Aggregation and Water Retention in Relation to Physical Constants of Some Vertisols

D.P.S. DIWAKAR* AND R.N. SINGH

Soil Survey and land Use Planning Centre, Bihar Agricultural College, Sabour, Bhagalpur, Bihar - 813 210.

Abstract: *Vertisols and associated soils of sedentary and alluvial regions show higher degree of compaction due to swelling and shinkage phenomena resulting in lower saturated hydraulic conductivity. In Vertisols macroaggregates are always higher than microaggrates which increasing with depth. In Entisols though the macroaggregates are higher than microaggregates in the surface layers, these decrease with depth. This differential aggregation seems mainly duee to the variations in clay and organic matter content supported by highly significant positive corrrelation of cmumulative macro-aggregates with clay, fine clay and organic carbon content. These aggregates also have highly significant positive correlation with mean weight diameter. Vertisols of sedentary region show higher macroaggregates in virgin soils than that in cultivated ones. Most of the soil water is released within suction range of 100-200 kPa. The moisture retention and its availability are found to be the functions mainly of nature and amount of clay and organic matter content* (**Key words**: *sedentary, alluvium, macroaggregates; suction, retention).*

Favourable physical properties are essential requisite for higher productivity of Vertisols. Study of soil aggregation, moisture retention, aeration and expansion are important for proper soil management. Aggregation determines soil-air-water reltionship and influences plant growth. The amount of water stable aggregates is found to be a good index for the measurement of soil structure. The present investigation was undertaken to study the aggregates and moisture charararacteristics of some Vertisols and associated soils.

MATERIAL AND METHODS

Five pedons from Vertisols and associated soils occurring in part of Nawadah, Rohtas, Bhojpur and Begusarai districts which spread between 24°31' 25°13' N and 84°11' and 86°10'E in Bihar were selected. The physical constants were determined by standard methods. The bulk density was determined by core method.

* *Deptt. Soil Science, Tirhut College of Agriculture, Dholi, Muzaffarpur, Bihar-843 121.*

Undisturbed air dried soil lumps broken at the natural cleavages were analysed with Yoders wet sieving apparatus (Richards 1954) for water stable aggregates. The moisture retention at different suctions were determined by pressure plate apparatus (Richards 1947). The variation in bulk density and moisture content were studied to determine soil moisture characteristics curve.

RESULTS AND DISCUSSION

Physical Constants : The soil physical constants are presented in Table 1. The saturated hydralutic conductivity of these soils is low. The dominant clay mineral in these soils is smectite, which on moisture absorption swells and macro pores are reduced leading to the decreased hydaulic conductivity as is evident from the highly significant negative correlation of hydraulic conductivity with expansion (r = -0.5611). Soni and Chakravarti (1959) reported lower values of hydraulic conductivity for heavy soils of Bihar. The expansion of the soils is related to the clay content, total aggregate (r = 0.5225) and macroaggregates (r = 0.4653). Highly significant negative correlation of bulk density with pore space (r = -0.7692) indicates higher degree of compaction.

TABLE 1. Some physical constants of the soils

Horizon with depth (cm)	BD (mgm^{-3})	HD ($cmhr^{-1}$)	Expansion (m^3m^{-3})	Pore space (%)
Secondary Soils -				
Pedon 1, Shahpur, Low land, Udic Chromusterts				
Ap (0-35)	1.36	0.08	0.20	48.6
A11 (35-62)	1.40	0.07	0.25	47.5
A12 (62-88)	1.41	0.08	0.32	43.0
AC (88-135)	1.45	0.09	0.20	39.2
Pedon 2, Uparidih, upland, Udic Chromusterts				
A (0-22)	1.36	0.08	0.20	48.6
A11 (22-73)	1.35	0.08	0.22	49.1
A12 (73-130)	1.38	0.08	0.24	47.9
Old Alluvial Soils -				
Pedon 3, Karmaini, Low Land Udorthentic Chromusterts				
Ap (0-20)	1.45	0.07	0.27	39.6
A11 (20-60)	1.42	0.07	0.26	46.4
A12 (60-107)	1.38	0.07	0.29	47.9
A13 (107-155)	1.36	0.07	0.36	48.6
Pedon 1, Karmaini, Upland, Udorthentic Chromusterts				
Ap (0-30)	1.35	0.07	0.22	49.1
A11 (30-57)	1.34	0.07	0.22	49.4
A12 (57-92)	1.40	0.07	0.16	47.5
A13 (92-130)	1.42	0.08	0.15	46.4
AC (130-155)	1.38	0.09	0.13	47.9
Young Alluvial Soils -				
Pedon 5, Kushmhaut Chor, Lowland, Vertic ustorthents				
Ap (0-21)	1.31	0.08	0.16	49.3
A1 (21-44)	1.29	0.07	0.15	48.6
IIC (44-62)	1.36	0.09	0.12	45.4
IIIC(62-91)	1.40	0.36	0.09	46.7
IVC (91-120)	1.39	0.49	0.08	46.9

HD-Hydraulic conductivity

Water Stable Aggregates: The data on different sized aggregates (Table 2) indicate that the 0.1-0.25 mm and 0.5-1.0 mm diameter classes constitute higher percentage than the rest in almost all the soils. In Vertisols of sedentary region, the macro-aggregates are higher in virgin soils (Pedon 2) than that in cultivated ones (Pedon 1). This may be attributed to minimum human disturbance, a condition favourable for the formations of macroaggregates. The same is also applicable to the Vertisols of old alluvial region. These Vertisols show higher macroaggregates than micro ones and there is a sharp increase in macroaggregates with depth. This increase in macroaggregates will be attributed to an extra pressure generated by fracture along the wetting front in the lower layer forming macroaggregates at faster rate. Kauraw *et al.* (1983) reported increase in macroaggregates with depth in fine textured soils. In Chour land soils (pedon 5) of young alluvial region, the macroaggregates are higher than microaggregates in surface layer whereas macroaggregates decrease and macroaggregates increase with depth. This may be attributed to the higher clay content in Vertisols and higher organic carbon content in surface layers of Entisols. The cumulative aggregates are observed to be around 80 per cent throughout the depth in Vertisols and restricted to surface layers in Entislos. Correlation studies (Table 4) also support the above trend. The cumulative and macroaggregates show highly significant positive correlation with clay, fine clay, organic carbon and mean weight diameter (MWD). The mean weigh diameter is considered as the index of aggregation. It is significantly correlated with organic carbon content (r = 0.064) and mocroaggrregates (r = -0.696). Similar observations have also been reported by Singh and Chatterjee (1966), and Biswas and Ali (1969).

Soil Water Retention: The data (Table 3) show a general decrease in soil water content with increasing soil water suctions. It is also oberved that the change in suctions from 0 to 33 kPa releases more water in Vertisols (sedentary and old alluvial) than that of Entisols (young alluvial). The variations in water content at different suctions within the Pedons may be attributed to the variation in nature and amount of clay minerals and organic matter content of these soils. Bartelli and Peters (1959) suggested clay fraction to be the dominant modifier of water retention at higher

TABLE 2. Individual and cumulative size of water stable aggregates

Depth (cm)	Individual size (%)						Cumulative size (%)					Macro-aggregates (%)	MWD (mm)
	0.1-0.25	0.25-0.5	0.5-1.0	1.0-2.0	2.0-5.0	Above 5.0	0.1-0.5	0.1-1.0	0.1-2.0	0.1-5.0	Above 5.0 **		
	< (mm) >												
SEDENTARY SOILS: *PEDON 1, SHAHPUR, LOW LAND, UDIC CHROMUSTERTS*													
0-35	28.7	11.3	17.2	6.9	2.8	0.2	40.0	57.2	64.1	66.9	67.1	38.4	0.5
35-62	20.4	10.0	27.9	17.7	6.1	0.6	30.4	58.3	76.0	82.1	82.7	62.3	0.8
62-88	17.3	16.3	34.8	18.8	3.1	1.1	33.6	68.4	87.2	90.3	91.4	74.1	0.8
88-135	17.9	14.4	29.2	17.6	5.5	5.7	32.3	61.5	79.1	84.6	90.3	72.4	1.1
PEDON-2, UPARIDIH, UPLAND, UDIC CHROMUSTERTS													
0-22	9.2	6.5	15.5	9.6	5.6	45.2	15.7	31.2	40.8	46.4	91.6	82.4	3.4
22-73	20.4	16.7	27.7	12.7	5.2	1.2	37.1	64.8	77.5	82.7	83.9	63.5	0.8
73-130	5.9	5.2	22.9	17.0	7.8	34.7	11.1	34.0	51.0	58.8	93.5	87.6	3.0
OLD ALLUVIAL SOILS: *PEDON-3 KARMAINI, LOW LAND, UDORTHENTIC CHROMUSTERTS*													
0-20	21.9	15.5	27.2	7.0	2.9	13.2	37.4	64.6	71.6	74.5	87.7	65.8	1.4
20-60	21.7	19.2	31.7	9.3	2.8	0.3	40.9	72.6	81.9	84.7	85.0	63.3	0.6
60-107	15.7	15.2	34.7	17.0	3.4	0.4	30.9	65.6	82.6	86.0	86.4	70.7	0.8
107-155	11.5	14.2	30.5	13.7	2.8	0.2	25.7	56.6	69.9	72.7	72.9	61.4	0.7
PEDON-4, KARMAINI, UPLAND, UDORTHENTIC CHROMUSTERTS													
0-30	21.8	16.4	26.8	7.2	2.8	12.6	38.2	65.0	72.2	75.0	87.6	65.8	1.3
30-57	20.4	18.7	31.5	8.3	1.9	0.2	39.1	70.6	78.9	80.8	81.0	60.6	0.6
57-92	14.8	14.5	39.9	13.7	2.3	0.3	29.3	69.2	82.9	85.2	85.5	70.7	0.7
92-130	13.6	14.1	41.0	15.6	3.1	0.1	27.7	68.7	84.3	87.4	87.5	73.9	0.7
130-155	15.2	16.9	30.6	10.5	3.0	0.1	32.1	62.7	73.2	76.2	76.3	61.1	0.6
YOUNG ALLUVIAL SOILS: *PEDON-5, KUSHMHAUT CHOUR, LOW LAND, VERTIC USTORTHENTS*													
0-21	7.8	6.6	13.5	7.2	11.8	40.7	14.4	27.9	35.1	46.9	87.6	79.8	3.2
21-44	8.0	9.5	31.5	19.8	16.2	2.3	17.5	49.0	68.8	85.0	87.3	79.3	1.4
44-62	25.6	16.2	12.7	6.6	1.2	1.6	41.8	54.5	61.1	62.3	63.9	38.3	0.5
62-91	26.4	14.8	5.6	4.4	2.5	2.3	41.2	46.8	51.2	53.7	56.0	29.6	0.4
91-120	22.6	2.4	2.9	0.5	0.8	0.3	25.0	27.9	28.4	29.2	29.5	6.9	0.2

* Micro aggregates, ** Total aggregates; MWD- Mean weight diameter

TABLE 3. Soil moisture retention at different suctions

Horizon with depth (cm)	Moisture retention (%) 0 kPa	33 kPa	100 kPa	0.2 MPa	0.5 Mpa	1.0 Mpa	1.5 Mpa	Avail. moisture (%)
SEDENTARY SOILS: *PEDON 1, SHAHPUR, LOW LAND, UDIC CHROMUSTERTS*								
Ap (0-35)	48.7	22.0	19.9	17.8	15.4	14.4	13.6	8.4
A11 (35-62)	46.1	27.3	21.7	18.6	17.1	16.1	14.4	12.9
A12 (62-88)	54.0	28.1	25.0	22.7	20.4	16.5	14.8	13.3
AC (88-135)	46.0	25.1	20.7	18.5	16.1	15.0	14.2	10.9
PEDON 2, UPARIDIH, UPLAND, UDIC CHROMUSTERTS								
A (0-22)	44.3	22.1	19.9	18.1	14.2	12.9	12.0	10.1
A11 (22-73)	50.2	24.4	20.2	18.1	16.1	14.6	13.7	10.8
A12 (73-130)	46.5	25.5	21.3	19.1	16.8	16.0	14.4	11.2
OLD ALLUVIAL SOILS: *PEDON 3, KARMAINI, LOW LAND, UDORTHENTIC CHROMUSTERTS*								
Ap (0-20)	57.3	27.0	22.3	20.5	18.6	17.0	14.7	12.3
A11 (20-60)	50.6	29.4	24.0	21.7	17.4	16.3	14.2	15.2
A12 (60-107)	56.5	31.6	27.7	23.7	20.6	18.3	15.2	16.4
A13 (107-155)	55.7	32.7	24.5	21.1	20.5	18.7	15.9	16.9
PEDON 4, KARMAINI, LOW LAND, UDORTHENTIC CHROMUSTERTS								
Ap (0-30)	50.0	26.2	21.5	19.4	16.2	15.5	13.5	12.8
A11 (30-57)	51.8	28.6	22.7	20.4	18.0	17.3	14.7	14.0
A12 (57-92)	44.5	29.4	23.6	21.9	19.7	18.1	15.5	14.0
A13 (92-130)	46.4	29.1	23.8	21.3	18.8	17.0	14.4	14.7
AC (130-155)	38.6	24.7	18.5	16.9	14.7	12.9	12.2	12.5
YOUNG ALLUVIAL SOILS: *PEDON 5, KUSHMHAUT CHOUR, LOW LAND, VERTIC USTORTHANTS*								
Ap (0-21)	48.5	36.8	30.7	28.4	25.6	24.4	18.7	12.0
A1 (21-44)	47.6	35.9	29.9	27.6	23.9	20.9	16.5	13.4
IIC (44-62)	45.6	32.3	24.5	22.3	20.4	18.2	15.1	9.4
IIIC (62-91)	43.3	24.2	16.8	14.4	11.3	9.8	8.2	8.6
AC (130-155)	43.4	24.4	14.2	12.1	8.4	6.6	5.7	8.5

energy leve, while Marshall (1959) stated that the soil water retention at higher tension was mainly a function of amount and nature of clay.

In general, water retention curves (Fig. 1) show that the water content changes very rapidly in the lower tension range than in the higher range. Above 200 kPa tension, the curves seem to be parallel to x axis indicating thereby small release of water beyond this tension. There soils are oberved to retain moisture even at very high tension (1500 kPa). The higher water retentivity of these soils may be attributed to higher smectitic clay mineral in Vertisols and organic matter content in Entisols.

The available moisture content is observed to be better correlated with clay than with silt and organic matter content. It is also evident from the highly significant positive correlation of available moisture with clay, fine clay and expansion of the soils (Table 4). This corroborates the findings of Hirekerubar *et al.* (1991). The available moisture content seems to have been also affected by macro and cumulative aggregates.

From the foregoing discussion, it appears that the retention and availability of water is chiefly a function of amount and nature of clay. The variation in shape of water retention curves reflects water retention and release in accordance withn texture, nature of clay and to some extent with organic matter content. It is also apparent that macro and cumulative aggregates which are related to clay, fine clay and organic carbon content.

TABLE 4. Correlation coefficient (r) between siol parameters

Variables	Org. C	Clay	Fine Clay	MWD	BD	HC	Expansion
Cumulative aggregates	0.457*	0.735**	0.750**	0.511*	-	-0.857**	0.522*
Macroaggregates	0.466*	0.673**	0.701**	0.632**	-	-0.783**	0.465*
Macroaggregates	-0.326	-0.292	-0.342	-0.695**	0.318	0.339	-
MWD	0.639**	0.271	0.246	1.000	0.299	-0.288	-
AWC	-	0.605**	0.643**	-	-	-0.528*	0.617**
Pore space	-	-	-	-	-0.769**	-	-
Expansion	-	-	-	-	-	-0.561**	-

* significant; ** highly significant

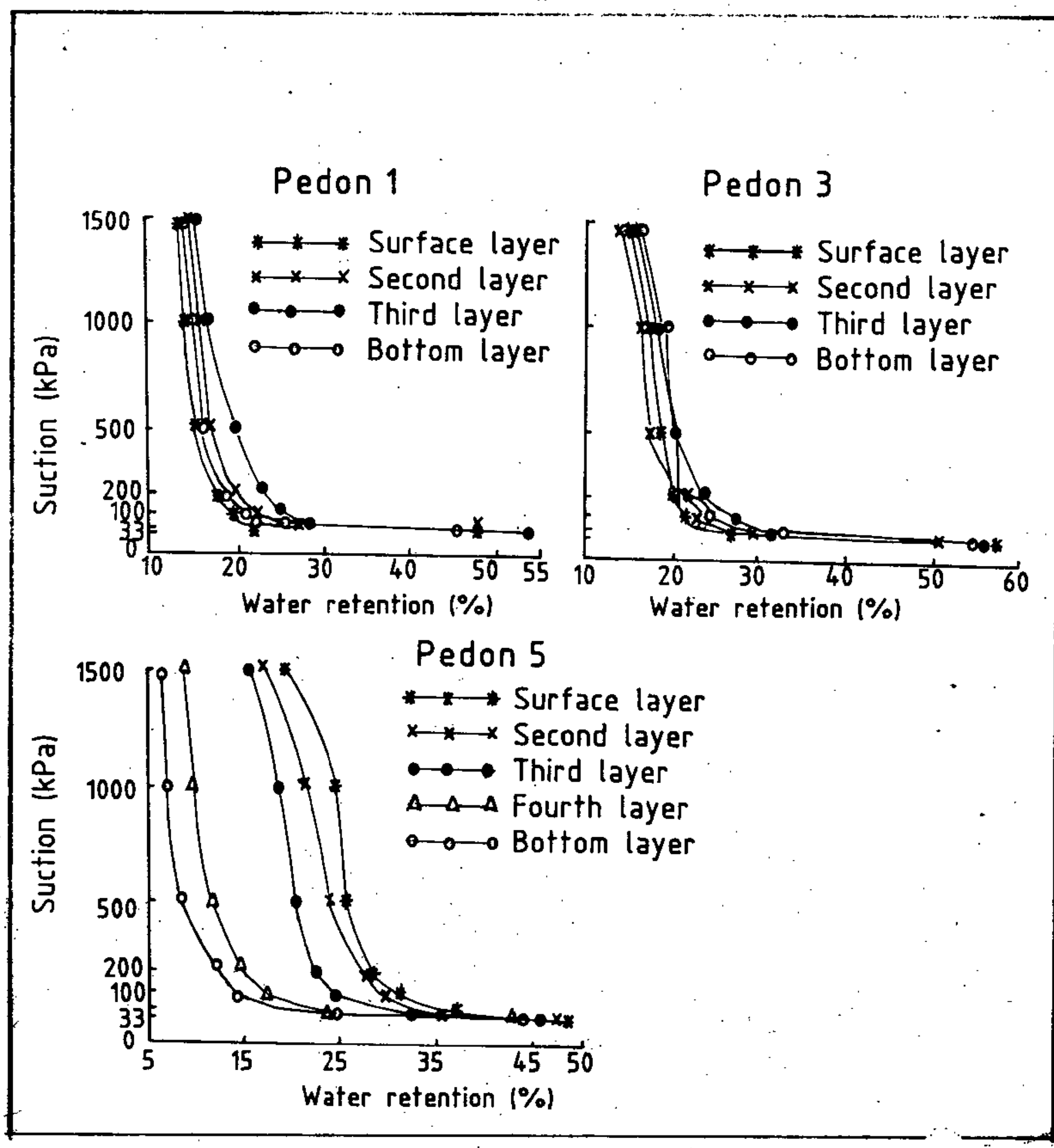

Fig. 1. Water retention at different suction in Vertisols

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