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CYANOPHYCEAN ALGAE INHABITING SODIC SOIL EXHIBIT DIVERSE MORPHOLOGY: AN ADAPTATION TO HIGH EXCHANGEABLE SODIUM

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ABSTRACT

A soil pot experiment was conducted in soils containing two exchangeable sodium percentage (ESP) levels *i.e.* normal (4.37) and high (54.5) ESP levels. The soils used in experiment were collected from different natural conditions to asses the algal biodiversity and changes in morphology of algae. The genera reported at high ESP were *Oscillatoria*, *Lyngbya* and colony of *Anabaena* while in normal soil these were absent. The heterocyst chain was also observed in soil of high ESP while in normal soil it was not reported. The width of heterocyst was much different than those reported. The chemical properties of soil e.g. pH, exchangeable sodium and ESP were decreased while organic carbon and total nitrogen contents were increased after one year algal growth.

Key words: Cyanophycean algae, heterocyst, sodic soil, exchangeable sodium percentage.

INTRODUCTION

Environmental constraints including salinity and alkalinity significantly influence the diversity of micro-organisms, their number, morphology and activity in the soil. Work on diversity of cyanophycean algae has been carried out by several algologists (Desikachary 1959, Anand *et al.* 1995, Fernadez *et al.* 1999, Prasad and Srivastava 1992, Sen and Gupta 1998, Watanabe 1996, Tewari *et al.* 1999, Misra *et al.* 2001, Verma *et al.* 2002, Misra and Srivastava 2005). Role of cyanophycean algae in agriculture is well known. As heterocyst fixes nitrogen, the heterocystous forms are used as manure. Any change in morphology particularly heterocyst of cyanophycean algae due to alkalinity stress will certainly affect the nitrogen fixation capacity.

Salt affected soils are highly deficient in organic matter and nitrogen. The efficiency of applied nitrogen fertilizers is very poor due to extensive losses through volatilization in salt affected soils (Gandhi and Paliwal 1976, Rao and Batra 1983). So, algalization has a supplementing effect on the crop yield. Several trails under different agro-climatic conditions with different paddy- cultivars have shown significant increase in paddy yield due to algalization (Goyal 1993, Roger 1991, Dubey and Rai 1995, Gopalaswamy *et al.* 1997). Besides crop yield, 20-30 kg chemical N/ha per season can also be saved by using algal biofertilizer in the paddy crops (Goyal 1996, Singh *et al.* 1992). In the present study diversity of cyanophycean algae and changes in morphology due to highly sodic stress condition and comparison with the already reported genera were studied.

MATERIALS AND METHODS

Soil samples were collected from different places like cultivated land and barren land from Banthra, Lucknow (U.P.), India between 26,°40′-26°, 45′ N latitude and 80,°45′-80,°53′ E longitude on the Lucknow-Kanpur highway at an elevation of 129 m above the mean sea level. The meteorological parameters indicate that the climate of the area is semi-arid, subtropical and monsoonal with an average annual rainfall of 872 mm. The mean maximum and minimum temperatures were 39.1°C and 7.6°C, respectively.

Soils were collected from two different sites, site 1 was collected from garden block of Department of Botany, University of Lucknow, Lucknow, which serves as control and site 2 was collected from Banthra which was totally barren land in which only some *Callotropis procera* and some grasses along with *Acacia* at some places were grown. The soil samples were processed for analysis and the processed samples were analyzed for different chemical characteristics of the soils viz. pH, EC, organic carbon, exchangeable cations and exchangeable sodium percentage (ESP). Soil pH and EC were determined by pH meter and electric conductivity meter method, respectively, in 1:2 soil water ratio (Jackson 1973). Organic C was determined by Wakley and Black's (1943) rapid titration method. Exchangeable cations and CEC were determined by ammonium acetate extractant (Bower *et al.* 1952). The cations extracted from soils by ammonium acetate were determined by flame photometer (Jackson 1973). Soils (5 kg in each pot) were filled in clay pots lined with polythene sheet to check the leaching of water and salts, in replicates. Water was filled in the pot. After some time, observations were taken. Algal samples were collected from each pot. Collections of algae were made by using scalpel/knife and preserved in 4% formalin. For detailed study algae were stained with methylene blue and examined in Nikon Labophot-II microscope.

RESULTS

The soil analysis results showed that there were decrease in soil pH, exchangeable Na and ESP and increase in organic C and total N (Fig. 1) after one year algal growth. Time to time observation revealed that there was bloomed algal growth in pot having high sodic stress which has very high pH (10.13), exchangeable sodium 8.46 cmol kg^{-1} and ESP 54.5 as indicated in Table 1 while in normal soil no markable changes were observed. The microscopic study revealed that three species of *Oscillatoria* (*Oscillatoria tenuis* Ag. ex Gomont, *O. limosa* Ag. ex Gomont, *O. rubescens* Dc. ex Gomont), two species of *Lyngbya* (*Lyngbya polysiphoniae* Fremy, *Lyngbya hieronymusii* Lemm.), colony and chain of *Anabena* were observed in highly sodic stressed soils (Plate 1). Some morphological changes were observed in *Lyngbya* and *Anabena* (Table 2).

Table 1. Chemical properties of the soils.

Soil Properties	Normal Soil	Sodic Soil
Soil pH (1:2)	7.98±0.168	10.13±0.036
Soil EC (dSm^{-1})	0.682±0.036	0.755±0.027
Org C (%)	0.370±0.522	0.173±0.015
Avail.K (kg ha^{-1})	329±19.31	364.5±16.67
Exch. Na (c mol kg^{-1})	0.869±0.022	8.46±0.243
Exch. K (c mol kg^{-1})	1.25±0.15	0.501±0.043
Exch Ca+Mg (c mol kg^{-1})	12.23±0.153	8.83 ± 0.580
CEC (c mol kg^{-1})	19.83±0.252	15.45±0.586
ESP (%)	4.37±0.086	54.5±3.491

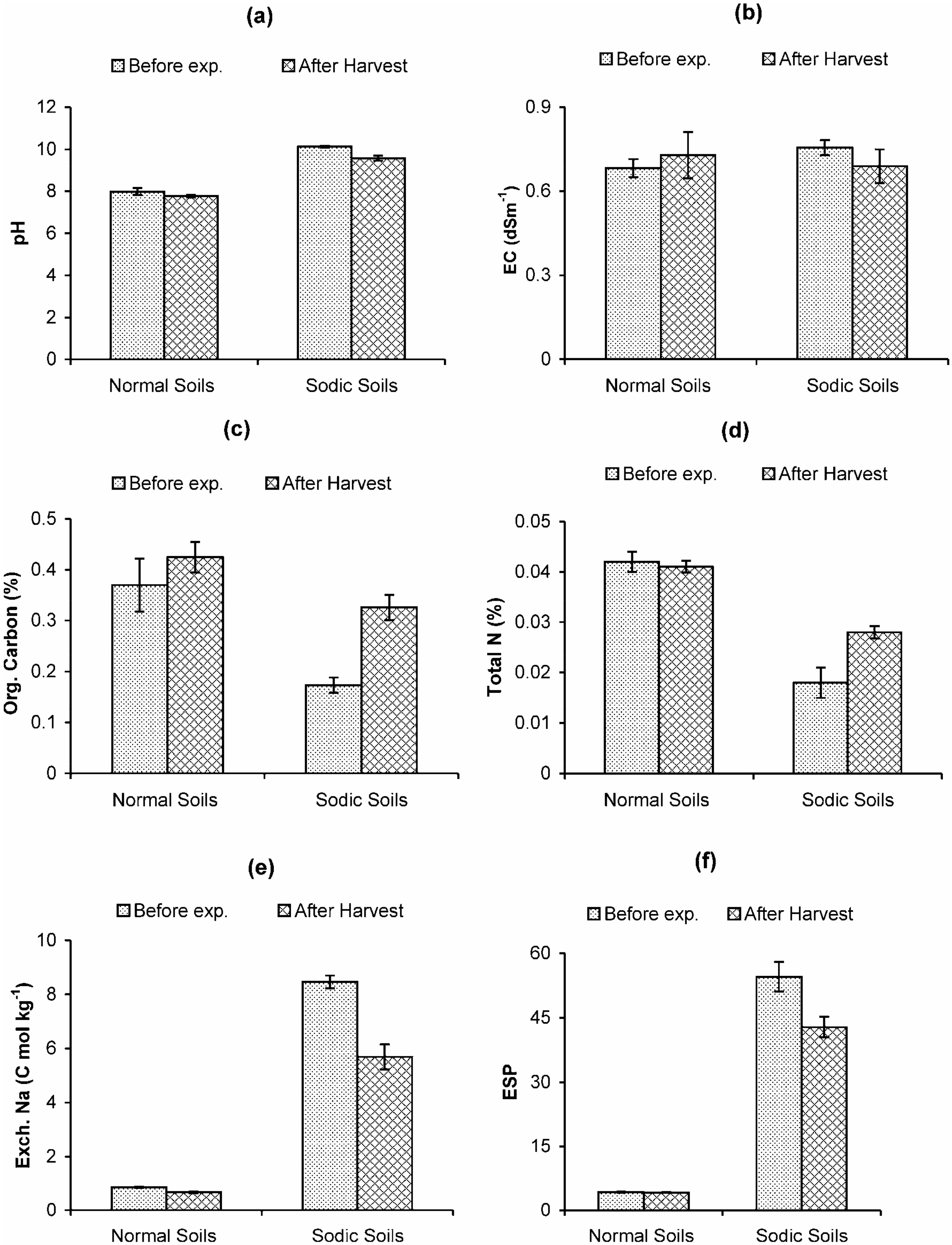

Fig. 1. Changes in chemical properties of soil before experiment and after harvesting of the algal growth: (a) soil pH, (b) soil EC, (c) organic carbon, (d) total nitrogen in soil, (e) exchangeable Na in soil, (f) exchangeable sodium percentage (ESP).

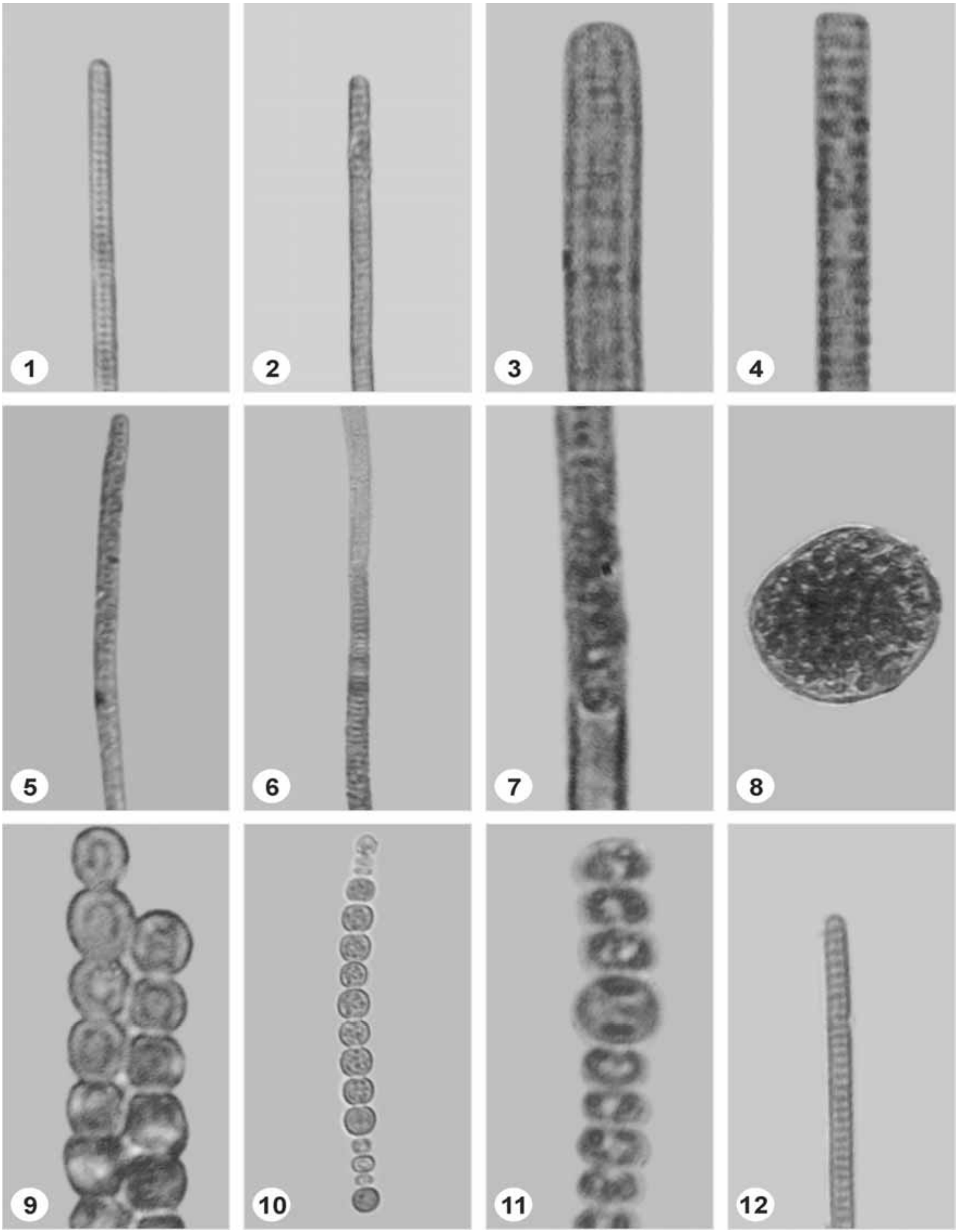

Plate 1. (1, 2: *Oscillatoria tenuis* Ag. ex Gomont x 1150**;** 3: *Oscillatoria limosa* Ag. ex Gomont x 1300**;** 4: *Oscillatoria limosa* Ag. ex Gomont x 750; 5: *Oscillatoria rubescens* Dc. ex Gomont x 800; 6: *Lyngbya polysiphoniae* Fremy x 1000; 7: *Lyngbya hieronymusii* Lemm.x 1400; 8: Colony of *Anabaena* Bory x 650; 9: Heterocyst chain of *Anabaena* Bory; 10: *Anabaena orientalis* Dixit x 1000; 11: *Anabaena orientalis* Dixit x 2000; 12: *Oscillatoria tenuis* Ag. ex Gomont x 1150).

Table 2. Morphological observation of cyanophycean algae in sodic stress soils and comparison with normal condition.

Species	Reported in normal condition (Desikachary 1959)	In present study
Oscillatoria tenuis Ag. ex Gomont (Plate-1; Figs. 1,2,12)	Cell L= 2-5 µm, W= 5-6.5 µm	Cell L= 2-2.5 µm, W= 4-5 µm
O. limosa Ag. ex Gomont ((Plate-1; Figs. 3,4)	Cell L= 2-5 µm, W= 13-16 µm	Cell L= 5-6 µm, W= 10-12 µm
O. rubescens Dc. ex Gomont (Plate-1; Fig. 5)	Cell L= 2-4 µm, W= 6-8 µm	Cell L= 3-4 µm, W= 5 µm
Lyngbya polysiphoniae Fremy (Plate-1; Fig. 6)	Cell L= 1 µm, W= 2 µm Filament W = 4 µm	Cell L= 2µm, W= 4 µm Filament W = 5 µm
Lyngbya hieronymusii Lemm. (Plate-1; Fig. 7)	Cell L= 2.5 - 4µm, W= 11-13 µm Filament W = 12-14 µm	Cell L= 6 µm, W= 10 µm Filament W = 14 µm
Colony of *Anabena* Bory (Plate-1; Fig. 8)	Absent	Colony dia.= 50-55 µm
Heterocyst chain of *Anabena* Bory (Plate-1; Fig. 9)	Absent	Present
Anabena orientalis Dixit (Plate-1; Figs. 10,11)	Cell L= 3.7 – 4.8µm, W= 2.5-4 µm Akinete L= 14.8-16.6 µm W = 7.4-9.2 µm Heterocyst L= 7.4-9.2 µm W = 4.8-5.5µm	Cell L= 5 µm, W= 5-5.5µm Akinete L= 8.5 µm W= 8 µm Heterocyst L= 8 µm W = 9 µm

L= Length, W= Width, dia. = Diameter

DISCUSSION AND CONCLUSION

Calcium carbonate is invariably present in alkali soils. Under favorable conditions, microbiological decomposition of organic matter added by pioneer colonizers like blue green algae (BGA) initiate natural reclamation (Singh 1950) through production of organic acids, which react with calcium carbonate, releasing calcium that in turn replaces the sodium of the exchange complex. There are report on the use of BGA as agent for reclamation of alkali soils due to their ability to secret organic acids and immobilized sodium in the biomass (Singh 1950, Subhashini and Kaushik 1985). Similar observations were found in present study which was change in chemical properties of the soils. These algae have capacity to reclaim "*usar* soil" through a series of successive algal growth in a water logged condition as indicated by several workers and in present study also. One of the important observations regarding morphology of BGA in the present study, showed differences in length and width of cell in comparison with normal condition which may be due to sodic stress condition. Besides the morphological observation, authors have also recorded several heterocysts, in the form of chain (Plate 1, Fig. 9). The presence of heterocysts chain in sodic stress soils will certainly fix high atmospheric N_2 in comparision to normal one, because these heterocysts are important site of nitrogen fixation and thus increase soil fertility. However, non-heterocystous forms also fix N_2 usually under aerobic condition (eg. *Oscillatoria*). On the surface of saline "*usar* soil" BGA developed during rainy season, form thick stratum of *Anabaena* (Plate 1; Figs. 10, 11) and *Oscillatoria* (Plate 1; Figs. 1-5, 12). The present study of one year experiments clearly shows the sodic land reclamation is possible by growing these species of BGA in sodic land in successive years.

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