Some Vertisols and Associated Soils of Bihar : Mineralogy and Genesis of Concretions and Nodules

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Abstract : *The mineralogical study of fine sand fraction indicates the presence of light (feldspar, quartz and mica) and heavy minerals (garnet and tourmaline) in sedentary; and only light minerals in old as well as young alluvial soils. Among the clay minerals, smectite dominates with fair amount of kaolinite and illite in all Vertisols; while illite dominates only in Entisols.*

Genetically, the clay minerals in these soils (Chromusterts and Ustorthents) seem to be geogenic and pedogenic. The formation of smectite appears to be under impeded drainage, water logging and basic environment. Mica is observed to be derived from feldspar and micaceous parent material. Some of the orthoclase appears to have weathered to kaolinite. The major portion of kaolinite has been inherited from the parent material.

The calcium carbonate concretions (conca) are irregular and longer. Ferruginous nodules (consirs) are smooth and of round shape. High silica in conca and in consirs indicate the sand fractions being utilised as nuclei during precipitation. These concretions and nodules seem to be pedogenic. ***(Key words :*** *mineralogy, parent materials, carbonate and ferrugenous concretions, x-ray diffraction).*

Calcium carbonate concretions and ferruginous nodules are common in heavy soils of India (Roy & Barade 1962; Sehgal & Stoops 1972). The old alluvial soils of Bihar contain ferruginous nodules and lime concretions (Jha 1972; Diwakar & Singh 1993). However, the knowledge on minerals, concretions and nodules occurring in these Vertisols and associated soils are scanty. The studies on this aspect help in understanding the weathering processes that govern soil environment and release of nutrients.

MATERIAL AND METHODS

The study area lies between 24^{0}31' and 25^{0}13 Lat. and 84^0 11' and 86^0 10' E Long. covering the part of Nawadah, Rohtas, Bhojpur and Begusarai districts at 40-116 m MSL, receiving 1097 to 1258 mm rainfall. Five pedons two each from Senduna (sedentary) and Pithwaiya (old alluvium) series; one from Aurahi (young alluvium) series were selected.

The soil samples (< 2 mm) were freed from carbonates, organic matter and iron oxide coatings using the sodium dithionite citrate procedure (Mehta & Jackson 1960). The clay fractions were separated by sedimentation procedure and sand by sieving. Identification of primary minerals was done by mounting sand fractions (0.25-0.05 mm) on microscopic slide with Canada balsam and observed under a petrological microscope.

The clay fractions were Mg and K-saturated and mounted on glass slides. Mg-saturated clays were glycerol solvated and K-clays were heated separately at 300^{0}C (and 550^0 C. Clay minerals were analysed by x-ray diffraction analyser.

The concretions were sieved, washed and dried. Calcium Carbonate (Conca) and ferruginous nodules (Consirs) were separated by using high power magnet. The shape, size and colour were studied by standard methods. The concretion (powder) was fused with anhydrous Na_2CO_3 and fusion extract was used for elemental analysis by standard methods. Some of the concretion slides were studied on Tur N 62 x-ray Machine (Cu/Kα radiation & Ni filter) for diffractograms.

TABLE 1. Primary minerals in fine sand fractions of the soils

Depth (cm)	Light minerals							Heavy minerals		Expected parent material	Grain size and shape
	Feldspars		Mica		Others						
	O	Pl	M	B	Q	Sq	Op	G	H		
Sedentary soils :	**Pedon 1, Shahpur, low land, Udic Chromusterts**										
0-35	8+	3+	6+	2+	7+	-	-	5+	-	Granite gneiss, mica-schist	Coarse, Subangular
88-135	8+	3+	7+	2+	6+	-	-	4+	5+	Granite gneiss, mica-schist	to semiround
	Pedon 2, Uparidih, upland, Udic Chromusterts										
0-22	8+	2+	6+	3+	7+	-	-	4+	5+	Granite gneiss, mica-schist	Coarse, Subangular
73-130	8+	3+	6+	2+	7+	-	-	5+	4+	Granite gneiss, mica-schist	to semiround
Old alluvial soils :	**Pedon 3, Karmaini low land, Udorthentic Chromusterts**										
0-20	7+	4+	3+	-	8+	5+	6+	-	-	Quartzite, granite gneiss	Coarse, semiround to
107-155	7+	3+	4+	-	8+	6+	5+	-	-	Quartzite, granite gneiss	round,elongated, subangular
	Pedon 4, Karmaini, upland, Udorthentic Chromusterts										
0-30	7+	4+	3+	-	8+	6+	5+	-	-	Quartzite, granite gneiss	Coarse, semiround to
130-155	7+	4+	3+	-	8+	5+	6+	-	-	Quartzite, granite gneiss	round,elongated, subangular
Young alluvial soils :	**Pedon 5, Kushmhaut Chour, low land, Vertic Ustorethents**										
0-21	4+	7+	8+	5+	6+	-	-	-	-	Mica-Schist, granite gneiss	Coarse, Subangular,
91-120	4+	7+	8+	5+	6+	-	-	-	-	Mica-Schist, granite gneis	semiround

Note : Dominance sequence : 8+, 7+, 6+, 5+, 4+, 3+, 2+, 1+
Dominant <--------> less dominant

O- Orthoclase, Pl-Plagioclase, M-Muscovite
Q-Quartz, Sq-Stained quartz, Op-Opaque,
G-Garnet, T-Tourmaline, B- Biotite

RESULTS AND DISCUSSION

Mineralogy Of Fine Sands : The mineral analysis of fine sand fractions (0.05 - 0.25 mm) showed wide variations (Table 1). The frequency distribution showed the dominance of light mineral fractions in sequence of orthoclase (feldspars), quartz followed by muscovite (mica), garnet and tourmaline in fine sand fractions of sedentary soils (Pedons 1 & 2). Alluvials soils (Pedons 3 to 5) consists of only light minerals. The fine sand fractions contain quartz followed by orthoclase (feldspars), stained quartz and opaque minerals (old alluvial soils, Pedons 3 & 4), whereas muscovite (mica) followed by plagioclase (feldspars), quartz and biotite (mica) in pedon 5 (young alluvial soils). Feldspars are reported to be the common constituents of the coarser fraction of basaltic soils (Smith 1962) while quartz, and garnite, of micaceous soils (Menon & Mariakulandai 1957). It is also evident from the rocks found in plateau

TABLE 2. Chemical compostion of clays

Depth (cm)	Ignition loss (%)	SiO_2	R_2O_3	Al_2O_3	Mn_2O_3	Fe_2O_3	CaO	MgO	K_2O	P_2O_5	CEC Cmol (P+) kg^{-1}	SiO_2/R_2O_3	SiO_2/Al_2O_3	SiO_2/Fe_2O_3	Al_2O_3/Fe_2O_3
		(%)													
Sedentary soils:	**Pedon 1, Shahpur, low land, Udic Chromusterts**														
0-35	13.2	52.50	38.65	33.23	0.04	5.33	3.75	3.02	2.12	0.05	73.0	2.4	2.7	26.5	9.9
88-135	15.8	52.49	38.87	32.46	0.04	6.18	3.90	2.46	2.62	0.19	76.3	2.5	2.8	22.4	8.2
	Pedon 2, Uparidih, upland, Udic Chromusterts														
0-22	13.0	52.92	38.88	32.59	0.02	6.18	3.70	2.48	2.12	0.09	71.8	2.5	2.6	22.6	8.2
73-130	15.0	53.88	36.65	31.46	0.04	5.05	3.30	3.38	2.80	0.10	74.7	2.6	2.9	28.1	9.6
Old alluvial soils :	**Pedon 3, Karmaini, lowland, Udorthentic Chromusterts**														
0-20	15.0	52.65	39.51	33.78	0.02	5.62	3.29	2.78	2.09	0.09	65.0	2.4	2.7	25.1	9.5
107-155	15.7	54.64	36.16	31.33	0.04	6.74	3.32	3.40	2.58	0.05	91.6	2.6	3.0	21.7	7.3
	Pedon 4, Karmaini, upland, Udorthentic Chromusterts														
0-30	13.8	52.51	39.14	32.33	0.04	6.74	3.75	2.48	2.23	0.03	65.6	2.4	2.8	20.8	7.6
130-155	13.7	54.50	35.78	30.07	0.05	5.62	3.70	3.69	2.31	0.04	86.6	2.7	3.1	25.9	8.4
Young alluvial soils :	**Pedon 5, Ksushmhaut Chour, low land, Vertic Ustorthents**														
0-21	12.1	50.52	39.66	33.37	0.05	6.24	3.25	2.85	3.72	0.08	55.4	2.4	2.6	21.6	8.4
91-120	11.9	54.15	35.27	28.02	0.06	7.19	3.30	3.36	3.64	0.20	69.7	2.8	3.3	20.1	6.1

region. The presence of readily weatherable minerals (feldspars, mica, etc.) is found to be responsible for higher nutrient reserves as they release ions like Cu, Mg and K on decomposition.

Clay Mineralogy : The CEC's of the clays (Table 2) ranges from 65 to 92 c mol(P^+) kg^{-1} except in clays of top layer of pedon 5. The values of SiO_2/R_2O_3 (2.4 to 2.8), SiO_2/Al_2O_3 (2.6 to 3.3), SiO_2/Fe_2O_3 (20.1 to 28.1) and Al_2O_3/Fe_2O_3 (6.1 to 9.9) indicate the dominance of 2:1 type of clay minerals.

High CaO and MgO content, and high CEC suggest the clay minerals to be of smectitic nature. In the surface layer of pedon 5, lower CEC (55.4 C mol (P^+) kg^{-1}), and higher K_2O content indicate the dominance of illite. It has been further confirmed by X-ray diffractograms. In majority of the cases, the peaks in diffractograms, are at around 14, 10 and 7 Å(Table 3). The diffractograms of Mg-saturated clays (Pedon 1, 3, 5 and bottom layer of Pedon 5) indicate strong peaks at around 14 Å followed by sharp peaks at around 7 and 10Å suggesing the minerals to be in the order of smectite, kaolinite and illite (Table 3). The reflections show the clay minerals in the order of smectite, illite and kaolinite (pedon 2) and illite, smectite and kaolinite in the clays of the first layer of Chourland soils (Pedon 5). Further, peak positions of the clay samples on glycerol solvation, potassium treatment and their heating at 300°C and 550° C confirm the presence of these minerals. The second order reflections at around 5.0, 3.5 and 3.3 Å again

TABLE 3. Peaks in X-ray diffractograms and relative abundance of clay minerals.

Pedons with depth (cm)		X-ray Peak Positions (Å)						Clay minerals			
		First Order reflections			Second order reflections			Smectite	Illite	Kaolinite	Vermiculite
		Strong	Sharp	Less intense	Strong	Sharp	Less intense				
1	(0-35)	14.16	7.25	9.93	5.01	3.58	3.33	+++	+	++	Tr.
	(88-135)	13.90	7.20	9.95	5.10	3.60	3.33	+++	+	++	Tr.
2	(0-22)	14.30	9.97	7.06	5.09	3.53	3.33	+++	++	+	Tr.
	(73-130)	14.20	9.95	7.08	5.20	3.53	3.33	+++	++	+	Tr.
3	(0-20)	14.12	7.03	9.96	5.20	3.51	3.33	+++	+	++	Tr.
	(107-155)	14.12	7.03	9.93	5.04	3.51	3.33	+++	+	++	Tr.
4	(0-30)	14.26	7.00	9.94	5.09	3.50	3.33	+++	+	++	Tr.
	(130-155)	16.16	7.16	10.05	5.22	3.58	3.33	+++	+	++	Tr.
5	(0-21)	10.05	14.07	7.08	5.00	3.54	3.33	++	+++	+	Tr.
	(91-120)	14.07	7.00	9.93	5.10	3.50	3.33	+++	+	++	Tr.

Tr=traces

confirmed above observations.

Thus, almost all the pedons showed a dominance of smectite with fair amount of illite and kaolinite. Dominance of smectitic group of clay minerals in fine textured and dark coloured soils has also been reported by Kaswala and Deshpande (1986).

Genesis of Clay Minerals : The genesis of clay minerals i.e. smectite, Illite and kaolinite present in varying proportions in these soils can be explained on the basis of a group of conducive factors. It appears that slightly alkaline reaction, abundance of MgO and poor drainage have accelerated the formation of smectite.

The presence of illite in these soils is an indicative of the influence of the micaceous parent material. It is also apparent that the influence of the K_2O content of these soils (especially Chourlands) (Pedon 5) is sufficiently high for the formation of illite. The transformation of orthoclase into illite might have taken place as follows :

Partially altered Orthoclase —> Mica in fine sand —> Illite in clay .

The transformation of orthoclase feldspar to illite has also been reported by Stephens (1952). The feldspar is almost dominant mineral in fine sand fractions (Table 1). The partial hydrolytic decomposition of feldspar might have led to the formation of mica which is further transformed to kaolinite. Feldspars are believed to weather to mica in fine sand and then to montmorillonite under alkaline conditions (Jackson & Sherman 1953).

The restricted drainage and high base status have provided suitable environment for the formation of smectite from less weathered fragments, which have supplied Si, Mg and Fe. Therefore, kaolinite could have not been formed by alteration of smectite and hence, some of the orthoclase feldspars might have weathered to kaolinite under the prevailing conditions.

These soils have developed on the parent materials originating from quartzite, mica-schist, granite gneiss, etc. The sediments are partially weathered. It is also evident from the dominance of mica and feldspar in the fine sand fraction. Thus, it may be inferred that the clay minerals are both pedogenic

TABLE 4. Relative shape, size and colour of the concretions.

Horizon	Calcium Carbonate concretions				Ferruginous nodules			
	Shape	Size (mm)	Colour		Shape	Size (mm)	Colour	
Sedentary soils : Pedon 1, Shahpur, low land, Udic Chromusterts								
Ap	irr-longer	1.0-13.0	10YR7/3	very pale brown	round	1.0-9.0	10YR4/1	dark grey
A11	irr-longer	1.0-11.0	10YR7/2	light grey	round	1.0-9.0	10YR4/1	dark grey
A12	irr-longer	1.0- 8.0	10YR7/2	light grey	round	1.0-6.0	10YR3/1	very dark grey
AC	irr-longer	1.0-17.0	10YR6/2	light brownish grey	round	1.0-8.0	10YR3/1	very dark grey
Pedon 2, Uparidih, upland, Udic Chromusterts								
Ap	irr-longer	2.0-15.0	10YR7/3	very pale brown	round	1.0-9.0	10YR3/2	very dark grey
A11	irr-longer	1.0-14.0	10YR7/3	very pale brown	round	1.0-7.0	10YR3/1	very dark grey
A12	irr-longer	1.0-10.0	10YR7/3	very pale brown	round	1.0-8.0	10YR3/3	dark brown
Old alluvial soil : Pedon 3, Karmaini, low land, Udorthentic Chromusterts								
Ap	irr-longer	2.5-10.0	10YR7/3	very pale brown	round	1.0-9.0	10YR3/2	very dark greyish brown
A11	irr-longer	2.5-10.0	10YR6/4	light yellowish brown	round	1.0-7.0	10YR3/2	very dark greyish brown
A12	irr-longer	1.0-13.0	10YR7/2	light grey	round	1.0-5.0	10YR3/1	very dark grey
A13	irr-longer	1.0-10.0	10YR6/3	pale brown	round	1.0-4.0	10YR3/1	very dark grey
Pedon 4, Karmaini, upland, Udorthentic Chromusterts								
Ap	irr-longer	1.0- 4.0	10YR6/2	light brownish grey	round	1.0-4.5	10YR3/1	very dark grey
A11	irr-longer	1.0- 2.0	10YR6/2	light brownish grey	round	1.0-6.0	10YR4/1	dark grey
A12	irr-longer	1.0- 3.0	10YR6/3	pale brown	round	1.0-6.0	10YR3/1	very dark grey
A13	irr-longer	1.0- 3.0	10YR6/2	light brownish grey	round	1.0-4.0	10YR4/1	dark grey
AC	irr-longer	1.0-12.0	10YR7/3	pale brown	round	1.0-5.0	10YR4/1	dark grey

and inherited from the parent material (geogenic).

Concretions and Nodules : The calcium carbonate concretions (conca) were found to be irregular and elongated in shape and almost larger in size (up to 17 mm), while ferruginous nodules (consirs) were round and relatively smaller in size (up to 9 mm) (Table 4).

It was further noted that the size of concretions and nodules was higher in sedentary soils than those of alluvial. Such variations in the size might be due to differential dissolution and reprecipitation of concretions under the influence of increased PCO_2 restricting their size growth in old alluvial soils. It is due to longer wetness of these soils under the influence of canal irrigation. The variable colours of conca (10YR 6/2 to 10 YR 7/3) with higher value and chroma and of consirs (10 YR 3/1 to 10YR 4/1) with relatively lower value and chroma might be attributed to their chemical composition. From the variable colour and irregular shape, the conca may be

TABLE 5. Percentage distribution (by weight) of the concretions in the soils.

Depth (cm)	Calcium carbonate concretions						Ferruginous nodules					Grand Total
	1.0	1.1-3.0	3.1-6.0	6.1-9.0	> 9.0	Total	1.0	1.1-3.0	3.1-6.0	6.1-9.0	Total	
	<---------- (mm) ---------->						<---------- (mm) ---------->					
Sedentary soils :	**Pedon 1, Shahpur, low land, Udic Chromusterts**											
0-35	0.14	0.26	0.84	2.16	2.84	6.24	0.37	0.45	0.30	0.82	1.94	8.2
35-62	0.24	0.22	-	-	2.64	3.10	0.26	0.48	0.53	1.02	2.29	5.4
62-88	0.31	0.35	1.04	0.83	3.73	6.26	0.43	0.87	0.85	-	2.15	8.4
88-135	1.36	4.08	-	4.42	26.99	36.85	1.02	2.06	3.82	2.14	9.04	45.9
	Pedon 2, Uparidih, Upland, Udic Chromusterts											
0-22	-	0.18	0.85	5.44	19.73	26.20	0.41	0.48	0.64	2.18	3.71	29.9
22-73	0.10	0.16	-	4.20	7.89	12.35	0.59	0.75	0.77	0.74	2.85	15.2
73-130	0.12	0.20	0.46	3.37	5.60	9.75	0.44	1.24	0.94	0.82	3.45	13.2
Old alluvial soils :	**Pedon 3, Karmaini, low land, Udorthentic Chromusterts**											
0-20	-	0.24	-	-	5.32	5.56	-	1.18	0.86	-	2.04	7.6
20-60	-	0.26	-	-	4.82	5.08	0.55	0.68	0.65	1.44	3.32	8.4
60-107	0.10	0.58	0.56	3.56	1.78	6.58	0.22	0.42	0.26	-	0.90	7.5
107-155	0.15	0.34	0.99	-	1.45	2.93	0.28	0.74	0.57	-	1.59	4.5
	Pedon 4, Karmaini, Upland, Udorthentic Chromusterts											
0-30	0.19	0.19	0.71	-	-	1.09	0.17	0.29	0.37	-	0.83	1.9
30-57	0.20	0.11	-	-	-	0.31	0.22	0.22	0.59	-	1.03	1.3
57-92	-	0.43	-	-	-	0.43	0.23	0.18	0.23	0.21	0.85	1.3
92-130	-	0.43	-	-	-	0.43	0.17	0.28	0.14	-	0.59	1.0
130-155	-	0.64	-	-	1.78	2.42	0.15	0.16	0.87	-	1.18	3.5

inferred to be of pedogenic origin, whereas consirs appear to have round shape and smooth surface to be of detrital origin, nevertheless their round shape may also be attributed to their concentric formation and to some extent due to argillipedoturbation in these soils with Veritc characters. However, this might not appear very sound since it is really difficult to differentiate between detrital and pedogenic concretions (Arnaud 1979). The utilization of conca and consirs as nuclei for the precipitation of iron and manganese oxides and calcium carbonate, respectively supports them to be of pedogenic origin. Sehgal and Stoops (1972), Brikeland (1974) and Bhargava *et al.* (1981) also reported such concretions to be of pedogenic origin.

The distribution of concretions (Table 5) shows that the percentage of total concretions is higher in sedentary than that in the old alluvial soils. It might be argued that maximum formation of concretions would occur some where between the wettest and driest situation. This might be the reason of higher percentage of both conca ans consirs in sedentary soils where moisture condition (periodic oxidation & drying) appears to be more conducive than the old alluvial soils of Sone Command, where wetness is prevalent for a longer period. The irregular distribution of conca and consirs might be attributed to the Vertic characters of these soils. These are in conformity with the views of Schwertmann and Fanning (1976). Over and above, the percentage of R_2O_3 and

TABLE 6. Chemical composition (%) of the concretions

Depth (cm)	Calcium carbonate concretions									Ferruginous nodules								
	SiO_3	R_2O_3	Al_2O_3	Fe_2O_3	Mn_2O_3	P_2O_5	K_2O	$CaCO_3$	$MgCO_3$	SiO_2	R_2O_3	Al_2O_3	Fe_2O_3	Mn_2O_3	P_2O_5	K_2O	$CaCO_3$	$MgCO_3$
Sedentary soils : Pedon 1, Shahpur, low land, Udic Chromusterts																		
0-35	17.4	6.0	3.9	1.67	0.36	0.04	1.8	72.4	6.3	35.0	41.0	28.4	3.5	9.1	0.03	2.7	7.5	16.1
88-135	18.0	4.0	2.0	1.75	0.19	0.04	1.8	69.9	6.3	20.8	25.0	17.0	5.0	3.0	0.02	2.4	34.9	19.1
Pedon 2, Uparidih, upland, Udic Chromusterts																		
0-22	14.8	8.0	6.4	1.34	0.20	0.03	1.8	72.4	4.2	32.8	38.0	14.8	18.0	5.2	0.03	3.6	16.5	10.7
73-130	12.6	8.0	6.3	1.52	0.14	0.03	1.7	72.4	6.3	30.6	40.0	17.2	18.0	4.8	0.04	6.8	13.0	10.7
Old alluvial soils : Pedon 3, Karmaini, low land, Udorthentic Chromusterts																		
0-20	24.6	6.0	3.9	1.90	0.20	0.04	2.0	67.4	2.1	30.2	47.0	16.5	23.6	6.7	0.17	2.5	12.5	8.4
107-155	25.2	8.0	5.5	2.15	0.33	0.04	2.2	59.9	6.3	30.8	48.0	16.4	25.8	5.5	0.25	2.4	14.0	9.8
Pedon 4, Karmaini, Upland, Udorthentic Chromusterts																		
0-30	20.5	12.0	8.9	2.67	0.40	0.07	4.1	57.4	8.5	30.5	45.0	16.0	25.3	3.6	0.12	2.7	18.1	5.3
131-155	22.0	10.0	7.3	2.23	0.43	0.04	2.2	57.4	8.4	28.5	40.0	22.6	12.8	4.5	0.14	2.7	19.3	10.5

$CaCO_3$ of the soils also influenced the distribution of conca and consirs as evident from their relations with R_2O_3 (r=0.1418 & 0.132) and $CaCO_3$ (r=0.624 & 0.723), respectively.

The data on the chemical composition of the concretions (Table 6) indicated higher SiO_2 content of consirs than of conca which is probably due to more utilization of sand fractions as nuclei for the precipitation of Fe and Mn oxides. This is further supported by significant relation of SiO_2 in soils with the SiO_2 in consirs (r=0.5034). The constituents like Al_2O_3, Fe_2O_3, Mn_2O_3, etc. seem to have direct influence on the formation of these concretions; as R_2O_3 of soils is significantly correlated with R_2O_3 of conca (r=0.6048) and consirs (r=0.6114*). As expected, the $CaCO_3$ content (57.4 to 72.4 %) and R_2O_3 content (25 to 48 %) seem to be the main constituents of conca and consirs, respectively. The $MgCO_3$ is higher in consirs (19.1 %) than in conca (8.5 %). This corroborates the findings of Arnaud (1979) and Magaritz and Kafri (1979).

The X-ray diffractograms of conca and consirs show a broader and diffused peak at 7.5 (expected due to gypsum) indicating the minerals to be poorly crystalline. The sharp peaks at 3.02 followed by weak reflections at 2.46, 2.28, 2.08, 1.90 and 1.85 show the presence of well crystallised calcite.

The X-ray data and chemical composition (Table 3) reveals the formation of the conca and consirs to be controlled by dissolution and reprecipitation of $CaCO_3$, $MgCO_3$, Fe_2O_3, Mn_2O_3, etc. around the skeletal grains of sand or even conca and consirs themselves. The precipitation and redissolution of these components seems to be governed by the factors like pH, cations, fluctuating water-table, restricted drainage, etc. An increase in PCO_2 due to impeded drainage, roots and microbial activities results in redissolution of these compounds leading to their downward movement in the pedons. They precipitate again on desication as they are not lost due to impeded drainage and high clay content of these soils.

The essential plant nutrients are fixed with conca and consirs (Table 3) leading to their deficiencies. The excess of concretions may form hard pans resulting in further decrease in permeability of soils. This contention is further strengthened by positive correlation of bulk density with the percentage of conca (r = 0.25) and consirs (r = 0.43).

REFERENCES

Arnaud, R.J.ST. (1979) Nature and Distribution of Secondary Soil Carbonates (within land scapes) in relation to soluble Mg/Ca ratios. *Can. J. Soil Sci.* **59:** 87.

Bhargava, G.P., Pal, D.K., Kapoor, B.S. & Goswami, S.C. (1981) Characteristics and Genesis of some sodic soils in the Indo Gangetic Plains of Haryana and Uttar Pradesh. *J.Indian Soc. Soil Sci.* **29:** 61.

Brikeland, I.W. (1974) *Pedology, Weathering and Geomorphological Res.* Oxf. Univ. Press, New York.

Diwakar, D.P.S. & Singh, R.N. (1993) Tal land soils of Bihar I: Occurrence and Genesis of Concretions and Nodules. *J.Indian Soc. Soil Sci.* **41:** *111*

Jackson, M.L. & Sherman, G.D. (1953) Chemical Weathering of Minerals in Soils. *Adv. Agron.* **5:** 219

Jha, P.P. (1972) Classification of soils of Bihar. *Soil of India, FAI,* New Delhi.

Kaswala, R.R. & Deshpande, S.B. (1986) Silt and Clay Mineralogy of Black Alluvial Soils of Gujarat. *J. Indian Soc. Soil Sci.* **34:** 160.

Margaritz, M. & Kafri, V. (1979) Concentration of Mg in Carbonate Nodules of Soils, as Indication of Fresh Ground Water contamination by intruding Sea water. *Chem. Geol.* **27:** 143.

Mehar, O.P. & Jackson, M.L. (1960) *Clays Clay Miner.* **5:** 317.

Menon, P.K. R. & Mariakuladai, A. (1957) The Soils of Madras I : The Black Soils of Madras. *Madras Agric. J.* **44:** 175.

Roy, B.B. & Barade, N.K. (1962) Some characteristics of Black soils of India. *Soil Sci.* **93:** 142.

Schwertmann, U. & Fanning, D.S. (1976) Iron-manganese concretions in hydrosequence of soils in Vavaria *Soil Sci. Am.* **40:** 731.

Sehgal, J.L. & Stoops, G. (1972) Pedogenic Calcite Accumulation in Arid and semi-arid Regions of Indo-Gangetic Alluvial Plains of earthwhile Punjab (India), their Morphology and Origin. *Geoderma,* **8:** 59(En).

Stephen, I. (1952) A study of Rock weathering with Reference to the Soils of the Malvern Hills I : Weathering of Biotite and Granite. *J. Soil Sci.* **3:** 20

Suarez, D.L. (1977) Ion Activity Products of $CaCO_3$ in water below Root Zone. *Proc. Soil Sci. Soc. Am.* **41:** 32.