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Characterization of Salt Affected Soils of Southern Rajasthan

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Abstract: Five representative pedons were selected based on Image interpretation (IRS LISS-III) to characterize the salt affected soils of district Chittorgarh, Rajasthan. Soil samples were collected at an interval of 15 cm to a depth upto 90 cm. The soils were sandy clay loam to clay loam in texture, sub-angular blocky to massive in structure and calcareous sodic in nature. The sodicity and calcareousness increased with depth of the pedons examined. Further, the clay content was higher in substratum, leading to an increased CEC values indicating a main contributor, since the organic carbon content of the soils under study is low. Among soluble ions Na^+ and Cl^- dominated followed by Ca^{+2} and HCO_3^- in the saturation extract. Calcium and sodium are the major contributing exchangeable cations followed by magnesium. Two pedons (P_1-Bhopalsagar and P_2-Tana) of tehsil Kapasin categorized under slight to moderate, while three pedons (P_3-Kanakhera, P_4-Dungla and P_5-Idra) of tehsil Rashmi and Dungla under moderate to highly sodic category requiring proper reclamation as well as management alternatives for sustainable crop production.

Key words: Salt affected soil, characterization, southern Rajasthan.

Salt affected soils present diverse problems and differ greatly from normal soils in respect of morphological features, physical properties and chemical characteristics. They show wide variations from place to place and have been distinguished into certain categories, the important ones being the saline and sodic soils. Salt affected soils occur to a lesser or greater extent in practically all the districts of Rajasthan, however, their nature is location specific. Such soils cover an area of nearly 14.62 Mha in the country and 0.50 Mha in Rajasthan. Out of this 0.403 Mha of land is suffering from salinity, while, 0.097 Mha of land is suffering from sodicity (Bhargava and Kumar 2004). Further, the records available for salt affected lands reveal that about 3.3% of gross cultivated area is salt affected in district Chittorgarh (Anonymous, 2005). Systematic studies on the characterization of salt affected soils are of prime importance in taking reclamation measures and evolving/suggesting suitable agronomic practices. Looking at the magnitude of the problem district Chittorgarh was chosen for proposed investigation to characterize the salt affected soils so that in future it may serve as a tool for planning and suggesting management needs of the area.

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Materials and Methods

The study area lies between 23°32′ and 25°13′ north latitude and 74°12′ and 75°49′ east longitude and comprise typical wastelands of Chittorgarh district of Rajasthan. The area experiences mean annual precipitation of about 852.1 mm, which is quite erratic 80% of which is received during the monsoon season from July to August. The minimum and maximum temperatures are 4°C and 40°C, respectively and the mean annual temperature is 22°C. The soil moisture control section remains moist for >90 cumulative days qualifying for Ustic moisture regime and the temperature regime is hyperthermic. The climatic classification of the district is "Semi-arid (dry), small or no seasonal water surplus, hyperthermic, a summer concentric type" as suggested by Mandal *et al.* (1999).

Five representative pedons were selected based on information obtained through satellite imageries from the State Remote Sensing Application Centre, Jodhpur. These sites were located in Kapasin (P_1 and P_2), Rashmi (P_3) and Dungla (P_4 and P_5) tehsil of district Chittorgarh (Table 1). All the five pedons exposed in typical salt affected blocks were examined up to a depth of 90 cm and samples were collected at an interval of 15 cm for detailed study in

Table 1. Topographical and location of soil pedons

Profile No.	Location	Village	Land form	Parent material	Drainage	Present land use
P_1	74°13′E, 24°51′N	Bhopalsagar, Mal, Kapasin	Nearly level plain	Alluvium	Well drained	Cultivated to single crop of barley
P_2	74°12′E, 24°43′N	Tana (Akola), Kapasin	Gently sloping plain	Alluvium	Moderately well drained	Pasture/barren
P_3	74°14′E, 24°55′N	Kanakhera, Rashmi	Nearly level plain	Alluvium	Well drained	Pasture
P_4	74°20′E, 24°30′N	Dungla	Gently sloping land	Alluvium	Well drained	Cultivated to single crop of wheat
P_5	74°16′E, 24°36′N	Idra, Dungla	Nearly leveled plain	Alluvium	Moderately well drained	Cultivated to single crop of sorghum (fodder)

laboratory. These samples were characterized using standard analytical techniques (Richards, 1954; Jackson, 1979). These pedons were categorized on the basis of sodicity appraisal (Saxena and Verma, 1995) using weighted mean of ESP of pedons under.

Results and Discussion

Morphological characteristics of soils

Morphological characteristics of the soils (Table 2) indicate that the soils are very dark grayish brown (10 YR 3/2) to dark brown (10 YR 3/3) and dark grayish brown (10 YR 4/2) to light brownish gray (10 YR 6/2) in color. Soils are darker in surface layer and it becomes lighter in lower depth. Dark color is attributed to chelation and complexation of organic colloids on the surface of clay particles (Dudal and Eswaran, 1988) or due to discrete clay minerals (Buhmann and Schoeman, 1995). The removal of free iron under reducing conditions imparts the soil mineral grain to appear gray (Boul *et al.,* 1998). The color variation in the soils of substratum in contrast to surface layer evidenced higher value and lower chroma which can be attributed to the presence of high amount of free $CaCO_3$ (Table 3) and to the saturation and reduction coupled with mixing of organic matter and soil matrix with carbonate (Randall *et al.,* 1996).

The texture of soils under study varied from loam to clay loam. However, in bottom most layer of pedon P_2 clayey texture was recorded. Further, it was also observed that soil texture becomes heavier (improved) as one proceeds down the depth of pedons. The variation in the texture of soil pedons may be attributed to the differential degree of weathering as well as transportation and accumulation of alluvium from short distances over the years on the original parent material (Mehta *et al.,* 1969; Singh *et al.,* 1994). The other factor which might be responsible for such variations may be due to the differences in weathering activity in different pedons (Kumar and Kumar, 1993).

The morphological description reveals that the soils have sub-angular blocky structure with weak to moderate strength indicating a process of profile development (Kumar and Kumar, 1993), however, in substratum of all the pedons structure become massive indicating lack of development or destruction of soil structure due to prevailing moist conditions in the soils after the depth of 60 cm (Mehta *et al.,* 1969). Perusal of data on morphological features (Table 2) indicated that all the pedons under study produced effervescence when subjected to treatment with dilute HCl, and effervescence become violent as one proceeds down the depth of pedon indicating an increase in the content of $CaCO_3$ as is also evidenced by the content of $CaCO_3$ observed (Table 3). Further, calcium carbonate concretions of different sizes were observed especially in the subsurface horizon creating severe physical hindrance for capillary movement of moisture within the pedon and downward growth of roots (Sharma *et al.,* 1996).

Less annual rainfall (850 mm) in the study area, restricted the leaching of bicarbonate in soils because of poor hydraulic conductivity (Balpande *et al.,* 1996) and therefore, precipitation of carbonate occurs throughout the pedon depth (Table 2) indicating accumulation of pedogenic carbonate (Pal *et al.,* 1999).

Physico-chemical characteristics

The physico-chemical characteristics of the soils of different pedons (Table 3) indicated that

Table 2. Morphological characteristics of soil

Depth	Color	Texture	Structure	Consistency	Effervescence
P_1 (Bhopalsagar, Mal, Kapasin)					
0-15	10 YR 3/2	scl	m2sbk	fr ss p_o	es
15-30	10 YR 3/2	scl	m2sbk	fr ss p_o	ev
30-45	10 YR 3/2	scl	m2sbk	fr ss p_o	ev
45-60	10 YR 3/2	scl	m2sbk	fr ss p_s	ev
60-75	10 YR 3/3	cl	massive	fr ss p_s	ev
75-90	10 YR 3/3	cl	massive	fr ss p_s	ev
P_2 (Tana, Akola, Kapasin)					
0-15	10 YR 3/2	scl	m2sbk	fr ss p_o	e
15-30	10 YR 3/2	scl	m2sbk	fr ss p_o	e
30-45	10 YR 3/2	scl	m2sbk	fr ss p_o	e
45-60	10 YR 3/3	cl	m2sbk	fr ss p_s	e
60-75	10 YR 3/3	cl	m2sbk	fr ss p_s	es
75-90	10 YR 4/4	c	massive	fr s p	ev
P_3 (Kanakhera, Rashmi)					
0-15	10 YR 4/3	scl	m2sbk	fr ss p_o	es
15-30	10 YR 4/3	scl	m2sbk	fr ss p_s	es
30-45	10 YR 4/3	scl	m2sbk	fr ss p_s	es
45-60	10 YR 4/4	scl	m2sbk	fr ss p_s	es
60-75	10 YR 5/2	scl	m2sbk	fr ss p_s	es
75-90	10 YR 5/2	cl	massive	fr ss p_s	ev
P_4 (Dungla)					
0-15	10 YR 3/2	l	f1sbk	fr ss p_o	es
15-30	10 YR 3/2	l	m1sbk	fr ss p_o	es
30-45	10 YR 4/3	scl	m1sbk	fr ss p_o	ev
45-60	10 YR 5/2	scl	m2sbk	fr ss p_s	ev
60-75	10 YR 6/2	cl	massive	fr ss p_s	ev
75-90	10 YR 6/2	cl	massive	fr ss p_s	ev
P_5 (Idra, Dungla)					
0-15	10 YR 4/2	cl	m2sbk	fr ss p_s	es
15-30	10 YR 4/2	cl	m2sbk	fr ss p_s	ev
30-45	10 YR 5/2	cl	m2sbk	fr ss p_s	ev
45-60	10 YR 5/3	cl	m2sbk	fr ss p_s	ev
60-75	10 YR 6/2	cl	massive	f s p	ev
75-90	10 YR 6/2	cl	massive	f s p	ev

Texture: l-loam, cl-clay loam, scl-sandy clay loam, c-clay; Structure: m-medium, 2-moderate, sbk: sub-angular blocky; Consistence: fr-friable, f-firm, s-sticky, p-plastic, ss-slightly sticky, p_o-non plastic, p_s-slightly plastic; Effervescence: e-slight effervescence, es-strong effervescence, ev-violent effervescence.

the soil particle density varied from 2.46 to 2.69 Mg m^{-3} and, it did not exhibit greater variation within or among the pedons. Likewise, bulk density values (1.42 to 1.58 Mg m^{-3}), which showed a negative correlation with organic carbon (r=-0.51**), tended to increase with depth of the pedon. This could be attributed to clogging of pores by dispersed clays in subsoil layers (Mathan and Mahendran, 1994) and reduction of organic carbon (Yeresheemi *et al.*, 1997). Owing to similar causes, per cent porosity (38.52 to 44.53%) also reduced down the layers of pedons under study.

There was a wide variation in clay content of soils of pedons under study, which is varied from 19.17 to 41.61%. It is further inferred from

Table 3. Physico-chemical characteristics of soil

Depth (cm)	pH	ECe (dS m^{-1})	OC (g kg^{-1})	$CaCO_3$ (g kg^{-1})	Sand (%)	Silt (%)	Clay (%)	BD (Mg m^{-1})	PD (Mg m^{-1})	Porosity (%)
P_1 (Bhopalsagar, Mal, Kapasin)										
0-15	9.11	1.51	6.9	137	52.62	13.42	33.96	1.53	2.59	40.92
15-30	9.28	1.47	5.2	145	48.91	22.31	28.78	1.54	2.56	39.84
30-45	9.31	1.90	4.6	147	56.69	18.65	24.66	1.56	2.58	39.53
45-60	9.27	2.12	2.9	150	44.80	18.82	36.78	1.57	2.58	39.14
60-75	9.39	2.03	1.8	194	44.71	21.47	33.82	1.56	2.54	38.58
75-90	9.41	2.14	1.5	364	41.07	22.04	36.89	1.58	2.57	38.52
P_2 (Tana, Akola, Kapasin)										
0-15	8.29	3.96	7.6	37	62.90	6.64	30.46	1.44	2.52	42.86
15-30	8.77	1.77	6.7	45	53.79	13.58	32.63	1.49	2.57	42.02
30-45	9.07	1.43	6.4	62	59.82	12.68	27.50	1.53	2.59	40.92
45-60	9.14	1.92	5.2	67	44.68	18.51	34.81	1.55	2.63	41.06
60-75	9.33	1.76	3.4	92	45.18	17.72	37.10	1.58	2.63	39.92
75-90	9.46	2.17	1.8	310	38.85	19.54	41.61	1.56	2.64	40.91
P_3 (Kanakhera, Rashmi)										
0-15	8.06	0.91	6.6	128	57.50	16.33	26.17	1.44	2.47	41.7
15-30	8.65	0.97	5.7	96	44.37	19.57	36.06	1.48	2.46	39.84
30-45	9.11	1.42	3.8	71	53.81	18.06	28.13	1.51	2.52	40.08
45-60	9.46	1.41	2.2	87	58.29	19.03	22.92	1.54	2.58	40.31
60-75	9.61	1.58	1.8	133	48.68	18.41	32.91	1.58	2.64	40.15
75-90	9.69	1.76	1.4	285	38.62	31.37	29.81	1.56	2.67	41.57
P_4 (Dungla)										
0-15	8.16	1.63	7.2	125	47.61	30.77	21.63	1.47	2.52	41.67
15-30	8.76	1.29	4.9	143	53.40	27.43	19.17	1.53	2.55	40.00
30-45	9.08	1.04	2.5	237	52.66	23.52	23.82	1.56	2.59	39.77
45-60	9.15	1.31	1.2	411	46.13	26.10	27.77	1.52	2.58	41.08
60-75	9.23	1.83	0.8	587	43.08	27.11	29.81	1.57	2.66	40.98
75-90	9.57	1.81	0.4	610	48.32	18.81	32.87	1.54	2.63	41.44
P_5 (Idra, Dungla)										
0-15	8.77	2.81	3.7	63	34.15	37.22	28.63	1.42	2.56	44.53
15-30	9.26	1.49	2.5	156	39.41	34.45	26.14	1.47	2.61	43.68
30-45	9.45	1.51	1.8	172	36.74	41.64	31.62	1.51	2.63	42.58
45-60	9.48	1.37	1.5	181	32.3	33.73	33.97	1.52	2.67	43.07
60-75	9.65	1.56	1.2	187	30.76	36.81	32.43	1.53	2.66	42.48
75-90	9.67	1.79	0.8	190	32.85	31.53	35.62	1.56	2.69	42.01

the perusal of data that clay fraction, in general, is more concentrated in the subsurface layers of the various pedons leading to its accumulation in subsurface layers which can be attributed to mass movement of fine clay (Pal *et al.,* 1999). However, the movement of clay has not been enough to contribute appreciable textural changes in the soil. The sand fraction in soils of study area, in general, exhibited an decreasing trend along with depth of pedon, while, silt fraction did not register any trend with depth of pedon. The irregular distribution of silt fraction in different pedon might be due to differential deposition and erosion cycles along with parent material discontinuity (Qureshi *et al.,* 1996; Bhaskar and Nagaraju, 1998; Nayak *et al.,* 2000). Further, these soils are characterized by a high sand/silt ratio, ranging between 0.8 to 9.5. Smith and Wilding (1972); Sidhu *et al.* (1976) and Ray *et al.* (1997) reported that if difference of sand/silt ratio is more than 0.20 between adjacent horizons it indicates lithological discontinuity. The differences of greater than 0.2 of sand/silt ratio between adjacent horizons in the present investigation was extensive in most of the pedons under study indicating lithological discontinuity in these soils. This may be due to the influence of alluvial material transported by the local stream/ephemeral and deposited in this region.

Soils under study were alkali in nature and the pH value ranging from 8.06 to 9.69 with a weighted mean 8.99 to 9.38. The low pH on surface in some profiles is due to application of tank bed soils on surface of these soils, which is a common practice in these area for making these soils suitable for cultivation. The pH value showed an increase with an increase in the sodicity (ESP) of the soils under study which is also evidenced by significant positive correlation (r=0.78**) (Tiwari *et al.,* 1983; Kumar and Kumar, 1993; Challa *et al.,* 2000; Garg *et al.,* 2000). The ECe of the soils under study ranged between 0.91 to 3.96 dS m^{-1} with a weighted mean of 1.34 to 2.17 dS m^{-1}. The low ECe and high pH and ESP as observed in present study also indicates high degree of sodicity (Challa *et al.,* 2000).

The organic carbon content under present investigation ranged between 0.4 to 7.6 g kg^{-1}, which decreased with the depth (Miller and Donahue, 1982) and was always less than one per cent due to its rapid decomposition and mineralization under prevailing condition of high temperature and low rainfall. The $CaCO_3$ content of these soils varied from 37 to 610 g kg^{-1} and its content increased with depth of the pedons explaining the downward movement of calcium and its subsequent precipitation (Joshi and Kadrekar, 1987; Pal *et al.,* 1999; Challa *et al.,* 2000). Further, a higher amount of $CaCO_3$ in subsoils also deteriorates drainage conditions (Nayak *et al.,* 2000). Examination of soluble cations and anions in the saturation extract showed a preponderance of sodium among cations and chloride followed by bicarbonate among anions, while the contents of calcium and magnesium were almost comparable in magnitude. The dominance of water soluble sodium followed by calcium and magnesium and higher value of chloride as compared to other anions in salt-affected soils have also been reported by Sharma and Bhargava (1993); Yeresheemi *et al.* (1997); Challa *et al.* (2000) and Nayak *et al.* (2000). The carbonate is almost negligible, while, potassium is present in lower amount.

The cation exchange capacity (CEC) exhibited a range between 14.7 to 26.9 cmol (p+) kg^{-1} (Table 4) as a consequence of variation in their clay fraction. The CEC observed in these soils is essentially contributed by their clay content (r = 0.83**), since the soils of the region are low in organic carbon (Table 3) content contributing least towards this parameter (Yeresheemi *et al.,* 1997). Among the exchangeable cations, Ca^{++} dominates the exchange complex though Na^{+} also possess comparable value with Ca^{++} which followed by Mg^{++} (Table 4). It was also observed that as the finer fraction (Table 3) increased, there was a corresponding increase in exchangeable bases which can be attributed to an increase in clay content provided more exchange sites to get the cations adsorbed on it (Datta *et al.,* 1990; Yeresheemi *et al.,* 1997).

The ESP of soils under study indicated a wide variation ranging 16.97 to 45.37%, which increase with depth and showed a significant correlation with pH (r=0.78**). The SAR of soils under study also indicated a wide variation ranging 2.96 to 12.65, which increases with depth and showed a positive correlation with pH and ESP. The tendency of ESP to increase with the depth of pedons indicates the beginning of the sodification process in subsoil layers (Balpande *et al.,* 1996; Challa *et al.,* 2000). These pedons were categorized on the basis of sodicity appraisal (Saxena and Verma, 1995) using weighted mean of ESP. The pedons P_1 and P_2 falls under slight to moderate sodic (ESP 15-30), while, pedons P_3, P_4 and P_5 under moderate to highly sodic soils. The low ECe reported in present investigation also indicates high degree of sodicity.

The taxonomic classification of the salt affected soils investigated in present investigation was worked out based on morphological (Table 2), physico-chemical properties (Table 3) of soils (Soil Survey Staff, 1998). The taxonomic classification upto family level for investigated soils is as follows:

- P1, P4, P5-Loamy, mixed, hyperthermic, *Typic Calciustepts*
- P2, P3-Loamy, mixed (calcareous), hyperthermic, *Typic Haplustepts*

Table 4. Water soluble ions (me L^{-1}) and exchangeable phenomenon [cmol (p^+) kg^{-1}] of soil

Depth (cm)	Water soluble ions								SAR	Exchangeable bases				CEC	ESP
	Ca^{2+}	Mg^{2+}	Na^+	K^+	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2+}		Ca^{2+}	Mg^{2+}	Na^+	K^+		
P_1 (Bhopalsagar, Mal, Kapasin)															
0-15	3.5	1.9	9.1	0.9	0	7.2	6	2.7	5.54	9.32	7.82	5.71	0.37	25.33	22.54
15-30	3.0	1.8	9.4	0.6	0	6.6	7	1.8	6.06	7.79	5.80	4.89	0.44	20.65	23.68
30-45	3.6	2.4	11.9	0.8	0	6.0	8	5.2	6.92	6.10	4.90	4.47	0.25	17.43	25.64
45-60	3.9	2.3	14.5	0.7	0	6.6	11	4.4	8.24	8.43	7.02	6.12	0.67	23.79	25.72
60-75	3.7	2.0	14.6	0.3	0	6.4	8	5.8	8.34	7.37	6.51	5.69	0.60	22.88	24.87
75-90	3.8	2.4	15.4	0.6	1.6	6.0	11	3.0	8.75	8.80	5.70	7.32	0.82	24.39	30.01
P_2 (Tana, Akola, Kapasin)															
0-15	2.4	1.8	4.3	1.0	0	3.6	5	2.2	2.96	7.23	5.71	3.17	0.82	18.67	16.97
15-30	2.1	2.4	5.6	1.9	0	4.0	6	2.9	3.07	8.12	6.92	3.68	1.00	21.39	17.20
30-45	2.7	2.0	8.9	0.8	0	4.8	9	1.2	5.82	6.21	5.71	3.26	1.20	17.65	18.47
45-60	2.4	2.3	13.2	1.1	0	6.2	11	2.8	8.63	7.37	4.67	4.39	0.52	18.31	23.97
60-75	2.2	2.6	12.0	0.9	0	6.4	11	1.4	7.74	8.70	3.44	6.43	0.76	20.81	30.90
75-90	2.8	2.7	14.7	1.3	1.6	5.6	13	Tr	8.85	9.28	6.50	8.61	0.70	26.92	31.98
P_3 (Kanakhera, Rashmi)															
0-15	1.8	1.2	0.8	5.2	0	3.0	5	1.8	10.51	6.80	5.71	3.52	1.25	18.96	18.54
15-30	2.0	1.4	0.6	5.6	0	3.2	5	2.2	11.01	7.00	5.23	4.89	0.87	19.37	25.24
30-45	2.4	2.5	0.7	8.9	0	4.8	9	2.2	9.87	5.96	4.70	5.81	0.92	18.69	31.09
45-60	2.4	2.3	0.4	9.5	0	4.6	8	3.5	9.71	5.21	3.92	5.92	0.51	17.18	34.46
60-75	2.7	2.5	0.5	10.1	0	5.2	9	1.7	12.65	6.81	3.50	7.89	0.76	20.73	38.06
75-90	2.5	2.8	0.9	10.9	3.2	4.8	10	Tr	12.23	6.12	3.82	9.71	0.44	21.4	45.37
P_4 (Dungla)															
0-15	2.9	2.5	10.3	0.7	0	4.6	7	5.5	6.28	6.12	4.25	3.87	0.28	16.49	23.47
15-30	2.1	1.4	8.4	0.6	0	4.0	7	2.7	6.36	5.37	2.23	4.71	0.51	14.65	32.15
30-45	1.8	1.2	6.8	0.7	0	2.4	8	1.1	5.37	5.73	4.30	6.13	0.49	17.54	34.95
45-60	2.1	2.0	9.3	0.3	0	3.8	9	Tr	6.50	6.50	3.78	7.21	0.44	19.79	36.43
60-75	2.5	2.7	12.7	0.2	0	6.2	13	Tr	7.89	5.71	3.92	8.31	0.82	20.36	40.81
75-90	2.3	2.1	13.3	0.4	0	6.4	12	Tr	8.99	4.87	4.00	8.96	0.87	20.12	44.53
P_5 (Idra, Dungla)															
0-15	6.8	4.2	16.2	0.9	0	6.8	16	5.5	6.91	6.79	5.12	5.81	0.37	20.17	28.80
15-30	3.5	2.8	8.1	0.7	0	4.6	8	1.8	4.58	5.83	5.10	6.97	0.35	19.86	35.09
30-45	3.2	2.0	10.9	0.8	0	4.0	9	2.2	6.77	5.76	5.00	8.13	0.25	21.19	38.37
45-60	2.4	2.1	9.1	0.3	0	4.8	7	1.8	6.15	6.00	4.80	8.72	0.27	21.54	40.48
60-75	1.8	1.2	11.9	0.8	0	3.6	9	2.7	9.75	5.80	4.30	9.06	0.43	21.57	42.00
75-90	2.0	2.3	12.5	1.1	0	5.2	11	1.1	8.50	6.12	4.64	9.11	0.41	22.08	41.26

The progressive alkalization of the soils of study area lead to make these soils unsuitable for cultivation since the plant growth can be restricted or entirely prevented by increased level of sodicity in these soils in time to come. Thus, these soils have to be reclaimed by using chemical amendment in integration with organic amendments accompanied with green manuring with dhaincha, which further enhances the process of reclamation of sodic soils. Adoption of alkali tolerant cultivars could help in boosting up of the crop production in the area.

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