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A quantitative study of attached algae on two substrates (natural and artificial) in a lotic ecosystem

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Abstract:

The attached algae have a big role in lotic ecosystems. This study conducted to explain the different quantity of the attached algae on different substrates. Two macrophytes were selected as a natural substrate (*Certophyllum demersum* and *Hydrilla verticillata*) and artificial substrates and sampling taken monthly, from March 2013 to December 2013 from Tigris river within Al-Jadria campus of the University of Baghdad in the center of Baghdad city. Four biodiversity indices (Shannon-Weaver, richness, evenness and similarity) were calculated. The study showed a variation in the total number of attached algae on different substrates. The higher number of total algae was recorded on artificial substrates (26.68×10^4 individual/g WW) which represented as 44%. While the lowest number of benthic algae (8.76×10^4 individual/g WW) was on *H. verticllata* and expressed as 23%. Also, different index values recorded on various substrates.

Keywords: Benthic algae, Artificial substrate, Natural substrate, Lotic ecosystem .

Introduction

Many authors were emphasized the importance of submerged macrophytes in aquatic ecosystems due to their roles as primary producers, a good habitat for other organisms as algae and its role in nutrient cycling [1, 2, 3]. The *C. demersum* is a dominant species in different aquatic ecosystems in Iraq [4]. While *H. verticillata* is recorded as introduced species for the first time by Alwan [5]) in Abu-Ziirig marsh (southern Iraq), then registered in the northern Iraqi rivers (the little Zab river) by Al-Mandeel [6].

Algae group occurrence in different habitats. In an aquatic ecosystem found as plankton or periphyton. [1]. Wetzel [7] referred to algae grown on the macrophytes surface as periphyton. Graham et al. [8] stated that the periphyton algae attached to the different substrate include biotic or non-biotic material. The benthic algae have a significant role in the aquatic environment through their role in primary production, food chain and nutrient circulation [9]. The distribution and density of benthic algae were affected by different environmental and biological parameters; light intensity, daylight duration, temperature, salinity, nutrients, total organic carbon, sediment texture, aquatic geomorphology, water movement, competition and predation rate [10].

These algal communities are considered important freshwater ecosystem components due to their role food and refuge for many aquatic animals [11,12]. These communities have the influence on the growth of the host plant by reducing the light penetration and competition on nutrients [[13, 14]. Cattaneo and kalff [15] revealed that the chlorophyll contents of epiphytic algae on two different substrates (natural and artificial) showed the same temporal trends. Whereas, Rodusky and Anderson [16] obtained from his study different biomass of the attached algae on different substrates.

The higher biomass were recorded on an artificial substrate while the lowest value was on the host plant (*Potamageton*), but they found the same dominance groups (Diatoms and filamentous green algae) on both substrates. Tunca et al. [17] found different species composition of epiphytic algae on various macrophytes while the diversity values were the same on host plants.

Hassan et al. [18] recorded the highest number of diatoms and high values o Shannon index on *C. demersum* in comparison with other studied host plants.

This study aimed to explore the temporal and differentiation of epiphytic algae, which were growing on artificial and natural substrate in the Tigris river within Baghdad city, Iraq.

Material and Methods

Two submerged macrophytes were collected from the Tigris River (Figure 1), in addition to plastic slides 75 cm x25 cm were used as an artificial substrate. The sampling was taken from Al-Jadiriya campus of the University of Baghdad on the Tigris river during the period between March and December 2013.

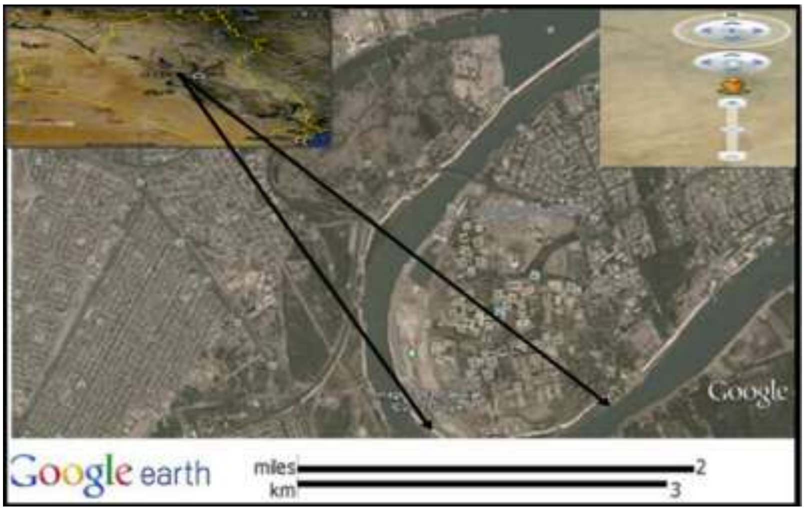

Figure1. Map of Iraq (on the right) and the study area (on the left).
(The two arrows indicate the student station on the Tigris River.

The physicochemical parameters were measured in the study area, including temperature (air and water), pH, electric conductivity (EC) and total dissolved solids (TDS) by the multimeter (HANA model H19811). The salinity (‰) was calculated from EC values according to Golterman et al. [19]. Light penetration, water flow, and turbidity were measured by using the Secchi disc, current meter (Milwaukee) and Turbidity meter (Lovibond), respectively. Other parameters such as dissolved oxygen (DO), biochemical oxygen demand (BOD_5), total suspended solids (TSS), total alkalinity (TK), total hardness (TH), calcium (Ca^{+2}), and magnesium (Mg^{+2}) were measured according to APHA [20]. Nutrients were measured as follows: total nitrogen (according to [21], total phosphorus [22]. And reactive silicate [23].

The sample of macrophytes was placed in the plastic sack with little river water and added to each sac 3ml of buffered formalin. For the qualitative study, 10g from each host plant were taken to separate the attached algae by scraping and shaken vigorously [24]. The separation of attached algae from the artificial substrate was done by scrapping [25, 25]. Preservation and sedimention method were used for depositing the attached algae [27], and subsequently prepare slides for algal counting according to methods described by Martinez et al. [28] and Hadi [29].Several references were used for the identification of algae[30-33]. Four biodiversity indices were used in this study (table 1).

Table 1. The used diversity indices in this study

	Index	Equation	Abbreviation	Reference
1	Margalef's Richness (D)	$D = S - 1/InN$	S= Total number of different species N- total number of individuals	[34]
2	Shannon-Weaver (H')	$H' = \sum_{n=1}^{s} Pi\ log2Pi$	S= Total number of species P_i= the proportion of species about the total number of species	[35]
3	Jaccard similarity (S)	$S\% = \frac{a}{a+b+c} x\ 100$	a= the number of species common to both host plants. b= the number of species in the first host plant, but not the second plant. C= the number of species in the second host plant, but not the first plant.	[36]
4	Evenness (J)	$J = \frac{H'}{In\ S}$	H′= the value of Shannon index In S= the total number of species observed	[37]

Results and Discussion

The Baghdad city located in the subtropical desert biome, there is seasonal variation in temperature [38, 39]. The results revealed the significant differences between temperature and both BOD (r=0. 630) (Tables 2). The pH values of the river were ranged from 7.24 to 8.6. This narrow range is characterized features of Iraqi water ecosystems [40]. The river considered as freshwater (EC >2000 and S‰ >0.5) according to APHA [41] and Gupta [42]. TSS values were higher in autumn and winter, and lowest values were in spring and summer.

In agreement with these results [27] reported that mixed culture of *Spirulina* spp., showed a remarkable capacity to degrade the widely used organophosphorus herbicide glyphosate, that served as the sole source of phosphorus for cyanophytal growth. Also, [28] study the tolerance of six cyanophytal strains to the herbicide up to millimolar concentrations. Four strains (*Arthrospira fusiformis*, *Leptolyngbya boryana*, *Microcystis aeruginosa* and *Spirulina platensis*) were able to use the phosphonate as the sole phosphorus (P) source for growth while two strains (*Anabaena* sp., and *Nostoc punctiforme*) EPSP synthase, which is in line with the findings of [29] whom reported that tolerance of *Anabaena variabilis* ATCC 29413 is related to the presence of *A. variabilis* ATCC 29413 is related to the presence of a resistant form of the target enzyme EPSP [30] too.

Table 2. Mean (Standard Error ±SE) values of physicochemical parameters during the study period.

Parameters	Spring		Summer		Autumn		Winter	
	Mean	±SE	Mean	±SE	Mean	±SE	Mean	±SE
Air Temperature°C	29.63 ^{b}	1.09	37.06 ^{a}	0.79	29.92 ^{b}	1.63	11.75 ^{C}	0.63
Water Temperature °C	21.13 ^{c}	0.69	29.13 ^{a}	0.68	23.92 ^{b}	0.52	10.75 ^{d}	0.63
pH	7.53 ^{b}	0.05	7.24 ^{c}	0.08	7.63 ^{b}	0.02	8.28 ^{a}	0.05
Electric Conductivity (EC) µS/cm	223.59 ^{b}	4.6	706.88 ^{a}	10.67	796.67 ^{a}	28.64	660 ^{a}	84.85
Total Dissolved Solids (TDS)mg/l	150.93 ^{c}	2.65	353.13 ^{ab}	4.93	410.83 ^{a}	3.15	327.5 ^{b}	40.08
Salinity(S‰)	0.13 ^{b}	0	0.43 ^{a}	0.01	0.45 ^{a}	0.02	0.4 ^{a}	0.05
Light Penetration (cm)	12.5 ^{a}	1.96	9.0 ^{a}	0.86	11.5 ^{a}	1.73	11.25 ^{a}	1.31
Turbidity(NTU)	34.63 ^{a}	14.86	17.04 ^{ab}	5.45	11.39 ^{ab}	3.48	3.77 ^{b}	2.89
Dissolved Oxygen (DO) mg/l	8.55 c	0.41	7.39 C	0.24	17.0 b	0.79	23.9 a	0.8
Total Suspended Solids (TSS) mg/l	0.03 ^{b}	0	0.06 ^{a}	0	0.08 ^{a}	0.02	0.07 ^{a}	0.01
Total Alkalinity(TK) (mg $CaCO_3$/l)	140.63 ^{bc}	15.63	109.56 ^{c}	5.39	190 ^{b}	4.52	272.5 ^{a}	33.26
Total Hardness (TH) (mg $CaCO_3$/l)	297.5 ^{c}	33.51	315.5 ^{c}	13.74	484.42 ^{b}	23.83	913 ^{a}	39.95
Calcium mg $CaCO_3$/l	84.77 ^{b}	14.24	68.9 ^{b}	2.85	151.12 ^{a}	2.92	179.13 ^{a}	40.15
Magnesium mg $CaCO_3$ /l	51.69 ^{c}	5.47	60.55 ^{bc}	3.58	80.3 ^{b}	4.61	177.68 ^{a}	13.04
Total Nitrogen µg/l	5.58 ^{c}	0.24	15.58 ^{a}	0.78	12.58 ^{b}	1.68	5.31 ^{c}	0.48
Total Phosphorus µg/l	0.12 ^{a}	0.009	0.07 ^{a}	0.02	0.07 ^{a}	0.014	0.13 ^{a}	0.04
Reactive Silicate µg/l	526.2 ^{ab}	15.01	552.95 ^{a}	5.31	466.95 ^{b}	14.1	334.72 ^{c}	50.92

Different letters mean significant, otherwise are not significant

These variations caused by soil washing by rains and a water level of the river, as well as, the geological features [1]. Turbidity values were ranged from 3.77 NTU in winter to 34.63 NTU in spring. Light penetration (LP) and water flow (WF) were varied as follows: 9.00-12.50 and 0.05-0.12 m/min in summer and spring for LP and winter and autumn for WF, respectively (Table 2) . The DO in all the study period revealed a good aeration status in the river. BOD values were ranged from 201mg/l in spring to 11.04mg/l in summer, these results caused by the high degree of the temperature in the summer and the pollution level in the river, as well as, its inverse relationship with DO [43]. Wetzel [1] mentioned that the highest level of the water table and condense aquatic plants have the role to reduce the organic contents.

The Iraqi water ecosystems characterized as alkaline water and this due to its bicarbonate contents [44]. The river was very hard (297.50-913.00 mg $CaCO_3$/l). Ca^{+2} and Mg^{+2} concentrations were as follows: 86.90- 179.13mg/l (in summer and winter) and 51.69-177.68mg/l (in spring and winter), respectively. Total phosphorus concentration was less than 5µg/l which indicated that the river considered as ultra-oligotrophic throughout the study period [1, 45]. Total nitrogen concentration revealed that the river was between oligotrophic and mesotrophic system [46]. Reactive silicate ranged from 334.72 µg/l in winter to 552.98 µg/l in summer. Higher concentrations of silicate are well known in Iraqi ecosystems that the silicate concentration found in water stream more than an algal requirement and also, due to the alkaline features of these ecosystems [40, 47].

A temporal variation of the total number of epiphytic algae and also among the different used substrates (natural and artificial) was recorded (Table 3).

Table 3. Mean total number of epiphytic algae (individual x10^4 individual/ g WW) and standard error (±SE) during the study period.

Host plant		Spring	Summer	Autumn	Winter
C.demersum	Mean	$6.25\times10^{4\ b}$	16.58×10^{4a}	14.47×10^{4a}	$11.09\times10^{4\ ab}$
	±SE	0.9×10^4	11.5×10^4	1.7×104	1.7×10^4
H. verticillata	Mean	9.58×10^{4a}	5.76×10^{4a}	8.57×10^{4a}	10.08×10^{4a}
	±SE	0.5×10^4	0.7×10^4	1.05×10^4	2.02×10^4
Artificial substrates	Mean	$7.6\times10^{4\ c}$	11.91×10^{4ac}	26.68×10^{4a}	$19.46\times10^{4\ ab}$
	±SE	1.2×10^4	0.5×10^4	0.57×10^4	5.1×10^4

Different letters mean significant, otherwise are not significant

The total number of epiphytic algae on artificial substrates ranged from 7.6x10^4individual/g WW in spring 2013to 26.86x10^4individual/g WW in Autumn, 2013. The total number of Epiphytic algae differed among the natural substrate as follows: on *C. demersum* ranged was 6.25x104 individual/ g WW in Spring to 16.58x 10^4 individual/ g WW in Summer and for *H. verticillata* was 5.7x10^4 individual/ g WW in Summer to 10.08x10^4individual/ g WW in winter (Figure2).

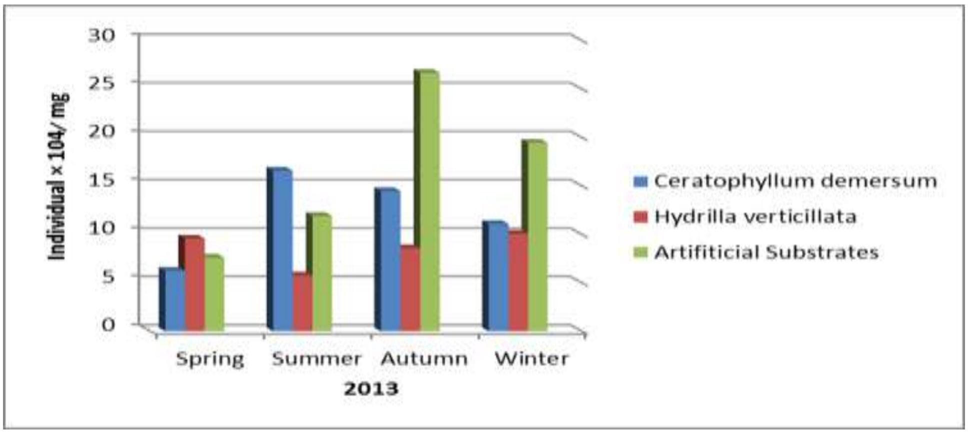

Fig. 2. Seasonal variation of the total numbers of Epiphytic algae on the studied substrate in Tigris River during the study period

A significant variation among seasons were noticed in the algal community on an artificial substrate. This result might be due to the suitable environmental factors for algae in autumn such as moderate temperature during this season and the availability of nutrients in contrast with other seasons. Also, the results showed different total numbers among the main algal groups; Bacillariophyceae (Diatoms) was dominant throughout the study period (Figure 3). This diatoms dominance was very known in Iraqi aquatic ecosystems [48], these algae have the ability to tolerate environmental alteration and

stress [13, 49]. The second abundance algal groups were Cyanophyceae and followed by Chlorophyceae. This abundance might be due to the ability of Cyanophyceae to tolerate the high temperature and the pH values alteration, furthermore, its ability to produce toxins and store the nitrogen and phosphorus [49].
The *C. demersum* was ranked the second substrate (natural substrate) regarding the importance as quantitative terms of algae after an artificial substrate (Figure 2). The total number of epiphytic algae ranged from 6.25×10^4 individual/ g WW in spring to 16.58×10^4 individual/ g WW in summer. A significant difference noticed among the seasons in a total number of attached algae on it ($P<0.05$) expect between summer and autumn (Table 3). The total number of algae was raised upon *C. demersum*in summer that it might be due to the long daylight period, light intensity and availability of nutrient due to decomposition [18]. Meanwhile, this host plant characterized by their leafy bodies which make it availability natural substrate for algal growth and diversity [50, 51]. Also, a variation in the total number of algal groups noticed on this host plant.

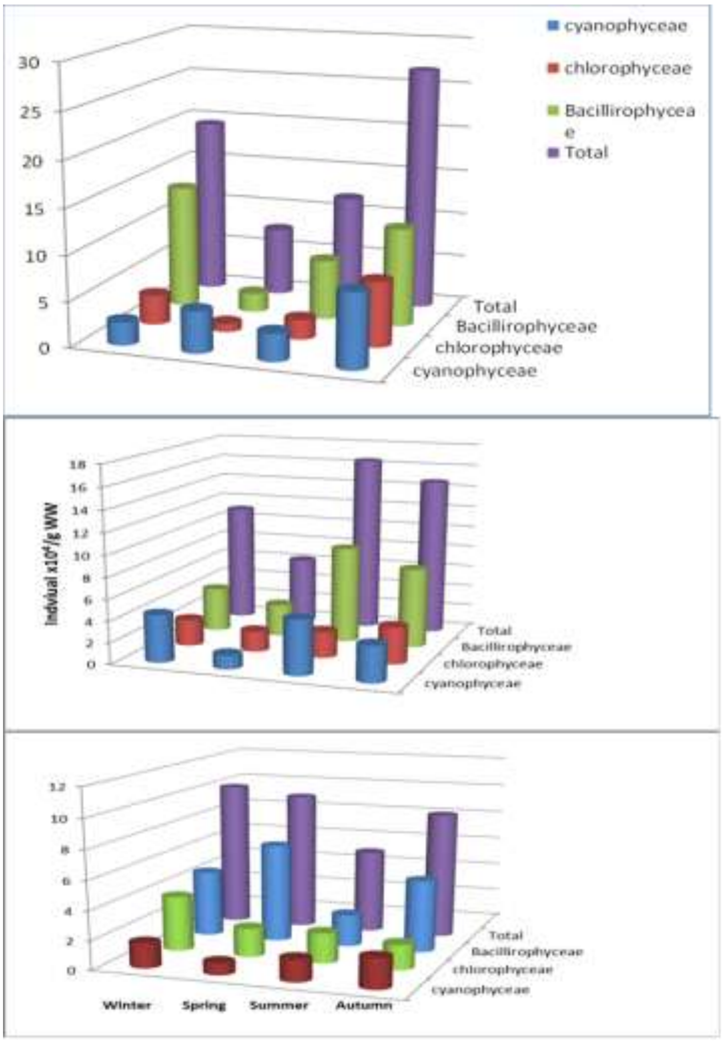

Fig. 3. Total number of the main groups of epiphytic algae on the studied host during the studied sessions. A= artificial substrate, B= *C. demersum*, C= *H. verticillata*

The second host plant (*H. verticillata*) was recorded the lowest total number of attached algae in contract with other substrates in this study (figure 2). The highest number of attached algae on this host plant recorded in winter. This plant is an invasive species and recorded in the southern Iraqi marshes by Alwan [5]. Its abilities to grow in low light intensity and

have the capacity to compete for other native macrophytes which these reasons make it exist in the river more than other macrophytes [52,53]. Figure 4 illustrated the variation in the total number of attached algal groups on this plant.
A significant variation noted between all the used substrate in spring (Table 3). Also, there was a significant difference between the total number of the attached algae on *C. demersum* in spring and both summer and autumn. The total number of attached algae on an artificial substrate revealed a significant difference between winter and spring, as well as, between spring and autumn. While, on *H. verticillata* was no significant differences between seasons (Figure 2).
The highest value of richness was 4.73 on the *C.demersum* in autumn, and the lowest value was 1.3 on the artificial substrate (Figure 4). These results depend on the characterized features of the host plant and the availability of the suitable environmental factors for growth [32]. All the substrates in this study recorded the lowest values in richness index in spring while the highest values were recorded in autumn except for *H. verticillata* in summer (Table 3).

Shannon- Weaver index values on different substrates as follows*:* 2.39-3.03 for an artificial substrate in spring and winter, respectively, 1.89- 4.22 for *C.demersum*in spring and summer, respectively (Figure 4). While for *H. verticillata* was 3.06 in spring and 3.59 in summer (Table 3). These index values higher than recorded by Kassim et al. [54] in the Tigris river on *C.demersum*.

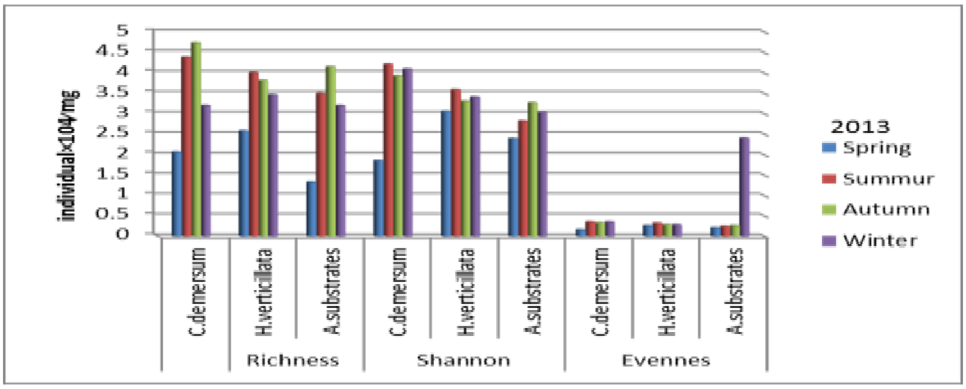

Fig. 4. Seasonal variation in biodiversity index of epiphytic algae on the studied substrate in Tigris River during the study period.

Shannon- Weaver index values on different substrates as follows*:* 2.39-3.03 for an artificial substrate in spring and winter, respectively, 1.89- 4.22 for *C.demersum*in spring and summer, respectively (Figure 4). While for *H. verticillata* was 3.06 in spring and 3.59 in summer (Table 3). These index values higher than recorded by Kassim et al. [54] in the Tigris river on *C.demersum*.
Evenness index was recorded in different values for the studied substrates. The natural substrates were recorded higher values than artificial substrate (Figure 4). The lowest values for all substrates were recorded in spring while the higher values in natural substrates in summer. The sequences of the 3i203n0dex values were as follows: *C.demersum*>*H. verticillata*> an artificial substrate in all seasons except in spring was as *H. verticillata*> an artificial substrate> *C.demersum*. These results related to the rise of the identified alg20al species and their proportion stability, which they contribute to the convergence of evenness index significantly [55].
The results of the Jaccard similarity index revealed that the highest value recorded (46%) between summer and autumn for artificial substrate and the lowest value (10%) obtained between winter and summer for *C.demersum*. The highest values (30%) of the index were recorded between *H. verticillata* and artificial substrate. These results might be related to the geometry of the substrate and its nature, as well as, the effect of environmental factors [47, 56].

Conclusions

The benthic algae in this study preferred the artificial substrate which recorded the high quantity of benthic algae compares with natural substrate. Diatoms were the dominant group of algae in all types of the studied substrates. According to the results of this study, it's important to take into consideration the quantity of the benthic algae on the artificial substrate when the primary production measured of the lotic ecosystem.

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