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Advances of Research in Soil Chemistry in Sudan

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Abstract: Soil is a combination of organic and inorganic solids, water and air. Soil chemistry focuses on studying the chemical reactions and processes between these components and, particularly, the fate of contaminants n soil chemistry in Sudan. The review will give an in site of the most important aspect the executed research in tackling the productivity of the agricultural sector. Therefore, reviewed studies primarily focused on the reactions between plant nutrients and soil.Pioneers scientists noted that the nitrogen in the soils of Gezira is deficient, due to low organic matter, hence, nitrogen was considered as the main yield-limiting factor. Since then, adsorption experiments have carried out to study the adsorption of urea and ammonia in Gezira soils. Meager research on adsorption of phosphorus and potassium has been carried out in Sudan soils. Salt-affected soils are widespread in different states of the country such as Northern, River Nile, Khartoum Gezira, and White Nile states, therefore, adsorption experiments of macro- and micronutrients onto salt affected soils in Sudan has been studied by many researchers. In spite of the amount and progress that had been achieved in soil chemistry research in Sudan, it is high time to recognize the future directions the research and innovations need to address on soil chemistry in Sudan, Thus, our future research should focus on food security with quest for improvement in the quality of life and preserving our country free from any kind of environmental hazards by adopting recent advances in methods and technologies.

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INTRODUCTION

Sudan is the third largest country in Africa. Sudan area is about 1,886, 068 km^2(728,215 square miles) and has an estimated population of 42.51 million in 2018, a significant increase from the 34,847,910 estimated in 2013(Kavanaugh, 2014). Sudan endowed with many natural resources such as numerous climatic conditions combined with fertile soil and water resources come from rivers, seasonal streams and groundwater. Sudan lies within the tropical climate and was divided into the following climatic zones: savannah, semi-arid, and arid (Van der Kevie,1973). Soils of Sudan were classified, depending on climate zone, to five groups; soil of desert region, soil of arid region, soil of semi - arid climate, soil of monsoon climate, and soil of highland climate.Research concentrated on central clay plain which is regarded as the backbone of Sudan agriculture, where most of the irrigated schemes are located, especially in the Gezira is which conducted outstanding in the amount of research devoted to evolving and perfecting an agricultural system, centering around cotton. The soils of the Sudan Gezira are classified asVertisols, beings alkaline heavy clay soils with the clay mineral largely montmorillonite alkaline and calcareous and is poor in carbon and nitrogen (Fadl,1971).

Sudan is a plain whose land consists of fertile clay soil, sand dunes and some volcanic mountains, which makes it characterized by a variety of soil and its characteristics. Sudan has distinct characteristics in terms of climate and rainfall in the semi-desert region between 75-300 mm and in the central Sudan rainfall is between 300 - 800 mm per year falling in summer. This diversity in soil, rainfall and temperature is varied in vegetation, where desert in the north followed by semi-desert areas and in the middle prevail the poor and rich savannah climate covering areas stretching from Darfur states westward to the Ethiopian and Eritrean borders in the east and then the tropical climate in southern Sudan. The diversity of climates and environments has enabled the production of some crops throughout the year in summer and winter.

Soil chemistry as a cornerstone of soil science was traditionally focused on the chemical reactions in soils that affect plant growth and plant nutrition such as; soil chemical reactions and processes including ion exchange, soil acidity, soil salinity, redox, precipitation-dissolution and sorption phenomena. The soil chemistry emphasis now is on the environmental soil chemistry which concerns more about inorganic and organic contaminants in soil, water and air and their impact on plant, animal, and human health(Sparks,2001).A considerable number of studies on soil chemistry were done on in Sudan soil. The necessity for improvement of soil chemistry research urges to review what was done and to identify the future directions in the area of soil chemistry research. This is an effort to review what was executed in the past in soil chemistry research in Sudan.

CLAY MINERALOGY OF SUDAN SOIL

Mineralogical studies conducted to investigate the mineralogical homogeneity of the soil profile, identification and characterization of clay minerals are one of the basic requirements for soil classification as well as better understanding of soil genesis and assess the status of soil fertility management strategies to maximize the efficiency of nutrient uptake from soil and fertilizers (Carroll,1962; Khodary,2007). Mineralogical studies of the Sudan soil were started at beginning by Blockhuis *et al.* (1964)who found that the clay fraction of some soils of the central clay plains of Sudan are mixture of montmorillonite- elite type followed by Ayed (1968) who stated that the soils of Sudan are of quite uniform mineralogy, with montmorillonite being the dominant clay fraction, with moderate amounts of illite as well as small amounts of quartz, mica, and chlorite. Adam (1983) and Adam, *et al.*,(1983) studied them ineralogical properties using X-ray diffraction (XRD), dissolution, and Ca/Mg and K/NH_4 cation exchange capacities(CEC)in the major soil series in Gezira scheme including: Hosh, Suleimi, and Laota soil series. They found that these soils have similar sand, silt, and clay mineralogy. The sand fractions are composed of quartz, plagioclase, K feldspars, anatase, and amphiboles.

The silt fractions contain, in addition to the above mentioned minerals, kaolinite, mica, and chlorite. The coarse clay is composed of chlorite, kaolinite, smectite, plagioclase and K-feldspars, quartz, and mica. The fine clay is predominantly smectite (a mixture of montmorillonite and beidellite), kaolinite, and mica. Calcite is the dominant mineral in the gray hard nodules. The uniform physiographic position and similar mineralogy of these soils suggests that they have a common origin. The similarity in mineralogical composition to that of the recent sediments of the Blue Nile and its tributaries supports the contention that the Gezira soils have inherited their mineralogical properties from the source area of the sediments in the Ethiopia high plateau.

The mineralogy of Almanagil soils in Gezira scheme soil were studied by (El Tom,1970) using XRD, CEC, and surface area. He found that montmorillonite is the dominant clay mineral and Kaolinite and possibly vermiculite is also present as well as a trace of quartz. He also, concluded the similarity among Gezira soils including Almanagil and he attributed that to the effect of similar soil forming factors prevailed in the Gezira, especially climate, parent material and topography. The mineralogy results of Almanagil were confirmed by Elhag *et al.* (2015) who stated that the clay mineralogy of Almanagil Ridge is smectite, chlorite, illite, and kaolinite as the major clay minerals in the soil of the study area. They concluded that the XRD mineralogy indicated that the Vertisols and Aridisols of the study area had the same origin as that of the Gezira soils.

Fadul (1969; 1971) compared the mineralogical data of Gezira and Kenana soils and found that the clay fraction of the Gezira and Kenana soils is montmorillonite being the dominant clay mineral accompanied by kaolinite and Quartz as an accessory mineral with no evidence of chlorite. The mineralogical comparisons studies between the soils of the central clay plain was continued by Deng, and Marchelo-d'Ragga (2017) by selecting transect from east of Rahad River, across Gezira, and west of the White Nile. Their mineralogical investigations for the primary clay revealed high content of quartz, and muscovite. The proportions of smectite, kaolinite were relatively higher compared to smectite especially in the sub-soils and illite and chlorite were lower. They concluded that the identified clay minerals in the studied soils were originated from the Ethiopian high Plateau and mixed with limestone material during transportation. This study indicated that part of the White Nile and the remaining soils have been derived from the Ethiopian plateau which is dominated by basic and ultra-basic rocks. These rocks give rise to the dominance of smectites clays. Quartz, Muscovite and Illite are the main primary minerals in the studied soils with minor amount of zeolite, pyroxene and calcite minerals.

Ahamed *et al.* (1991) examined soil samples from four localities namely: El Gezira, El Gunaid, El Mukabrab, and El Gash using Mössbauerspectros-copy, XRD, transmitted light microscopy, and chemical analyses. They found Quartz, feldspars, clay mineral, iron and titanium oxides, and traces of pyroxene and amphibole. The main sources of these materials are the basic igneous and metamorphic rocks of the Abyssinian plateau as well as the eolian sands to the east of the Nile River (particularly for El Mukabrab soil). The less than 2-μm fraction contains smectite and chlorite as the dominant clay minerals with subordinate amounts of kaolinite. Mössbauer data also indicate that about 95% of the iron is in the ferric state which is mainly located in the structure of smectite and chlorite. The chemical composition of the Entisols and recent Vertisols is relative to the content of silicon, aluminum, iron, titanium, calcium, magnesium, potassium barium,cobalt manganese nickel and zinc. Sulieman *et al.* (2015) studied the origin and distribution of heavy minerals in the alluvium of Nile River terraces, Khartoum North and the heavy mineral assemblages in the very fine sand. They found that quartz was dominant in the opaque minerals in all sediments. The non-opaque heavy minerals were dominant by zircon, tourmaline, rutile, garnet, sillimanite, and alusite. Their results revealed that the ultra stable minerals (zircon, tourmaline and rutile) were found in all sediments.

Garnet, sillimanite and andalusite were also found. They concluded that most heavy minerals in the study area are originally derived from gneisses and schist metamorphic rocks and some igneous rocks of the Ethiopian plateau. Moreover, Sulieman *et al.*(2016) stated that, in alluvium terraces of the River Nile at Khartoum North in three river Nile terraces soil that the most abundant clay mineral was smectite, followed by illite, kaolinite and chlorite. Mineralogy analysis indicated that the Entisols and Aridisols of the River Nile terraces in the study area had the same origin as that of the igneous and metamorphic rocks from Ethiopian plateau**.** The mineralogical studies of the Sudan soil were concentrated in the central clay plain of Sudan except for few studies such as Elgubshawi and Elamin (1995) who studied the mineral composition of Gardud soil in Kordofan state and they found that dominant clay minerals are kaolinite, montmorillonite and illite.

NITROGEN CHEMISTRY

Studies on nitrogen (N) level in Gezira soils started by pioneers more than a hundred year ago. Beam (1911) reported a low N contents in all Gezira soils (0-0.04%N). Later, this was confirmed by Hiepko (1967) who stated that all soil types which are of economic importance are deficient in N as a result of the prevailing climatic factors in Sudan (low precipitation and high temperature). Urea and ammonium sulphate are the main nitrogenous fertilizers used in Sudan Gezira. So, the reaction between soil and N fertilizers can play a critical role in the efficiency of fertilizer N and its impact on the indigenous soil N supply to crops(N uptake). In this context, Musa (968 a, b) studied the transformation of urea and ammonium sulphate in the Gazira soil, under field conditions. He found that the pattern of the transformation was nearly the same for the two levels of nitrogen added but there was a difference in magnitude. Urea hydrolysis was arrested during the first week in an open-bag system in the summer months. There was a marked accumulation of nitrite in the first two weeks especially in moist closed bags, thereafter it decreased to low values. Nitrate accumulated gradually under winter conditions, more so with closed bags than open ones. By contrast, little nitrate nitrogen was formed during the hot summer months, this being associated with high ammonia accumulation throughout the incubation period. The highest rate of ammonia loss occurred during the first week after application of both fertilizers, thereafter decreasing to lower values. The cumulative ammonia loss was higher with higher application of N. Ammonium sulphate gave consistently higher ammonia losses than urea and losses from open soil system were generally less than from soil in polythene bags. With lowest irrigation level used, ammonia loss attained a sizeable value throughout the incubation period with both fertilizers. With higher moisture levels, the magnitude of ammonia loss decreased appreciably, much more so with urea than with ammonium sulphate. Induced drying and rewetting prolonged the duration of loss and increased the magnitude of cumulative loss. An appreciable loss of ammonia may take place from fertilized Gezira Soil under warm conditions. Low moisture levels and high fertilizer concentration; this may be the case with patchy fertilizer distribution and frequent light showers during early summer. So, it is advisable to apply urea or ammonium sulphate when conditions are most favorable for nitrification. The research aboutthe reaction between soil and N fertilizers continued by Said(1972) who found that the adsorption capacity of urea in three series and alluvium in the order Vertisols were ranked as Suleimi >Hosh> Loata> alluvium of Blue Nile. The fixation of ammonia in these soils varies because of the differences in methodology, soil type, mineralogical composition, and agro-climatic conditions. Said (1973) stated that the Gezira soils contain appreciable amounts of fixed ammonium and the values for the surface soils varied from 0.25–0.30 mmol+/100g. The soils under investigation have the capacity to fix a large quantity of applied ammonium and the ammonium-fixing capacity increased with depth reaching a maximum in the grey layer at a depth of about from 70 to 140 cm below which it decreased again. He also added that the amount of fixed ammonium was found to depend on the type and amount of the clay minerals present. In addition, the amount of fixed ammonium will increase with the increase in the frequency and dose of NH_4-N fertilizers application (Said, 1973). High losses of N in the form of ammonia was observed by Musa (1968a) and the rate of loss of ammonia is certainly related to the rate of urea hydrolysis in soils and which is primarily hydrolysed through the action of urease. Thus, any treatment that inhibits the activity of urease reduces the rate of urea hydrolysis in soils. In this context, Abdel Magid and El – Mahi (1983) studied the effect of urease inhibitors on the urea hydrolysis in some Sudanese soils belonging to the orders of Vertisol and Entisol. The analysis showed that the rate of urea hydrolysis was significantly affected by soil type rather than treatment. It seems that K_1 (reaction constant) is associated with the soils' initial urease activity as it closely correlates with the Michaelis constant (km).The gradient, K_2, being significantly affected by soil type as well as treatment is probably associated with the induced urease activity with time and it, therefore, varied with variations in soils and treatments. Of the so-called urease inhibitors used in this study $Ca(OH)_2$, p-benzoquinone (PBQ) and orthophosphoric acid (OP) only PBQ reduced urea hydrolysis while the other chemicals have effects possibly related to modifying the soil pH. Inhibitor treated soils had substantial amounts accounted for N which was believed to be present, presumably, in the form of carbamate.

Sudan is dominated by arid and semi-arid climatic zones that favor the formation of salt affected soils (Nachtergaele, 1976; Mustafa,1986). Therefore, research on reaction between salt affected soils and macro and micronutrients received a considerable attention by Sudanese researchers. For instance, Awadelkarim (1989) studied the chemical fate of applied urea in three soil orders in Sudan, Aridisols, Vertisols and Entisols under salt affected condition. The research focused on the main problem that faces the use of urea in such soils i.e. the rapid hydrolysis of urea to ammonium carbonate ($(NH_4)_2CO_3$) and, hence, the gaseous loss of nitrogen through ammonia volatilization process shortly after application.The rate of urea hydrolyses and loss of N were found more serious in salt-affected soils which are generally low in available nutrients, particularly N. The outcome of such studies indicated that for Entisols (Shambat Gerf soil), the rate of urea hydrolysis decreased with increasing salinity level from 40 to 200 mmol+L^{-1}, especially at high levels of sodicity. This was attributed to the high concentration of salt which adversely affect the microbial growth and, hence, the microbially induced urease activity which caused reduction in the rate of urea hydrolysis. The initial rates of urea hydrolysis in Vertisols (Gedarif soil) were lower than that of Entisols and this was due to the high clay content of Vertisols and, therefore, high surface charge density that may cause strong adsorption of urease and a decrease in its activity. The same trends were observed in Aridisols (Droushab soil) where the high pH values in such soils probably suppressed the production of microbial induced urease activity through negative effect on microbial proliferation.

Wide oil survey first started in Sudan in the mid-1970s, and commercial quantities of oil began to export in October 2000. Crude oil is produced in the south western Sudan and refined by Khartoum refinery. Khartoum Refinery was built to produce benzene and butane gas for domestic consumption and export. Improper disposal of waste aqueous ammonia produced by Khartoum Refinery can be one of the main causes of pollution in Khartoum state. During refining into different commercial products, anhydrous ammonia is produced, and then injected into our water to maintain a pH level of around 6.5, which assists in preventing corrosion of the pipes in the refinery, before its final disposal. The resulting aqueous ammonia (NH_4 OH) is diluted with water to reduce its concentration was between 10 and 18% before it disposed off. This discharge may potentially contaminate the surrounding area, damage the soil and pollute the surface and underground water as well as the air Mahjoob *et al.,* (2016 a). Therefore, studies on the possibility of environmentally safe disposal waste ammonia in soil produced by Khartoum Refinery, posing health and environmental hazards are needed. Adam,(2005) and Adam and El –Mahi (2012) studied ammonia transformation and adsorption onto three soil orders (Entisols, Vertisols and Aridisols) were studied by incubation and adsorption using quantity/intensity, Freundlich and Langmuir adsorption isotherms.The efficiency of aqueous ammonia compared with urea as a N fertilizer was investigated via *Sorghum bicolor.* L as a test crop. They found that aqueous ammonia underwent successful transformation to NO_3 in Khartoum State soils at 25 – 28 ºC in the laboratory in a maximum of 25 days according to a general polynomial second degree equation: $Y= a + bx^2 + cx$. Ammonia application to soil significantly increased the yield of forage sorghum and ammonia proved to be of similar efficiency to urea fertilizer when applied either by direct injection or mixed with irrigation water. Chemical constituents of waste ammonia, other than N such as lead, cadmium, copper, and nickel were too low to be harmful to plants and animals feeding on them according to WHO standards. These heavy metals are also expected to precipitate as hydroxides and carbonates in the alkaline calcareous soils of Khartoum State and will not be vulnerable for leaching to underground water or available for plant uptake. Another experiment by Mahjoob *et al.*, (2016 b**)** revealed that N, P and K content of forage sorghum leaf increased by application waste ammonia produced by Khartoum Refinery.

CHEMISTRY PHOSPHORUS

Research in P fraction was studied by Said (1975) who found that the total P values were generally high throughout the profiles (406 to 700 ppm) increasing with depth to reach a maximum at 50 to 145cm and then declining. They decreased in magnitude from the south to the north of the area in the order Hag Abdulla >Tayiba>Turabi. Most of the inorganic phosphorus was present as calcium phosphate which varied between 280 and 510 ppm. Residual phosphate came next in abundance while aluminum and iron phosphates were present in relatively small amounts.

Sodium bicarbonate extractable phosphorus was low, varying between 1.4 and 4.5ppm. Organic phosphorus was generally low and the values decreased with depth. There was also a decrease in organic phosphorus from south to north, related to a decrease in the organic carbon content. The C:P ratios of the profiles were less than 200 indicating the possibility of mineralization. Superphosphate added to the soil was mostly retained as calcium phosphate, followed by aluminum and iron phosphates. A small amount was retained as residual phosphate and none as organic phosphorus. There was very little downward movement of applied phosphate in this heavy-textured soil. Ahmed *et al.*,(2018) studied P fraction from three soil orders: Aridisols (Um Dum soil), Alfisols (Hagu soil) and Vertisols (Hosh soil). They found that the soils had low total, organic and available P contents. Most of the inorganic soil P was present in the Fe-Al fraction in Um Dum soil (> 50%), and about 40% of this fraction in Hagu soil, but, only 20% in Hosh soil. The Ca-P fraction constituted > 60% in Hosh soil, about 40% in Hagu soil and 20 % in Um Dum soil. The available P in the top soils studied was positively related to the percent sum of Al+Fe -P of the total P, and was negatively related to the percent Ca-P fraction content of the total P. It has been proposed that the P sorption starts by exchange with singly coordinate Fe or Al- OH clay (OH^- edge group and quickly reorganizes into more stable and less soluble ring forms especially at pH more than 7.0. Alkaline pH more than 8.0 in soil like Hosh, will in the presence of Ca, favors with time, the formation of inactive less soluble form like octacalcium phosphates and apatites at the expense of the initial Al and Fe-P forms which are less stable at alkaline pH. The high temperature may make raise the P status of these soils to satisfactory levels hard to realize. Thus, it is important to study the effects of temperature on P sorption in these arid-zone soils.

Therefore, EI-Mahi, *et al.* (2001) studied the effects of temperature on P sorption and desorption onto two soil series namely: Hagu and Hosh series. During the equilibration times used, the results indicated that at low P application, sorption increased and desorption decreased with increase in temperature from 20 to 40°C. However, at high P application, sorption decreased and desorption increased with the same increase in temperature. At high P application two discrete pools of sorbed P seem to be present, a fast desorbable pool and a slow desorbable one, with desorption of the first being more sensitive to increase in temperature.

Sudanese researchers are looking for the reason behind low available P especially in salt affected soils. In this context, Elmahi and Mustafa (1980) on two montmorillonitic soils, El-hag Abdalla (Vertisols) and EL-Damer (Aridsols) their results showed that P retention increased with increase in concentration of C or decreased in (SAR). This effect should be considered when appraising phosphorus fertilizer application to salt affected soils.

Phosphorus adsorption isotherms and buffering capacity are powerful tools for predicting the response of different soil types to applied P fertilizers. To know the potentiality of Sudan soil to sorb P Amel and Sirelkhatim (2012) conducted a laboratory experiment onto selected soil series from different sites in Sudan. Their results indicated that at any specific P concentration, the amount of P sorbed by Entisols was higher than that of other soils. The order of soils sorption according to their adsorption capacities using Freundlich equation were 917, 330, 315, 269, 214 and 80 mg P kg-1 soil for River Nile banks (Entisols), Dongola 2 (Aridisols), Permanent Fallow (Virgin Vertisols), Remitab (Cultivated *Vertisols*),Khashmelgirba (Vertisols) and Dongola1 (Aridisols), respectively. The soil's ability to sorb the added P increases due to the increase in the affinity sites of clay and iron content Amel and Sirelkhatim (2012).

POTASSIUM CHEMISTRY

Potassium research on Sudan soil generally is meager, due to a long-standing perception among agriculturist in a different specialized discipline that Sudanese soils are rich in K and the response of crops is limited. This perception have led scientists to think that K fertilization in these soils is negligible (El khider, 2003). Vageler and Alten (1932) thought that this lack of response by cotton crop to K application may be due to the high fixation of K element. Similar results were reported by Finck (1962) on Gezira soil and, in Hashabasoil (White Nile State). He also found that the exchangeable K is high and K in the plant is above the deficiency range hence, and he concluded that the cotton crops are well provided with K. Sudan soil survey reports showed marked variability of soluble and exchange K in various soil series studied such as Wad Hadad, Wadelataya, Gamoyah, Suilmi, where they found that the amount of K was about 1.0 Cmol+/kg soil, and in Remitab and Dinder 0.9Cmol+/kg soil (Idris 1998; Farah,1979), Gadambalia, Tozi series were 0.2 Cmol+/kg, Shaheet is 0.3 Cmol+/kg. (Hunting, 1966), Alfisols Hago series 0.4 Cmol+/kg and in Entisols, Nasedeen series 0.4 Cmol+/kg (Adam 1976, Idris 1990). The content of exchangeable K is low in the soil of the central clay plain and does not exceed 2.0 Cmol+/kg of soil (Buursink, 1971).Moreover, serious researches on K chemistry have not been attempted, except Finck (1962) and Fadl (2009) since K application seemed to give no significant effects on plant growth in trials conducted by different researchers in some few locations in central Sudan. Fadl (2009) studied the chemical potential of exchangeable and fixed K in some Sudan soils, namely, El Goz and Gardud soils (North Kordofan state),Tozi soil (Blue Nile state),Sarafsaid soil (Elgedarif state) Shambat soil (Khartoum state), Wadelataya and Suilmifrom soils (Gezira state) and Hagu soil (Sennar state).These soils were evaluated using a modified quantity/intensity approach, and the results showed that equilibrium concentration ratio value is lower than the recommended in literature for many soils and crops.

MICRONUTRIENTS CHEMISTRY

First research on the chemistry of micronutrient in Sudan soil was reported by Adam and Anderson (1983) who studied the effect of soil moisture on the DTPA-extractable micronutrient cation under aerobic conditions on three major soil series comprising the Gezira scheme are Hosh, Suleimi, and Laota. They found that DTPA-extractable Cu, Fe, Mn and Zn from air-dry soil samples were much higher compared to values from their incubated counterparts. For the three soils the CO_2 production (microbial activity) reached the maximum in 5 weeks and then leveled off while the lowest values of micronutrient cation from the incubated soils were obtained between 2 to 8 weeks. They suggested that the hot dry months preceding crop growth should increase clay surface acidity and hence availability of micronutrients cations. Elamin, *et al.*,(2000 a)studied copper (Cu) retention in three major series in Gezira soils namely: Vertisols (Hosh and Suleimi series) and Aridisols (Laota series). Their results reveal that Cu retention decreased as salt concentration (C) increased, with maximum adsorption occurring at low C having high pH and high negative charge. Sodium adsorption ratio (SAR) had little effect on Cu adsorption as precipitation prevailed at high pH. It was found that the adsorption capacity of the three soils was similar, despite the variation in $CaCO_3$ and clay contents, and hence the cation exchange capacity. Copper was more soluble in the saline phases of the Gezira soils, whereas sodicity had little effect.

Adsorption of boron (B)on the three major soil series of the Gezira, Hosh, Suleimi and Loata was studied by Hussein (1988) and EI-Mahi, *et al.*(1999). Boron adsorption in the three soil samples was found to decrease with increase of C and decrease in pH below 8 at which the prevailing ionic form of B is B $(OH)_3$ which is weakly adsorbed whereas the concentration of $B(OH)_4^-$, is strongly adsorbed, is low. As the C increased the ionic strength increased, therefore B activity decreased. Decrease of B activity is believed to decrease B adsorption. Due to flocculation at high C, the extent of active sites of sesquioxides, clays and allophane on which B is adsorbed is reduced. Therefore, B adsorption will be reduced. The pH also decreased below 8 as C increased. Therefore, maximum adsorption was obtained in low electrolyte concentrations where the pH is above 8. The SAR was found to have a highly significant effect on B adsorption on the three soils at 1 µg B/ml. B adsorption in 3 mmol+/L increased as SAR increased from 0 to 5 and decreased above that where the pH become >9. Variations in B adsorption were attributed to the pH effect. The effect of SAR on B adsorption at high C will be masked by reduction of pH by high electrolyte concentration. The effects of C and SAR on Zincsorption was studied in three arid-zone smectitic sites in the Gezira Scheme (Sudan). The orders of these soils are Vertisols (El-Hosh and El-Suleimi) and Aridisols (El-Laota). Zinc retention decreased as C concentration increased, where maximum sorption occurred at low electrolyte concentration in soils having high pH and high negative charge. Sodium adsorption ratio had little effect on Zn sorption as precipitation prevailed at high pH. It was also found that the sorption capacity of the three soils were similar despite the variation in $CaCO_3$ and clay contents, hence CEC and surface area. The results indicated that Zn was more soluble in the saline phases of Gezira soils, whereas sodicity had little effect(Hussein, 2001).Similar pattern was reported by Elamin *et al.* (2000b) who studied the salinity and sodicity effects on manganese (Mn) sorption on three soil sites in Gezira scheme namely, Vertisols (El-Hosh and El-Suleimi) and Aridisols (El-Laota).Their results indicated that saline soils sorbed less Mn and had higher equilibrium Mn concentrations. Sodic soils retained more Mn but had low equilibrium concentrations. Sodicity had a pronounced effect only on increasing Mn retention at higher SAR values. Salinity tended to alleviate sodicity effects on Mn retention, but soluble salts that increased soil pH decreased Mn concentration.

CALCAREOUS SOIL

In Sudan appreciable amounts of calcium carbonate has been reported (Green,1928; Ismail,1991; Ibrahim, 2008). So, experiments concerning calcium carbonate in Sudan soil has been studied by many researchers. For instance, El Mahi, *et al.* (1987) conducted a simple titrimetric method for estimation of Ca and Mg carbonates in soils. It involves the determination of acid soluble Ca and Mg of the carbonate phase after the removal of soluble and exchangeable cations by ammonium acetate. The results obtained by the proposed method were compared with those obtained by acid neutralization, calcimeter, and titrimetric methods. The proposed method has the advantage of estimating Ca and Mg carbonates. The proposed method requires no special equipment and is less time-consuming if it follows the routine determination of exchangeable cations or the cation exchange capacity. Elfaki *et al*,(2016) assess and compare between calcimetric and titrimetric of different soils in central of Sudan. They found that there are no significant differences between calcimeter and titration methods for calcium carbonate estimation in mostsoil types in Sudan. Additionally, time would be saved; fewer amounts of chemicals would be used. They recommended using calcimeter method for $CaCO_3$ estimation for soils of Sudan.

CONCLUSION

Soil chemistry research in Sudan soil is very little and needs more attention and investigation. This is because the number of scientists who are working in soil chemistry throughout the country is low and if they are available, they conducted their research on soil fertility other than soil chemistry. In addition, soil chemistry research faces a lot of limitations such as; physical and human capacity building, old and defected laboratory equipments, lack of proper training to the research and technical staff due to the lack of training opportunities abroad and poor research budget, moreover, studies on environmental soil chemistry in Sudan is very little. The researchers in soil chemistry in Sudan must cooperate and be exposed to colleagues worldwide by their contribution to solving the global challenges facing the environment today such as; greenhouse gas emissions, climate change, soil contamination water quantity and quality, and food security. Future research should be aimed at securing the food for the people withfocusing on environmental quality by using recent advances in methods and technologies.

Soil chemistry problems in Sudan need special workshops or symposia to discuss the trends in graduate education and training, interdisciplinary research and funding opportunities in environmental soil chemistry, and cooperation aspects of soil chemists with colleagues in other related sciences.

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تطورات البحث في كيمياء التربة في السودان

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مستخلص البحث: التربة عبارة عن خليط من المواد العضوية وغير العضوية الصلبة والماء والهواء. ترتكز كيمياء التربة على دراسة التفاعلات الكيميائية والعمليات بين هذه المكونات خاصة دراسة مصير ملوثات العناصر الغذائية داخل التربة. هذا الاستعراض هو محاولة لتلخيص البحوث المنشورة سابقًا في كيمياء التربة في السودان. الاستعراض هو أيضا اقتراح للتركيز إلى الجانب الأكثر أهمية للموضوع فيما يتعلق بإنتاجية القطاع الزراعي. لذلك ، ركزت هذه الدراسات في المقام الأول على التفاعلات بين المغذيات النباتية والتربة. لاحظ العلماء الرواد أن النيتروجين في تربة الجزيرة منخفض جدًا ، نظرًا لانخفاض المادة العضوية، وبالتالي، فقد اعتبر النيتروجين العامل الرئيسي الذي يحد من انتاج المحاصيل. منذ ذلك الحين ، أجريت تجارب لدراسة ادمصاص اليوريا والأمونيا في تربة الجزيرة. أجريت القليل من الأبحاث حول ادمصاص الفسفور والبوتاسيوم في تربة السودان. تنتشر التربة المتأثرة بالأملاح على نطاق واسع في مختلف ولايات البلاد ، مثل الشمال ونهر النيل والخرطوم والجزيرة والنيل الأبيض، وبالتالي، فإن العديد من الباحثين قاموا بدراسة تجارب الادمصاص للعناصر الغذائية الكبرىوالصغرى في التربة المتأثرةبالأملاح. على الرغم كمية وتقدم الابحاث الذي تم إحرازه في أبحاث كيمياء التربة في السودان، فقد حان الوقت للتعرف على الاتجاهات المستقبلية للبحوث المبتكرة في كيمياء التربة في السودان، وبالتالي، ينبغي أن تركز بحوثنا في المستقبل على إطعام شعبنا بالسعي من أجل تحسين نوعية الحياة والحفاظ على بلدنا خاليًا من أي نوع من المخاطر البيئية باستخدام التطورات الحديثة في الأساليب والتقنيات.

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