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Studies on Indian Zygnemales [1]

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I. — *ZYGOGONIUM TALGUPPENSE* sp. nov. (fig. 1)

This alga was growing, together with *Stigonema* and other blue-green algae, on moist ground in a plantation of *Areca*-palms at Talguppa in the Mysore Province. It formed a thin felt-like mat on the soil-surface, in which the filaments were intricately intermingled with one another. The upper parts of the filaments were broader and had denser contents than the lower parts, the transition in size being quite gradual. The cells of the upper parts of the threads were 17-20 μ broad and 30-90 μ long, while those of the lower parts were 12-16 μ broad and 30-60 μ long. Branching was frequently met with in the lower portion of the stratum (fig. 1, *I*); the branches consisting of one to four cells. Very occasionally there was branching to the second degree, the secondary branches consisting of one or two cells only (fig. 1, *L*).

The single chloroplast is axile and appears to consist of two rounded and slightly lobed portions connected by a median bridge; each half of the chloroplast contains a pyrenoid, while the nucleus is apposed to the narrow median bridge (fig. 1, *B-D*). The cell-

(1) From the Department of Botany, East London College, University of London.

wall is at first thin, but later often thickens and shows some lamellation.

FORMATION OF AZYGOSPORES. — Though the filaments were intricately intertwined, neither scalariform nor lateral conjugation was observed. Formation of azygospores was, however, taking place plentifully throughout the stratum. The cells producing them first exhibit a swelling on one side and into this most of the cell-contents, including the chloroplast and the nucleus, pass, the chloroplast often appearing arched at this time (fig. 1, *E*). A curved wall is then formed cutting off the swollen portion from the remainder as a lens-shaped cell. Only a small quantity of cytoplasm is left in the original cell. The protoplasmic contents of the lenticular cell soon becomes surrounded by a special internal membrane which, on the outside, closely follows the contour of the dilation, while on the inside it is closely apposed to the curved wall which cut off the swelling from the rest of the cell (fig. 1, *E*, *H*, *K*); especially on the inner side the two membranes are so close together that it is often difficult to recognize them as distinct structures (cf. fig. 1, *A*, *G*). Later, when the sporewall, formed from the inner envelope, becomes thicker and the wall that first cut off the swelling gelatinises to some extent, the two envelopes appear quite distinct (fig. 1, *E*). About this time the dilated outer wall of the original cell becomes mucilaginous and somewhat refractive in appearance.

These changes during the formation of azygospores agree very closely with those recorded by HODGETTS (1) in the conjugating cells of *Zygogonium ericetorum*. Here most of the protoplasm of the two conjugating cells, including the chloroplasts and the nucleus, pass into the conjugation-processes and become cut off by a curved wall to form a gametangium. After the two processes have met and before their ends break down, the contents of each gametangium become surrounded by a new wall. The walls between the conjugation processes now break down and the two walled gametes later fuse by putting forth a beak-like projection. In the alga under discussion, as in *Z. ericetorum*, a curved wall cuts off a gametangium within the lateral swelling, which may be taken to correspond to a

(1) W.-J. HODGETTS. — New Phyt., XVII, 1918, pp. 242-244.

conjugation-process, after most of the contents have passed into the latter. Thereupon a new envelope is secreted round the contents of the gametangium, whilst the dilated portion of the original wall gelatinises to some extent. We are therefore clearly dealing with a *Zygogonium*, although in this case conjugation does not take place and only azygospores are formed. Ripe spores were not present in the material and it is not possible to state the nature of the wall of the mature zygospore.

Owing to the greater width and denser contents of the cells in the upper parts of the filaments, the azygospores formed in them are much larger than those formed in the lower ones (cf. fig. 1, *E* and *F*). The azygospores vary in shape from ellipsoid to nearly globose and measure 17-26 μ in breadth and 20-34 μ in length in the upper cells and 12-14 $\mu \times$ 13-16 μ in the narrowest cells. Another point of interest is that the azygospores of adjacent cells, especially in the lower filaments of the stratum, are frequently grouped in pairs on either side of the dividing wall (fig. 1, *D*). This suggests some kind of attraction during the formation of the processes (swellings) and recalls an early stage of lateral conjugation, although no such conjugation has been observed.

So-called aplanospores were not observed. Their formation has been described by WEST and STARKEY (1) in *Zygogonium ericetorum* in the following words : « Numerous aplanospores were formed in January and February, one spore being formed in each cell. A curious fact should be here recorded, *viz.*, that in most cases the whole contents of the cell were not used up in the formation of the spore, a small part of the protoplast being excluded (fig. 3, *D* and *E*). » At the time of writing the authors were under the impression that they were dealing with a *Zygnema*, and the significance of the whole contents of the cells not being used in the formation of the spores was therefore missed. Aplanospore-formation in *Zygogonium*, however, clearly follows in this respect the same method as the above-described azygospore- and zygospore-formation.

The single chloroplast and the mode of formation of the azygospores in the present alga recalls *Zygogonium ericetorum* as defined

(1) *New Phytologist*, XIV, 1915, p. 199.

by DE BARY (1) and subsequently confirmed by HODGETTS (2). Though no conjugation takes place, a similar process is gone through in the formation of the azygospores. Such azygospores have not hitherto been recorded for *Zygogonium*. HODGETTS reports azygospores for *Z. ericetorum* (3), but they are really cases of arrested scalariform conjugation and not comparable to the azygospore-formation shown by the alga here described.

The latter also differs from *Z. ericetorum* in the decreasing width of the lower parts of the filaments, which conditions the gradually decreasing size of the azygospores from the top downwards, in the frequent branching of the filaments, and in the usually longer cells. Its azygospores are much larger than the « azygospores » of *Z. ericetorum*, those recorded by HODGETTS (4) being 15 μ wide and 22-25 μ long. These differences are sufficient to warrant the establishment of a distinct species which may be called :

Zygogonium talguppense sp. nov. (fig. 1)

Filaments forming a thin felt on moist soil, gradually decreasing in width from above downwards, often branching in the lower parts of the stratum; cells of the upper filaments 17-20 μ broad and 30-90 μ long, those of the lower filaments 12-16 μ broad and 30-60 μ long. Azygospores developed within a gametangium formed in a lateral swelling and cut off from the parent-cell by a curved wall; azygospores ellipsoid to subglobose 12-26 μ broad and 13-34 μ long; zygospores not known.

HAB. — On moist soil in a plantation of *Areca*-palms at Talguppa in the Mysore Province.

(1) DE BARY. — Untersuch. uber die Familie der Conjugaten. Leipzig, 1858, pp. 79, 80.

(2) *Loc. cit.*

(3) *Loc. cit.*, p. 217, fig. 2, *E.*

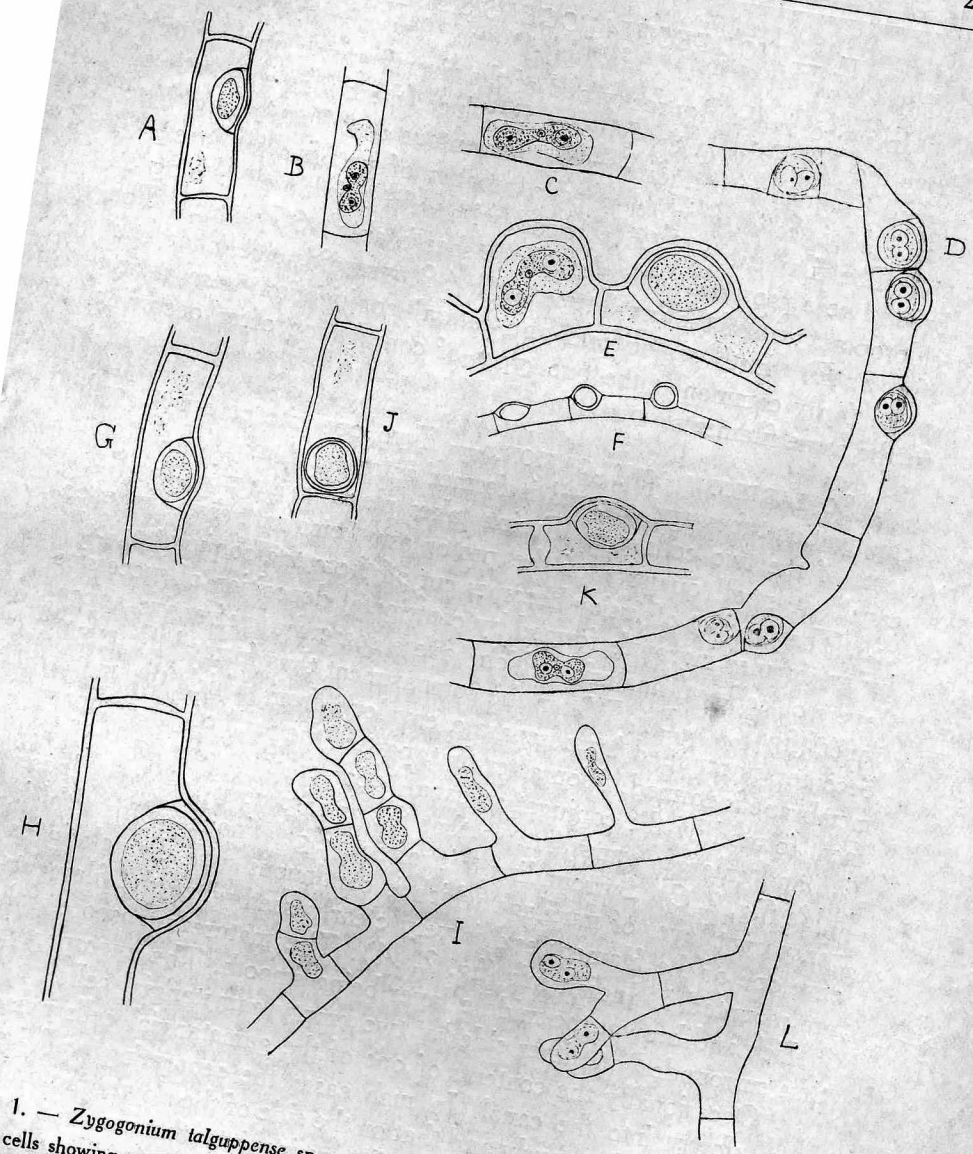

Fig. 1. — *Zygogonium talguppense* sp. nov. : *A*, *G*, *H*, *K*, Azygospore-formation ; *B*, *C*, cells showing contents; *D*, a filament with azygospores; *E*, two cells from the upper part of a filament; *F*, lower part of a filament; *I* and *L*, branching filaments; *J*, a cell with an azygospore seen from above. *A-E*, *G*, *J*, *K* × 980; *I*, *J*, *L* × 650; *H* × 1860.

II. — *MOUGEOTIA JOGENSIS* sp. nov. (fig. 2)

In a pool in the dry rocky bed of the river Saravati, immediately above the Jog Falls in the Mysore Province, there was a growth of various Conjugatae including many filamentous desmids. Among these was a *Mougeotia* which showed a number of peculiar features.

The filaments, 22-26 μ broad with cells 5-9 times as long as broad, were provided with a mucilage sheath about 6-7 μ thick. The chloroplast was of the usual type, with 4-9 pyrenoids embedded in it (fig. 2, *E*). Both scalariform and lateral conjugation were taking place fairly commonly, the two types of conjugation often occurring in the same filaments.

SCALARIFORM CONJUGATION. — Two opposite cells put forth conjugation-tubes and a canal is formed into which most of the contents of the two cells pass. Fusion takes place in the middle of the canal. A small quantity of the protoplasm remains behind in each cell. The product of fusion becomes cut off from the conjugating cells by an annular ingrowth formed by centripetal deposition of successive layers of cell-wall material which have a somewhat refractive appearance (fig. 2, *A*, *D*). Within the compartment thus formed the zygote becomes surrounded by a separate envelope from which the mature membrane is formed. Soon after that, part of the wall of the compartment formed by the conjugation-canal becomes gelatinous and refractive and enlarges somewhat, so that the zygospore is left lying loose inside (fig. 2, C). Surrounding this refractive gelatinous wall is a thick transparent layer of mucilage which is continuous with the gelatinous envelope of the filament and is very clearly seen when the filaments are mounted in Indian ink (fig. 2, *A*). The mature zygospore-wall is thick and brown, the middle layer being smooth. The zygospore is thus surrounded on either side by two empty gametangial cells.

Occasionally the contents of one of the gametangial cells passes more slowly into the canal. In such cases the separating walls are not formed simultaneously and that on the side of the slower protoplast is completed while the latter is still passing into the canal; it may have to pass through quite a narrow opening (fig. 2, *A*). The slower gamete may perhaps be regarded as female. A case of abnormal conjugation is shown in fig. 2, *D*.

LATERAL CONJUGATION. — Processes are put forth close together from adjacent cells (fig. 2, G) and, after they have come into contact with each other, the separating walls are absorbed and a canal is formed (fig. 2, *F*). The contents of the two cells, except for a small quantity of protoplasm, pass into the canal which becomes swollen. The product of fusion then becomes separated from the empty cells by ingrowths similar to those formed during scalariform conjugation, and the zygote develops its own membrane and, as in the other method of conjugation, ultimately lies loose in the compartment thus formed (fig. 2, *J*, *K*). The mature zygospores are globose or ellipsoidal and measure 47-52 μ in diameter.

During lateral conjugation the two processes sometimes appear to arise at some distance from each other and it looks as though they *grew towards each other* and fused (fig. 2, *I*, *L*). It is, however, possible that the two processes have become separated subsequently by elongation of the part of the filament lying between them.

Occasional formation of azygospores was observed. A lateral protuberance (fig. 2, *B*) appears in the middle of a cell into which most of the cell-contents enter forming a rounded swelling, which is soon cut off from the cell by a thick annular refractive septum. The contents of the swelling surround themselves with a separate membrane inside the original wall and finally lie loose within it (fig. 2, *H*).

In the possession of a gelatinous sheath around the vegetative filaments and around the zygospore this alga resembles such species as *Mougeotia gelatinosa* Wittrock (1), *M. maltæ* Skuja (2), and *M. cyanea* Transeau (3). The conjugation-canal does not, however, completely gelatinise as in the species just named, but remains fairly firm and slightly refractive with a broad transparent layer of mucilage round it. The present form further differs, from all the three species named, in the fact that the zygospores lie loosely in the canal, in the mode of separation of the empty gametangial cell by annular ingrowths of refractive cell-wall material, and in the frequent lateral conjugation. Its filaments are very much broader. The zygospores of *M. gelatinosa*

(1) WITTROCK & NORDSTEDT, Alg. Exsice, fasc. 21, n° 957, *Bot. Notiser*, 1889, p. 163.

(2) *Act. Hort. Bot. Univ. Latviensis*, I, 1926, p. 106.

(3) *Ohio Journ. Science*, XXVI, 1926, p. 321.

and *M. cyanea* are compressed-ovoid, whereas they are globoid or ellipsoidal in the present alga; they are much larger than those of *M. maltæ*. The Indian alga is therefore best regarded as a new species:

Mougeotia jogensis sp. nov. (fig. 2)

Vegetative cells 22-26 μ broad, with a mucilaginous sheath about 6-7 μ thick. Chloroplast plate-like with 4-9 pyrenoids, occupying about one-half the length of the cell; conjugation scalariform and lateral; the zygote becomes cut off from the conjugation cells by annular stratified ingrowths; mature zygospore brown, globose or ellipsoidal, lying loosely inside the enlarged conjugation-canal which is slightly refractive and is surrounded by a transparent mucilaginous sheath, continuous with that surrounding the vegetative filaments ; middle layer of zygospore-wall smooth; zygospore 47-52 μ in diameter.

HAB. — In a pool in the rocky bed of the river Saravati above Jog Falls, Mysore Province. (M. A. Sampathkumaran.)

III. — *MOUGEOTIA ADNATA* sp. nov. (fig. 3)

This alga was growing on rocks over which water was slowly trickling among gelatinous blue-green algae, on the slope of a hill at Periyar in S. India. It was attached to the substratum by means of rhizoid-like outgrowths from the cells.

The filaments 15-17 μ broad are envelopped in a thick gelatinous sheath 6-8 μ thick and a similar dense layer of mucilage covers the zygospores. The cells are 12-16 times as long as broad, and contain the usual plate-shaped chloroplasts with 4-10 pyrenoids (fig. 3, *D*). The threads are attached to the substratum by rhizoids (cf. p. 10).

SEXUAL REPRODUCTION. — Both lateral and scalariform conjugation were frequent, but the former was the commoner. During lateral conjugation two processes are put out close to one another from adjacent cells of the filament (fig. 3, *E*) and these appear to fuse (fig. 3, *F*). The contents of the conjugating cells fuse and form

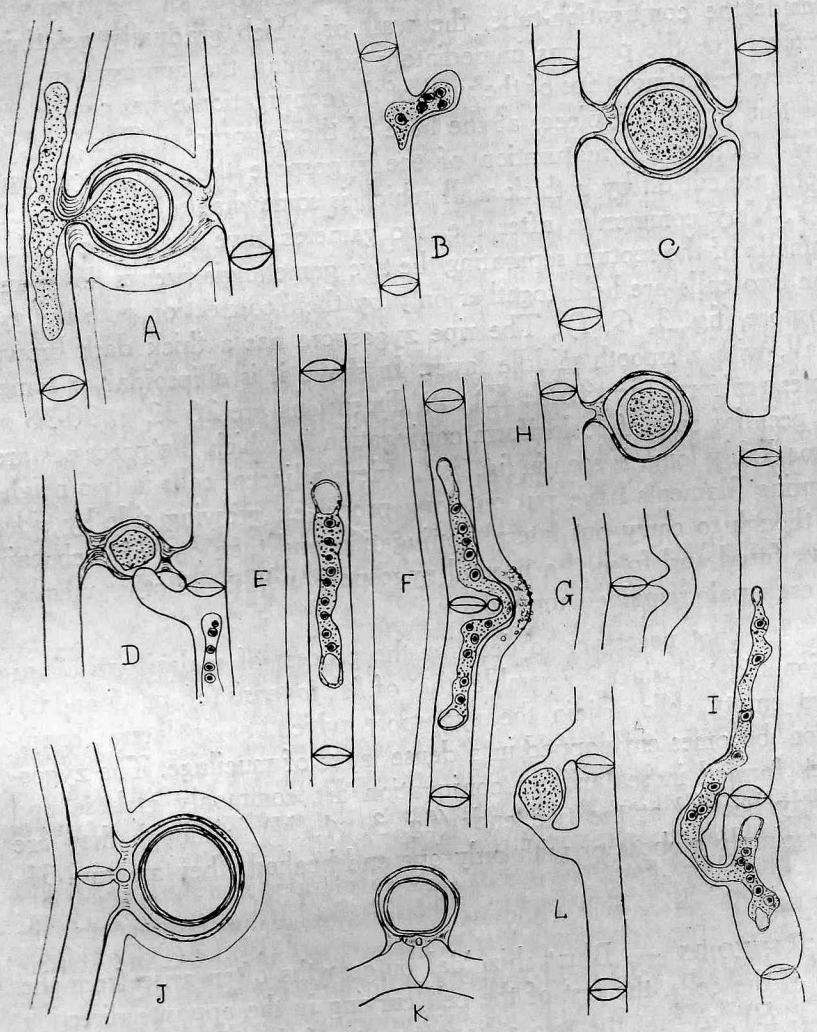

Fig. 2. — *Mougeotia jogensis* sp. nov. : *A*, *C*, scalariform conjugation; conjugation not yet complete in *A*; *B*, *H*, azygospore-formation; *D*, a case of abnormal scalariform conjugation where three cells have attempted conjugation; *E*, single cell showing chloroplast and gelatinous sheath; *F*, *G*, *J*, *K*, various stages in lateral conjugation; *I*, *L*, lateral conjugation, where the processes are well removed from each other. (All × 650.)

a zygospore in the middle of the canal (fig. 3, *G*, *H*, *J*, *K*). A thin delicate membrane is formed round the contents of the zygospore inside the conjugation-tube, the wall of which gradually gelatinises except for the portions immediately adjoining the conjugating cells. These persisting strips of the wall of the conjugation-canal can be seen as thin projecting pieces at the base of the zygospores (fig. 3, *A*, *C*, *G*). During the maturation of the zygospore the adjoining empty cells are cut off by a thick wall which is somewhat refractive (fig. 3, *C*). Very commonly, after the two gametes have fused, the middle lamella of the septum separating the two gametangia breaks down and the two cells are held together only by their connection with the zygospore (fig. 3, *G*, *I*). The ripe zygospore has a thick dark brown wall, with a smooth middle layer. In shape it is ellipsoidal or sometimes reniform (fig. 3, *H*, *K*); its dimensions are 26-32 $\times$ 30-38 μ. A peculiar case of scalariform conjugation in which the processes are remarkably long, is seen in fig. 3, *L*. Here adjacent cells in two neighbouring filaments have put out long processes, growing side by side, as though to carry out lateral conjugation and then one of each pair have fused and formed a normal zygospore, whilst the other member of each pair remained unused.

It is not necessary to describe the process of scalariform conjugation in detail, since it resembles that of *M. jogensis* (cf. pp. 5 and 6). Two empty cells adjoin the zygospore which, as in lateral conjugation, becomes envelopped in a dense layer of mucilage. The zygospores formed in scalariform conjugation are commonly globose and slightly beaked at the two ends (fig. 3, *A*, *N*), although they are often simply globose or with only one end beaked; they measure 31-33 μ $\times$ 35-37 μ.

RHIZOIDS. — Blunt rhizoidal outgrowths often arise from the sides of the cells, the rest of the cell curving in the opposite direction (fig. 3, *B*), so that the two adjacent parts of the filament grow upwards. Very often the rhizoids are branched. As other workers have pointed out, there is much resemblance between such rhizoids and the ordinary conjugation-processes. Both are no doubt usually formed as a result of a contact stimulus and possibly this would explain the peculiar cases shown in fig. 3, *L* and *M*.

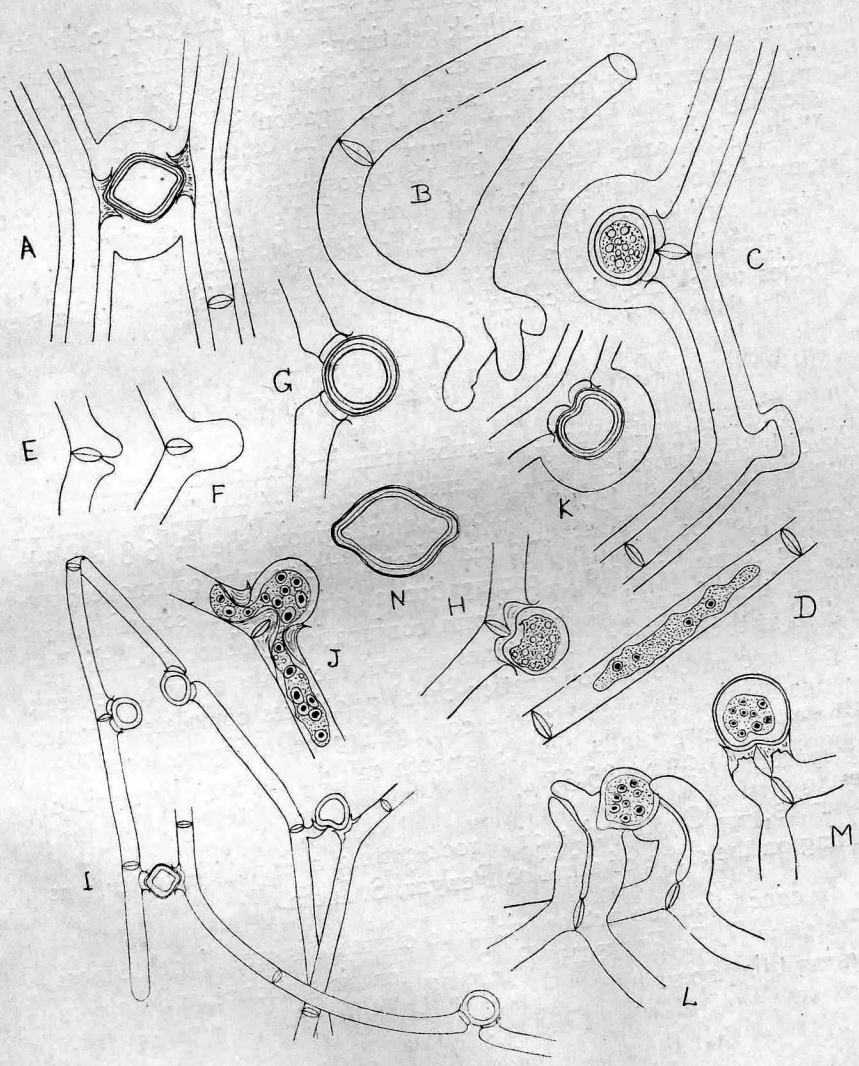

Fig. 3. — *Mougeotia adnata* sp. nov. : *A*, Scalariform conjugation; *B*, cell with rhizoids ; *C*, a filament showing lateral conjugation and a commencing rhizoid; *D*, a cell showing chloroplast; *E*, *F*, *H*, *J*, *K*, lateral conjugation; *I*, filament showing both lateral and scalariform conjugation; *L*, *M*, abnormal conjugation (cf. p. 9 and 10); *G*, cells in which the septum has broken down and which are held together only by the zygospore (see also I); *N*, a zygospore formed during scalariform conjugation. *I* × 360; *N* × 980; the rest × 740.

This species of *Mougeotia* appears well adapted to its terrestrial habitat in possessing thick gelatinous sheaths around filaments and zygospores which will serve as a protection against rapid dessiccation. The tendency for profuse lateral conjugation is probably also to be ascribed to the habitat. The Indian Alga resembles *M. gelatinosa* Wittrock in some respects, but its zygospores have not got the compressed-ovoid shape typical of those of the latter species, nor has lateral conjugation been recorded in *M. gelatinosa*. The habitat is also peculiar. The differences warrant the establishment of a new species which may be called :

Mougeotia adnata sp. nov. (fig. 3)

Filaments attached to the substratum by branched or unbranched rhizoids and provided with a dense envelope of mucilage; filaments without the sheath 15-17 μ broad; mucilaginous sheath 6-8 μ thick. Conjugation both lateral and scalariform, the former commoner; zygospore formed in lateral conjugation elliptic-globose, sometimes reniform, that formed in scalariform conjugation globose and slightly beaked at the two ends, sometimes without the beaks or with the beak only at one end. The conjugation-canal gelatinises completely except for small strips adjacent to the conjugating cells. Zygospores with thick dark brown walls, with a smooth middle layer; dimension of zygospores, 31-33 $\times$ 35-37 μ.

HAB. — On the side of a rock-cutting over which water was trickling on the slope of a hill at Periyar, S. India.

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