Original Research Article

Variability in Some Soil Physical and Chemical Properties of Shambat Farm, Khartoum- Sudan

ABSTRACT:

An experiment was conducted in the farm of the Faculty of Agricultural Studies, Sudan University for Science and Technology, this soil belong to the Central Clay Plain of the Sudan which has been formed by alluvial deposit of the Nile, primarily of basaltic origin, and it consider largely as Vertisols. The main objectives of this study were: to show differences or similarities of the sampled sites in order to provide more information on variability of the soil farm, to further investigate these soil as a step toward their improvement and management, and to study the possibility of technology and research findings transferring from one site to another. For these purposes, some physical and chemical properties at five sites across the farm have been investigated.The results indicated that the soils are variably affected by saline and sodic conditions. Non-saline, slightly saline, moderately saline sub soil and non sodic to moderately sodic soils are found in the farm. Soil texture is clayey throughout, and hydraulic conductivity is very slow to slow .The whole of soil profile is compacted except at the surface layer, the average bulk density is very high when the soil is dry. The soils under investigation are characterized by high water retention but rather narrow range of available moisture as noticed from the difference between the moisture retained between field capacity and wilting point.

Keywords: Cation Exchange Capacity, Sodium Adsorption Ratio, Exchangeable Sodium Percentage.

1. INTRODUCTION:

Soil physical, chemical and biological properties affect many processes in the soil that make it suitable for agriculture practices and other purposes. Texture, structure, and porosity influence the movement and retention of water, air and solutes in the soil, which subsequently affect plant growth [1]. Most soil chemical properties are associated with the colloid fraction and affect nutrient availability, and, in some cases, soil physical properties furthermore the physical properties and chemical composition largely determine the suitability of a soil for its planned use and the management requirements to keep it most productive [2]. Soil chemical such as Soil organic matter encourages granulation, increases cation exchange capacity (CEC) and is responsible for adsorbing power of the soils up to 90 %. Cations such as Ca2+, Mg2+ and K+ are produced during decomposition [3].

The primary physical processes associated with high sodium concentration are soil dispersion and aggregate swelling. When sodium –induced soil dispersion causes loss of soil structure, the hydraulic conductivity is also reduced. The deterioration of these physical properties is affected by both soluble salt and exchangeable sodium. Soil compaction changes pore space size, distribution, and soil strength. One way to quantify this change is by measuring the bulk density. As the pore space is decreased within a soil, the bulk density is increased. Soils with a higher percentage of clay and silt, which naturally have more pore space, have a lower bulk density than sandier soils [4]. Infiltration rate in soil science is a measure of the rate at which soil is able to absorb rainfall or irrigation [5]. It is measured in inches per hour or millimeters per hour. The rate decreases as the soil becomes saturated. If the precipitation rate exceeds the infiltration rate, runoff will usually occur unless there is some physical barrier. It is related to the saturated hydraulic conductivity of the near-surface soil. The rate of infiltration can be measured using an infiltrometer [6]. Hydraulic conductivity and cumulative infiltration of water are two interrelated parameters [7]. Expansive soils experience three dimensional volume changes during wetting and drying cycles, increasing volume when wetting and decreasing volume when drying; hence often have some shrink-swell potential as a result of wetting-drying cycles [8]. The objective of this study is to indicate similarities or differences in soil chemical, physical and mechanical properties at five sites occurring within the farm of Faculty of Agriculture Studies (SUST).The study is expected to high light the effect of soil on the finding of field experiment conducted by version researchers within the farm.

2. MATERIAL AND METHODS:

2.1 STUDY AREA:

This study was conducted at Shambat research farm (LAT: 15º 40'N LONG: 32º 32'E and ALT: 380 M), College of Agricultural Studies, Sudan University of Science and Technology. The main daily temperature is 29.3℃. Average maximum temperature reaches 47.3 ℃ in May while the minimum temperature is 5.5 ℃ in February. The mean relative humidity is 28% and show some variation ranges from 16% in April to 45% in August. The average annual rainfall is about 147.5 mms, with most of the rain falling in June –October.

The results of model were directly compared with the laboratory experimental ones using some statistical measurements.

2.2. METHODS OF DATA COLLECTION

2.2.1. FIELD METHODS AND SOIL SAMPLES

Five pits were opened at the experiment sites, studied in the field and described following the formats of the [9]; Guide lines of soil profile Description. Soil samples were collected from the genetic horizons of profiles and they are classified according to the American System of Soil Taxonomy [10].

2.2.2 LABORATORY ANALYSES

For each soil sample collected from the profile pits the following analyses were made at the lab of College of Agricultural Studies (SUST) and the lab of Faculty of Engineering (SUST): Soil reaction, Electrical conductivity, soluble cations and anions, Total nitrogen, Available phosphors, Cation Exchange Capacity: Exchangeable cations, Mechanical analysis, Hydraulic conductivity, Bulk density and Field Capacity all these analysis was done according to the method that described by [11]. Soil Organic Carbon and Organic matter was measured according to method of [12]. Soil Calcium Carbonate was measured using Eijkelkampcalcimeter that described by [13] and the Liquid Limit (LL), Plastic Limit (PL) by the method of [14].

2.3. STATISTICAL ANALYSIS

Means and variations acquired by ANOVA were employed for correlating the variations on soil chemical, physical and mechanical properties.

3. RESULTS AND DISCUSSIONS

The chemical and physical soil analysis of soil profiles are given in Table 1 and Table 2 respectively. The plastic limit and liquid limit results are shown in Table 4 and Fig 2. To obtain the Liquid Limit (LL), Plastic Limit (PL) and plasticity index (PI), the sample is treated with HCL to remove CaCo3, washed off the soluble salts and then dispersed with calgon. The pipette is used to sample the clay fraction, coarse sand, and fine sand separated by wet sieving and silt obtained by different as follow:

$$\text{Silt\%} = [100-(\%\text{clay}+\%\text{c.s} + \text{f.s})] \qquad (1)$$

The original liquid limit test of Atterberg's involved mixing a part of clay in a round-bottomed porcelain bowl of 10–12 cm diameter [14], while the plastic limit (PL) is defined as the moisture content (%) at which the soil when rolled into threads of 3.2 mm in diameter, will crumble. It is the lower limit of the plastic stage of soil [14]. Fig 2 shows the values of Atterbergs` limits for different soil samples. The plasticity index is the difference between PL and LL (LL-PL).

Table 1. Chemical Soil Analysis

Pit No.	Lab No.	Depth	CaCo3 %	ECe dS/m	pH	CEC	ESP	SAR	OM %	Olsen P	Total N %
	1	0- 15	4	1.0	7.3	43	2	4	1.6	7.8	0.12
	2	15- 45	4	1.6	7.4	43	15	9	1.4	3.2	0.10
1	3	45- 75	4	2.3	7.5	36	22	9	1.2	4.3	0.09
	4	75- 120	4	2.2	7.5	31	26	12	1.0	3.5	0.11
	5	120- 200	3	4.9	7.4	36	39	15	0.9	7.8	0.06
	6	0- 35	6	0.7	7.7	38	10	3	1.6	8.0	0.13
	7	15- 35	6	0.7	7.6	36	14	7	1.2	2.7	0.20
2	8	35- 80	5	1.6	7.7	37	24	12	1.2	3.4	0.10
	9	80- 130	3	8.0	7.5	39	30	25	1.0	3.5	0.08
	10	130- 200	2	3.0	8.0	39	28	17	0.7	3.6	0.06
	11	0- 15	6	1.1	7.8	42	7	4	1.6	4.2	0.13
	12	15- 35	7	1.2	7.7	42	14	9	1.4	5.2	0.12
3	13	35- 55	9	5.7	7.4	37	27	14	1.2	5.8	0.11
	14	55- 120	4	11.4	7.3	43	22	23	1.0	5.9	0.08
	15	120- 200	3	12	7.4	54	24	20	0.7	3.8	0.13
	16	0- 30	4	0.4	7.7	44	3	3	1.6	4.1	0.14
4	17	30- 60	5	0.4	7.7	46	2	1	1.2	3.3	0.09
	18	60- 100	5	0.7	7.6	50	6	5	1.0	3.6	0.08
	19	100- 170	8	0.8	7.6	52	2	4	0.9	2.4	0.10
	20	0- 5	4	1.7	8.2	55	7	10	1.7	3.6	0.08
	21	5- 25	5	1.3	8.7	58	6	8	1.6	4.8	0.18
5	22	25- 70	6	3.0	8.6	63	10	16	1.4	2.2	0.12
	23	70- 130	4	5.5	8.3	57	24	18	1.0	1.6	0.08
	24	130- 200	4	2.8	9.0	66	20	20	0.7	1.6	0.12

Table 2. Physical Soil Analysis

Pit No.	Lab No.	Depth	Sand	Silt	Clay	Texture	Bulk Density g/cm3	Porosity %	H.C cm3/h
	1	0- 15	16	46	38	ZCL	1.6	29	0.09
	2	15- 45	9	46	45	ZC	1.7	22	0.05
1	3	45- 75	16	38	46	C	1.7	29	0.04
	4	75- 120	15	41	44	ZC	1.8	22	0.03
	5	120- 200	12	49	39	ZCL	1.8	25	0.02
	6	0- 35	22	48	30	CL	1.5	38	0.3
	7	15- 35	22	46	32	CL	1.6	33	0.3
2	8	35- 80	25	47	28	CL	1.6	33	0.05
	9	80- 130	19	48	31	ZCL	1.6	33	0.05
	10	130- 200	5	55	39	ZCL	1.8	25	0.06
	11	0- 15	21	52	27	ZCL	1.6	29	0.08
	12	15- 35	20	39	41	C	1.7	22	0.05
3	13	35- 55	17	39	44	C	1.8	22	0.08
	14	55- 120	8	77	15	ZL	1.6	33	0.08
	15	120- 200	8	71	21	ZL	1.6	33	0.07
	16	0- 30	13	55	32	ZCL	1.6	33	0.2
4	17	30- 60	12	39	49	C	1.8	25	0.09
	18	60- 100	8	51	41	ZC	1.7	29	0.06

	19	100- 170	19	63	18	ZL	1.5	33	0.05
	20	0- 5	6	72	22	ZL	1.6	36	0.2
	21	5- 25	15	57	28	ZCL	1.7	29	0.15
5	22	25- 70	20	39	41	C	1.8	22	0.05
	23	70- 130	17	47	38	ZCL	1.8	25	0.06
	24	130- 200	10	64	26	ZL	1.6	33	0.07

Table 3. Averages and variations of some chemical and physical soil analysis.

Pit No.	H.C cm3/h	Porosity %	CaCo3 %	ECe dS/m	pH	CEC	ESP	SAR	OM %	Olsen P	Total N %
1	0.05a	25.40^{ab}	3.80^{a}	2.40^{b}	7.42^{b}	37.80^{b}	28.80^{a}	9.80^{a}	1.22^{a}	5.32^{a}	0.10^{a}
2	0.15a	32.40^{a}	4.40^{a}	2.80^{b}	7.70^{b}	37.80^{b}	21.20^{a}	12.80^{a}	1.14^{a}	4.24^{a}	0.11^{a}
3	0.07a	27.80^{a}	5.80^{a}	6.28^{a}	7.52^{b}	43.60^{b}	18.80^{a}	14.0^{a}	1.18^{a}	4.98^{a}	0.11^{a}
4	0.09a	29.0^{a}	5.20^{a}	0.54^{c}	7.64^{b}	39.92^{b}	3.0b	3.0^{b}	1.12^{a}	2.86^{b}	0.10^{a}
5	0.11a	29.0^{a}	4.60^{a}	2.86^{b}	8.56^{a}	59.80^{a}	13.40^{a}	14.40^{a}	1.28^{a}	2.76^{b}	0.12^{a}

Mean values with different superscript letters in the same column differ significantly ($p < 0.05$).

Table 4. Liquid and Plastic limits.

Item	S1A	S1B	S2A	S2B	S3A	S3B
LL %	55	53	36	46	45	48
PL %	27	26	20	17	17	16
PI %	28	27	16	30	29	38

3.1. PHYSICAL AND MECHANICAL PROPERTIES

The results of particles size distribution analysis for all profiles are given in Table 1, the results indicated that the Clay content dominantly varies between 31-49%, silt between 38-63% and sand between 6-25%. The highest clay content was reported at pit No .1 and pit No.4. The optimum basic infiltration rate for irrigation is considered to be in the range of 6.5 cm/h; according to [15] the infiltration category in shambat farm is slow (2.0cm/h). In general, permeability decreases with increasing density, and is affected by saline and sodic condition. In addition, the pore size distribution influences the rate of change of infiltrability. The results of hydraulic conductivity ranging from slow to very slow (0.02-0.3cm/h), according to [16]. Table 2.The values of bulk density on dry soil samples vary between 1.5-1.8g/cm3. The top soil is a slightly compacted at all sites .The sub soil is markedly very compacted in all pits except pit No 2, (Table 2). It has been shown that when the bulk density of medium to fine textured sub soil exceeds about 1.7gm/cm3, hydraulic conductivity values will be so low that drainage problems can be expected [11]. The total porosity of the studied soils lies between 32-43% which is by far less than the capacity of the soil to retain water at saturation (SP). This could be due to creation of more space during sample preparation as a result of crushing and sieving; (Table 2).The value of plastic limits of the soil samples varied from 15-26 and liquid limits were ranging from 36-55, resulting in a relatively high plasticity index. The Vertisols offer extremes of consistence -they are very hard when dry and very sticky and plastic when wet according to [17].

3.2. CHEMICAL PROPERTIES

The results of soil pH for the surface soil samples ranges between 7.3 and 7.9.These values are mildly alkaline and are found in pits 1-2-3 and 4. In pit 5, reaction to moderately alkaline (pH= 7.9)

[11]. The electrical conductivity values of the saturation extracts range between (0.4 - 12.0 ds/m).The weighted average of the soluble salts within the depth 200cm indicate slight level of salinity(0.57 ds/m) in (pit 4);and moderate (3.1 ds/m) salinity in (pits 1-2-5) and high (9.3 ds/m) salinity in (pit 3),Table1and Table 3 and Fig. 1.

The ESP value of 15 is often regarded as the boundary between sodic and non-sodic soil .In general term, high ESP values have a greater deterious effect on soils with 2:1 lattice clays .Although the onset of adverse physical condition occurs more generally at higher ESP levels in montmorillonitic clays; as indicate by [11], Table1 and Fig 1.The critical value of SAR that indicate problem is slightly lower than ESP. The SAR value of only 12 is considered harmful the lower SAR values acquired by pit 4, Table 3.

The Cation Exchange Capacity values ranged from 31 to 66 meq/100g.soil .There is considerable variation from sample to sample and the results confirm that percent clay is directly related to C.E.C as expressed in meq/100g soil. Actually C.E.C values are associated with both clay content, type of minerals and organic matter. In addition silt has a slight effect on C.E.C value; According to [2].Table 1. The Exchangeable Sodium Percent values ranged from 0.9 to 18.The general pattern is one of non sodic soil. However, in certain places the top soil is slightly affected with sodium (ESP = 6). The subsoil is markedly sodic in pits 1-2-3-5 (ESP =24); Table 1. Generally, the pit 4 showed a lower CEC and ESP values than the other sites, Table 3. The values of phosphorus range between 2 to 8.0 ppm and the total nitrogen values ranged from (0.08-0.18ppm). The results indicated that available phosphorus is very poor in these soils and also total nitrogen values were very low level [18]-[19]. Similarly, organic matter is very low and the result obtained for organic carbon is in between (0.4-1.0%), as shown in Table 1. The values of calcium carbonate range from 2-9%, (Table 1). Calcium carbonate has an Effect on most of the physical properties of soil including; particle size distribution, bulk density, permeability and available moisture; more important is the effect of calcium carbonate on availability of nutrients specially phosphorus and microelements, [20].

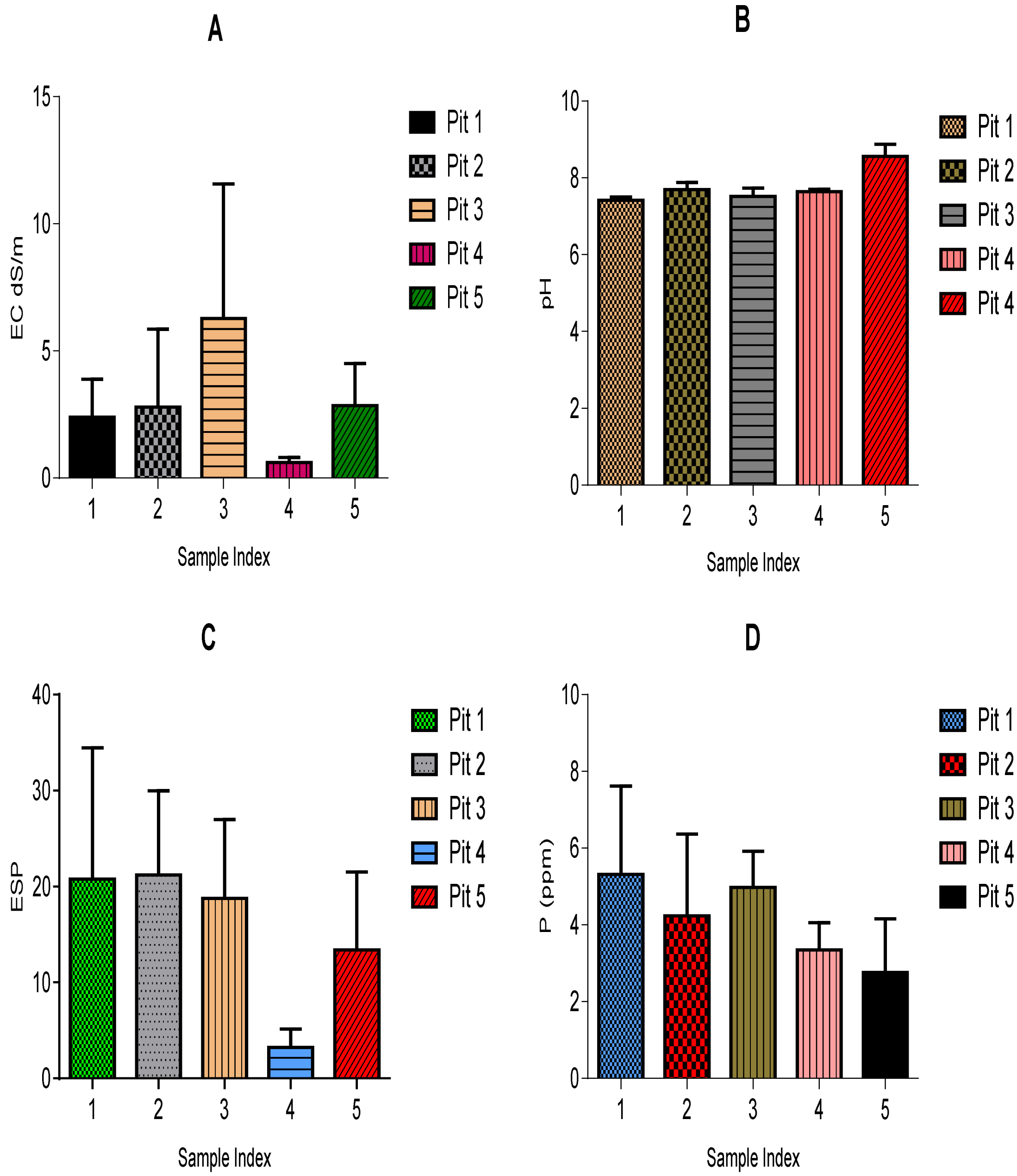

FIGURE. 1. Values of EC (A), pH (B), ESP (C), and P (D) for different pits.

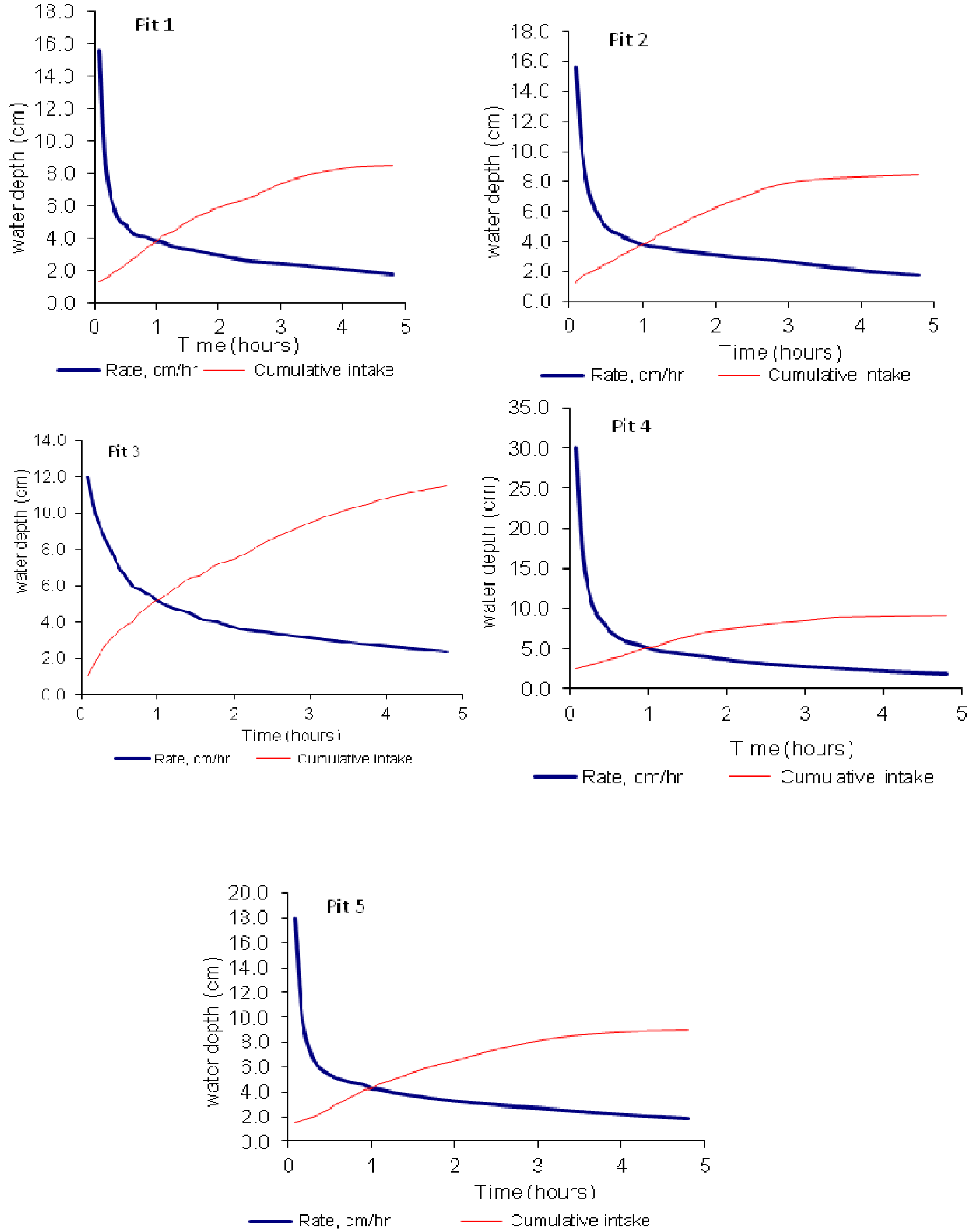

FIGURE. 1 Double-ring infiltrometer test results for rate and cumulative intake.

4. CONCLUSION

The study was carried out to conduct the physical and chemical similarities or differences between five sites included in the farm of the College. The results of this work have indicated that the soil variably affected by salinity and sodicity. Non-saline, slightly saline, and moderately saline, sub soil, non sodic to moderately sodic soils are all found in the farm. Soil texture is clay throughout, and hydraulic conductivity is very slow to slow. The whole soil profile is compacted except at the surface layer and average bulk density is very high when the soil is dry , these soil are characterized by high water retention but rather narrow range of available moisture as evidenced from the difference between the moisture retained between field capacity and wilting point .therefore, they generally have mildly alkaline reaction.

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