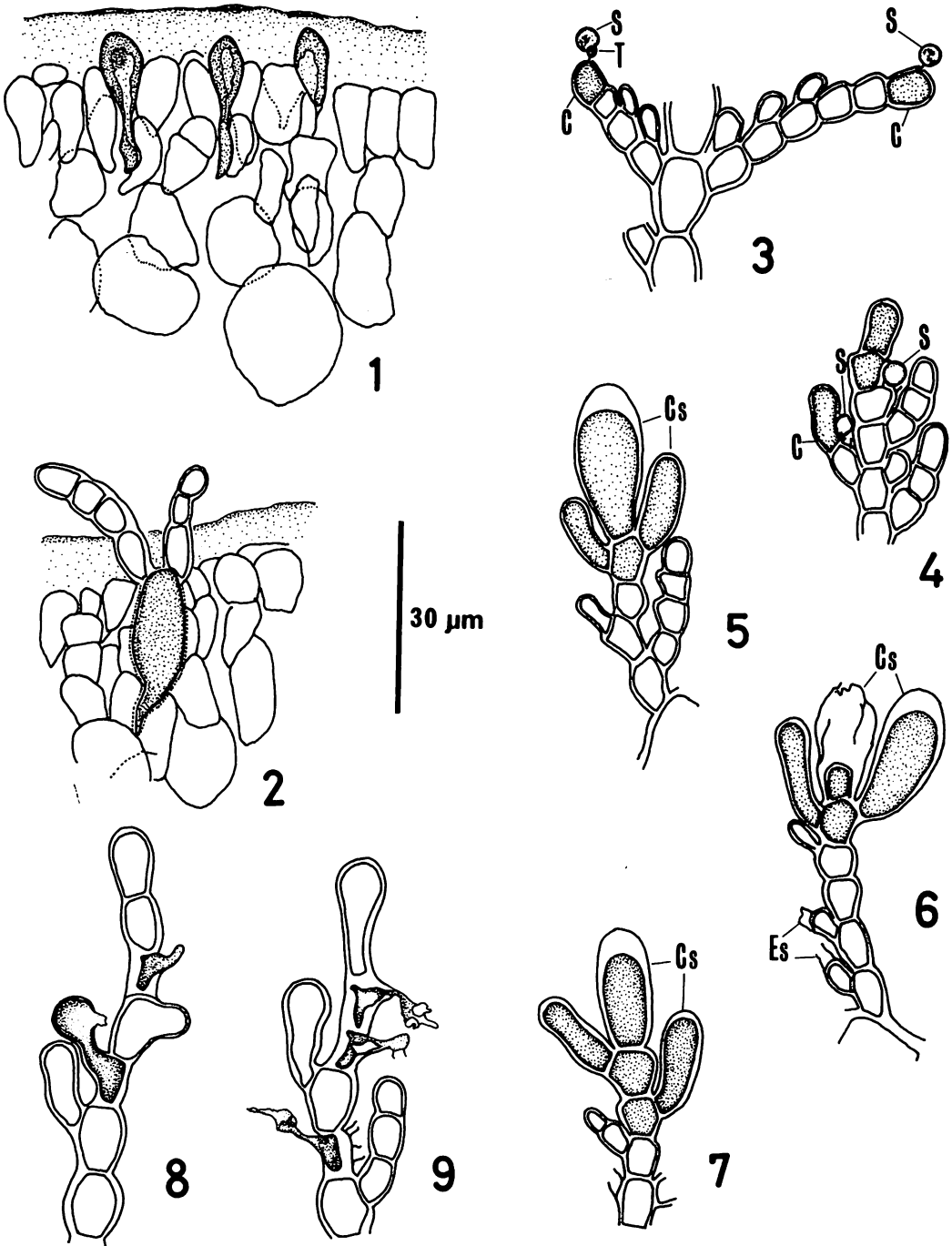
Figs. 1-9. *Audouinella kurogii* Y. P. LEE et LINDSTROM

Fig. 1. Germinating spores penetrating between the cortical cells of the host. Fig. 2. Two erect filaments beginning to grow from a spore transformed into a basal cell as it penetrates between the cortical cells of the host. Fig. 3. Two terminal carpogonia with trichogynes and attached spermatia, trichogyne on left showing spatulate shape. Fig. 4. Enlargement and transverse division of the fertilized carpogonium. Fig. 5. Typical carposporophyte with the proximal cell of a fertilized carpogonium and three carposporangia. Fig. 6. Typical carposporophyte with an empty carposporangium into which a second carposporangium has begun to bud out. Fig. 7. A carposporophyte composed of a fertilized carpogonium in which two transverse cell divisions occurred prior to carposporangia production. Figs. 8 and 9. Formation of balloon-like bodies, which subsequently rupture and release most of the contents of the mother cells. S=spermatium, T=trichogyne, C=carpogonium, Cs=carposporangium, Es=empty spermatangium.

ments.

Erect filaments develop parallel or somewhat obliquely to the plane of the host surface (Fig. C), giving the appearance of a brittle star when seen from above (Fig. D); filaments perpendicular to the host

surface were not observed. The filaments gradually taper toward the apex, being 8–10 μm wide in the lower part and about 5 μm wide in the upper part of the filaments. Most cells of the main axis produce opposite pairs of short, determinate



branches near their distal ends (Fig. E). These pinnate branches are also arranged on a plane parallel to the host surface. Opposite branches are not always equal in length. Cells of erect filaments and branches are obovoid to short club-shaped or oblong.

The cell wall, including that of empty sporangia and spermatangia, is very transparent and hardly discernible even when stained with cotton blue. However, the cell wall is quite thick (to 5 μm) in the lower portion of the main axis (Fig. F).

Some cells near the apices of the main axis and the branches, or even the carposporophyte cells, have protruding balloon-like bodies filled with the contents from the mother cells which, as a result, become pale and shrivel as the balloon-like bodies enlarge (Fig. 8). The balloon-like bodies eventually burst (Fig. 9).

No hairs were observed although spine-like cells were sometimes seen terminally (Fig. G).

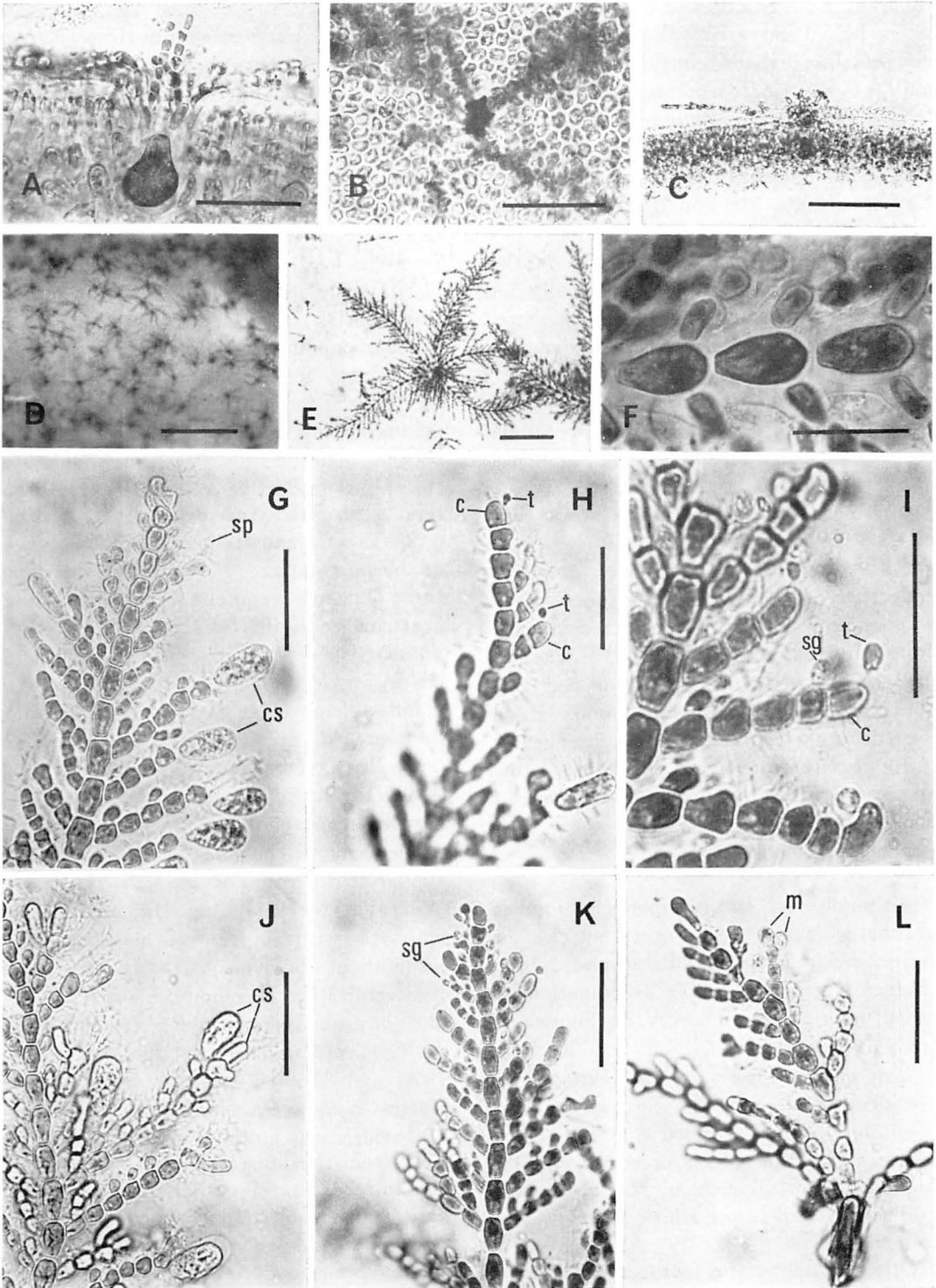
Sexual Reproduction and Postfertilization Development: Carpogonia are borne terminally on the main axis and branches (Fig. H). They are hardly distinguishable

from vegetative cells unless they have trichogynes, being 4–5 μm wide by 6–7 μm long. Trichogynes are usually inserted laterally on the distal side of the carpogonia. They arise as small papilla-like protrusions and enlarge up to 6 μm in length with a short, narrow neck and become spatulate (Fig. I). The contents of the trichogyne are very dense.

Carposporophytes are very simple. After fertilization (Fig. 3) carpogonia enlarge distally and divide by a transverse wall near where the trichogyne was inserted (Fig. 4). The distal cell continues to enlarge and, as a result, becomes a terminal carposporangium. Meanwhile, the proximal cell gives rise to another protrusion laterally that will also become a carposporangium, and a third carposporangium is subsequently produced opposite the second (Fig. 5). There are usually three sites of carposporangia formation in a carposporophyte. While the second carposporangium is liberating its carospore, the third one is maturing, and a new carposporangium begins to regenerate in the empty sporangium of the first (Fig. 6, Fig. J). Rarely, the distal cell, rather than developing into a carpospo-

Figs. A-L. *Audouinella kurogii* Y. P. LEE et LINDSTROM

Fig. A. A basal cell which has become furrowed in the upper half and appears ampulliform. Scale=50 μm . Fig. B. Stellate appearance of a basal cell as seen from above. Scale=50 μm . Fig. C. "Erect" filaments showing characteristic development parallel or slightly oblique to the plane of the host in side view. Scale=30 μm . Fig. D. A community of plants on the host tissue showing the characteristic brittle star shape. Scale=1 mm. Fig. E. Short, determinate opposite branches arising laterally from the distal end of almost every cell. This figure also shows the characteristic brittle star appearance of the plant. Scale=50 μm . Fig. F. Thick but nearly transparent cell wall in lower portion of the main axis. Stellate plastids are visible near the distal end of each cell. Scale=20 μm . Fig. G. Terminal spine-like cells. Scale=30 μm . Fig. H. Apical portion of a plant showing carpogonia with trichogynes containing dense material borne terminally on the main axis and branches. Scale=20 μm . Fig. I. Carpogonium with an enlarged spatulate trichogyne. The cell beneath the carpogonium has produced a lateral spermatangium. Scale=20 μm . Fig. J. Carposporangia at various stages of maturity, including one budding out into an empty, sporangium. Scale=30 μm . Fig. K. Spermatangia borne terminally and laterally singly or in pairs on branches and on the main axis. Scale=30 μm . Fig. L. Monosporangia borne in pairs on a branch. Scale=30 μm . sp=spine-like cells, cs=carposporangium, c=carpogonium, t=trichogyne, sg=spermatangium, m=monosporangium.



rangium itself, enlarges distally and divides again by a transverse wall. The terminal cell of this division continues to enlarge and becomes a carposporangium, both cells below the carposporangium which were derived from the fertilized carpogonium producing lateral carposporangia (Fig. 7). Carposporangia are obpyriform to oblong, 9–11 μm wide by 18–22 μm long.

Spermatangia are borne laterally on the main axis and laterally or terminally on branches, often in pairs, and are globose, 2–3 μm in diameter (Fig. K). They usually appear in proximity to carpogonia.

Plants are monoecious.

Asexual Reproduction: Monosporangia are terminal or lateral on the branches and are about 5 μm in diameter (Fig. L). Plants bearing monosporangia were very rare in the material at hand.

Phenology: Except for July, monthly collections of the host have been made where this alga was first collected in early June. In early August, a few degenerate plants, consisting of the basal cell and short, sterile filaments, were found. However, in early September and subsequently (through late November) no plants of this species could be found on *Constantinea*.

Discussion

Although *Au. kurogii* shares a number of characteristics with other species of Acrochaetiaceae, it exhibits several unique characteristics and has a combination of other features which easily distinguish it from other taxa.

Two characteristics of *Au. kurogii* are not shared with other species which have been heretofore described: 1) The erect filaments of this plant produce opposite branches from all cells of the main axis. 2) The cell wall is very thick (to 5 μm) and transparent.

Other characteristic features of *Au. kurogii* include a large single basal cell, erect filaments parallel to the plane of the host surface, and distinctive carposporophyte morphology.

1) A large single basal cell: In this respect *Au. kurogii* resembles *Acrochaetium affine* HOWE et HOYT (1916) and *Ac. macropoda* DANGEARD (1952). However, the basal cell is larger than that of either of these two species. Furthermore, it differs from *Ac. affine* in that the latter species has upright filaments, parietal plate plastids, and development of accessory cells from the basal cell which result in a kind of multicellular base. *Au. kurogii* also differs from *Ac. affine* in the morphology of the carpogonium and the carposporangia formation. It differs from *Ac. macropoda* in that the latter species has upright filaments bearing few branches and cells with parietal plate plastids. Monosporangia are the only reproductive cells which have been reported for *Ac. macropoda*.

2) Erect filaments parallel to the plane of the host surface: *Au. kurogii* develops erect filaments parallel to the plane of the host surface as in *Kylinia rosulata* ROSENVINGE (1909), *K. scapae* LYLE (1931) and *Ac. kylinoides* FELDMANN (1958). However, it differs from these three species in that they are all epiphytic and composed of few-celled erect filaments.

3) Distinctive carposporophyte morphology: The morphology of the carpogonium, particularly trichogyne shape, is rather similar to that of *Au. australis* (LEVRING) WOELKERLING (1971), but *Au. australis* is epiphytic with short erect filaments with or without branches, and is dioecious. Postfertilization development and the simple carposporophyte resemble those of *Kylinia rosulata* ROSENVINGE (FELDMANN 1958) and *Ac. polyblastum* (ROSENVINGE) BØRGESEN (STEGENGA & BORSJE 1977), species which are quite morphologically distinct from the present species.

Plants bearing monosporangia were very rare in the materials at hand. In contrast, monosporangia are quite common in most other species of Acrochaetiaceae. Their scarcity in the present material may be due to one of several factors: 1) The season when this plant was collected is the optimum time for this plant to produce

sexual reproductive structures and carposporangia rather than monosporangia; consequently, it is thought that this plant produced monosporangia already and liberated most of them prior to collection. 2) The local environment inhibits this plant from producing monosporangia. 3) This plant has tended to lose its ability to produce monosporangia during its evolution.

Genera of the Acrochaetiaceae have been variously delimited on the basis of plastid morphology, occurrence of pyrenoids, basal system morphology, and mode of reproduction. According to basal system, this species belongs to the genus *Kylinia* (ROSENVINGE 1909; KYLIN 1944) which is characterized by having a unicellular base. On the other hand, based on plastid morphology, this species should be referred to the genus *Chromastrum* (PAPENFUSS 1945) which possesses stellate plastids. However, recent culture studies have shown that some taxa with unicellular bases alternate with taxa with multicellular bases in their life histories (KNAGGS & CONWAY 1964; WEST 1968; BORSJE 1973; BOILLOT & MAGNE 1973; STEGENGA & VROMAN 1976; STEGENGA & BORSJE 1977; STEGENGA 1978). Other studies have shown that plastid morphology is a species-constant but not a genus-constant character (WOELKERLING 1971). Therefore, we prefer to follow WOELKERLING (1971, 1973) and DIXON and IRVINE (1976, 1977) and use the genus name *Audouinella* for this species until further knowledge of the Acrochaetiaceae is accumulated.

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References

- BOILLOT, A. et MAGNE, F. 1973. Le cycle biologique de *Kylinia rosulata* ROSENVINGE (Rhodophycée, Acrochaetiales). Bull. Soc. Phycol. Fr. 18: 47-53.
- BORSJE, W. J. 1973. The life history of *Acrochaetium virgatulum* (HARV.) J. AG. in culture. Br. phycol. J. 8: 205.
- DANGÉARD, P. 1952. Algues de la presqu'île du Cap Vert (Dakar) et de ses environs. Botanique 36: 193-239.
- DIXON, P. S. and IRVINE, L. M. 1976. Checklist of British marine algae-third revision. Rhodophyta. Florideophyceae. (Ed. M. PARKE and P. DIXON) J. mar. biol. Ass. U. K. 56: 532-540.
- DIXON, P. S. and IRVINE, L. M. 1977. Seaweeds of the British Isles. I. Rhodophyta. Part 1. Introduction, Nemaliales, Gigartinales. Brit. Mus. (Nat. Hist.), London, 252 pp.
- FELDMANN, J. 1958. Le genre *Kylinia* ROSENVINGE (Acrochaetiales) et sa reproduction. Bull. Soc. bot. Fr. 105: 493-500.
- HOWE, M. A. and HOYT, W. D. 1916. Notes on some marine algae from the vicinity of Beaufort, North Carolina. Mem. N. Y. Bot. Garden 6: 105-123.
- KNAGGS, F. W. and CONWAY, E. 1964. The life history of *Rhodochorton floridulum* (DILLW.) NÄG. I. Spore germination and the form of the sporelings. Bull. Br. Phycol. Soc. 2: 339-341.
- KYLIN, H. 1944. Die Rhodophyceen der Schwedischen Westküste. Acta Univ. Lund. (N. F. Avd. 2) 40: 1-104.
- LYLE, L. 1928. Marine algae of some German warships in Scapa Flow and of the neighboring shores. J. Linnean Soc., London, Bot., 158: 231-257.
- PAPENFUSS, G. F. 1945. Review of the *Acrochaetium-Rhodochorton* complex of red algae. Univ. Calif. Publ. Bot. 18: 299-334.

- ROSENVINGE, L. K. 1909. The marine algae of Denmark. I. Rhodophyceae I. K. danske Vidensk. Selsk. Skr. 7: 1-151.
- STEGENGA, H. 1978. The life histories of *Rhodochorton purpureum* and *Rhodochorton floridulum* (Rhodophyta, Nemaliales) in culture. Br. phycol. J. 13: 279-289.
- STEGENGA, H. and BORSJE, W. J. 1977. The morphology and life history of *Acrochaetium polyblastum* (ROSENV.) BØRGESEN and *Acrochaetium hallandicum* (KYLIN) HAMEL (Rhodophyta, Nemaliales). Acta Bot. Neerl. 26: 451-470.
- STEGENGA, H. and VROMAN, M. 1976. The morphology and life history of *Acrochaetium densum* (DREW) PAPENFUSS (Rhodophyta, Nemaliales). Acta Bot. Neerl. 25: 257-280.
- WEST, J. A. 1968. Morphology and reproduction of the red alga *Acrochaetium pectinatum* in culture. J. Phycol. 4: 89-99.
- WOELKERLING, W. J. 1971. Morphology and taxonomy of the *Audouinella* complex (Rhodophyta) in Southern Australia. Aust. J. Bot., Suppl. 1: 1-91.
- WOELKERLING, W. J. 1973. The morphology and systematics of the *Audouinella* complex (Acrochaetiaceae, Rhodophyta) in Northeastern United States. Rhodora 75: 529-621.

李 龍 弼・S. C. リンドストローム：北海道東岸に発見された紅藻 *Acrochaetiaceae* の一新種 *Audouinella kurogii* (ハネベニノイト)

根室の納沙布岬で採集したオキツバラに *Audouinella* 属の特色のある一植物が着生しているのが見付かり、これを新種 *A. kurogii* Y. P. LEE et LINDSTROM (ハネベニノイト, 新称, 黒木) として記載した。本植物は一つの大きな内生的基部細胞を持ち、それから羽状分枝の直立糸が水平の方向に放射状に発達し、細胞は一つの星状の色素体と透明な厚い細胞壁を有し、受精した造果器は極めて簡単な果胞子体をつくる。(060 札幌市北区北10条西8丁目 北海道大学理学部植物学教室)