Journal of Coastal Life Medicine

journal homepage: www.jclmm.com

Original article doi: 10.12980/jclm.4.2016j6-10

Ecological and biochemical analyses of the brown alga *Turbinaria ornata* (Turner) J. Agardh from Red Sea coast, Egypt

Mohamed Ali Deyab, Fatma Mohamed Elnabawy Ward*

Department of Botany, Faculty of Science, Damietta University, Damietta, Egypt

ARTICLE INFO

Article history:
Received 8 Jan 2016
Received in revised form 18 Jan 2016
Accepted 17 Feb 2016
Available online 2 Mar 2016

Keywords:
Turbinaria ornata
Heavy metals
Macroalgae
Phaeophyta
Phytochemical composition
Red Sea

ABSTRACT

Objective: To study ecological parameters and biochemical composition of brown seaweed, *Turbinaria ornata* (*T. ornata*) collected from Hurghada shores, Red Sea coast of Egypt during September, October and November, 2015.

Methods: *T. ornata* and its associated seaweeds were collected, identified and their abundances were estimated. Water of collection site was analyzed physicochemically as well as qualitative and quantitative analyses of phytoplankton. *T. ornata* was analyzed for protein, total carbohydrate, lipids, alginic acid, agar, pigments, minerals and heavy metals.

Results: The results showed that macroalgal species recorded along Hurghada shores belong to Phaeophyta, Rhodophyta and Chlorophyta. At collection site, the moderate temperature, slight alkaline pH, low turbidity, high dissolved oxygen and valuable nutrient content of saline water exerted the massive growth of *T. ornata* with maximum abundance (24%) during October. The phytoplankton community was quite diverse with a maximum numbers of taxa (104.2×10^8 cell/L) recorded during October. Analysis of *T. ornata* alga powder showed that high soluble carbohydrate (2.80 ± 0.10 mg/g dry/weight) and chlorophyll c ($0.001\,7 \pm 0.000\,1$ mg/g fresh weight) contents were recorded during September; while high contents of protein (37.70 ± 0.60 mg/g dry weight), lipids (3.10 ± 0.06 mg/g dry weight), polysaccharides (agar and alginates), carotenoids ($0.016\,0 \pm 0.000\,4$ mg/g fresh weight), minerals and heavy metals were recorded during November.

Conclusions: The study revealed that physicochemical analyses of water were varied slightly during the three months and suitable for the growth of *T. ornata*. It contains high amount of most biochemical constituents during October.

1. Introduction

The marine environment in which seaweed exists possesses great taxonomic diversity and synthesis metabolites with varied structure with interesting biological activities for food material and medical applications. Marine macroalgae grow in harsh environments, with variable water currents, a restricted nutrient supply, and high concentrations of salt, sunlight, and oxygen, which may foster the production of natural compounds[1]. The growth and chemical composition of marine macroalgae are significantly affected by their environmental conditions. The physico-chemical parameters determine the occurrence of particular seaweeds at particular place at particular season[2]. Hence the study of the physico-chemical characters of marine ecosystem is also very important. Marine organisms, especially algae are rich sources of natural bioactive products. Seaweeds have come up step by step starting with using them as food, later as raw material for industrial, medicinal, pharmaceutical and cosmetic purposes[3], associated with their high contents of protein, polysaccharides, minerals, essential fatty acids, carotenoids and vitamins which are related to several environmental factors[4,5]. Marine algae contain more than 60 trace elements in a concentration, which are much higher than that in terrestrial plants and have various pharmacological activities[6]. The Red Sea is a rich and diverse ecosystem. The rich diversity is in part due to the 2 000 km of coral reef extending along its coastline. Over 500 species of seaweeds have been recorded in the Red Sea[7]. *Turbinaria ornata* (*T. ornata*) belongs to kingdom: Chromista, subkingdom: Harosa, infrakingdom: Heterokonta, phylum: Ochrophyta, subphylum: Phaeista, infraphylum: Limnista, superclass: Fucistia, class: Phaeophyceae, order: Fucales, family:

*Corresponding author: Fatma Mohamed Elnabawy Ward, Department of Botany, Faculty of Science, Damietta University, Damietta, Egypt.
Tel: 01060743175
E-mail: fatma2028@yahoo.com
Foundation Project: Supported by the Department of Botany, Damietta University, and Damietta, Egypt as a part of MSc programme (Grant No. 110/2012).
The journal implements double-blind peer review practiced by specially invited international editorial board members.

Sargassaceae, genus: *Turbinaria*, species: *T. ornata*[8]. This alga is a perennial brown alga native to coral reef ecosystems in tropical areas of the Pacific and Indian Ocean[9]. Biochemical composition of *T. ornata* reveals their suitability to be a good source for human consumption[10].

Brown algae are economically valuable seaweeds as a source of raw material for the extraction of polysaccharides (*e.g.* alginate, laminaran, cellulose and fucoidan)[11]. *T. ornata* was distinctive for its high content of alginic acid[12]. Alginic acid is a complex carbohydrate polymer consisting of D-mannuronic acid and L-guluronic acid residues linked by 1–4 positions. Cell walls of brown seaweeds are made of cellulose and alginic acid. Alginates are comprised of two uronate sugars and the salts of mannuronic and guluronic acid derived from alginic acid[13].

Therefore the present study was undertaken to investigate ecological parameters and biochemical composition of one commonly occurring brown seaweed. *T. ornata* was collected from Hurghada shores, Red Sea coast of Egypt during September, October and November, 2015.

2. Materials and methods

2.1. Study area

Collection site was along the semi-exposed shores of Hurghada, Red Sea coast of Egypt (Figure 1). It is one of the most important places of interest for algal growth in Egypt. The latitude is 27°13' N and the longitude is 33°45' E.

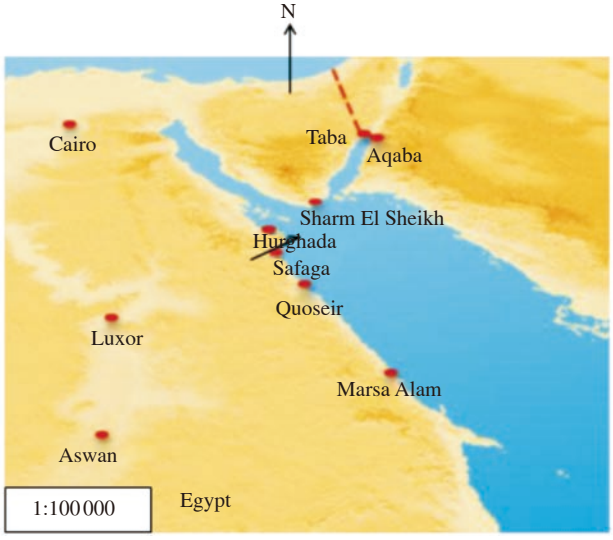

Figure 1. Map of Red Sea coast of Egypt showing the study site of Hurghada shores.

2.2. Sampling

Water samples, *T. ornata* and its associated seaweeds were collected biweekly during low tide in September, October and November, 2015 (Figure 2). Macroalgae were collected using five quadrates (1 m × 1 m) to record the cover of each species according to Londo-scale[14] and weighing the fresh weight for quantitative assessment of abundance. Identification and nomenclature of macroalgae were based on the following reference[15] and verified with illustrations by De Széchy *et al.*[16].

Figure 2. Natural habit of *T. ornata*.

2.3. Physico-chemical analysis of water

Temperature, pH, turbidity and salinity were measured directly at the sampling site. Dissolved oxygen was measured in laboratory according to Manivasakam[17]. Biochemical oxygen demand was determined by the method described by American Public Health Association[18]. SO_4^- and NO_3^- were determined according to Trivedy and Goel[19]. Alkalinity was determined according to Kumar and Shailaja[20]. NH_4^+ was determined according to Dawes *et al.*[21]. Inorganic PO_4^- were determined according to American Public Health Association[18]. Minerals: K, Ca and Na were determined using flame photometer (Department of Botany, Faculty of Science, Damietta University, Egypt) according to Sudharsan *et al.*[22]. Five heavy metals: Cu, Co, Zn, Fe and Mn in water sample were determined using Perkin-Elmer-2380 atomic absorption spectroscopy (Department of Chemistry, Faculty of Science, Damietta University, Egypt) as described by Sudharsan *et al.*[22].

2.4. Qualitative and quantitative analyses of phytoplankton

The preserved water samples were examined microscopically after preparation according to the procedures described by Main *et al.*[23]. Identification of present algal taxa (species and varieties) was made according to Botes[24] and Guiry and Guiry[8]. Finally, the number of each phytoplankton variety was counted by using haemocytometer (Department of Botany, Faculty of Science, Damietta University, Egypt)[25].

2.5. Preparation of T. ornata samples

T. ornata was washed with tap water and distilled water to remove all the salt on the surface. The seaweed was shade dried then kept in an oven 60 °C for 4 h. Finally, it was ground and stored in polyethylene bags at room temperature.

2.6. Biochemical analysis of T. ornata

The protein content of *T. ornata* was determined

spectrophotometrically according to Bradford[26]. Total carbohydrate was determined spectrophotometrically using anthrone method according to Hedge and Hofreiter[27]. Lipids content was determined according to Van *et al.*[28]. Alginic acid was determined by the Na alginate method according to Sari-Chmayssem *et al.*[29] and by the Ca alginate method according to Dawes[30]. Agar was extracted from *T. ornata* as described by Roberts *et al.*[31]. Pigments (chlorophyll a, chlorophyll c and carotenoids) were extracted according to the method described by Kumar *et al.*[32], determined and calculated according to the formula of Lichtenthaler and Buschmann[33], and Jeffrey and Humphrey[34].

The dried algal materials were digested according to Awheda *et al.*[35]. Minerals (Na, Ca and K) were determined in the digested samples using flame photometer (Department of Botany, Faculty of Science, Damietta University, Egypt) according to Sudharsan *et al.*[22]. Determination of heavy metals (Cu, Co, Zn, Fe and Mn) in digested algal sample was made directly on each final solution using Perkin-Elmer 2380 atomic absorption spectroscopy (Department of Chemistry, Faculty of Science, Damietta University, Egypt) as described by Sudharsan *et al.*[22]. The concentration of each element was determined with calibration curve and expressed in mg/g dry weight.

$$\text{Element (mg/g dry weight)} = \text{C (mg/L)} \times \frac{1}{1\,000} \times \frac{\text{Total volume}}{\text{Volume used}} \times \frac{1}{\text{Dry weight}}$$

where C (mg/L) is concentration of element obtained from the calibration curve.

2.7. Statistical analysis of results

All determinations were performed at least in triplicate. All data were expressed in terms of mean ± SD and analyzed for variance and the least significant difference (LSD) using One-way ANOVA ($P < 0.05$). SPSS version 18.0 for windows was used in this study

3. Results

3.1. Collection of macroalgal materials

At Hurghada shores, Red Sea coast of Egypt, the quadrates results indicated that the total covering flora was about 28%, 25% and 20% of quadrate meter in September, October and November respectively. The macroalgal species recorded along the study area were Phaeophyta, 7 species as the main group [*T. ornata, Cystoseira trinodis* (*C. trinodis*), *Cystoseira myrica* (*C. myrica*), *Sargassum muticum* (*S. muticum*), *Hormophysa cuneiformis* (*H. cuneiformis*), *Dictyota dichotoma* (*D. dichotoma*) *and Padina minor* (*P. minor*)]; Rhodophyta, 4 species [*Laurencia papillosa* (*L. papillosa*), *Digenea simplex* (*D. simplex*), *Jania rubens* (*J. rubens*) and *Corallina officinalis* (*C. officinalis*)] and Chlorophyta, 2 species [*Caulerpa racemosa* (*C. racemosa*) and *Halimeda tuna* (*H. tuna*)] and seagrass [*Halophila johnsonii* (*H. johnsonii*)]. Abundance of *T. ornata* was 13.0%, 24.0% and 21.5% during September, October and November. Figures 3–5 summarize abundance of *T. ornata* and its associated seaweeds during September, October and November.

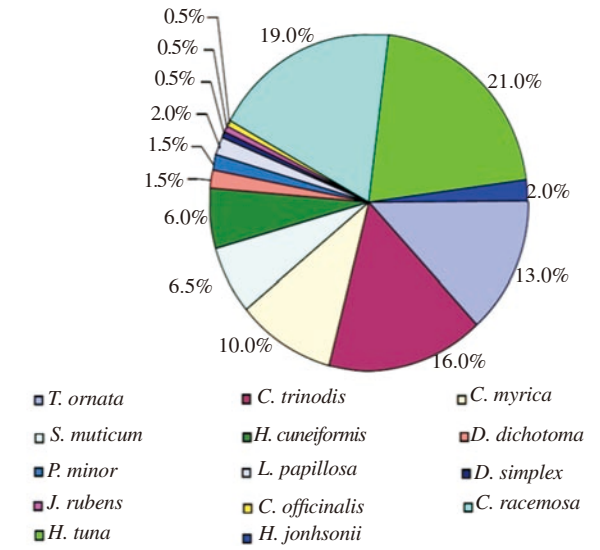

Figure 3. Abundance of *T. ornata* and its associated seaweeds during September.

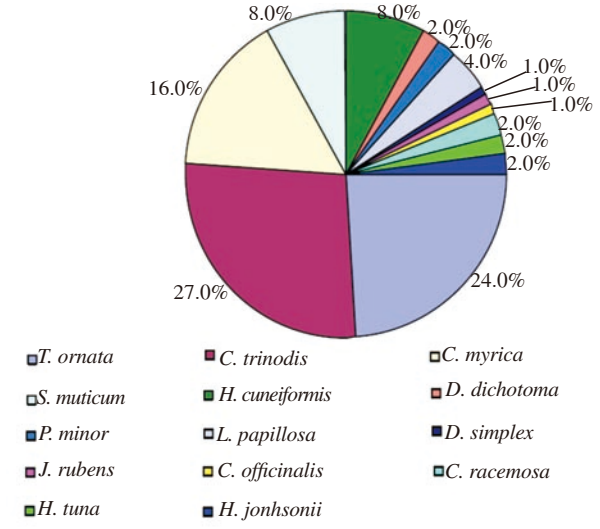

Figure 4. Abundance of *T. ornata* and its associated seaweeds during October.

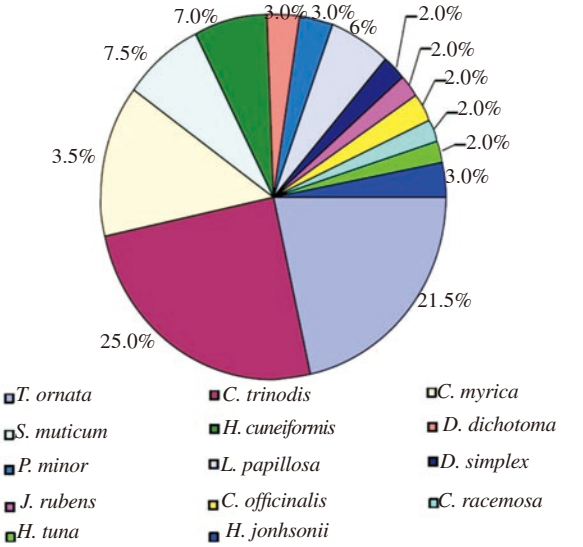

Figure 5. Abundance of *T. ornata* and its associated seaweeds during November.

3.2. Physicochemical analysis of water

Table 1 shows that collected water has moderate temperature, slight alkaline pH and low turbidity. Dissolved oxygen and biochemical oxygen demand concentrations were relatively stable with a mean value of (12.600 ± 0.147) mg/L and (1.633 ± 0.010) mg/L respectively. The relative high concentrations of NO_3^-, SO_4^-, NH_4^+ and inorganic PO_4^- at the study site were recorded during September of (0.070 ± 0.001) mg/L, (310.000 ± 2.510) mg/L, (0.800 ± 0.010) mg/L and (0.290 ± 0.010) mg/L respectively. K and Ca concentrations of water had relatively the same values but Na concentrations were recorded the highest values. Higher minerals content was found during September and lower during November. Concentrations of each heavy metal did not vary much during September, October and November for the study site, while significant variation was recorded with the type of heavy metal. The physicochemical analysis of water indicated that most parameters were significantly changed along the study period ($P < 0.05$).

Table 1
Physicochemical analysis of water during September, October and November.

Parameters	September	October	November
Temperature (°C)	27.000 ± 0.410	25.000 ± 0.620	24.000 ± 0.410
pH	7.800 ± 0.050	8.300 ± 0.060	8.400 ± 0.050
Turbidity (NTU)	13.900 ± 0.060	13.600 ± 0.050	13.500 ± 0.040
TA (meq/L)	2.900 ± 0.060	2.600 ± 0.050	2.300 ± 0.050
Salinity (g/L)	41.000 ± 0.040	40.400 ± 0.040	40.100 ± 0.050
DO (mg/L)	12.300 ± 0.150	12.600 ± 0.170	12.900 ± 0.120
BOD (mg/L)	1.700 ± 0.010	1.600 ± 0.010	1.600 ± 0.010
NO_3^- (mg/L)	0.070 ± 0.001	0.070 ± 0.001	0.050 ± 0.001
SO_4^- (mg/L)	310.000 ± 2.510	280.000 ± 2.540	290.000 ± 2.330
NH_4^+ (mg/L)	0.800 ± 0.010	0.700 ± 0.010	0.700 ± 0.010
PO_4^- (mg/L)	0.290 ± 0.010	0.280 ± 0.010	0.270 ± 0.020
Total K (mg/L)	401.400 ± 3.900	392.200 ± 2.200	379.100 ± 3.100
Total Ca (mg/L)	423.000 ± 2.100	412.000 ± 2.500	399.000 ± 3.900
Total Na (mg/L)	12510.000 ± 4.300	12453.000 ± 5.030	12200.000 ± 5.100
Total Cu (mg/L)	1.120 ± 0.020	1.070 ± 0.030	1.030 ± 0.020
Total Co (mg/L)	0.620 ± 0.010	0.590 ± 0.020	0.540 ± 0.010
Total Zn (mg/L)	0.560 ± 0.003	0.510 ± 0.003	0.470 ± 0.004
Total Fe (mg/L)	0.550 ± 0.020	0.490 ± 0.020	0.460 ± 0.010
Total Mn (mg/L)	0.330 ± 0.005	0.290 ± 0.003	0.280 ± 0.005

TA: Total alkalinity; DO: Dissolved oxygen; BOD: Biochemical oxygen demand.

3.3. Qualitative and quantitative analyses of phytoplankton

A total of 23 species belong to 18 different algal genera identified at the study station during September, October and November. The phytoplankton community was quite diverse with Bacillariophyta (14 genera, 19 taxa) as the main algal group, followed by Chlorophyta (2 genera, 2 taxa), Cyanophyta (1 genus, 1 taxon) and Dinophyta (1 genus, 1 taxon). As shown in Table 2, the maximum numbers of taxa (104.2×10^8 cell/L) were recorded during October, while the minimum number of taxa (95.2×10^8 cell/L) was recorded during September.

3.4. Biochemical analysis of T. ornata

As shown in Table 3, high contents of protein and lipids in *T. ornata* were (37.70 ± 0.60) mg/g dry weight and (3.10 ± 0.06) mg/g dry weight respectively during November. While high content of soluble carbohydrates was (2.80 ± 0.10) mg/g dry weight during September. *T. ornata* content of alginic acid was varied according to the used method. Higher alginate content in *T. ornata* was found during November and lower during September. The maximum alginate in *T. ornata* was (393.00 ± 2.50) mg/g dry weight (39.3%) by Ca alginate method. The lowest alginate content of *T. ornata* was (198.00 ± 2.50) mg/g dry weight (19.8%) by Na alginate method. Alginates content in *T. ornata* showed significant (LSD at 0.01 level) variation during the three months. Agar content in *T. ornata* ranged from (117.00 ± 2.50) mg/g dry weight (11.7%) was recorded during November and (83.00 ± 1.50) mg/g dry weight (8.3%) was recorded during September. Significant (LSD at 0.01 level) variation was observed in agar content of *T. ornata*.

Table 2
Qualitative and quantitative analyses of phytoplankton in collected water in September, October and November.

Phytoplankton		Number of cell/L × 10^8		
		September	October	November
Bacillariophyceae	*Pinnularia viridis*	2.0	2.0	2.4
	Navicula salinarum	2.0	2.1	2.6
	Navicula distans	-	1.9	2.5
	Navicula fusea	1.8	1.8	-
	Pleurosigma elongatum	3.9	4.2	4.2
	Gyrosigma acuminatum	3.7	4.0	5.2
	Cocconeis costata	3.9	4.0	3.9
	Fragillaria capucina	2.0	2.1	2.3
	Synedra undulate	1.8	1.9	2.4
	S. ulna var. aequalis (kutz)	-	2.0	2.6
	Tabellaria fenestrata	3.6	3.8	4.2
	Diatoma elongatum	1.6	1.7	2.1
	Achnanthes andicola	5.5	6.0	6.1
	Amphora acuta	3.7	4.1	-
	Amphora commutata	3.8	4.0	4.3
	Nitzschia closterium	7.8	7.9	8.5
	Peridinium sp.	4.0	4.2	4.1
	Cyclotella ocellata	5.4	5.6	6.2
	Cyclotella comta	-	2.0	2.2
Chlorophyceae	*Chlorella zofingiensis*	33.0	33.0	37.5
	Chlorella subprotumidum	1.9	2.0	2.6
Cyanophyceae	*Spirulina subsalsa*	1.8	2.1	2.9
Dinophyceae	*Proprocentrum micans*	2.0	1.8	2.5
	Total number	95.2×10^8	104.2×10^8	111.3×10^8

Table 3
Biochemical analysis of *T. ornata*. mg/g dry weight.

Parameters	Protein	Carbohydrate	Lipid	Na-alginate	Ca-alginate	Agar
September	32.30 ± 0.70	2.80 ± 0.10	2.50 ± 0.05	198.00 ± 2.50	306.00 ± 3.20	83.00 ± 1.50
October	35.40 ± 0.60	2.40 ± 0.10	2.60 ± 0.05	242.00 ± 3.40	378.00 ± 3.10	102.00 ± 1.20
November	37.70 ± 0.60	2.20 ± 0.20	3.10 ± 0.06	253.00 ± 2.80	393.00 ± 2.50	117.00 ± 2.50

Chlorophyll and carotenoid content have been presented in Table 4. Pigments analysis showed that content of chlorophyll a of *T. ornata* was higher than carotenoids. *T. ornata* contained a very small content of chlorophyll c. Content of chlorophyll a of *T. ornata* did not vary much during September, October and November with a mean value (0.0193 ± 0.0002) mg/g fresh weight. Chlorophyll c and carotenoids contents were varied along the three months. Chlorophyll c in *T. ornata* exhibited a range from (0.0009 ± 0.0001) to (0.0017 ± 0.0001) mg/g fresh weight, while carotenoids exhibited a range from (0.0120 ± 0.0006) to (0.0160 ± 0.0004) mg/g F. weight. The relative high content of *T. ornata* of chlorophyll c and carotenoids were recorded during September and November respectively.

Table 4
Pigments analysis of *T. ornata*. mg/g fresh weight.

Pigments	Chlorophyll a	Chlorophyll c	Carotenoids
September	0.0190 ± 0.0001	0.0017 ± 0.0001	0.0120 ± 0.0006
October	0.0200 ± 0.0001	0.0011 ± 0.0001	0.0130 ± 0.0002
November	0.0190 ± 0.0003	0.0009 ± 0.0001	0.0160 ± 0.0004

The relative high contents of heavy metals (Cu, Co, Zn, Fe and Mn) and minerals (Na, Ca and K) in *T. ornata* were recorded during

November, while the relative low contents were recorded during September (Table 5). Minerals in *T. ornata* were varied slightly between (24.11 ± 0.11) mg/g dry weight to (36.10 ± 0.16) mg/g dry weight for Ca and Na at the study site during September and November respectively. Na, Ca and K were varied significantly (LSD at 0.01 level) during study period. The contents of all heavy metals in *T. ornata* were higher than their contents in the surrounding water. Heavy metals content showed significant (LSD at 0.01 level) variation during September, October and November according to the type of heavy metal.

Table 5
Elements content of *T. ornata* during September, October and November. mg/g dry weight.

Elements	September	October	November
Na	28.91 ± 0.15	30.67 ± 0.11	36.10 ± 0.16
Ca	24.11 ± 0.11	27.16 ± 0.15	29.40 ± 0.15
K	32.44 ± 0.73	33.78 ± 0.64	35.20 ± 0.70
Cu	0.65 ± 0.01	0.71 ± 0.01	0.75 ± 0.01
Co	0.85 ± 0.01	0.88 ± 0.01	0.94 ± 0.01
Zn	0.64 ± 0.01	0.65 ± 0.01	0.69 ± 0.01
Fe	0.46 ± 0.01	0.47 ± 0.01	0.49 ± 0.01
Mn	0.51 ± 0.01	0.55 ± 0.01	0.58 ± 0.01

4. Discussion

In our study, the macroalgal community was quite diverse with Phaeophyta (7 species, 6 genera) as the main group, Rhodophyta (4 species, 4 genera), Chlorophyta (2 species, 2 genera) and sea grass (Halophila)[36]. Recorded 57 species of seaweeds (18 belong to Phaeophyta, 18 species belong to Chlorophyta and 21 species belong to Rhodophyta) inhabit in the Egyptian Red Sea coasts at Hurghada. The decrease of the total species number of seaweeds and variation of seaweeds composition in the same study area may be due to pollution, manual removal of seaweeds vegetation and the concrete structures which greatly changed the habitat of macroalgae[37]. *T. ornata* varied in its quantitative abundance. The highest growth of *T. ornata* was 19 kg fresh weight/m^2 (24%) during October followed by 17 kg fresh weight/m^2 (21.5%) during November and 10.3 kg fresh weight/m^2 (13%) during September. This agreed with Nazni and Renuga[38] who concluded that the highest growth of *T. ornata* was found in October on the semi-exposed shore in Thailand.

In our study, temperature of collected site was changed in a small range [from (24.00 ± 0.41) to (27.00 ±0.41) ℃] during study period. Temperature affects the growth stages of macroalgae as tide level. Temperature is considered as a vital environmental factor controlling the growth and metabolic rates of marine organisms, especially on metabolic processes of photosynthesis and respiration in macroalgae[39]. Dissolved oxygen in water affects the oxidation-reduction state of nutrients and diversity of aquatic biota[17]. The physicochemical analysis of studied water indicated that all parameters were more or less stable and relative suitable for algal growth. This may be due to the relative stability of ecological parameters of Red Sea during study period. The relative decrease of temperature, total alkalinity, salinity from September to November were parallel with Egyptian climate where water evaporation decreased and ran off beginning during October and increased during November[4]. Low degrees of turbidity, high dissolved oxygen and low biochemical oxygen demand may be due to low water pollution and low wave action at the study area. Unpolluted natural water contain only minute amount of NO_3^-[19]. Low content of PO_4^-, NO_3^- and NH_4^+ in studied water indicated the oligo-mesotrophic status of water.

The relative high protein [(37.70 ± 0.60) mg/g dry weight] and lipids [(3.10 ± 0.06) mg/g dry weight] in *T. ornata* were recorded during mature stage of alga in November, while the relative high soluble carbohydrate [(2.80 ± 0.10) mg/g dry weight] was recorded during the high growth rate of alga in September. The relative low content of protein, lipids and carbohydrate in *T. ornata* may be due to the relative low trophic (oligo-mesotrophic) status of the Red Sea water. Natural products such as Na-alginate, Ca-alginate and agar contents in *T. ornata* were lower than that obtained by Chee *et al.*[40] in *T. ornata* of Port Dickson, Peninsular Malaysia. This was due to difference in wave action and possibly other environmental parameters that can affect algal growth. The results were in agreement with Chee *et al.*[40] that the Ca-alginate method gave higher percentage yield of alginic acid than the Na-alginate method.

Chlorophyll a content of *T. ornata* was relatively stable during study period. The decrease of chlorophyll c content in *T. ornata* was alternate with the increase of carotenoids content gradually from September, October and November. This may be due to the pigment content was influenced by environmental parameters. This was in parallel with increasing the maturation state of *T. ornata*[38]. Minerals analysis of *T. ornata* showed that higher contents of Na, K and Ca were recorded during November. Ca was higher than that recorded by Zubia *et al.*[41]. This high concentration of Ca may be due to the geographic changes of sediment and shores.

The results showed that heavy metals contents in *T. ornata* were higher during November than their contents during October and September. This may be due to the long-term variations of heavy metals level in the marine environment. Metal content in macroalgae depends on various biological (*e.g.* species phylogeny, thalus morphology, growth strategy, generation) and environmental factors (*e.g.* concentration and availability of elements in water, interactions between chemical elements, temperature, season, salinity, pH, light intensity, area geology)[42]. Heavy metals contents in surrounding water were relatively decreased from September to November, which was mainly due to relative decrease of temperature, salinity and other environmental factors. The environmental status of an area, temperature, pH, the level of salinity, the waves of the sea, sun light and season changes, all affect the level of heavy metals concentration. The considerable high heavy metals content in *T. ornata* than that found in sea water may be due to algal accumulation of heavy metals. This may be attributed to the presence of charged polysaccharides and alginic acid in the cell walls of brown seaweeds[43].

Thus results of the present study concluded that physicochemical analyses of the studied water at Hurghada (Red Sea coast) were varied slightly during the three months. This indicated that water were oligo- or mesotrophic. Biochemical analysis of *T. ornata* showed its content of vital components (protein, carbohydrates, lipids, minerals and metals) and economic components (alginates and agar). *T. ornata* can be regarded as an under-exploited source of health benefit molecules for food processing and nutraceutical industry.

Conflict of interest statement

We declare that we have no conflict of interest.

Acknowledgments

The authors would like to express their deep thanks and gratitude to all participants in this study for their valuable advice, guidance and unlimited support throughout the whole work. This study was supported by a grant from the Department of Botany, Damietta University, and Damietta, Egypt as a part of MSc programme (Grant No. 110/2012).

References

[1] Poore AG, Graba-Landry A, Favret M, Sheppard Brennand H, Byrne M, Dworjanyn S. Direct and indirect effects of ocean acidification and

warming on a marine plant-herbivore interaction. *Oecologia* 2013; **173**: 1113-24.

[2] Jung KA, Lim SR, Kim Y, Park JM. Potentials of macroalgae as feedstocks for biorefinery. *Bioresour Technol* 2013; **135**: 182-90.

[3] Chennubhotla VSK, Rao MU, Rao KS. Commercial importance of marine macro algae. *Seaweed Res Utiln* 2013; **35**(2): 118-28.

[4] Jeeva S, Antonisamy JM, Domettila C, Anantham B, Mahesh M. Preliminary phytochemical studies on some selected seaweeds from Gulf of Mannar, India. *Aisan Pac J Trop Biomed* 2012; **2**(Suppl 1): S30-3.

[5] Polat S, Ozogul Y. Seasonal proximate and fatty acid variations of some seaweeds from the northeastern Mediterranean coast. *Oceanologia* 2013; **55**: 375-91.

[6] Dhargalkar VK. Uses of seaweeds in the Indian diet for sustenance and well-being. *Sci Cult* 2014; **80**: 192-202.

[7] Gouda EA. Obstacles to sustainable tourism development on the Red Sea Coast. *Int J Innov Educ Res* 2015; **3**: 165-76.

[8] Guiry MD, Guiry GM. AlgaeBase. Galway: World-wide electronic publication; 2015. [Online] Available from: http://www.algaebase.org/search/species/detail/?species_id=W2e71be855867c31e [Accessed on 21st December, 2015]

[9] Liu F, Pang S. Mitochondrial genome of *Turbinaria ornata* (Sargassaceae, Phaeophyceae): comparative mitogenomics of brown algae. *Curr Genet* 2015; **61**: 621-31.

[10] Viswanathan S, Nallamuthu T. Extraction of sodium alginate from selected seaweeds and their physiochemical and biochemical properties. *Int J Innov Res Sci Eng Technol* 2014; **3**: 10998-1003.

[11] Kadam SU, Tiwari BK, O'Donnell CP. Extraction, structure and biofunctional activities of laminarin from brown algae. *Int J Food Sci Technol* 2015; **50**: 24-31.

[12] Subramanian V, Ganapathy K, Dakshinamoorthy B. FT-IR, ^{1}H-NMR and ^{13}C- NMR spectroscopy of alginate extracted from *Turbinaria decurrens* (Phaeophyta). *World J Pharm Pharm Sci* 2015; **4**: 761-71.

[13] Pawar SN, Edgar KJ. Alginate derivatization: a review of chemistry, properties and applications. *Biomaterials* 2012; **33**: 3729-305.

[14] Londo G. The decimal scale for releves of permanent quadrates. In: Knapp R, editor. *Sampling methods and taxon analysis in vegetation science.* Hague: Handbook of Vegetation Science; 1984, p. 45-9.

[15] De Clerck O, Guiry MD, Leliaert F, Samyn Y, Verbruggen H. Algal taxonomy: a road to nowhere? *J Phycol* 2013; **49**: 215-25.

[16] De Széchy MTM, Guedes PM, Baeta-Neves MH, Oliveira EN. Verification of *Sargassum natans* (Linnaeus) Gaillon (Heterokontophyta: Phaeophyceae) from the Sargasso Sea off the coast of Brazil, Western Atlantic Ocean. *Check List* 2012; **8**: 638-41.

[17] Manivasakam N. *Industrial effluents origin, characteristics, effects analysis and treatment*. Coimbatore: Sakthi Publications; 1997.

[18] American Public Health Association. *Standard methods for the examination of water and wastewater*. Washington DC: American Public Health Association; 1992, p. 18.

[19] Trivedy RK, Goel PK. *Practical methods in ecology and environmental science*. Karad: Environmental Publications; 1987.

[20] Sunil Kumar M, Shailaja R. *Water studies: methods for monitoring water quality.* Bangalore: Center for Environmental Education; 1998.

[21] Hughes DE, Wimpenny JWT, Lloyd D. The disintegration of micro-organisms. In: Norris JR, Ribbons DW, editors. *Methods in microbiology.* Vol. 5B. London: Academic Press Inc; 1971, p. 4.

[22] Sudharsan S, Seedevi P, Ramasamy P, Subhapradha N, Vairamani S, Shanmugam A. Heavy metal accumulation in seaweeds and sea grasses along southeast coast of India. *J Chem Pharm Res* 2012; **4**: 4240-4.

[23] Main C, Doll C, Bianco C, Greenfield DI, Coyne KJ. Effects of growth phase, diel cycle and macronutrient stress on the quantification of *Heterosigma akashiwo* using qPCR and SHA. *Harmful Algae* 2014; **37**: 92-9

[24] Botes L. *Phytoplankton identification catalogue: Saldanha Bay, South Africa, April 2001*. London: IMO, Global Ballast Management Programme; 2003.

[25] El-Din SMB, Hamed AHS, Ibrahim AN, Shatta AKM, Abo-Sedera SA. Phytoplankton in irrigation and draining water canals of East Nile Delta of Egypt. *Global J Biol Agric Health Sci* 2015; **2**: 56-60.

[26] Bradford MM. A rapid and sensitive method for the quantification of microgram quantities of protein utilizing the principle of protein-dye binding. *Anal Biochem* 1976; **72**: 248-54.

[27] Hedge JE, Hofreiter BT. *Carbohydrate chemistry.* 17th ed. New York: Academic Press; 1962.

[28] Van Wychen S, Ramirez K, Laurens LML. Determination of total lipids as fatty acid methyl esters (FAME) by *in situ* transesterification. Golden: National Renewable Energy Laboratory; 2015, p. 5. [Online] Available from: http://www.nrel.gov/docs/fy16osti/60958.pdf [Accessed on 21st December, 2015]

[29] Sari-Chmayssem N, Taha S, Mawlawi H, Guégan JP, Jefti J, Benvegnu T. Extracted and depolymerized alginates from brown algae *Sargassum vulgare* of Lebanese origin: chemical, rheological, and antioxidant properties. *J Appl Phycol* 2015; doi: 10.1007/s10811-015-0676-4.

[30] Dawes CJ. *Marine botany*. New York: John Wiley and Sons Inc; 1981.

[31] Roberts DA, Paul NA, Dworjanyn SA, Hu Y, Bird MI, de Nys R. *Gracilaria* waste biomass (*sampah rumput laut*) as a bioresource for selenium biosorption. *J Appl Phycol* 2015; **27**: 611-20.

[32] Kumar P, Ramakritinan CM, Kumaraguru AK. Solvent extraction and spectrophotometric determination of pigments of some algal species from the shore of puthumadam, Southeast Coast of India. *Int J Oceans Oceanogr* 2010; **4**: 29-34.

[33] Lichtenthaler HK, Buschmann C. Chlorophylls and carotenoids: measurement and characterization by UV-vis spectroscopy. In: Wrolstad RE, Acree TE, Decker EA, Penner MH, Reid DS, Schwartz SJ, et al., editors. *Current protocols in food analytical chemistry*. New York: John Wiley and Sons; 2001, p. 1-8.

[34] Jeffrey SW, Humphrey GF. New spectrophotometric equations for determining chlorophylls a, b, c1 and c2 in higher plants, algae and natural phytoplankton. *Biochemie und Physiologie der Pflanzen* 1975; **167**: 191-4.

[35] Awheda I, Ahmed AY, Smida FA, Elwahaishi SS, Fahej MAS. Determination of heavy metals, Mn, Fe, Co, Cu, Zn, Cd and Pb in *Sargassum vulgar* and *Pterocladia capillacea* Marine Algae in Libyan Coast of Al-Khoms. *Int J Adv Res* 2015; **3**: 384-9.

[36] Negm SNM. Ecological, biological and phytochemical studies on some marine algae from the Red Sea coast of Egypt [dissertation]. Cairo: Cairo University; 1988.

[37] Abouhend AS, El-Moselhy KM. Spatial and seasonal variations of heavy metals in water and sediments at the Northern Red Sea coast. *Am J Water Resour* 2015; **5**: 39-42.

[38] Nazni P, Renuga. Nutrient composition of the selected brown seaweeds from Mandapam Coastal Regions; Southeast Coast of India. *Int J Agric Food Sci* 2015; **2**: 38-42.

[39] Zou DH, Gao KS. The photosynthetic and respiratory responses to temperature and nitrogen supply in the marine green macroalga *Ulva conglobata* (Chlorophyta). *Phycologia* 2014; **53**: 86-94.

[40] Chee SY, Wong PK, Wong CL. Extraction and characterisation of alginate from brown seaweeds (Fucales, Phaeophyceae) collected from Port Dickson, Peninsular Malaysia. *J Appl Phycol* 2011; **23**: 191-6.

[41] Zubia M, Payri CP, Deslandes E, Guezennec J. Chemical composition of attached and drift specimens of *Sargassum mangarevense* and *Turbinaria ornata* (Phaeophyta: Fucales) from Tahiti, French Polynesia. *Bot Mar* 2014; **6**: 562-71.

[42] Wasi S, Tabrez S, Ahmad M. Toxicological effects of major environmental pollutants: an overview. *Environ Monit Assess* 2013; **185**: 2585-93.

[43] Murugaiyan K, Narasimman S. Elemental composition of *Sargassum longifolium* and *Turbinaria conoides* from Pamban Coast, Tamilnadu. *Int J Res Biol Sci* 2012; **2**: 137-40.