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Exploring and Documenting *Wadi* Phycodiversity: *Cosmarium yassinii* sp. nov. (Desmidiaceae, Charophyta)—A New Desmid Species from Egypt

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Abstract

A new desmid microalga species, *Cosmarium yassinii* A.A. Saber, El-Sheekh, Kouwets et Cantonati sp. nov., was isolated from two hyper-arid mountain valleys, so-called "wadis", in the Eastern Desert of Egypt. The distinctive morphological features of this new species were established using light and scanning electron microscopy observations, and also by documenting its life-cycle stages. Taxonomically, *C. yassinii* is characterized by a cell wall sculpture consisting of isolated granules or small warts arranged circularly in the swollen mid-region of each semicell, never forming parallel vertical ridges or costae as in morphologically similar species, and the interesting shape of the marginal granules appears as small emarginate "combs" or crenae, including its knobby zygospores. Similarities and differences with the morphologically most closely related species are discussed in detail. Ecologically, *C. yassinii* seems to prefer alkaline freshwater environments with lower nutrient concentrations and a $NaCl/HCO_3$ water type. The detailed assessment and documentation of the biodiversity of these peculiar freshwater ecosystems are a fundamental prerequisite to adequately inform their protection strategies.

Keywords: desmids; Africa; life-cycle stages; novel species; fine ultrastructure

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1. Introduction

The desmid genus *Cosmarium* Corda ex Ralfs is the most species-rich genus in the family Desmidiaceae [1,2]. The state-of-the-art taxonomy of the genus *Cosmarium* is confused by problematic species identification. Poor original descriptions and figures (if any)

that are inadequate for a reliable determination have resulted, on the one hand, in many misidentifications and misinterpretations, and, on the other hand, in a large series of infraspecific taxa, either differing in minor detail or not related to the species in question at all [2]. The genus *Cosmarium* is distinguished by its solitary cells with a shallow-to-deep median constriction, morphologically diverse semicells that are rounded, elliptical, oblong, pyramidate, or quadrate to rectangular, with rounded or undulated margins. The cell wall is smooth or ornamented with scattered pores, granules, verrucae, etc., the chloroplast, generally, is axial with one or two pyrenoids per semicell, and some species may have a conspicuous mucilage sheath surrounding the cells [2]. From the phylogenetic point of view, the genus *Cosmarium* has been suggested to be polyphyletic [3,4].

Currently, there are 1355 taxonomically accepted species of *Cosmarium* with many more subspecies, varieties, and formae. In addition, there are 476 names currently of uncertain status, along with names which have not been checked to date [5]. Many of these species occur in moderately acidic to alkaline, nutrient-poor waters and even in terrestrial ecosystems [2]. The presence of this species is most often used as bioindicators in environmental protection and management because they are sensitive and responsive to their immediate environment [6,7]. Nonetheless, several desmid species have been found to successfully establish themselves in various eutrophic habitats [8], and their possible physiological mechanisms to absorb these excess nutrients have also been interpreted [9].

The African continent is a biodiversity hotspot for desmids (e.g., [10]), and, in particular, *Cosmarium*, and several endemic species have been reported so far in its aquatic habitats [5]. For instance, Levanets and Janse van Vuuren [11] established *C. knopkirri* Levanets et Janse van Vuuren from a freshwater inland wetland system in northern Mozambique. Saber et al. [12] recently discovered *Euastrum elfarafraense* Saber, Kouwets, Haworth et Cantonati from an agricultural ditch fed by the rheocrenic, slightly hot spring 'Ain El-Balad' in the El-Farafra Oasis, Western Desert of Egypt. Janse van Vuuren and Levanets [13] confirmed the restricted and endemic distribution of the rare, asymmetrical desmid *Prescottiella sudanensis* Grönblad, Prowse et A.M. Scott ex Levanets et Janse van Vuuren only in a few countries in equatorial Africa.

Valleys, also called *wadis*, are considered fascinating and unique desert ecosystems as they constitute natural drainage systems for waters of floods and rains [14]. These waters and the geological nature of these hyper-arid desert systems support the propagation and conservation of taxonomically interesting and cryptic algal taxa largely different from those found in other Egyptian environments like the Nile basin and lakes, suffering from huge human industrial and agricultural pressures and urbanization [15]. The exploration of the hidden algal diversity in the Egyptian desert habitats is considered a great challenge, but the expected outcomes seem very promising [16]. Overall, taxonomic studies on desmids from Egypt are rather scarce, and little is known about the current diversity and distribution of that algal group, and, in particular, the genus *Cosmarium* [17,18]. Based on previous taxonomic and floristic studies, there are 29 taxa of *Cosmarium* known from Egypt. Most of them are cosmopolitan [17] and only the endemic species *C. margaritiferum* var. *egyptiacum* El-Nayal was found in a pond in the Kharga Oasis [19].

In studies devoted to unravelling the algal diversity in the mountain valleys of the Egyptian Eastern Desert, an interesting *Cosmarium* species was isolated and could not be identified with the available literature. In the present paper, we discuss the taxonomy and ecology of this novel desmid species, proposed herein as *Cosmarium yassinii* sp. nov., as well as compare its key diagnostic features with the species that are morphologically most similar.

2. Materials and Methods

2.1. Field Areas and Sample Collection

The samples were collected from Wadi El-Atshan (25°49.558′ N, 34°3.880′ E) in November 2017 and Wadi El-Naq'at (27°03′08.9″ N, 33°16′54.4″ E) in February 2018. The two wadis are placed in the Eastern Desert of Egypt. Specimens of *C. yassinii* sp. nov. were isolated from the black dried spots found on the rocky surfaces of Wadi El-Atshan. These spots were formed after water desiccation in the valley (Figure 1A). This wadi has a hot hyper-arid desert climate, with a low annual precipitation and high summer temperatures, and limited rainfall during winter seasons [20]. It is located approximately 10 km west of Quseir city, Red Sea Governorate. Occasionally, it receives intermittent streaming rainfalls that encourage the growth of terrestrial desiccation-resistant microalgae on its rocks. Wadi El-Naq'at is also a hot hyper-arid valley close to Wadi El-Atshan. In this valley, the samples were collected from the periphytic algal mats growing on the soil beneath the rock surfaces (Figure 1B).

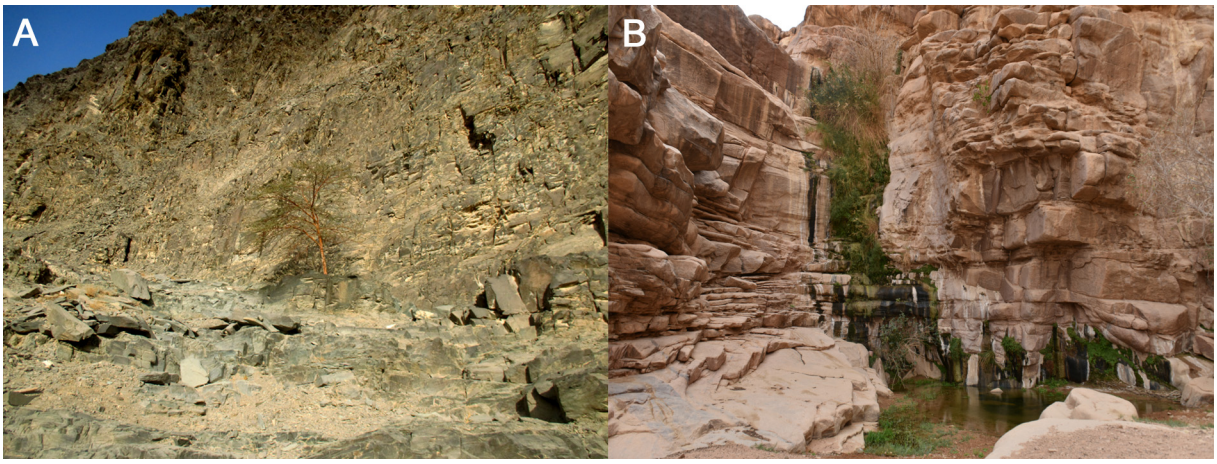

Figure 1. Sampling sites of *Cosmarium yassinii* sp. nov. from Wadi El-Atshan (**A**) and Wadi El-Naq'at (**B**) located in the Eastern Desert of Egypt.

2.2. Sample Processing

The periphytic materials collected from Wadi El-Naq'at were placed in clean polyethylene bottles using a brushing syringe [21]. In a chilled icebox, the algal specimens were carried to the laboratory for further investigation. Both the black dried algal materials collected from Wadi El-Atshan and the living specimens of *C. yassinii* found in the periphytic materials of Wadi El-Naq'at were cultivated on Bold's Basal Medium (BBM) [22,23], under controlled growth chamber conditions (24 ± 1 °C; 16:8 h light/dark cycle; illumination provided by 20 W cool white fluorescent lamps at 55 µmol photons m^{-2} s^{-1}). Details of cell morphology, chloroplast, autofluorescence, and life cycle stages were examined using a Zeiss Axioskop 2 microscope (Zeiss, Jena, Germany) equipped with an Axiocam digital camera, and a BEL® photonics biological microscope fitted with a Canon Powershot G12 digital camera (BEL® Engineering, Monza, Italy). The cell measurements (n = 25) of the holotype material of Wadi El-Atshan were mainly dependent on the culture at the stationary growth phase (ca. 4 weeks). However, measurements and observations on the periphytic materials found in Wadi El-Naq'at were performed on both freshly collected and cultured material. For LM observation of cell wall ornamentation, selected specimens were treated with cold hydrogen peroxide (30% final conc.) for 30 min. For scanning electron microscopy observations, we followed the protocol adapted by Ramos et al. [24]. The cells were adhered to a glass coverslip with poly–L–lysine (Sigma, 1:10 in distilled water) to improve adhesion. Coverslips with attached *Cosmarium* material were dehydrated through

a graded acetone series (30, 50, 70, 85, 95, 100%, 10 min each), then dried at the critical point using a Leica EM CPD030 apparatus (Thomas Scientific, LLC Company, Minneapolis, MN, USA); the prepared stubs were sputter-coated with gold and examined with an LEO XVP scanning electron microscope (Carl Zeiss SMT Ltd., Cambridge, UK) at MUSE (Museo delle Scienze, Trento, Italy). Photomicrographs were arranged into plates using Adobe Photoshop (version CS 4, Adobe Systems Inc., San Jose, CA, USA).

The slides and fixed specimens (2% v/v formaldehyde final conc.) were deposited at the Phycology Unit, the Botany Department, Faculty of Science, Ain Shams University [25], Cairo, Egypt, and the phytobenthic algae collection of the MUSE, Trento, Italy [25]. The morphological terminology was primarily described following Kouwets [2].

2.3. Hydrochemical Characterization

At sampling time, we did not find water on the rocky ground of Wadi El-Atshan to be collected and analyzed. However, and fortunately, physical and chemical variables of rainwater in Wadi Al-Naq'at, which shares the same geological nature, were analyzed. In situ measurements of pH, temperature, electrical conductivity (EC), and total dissolved solids (TDSs) were taken using a calibrated portable metre (HANNA HI 991301, Hanna® Instruments Co., Ltd., Woonsocket, RI, USA). Major ions including Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, HCO_3^-, CO_3^{2-}, SO_4^{2-}, along with trace elements and metals, were quantified by ionic chromatography (ICS 1500 Dionex Corp., Sunnyvale, CA, USA) according to Chapman and Pratt [26]. Nutrients such as NO_3^-, NO_2^-, NH_4^+, soluble reactive phosphorus (SRP), and total phosphorus (TP) were measured by molecular absorption spectrometry [27]. Silicate (SiO_2) concentration was estimated by the molybdosilicate method [27].

3. Results

In samples collected from the two hyper-arid wadis El-Atshan and El-Naq'at in Egypt, a Cosmarium species was discovered that could not be satisfactorily identified using the available literature. Therefore, it is here described as a new species.

Phylum: Charophyta
Class: Zygnematophyceae
Order: Desmidiales
Family: Desmidiaceae
Genus: *Cosmarium*

Cosmarium yassinii A.A. Saber, El-Sheekh, Kouwets et Cantonati sp. nov.

Description (Figures 2–5): Cells, medium-sized, very slightly longer than broad, deeply constricted; sinus narrowly linear with a slightly dilated extremity. Semicells trapeziform to subsemicircular with rounded basal angles and slightly convex sides, apex rather narrow and truncate; cell wall ornamented with radiating series of granules or small warts crossing the sides; granules—sometimes with the exception of those in the lower series—gradually doubling towards the margin, producing a marked crenate outline with 1–4 single granules at the basal angle and 5–7 crenae along the lateral side, in the centre with a broad tumour ornamented with about 21–26 small, occasionally subdivided warts in an irregular concentric disposition. Between marginal and central ornamentation, a smooth zone is present. Apical view elliptic with the ornamented central tumour clearly visible on each side, lateral view broadly ovate. Chloroplast axile with a single pyrenoid. Zygospore globose, ornamented with numerous somewhat flattened bulges, about nine visible along its margin; mesospore wall dark brown. Cell dimensions: length (28–) 30–37 µm, breadth 29–35 µm, length/breadth ratio 1.03–1.28, isthmus 10–12.5 µm. Zygospores dark brown with a knobby wall, 32–38 µm in diameter.

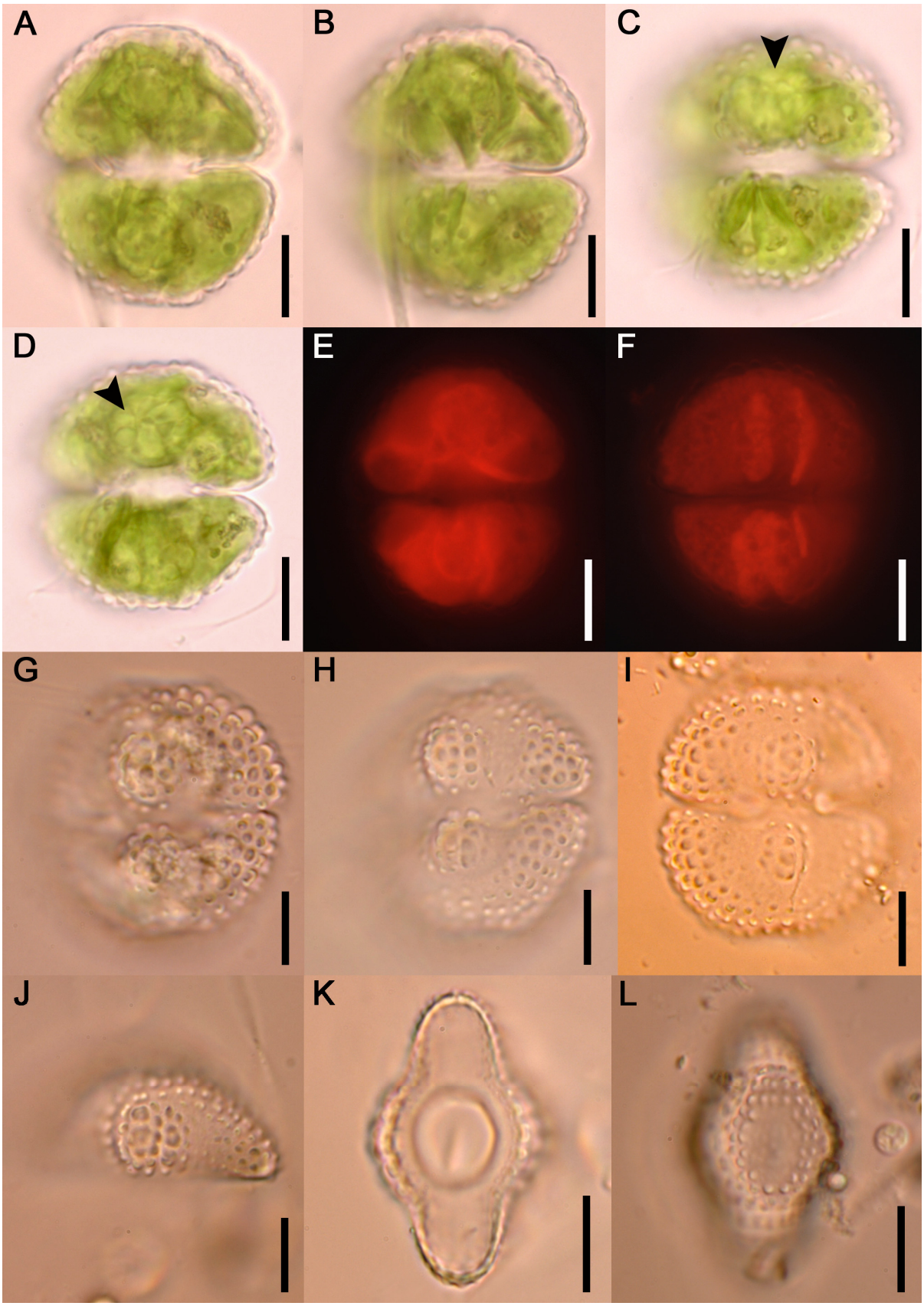

Figure 2. Light micrographs of *Cosmarium yassinii* sp. nov.; (**A**–**D**) front view of the vegetative cells. Note the large circular pyrenoid (arrowhead); (**E**,**F**) autofluorescent plastids; (**G**–**J**) detail of cell wall granules in frontal view; and (**K**,**L**) vertical view. Scale bars = 10 µm.

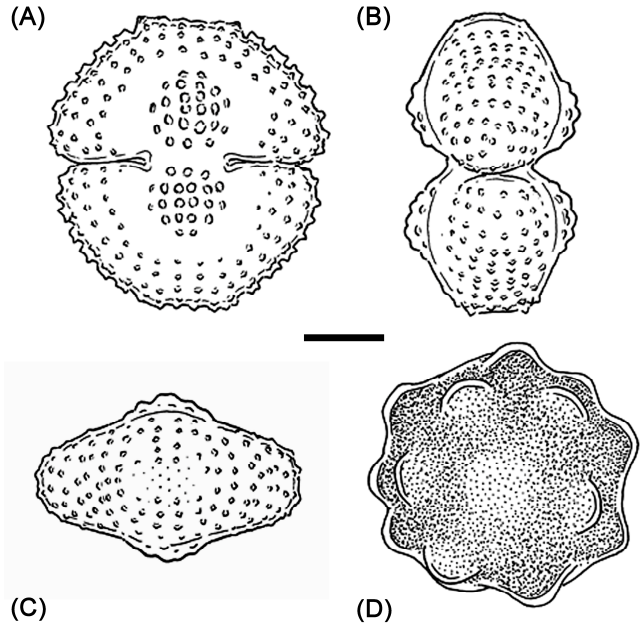

Figure 3. Line drawings of *C. yassinii* sp. nov.; (**A**) front view; (**B**) lateral view; (**C**) apical view; and (**D**) zygospore. Scale bar = 10 µm.

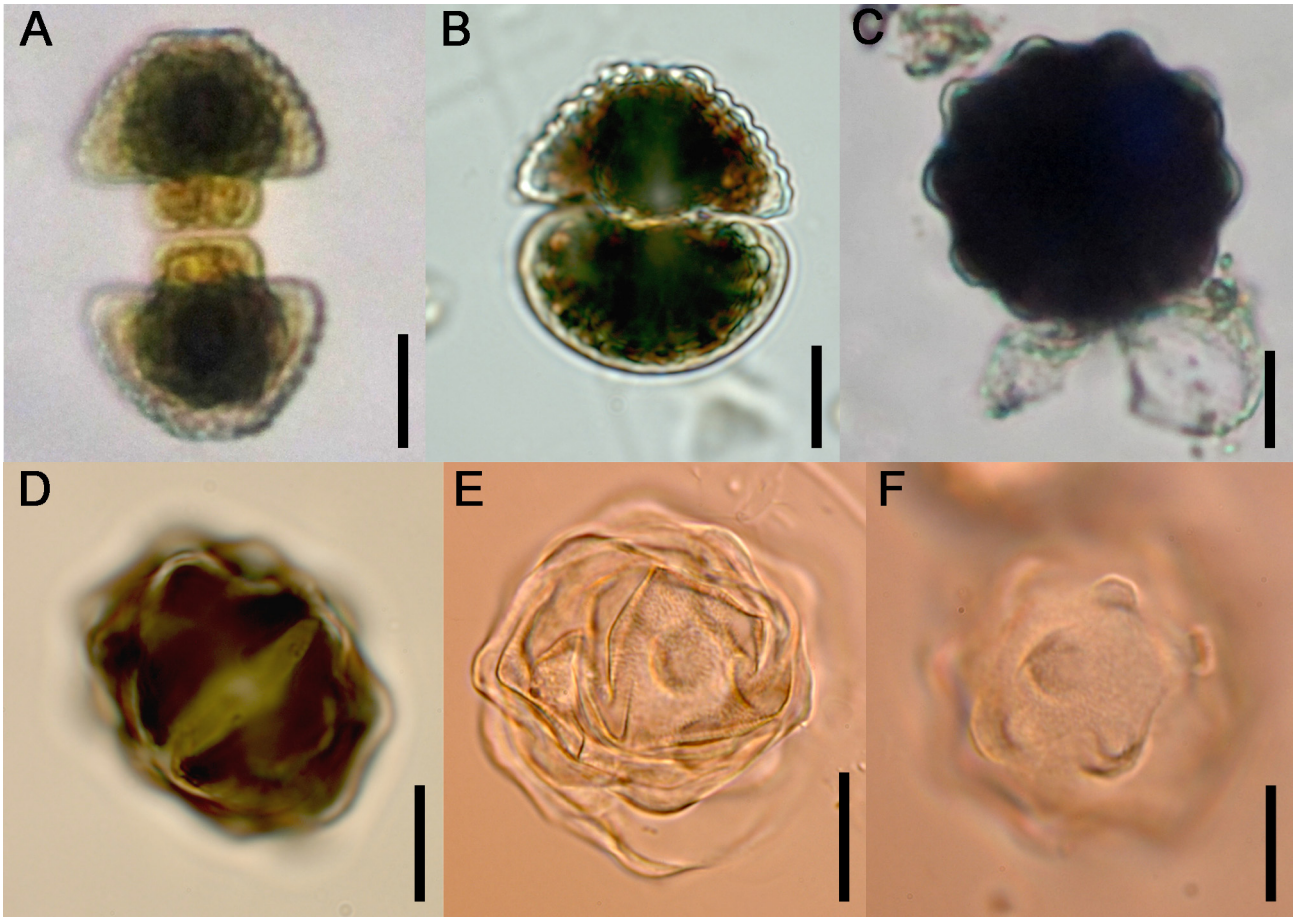

Figure 4. Reproduction in *Cosmarium yassinii* sp. nov. (**A**) Two immature cells resulting from vegetative reproduction stained by iodine solution; (**B**) first vegetative division of a germling cell after germination of a zygospore (lower semicell is part of the original germling); (**C**) zygospore formation; and (**D**–**F**) detail of zygospore wall sculpture. Zygospores are treated with H_2O_2 in subfigures (**E**,**F**). Scale bar = 10 µm.

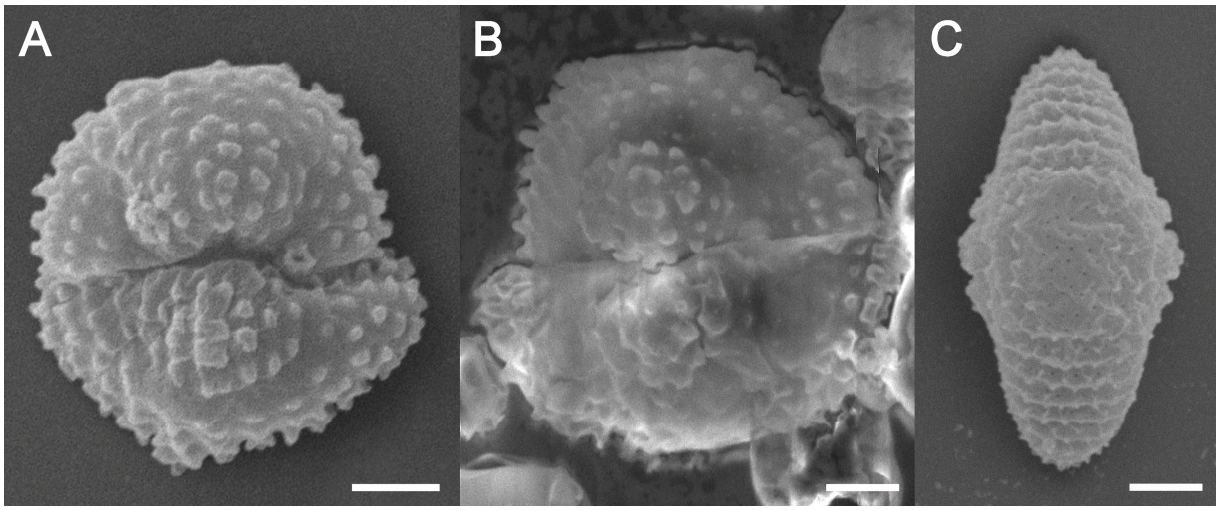

Figure 5. SEM photomicrographs of *Cosmarium yassinii* sp. nov.; (**A**,**B**) front view. The central granules are arranged circularly in the mid-region of each semicell and the marginal granules are small and emarginate; (**C**) apical view. Scale bar = 5 µm.

Holotype: the original material of *Cosmarium yassinii* sp. nov. (slide and fixed specimen; 2% *v*/*v* formaldehyde final conc.) was deposited in the collections of the Phycology Unit (No. 341), Botany Department, Faculty of Science, Ain Shams University in Cairo (Egypt) (CAIA); accession code: CAIA PBA–1803. This material, partially shown here in Figures 2–5, was collected by Abdullah A. Saber on 5 November 2017 from Wadi El-Atshan, the Egyptian Eastern Desert. Figure 3 illustrates the holotype.

Isotype: Subsample of the holotype material was preserved in formaldehyde (2%) final conc. and deposited in the phytobenthic algae collection at the MUSE—Museo delle Scienze, Research and Collections Department (Limnology and Phycology). Accession number: cLIM009 FITB 1042.

Registration: http://phycobank.org/106500 (accessed on 10 January 2026).

Type locality: The hyper-arid valley "Wadi El-Atshan" in Egypt's Eastern Desert (25°49.558′ N, 34°3.880′ E, 263 m a.s.l.).

Etymology: The specific epithet "*yassinii*" is a dedication to Yassin, son of the first author Abdullah A. Saber to express his truly deep love for him.

Ecology and co-occurring species: A freshwater desmid with a good tolerance to environmental drying. It has been recorded in the inventory of algal and cyanobacterial taxa isolated from the terrestrial biome in Wadi El-Atshan. Additionally, it was occasional (<5%) in occurrence in the periphytic materials collected from Wadi El-Naq'at. The values of hydrochemical variables measured at Wadi El-Naq'at were as follows: water temperature: 20.4 °C, alkaline pH: 8.81, electrical conductivity: 550 µS.cm^{-1}, TDS: 352 mg.L^{-1}. Major anions and cations had values of a typical freshwater with the dominancy of Na^+: 81.43 mg.L^{-1}, K^+: 13.05 mg.L^{-1}, Ca^{2+}: 25.48 mg.L^{-1}, Mg^{2+}: 4.28 mg.L^{-1}, Cl^-: 121.43 mg.L^{-1}, HCO_3^-: 112.89 mg.L^{-1}, and SO_4^{2-}: 10.78 mg.L^{-1}. In general, *C. yassinii* seems to prefer freshwater habitats with NaCl/HCO_3 water type. The concentrations of N compounds were extremely low whilst P was high: NO_3^-: 43.0 µg.L^{-1}, NH_4^+: 15.0 µg.L^{-1}, SRP: 40.5 µg.L^{-1}, and TP: 95.0 µg.L^{-1}. Metals were in normal averages of desert habitats: Fe, Zn, Cu, and Mn were 100, 10.0, 6.0, and 4.5 µg.L^{-1}, respectively. SiO_2: 750 µg.L^{-1}.

Co-occurring algal and cyanobacterial taxa included the following: *Chlamydomonas proboscigera* Korshikov, *Gonium pectorale* O.F.Müller, *Desmodesmus abundans* (Kirchner) E.H. Hegewald, and *Leptolyngbya* sp. Anagnostidis and Komárek in the terrestrial community of Wadi El-Atshan; *Chroococcus minutus* (Kützing) Nägeli, *Gloeothece rupestris* (Lyngbye)

Bornet, *G. membranacea* (Rabenhorst) Bornet, *Scytonema myochrous* (Dillwyn) C.Agardh ex Bornet et Flahault, *Hallasia* cf. *reticulata* (Hallas) Rosenvinge ex Curzda, *Spirogyra fluviatilis* Hilse, and *Achnanthidium* sp. Kützing in Wadi El-Naq'at.

4. Discussion

At a first glance, the present new species *C. yassinii* appears closely related to a large group of forms that are generally associated with *C. formosulum* Hoff in Nordstedt [28], originally described from the Danish isle of Bornholm. These forms are characterized by trapeziform semicells with broadly rounded basal angles, more or less convex sides, and a truncate apex. The cell wall ornamentation consists of a radiating series of small granules that become doubled towards the margin in the upper half of the semicell, resulting in a crenate outline, and a central swelling with mostly five to seven vertical series of warts that may (partly) merge into vertical ridges (costae); occasionally, a more random disposition of the warts is shown. On the isthmus side of this swelling, a horizontal row of small granules is frequently present. However, these forms have two pyrenoids in each semicell instead of only one in *C. yassinii*.

In recent times, several forms have been separated from this complex and described as new species (Table 1): *C. pseudoformosulum* van Westen [29], *C. arcticoformosulum* Kouwets, and *C. formosuloides* Kouwets; compare also *C. bailleulense* Kouwets, *C. sparganicola* Kouwets and *C. pseudoquasillus* Kouwets [2]. Moreover, a constant source of taxonomic confusion can be found in the distinction between *C. formosulum* and *C. nathorstii* Boldt that was almost simultaneously described from Greenland (see the extensive discussion in Kouwets [2]; compare also Zwart [30]). Finally, a form somewhat more distantly related is *C. subcostatum* Nordstedt in Nordstedt and Wittrock, which is characterized by truncate subsemicircular semicells and the assumed presence of only one pyrenoid per semicell.

The various species mentioned above are separated on the basis of differences in the pattern of especially the central granules or warts. A complicating matter in this respect is the intraspecific variation emphasizing the fact that populations rather than single cells should be evaluated. The importance of a detailed study of form and ornamentation cannot be overemphasized, as past superficial considerations have led to so-called "force fitting" (giving a species a well-known name based on superficial similarity for lack of a better alternative), which has resulted in "taxonomic drift" (the broadening and shifting of a species' characters).

Furthermore, the ecology of most species of this group is somewhat overlapping: they seem to prefer meso- to slightly eutrophic environments, and only *C. bailleulense* and *C. sparganicola* are more mesotraphentic. Reports from acidic, oligotraphentic environments should therefore be considered doubtful. The present form most luckily differs in various respects from *C. formosulum* and associated species, justifying the description of *C. yassinii* as a separate species. The single pyrenoid per semicell and the characteristic zygospore clearly sets it apart.

Well-documented reports of *C. formosulum* (including combinations with *C. nathorstii*; the other species have only recently been described) from North Africa, and especially Egypt, are extremely scarce. Gauthier–Lièvre [31] listed *C. formosulum* var. *nathorstii* (Boldt) W. et G.S. West from Algeria, measuring 43–50 × 36–48 µm, but without a figure or further details. However, conspecificity with the present material seems out of question. Most interestingly, from a locality in the southeast of Libya, Compère [32] mentioned a small form of *C. subcostatum* with one pyrenoid per semicell, measuring 27–33 × 22–27 µm. The accompanying figure shows a remarkable similarity with the present species. He compared his form with other reports (Compère [32] and references herein), but these forms, in our opinion, all represent different species [33].

Table 1. Morphometric features and data of *Cosmarium yassinii* sp. nov. compared with morphologically similar species.

Species/Features	*Cosmarium yassinii* **sp. nov.**	*Cosmarium formosulum* **Hoff**	*Cosmarium pseudoformosulum* **Van Westen**	*Cosmarium arcticoformosulum* **Kouwets**	*Cosmarium formosuloides* **Kouwets**	*Cosmarium bailleulense* **Kouwets**	*Cosmarium sparganicola* **Kouwets**	*Cosmarium pseudoquasillus* **Kouwets**
Reference	This study	Kouwets [2]	Kouwets [2]	Kouwets [2]	Kouwets [2]	Kouwets [2]	Kouwets [2]	Kouwets [2]
Cell outline	slightly longer than broad	medium-sized, up to about 1/4 longer than broad	medium-sized, about as long as broad or slightly longer	medium-sized, slightly longer than broad	medium-sized, generally very slightly longer than broad	medium-sized, very slightly longer than broad, subcircular in outline	medium-sized and slightly longer than broad	rather large, hexagonal in general outline
Semicells	trapeziform to subsemicircular with rounded basal angles and slightly convex sides, apex rather narrow and truncate	trapeziform to subsemicircular with rounded basal angles and slightly convex sides, apex truncate	subsemicircular to trapezoid, basal angles broadly rounded, sides slightly convex, apical angles rather obtuse, apex straight	trapeziform to subsemicircular with rounded basal angles and convex, strongly converging sides, apex truncate	subsemicircular to depressed trapeziform, basal angles broadly rounded, sides convex and converging, apical angles obtuse and indistinct, apex more or less straight, outline indistinctly 6–7-crenate, crenae in the lower half of the sides simple, in the upper half emarginate, apex including the angles 6-crenate	subsemicircular in outline with rounded basal angles and a faintly convex apex, sides 7–8-crenate, apex 4-undulate	trapeziform in outline, basal angles broadly rounded, sides straight to faintly convex and rather strongly convergent, apical angles obtuse, apex straight	subtrapeziform to somewhat truncate-pyramidate, basal angles broadly rounded, sides straight to slightly convex and strongly convergent, apical angles rater acute, apex straight
Cell wall ornamentation	radiating series of granules crossing the sides, gradually doubling towards the margin producing a marked crenate outline with 1–4 single granules at the basal angle and 5–7 crenae along the lateral side, in the centre about 21–26 small, occasionally subdivided warts in an irregular concentric disposition	radiating series of small granules crossing the sides, those near the centre of the semicell single, granules (exept those near the basal angles) generally gradually doubling towards the margin, producing a crenate outline with 6–7 crenae visible along one side, in the centre—separated from the marginal granules by a smooth zone—with a broad tumour ornamented with 5–7 longitudinal series of granules that may appear as flattened warts and sometimes (partly) merge into longitudinal warts or ribs (costae), between central ornament and isthmus frequently with a horizontal series of 5–7 small granules	radiating series of granules that are gradually doubling towards the margin and crossing the sides, centre slightly inflated and ornamented with more or less vertical series of small warts generally suggesting a somewhat circular arrangement, no smooth area between marginal and central ornamentation	radiating series of small granules crossing the sides, forming 4–5 concentric intramarginal series in frontal view, granules in the upper half generally gradually doubling towards the margin, producing an undulate-crenate outline with 8–10 undulations visible along each side and (including apical angles) 6 along the apex, in the centre—separated from the marginal granules by a more or less clearly marked smooth zone—with a broad tumour ornamented with 5–7 longitudinal series of granules that may appear as flattened warts and generally (partly) merge into longitudinal warts or ribs, between central ornamentation and isthmus frequently with a horizontal series of 5–7 small isolated granules	with slightly irregular, radiating intramarginal series of small granules corresponding to the crenae, centre of the semicell ornamented with a group of some 20–30 small warts, basically disposed in 5 vertical series flanked by a few additional warts, those in the upper half of the central series frequently split, the outer two series curved inwards, between central and marginal ornamentation with a smooth zone	with radiating series of small conical granules, in frontal view forming 3–4 concentric semicircles, except in the 1–2 series near the sinus the granules gradually become geminate towards the margin, centre of the semicell with three elongate ridges of partly merged warts flanked by 2–3 isolated warts, above the isthmus with a horizontal row of 5–7 small granules	with short, intramarginal series of small conical granules running across the sides, granules generally single resulting in an undulate semicell outline but frequently a smaller or larger number of granules appear geminate or doubled which does not result in the formation of crenae, centre of the semicell with a horizontal band of circa five vertical series of two or three warts that may be subdivided, occasionally flanked by a few isolated, somewhat flattened warts, at the side of the isthmus with a horizontal series of five or six granules, between marginal and central ornamentation with a small smooth zone	with radiating series of acute granules that are single near the semicell centre, those in the upper half of the semicell becoming geminate and doubled towards the margin, giving sides and apex an undulate-crenate appearance, centre with a supra-isthmial tumour ornamented with larger wart-like granules in a rather variable pattern, sometimes more or less surrounded by a smooth zone

Table 1. *Cont.*

Species/Features	*Cosmarium yassinii* sp. nov.	*Cosmarium formosulum* Hoff	*Cosmarium pseudoformosulum* Van Westen	*Cosmarium arcticoformosulum* Kouwets	*Cosmarium formosuloides* Kouwets	*Cosmarium bailleulense* Kouwets	*Cosmarium sparganicola* Kouwets	*Cosmarium pseudoquasillus* Kouwets
Length (µm)	(28–) 30–37	37.5–50 (−60)	33–41	44–50	35–41	43–45	44.5–49	48–62
Breadth (µm)	29–35	33–42 (−50)	29.5–35.5	42.5–45	33.5–38	40–42.5	40–42	45–52
L/B ratio	1.03–1.28	1.07–1.25	1.07–1.19	1.04–1.1	1.0–1.08	1.06–1.08	1.11–1.16	1.07–1.19
Isthmus (µm)	10–12.5	11–15 (−17.5)	8–10	13.5–15	11–12	ca.12 µm	14–15	15–17
Apical view	elliptic with the ornamented central tumour clearly visible on each side	elliptic with the central ornamented tumour clearly visible on each side	elliptic with broadly rounded poles and a slight median inflation	elliptic with the central ornamented tumour clearly visible on each side	elliptic with a slightly swollen centre and broadly rounded poles	elliptic with a granulate central swelling	elliptic with broadly rounded poles	elliptic with a granulate tumour on either side
Lateral view	broadly ovate	broadly ovate	subcircular	subcircular	circular	subcircular	subcircular	ovate with a basal granulate tumour on either side
Chloroplast	axile with a single pyrenoid	axile with two pyrenoids	axile with two pyrenoids	axile with two pyrenoids	axile with two pyrenoids	axile with two pyrenoids	axile with two pyrenoids	axile with two pyrenoids
Zygospore	globose and ornamented with numerous somewhat flattened bulges; mesospore wall dark brown; 32–38 µm in diameter	globose, densely covered with furcate to delicately crowned spines on a broadly conical base, about 15 spines visible along the margin; diameter including spines 47 µm, excluding spines 36 µm.	unknown	unknown	unknown	unknown	unknown	unknown

Also, concerning the morphology of the zygospore, *C. yassinii* appears to be not closely related to *C. formosulum*. Under var. *nathorstii*, Homfeld [34] presented a somewhat sketchy drawing of a zygospore that is globose and covered with relatively short, forked spines on an inflated basis. Similar spores were reported from cultures of a form of *C. formosulum* from North America by Starr [35]. Most interestingly, in the same paper, Starr (l.c.) also reported the zygospore of *C. subcostatum*, which is similar to that of *C. formosulum* but with longer and more slender spines. This type of zygospore is commonly found in *Cosmarium* species with a crenate outline (compare Kouwets [2]). However, the zygospore of the present species is globose with a knobby wall caused by numerous depressed, rounded bulges, a type less commonly found in *Cosmarium* (compare, e.g., *C. brebissonii* Meneghini ex Ralfs and *C. margaritiferum* Ralfs, and also species with more prominent protuberances as, e.g., *C. pseudopyramidatum* Lundell and *C. porteanum* Archer; see Kouwets [2]).

It is clear that *wadis* constitute a unique and interesting environment. Future research could therefore yield even more undescribed desmids, further characterizing these ecosystems and documenting their biodiversity. This knowledge is the main prerequisite for adequate protection.

5. Conclusions

The discovery and description of *Cosmarium yassinii* sp. nov. contribute significantly to a better understanding of the biodiversity within the genus *Cosmarium* in Egypt. The unique morphotaxonomic traits, particularly the distinctive cell wall pattern characterized by the isolated granules arranged circularly in the swollen mid-region of each semicell, the interesting shape of the marginal granules that appear as small emarginate "combs" or crenae, and its knobby zygospores set *C. yassinii* clearly apart from all known similar *Cosmarium* species. This finding reinforces the importance of continued taxonomic studies on desmids, and microalgae in general, in various Egyptian habitats, particularly in the less-studied desert ecosystems, to adequately inform their protection and conservation.

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