Available online at www.garmian.edu.krd

Passer Journal of Basic and Applied Sciences

Passer 8 (Issue 2) (2026) 969-978

Original Article

A morphological study of Chlorophyta in Soran district, Erbil Governorate, Kurdistan Region of Iraq

Balkes Haje Rasul * [1], Farhad Hassan Aziz [2], Janan Jabbar Toma [2]

[1] *Biology Department, Faculty of Science, Soran University, Soran Independent Administration 44008, Kurdistan Region, Iraq.*
[2] *Environmental Sciences and Health Department, College of Science, Salahaddin University, Erbil 44001, Kurdistan Region, Iraq.*

Received 01 January 2026; revised 21 August 2026;
accepted 09 August 2026; available online 28 August 2026

DOI: 10.24271/PSR.2026.570068.2494

ABSTRACT

Chlorophyta (green algae) represent one of the most diverse and ecologically significant groups of freshwater algae worldwide; however, their diversity and distribution remain poorly documented in the Kurdistan Region of Iraq. Recent global studies have significantly advanced our understanding of Chlorophyta taxonomy through integrated morphological and molecular approaches, yet comprehensive floristic surveys in Iraq are scarce, particularly in spring-fed freshwater ecosystems. This study aimed to fill this knowledge gap by investigating the non-diatom algal species composition in fifteen spring-fed sites within the Soran administrative region (extending from Haje-omaran to Soran), Erbil Governorate, Kurdistan Region of Iraq. Monthly samples were collected between March 2024 and February 2025. Through morphological analysis, twenty-four taxa of Chlorophyta were documented as new records for the Iraqi algal flora. These included species from the genera *Scenedesmus* sensu lato, *Scenedesmus calyptratus, Scenedesmus similagineus, Desmodesmus granulatus, Desmodesmus serratus, Desmodesmus dispar, Oedogonium americanum, Oedogonium capitellatum, Oedogonium cymatosporum, Oedogonium borisianum, Oedogonium macrandrium, Oedogonium minus, Monoraphidium arcuatum, Monoraphidium tortile, Mougeotia depressa, Spirogyra distenta, Spirogyra chuniae, Spirogyra insignis, Zygnema carinthiacum, Closterium sublaterale, Cosmarium blytii, Cosmarium boeckii, Cosmarium pseudoretusum, and Cosmarium sublaterale.* All newly recorded taxa were morphologically documented with detailed descriptions and measurements of both vegetative and reproductive structures. These findings significantly expand the known algal diversity of Iraq and provide a foundational baseline for future phycological studies in the region.

Keywords: Iraq algal flora, spring site, first record, seasonal variation.

1 Introduction

The quality of water in all aquatic systems worldwide—both above and below ground—is influenced by anthropogenic activities. Freshwater algae act as essential primary producers within these ecosystems, providing the primary energy input for associated organisms [1]. Algae are among the most important organisms in aquatic ecosystems, serving as the primary source of oxygen and forming the base of the food chain. They are broadly classified into macroalgae (large algae) and microalgae (small algae). Recently, algae have gained significant attention in nanotechnology, industrial applications, and the production of micro-antibiotics, largely due to their diverse bioactive properties rather than toxicity.

* Corresponding author
E-mail address balkes.rasul@soran.edu.iq (Instructor).
Peer-reviewed under the responsibility of the University of Garmian.

Cyanobacteria played a pivotal role in Earth's evolutionary history through their oxygenic photosynthesis, which dramatically altered the planet's atmospheric composition. Their presence and abundance also serve as reliable indicators of water productivity, quality, and contamination [2, 3]. Chlorophyceae and other diverse microalgae synthesize bioactive metabolites—including proteins, lipids, pigments, and amino acids—that confer antimicrobial and antioxidant activities, serve as biofuel precursors, and mediate nanoparticle biosynthesis [4]. It is imperative to identify and isolate novel, rare Chlorophyceae species from diverse habitats and maintain them in culture collections for future research, as such strains may harbor valuable bioactive compounds with significant biotechnological and therapeutic applications [5]. Water treatment using microalgae represents an eco-friendly technology. Understanding the decomposition pathways of trace organic pollutants by microalgae can help develop specific methods to improve the efficiency of microalgae-mediated degradation [6]. Environmental changes and anthropogenic activities are causing a sharp decline in the numbers of many algal species with high floral diversity. At the same time, undescribed algal species are still being discovered, suggesting that biodiversity may be lost before it is properly identified and cataloged. Springs are a natural form of groundwater flow to the Earth's surface. They act as a critical link between underground and surface water systems. Springs are found worldwide and vary greatly in shape, size, and discharge.

They play an important role in public health, the economy, tourism, agriculture, and other human activities [7]. Despite their ecological and hydrological importance, comprehensive phycological surveys of spring-fed ecosystems in the Kurdistan Region of Iraq remain remarkably scarce. In particular, the Soran administrative region has never been systematically investigated for its non-diatom algal diversity, leaving a substantial gap in the baseline knowledge of Iraqi freshwater algal flora. Moreover, while Chlorophyta are known for their ecological significance and biotechnological potential, the species composition of green algae in this region has not been documented.

To address this knowledge gap, the present study was designed to answer the following research question: What is the species composition and diversity of non-diatom (Chlorophyta) algae in the spring-fed sites of the Soran administrative region, and do these represent new records for the algal flora of Iraq and the Kurdistan Region?

Accordingly, the specific objectives of this study were to: (i) collect and identify non-diatom algal taxa from fifteen springs across the Soran region; (ii) morphologically document all newly recorded Chlorophyta species with detailed descriptions of vegetative and reproductive structures; and (iii) contribute baseline data on freshwater algal biodiversity in Iraq.

2 Materials and Methods:

2. 1 Describe the studied area

Soran is one of the largest and most important districts in Erbil Governorate, well-known for its natural water resources and tourism potential. And it comprises several districts and sub-districts such as Haji Omran, Choman, Qasr, Rwanduz, and Khalifan. The study area is located in northeastern Iraq at coordinates 36.6539°N and 44.5421°E, extending from latitude 36.6539°N and longitude 44.5421°E. At an altitude of approximately 1,200 meters above sea level. The region is characterized by its unique geology, water sources, climate, and soil conditions due to its location within the Zagros Mountains[8]. This mountainous terrain produces numerous natural springs, which are essential sources of freshwater for local communities and livestock.

The sampling sites were distributed among the districts as follows: Sites 1, 2, 3, 4, and 5 are located within Choman District; Sites 6, 7, 8, and 9 are shared between Qasr and Rwanduz districts; and the remaining sites are located within Khalifan and Malakan districts “Figure 1" and " Table 1 “.

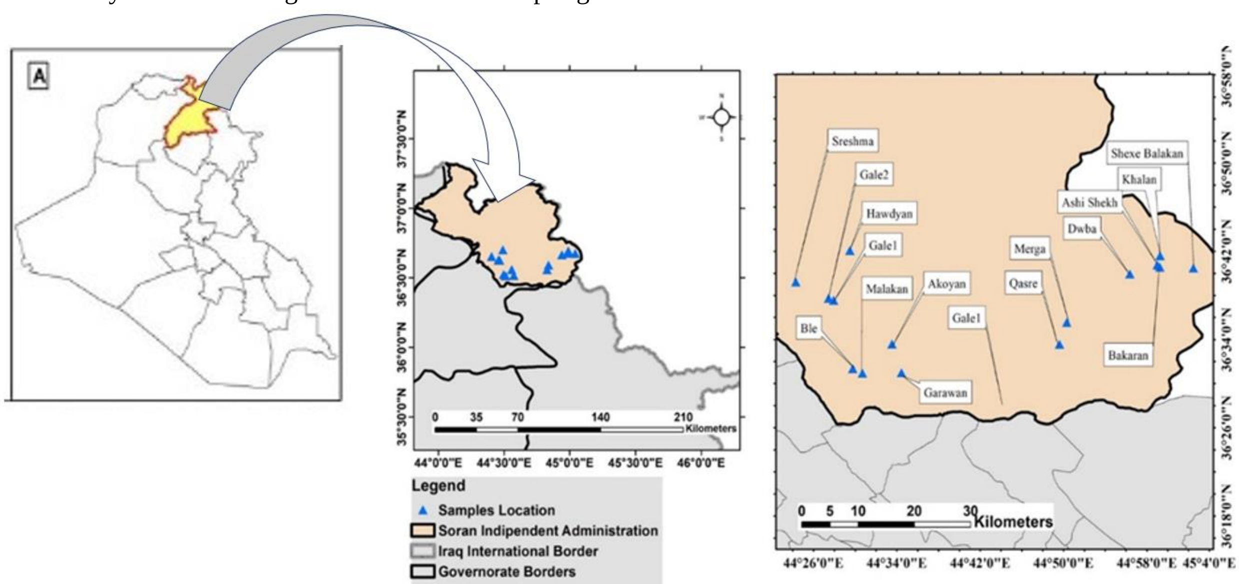


Figure 1: Map showing the study area: (A) Iraq map, (B) Soran independent administration map, (C) sampling sites.

Table 1: Geographical coordinates and elevation of the studied sites within Soran independent administration.

Site	Location	X_Field	Y_Field	Height
1	Shekhe Balakan	45.040824	36.675352	1779m
2	Khalan	44.987777	36.693740	1685m
3	Bakaran	44.987344	36.676259	1610m
4	Ashe Shekh	44.987344	36.676259	1521m
5	Dwba	44.939418	36.665834	1253m

6	Merga	44.838565	36.592635	1198m
7	Qasre	44.826916	36.559788	1085m
8	Garawan	44.558500	36.565038	755m
9	Akoyan	44.573720	36.516546	1078m
10	Hawdyan	44.491611	36.701395	568m
11	Gale 1	44.465511	36.626497	522m
12	Gale 2	44.457355	36.629091	742m
13	Sreshma	44.405018	36.653759	852m
14	Ble	44.496157	36.523108	952m
15	Malakan	44.511539	36.516173	1012m

Phytoplankton samples were collected using a 20-µm mesh plankton net and preserved in 50–100 mL vials. Benthic algae, including epilithic algal taxa, were collected by scraping the surfaces of macrophytes and rocks using a spoon, forceps, and a toothbrush. Samples were collected from each site and placed in two sealed polyethylene vials. One vial was preserved with 1 mL of Lugol's solution. Flagellate algal morphotypes were identified as quickly as possible before fixation to avoid loss of taxonomic characteristics [9, 10]. Various species were captured utilizing a digital microscope camera (Model No.: SCMOS05100KPB). Morphological identification was performed at the lowest taxonomic level using standard taxonomic keys and references [11]. The newly recorded species were identified based on the latest algal checklist for Iraq [12, 13].

3 Results

A comprehensive 12-month survey (March 2024–February 2025) was conducted across 15 limnologically diverse spring-fed sites within Soran district, Erbil Governorate, Kurdistan Region of Iraq. The study documented 24 species of Chlorophyta previously unrecorded in the Iraqi algal flora, representing significant new records for both the Kurdistan Region and the national algal inventory. Detailed taxonomic descriptions for all species are presented in List 1, while their spatial distribution and percentage occurrence across the sampled sites are summarized in Table 2. Notably, ten of the sampled localities (Sites 2, 3, 6, 7, 8, 9, 10, 13, 14, and 15) constituted previously uncharacterized algal habitats within this ecoregion.

Analysis of genus-level distribution revealed Oedogonium and Cosmarium as the most species-rich genera, with six and four species identified, respectively. Scenedesmus was represented by three species, alongside Desmodesmus (three species), Spirogyra (three species), Monoraphidium (two species), and the remaining genera each represented by a single species.

List 1: Classification of algal taxa new records.

Division: Chlorophyta
Class: Chlorophyceae
Order: Chlorococcales
Family: Scenedesmaceae
Scenedesmus **Meyen, 1829**
S. sensulatom* **Kutiz, *1880*
S. calyptratus* **(Comas)
** S. similagineus* ***(Hortob)***
Desmodesmus **Chodat. E. Heg**.
**D. granulatus* West et
D. serratus* **(Corda) Fridle 1999
D. dispar* (Brebisson) **Hegewald 2000
Order: Oedogoniles
Family: Oedogoniaceae
Oedogonium **Link 1820.**
O. americanuum* **Transenn 1917
O. capittellatum* **(Wittrock) 1874
O. cymatosporum* **Wittrock 1870
O. borisianm* (Le clere) Wittrock 1870**
O. macrandrium Wittrock* **1870
O. minus* ***Wittrock 1874*
Order: Sphaeropleales
Family: Selenastraceae
Monoraphidium **Komarkova 1969**
M. Tortile* ***West et G.S.*
M. arcuatum* (Korshikov) Hindak 1970**
Order: Zygnematales
Family: Zygnemtaceae
Mougeotia **(C. A. Agardh) Wittr., 1824.**
M. depressa* **(Hassall) Wittrock 1880)
Spirogyra **Link 1820.**
S. distenta* **(Transeu)
S. insignis* (Hassal) Kutzing**
S. chuniae* **Jao 1933
Zygnema Agardh **1824.**
Z. carinthiacum* **Beck- Mannagetta 1929
Family: Desmidiaceae
Closterium **Ralfs 1848.**
Cl. Sublateral* **rozheka 1955
Cosmarium **Ralfs lepo1848.**
C. boeckii* **Wille 1880d
C. psudoretusum* **var. Africanµm
C. sublaterale Ruzicka* **1955
C. blytii* **Wille 1880

Table 2: New records with its percentages in the sites during the studied period.

No.	Name of Algal genus	New Recorded species	%
1.	*Scenedesmus* sensulatom	2	5.26
2.	*Scenedesmus* calyptratus (Comas)	1	2.63
3.	*Scenedesmus* similagineus (Hortob)	1	2.63
4.	*Desmodesmus* granulatus West et	1	2.63
5.	*Desmodesmus* serratus (Corda) Fridle 1999	3	7.89
6.	*Desmodesmus* dispar (Brebisson) Hegewald 2000	1	2.63
7.	*Oedogonium americanum*Transenn 1917	3	7.89
8.	*Oedogonium* capitellum (Wittrock) 1874	2	5.26
9.	*Oedogonium* cymatosporum Wittrock 1870	1	2.67
10.	*Oedogonium* borisianm (Le clere) Wittrock 1870	1	2.63
11.	*Oedogonium* macrandriµm Wittrock 1870	1	2.63
12.	*Oedogonium* minus Wittrock 1874	2	5.52
13.	*Monoraphidiµm* tortile West et G.S.	1	2.63
14.	*Monoraphidium* arcuatµm (Korshikov) Hindak	1	2.63
15.	*Mougeotia* depressa (Hassall) Wittrock 1880)	1	2.63
16.	*Spirogyra* distenta (Transeu)	2	5.26
17.	*Spirogyra* insignis (Hassal) Kutzing	2	5.26
18.	*Spirogyra* chuniae Jao 1933	1	2.63
19.	*Zygnema* carinthiacum Beck- Mannagetta 1929	1	2.63
20.	*Closterium* Sublateral rozheka 1955	1	2.63
21.	*Cosmarium* boeckii Wille 1880d	2	5.26
22.	*Cosmarium* psudoretusµm var. Africanµm	2	5.26
23.	*Cosmarium* sublaterale Ruzicka 1955	3	7.89
24.	*Cosmarium* blytii Wille 1880	1	2.63
Total		**38**	**100**

3. 1 Description of the New Records:

***Scenedesmus sensulatom* (Pl.1, Fig.1-a).**

This genus of freshwater green algae typically formed colonial structures consisting of two to sixteen cells. Individual cells featured a single, parietal chloroplast. Their external morphology was variable, presenting as smooth or ornamented with spines, ridges, and other sculptural features. Ecologically, these algae **served** as valuable bioindicators of water quality and were frequently prevalent in nutrient-enriched (eutrophic) habitats [14] . It was found in Hwdyan spring in April 2024. (Pl 52, Fig. 20).

***Scenedesmus calyptratus* (Pl.1, Fig.1-b)**

This species characteristically developed coenobia consisting of four elongate cells, arranged linearly or in a gentle arc. These colonies were frequently surrounded by a delicate, transparent mucilage sheath. The individual cells were cylindrical with rounded or attenuated apices and possessed a single parietal chloroplast, each containing a pyrenoid. Ecologically, it commonly proliferated in eutrophic conditions and was frequently employed as a model organism in phytoplankton research, owing to its pronounced sensitivity to environmental parameters [15]. It was found in Hwdyan spring in June 2024. (Pl 51, Fig. 78).

***Scenedesmus similagineus (*Pl.1, Fig.1-c)**

This species formed coenobia (colonies) typically composed of 4–16 cylindrical cells arranged in a single or zig-zag chain. The cells were elongated with rounded or slightly pointed ends and measured approximately 10–25 µm in length. Unlike some other *Scenedesmus* species, *S. similagineus* lacked prominent spines or cell wall ornamentations, presenting a smooth appearance. It contained a single parietal chloroplast with one pyrenoid per cell [15]. It was Found in Khalan Spring in June 2024. (Pl 50, Fig. 25).

***Desmodesmus granulatus (*West et G.S. West) Tsurenko 2000 *(*Pl.1, Fig.2-a).**

Coenobium were straight, consisting of a single row of 4–8 cells with the ends in line or of alternating cells; cells (2–) 3.5–12 µm wide, (5–) 7–12 (–24) µm long, were elongate-ovoid to cylindrical-ovoid, with apices broadly rounded and outermost wall of marginal cells convex; cell walls were yellow, granular, with granules randomly arranged or forming longitudinal rows (rarely ridge-like) that were sometimes more clearly visible at apices [16] . It was found in Khalan Spring in April 2024. Pl. 112I (p. 444).

Desmodesmus serratus (Corda) An, Friedl et *(*Pl.1, Fig.2-b).

Coenobium were of 2, 4 or 8 linearly arranged cells; cells 2.5–7 µm wide, 17.8–20 µm long, were elongate-ovoid, with 1–4 teeth on rounded or sometimes almost truncate apices, bearing longitudinal and continuous rows of teeth on inner cells; teeth were confined to the outer convex wall of marginal cells (sometimes teeth small and indistinct, or as longitudinal rows of granules); cell walls were smooth except for teeth in longitudinal rows or occasionally scattered [16]. It was found in Duba spring in June 2024. P1. 112B (p. 444).

Desmodesmus dispar (Brébisson) E. Hegewald 2000 (Pl.1, Fig.2-c).

Coenobium of (2-14) linearly or slightly alternately arranged and tightly packed cells; cells (2.3-)4-9 µm wide, (8-18.6-16.5 µm

long, elongate-ovoid to cylindrical, tapering to rounded or polygonal apices bearing 1 or 2 short spines, with spines arising laterally on apices and diagonally opposite on adjacent cells an lying almost perpendicular to long axis of coenobium spines on adjacent cells often facing in opposite direction [16]. It was found in Akoyan spring in June 2024. Pl. 110K (p. 438).

Oedogonium americanum Transeau, 1917 (Pl. 1, Fig. 3-a)

Macrandrous; dioecious. Vegetative cells were cylindrical, 28–48 µm in diameter, 40–100 µm long. Oogonia were solitary; globose to depressed-globose, or somewhat ellipsoid; opening by a superior pore; 40–76 µm in diameter, 48–70 µm long. Oospores were globose to ellipsoid-globose (or depressed-globose); median wall was scrobiculate; 38–74 µm in diameter, 46–56 µm long. Antheridia were 20–28 µm in diameter, 4–12 µm long [17]. It was found in Ashe shekh spring in April 2024. P1. 43, Figs. 18.

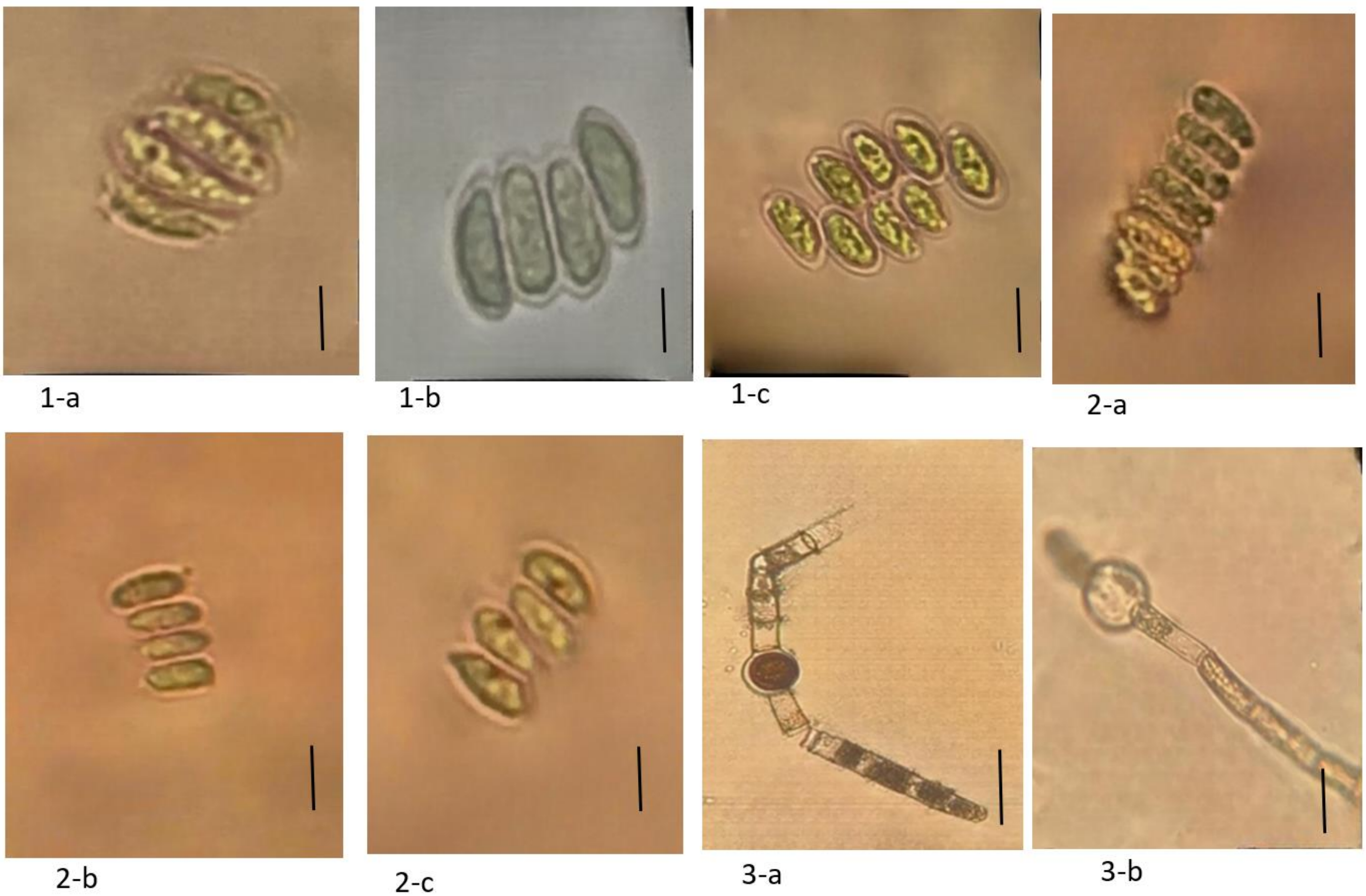


Plate (1): *1-a Scenedesmus sensulatom, 1-b S. calyptratus,1-c S. similagineus, 2-a Desmodesmus granulatus,2-b D. serratus, 2-c D. dispar, 3-a Oedogoniμm americanuμm,3-b O. capittellatμm.* **scale bar=10μm**.

Oedogonium capitellatum Wittrock, 1874 (Pl. 1, Fig. 3-b)

Cells were swollen at the distal end (capitulate), 6–9 µm wide, 3–7 times as long as wide; terminal cell was hair-like, basal cell was almost hemispherical; oogonium was single, depressed or almost depressed-spherical, 20–25 µm wide, 17–23 µm long, opening by a median operculum; oospore was depressed-spherical, 18–23 µm wide, 15–19 µm long, filling or nearly filling the oogonium, walls were smooth; cell was similar to adjacent vegetative cells [16]. It was found in Malakan spring in June 2024 Pl. 124F (p. 509).

Oedogonium cymatosporum Wittrock & Nordstedt (Pl. 2, Fig. 1-a)

The vegetative cells were cylindrical, measuring 8–10 µm in width and 4–7 times longer than wide. The oogonium was typically solitary, occasionally paired, depressed-spherical in shape, 30–40 µm wide by 27–40 µm long, and opened through a median cleft-like pore. The oospore was depressed-spherical, 27–35 µm wide by 22–33 µm long, either fully or partially occupying the oogonium, with walls ornamented by small pits. The species was monoecious and macrandrous [16]. It was found in Malakan spring in June 2024. Pl. 125B (p. 512).

Oedogonium Borisianum (LeCl.) Wittrock 1875 (Pl.2, Fig.1-b).

Vegetative cells were cylindrical, (15–) 18.5–24 µm in diameter, (45–) 55–59 (–140) µm long. Oogonia were 1–5; obovoid or angularly ellipsoid; opening by a superior pore; (33–) 40–50 µm in diameter, 55–90 µm long. Oospores were obovoid; filling the oogonia in diameter but not in length; wall was thick, smooth; (35–) 47–49 µm in diameter, (48–) 55.5–57 (–60) µm long. Dwarf male plants were 8–10 µm in diameter, (11–) 12–15 (–16) µm long, on the much enlarged suffultory cell 37 µm in diameter, 55 (–92) µm long [16]. It was found in Qasre spring in July 2024. P1. 35, Figs. 8, 9.

Oedogonium macrandrium Wittrock, 1871 (Pl. 2, Fig. 1-c)

Vegetative cells were cylindrical, 14.8–16 (–20) µm in diameter, 40–51.8 (–100) µm long. Oogonia were 1–4; sub-globose or ovate-globose; operculate; division superior; 36–42 µm in diameter, (43–) 48–54 µm long. Oospores were globose; wall was smooth; (31–) 34–37 µm in diameter. Dwarf male plants were 2- or 4-celled; stipe was 14.8 µm in diameter, 33.3 µm long; scattered on the female plant. Antheridia were exterior, 7.4–10 µm in diameter, 7–10 µm long [16]. It was found in Qasre spring in July 2024. Pl. 41, Fig. 1.

Oedogonium minus (Wittr.) Wittrock, 1875 (Pl. 2, Fig. 1-d)

Vegetative cells were cylindrical, measuring 14.8–16 µm (rarely up to 20 µm) in diameter and 40–51.8 µm (exceptionally to 100 µm) in length. Oogonia occur singly or in groups of up to four; they were sub-globose to ovate-globose, operculate, and divided superiorly, with diameters of 36–42 µm and lengths ranging from 43 to 154 µm. Oospores were globose with a smooth wall, measuring between 31 and 37 µm (typically 34–37 µm) in diameter. [16]. It was found in Gale 2 spring in October 2024. (P1. 34, Figs. 7-9).

Monoraphidium arcuatum (Korshikov) Hindák, 1970 (Pl. 2, Fig. 2-a)

Cells (0.8-)1-3(-4.5) µm wide, 18-60(-90) µm long, were narrowly spindle-shaped, arched to slightly sigmoid and screw-shaped, narrowing equally to each finely pointed apex, sometimes slightly curved [16]. It was found in Akoyan spring in April 2024. (Pl. 117I (p. 457).

Monoraphidium tortile (West & G.S. West) (Pl. 2, Fig. 2-b)

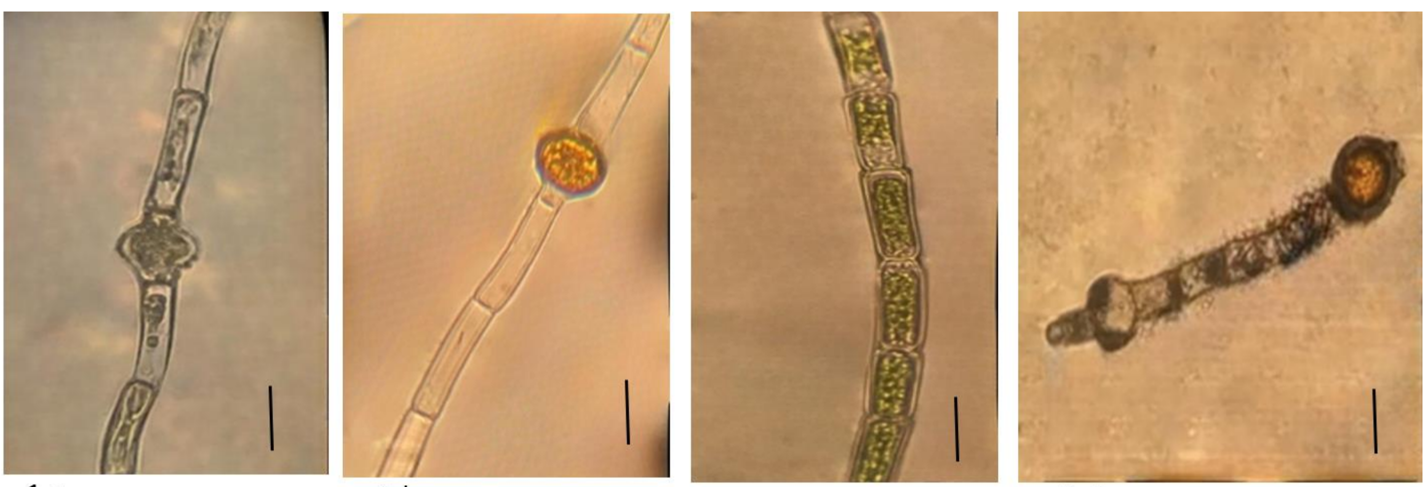
Cells 0.5-3|-4) µm wide, 11-33(-40) µm long, more than 60 times longer than broad, narrowly spindle shaped, sometimes asymmetrical, straight, rarely slightly curved or sigmoid, gradually narrowing to needle-like apices [16]. It was found in khalan spring in April 2024. Pl. 118F (p. 45).

Mougeotia depressa (Hassall) Wittrock 1880 (Pl.2, Fig.3).

Cells 7-12 µm wide, 35-144µm long; conjugation was ladder-like and lateral; zygospores were formed in conjugating tubes, compressed and elongate-ellipsoid with long axis parallel to filaments, 12-14µm wide, 28-32 µm long, median wall was punctate and brown [16]. It was found in Qasre spring in April 2024. Pl. 143F (p. 581).

Spirogyra distenta transet 1934 (Pl.2, Fig.4).

Vegetative cells were 48–52 × 81–180 µm, with plane end walls; 2 chloroplasts, making 1.5 to 2 turns. Conjugation was scalariform; tubes were formed, sterile cells were inflated; zygospores were ovoid, 49–55 × 50–100 µm [18]. It was found in Qasre spring in April 2024. P1. 40, Figs.15.



1-a 1-b 1-c 1-d

Plate (2): 1-a *Oedogoniμm cymatosporμm,* 1-b *O. borisianm,* 1-c *O. macrandriμm,*1-d *O. minus,* 2-a *Monoraphidiμm arcuatμm,* 2-b *M. Tortile* ,3- *Mougeotia depressa,* 4-*Spirogyra distenta.* scale bar=10μm.

***Spirogyra chuniae* Jao 1935. (Pl.3, Fig.1-a).**

Vegetative cells were 28-39 × 67-130 w, with replicate end walls; Vegetative cells 28-39 × 67-130 M, with replicate end walls; 1 chloroplast, in some cells 2, making 2 to 5.5 turns in the cells; zygospores were ellipsoid with pointed ends, 35-43 × 70-119; median spore wall was yellow smooth [19]. It was found in Duba spring in June 2024. Pl 10, Fig. 105.

***Spirogyra insignis* (Hassall) Kützing 1849 (Pl.3, Fig.1-b).**

Cells 36–45 µm wide, 50–590 µm long, end walls were ring-like and folded (replicate); chloroplasts 2–4 (frequently 3), making 0.5–1.5 turns of the cell; conjugation was ladder-like, conjugation tubes were formed by both gametangia; fertilized cells were shortened and inflated, especially adjacent to male gametangia cells; zygospores were elongate-ellipsoid, 28–48 µm wide, 60–128 µm long, outer wall was thin, smooth, colorless, median wall was thick and smooth [16]. It was found in Asheshekh and Hawdyan springs in June 2024 P1. 149T (p. 596).

***Zygnema carinthiacum* Beck 1929. (Pl.3, Fig 2).**

Vegetative cells were 25–30 × 25–100 µm. Conjugation was scalariform; zygospores were in one of the gametangia; receptive gametangia were much enlarged; zygospores were globose to ovoid, 32–35 × 36–52 µm; median spore wall was blue and scrobiculate; pits were 3–4 µm in diameter[19]. It was found in khalan spring in June 2024, (p l.66, Fig. 213. a-b).

***Closterium sublaterale* Rüzicka 1955. (Pl.3, Fig 3).**

Cells 33-46.6 µm wide, (195-224-346 µm long, (6-) 7.3-8.4 times longer than broad, were slightly curved 46-67° of arc), dorsal margin was more convex than an almost straight or broad and slightly swollen ventral margin, narrowing towards broad sloping subtruncate apices (5.47.7 µm wide), with end vacuoles having a number of small crystals,[16]. It was found in Qasre spring in April 2024 Pl. 157D (p. 630)

***Cosmarium blytii* Wille 1880 (Pl.3, Fig 4-a).**

Cells 7–16 µm wide, 10–19 µm long; sinus was deep, narrow, linear; semi-cells were approximately semicircular-trapeziform with truncate, 4-crenate apex, the two outer crenation were somewhat flat; lateral margins were 3-crenate, also flat with the upper crenation the largest; semi-cell face had 1–2 rows of granules within the margins and one distinctive central papilla, best seen in side view. Cosmopolitan, mostly in acid but also in alkaline waters (pH 5–8) [16]. It was Found in Ble spring in August 2024. (Pl. 163R (p. 665).

***Cosmarium boeckii* Wille 1880 (Pl.3, Fig 4-b).**

Cells 27–35.5 µm wide, 29–40 µm long; sinus was narrow and linear, opening towards the outside; semi-cells were trapeziform-semicircular with convex sides and about 3, often granulate, undulations increasing in size towards apices, with subapical undulation sometimes crenate and granulate, apices were truncate or weakly undulate[16]. It was found in Qasre spring in April 2024. (Pl.164B (p. 669).

***Cosmarium Pseudoseptum* Kuetz 1880 (Pl.3, Fig 4-c).**

This unicellular green alga from the family Desmidiaceae was recognized for its small, compressed cells with a distinct median constriction (sinus) separating the two semi cells. Typically found in acidic, nutrient-poor freshwater habitats like bogs and ponds, this species exhibited a rounded or slightly flattened shape with finely ornamented cell walls [20]. It was found in Qasre spring in April 2024. (Pl.20, fig. 2a (p.320).

***Cosmarium sublaterale (*West & West, 1904). (Pl.3, Fig 4-d).**

This freshwater desmid species was characterized by its bilaterally symmetrical, deeply constricted cells with ornamented semi cells and a prominent isthmus. This species was commonly found in acidic, oligotrophic habitats such as peat bogs and soft-water ponds, where it thrived in low-mineral conditions. Microscopic examination was essential for accurate identification, particularly to distinguish it from similar species based on cell shape, wall ornamentation, and chloroplast structure [20]. It was found in Merga spring in June 2024. (Pl.20, fig. 5g (p.378).

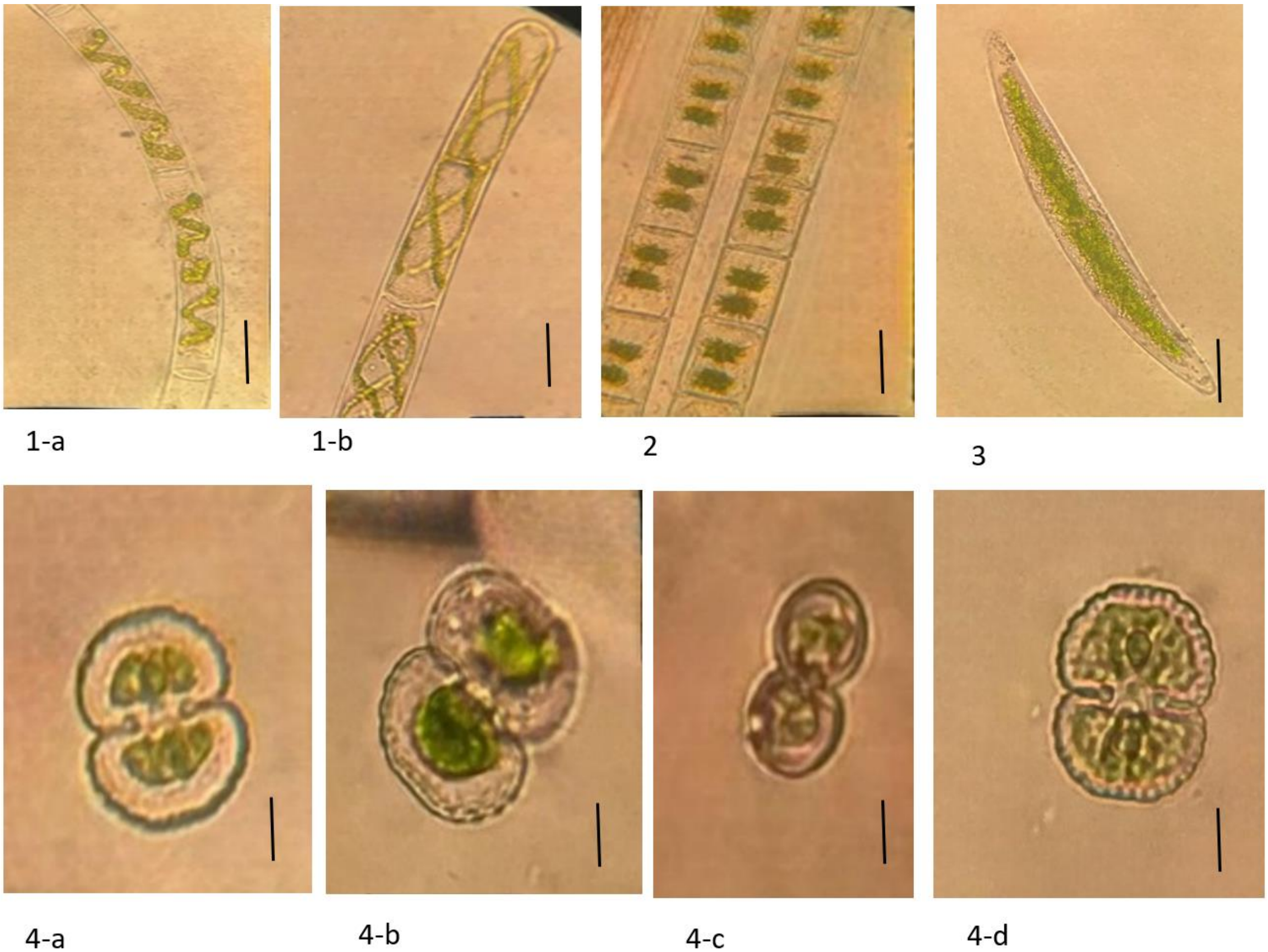


Plate (3): 1-a *Spirogyra chuniae,* 1-b *S. insignis,* 2- *Zygnema carinthiacum,* 3- *Closterium sublaterale,* 4-a *Cosmarium blytii,*4-b *C. boeckii,* 4-c *C. psudoretusum,* 4-d *C. sublaterale.* **scale bar=10µm.**

4 Discussion

The present study represents the first comprehensive phycological survey of the spring-fed ecosystems in Soran district, Erbil Governorate, Kurdistan Region of Iraq. The documentation of 24 Chlorophyta species previously unrecorded in Iraq substantially expands the known algal diversity of the region and contributes critical baseline data to the national algal inventory. The documentation of these novel species substantially expands the known biogeography of Chlorophyta in the region and contributes critically to regional biodiversity databases.

The dominance of *Oedogonium* (six species) and *Cosmarium* (four species) as the most species-rich genera may be attributed to adaptive physiological advantages that enable them to thrive in the environmental condition's characteristic of spring-fed habitats. Genera such as Scenedesmus-represented here by three species alongside *Desmodesmus* (three species) and Spirogyra (three species) - are recognized for high productivity and possess cellular membrane structures that facilitate heavy-metal absorption [21]. This physiological trait may confer a competitive advantage in spring ecosystems where mineral content can be elevated due to groundwater interactions with surrounding geological formations. The presence of Scenedesmus, Desmodesmus, and Spirogyra during late spring aligns with their documented tolerance for lower temperatures, a finding consistent with prior research [22]. This seasonal pattern suggests that water temperature fluctuations in the studied springs influence the temporal distribution of these genera. Similarly, *Monoraphidium,* represented by two species in this study, is noted for its adaptive capacity to withstand fluctuations in environmental parameters, a result corroborated by existing literature [23]. Such plasticity likely enables these species to colonize and persist in the variable physicochemical conditions of spring ecosystems.

The remaining documented genera were each represented by a single species, suggesting a relatively low diversity for these taxa in the sampled habitats. The proliferation and seasonal prevalence of specific algal groups can be attributed to their pronounced adaptive resilience. Algae broadly exhibit considerable tolerance to environmental stressors, including variations in pH, temperature, and other ecological factors [24]. This resilience may explain the successful establishment of newly recorded species in these spring sites. The introduction of these newly recorded species is anticipated to enhance the ecological characterization of the spring sites surveyed, which constitute the first such study within this region [25]. Overall, the findings of this investigation align with and extend the conclusions of related regional studies [7]. providing a foundational framework for future phycological research in the Kurdistan Region of Iraq. Moreover, the baseline data established here may serve as a valuable reference for monitoring ecological changes and assessing water quality in these critical freshwater ecosystems.

5 Conclusion

This study documented 24 Chlorophyta species previously unrecorded in Iraq, significantly expanding the known algal diversity of the Kurdistan Region. *Oedogonium* (six species) and *Cosmarium* (four species) were the most species-rich genera. Field surveys at ten sites - Khalan, Bakaran, Merga, Qasre, Garawan, Akoyan, Hawdyan, Sreshma, Ble, and Malakan springs - revealed these as previously unexplored algal habitats with high biodiversity value. The presence of diverse green algal assemblages confirms the utility of phytoplankton as reliable bioindicators of spring water quality in Soran district, Erbil Governorate, Kurdistan Region of Iraq. These findings align with recent cyanobacterial records from the same region [26] and contribute to the broader knowledge of algal biodiversity in Iraqi freshwater ecosystems [27] . Future studies integrating morphological and molecular approaches, as demonstrated in recent regional research [28] would further enhance taxonomic accuracy and biodiversity assessments.

Acknowledgments

We would like to sincerely thank Soran University – Soran Independent Administration and Salahaddin University–Erbil, Kurdistan Region, Iraq for supporting this research.

Authors Contribution Statements

Farhad Hassan Aziz H. A. and Janan Jabbar Toma both participated in the development of the research idea. Farhad Hassan Aziz developed the theory and performed the computation. Janan Jabbar Toma and Balkes Haje Rasul performed the identification of all new algal records, with supervision and guidance from Farhad Hassan Aziz and Janan Jabbar Toma. All authors discussed the results and contributed to the final manuscript. Authors' declaration

Conflicts of Interest: None. - We hereby confirm that all the Figures and Tables in the manuscript are our own.

References

[1] Kaparapu, J. Algae in Fresh Water Ecosystem. Phykos. **46**, 25-31, 2016.

[2] Zeng, X. and Zhang, C.C. The making of a heterocyst in cyanobacteria. Annual Review of Microbiology. **76**(1), 597-618, 2022.

[3] Toma, J.J. and Aziz, F.H. Algal study in springs and streams from Shaqlawa district, Erbil Province, Iraq I-Euglenophyta. Baghdad Science Journal. **19**(3), 0483-, 2022.

[4] Abd, I. and M-Ridha, M. Tetracycline antibiotic removal from aqueous solution using Cladophora and Spirulina algae biomass; **52**, 336-47, 2021.

[5] Satpati, G. and Pal, R. New and rare records of filamentous green algae from Indian Sundarbans Biosphere Reserve. Journal of Algal Biomass Utilization. 7, 159-75, 2016.

[6] Liu, Y., Sui, J., Fan, X., et al. Lakshmikandan M, Sun C, et al. Mitigating quinolones contamination using Cyanophyta, Chlorophyta, and Bacillariophyta: Removal efficiency, degradation pathways and products. Journal of Water Process Engineering. **71**, 107316, 2025.

[7] Toma, J.J. and Aziz, F.H. Algal study in springs and streams in Shaglawa District, Erbil Province-Iraq III-Chlrophyceae without Zygnematales Iraqi Journal of Agricultural Sciences. **54**(1), 70-84, 2023.

[8] Toma, J.J. and Aziz, F.H. New records of algae in Shaqlawa district, Erbil, Kurdistan region of Iraq. Al-Nahrain Journal of Science. **24**(3), 55-62, 2021.

[9] Shareef, C.M. and Aziz, F.H. New Records of Non-Diatom Algae in Aquatic Habitat along Greater Zab River Path from Bekhma to Gwer District in Erbil Province, Iraq. Baghdad Science Journal. **20**(5 (Suppl.)), 15-32, 2023.

[10] Mahdi, Z.M. and Al-Hussieny, A.A. Classification of Some Species Algae in the Tigris River within the City of Baghdad-Iraq. **2022**, 238.

[11] Wang Z, Akbar S, Sun Y, Gu L, Zhang L, Lyu K, et al. Cyanobacterial dominance and succession: Factors, mechanisms, predictions, and managements. Journal of Environmental Management. **297**, 113281, 2021.

[12] Maulood BK, Hassan FM, Al-Lami AA, Toma JJ, Ismail AM. Checklist of algal flora in Iraq. Ministry of Environment, Baghdad.94. 2013.

[13] Aziz FH, Ahmed AQ. Updated checklist of freshwater algal flora of Kurdistan region of Iraq: Checklist of algal flora of Kurdistan. Zanco Journal of Pure and Applied Sciences. **34**(2),75-117, 2022.

[14] Komárek J, Fott B. Chlorophyceae (Grünalgen), Ordnung: Chlorococcales, Das Phytoplankton des Süßwassers. 7 (Teil 1): E. Schweizerbart'sche Verlagsbuchhandlung; (Leave blank or add "1044 pp." in the "Pages" field). 1983.

[15] Hegewald E. Taxonomy and phylogeny of Scenedesmus (Chlorococcales, Chlorophyta): A morphological and biochemical approach. Algological Studies. **100**, 39-65, 2000.

[16] John W, Sheath R, Kociolek P. Freshwater Algae of North America: Ecology and Classification. 2nd Edition ed. United States: Elsevier; 2015.

[17] Prescott GW. Algae of the Western Great Lakes Area. 6th Edition 6th Edition ed. William C Brown CO Publishers: Dubuque, Lowa.; 1970.

[18] Prescott GW. How to KnownFreshwater Algae. William C Brown CO Publishers: Dubuque, Lowa.; 1968.

[19] Kim J-H. New records of the genus Spirogyra (Zygnemataceae, Conjugatophyceae) in Korea. Journal of Ecology and Environment. **38**, 611-8, 2015.

[20] Coesel PFM. Biogeography of desmids. In: Kristiansen J, editor. Biogeography of Freshwater Algae: Proceedings of the Workshop on Biogeography of Freshwater Algae, held during the Fifth International Phycological Congress, Qingdao, China, June 1994. Dordrecht: Springer Netherlands; 41-53, 1996.

[21] Szymańska H, Krzyk A, Mętrak M. Some species of Oedogoniales (Chlorophyceae) from small astatic water bodies in the post-agricultural landscape (Masurian Landscape Park, NE Poland). Phytotaxa. **2015**, 121-44.

[22] Toma J, and Aziz F. Algal study in springs and streams in Shaqlawa district, Erbil Province-Iraq III- Chlorophyceae without Zygnematales. **54**, 70-84, 2023.

[23] Bogen C, Klassen V, Wichmann J, La Russa M, Doebbe A, Grundmann M, et al. Identification of Monoraphidium contortum as a promising species for liquid biofuel production. Bioresource technology. 133, 2013.

[24] Aziz FH, Rasoul BH. Thirty two algae new records reported in ponds at Gwer Sub-district, Erbil-Kurdistan Region, Iraq. Bulletin of the Iraq Natural History Museum (P-ISSN: 1017-8678, E-ISSN: 2311-9799). **14**(1), 27-42, 2016.

[25] Osama A, Dwaish AS. Investigation of Some Ecological Factors and Isolation Techniques for Some Local Algae in Iraq. Annals of RSCB. **25**(6), 18395-402, 2021.

[26] Rasul BH, Aziz FH, Toma JJ. New Records of Cyanophyta in Soran Independent Administration, Kurdistan Region of Iraq. Passer Journal of Basic and Applied Sciences. **8**(1), 101-10, 2026.

[27] Naser M, Yasser A, Onyeaka H, Schoelynck J, Ríos-Escalante PRDl, Essl F. Potentially Invasive and Non-Native Algal Taxa in Iraq: Distribution, Ecological Risks, and Research Gaps. Diversity. **18**(8), 451, 2026.

[28] Rasul BH, Aziz FH, Toma JJ. Modern DNA Detection via Traditional Methods: Conforming Algal Species in Soran Independent Administration, Kurdistan Region of Iraq. Baghdad Science Journal. **23**(3), 914-23, 2026.