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A Comparative Study of Algal Communities on Cultivated and Uncultivated Soils

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Abstract: The algal communities of cultivated land, reclaimed desert and waste land in relation to physico-chemical characters were followed during the study period (1996-1997). Organic carbon, ammonia-N and Phosphate levels of soil samples are the major controlling factors affecting algal growth and distribution of algae in these sites. Also, the diversity of algal species was strongly affected by vegetation seasons. The decrease number of algae in the waste land compared to other soil samples may be due to high salinity of this soil. A positive correlation of algal abundance and diversity (mainly diatoms and green algae) during succession with levels of PO_4-P was observed in reclaimed desert. Blue-green algae were more dominant in the cultivated soil and waste soil than in reclaimed desert.

Key words: Algal communities, cultivated and uncultivated soils

Introduction

In recent years, the reconstruction of long-term environmental changes has become more and more important in ecological studies. Algae have been isolated from soils worldwide, including the Antarctic (Cameron and Devaney, 1970; Curl and Becker, 1970; Broady, 1976, 1979a, b) tropics (Durrell, 1964) and desert regions (Forest ad Weston, 1966; Friedman *et al*., 1967; Garcia Pichel and Belnap, 1996; Flechtner *et al*., 1998). The algal floras of cultivated and uncultivated soils were studied by several investigators (Gonzalves and Gangla, 1949). Pantastico and Suayan (1973) studied algal succession in rice fields in philippines identifying 21 species in four divisions. Chlorophyta, Cyanophyta, Chrysophyta and Euglenophyta. 45 species were identified by Ashley *et al*. (1985) from the top soils of three different vascular plant habitats in the USA.

Cultivated soil supports a more abundant flora of blue-green algae than virgin soils in Africa (Esmarch, 1910; Tiffany, 1951; Trainor, 1978). The heterocystous blue-greens and the most important nitrogen fixing organisms in many agricultural soils (Allison and Morris, 1930), however, non-heterocystous fix nitrogen as well (Stewart, 1973; Gallon, 1980; Kailas *et al*., 1983). In general the diversity of cyanobacteria species in the crust is not very large it is essentially composed of the group LPP (*Lyngbya, Plectonema, Phormidium*; Rippka *et al*., 1979) accompanied by heterocystous form (*Nostoc, Anabaena, Scytonema*), Oscillatoriales and unicellular species. These extremely resistant micro-organisms have been studied in deserts world wide (Lange *et al*., 1992; Johansen, 1993; Verrecchia *et al*., 1995). The most important environmental factors which control algal population in soil are light, humidity, temperature, organic carbon, availability of nutrients and pH value (Hoffmann, 1989; Eldridge and Greene, 1994). The perpose of the present study was to continue to expand the nature of soil algal studies by determining the qualitative and quantitative changes in the algal microflora over an extensive period and to relate these changes to the chemical and physical environment. Three sites with differing vegetation were selected for this study.

Sites description: Twenty surface soil samples (5 replicates from 4 seasons, 1996-1997) were collected from the region of Assint, Egypt (Fig. 1). This semi-arid region are characterized by temporal variability in rainfall. Temperatures are hot in summer and mild to cold in winter. These soils are low in nutrients and minerals. The samples were taken at a depth of 1-3 cm from the cultivated land site I (cultivated by *Medicago sativa* in autumn, winter and spring and by *Zea mays* in summer); reclaimed desert site II cultivated by *Solanum malonquena* and *Hipiscus esculentus* in autumn, winter and spring and by *Sesamum indicum* in summer) and waste land site III.

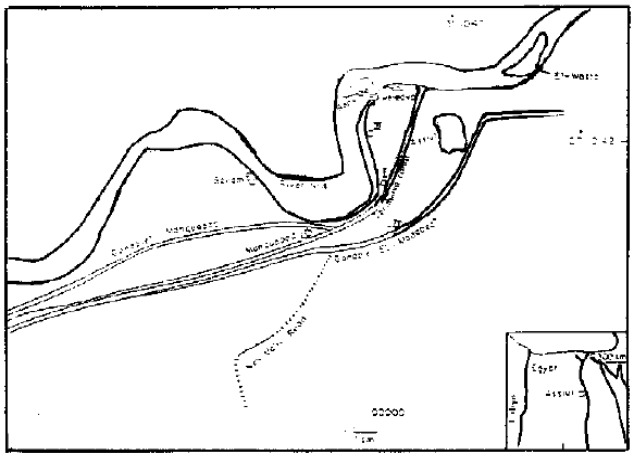

Fig. 1: A map showing the sites surveyed at Assiut area

Materials and Methods

Algal biomass was calculated as phaeophytin-a pigment according to Lynn (1972) using the following formula:

$$\text{Chlorophyll-a (mg m}^{-2}) = \frac{26.73(665b\text{-}750b) \times (665a\text{-}750a) \times v}{A}$$

Where:
665 a = optical density reading at 665 nm after acidification
665 b = optical density reading at 750 nm before acidification
750 a = optical density reading at 750 nm before acidification
665 b = optical density reading at 750 nm before acidification
v = volume in liters of extracting solution
A = Area of the sample

$$\text{Algal biomass (kg ha}^{-1}) = \text{Chlorophyll-a (mg m}^{-2}) \times 3.15$$

The media were used for isolation of cyanobacteria (Rippka and Herdmann, 1993); diatoms (Chu, 1942) while Bold's basal medium (Bischoff and Bold, 1963) was used for isolation of green algae. Wet weight of each of the randomly taken soil samples was determined. Subsequently, 10 ml of liquid medium were added to the test tubes containing the weighed samples. These were

Table 1: Physico-chemical characteristics of various soil habitats (mg. g. soil-1) at Assiut area during the period from November 1996 to October 1997. Each value represents the mean of five replicates ± SE

Sites	Cultivated soil (Site I)				Reclaimed desert (Site II)				Waste Parameters land (Site III)			
	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer
Soil Temp.°C	22.0±1.0	18.0±1.0	25.0±1.0	35.0±1.0	20.0±0.5	17.0±0.5	30.0±1.0	40.0±1.0	27.0±0.5	18.0±1.0	37.0±1.0	37.0±1.0
pH	8.1±0.05	7.0±0.0	7.5±0.15	7.9±0.09	8.8±0.2	7.3±0.1	7.6±0.1	7.9±0.06	8.0±0.6	7.4±0.15	7.6±0.03	7.7±0.02
Total alkalinity	31.0±4.0	15.0±0.09	9.0±0.9	8.0±1.0	65.0±0.0	17.0±2.0	5.0±1.0	10.0±0.4	33.0±2.0	20.0±0.0	13.0±1.0	7.0±0.9
Electric conductivity (μ moh cm^{-1})	95.0±8.0	60.0±1.0	74.0±4.0	103.0±2.0	70.0±6.0	89.0±1.0	72.0±2.0	102.0±11.0	123.0±10.0	76.0±1.0	94.0±10.0	126.±11.0
Moisture content %	9.0±0.6	7.0±0.2	24.0±3.0	30.0±0.5	6.0±1.0	7.0±0.1	4.0±1.0	4.0±0.8	5.0±0.5	3.0±0.6	11.0±0.4	20.0±1.5
Organic carbon	2.1±0.03	2.5±0.4	2.2±0.1	1.4±0.1	1.5±0.1	2.8±0.1	4.7±0.1	3.0±0.5	1.7±0.07	2.3±0.1	2.8±0.1	7.4±0.1
Cl^{-}	66.0±5.0	50.0±1.0	79.0±9.0	32.3±1.5	86.3±7.6	43.6±0.5	51.0±1.7	70.0±6.0	64.0±2.5	29.0±2.3	52.0±1.0	62.0±0.1
SiO_3^{-}	44.0±5.0	44.0±3.0	61.0±3.0	41.0±0.1	59.0±3.0	67.0±2.0	57.0±1.0	51.0±2.0	41.0±2.0	40.0±3.0	51.0±7.0	45.0±5.0
NO_3N	33.0±1.0	10.0±3.0	24.0±3.0	16.0±4.0	14.0±4.0	9.0±1.0	27.0±1.0	17.0±3.0	26.0±3.0	5.±1.0	6.0±1.0	4.0±1.0
Amm. N^{-}	0.63±0.03	10.8±0.6	10.6±1.6	11.2±0.87	0.53±0.17	6.5±0.51	3.1±0.5	4.26±0.28	0.56±0.1	7.2±0.1	8.1±1.2	1.7±06
$PO_4^{-}P$	9.0±0.1	15.8±1.0	57.6±2.0	41.0±4.0	21.0±3.0	12.4±0.5	80.0±5.0	10.1±1.0	16.0±2.0	13.0±1.0	55.0±5.0	47.0±8.0
SO_4^{-}	39.0±1.0	26.0±6.0	44.0±1.0	26.0±1.0	38.0±1.0	16.0±1.0	36.0±1.0	30.0±1.0	33.0±0.0	22.0±3.0	29.0±3.0	12.0±1.0
Ca^{+2}	13.3±2.8	5.2±0.2	6.5±0.5	3.5±0.5	11.3±0.5	3.2±0.2	5.0±0.0	3.6±0.5	15.0±1.0	8.2±2.0	8.0±0.0	3.5±0.5
Mg^{+2}	14.0±1.0	20.0±1.0	43.0±3.0	8.0±0.3	5.0±0.5	16.0±0.7	15.0±2.0	38.0±0.3	51.0±1.0	19.0±0.6	9.0±3.0	4.4±0.3
K^{+}	1.2±0.07	0.9±0.05	1.3±0.1	1.8±0.07	0.68±0.04	1.1±0.1	2.4±0.16	3.05±0.17	1.67±0.22	1.39±0.32	1.33±0.36	3.8±0.41
Na^{+}	8.7±0.6	8.5±0.5	5.0±1.0	7.5±0.5	1.7±0.5	7.0±1.0	4.0±2.0	6.7±0.5	9.3±0.5	8.3±0.6	9.1±0.3	14.5±1.5

Table 2: The total algal biomass (kg ha^{-1}) counts (colonies x 103 g^{-1}) of soil algae and the percentage of four algal group at the sites surveyed during the period from November 1996 to October 1997. Each value represents the mean of five replicates ± SE

Sites	Cultivated soil (Site I)				Reclaimed desert (Site II)				Waste Parameters land (Site III)			
	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer
Total algal biomass	8.5±0.9	2.3±0.1	5.3±0.1	2.4±0.3	8.1±0.1	2.6±0.3	1.4±0.1	0.14±09	5.8±0.3	0.2±01	2.8±0.2	0.38±0.05
Total algal counts	31.3±2.8	9.3±1.2	5.1±0.9	14.2±0.2	10.8±1.1	11.4±1.1	51.9±3.7	27.2±2.1	3.1±0.9	3.5±0.5	14.3±0.3	5.6±0.7
Chlorophyta	20.9±1.3	4.2±0.1	1.6±0.1	11.5±0.5	1.8±0.1	3.2±0.1	7.7±0.5	1.7±0.2	2.5±0.1	2.9±0.1	2.7±0.1	3.4±0.07
%	52.1±43	45.6±1.0	32.1±2.0	80.1±3.6	13.9±0.9	29.6±0.8	14.4±0.8	6.9±0.7	82.2±2.8	79.2±2.7	38.8±0.7	63.2±1.4
Cyanophyta	1.1±0.1	1.3±0.1	2.1±0.3	1.5±0.3	0.93±0.1	2.3±0.1	27.5±3.1	1.5±0.2	0	0.55±0.01	7.2±0.5	2.3±0.06
%	5.5±0.3	15.7±1.0	39.1±6.0	12.1±2.1	10.3±0.9	20.4±0.8	52.7±4.5	5.9±0.7	0	20.9±0.27	35.5±3.4	36.8±1.2
Bacillariophyta	9.2±1.3	3.9±0.7	1.4±0.1	1.2±0.1	8.1±0.7	5.6±0.5	15.2±1.9	24.0±1.1	0.56±03	0	4.4±0.3	0
%	42.8±4.3	38.6±7.0	27.9±2.0	6.9±0.7	75.7±6.3	49.9±4.0	30.6±3.0	87.3±0.8	17.9±0.1	0	25.7±2.0	0
Euglenophyta	0	0	0	0	0	0	1.6±0.1	0	0	0	0	0
%	0	0	0	0	0	0	3.3±0.2	0	0	0	0	0

Table 3: Occurrence remarks of algal species collected from cultivated land (Site I), recliamed desert (Site II) and waste land (Site III) during the study period. (4 = abundant, 3 = frequent, 2 = scarce and 1 = rare)

Algal Taxa	Cultivated and waste land sites											
	I				II				III			
	A	B	C	D	A	B	C	D	A	B	C	D
Chlorophyta												
Actinastrum hantzschii Lagerh		1										
Ankistrodesmus convolutus (Nag.) Rab		2			2	2	2		2			
Botryococcus braunii Kutz	3	3			3	3				3		3
Chlamydomonas cylindrica Chod				2				2				2
C. debaryana Gorosch		1	1									
C. reinhordtii Dang		1							1			
Chlorella kessleri Fott and Novak	3		3	3		3		3	3	3		3
Chlorococcum humicola (Nag)				2		2	2					2
Chlorosarcinopsis mior Groover and Bold	1								1			
Coelastrum microscopicum Nag	1											
Crucigenia fenestrata Schmidle		2				2			2			
C. rectangularis (Nag.) Kom						1						
Desmococcus virids (Ag.) Brand			1					1				
Dictyosphaerium sp.									1			
Eudorina elegans Ehr.	2			2	2							
Gleocystis ampla (Kutz.) Lug.					1							
Gongosira incrustans (Reinsch) Schmidle		1										
Oocystis bispora Nag.	2	2									2	
O. boreg Snow	3		3		3					3	3	3
O. tainoensis Kom									1			
Panadorina morum Bory	1					1						
Protosiphan botryoides Klebs	1			1								
Scenedesmus armatus Chod	1				1							
S. crassus Chod				1								
Sphaerocystis schroeteri Chodat										1		
Tetracystis isobilateralis Brown and Bold	2				2				2	2		
Ulothrix zonata (Weber and Mohr) Kutz		1										1
Total	12	8	4	6	7	8	2	4	5	6	2	6
Bacillariophyta												
Achnanthes fexella (Kz.) Brun.							1					
A. hauckiana Grunow						2		2				
A. lanceolata (Breb). Grun. Cland Grun		2				2		2		2		
A. limentica (Kutz)						1						
A. natalensis Cholonoky							1					
A. ovalis (Kutz) Kutz							1					
A. ribardnii (Kutaz) Kutz							2	2				
Aulacoseiva italica (Her.) Simonsen					1							
Bacillaria paradoxa Gmel. Hustedt							2	2				
Cocconeis placentua (Ehr.) Cl								1				
Cyclotella lagerhemii (Kutz)				1								
Diatomella balfouriana Grev.							1					
Diatoma elongatum (Lyngb) Agardh							1					
Eucocconeis flexella (Kutz) Cl.							1					
Fragilaria vaucheriae (Kg.) Boye Pet.							1					
Hantzschia amphioxys (Ehr.) Grun., Cl.	4	4		4	4	4	4	4				
Naviscula bicapitala Cleve	1						1					
N. byalosirella Hustedt.	1											
N. elginensis Gred. Ralfs							1					
N. pseudoxigue Cholonky.								1				
N. soluta Hustedt.							1					
N. tenelloides Hust. Nach. Hustedt.							1					
N. tuscula Ehrenberg					1							
Nitzschia aerophila Hustedt	1				1							
N. amphibia Grun					1							
N. candemnata Hustedt								1				
N. dubia W. Smith									1			
N. fontifuga Cholnoky						1						
N. forofica Cholnoky					2		2	2				
N. frequens Hustedt		2			2	2						
N. fundii Hustedt		1				1						

N. kutzingiana Hilse					1									
N. linearis W. Smith	2				2	2								
N. navicularis (Breb.) Grun	3	3			3	3		3				3		
N. palea (Kutz.) W. Smith		2			2	2		2						
Pinnularia distans Late (Bret) W. Smith					1									
P. late (Breb) W. Smith					1									
P. virids Ehrbg					1									
Stauroneis constricta Nach, W. Smith					1									
Total	6	6	0	2	15	10	15	11	1	1	1	0		
Cyanophyta														
Anabaena circinalis Rabh.					1									
A. spiroides Lemmermann		2	2							2				
A. subcylindrica Borge		1								1				
Aphanocapsa rivularis West and West				1										
Aphanizomenon flos-aquae Ralfs.						1								
Arthrospira gomontiana Setchell				2		2			2	2				
A. jenneri (Kuetz.) Stizenberger				3		3	3	3	3	3		3		
Cylindrosperinum marchicum Lemmerman.										1				
Gloeotrichia echinulata (J. E. Smith) Richter												1		
Lyngbya contorta Lemmerman		1												
L. diguetii Gomont		1												
L. lagerbeimii (Moebius) Gomont	3		3			3	3	3			3			
L. muralis Kutz							1							
L. spirulina Gomont.											1			
L. spirulinoides Gomont.							1							
L. muralis Kutz.		1		1										
L. tenue Gomont											1			
Nostoc commune Vaucher		1												
N. linckia Borned and Thuret									2	2		2		
N. microscopicum Carmichael			1											
N. muscorum C. A. Agardh.												1		
N. paludosum Kuetzing			2							2	2			
N. punctiformae (Kuetzing) Hariot			1								1			
N. sphaericum Vaucher			1											
Oscillatoria acuminata Gomont.							1							
O. agardhii Gomont.		1												
O anguina (Bory) Gomont.							1							
O. angustissima West and West	3	3		3	3			3		3				
O. beggiatoformis Gomont. Herbier Thuret				1				1						
O. formosa Bory.	3				2			2		2				
O. subsalsa Oersted						2		2		2		2		
Phormidium ambigum Gomont				1										
P. favosusm (Bory) Gomont.		1												
P. muciolas Naumann				2		2	2							
Pseudoanabaena sp.		2				2				2				
Scytponema archangelii Born and Flah			1											
Spirulina laxa G. M. Smith				3	3		3	3				3		
S. major Kuetzing							1							
S. nordstedtii Gomont.					1		1							
Stigonema mucicola Borzi			1											
Trichodesmum lacustris Klebehm			1									1		
Wollea saccata (Wolle) Bornet and Flahault.		1										1		
Total	3	10	9	9	14	7	10	7	4	10	5	9		
Euglenophyta														
Euglena archaeoplastidiata Chade Faud.							1							
E. caudata Hubner							1							
Total	0	0	0	0	0	0	2	0	0	0	0	0		
Total	21	25	13	17	27	25	29	22	10	17	8	15		
Total by Site	76				103				50					
Total by Season	Autumn 58			Winter 67			Spring 50			Summer 54				

A = Autumn, B = Winter, C = Spring, D = Summer

agitated thoroughly with the help of a Vortex mixer. Two serial dilutions were made from the original solution. From each dilution, 0.1 ml was plated on solid medium. This resulted in a final dilution of 10^{-3}. The batches were then inocubated at 30 ± 1°C for procaryotic algae and at 20 ± 1°C for eukaryotic algae in 16/8 hrs light-dark cycle with a light intensity of 3000-4000 Lux. After 25 and/or 30 days of inoculation the number of colonies were proportioned to dry weight soil (Rahno *et al.*, 1978). Isolates were obtained by taking a small amount of cells from a colony and transferred to a sterile test tube containing a specific liquid medium. The isolates were left to grow for 30-40 days in a lightened incubation chamber. Intensive isolations were conducted approximately every three months. Permanent diatom slides were prepared from all diatom cultures, they cleaned by soaking in

hydrogen peroxide overnight. Then, they rinsed and centrifuged repeatedly. The entire pellet was mounted on a cover slip dried and then mounted. Other alga were identified directly by a light microscope by wet mounts. Algal organisms were examined and photographed using microscope MC 63 with camera attachment M 35 automatic control (Ziess).

Standard taxonomic references were consulted for most identifications (Petersen, 1935; Ettl, 1978; Komarek and Fott, 1983; Krammer and Lang-Bertalot, 1986, 1988, 1991; Sant'Anna and Azevedo, 1995).

Physical and chemical analyses of the collected soil samples: The mechanical analysis of soil samples was carried out using hydrometer method as descriped by. The cultivated land (Site I) has a sandy loam with 63% sand and 38% silt. The reclaimed desert (Site II) is sander 76% sand and thus a loamy sand while the waste land (Site III) contains the finest soil, a silt loam with 70% silt. The percentage of soil moisture content was calculated. Soil temperature was measured in situ. Soil water suspension (1:5) was used to determine the pH using a digital pH-meter (Schott Gerte N 37 a pH 90 WTW). The total alkalinity (bicarbonate) was determined according to Jackson (1977). The versene titration method was employed for Ca^{2+} and Mg^{2+} determination (Schwarzenbeck and Biederman, 1948). Na^{+} and K^{+} were detected by the flame photometric technique (Williams and Twine, 1960). Organic carbon in percent was calculated using rapid titration method. Total nitrogen was determined colourimetrically according to Allen (1959). The method descriped by Dewis and Fertias (1970) was used for the determination of orthophosphate.

Results and Discussion

The distribution and diversity of algae at the three sites surveyed could be correlated to soil texture accordingly, the most species were recorded in the cultivated Sites I and II (103 and 76 species, respectively) which contains high amounts of sand and the lowest number of species (50) was isolated in the waste land Site III which contains high amounts of silt (Table 1). The development on the texture of the soil. Finer particles seem to promote their occurrence, however, soil crusts are also known to occur from sand-dunes (Yair, 1990; Lange *et al*., 1992). Seasonal variation in soil temperature of the cultivated and waste land sites showed relatively high temperature during spring and summer (30-40°C), while the minimum temperature was recorded (18°C) during winter. Accordingly, the algal biomass and distribution of the study sites could be mainly correlated to alternations in soil temperature. Lund (1962) and Trainor (1962) reported that some algae are extremely resistant to low temperatures and others are able to tolerate high temperatures under dry conditions. On the other hand, the pH value of the soil samples tended to be neutral in winter and slightly alkaline in other seasons (7.0-8.0). Among the different algal groups, blue-greens and diatoms generally dominated in neutral and lkaline soils (Table 1). Starks *et al*. (981) found that members of Cyanophyceae dominated in alkaline soils, while the Chlorophyceae were better represented in acidic soils. The role of chemical characters of the soils is very important in distribution of algae. It seemed probably that the organic carbon, ammonia-N and bicarbonate contents of soil samples (Table 1, 2) are the major controlling factors affecting the growth and distribution of algae in these sites. In relation to this speculated that the organic nutrients may have a greater effect on the algae n terms of fertilization than inorganic nutrients. Eutrofication may delimit the diversity of algal species (Sheath and Munawar, 1974). The increase in ammonia-N of the crust soil in winter and spring seasons may be attributed to the dominance of cyanobacteria mainly N_2-fixer blue greens (Table 1). McGregor and Johnson (1971) reported that algal organisms in the cultivated soil fixed from 3 to 4g. N/hr/ha of crust following rainfall.

The decreased number of algae in the waste land (Site III) compared to other soil samples may be due to high salinity of this soil. However, it was reported that sodium values increase the number of Cyanophyta as compared to Chlorophyta (Table 1, 2). The same result was obtained by Shubert and Starks (1980). On the other side a positive correlation of algal abundance (mainly Chlorophyta) during succession with levels of PO_4-P was observed in the reclaimed desert. King and Ward (1977) showed that phosphorus was the major growth-nutrient in soil.

The cryptogamic crust community imparts other benefits to the desert ecosystem, including the fixation of significant amount atmospheric nitrogen by blue-green algae as well as by bacteria associated with certain moss species (Snyder and Wullstein, 1973; Rychert and Skujins, 1974; Reddy and Giddens, 1975; St. Clair *et al*., 1984). It has also been observed that vascular plant seedling development tends to faciliated in areas where crust development is pronounced (Nebeker ad St. Clair, 1980). The phenomenon may be due in part to the improved water and nutrient relationship typical of crusted soils (Booth, 1941; Mayland and Mclntosh 1966).

Fifty two genera (110 species) of algae were identified, purified and isolated from the cultivated land sites and waste land site; 21 genera (27 species) belong to Chlorophyta, 14 genera (39 species) belong to Bacillariophyta, 16 genera (42 species) belong to Cyanophyta and one genus (two species) to Euglenophyta. The data in Table 3 showed that some species were recorded only from the cultivated soil and were very related to the growing season, for example, *Cyclotella lagerhaemii, Hanztschia amphioxys, Chlorococcum umicola, Endorina elegans, Protosiphon botryoides, Scenedesmus crassus, Aphanocapsa rivularis, Arthrospira gomeutiana, Arthrospira jenneri, Lyngbya symploca, Phormidium ambigum, Phormidium mucicola* and *Spirulina laxa* were isolated when the soil was cultivated by zea mays in summer season. Cultivated soil supported a more diverse flora of the blue greens than virgin soil (Esmarch, 1910; Ciferri, 1960). Also, three species, namely *Oocystis tainoensis, Sphaerocystis schroeteri* and *Lyngbya tenue* were isolated only from the waste land. In general, the appearance of any species from various soil habitats is governed by several environmental factors and growing season as well as the assay media used, a prospect which awaits further considerations.

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