Baghdad Science Journal

Volume 23 | Issue 6 Article 6

6-17-2026

Investigation of the Combined Effects of Temperature and Nutrients on Chlorophyll-a Concentration in the Tigris River, Baghdad

Yaqeen Ameen
Department of Biology, College of Science for Women, University of Baghdad, Baghdad, Iraq, yaqeen.ameen2302m@csw.uobaghdad.edu.iq

Jinan S. Al-Hassany
Department of Biology, College of Science for Women, University of Baghdad, Baghdad, Iraq, jinnansz_bio@csw.uobaghdad.edu.iq

How to Cite this Article

Ameen, Yaqeen and Al-Hassany, Jinan S. (2026) "Investigation of the Combined Effects of Temperature and Nutrients on Chlorophyll-a Concentration in the Tigris River, Baghdad," *Baghdad Science Journal*: Vol. 23: Iss. 6, Article 6.
DOI: https://doi.org/10.21123/2411-7986.5321

BAGHDAD SCIENCE JOURNAL 2026;23(6):2047–2055

RESEARCH ARTICLE

Investigation of the Combined Effects of Temperature and Nutrients on Chlorophyll-a Concentration in the Tigris River, Baghdad

Yaqeen Ameen *, Jinan S. Al-Hassany

Department of Biology, College of Science for Women, University of Baghdad, Baghdad, Iraq

ABSTRACT

Rivers are exposed to global warming and eutrophication, which in turn affect phytoplankton biomass in rivers. This study investigates the changes in Chl-a concentration, an indicator of phytoplankton biomass. A microcosm experiment was conducted, with water sampling from the Tigris River in Baghdad during the wet season. Temperature increase was based on raising the temperature by 3 °C higher than the ambient temperature, while nutrient enrichment was based on the mean values of soluble reactive NO_{3-1} and PO_{4-3} verified in the Tigris River. Variations in Chl-a concentration are associated with changes in WT and nutrient enrichment; NO_{3-1} and PO_{4-3}. Our results showed that the Chl-a concentration was 0.8 μg/l in the control microcosm. Temperature increase led to an increase in Chl-a of Temperature microcosm 1 μg/l, enrichment of nutrient, in turn, led to an increase in Chl-a of NO_{3-1} and PO_{4-3} microcosms to 1.2 and 0.8 μg/l, respectively, so the temperature increase and nutrient enrichment together led to a greater increase in Chl-a of $T+NO_{3-1}$ and $T+PO_{4-3}$ microcosms 1.2 and 1.1 μg/l, respectively, than if it were a single effect, which constitutes the highest concentration of Chl-a during the experiment. The effects of temperature and/ or nutrient can change the concentration of Chl-a. Nutrient enrichment. NO_{3-1} and PO_{4-3}, were identified as key contributors to Chl-a concentration, while warming influences the growth of Chl-a by enhancing metabolic and photosynthetic processes under nutrient-enriched conditions.

Keywords: Chlorophyll-a, Nutrient enrichment, Phytoplankton, Temperature increase, Tigris river

Introduction

Eutrophication is the systematic response of a freshwater ecosystem to processing factors, particularly nutrients from soil and the discharge of wastewater into these water sources. Previous studies have identified different factors that promote eutrophication, primarily chlorophyll-a, nutrients (NO_{3-1} and PO_{4-3}), and water temperature.[1,2] Chlorophyll-a, an indicator of phytoplankton biomass,[3] is directly related to the availability of (NO_{3-1} and PO_{4-3}).[4]

Tigris River, the study site, is one of the longest rivers in the Middle East. With the country's growing population and expanding economic activities, the demand for water for various uses has increased. This has been due to the significant pressure on Iraq's water resources over the past twenty years, particularly in terms of the available water supply.[5] Iraqi researchers focused on different ways to assess water quality,[6,7] while using Chl-a phytoplankton as a biological indicator.[8]

Water temperature (WT) is a major factor affecting the growth rates of phytoplankton, species distribution, and the nutrient cycle in the water system.[9] For this study, WT in the microcosms was changed to reflect the warming scenario as projected by the IPCC.[10] As for nutrients, nitrate (NO_{3-1}) and phosphate (PO_{4-3}), are vital for the growth of phytoplankton and affect chlorophyll-a,[11] excessive nutrients from runoff cause eutrophication

Received 14 July 2025; revised 17 January 2026; accepted 27 January 2026.
Available online 17 June 2026

* Corresponding Author
E-mail addresses: yaqeen.ameen2302m@csw.uobaghdad.edu.iq (Y. Ameen), jinnansz_bio@csw.uobaghdad.edu.iq (J. S. Al-Hassany).

https://doi.org/10.21123/2411-7986.5321

and harmful algal blooms,[12] algal bloom can alter aquatic food webs, which can be harmful to the life of freshwater.[13] The enrichment of phosphorus in the water poses a risk of future eutrophication.[14]

Based on previous research and available data for the Tigris River, water temperature (WT) and nutrients ($NO_{3^{-1}}$ and $PO_{4^{-3}}$) were hypothesized to control chlorophyll-a.[15] To understand the combined effects of temperature and nutrients on chlorophyll-a, we employed a microcosm experiment to investigate this topic. The aim of the study was to elucidate the impact on Chl-a in the Tigris River in response to increasing warming and eutrophication, which are assumed to enhance competitive interactions between different phytoplankton taxa, leading to an increase in phytoplankton biomass. So it is predicted that the effects of combined factors may be greater than the sum of the individual effects, which forms a future scenario in terms of temperature and nutrient content.

Methods and materials

Microcosm experiment design

In our study, a microcosm experiment was conducted Fig. 1. Water sampling from the (AL-Gherai'at site) was on January 8th 2025. It consisted of 18 outdoor insulated polyethene microcosms; each microcosm had a capacity of 20 L. Water sampling from the Tigris River included three replicates of the 6 treatments. The temperature increase was based on raising the temperature 3 °C above the ambient temperature. The nutrient enrichment was based on the mean values of soluble reactive and verified in the Tigris River, to stimulate nutrient loading, solutions of $NaNO_3$ and Na_2HPO_4, (5 mg/l and 1 mg/l, respectively) were used. Each gram of $NaNO_3$ contains 0.72 grams of nitrate, so we added 100 mg of this compound to each $NO_{3^{-1}}$ and $T+NO_{3^{-1}}$ treatment. Each gram of Na_2HPO_4 contains 0.66 grams of phosphate, so we added 20 mg of this compound to each $PO_{4^{-3}}$,

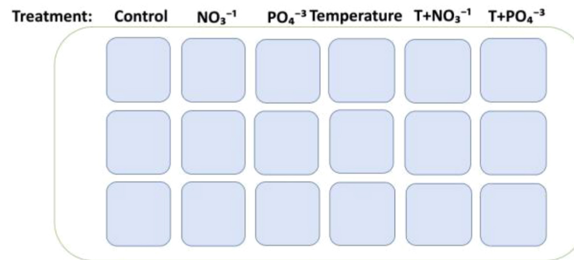


Fig. 1. Schematic representation of the experimental design.

and $T+PO_{4^{-3}}$ treatment on the 1st day of the experiment. We adjusted the pH of the medium after adding the nutrient salts to minimize the potential effect of sodium salts on pH and salinity, ensuring pH stability across all treatments. Salinity remained within the normal range for our study, and the effect of sodium from the added salts was minimal.

Microcosms were performed as follows: (a) Ambient temperature microcosms: Control treatment (no nutrient enrichment), $NO_{3^{-1}}$ treatment, and $PO_{4^{-3}}$ treatment. (b) Heated microcosms: Temperature treatment (no nutrient enrichment), $T+NO_{3^{-1}}$ treatment, and $T+PO_{4^{-3}}$ treatment.

Analytical methods

Triplicate subsamples were collected and analysed eight times during the study period from January 8^{th} to February 1^{st} 2025, subsamples were taken to estimate Physico-chemical variables (WT, pH, EC, Salinity, DO, CO_2) in the field, while $NO_{3^{-1}}$, $PO_{4^{-3}}$, DOC, and biological analysis of phytoplankton chlorophyll-a (Chl-a, proxy phytoplankton biomass) were analyzed in the laboratory, according to the methods mentioned in Table 1.

Statistical analyses

Statistics were based on microcosm-specific means and standard deviations (Mean ± SD) of measured response variables. A two-way ANOVA test was used to

Table 1. Methods of Physico-chemical and biological variables.

Variable	Method	Equation	Unit	Reference
WT	Water Quality Multimeter (Yieryi, China)	-	°C	-
pH	Water Quality Multimeter (Yieryi, China)	-	-	-
EC	Water Quality Multimeter (Yieryi, China)	-	μs/cm	-
Salinity	Calculated from EC	Salinity ‰= EC (μs/cm) × 0.00064	ppt or ‰	16
DO	Dissolved Oxygen Analyzer (Yieryi)	-	mg/l	-
CO_2	Titrimetric by using Na_2CO_3 and HCl	$CO_2 = (A+B \times 4.4) \times 10$	μM	17,18
$NO_{3^{-1}}$	UV-Visible Spectrophotometric	-	mg/l	19
$PO_{4^{-3}}$	UV-Visible Spectrophotometric	-	mg/l	20
DOC	DOC Determination by Filtration (0.45 μm)	The final value of TOC after filtering = DOC	mg/l	21
Chl-a	Acetone Extraction Spectrophotometer	μg Chl-a = 11.9 [2.43 (Db-Da)] (V/L) (1000/S)	μg/l	22

Table 2. Summary statistics (Mean ± SD) of the physicochemical and biological variables were measured throughout the study period for the microcosm experiment.

Treatment	Ambient Temperature Microcosms			Heated Microcosms		
Variable	Control	NO_3^{-1}	PO_4^{-3}	Temperature	$T+NO_3^{-1}$	$T+PO_4^{-3}$
WT (°C)	16.3 ± 0.9	15.8 ± 0.8	15.6 ± 0.7	18.7 ± 0.9	19.4 ± 1.3	20.2 ± 0.6
pH	8.2 ± 0.3	7.8 ± 0.6	8.3 ± 0.2	8.3 ± 0.1	8.3 ± 0.1	8.3 ± 0.2
Salinity (‰)	0.3 ± 0.06	0.3 ± 0.05	0.3 ± 0.05	0.4 ± 0.08	0.4 ± 0.08	0.5 ± 0.1
EC (μs/cm)	576.5 ± 89.4	589.7 ± 90	569.9 ± 87.6	638.2 ± 125	669 ± 122.4	804.1 ± 261.1
DO (mg/l)	7.9 ± 0.4	7.7 ± 0.4	7.8 ± 0.4	7.8 ± 0.3	7.6 ± 0.5	7.2 ± 0.7
CO_2 (μM)	176.1 ± 13.8	181.8 ± 26.3	178.1 ± 12.1	187.7 ± 19.8	192.3 ± 21.5	209.7 ± 25.8
NO_3^{-1} (mg/l)	1.7 ± 1.1	3.5 ± 2.3	0.5 ± 0.2	1.7 ± 0.8	4.7 ± 1.1	1.2 ± 0.5
PO_4^{-3} (mg/l)	0.3 ± 0.5	0.2 ± 0.3	1.9 ± 0.6	0.06 ± 0.02	0.2 ± 0.5	3.2 ± 0.9
DOC (mg/l)	7.6 ± 3.2	6.4 ± 3	7.1 ± 3	7 ± 2.8	8 ± 3.4	5.9 ± 2.7
Chl-a (μg/l)	0.8 ± 0.5	1.2 ± 2	0.8 ± 0.5	1 ± 0.8	1.2 ± 0.8	1.1 ± 1

Table 3. Two-way ANOVA analysis showing the effects of Time, Treatments, and the interactions between them on the studied environmental variables.

	Time		Treatment		Time × Treatment	
Variable	*F*-value(*df*)	*p*-value	*F*-value(*df*)	*p*-value	*F*-value(*df*)	*p*-value
WT	59.31(6,84)	< 0.0001	439.56(5,84)	< 0.0001	3.57(30,84)	< 0.0001
pH	22.28(6,84)	< 0.0001	9.57(5,84)	< 0.0001	3.28(30,84)	< 0.0001
Salinity	46.21(6,84)	< 0.0001	22.31(5,84)	< 0.0001	1.91(30,84)	0.01
EC	42.20(6,84)	< 0.0001	22.03(5,84)	< 0.0001	1.81(30,84)	0.01
DO	94.62(6,84)	< 0.0001	26.10(5,84)	< 0.0001	1.91(30,84)	0.01
CO_2	42.11(6,84)	< 0.0001	23.00(5,84)	< 0.0001	1.65(30,84)	0.03
NO_3^{-1}	1.27(6,84)	0.27	40.32(5,84)	< 0.0001	0.89(30,84)	0.62
PO_4^{-3}	1.67(6,84)	0.13	127.95(5,84)	< 0.0001	0.68(30,84)	0.87
DOC	10.42(6,84)	< 0.0001	2.02(5,84)	0.08	1.19(30,84)	0.25
Chl-a	2.88(6,84)	0.001	0.90(5,84)	0.65	2.29(30,84)	0.02

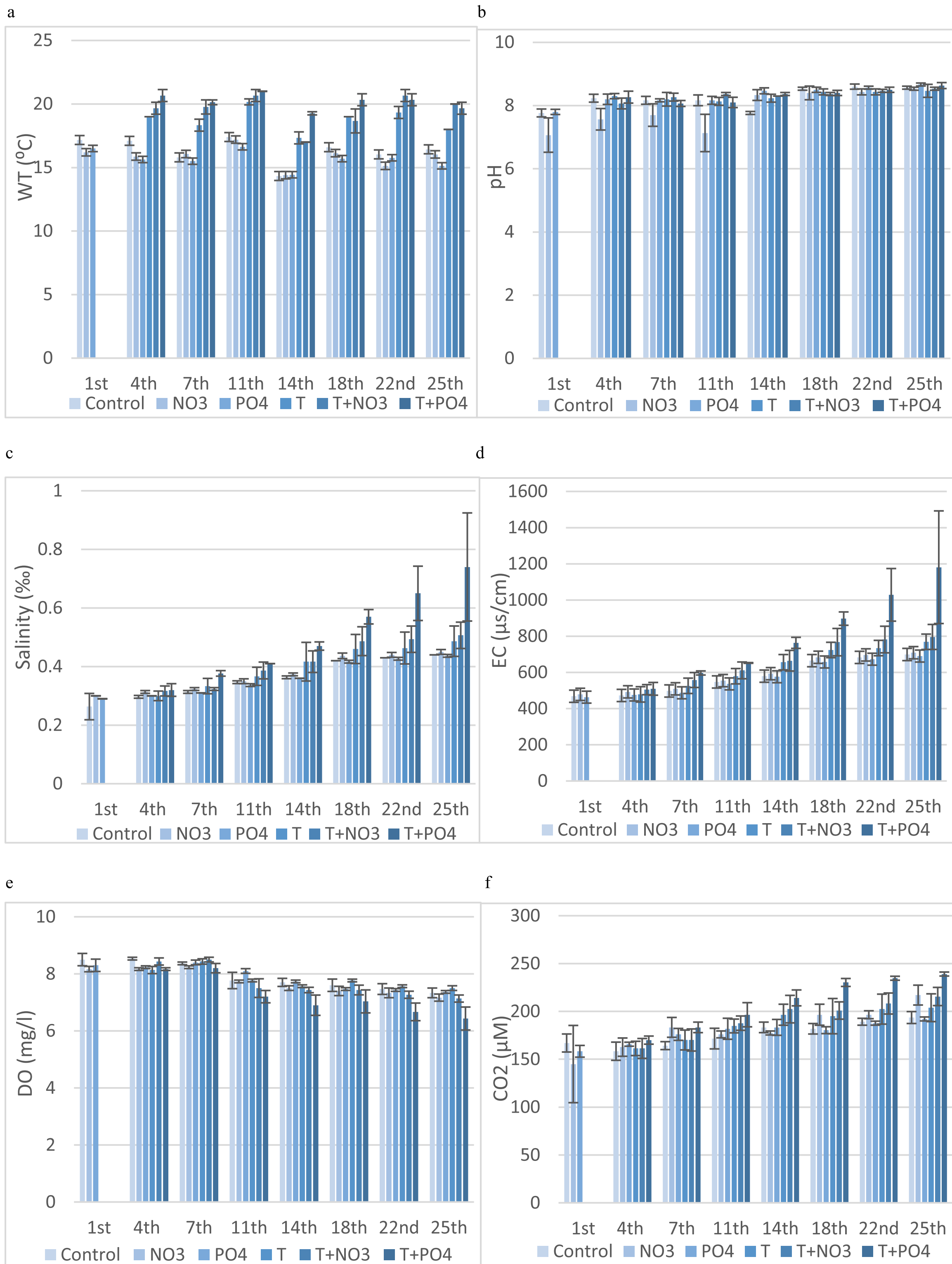
Significance level: < 0.05.

show if the variables changed significantly between time, treatments, and interactions between them. A standard t-test was used to test the differences in water chemistry between the control treatment and (NO_3^{-1}, PO_4^{-3}, Temperature, $T+NO_3^{-1}$, and $T+PO_4^{-3}$ treatments). Further, correlations between Chl-a and variables were calculated by using the Pearson correlation coefficient (r).

Results

Statistics (Mean ± SD) of the physicochemical and biological variables measured throughout the study period for the microcosm experiment are presented in Table 2. These variables changed significantly during the study period Table 3.

Water temperature ranged between 14.3 ± 0.28 °C in the control microcosm on the 14th day and 21 ± 0 °C in the heated PO_4^{-3} microcosm on the 11th day Fig. 2-a. WT value was affected by temperature increase and/or nutrient enrichment Table 4. pH ranged between 7 ± 0.5 in the NO_3^{-1} microcosm on the first day, and 8.6 ± 0.04 in PO_4^{-3} microcosm on the last day Fig. 2-b. pH value was only affected by the individual effect of NO_3^{-1} enrichment, but not affected by the individual effects of PO_4^{-3}, temperature, the combined effect of $T+NO_3^{-1}$, and $T+PO_4^{-3}$ Table 4. Salinity ranged between 0.26 ± 0.04 ‰in the control microcosm on the first day and 0.74 ± 0.18 ‰in the $T+PO_4^{-3}$ microcosm on the last day Fig. 2-c. Salinity was affected by individual effect of NO_3^{-1}, temperature, the combined effect of $T+NO_3^{-1}$, and $T+PO_4^{-3}$, but not affected by individual effect of PO_4^{-3} Table 4. Electrical conductivity (EC) ranged between 463.3 ± 0.94 μs/cm in the PO_4^{-3} microcosm on the first day and 1181.3 ± 311.1 μs/cm in the $T+PO_4^{-3}$ microcosm on the last day Fig. 2-d. EC is affected by temperature increase and/or nutrient enrichment Table 4. Dissolved oxygen (DO) ranged between 8.5 ± 0.04 mg/l in the control microcosm on the fourth day and 6.4 ± 0.4 mg/l in the $T+PO_4^{-3}$ microcosm on the last day Fig. 2-e. DO was affected by the individual effect of NO_3^{-1}, combined effects of $T+NO_3^{-1}$, and $T+PO_4^{-3}$, but not affected by the individual effect of PO_4^{-3} and Temperature Table 4. CO_2 ranged between 145 ± 40.3 μM in the NO_3^{-1} microcosm on the first day and 239 ± 2 μM in the $T+PO_4^{-3}$ microcosm on the last day Fig. 2-f. CO_2 was


a
WT (ºC)
0 5 10 15 20 25
1st 4th 7th 11th 14th 18th 22nd 25th
Control NO3 PO4 T T+NO3 T+PO4
b
pH
0 2 4 6 8 10
1st 4th 7th 11th 14th 18th 22nd 25th
Control NO3 PO4 T T+NO3 T+PO4
c
Salinity (‰)
0 0.2 0.4 0.6 0.8 1
1st 4th 7th 11th 14th 18th 22nd 25th
Control NO3 PO4 T T+NO3 T+PO4
d
EC (µs/cm)
0 200 400 600 800 1000 1200 1400 1600
1st 4th 7th 11th 14th 18th 22nd 25th
Control NO3 PO4 T T+NO3 T+PO4
e
DO (mg/l)
0 2 4 6 8 10
1st 4th 7th 11th 14th 18th 22nd 25th
Control NO3 PO4 T T+NO3 T+PO4
f
CO2 (µM)
0 50 100 150 200 250 300
1st 4th 7th 11th 14th 18th 22nd 25th
Control NO3 PO4 T T+NO3 T+PO4

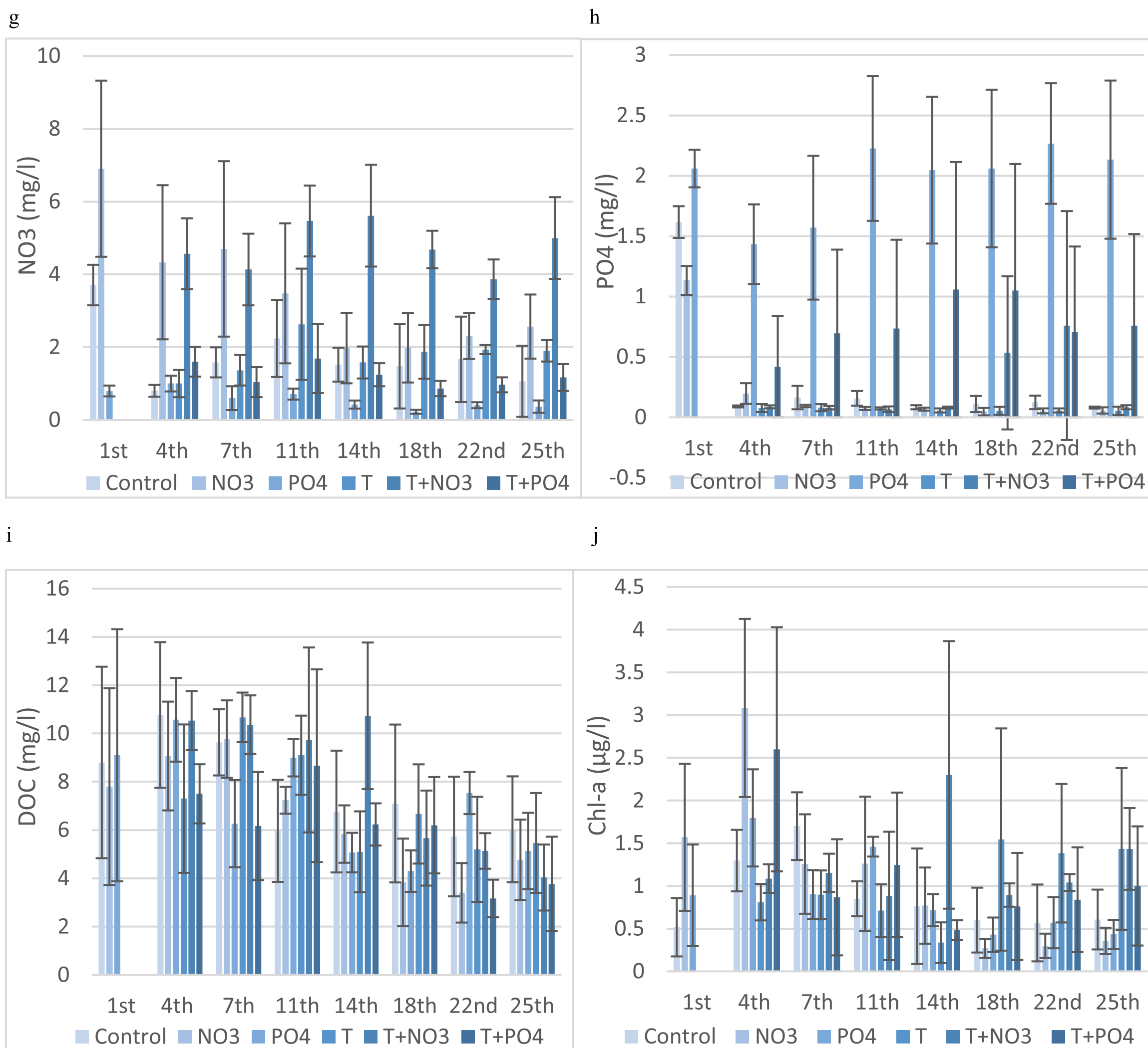


Fig. 2. Physico-chemical and biological variables throughout the microcosm experiment.

affected by the individual effect of Temperature, the combined effect of T + NO_3^{-1}, and T + PO_4^{-3}, but not affected by the individual effect of NO_3^{-1} and PO_4^{-3} Table 4. NO_3^{-1} ranged between 0.22 ± 0.05 mg/l in PO_4^{-3} microcosm on the 18^{th} day, and 6.9 ± 2.41 mg/l in NO_3^{-1} microcosm on the 14^{th} day Fig. 2-g. NO_3^{-1} was affected by the individual effect of NO_3^{-1}, PO_4^{-3}, and the combined effect of T + NO_3^{-1}, but not affected by the individual effect of Temperature, and the combined effect of T + PO_4^{-3} Table 4. PO_4^{-3} ranged between 0.04 ± 0.03 mg/l in NO_3^{-1} microcosm on the 18^{th} day, and 3.76 ± 0.75 mg/l in T + PO_4^{-3} microcosm on the last day Fig. 2-h. PO_4^{-3} was affected by the individual effect of NO_3^{-1}, PO_4^{-3}, Temperature, and the combined effect of T + PO_4^{-3}, but not affected by the combined effect of T + NO_3^{-1} Table 4. Dissolved organic carbon (DOC) ranged between 3.1 ± 0.7 mg/l in the T + PO_4^{-3} microcosm on the 22^{nd} day and 10.7 ± 3 mg/l in the control microcosm on the fourth day Fig. 2-i. DOC was not affected by temperature and/or nutrient enrichment at all Table 4.

Chlorophyll-a ranged between 0.27 ± 0.1 μg/l in the ambient temperature NO_3^{-1} microcosm on the 18^{th} day and 3.08 ± 1 μg/l in the ambient temperature NO_3^{-1} microcosm on the fourth day Fig. 2-j. Our results showed the concentration of Chl-a 0.8 ± 0.5 μg/l in the control microcosm. Temperature increase led to an increase in Chl-a in the Temperature microcosm (1 ± 0.8 μg/l). Nutrient enrichment, in turn, led to an increase in Chl-a in the NO_3^{-1} and PO_4^{-3} microcosms (1.2 ± 2 and 0.8 ± 0.5 μg/l, respectively), so the temperature increase and nutrient enrichment together led to a greater increase in Chl-a of T + NO_3^{-1} and T + PO_4^{-3} microcosms, 1.2 ± 0.8 and 1.1 ± 1 μg/l, respectively, than if it were a single effect, which constitutes the highest concentration of

Table 4. Summary statistics (T-test); Effects of Physico-chemical and biological variables measured throughout the microcosm experiment.

Variable	Control vs. Treatment	t-value	p-value
WT	NO_{3-1}	3.57	0.0007
	PO_{4-3}	5.61	< 0.0001
	Temperature	-15.16	< 0.0001
	$T + NO_{3-1}$	-14.05	< 0.0001
	$T + PO_{4-3}$	-24.46	< 0.0001
pH	NO_{3-1}	2.78	0.005
	PO_{4-3}	-1.58	0.06
	Temperature	-0.38	0.35
	$T + NO_{3-1}$	-0.82	0.20
	$T + PO_{4-3}$	-0.64	0.26
Salinity	NO_{3-1}	-3.4	0.001
	PO_{4-3}	-0.10	0.45
	Temperature	-2.82	0.005
	$T + NO_{3-1}$	-4.78	< 0.0001
	$T + PO_{4-3}$	-4.89	< 0.0001
EC	NO_{3-1}	-4.98	< 0.0001
	PO_{4-3}	3.92	0.0003
	Temperature	-2.81	0.005
	$T + NO_{3-1}$	-5.24	< 0.0001
	$T + PO_{4-3}$	-4.84	< 0.0001
DO	NO_{3-1}	3.74	0.0005
	PO_{4-3}	0.47	0.31
	Temperature	0.08	0.46
	$T + NO_{3-1}$	3.42	0.001
	$T + PO_{4-3}$	7.61	< 0.0001
CO_2	NO_{3-1}	-1.40	0.08
	PO_{4-3}	-0.91	0.18
	Temperature	-3.29	0.001
	$T + NO_{3-1}$	-4.57	< 0.0001
	$T + PO_{4-3}$	-8.07	< 0.0001
NO_{3-1}	NO_{3-1}	-3.79	0.0004
	PO_{4-3}	4.77	< 0.0001
	Temperature	-1.23	0.11
	$T + NO_{3-1}$	-9.49	< 0.0001
	$T + PO_{4-3}$	1.12	0.13
PO_{4-3}	NO_{3-1}	2.17	0.02
	PO_{4-3}	-10.17	< 0.0001
	Temperature	3.57	0.0009
	$T + NO_{3-1}$	-1.07	0.14
	$T + PO_{4-3}$	-14.14	< 0.0001
DOC	NO_{3-1}	1.40	0.08
	PO_{4-3}	0.69	0.24
	Temperature	0.38	0.35
	$T + NO_{3-1}$	-0.61	0.27
	$T + PO_{4-3}$	1.73	0.05
Chl-a	NO_{3-1}	-3.44	0.001
	PO_{4-3}	-3.66	0.001
	Temperature	-2.49	0.01
	$T + NO_{3-1}$	-3.07	0.004
	$T + PO_{4-3}$	-2.46	0.01

Significance level: < 0.05.

Chl-a during experiment Fig. 3. Chl-a was affected by temperature increase and/or nutrient enrichment Table 4. Chl-a was affected by WT, pH, DO, CO_2, NO_{3-1}, PO_{4-3} and DOC, but not affected by salinity and EC Table 5.

Table 5. Effects of the Physico-chemical variables on chlorophyll-a.

Chl-a vs. Variable	Pearson correlation coefficient (r)	p-value
WT	0.18	0.03
pH	-0.21	0.01
Salinity	-0.12	0.13
EC	-0.13	0.12
DO	0.19	0.02
CO_2	-0.18	0.03
NO_{3-1}	0.29	0.0004
PO_{4-3}	-0.17	0.04
DOC	0.41	< 0.0001

Significance level: < 0.05.

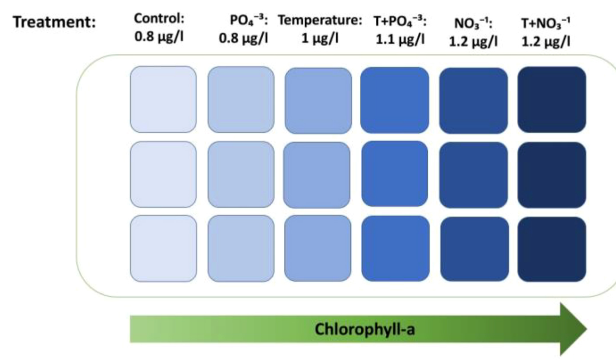


Fig. 3. Schematic representation of our results for Chl-a concentration.

Discussion

Our experiment has provided a remarkably consistent pattern in the short-term response of chlorophyll-a concentrations. The cellular chlorophyll content of phytoplankton was stimulated by both increasing temperature and adding nutrients, an effect that was synergistically enhanced under the combined effects of temperature and nutrient enrichment.

The marked stimulatory effect of nitrate and phosphate additions on phytoplankton biomass confirmed our expectations. However, nutrient enrichment effects on chlorophyll-a concentrations differed between the treatments and between the types of nutrient (NO_{3-1}, PO_{4-3}), indicating species-specific resource requirements. phytoplankton cells regulate their content of chlorophyll-a dependent on nitrogen availability,[23] but reductions in nitrogen loading at high phosphorus levels may lead to an increase in chlorophyll-a and a decrease in water clarity, resulting in a clear deterioration in water quality,[24] combination of high temperatures and phosphorus loading stimulated the maximum biomass built by the phytoplankton community,[25] these mainly reflected in nutrient-enriched microcosms, while low chlorophyll-a concentrations are reflected in nutrient-poor microcosms (Control and Temperature microcosms).

The short duration of our experiment may have prevented individual phytoplankton populations and communities from fully adapting to the increased temperatures, thus affecting the phytoplankton biomass's response to warming. Conversely, sudden temperature changes can exacerbate negative growth effects, particularly in the context of global warming, precisely because thermal acclimatization requires longer exposure periods.[26]

Warm water promotes the growth of phytoplankton,[27] and this was mainly reflected in heated microcosms. However, in this study, chlorophyll-a concentration decreased in some heated microcosms as WT increased, possibly because WT exceeded that which is suitable for the growth of most phytoplankton, and high WT began to inhibit phytoplankton photosynthesis.[28]

An increase was observed for pH value during the experiment; mild alkaline conditions may result in elevated chlorophyll-a.[29] An increase was observed for salinity and EC during the experiment. Our studies indicated that salinity and EC have no significant effect on chlorophyll-a, which could be attributed to the complicated interplay between several environmental elements (WT, pH, DO, and carbon sources) with species composition and ecological dynamics.[30] A decrease was observed in the DO concentration during the experiment. Although DO was high in the first days of the experiment due to low organism activity under low temperature such as respiration.[31] An increase was observed for CO_2 concentration during the experiment, high CO_2 leads to increasing phytoplankton biomass.[32] DOC influences algal blooms and overall ecosystem health.[33]

To isolate the impact of the altered variable on chlorophyll-a concentration, all environmental variables were held constant in this study. As a result, changes in chlorophyll-a concentration primarily represent the responses of phytoplankton and may also be affected by other biotic factors, such as zooplankton grazing and interspecies interactions, which were not examined in our study. Future studies should include the structure and abundance of phytoplankton and zooplankton communities to better illustrate the ecosystem responses.

Conclusion

A study proved that temperature increase and/ or nutrient enrichment influence physicochemical variables, which in turn influence chlorophyll-a across a microcosm experiment. Nutrient enrichment; $NO_{3^{-1}}$ and $PO_{4^{-3}}$, identified as the main contributors to chlorophyll-a concentration, while temperature affects chlorophyll-a growth by enhancing metabolic processes and photosynthesis under nutrient-rich conditions. The relationship between elevated temperature and/ or nutrient enrichment and chlorophyll-a may be more complex under climate change and eutrophication. Furthermore, the experimental study designs can't accommodate the complexity of freshwater ecosystems. Furthermore, studies are needed to integrate the experimental method and field observation to better understand the impacts of climate change on aquatic ecosystem dynamics.

Authors' declaration

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are ours. Furthermore, any Figures and images that are not ours have been included with the necessary permission for republication, which is attached to the manuscript.
- No animal studies are present in the manuscript.
- No human studies are present in the manuscript.
- Ethical Clearance: The project was approved by the local ethical committee at the University of Baghdad.

Authors' contributions statements

Y. A. and J. S. A. contributed to the design and implementation of the Microcosm Experiment, to the analysis of the data, to the statistical analysis of the results, and to the writing of the manuscript.

References

1. Al-Thani JA, Soliman Y, Al-Maslamani IA, Yigiterhan O, Al-Ansari EMAS. Physical drivers of chlorophyll and nutrients variability in the Southern-Central Arabian Gulf. Estuar Coast Shelf Sci. 2023;283:108260. https://doi.org/10.1016/j.ecss.2023.108260
2. Mamun M, Jargal N, An K-G. Spatio-temporal characterization of nutrient and organic pollution along with nutrient-chlorophyll-a dynamics in the Geum River. J King Saud Univ Sci. 2022;34:102270. https://doi.org/10.1016/j.jksus.2022.102270
3. Choe JY, Yusof KMKK, Rohani, S. A raw data on the Physico-chemical water parameters and sedimentation rates of two different aquatic macrophytes in Tasik Berombak, Malaysia, Data Brief. 2023;49:109397. https://doi.org/10.1016/j.dib.2023.109397
4. Damar A, Prismayanti AD, Rudianto BY, Ramli A, Kurniawan F. Algae bloom phenomenon in Jakarta Bay as symptoms of severe eutrophication: monitoring results of 2014–2016. IOP Conf Ser Earth Environ Sci. 2021;744:012009. https://doi.org/10.1088/1755-1315/744/1/012009

5. Alharbawee NA, Mohammed AJ. Water quality assessment of Tigris River using multivariate statistical techniques. Iraqi J. Sci. 2024, 65(3);1266-1275. https://doi.org/10.24996/ijs.2024.65.3.8
6. Al-Janabi ZZ, Al-Bahathy IAA, Al-Hassany JS, Al-Ani RR, Naje AS and Maktoof AA. Environmental impact of Al-Dalmaj marsh discharge canal on the main outfall drain river in the eastern part of Al-Qadisiya city and predicting the IQ-WQI with sensitivity analysis using BLR. Nat. Environ. Poll. Tech. 2025;24(1):D1661. https://doi.org/10.46488/NEPT.2025.v24i01.D1661
7. Fazaa NA, Dunn JC, Whittingham MJ. Pollution threatens water quality in the Central Marshes of Southern Iraq. Baghdad Sci. J. 2021;18(4):30. https://doi.org/10.21123/bsj.2021.18.4(Suppl.).1501
8. Al-Saedy RN, Al-Hassany JS, Mashee FK. A Study of the Analysis of Chlorophyll-a Phytoplankton in the Tigris Rivers for Some Regions of Iraq by Using GIS Techniques. Asian J. Water Environ. Pollut. 2024;21(5):85-93. https://doi.org/10.3233/AJW240063
9. Fung M, Phipps S, Lehrter J. Abrupt chlorophyll shift driven by phosphorus threshold in a small subtropical estuary. Front Mar Sci. 2022;1–17. https://doi.org/10.3389/fmars.2022.990404
10. Intergovernmental Panel on Climate Change (IPCC). Summary for policymakers. In: Masson-Delmotte V, Zhai P, Pirani A, Connors SL, Péan C, Berger S, *et al.*, editors. Climate change 2021: The physical science basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press; 2021. p. 3-32.
11. El-Mezayen MM, Abd El-Hamid HT. Assessment of water quality and modeling trophic level of lake Manzala, Egypt using remotely sensed observations after recent enhancement project, J. Indian Soc. Remote Sens. 2023;51(1):197-211. http://dx.doi.org/10.1007/s12524-022-01635-3
12. Mohammadpour A, Gharehchahi E, Gharaghani MA, Shahsavani E, Golaki M, Berndtsson R, Khaneghan AM, Hashemi H, Abolfathi S. Assessment of drinking water quality and identifying pollution sources in a chromite mining region, J. Hazard. Mater. 2024;480:136050. https://doi.org/10.1016/j.jhazmat.2023.136050
13. Sterner RW. The Laurentian Great Lakes: a biogeochemical test bed. Annu. Rev. Earth Planet. Sci. 2021;49:201-229. https://doi.org/10.1146/annurev-earth-071420051746
14. Duan YA, Chen XS, Huang Y, Zhang Y, Wang P, Duan XX, Qin XY, Zou YA, Deng ZM, Zhao QL. Potential risk of eutrophication in the deepest lake of Southwest China: Insights from phosphorus enrichment in bottom water. J Contam Hydrol. 2023 Feb;253:104127. https://doi.org/10.1016/j.jconhyd.2022.104127
15. Fadhel MN. Pollution investigation on Tigris River within Mosul Area, Iraq. Plant Archives. 2020;20(2):1273-7.
16. Mackereth FJH, Heron J, Talling JF. Water analysis: some revised methods for limnologists. Ambleside: Freshwater Biological Association; 1978. 120 p. (Scientific publication; no. 36). https://doi.org/10.1002/iroh.19790640404
17. Hadi RAM. Algae studies on the River Usk [dissertation]. Cardiff (UK): University College Cardiff; 1981.
18. Golterman HL, Clymo RS, Ohnstad MAM. Methods for Physical and Chemical Analysis of Fresh Waters, Oxford, Blackwell Scientific Publications; 1978.
19. APHA. Standard Methods for the Examination of Water and Wastewater. 23rd Edition, American Public Health Association, American Water Works Association, Water Environment Federation, Washington D.C. - References - Scientific Research Publishing; 2017.
20. Lind OT. Hand book of common method in limnology. St. louis: C. V. mosby co.; 1979.
21. Williams CJ, Yamashita Y, Wilson HF, Jaffé R, Xenopoulos MA. Unraveling the role of land use and microbial activity in shaping dissolved organic matter characteristics in stream ecosystems. Limnol Oceanogr. 2010;55(3):1159-1171. https://doi.org/10.4319/lo.2010.55.3.1159
22. Vollenweider RA. A Manual on Methods for Measuring Primary Production in Aquatic Environments. IBP Handbook No. 12. – Oxford and Edinburgh: Published for the International Biological Programme by Blackwell Scientific Publications. 1969;213 pp. 45 s https://doi.org/10.1002/iroh.19700550415
23. Halsey KH, Jones BM. Phytoplankton strategies for photosynthetic energy allocation. Annu Rev Mar Sci. 2015;7:265-97. https://doi.org/10.1146/annurev-marine-010814-015813
24. Filstrup CT, Downing JA. Relationship of chlorophyll to phosphorus and nitrogen in nutrient-rich lakes. Inland Waters. 2017;7(4):385-400. https://doi.org/10.1080/20442041.2017.1375176
25. Yu C, Li C, Wang T, Zhang M, Xu J. Combined effects of experimental warming and eutrophication on phytoplankton dynamics and nitrogen uptake. Water. 2018;10(8):1057. https://doi.org/10.3390/w10081057
26. Harvey BP, Marshall KE, Harley CDG, Russell BD. Predicting responses to marine heatwaves using functional traits. Trends Ecol. Evol. 2022;37:20–29. https://doi.org/10.1016/j.tree.2021.09.003
27. Mahdian M, Noori R, Salamattalab MM, Heggy E, Bateni SM, Nohegar A, Hosseinzadeh M, Siadatmousavi SM, Fadaei MR, Abolfathi S. Anzali Wetland Crisis: unraveling the Decline of Iran's Ecological Gem, J. Geophys. Res. 2024;129:1-18. https://doi.org/10.1029/2023JD039538
28. Thorel M, Fauchot J, Morelle J, Raimbault V, Le Roy B, Miossec C, Kientz-Bouchart V, Claquin P. Interactive effects of irradiance and temperature on growth and domoic acid production of the toxic diatom Pseudo-nitzschia australis (Bacillariophyceae). Harmful Algae. 2014;39:232-241. https://doi.org/10.1016/j.hal.2014.07.010
29. Melad RS, Nonato RL, Salazar DJ, Ligaray MV, Choi AES. Spatial assessment of water quality in Mananga River in Talisay City, Cebu, Philippines, Results. Eng. 2024;24(2):103030. https://doi.org/10.1016/j.rineng.2024.103030
30. Wang Z, Li Q, Tian Y, Li X, Chen X, Tian Y. Xue J. Effect of land use and environmental variables on phytoplankton community structure in high-elevation river, upper Yangtze River, China. Front. Environ. Sci. 2023;11:1084461. https://doi.org/10.3389/fenvs.2023.1084461
31. Mahaffey C, Palmer M, Greenwood N, Sharples J. Impacts of climate change on dissolved oxygen concentration relevant to the coastal and marine environment around the UK. MCCIP Science Review. 2020;2002:31-53. https://doi.org/10.14465/2020.arc02.oxy
32. Hamdan M, Byström P, Hotchkiss ER, Al-Haidarey MJ, Ask J, Karlsson J. Carbon dioxide stimulates lake primary production. Sci Rep. 2018;8(1):10878. https://doi.org/10.1038/s41598-018-29166-3
33. Sánchez-Pérez ED, Pujo-Pay M, Ortega-Retuerta E, Conan P, Peters F, Marrasé C. Mismatched dynamics of dissolved organic carbon and chromophoric dissolved organic matter in the coastal NW Mediterranean Sea. Sci. Total Environ. 2020;746:141190. https://doi.org/10.1016/j.scitotenv.2020.141190

دراسة التأثيرات المشتركة لدرجة الحرارة والمغذيات على تركيز الكلوروفيل-أ في نهر دجلة، بغداد

يقين أمين، جنان شاوي الحساني

علوم الحياة، كلية العلوم للبنات، جامعة بغداد، بغداد، العراق.

الخلاصة

تتعرض الأنهار لظاهرة الاحتباس الحراري والتخثث، مما يؤثر بدوره على الكتلة الحيوية للعوالق النباتية فيها. تبحث هذه الدراسة في التغيرات التي تطرأ على تركيز الكلوروفيل-أ، وهو مؤشر على الكتلة الحيوية للعوالق النباتية. أُجريت تجربة مصغرة، حيث جُمعت عينات مياه من نهر دجلة في بغداد خلال موسم الأمطار. استندت زيادة درجة الحرارة إلى رفعها بمقدار 3 درجات مئوية فوق درجة الحرارة المحيطة، بينما استند إثراء المغذيات إلى متوسط قيم التي تم التحقق منها في نهر دجلة. ترتبط التغيرات في تركيز الكلوروفيل-أ بالتغيرات في درجة حرارة الماء وإثراء المغذيات؛ النترات والفوسفات. أظهرت نتائجنا أن تركيز الكلوروفيل-أ بلغ 0.8 ميكروغرام/لتر في النظام البيئي المصغر الضابط. أدى ارتفاع درجة الحرارة إلى زيادة تركيز الكلوروفيل-أ في النظام البيئي المصغر ذي درجة الحرارة بمقدار 1 ميكروغرام/لتر، بينما أدى إثراء المغذيات بدوره إلى زيادة تركيز الكلوروفيل-أ في النظامين البيئيين المصغرين ذوي النترات والفوسفات بمقدار 1.2 و0.8 ميكروغرام/لتر على التوالي. وبذلك، أدى ارتفاع درجة الحرارة وإثراء المغذيات معًا إلى زيادة أكبر في تركيز الكلوروفيل-أ في النظامين البيئيين المصغرين ذوي درجة الحرارة مع النترات والفوسفات بمقدار 1.2 و1.1 ميكروغرام/لتر على التوالي، مقارنةً بتأثير كل منهما على حدة، وهو ما يمثل أعلى تركيز للكلوروفيل-أ خلال التجربة. أظهرت النتائج ان درجة الحرارة و/أو المغذيات يمكن أن تؤثرعلى تركيز الكلوروفيل-أ. وقد تم تحديد إثراء المغذيات، وخاصة النترات والفوسفات، كعوامل رئيسية في زيادة تركيز الكلوروفيل-أ، بينما يؤثر ارتفاع درجة الحرارة على نمو الكلوروفيل-أ من خلال تعزيز عمليات التمثيل الغذائي والتمثيل الضوئي في ظل ظروف غنية بالمغذيات.

الكلمات المفتاحية: الكلوروفيل-أ، اثراء المغذيات، العوالق النباتية، ارتفاع درجة الحرارة، نهر دجلة.