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Characterization of some salt-affected soils of Amethi, Uttar Pradesh

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The present study describes the characteristics of soils of Amethi area in Sutanpur district of Uttar Pradesh (U.P.) where a massive reclamation project is under way by the World bank. The study area is located between 26^{0} 17.39^{1} N latitude and 8^{0} $49.35^{'}$ longitude at an altitude of 95 m above MSL and comprises typical sodic wastelands. The area experiences mean annual precipitation of about 661 mm, and annual mean maximum and minimum temperatures are 44 and 4.1^{0}C, respectively. The soils are developed in alluvium and form a part of the Indo-Gangetic Plains. The soil samples were collected during the month of October, 2005. A representative sodic soil profiles was exposed in village Kanaksinghpur for characterizing different parameters of each horizon. In addition to that, eleven surface (0-15 cm) soil samples were collected from different villages namely Kanksinghpur (1), Chandoki (2), Hardoi (2), Korari Harshah (2), Samra (2), Sanha (1) and Katarva (1) representing sodic soils of the area. Processed soil samples were analyzed for various chemical and physical properties using standard methods (Richards 1954; Black 1965). For the estimation of available nitrogen, phosphorus and potassium, the methods outlined by Subbaiah and Asija (1956), Olsen *et al.* (1954) and Black (1965) were adopted, respectively. The micronutrients extracted by DTPA-CaCl2-TEA (Lindsay and Norvell 1978), were determined by ICP-OES. The data were subjected to statistical analysis.

The physical and chemical characteristics (Table 1) indicated sodic nature of the soils. The pH of the saturated paste (pHs) ranged from 9.9 to 10.3 for soil profile and it varied from 8.2 to 10.4 in surface soils. The exchange complex of all the horizons through out the soil profile is dominated by Na^+ followed by Ca^{2+}, Mg^{2+} and K^+ ions. The ESP varied from 69.3 to 90.0 and increased with depth. In surface soils, ESP varied from 18 to 84 with a mean value of 66. The electrical conductance of the saturation extract (ECe) ranged from 4.2 to 37.3 dSm^{-1}, indicating higher concentration of soluble salts especially in the surface layers. In surface samples, ECe varied from 1.2 to 47.1 dSm^{-1} with a mean value of 24.2 $dS\ m^{-1}$. Hence based on the criteria of U. S. Salinity Laboratory (Richards 1954) some of these soils may be classified as saline-alkali soils. Soils will require both leaching of the salts and application of the amendments to lower their pH and ESP. But considering the fact these soils are highly dispersed and have low permeability, leaching of the soils is not possible. These soils are being reclaimed by application of amendment only. Analysis of the saturated extract (Table 2) showed that carbonates and bicarbonates are the dominant anions while Na^+ is the dominant cation. Concentration of Ca^{2+}, Mg^{2+} and K^+ ions are very low in these soils. The ratio of $[(CO_3^{2-}+HCO_3^-)/(Cl^-+SO_4^{2-})]$ and $[Na^+/(Cl^-+SO_4^{2-})]$ is >1 indicating the dominance of salts capable of alkaline hydrolysis. Hence irrespective of the ECe, these soils are to be treated as alkali soils (Chhabra 2005). When an attempt was made to leach excess soluble salts from these soils, their pH and ESP were increased, causing decreased infiltration rate. Such soils could not be reclaimed without the application of chemical amendments, which was required to lower their ESP, a prerequisite to improve their physical and chemical properties (Chhabra 2005).

The clay content ranged from 8.0 to 36.2 per cent and shows the presence of argillic horizon. The presence of argillic horizon, high Na^+ content and pH justify "natric" as diagnostic subsurface horizon, which is one of the characteristics of the Natrustalfs. In surface soil samples, sand, silt and clay content varied from 32.8 to 58.6, 27.0 to 40.6 and 7.2 to 26.6 per cent with mean values of 47.2, 35.8 and 17.0 per cent, respectively (Table 1). The organic carbon

Table 1. Physical and chemical characteristics of soils

Horizon	Depth	pHs	ECe	O.C.	ESP	$CaCO_3$	CEC	Exchangeable cations				Sand	Silt	Clay
								Na^+	K^+	Ca2+	Mg2+			
	(cm)		(dS m^{-1})	(%)		(%)	cmol (p^+) kg^{-1}}					(%)		
Ap	0-25	10.1	37.3	0.15	69	2.32	8.60	5.96	0.20	1.99	0.30	58.2	33.8	8.0
B1	25-45	10.3	32.4	0.14	72	2.32	10.95	8.43	0.23	1.94	0.30	46.4	34.8	18.8
B11	45-70	10.3	20.2	0.09	88	1.29	13.91	12.30	0.29	0.91	0.37	39.4	30.2	30.4
B12	70-90	10.1	4.7	0.07	90	1.29	13.47	12.12	0.27	0.70	0.30	37.4	26.4	36.2
C	>90	9.9	4.2	0.06	77	1.29	12.61	9.74	0.21	1.39	1.16	41.6	31.2	27.2
Ap	0-15	8.2-	1.2 - 47.1	0.12-	17	0.77 -	4.52 -	3.17 -	0.03 -	0.50 -	0.10 -	32.8 -	27.0 -	7.2 -
				0.41	84	3.35	8.30	6.86	0.80	2.12	1.26	58.6	40.6	26.6
		10.4*	(24.2)**	(0.24)	(66)	(1.71)	(6.79)	(4.84)	(0.23)	(1.23)	(0.47)	(47.2)	(35.8)	(17.0)

* Range and ** mean values

Table 2. Ionic composition (me L^{-1}) of saturation extract of soils

Horizon	Depth	Na^+	K^+	$Ca^{2+}+Mg^{2+}$	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	$CO_3^{2-}+HCO_3^-$/	Na^+/
	(cm)								$Cl^-+SO_4^{2-}$	$Cl^-+SO_4^{2-}$
Ap	0-25	383.82	0.56	5.59	285.12	62.51	40.54	89.57	2.67	2.94
B1	25-45	332.31	0.50	7.18	235.04	40.72	42.31	23.25	4.20	5.06
B11	45-70	210.12	0.41	4.47	75.06	50.04	60.15	29.36	1.39	2.34
B12	70-90	46.27	0.25	2.68	-	18.82	18.82	10.86	0.63	1.55
C	>90	42.11	0.10	0.89	-	14.21	18.93	10.06	0.49	1.45
Ap	0-15	8.29-494.92*	0.13-1.3	1.82-8.52	5.22-384.92	0.87 - 101.25	5.91 - 55.77	Tr - 65.74	1.03-26.50	1.40-27.58
		(247.25)**	(0.64)	(3.77)	(152.08)	(45.43)	(25.02)	(28.47)	(6.74)	(7.58)

* Range and ** mean values

Table 3. Available macro-and micronutrient status of soils

Horizon	Depth (cm)	Available macronutrients ($kg\ ha^{-1}$) N	P	K	Available micronutrients ($mg\ kg^{-1}$) Cu	Fe	Mn	Zn
Ap	0-25	40.77	18.94	403.2	1.04	20.50	4.64	0.54
BI	25-45	37.63	17.16	392.0	1.99	11.14	3.41	0.29
B11	45-70	15.68	18.28	425.6	1.42	9.19	3.45	0.47
B12	70-90	5.14	11.59	392.0	0.79	9.16	5.63	0.56
C	>90	6.27	7.13	336.0	0.44	5.93	2.43	0.40
Ap	0-15	32.17 - 138.34* (73.78)**	4.5 - 47.03 (19.41)	212.8 - 680.0 (457.2)	0.32-2.03 (1.25)	5.20-20.90 (12.59)	2.87-21.52 (8.92)	0.11-0.85 (0.54)

* Range and ** mean values

content varied from 0.06 to 0.15 per cent, being maximum in the surface soils. These results showed that these soils have low organic carbon and thus low fertility status. That is due to the poor natural vegetation and non-cultivation of the soil for crops. The amorphous $CaCO_3$ content varied from 0.77 to 2.32 in the surface soils. The CEC varied from 8.60 to 13.91 cmol (p^+) kg^{-1} in the soil profile whereas in surface soils, it varied from 4.52 to 8.17 cmol (p^+) kg^{-1} with a mean value of 6.79 cmol (p^+) kg^{-1}. In case of profile, CEC increased with depth and it was due to higher clay content of the lower horizons.

The soil under study contained very low amount of available N (32.17 to 138.00 kg ha^{-1}) in surface soil samples as well as in profile which decreased with depth (Table 3). The low levels may be ascribed by several factors, such as lower organic carbon, resulting from sub-optimal vegetations, high pH and ESP of soil, favouring higher volatilization losses, reduced nitrification and activity of N fixing bacteria (Bhardwaj 1975). Significant positive correlation of available N with organic carbon could be due to adsorption of ammonical N by humus complex (Kanthaliya and Bhatt 1991). Its significant negative association with soil pH and ESP is well documented. The available P was in medium to high (except few) and varied from 4.50 to 47.03 whereas, available K showed high range and varied from 212.8 to 680.0 kg ha^{-1} (Table 3). Hence, these soils may not respond to application of P and K especially in the initial years of reclamation as confirmed by Chhabra (1985). The available P and K were not correlated with soil characteristics. The availability of Cu, Fe and Mn was generally above the critical limit, and Zn was deficient (Table 3). These observations are in accordance with the inference that sodic soil which have high pH are responsive to Zn fertilization, in spite of their sufficient Zn reserve (Singh *et al.* 1984). Lack of close association of available micronutrients with organic carbon indicates inorganic phase as their major source (Arora and Sekhon 1981).

The soils of Amethi have high sodicity with the exchange complex is dominated by Na^+ followed by Ca^{2+}, Mg^{2+} and K^+ ions. Composition of saturated paste extract showed that carbonates and bicarbonates are the dominant anions and Na^+ as dominant cation. Based on these parameters and the criteria of Chhabra (2005), these soils are classified as alkali soils instead of saline-alkali soils. These soils were very deficient in available N, medium to high in P and sufficient in K. Among the micronutrients, Zn is the most limiting nutrient.

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