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Influence of cyanobacteria on improving alkaline soil fertility, growth and yield of paddy

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Abstract

The highly saline adaptable species of cyanobacteria viz., *Phormidium fragile* and *Oscillatoria curviceps* showed high potential for reclamation of alkaline soil with *P. fragile* being more effective. pH, electrical conductivity and exchangeable sodium percentage were reduced significantly due to the treatment of these cyanobacteria. Paddy grown in alkaline soils treated with these cyanobacteria had higher chlorophyll content, shoot length, root length, fresh weight, dry weight and grain weight.

Keywords : cyanobacteria, *Oscillatoria curviceps, Phormidium fragile*, rice yield, soil fertility, soil reclamation

INTRODUCTION

Soil salinity and alkalinity appear to be major problems in Indian agriculture as alkali (sodic) soil has a high pH, high exchangeable sodium and measurable amount of carbonates and undergoes extensive clay dispersion leading to poor hydraulic conductivity and reduced soil aeration (Gupta and Abrol, 1990). As a consequence, crop production of these soils is poor and in many such lands no cultivation could be made and left barren. The reclamation of sodic soil involves chemical amendment and biological treatment methods (Duraisamy *et al.,* 1986). Reclamation by biological methods is much slower and depends on the quality and quantity of incorporates used to make green manure. Cyanobacteria, a phototrophic organism, grows extensively on alkaline soils and other extreme environments. Because of their eco-economic advantages in addition to heat stress tolerance, ecological adaptability, and ability to absorb sodium and also fixation of nitrogen (Stamatakis *et al.*, 1999; Hagemann *et al.*, 1989), soil cyanobacteria can be used to reclaim the soil (Kaushik and Subhashini, 1985). We examined the potentials of backwater cyanobacteria towards the reclamation of alkaline soil and the efficacy of such reclamation by assessing the growth and yield of paddy in such reclaimed soils.

MATERIALS AND METHODS

Soil Analysis

Alkaline soil samples were collected from Kattumavadi, Pudukkottai district and their pH, Electrical Conductivity (EC), Cation Exchange Capacity (CEC), Exchangeable Sodium Percentage (ESP), exchangeable magnesium, calcium, available nitrogen (N), phosphorous (P) and potassium (K) were determined by using the methods of soil chemical analysis described by Jackson (1967).

Cyanobacteria

Two saline tolerant cyanobacterial species viz. *Phormidium fragile* and *Oscillatoria curviceps* that were isolated from backwaters of Kattumavadi were used for the experiments.

Immobilization of cyanobacteria

Immobilization of cyanobacterial cells were carried out in polyurethane foams that were prepared by cutting 1.5 cm^3, washed twice with distilled water, autoclaved at 121°C for 15 minutes and cooled to room temperature. Each foam piece was inoculated with known amount of homogenous suspension of 7 days old culture to ensure uniform inoculum in all foam pieces and transferred to ASN III medium (without NaCl)

Columns Culture and Pot Culture

Poly Vinyl Chloride (PVC) columns (30 cm in depth, 14 cm in diameter) with a drain at the base were used for experiments. Each column was packed with uniform bulk density of soil to the depth of 25 cm. Free and immobilized cyanobacteria with poly urethane foam of *P. fragile* and *O. curviceps* were used to find the potential of reclamation of alkaline soil. After 40 days, the soil (to a depth of 10 cm) layers were analyzed.

Pot culture experiments were performed under natural condition in triplicate. Rice variety ADT 36 seedlings were transplanted to mud pots containing alkaline soil in the frequency of 3 plants per pot. Various parameters such as shoot length, root length, fresh weight, and dry weight, chlorophyll content of paddy and grain weight (per 1000 grains) were analysed.

RESULTS AND DISCUSSION

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Table 1. Effect of cyanobacteria on reclamation of alkaline soil (Changes in chemical parameters from outdoor column experiments). Values are $\bar{X} \pm$ *S.E.*

S.No	Parameters	Unsterilized Soil					Sterilized Soil				
		Control	*P. fragile*		*O. corniceps*		Control	*P. fragile*		*O. corniceps*	
			Free	Immobilized	Free	Immobilized		Free	Immobilized	Free	Immobilized
1	pH	8.67 ±0.58	7.5 ±0.002	7.48 ±0.027	8.61 ±0.0053	8.35 ±0.0012	8.65 ±0.0057	7.62 ±0.0052	7.4 ±0.0053	8.62 ±0.0052	8.50 ±0.085
2	Electrical Conductivity (EC) dsm^{-1}	2.6 ±0.012	0.95 ±0.011	0.85 ±0.0812	1.25 ±0.015	1.21 ±0.01	2.9 ±0.001	1.00 ±0.1	0.85 ±0.002	1.23 ±0.005	1.2 ±0.002
3	Cation Exchange Capacity (CEC) $meq\ 100g^{-1}$	15.42 ±0.201	25.00 ±0.208	32.20 ±0.01	25.32 ±0.005	30.05 ±0.136	15.45 ±0.206	24.00 ±0.057	32.25 ±0.06	20.25 ±0.08	30.00 ±0.208
4	Exchangeable Sodium $meq\ 100g^{-1}$	7.5 ±0.005	4.0 ±0.06	3.25 ±0.15	5.2 ±0.08	4.0 ±0.114	8.00 ±0.05	4.2 ±0.026	3.25 ±0.08	5.0 ±0.02	4.28 ±0.05
5	Exchangeable Sodium Percentage (%)	48.63 ±0.615	16.0 ±0.6	15.09 ±0.002	20.53 ±0.136	19.31 ±0.14	51.77 ±0.011	17.5 ±0.012	15.00 ±0.15	2469 ±0.13	19.26 ±0.208
6	Available Nitrogen (%)	0.0081 ±0.0007	0.0085 ±0.0006	0.009 ±0.0007	0.0091 ±0.0007	0.0093 ±0.0007	0.008 ±0.0001	0.009 ±0.0005	0.009 ±0.0004	0.009 ±0.0004	0.009 ±0.0004
7	Available Phosphorous (%)	0.002 ±0.006	0.0025 ±0.006	0.0022 ±0.0062	0.0032 ±0.003	0.0033 ±0.0034	0.008 ±0.004	0.002 ±0.003	0.0022 ±0.006	0.0035 ±0.003	0.0033 ±0.003
8	Available Potassium (%)	0.0015 ±0.0012	0.0011 ±0.001	0.001 ±0.0015	0.0021 ±0.0021	0.0025 ±0.0021	0.0015 ±0.004	0.0011 ±0.001	0.001 ±0.001	0.0021 ±0.001	0.0025 ±0.0023
9	Exchangeable calcium $meq\ 100g^{-1}$	4.21 ±0.08	4.56 ±0.1	465 ±0.57	5.180 ±0.68	5.25 ±0.65	4.2 ±0.111	4.5 ±0.115	46 ±0.057	5.13 ±0.065	5.28 ±0.01
10	Exchangeable Magnesium $meq\ 100g^{-1}$	5.2 ±0.02	4.82 ±0.13	4.6 ±0.1	4.86 ±0.3	482 ±0.025	5.2 ±0.15	4.8 ±0.20	46 ±0.05	49 ±0.01	4.85 ±0.20

Table 2. Growth parameters of Paddy (Values are from outdoor pot culture experiments in alkaline soils subjected to various treatments and control). Values are X ± *S.E.*

S.No.	Name of the Parameters	Unsterilized Soil					Sterilized Soil				
		Control	*P.fragile*		*O.curviceps*		Control	*P.fragile*		*O.curviceps*	
			Free	Immobilized	Free	Immobilized		Free	Immobilized	Free	Immobilized
1.	Total chlorophyll content	0.0894 ±0.08	0.2135 ±0.015	0.2262 ±0.025	0.2030 ±0.02	0.2170 ±0.13	0.0866 ±0.001	0.2139 ±0.02	0.2256 ±0.20	02023 ±0.05	0.2172 ±0.01
2.	Shoot length (cm)	42 ±0.42	70 ±0.02	69 ±0.13	54 ±0.11	55 ±0.20	40 ±0.106	65 ±0.106	68 ±0.5	53 ±0.208	55 ±0.005
3.	Root length (cm)	11.2 ±0.025	13.7 ±0.026	13.5 ±0.075	12.5 ±0.007	12.5 ±0.11	10 ±0.02	12.5 ±0.01	13 ±0.025	12 ±0.02	12.7 ±0.1
4.	Fresh weight of plant (g)	7.46 ±0.02	12.5 ±0.011	13.48 ±0.15	10.76 ±0.11	10.30 ±0.01	6.73 ±0.02	11.83 ±0.01	12.86 ±0.11	10.5 ±0.05	10.26 ±0.08
5.	Dry weight of plant (g)	1.30 ±0.005	2.88 ±0.02	2.15 ±0.005	1.98 ±0.02	1.99 ±0.135	1.22 ±0.025	2.65 ±0.01	2.12 ±0.01	2.1 ±0.06	1.99 ±0.08
6.	Weight of 1000 grains (g)	7.5 ±0.005	18 ±0.06	17.5 ±0.008	16 ±0.025	15.5 ±0.007	7.0 ±0.3	18.50 ±0.08	17.7 ±0.11	16.8 ±0.2	16 ±0.003

Reclamation of soil

The pH and EC values in the soils were significantly reduced ($P < 0.05$; DMRT) after the treatment with *P. fragile* and *O. curviceps* (Table 1). Both the free and immobilized cyanobacteria treatments resulted in significant ($P < 0.05$; DMRT) reduction of exchangeable sodium. The CEC increased with both free and immobilized cells of *P. fragile* and *O. curviceps* treatments. Further, the cyanobacterial treatment caused significant ($P < 0.05$; DMRT) reduction in ESP as well. The results on the availablility of N, P and K revealed that available nitrogen was slightly increased in all kinds of treatments with cyanobacterial cells. No significant changes were observed in available phosphorous and potassium after treatments. Exchangeable calcium increased slightly after inoculation of free and immobilized species of *P. fragile* and *O. curviceps* (Table 1).

Subhashini and Kaushik (1981) also reported that the pH and Electrical Conductivity of the alkaline soil decreased when treated with cyanobacteria and gypsum mixtures. Pandiarajan and Kannaiyan (1996) also reported similar results and suggested that the combination of cyanobacteria with some natural products and chemical fertilizers for better reclamation of alkaline soil. However it was found that in the present investigation, cyanobacteria itself could reclaim alkaline soil.

Influence of cyanobacteria on paddy

Assessment of paddy growth and yield potential of rice in the reclaimed soils treated with the cyanobacteria *P. fragile* and *O. curviceps* showed that the chlorophyll content, shoot length, root length, fresh and dry weight of paddy have got significantly increased in all treatments with backwater cyanobacterial species over the control (Table 2). Among the treatments, the highest grain yield (160% greater than control) was obtained with *P. fragile* (Table 2).

Paddy growth was reported to be high with algal inoculation combined with nitrogen fertilizer by Sharma and Mishra, (1986) also. A significant increase in plant height over control when cyanobacteria were inoculated in combination with paddy straw or gypsum was earlier reported by Pandiarajan and Kannaiyan, (1996) as well. Puste and Das (2002) have also reported that the influence of cyanobacteria on the weight gain of the grain and straw yield.

The present investigation showed that backwater cyanobacterial strains *viz., Phormidium fragile* and *Oscillatoria curviceps* could be used to reclaim alkaline soil without supporting materials or chemical fertilizers. Hence these backwater species could be employed for effective reclamation of alkaline soils. Further more, these Cyanobacterial species could as well be used as nitrogen sources and serve as a cheap source of natural biofertilizer in addition to amelioration of alkaline soils.

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