GENUS ZYGNEMOPSIS IN NORTHERN INDIA.

BY M. S. RANDHAWA, M.Sc., I.C.S.
(Fyzabad.)

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In 1934, the author described a new member of the Conjugate Gnosella indica, as a new genus and a new species. In subsequent years and particularly in 1937, he came across five more species which may be referred to this new genus.

Before dealing with these new species, which form the subject-matter of this paper, it is advisable to review the history of this new genus which occupies a unique position in the order Zygnemales due to its transitional nature. That these algae stand midway between Debarya and Zygnema there is no doubt. If one were to consider the character of their chloroplasts only, then there is nothing to differentiate these from the other species of Zygnema. In fact in a purely vegetative stage, nobody can distinguish these algae from some species of Zygnema. In their reproductive phase these algae show a considerable resemblance with some species of Debarya with certain peculiarities of their own. Mucilaginous lamellae of pectic cellulose, very wide conjugation canals, marked geniculation of conjugating filaments, and isogamous conjugation with the zygospores extending into the gametangia are the features which these algae have in common with Debarya. Due to its resemblance with Debarya, Transeau in 1915 described certain species which are now referable to this genus as Debarya americana Trans. and Debarya decussata Trans. In 1925 he described Debarya spirale (Fritsch) Trans. Czurda who bases his classification of Zygnemales on the character of the chloroplasts only, in Heft 9 of Susswasserflora Mitteleuropas described all these three forms as species of Zygnema.

However, apart from the resemblance of these forms in their vegetative phase with Zygnema, and in their conjugation with Debarya, they have certain peculiarities of their own. Firstly, the zygospores of these algae show a great variety in shape and structure even in the same species. Secondly, all these are characterised by the presence of peculiar triangular zygospores produced as a result of the fusion of the terminal cell of a filament with the intercalary cell of another filament. Thirdly, in the presence of spindle-shaped or oval aplanospores these algae differ from most known species of Debarya.
Moreover, if these algae are placed in the genera *Zygnema*, and *Debarya* according to the whim of the taxonomist, it will cause a great confusion. Their transitional nature is evident by the combination of the features of *Zygnema* and *Debarya* which they show, and they mark a definite stage in the evolution of the *Zygnemales*. So the best course is to include all these in a new genus which the author named in 1934 as *Ghosella* and Transeau in the same year as *Zygemopsis*. In the present paper the author has adopted the generic name suggested by Transeau, for it is more descriptive of the nature of the algae described under it. So far in all fourteen species have been described from Europe, South Africa, America and China, as belonging to this genus. With the addition of the six Indian species the total stands at twenty.

Genus *Zygemopsis* is described as follows:—


Vegetative cells with plane end walls; two more or less rounded or semistellate chloroplasts containing a central pyrenoid, in each cell. In some rare cases one or three to five chloroplasts may be seen in each cell. Reproduction takes place by isogamously produced zygospores, and spindle-shaped aplanospores. No lateral conjugation takes place in any known species. Marked geniculation of the mating filaments takes place during conjugation. The gametangia become filled with a dense pectic cellulose colloid, which in most species is secreted in lamellae, and in a few in a homogeneous mass. The spore wall is composed of three layers, of which the mesosporang is yellowish to brownish in colour and is variously sculptured at maturity. The zygospores show a great variety in shape, even in the same species. The remains of the gametangia persist around the zygospores in the form of horn-like structures. Peculiar triangular zygospores produced as a result of the fusion of the terminal cell of a filament with the intercalary cell of another are also seen.

1. *Zygemopsis indica* Randhawa (Fig. 1).

Vegetative cells 10–15 μ broad, 4–5 times as long, each with two rounded or semistellate chloroplasts, with one pyrenoid in each, surrounding the centrally situated nucleus (Fig. 1, 1).

Conjugation.—Conjugation scalariform, distinct geniculation of filaments takes place. Conjugation canals very wide (Fig. 1, 2). Deposition of shining white lamellæ of pectic cellulose takes place in the gametangia. Conjugation between 5 or more filaments quite common.
Fig. I. *Zygnemopsis indica* Randhawa.

1. A vegetative filament showing cells and chloroplasts. 2. A stage in conjugation showing wide conjugation canals and lamellation. 3. Two conjugating filaments showing ripe zygospores. 4. A filament showing a triangular zygospore and an aplanospore (a). 5. A ripe zygospore showing the spore walls, mesospore (m) shows punctuation. Lamellae are not shown in the walls. 6. Shows quadrately ovoid zygospores.

All figs. × 660.
Zygospores in the conjugation canal, also extending into the gametangia. The joints of the ripened cells get loosened, resulting in the detachment of the zygospores which retain the four horn-like remains of the gametangia. The zygospores are 36-46 µ in diameter exclusive of their mucilaginous coats, and including these may be as broad as 56 µ. When fully mature these are deep yellow in colour, and show a great variety in shape, some being quadrately ovoid (Fig. I, 6), some irregular but the majority are of the globose type. The zygospore wall is composed of three layers of which the exospore is thin, smooth, light blue, the mesospore is thick, chocolate brown, and the endospore is yellowish brown. The zygospore wall shows punctuation on its surface in the form of very small circular depressions (Fig. I, 3, 5 and 6).

Peculiar zygospores with three horn-like outgrowths, resulting from the conjugation of a terminal cell of a filament with an intercalary cell of another, are also seen (Fig. I, 4).

Aplanospores.—Spindle-shaped aplanospores are also commonly seen (Fig. I, 4).

Habit.—Free floating in a yellowish mass in a fresh-water pond near V. Hamira, district Jullundar, and V. Shahpur, district Hoshiarpur, Punjab, in the months of February, March and April 1930.

2. Zygnemopsis splendens sp. nov. (Fig. II).

This alga has been collected mixed with a species of Mougeotia from various ponds and paddy fields in villages Mhow-Jadubanspur and Rampur, district Fyzabad, in the months of January, February and early March 1937.

Vegetative cells 12-14 µ broad, 30-42 µ long, each containing two irregularly rounded chloroplasts, each with a central pyrenoid. The protoplasm of the cells secretes a shining white pectic cellulose substance. Septa of the cells plane (Fig. II, 1).

Reproduction.—Scalariform conjugation is the usual mode of reproduction. As compared with the other species of genus Zygnemopsis, the conjugation canals are comparatively narrow (Fig. II, 2). The protoplasm secretes a shining white pectic cellulose substance which fills the gametangia in a homogeneous mass, unlike the other species of Zygnemopsis, where it is secreted in layers. This is a typically isogamous species and zygospores are found more or less in the middle, and extend into the gametangia only very slightly in immature condition. The zygospores are of various shapes, being heart-shaped, diamond-shaped, or potato-shaped in appearance (Fig. II, 3 and 4). The remains of the gametangia persist around the zygospores, which dissociate from each other by the loosening of the joints.
Fig. II. *Zygnemopsis splendens* sp. nov.

1. A filament showing chloroplasts and cells. 2. An early stage in conjugation showing narrow conjugation canals. 3. Two conjugating filaments showing azygospores (a). 4. An advanced stage in conjugation showing the shapes of zygospores and absence of lamellation. 5 and 6. Show dissociation of ripe zygospores with the remains of gametangia around them.

All figs, × 660.
The immature zygospores are 16–20 μ long, exclusive of the remains of gametangia. The spore wall bears reticulations on its surface which are faintly brown in colour in immature zygospores, (Fig. II, 5). Mature zygospores were collected on 25th March 1937. These are quadrately ovoid and in some cases more or less conical in shape. As compared with the immature zygospores these are considerably bigger in size being 26–30 μ broad, and 40–50 μ long. The exospore is thin, smooth, light blue in colour and is separated by a wide space filled with brownish yellow matter from the brownish mesospore which bears minute reticulations on it (Fig. II, 6).

Azigosposres.—In some cases it was noticed that the gametes failed to meet, and their contents independently develop into azigosposres (Fig. II, 3).

Affinities.—This species differs from all the other known species of Zygnemopsis, in the secretion of pectic cellulose in a homogeneous mass, in the absence of lamellation and the peculiar shape of its zygospores.

3. Zygnemopsis lamellata sp. nov. (Figs. III and IV).

This beautiful member of the Zygnemales was found free-floating in a darkish purple mass in Tons Nadi under the bridge near the tahsil buildings at Akbarpur, district Fyzabad, U.P., on 15th February 1937. Another specimen was collected on 25th March 1937 from Tirwa Nadi, near Tanda. This alga shows a luxuriant growth in the slowly flowing fresh-water streams of Fyzabad District.

The vegetative cells are 15–18 μ broad and 32–42 μ long. There are two rounded or more or less semistellate chloroplasts in each cell. The periphery of the cells are full of pectic cellulose which is shining white in appearance.

Reproduction.—Reproduction in this species takes place by means of aplanosores and zygospores produced by isogamous conjugation.

(i) Conjugation.—The process of conjugation in this species is typically isogamous. The conjugation canals are immensely wide. The chloroplasts show a movement towards the middle part of the conjugation canal, as is evident from their fore and aft position. Surrounding the chloroplasts are numerous granules. Mucilaginous lamellae composed of shining white pectic cellulose are secreted by the retracting protoplasm as in Zygnemopsis indica (Fig. III, 2). The conjugating filaments show a marked geniculation, while the cell contents become very much vacuolated (Fig. III, 3).

The zygospores are of a dark bluish green colour and occur in such large numbers that they give a dark bluish colour to the water of rivulet from where the alga was collected. They present a great variety in shape, in some cases they are quadrangular with plane sides, and in some cases these
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**Fig. III.** *Zygnemopsis lamellata* sp. nov.

1. Shows a filament with cells and chloroplasts.  2 and 3. Show early stages in conjugation.  4 and 5. Show different shapes of zygospores with their markings.

All figs. × 660.
are quadrangular with concave sides, and the corners obtuse (Fig. III, 4). In some rare cases the zygospores were diamond-shaped (Fig. IV, 2), but on the whole the globose shape is more common (Fig. IV, 1). The zygospores are 44–52 μ in diameter. The spore wall is composed of three layers, of which the exospore is also fairly thick and greenish blue in colour, the mesospore is dark bluish green in colour, and the endospore is thin, light bluish in colour. The spore wall bears foveolate type of reticulations on its surface, and when crushed, punctation in the form of small dots is also noticeable on the surface of the spores (Fig. IV, 1). The zygospores get loosened from each other, and float about with four horn-like remains of the gametangia at their sides.

A peculiar type of triangular zygospores seen in Z. indica are also seen in this species. These result from the conjugation of the end cells of some filaments which meet vertically the cells of a filament lying horizontally. The result is the formation of these triangular zygospores with three horn-like sides (Fig. IV, 3).

(ii) Aplanospores.—Unlike other species of Zygnemopsis, reproduction by means of aplanospores is just as common as that by the aid of zygospores. Such aplanospores were also seen in Z. indica, but in that species, these are rather rare. In some cases it was seen that while normal conjugation is taking place in a part of two filaments, the remaining part of one is producing aplanospores. In early stages the middle part of a cell begins to expand laterally, while the chloroplasts become surrounded by granular matter. The cells become filled with a solid mass of pectic cellulose at the sides, while around the chloroplasts a reticulum is secreted, which is irregular in earlier stages (Fig. IV, 4). Later on the network secreted in each chloroplast expands, and both the networks meet in the middle forming a cylinder (Fig. IV, 5). A thick, brown and smooth exospore spindle-shaped in outline separated from the reticulate mesospore by a wide distance develops in mature spores (Fig. IV, 7 and 8). However, some aplanospores are typically oval in shape. The mesospore is thick brown with foveolate reticulations. The aplanospores are 24–36 μ broad, and 40–74 μ long, inclusive of the mucilaginous walls. Excluding the mucilaginous sheath these are 18–24 μ broad.

Affinities.—This alga differs from Zygnemopsis indica Randhawa in the presence of foveolate reticulations on the surface of spore walls, the peculiar structure of its aplanospores, and the broader size of its cells and zygospores. It differs from Z. quadrata. Jao in the white colour of its lamellae, reticulations on its spore walls, which are scrobiculate in the Chinese species, and the absence of a suture. There is a slight resemblance between
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Fig. IV. *Zygnemopsis lamellata* sp. nov.

1 and 2. Show different type of zygospores. 3. Shows a triangular zygospore. 4, 5 and 6. Show different stages in the development of aplanospores. 7 and 8. Show ripe aplanospores.

All figs. × 660.
the aplanospores of this form with those of *Debarya reticulata* Transeau 1925, whose zygospores are not known, but those of the present form differ in the absence of thickenings at the poles, as well as the presence of well-marked foveolate reticulations. All these differences from the related species, warrant the establishment of a new species which is called *Zygnemopsis lamellata*.

*Zygnemopsis lamellata* sp. nov. (Figs. III and IV).

Vegetative cells 15–18 μ long, 32–42 μ broad, each with two semistellate chloroplasts bearing a pyrenoid in the middle. Reproduction by means of globose or quadrangular zygospores 44–52 μ in diameter, dark bluish green in colour, extending into the gametangia. Lamellæ of pectic cellulose secreted in the gametangia. Mesospore thick, dark bluish green with foveolate reticulations. Spindle-shaped or oval aplanospore also abundantly seen.

**Habit.**—Found in a dark purple mass in Tons Nadi near Akbarpur, district Fyzabad, U.P., on 15th February 1937 and on 25th March 1937 from Tirwa Nadi, Tahsil Tanda, in the same district.

4. *Zygnemopsis Iyengari* Randhawa nov. comb.

(*Zygema Iyengari* Randhawa) (Figs. V and VI).

This species of *Zygnemopsis* was found free-floating in a yellowish brown mass in small puddles of water around Pikia Nadi near Rajeh Sultanpur, Tahsil Tanda, district Fyzabad, U.P., mixed with *Mougeotia lepus* sp. nov. and numerous species of desmids.

The vegetative cells are 12–16 μ broad and 5–8 times as long, being narrower and longer as compared with those of *Z. lamellata*. There are two more or less rounded chloroplasts in each cell (Fig. V, 1).

**Conjugation.**—The early stages in conjugation are very similar with those of *Z. indica* and *Z. lamellata*, and in the absence of mature spores with their characteristic markings it is impossible to distinguish between the various species. The conjugation canals are wide, well-marked lamellæ of pectic cellulose appear, and the conjugating filaments show geniculations (Fig. V, 2 and 3). When stained with iodine the chloroplasts with their central pyrenoids show a wheel-like structure with a number of spokes radiating outwards (Fig. V, 3, 4 and 5). The arms of the gametangia become filled with pectic cellulose resulting in the confinement of the protoplasm and the chloroplasts in a squarish space in the middle of the conjugation canals (Fig. V, 4). Later on the outer part may become hexagonal in outline,
Fig. V. *Zygnemopsis* Iyengari sp. nov.

1. Shows a vegetative filament. 2, 3, 4 and 5. Show different stages in conjugation.

All figs. × 660.
and lamellation becomes very much faint, being noticeable only around
the periphery of the central mass of protoplasm (Fig. V, 5).

When fully mature the zygospores completely fill the conjugation canals,
and not a trace of pectic cellulose being seen laterally. The spore wall is
composed of two layers, of which the exospore is light bluish green with a
brownish tinge. In some zygospores the exospore is as thick as the meso-
spore and shows thickenings at the four poles (Fig. VI, 1). The mesospore
is separated from the exospore by a space filled with a yellowish brown
matter. In mature spores it is thicker than the exospore, and is yellowish
brown in colour. The mesospore is very complexly sculptured, being raised
into a number of ridges which are more noticeable in a lateral view (Fig. VI, 3).
Denticulate markings in the form of small spine-like projections are also
noticeable, and there may also be wave-like reticulate markings on some
of the zygospores (Fig. VI, 2). Triangular zygospores are also frequently
seen (Fig. VI, 5). Mature zygospores are 44-54 μ in diameter.

*Applanospores.*—Asexual reproduction by means of barrel-shaped, spindle-
shaped, or globose aplanospores takes place quite commonly in this species.
While some filaments may be reproducing exclusively in an asexual manner
with plenty of aplanospore formations, others show conjugation side by
side with aplanospore formation (Fig. VI, 1). The aplanospores develop
from the ordinary vegetative cells by swelling of the middle part and appear-
ance of granular matter around the chloroplasts (Fig. VI, 6). Extensive
secretion of pectic cellulose in a homogeneous mass takes place and a reti-
culum develops in the protoplasm (Fig. VI, 7). When mature the aplanos-
spores are globose or spindle-shaped with a number of parallel ridges on
the surface (Fig. VI, 9, 10, 11 and 12). The aplanospores are 24-28 μ in
diameter normally, while in one case these were as broad as 32 μ and 54 μ
long.

*Affinities.*—In September 1936, the author described a new species of
*Zygnema* as *Z. Iyengari*. That aplanosporic species resembles the present
one in the shape of its aplanospores, the only difference being that the cells and
aplanospores of the present form are longer and narrower. *Zygnema Iyengari*
is obviously an aplanosporic species of *Zygnemopsis* and is renamed as
*Zygnemopsis Iyengari*. *Z. Iyengari* differs from the related species *Z. indica*
in the presence of ridges on its zygospores and the peculiar shape and structure
of its aplanospores.
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1. Shows conjugation and asexual reproduction by aplanospores (a) at the same time.
2. Shows ripe zygospore. Mark the reticulate markings on the middle one.
3. Shows lateral view of two zygospores showing ridges.
4. Shows ripe zygospores.
5. Shows asyogospores resulting from the fusion of the terminal cell with an intercalary cell.
6 and 7. Show early stages in the development of aplanospores.
8 to 12. Show different types of aplanospores with their markings.

All figs. × 660.
Zygnemopsis Iyengari nov. comb. (Zygnema Iyengari).
(Figs. V and VI). Randhawa.

Vegetative cells 12–16 \( \mu \) broad, 5–8 \( \mu \) times as long, each cell with two rounded chloroplasts bearing each a central pyrenoid. Zygospores globose, 44–54 \( \mu \) in diameter, with a thick bluish green exospore separated by a space filled with light yellowish brown matter from the yellowish brown mesospore. Spore wall with ridges and denticulation on surface. Asexual reproduction by barrel-like, or spindle-like aplanospores bearing a number of parallel ridges on surface, 24–28 \( \mu \) in diameter.

**Habit.**—Free-floating in Pikia Nadi, near Rajeh Sultanpur, district Fyzabad, U.P., on 15th January, 1937.

5. *Zygnemopsis globosum* sp. nov. (Fig. VII).

This species of *Zygnemopsis* was found free-floating in an irrigation channel leading to paddy fields from a Jhil near Tanda on 26th March, in a dirty brown mass mixed with a species of *Chara* and *Oedogonium*.

The vegetative cells are 12–14 \( \mu \) broad and 36–72 \( \mu \) long, and each cell usually contains two rounded chloroplasts, but in some cells there is only one chloroplast in each cell (Fig. VII, 1).

Conjugation is typically isogamous as in other species of *Zygnemopsis* and plenty of mucilage secretion in the forms of lamellae takes place. Conjugation between three or more filaments is quite common. Conjugation canals are very wide and marked geniculation of filaments takes place (Fig. VII, 3, 4 and 5). Ripe zygospores are yellowish in colour. The outermost covering in most cases is formed of two thick layers of shining white pectic cellulose, beneath which are noticeable the two layers of the spore wall. The exospore is dark yellowish brown in colour and separating it from the mesospore is a space filled with brownish matter. The mesospore is brownish green or dark brown. The spore wall bears polygonal or irregularly rounded reticulations. The meshes of the reticulum are very wide as compared with those of *Z. lamellata* being 4–6 \( \mu \) apart. The zygospores are typically rounded in shape, hence the specific name globosum (Fig. VII, 6). Very rarely quadrangular zygospores with thickened poles are also seen (Fig. VII, 7). Zygospores are 44–50 \( \mu \) in diameter.

**Aplanospores.**—Very rarely one may come across spindle-shaped aplanospores 30–32 \( \mu \) broad and 40–44 \( \mu \) long, with reticulations on spore wall (Fig. VII, 8).

**Affinities.**—This species comes nearest to *Z. lamellata* from which it differs in its narrower and longer cells, fewer lamellae in each cell, its zygospores with their broad reticulations, and the simpler structure of its aplanospores.
Fig. VII. *Zygnemopsis globosum* sp. nov.

1. Shows a filament, mark the single chloroplast in one cell. 2. Shows three filaments conjugating together. 3, 4 and 5. Show different stages in conjugation. 6 and 7. Show ripe zygospores with the reticulate markings. 8. Shows an aplanospore.

All figs. × 660.
Zyg nemopsis globosum sp. nov. (Fig. VII).

Vegetative cells 12–14 μ broad, 36–72 μ long, each cell with one or two rounded chloroplasts. Zygospores, globose 40–50 μ broad. Spore wall with very broad reticulation on surface. Aplanospores spindle-shaped, rare, 30–32 μ broad and 40–44 μ long.

Habit.—Found mixed with a species of Oedogonium in a water channel near a Jhil at Tanda, district Fyzabad, U.P., on 25th March 1937.

6. Zyg nemopsis minutum sp. nov. (Fig. VIII).

This alga was found mixed with Zyg nemopsis lamellata Randhawa and Zyg nemena Oudhensis sp. nov. in a greyish mass free-floating in Tons Nadi near tahsil buildings, Akbarpur, Fyzabad, U.P., on 25th March 1937.

Vegetative cells are 8–10 μ broad and 36–46 μ long. Each cell contains two irregularly rounded chloroplasts. The septa are plain, and the cells have a tendency to dissociate from each other. The filaments appear like a colony of Cylindrocystis produced as a result of transverse separation in a horizontal plane (Fig. VIII, 1).

Reproduction.—Reproduction takes place by means of aplanospores and very rarely by means of zygospores. Conjugation is isogamous, and it appears from the absence of jointed conjugating cells that either conjugation takes place between disjointed unicells or that the dissociation of conjugating cells takes place immediately after the conjugation canals have been established. Such H-shaped pairs of conjugating cells may be seen free-floating in water. The protoplasm secretes a shining white pectic cellulose substance in a homogeneous mass as in Zyg nemopsis spl endens Randhawa (Fig. VIII, 2, 3 and 4). Zygospores are squarish when mature and retain the stumpy arm-like remains of the gametangia. Zygospores are 22–24 μ broad excluding the mucilaginous coat and inclusive of it may be as broad as 30 μ. When mature the zygospores are dark chocolate brown in colour. The spore wall bears small reticulation on surface and is composed of two layers, a thin and hyaline exospore and a thick dark brown mesospore (Fig. VIII, 5). Three-horned zygospores, produced as a result of the fusion of the terminal cell of a filament with the intercalary cell of another, are also seen (Fig. VIII, 7).

Aplanospores.—The commonest mode of reproduction in this species is by means of cudgel-shaped aplanospores. The middle part of a cell gets swollen and the sides get curved (Fig. VIII, 8). Then the spore walls appear in the swollen middle part. In early stages the aplanospores resemble those of Zyg nemopsis Iyengari in shape (Fig. VIII, 6, 9 and 10). However in mature aplanospores, the curvature of the arms becomes very conspicuous,
Fig. VIII. *Zygnemopsis minutum* sp. nov.

1. Shows a vegetative filament and dissociation of cells.  2 and 3. Show early stages in conjugation.  4. Shows an immature zygospore.  5. Shows a mature zygospore. Mark the reticulate sculpturing of the spore wall.  6. Shows an aplanospore.  7. Shows a three-horned zygospore along with an aplanospore.  8, 9 and 10. Show different stages in the development of an aplanospore.  11. Shows a mature aplanospore.

All figs. × 660.
and resemblance with aplanospores of some species of Mougeotia becomes marked. In fact the author, before he came across vegetative cells, had actually diagnosed these as aplanospores of a species of Mougeotia. The aplanospores are dark chocolate brown in colour and are 18–20 μ broad and 18–30 μ long. The structure of the spore wall is the same as that of zygospores (Fig. VIII, 11).

Affinities.—This delicate species of Zygnemopsis resembles Zygnemopsis desmidioides. Transeau (West) nov. comb. = (Debarya desmidioides West) in the size and structure of vegetative cells, and the dissociation of cells and zygospores. But differences from Z. desmidioides are also well marked. Firstly no lamellation is noticeable in the gametangia; secondly, the bigger size of zygospores and presence of reticulations on spore wall; and thirdly, the presence of peculiar cudgel-shaped aplanospores. Hence, it is feasible to regard the Indian form as a new species, which is named as Z. minutum sp. nov.

Zygnemopsis minutum sp. nov.


Conclusion.

Before closing, I sincerely thank Professors Ghose and Bharadwaja for so kindly lending the relevant literature, without which the proper study of these new algaæ would not have been possible.

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