On the Tetraspore-Germination of Culacanthus okamurai YAMADA

On the Tetraspore-Germination of *Culacanthus okamurai* YAMADA[1)]

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Caulacanthus okamurai YAMADA is a member of the family Sphaerococcaceae, order Gigartinales (OKAMURA 1936) and is distributed along the coasts from Formosa to Hokkaido, Japan (YAMADA 1933). It was first referred to *Endocladia complanata* HARVEY by OKAMURA whose precise description and nice figures were given in his "Icones" (1908). Afterwards YAMADA (1933) examined Harvey's original specimens and concluded that Okamura's *Endocladia* was quite different from Harvey's *Endocladia complanata*. And he described Okamura's plant as a new species, *Caulacanthus okamurai*, instead of *Endocladia complanata* HARVEY.

Since the genus *Caulacanthus* was established by KÜTZING in 1843 with the type species, *Caulacanthus ustulata*, its systematic position has been discussed for a long time. The genus *Caulacanthus* has formerly been placed in the family Gelidiaceae (BORNET et THURET 1876, SCHMITZ 1889); but FELDMANN and HAMEL (1934) emphasize that the correct systematic position of the genus is in the family Sphaerococcaceae, basing this view upon the facts that the apical cell is divided by oblique walls, that the tetrasporangia are zonately divided and that the cystocarp shows a great resemblance to that of the genus *Heringia* (KYLIN 1932).

Then FELDMANN (1938) observed the germination of the tetraspores of the Mediterranean species, *Caulacanthus ustulata*, and arrived at the conclusion that this species follows Kylin's "Haftscheibentypus" in the mode of tetraspore germination, but it was very different from what is the case in the Gelidiales.

Culture experiments of the tetraspores of *Caulacanthus okamurai* were carried out in the laboratory of Ryukyu University in 1959, 1960 and 1961. The author gained the result that the method of the germination was very different from that investigated by FELDMANN. On the other hand, the author could observe the germination of tetraspores of *Gelidium sp.* and that of *Gelidiella acerosa*, and confirmed that they were similar to what is called the gelidial type described by INOH in 1947. In the present paper the result is described in detail.

Before going further, the author wishes to express his hearty thanks to the late Professor Sokichi SEGAWA, Department of Fisheries of Kyushu University, for suggesting this investigation as well as constant guidance in the course of the work. His cordinal thanks are also due to Professor Yukio YAMADA, Department of Botany of Hokkaido University, for his revising the manuscript. Finally his thanks are also due to Dr. Minoru KATADA, Kisarazu Fishery Reserch Laboratory of Tokyo University of Fisheries, and Dr. Tadao YOSHIDA, Tohoku Regional Fisheries Research Laboratory, for their kind help in preparing the manuscript.

I) This work was aided by a grant from the University of the Ryukyus.

Materials and Observation

The materials used for the culture experiments in the laboratory were collected from the coasts of Naha and Nashiro, Okinawa Island, Ryukyu, Japan. They aggregated on the rocks at high-tide level togethor with some other algae, such as *Gelidium pusillum* and *Bostrychia tenella.*

The tetrasporangia form nemathecia-like sori in slightly thickened branchlets in general, and are zonetely divided. Great numbers of mature individuals provided with tetrasporangia were collected during October and November. Some fragments of the frond with ripe tetrasporangia were taken from the collected plants, and were placed on the slide-glasses in the vessels filled with filtered

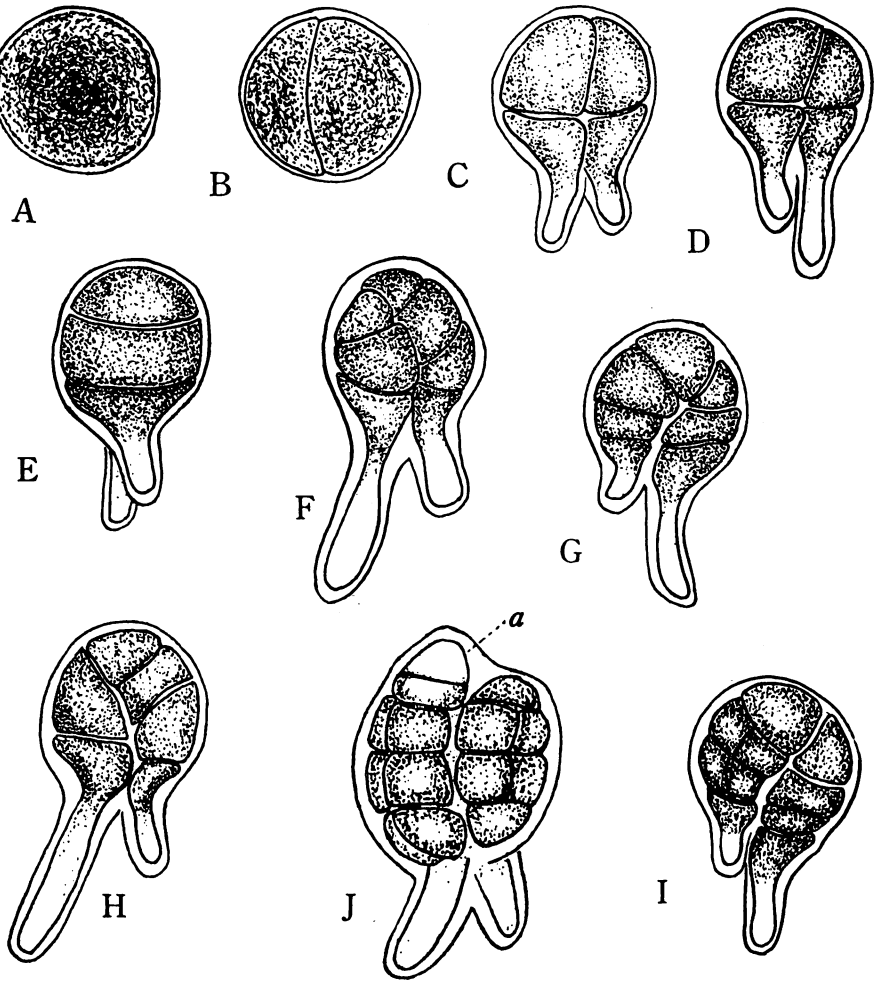

Fig. 1. Various stages in the early development of the tetraspore of *Caulacanthus okamurai.*
A. Adhered spore. B. First cell division (surface view). C, D. Second cell division and the development of a primary rhizoid. E–I. The young germlings. J. The young germling three weeks old, showing an apical cell (*a*). (×550)

sea-water which were left in that condition. Many liberated tetraspores settled on the slide-glasses after 24 hours. Such slide-glasses were transferred into other vessels, and thus the cultures were set.

The liberated tetraspores are spherical in shape, measuring 24–31 microns (usually 25 microns) in diameter. Although they are naked when liberated, later they are enclosed by a thin membrance at the time of germination. In the spores there are many brownish red pigments and substances and a comparatively large nucleus is seen in the center of the spore (Fig. 1, A). They begin to germinate during several hours after liberation. The first cell division takes

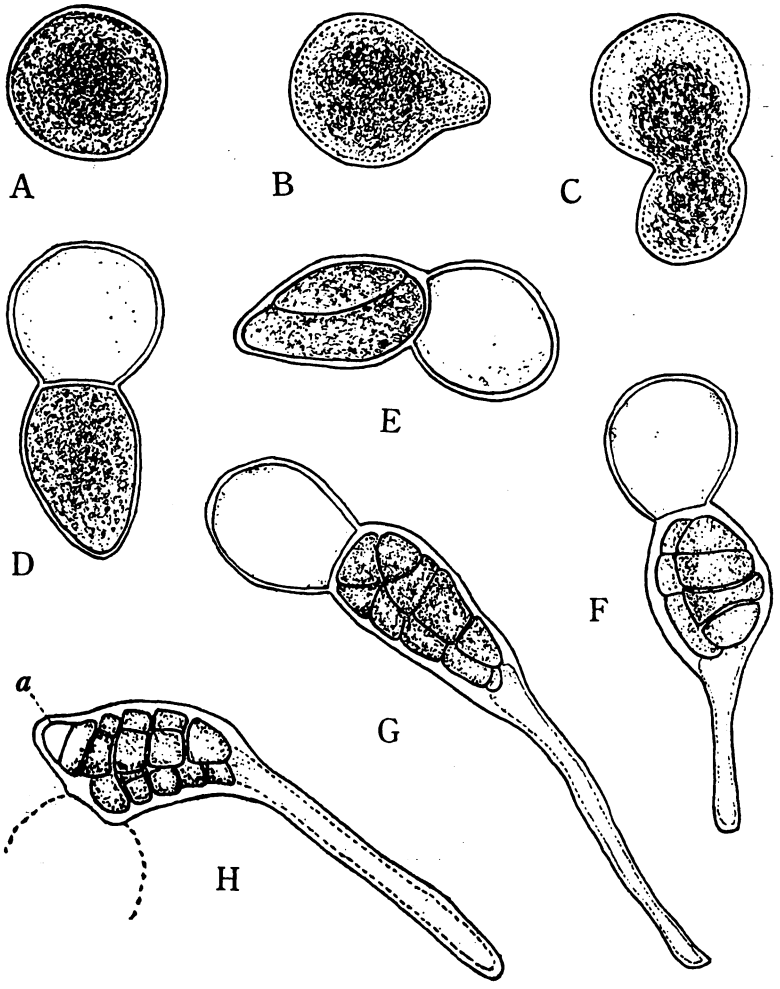

Fig. 2. Various stages in the early development of the tetraspore of *Gelidium sp.*.
A. Adhered spore. B, C. Pushing out a germ tube within 24 hours after being liberated. D. Formation of an initial cell of germling. E. First cell division of the initial cell. F, G. The germlings with a slender rhizoid three days old. H. The young germling four days old, showing an apical cell (*a*). (×550)

place somewhat oblique or vertical to the substratum, so that most spores are divided into two unequal daughter cells (Fig. 1, B). But a few spores show an exceptional germination. One or two days after liberation, the second cell division takes place near to the basal portion of the spore-cell in somewhat of a right angle to the first wall. Consequently each of the daughter cells is divided into two cells, the upper cell and the basal one. Simultaneously, each of the basal cells sends out a slender rhizoid, which gradually elongates and shows lack of pigment (Fig. 1, C, D). After that no further cell division occurs in the basal cell. On the other hand, in the upper cells successive cell divisions take place, but the cell division of the small cell tends to occur later than that of the larger cell (Fig. 1, E–I).

The germlings, being increased in number of small segments by the transverse and longitudinal cell divisions, show two well distinguishable unequal cell-groups each of which developed from two daughter cells of the tetraspore (Fig. 1, I, J). Such morphogenic character is quite similar to that of gelidiaceous algae (Fig. 2, F–H). They gradually increase in volume and attain 35–40 microns in diameter. About three weeks after liberation, an apical cell of thin color is formed at the tip of the small cell-group (Fig. I, J). The further fate of the germlings have not been followed.

Discussion and Conclusion

From the results described above the writer can conclude that the characteristic features in the germling of *Caulacanthus okamurai* are as follows: (1) the first cell division which takes place vertically to the substratum dividing the spores into two unequal daughter cells, the second cell division which takes place at a right angle to the first wall, (2) the multicellular germling which shows two unequal cell-groups, that is a large cell-group and small one, originated from the daughter cells of the spores, and (3) the apical cell which is formed at the apical region of the small cell-group.

FELDMANN (1938) studied the development of spores of *Caulacanthus ustulatus* and compared it with that of gelidiaceous algae and he stated in his paper as follows; "…le mode de développement des tétrasporanges du *Caulacanthus ustulata* s'effectue d'une manière tout à fait différente de celle que l'on observe chez les Gélidiales. Il appartient au type nommé par KYLIN (1917): "*Haftscheibentypus*" et par CHEMIN (1939): type moruléen ou type *Dumontia*." It seems that the mode of its development corresponds to "der mittelbare Scheibentypus" which was proposed by INOH (1947). The development of the tetraspore of *Caulacanthus okamurai* is remarkably different from that of *Caulacanthus ustulata*. It approaches the erect type (KYLIN 1917, INOCH 1947), which was observed in Ceramiales, from the facts that the apical region and the rhizoidal one are determined in the earlier stage of the development of the spore, and that all the germlings are erect. However, it is analogous to the gelidial type from the view point of the method of cell division, although, in the gelidiaceous species the spores elongate

and all the contents move into new elongation which is separated by a cell wall from the original spore; then, in this new cell the special divisions take place to form a characteristic germling peculiar to the Gelidiaceae, while in *C. okamurai* the first division divides the spore itself into two daughter cells, both being divided by the successive divisions as mentioned above.

The gelidial type of spore development is well known in four genera belonging to the family of Gelidiaceae without exception, such as *Gelidium capilaceum* (KILLIAN 1914), *G. amansii* (INOH 1941, UEDA and KATADA 1943, KATADA 1955, YAMAZAKI 1960), *G. pacificum*, *G. divaricatum* (KATADA 1955), *G. pusillum* (KATADA 1955), *G. crinale* (FELDMANN 1938), *Gelidium sp.* (shown in Fig. 2 in this paper), *Pterocladia tenuis* (UEDA and KATADA 1943, KATADA 1955), *Acanthopeltis japonica* (KATADA 1955), *Gelidiella tenuissima* (FELDMANN, in 1938, alluded to the development of the spore of this species which was similar to that of Gelidiaceae), and *G. acerosa* (CHIHARA and KAMURA in preparation).

Among the above workers, UEDA and KATADA (1943), and KATADA (1955) discovered the peculiar facts that the initial cell is divided into two unequal cells with the longitudinal cell wall at the axis of the germ-tube, that the germling being increased in number of small cells after the transverse and and longitudinal cell divisions, preserves two unequal cell-groups which developed from the daughter cells, and that the apical cell is formed at the apical region of the small cell-group. The present author could observe the gelidial type in *Gelidium sp.* and showed it in Fig. 2 in this paper.

In the gelidial type, a formation of the germ-tube is similar to "der mittelbare Fadentypus" as well as "der mittelbare Scheibentypus", so that INOH (1947) had hypothesized the phylogenical relationship among them. KATADA (1955) inferred that the gelidial type is related in character to the erect type more than the latter two, from the facts that the apical cell and the rhizoidal region are determined in the earlier stage of the development of the spore. It seems that the mode of development of the spore of *Caulacanthus okamurai* plays an important role in determining its systematic relationship. This pattern may be named as 'immediate gelidial type'.

As to the systematic position of the genus *Caulacanthus*, FELDMANN and HAMEL (1934) emphasized that its correct systematic position is in the family Sphaerococcaceae, basing this view upon the facts that the apical cell is divided by oblique walls, that the tetrasporangia are zonetely divided and that the cystocarp shows a great resemblance to that of genus *Heringia* (KYLIN 1932).

Although YAMADA described a new species, *Caulacanthus okamurai*, based upon the morphological structure of frond and tetrasporangia without examination of cystocartic specimens, recently SEGI (1952) discovered some female specimens and reported briefly on them. He stated in his paper that *Caulacanthus okamurai* should be transferred to the Gelidiales. From a morphogenic view of its spore-germination, the present author agrees with Segi's opinion.

More recently TAYLOR (1960) established a new family of Wurdemaniaceae, based on a species, *Wurdemania miniata* (HARVEY) FELDMANN and HAMEL, of an

uncertain position. Comparing the structure of *Wurdemania miniata* with that of *Caulacanthus okamurai*, there is only a general similarity in which the tetrasporangium of each species is zonetely divided. The relationship between both species is a problem of interest.

Summary

The germling arising from the tetraspore of *Caulacanthus okamurai* is described and discussed.

The first cell division takes place vertically to the substrutum and divides into two unequal daughter cells. The second cell division takes place at a right angle to the first wall, simultaneously the primary rhizoid appears from each of the basal cells. The multicellular germling preserves two unequal cell-groups originating from the daughter cells of the spore. The apical cell is formed at the apical region of the small cell-group.

This pattern may be named as 'immediate gelidial type'. It seems that this species should be placed within Gelidiales from the view point of the germination of the spores.

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