Pak.J.Bot., 26(2): 203-213,1994.

STUDIES ON THE FRESHWATER ALGAE OF MAKKAH AREA, SAUDI ARABIA

M.E.E. EL-NAGGAR

Department of Botany,
Faculty of Science, University of Mansoura, Mansoura, Egypt.

Abstract

The composition and distribution of fresh-water algae in Makkah area of Saudi Arabia were investigated. Of a total number of 107 species recorded, 37 belong to Cyanophyta, 34 to Bacillariophyta, 29 to Chlorophyta, 6 to Euglenophyta and 1 to Pyrrhophyta. The most common genera were *Oscillatoria* (14 spp.), *Spirogyra* (8 spp.), *Navicula* (7 spp.), *Nitzschia* (7 spp.), *Gloeocapsa* and *Euglena* (each with 4 spp.) where *Merismopedia elegans, Oscillatoria amphibia* and *O. tenuis* were most widely distributed. Al-Taif locality had 64 algal species. Among the dominant algae in Makkah area, the green alga *Oedogonium gracilis* was chemically investigated and was characterized by having high amount of ash and protein, 17 amino acids where glutamic acid, alanine, aspartic acid and leucine were predominant.

Introduction

Saudi Arabia, located in the arid province of the world (Thornthwaite, 1948) has hot and dry climate where the amount of rainfall vary greatly in different regions and in different years (Zahran, 1983). A review of the literature has revealed that the algal flora of Saudi Arabia is relatively little known and most of these studies dealt with the marine algae (Forskal, 1775; Borgesen, 1932; Mohsen, 1972; Aleem, 1978, 1981; Dowidar *et al.*, 1978; Mandura *et al.*, 1987). Little attention has been given to the fresh-water algae where Abdel-Mohsen & Bokhary (1969a,b) studied the distribution and periodicity of fresh-water algae in Riyadh area and revealed some physiological aspects concerning 4 algae grown under controlled conditions. Seasonal variations in soil, algal microflora and their activiies in Riyadh region were examined by Abu-Zinada & El-Hussaeini (1975). Khoja *et al.*, (1984) studied the algal flora of Al-Kharj area (Riyadh region) and Al-Baha area (Southern region).

Apart from the work of Mohsen & Al-Amoudi (1989) on the occurrence of Cyanobacteria and their possible toxicity in Makkah province, the information on the taxonomic composition and distribution of algae in Makkah area is lacking. The present studies were therefore, initiated to describe the composition and distribution of algal vegetation in Makkah area. Since *Oedogonium gracilis* was found predominant in Bahrah locality, its phytochemical studies was also carried out.

Material and Methods

Makkah area is located in the western region of Saudi Arabia where the variations in geology, topography and environmental conditions are quite evident (Abdel-

Rahman & Balegh, 1974; Zahran, 1983). Four localities in Makkah area (Fig.1) selected for study were:

(i) Bahrah (33 km west of Makkah),
(ii) Al-Jumum (28 km north of Makkah),
(iii) Al-Sharayi (30 km east of Makkah) and
(iv) Al-Taif (80 km south of Makkah).

The water in these localities except Al-Taif, is pumped from wells and stored temporarily in concrete reservoirs for irrigation. Algal samples were taken from such reservoirs and irrigation ducts for study from October 1988 to May 1989. Algal materials were preserved in 4% formalin and microscopically examined. At the time of sampling, water temperature was recorded and pH values determined by portable Beckman pH meter (model 72). Diatoms were examined in the cleaned frustules preparation (Jouse *et al.*, 1949) with a suitable quantity of mountant of sufficiently high refractive index (R.I. = 1.66) (Hanna, 1949; Eliashev, 1957). The algal taxa were identified according to Zabelina *et al.*, (1951), Popova (1955), Desikachary (1959), Prescott (1962, 1978), Philipose (1967) and Aleem *et al.*, (1982).

According to El-Naggar (1977), the frequency of occurrence of various organisms are expressed by number where:

1. Single1-5 individuals in all preparations.
2. Very rare 10-15 individuals in all preparations.
3. Rare 25-30 individuals in all preparations.
4. Common 1-5 individuals in each row of cover slip.
5. Very common 5-15 individuals in each row of cover slip.
6. Mass or abundant 1 or more individuals in each microscopic field.

Phytochemical Evaluation: Samples of *Oedogonium gracilis* (Wittr) Triffany were collected from Bahrah during January, 1989, purified, dried in air and ground to fine powder. Water soluble ash, acid insoluble ash, protein, crude fibre and total lipids were determined according to Humphries (1956), Ward & Johnson (1962), Anon., (1975) and El-Naggar (1980).

Phytochemical screening was carried out using the procedure of Wall *et al.*, (1954). Total amino acids were extracted according to Block & Bolling (1951) which were identificied and estimated using Amino Acid Analyzer Beckman 118 CL.

Results

Algal Vegetation: The total number of algal taxa in Makkah area was composed of 107 species and 47 genera which comprised of 37 species and 14 genera in Cyanophyta, 34 species and 14 genera in Bacillariophyta, 29 species and 15 genera in Chlorophyta, 6 species and 3 genera in Euglenophyta and one species and one genus in Pyrrhophyta (Table 1). The most common genera were *Oscillatoria* (14 speices), *Spirogyra* (8 species), *Navicula* (7 species), *Nitzschia* (7 species), *Gloeocapsa* and *Euglena* (each with 4 species). The composition and distribution of algal flora in Makkah area differed greatly from site to site (Tables 1 & 2).

Bahrah Locality: Thirty one species of algae belonging to Cyanophyta, Chlorophyta and Bacillariophyta were recorded in Bahrah locality. It is evident from Table 2 that

Table 1. Frequency of ocurrence of fresh water algae at different localities of Makkah area. (1 = single, 2 = very rae, 3 = rare, 4 = common 5 = very common, 6 = mass)

Algal taxa	Locality	Bahrah	Al-Jumum	Al-Sharayi	Al-Taif
	pH	7.9	8.2	8.6	6.6
	Water temp. °C	31	28	30	20
Cyanophyta					
Synechococcus elongatus Naeg		2	-	3	1
Chroococus minor (Kutz.) Naeg.		-	3	-	-
C. minutus (Kutz.) Naeg.		1	2	4	-
C. giganteus W. West.		4	-	-	-
Merismopedia elegans A. Braun		3	2	3	4
M. tenuissima Lemm.		5	-	-	-
Gloeocapsa alpina (Naeg.) emend		4	-	-	1
G. aeruginosa (Carm.) Kutz.		-	-	3	-
G. punctata Naeg.		-	-	-	1
G. sp.		-	-	-	1
Aphanocapsa rivularis (Garm.) Rabenhorst		4	2	-	-
A. grevillei (Hass.) Rabenhorst.		2	-	-	-
Microcystis aeruginosa Kutz.		-	-	-	1
Aphanotheca gelatinosa (Henn.) Lemm.		-	2	-	-
Gomphosphaeria aponina Kutz.		3	-	-	1
G. lacustris Chodat		-	-	-	3
Coelosphaerium dubium Grunow		2	-	-	-
Oscillatoria amphibia Ag.		3	2	1	1
O. okeni Ag.		4	-	-	-
O. limsoa Ag.		1	-	-	4
O. tenuis Ag.		1	2	3	1
O. angusta Koppe		-	2	-	-
O. sancta (Kutz.,) Gomont		-	3	-	-
O. acutissima Kutferath		-	-	-	1
O. angustissima West & West		-	-	-	3
O. amoena Gomont		-	-	-	2
O. limnetica Lemm.		-	-	6	-
O. terebriformis (Ag.) Elenk emend		-	2	2	2
O. rubescens De Cand		-	-	3	-
O. sp. 1		-	-	3	-
O sp. 2		-	-	2	-
Spirulina princeps (W. & W) West		-	3	1	1
Lyngbya major Meneghini		3	-	2	-
L. martensiana Meneghini		-	3	-	4

Table 1 (Cont'd)

Algal taxa	Locality	Bahrah	Al-Jumum	Al-Sharayi	Al-Taif
	pH	7.9	8.2	8.6	6.6
	Water temp. ^{o}C	31	28	30	20
L. sp.		-	-	1	-
Anabaena sp.		4	-	-	-
Aphanizomenon flos-aquae (L.) Ralfs		5	-	5	-
Chlorophyta					
Chlamydomonas globosa Snow		2	-	-	5
Shroederia setigera (Schroed) Lemm.		-	-	-	1
Ankistrodesmus falcatus (Corda) Ralfs.		-	-	-	2
A. falcatus var. tumidus (W.& W.) G.S. West		-	-	-	3
Actinastrum hantzschii Lagerheim		-	-	-	1
Scenedesmus bigugatus (Turbin) Kutz.		-	-	-	3
S. quadricauda Var. quadrispina (Chodat) G.M. Smith		-	-	-	1
Ulothrix tenerrima Kutz.		-	-	-	6
Schizomeris leibleinii Kutz.		-	3	-	-
Stigeoclonium lubricum (Dillw.) Kutz.		-	6	-	-
Cladophora glomerata (L.) Kutz.		-	-	-	6
C. fracta (Dillw.) Kutz.		-	-	-	2
Rhizoclonium heiroglyphicum (C.A. Ag.) Kutz.		-	6	-	3
Oedogonium giganteum Kutz.		-	-	-	1
O. gracilis (Wittr.) Triffany		6	-	4	-
O. sp.		-	-	-	3
Entransia dichloroplasts Press		1	-	-	-
Spirogyra gratiana Transeau		2	-	3	-
S. ellipsospora Transeau		5	-	-	-
S. aequinoctialis G.S. West		4	-	-	-
S. rhizobranchialis Jao		-	-	6	-
S. jucllebornci Schmidle		-	-	-	6
S. micropunctata Transeau		-	-	-	3
S. sp. 1		3	-	-	-
S. sp. 2		-	-	-	3
Mougeotia sp.		-	4	-	-
Cosmarium margaritatum (Lund.) Roy & Biss.		4	-	4	2
C. panamense Presc.		2	3	5	-
C. sp.		3	-	3	-
Euglenophyta					
Euglena proxima Dang.		-	2	-	1

Table 1 (Cont'd)

Algal taxa	Locality	Bahrah	Al-Jumum	Al-Sharayi	Al-Taif
	pH	7.9	8.2	8.6	6.6
	Water temp. ^{o}C	31	28	30	20
E. minuta Prescott		-	-	1	-
E. gracilis Klebs		-	-	1	-
E. oxyuris var. minor Prescott.		-	-	1	-
Phacus accuminatus Stokes		-	2	-	-
Trachelomonas robusta Swirenko		-	-	-	1
Pyrrhophyta					
Stylodinium globosum Klebs		-	-	-	3
Bacillariophyta					
Cyclotella meneghiniana Kutz.		-	5	2	1
C. comta (Ehr.) Kutz.		-	-	-	3
C. comta var. paucipunctata Grun		-	-	-	1
Stemphanodiscus astraea (Ehr.) Grun		-	2	-	3
S. hantzschii Grun		-	-	-	2
Cocconeis placentula Ehr.		-	-	-	2
C. pediculus Ehr.		-	-	-	1
Achanthus coarctata Breb.		-	-	-	4
Fragilaria brevistriata Grun.		-	-	-	3
Asterionella formosa Hass.		-	-	-	3
Synedra ulna (Nitzch) Ehr.		-	-	-	5
S. nitzschoides Grun		-	-	-	3
Stauroneis anesps Ehr.		-	2	-	-
Navicula pygmea Kutz.		3	-	-	4
N. noruhumbrica A.S.		-	-	1	-
N. radioa Kutz.		-	1	-	-
N. scutum Schamann		-	-	1	1
N. serians Breb.		-	-	-	1
N. lovenii Nov.		-	-	-	1
N. sp.		1	-	-	-
Amphora ovalis Kutz.		-	-	-	4
Cymbella latens Krasske		-	1	-	1
C. cistula (Hemp.) Grun.		-	-	-	1
Gomphonema olivaceum (Lyngb.) Kutz.		2	4	-	-
G. parvulum (Kutz.) Grun		-	3	-	-
G. sp.		-	-	-	3
Gomphoneis herculeans (Ehr.) Cleve.		-	-	-	3
Nitzschia palea (Kutz.) W. Smith		-	3	-	4
N. amphibia Grun		-	-	-	5

Table 1 (Cont'd)

Algal taxa	Locality	Bahrah	Al-Jumum	Al-Sharayi	Al-Taif
	pH	7.9	8.2	8.6	6.6
	Water temp. ^{O}C	31	28	30	20
N. lanceolata W. Sm.		-	-	-	4
N. amphioxys (Ehr.) Grun		-	2	-	-
N. salinicola Aleem & Hust.		-	3	-	1
N. sinuata (W. Sm) Grun.		-	-	-	1
N. sigmoidea (Ehr.) W. Sm.		-	-	-	1

Cyanophyta was most dominant where *Merismopedia tenuissima*, *Aphanizomenon flosaquae* and *Chroococus giganteus* were very common. *Oscillatoria* (4 species) was recorded as highest represented genus (Table 1). In Chlorophyta, *Oedogonium gracilis, Spirogyra ellipsospora, S. aequinoctialis* and *Cosmarium margaritatum* were of common occurence. Bacillariophyta was recorded as least represented division with 4 species.

Al-Jumum Locality: Freshwater algae of Al-Jumum were represented by 28 species and 20 genera belonging to 4 divisions (Tables 1 & 2). Cyanophyta was most dominant (12 species) followed by Bacillariophyta (9 species), Chlorophyta (5 species) and Euglenophyta (2 species). Members of Chlorophyta were quantitatively high. The

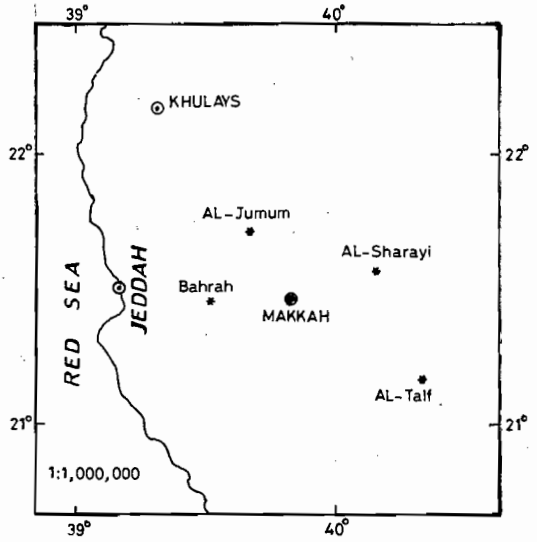

Fig.1. Sketch map of the western region of Saudi Arabia showing the studied localities (*) at Makkah area.

Table 2. Correlation of algal divisions in the freshwater algae of Makka area.

Algol Division	No. of taxa			
	Bahrah	Al-Jumum	Al-Sharayi	Al-Taif
Cyanophyta	17	12	15	17
Chlorophyta	10	5	6	17
Euglenophyta	0	2	3	2
Pyrrhophyta	0	0	0	1
Bacillariophyta	4	9	3	27
Total	31	28	27	64

large standing crop of green algae was mainly due to the preponderance of *Rhizoclonium heiroglyphicum* and *Stigeoclonium lubricum*. In contrast, the productivity of blue green algae was rare or very small throughout the period of study (Table 1). The productivity of Bacillariophyta during the period of investigation was relatively low and a considerable growth was manifested by *Cyclotella meneghiniana* and *Gomphonema olivaceum* (Table 1). The least represented algal division was Euglenophyta (2 taxons), both in terms of quality and quantity (Table 1).

Al-Sharayi Locality: Of the 27 species identified in Al-Sharayi, Cyanophyta (15 species) was dominant with Bacillariophyta and Euglenophyta the least represented divisions (Tables 1 & 2).

Although the species composition of Chlorophyta (6 species) was relatively low, yet they were quantitatively abundant during the period of study. The characteristic species of green algae were *Spirogyra rhizobranchialis*, *Cosmarium panamense, Oedogonium gracilis* and *Cosmarium margaritatum* with high productivity (Table 1). The maximum productivity of blue green algae was mainly due to high growth of *Oscillatoria limnetica, Aphanizomenon flosaquae* and *Chroococcus minutus* (Table 1) where *Oscillatoria* (7 species) was the most frequent genus followed by *Cosmarium* and *Euglena* (each with 3 species).

Al-Taif Locality: Compared with other locations, a significant increase in number of species was recorded in Al-Taif (Tables 1 &2). The algal population of Al-Taif was composed of 64 taxa, belonging to Bacillariophyta (27 species), Cyanophyta (17 species), Chlorophyta (17 species), Euglenophyta (2 species), and Pyrrhophyta (1 species). Although deversity of Bacillariophyta was very high, yet the productivity of algal flora appeared to be mainly dependent on the growth of certain species of green algae viz., *Ulothrix tenuissima*, *Cladophora glomerata*, *Spirogyra jucllebornci* and *Chlamydomonas globosa*. On the other hand, *Spirogyra* (3 species) was the most frequent genus followed by *Scenedesmus, Cladophora, Oedogonium and Ankistrodesmus* (each with 2 species) (Table 1). The productivity of Bacillariophyta was mainly due to the high growth of *Syndra ulna* and *Nitzschia amphibia*, followed by *Achnanthes coarctata*, *Navicula pygmea*, *Amphora ovalis*, *Nitzschia palea* and *N. lanceolata* (Table 1). In

Cyanophyta, the dominating genus was *Oscillatoria* (7 spp.) followed by *Gloeocapsa* (3 species). *Merismopedia elegans, Oscillatoria limosa* and *Lyngbya martensiana* were found in high growth.

PHYTOCHEMICAL EVALUATION

Results of pharmacopoeial constants of *Oedogonium gracilis* showed the highest value of ash (26.4%) with water soluble ash (4.9%), acid insoluble ash (2.0%) followed by protein (19.0%), crude fibre (9%) and lipid (29%). Phytochemical screening of the alga revealed the presence of alkaloids, carbohydrates, glycosides, tannins, saponins and unsaturated sterols where flavonoids were absent. Such similar observation have been made by El-Nagger (1977). In the protein hydrolyzate of the algal material, 17 amino acids were detected where glutamic acid, alanine, aspartic acid and leucine were the principal amino acids; valine, isoleucin, phenylalanine, serine, threonine, glycine and lysine occurred in amounts ranging from 4.3 to 6.9% of the total amino acids and histidine and cystine were present at lower levels as compared with other amino acids.

Table 3. Amino acid composition of *Oedogonium gracilis* (Values expressed as g amino acid/100 g total amino acids

Amino Acid	Concentration
Alanine	11.3
Arginine	3.8
Aspartic acid	10.2
Cystine	0.5
Glutamic acid	13.4
Glycine	6.6
Histidine	0.8
Isoleucine	4.7
Leucine	9.0
Lysine	6.9
Methionine	3.8
Phenylalanine	5.5
Proline	4.0
Serine	5.9
Threonine	6.3
Tyrosine	2.4
Valine	4.3

Discussion

The present study showed a wide range of variations in algal flora of Makkah area. Algal population of Bahrah, Al-Jumum and Al-Sharayi were composed mainly of Cyanophyta which may be attributed to the fact that these organisms flourish under pH value of more than 7 (Lund, 1962; Jurgensen & Davey, 1968; Brock, 1973; Salama & Kobbia, 1982). The pH values in these localities varied between 7.9 and 8.6.

In Al-Taif, Bacillariophyta was the dominant group. Canale & Vogal (1974) reported that with increase in temperature algal groups changed from diatom to green algae and then to blue green algae. The lowest range of temperature was recorded in Al-Taif. Moreover, in this locality, snow and ice are common in the highest places e.g., Al-Hada. This may explain the presence of numerous species of Bacillariophyta. In conformity with this conclusion, El-Naggar (1977) stated that diatoms contributed largest number in habitats of low temperature. It is evident from the present pattern of occurrence and distribution of algal flora that Al-Taif contributed largest number of species (64 spp). This may be attributed to abundant rains and relatively low temperature. The average annual amount of rains received in this locality is 156.2 mm (Zahran, 1983).

During the studies, the total number of Euglenophyta did not exceed 6 species. Moreover, *Euglena* species were not found in Bahrah. The productivity of Euglenophyta was very low throughout the period of study. All members were present as very rare. This limited number of *Euglena* species is a reflection of low pollution of water since *Euglena* flourish in water of high organic matter.

The most widely distributed species in the investigated area were *Merismopedia elegans, Oscillatoria amphibia* and *O. tenuis* followed by *Synechococcus elongatus, Chroococcus minutus, Oscillatoria terebriformis, Spirulina princeps, Cosmarium margaritatum, C. panamense* and *Cyclotella meneghiniana*. Many species recorded in the present study have also been previously reported from similar environments by Aleem *et al.*, (1982), Khoja *et al.*, (1984) and Mohsen & Al-Amoudi (1989).

The amino acid pool of *Oedogonium gracilis* follow the same trends as those reported for *Chlamydomonas* sp., (Chau *et al.*, 1967) and *Scenedesmus obliquus* (El-Ashwah *et al.*, 1976), all of which show alanine, aspartic acid, leucine and glutamic acid to be the predominant amino acids in green algae. A comparison of essential amino acids occurring in *O. gracilis* with those occurring in FAO provisional amino acid pattern (1957) revealed that this alga can be used as a source for production of protein. The FAO pattern represented a good approximation of an ideal protein for human nutrition. According to this pattern the essential amino acids are leucine and isoleucine (9%), lysine (4.2%), methionine (2.2%), cystine (2.0%), phenylalanine (2.8%), threonine (2.8%), valine (4.2%), tryptophane (1.4%) and histidine (0.0%). Besides, the presence of alkaloids, carbohydrates, glycosides, tannins, saponins and sterols indicates that this alga can also be considered among commercial and beneficial algae in feed and medicine.

References

Abdel-Mohsen, A.F. and H.A. Bokhary. 1969a. A study on distribution and periodicity of freshwater algae in Riyadh area as related to environment. *Bull. Fac. Sci. Univ. Riyadh*, 1: 2-57.

Abdel-Mohsen, A.F. and H.A. Bokhary. 1969b. Studies on four freshwater algae from Riyadh area grown under controlled cultural conditions. *Bull. Fac. Sci. Univ. Riyadh*, 1: 58-118.

Abdel-Rahman, A.A. and S.E. Balegh. 1974. Analysis of the climatic elements in Saudi Arabia. *Bull. Fac. Sci. Riyadh Univ.* 6: 98-126.

Abu-Zinada, A.H. and T. El-Hussaeini. 1975. Seasonal variations in soil microflora and their activities in Riyadh region, Saudi Arabia, I.Algae. *Bull. Fac. Sci., Univ. Riyadh*, 7: 1-16.

Aleem, A.A. 1978. Contributions to the study of the marine algae of the Red Sea. III. Marine algae from Obhor, in the vicinity of Jeddah, Saudi Arabia, *Bull. Fac. Sci., K.A.U. Jeddah* 2: 99-118.

Aleem, A.A. 1981. Contributions to the study of the marine algae of the Red Sea. V. New or little known algae from the west coast of Saudi Arabia, *Bull. Fac. Sci., K.A.U., Jeddah*, 5: 1-49.

Aleem, A.A., A.K. Khafaje and B.A. Al-Bassam. 1982. An algal community from hot springs at Al-Qaseem, Saudi Arabia. *Bull. Fac. Sci., K.A.U. Jeddah*, 6: 73-75.

Anonymous, 1975. *Official methods of analysis*. Association of Official Agricultural Chemists. 12th ed. Washington, D.C., USA.

Block, R.H. and D. Bolling. 1951. *The amino acid composition of proteins and foods.* Charles, C. Thomas. Springfield, III.

Borgesen, F. 1932. A revision of Forskal's algae mentioned in flora aegyptiaco-arabica and found in his herbarium in the Botanical Museum of the University of Copenhagen. *Dansk. bot. Ark.*, 8: 15 p, 4 figs.

Brock, T.D. 1973. Evolutionary and ecological aspects of the Cyanophytes In: *The Biology of Blue Green Algae*". (Eds.), Carr, N.G. and B.A. Whitton. University of California Press, Berkeley, California, U.S.A., p. 487-500.

Canale, R.P. and A.H. Vogel. 1974. Effect of temperature on phytoplankton growth. *J. Environ. Eng. Civ. Am. Soc. Civ. Eng.*, 100: 229.

Chau, Y.K., L. Chuecas and J.P. Riley. 1967. The component combined amino acids of some marine phytoplankton species. *J. Mar. Biol. Ass. U.K.*, 47: 543-554.

Desikachary, T.V. 1959. *Cyanophyta. Monographs on algae*. Acad. Press, New York and London, 656 pp.

Dowidar, N.M., S.A. Raheem El-Din, and A.A. Aleem. 1978. Phytoplankton population in the region of Obhor (Jeddah, Saudi Arabia), *Bull. Fac. Sci., K.A.U., Jeddah*, 2: 271-292.

El-Ashwah, E.T., M.M. Abdel-Magid, F.A. Ismail and A.K. Said. 1976. Green algae *Scenedesmus obliquus-3* as food supplement II. Biological evaluation of algal protein. *First Arab Conference of Food Science and Technology*, pp. 145-158.

Eliashev, A.A. 1957. Simple methods to prepare a mounting medium of high refractive index for the diatom analysis. *J. Sci. Res., Ins. Geol.* USSR., 4: 74.

El-Naggar, M.E.E. 1977. *Studies on the algae in Dakahlia area*. M.Sc. Thesis, Fac. Sci. Mansoura Univ., Egypt.

El-Naggar, M.E.E. 1980. *Studies on the natural products of some marine algae.* Ph.D. Thesis. Fac. Sci. Mansoura Univ., Egypt. Anonymous. 1957. *FAO nutritional studies*, series No. 16, Rome.

Forskal, p. 1775. *Flora aegyptiaco-arabica*, Copenhagen 32 CXXV12, 219.

Hanna, G.D. 1949. A sysnthetic resin which has unusual properties. *J. Roy. Micr. Soc.*, 69: 25.

Humphries, E.C. 1956. *Modern methods of plant analyses* (Eds.) K. Paech, and M.V. Tacey. Vol. 1. Springer Verlag, Berlin. p. 468-502.

Jouse, A.P., A.J. Proschkina-Lavrenko and V.S. Sheshukova. 1949. *Diatom analysis* Vol. 1. Gorgeolizdat. Leningard. 239 pp.

Jurgensen, M.F. and C.B. Davey. 1968. Nitrogen-fixing blue-green algae in acid forest and mursery soils. *Can. J. Microbiology*, 14: 1179.

Khoja, T.M., M. Mady and M.I. Hussain. 1984. Freshwater algae from Saudi Arabia, I. Blue-green algae (Cyanobacteria), Chlorophyta and Bacillariophyta. *J. Coll. Sci. King Saud Univ.*, 15: 113-125.

Lund, J.W.G. 1962. Soil algae In: Physiology and Biochemistry of Algae (Ed.) R.D. Lewin, Academic Press, New York, USA. p. 759-766.

Mandura, A.S., S.M. Saifullah and A.K. Khafaji. 1987. Mangrove ecosystem of Southern Red Sea Coast of Saudi Arabia. *Prog. Saudi Biol. Soc.*, 10-165-193.

Mohsen, A.F.A. 1972. Contribution to the marine algal flora of the Red Sea shore bordering Jeddah Zone, (1) Cyanophyta and Rhodophyta, *Bull. Fac. Sci., Riyadh Univ.* 4: 113-133; (2) Phaeophyta, ibid, 135-150; (3) Chlorophyta, ibid, 151-169.

Mohsen, A.F. and O.A. Al-Amoudi. 1989. Occurrence of Cyanobacteria and their possible toxicity. *J.K.A.U. Sci.*, 1: 15-22.

Philipose, M.T. 1967. *Chlorococcales*. Indian Council of Agric. Res., New Delhi. 363 pp.

Popova, T.G. 1955. *Fresh water algae of URSS*. Fasc. 7-Euglenophyta. Pob. "Soretskaa Nauka" Moskow. 282 pp.

Prescott, G.W. 1962. *Algae of the Western Great Lakes Area*. Wm. C. Brown Co. Inc., Dubuque, Iowa, U.S.A., 977 pp.

Prescott, G.W. 1978. *How to know the freshwater algae*. Wm. C. Brown Co. Dubuque, Iowa, 293 pp.

Salama, A.M. and I.A. Kobbia. 1982. Studies on the algal flora of Egyptian soils: II. Different sites of a sector in the Lybian Desert. *Egypt. J. Bot.*, 25: 139-158.

Thornthwaite, C.W. 1948. An approach towards rational classification of climates. *Geog. Rev. London*, 38: 55-94.

Wall, M.B., M.M. Krider, C.R. Kremson, C.R. E-ddy, J.J. Williaman, D.S. Corell and H.S. Gentry. 1954. Steroidal sapogenins. VII. Survey of plants for steroidal sapogenins and other constituents. *J. Pharm. Soc.*, 43: 1.

Ward, G.M. and F.B. Johnson. 1962. *Chemical methods of plant analysis*. Canada Dept. Agric., 10(64): 1.

Zabelina, M.M., I.A. Kiselov, A.I. Proschkina-Lavrenko and V.S. Sheshukova. 1951. *Freshwater algae of URSS*. Fasc. 4-Bacillariophyta. Pob. "Sovetskaa Nauka" Moskow. 488 pp.

Zahran, M.A. 1983. *Introduction to plant ecology and vegetation types of Saudi Arabia*. Scientific Council, King Abdulaziz University, Jeddah. Saudi Arabia, 142 pp.

(Received for Publication 17 August 1993)