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Investigation of the Effects of Soil Physico-chemical and Hydraulic Properties on *Citrullus lanatus* and *Cucumis sativus* in Southwestern, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Authors GAA and TAA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors GAA and TAA managed the analyses of the study. Author ADA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

In this era of agricultural transformation by the federal government of Nigeria, no opportunity that can assist in achieving food security is ignored. Several crops which were previously underutilized are now being promoted for sustainable utilization. Such crops among others include watermelon (*Citrullus lanatus*) and cucumber (*Cucumis sativus*). Achieving efficient production and high yield requires adequate knowledge about the soil and climatic conditions that are favourable to these two crops under investigation. This study aimed at investigating the effects of physico-chemical and hydraulic properties of southwestern soils on the crops. Soil sample were randomly taken from different locations on the selected farms where the selected crops are being cultivated. The soil was taken at different depths (0-15 cm, 15-30 cm and 30-45 cm) and the sample were taken to the laboratory and to determine their moisture content, pH, electrical conductivity, exchangeable cations and texture and the results of the soil test were then subjected to appropriate statistical

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analyses. The results show that bulk density, moisture content (M.C) at field capacity and permanent wilting point (PWP), and the total available water at different depths of soil for cucumber (*C. sativus*) and watermelon (*C. lanatus*) at the selected farm range from 1.22 g/cm^3 to 1.6 g/cm^3 and 8.83 cm/m and 13.30 cm/m respectively. Also, the result of pH, electrical conductivity and exchangeable cations range from 5.27 to 5.26, 85.85 to 96.20 mS/cm and 0.29 cmol/kg to 0.40 cmol/kg, respectively. The assessments of water management practices adopted by the farmers at the selected farms and the soils on which the selected crops are been cultivated hereby provide information on the suitability of the soils in the area as well as other similar soils in Nigeria for the crops' cultivation as well as potential amendments.

Keywords: Soil; properties; Citrus lanatus; Cucumus sativus.

1. INTRODUCTION

Soil parameters such as pH, electrical conductivity, exchangeable cations, bulk density and its moisture content affect the water infiltration characteristics of the soil and plant growth. The soil physical condition affects the ability of plant roots to acquire nutrients from the soil. Excessive tillage which results in soil compaction and destruction of soil structure also affect the physical properties of the soil. According to [1], a fertile soil is more than just having adequate levels of the essential nutrients, for plants to take up adequate amounts of nutrients the soil must have good tilth or quality. Consequently, planting of certain crops in some climes are greatly affected by both soil properties and varying climatic conditions. *Citrullus lanatus* and *Cucumis sativus* are warm season crops which grow best during a warm day and they are one of the most cultivated vegetable crops that have a short cycle and high economic value in dry season farming [2]. *C. lanatus* of family *Cucurbitaceae* is commonly known as watermelon. The fruits when ripe, are edible and largely used for making confectionery. It is has a high nutritive values and its medicinal values are well documented [3]. *C. lanatus* is one of the most widely cultivated crops in the world at large and the global production in 2002 reached 89.9 million mega grams [4,5,6]. China was reported to be the leading country in the production of watermelon followed by Turkey, United States, Iran and Republic of Korea [6,7]. The maturity period for watermelon is between 70 and 90 days, depending on the variety. *C. sativus*, popularly known as a cucumber is also an important vegetable and a member of the Cucurbitaceae family [8]. It is among the oldest vegetables cultivated by man [2] and a very important vegetable globally [9,10]. Both crops are most preferred exotic vegetables in Nigeria for its nutritional and medicinal values. Their accessibility to all social classes in the country gives some farmers greater opportunity to tap their economic potentials.

For *C. lanatus* and *C. sativus* to produce good yields, soils used for cultivation must possess good physico-chemical and hydraulic properties. The cultivation of these crops could still be considered very low in Nigeria with respect to the existing huge population. Many farmers do not have access to cultivable soils with required physicochemical and hydraulic properties while most of them depend on irrigation to cultivate these vegetables. The dependency on irrigation for efficient production limits their cultivation to areas where there is constant supply of agricultural water. This in effect limits the crops' production. Many farmers embark on cultivation of these crops without adequate knowledge of the quality of the soil. There is need to assess the type of water management practices adopted by the farmers in these farms and assess the soils on which these vegetables are cultivated in order to ascertain their properties. This will provide information on the suitability of the soils for cultivation or required amendments in order to ensure optimum crop yield and better return on the farmers' investment. Hence this study, investigate the effect of soil physico-chemical and hydraulic properties on the gowth of *C. lanatus* (water melon) and *C. sativus* (cucumers) in southwestern, Nigeria.

2. MATERIALS AND METHODS

2.1 Study Area

The farms used for this study lie between latitude 8^o 37$^'$ 29.84$^{''}$N and 8^o 37$^'$ 39.28$^{''}$N and longitude 3^o 36$^'$ 37.07$^{''}$E and 3^o 36$^'$ 42.07$^{''}$N. These farms are located at the northeastern part of Sepeteri town, in the humid tropical region of southwestern Nigeria. The temperature range of the region is 20-32˚C. The town lies in the Guinea Savannah zone with tall grasses, shrubs and luxuriant trees. The relief of the area is mainly undulating lowland terrain. River Ogun is the main river whose tributaries drain the whole town and its environs. One of the tributaries of this river is dammed to create the reservoir used in for the Sepeteri Irrigation Project. The soils in the area is mainly Alfisols (*Haplustalf*) derived from the pre-Cambrian basement complex rocks of the Savannah region of Nigeria [11].

2.2 Soil Sampling and Analyses

Two farms each at different locations of Sepeteri Irrigation Project site in Ogun-Osun hydrological zone, where *C. lanatus* and *C. sativus* are cultivated by different farmers were identified and selected for this study. A stratified random sampling technique was adopted to select the farms. Farms 1 and 3 were used for the cultivation of cucumber while Farms 2 and 4 were used for the cultivation of watermelon. The farms were studied to determine and investigate the method of water applications, as well as other practices related to water management techniques adopted by the farmers subject to the availability of climatic data. Soil samples were collected in all the selected farms using soil auger at three different depths (0-15 cm, 15-30 cm and 30-45 cm). The samples collected were taken to the laboratory at the soil and land resources department of Obafemi Awolowo University to determine their moisture content, pH, electrical conductivity, exchangeable cations and texture.

2.3 Statistical Analysis

The results of the soil test were then subjected to appropriate statistical analyses.

3. RESULTS AND DISCUSSION

3.1 Irrigation Interval and Soil Texture

C. lanatus and *C. sativus* require a continuous water supply to prevent water stress for high quality and yields. These vegetables need more water during seed germination, flowering, and fruit enlargement. From the study, it was observed that water was not a constraint as the frequency of irrigation for the selected farms ranges between 2-3 days (Table 1). According to [1] the frequency of irrigation is largely dependent on soil type and weather conditions. The results of soil textural analyses of the four farms are also shown in Table 1. The texture of the soils in farms F1, F3 and F4 are sandy loam while that of farm F2 is loam. The soil textures are suitable for the cultivation of cucumber and watermelon, but it must be considered along with other influencing factors such as pH and other chemical parameters.

3.2 Soil pH, Electrical Conductivity and Exchangeable Cations

The pH of the soil samples collected from the four farms ranged from 5.27 and 5.56. This implies that the soils were slightly acidic and soil pH affects microbial and plant growth. Both crops can absorb required nutrients and perform better in soils with pH values between 6.0 and 6.5. [12] stated that the preferred pH for almost all vegetables is between 5.5 and 6.5. [13] noted that root injury is observed at pH 5.0 for these crops. Lateral root development is suppressed, and in some cases, roots tip were killed because of the low pH values. These results showed that the soils require some amendments to raise the pH values of the soil to the range that allows optimal performance. It is therefore expected that the pH will negatively affect the performance of the crops compared to the same soil with right pH range. Liming could be done to raise the pH of the soil to the required level. The slightly acidic nature of the soil could be attributable to the previous use of inorganic fertilizers in the area. [14] suggested that in view of the acidic soil reactions, the use of fertilizers with residual acidic effects like urea should be avoided. The soil with low in organic carbon, total nitrogen, available phosphorus and exchangeable cations are recommend for sustainable crop production in agro-ecological zones of Nigeria [15]. From the result of the statistical analysis (Table 2), the soil pH of the Farms considered were significantly different ($P<0.05$). Moreover, the soil pH varies significantly among the Farms.

Table 3 showed the interaction of soil depths, plots and soil pH. It can be deduced from the table that the pH values were significantly different for the soil samples collected at different soil depths, since (F (2, 96) = 10.669, $p < 0.05$) and that the values were significantly different for the soil samples collected from different plots, since (F (3, 96) = 2.813, $p < 0.05$). There was no significant interaction between the soil depths and plots on the pH values of the soil samples, since (F (6, 96) = 0.460, $p > 0.05$).

Table 1. Area coverage and irrigation interval of *C. lanatus* and *C. sativus*

Farm	Crop planted	Area coverage, ha	Planting date	Soil type	Irrigation interval, days
F1	Cucumber	22.50	Oct 20	Sandy loam	3
F2	Watermelon	20.10	Oct 3	Loam	3
F3	Cucumber	32.40	Sep 29	Sandy loam	2
F4	Watermelon	15.60	Oct 09	Sandy loam	2

Table 2. Variation of chemical properties at different farms

Farm	pH	EC (mS/cm)	Na^{+}	Ca^{2+}	K^{+}	Mg^{2+}
			cmol/kg			
F1	5.52^{a}	90.38^{a}	0.15^{b}	1.64^{a}	0.20^{a}	0.23^{a}
F2	5.42^{ba}	85.85^{a}	0.19^{a}	1.61^{a}	0.19^{a}	0.20^{a}
F3	5.27^{b}	96.20^{a}	0.19^{a}	1.57^{a}	0.20^{a}	0.22^{a}
F4	5.56^{a}	94.28^{a}	0.21^{a}	1.69^{a}	0.20^{a}	0.22^{a}

**Means with the same letter are not significantly different (P < 0.05)*

Table 3. Effect of soil depths, plots and their interaction on soil pH

Source	Type III sum of squares	Df	Mean square	F	Sig.
Corrected Model	5.556^{a}	11	.505	2.958	.002
Intercept	2733.101	1	2733.101	16005.145	.000
Soil depth	3.644	2	1.822	10.669	.000
Plot	1.441	3	.480	2.813	.043
Soil depth * Plot	.471	6	.078	.460	.837
Error	16.393	96	.171		
Total	2755.050	108			
Corrected Total	21.949	107			

Electrical conductivity is an indication of soil salinity. The results of the electrical conductivity of soils in the Farms ranged from 85.85 to 96.20 mS/cm (Table 2). The electrical conductivity of the soils in the farms was significantly different (P<0.05). The results of analysis indicated that the soils had very high salinity value. According to FAO standard on salinity tolerance, any value higher than 16 mS/cm is considered high salinity. Based on this threshold value, the high salinity is not appropriate for vegetable growth. In other to get maximum yield for cucumber and watermelon production in all the studied farms, there is the need to reduce the soil's salinity.

Table 4 showed the interaction of soil depths, plots and electrical conductivity. It indicates that the electrical conductivity values were not significantly different for the soil samples collected at different soil depths, since (F (2, 96) = 1.303, $p > 0.05$) and that the values were not significantly different for the soil samples collected from different points, since (F (3, 96) = 1.704, $p > 0.05$). There was no significant interaction between the soil depths and plots on the Electrical conductivity values of the soil samples, since (F (6, 96) = 1.315, $p > 0.05$).

Considering the mean values of exchangeable cations in the soil samples (Table 2), values considered to be critical according to [14] were 0.40 cmol/kg for Mg^{2+}, 0.20 cmol/kg for K^{+} and 0.20 cmol/kg for Ca^{2+}. From the results of the analysis it is inferred that Mg^{2+} is considered tolerable.

3.3 Soil Bulk Density, Moisture Content and Total Available Water

Table 5 showed the results of bulk density, moisture content (M.C) at field capacity and permanent wilting point (PWP), and the total available water at different depths of soil for cucumber and watermelon. The bulk density of soils varied among the Farms. The range is from 1.22 g/cm^3 on soil depth of 15-30 cm in Farm 1 to 1.6 g/cm^3 on the same farm at depth 30-45 cm. High bulk density is an indicator of low soil porosity and soil compaction. The bulk density of the soils falls within an acceptable value (< 1.40 g/cm^3) for sandy loam soil according to [16]. The values of bulk density in Farm 2 were much higher. It ranges between 1.43 g/cm^3 for soil depth of 0-15 cm and 1.58 g/cm^3 for soil depth of 15-30 cm and this is attributable to the texture of the soil in the Farm. High bulk density could be as a result of compaction caused by tractor passes because the farms with high densities were those pulverized by tractor. This conform to the findings of [17] who reported that soil bulk density increased significantly with an increase in compaction depending on the number of passes of tractor wheel.

The total available water (TAW) for plant use in the root zone is commonly defined as the range of soil moisture held at a negative apparent pressure of 0.1 to 0.33 bar (a soil moisture level called 'field capacity') and 15 bars (called the 'permanent wilting point'). The TAW will vary from 25 cm/m for silty loams to as low as 6 cm/m for sandy soils [18]. TAW is the difference between field capacity and wilting point moisture contents multiplied by the depth of the root zone, RD (which is 1.1 m for cucumber and 1.2 m for watermelon [18]. [13] noted that:

$$TAW = (\theta_{fc} - \theta_{wp})\ RD$$

From Table 5, it is observed that the values of TAW for cucumber in the soils range between 8.83 cm/m and 13.24 cm/m while that of watermelon is between 8.86 cm/m and 13.30 cm/m. The two crops therefore fall within the expected range for healthy crop growth and yield. This is achieved by the regular supply of moisture and prevention of water stress on the farms.

Table 4. Effect of soil depths, plots and their interaction on soil electrical conductivity

Source	Type III sum of squares	Df	Mean square	F	Sig.
Corrected Model	41288.161[a]	11	3753.469	1.419	.177
Intercept	1528269.605	1	1528269.605	577.636	.000
Soil depth	6895.487	2	3447.743	1.303	.276
Plot	13523.088	3	4507.696	1.704	.171
Soil depth * Plot	20869.586	6	3478.264	1.315	.258
Error	253990.324	96	2645.733		
Total	1823548.090	108			
Corrected Total	295278.485	107			

Table 5. Bulk density and Moisture contents at different depths of soil for cucumber and watermelon

Farm	Soil depth (cm)	Bulk density, g/cm^3	M.C at field capacity (θ_{fc}) %	M.C at PWP (θ_{wp}) %	TAW for cucumber (cm/m)	TAW for watermelon (cm/m)
	0-15	1.35	32.34	22.32	11.02	
F1	15-30	1.22	30.23	21.15	9.99	
	30-45	1.6	31.45	23.39	8.87	
	0-15	1.43	30.43	19.35		13.30
F2	15-30	1.58	26.45	16.31		12.17
	30-45	1.45	26.55	18.21		10.01
	0-15	1.21	32.66	24.63	8.83	
	15-30	1.32	30.23	18.19	13.24	
F3	30-45	1.35	28.34	17.72	11.68	
	0-15	1.34	29.21	21.16		9.66
F4	15-30	1.26	28.01	20.63		8.86
	30-45	1.54	30.42	23.2		8.66

**Mean values of observation*

4. CONCLUSION

The assessments of water management practices adopted by the farmers in Sepeteri irrigation farms and the soils on which cucumber and watermelon are cultivated have been carried out hereby providing information on the suitability of the soils in the area as well as other similar soils in Nigeria for the crops' cultivation as well as potential amendments. The results of the study indicated that soils were acidic and highly saline for *C. lanatus* and *C. sativus* cultivation. The study also concluded that the higher bulk density recorded in Farm 2 is attributable to the soil compaction by tractor wheel during land preparation and that the total available water required by both crops are adequate through the 3-day irrigation interval. It is, therefore, necessary to make the following recommendations: The work should be expanded to cover wider area in Sepeteri and other areas in the Ogun-Osun River basin, and then to other hydrological zones in the country to determine the most suitable regions for the cultivation of cucumber and watermelon and provide food and employment opportunity for the teaming youth population. Ammendment options should also be researched into to allow better production in areas that are less suitable for the cultivation of the crops.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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