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EDAPHIC PROPERTIES AND SOIL CYANOBACTERIA OF SOUTH WESTERN SAUDI ARABIA

By

IBRAHIM A. ARIF AND A.M.A. EL-SYED

Department of Botany & Microbiology

College of Science, King Saud University

P.O.Box 2455, Riyadh 11451

Saudi Arabia,

خواص وسيانوبكتيريا التربة في المنطقة الجنوبية الغربية من المملكة العربية السعوية

ابراهيم عبد الواحد عارف و علاء الدين محمد عبد المعروف السيد

قسم النبات والأحياء الدقيقة - كلية العلوم - جامعة الملك سعود

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تم عمل دراسة مسحية على خمس مواقع، ثلاثة بكل منها في المنطقة الغربية من المملكة العربية السعودية عام ١٩٩٢م، وقد استهدفت الدراسة الخواص الفيزيائية والكيميائية للمواقع ومجتمعاتها الطحلبية، وقد كانت أنواع التربة قاعدية الرقم الهيدروجني ومعتدلة الكلسية وتميزت بتركيب رملي طيني، تراوح التوصيل الكهربي والأملاح الذائبة بعينات التربة بين ٠,١٩٦ - ٢,٢٢٨ ميلليمولز / سم و ١٣٧,٢ - ١٥٥٩,٦ جزء بالمليون، على التوالي، وقد كان الكالسيوم هو الايون الموجب الذائب الرئيسي على حين شكلت الكبرتيات والكلوريدات والبيكربونات الأنيونات الرئيسية.

تم التعرف على ما مجموعة ٢٢ نوعاً من السيانوبكتيريا والطحالب من عينات التربة عقب تجفيفها وزراعتها على بيئات صناعية مثراه. وقد تضمنت هذه الأنواع ١٩ سيانوبكتيريا «نوعين من الطاحب الخضراء المزرقة» ونوعاً واحداً من الدياتومات، كان من ضمن أنواع السيانوبكتيريا ٧ أنواع هي نوستوك إدافيكام، نوستوك مسكورام وفورميديام بوهنيراي وفورميديام فوفوكلارام وفورميديام تنيو وبلير وكابسا ماينور، وسينيكوكوكاس أريوجينوزاس ومثلث تسجيلات جديدة للفلورا السعودية.

Key words: Edaphic Properties, new records, *Nostoc edaphicum, Pleurocapsa minor,* soil and thermophilic cyanobacteria

ABSTRACT

Three sites at each of five localities, in the South Western Region of Saudi Arabia were surveyed during 1992, for their soil physico-chemical properties, and cyanobacterial communities. The soils were moderately calcareous, and characterized as sandy loam textured and alkaline. Electrical conductivity and total soluble salts ranged between 0.196-2.228 mmhos cm^{-1} and 137.2-1559.6 ppm, respectively. Calcium was the major soluble cation, and sulphate, chloride and bicarobonate were the principal anions.

A total of 22 cyanobacterial and algal species were identified from the 15 soil samples following rehydration and culture in different enriched media. The species included 19 cyanobacteria, 2 Chlorophyta and 1 Bacillariophyta. 7 cyanobacteria: *Nostoc edphicum, N. muscorum, Phormidium bohneri, P. favcolarum. P. tenue, Pleurocapsa minor and Synechococcus aeruginosus* are new records for the Saudi Arabian Flora.

INTRODUCTION

Soil cyanobacteria have been recorded over a long time and have been recognised as an important component of microbial communities (1).

Soil cyanobacteria are cosmopolitan and widespread in different ecological habitat, they have been reported from desert and arid soils (2) the arctic, temperate/ tropical regions (3). marshy land (4). and saline soils (5). The wider range of distribution represents their importance as one of the major components of soil microbial photosynthetic communities.

Starks et al ., (3) reported that soil type, moisture content, soil pH, temperature and light are considered as important ecological factors for the survival and persistence of soil cyanobacteria and algae.

The soil of Saudi Arabia in term of cyanobacteria and algal studies has received little attention. Chantanachat and Bold (2) reported seven green algae and four cyanobacteria from various localities. Later on, in 1975 Abu Zinada and El-Huseiny (6) reported 14 genera of cyanobacteria from agricultural fields in the Riyadh Region. Since then, no further study has been carried over, until the recent work by Arif (5), in which six species of cyanobacteria and five green algae were reported from the saline soil in the Al Qseem Region.

Soil cyanobacteria occur in different habitats of Saudi Arabia (6), and have not been studied comprehensively. The intent of the present study is to report soil cyanobacteria and, to determine to what extent the physico-chemical features of the soil permit their viability, in the different environments of South Western Saudi Arabia.

MATERIALS AND METHODS

Soil Sampling

Three sites in each of five localities were chosen in the SW Region of Saudi Arabia. A total of 15 samples were collected from consistent depth at all sites ranging from 1-20 cm at each site, through August to September 1992. Samples were collected using sterile knives and scoops then transferred into small polyethylene bags. There was no marked cyanobacterial or algal growth in the soil at the time of collection. The soil samples were transported to Riyadh in an ice-chest and stored in a cold dry room. The samples of each site were mixed thoroughly and a representative sample was prepared, part of the sample was removed for soil analyses, and the rest was used for culture purposes.

Soil analyses

Soil temperature was measured in the field using an Ele soil thermometer. Soil particle size distribution measured was conducted following Bouyoucos hydrometer method (7). Total salt and total water holding capacity were determined according to the methods summarized by Al-Mashhadi et al. (7). Organic matter content was determined according to Abudhabi (8). Soil pH was measured using a pH electrode (Pye-unicam) on soil paste. Carbonates, bicarbonates and chlorides were determined by the procedures given by Richards (9). Sulphates were measured according to APHA (10) and nitrates as per Bremmer methods (11). Phosphates were measured colourometrically (12), sodium and potassium by atomic absorption spectroscopy (Perkin-Elmer 2580). Calcium and magnesium were measured according to the method given by Cheng and Bary (13). Each experiment was performed in triplicated.

Culture technique

An aliquot representing 0.5 g of soil from each site was inoculated into four different media; Chu 10 (14), Bold basal medium (15), PHM-1 medium (16) and soil extract medium (17). Cultures were incubated at 25, 35 and 45 °C under continuous illumination from cool white fluorescent lamps (42 mE m-2 s-1).

In some instance several subcultures were made to follow growth stages not present in the preliminary investigation.

Taxonomy.

Most of the cyanobacteria were identified by following Desikachary (18) and Geitler (19), while green algae and diatoms by Prescott (20). However, a few taxa were not identified to species, where size/width was used for determining the taxon.

Study sites

The sites chosen for this study are located around five cities (Al Baha, Sabt Al Alaia, Al Namas, Abha & Jizan) in south western Saudi Arabia (Fig. 1). The topography of the

study sites is composed mostly of a chain of Hijaz Mountains, and subject to torrential rains. Subsequently, many higher plants were reported from this region (21).

Climatical data for the cities are given in Table 1. The mean maximum and minimum annual temperature were in the ranges of 20-39 °C and 7-25 °C, respectively. The mean annual rainfall ranged from 52-495 mm.

RESULTS

Soil physical and chemical properties

physical properties of the 15 sites varied considerably from site to site (Table 2). The overall characteristics of the soil were determined as moderately calcareous, sandy-loam textured and alkaline. The moisture content varied between 18 % at site B of Al Baha to 60 % at site B of Jizan.

Chemical analysis of the study sites is given in Table 3. Values of pH ranged from 7 at site A Sabt Al Alaia to 8.5 at site C of Abha. Conductivity of all sites was less than 2.3 mmhos cm^{-1}. The highest total soluble salts (1559.5 mg ml^{-1}) was recorded at site A In Jizan as opposed to the lowest (137.2 mg ml^{-1}) at site C in Abha. Calcium appeared to be the predominant soluble cation, exceeding Na^{+}. The principle soluble anions were sulphate, chloride and bicarbonate. Organic matter was recorded at all sites in between the range of 0.1-0.5%.

Communities and species diversity

Visually conspicuous cyanbacteria and algal growth appeared in 90 % of cultures after 10-12 days, but identification followed after 26 days of incubation. Table 4 shows a list of cyanobacteria and algae identified from the 15 sites, with the frequency and distribution of the species. A sum of 22 species were recorded; 19 were cyanobacteria, 2 Chlorophyta and 1 Bacillariophyta. The greatest number of cultures with positive growth were recorded at 35 °C followed by 25 °C. A few thermophilic species appeared successfully in cultures grown at 45 °C.

The highest diversity of species appeared in cultures from site A Sabt Al Alaia which had 7 species, whereas the lowest diversity was recorded at site A of Jizan in which one species was recorded, Five heterocystous cyanobacterial species were observed. in contrast to 14 non-heterocystous taxa. Three species of cyanobacteria *Phormidium favcolarum, P. tenue and Synechococcus aerüginosus* were reported from Abha and Jizan as opposed to 4 Nostoc *edaphicum*, N. muscorum, Phormidium bohneri and *Pleurocapsa minor* reported from Al Baha, Sabt Al Alaia and Namas. The most common species was *Chlorogleopsis fritschii* being isolated from 14 sites with 93 % frequency, followed by *phormidium* sp from 9 sites (67 %), and finally *Synechococcus aeruginosus* and Nostoc sp, from 5 sites with 33 % frequency.

DISCUSSION

The soil tend to be alkaline in most of the study sites, pH ranged from 7.27-8.50 with an exception at site A of Sabt Al Alaia, where it was neutral. The alkaline pH is generally a characteristic feature of arid soils (22, 23). The electrica conductivity for all sites was less than 4 mmhos cm^{-1} which idicates that the soil is not saline (9). Alexander (1) reported that soil with loamy texture contains high saturation percent, site A of Sabt Al Alaia demonstrated the highest saturation percent of 4. 08 %., probably because of the loamy nature.

Although, most of the sites yielded cyanobacterial or algal growth however, there were marked variations in the distribution and frequency at sites. It seems that soil texture and saturation percentage played important role in frequency variations and growth distribution rather than soil salinity and/or soil pH. Shield and Durrell (23) believed that the soil physical texture that regulates the moisture content is more influential than soil chemical structure . Fairchild and Wilson (24) reported that neutral soil yields more cyanobacteria and algal growth as opposed to alkaline soil. This could be observed in site A of Sabt Al Alaia in which the pH was 7 and yielded more growth as against the other sites.

Soil cyanobacteria and algae recorded from the 15 sites (Table 4) included 22 species; 19 cyanobacteria , 2 Chlorephyta and 1 Bacillariophyta. The least number of soil microbial photosynthetic communities was from the Jizan area suggesting that the extreme climatical conditions have restricted their survival.

The maximum number of cyanobacteria and their high frequency revealed by the present study, is in good agreement with the description given by Round (25) and

chantanachat & Bold (2) . Round (25) and Hussain & Khoja (26) described that cyanobacteria can survive adverse ecological conditions far better than the other groups of photosynthetic microorganism. Natural and alkaline substrata favour the growth of cyanobacteria (4, 1). Diatoms can grow either in acidic and/or alkaline medium but, the soil chemical structure and temperature can substantially limit their growth (27).

Seven species of cyanobacteria *Nostoc edaphicum, N. muscorum, phormidium bohneri, p. fovcolarum, P. tenue, Pleurocapsa minor and Synechococcus aerüginosus* are new records for saudi Arabia. Thermophilic cyanobacteria *Mastigocladus laminosus, phormidium tenue* and *Pleourocapsa minor* were recorded for the first time form Saudi Arabian soil samples although these strains are common in hot springs of Saudi Arabia (28).

Chlorogloepsis fritschii occurred in all sites with 93% frequency except at site A of Jizan. This is probably due to the high temperature recorded in Jizan. Arif (5) did not have growth of *C. fritschii* at temperatures higher than 40 °C. Fay & Fogg (29) reported that optimum productivity of this species was recorded at a temperature less than 40 °C .

It is hoped that the present investigation of the environments of the South Western Region of Saudi Arabia will attract the interest of more microbiologists, where a considerable number of taxa of microbial flora is expected from the Hijaz Mountains.

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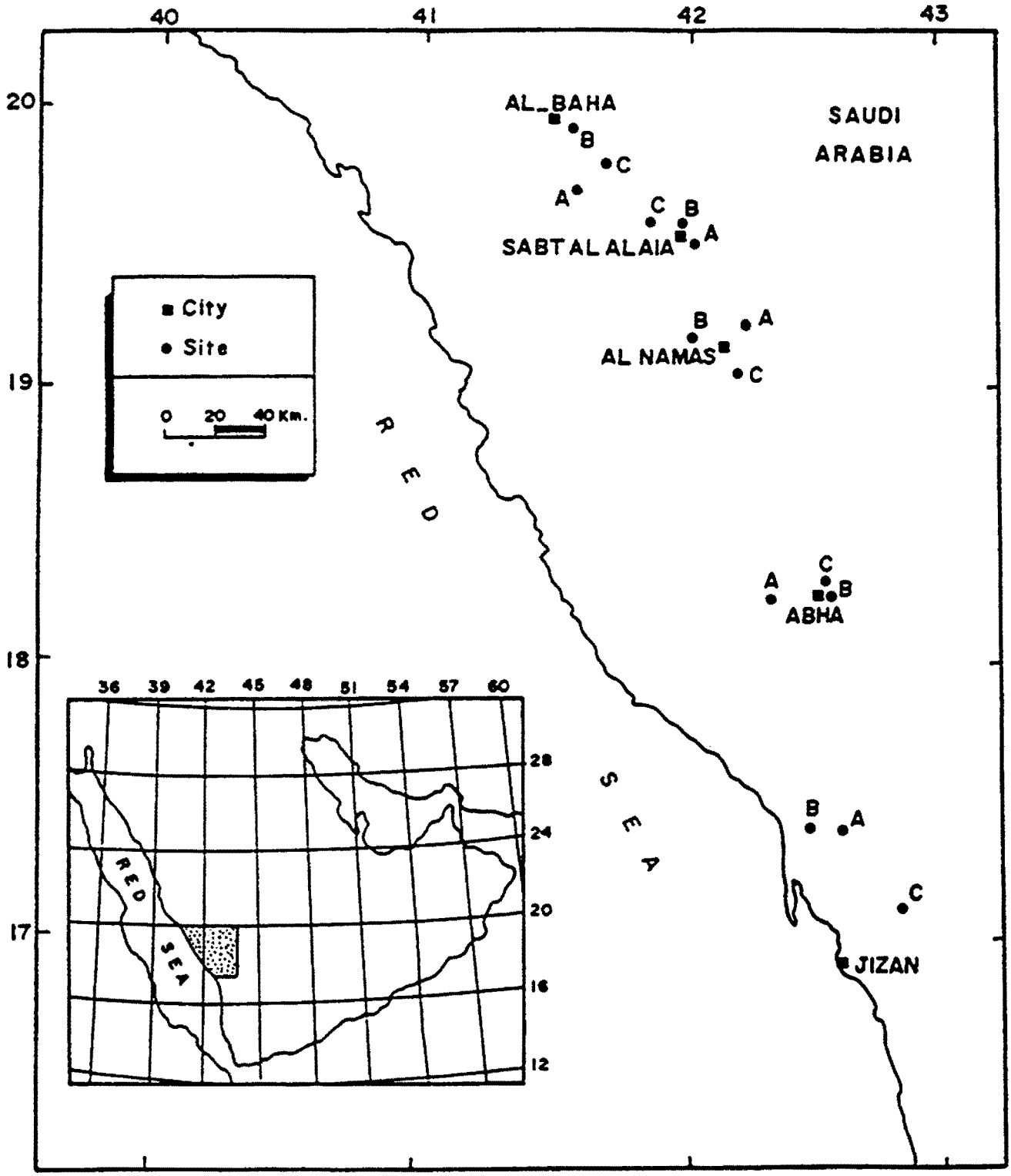

FIG.1: Location of sites surveyed.

Table 1: Climatic data for the cities of the study sites.

City	Altitude (m)	Mean of annual maximum temperature (°C)	Mean of annual minimum temperature (°C)	Mean of annual rainfal (mm)
ALBAHA	2200	20	11	333.8
SABT ALALAIA	1850	29	7	197.5
ALNAMAS	2600	15.22	9	495
ABHA	2200	22.4	12	332
JIZAN	7	39	25	52

Source: Department of Hydrology, Ministry of Agriculture (Personal Communication, 1993).

Table 2. Soil physical properties of the study sites.

Location	Site	Temperature (°C)	Moisture content (%)	* SP (%)	Mechanical Analysis Sandy of Soil			Soil Texture
					Sandy (%)	Silt (%)	Clay (%)	
ALBAHA	A	33	25	23.7	76	14	10	Sandy loam
	B	38	18	27	70	19	11	Sandy loam
	C	32	25	24.7	79	12	9	Sandy loam
SABT ALALAIA	A	38	25	40.8	43	41	16	Loam
	B	32	43	35.7	63	22	15	Sandy loam
	C	40	20	29.2	75	14	11	Sandy loam
ALNAMAS	A	25	46	31.7	54	36	10	Sandy loam
	B	29	37	38.3	57	29	14	Sandy loam
	C	30	34	29.3	75	14	11	Sandy loam
ABHA	A	22	38	39.2	26	57	17	Sandy loam
	B	35	23	35	75	19	6	Sandy loam
	C	32	35	38.3	73	16	11	Sandy loam
JIZAN	A	45	45	28.3	86	7	7	Loamy Sand
	B	41	60	31.8	79	10	11	Sandy loam
	C	42	55	29.5	83	7	10	Loam Sand

* Saturation Percentage
A,B & C: Codes for sites around location.

Table 3: Soil Chemical properties of study sites.

Location	Site	pH	EC (mmhos cm^{-1})	Total soluble salts (p.p.m.)	Na	K	Ca	Mg	CO_3	HCO_3	Cl	SO_4	NO_3	PO_4	Organic matter (%)
					Meql^{1}				Meql^{1}						
ALBAHA	A	7.27	0.402	281.4	0.435 ±0.024	0.205 ±0.07	3 ±0.17	1.5 ±0.20	-	2.15 ±0.02	1 ±0.1	1.51 ±0.01	0.33 ±0.09	0.581 ±0.028	0.4 ±0.07
	B	7.7	0.522	365.4	0.696 ±0.015	0.08 ±0.002	4 ±0.44	1 ±0.17	-	4.10 ±0.018	1.6 ±0.3	1.84 ±0.17	0.21 ±0.036	0.726 ±0.027	1 ±0.05
	C	7.8	0.3696	258.7	0.533 ±0.013	0.212 ±0.019	4.7 ±0.260	0.1 ±0.02	-	2.5 ±0.40	0.8 ±0.2	0.95 ±0.02	0.33 ±0.059	0.254 ±0.004	0.5 ±0.04
SABT ALALAIA	A	7	0.6522	456.54	0.565 ±0.06	0.138 ±0.011	6 ±0.20	0.5 ±0.17	-	4.60 ±0.26	2 ±0.1	2.72 ±0.21	0.235 ±0.023	0.835 ±0.053	2.01 ±0.87
	B	7.67	0.4131	289.17	0.696 ±0.06	0.149 ±0.69	3 ±0.30	0.7 ±0.12	-	2.30 ±0.33	1 ±0.23	0.90 ±0.06	0.245 ±0.027	0.180 ±0.071	0.8 ±0.56
	C	7.97	0.2500	175	0.446 ±0.071	0.036 ±0.081	2.5 ±0.10	0.5 ±0.05	-	2.25 ±0.9	0.6 ±0.3	1.31 ±0.21	0.204 ±0.016	1.258 ±0.063	0.6 ±0.11

Table 3. cont.

JIZAN	A	7.80	2.2280	1559.6	2.957 ±0.49	2.462 ±0.030	21 ±0.31	1.5 ±0.10	-	1.10 ±0.26	0.4 ±0.1	21.84 ±0.03	0.311 ±0.048	0.702 ±0.140	0.2 ±0.07
	B	8.11	0.6196	433.7	4.478 ±0.03	0.123 ±0.082	3 ±0.20	0.3 ±0.05	-	1.15 ±0.10	2 ±0.1	5.88 ±0.90	0.318 ±0.041	0.327 ±0.025	0.1 ±0.35
	C	7.94	0.2065	144.6	6.087 ±0.08	0.195 ±0.020	4.5 ±0.26	1.5 ±0.20	-	1.30 ±0.20	3.2 ±0.3	9.507 ±0.28	0.264 ±0.015	1.089 ±0.019	0.5 ±0.01
ALNAMAS	A	7.52	0.359	251.3	0.326 ±0.075	0.067 ±0.007	2.5 ±0.12	1 ±0.30	-	0.85 ±0.11	0.6 ±0.1	1.240 ±0.21	0.242 ±0.010	0.699 ±0.016	0.5 ±0.08
	B	7.56	0.609	426.3	0.50 ±0.050	0.421 ±0.019	5.5 ±0.44	1 ±0.50	-	0.85 ±0.04	2.4 ±0.3	4.467 ±0.01	0.440 ±0.026	0.537 ±0.042	2.7 ±0.44
	C	7.66	0.337	235.9	0.326 ±0.039	0.923 ±0.017	3.4 ±0.53	0.1 ±0.001	-	2.90 ±0.20	0.6 ±0.1	2.680 ±0.35	0.265 ±0.016	1.282 ±0.024	0.6 ±0.07
ABHA	A	8.11	0.294	205.8	2.174 ±0.017	0.008 ±0.001	1.5 ±0.10	1 ±0.30	-	2.25 ±0.22	0.6 ±0.2	4.266 ±0.65	0.220 ±0.026	0.242 ±0.030	0.5 ±0.1
	B	7.96	0.370	259	0.467 ±0.073	0.10 ±0.005	3 ±0.15	0.4 ±0.05	-	1.80 ±0.10	0.8 ±0.1	0.62 ±0.01	0.318 ±0.010	0.018 ±0.029	0.3 ±0.09
	C	8.50	0.196	137.2	0.239 ±0.015	0.46 ±0.044	2 ±0.17	0.2 ±0.01	-	1.50 ±0.20	0.6 ±0.1	1.17 ±0.03	0.223 ±0.083	0.271 ±0.139	0.5 ±0.016

Data are Menas of three replicates ± S.D.

A, B & C: Codes for sites around locations.

Table 4: List of soil cyanobacteria and algae recorded from study sites. (Relative frequency in terms of percentage is given for each taxon.)

Taxa																Frequency
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	%
Cyanobacteria																
Chlorogloepsis fritschii (Mitra) Mitra et Pandey	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	93
Chroococcus > 8 < 16 μ m	-	-	-	+	-	-	-	-	-	+	-	-	-	-	-	13
Chroococcus minutus (Klütz.) Näg.	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	7
* *Mastigocladus laminosus* Chom	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	7
Nodularia spumigena Mertens	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	13
Nostoc edaphicum Kondratieva	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	7
N. muscorum Agardh	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	7
Nostoc 80 μm	+	-	-	+	-	-	-	+	+	-	-	-	-	+	-	33
Oscillatoria 50 μm	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	7
Oscillatoria formosa Bory	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	7
Phormidum bohneri Schmidie	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	7

table 4 cont.

Phormidum bohneri schmidie	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	7
P. fovcolarum (Montagne) Gomont	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	13
* *P. tenue* (Menegh.) Gomont	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-	7
Phormidium 40 μm	+	+	+	+	-	+	-	+	-	-	+	-	-	+	+	67
* *Plectonema gracillimum* (Zopf) Hansg.	-	-	-	-	-	+	-	-	-	-	-	-	+	-	-	13
* *Pleurocapsa minor* Hansg. em. Geitler.	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	13
Synechococcus aeriüginosus Näg.	-	-	-	+	-	-	-	+	-	+	+	-	-	-	+	7
Synechococcus sp.	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	13
Chlorophyta																
Chorella sp.	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-	13
Scenedesmus sp.	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	13
Bacillariophyta																
Navicula sp.	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	7

*Cultures grown at 45 °C.

Frequency (No. of samples where present.)

A, B & C: Codes for sites around locations.