Algal Flora of Egyptian Soils
1. The occurrence of Cyanobacteria and Algae in some habitats

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The culturing of reclaimed soils (from Burg El-Arab and Modiriya El-Tahrir areas) and old soils of Nile Valley (from Dakahlia , Giza and Luxor areas) on Myre's, Chu's No 10 and Beijerinck's artifiial media contributed to the isolation and identification of 78 algal taxa related to 31 genera belonging to Cyanophycophyta (52.6 %), Chlorophycophyta (28.2%), Xanthophycophyta (8.9 %), Bacillariophycophyta (7.7 %) and Euglenophycophyta (2.6 %). No single region contains all taxa recorded in the investigated soils. Although, each soil had its own characteristic algal flora and edaphic factors , they participated mostly in the production of *Chlamydomonas komma* Skuja, followed by *Amorphonostoc punctiforme* (Kütz.) Elenk., *Stratonostoc linckia* f. *spongiaeforme* (Ag.) Kütz, *Calothrix elenkinii* Kossinsk., *Hantzschia amphioxys* f. *capitata* O. Mull., *Chlorocloster raphidioides* Patch., *Chlorella vulgaris* Beij. and *Scenedesmus bijugatus* (Turp.) Kütz. The edaphic properties showed that slightly alkaline to alkaline pH reaction favoured the prevailence of members of Cyanobacteria in the investigated soils. The representation of iron - tolerated taxon *Chloridella ferruginea* Pasch. between the yellow green algae recorded in Dakahlia emphasized the relativley high level of iron in this soil. The present work added 38 new taxa to Egyptian algal flora. However, full descriptions as well as expressive illustrations and / or photos of the new reccords will be the subject of a future publication.

Key words: edaphic factors, new records, soil algae.

Introduction

The ecology of soil algae has been much less studied than that of heterotrophic microorganisms (Fogg *et al*., 1973). Smith (1978) claimed that, algae are the most experimentally neglected organisms in the soil. Studying the physico-chemical properties of soil gave important information on the environments available to many soil microorganisms including algae which live within them. Soils and their edaphic factors are characterized by high variability (Wopereis *et al*., 1988 ; Hook *et al*., 1991; Van der Zee and Boesten, 1991 and Hantschel *et al*., 1994). The algal flora of Egyptian soil has not yet been satisfactorily explored; the relatively few studies have been carried out in a sporadic manner. The common algal species and soil characteristics were reported from the cultivated lands, arid and saline soils of various parts of Egypt (El-Nayal, 1935; Abdin, 1954; El-Ayouty & Ayyad, 1972; Kobbia & El-Batanouny, 1975; El-Ayouty *et al*., 1977;

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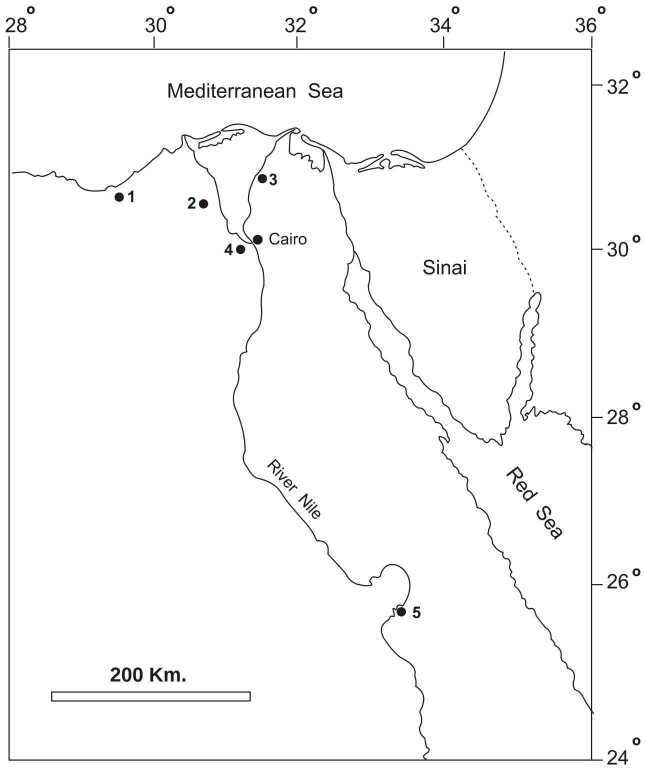
Hamouda, 1981; Salama & Kobbia, 1982; Abou-El-Kheir & Mekkey, 1987; Kobbia & Shabana,1988; Ahmed, 1994; and El-Ayouty, 1998).

The present work aims to evaluate and give a highlight about the algal flora inhabiting Egyptian desert reclaimed and old Nile Valley soils and their edaphic factors.

Materials and Methods

The surface of soil strata down to a depth of 17cm (Gollerback and Shtina, 1969), from desert reclaimed soils (in Burg El-Arab, longitude 29º 45'; latitude 31º and Modiriya El-Tahrir, longitude 31º; latitude 30º 45') and old Nile Valley soils (in Dakahlia, longitude 31º 30' ; latitude 32º 15', Giza, longitude 31º; latitude 30º and Luxor, longitude 32º 30'; latitude 25º 45' – Map 1) were collected in clean air-tight plastic bags.

In laboratory, each soil sample was divided into two portions. One portion was used for determining physico-chemical properties of the soil, and the other portion was utilized for culturing of algae.



Map (1). Regions of material collection
1. Burg El-Arab; 2. Modiriya El-Tahrir; 3. Dakahlia; 4. Giza & 5. Luxor

Soil analysis methods included determination of organic matter (Walkley, 1935 & 1947), potassium (Williams, 1941), calcium, chloride, carbonate, bicarbonate (Reitemeier, 1943), magnesium (Kitson & Mellon, 1944), electrical conductivity (Campbell *et al*., 1949), silicates , density, porosity, saturation percentage (Richards *et al*., 1954), soil pH (Jackson, 1958), sulphate (Dewis & Freites, 1970), total phosphorus (Tan, 1996), mechanical properties, texture and available micronutrients (Brauah & Barthokur, 1997) have been carried out.

Culturing and isolation of algae were carried out in illuminated solid and liquid states of Myre's (Venkataraman, 1969), Beijernick's and Chu's No 10 (Stein, 1979) artificial media, at 25 ºC under 4000 lux, continuos illumination for 25-45 days in Precision incubator of model 818.

Algae were identified during the exponential phase according to Zabelina *et al*. (1951), Gollerbakh *et al*. (1953), Kiselov *et al*., (1953), Korsanov *et al*. (1953), Popova (1955), Dedesenko *et al*. (1959), Desikachary (1959), Philipose (1967) and Komarenko & Vasileva (1975 , 1978).

Results & Discussion

The results presented in Table 1, show that, the texture of the investigated soils varied considerably from one sample to another, being sandy for Modiriya El-Tahrir, clay-sand for the sample of Burg El-Arab, clay (USDA, 1992) or clay-loam for the soils of Giza and Dakahlia and loam-clay for the sample of Luxor. The soil bulk density is subsequently variable being (1.87 gcm^{-3}) at Luxor, moderate (1.44 gcm^{-3}) in Modiriya El-Tahrir (USDA, 1992), and displayed a decreasing order in the other soils (Table 1). On the other hand, the real density of the studied soils followed another order where the relatively high values (2.61 gcm^{-3} and 2.56 gcm^{-3}) characterized the sandy and clay-sandy soils of Modiriya El-Tahrir and Burg El-Arab areas respectively , followed by the loam-clay soil at Luxor (2.31 gcm^{-3}). The relatively low values of real density were strictly associated with moderate clay soils of Dakahlia and Giza (Table 1).

The physical analysis of soils also showed that, the soil porosity was unexpectedly higher in clay-sand soil of Burg El-Arab than in sandy textured soil of Modiriya El-Tahrir. Other soils displayed porosity % very close to the sandy soil of Modiriya El-Tahrir except for the loam-clay soil of Luxor which attained the lowest porosity (Table 1). The soil saturation percentages coincided strongly with texture variation of the investigated soils. The highest saturation percentage characterized the Nile alluvial soil of Giza, while the lowest one was that of the sandy soil of Modiriya El-Tahrir. Other soils have saturation percentages which lie in a median position inbetween. The soil reactions were mildly alkaline to alkaline as indicated by pH values which ranged from 7.77 to 8.28 in the soils of Luxor and Giza respectively. According to the soil classes (USDA, 1954), the studied soil samples were generally non-saline as indicated by EC_e values which were below 2 ds m^{-1} except for the soil of Giza of slightly saline in which EC_e value lies in the range of 2- 4 ds m^{-1} (Table 1).

(Table 1). Physico-chemical properties of the investigated soils.

Parameter	Localities				
	Burg El-Arab	Modiriya El-Tahrir	Dakahlia	Giza	Luxor
Mechanical analysis/sand %	35.76	91.093	10.47	17.95	20.47
Mechanical analysis/ silt %	21.18	6.22	33.14	35.17	45.15
Mechanical analysis/ clay %	43.06	1.85	56.39	48.88	36.38
Texture	clay-sand	sand	clay-loam	clay-loam	loam-clay
Bulk density (gcm^{-3})	1.03	1.44	1.13	1.23	1.87
Real density (gcm^{-3})	2.56	2.61	1.96	2.12	2.31
Porosity %	59.76	44.80	42.35	41.9	19.05
Saturation percentage	26	14	66	80	40
pH	8.04	7.83	7.79	8.28	7.77
Electric conductivity (dsm^{-1})	0.6	0.8	0.7	3.6	0.5
Total dissolved salts (ppm)	1249.2	366.6	643.3	1532.82	549.73
Ca^{++} (ppm)	106.2	41.1	58.8	109.02	67.5
Mg^{++} (ppm)	35.9	16.4	21.2	57.8	30.7
Na^{+} (ppm)	306.9	43.02	108.9	227.4	45.7
K^{+} (ppm)	46.8	6.64	12.3	25	3.13
CO_3^{--} (ppm)	-	-	-	-	-
HCO_3^{-} (ppm)	256.1	200	225.6	274.4	182.9
$SO_4^{=}$ (ppm)	67.3	21.6	79.3	223.1	166.3
Cl^{-} (ppm)	609.9	46.8	137.2	392.7	53.5
Si %	1.06	1.17	2.13	1.45	1.4
SiO_2 %	2.26	2.5	4.25	3.10	3
Organic matter %	0.28	0.78	2.04	3.67	2.12
Nitrogen macronutrient mg/kg^{-1}	287	230	315	395	290
Phospohorus macronutrient mg/kg^{-1}	14.1	11.2	17	147	9.8
Fe micronutrient mg/kg^{-1}	3.9	6.4	18.6	12.9	11.6
Mn micronutrient mg/kg^{-1}	7.7	4.5	17.8	2.3	13.2
Zn micronutrient mg/kg^{-1}	0.9	0.5	1.8	4.7	0.4
Cu micronutrient mg/kg^{-1}	0.2	0.2	2.8	4.1	0.9
Total N mg/kg^{-1}	640	770	840	890	950
Total P mg/kg^{-1}	1000	950	1100	1250	1300

Concerning the cationic composition, the soil saturated extracts of the investigated soils were mostly dominated by Na^{+} followed by Ca^{++}, Mg^{++} and K^{+} except for the sample of Luxor where Ca^{++} was the dominant cation, followed by Na^{+}, Mg^{++} and K^{+}. (Table 1). Among the anionic composition, the soil saturated extracts of Burg El-Arab and Giza were characterized by the domination of Cl^{-}, followed by HCO_3^{-}, SO_4^{--}, while those of Modiriya El-Tahrir, Dakahlia and Luxor were characterized by the dominance of HCO_3^{-} (Table 1). The contents of silica in the studied soil samples varied from 1.06 % to 2.13 % for the samples of Burg El-Arab and Dakahlia respectively. The results in Table 1, revealed that all the investigated soils were impoverished in the amounts of organic matter and the total and available nitrogen contents , whereas , the total, available phosphorus and avialble Fe and Mn indicated that all the studied soils were well supplied with macro- and micronutrients. Available Zn and Cu indicated sufficiency of the soils of Dakahlia and Giza in both micronutrients, while the other soils were dificient in these nutrients (according to their critical levels reported by Lindsay and Norvell, 1978).

The culturing on reclaimed soils from Burg El-Arab, Modiriya El-Tahrir and old soils of Nile Valley from Dakahlia, Giza and Luxor areas on Myre's, Beijernick's and

Chu's No 10 artificial media contributed to the isolation and identification of 78 algal and cyanobacterial taxa related to 31 genera belonging to Cyanophycophyta (52.6 %), Chlorophycophyta (28.2 %), Xanthophycophyta (8.9 %), Bacillariophycophyta (7.7 %) and Euglenophycophyta (2.6 %) (Table 2&3). In agreement with these results, Bold and Wynne (1978) and Metting (1981) stated that, the algal flora of the soil includes members of cyanobacteria, green algae, diatoms, yellow-green algae, euglenoids and red algae. It is evident from the present study that, the number of algal taxa found in each region was 20 taxa isolated from soil of Burg El-Arab; 26 taxa isolated from soil of Modiriya El-Tahrir; 35 taxa isolated from soil of Dakahlia; 26 taxa isolated from soil of Giza and 35 taxa isolated from soil of Luxor.

The present investigation indicated that Cyanophycophyta was represented by the highest number of taxa (Fig. 1), from which 17 taxa (41.46 %), were related to heterocystous forms. This observation could be interpreted as due to the slightly alkaline to alkaline pH values of the soils, which favour the prevailing of blue-green algae (Shields & Durrell, 1964; Singh *et a*l., 1990; Arif, 1992; Nair *et al.*, 1993 and Lukesova & Hoffmann, 1996).

The recorded Chlorophycophyta was comprised only of members of Orders Chlamydomonales and Chlorococcales with *Chlamydomonas* and *Scenedesmus*, each one was represented by 10 species. The most widespread species which was isolated from all investigated soils was *Chlamydomonas komma* Skuja. In accordance with this observation, Gollerbakh and Shtina (1969) indicated that, the most common and highly distributed green algae in the soil are members of the genera *Chlamydomonas*, *Chlorella*, *Chlorococcum*, followed by *Ankistrodesmus* and *Scenedesmus*.

The most characteristic alga found between the recorded members of Xanthophycophyta (7 taxa) was the iron-tolerating *Chloridella ferruginea* Pasch. (Dedesenko-Schegolova and Gollerbach, 1962) in the soil of Dakahlia governorate with a relatively high content of iron. Patrick (1972) and Pipe and Shubert (1984) indicated that algae are sensitive indicators.

The quality and the species diversities of Bacillariophycophyta and Euglenophycophyta were low and this may be attributed to the relatively low contents of available silica and organic matter in the studied soils (Smith 1950; Jhan 1951).

The most conspicuous feature about the algae isolated from the investigated soils was their heterogenicity, a fact which is in conformity with the differences of physical and chemical properties of the soils in the studied localities. This observation was confirmed also by the relatively low percentages of similarity indices between the algal floras of the studied soils (Table 4). A similar picture has been reported by Zhuravlev (1984); Bahati and Rajarao (1990) and Likhitkar and Tarai, (1994), who pointed out that, each algal category was associated with particular soil.

Although, each soil had its own characteristic algal flora, they participated mostly by the occurrence of *Chlamydomonas komma* Skuja, followed by *Amorphonostoc punctiforme* (Kütz.) Elenk., *Stratonostoc linckia* f. *spongiaeforme* (Ag.) Kütz., *Calothrix elenkinii* Kossinsk., *Hantzschia amphioxys* f. *capitata* O. Mull. and *Chlorocloster raphidiodes* Pasch., *Chlorella vulgaris* Beig. *and Scenedesmus bijugatus* (Turp.) Kütz. (Table 2).

Table (2). Distribution of soil algae among the investigated soils.

Algal taxa	Localities				
	Burg El-Arab	Modiriya El-Tahrir	Dakahlia	Giza	Luxor
Division Cyanophycophyta					
Dactylococcopsis acicularis Lemm.					+
Gloeocapsa minuta (Kütz.) Hollerb.	+				
Cyanothrix gardneri (Fremy) I. Kissel.		+		+	+
Chroococcopsis gigantea Geitler	+				
Myxosarcina chroococcoides Geitler	+				
Amorphonostoc paludosum (Kütz.) Elenk.	+				+
Amorphonostoc punctiforme (Kütz.) Elenk.	+	+		+	+
Sphaeronostoc coeruleum (Lyngb.) Elenk.				+	+
Sphaeronostoc pruniforme (Ag.) Elenk.		+	+		
Stratonostoc linckia f. *calcicola* (Breb.) Elenk.			+	+	
Stratonostoc linckia f. *carneum* (Ag.) Elenk.			+		
Stratonostoc linckia f. *spongiaeforme* (Ag.) Kütz.		+	+	+	+
Nematonostoc flagelliforme (Berk. et Curt.) Elenk.			+		
Anabaena constricta (Szaf.) Geitler	+		+		
Anabaena jacutica Kissel.		+			
Anabaena oscillaroides Bory.					+
Anabaena sphaerica Born. et Flah.		+	+		
Anabaena spiroides Kleb.	+				
Anabaena variabilis Kütz.	+			+	
Cylindrospermum stagnale (Kütz.) Born. et Flah.					+
Calothrix elenkinii Kossinsk.	+	+		+	+
Calothrix intricata F. E. Fritsch		+			
Oscillatoria deflexoides Elenk. et Kossinsk.		+	+	+	
Oscillatoria formosa Bory.			+		
Oscillatoria gracilis Bocher.					+
Oscillatoria limosa f. *late-aeruginosa* (Kütz.) Elenk.			+		
Phormidium corium (Ag.) Gom.					+
Phormidium cebennense Gom.	+				
Phormidium jadinianum Gom.				+	+
Phormidium papyraceum (Ag.) Gom.		+			
Phormidium valderiae (Delp.) Geitler					+
Lyngbya bipunctata Lemm.					+
Lyngbya lagerheimii (Mob.) Gom.			+		+
Lyngbya martensiana Menegh.					+
Lyngbya ochracea (Kütz.) Thur.	+				
Schizothrix coriacea (Kütz.) Gom.				+	
Schizothrix fragilis (Kütz.) Gom.			+		
Schizothrix vaginata (Nag.) Gom.		+	+	+	
Microcoleus cataractarum Hansg.	+				
Microcoleus chthonoplastes (F.I. Dan.) Thur.					+
Microcoleus delicatulus W. et. G. S. West			+		
Division Bacillariophycophyta					
Navicula cryptocephala Kütz.	+				
Navicula muralis Grun.			+		+
Navicula gregaria Donk.			+		
Nitzschia amphibia Grun.					+
Nitzschia palea (Kütz.) W. Sm.	+	+	+		
Hantzschia amphioxys f. *capitata* O. Mull.		+	+	+	+

Table (2), continued.

Algal taxa	Localities				
	Burg El-Arab	Modiriya El-Tahrir	Dakahlia	Giza	Luxor
Division Xanthophycophyta					
Pleurochloridella vaculota Pasch.			+	+	+
Chloridella ferruginea Pasch.			+		
Chlorocloster raphidiodes Pasch.		+	+	+	+
Botrydiopsis eriensis Snow.		+		+	
Botrychloris minima Pasch.	+				
Tribonema elegans Pasch.				+	+
Tribonema minus Hazen.			+		
Division Euglenophycophyta					
Euglena gracilis Klebs					+
Euglena viridis Ehr.		+	+	+	
Division Chlorophycophyta					
Chlamydomonas atactogama Korsch.	+	+		+	
Chlamydomonas dactylococcoides Scherff.					+
Chlamydomonas komma Skuja	+	+	+	+	+
Chlamydomonas incerta Pasch.				+	
Chlamydomonas notigama Korsch.			+		
Chlamydomonas parietaria Dill.		+	+	+	
Chlamydomonas peryi Gorosch.			+	+	+
Chlamydomonas reinhardii Dang.		+			
Chlamydomonas snowiae Printz.			+		+
Chlamydomonas stellata Dill.		+	+	+	
Chlorococcum humicolo (Naeg.) Rabenh.	+			+	+
Chlorella vulgaris Beijer.	+		+	+	+
Scenedesmus arcuatus var. *capitatus* G. M. Smith					+
Scenedesmus armatus var. *dispar* Philip		+			
Scenedesmus bernardii G. M. Smith		+	+		
Scenedesmus bijugatus (Turp.) Kütz.	+	+		+	+
Scenedesmus bijugatus var. *alternans* (Reish) Hansg.			+		
Scenedesmus dimorphus (Turp.) Kütz.		+	+		+
Scenedesmus obliquus (Turp.) Kütz.					+
Scenedesmus quadricauda var. *quadrispina* Chodat G. M. Smith		+	+		
Scenedesmus platydiscus (G. M. Smith) Chodat.					+
Scenedesmus tropicus Crow.			+		

Table (3). Correlation of algae and their percentages.

Algal division	Number of taxa	Number of genera	%
Cyanophycophyta	41	17	52.6
Bacillariophycophyta	6	3	7.7
Xanthophycophyta	7	6	8.9
Euglenophycophyta	2	1	2.6
Chlorophycophyta	22	4	28.2
Total	78	31	100

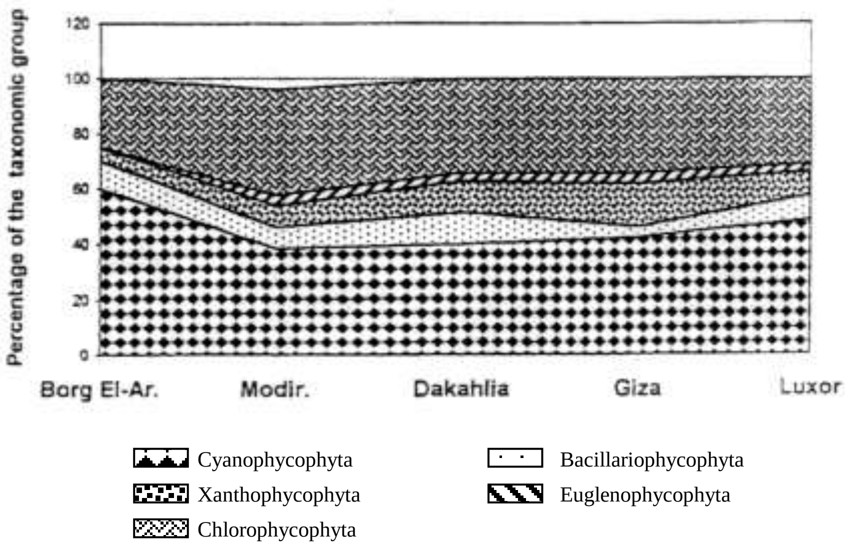


Fig. 1. Percentages of different algal groups in the investigated soils.

Table (4). Similarity matrix between the investigated soils in %.

locality	Burg El-Arab	Modiriya El-Tahrir	Dakahlia	Giza	Luxor
Burg El-Arab					
Modiriya El-Tahrir	20.69				
Dakahlia	12.70	32.97			
Giza	25.81	36.58	29.85		
Luxor	20.29	22.78	23.91	32.97	

Referring to the previous published accounts of freshwater and soil algae of Egypt (El-Nayal, 1935; Abdin,1954; El-Ayouty & Ayyad, 1972; Kobbia & El-Batanouny, 1975; El-Ayouty *et al*., 1977; Hamouda, 1981; Salama & Kobbia, 1982; El- Sawy, 1983; Abou-El-Kheir & Mekky, 1987; Kobbia & Shabana, 1988; Shaaban, 1994; El-Awamri *et al*., 1996; Shaaban & Hamed, 1997 a & b; Shaaban *et al*., 1997a and Shaaban *et al*., 1997b), the present contribution added 38 new algal taxa to Egyptian algal flora (Table 5); however, full descriptions as well as expressive illustrations and /or photos of the new records will be the subject of a future publication.

In conclusion, the present study emphasized that the number of algal taxa isolated from the reclaimed soils of Burg El-Arab and Modiyria El-Tahrir areas were relatively low compared with those isolated from the old soils of Nile Valley especially of Dakahlia governorate and Luxor area.

Table (5). New algal records to Egyptian Algal flora.

Algal taxa	Localities				
	Burg El-Arab	Modiriya El-Tahrir	Dakahlia	Giza	Luxor
Division Cyanophycophyta					
*Cyanothrix gardner*i (Fremy) I. Kissel.		+		+	+
Chroococcopsis gigantea Geitler	+				
Myxosarcina chroococcoides Geitler	+				
Sphaeronostoc coeruleum (Lyngb.) Elenk.				+	+
Sphaeronostoc pruniforme (Ag.) Elenk.		+	+		
Nematonostoc flagelliforme (Berk. et Curt.) Elenk.			+		
Anabaena jacutica Kissel.		+			
Calothrix elenkinii Kossinsk.	+	+		+	+
Calothrix intricata F. E. Fritsch		+			
Oscillatoria gracilis Bocher.					+
Phormidium cebennense Gom.	+				
Phormidium jadinianum Gom.				+	+
Lyngbya bipunctata Lemm.					+
Schizothrix fragilis (Kutz.) Gom.			+		
Schizothrix vaginata (Nag.) Gom.		+	+	+	
Microcoleus cataractarum Hansg.	+				
Microcoleus delicatulus W. et. G. S. West			+		
Division Xanthophycophyta					
Pleurochloridella vaculota Pasch.			+	+	+
Chloridella ferruginea Pasch.			+		
Chlorocloster raphidiodes Pasch.		+	+	+	+
Botrydiopsis eriensis Snow.		+		+	
Botrychloris minima Pasch.	+				
Division Euglenophycophyta					
Euglena gracilis Klebs					+
Division Chlorophycophyta					
Chlamydomonas dactylococcoides Scherff.					+
Chlamydomonas komma Skuja	+	+	+	+	+
Chlamydomonas incerta Pasch.				+	
Chlamydomonas notigama Korsch.			+		
Chlamydomonas parietaria Dill.		+	+	+	
Chlamydomonas peryi Gorosch.			+	+	+
Chlamydomonas snowiae Printz.			+		+
Chlamydomonas stellata Dill.		+	+	+	
Scenedesmus arcuatus var. *capitatus* G. M. Smith					+
Scenedesmus armatus var. *dispar* Philip		+			
Scenedesmus bernardii G. M. Smith		+	+		
Scenedesmus bijugatus var. *alternans* (Reish) Hansg.			+		
Scenedesmus dimorphus (Turp.) Kutz.		+	+		+
Scenedesmus platydiscus (G. M. Smith) Chodat.					+
Scenedesmus tropicus Crow.			+		

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