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EFFECTS OF CYANOBACTERIA ON SOIL PROPERTIES IN FOREST AND CULTIVATED LANDS OF MADHUPUR TRACT

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Abstract

A laboratory experiment was conducted at the Department of Soil Science of Bangladesh Agricultural University, Mymensingh to assess the effect of cyanobacteria on soil properties of cultivated and forest lands of Madhupur Tract. The population of cyanobacteria in two soils from Madhupur and one fromfrom BAU farm was counted followed by their identification up to genera level by fluorescence microscope. A marked variation was observed in cyanobacterial population among the soils: 27.8×10^5 g^{-1} in BAU farm soil, 2.70×10^5 g^{-1} in Madhupur cultivated soil and 1.62×10^5 g^{-1} in Madhupur forest soil. A total of 21 isolates were identified from all the soils taking eight isolates from each of Madhupur cultivated and BAU farm soils, and five from Madhupur forest soil . Of the 21 isolates, six isolates taking two from each soil were inoculated into all the three soils to see their effect on soil properties. These were *Fischerella* Mc and *Aulosira* Mc from Madhurpur cultivated soil; *Calothrix* Mf and *Scytonema* Mf from Madhurpur forest soil; *Anabaena* Bf and *Nostoc* Bf from BAU farm soil. The results reveal that there was an increase of soil pH, organic matter, total N, available P, exchangeable Ca, available S and CEC and a decrease in exchangeable K and exchangeable Na concentrations. The impact of different isolates on most of the soil properties was significant except their effect on exchangeable K for all soils, exchangeable Na for BAU farm soil and CEC for Madhurpur cultivated soil. Usually isolates showed better performance in their native soils than in other soils and cyanobacteria inoculation showed a positive indication towards improving fertility of soils.

Keywords: BAU farm, Cynabacterial population, N_2 fixation, Soil fertility

Introduction

Cyanobacteria are widely distributed in many habitats. Many of them have a capability to fix atmospheric N (N_2) and thereby improve the nitrogen status of soil. As photosynthetic organism, they can also fix atmospheric CO_2, thus reduce its concentration, and thereby help decrease the greenhouse effect. They can improve soil

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organic matter, stable aggregates, increase P availability by surface bound and extracellular phosphates activities, control soil erosion and maintain soil ecosystem (Kaushik and Murti, 1981).

Cyanobacteria grow abundantly in tropical and subtropical regions and are particularly common in rice fields (Dey *et al.,* 2010). The occurrence of these organisms are ubiquitous and has been recorded in soils throughout the world, but no definite geographical locations of families, genera or species has yet been presented. Kaushik (2000) reported that application of cyanobacteria biofertilizers to rice crops improves soil structure (aggregation), increases P availability and in saline alkali soils reduces soil pH, hence there is an overall improvement of physical, chemical and nutritional properties of soil. The present agriculture practices heavily rely on the application of chemical fertilizers and pesticides, and practices like intensive tillage and excess irrigation which otherwise lead to ever increasing cost of agricultural production, over exploitation of natural resources likes oil and water, and also create environmental pollution (Kumar *et al.,* 2012). Soil properties such as texture, mineralogy composition, organic matter and nutrients contents, pH, and electrical conductivity greatly influence cyanobacterial growth and EPS production. So far, most of cyanobacteria inoculation experiments have been performed on sandy soils (Lan *et al.*, 2017, Mugnai *et al.*, 2018). Cyanobacteria are more abundant in habitat in which moisture is adequate and light is accessible. Some Cyanobacteria grow in hot springs at temperatures as high as 90^0C, although the optimal growth temperatures of these thermal cyanobacteria are between 50 to 54^0C (Haque, 2004). They have been widely used as biofertilizers in agriculture, mainly in paddy rice fields in Asia (Prasanna *et al.,* 2009, 2013; Priya *et al.*, 2015; Singh *et al.,* 2016).

Cyanobacteria can contribute to about 20-30 kg N ha^{-1} as well as the organic matter to the soil, quite significant for the economically weak farmers unable to invest for costly chemical nitrogen fertilizer (Issa *et al.,* 2014). In Bangladesh, there is a bright scope for utilizing cyanobacteria because it is a major rice growing country. The rice field provides congenial atmosphere for the establishment of cyanobacteria. Besides this, most of the farmers of this country belong to low income category, getting cheap source of N is very much helpful for them.

Materials and Methods

Soil sample collection and processing

The experiment was conducted at the Soil Science Laboratory of the Department of Soil Science of Bangladesh Agricultural University (BAU), Mymensingh. Three types of soils were selected for the study – (i) Madhupur rice field soil (cultivated soil), (ii) Madhupur forest soil and (iii) BAU farm soil. Soil samples were collected from 0-15 cm depth of soil. After collection, soils of each location were mixed thoroughly by hand on a thick brown paper sheet to make a composite sample at the Soil Science Laboratory, BAU, Mymensingh. Soil samples were air dried, ground and passed through a 2 mm sieve. Thereafter the samples were analyzed for physico-chemical properties.

Soil analysis

Particle size analysis of soil samples was done by hydrometer method (Piper, 1950) and the textural classes were determined following Marshal's Triangular Coordinates using USDA system. Soil pH was measured with the help of a glass electrode pH meter, the soil water ratio being 1:2.5 as described by Jackson (1962). Organic carbon of soil was determined by wet oxidation method with 1N $K_2Cr_2O_7$ and conc. H_2SO_4 (96%) mixture, followed by rapid titration with freshly prepared 1N $FeSO_4$ solution (Walkley and Black, 1935). Organic matter content was then calculated by multiplying the percent organic carbon with the Van Bemmelen factor, 1.73. Total N content of soil was determined by semi Micro-Kjeldahl method. The samples were digested with 30% H_2O_2, conc. H_2SO_4 and catalyst mixture (K_2SO_4:$CuSO_4.5H_2O$: Se in the ratio 100:10:1). Nitrogen in the digest was trapped by boric acid indicator solution following distillation with 40% NaOH and titration was made with 0.01 N H_2SO_4 (Brammer, 1965).

For the determination of available P, extraction was made with 0.5M $NaHCO_3$ adjusted at pH 8.5 following the method of Olsen *et al.,* (1954). The P in the extract was then determined by developing blue colour using stannous chloride was measured by spectrophotometer at 660 nm wave length and available P was calculated with the help of a standard curve. Available S content of soil was extracted from the soil with $CaCl_2$ solution (0.15%) followed by its determination by Bardsley and Lanacaster (1965) and soil S concentration in the extract was determined turbidimetrically of the intensity of turbid by spectrophotometer at 420 η m. Exchangeable Na & K (Pratt, 1965) and Ca (Heald, 1965) were determined by flame photometer on the neutral ammonium acetate 9NH_4OAC) extract.

CEC

CEC was measured by sodium saturation method where NaOAc was used to leach out all the cations from the exchange sites, excess salt was removed by washing with iso-propanol, and finally Na brought into solution by extracting with 1M NH_4OAc, pH 7.0 (Chapman, 1965). The Na concentration of extract was measured by atomic absorption spectrophotometer.

Microbiological experiment

Twenty one cyanobacterial isolates were identified from the selected soils. Among them six isolates viz., *Anabaena* S, *Nostoc* S, *Fishcherella* Mc, *Aulosira* Mc, *Calothrix* Mf and *Scytonema* Mf had been selected for inoculation. The selected isolates were grown in the laboratory in conical flask in modified version of Chu 10D-N medium (Sinclair and Whitton, 1977) at room temperature (25±2°C) under constant light of 100 watt bulbs fixed at 20 cm apart and 50 cm away from the culture. An equal amount of cyanobacterial cultures of all these six isolates were homogenized by reciprocating shaker and followed by hand shaking. Homogenized cultures were inoculated in 200 g of soil kept in plastic pots collected from all the three selected areas. All individual isolate was considered as a treatment and three replications were maintained. A treatment without cyanobacteria inoculation was maintained as control. Thus, there were seven treatments including control. They were as follows: T_1: Control; T_2: *Fishcherella* Mc; T_3: *Aulosira* Mc; T_4: *Anabaena* Bf; T_5: *Nostoc Bf*; T_6: *Calothrix* Mf; T_7: *Scytonema* Mf. Water was added to the pots from time to time to keep the soil moist so that cyanobacteria can easily grow and the inoculated pots were kept under light for 90 days. After this period soil properties such as soil pH, organic matter, total N, available P, exchangeable K, exchangeable Ca, available S, exchangeable Na and CEC were determined. The readings were converted to most probable number (MPN) of cyanobacteria for determination of abundance of organisms in soil And a modified version of Chu 10D-N medium (Sinclair and Whitton, 1977) was used to study the growth of cyanobacteria.

Statistical analysis

Completely randomized design was followed for the experiment. The collected data were analyzed statistically by F-test (LSD value at 5% level) to ascertain the treatment effects and the means were ranked by Duncan's Multiple Range (DMRT) (Gomez and Gomez, 1984).

Results and Discussion

Soil pH

Soil pH increased in all cases due to the treatment of soils with cyanobacterial isolates (Table 1). The ability of cyanobacteria to change the soil pH was not same for all soils. It differed from soil to soil and from isolate to isolate. The soil pH value increased up to 7.01 due to application of cyanobacterial isolates in Madhupur cultivated soil from 6.22 recorded in control. The maximum increase was recorded due to the treatment of *Fishcherella* Mc and the minimum increase was recorded for *Calothrix* Mf treatment. In Madhupur forest soil, the pH value of control was 5.60. The maximum increase was observed due to application of *Calothrix* Mf and the minimum increase was for *Aulosira* Mc. In BAU farm soil, the pH value of control was 6.89 and the highest increase in pH value (7.2) was due to application of *Anabaena* S, while the lowest pH (6.99) was recorded due to both *Fishcherella* Mc and*Scytonema* Mf applications. It is noted that the pH of Madhupur cultivated soil, Madhupur forest soil and Soil Science Farm soil turned to neutral condition as influenced by cyanobacteria application. As the pH of three soils changed towards neutral, it might be said that cyanobacteria play an important role in lowering acidity of soils. Saha and Mandal (1979) reported that algal growth caused an increase in soil pH. This finding can be considered as supportive to the current results.

Organic matter

Soil organic matter content increased due to application of cyanobacterial isolates. The increase was statistically significant (Table 1). In Madhupur cultivated soil, the highest organic matter content of 2.56% was observed due to the inoculation of *Fishcherella* Mc followed by organic matter contents of 2.46, 2.45, 2.41 and 2.40% due to the application of *Aulosira* Mc, *Nostoc* S, *Anabaena* S, *Scytonema* Mf and *Calothrix* Mf, respectively. The lowest organic matter content was 1.97% in control.

Table 1. Effects of different cynabacterial isolates on pH, organic matter and total N content of soils

Treatments	Soil pH			Organic matter content			Total N concentration (%)		
	Madhupur cultivated soil	Madhurpur forest soil	BAU farm soil	Madhupur cultivated soil	Madhurpur forest soil	BAU farm soil	Madhupur cultivated soil	Madhurpur forest Soil	BAU farm soil
Control	6.22	5.60	6.89	1.96 e	1.24 g	1.94 d	0.135	0.076	0.125
Fischerella Mc	7.01	6.80	6.99	2.56 a	1.50 d	2.27 bc	0.175	0.084	0.160
Aulosira Mc	7.00	6.55	7.04	2.50 b	1.62 c	2.23 bc	0.170	0.080	0.175
Anabaena Bf	6.80	6.65	7.20	2.45 c	1.34 f	2.35 ab	0.155	0.087	0.175
*Nostoc***f**	6.79	6.70	7.15	2.46 c	1.48 e	2.40 a	0.165	0.082	0.165
Calothrix Mf	6.65	6.99	7.01	2.40 d	1.67 b	2.17 c	0.170	0.091	0.155
Scytonema Mf	6.75	6.89	6.99	2.41 d	1.69 a	2.20 c	0.160	0.111	0.145
SE (±)	0.06	0.05	0.07	0.04	0.04	0.05	NS	NS	NS

Mc= Madhurpur cultivated soil, Mf= Madhupur forest soil and Bf= BAU farm soil. In a column, the figure(s) having common letter(s) do not differ significantly at 5% level of significance. SE=Standard error of means, NS= Not significant

The minimum increase of organic matter in soil was recorded in *Calothrix* Mf cyanobacteria inoculation. In Madhupur forest soil, the highest organic matter content of 1.69% was due to the use of *Scytonema* Mf followed by organic matter in *Calothrix* Mf, *Aulosira* Mc, *Fishcherella* Mc, *Nostoc Bf* and *Anabaena* f. The lowest organic matter was recorded in control treatment (1.24%). The minimum increase of organic matter was due to use of *Anabaena* Bf. In BAU farm soil, the highest organic matter content of 2.40% was observed in *Nostoc* Bf inoculation which was statistically similar to 2.35% due to application of *Anabaena* Bf. Again the organic matter content recorded in *Anabaena* S inoculation was statistically similar to the organic matter recorded in *Fishcherella* Mc and *Aulosira* Mc inoculation. The lowest organic matter (1.91%) was found in absence of cyanobacterial isolates. The minimum increase of organic matter was recorded in *Calothrix* Mf inoculation. Islam *et al.* (1993) observed that the growth of cyanobacteria in soil can increase organic matter in soil up to 840 kg ha^{-1}. Our result is in good agreement with the present finding. Because cyanobacteria use the energy of sunlight to drive photosynthesis, a process where the energy of light is used to synthesize organic compounds from carbon dioxide.

Total N

Results show that there was an increase in total N concentration of all the studied soils with cyanobacterial inoculation (Table 1). The increase in total N was statistically significant. There was a variation in the ability of the cyanobacterial isolates in increasing N concentration in different soils. In Madhupur cultivated soil, the highest total N concentration (0.175%) was observed in *Fishcherella* Mc inoculation which was statistically identical to those resulted from of the inoculation of *Aulosira* Mc and *Calothrix* Mf cyanobacteria. The value of total N concentration of 0.135% was the lowest as recorded in control. The minimum increase in total N concentration was due to the inoculation of *Anabaena* B**f**. In Madhupur forest soil, the highest total N concentration (0.111%) was recorded in *Scytonema* Mf cyanobacteria inoculation, followed by the total N concentration of 0.091, 0.087, 0.084 and 0.082% in the *Calothrix* Mf, *Anabaena* S, *Fishcherella* Mc and *Nostoc* B**f** inoculation, respectively. The lowest N concentration was 0.076% which was recorded in control treatment. The minimum increase was recorded due to the addition of *Nostoc* S cyanobacteria. In Soil Science Farm soil, total N concentration (0.175%) was maximum and was observeddue to the effect of *Aulosira* Mc and *Anabaena* S. The effects of *Nostoc* S, *Fishcherella* Mc and *Calothrix* Mf cyanobacteria were statistically similar on total N content of soil at BAU farm. The lowest total N conc. (0.125%) was observed in control. The minimum increase was due to addition of *Calothrix* Mf. Haque (2004) observed a value of 0.140 to 0.180% increase in total N of soils due to application of cyanobacterial isolates. Thus, our present results indicate that N status of soils can be increased by the application of cyanobacterial isolates.

Available P

Available P in different soils was influenced by different isolates of cyanobacteria (Table 2). Results indicate that available P in the studied soils increased significantly by the treatments. The maximum available P (18.8 ppm) in Madhupur cultivated soil was recorded in *Aulosira* Mc inoculation which was statistically identical to 18.1, 18.1, 18.0 and 18.2 ppm recorded in *Anabaena* B**f**, *Nostoc* B**f**, *Calothrix* Mf and *Scytonema* Mf inoculation, respectively. The lowest value of 16.8 ppm was found in control. The minimum increase in available P was recorded with the application of *Fishcherella* Mc. In Madhupur forest soil, the highest available P of 8.69 ppm was recorded in *Scytonema* Mf inoculation, followed by 8.50, 8.00, 7.89 and 7.60 ppm in *Calothrix* Mf, *Nostoc* S, *Aulosira* Mc and *Fishcherella* Mc inoculation, respectively. The lowest available P of 7.30ppm was recorded in control. The minimum increase in available P was due to the treatment of *Anabaena* S (7.45ppm). In BAU farm soil, the highest P concentration P was 12.0 ppm due to the application of *Anabaena* B**f** which was statistically identical to those noticed in all the treatments except in control. The lowest value of available P (10.9 ppm) in these soils was recorded in control which was statistically identical to that recorded in *Aulosira* Mc. Kaushik (2000) reported that application of cyanobacterial biofertilizer helped increase the availability of P.

Exchangeable K

Isolates of cyanobacteria had no significant effect on the exchangeable K concentration of the selected soils (Table 2). Results indicate that exchangeable K concentration in the studied soils by value decreased due to the application of cyanobacterial isolates. In Madhupur cultivated soil, the highest exchangeable K concentration was 0.309 me% in control and the lowest was 0.284me% due to the application of *Fishcherella* Mc. In Madhupur cultivated soil, the effects of *Nostoc* Bf and *Scytonema* Mf application were same which was 0.297 me%. The minimum decrease in exchangeable K was recorded in *Scytonema* Mf and *Nostoc* Bf inoculation. In Madhupur forest soil, the highest exchangeable K concentration was recorded 0.160me% in control. The lowest exchangeable K concentration was 0.153me% due to the application of *Calothrix* Mf which was followed by exchangeable K in *Scytonema* Mf, *Nostoc* Bf, *Fishcherella* Mc and *Anabaena* Bf inoculation. The minimum decrease in exchangeable K was recorded in *Aulosira* Mc added soils. The highest exchangeable K (0.236 me%) concentration was recorded at BAU farm soil in case of control. The lowest exchangeable K was 0.215me% recorded in soils applied with both *Nostoc* S and *Fishcherella* Mc. The minimum decrease in exchangeable K was found in soils inoculated with *Calothrix* Mf and *Aulosira* Mc. Haque (2004) reported that the exchangeable K decreased due to the treatment with cyanobacteria but this decrease was statistically insignificant. This finding resembled the finding recorded in the present study.

Exchangeable Ca

Exchangeable Ca also increased due to different of cyanobacterial isolates and such increase was statistically significant (Table 2). In Madhupur cultivated soil, the highest exchangeable Ca concentration was 4.95 me% due to the inoculation of *Fishcherella* Mc followed by the application of *Aulosira* Mc, *Calothrix* Mf, *Nostoc* Bf, *Scytonema* Mf and *Anabaena* Bf. The lowest exchangeable Ca of 4.43 me% was observed in the control treatment which was statistically identical to those observed with the treatment *Anabaena* Bf and *Scytonema* Mf. The maximum and minimum increase in exchangeable Ca concentration was due to addition of *Fishcherella* Mc and *Anabaena* S, respectively. In Madhupur forest soil, the highest exchangeable Ca concentration was 5.36 me% in soils inoculated with *Calothrix* Mf followed by the addition of *Scytonema* Mf, *Fishcherella* Mc, *Aulosira* Mc, *Nostoc* Bf and *Anabaena* Bf, respectively. The lowest value of exchangeable Ca (4.40 me%) was recorded in control. The minimum increase in exchangeable Ca was due to use of *Anabaena* Bf. In BAU farm soil, the highest exchangeable Ca concentration (4.53 me%) was recorded in soils inoculated with *Anabaena* Bf which was statistically identical to 4.43 and 4.33 me% due to the application of *Nostoc*Bf and *Fishcherella* Mc, respectively. The lowest value of exchangeable Ca (3.91 me%) was recorded in the control treatment. The minimum increase in exchangeable Ca was due to the effect of *Scytonema* Mf. frit

Available S

Different isolates of cyanobacterial treatments showed a significant increase in available S content for all types of soil (Table 3). In Madhupur cultivated soil, the highest available S (15.5ppm) was recorded in soils inoculated with *Aulosira* Mc, which was statistically identical to 15.5, 15.4, 15.3 and 14.8 ppm available S recorded in the inoculation of *Fishcherella* Mc, *Anabaena* Bf, *Nostoc* Bf and *Scytonema* Mf, respectively. But the effect of *Nostoc* Bf and *Scytonema* Mf was statistically identical to the effect of *Calothrix* Mf.

Table 2. Effects of cynabacterial isolates on available P, exchangeable K and exchangeable Ca concentrations of soils

Treatments	Available P concentration (ppm)			Exchangeable K concentration (me%)			Exchangeable Ca concentration (me%)		
	Madhupur cultivated soil	Madhurpur forest soil	BAU farm Soil	Madhupur cultivated soil	Madhurpur forest soil	BAU farm soil	Madhupur cultivated soil	Madhurpur forest Soil	BAU farm soil
Control	16.8 c	7.30 g	10.8 b	0.309	0.160	0.236	4.43 d	4.40 g	3.91 d
Fischerella Mc	17.5 bc	7.60 e	11.6 a	0.284	0.156	0.215	4.95 a	4.99 c	4.33 ab
Aulosira Mc	18.7 a	7.89 d	11.4 ab	0.285	0.159	0.227	4.69 b	4.83 d	4.17 bc
Anabaena S	18.1 ab	7.45 f	12.0 a	0.296	0.157	0.220	4.48 d	4.56 f	4.53 a
Nostoc S	18.1 ab	8.00 c	11.9 a	0.297	0.155	0.215	4.63 bc	4.75 e	4.43 a
Calothrix Mf	18.0 ab	8.50 b	12.0 a	0.302	0.153	0.227	4.69 b	5.36 a	4.07 cd
Scytonema Mf	18.2 ab	8.69 a	11.7 a	0.297	0.154	0.221	4.58 cd	5.30 b	4.06 cd
SE (±)	0.15	0.11	0.11	NS	NS	NS	0.04	0.07	0.05

Mc= Madhurpur cultivated soil, Mf= Madhupur forest soil and Bf= BAU farm soil. In a column, the figure(s) having common letter(s) do not differ significantly at 5% level of significance. SE=Standard error of means, NS= Not significant

The lowest available S (13.2 ppm) concentration was recorded in control. The minimum increase in available S concentration was recorded in *Calothrix* Mf. In Madhupur forest soil, the highest available S concentration (9.91ppm) was recorded in *Calothrix* Mf. This was followed by 9.87, 9.65, 9.60, 9.56 and 4.49 ppm due to the effects of *Scytonema* Mf, *Nostoc* Bf, *Aulosira* Mc, *Anabaena* Bf and *Fishcherella* Mc, respectively. The lowest available S concentration was recorded in control. The minimum increase in available S concentration was recorded due to the inoculation of *Fishcherella* Mc. In BAU farm soil, the highest available S concentration was 17.6 ppm recorded due to the effect of *Anabaena* Bf inoculation. Available S concentration was statistical identical due to the effect of *Nostoc* Bf, *Calothrix* Mf, *Fishcherella* Mc and *Aulosira* Mc. The lowest available S concentration was recorded in control. The minimum increase in available S was due to the addition of *Scytonema* Mf. Paul and Clark (1989) reported that algal sulphate esters show a 2 - 3% of the total organic S in soils which are mineralized under favourable conditions to available SO_4^{-2}. This clearly indicates that cyanobacterial biomass might be the cause for increasing available S in soil. Thus it is found that cyanobacterial isolates clearly increase the available S concentration in soils.

Exchangeable Na

Effects to the different treatments on exchangeable Na (me%) of the selected soils under study are shown in Table 3. Exchangeable Na in soil was decreased by different cyanobacterial isolates. The decrease in exchangeable Na was statistically significant in case of Madhupur cultivated and forest soil but not significant in case of BAU farm soil. In Madhupur cultivated soil, the highest exchangeable Na (0.783 me%) percentage was recorded in control and the lowest exchangeable Na (0.716 me%) was due to the application of *Aulosira* Mc, which was statistically identical to the effect of *Aulosira* Mc (0.717 me%) and *Calothrix* Mf (0.732 me%), respectively. The minimum decrease in exchangeable Na concentrations was due to the effect of *Scytonema* Mf. In Madhupur forest soil, the highest exchangeable Na (0.59 me%) was recorded in control and the lowest exchangeable Na (0.50 me%) was by the application of *Scytonema* Mf, which was followed by the addition of *Calothrix* Mf, *Nostoc* Bf, *Aulosira* Mc, *Fishcherella* Mc and *Anabaena* Bf, respectively. The minimum decrease of exchangeable Na was recorded in the treatment of *Anabaena* Bf. In BAU farm soil, the highest exchangeable Na percentage of 0.716 me% was recorded in the control treatment and the effect of *Aulosira* Mc. The lowest value of exchangeable Na of 0.662 me% was recorded in *Nostoc* Bf inoculation. The minimum decrease of exchangeable Na was observed in*Scytonema* Mf. Sodium is essential for the growth, N fixation and photosynthetic functions of cyanobacteria (Apte and Thomas, 1983). Subhashini and Kaushik (1981) reported that the exchangeable Na status can be brought down appreciably by the addition cyanobacterial isolates. The reduction in exchangeable Na by cyanobacteria was reported by Hashem et al. (1995) and Hashem (1997). These findings indicated that the decrease in exchangeable Na level might be due to its utilization by the cyanobacterial isolates.

Table 3. Effects of different cynabacterial isolates on available S , exchangeable Na and CEC value of soils

Treatments	Available S concentration (ppm)			Exchangeable Na (me%)			Cation Exchange Capacity (me%)		
	Madhupur cultivated soil	Madhurpur forest soil	BAU farm soil	Madhupur cultivated soil	Madhurpur forest soil	BAU farm soil	Madhupur cultivated soil	Madhurpur forest soil	BAU farm soil
Control	13.2 c	9.21 g	16.1 d	0.783 a	0.59 a	0.716	14.0	13.4 g	9.19 b
Fischerella Mc	15.5 a	9.49 f	17.2 b	0.716 c	0.55 c	0.705	14.7	13.5 d	9.61 a
Aulosira Mc	15.5 a	9.60 d	17.0 bc	0.717 c	0.54 d	0.716	14.7	13.4 f	9.75 a
Anabaena S	15.4 a	9.56 e	17.6 a	0.740 b	0.56 b	0..664	14.6	13.5 c	10.2 a
Nostoc S	15.3 ab	9.56 c	17.3 b	0.741 b	0.53 e	0.662	14.3	13.4 e	9.95 a
Calothrix Mf	14.5 b	9.91 a	17.2 b	0.732 bc	0.52 f	0.665	14.3	13.5 b	9.19 a
Scytonema Mf	14.8 ab	9.87 b	16.9 c	0.742 b	0.50 g	0.669	14.1	13.5 a	9.47 a
SE (±)	0.18	0.05	0.1	0.01	0.01	NS	NS	0.03	0.04

Mc= Madhurpur cultivated soil, Mf= Madhupur forest soil and Bf= BAU farm soil. In a column, the figure(s) having common letter(s) do not differ significantly at 5% level of significance. SE=Standard error of means, NS= Not significant

Cation Exchange Capacity (CEC)

CEC of the selected soils presented in the Table 3. The results showed that CEC was increased in cyanobacterial isolates inoculation. But the increase was significant in Madhupur forest and BAU farm soil and insignificant in Madhupur cultivated soil. In Madhupur cultivated soil, the highest CEC was 14.7 me% due to addition of *Aulosira* Mc. The lowest value was noted 14.0 me% in the control treatment. The minimum increase in CEC was due to treatment of *Scytonema* Mf. In Madhupur forest soil, the highest CEC of 13.5 me% was recorded in *Scytonema* Mf in soil, followed by the application of *Calothrix* Mf, *Anabaena* Bf, *Fishcherella* Mc and *Nostoc* Bf. The lowest value (13.40 me%) was recorded in the control. The minimum increase of CEC was observed in *Aulosira* Mc treated soil. In BAU farm soil, the highest CEC of 10.18 me% was recorded due to the application of *Anabaena* Bf. Rest of them are statistically identical with this. The lowest CEC was 9.19 me% recorded in control which was statistically identical with *Calothrix* Mf.

Conclusion

Selected cyanobacterial isolates showed a considerable impact on the chemical properties of soils. Cyanobacteria can be used to improve soil fertility, especially for the purpose of increasing the level of soil organic matter, total N, available P, available S, exchangeable Ca and CEC and also in decreasing soil acidity. In most of the cases, cyanobacterial isolates performed the best in the soils of their habitats. As a result, *Fischerella* Mc and *Aulosira* Mc showed the best results in case of Madhupur cultivated soil compared to other soils. Further research works at field and incubation levels should be carried out in a manner for practical and applied purposeseritseh and to identify their best uses.

Conflicts of Interest

The authors declare no conflicts of interest regarding publication of this paper.

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