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Measurement of Ground Electrical Conductivities of Different Soil Type and Their Effect on Growth Rate of Plant

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Abstract

The purpose of this paper is to examine the contribution of ground electrical conductivity on growth rate of plants. Wenner array method of measuring ground conductivity has been employed. Three types of soil samples were used for the study; loamy, clayey and sandy soil. The results show that loamy soil has the highest mean conductivity of 3.752×10^{-3} $(\Omega m)^{-1}$ followed by clayey with value of 2.121×10^{-3} $(\Omega m)^{-1}$ and sandy soil has the least mean conductivity of 4.023×10^{-4} $(\Omega m)^{-1}$. Comparison is made between the present results with those of Hack and both have good agreement. The effect of this parameter on growth rate of three vegetable crops selected for the study; *Amaranthus Cruenthus, Amaranthus Tricolar and Solanum Macrocarpon* were also investigated. The results show that loamy soil with highest electrical ground conductivity has greatest tendency to support the growth rate of crops.

Keywords: electrical conductivity, loamy, clayey, sandy, soil, apparent resistivity, growth rate, electrode

Introduction

Soil is a natural material formed from a variable mixture of broken and weathered mineral and decaying organic matter, which covers the earth in a thin layer. Soil is of the utmost important to man because it supports the growth of plants, which therefore sustain human existence (Ghildyal, 1987).

The processes of soil formation have been attributed to the weathering process of rocks. Weathering is basically a combination of disintegration and synthesis. It takes place when rocks are first broken down into smaller rocks and eventually into individual minerals of which they are composed. The factors, which determine the rate, type and quality of the soil formed in a particular area, include the nature of the parent materials, climate, topography, organic influences or biotic factors and time. The combination of these factors determines the soil texture. The enormous variation in electrical resistivity of different rocks and minerals will invariably contribute to the reason why different types of soil will have varying electrical resistivity as well (Nadler and Frenkel, 1980)

There are three basic types of soil; these are sandy, clayey and loamy soils. Sandy soil type is predominantly quartz in size whose diameter may vary from about 2 mm to 0.02 mm. It is generally coarse grained, loose, gritty and well aerated. It is well drained since percolation is easy but capillary is low due to large individual pores. Sandy soil heats up rapidly during the day and cools down quickly during the night. Since heat destroys soil microorganism, which have a great role in humus accumulation, and there is also a high rate of leaching, it is therefore expected that it will not enhance an increase in soil conductivity.

Clay particles have large surface area and a high power of water holding capacity. Soil rich in clay are generally very sticky and when they are wet, they are not easily permeable to water. They contain very little air due to the very narrow pore spaces, which reduce drainage and encourage capillary uptake and water retention. For this reason, the higher the amount of clay in a soil, the less the amount of water available to plants.

Loamy soil has a good combination of silt and clay fractions. This is one of the best soils for crop production because it combines the good physical qualities of silt with the good chemical quantities of clay (Nyle, 1990 and Berria, 1981)

In this work, the Wenner array method has been used to measure the soil electrical conductivity of the three soils. The effects of these parameters on growth rate of plant were also examined. The plants selected for the study are Spinach green (*Amaranthus Cruenthus*), Spinach white (*Amaranthus Tricolar*) and Egg - plant (*Solanum Macrcurpon*). The growth rate of each of these vegetables on the three samples of soil types was carried out using a linear measurement of height of the plant. These were achieved by taking measurement of increase in height of the plant everyday at a constant time (t) for two months.

Theory

One of the most commonly used geophysical techniques in the detection of electrical conductivity of soil is the electrical method. A number of such techniques have been developed. The Wenner array method, which has good accuracy (Parasnis, 1986), has been employed in this work. The purpose of the method is the determination of the subsurface resistivity contribution by conducting measurements at the surface of the earth. To achieve this, electric current is induced into the ground via two electrodes and the potential difference, which is caused by the induced current, is measured in two other electrodes. The measured potential gives an image for the difficulty of the current flow through the subsurface. This is an indication of the electrical resistance of the subsurface.

Consider a piece of solid conductor of length L and cross sectional area A, the relationship between the resistivity ρ, resistance R, the measured current I, and the potential difference V is given by (Watkins, 1982)

$$\rho = R\left(\frac{A}{L}\right) = \frac{\Delta V}{I}\frac{A}{L} \tag{1}$$

Since resistivity is a function of length and cross sectional area, for small change in the conductor size therefore,

$$\rho = \frac{\Delta V / L}{I / \Delta A} \tag{2}$$

A typical schematic diagram of Wenner Array Method is shown in Fig.1. The potential difference between electrodes C and D for a semi-infinite earth of uniform resistivity ρ, is expressed by (Dobrin and Savit, 1988)

$$\Delta V = V_C - V_D = \frac{I\rho}{2\pi} K \tag{3}$$

where K is the geometric factor defined as

$$K = \left[\left(\frac{1}{r_1} - \frac{1}{r_2}\right) - \left(\frac{1}{R_1} - \frac{1}{R_2}\right)\right] \tag{4}$$

$r_1 = R_2 = a$ and $r_2 = R_1 = 2a$

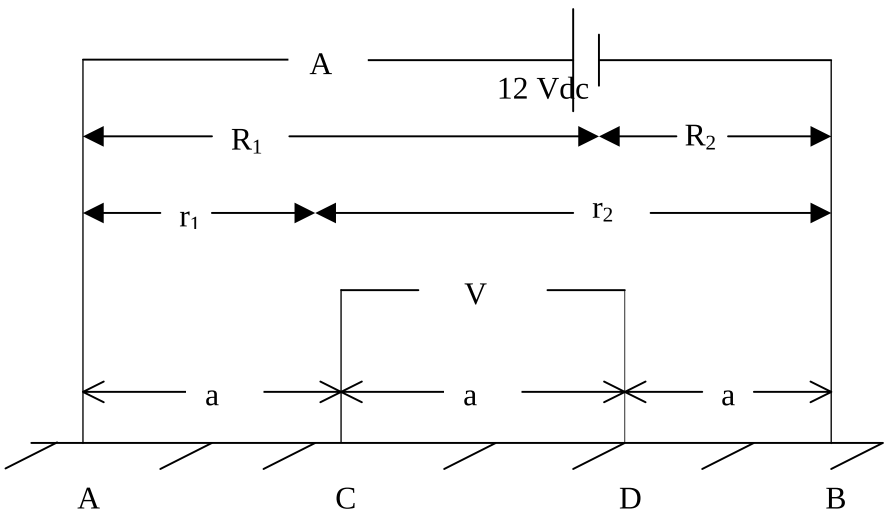

Figure 1: Schematic diagram of Wenner Array method.

The apparent resistivity can then be computed from

$$\rho_a = \frac{2\pi\Delta V}{I} K^{-1} \tag{5}$$

$$= \frac{2\pi\Delta V}{I} \frac{1}{\left[\left(\frac{1}{a} - \frac{1}{2a}\right) - \left(\frac{1}{2a} - \frac{1}{a}\right)\right]}$$

$$= \frac{2\pi\Delta V}{I} \frac{1}{\left[\left(\frac{1}{2a}\right) - \left(\frac{-1}{2a}\right)\right]}$$

$$= \frac{2\pi\Delta V}{I} \frac{1}{2/2a}$$

$$\rho_a = \frac{2\pi a\Delta V}{I} \tag{6}$$

Equation (6) has been obtained by substituting equation (4) into equation (5). It can be observed that the apparent resistivity is independent on the position of the electrode and is not been affected even though the potential electrodes are interchanged. It is assumed that the apparent resistivity is uniform within the subsurface (Dobrin and Savit, 1988); this value will then be equal to the true resistivity of the subsurface structure of the soil. Therefore, the ground electrical conductivity can be calculated from the relation

$$\sigma = \rho^{-1} \tag{7}$$

Materials and Methods

Measurement of Ground Electrical Conductivity

This study was conducted at the Federal University of Technology, Akure Nigeria. During the field measurements, four aluminium probes (50 cm long), were used as electrodes. One 12V dc accumulator, one digital voltmeter, one milli-ammeter, mallet, insulated cables are some of the material used to investigate the resistivity of the earth.

Ground electrical conductivities of the three soils considered for the study were determined using the technique that has been described above. The measurements are for probe separation 'a', which vary between 0.05 m and 0.50 m of 0.05 intervals. This distance is one-third of the distance between the two outer current electrodes. It therefore follows that the distance between the outer current electrodes would vary between 0.15 m and 1.50 m.

Measurements of Growth Rate of The Plants

For plants, soil is the factor of major importance, and therefore the soil physical characteristic may have significant contribution to its growth. The growth of plant may be measured in many different ways. The parameter chosen depends on the particular part of plant to be measured. The different ways that can be used include: growth in height, growth in volume, growth in surface area of the leaves etc. In this work, growth in height method has been employed. It is simple, speedy and non-destructive.

Results and Discussion

Data from resistivity measurement are customarily presented and interpreted in the form of values of apparent resistivity ρ_a. Apparent resistivity is defined as the resistivity of an electrical homogeneous and isotropic half-space that would yield the measured relationship between the applied current and the potential difference for a particular arrangement and spacing of electrodes. The apparent resistivities of loamy, clayey and sandy have been measured using the Wenner array method. The variation of soil conductivity with probe separation ‘a’ for the three soils considered are presented in Fig 2. The conductivity of a particular soil is not constant despite the equal interspacing between the electrodes. For instance, the highest conductivity of $5.010\text{x}10^{-4}$ $(\Omega m)^{-1}$ was observed at distance of 45 cm while the lowest conductivity of $3.268\text{x}10^{-4}$ $(\Omega m)^{-1}$ was observed at distance of 20 cm for sandy soil. For clay soil, the conductivity ranges between $6.466\text{x}10^{-4}$ $(\Omega m)^{-1}$ and $4.974\text{x}10^{-3}$ $(\Omega m)^{-1}$ at distance of 5 cm and 10 cm respectively. For loamy soil, the conductivity ranges between $1.764\text{x}10^{-3}$ $(\Omega m)^{-1}$ and $7.261\text{x}10^{-3}$ $(\Omega m)^{-1}$ at distance of 40 cm and 15 cm respectively. The variation of the conductivity is expected because it depends not only on the apparent resistivity, but also on the nature of the topsoil. The greater soil porosity, the more easily electricity is conducted. Increasing concentration of electrolytes (salts) in soil water will dramatically increase soil electrical conductivity. Mineral soil containing high levels of organic matter (humus) and/or 2:1 clay minerals have a much higher ability to retain positively charged ions (such as Ca, Mg, K, Na, NH_4, or H) than soil lacking these constituents (Jaynes et al, 1994; Williams 1987). The presence of these ions in the moisture-filled soil pores will enhance soil electrical conductivity in the same way that salinity does (Rhoades and Corwin 1981). Soil electrical conductivity decreases slightly as temperature decreases toward the freezing point of water. Below freezing, soil pores become increasingly insulated from each other and overall soil electrical conductivity declines rapidly. All these factors might have contributed to the variation in the electrical conductivity.

Table 1: Comparison of electrical conductivities $(\Omega m)^{-1}$ of the present study with those of Hack (2000).

	Loamy	Clayey	Sandy
Present study	$3.752\text{x}10^{-3}$	$2.121\text{x}10^{-3}$	$4.023\text{x}10^{-4}$
Hack, 2000	$2.8\text{x}10^{-3}$	$6.67\text{x}10^{-3}$	$2.00\text{x}10^{-4}$

The mean ground electrical conductivity obtained is 3.752x10^{-3} $(\Omega m)^{-1}$ for loamy soil, 2.121x10^{-3} $(\Omega m)^{-1}$ for clayey soil and 4.023x10^{-4} $(\Omega m)^{-1}$ for sandy soil. Obviously, this shows that loamy has the highest, followed by clayey and then sandy soil. Table 1 shows that the result of the present work compare very well with similar one by Hack (2000).

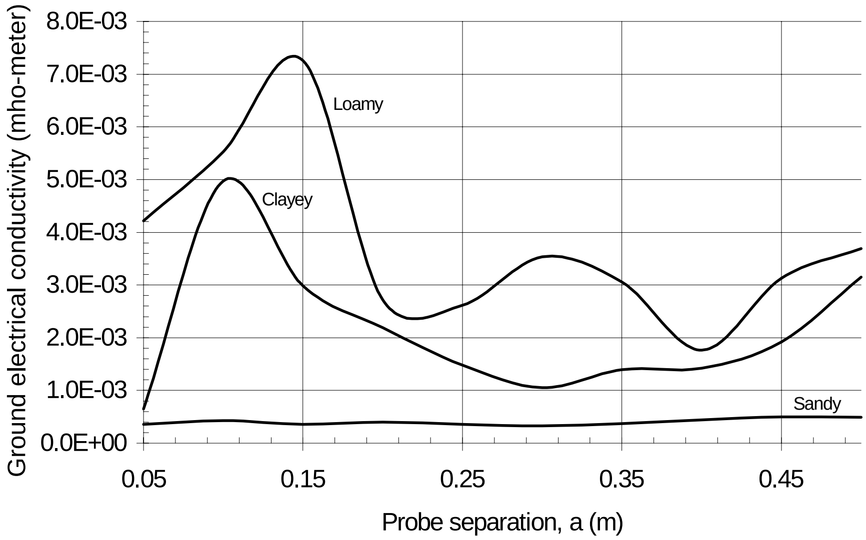

Figure 2: Variation of ground electrical conductivity with probe separation 'a' for for the three selected soil types.

The overall pattern of growth for Spinach green (*Amaranthus Cruenthus*), Spinach white (*Amaranthus Tricolar*) and Egg plant (*Solanum Macrocarpon*) on the three soil types are shown in Figs 3, 4 and 5 respectively. As the seedlings emerge from the soil, there is a period of accelerating growth. This is sometimes referred to as a period of "exponential" growth phase. This is followed by a linear growth phase and then a period when growth declines (Miller Raymond, 1992 and Berria, 1981).

The rate of growth is commonly expressed in terms of absolute rate G. It is defined as the height of the plant measured over a time interval. It can be evaluated from the "exponential" growth phase of the plant and is given by (Miller Raymond, 1992 and Tindal, 1983)

$$G = \frac{dH}{dt} = \frac{H_2 - H_1}{t_2 - t_1} \tag{8}$$

The results of the absolute growth rate of the three crops considered in this study are shown in Table 2.

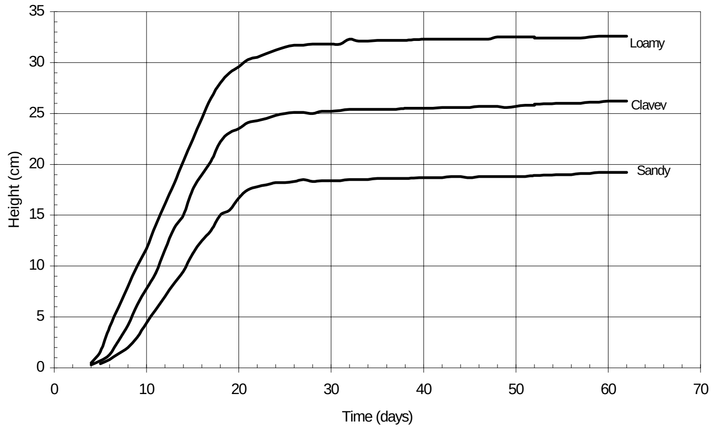

Figure 3: Growth pattern of Spinach green (Amaranthus Cruenthus)

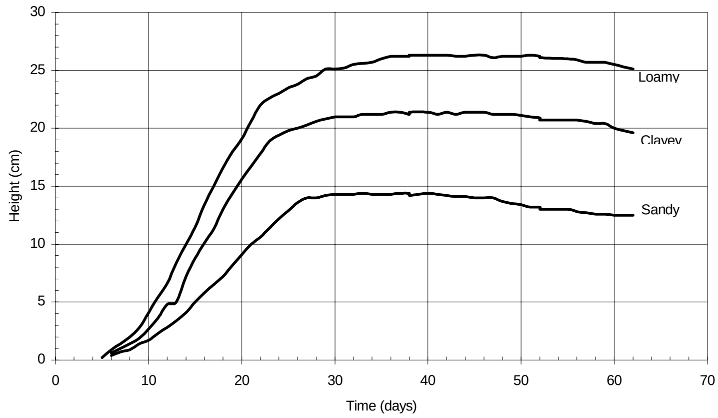

Figure 4: Growth pattern of Spinach white (Amaranthus Tricolar)**.**

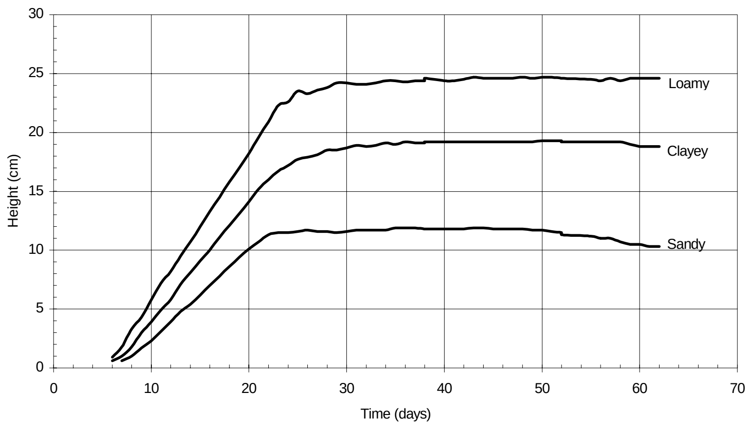

Figure 5: Growth pattern of Egg plant (Solanum Macrocarpon)

Table 2: Absolute growth rate of the three crops considered.

	G (cm/day)		
	Loamy soil	Clayey soil	Sandy soil
Amaranthus Cruenthus	2.000	1.773	1.333
Amaranthus Tricolar	1.520	1.291	0.792
Solanum Macrocarpon	1.273	1.014	0.780

The absolute growth rate is highest in loamy soil, followed by clayey soil and then sandy soil. For instance *Amaranthus Cruenthus* has absolute growth rate of 2 cm/day in loamy soil, it decreases to 1.773 cm/day in clayey and further decreases to 1.333 cm/day in sandy soil. The same trend is observed for *Amaranthus Tricolar* and *Solanum Macrocarpon*. It therefore follow that loamy soil with the highest mean conductivity has the greater tendency to support the growth rate of crops. It is the most conducting soil of the three soils under study.

Conclusion

In this work, electrical ground conductivities of loamy, clayey and sandy soil have been measured. The variation of conductivity with distance was also investigated. The results show that loamy soil has the highest mean conductivity of 3.752×10^{-3} $(\Omega m)^{-1}$ followed by clayey soil with value of 2.121×10^{-3} $(\Omega m)^{-1}$ and sandy soil has the least mean conductivity of 4.023×10^{-4} $(\Omega m)^{-1}$. The effects of this parameter on the growth rate of three vegetable crops selected for the study; *Amaranthus Cruenthus*, *Amaranthus Tricolar* and *Solanum Macrocarpon* have been examined. The results of the investigation show that loamy soil with the highest ground electrical conductivity has the greatest tendency to support the growth rate of crops. The implication of this is that a properly delineated ground electrical conductivity in the soil will help to determine areas that will support high yield of staple food crops. The in-situ method as conducted in this work in the determination of the effects of ground electrical conductivity on soil fertility is without the drawback of a size restricted characterization area and long laboratory processes of soil analysis.

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