

Studies on the Charophyta in Formosa(I)

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Studies on the *Charophyta* in Formosa I *

(3 Plates)

by Kōzō IMAHORI.

I. Introduction.

Charophyta in Formosa have received very little attention from botanists, and there is no noteworthy report about them, except several fragmentary reports of my own, published in the last few years. The present work deals mainly with the systematic, the ecological and phytogeographical aspects of them. The present work is not complete because the exploration from July to August, 1941, was limited to the west half of Formosa alone, and we regret to say that the author cannot go to Formosa for the time being under the present situation. Besides, a worse thing is that almost all of the valuable specimens were burned up by the flash of the atomic bomb, at Hiroshima in August, 1945. So the present paper is the outcome of the review of all my descriptions and herbarium-notes which luckily remained.

The exploration ranged over Taihoku, Shinchiku, Taichu, Tainan and Takao Prefectures, and the main locations of the collected specimens are shown in Fig. 1.

The collections were made by wading in shallow water or dredging with a plant hook, whose weight is about 1/2 pound, in deeper water. Though a number of specimens were pressed for herbarium purposes, the majority of the plants were at once put into glass tubes containing about 4% formalin, as dried specimens do not give such a satisfactory result for determination of species. These specimens amount to 151, of which 96 were Genus *Chara* and 55 were Genus *Nitella*.

As it is clear that many problems are still to be solved in order to complete our knowledge concerning the east Asiatic *Charophyta*, it is the earnest desire to bring about the day when the wrighter can explore all over east Asia.

* Contribution from the Laboratory of Systematic Botany of the Faculty of Science, Kanazawa University, No. 6.

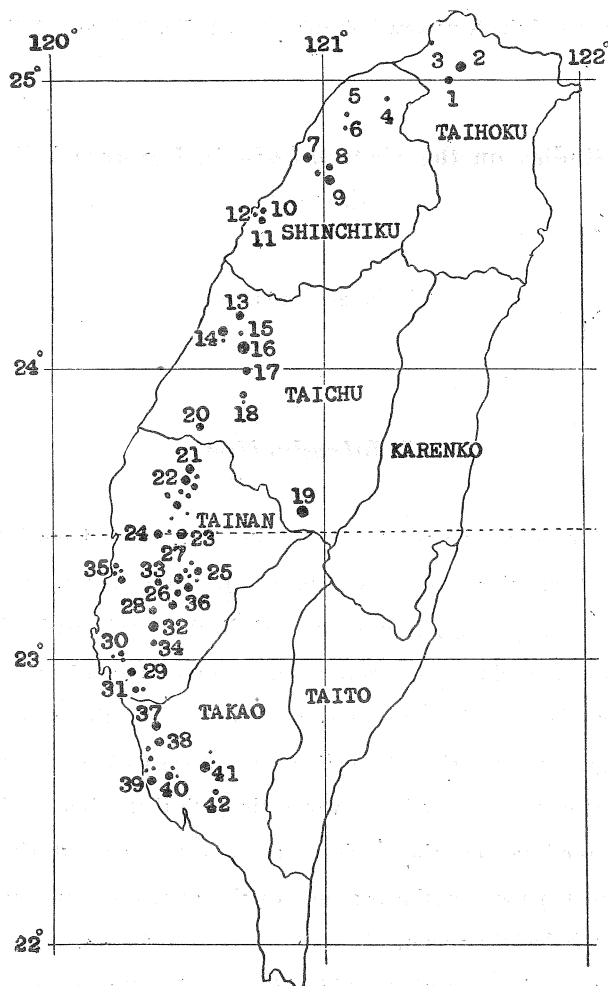


Fig. 1. Geographical locations of collected specimens.

- | | | | |
|--------------|-----------------|-------------------|----------------|
| 1. Taihoku | } Taihoku Pref. | 21. Dairinsho | } Tainan Pref. |
| 2. Naiko | | 22. Tamio | |
| 3. Koto | | 23. Kagi | |
| 4. Toen | | 24. Koriyo | |
| 5. Chureki | | 25. Hakkasho | |
| 6. Koko | | 26. Shinei | |
| 7. Shinchiku | | } Shinchiku Pref. | |
| 8. Tojuho | 28. Rinshoei | | |
| 9. Hocho | 29. Tainan | | |
| 10. Koryo | 30. Kaibi | | |
| 11. Shinko | 31. Sharoken | | |
| 12. Daisho | 32. Banshiden | | |
| 13. Gaiho | } Taichu Pref. | | 33. Ujurin |
| 14. Seiton | | 34. Kwandensho | |
| 15. Hokuton | | 35. Hokumon | |
| 16. Taichu | | 36. Rokko | |
| 17. Shako | | 37. Okayamagai | |
| 18. Nanto | | 38. Nanshi | |
| 19. Hosha | | 39. Takao | |
| 20. Hokuto | | 40. Hozan | } Takao Pref. |
| | | 41. Heito | |
| | | 42. Choshu | |

II. Ecological Observation.

As the object of exploration was mainly taxonomy, ecological observation was rather an auxiliary work. But there were some remarkable data, in which the hydrogen-ion concentration and Cl-content as ecological factors, seemed to be most interesting.

a) **Water depth.** The *Charophyta* are, in general, entirely submerged water plants, but in Formosa, subterrestrial states were often discovered. For example, *Chara vulgaris* L. ssp. *squamosa* which was found in the Mt. Niitaka, was growing in a slightly moist ditch. In general, *Charophyta* of Formosa grow in rather shallow, stagnant or flowing water as shown in Table 1. There are many ponds in Formosa, but there

Table 1. The depth of water and amount of collected plants in it.

Habit	depth (m)	amount of the collected plants
rice fields	0 ~ 0.1	33
salt field	0.01	2
bog-lands	0 ~ 1	40
ponds	0.5 ~ 2	13
lakes	2 ~ 10	3
ditches	0 ~ 0.5	26
small rivers	0.3 ~ 1	34

was only poor vegetation in almost all of these ponds, because the bottoms of these ponds are rummaged by buffaloes.

As Dr. B. P. PAL (1932) has pointed out, plants which grow in deep water are almost all sterile or with few gametangia, but almost all of shallow water plants have many gametangia. The moderate light of the shallow water may facilitate the reproduction of the *Charophyta*.

b) **Hydrogen-ion concentration of water.** A few botanists have discussed this factor during the last decade. The first work was reported by Dr. PAL (1932). His conclusion is that the high value of pH is favourable to the growth of *Charophyta*, while a pH below a certain limit (about 8.0) inhibits their growth. Secondly, Dr. ZANEVELD (1941) says as follows: "Pal's conclusion is not in contradistinction to the data here given, but a minimum pH of 8.0 is certainly too high for the Malaysian species". His datum is very interesting, that most species of *Nitella* are slightly acidophilous and those of *Chara* are neutrophilous or basophilous. On the other hand, Dr. S. OLSEN (1944) had the opinion that only a few species occur in waters with great pH fluctuations, while the greater number occur in alkaline waters.

The result of the author's investigation is indicated in tables 2 and 3. These data most resemble those of ZANEVELD, but there is not much difference in the pH value between the water for *Nitella* and that for *Chara*, and both are rather acid.

Table 2. Hydrogen-Ion concentrations of Genus *Nitella*

species	Lowest buffer	Highest buffer
1. <i>flexilis</i>	5.6	6.1
2. <i>acuminata</i>	5.5	6.2
var. <i>capitulifera</i>	6.2	6.3
3. <i>tenuissima</i> var. <i>callista</i>	5.8	5.8
4. <i>gracilis</i>	5.6	5.6
5. <i>polycarpa</i>	6.2	6.6
6. <i>axilliformis</i>	5.9	6.2
7. <i>sublucens</i>	6.2	6.2
8. <i>axillaris</i>	5.9	6.0
average	5.9	6.1

Table 3. Hydrogen-Ion concentrations of Genus *Chara*

species	Lowest buffer	Highest buffer
1. <i>Braunii</i>	5.9	6.2
2. <i>corallina</i>	6.0	6.0
3. <i>hydropitys</i>	5.8	6.3
4. <i>gymniopitys</i>	5.8	6.0
var. <i>tarvonia</i>	6.0	6.5
var. <i>flaccida</i>	6.0	6.3
5. <i>Bentharii</i>	5.7	6.3
6. <i>pseudo-hydropitys</i>	6.2	6.5
7. <i>vulgaris</i> ssp. <i>squamosa</i>	6.0	6.2
8. <i>zeylanica</i>	6.1	6.4
9. <i>fragilis</i>	6.3	6.5
10. <i>brachypus</i> var. <i>major</i>	6.0	6.3
11. <i>pseudo-brachypus</i>	5.9	6.8
average	6.0	6.4

c) **Cl-content in water.** The action of this factor in relation to *Charophyta* has not previously received much attention from botanists. Although almost all *Charophyta* are normally found in fresh water, there are some *Charophyta* growing occasionally in a sea, for instance, *Chara crinita*, *Chara ceratophylla* and *Chara hispida* were discovered in the Baltic Sea. But as Dr. J. GROVES mentioned, that sea is particularly low in point of salinity, containing less than one per cent of salt. As the author have recently reported there was *Chara zeylanica* in a salt field, near Hokumon, Tainan Prefecture, which were in abundant growth, with many gametangia. Water of the salt field contained 20.0gr. per litre. This species is occasionally found in polyhaline water, also in other countries, and the highest percentage which was reported hitherto is 20.0 gr. per litre,

in Ceylon. Such a salt water may represent the maximum concentration in which *Charophyta* can flourish. Besides this species, *Chara gymnophytis* var. *flaccida* was found in swamp near Keiteiryo, Tainan Prefecture, the water of which contained 4.5 gr. Cl per litre.

III. Phytogeographical View.

Formosa is an island situated 22°—25° N., and it belongs phytogeographically to the

Table 4. Geographical distribution of Genus *Nitella*.

[illegible]

palaeotropical floral zone. The present investigation of *Charophyta* proved that the flora in Formosa have much in common with palaeotropical flora. The data is shown in "The Systematic Studies" and the following tables, 4 & 5.

Table 5. Geographical distribution of Genus *Chara*.

	1. <i>Braunii</i>	2. <i>corallina</i>	3. <i>hydrophytis</i>	4. <i>Bentharii</i>	5. <i>gynaeophytis</i>	var. <i>taivanica</i>	var. <i>flaccida</i>	6. <i>pseudo-hydrophytis</i>	7. <i>vulgaris</i> ssp. <i>sguanoca</i>	8. <i>seylanica</i>	9. <i>fragilis</i>	10. <i>brachypus</i>	var. <i>major</i>	11. <i>pseudo-brachypus</i>	TOTAL
Japan	+	+		+	+		+			+	+				7
China	+			+	+				+						4
Philippine Isls.	+	+	+	+			+			+		+			7
Sumatra			+		+		+			+					4
Java		+	+	+	+		+			+		+			7
Borneo		+			+		+			+					4
Celebes					+		+								2
Malay Peninsula			+	+	+		+			+					5
Indo-China					+		+				+	+			4
Siam		+	+							+					3
Burma		+	+		+		+		+	+		+			7
India	+	+	+	+	+		+		+	+	+	+			10
New Guinea					+							+			2
Marianne Isls.							+			+					2
Hawaian Isls.										+					1
Asia (remaining parts)	+		+						+			+			4
Australia (remaining parts)	+	+		+	+		+			+	+	+			8
North America	+		+							+	+				4
Central America	+		+								+				3
South America	+		+								+				3
Africa	+	+	+	+	+		+		+	+	+	+		+	11
Europe	+								+		+				3
F { Taihoku				+							+				2
O { Shinchiku	+				+										2
R { Taichu		+	+	+		+	+		+						6
M { Tainan	+		+	+	+	+	+	+		+	+	+		+	11
O { Takao	+	+		+		+		+	+					+	7
S {															
A {															

The tables show that Formosa possesses in total 8 species of *Nitella* and 11 species of *Chara*, whereas no representative of the other genera have thus far been found.

In the genus *Nitella* only one species is endemic, whereas the genus *Chara* has one species and 2 varieties restricted to this island. One species and one variety, which are

endemic for Japan, were discovered. *Nitella polycarpa* which was recorded only in Burma is entered in the flora of Japan and Formosa, by the author. Moreover, it is found that flora of Formosa have many similarities to those of tropical Africa ; 2 species and 1 variety of *Nitella*, and 9 species and 1 variety of *Chara* are common to these two districts, among which *Chara pseudo-brachypus* and *Nitella tenuissima* var. *callista* are endemic for Africa.

Flora of Formosa are more related to those of tropical Asia and Australia, of course. 3 species of *Nitella*, and 8 species and 1 variety of *Chara* are in common with the flora of the above mentioned districts. Almost all of these species or varieties are found only in the tropical or subtropical regions. The cosmopolitan species for 5 continents are *Nitella gracilis*, *Chara Braunii* and *C. fragilis*. The exception is *Nitella flexilis* which is recorded only in the temperate or frigid zone.

In conclusion 19 species and 3 varieties are determined, of which 15 species and 1 variety are in common with the palaeotropical flora, and 2 species and 2 varieties are endemic for this island. This result shows that Formosa is situated clearly in the palaeotropical floral zone.

The Philippine Islands are not only nearest to Formosa geographically but phytogeographically, as the present writer reported in 1948. 7 common species are found and only the following 2 species are found in the Philippines and not in Formosa ; *Chara brachypus*, *Nitella furcata*.

IV. Systematic Studies.

As the author have described in tables 2 & 3, 8 species including 2 varieties of *Nitella* and 11 species including 1 subspecies and 4 varieties of *Chara* are determined. Other genera of *Charophyta* are not found in this investigation but some genera may be discovered by further research. Among the investigated species, *Nitella flexilis*, *N. polycarpa*, *N. axillaris*, *Chara corallina* and *C. vulgaris* ssp. *squamosa* are new to this island. Moreover 1 new species and 1 new variety, in addition to 2 newly combined varieties are established. Besides, the new view concerning the relation among species which are closely resemblant to each other are expressed, and this fact must be discussed in a future work.

CHAROPHYTA MIGULA, die Charac., 1890, p.94 ; J. GROVES & BULLOCK-WEBSTER, British Charoph., 1, 1920, p. 4 ; ENGLER-GILG, Syllab. d. Pflanz.-famili., 7 Aufl., p. 24 ; PRENTZ in ENGLER & PRANTL, Nat. Pfl.-fam., 3, ed. 2, 1927, p. 412 ; ZANEVELD in Blumea 4, 1940, p. 47 ; MORIOKA in Journ. Jap. Bot., 17, 1941, p. 29.

Fam. **CHRACEAE** LOUIS CLAUDE RICHARD, HUMBOLT & BOMPLAND, Nov. Gen. Spec. Pland 1, 1815, p. 38 ; KÜTZING, Spec. Alg., 1849, p. 513 ; MIGULA, die Charac., 1897, p. 94 ; PRINTZ in ENGLER & PRANTL, Nat. Pfl.-fam., 3, ed. 2, 1927, p. 412 ; ZANEVELD in Blumea 4, 1940, p. 47 ; MORIOKA in Journ. Jap. Bot., 17, 1941, p. 29 ; WOOD in Ohio Journ. Sci., 47, 1947, p. 244.

Syn. *Chareae* KÜTZING, Phycol. gener. 1843, p. 313.

sub. *Bryophyta* subfam. *Characeae* HY in Bull. Soc. Bot. Francem 60, 1913, Mém. 26, p. 4.

Ordo *Charales* FRITSCH, Struct. and repred. Alg. 1, 1935, p. 447.

Key to the tribes and genera.

- 1a. Cells of coronula in two rows, each of five cells ; cortex and stipulodes wanting (Tribe NITELLEAE)2
- 1b. Cells of coronula in a single row of five cells (Tribe Chareae)3
 - 2a. Branchlets one or more times furcate, antheridia terminal in the furcation of the branchlets *Nitella*
 - 2b. Branchlets not furcate or furcate so that the main ray is more developed than the other lateral one, antheridia lateral in the furcation of the branchlets or at the base of whorl *Tolypella*
(not found in Formosa)
- 3a. Stipulodes absent4
- 3b. Stipulodes present5
 - 4a. Bract-cells and bracteoles present *Nitellopsis*
(not found in Formosa)
 - 4b. Bract-cells and bracteoles absent *Protochara*
(not found in Formosa)
- 5a. Oogonium situated below the antheridium, ecorticate, monoecious
..... *Lamprothamnium*
(not found in Formosa)
- 5b. Oogonium and antheridium situated side by side *Lychnothamnus*
(not found in Formosa)
- 5c. Oogonium situated above the antheridium *Chara*

A. NITELLEAE GANTERER

Tribus *Nitelleae* GANTERER Oesterr. Char., 1847, p. 8, *pro parte* : von LEONHARDI in Lotos 13, 1863, repr. p.9 ; GROVES & BULLOCK-WEBSTER, Brit. Charoph. 1, 1920, p. 95 ; GROVES in Journ. Linn. Soc., Bot., 1924, p. 360 ; PRINTZ in ENGLER and PRINTL, Nat. Pfl-fam. 3, ed. 2, 1927, p. 426 ; PAL in Journ. Linn. Soc., Bot., 49, 1932, p. 64 ; GROVES & ALLEN in Proc. Roy. Soc. Queensl. 46, 1935, p. 40 ; ZANEVELD in Blumea 3, 1939, p. 377 ; ibid. 4, 1940, p. 48 ; WOOD in Ohio Journ. Sci., 47, 1947, p. 244. Syn. Gen. *Nitella* AGARDH, Syst. Alg. 1824, p. 27 ; P. P. A. BRAUN in N. DENKSCHR. Schweiz Ges. Naturw. 10, 1849, p. 12 ; ibid. in Hooker's Journ. Bot. 1, 1849, pp. 195, 292.

Chara epigynae A. BRAUN in Ann. Sci. Nat., Sér. 2, 1, 1834, p. 350 ; ibid. in Flora 18, 1835, pp. 12, 49 ; ibid. in Linnaea 17, 1843, p. 113.

Fam. *Nitelleae* A. BRAUN in COHN, Krypt. Fl. Schles. 1, 1876, pp. 368, 395 ; T.

F. ALLEN, Charac. America 1, 1888, p. 38 ; G. O. ALLEN in Journ. Bombay Nat. Hist. Soc. 30, 1925, p. 592.

Subfam. *Nitelleae* A. BRAUN ap. MIGULA, die Charac., 1897, p. 94 ; ROBINSON in Bull. New York Bot. Gard. 4, 1906, p. 253 ; VERDAM in Blumea 3, 1938, p. 6 ; MORIOKA in Journ. Jap. Bot. 17, 1941, p. 29.

Plants monoecious or dioecious, always ecorticated, usually flexible and transparent, sometimes incrustated especially on Tolypella. Branches similar to the main stem or differentiate as fertile branches, which are usually small, compact and sometimes enveloped with mucus. Branchlets 5—8 in a whorl, simple or one or more times furcated with one-celled rays, except the ultimate ray which is occasionally 2 or more celled. Gametangia produced at the furcation of branchlets, rarely at the base of whorls. Oogonia sessile or with short stalks, usually smaller than that of *Chareae*. Coronula in two rows, each of five cells. Oospore occasionally with characteristic decorations. Antheridia usually with short stalks, rarely with elongated stalks.

Gen. *Nitella* AGARDH

Syst. Alg., 1824, p. 27, *pro parte* : LEONHARDI in Lotos 13, 1863, p. 69 ; GROVES in Journ. Bot. 9, 1880, p. 163 ; MIGULA, die Charac., 1897, p. 95 ; GROVES & BULLOCK-WEBSTER, Brit. Charoph., 1920, p. 95 ; J. GROVES in Journ. Linn. Soc., Bot., 46, 1924, p. 360 ; G. O. ALLEN in Journ. Bombay Nat. Hist. Soc. 30, 1925, p. 592 ; PRINTZ in ENGLER & PRANTL, Nat. Pfl-fam. 3, ed. 2, 1927, p. 426 ; PAL in Journ. Linn. Soc., Bot., 49, 1932, p. 66 ; ZANEVELD in Blumea 4, 1940, p. 49 ; MORIOKA in Journ. Jap. Bot., 17, 1941, p. 30 ; WOOD in Ohio Journ. Sci. 47, 1947, p. 244 ; *ibid.*, in Bull. Torr. Bot. Club 75, 1948, p. 283 ; *ibid.* in Biol. Bull. 96, 1949, p. 185.

Syn. *Nitella* sect. *Furcata* BRAUN in N Denks. Schweiz. Ges. Naturw. 10, 1849, p. 6 ; KÜTZING, Spec. Alg., 1849, p. 513.

Nitella subgen. *Nitella* A. BRAUN in Hooker's Journ. Bot. 1, 1849, pp. 195, 292.

Nitella sect. *Ebracteatae* WALLM., Försök Syst. Charac. 1853, pp. 12, 15.

Nitella subgen. *Eunitella* A. BRAUN, Charac. Afrik., 1867, p. 796.

Monoecious or dioecious. Plants generally light green to dark green, not incrustated. Branchlets one or more times furcate with more or less equal rays ; fertile branchlets occasionally contracted into heads, frequently covered with dense mucus. Gametangia usually produced at the furcations, rarely at the base of whorls, solitary or aggregate. Oogonia sessile or with short stalks, produced laterally so that in the monoecious species just below the antheridia. Antheridia sessile or stalked. Oospores laterally compressed, occasionally with fine decorations.

Key to the species and varieties.

- 1a. Dactyls strictly one-celled (*Anarthrodactylae*) 2
- 1b. Dactyls 2~3 celled (*Arthrodactylae*) 4
- 2a. Oospore large (500~580 μ) *1. N. flexilis*

Loc. : Hishito, Hakkasho, Tainan Pref., Aug. 14, 1941, K. I. No. 303 ; Rokko, Sobun, Tainan Pref., Aug. 23, 1941, K. I. Nos. 374, 375 ; Naiko, Taihoku Pref., Aug. 26, 1941, K. I. No. 393.

Distr. : Asia (Japan and Kamchatka), Europe and North America.

Nitella flexilis is one of the most variable species, sometimes attaining a height of more than 1 metre but easily distinguished from the other resembling species by the oospore, the length of which attains more than $500\ \mu$. As this species was discovered hitherto only in the temperate region, it is remarkable that it appeared in the sub-tropical region, 22° N.

2. *Nitella acuminata* A. BRAUN,

in Hooker's Journ. Bot. 1, 1849, p. 292 ; A. BRAUN in Monatsber. Kön. Akad. Wiss. Berlin, 1858, p. 356 ; J. GROVES in Philipp. Journ. Sci. 19, 1921, p. 663 ; *ibid.* in Journ. Linn. Soc. Bot., 46, 1922, p. 97 ; *ibid.* 1924, pp. 361, 365 ; G. O. ALLEN in Journ. Bombay Nat. Hist. Soc. 30, 1925, p. 597 ; GROVES & STEPHENS in Transact. Roy. Soc., Bot., 13, 1926, p. 147 ; G. O. ALLEN in Journ. Bot. 65, 1927, p. 336 ; *ibid.* in Journ. Ind. Bot. Soc., 7, 1928, p. 53 ; J. GROVES in Journ. Linn. Soc., Bot., 48, 1928, p. 127 ; PAL in Journ. Burma. Res. Soc., 18, 1929, p. 113 ; DIXIT in Journ. Ind. Bot. Soc., 10, 1931, p. 205 ; MIGULA in Hedwigia 70, 1931, p. 211 ; PAL in Journ. Linn. Soc., Bot., 49, 1932, pp. 64, 66 ; J. GROVES in Journ. Bot. 73, 1935, p. 46 ; ZANEVELD in Blumea 3, 1939, pp. 378, 381 ; *ibid.* 4, 1940, p. 54 ; WOOD in Farlowia 3, 1948, p. 345 ; IMAHORI in Journ. Jap. Bot. 22, 1948, p. 44 ; *ibid.* in Bot. Mag. Tokyo, 63, 1950, p. 233.

Plants moderately stout, light to brownish green. Internodes as long as to 2 times the length of the branchlets. Sterile branchlets 6~7 in a whorl, up to 4 cm long, well developed ; in adult specimens curving outward, once furcate ; although the relative length of the primary and the secondary rays is variable, primary rays 4~5 times the length of secondary rays, in general ; secondary rays, 2~3, acuminate, always unicellular. Fertile branchlets forming dense head, but not enveloped in mucus, once furcate ; dactyls 2~3, acuminate or conical. Gametangia occur together at the furcations of branchlets, not enveloped in mucus. Oogonia solitary or geminate, sessile, $450\sim 520\ \mu$ long by $340\sim 360\ \mu$ broad ; spiral cell showing 8~9 convolutions ; coronula rather small, $33\sim 36\ \mu$ high and $45\sim 55\ \mu$ broad at the base, persistent. Oospore reddish brown to dark brown, $260\sim 300\ \mu$ long by $250\sim 270\ \mu$ broad, with 5~7 ridges ; membrane minutely granular, diaphanous. Antheridia solitary, sessile, strictly terminal, $220\sim 270\ \mu$ in diameter.

Hab. : in rice-fields and bog-lands, pH. 5.5~6.2, with *Nitella tenuissima* var. *callista*, *Chara gymnopitys*, *C. hydropitys* and *C. pseudohydropitys*.

Loc. : Hocho, Shinchiku Pref., Aug. 6, 1941, K. I. No. 252 ; Kwandensho (Tainan Pref., Aug. 21, 1941, K. I. No. 345 ; Seiton, Taichu Pref., Aug. 9, 1941, K. I. No. 397.

Distr. : Asia (Ceylon, Philippine Islands, India, Burma, Malaysia and Japan), N. & S. America and Africa.

Nitella acuminata is widely distributed in the tropical and subtropical regions, and is a variable species. Especially is the length of dactyls extremely variable, some of them are very long, up to 1.5 cm and others are hardly visible to the naked eye. Usually the dactyls are rather shorter than those of *Nitella flexilis*. Except for this character, *Nitella acuminata* is easily distinguished from *N. flexilis*, in respect to the shape of dactyls, color of oospore and decoration of that membrane. Besides these above mentioned specimens, there are many plants of *Anarthrodactylae*, which are considered as belonging to this species, but they are not determine precisely because they are all sterile.

***Nitella acuminata* A. BRAUN var. *capitulifera* (ALLEN) m. comb. nov.**
Syn. *Nitella capitulifera* ALLEN in Bull. Torrey Bot. Club 23, 1896, p. 235 ; MAKINO in Journ. Jap. Bot. 6, 1929, p. 375 ; MORIOKA in Journ. Jap. Bot. 17, 1941, p. 59 ; IMAHORI in Bot. Mag. Tokyo, 63, 1950, p. 233.

Plants monoecious, flexible, bright to dark green, 20~70 cm long. Internodes almost in equal length of the branchlets, 0.7~1 mm in diameter. Sterile branchlets 5~7 in a whorl, once furcate ; the primary rays 3~6 times the length of the secondary rays, 500~700 μ broad, with 2~4 dactyls ; dactyls always unicellular, acuminate form. Fertile branchlets forming dense heads, unifurcate. ♀ and ♂ gametangia produced at the node together. Antheridia 280~330 μ in diameter. Oogonia solitary or geminate, 450~550 μ long by 320~360 μ broad, with 9~10 convolutions ; coronula rather small, 36~44 μ high and 55~65 μ broad at the base. Oospore reddish brown to dark brown, 290~340 μ long by 250~260 μ broad with 6~7 rather prominent ridges ; membrane quite smooth.

Hab. : in ditches, rice-fields and small rivers. pH. 6.2~6.3, with *Chara Benthamii*, *C. hydropitys* and *C. pseudo-hydropitys*.

Loc. : Koryo, Toseki, Tainan Pref., Aug. 13, 1941, K. I. Nos. 292, 294 ; Rinhoei, Tainan Pref., Aug. 15, 1941, K. I. No. 313 ; Kantakushi, Hakkasho, Tainan Pref., Aug. 14, 1941, K. I. No. 304 ; Hishito, Hakkasho, Tainan Pref., Aug. 14, 1941, K. I. No. 305.

Distr. : Asia (Japan and Formosa only).

The var. *capitulifera* is distinguished from *Nitella acuminata* mainly by the decoration of oospore-membrane, and the other characters are almost the same, especially are the size of oospores and characters of their ridges quite similar. Both plants produce oogonia aggregately, both antheridia are of equal size and with similar dactyls. Moreover *Nitella acuminata* is a very variable species generally, as we have mentioned. Consequently, it is natural to consider that the present plant belongs to *N. acuminata* as a separate variety. On the other hand, var. *capitulifera* is confused with *Nitella acuminata* var. *subglomerata* (= *N. subglomerata*) too. Concerning this subject,

ZANEVELD (1940) wrote as follows, "Most probably, T. F. Allen's *N. stellaris*, *N. stellaris*, *N. capitulifera* and *N. subspicata* also belong to our var. *subglomerata*." But *N. subglomerata* is easily distinguished by the netted decoration of oospore-membrane, and twice furcate branchlets as ALLEN (1896) pointed out "It differs from *subglomerata*, also, by its more inflated terminals, which are usually quite short and unequal, as well as by the character of the oospore."

According to Allen's description (1896), fertile branchlets of this plant furcate generally twice. But every specimen of this variety, which were collected from Japan and Formosa, have only unifurcated branchlets, in accordance with Morioka's description (1941).

3. *Nitella tenuissima* KÜTZING,

in Phyc. Gen. 1843, p. 319 ; *ibid.* Sp. Alg. 1849, p. 515 ; ALLEN in Bull. Torr. Bot. Club, 2, 1871, p. 9 ; GROVES in Journ. Bot. 18, 1880, p. 163 ; SAIDA in Bot. Mag., Tokyo, 1, 1887, p. 36 ; MIGUIA, die Charac. 1890, p. 173 ; J. GROVES. & BULLOCK-WEBSTER in Brit. Charoph. 1, 1920, p. 120 ; H. & J. GROVES in Journ. Bot. 22, 1884, p. 5 ; WOOD in Farlowia 3, 1948, p. 372.

var. *callista* J. GROVES (Plate I)

in Journ. Linn. Soc., Bot., 48, 1928, p. 129 ; ZANEVELD in Blumea 3, 1939, p. 379 ; IMAHORI in Bot. Mag. Tokyo, 62, 1949, p. 1 ; *ibid.* 63, 1950, p. 233.

Plants monoecious, extremely graceful and slender, bright green. Fertile and sterile whorls similar ; whorls usually of 6 branchlets. Branchlets 2~3 times (rarely 4 times) furcate ; primary rays ca. $\frac{3}{5}$ the length of entire branchlets, 50~60 μ broad, with 5~6 secondary rays ; secondary rays 40~50 μ broad with 3~5 tertiary rays ; tertiary rays 30~40 μ broad, with 3~4 quaternary rays. Dactyls always 2-celled, ca. 20 μ broad ; ultimate cell elongated and acuminate, 25~70 μ long, 14~17 μ broad at the base. ♀ and ♂ gametangia produced together at all the furcations, especially at the second. Antheridia ca. 110 μ in diameter. Oogonia frequently geminated, 260~300 μ long by 170~210 μ broad, with 8~9 convolutions ; coronula 25~30 μ high and 40~45 μ broad at the base. Oospore light brown. 170~200 μ long by 160~170 μ broad with 6 prominent ridges ; membrane reticulate.

Hab. : in bog-lands, pH. 5.8, with *Nitella acuminata*. *Chara gymnopitys* and *C. pseudo-hydrotitys*.

Loc. : Kwandensho, Tainan Pref., Aug. 21, 1941, K. I. No. 344.

Distr. : Madagascar, Formosa.

This variety is easily distinguished from *Nitella tenuissima* by the slender dactyls, by long ultimate cell of dactyls and by fertility of the first furcation of branchlets. It is very interesting that the Madagascanian endemic variety was discovered in such a distant place.

4. *Nitella gracilis* AGARDH,

in Syst. Alg., 1824, p. 125 ; NORDSTEDT in Bot. Notiser, 1863, p. 38 ; ALLEN in Bull. Torr. Bot. Club 2, 1871, p. 10 ; J. GROVES in Journ. Bot. 18, 1880, p. 164 ; BRAUN & NORDSTEDT in Fragm. Mon. Charac. 1882, p. 58 ; SAIDA in Bot. Mag., Tokyo, 1, 1887, p. 11 ; MIGULA, die Charac. 1890, p. 159 ; ALLEN in Bull. Torr. Bot. Cl. 21, 1894, p. 524 ; *ibid.* 25, 1898, p. 75 ; J. GROVES & BULLOCK-WEBSTER, Brit. Charoph. 1, 1920, p. 117 ; MAKINO in Journ. Jap. Bot. 6, 1929, p. 373 ; WOOD in Farlowia 3, 1948, p. 384 ; IMAHORI in Bot. Mag., Tokyo, 63, 1950, p. 233.

Chara gracilis SMITH in Eng. Bot. 1810, p. 2140 ; A. BRAUN in Ann. Sc. Nat. sér. 2, 1834, p. 351 ; *ibid.* in Flora 18, 1835, p. 53.

Chara flexilis var. *gracilis* S. F. GRAY, in Nat. Arr. Brit. 1821, p. 28.

Chara exilis "Barbieri" AMICI in Mem. Acad. Modena 1, 1827, p. 216.

Monoecious. Plants very slender, 10~20 cm high. Internodes 1~2 times the length of branchlets, 250~350 μ wide. Branchlets 6~7 in a whorl, 2~3 times furcate ; primary rays about a half the total length, 90~130 μ wide ; secondary rays usually 5, 60~70 μ length ; tertiary rays 4~5, 55~70 μ wide, of which 1 or 2 again furcate. Dactyls 2- or 3-celled ; the ultimate cell 50~80 μ long by 15~28 μ wide. ♀ and ♂ gametangia produced together at all the nodes. Antheridia about 300 μ in diameter. Oogonia solitary, 510~530 μ long by 360~400 μ wide with 8~9 convolutions ; coronula persistent, 25~30 μ high and 45~55 μ broad at the base. Oospores 270~310 μ long by 230~270 μ wide with 6~7 dull ridges, bright to dark brown ; membrane finely granulate.

Hab. : in rice fields, pH. 5.6.

Loc. : Hokumon, Daitonsho, Taichu Pref., Aug. 9, 1941, K. I. No. 262.

Distr. : Asia (Japan) Europe, North and South America, New Caledonia and Africa.

The very slender stem and branchlets give this species a very distinct appearance, and it cannot easily be mistaken for any of the other *Nitella* in Formosa except for *Nitella tenuissima* var. *callista*, from which *N. gracilis* differs by the dactyls which are occasionally 3-celled and the decoration of the oospore-membrane. Though *N. gracilis* is a rather cosmopolitan species, it is found generally in the temperate regions. In Formosa there was a mass of these plants growing in a rice-field near Taichu City (24° 10'N.), which may be the southern most limit of this species in the Northern hemisphere.

5. *Nitella polycarpa* PAL (Plate II)

in Journ. Linn. Soc. Bot., 49, 1932, p. 77 ; ZANEVELD in Blumea 4, 1940, p. 100 ; IMAHORI in Bot. Mag. Tokyo, 63, 1950, p. 233.

Monoecious. Plants green to dark green, 20~30 cm long. Internodes 1~2 times the length of the branchlets. Fertile and sterile whorls similar. Branchlets 6 in a whorl, 3~4 times furcate. Primary rays 1/2~1/3 the length of the total branchlets, 250~300 μ thick ; secondary rays 4~5, generally 1/2 the length of the primary rays, ca. 250 μ thick ; tertiary rays 4, almost equal length of the secondary, ca. 220 μ thick

; quaternary rays 2~3, almost equal length of the secondary rays also ; quinary rays 2~3. Dactyls generally unequal in length, or all much abbreviated, 2- rarely 3-celled ; ultimate cell conical, 55~75 μ long, 25~35 μ broad. Gametangia produced at every furcation of branchlets. Antheridia often subterminal, ca. 250 μ in diameter. Oogonia produced not only at the nodes of branchlets but also at the base of whorls, 2~3 aggregate, ca. 400~450 μ long and 290~350 μ broad ; coronula elongated, 45~55 μ high, 60~70 μ broad at the base. of which which upper cells 2 times the length of the lower ones. Oospore light brown, 250~270 μ long, 200~220 μ broad, showing 6 ridges ; membrane nodose-reticulate.

Hab. : in ditches and bog-lands, pH. 6.2~6.6

Loc. : Kakato, Koheki Tainan Pref., Aug. 15, 1941, K. I. No. 306 ; Ujurinho, Shinei, Tainan Pref., Aug. 15, 1941, K. I. Nos. 307~309.

Distr. : Asia (Burma, Japan and Formosa)

This species has been known only in Toungoo, Burma, which is the type locality. The present plants were growing thick in a very large bog-land in company with *Nitella subblucens*. *Nitella polycarpa* is most remarkable for the oogonia which are produced in aggregate at not only the furcations but at the base of whorls. This species approaches *Nitella furcata*, but we can easily discriminate between them by the above mentioned characters.

6. *Nitella axilliformis* m. sp. nov. (Plate III)

Planta monoecia, 20~30 cm alta, mediocriter robusta. Internodia quam ramuli 1~2-plo longiora. Verticilli steriles 5~6, 1~2 tim furcati ; radii primarii magni ; radii secundarii 3~5, brevissime vel elongati, quorum interdum iterum in radiis 3~4 tertiariis sunt. Dactyli abbreviati et mucronati, vix conspecti, sed raro elongati. Verticilli fertilibus ad basis verticillorum sterilibus dense congeste, 1~2-tim furcati ; radii primarii 1/2 longiori ramulorum ; radii secundarii 3~4, quorum 1~2 iterum 3~4 tertiariis divisus. Oogonia solitaria ad furcationes primaris, 400~430 μ longa et 320~340 μ lata ; coronula parva, 30~35 μ alta, 60~70 μ lata. Oospora globosa vel subglobosa, flavo-brunnea, 250~270 μ longa 230~250 μ lata ; striis 6~7 ; membrana irregulariter reticulata. Antheridia 180~210 μ in diametro.

Hab. : in ditches, small rivers and bog-lands, pH. 5.9~6.2, with *Chara pseudo-brachypus*, *C. gymnopitys*, *C. Braunii* and *Nitella acuminata*.

Loc. : Tamio Tainan Pref., Aug. 12, 1941, K. I. No. 289 ; Machoko, Tainan Pref., Aug. 14, 1941, K. I. No. 299 ; Kwandensho, Tainan Pref., Aug. 21, 1941, K. I. No. 355.

Distr. : Formosa and Japan.

The ditch in Tamio, where this new species was discovered at first, was about 1 metre deep, the water of which contained iron. On both sides of the ditch there grew *Phalaris* sp. mixed with *Ranunculus* sp. At the bottom of this ditch, there was a

mass of *Charophyta*, the new species, growing together with the above mentioned species of *Charophyta*. In the other two localities, only this species and no others was found.

Nitella axilliformis belongs to *Nitella translucens* group, which includes *N. brachyteles*, *N. sublucens*, *N. translucens*, *N. axillaris* and *N. Morongii*. Among them, *N. axilliformis* most resembles *N. axillaris*, in the position of the compact fertile whorls, length of oospores and decorations of oospore-membranes. But *N. axilliformis* is easily distinguishable by the sterile branchlets which are occasionally twice furcate. Though *N. Morongii* resembles the present species by the twice furcate sterile branchlets, it is discriminated by the decoration of oospore-membrane.

Now a key of the *Nitella translucens* group will be shown as follows.

- 1a. Sterile branchlets furcate only once2
- 1b. Sterile branchlets furcate 1~2 times5
 - 2a. Fertile and sterile branchlets similar in their length *N. brachyteles*
 - 2b. Fertile branchlets congested in heads3
- 3a. Oogonia produced at the base of whorls *N. sublucens*
- 3b. Oogonia not produced at the base of whorls4
 - 4a. Fertile heads placed only axillary *N. axillaris*
 - 4b. Fertile heads placed not only axillary but terminally *N. translucens*
- 5a. Decoration of oospore-membrane reticulate *N. axilliformis*
- 5b. Decoration of oospore-membrane granulate *N. Morongii*

7. *Nitella sublucens* ALLEN

in Bull. Torrey Bot. Club 22, 1895, p. 70 ; MAKINO in Journ. Jap. Bot. 6, 1929, pp. 373, 396 ; MORIOKA in Journ. Jap. Bot. 17, 1941, p. 65 ; IMAHORI in Bot. Mag., Tokyo, 63, 1950, p. 233.

Syn. *Nitella translucens*, SAIDA in Bot. Mag., Tokyo, 1, 1887, p. 12 (= *N. sublucens*, fide MAKINO)

Monoecious. Plants moderate stout, 15~30 cm high, blue to dark green. Internodes 1~2 times the length of the branchlets, 0.7~0.9 mm thick. Sterile branchlets 5~6 in a whorl, only once furcate ; primary rays elongated and thick, surmounted by a crown of 4~3 dactyls ; dactyls very minute and acute, two-celled, 150~300 μ long and 50~70 μ broad at the base. Fertile whorls contracted into dense terminal or axillary heads, not enveloped in mucus. Branchlets 5~6, usually twice furcate ; ultimate rays 3~4, 2-celled, abbreviated and conical. Oogonia aggregated at the base of whorls and at the 1st furcations of branchlets, 320~360 μ long and 300~350 μ broad with 8~9 convolutions ; coronula rather small, 35~45 μ high and 55~65 μ broad at the base. Oospore 280~310 μ long by 250~280 μ broad with 6~7 ridges ; membrane coarsely granulate. Antheridia produced at the primary furcation, about 220 μ in diameter.

Hab. : in bog-lands, pH. 6.2, with *N. polycarpa* and *C. gymnopitys*.

Loc. : Ujurinho, Shinei, Tainan Pref., Aug. 15, 1941, K. I. No. 310.

Distr. : Japan, new to Formosa.

Though Formosa is near to Japan geographically, it is very interesting that two Japanese endemic species — *Nitella acuminata* var. *capitulifera* and *N. sublucens* — were discovered in Formosa, which is separated in the floral zone. This species so resembles *Nitella translucens* that ZANEVELD(1940) decided to include *N. sublucens* in *N. translucens* as a variety. But it is proper to separate these species because those characters, i. e., clustered oogonia at the base of whorls and granulate membrane of oospores, are sufficiently significant characters to do so.

8. *Nitella axillaris* A. BRAUN

in Monatsb. Kön. Akad. Wiss. Berlin, 1858, p. 356 ; BRAUN & NORDSTEDT in Abh. Kön. Akad. Wiss. Berlin, 1882, pp. 11, 48 ; NORDSTEDT in Hedwigia 7, 1888, pp. 182, 194 ; ibid. in Act. Univers. Lund. 25, 1889, p. 9 ; T. F. ALLEN in Bull. Torr. Bot. Cl., 25, 1898, p. 73 (nom. tant) ; H. & J. GROVES in Urran. Symb. Antill 7, 1911, pp. 30, 34 ; GROVES & ALLEN in Journ. Bot. 65, 1927, p. 336 ; G. O. ALLEN in Journ. Ind. Bot. Soc. 7, 1928, p. 55 ; ZANEVELD in Blumea 4, 1940, p. 69 ; DAILY in Butler Univ. Bot. St. 6, 1944, p. 154 ; WOOD in Farlowia 3, 1948, p. 365.

Syn. *Nitella translucens*, IMAHORI in Bot. Mag. Tokyo, 63, p. 233 (= *N. axillaris* fide IMAHORI)

Nitella axillaris A. BRAUN var. *javanica* A. BRAUN in Abh. Kön. Akad. Wiss. Berlin, 1882, p. 49.

Plants monoecious, rather stout, 20~50 cm high, blue to dark green. Internodes moderately long, 3~5 times the length of the branchlets. Sterile branchlets large and stout, 6 in a whorl, once furcate ; primary rays very long and stout, with 3~4 very minute dactyls ; dactyls mucronate, invisible with naked eye, always 2-celled but the upper conical cells are easily dropped out. Fertile whorls contracted into dense heads, produced in the axils of the whorls of the sterile branchlets only. Branchlets 4~6 in a whorl, 1~2 times furcate ; primary rays $3/5$ the length of the entire branchlets ; secondary 3~4, of which 1~3 again furcate into 3 tertiary rays. Dactyls 2-celled, conical. ♀ and ♂ gametangia sessile, produced together at the first furcations, usually. Antheridia terminal, 240~280 μ in diameter. Oogonia solitary or geminate, 340~360 μ long by 300~320 μ broad with 7~8 convolutions ; coronula moderately small, 40~45 μ high and 30~45 μ broad at the base. Oospore light yellowish brown, 260~290 μ long, and 250~270 μ broad, with 6 broad ridges ; membrane finely reticulate.

Hab. : in small rivers, pH. 5.9~6.0, with *Chara vulgaris* ssp. *squamosa*.

Loc. : Okayamagai, Takao Pref., Aug. 17, 1941, K. I. Nos. 328, 329 ; Sobun, Tainan Pref., Aug. 23, 1941, K. I. No. 373 ; Naiko, Taihoku Pref., Aug. 26, 1941, K. I. No. 386.

Distr. : Asia (Malaysia, Java, India and Japan), Central and North America.

This species is widely distributed in tropical and subtropical regions of Asia and America. The wrighter has also discovered this species in Satuma, Japan, which may be the northern limit in the northern hemisphere for this species.

Braun separated this species from *Nitella translucens* AGARDH, on the basis of the oospores and the fertile heads which occur only in the axils and never terminally as in *Nitella translucens*. But as ZANEVELD (1940) pointed out, it is doubtful whether or not to separate these species. That is to say, the length of the oospores is not only scarcely different, but color, ridges and decorations of both oospores are quite similar. The characters by which we can discriminate these species are only the position of the fertile whorls and the diameter of antheridia, as shown in the following table 6.

Table 6. The diameter of antheridia of *N. translucens* and *N. axillaris*, measured by some authors.

<i>N. translucens</i>	<i>N. axillaris</i>
380 μ (MIGULA, 1890)	220~270 μ (ZANEVELD, 1940)
250~375 μ (GROVES & BULLOCK-WEBSTER, 1920)	220~300 μ (WOOD, 1948)

Now I propose to unite *Nitella axillaris* Braun to *Nitella translucens* as the variety.

(to be continued)

EXPLANATION OF THE PLATES

PLATE I. *Nitella tenuissima* KÜTZ. var. *callista* J. GROVES

- Habit, natural size.
- Branchlet with oogonia and antheridia, $\times 16$.
- Ripe oogonium and antheridium, $\times 120$.
- Geminate oogonia, $\times 120$
- Coronula, $\times 540$
- Endcells, $\times 540$
- Oospore, $\times 180$
- Oospore-membrane with decoration, $\times 1200$

PLATE II. *Nitella polycarpa* PAL

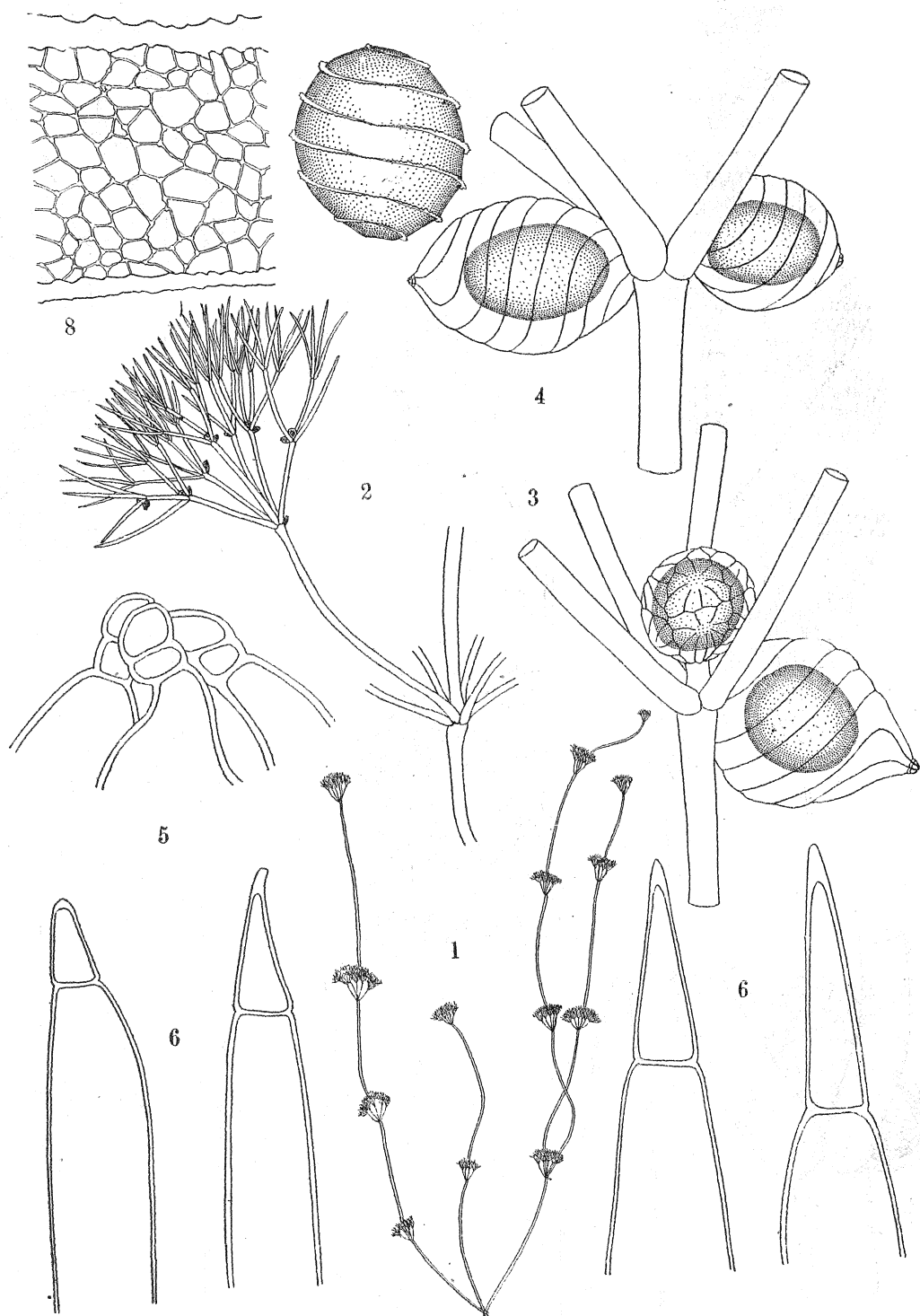
- Plant, natural size.
- Base of whorl, showing one complete branchlet, $\times 6$
- Terminal oogonium and subterminal antheridium, $\times 60$
- Aggregate oogonia at a furcation of a branchlet, $\times 60$
- Aggregate oogonia at a base of a fertile whorl, $\times 30$
- Coronula, $\times 540$
- 3-celled dactyl, $\times 120$.
- 2-celled dactyl, $\times 120$
- One moderately abbreviated and 1 much abbreviated dactyls, $\times 120$
- All much abbreviated dactyls, $\times 120$
- 2 abbreviated and 1 elongated dactyls, $\times 42$.
- Oospore, $\times 120$.
- Decoration of the oospore-membrane, $\times 900$.

PLATE III. *Nitella axilliformis* IMAHORI

- Plant, natural size.
- A fertile branchlet with a oogonium, $\times 60$
- ~8. variations of dactyls, $\times 40$.
- Coronula, $\times 400$.
- Oospore, $\times 120$.
- Decoration of oospore-membrane, $\times 540$.

Studies on the Charophyta in Formosa I

PLATE 1.



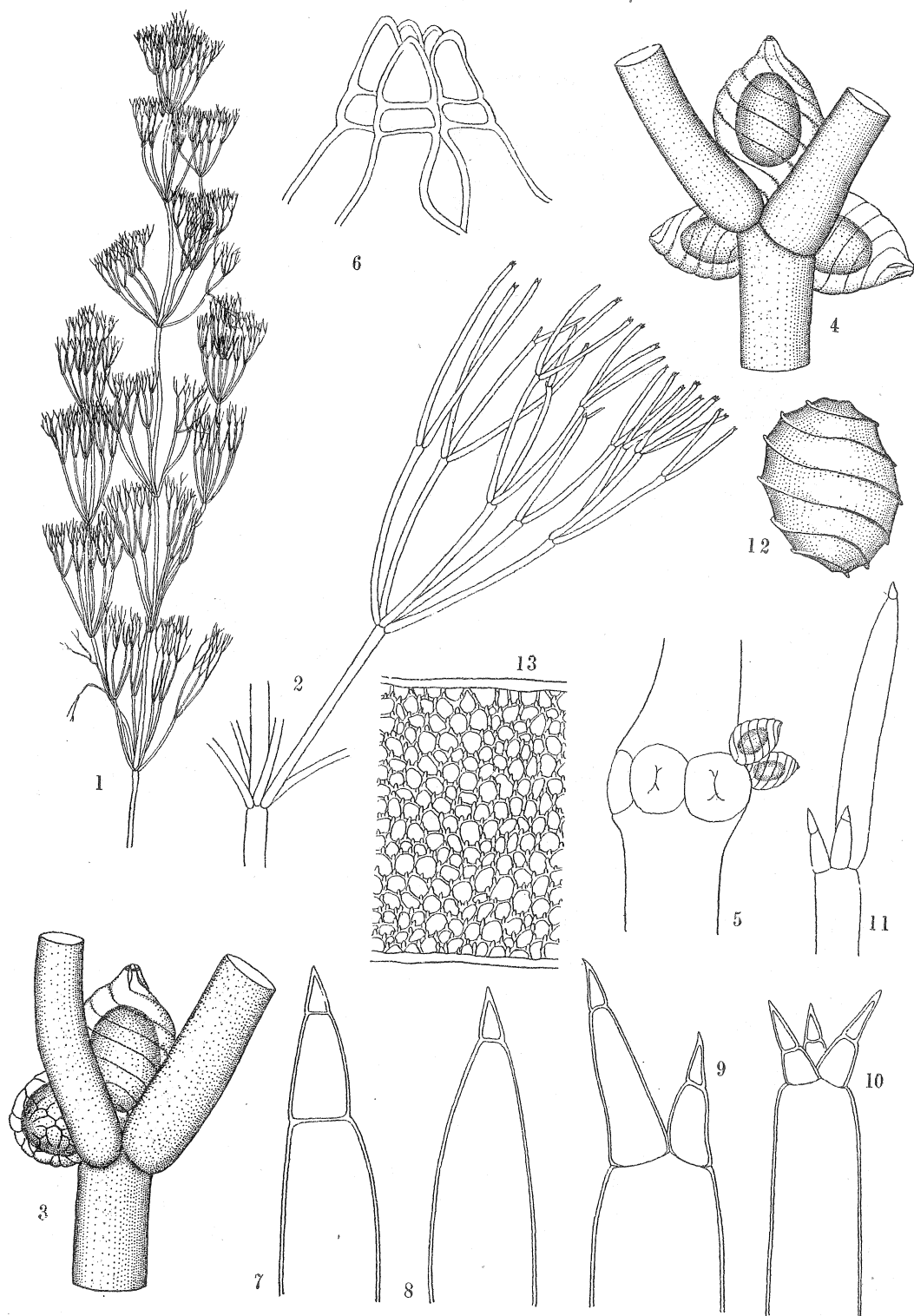


PLATE 3.

