Limitations and Productivity Potentials of Alkali Soils of North- West Indian Plains

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Abstract : *Alkali soils are wide spread in the Indo-Gangetic alluvial plains. They mostly have very high pH and excessive sodium carbonates and bicarbonates and are unfavorable to plant growth. High degree of sodium saturation leads to soil compaction. The availability of Ca, Mg, Fe and Mn is reduced considerably as these elements precipitate into nodular forms due to high pH. The plantation of Prosopis juliflora in these soils showed a marked improvement in morphological, physio-chemical and water transmission characteristics. They, in general, have low productivity but respond favourably to chemical and biological reclamation* (**Key words:** *Salinity, nodular forms, infiltration, pore spaces).*

Favourable climatic conditions and good soils make the Indo-Gangetic plain most productive agricultural region. However, large acreage of this region is lying waste as a result of soil alkalisation. In order to improve the productivity of such type of land and to bring them into the production system on sustainable basis, it is important to study these soils for their distribution, characterisation and productivity potentials.

MATERIAL AND METHODS

Salt affected soils in Etah district of Uttar Pradesh have been identified, demarcated and mapped using IRS - LISS-II false colour composite satellite images for the period of Feb. 1991. A physiographic approach using photo elements of tone, texture, pattern and landuse with a judicious ground truth and field correlation was used in mapping salt affected soils. During field survey, the representative soil profiles were studied for morphology, and hydrological and drainage conditions. Horizonwise soil samples were collected and analysed for various constituents following standard analytical procedures. The effects of biological amelioration in two sets of alkali profiles were studied with *Prosopis juliflora*.

RESULTS AND DISCUSSION

Mapping Alkali Soils: Satellite data has considerably eased the mapping of alkali soils on a small and medium scale (Sharma & Bhargava 1988; Dwivedi *et al*.1987). The alkali soils with poor or no vegetative growth and with salt crust on the surface, are highly reflective and are recorded in a clear white tone on the satellite image which facilitates, its demarcation conveniently. Spectral similarity of salt affected and droughtly soils, on the FCC can be overcome by integration of thermal band data (Saxena *et al* 1991). The Indian Remote Sensing satellite LISS-II-FCC on paper format can be used to locate and map the alkali soils on 1:50,000 scale while the digital analysis has the potential to map the alkali soil in great details (Venkataratnam & Rao 1977)

Characteristics : The alkali soils have the dominance of sodium salts mostly of bicarbonates and carbonates. They have high exchangeable sodium (15 or more), and high pHs (> 8.5), and EC of saturation extract < 4 dSm^{-1}. They occupy microdepressions of the alluvial plain. Slope gradients generally remain 1 to 3 per cent (Sharma & Bhargava 1978). In villages such soils remain de-

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TABLE 1. Morphological characteristics of alkali soil from village Nangla Beach, Etah (U.P)

Depth (cm)	Horizon	Colour (%)	Mottling	$CaCO_3$	Fe-Mn nodules (%)	Texture	Structure	Root
0-18	A	Yellowish brown	-	-	Nil	Sl	Platy	Very few
18-44	BA	Olive brown	-	-	Nil	Scl	sbk	Very few
44-68	Bt1	Olive brown	-	5.0	1.5	Scl	sbk	Nil
68-98	Bt2	Olive brown	-	12.4	2.0	cl	sbk	Nil
98-130	BC	Olive brown	Brownish yellow	14.7	2.0	Scl	abk	Nil
130-160	CK	Grayish brown	Brownish yellow	31.0	1.0	l	abk	Nil

Topography : Gently sloping low lands; Drainage : Imperfect Sl = Sandy loam; Scl = Sandy clay loam; l = loam; Sbk = Subangular blocky; abk = Angular blocky.

TABLE 2. Physico-chemical characteristics of alkali soil from village Nangla Beach, Etah (U.P.)

Detph (cm)	pH	ECe dSm^{-1}	ESP	CO3+ HCO3 (me l^{-1})	BD (gcc^{-1})	Hyd. cond. (cm hr^{-1})	Cu	Mn	Fe	Zn
							(ppm)			
0-18	10.5	6.4	64	21	1.6	0.002	0.9	6.5	21	0.7
18-44	10.5	4.9	95	23	1.6	0.002	0.8	7.8	35	0.6
44-68	10.4	5.0	70	27	1.7	0.001	0.6	8.4	22	0.4
68-98	10.5	6.7	82	21	1.7	0.002	0.4	7.4	19	0.4
98-130	10.3	1.5	46	8	1.5	0.004	0.3	5.0	8	0.3
130-160	9.6	1.0	39	nil	1.4	0.010	0.3	5.5	6	0.2

void of vegetative cover with stray trees of *Acacia nilotica* and *Prosopis cineraria*. But in protective enclosures of the coarse grasses like *Dab. sporobolus marginatus* and *Diplachne fusca* are established well. Yellowish brown to olive brown matrix colour and presence of mottles (Table 1) in these soil indicate excessively wet environment in subsoil. Soil texture vary from sandy loam in the surface to clay loam or sandy clay loam at depth of 40 to 90 cm. Surface soil has platy structures followed by subangular to angular blocky structure in the subsoil. Due to the presence of white salt crust, the surface soil (in dry state) remains fluffy and loose. Horizons underlying the surface, become extremely hard and compact on drying. A calcic horizon with large calcium carbonate nodules exists usually below 1m depth (Table 1 & 2).

Limitations : The high degree of compaction caused by the collapse of structural aggregates and sealing of micro and macro pores is the most important physical limitation in alkali soils. Because of the compaction the alkali soils exhibit nearly impervious characteristics with extremely slow infiltration. The surface horizon becomes most limiting when it has high pH, ESP >15 or more and high carbonates with platy structure (Table 2). A calcic horizon with 20 to 30 per cent of calcium carbonate nodules exists at around 1 m depth has thickness of 30-40 cms (Table 1). The intranodular soils is generally loamy sand or sandy loam in texture and readily pervious to roots and water (Table 2).

Alkali soils have varying amounts of sodium carbonates and bicarbonates and a high degree of sodium saturation with pH often exceeds 10 (Table 2), causing unfavorable environment to plant growth. Soluble and exchangeable calcium and magnesium precipitate in such high pH (>10) environment as calcium carbonate rendering soils deficient in these elements. The availability of trace elements except

TABLE 3. Effect of *Prosopis juliflora* on morphological characteristics of alkali soil over a period of 7 years at Etah (UP).

Depth (cm)	Colour	Structure	Pores	Roots
0-11 (0-8)*	Light yellowish brown (Light brownish gray)	Platy (Sbk)	Common fine (Many fine, medium	Few fine (Common fine)
11-41 (8-37)*	Light olive brown (Olive brown)	Sbk (Sbk)	Common fine (Many fine, medium)	Few fine (Many fine, medium)
41-100 (37-100)*	Olive brown (Dark grayish brown)		Few fine (Many fine, medium)	Very few (Many medium, coarse)

* Figures in paranthesis denote Alkali soils planted with *P. juliflora.*

TABLE 4. Effect of *Prosopis juliflora* on physico-chemical characteristics of alkali soil, over a period of 7 years at Etah (U.P)

Depth (cm)	pH	ECe dSm^{-1}	ESP	Ca+Mg	CO_3^+ HCO3	Org. Matter %	$CaCO_3$ %	Clay %	CEC Cmol kg^{-1}
				<-----mel^{-1}	------->				
0-11	10.5	14.8	96.0	0.9	262.0	0.4	0.4	13.6	7.0
(0-8)*	(7.4)	(1.2)	(2.0)	(6.0)	(6.0)	(1.4)	(0.1)	(13.5)	(5.0)
11-41	10.3	12.3	76.0	1.5	200.0	0.4	0.8	15.7	9.5
(8-37)*	(7.9)	(0.4)	(2.0)	(2.5)	(3.0)	(0.9)	(1.0)	(17.2)	(6.3)
41-100	10.1	8.4	66.0	1.7	70.0	0.3	8.4	22.0	8.6
(37-100)*	(9.0)	(1.5)	(32.0)	(1.8)	(10.6)	(0.8)	(11.5)	(21.0)	(9.5)
100-141	9.6	2.0	58.0	1.2	14.8	0.4	58.6	21.0	7.3
(100-137)*	(9.7)	(1.9)	(60.0)	(0.9)	(11.6)	(0.8)	(64.5)	(22.0)	(8.5)

* Figures in parentheses denote alkali soil planted with *Prosopis juliflora.*

molybdenum and boron, also decreases due to high alkalinity and calcareous environment. The reclamation of surface soil by amendments improves infiltration and percolation leading to greater ground water recharge and reduces run off. The excess water accumulated on the surface is often required to be drained and is to be accomplished through shallow ditches dug along the natural slope gradient. A shallow ground water which seldom rises to a depth of less than 2 to 3 m and is receding each year due to more withdrawal than recharge in parts of Punjab and Haryana states, does not limit aerable farming at present. On the contrary in parts of Uttar Pradesh where ground water table prevails within 1 m and is not noticeably utilised for irrigation, a vertical drainage through a network of deep tubewells is necessary to alleviate limitations to several crops due to excessive wetness on initiation of amelioration programme.

Amelioration of Alkali Soil : The morphological and physico chemical characteristics of soils planted *P. juliflora* showed marked improvement over the original alkali soil (Table 3 & 4). The soil colour has changed from light yellowish brown to olive brown upto the middle of profile. Darkening of soil colour is due to an increment in the soil organic matter content. Soil structure in the surface has changed from platy to subangular thus allowing more water to percolate down the soil depth. Soil porosity has changed from common to fine pores to many fine and medium pores upto 100 cm depth. The magnitude of the plant roots has increased manifold. The original alkali soil contain very few fine roots upto a depth of 41 cm while the *P. juliflora* planted soil have many to abundant medium and coarse sized roots proliferating upto 100 cm depth and below. The value of soil pH, EC, ESP and carbonates plus bicarbonates have found decrease significantly while the values of calcium plus magnesium and organic matter have found improved substantially. The improved porosity, deep and extensive root proliferation, increased organic matter and reduced soil ESP has lessened the soil compactness as evidenced by decreased values of soil bulk density from 1.7 to 1.5 gcc^{-1}. Combined effect of all these clearly reflected in the enhanced hydraulic conductivity of the soil from the original value 0.002 and 0.001 to 1.12 and 065 cm hr^{-1} for surface and middle layer respectively. The soil contain a compacted calcium carbonate concretion layer between 100 to 147 cm depth restricts root penetration. However, on planting *Prosopis juliflora,* the hard layer becomes more porous so that roots of the plant penetrate easily.

Productivity Potential of Alkali Soil : The alkali soils usually remain untapped storehouse of intermediate products of weathering. Unless reclaimed, they have low productivity but their potential productivity is excellent (Sharma 1987). Soil depth and rooting zone is not limiting. Sandy clay loam textures provide excellent moisture storage characteristics and the illite mineralogy imparts favourable soil physical characteristics and the illite mineralogy imparts favourable soil physical characteristics and soil workability over a wide range of moisture content (Baver 1962). Due to calcarious nature, abundance of mica and relatively fresh assemblage of other minerals, the soil has an abundant nutrient reserve. After reclamation, these soils produce about 8-10 t ha^{-1} of food grains annually (Swarup & Singh 1989). Singh *et al.* (1983) reported a biomass production of 52 t ha^{-1} from *Prosopis juliflora* in the sixth year plantation on alkali soil at its Karnal. The presence of native calcium carbonate as discrete nodules throughout the sequum is the greatest asset of these soils. It makes use of any acidifying amendment like sulphuric acid or pyrite for reclamation. The favourable soil texture imparts high mechanical stability and as a result the drains dug in, near vertical walls are unlikely to cave in.

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