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CALCIUM CARBONATE CONTENT, SOME CHEMICAL AND PHYSICAL PROPERTIES OF THE SUDAN GEZIRA SOILS AND THEIR IMPLICATIONS

By

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Key Words: Aridisols, Calcium carbonate, Carbon: nitrogen ratio, Calcareous, Gezira soils, Recent alluvium, Soil-classification, Vertisols.

ABSTRACT

Eight soil pedons representing a range of aridisols, vertisols and recent alluvium were studied for various chemical and physical properties. Generally the soils were clayey except the recent alluvium which was loamy but poor in organic matter. The pH was alkaline, the EC_e was less than 1.0 dSm^{-1}. Carbon: nitrogen ratio was very narrow. Magnesium level did not pose a toxic hazard. The soils of the Gezira can be described as calcareous because of the relatively high content of their calcium carbonate.

INTRODUCTION

Various authors describe the soils of the Sudan Gezira with limited mention of calcium carbonate content. For example "the soils of the Sudan Gezira are classified as vertisols, being alkaline heavy clay soils with the clay mineral largely montmorillonite" (Said, 1973). Ishag *et al* (1987) stated "Soils are alkaline vertisols, deficient in nitrogen and organic matter." Ageeb (1988) commenting on the major constraints to wheat production in the Gezira "Poor drainage, low infiltration rate and waterlogging in poorly managed soils cause patchiness and low seed yields. In addition, the soil is alkaline (pH 8.5) and deficient in nitrogen (380ppm) and available phosphorus (4-6 ppm)". Robinson *et al.* (1969) wrote "In flights over the Gezira, at certain times of the year, salt effervescences can be observed on the surface". Robinson *et al.* (1969) did not identify what type of salts they had observed. Physical and chemical properties of the Gezira soils have been given by various authors (Greene, 1928; Jewitt, 1955; Finck, 1961; Bunting and Lea, 1962; Robinson *et al.* 1969).

In arid and semi-arid regions appreciable amounts of calcium carbonate are found in soils. Greene (1928) found considerable amounts of calcium carbonate in a soil profile at the Gezira Research Farm (cf. his Fig. 1). The influence of calcium carbonate content of soils on water holding capacities and nutritional status of the Gezira soils is generally neglected when studying the influence of soil texture. Black (1967) indicated that calcium carbonate is a natural constituent in many soils and its environment-controlled dissolution maintains soils continuously in a base-saturated condition. Abrol *et al.* (1969) stated that the manner in which calcium carbonate might behave would depend largely on the size fraction in which it occurred. Thind and Chahal (1983) pointed out that any soil with a calcium carbonate content greater than 4% can be described as a calcareous soil.

The carbon:nitrogen ratio of different soils has been of interest to soil scientists long ago (Stevenson, 1959). Said (1973) studied the C : N ratio of some Gezira soils but he concluded that the ratios were large because an arbitary recovery factor 0.75 was used (cf. his Table 4).

Therefore the present investigation was undertaken to estimate (a) the percentage content of calcium carbonate (b) the carbon : nitrogen ratio in some Gezira soils and (c) other physical and chemical properties which may add insight into the structure of the soils and their subsequent relations with irrigation system of the Gezira.

Study Area:

The study was conducted in the Sudan Gezira (13°30′ - 15°30°N, 32°30′ - 33°30°E) situated in the Central Clay Plain of the Sudan which lies mainly on the western part of the Blue Nile. The local climate of the Gezira is classed as semi arid, annual rainfall is about 342-424mm (Ishag *et al.*, 1985), mean temperature during the main crop sowing period is 25-39°C. For about 7-8 months of the year there is no rain. The natural vegetation is sparse throrn scrub (mainly *Acacia* species *Calotropis procera* and *Balanites aegyptiaca*) where it is in a drought-imposed dormant condition throughout most of the year.

MATERIALS AND METHODS

Eight surface soils, sampled from 0-30 cm zone were used in this study. Sites of sampling were chosen to represent the range of soils in the Sudan Gezira. Soils No. 1, 2 (group A-Aridisols) and soils No. 1-3 (group B-Vertisols) were kindly supplied by Soil Survey Administration, Ministry of Agriculture, Wad Medani, Sudan. Soils No. 4-5 (Vertisols) were sampled from Central Gezira. Soil (group C) was collected from the west bank of the Blue Nile (following flood period) near Hassa-Heissa (Fig. 1).

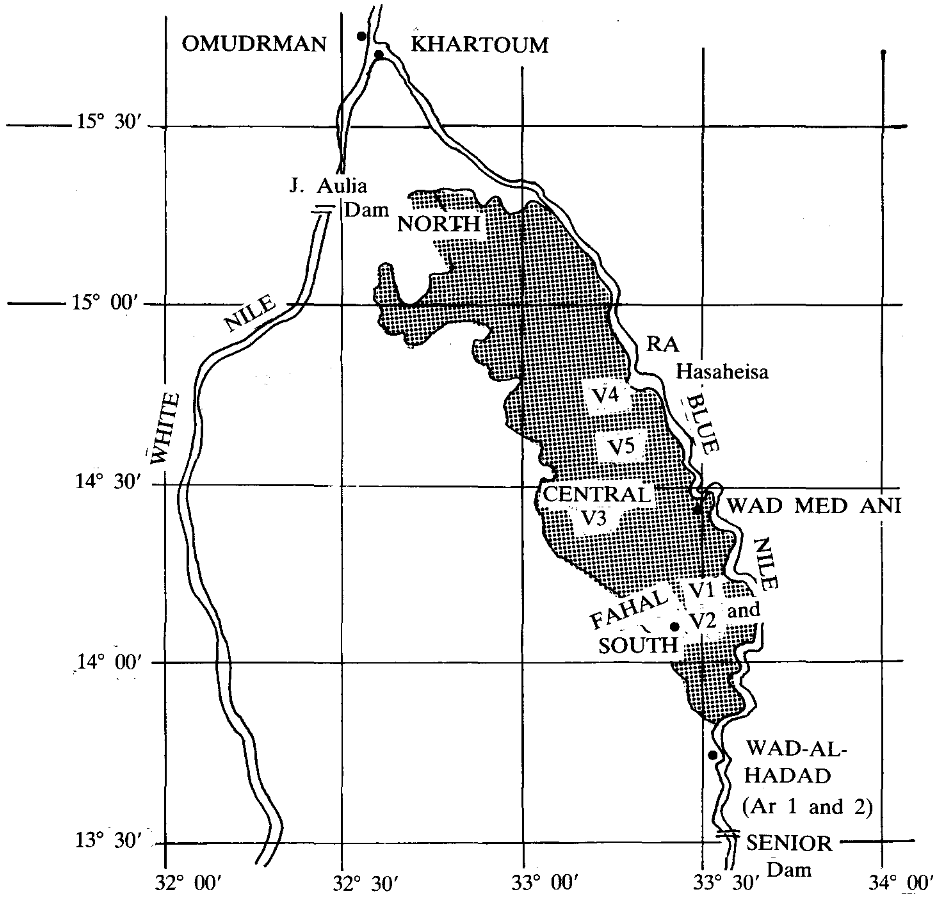

Fig. 1: Location map of Gezira area and soil survey areas.

Gezira Area Ar: 1 and 2 = Aridisols V1-V5 = Vertisols RA = Recent Alluvioum

All soil samples were air-dried ground to pass a 2mm sieve and analysed (three replicates from each sample were used). Soil texture was determined by the Bouyoucos hydrometer method (Day, 1965). Saturation percentage was determined on a soil paste made with distilled water. Electrical conductivity and pH were determined from saturation extract. Soluble cations and anions were determined from the saturation extract as follows: calcium and magnesium by titration with versenate, sodium and potassium were determined photometrically, carbonate, and bicarbonate by titration with H_2SO_4, chloride by titration with silver nitrate and sulphate by precipitation as barium sulphate. Calcium carbonate was determined by gravimetric loss of carbon dioxide (Richards, 1954), organic carbon by the Walkley-Black method, total nitrogen by Kjeltec Auto 1030 Analyser (Tecator AB-Sweden).

RESULTS

A full list of the site locations and major soil properties is given in Table 1. Three textural classes were represented in the soils. Clayey soils were more common than the others. There were six clayey, one sandy clay and one loamy soils. Saturation percentage was more because of higher (44-62%) amount of clay (results not shown here). The order of maximum water holding capacity (MWHC) should be CG2 = Wad-Al-Hadad 760 = CGI > Wad-Al-Hadad 822 > Recent alluvium = CG3 > Fahal 493 = Fahal 492. As expected and well-known the pH was similar (no significant difference) and alkaline in all soil samples. The electric conductivity of the saturation extract (EC_e) was generally very low, Central Gezira I soil and Recent alluvium had lower EC_e ($P < 0.05$) compared to the other six sites. The bicarbonate was generally high in all samples but significantly lower ($P < 0.05$) in Central Gezira and Recent alluvium soils. Soluble carbonates were invariably low, chlorides and sulphates were low but their content was similar in all locations. Generally Ca^{2+} and Mg^{2+} were low in Aridisols but gradually increased for Vertisols and the Recent alluvium samples. Generally Na was low in all sites but the lowest Na content ($P < 0.05$) was found in the Recent alluvium site. Potassium was extremely low in all studied sites. Calcium carbonate occurred throughout the sampled sites in an erratic pattern. From the results the order of $CaCO_3$ content was Fahal 492 > Fahal 493 = Wad-Al-Hadad 822 = Recent alluvium > Wad-Al-Hadad 760 = CG1, 2 and 3 ($P < 0.05$). $Ca^{2+} : Mg^{2+}$ ratio was more than unity in all sites. Organic matter was extremely low, it ranged between 0.40 (Aridisols) to 0.77% in the Recent alluvium. Likewise total nitrogen was 0.2% in Fahal (493) but was between 0.47 - 0.56% in Wad-Al-Hadad (822) and the Recent alluvium soils.

DISCUSSION

Robinson *et al.* (1969) argued that in climates such as in the Gezira a wide range of carbon : nitrogen ratio may be unfavourable preventing the easy release of nitrogen to cultivated plants. The results show that the C : N ratio is narrow enough compared to other soils (Stevenson, 1959). Black (1967) indicated that the relative availability of carbon and nitrogen in soils for the growth of soil microorganisms is represented by the ratio of C:N. Nitrogen mineralization and immobilization and

Table 1

Range of important physico-chemical characteristics of the soils.

Sr. No.	Class and Name of soil	S.P (Maximum water holding capacity)	pH	EC_e	mgl^{-1} (ppm) Anions Co_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Cations Ca^{2+}	Mg^{2+}	Na	K	Ca Co_3%	Ca:Mg	C:N	Soil Texture
(A)	Aridisols															
1	Wad-Al Hadad (822)	55.6±1.40*	8.41±0.21	0.52±0.01	5.0	217.0	45.0	36.0	16.0	5.0	104.0	5.0	7.98±0.19	3.2	1.60	Clay
2	Wad-Al Hadad (760)	59.4±1.48	8.40±0.21	0.62±0.01	5.0	240.0	34.0	89.0	26.0	5.0	120.0	5.0	5.91±0.15	5.2	0.77	Clay
(B)	Vertisols															
1	Fahal (492)	47.0±1.20	8.25±0.20	0.53±0.01	6.0	222.0	50.0	37.0	26.0	6.0	97.0	5.0	11.43±0.28	4.5	0.87	Sandy clay
2	Fahal (493)	47.7±1.19	8.40±0.20	0.66±0.02	5.0	219.0	61.0	79.0	24.0	6.0	124.0	5.0	7.68±0.19	4.5	1.61	Clay
3	CGI	58.9±1.47	8.19±0.20	0.48±0.01	7.0	194.0	34.0	76.0	31.0	12.0	78.0	5.0	6.04±0.15	2.6	1.14	Clay
4	CG2	65.1±1.62	8.15±0.20	0.63±0.01	8.0	231.0	53.0	109.0	36.0	13.0	113.0	5.0	5.90±0.14	2.8	1.40	Clay
5	CG3	49.9±1.24	8.18±0.20	0.76±0.02	4.0	161.0	63.0	156.0	42.0	6.0	120.0	5.0	5.90±0.17	7.0	1.26	Clay
(C)	Recent Alluvium	51.8±1.29	7.95±0.18	0.46±0.01	5.0	112.0	66.0	49.0	65.0	11.0	16.0	5.0	7.82±0.19	6.0	0.94	Loam

S.P = Saturated Percentage (MWHC)
EC_e = Electric Conductivity dSm^{-1} at 25^{0}C
CG = Central Gezira
C:N = Carbon:Nitrogen ratio
* = ± SE

their subsequent transformations in the soil are usually micro-biological processes. Narrow and very small C:N ratio in Gezira soils indicates the scantiness of both carbonaceous and nitrogenous food material necessary for the various microorganisms (this is expected because the Gezira area is very sparsely vegetated i.e. absence of residual effect of added plant material to the soil environment).

Soluble salts do not present a hazard or a problem to crop production in the Gezira as the EC_e is less than 1.0 dSm^{-1}.

Not only the amounts but the ratios of cations in the adsorbed phase or in soil solution are of vital importance in determining their behaviour in different soils. High concentrations of Mg^{2+} in the soil are more toxic to plants than any other concentrations of other neutral salts (Richards, 1954). The results show that a relatively wide Ca:Mg ratio to nullify and alleviate the toxic effect of magnesium is evident. Marschner (1986) pointed out that calcium is a non-toxic mineral nutrient, even in high concentration, and is effective in detoxifying high concentration of various other cations surrounding roots in the soil solution.

Calcareous soils ($pH > 7.0$) which cover more than 25% of the earth surface are very common in semi-arid and arid climates; their content of free calcium carbonate in the upper 30-40 cm is between a few percent to 95%. Pedogenic carbonates such as calcium affect soil chemistry and structure via decreased water penetrability, a well-buffered pH range of 8.0 to 8.4 (Lajtha and Schlesinger, 1988; Ismail, 1990). Such a relatively high pH decreases the availability of micronutrients such as manganese, copper, iron and zinc (Cooper et al., 1987). Calcium carbonate can control P levels in soil solutions through ion-pairing with calcium, physical sorption onto calcium carbonate (Cole and Olsen, 1959). The lowered crop response to P fertilization is attributed to the fixation of phosphorus by pedogenic $CaCO_3$ (McCalsin and Gledhill, 1980). Although the Gezira soil is rich in total phosphorus, yet its high pH rendered this phosphorus unavailable for plants (Ishag *et al.*, 1987). The results shown here are in agreement with Thind and Chahal (1983) finding that for calcareous soils, the relatively high pH values were due mainly to high contents of calcium, magnesium, sodium and bicarbonate (Table 1).

The soils of the Gezira are widely used for irrigation agriculture but the variation in topography poses problems for soil management. For example Jewitt *et al.* (1979) argued that as vertisols are in the dry state, vertical cracks may aid infiltration, but infiltration and vertical hydraulic conductivity will be slow in the wet uncracked soils. Virgo (1981) cautioned against permitting irrigated soils (Vertisols) to dry sufficiently to allow cracking and fissuring to aid infiltration as this would expose plants to moisture stress. "The lack of deep drainage in the Gezira soil and the limited quantities of total water it can hold" Ishag *et al.* (1985) may be a consequence of a hard pan formed by calcium carbonate and exchangeable sodium percentage (Robinson *et al.*, 1969). The efficiency by which irrigation and fall water are converted to dry matter in the Gezira soils can be increased by deep tillage to reduce run-off and improve infiltration with less cracking.

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محتوى كربونات الكالسيوم وبعض الخواص الكيميائية والفيزيائية لأراضي الجزيرة بالسودان

أحمد محمد علي اسماعيل

تمت دراسة الصفات الكيمائية والفيزيائية لثمانية أنواع من الأراضي مأخوذة من ثلاثة رتب : الأراضي الجافة والأراضي الداكنة الغائرة وأراضي سهل فيض النيل الأزرق .

اتصفت الأرض في رتبتى الجافة والداكنة الغائرة بقوام ثقيل بينما اتصفت تربة سهل الفيض بأنها طميية نتيجة لارتفاع نسبة السلت إلى ٣٨٪ وانخفاض نسبة الطين إلى ٢٦٪ .

تتميز الثمانية أنواع من الترب بقلة الأملاح لأن التوصيل الكهربي أقل من واحد ملسمن/سم . كذلك نجد أن الرقم الهيدروجيني في كل العينات قاعدي التفاعل والذي ينعكس أثره سلباً على يسر بعض العناصر المغذية للنبات . نجد أن المواد العضوية قليلة للغاية وهذا متوقع في مناخ حار جاف كمناخ الجزيرة . وأيضاً أن نسبة الكربون : النيتروجين في جميع الترب كانت متقاربة وأن محتوى هذه الترب من عنصر المغنسيوم أقل من الحد الحرج لدرجة السمية . وتحتوي جميع الترب التي تمت دراستها على نسبة كربونات كالسيوم يجعلها في نطاق الترب الجيرية أو الكلسية .