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Soil Profile Studies During Bioremediation of Sodic Soils Through the Application of Organic Amendments (Vermiwash, Tillage, Green Manure, Mulch, Earthworms and Vermicompost)

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Abstract: Present investigations were carried out during 1998-2000 at Shivri farm of Uttar Pradesh Bhumi Sudhar Nigam, Lucknow, India, to study the soil profile changes by the application of organic amendments "vermiwash, tillage, green manure, mulch, earthworms and vermicompost" in sodic soils. The soil quality was monitored upto the depth of 90 cms during the experiment. The comprehensive study of the soil profile during the sodic soil bioremediation process through vermitech showed that there is considerable improvement in the soil quality upto a depth of 30 cm in 2 years, which establishes the importance of bioremediation applying Vermitech through biological inputs, though predominantly effective in the surface layers. This biological method of reclamation is sustainable.

Key words: Sodic soils · Bioremediation · Sodicity · Vermitech · Vermicompost · Vermiwash · Soil profile

INTRODUCTION

Sodicity is a natural phenomenon related to the nature of the parent material and the process of pedogenesis, but there are sodic soils that arise from anthropogenic processes like improper land management practices, deforestation and inadequate drainage [1-3]. About 40% of the barren salt-affected soils of India are confined to the Indo-gangetic plains belonging to Uttar Pradesh, Haryana and Punjab. The highest alkali status of the soils is reported to be the major constraint impairing their productivity. Most of these soils have been reported to have formed under the influence of sodium carbonate, which, on hydrolysis, imparts a high pH and ESP, which adversely affects the physico-chemical and biological properties of such soils.

The reclamation of sodic soils requires improvement in soil structure for sustainable productivity that involves the addition of chemical or / and organic amendments, providing a source of Ca^{+2} ions to replace exchangeable Na^{+} ions, coupled with excess water to leach the Na^{+} from the root zone [4]. Intelligent and selective use of organic amendments like vermicompost, vermiwash, mulch (chiefly including plant residues like paddy straw) and green manure, and bio-inoculation of soil organisms like earthworms in sodic soil in this study, have proved effective in soil conditioning values and varying degrees of influence on soil properties [5]. The role of earthworms in soil formation and soil fertility is well documented and recognized [6-9]. An approach towards good soil management, with an emphasis on the role of soil inhabitants like earthworms, in soil fertility, is very important in maintaining balance in an ecosystem [10]. Large extents of land in India are affected by sodicity due to major degradation processes like sodication, water logging, chemical impairment and desertification [11]. The present investigation deals with the reclamation of sodic soil through the use of several organic amendments and highlights the role of earthworms in the process of soil reclamation.

MATERIALS AND METHODS

Experiments were conducted during 1998-2000 at Shivri farm of Uttar Pradesh Bhumi Sudhar Nigam, Lucknow, India, to study the process of reclamation of sodic soil through the combined application of several organic amendments in sodic soils.Cultures of *Perionyx excavatus* Perrier (epigeic) and *Lampito mauritii* Kinberg (anecic) species of earthworms were set up in cement tanks of size 2m x 1m x 1m (pH 9.5-10) and allowed to stabilise in sodic soil by the use of paddy straw and cattle

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dung at regular interval of 7 days over the soil bed and were used later in the field experiments. Vermicompost and vermiwash were produced by using the process of vermicomposting with the above cultures. Vermicompost was harvested every 45 days at the rate of 350 kg per tank. Vermiwash (leachate of earthworm-worked organic matter, soil and vermicompost) was produced using containers (300 litres capacity) fitted with tap at the rate of 7 litres per day. Other organic amendments like green manure (*Sesbania sp.*), farm yard manure (FYM) and mulch (Hay) were also used in experiments. Field experiments were carried out in sodic soil to study the effect of organic amendments followed by cultivation of wheat (*Triticum aestivum* variety *Raj* 3765) and paddy (*Oryza sativa* variety CSR-30).The experimental area (372.1 m^2) was divided into 10 plots, size of each 6.1×6.1 m for treatments. The combination of organic amendments is as follows:

Vermiwash (1kl/ha)+Tillage + Green manuring (*S. aculeata* @ 60 kg/ha) + Mulching @ 6 tonnes/ha + Earthworm inoculation (*P. excavatus* and *L. mauritii* in the ratio 1:2) + Vermicompost @ 6 tonnes/ha

The gradual addition of organic amendment was taken up as the earthworms cannot sustain in sodic soil and earthworms have never been used in reclamation of sodic soil. Some of the organic amendments like *S. aculeate*, mulching and farm yard manure have already been used in the earlier experiments for the reclamation of sodic soils [12,13]. Reclamation using the above amendments was carried out for period of 6 months followed by crop trials. Epigeic and anecic earthworms in the ratio 1:2 per hectare were introduced in the channel of size 6m x 0.5m (mulched with paddy straw) in the centre of the plots after tillage and green manuring for sodic soil bioremediation. Wheat and paddy was cultivated twice. Soil samples were collected as follows:

1. Initial sodic soil
2. Stage 1: Reclaimed soil (after ½ year) –reclamation using vermiwash, tillage, green manure, mulch, earthworms and vermicompost
3. Stage 2:Reclaimed soil (after 1 year)-after harvest of wheat and paddy
4. Stage 3: Reclaimed soil (after 1½ year) after harvest of wheat
5. Stage 4: Reclaimed soil (after 2 year) after harvest of paddy

These were subjected to physico-chemical analysis (pH, electrical conductivity, organic carbon, total Kjeldahl nitrogen, potassium, sodium and calcium) [14]. Exchangeable sodium percentage (ESP) or sodicity was also calculated [15].

RESULTS AND DISCUSSION

Table 1 to 5 show the trends observed in the chemical parameters of the soil profile namely, pH, electrical conductivity, organic carbon, available nitrogen,

Table 1: Soil chemical analysis pH

Depth (cm)	Sodic soil	Reclamation stage 1	2	3	4	Decrease in pH
00-15	09.6	09.4	09.1	09.0	08.4	1.2
15-30	10.4	09.7	10.2	10.1	09.9	0.5
30-45	10.2	10.0	10.1	10.2	10.0	0.2
45-60	10.4	10.0	10.1	10.3	10.1	0.3
60-75	10.4	10.0	10.2	10.5	09.8	0.6
75-90	10.5	10.0	10.1	10.6	10.3	0.2

Table 2: Electrical Conductivity (dSm^{-1})

Depth (cm)	Sodic soil	Reclamation stage 1	2	3	4	Decrease in EC
00-15	1.05	0.75	0.71	0.65	0.42	0.63
15-30	0.98	0.90	0.48	0.47	0.44	0.54
30-45	1.10	0.92	0.49	0.53	0.57	0.53
45-60	1.01	0.53	0.82	0.47	0.51	0.50
60-75	0.96	0.81	0.70	0.75	0.48	0.48
75-90	0.85	1.02	1.11	0.67	0.64	0.21

Table 3: Organic carbon (%)

Depth (cm)	Sodic soil	Reclamation stage 1	2	3	4	Decrease in OC %
00-15	0.24	0.51	0.52	0.52	0.82	0.58
15-30	0.16	0.18	0.31	0.49	0.63	0.47
30-45	0.15	0.18	0.28	0.33	0.52	0.37
45-60	0.13	0.15	0.15	0.18	0.25	0.12
60-75	0.18	0.19	0.21	0.21	0.33	0.15
75-90	0.18	0.25	0.27	0.28	0.33	0.15

Table 4: Available nitrogen (kg/ha)

Depth (cm)	Sodic soil	Reclamation stage 1	2	3	4	Increase in Av. N
00-15	337.60	442.40	564.80	664.80	836.80	499.2
15-30	258.40	303.20	494.40	497.60	611.20	352.8
30-45	286.00	353.20	427.20	509.20	664.80	378.8
45-60	291.20	336.00	336.00	403.20	460.00	168.8
60-75	303.20	325.60	370.40	370.40	439.20	136.0
75-90	336.20	360.00	404.80	427.20	439.20	103.0

Table 5: Sodicity (ESP)

Depth (cm)	Sodic soil	Reclamation stage 1	2	3	4	Decrease in Sodicity (ESP)
00-15	85.59	63.49	40.65	27.58	12.78	72.81
15-30	84.06	61.71	53.02	39.26	34.42	49.64
30-45	85.76	78.88	58.56	45.72	33.55	41.94
45-60	88.56	86.19	65.33	46.18	39.26	49.30
60-75	89.37	85.33	78.36	65.33	60.75	28.62
75-90	90.27	82.54	81.29	78.36	65.32	24.95

Table 6: Composite index based on soil physical and chemical analysis

Depth (cm)	pH	EC	OM	OC	N	P	K	Na	Ca	ESP	Composite index	Rank
00-15	1	1	1	1	1	1	1	1	1	1	10	1st
15-30	3	2	2	2	3	2	2	2	2	2	22	2nd
30-45	5	3	3	3	2	3	3	3	4	4	33	3rd
45-60	4	4	5	5	4	4	4	5	3	3	41	4th
60-75	2	5	4	4	5	5	4	4	5	5	43	5th
75-90	5	6	4	4	6	6	5	6	6	6	54	6th

Table 7: Earthworm numbers per square metre (Mean±SD) in sodic soil bio-remediation plots (Number of earthworms inoculated: *L. mauritii:* 42 and *P. excavatus* : 21)

S.No.	Amendment	Number of earthworms per square metre: *L. mauritii*	*P. excavatus*
1	[VWTGMEVC]	136.00±29.01	64.96±12.94

and sodicity (ESP), at specific depths and at different stages of sodic soil bioremediation through Vermitech during 1998-2000. Maximum decrease in pH (Table 1) and electrical conductivity (Table 2) was observed to the depth of 15 cm. Increase in organic carbon (Table 3) and available nitrogen (Table 4) was observed to the depth of 15 cm. Sodicity (ESP) (Table 5) was maximum to the depth of 15 cm.

This may be attributed to increase microbial activity resulting in production of organic acids [16-18], like humic acid from decomposition of plant litter and addition of compost [19,20], burrowing and cast deposition by earthworms. Addition of organic matter in the form of mulch, vermicompost and addition of earthworm casts results in increased bioavailability of these elements [18]. The application of green manure therefore enhances the reclamation action of organic manures like vermicompost by improving the physico-chemical properties of soil and by markedly decreasing soil pH. These observations correlate well with earlier studies [12,5], on the effects of amelioration treatments of sodic soils where application of compost was the most effective followed by mulching compared to that of gypsum in reclaiming sodic soils. Amending soil with vermicompost showed alteration in pH as also reported earlier by Stratton *et al.* [21]. Introduction of earthworms in sodic soil resulted in the production of humic acid during decomposition, thereby reducing soil alkalinity in terms of pH; as was also observed by Patcharapreecha *et al*. [12]. Increase plant litter incorporation, improved aggregation, better aeration and water relationships and the soil characteristics were observed following the establishment of earthworms in sodic soils [5,9]. Several workers have confirmed that adequate quantity of nitrogen was supplied by compost applications [22]. The effectiveness of vermicompost in sodic soil reclamation is due to the production of carbondioxide and humic acids, a drop in redox potential and the replacement of exchangeable Na^+ ions by Ca^{+2} ions leaching out of the root zone; thus reducing the ESP [13]. The introduction of earthworms in sodic soils through a unique buffering mechanism along with mulch as organic cover resulted in a natural colonization and establishment of the earthworm population (Table 7). The role of earthworms in such a process as an indicator and biomanager is critically important. Soils could be sustained through the use of organic amendments like vermicompost and inoculation of earthworms which facilitates humus formation and prevents leaching of nutrients from the soil by their slow release compared with conventional farming using chemical fertilisers [5,23,24].

Statistical analysis based on the composite index (Table 6) of various depths of the soil profile during sodic soil bioremediation indicates that the maximum improvement in soil quality is to the depth of 15 cm. The comprehensive study of the soil profile during the sodic soil bioremediation process through vermitech showed that there is considerable improvement in the soil quality upto a depth of 30 cm in 2 years, which establishes the importance of bioremediation applying Vermitech through biological inputs, though predominantly effective in the surface layers as reported by Nelson and Odes [25].

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