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Sirogonium sticticum (J.E. Sm.) Kütz. and *Zygnemopsis scorbiculata* P. Sarma & Kargupta from Hooghly in West Bengal, India

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ABSTRACT: In the present paper, two algal species viz. *Sirogonium sticticum* (J.E. Sm.) Kütz. and *Zygnemopsis scorbiculata* P. Sarma & Kargupta belonging to the family Zygnemataceae of the class Chlorophyceae have been reported for the first time from Hooghly district in West Bengal, India. These species are clearly different from each other on the basis of vegetative and reproductive characteristics. Both the species are filamentous and grown in ponds. One of the marked differences between the two species is that the former possesses straight and parallel chloroplasts while the later contains stellate chloroplasts in the cells of filaments. A study of the limnological profile and the relationship between water properties and distribution of these algal species has been assessed. Results of water analysis proved that temperature range between 24°C and 25°C, alkaline pH, DO with range of 6.6-7.0 mg l^{-1}, slight higher COD values, lower total alkalinity, TSS, TDS, SO_4^{2-} and nutrients values have a great impact on their seasonal occurrences.

Key Words: Taxonomy, limnology, *Sirogonium*, *Zygnemopsis*, West Bengal, India

INTRODUCTION

Filamentous green algae are one of the principal constituents of algal communities in freshwater habitats (Cambra and Aboal, 1992). Pharmaceutically, fresh water filamentous macroalgae are important resources of bioactive natural compounds because they can accumulate specific secondary metabolites in their cells which are valuable natural products for some applied applications like in the cosmetics, foods and pharmaceutical industries (Tipnee *et al.* 2015). They have significant potentiality as an alternative algal feedstock for biofuels production at commercial scale in a cost effective and sustainable manner (Yun *et al.* 2014) although from past three decades much efforts have been paid to the marine seaweeds and cyanobacteria in this respect, with a much lesser focus on the use of freshwater macroalgae (Yun *et al.* 2015).

They have the ability in the depletion of nutrient contents richer by particularly, nitrogen and phosphorous compounds from wastewater and other water bodies contaminated by agricultural run-off (Cole *et al.* 2014).

During the taxonomic survey of filamentous algae it has been noticed that they form floating algal mats during summer in the oligotrophic to eutrophic aquatic bodies. In terms of algal biomass and species composition, most important flora/taxa under the filamentous algal group in stagnant water bodies are species of *Hydrodictyon* Roth, *Pithophora* Wittr., *Rhizoclonium* Kütz., *Oedogonium* Link, *Spirogyra* Link, *Zygnema* C.A. Ag., *Mougeotia* C.A. Ag. and *Vaucheria* DC.

The members of Zygnematales are grass-green in vegetative condition and filamentous as the thallus organization. Their chloroplast shapes are variables like ribbon shaped, stellate and laminate and, show prominent periodicity that is closely concerned with seasonal changes of water properties and microclimatic conditions. They are also known as "Conjugatophyceae" (conjugating green algae) because they exchange their genetic materials through conjugation process. The number of currently accepted species of Conjugatophyceae in the Algae base is *Ca* 3,500 which is composed of about 10% among all the algal species (Guiry, 2013).

In West Bengal of India, the genera *Sirogonium* Kütz. and *Zygnemopsis* (Skuja) Transeau are undoubtedly less studied in the taxonomical level than some of other partners of this order (viz. *Spirogyra* Link and *Zygnema* C.A. Ag.). They prefer to grow in winter season, form climax in early summer season and then gradually form sexual spores at maturity in hot and humid summer in free floating condition as noted by the author. It has been also found that their spores remain dormant until the end of summer or before coming of monsoon. As soon as water is available in water bodies during rainy season (June-September), the dormant spores begin to germinate and produce vegetative filaments.

Zygnemataceae is unique among the algal groups for its wide distribution capability (Ali and Naz, 2011) and sexual reproduction process (Vaucher, 1803). The genus *Sirogonium* Kütz. is very common and most widely distributed whereas, *Zygnemopsis* (Skuja) Transeau is sparsely distributed in the freshwater bodies in West Bengal, India. These genera are generally grown in association with other Chlorophycean filamentous algal member's viz. *Spirogyra* Link, *Zygnema* C.A. Ag. and *Mougeotia* C.A. Ag. Molecular phylogenetic analyses through gene sequencing that encoding the large subunit of RUBISCO (*rbc*L) confirmed that the family Zygnemataceae is monophyletic in origin (McCourt *et al.* 2000; Gontcharov, 2008).

Previously, few works had been made for the identification of the members of Zygnemataceae from this region. Review of literatures showed that Martens (1869) first recorded the occurrence of Zygnemataceae from West Bengal. Dixit (1937), Singh (1941), Rattan (1964), Patel and Kumar (1975) and Ushadevi and Panikkar (1994) were made some important contributions on the taxonomy of *Sirogonium* Kütz. from India. Srivastava (1981a, b) had documented a new species as *Sirogonium iyengarai* M. Srivast. and a new variety as *S. floridanum* var. *morabadiensis* M. Srivast. from Bihar and Ranchi of India. After that, Singh and Srivastava (1992) reported one new variety as *Sirogonium sticticum* var. *pancheti* M. Singh and M. Srivast. from Dhanbad, Bihar, India.

Regarding taxonomy of *Zygnemopsis* (Skuja) Transeau, it was Das (1962) who first described a new species as *Zygnemopsis queensis* (*queense*) C.R. Das from Calcutta, West Bengal in India. Patel and Kumar (1971) discussed morphological and cytological characteristics of *Zygnemopsis godwardense* R.J. Patel and A. Kumar and later, they (1977) enlisted the species occurring in Gujarat. Prasad and Kumari Vijay (1977) documented a new species of this genus as *Z. vermae (vermaii)* B.N. Prasad and V. Kumari from India. Sharma and Kargupta (1986) also recorded three new species of this genus from Murshidabad and Birbhum districts in West Bengal, India with respect to shape, colour and measurements of vegetative and reproductive structures. Chalotra et al. (2013) described three species of the genus which were collected from fresh water bodies in Jammu and Kashmir. Earlier, Halder (2015) reported the occurrence of two species of the genus from Hooghly district in West Bengal, India. Keeping in view the paucity of the information thus, the present work was aimed to study taxonomy and documentation of the filamentous algal forms of class Chlorophyceae from West Bengal, India particularly the genera of *Sirogonium* Kütz and *Zygnemopsis* (Skuja) Transeau. that will give some additive information of those algal flora.

MATERIALS AND METHODS

The algal samples were collected in plastic and glass containers from two ponds at Dumurdaha (23°.03'N; 88°.43'E) and Chinsurah (22°.90'N; 88°.39'E) of the Hooghly district in West Bengal. Microscopic examinations were made by Olympus microscope (Model-CH20i). Algal samples were preserved in 4% formalin solution and the voucher specimens deposited in the Departmental Herbarium of the Department of Botany, University of Kalyani, Nadia, West Bengal. Identification of the taxa had been made following standard literatures viz. Randhawa (1959), Patel and Kumar (1971, 1977), Sharma and Kargupta (1986), Singh and Srivastava (1992), Ushadevi and Panikkar **(**1994) and Kant and Gupta (1998).

Each currently accepted name has been provided with its author's name. Limnological study was performed following the standard method described earlier by the author/s (Halder, 2015a, b, c, d; Halder and Sinha 2014, 2015; Halder 2016a, b).

RESULTS AND DISCUSSION

Two algal species *Sirogonium sticticum* (J.E. Sm.) Kütz. and *Zygnemopsis scorbiculata* P. Sarma & Kargupta of Zygnemaceae under the order Zygnematales of Chlorophyta had been reported for the first time from Hooghly district in West Bengal, India. The classification system proposed by Smith (1950) was followed for their systematic arrangements.

Order: Zygnematales; Family: Zygnemataceae

Genus: *Sirogonium* Kütz.

Sirogonium sticticum (J.E. Sm.) Kütz., Phyc. gen., 278. 1843; Randhawa, Zygnemaceae 424, fig 508, 1959; Pandey et al., in Biblioth. Phycol. 66: 256, 1984; Kant & Gupta, Algal Flora of Ladakh 128, pl 52, fig 5, 1998 **(Plate-1, figs. 1-2).**

Conferva stictica J.E. Smith, 1813.

Taxonomic description: Filaments unbranched, grass-green, at maturity become brownish-black; vegetative cells cylindrical, 110.0-120.0 µm long and 35.0-40.0 µm broad; chloroplast 4-6, nearly straight; septa plane; conjugation between shortened, slight reflexed or inflated gametangia; receptive gametangia enlarged or expanded; 135.0-145.0 µm long, 69.0-72.0 µm broad; zygospores ellipsoid to ellipsoid-ovoid; 80.0-90.0 µm long and 40.0-45.0 µm broad; median spore wall smooth and slight yellowish.

Habitat: Free floating in pond at Chinsurah, West Bengal, India

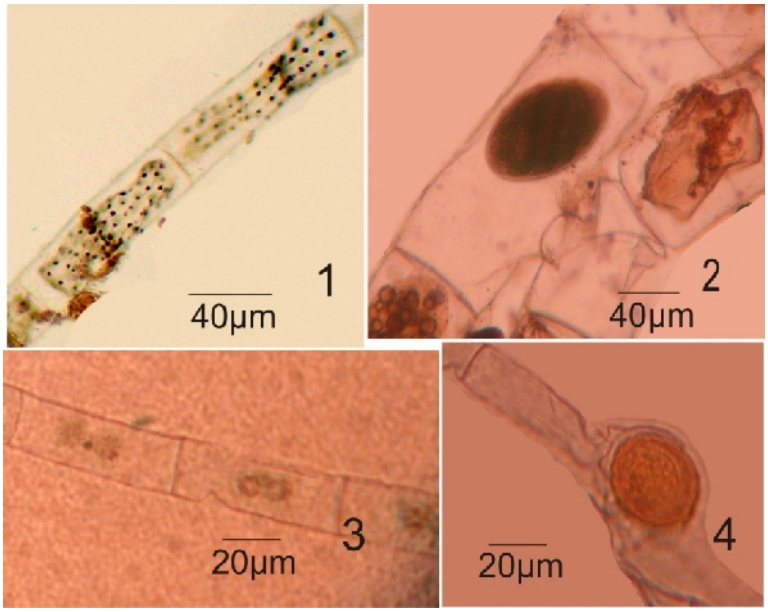

Plate-1, Figs. 1. *Sirogonium sticticum* filament, **2.** Zygospore in conjugating filaments, **3.** *Zygnemopsis scorbiculata* filament, **4**. Zygospore in receptive filament.

Collection no. NH 719, NH 720; dated: 01.11.2010

Occurrence: Abundantly grown in fresh water bodies.

Limnology of the pond: Temperature: 24°C; pH: 7.5; NO_3-N: 0.4 mg l^{-1}; PO_4^{3-}: 0.3 mg l^{-1}; DO: 7.0 mg l^{-1}; COD: 150.0 mg l^{-1}; SO_4^{2-}: 6.9 mg l^{-1}; TSS: 112.0 mg l^{-1}; TDS: 162.0 mg l^{-1}; total alkalinity: 128.0 mg l^{-1}.

Distribution: Europe, North and South America, Australia, New Zealand, Asia; In India it was recorded earlier from Bihar, Jammu and Kashmir, Jharkhand, Maharashtra, Punjab, Uttar Pradesh and West Bengal only.

Order: Zygnematales; Family: Zygnemataceae

Genus: *Zygnemopsis* (Skuja) Transeau

Zygnemopsis scorbiculata P. Sarma & Kargupta, Hydrobiologia 139: 249, figs 17-19, 1986; Kargupta & Jha in Algal flora of Bihar: Zygnemataceae 30, 2004 **(Plate-1, figs. 3-4).**

Taxonomic description: Filaments greenish-brown, vegetative cells 38.0-44.5 µm long and 13.0-15.0 µm broad; chloroplasts two, nearly rounded; pyrenoid single in each cell; zygospores get swollen and filled with refractive dense pertinacious-cellulose colloids; ovoid to depressed globose and almost filling the sporangium laterally; zygospore 25.0-29.0 µm long and 18.0-20.0 µm broad, brown-red; outer spore wall thick and wavy; median spore wall wrinkled or scorbiculate; spore surface with wavy corrugations and pitted.

Habitat: free floating in pond at Dumurdaha, West Bengal, India

Occurrence: Rarely occurred in the fresh water bodies.

Collection no. NH 1007; dated: 02.03.2011.

Limnology of the pond: Temperature: 25°C; pH: 7.6; NO_3-N: 0.25 mg l^{-1}; PO_4^{3-}: 0.46 mg l^{-1}; DO: 6.6 mg l^{-1}; COD: 160.0 mg l^{-1}; SO_4^{2-}: 6.6 mg l^{-1}; TSS: 126.0 mg l^{-1}; TDS: 158.0 mg l^{-1}; total alkalinity: 132.0 mg l^{-1}.

Distribution: So far, from India it was reported from Bihar and West Bengal only. None reports were found from other continents of the world.

In the present paper, for the identification of these species various features of zygospores like shape, size, color, number of layers in spore wall and their ornamentations in addition to vegetative characters and measurements were specially taken since they were considered the most valuable characteristics to identify the species. Hull *et al.* (1985) and Ferrer and Cáceres (2005) also considered these characteristics as provital for morpho-taxonomic study of algal species. These two species showed wide morphological variations both in vegetative and reproductive features.

In *Sirogonium sticticum* (J.E. Sm.) Kütz., cells of filaments are cylindrical, chloroplasts 3-6, more or less straight and parallel; zygospore is ellipsoid or ellipsoid-ovoid and formed inside one of the conjugating gametangia (receptive). The gametangium is extended and slight inflated by the end of its development and zygospore never touching its longitudinal walls (Fig. 2). The present study established the earlier findings (Patel and Kumar, 1975; Jha, 2010). On the contrary, in *Zygnemopsis scorbiculata* P. Sarma & Kargupta vegetative cells are rectangular, chloroplasts two, stellate; zygospore ovoid-globose, almost filling the sporangium laterally and zygospore wall scorbiculate with pits (Fig. 4). The taxonomic features and occurrence of the present specimen *Zygnemopsis scorbiculata* P. Sarma and Kargupta exhibited all the similarities with the descriptions of Sarma and Kargupta (1986) reported previously from West Bengal, India. During morpho-taxonomic study, Chalotra *et al.* (2013) found the species of *Zygnemopsis* (Skuja) Transeau grown as greenish, free floating, filamentous forms in ponds which is alike of the present work.

In respect of ecology, there is a scarcity of ecological data on the occurrence of these algae in the water bodies. Zygnemataceae are capable of growing in water bodies with varying degrees of alkalinity and acidity (Ali and Naz, 2011). In this investigation, it was observed that they grew in alkaline water (pH: 7.5-7.6), where primary nutrients such as nitrate-nitrogen (NO_3-N) and phosphate (PO_4^{3-}) values were in adequate amounts that helped their growth. The NO_3-N and PO_4^{3-} values were ranged between 0.25-0.4 mg l^{-1} and 0.3-0.46 mg l^{-1} in the pond waters. Dissolved oxygen (DO) value was found from 6.6-7.0 mg l^{-1} that indicated higher photosynthetic activities and lower oxygen demand for decomposition of organic matters in the ponds. The chemical oxygen demand (COD) was observed as slight higher (150.0-160.0 mg l^{-1}) while SO_4^{2-}, TSS, TDS and total alkalinity values were noted within the range of permissible limits as mentioned by Water Quality Standard, BIS (2012). Hainz *et al*. (2009) demonstrated that water chemistry was significant in occurrence of morphotypes of algae in different ecological niches. While working on these two species same conclusion could be made by the author because he has noticed that several limnological factors specifically pH, temperature, nitrate-nitrogen (NO_3-N), phosphate (PO_4^{3-}) and total alkalinity were responsible for their abundances in the ponds and other factors thrive their flourish in water bodies.

CONCLUSION

This taxonomic study would be helpful for identification of these taxa. The ecological study revealed that growth and abundances of these Chlorophycean algal species in the collection sites were regulated by a combination of various water parameters. Rising of water temperature, alkaline pH and high DO values helped their occurrences and distribution as well as required nutrient amounts provided their optimal conditions for growth and reproduction. The studied ponds were found oligotrophic in trophic status.

Further, investigation is needed to assess their nutritional and pharmaceutical values for possibility of using these algae as food supplements for human beings as many other algae have been used as an ingredients in both medicines and food preparations.

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