Journal of Scientific Agriculture 2026, 10: 66-73
https://doi.org/10.25081/jsa.2026.v10.9715

Research Article

Evaluation of soil health characteristics suitable for yam cultivation in Zaki-Biam, Benue State, Nigeria

Malum J. Flayin*, Adugba Joshua

Department of Agricultural and Biosystems Engineering, Joseph Sarwuan Tarka University, Makurdi, Nigeria

(Received: September 13, 2025; Revised: May 20, 2026; Accepted: June 05, 2026; Published: July 10, 2026)

*Corresponding author: Malum J. Flayin, E-mail: jf.malum@uam.edu.ng

Abstract

Soil salinity and sodicity are basic processes that characterize the suitability of soil conditions for plant growth. The soil conditions can be attributed to natural conditions such as climate, lithology, topography and pedology or anthropogenic activities such as mining, release of industrial waste, smelting of iron, incineration of fossil fuels and agricultural land use particularly irrigation agriculture. The presence of salts and sodium in high proportions in the root zone of growing crops hinders plant roots from withdrawing water from surrounding soils because it lowers the amount of water available to the plant, regardless of the amount of water present in the root zone. The objective of this study was to assess the soil health characteristics in the Zaki-Biam Area of Benue State, known for extensive yam farming. Five cultivated Yam farms (A-E) were selected at the Mbamena axis in Zaki-Biam. Soil samples were collected at a depth of 0 to 15 cm during the rainy season for three months (July-September). The physical proper ties of soil such as texture, bulk density, porosity, moisture content, organic matter or content and soil colour were analyzed. Chemical properties of soil, pH, Nitrogen, Phosphorus, Potassium, Sodium, Magnesium, Calcium, Cation exchange capacity (CEC), Exchangeable acidity (EA), Exchangeable base (EB), and electrical conductivity were also analyzed. The study revealed that sites A, D and E were sandy loam, while site B and C were clay loam. Physical characteristics of porosity, moisture content, and organic carbon were abundant in sites A, D and E than in site B and C. Chemical characteristics of pH, Nitrogen, potassium and percentage base saturation were moderate for sites and E. These soils class fall under 'very good' for the effective growth and yield of yams. Soil salinity concentrations were found to have ranged between 2.00 dS/m to 3.50 ds/m, a range rated as good for effective growth of yams. Sodium adsorption ratio (SAR) ranged between 8.00 to 12.99, which is suitable for the growth of tuber crops. Both soil salinity and SAR in Zaki-Biam soils are favourable for yam cultivation. It is recommended that farmers identify the early symptoms of salt-affected soils so as to make appropriate treatment to land and water (in case of irrigation) as well as knowing the crops to grow during rainy and irrigation seasons.

Keywords: Soil Health, Yam, Salinity, Cultivation, Characteristics, Benue State

Introduction

Soil is a non-renewable resource; once lost, it cannot be recovered in a human lifespan. Salinity and sodicity are the major causes of land degradation after soil erosion and have been a cause of decline in agricultural land productivity. Salinization can cause yield decreases of 10 to 25% for many crops and may prevent cropping altogether when it is severe leading to desertification (Awale *et al.,* 2017; Kihara *et al.,* 2020). Salinity in soils is categorized into cations and anions. The major cations are sodium, calcium, magnesium and potassium. The major anions are chlorides, sulphates and carbonates (Pros *et al.,* 2022). Cultivating in a land that has excess amounts of sodium can adversely impact soil structure, making some crops growth difficult. Highly saline and sodic soils can cause impediments in irrigation, depending on the type and amount of salts present, the specific plant species and growth stage, and the amount of water able to pass through the root zone (Sheferia *et al.,* 2021).

Excess salt and sodium in the root zone of growing crops hinder plant roots from withdrawing water from surrounding soil as it lowers the amount of water available to the plant, regardless of the amount of water actually in the root zone, and that leads to stunted and slow growth of crops, spotty stands of crops, no matter the amount of soil moisture. If the salinity concentration is high, some plants may wilt and die, no matter how much water the plants absorb (Demo *et al.,* 2025). High salinity and sodicity cause both hypertonic and hyperosmotic stress and can lead to the death of yam plants (Hasegawa *et al.,* 2000).

Among the cash crops, yam have become more popular and its consumption has sharply increased with well-being (Chang *et al.,* 2010).The yam is a perennial vine plant with tubers that are edible, medicinal, and used as health foods (Wanasundera & Ravindran, 2014). Yams received considerable attention among the medicinal plants (Renuka & Nishtha, 2022; Tareen *et al.,* 2025).

Yam (*Dioscorea* spp) belongs to the *Dioscoreaceae* family and are a staple food and major source of calories for about one-third of the world's population (IITA, 2008, 2020). The production is high in Africa and Nigeria alone accounts for 70% of world production (Thompson & Oduro, 2021; Dokua, 2025). People consume yams, sweet in flavour, as a cooked vegetable. In West Africa, it is often pounded into a thick paste after boiling (referred to as pounded yam) and is eaten with soup. Yams are also processed into flour, which is used in the preparation of another edible paste called Amala. Unlike cassava (*Manihot esculenta* Crantz), sweet potato (*Ipomoea batatas* L.) and aroids (*Colocasia esculenta* and *Xanthosoma sagittifolium*), yam tubers can be stored for periods of up to 4 or even 6 months at ambient temperatures. This characteristic helps sustain the food supply, especially during the difficult (food scarce) period at the onset of the wet season (Agbede & Adekiya, 2011).

The basic challenges farmers in Nigeria are facing are the problem of salinity and sodicity of soils as causes of land degradation. Sensitive crops (yam) lose their vigour when even slightly saline soils are above the recommended concentrations (Mau & Porporato, 2015).

Measuring salinity and sodium content in the soil can provide information on how saline and sodic the soil is, whether the salinity and sodicity are increasing or not (Shahid *et al.,* 2018). The knowledge will help in determining the soil amendment to be done and the suitable crops to be planted in such land condition. Thus the objective of the study is to assess the soil health physico-chemical characteristics of soils as it affects soils around yam farms in Zaki-Biam Area, Benue State, Nigeria.

Materials and Methods

Study area

The study Area was Zaki-Biam town in Benue state, Nigeria. Its geographical coordinates are 7°30'24" North, 9°36'37" East. The Area extent is about 1,408 km^2 with a population of 181,474 as at the 2006 census. The people's major farm activities are Yam cultivation.

Geology of the area

The area is situated in the Middle Benue Trough of Nigeria and predomi nantly composed of crystalline basement complex rocks, comprising of quartzite, siliferous rocks, and older granites. The Area is within the elevation above sea level of 190.2 meters. Zaki Biam is covered by cropland (48%), shrubs (26%), grassland (14%), and trees (12%) (Sule *et al.,* 2020).

Climate

Zaki-Biam lies within the humid zone with little seasonal temperature variation throughout the year (NMI, 2021). Two major seasons exist; rainy season between April and October and the dry season between November and March. Temperatures typically vary from 16.7 °C to 32.8 °C and is rarely below 13.3 °C or above 35.6 °C. Relative humidity ranges from about 34% in February to 71% in November/December (NMI, 2021).

Study site and soil sampling

The study was carried out in 5 selected yam farms in Mbemena axis of Zaki-Biam town, Benue state. Soil samples were collected from five different cultivated sites at 0 to 15 cm depth (rooting depth), and the pH was measured *in situ* (Figure 1). Auger and core soil samples were labelled and taken to the laboratory for analysis. Samples were taken once a month for a period of 3 months (July, August and September).

Laboratory analysis

Physical and chemical properties were determined using standard laboratory methods according to Soil Science Division Staff (2017). Soil physical properties determined are, soil texture, bulk density, total porosity, moisture content, organic content and matter, and soil aggregate stability; while chemical properties are soil pH, Nitrogen, Phosphorus, Potassium, Sodium, Magnesium, Calcium, Cation exchange capacity (CEC), Exchangeable acidity (EA), Exchangeable base (EB).

Results and discussions

Results

The analyzed results were tabulated as grain size of the soil particles with respect to textural class, percentage composition of sand, clay and silt (Table 1). Soil physical properties for the 3 months are as shown in Table 2. Chemical properties are shown in Tables 3 and 4.

Discussions

Soil physical properties as affected by salinity and sodicity

Physical properties of soil play an important role in determining soil's most suitable for agricultural, environmental and engineering uses. These are in the areas of retention, movement and availability of water and nutrients to plants; ease of penetration of roots of crops and flow of heat and air are directly associated with physical properties of the soil. The texture of the soil for site A, D and E was sandy loam while that of sites B and C was clay loam. Site A has a mean soil fraction of 74.60% sand, 14.80% clay, 10.80% silt; Site B; 44.45% sand, 45.49% clay, 9.96% silt; Site C; 42.80% sand, 45.60% clay, 11.60% silt; Site D had 70.44% sand, 17.45% clay, 13.11% silt, and Site E; 73.51% sand, 16.05% clay, 10.43% silt. Thus, soils at sites B and C had low infiltration and percolation rate while soils at sites A, D and E had high infiltration and percolation rates which are necessary for the effective growth of yam. Salinity and sodicity of a soil affects the textural class of soil as with high proportion of sand at the top layer of a soil, percolation and infiltration is high whereas soil with higher percentage of clay has little or no infiltration and percolation rate as stated by Diby *et al.* (2011), that tropical food species of *Dioscorea* grows more favourably in a deep, loose, textured loamy soil with good drainage. The similarities in textural class occurred between soil sites A, D and E as with soil sites B and C (Figure 2).

Moisture content mean values for the five sample sites were 20.14%, 13. 86%, 14.12%, 20.29% and 19.87% for sites A, B, C, D and E respectively. This implies soils of sites B and C have low moisture content for the effective growth of yam, compared with the recommended values (Table 5).

The result for bulk density (g/cm^3); showed the mean value, standard deviation and coefficient of variance for soils at site A was 1.32, 0.01 and 0.78 respectively, site B;

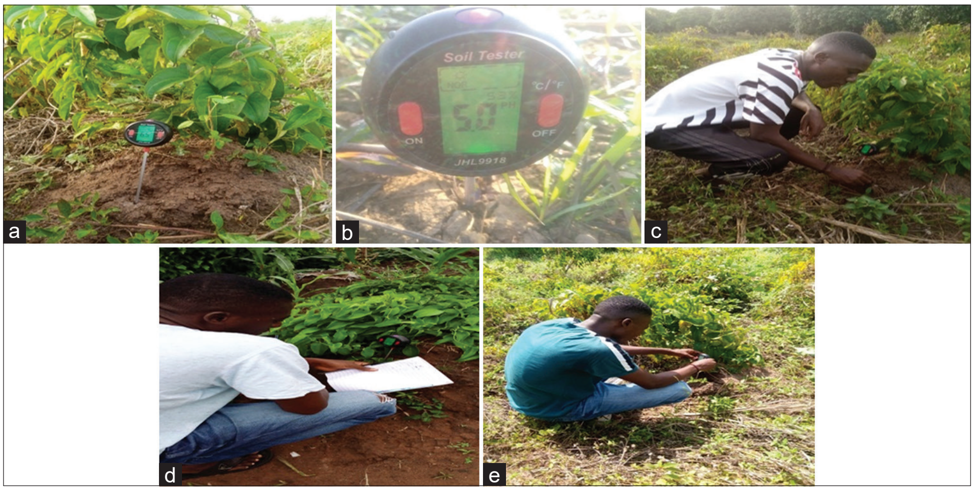

Figure 1: (a-e) pH testing at the five cultivated sites

Table 1: Grain size analysis of soil particles of the study areas

Site	Month	% Sand	% Clay	% Silt	Textural class
A	July	74.80	14.74	10.46	
	August	74.60	14.55	10.85	Sandy
	September	74.40	14.50	11.10	loam
	Mean	**74.60**	**14.80**	**10.80**	
	S.D	**0.18**	**0.18**	**0.28**	
	C.V	**0.27**	**1.29**	**2.57**	
B	July	44.46	45.64	9.90	
	August	44.48	45.60	9.92	Clay
	September	44.40	45.55	10.05	loam
	Mean	**44.45**	**45.59**	**9.96**	
	S.D	**0.01**	**0.02**	**0.09**	
	C.V	**0.02**	**0.07**	**0.68**	
C	July	42.55	45.80	11.65	
	August	43.40	45.60	11.00	Clay
	September	42.45	45.40	12.15	loam
	Mean	**42.80**	**45.60**	**11.60**	
	S.D	**0.43**	**0.10**	**0.48**	
	C.V	**0.38**	**0.97**	**4.13**	
D	July	69.80	17.20	13.00	
	August	70.20	17.82	13.98	Sandy
	September	71.32	17.33	12.35	loam
	Mean	**70.44**	**17.45**	**13.11**	
	S.D	**0.67**	**0.74**	**0.61**	
	C.V	**0.95**	**4.24**	**4.65**	
E	July	74.08	16.02	9.90	Sandy
	August	72.45	16.07	11.48	loam
	September	74.01	16.08	9.91	
	Mean	**73.51**	**16.05**	**10.43**	
	S.D	**0.77**	**0.09**	**0.77**	
	C.V	**1.08**	**0.19**	**4.17**	

S.D=Standard deviation, C.V=Coefficient of variance, Mean=Average values of July, August & September

Table 2: Physical properties of soils from the study sites

Site	Month	M.C %	B.D (g/cm^3)	Porosity %	O.C %	O.M %
A	July	20.18	1.30	50.57	0.78	1.35
	August	20.01	1.33	50.63	0.79	1.37
	September	20.22	1.31	50.71	0.80	1.38
	Mean	**20.14**	**1.32**	**50.64**	**0.79**	**1.36**
	S.D	**0.09**	**0.01**	**1.03**	**0.01**	**0.01**
	C.V	**0.42**	**0.78**	**2.01**	**1.20**	**1.02**
B	July	14.10	2.00	33.26	0.30	0.52
	August	13.20	2.02	33.01	0.31	0.54
	September	14.30	2.01	33.77	0.33	0.57
	Mean	**13.86**	**2.01**	**33.34**	**0.31**	**0.54**
	S.D	**0.48**	**0.01**	**0.31**	**0.02**	**0.02**
	C.V	**3.68**	**0.49**	**0.90**	**3.20**	**3.70**
C	July	14.23	2.03	33.25	0.31	0.54
	August	14.13	2.02	33.40	0.33	0.57
	September	14.00	2.04	33.65	0.32	0.55
	Mean	**14.12**	**2.03**	**33.43**	**0.32**	**0.55**
	S.D	**0.07**	**0.01**	**0.12**	**0.01**	**0.01**
	C.V	**0.47**	**0.49**	**0.34**	**2.50**	**2.37**
D	July	20.09	1.36	49.55	0.70	1.36
	August	20.30	1.34	49.68	0.67	1.34
	September	20.48	1.33	49.81	0.69	1.37
	Mean	**20.29**	**1.34**	**49.68**	**0.69**	**1.36**
	S.D	**0.15**	**0.01**	**1.11**	**0.01**	**0.02**
	C.V	**0.72**	**0.90**	**2.21**	**1.87**	**1.47**
E	July	19.78	1.33	49.48	0.71	1.37
	August	19.87	1.35	49.67	0.67	1.39
	September	19.96	1.36	49.81	0.68	1.38
	Mean	**19.87**	**1.38**	**49.65**	**0.68**	**1.38**
	S.D	**0.07**	**0.01**	**1.17**	**0.02**	**0.01**
	C.V	**0.35**	**0.70**	**0.24**	**2.65**	**2.11**
	E.S.M	**19.00**	**1.41**	**47.28**	**0.56**	**0.72**

M.C=Moisture content, B.D=Bulk density, O.C=Organic carbon, O.M=Organic matter, S.D=Standard deviation, C.V=Coefficient of variance, Mean=Average values of July, August & September

2.01, 0.01 and 0.49, site C; 2.03, 0.01 and 0.49, site D; 1.34, 0.01 and 0.90, and site E; 1.38, 0.01 and 0.70 respectively. This clearly shows that bulk density is moderate in soil sites A, D and E but high in B and C for effective growth of yam (Table 5). Sites B and C equally have low porosity and soil compaction and therefore impact the available water capacity, root growth and movement of air and water through soil. Bulk density increases with an increase in salt levels, whereas particle density and porosity decrease with an increase in salt levels. Any factor that influences soil pore space will affect bulk density. Changes in bulk density affect available water and air capacity and strongly influence permeability, drainage rate, traffic ability and penetration by the plant (yam) roots. An increase in bulk density in site B and C may be due to soil compaction (textural class).

Therefore, the effect of soil bulk density on yam performance was more prominent in sites B and C. An

Table 3: Some nutrient concentrations of soil from the study site

Site	Month	N %	P Mg L^{-1}	K (Cmol kg^{-1})	Na (Cmol kg^{-1})	Mg (Cmol kg^{-1})	Ca (Cmol kg^{-1})
A	July	0.08	2.10	1.93	0.22	2.70	2.98
	August	0.07	2.08	1.92	0.25	2.86	2.96
	September	0.06	2.09	1.91	0.24	2.88	2.98
	Mean	**0.07**	**2.09**	**1.92**	**0.24**	**2.81**	**2.97**
	S.D	**0.01**	**0.02**	**0.07**	**0.02**	**0.01**	**0.02**
	C.V	**11.7**	**0.96**	**3.64**	**8.33**	**2.81**	**0.67**
B	July	0.02	4.10	0.91	0.20	2.58	2.90
	August	0.04	4.08	0.89	0.22	2.60	2.89
	September	0.03	4.09	0.87	0.22	2.59	2.86
	Mean	**0.03**	**4.06**	**0.89**	**0.21**	**2.59**	**2.88**
	S.D	**0.01**	**0.01**	**0.02**	**0.01**	**0.01**	**0.03**
	C.V	**33.33**	**0.25**	**2.24**	**4.76**	**0.38**	**1.04**
C	July	0.03	4.08	0.90	0.23	2.60	2.91
	August	0.02	4.07	0.92	0.23	2.54	2.86
	September	0.03	4.05	0.89	0.24	2.62	2.88
	Mean	**0.02**	**4.07**	**0.90**	**0.23**	**2.58**	**2.88**
	S.D	**0.01**	**0.01**	**0.02**	**0.01**	**0.03**	**0.02**
	C.V	**25.00**	**0.25**	**2.28**	**4.34**	**1.16**	**0.69**
D	July	0.08	2.08	1.78	0.25	2.86	2.96
	August	0.07	2.07	1.89	0.23	2.70	2.98
	September	0.06	2.05	1.88	0.23	2.87	2.97
	Mean	**0.06**	**2.07**	**1.85**	**0.26**	**2.81**	**2.97**
	S.D	**0.01**	**0.02**	**0.08**	**0.02**	**0.05**	**0.01**
	C.V	**16.86**	**0.97**	**4.38**	**7.69**	**1.77**	**0.33**
E	July	0.07	2.06	1.86	0.21	2.87	2.95
	August	0.07	2.03	1.90	0.22	2.87	2.97
	September	0.05	2.01	1.79	0.23	2.86	2.99
	Mean	**0.06**	**2.03**	**1.85**	**0.27**	**2.87**	**2.97**
	S.D	**0.01**	**0.01**	**0.07**	**0.01**	**0.01**	**0.02**
	C.V	**16.86**	**0.49**	**2.47**	**3.70**	**0.35**	**0.67**
	E.S.M	**0.05**	**3.24**	**1.48**	**0.24**	**2.73**	**2.93**

N=Nitrogen, P=Phosphorus, K=Potassium, Na=Sodium, Mg=Magnesium, Ca=Calcium; S.D=Standard deviation, C.V=Coefficient of variance, E.S.M=Entire site mean, Mean=Average values of July, August & September

Table 4: Salinity concentration of soil from the study site

Site	Month	EC (dS/m)	pH	TEB (Cmol kg^{-1})	EA (Cmol kg^{-1})	CEC (Cmol kg^{-1})	%BS
A	July	2.81	6.50	4.19	0.10	4.29	97.66
	August	2.72	6.48	4.18	0.09	4.27	97.89
	September	2.80	6.46	4.17	0.07	4.24	98.35
	Mean	**2.77**	**6.48**	**4.18**	**0.09**	**4.27**	**97.96**
	S.D	**0.07**	**0.07**	**0.01**	**0.01**	**0.07**	**0.21**
	C.V	**2.53**	**1.01**	**0.22**	**11.11**	**0.33**	**0.27**
B	July	3.87	5.00	3.22	1.89	5.11	63.01
	August	3.92	5.15	3.20	1.87	5.07	63.12
	September	3.88	5.16	3.18	1.82	5.00	63.60
	Mean	**3.89**	**5.14**	**3.20**	**1.86**	**5.06**	**63.24**
	S.D	**0.04**	**0.02**	**0.02**	**0.01**	**0.02**	**0.25**
	C.V	**1.03**	**0.39**	**0.63**	**0.92**	**0.49**	**0.71**
C	July	4.01	5.14	3.34	1.81	5.15	64.85
	August	4.00	5.20	3.36	1.80	5.16	65.12
	September	4.03	5.19	3.33	1.83	5.16	64.53
	Mean	**4.01**	**5.18**	**3.34**	**1.81**	**5.16**	**64.83**
	S.D	**0.01**	**0.03**	**0.01**	**0.01**	**0.01**	**0.27**
	C.V	**0.34**	**0.51**	**0.28**	**0.97**	**0.24**	**0.37**
D	July	2.58	6.55	4.02	0.08	4.10	98.04
	August	2.62	6.50	4.13	0.07	4.20	98.33
	September	2.61	6.52	4.12	0.05	4.17	98.80
	Mean	**2.61**	**6.52**	**4.09**	**0.07**	**4.16**	**98.39**
	S.D	**0.01**	**0.07**	**0.08**	**0.01**	**0.07**	**0.31**
	C.V	**0.38**	**1.07**	**1.75**	**14.29**	**1.36**	**0.12**
E	July	2.79	6.34	4.08	0.09	4.20	97.14
	August	2.68	6.41	4.15	0.10	4.25	97.64
	September	2.73	4.04	4.04	0.08	4.12	96.42
	Mean	**2.71**	**6.37**	**4.10**	**0.09**	**4.19**	**97.06**
	S.D	**0.05**	**0.06**	**0.07**	**0.01**	**0.07**	**0.38**
	C.V	**0.80**	**0.88**	**1.70**	**11.11**	**1.38**	**0.31**
	E.S.M	**3.20**	**5.94**	**3.78**	**0.78**	**4.57**	**84.41**

EC=Electrical conductivity, TEB=Total exchangeable base, EA=Exchangeable acid, CEC=Cation exchange capacity, BS=Base saturation, Mean=Average values of July, August & September

increase in soil bulk density is known to reduce root elongation at low water contents Graveel *et al.* (2002).

Mean porosity of soil at site A was 50.64%, site B, 33.34%, site C, 33.43%, 0.12 and 0.34, site D 49.68%, and site E 49.65%. Soil of sites A, D and E are the most porous, this is probably due to the class of the soil which is sandy loam and the degree of scaling surfaces. Soils with moisture content within the range of 35-50% are porous and therefore suitable for the growth of yam (Table 5).

The mean values of soil organic carbon at site A was 0.79%, site B, 0.31%, C, 0.32%, D, 0.69%, and E 1.19%. Soils at sites B and C had lower values, therefore yam cultivated in sites A, D and E will yield more.

Percentage organic matter at soil site A was 1.36%, B, 0.54%, C, 0.55%, D, 1.36%, and E 1.38%. This shows soil organic matter is high in soils of sites A, D and E but low in soils at sites B and C (Table 5).

Soil chemical properties as affected by salinity and sodicity

Chemical properties of soil also play an important role in determining the soil most suitable for agricultural uses

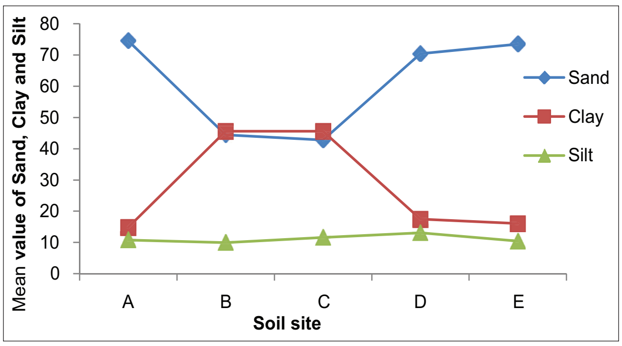

Figure 2: Grain size analysis of soil particles of the study area

in the course of movement and availability of water and nutrients to plants.

The mean result of soil Nitrogen (N) at sites A was 0.07%, B, 0.03%, C, 0.04%, D 0.06%, and E 0.06%. Nitrogen is a component of chlorophyll molecules which enables yam leaves to absorb sunlight energy by photosynthesis, for yam growth and yield. Sites B and C soils had low nitrogen; hence yam grown in the sites might have insufficient nitrogen to enhance better growth and yield. Meng *et al.* (2025), stated that saline and sodic soils are usually low in nitrogen which is an essential nutrient that improves the photosynthetic efficiency of yam and improves it yield.

The result of soil Phosphorus (P) at site A was 2.09 mg L^{-1}, B, 4.09 mg L^{-1}, C, 4.07 mg L^{-1}, D 2.07 mg L^{-1}, and E 2.03 mg L^{-1}. Soil in site B and C has higher phosphorus for better growth and yield of yams, whereas soil of sites A, D and E was moderate for yam growth and yield (Table 6 & Figure 3). According to Freeman and Coe (2010), the salinity of a soil causes excess phosphorus to reduce the ability of plants to take up required micronutrients, particularly iron and zinc. The build-up of phosphorus in lawns, pastures and croplands causes plants to grow poorly and even die.

Potassium (K) in soils at site A was 1.92 Cmol kg^{-1}, B, 0.89 Cmol kg^{-1}, C, 0.90 Cmol kg^{-1}, D, 1.85 Cmol kg^{-1}, and E was 1.85 Cmol kg^{-1}.

Mean concentration values of sodium (Na) for all sites (A, B, C, D and E) were 0.24 Cmol kg^{-1}, 0.21 Cmol kg^{-1}, 0.23 Cmol kg^{-1}, 0.26 Cmol kg^{-1}, and 0.27 Cmol kg^{-1} respectively. High salinity and sodicity in soils inhibit high sodium in soils, thus all the sites were affected, and hence sodium efficiency falls within 'moderate' class rating (Table 7).

Table 5: Mean concentrations of physical properties of soil from the study site compare with standard rating for effective growth of yam

Properties	Range*	Class* Rating	A	B	C	D	E
M.C (%)	< 15	Low		13.86	14.12		
	>15-30	Moderate	20.14			20.29	19.87
	> 30	High					
B.D g/cm³	< 1.30	Low					
	1.30-2.00	Moderate	1.32			1.34	1.38
	> 2.00	High		2.01	2.03		
Porosity(%)	< 45	Low		33.34	33.43		
	45-50	Moderate				49.68	49.65
	> 50	High	50.64				
O.C (%)	< 0.40	Low		0.31	0.32		
	0.40-1.40	Moderate	0.79			0.69	0.68
	> 1.40	High					
O.M (%)	< 1.35	Low		0.54	0.55		
	1.35-2.00	Moderate	1.36			1.36	1.38
	> 2.00	High					

M.C=Moisture content; B.D=Bulk density; O.C=Organic carbon; O.M=Organic matter. (Howeler, 1996; Dev, 1997; Hazelton & Murphy, 2007; Diby *et al.,* 2011)

Table 6: Mean macronutrient concentration from the study site compared with standard rating for effective growth of yam

Properties	Range*	Class* Rating	A	B	C	D	E
N (%)	<0.05	Low		0.03	0.04		
	0.05-0.06	Moderate				0.06	0.06
	>0.06	High	0.07				
P (mg/L)	<2.00	Low					
	2.00-4.00	Moderate	2.09			2.07	2.03
	>4.00	High		4.06	4.07		
K (Cmol/kg)	<1.0	Low		0.89	0.90		
	1.0-2.00	Moderate	1.92			1.85	1.85
	> 2.00	High					

N=Nitrogen; P=Phosphorus; K=Potassium. (Freeman & Coe, 2010; Esu, 2005)

According to Epstein and Bloom (2005), sodic soil build-up sodium in plants which causes toxic levels that in turns causes stunted growth of the plant, because it impairs plans from their ability to take-up adequate moisture.

Mean Magnesium (Mg) concentration for all sites (A, B, C, D and E) were 2.81 Cmol kg^{-1}, 2.59 Cmol kg^{-1}, 2.58 Cmol kg^{-1}, 2.87Cmol kg^{-1}, and 2.87 Cmol kg^{-1} respectively. Mean values of calcium (Ca) for all sites were 2.97 Cmol kg^{-1}, 2.88 Cmol kg^{-1}, 2.88 Cmol kg^{-1}, 2.97 Cmol kg^{-1}, and 2.97 Cmol kg^{-1} respectively.

According to Haby *et al.* (2000), the combined effects of magnesium and calcium salts in soils contribute to soil salinity which reduces the amount of sodium-induced dispersion. All concentrations both calcium and magnesium falls under the 'moderate' class (Table 7), which are all higher than concentrations of sodium.

Electrical conductivity (EC) at all sites was A 2.77 dS/m, B, 3.89 dS/m, C, 4.01dS/m, D 2.61 dS/m, and E, 2.71 dS/m. The results shows that saline soil has higher EC in site B and C whereas soil site A, D and E has lower salinity as per standard rating (Table 7). According to Chinnusamy *et al.* (2010), the salinity threshold of tuber crops (yam) ranged between 2.5-3 dS/m (based on saturated soil extract).

The sodium adsorption ratio (SAR) was computed using the formula (Singh *et al.,* 2020).

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$

Where Na^{+}, Ca^{2+}, and Mg^{2+} values are from analyzed concentration of the soil samples.

The mean SAR values for the five sites (A-E), were found to be 11.97, 12.22, 12.11, 11.76, and 12.86 respectively. All the soil sites had moderate SAR concentration (Table 7 & Figure 4). A high level of sodium ions in soil can affect the permeability of water in soils and can lead to infiltration problems.

Ahmed *et al.* (2011) asserted that the SAR of yam (based on saturated soil extract) is between 11 and 12, while John *et al.* (2016) and Mohan *et al.* (2024), stated

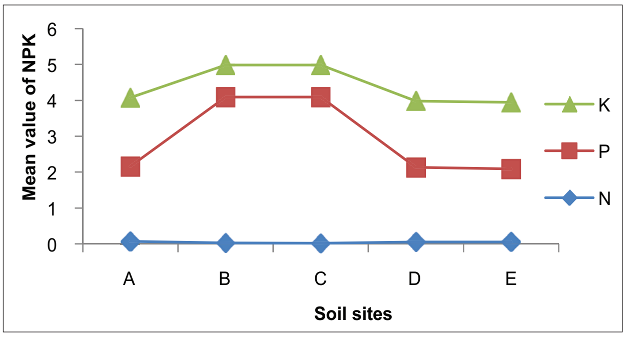

Figure 3: Soil site N, P and K (N = Nitrogen, P = Phosphorus, K = Potassium)

Table 7: Mean salinity and sodicity concentrations from the study site compared with standard rating for some chemical properties of soil for effective growth of yam

Properties	Range*	Class* Rating	Result from study Sites A	B	C	D	E
Na (Cmol/kg)	< 0.20	Low					
	0.20-0.30	Moderate	0.24	0.21	0.23	0.26	0.27
	> 0.30	High					
Mg (Cmol/kg)	< 2.00	Low					
	2.00-3.00	Moderate	2.81	2.59	2.62	2.81	2.87
	> 3.00	High					
Ca (Cmol/kg)	< 2.00	Low					
	2.00-3.00	Moderate	2.97	2.86	2.88	2.77	2.97
EC (dS/m)	< 2.00	Low					
	2.00-3.50	Moderate	2.77			2.61	2.71
	> 3.50	High		3.89	4.01		
SAR	< 5.00	Low					
	5.0-12.99	Moderate	11.97	12.22	12.11	11.76	12.86
	> 12.99	High					
%BS	< 70.00	Low		63.24	64.83		
	70.0-80.00	Moderate					
	> 80.00	High	97.96			98.39	97.06

EC=Electrical conductivity, SAR=Sodium adsorption ratio, %BS=Percentage base saturation. (Esu, 2005; Gidey, 2018; Tiri *et al.,* 2020)

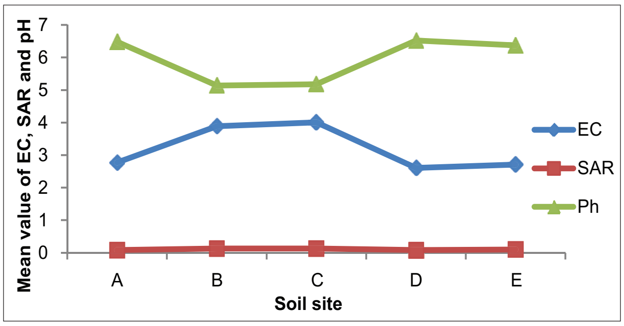

Figure 4: EC, SAR and pH concentrations in soil sites

that yams are highly efficient in the utilization of native and applied nutrients, the magnitude of response to fertilizers and salinity vary with the species.

Soil pH mean concentration for 5 sites are; A, 6.48, B, 5.14, C, 5.18, D, 6.52, and E, 6.37, respectively. The sites soils at A, D, and E are moderately acidic, whereas soils in sites B and C are more acidic. This clearly shows that all the site soils are basically acidic (Figure 3). Soil pH influences the equilibrium state of oxidation reaction and the solubility of several constituents and the ionic form of several elements. It may increases as a result of nutrient biocycling, low rainfall, burning and slow removal of bases due to high cropping intensity (Zebarth *et al.,* 2015).

Exchangeable base (TEB) concentrations from sites are: A, 4.18 Cmol kg^{-1}, B, 3.20 Cmol kg^{-1}, C, 3.34 Cmol kg^{-1}, D, 4.09 Cmol kg^{-1}, and E, 4.10 Cmol kg^{-1}. Site B and C had higher exchangeable base, whereas soils at site A, D and E has lower salinity and sodicity with respect to the low exchangeable base.

High values of exchangeable base indicates that calcium and magnesium are Exchangeable base (TEB) concentrations from sites are: A, 4.18 Cmol kg^{-1}, B, 3.20 Cmol kg^{--1}, C, 3.34 Cmol kg^{-1}, D, 4.09 Cmol kg^{-1}, and E, 4.10 Cmol kg^{-1}. Site B and C had higher exchangeable base, whereas soils at site A, D and E has lower salinity and sodicity with respect to the low exchangeable base. High values of exchangeable base indicates that calcium and magnesium are the dominant cations (Chapman, 2000).The rate of release of exchangeable base from the nonexchangeable form increases with increase in the intensity of soil weathering if the soil materials are uniform (Schöndorf *et al.,* 2025; Gustafsson *et al.,* 2025).

Therefore yam cultivated in site A, D and E will do better than those cultivated in site B and C based on the standard rating of the amount of exchangeable base needed for the effective growth and yield of yam.

Exchangeable acidity (EA) were: A, 0.09 Cmol kg^{-1}, B, 1.86 Cmol kg^{-1}, C, 1.81 Cmol kg^{-1}, D, 0.07 Cmol kg^{-1}, and E, 0.09 Cmol kg^{-1}. Site B and C had higher exchangeable acidity than sites A, D and E (Table 7). Exchangeable acidity has been identified to be inversely related to soil pH level, and the average value of EA for effective growth of any tuber crop is in the range of 0.5 Cmol/kg to 1.00 C mol/kg (Hazelton & Murphy, 2007).

Result of Cation exchange capacity (CEC) showed that site A had 4.27 Cmol kg^{-1}, B, 5.06 Cmol kg^{-1}, C, 5.16 Cmol kg^{-1}, D, 4.16 Cmol kg^{-1}, and E, 4.19 Cmol kg^{-1}. CEC was higher in site B and C than in soil site A, D and E (Table 7). The higher CEC in site B and C might be due to surface to sub-surface increase in clay fraction as observed in the site, suggesting that CEC was largely associated with fraction. It could also be due to leaching resulting in the downward movement of the cation exchange. CEC is the total capacity of the soil to hold exchangeable cations and essential nutrients and provides a buffer against soil acidity (CUCE, 2007). Saline and sodic soils tend to have higher clay fraction leading to higher CEC (Hazelton & Murphy, 2007).

Percentage base saturation (%BS) results showed site A had 97.96%, B, 63.24%, C, 64.83%, D, 98.39%, and E, 97.61%. Percentage base saturation of the soil in site A, D and E were moderate, indicating exchange complex was saturated more with basic cations. Base saturation is used in classifying the fertility level of soil with values greater or lower than 70% indicating fertile or low fertility of soils respectively (Tiecher *et al.,* 2022). This clearly shows that percentage base saturation was higher in site B and C (fertile), while soils of site A, D and E has low percentage base saturation(low fertility).The values obtained are in agreement with Baker and Amacher (1981) on soils of Nigerian semi-arid region. Key *et al*. (2009), Leticia *et al*. (2019) and Culman *et al*. (2021), stated that %BS represents the percentage of CEC occupied in the soil and it increases with increase in EB as found in site B and C. Mclean *et al.* (2013) also stated that 70% to 80% BS soils provides cations to plants more easily for effective growth of tuber crops (Yams).

Conclusion

Assessment of soil salinity and sodicity in some yam farms was conducted. Most soils were sandy loam and others clay loamy, which was more compacted, thereby limiting the infiltration and percolation rate of water needed for the tuber crop to grow effectively. Mean values of porosity, moisture content, organic carbon and organic matter were moderate in concentration. This explains why yams cultivated in some sites grow with poor yield due to the insufficient basic physical properties. Chemical properties of Nitrogen and potassium were moderate in some sites and lower in major areas. Phosphorus, sodium and magnesium were lower in major study sites. The study clearly showed that yam grows and yields well in soil with salinity concentration of 2.5 dS/m to 3.00 dS/m and sodicity (SAR) of between 8.00 to10.00. The highest pH value was 5.14 and 5.18 which is high for soil healthy growth of yams.

The study revealed that crop growth and yield could be predicted on the basis of the level of electrical conductivity (EC) and the sodium absorption ratio (SAR). These techniques can be adopted in precision farming for soil management and improved root crop yield in the study area.

Based on result obtained from the five different locations; farmers are advice to be identifying early symptoms of salt-affected soils so as to make appropriate land amendment as well as knowing the suitable crop to grow during rainy and irrigation seasons.

Farmers cultivating in salty affected soils are advice to grow salt tolerance crops such as Soya beans, rice and sorghum, and Carry out reclamation method to improve on the level of yam productivity on salty affected soils.

Author contributions

Malum J. Flayin: Conceptualization, Methodology, Validation, Data curation, Supervision, Formal analysis, review & editing. Adugba Joshua: Investigation, Visualization, Writing -draft & effecting corrections. All authors approved the final manuscript.

References

Agbede, T. M., & Adekiya, A. O. (2011). Soil properties and yam yield under different tillage systems in a tropical Alfisol. *Archives of Agronomy and Soil Science, 59*(4), 505-519. https://doi.org/10.1080/03650340.2011.652096

Ahmed, M., Rauf, A., & Makhdum, M. I. (2011). Growth performance of tuber crop under saline-sodic soil conditions. *Drainage Reclamation, 3*, 43-47.

Awale, R., Machado, S., Ghimire, R., & Bista, P. (2017). Soil health. In G. Yorgey & C. Kruger (Eds.), *Advances in dryland farming in the inland Pacific Northwest* (pp. 47-98). Washington State University.

Baker, D. E., & Amacher, M. C. (1981). The development and interpretation of a diagnostic soil-testing program. Pennsylvania State University Agricultural Experiment Station Bulletin (pp. 862-868).

Chang, K. J., Yoo, C. H., Kim, N. S., Hur, P. J., & Chang, Y. U. (2010). *Study on research system for mass culturing techniques of high yielding yam*. Research report by Daesan Foundation for Rural Culture.

Chapman, H. D. (2000). Total Exchangeable Base. In C. A. Black (Eds.), *Methods of soil Analysis Part II* (pp. 902-904). American Society of Agronomy Inc.

Chinnusamy, V., Jagendorf, A., & Zhu, J.-K. (2005). Understanding and improving salt tolerance in tuber crop. *Crop science, 45*(2), 437-448. https://doi.org/10.2135/cropsci2005.0437

CUCE. (2007). *Cation Exchange Capacity* (CEC). Agronomic fact Sheet series 22. Cornell University Cooperative Extension.

Culman, S. W., Brock, C., Doohan, D., Jackson-Smith, D., Herms, C., Chaganti, V. N., Kleinhenz, M., Sprunger, C. D., & Spargo, J. (2021). Base cation saturation ratios vs. sufficiency level of nutrients: A false dichotomy in practice. *Agronomy Journal, 113*(6), 5623-5634. https://doi.org/10.1002/agj2.20787

Demo, A. H., Gemeda, M. K., Abdo, D. R., Guluma, T. N., & Adugna, D. B. (2025). Impact of soil salinity, sodicity, and irrigation water salinity on crop production and coping mechanism in areas of dryland farming. *Agrosystems, Geosciences & Environment, 8*(1), e70072. https://doi.org/10.1002/agg2.70072

Dev, G. (1997). Soil fertility evaluation for balanced fertilization. *Fertilizer News, 42*, 3-34.

Diby, L. N., Tie, B. T., Girardin O., Sangakkara R., & Frossard E. (2011). Growth and nutrient use efficiencies of yams (*Dioscorea* spp.) grown in two contrasting soils of West Africa. *International Journal of Agronomy, 2011*, 175958. https://doi.org/10.1155/2011/175958

Dokua, D. S. (2025). *Total volume of yam produced in Africa in 2024, by country*. Retrieved from https://www.statista.com/statistics/1499222/africa-volume-of-yam-production-by-country/?srsltid=AfmBOoovhkZguv38MfIPp5aYlHFogToi3MK6pWeO2MPUjfrGb0pnimT7

Epstein, E., & Bloom, A. (2005). *Mineral nutrition of plants: Principles and perspectives*. Wiley & Sons.

Esu, I. E. (2005). *Soil characterization and mapping for food security and sustainable environment in Nigeria*. Proceedings of the 29th Annual Conference of the Soil Science Society of Nigeria (pp. 20-24).

Freeman, H. A., & Coe, R. (2010). Smallholder farmers' use of integrated nutrient-management strategies: patterns and possibilities in Machakos district of Eastern Kenya. In C. B. Barrett, F. Place & A. A. Aboud (Eds.), *Natural resources management in African agriculture: understanding and improving current practices* (pp. 143-154). CABI. https://doi.org/10.1079/9780851995847.0143

Gidey, A. (2018). Geospatial distribution modeling and determining suitability of groundwater quality for irrigation purpose using geospatial methods and water quality index (WQI) in Northern Ethiopia. *Applied Water Science, 8*, 82. https://doi.org/10.1007/s13201-018-0722-x

Graveel, J. G., Tyler, D. D., Jones, J. R., & McFee,W. W. (2002). Crop yield and rooting as affected by fragipan depth in loess soils in the southeast USA. *Soil and Tillage Research, 68*(2), 153-161. https://doi.org/10.1016/S0167-1987(02)00118-6

Gustafsson, J. P., Groeneveld, M., Karltun, E., Hydén, C. E., & Stendahl, J. (2025). Determining exchangeable base cations in forest soils: A comparison of three methods. *Journal of Plant Nutrition and Soil Science, 188*(5), 847-858. https://doi.org/10.1002/jpln.12017

Haby, V. A., Russelle, M. P., & Skogley, E. O. (2000). Testing soils for potassium, calcium and magnesium. In R. L. Westerman (Ed.), *Soil testing and plant analysis* (pp.181-227). SSSA.

Hasegawa, P. M., Bressnan, R. A., Zhu, J.-K., & Bohnert, H. J. (2000). Plant cellular and molecular responses to high salinity. *Annual Review of Plant Biology, 51*, 463-499. https://doi.

org/10.1146/annurev.arplant.51.1.463

Hazelton, P., & Murphy, B. (2007). Interpreting soil test results: What do all the numbers mean? (2nd ed.). CSIRO Publishing. https://doi.org/10.1071/9780643094680

Howeler, R. H. (1996). Diagnosis of nutritional disorders and soil fertility management of tuber. In G. T. Kurup, M. S. Palaniswami, V. P. Potty, G. Padmaja, S. Kabeerathumma & S. V. Pillai (Eds.), *Tropical tuber crops: problems, prospects, and future strategies* (pp. 181-193). CABI.

IITA. (2008). *Crop Improvement Division/Tuber Root Improvement Program* (Archival Reports Part III yam) Dioscorea spp. Ibadan, Nigeria (pp. 20-85). International Institute of Tropical Agriculture.

IITA. (2020). *Yam research for development*. International Institute of Tropical Agriculture.

John, K. S., George, J., Beegum, S. U. S., Shivay, Y. S. (2016). Soil fertility and nutrient management in tropical tuber crops: An overview. *Indian Journal of Agronomy, 61*(3), 263-273. https://doi.org/10.59797/ija.v61i3.4368

Key, J. L., Kurtz, L. T., & Tucker, B. B. (2009). Influence ratio of exchangeable calcium-magnesium on yield and composition of tuber crop. *Soil science, 93*, 265-270.

Kihara, J., Bolo, P., Kinyua, M., Nyawira, S. S., & Somer, R. (2020). Soil health and ecosystem services: Lessons from sub-Sahara Africa (SSA). *Geoderma, 370*, 114342. https://doi.org/10.1016/j.geoderma.2020.114342

Leticia, S. S., David, E. K., & Uttam, S. (2019). *Cation exchange capacity and base saturation.* UGA Cooperative Extension Circular 1040.

Mau, Y., & Porporato, A. (2015). A dynamical system approach to soil salinity and sodicity. *Advances in Water Resources, 83*, 68-76. https://doi.org/10.1016/j.advwatres.2015.05.010

Mclean, E.O., Hartwig, R. C., Eckert, D. J., & Triplett, G. B. (2013). Basic cation saturation ratios in two soils and their effect upon yields and nutrient content of *dioscorea alata. Soil Science Society of America Journal, 36*, 927-930.

Meng, Y., Wang, T., Zhou, X., Yang, X., Hernández, M., Zhou, T., Lv, Q., Ren, X., Feng, H., Pan, H., Hu, S. (2025). Evaluating the optimal land use pattern for saline-sodic soils from the perspective of nitrogen metabolism. *Environmental Technology & Innovation, 40*, 104363. https://doi.org/10.1016/j.eti.2025.104363

Mohan, C., Shankuntala, I., Hedge, V., Muthusamy, S. K., Thulasimani, K., Chunhan, V. B. S., & Dayal, V. (2020). *Potential tropical tuber crops: production technologies, value added and functional foods*. ICAR-CTCRI.

NMI. (2021). *Zaki-Biam Weather Statistics*. Norwegian Meteorological Institute.

Pros, K., Kim, K., Lee, Y., Park, J. W., & Han, G. H. (2022). Compositional characteristics of major inorganic anions in soil and plant water extracts from various farmlands. *Korean Journal of Soil Science and Fertilizer, 55*(4), 424-432. https://doi.org/10.7745/KJSSF.2022.55.4.424

Renuka, & Nishtha. (2022). *Dioscorea bulbifera* medicinal plant: Phytochemistry and salutary potential. *Modern Applications in Pharmacy & Pharmacology, 2*(5), 550. https://doi.org/10.31031/mapp.2022.02.000550

Schöndorf, D., Basdediós, N., Velescu, A., Fabian, T., Espinosa, C. I., & Wilcke, W. (2025). Kinetics of element release by weathering in soils of southern Ecuador: A comparison among different climatic and land-use regimes. *Geoderma, 456*, 117263. https://doi.org/10.1016/j.geoderma.2025.117263

Shahid, S. A., Zaman, M., & Heng, L. (2018). Introduction to soil salinity, sodicity and diagnostics techniques. In M. Zaman, S. A. Shahid & L. Heng (Eds.), Guideline for salinity assessment, mitigation and adaptation using nuclear and related techniques (pp. 1-42). Springer. https://doi.org/10.1007/978-3-319-96190-31

Sheferia, B. A., Alem, M. B., & Seid, A. (2021). Effects of saline water and irrigation interval on soil physicochemical properties. *Advances in Applied Science Research, 12*(10), 13.

Singh, K. K., Tewari, G., & Kumar, S. (2020). Evaluation of groundwater quality for suitability of irrigation purposes: A case study in the Udham Singh Nagar, Uttarakhand. *Journal of Chemistry, 2020*, 6924026. https://doi.org/10.1155/2020/6924026

Soil Science Division Staff. (2017). Soil survey manual. In C. Ditzler, K. Scheffe & H. C. Monger (Eds.). *USDA Handbook 18*. Government Printing Office.

Sule, A. A., Iseh, A. J., Gyobe, A. M., & Tyom, A. I. (2020). Radiological analysis of soil in Zaki-Biam, Ukum lga, Benue - Nigeria. *International Journal of Applied Physics, 7*(1), 61-71. https://doi.org/10.14445/23500301/IJAP-V7I1P110

Tareen, M. B. K., Saeed, N., Sultan, M., Chen, X., Li, J., & Yan, S. (2025). Yam as functional food: bioactive properties, health benefits, and applications. *Food, Nutrition and Health, 2*, 16. https://doi.org/10.1007/s44403-025-00022-3

Thompson, A. K., & Oduro, I. (2021). *Yams: Botany, production and uses*. CABI Digital Library.

Tiecher, T., Gatiboni, L., dos Santos, D. R., Bissani, C. A., Martins, A. P., Gianello, C., Dick, D. P., Bortoluzzi, E. C., Escosteguy, P. A. V., da Silva, L. S., Brunetto, G., Mallmann, F. J. K., Pauletti, V., Lourenzi, C. R., de Sousa, R. O., Carlos, F. S., & Azevedo, A. C. (2022). Base saturation is an inadequate term for Soil Science. *Revista Brasileira de Ciência do Solo, 46*, e0220125. https://doi.org/10.36783/18069657rbcs20220125

Tiri, A., Belkhiri, L., Asma, M., & Mouni, L. (2020). Suitability and assessment of surface water for irrigation purpose. In M. Eyvaz & E. Yüksel (Eds.), *Water chemistry*. IntechOpen Limited. https://doi.org/10.5772/intechopen.86651

Wanasundera, J. P. D., & Ravindran, G. (2014). Nutritional assessment of yam (*Dioscorea alata*) tubers. *Plant Foods for Human Nutrition, 46*, 33-39. https://doi.org/10.1007/BF01088459

Zebarth, B. J., Forge, T. A., Goyer, C., & Brin, L. D. (2015). Effect of soil acidification on nutrification in soil. *Canadian Journal of Soil Science, 95*(4), 359-363. https://doi.org/10.4141/cjss-2015-040