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Original Research Article

Electrical conductivity method for predicting yields of two yam (*Dioscorea alata*) cultivars in a coarse textured soil

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ABSTRACT

Apparent Soil Electrical Conductivity (ECa) measurement is a rapid and accurate tool for measuring soil physical and chemical properties affecting crop productivity. This study uses ECa to predict yam yield. Soil ECa was measured at the depth of 0–15 cm, 15–30 cm and 30–45 cm using Miller 400D resistance meter with multi-electrode Wenner array. Soil samples were collected at the aforementioned depths and analyzed for selected physical and chemical properties. Two cultivars of water yam, *Discorea alata* L. (TDa 00/00194 (D1) and TDa 00/00006 (D2)) were planted and yield data were collected after harvesting. Data collected were analyzed using correlation, nonlinear and multiple linear regression analysis using Origin statistical software (Pro. V.8.1). Soil ECa at 0–15 cm correlated with the yields of D1 and D2 with correlations (r) of 0.83 and 0.84, respectively. The relationship between ECa and D1 and D2 were best fit with a cubic function (with $r^2 = 0.70$ and 0.75, respectively). A Multiple linear regression model showed the interactive effect of soil physical and chemical properties as it affected the yields. The generated models showed that soil properties needed for growth and yields of D1 and D2 are different. Therefore, farmers should not plant both cultivars into the same soil environment or use blanket fertilizer application to achieve optimum performance.

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1. Introduction

Pedogenic and antropogenic factors often cause variation in the soil physical and chemical properties which have great influence on agricultural productivity. Naturally, soil is greatly heterogeneous as its physical and chemical properties changes from point to point which affect crop productivity (Aminuddin, Zulkefli, Abd Razak, Abdul Munir, & Abdul Rahim, 2003). The heterogeneous nature of the soil makes uniform or blank application of agricultural input such as fertilizer, irrigation, pesticides to be inadequate for obtaining maximum productivity (precision agriculture). Changes in crop productivity are functions of the changes in the physical and chemical properties of soil (Bauer & Black, 1994; Gardner & Clancy, 1996; Olson, McQuaid, Easterling, & Scheyer, 1996). In order to enhance yield, discriminate application of agricultural inputs is essential. This could be guided by carrying out a soil survey (Nieuwolt, Zaki Ghazali, & Gopinathan, 1982). These soil productivity indices were developed using soil physical and chemical properties to characterize variability between soil types in a field (Neill, 1979; Scrivner, Conkling, & Koeing, 1985). However, this method of soil productivity indices is expensive and time consuming due to the fact that it involves intensive soil sampling and laboratory analysis.

Apparent soil electrical conductivity (ECa) is one of the simplest, cost effective soil measurements available to measure and map soil physical and chemical properties variability within field (Chan, Amin, Lee, & Mohammud, 2006). The soil ECa measurements integrate many soil properties affecting crop productivity such as soil texture, cation exchange capacity, drainage conditions, organic matter level, salinity and subsoil characteristics (Aimrun, Amin, Ahmad, Hanafi, & Chan, 2007).

With field verification, it has been reported that the spatial measurements of soil ECa or electrical resistivity have potential for predicting crop yield variation caused by differences in soil physical and chemical properties (Joshua & Mokuolu, 2016). The rapid spatial measurement of soil ECa has been demonstrated using both mobile electromagnetic (EM) induction (McNeil, 1992; Rhoades, 1992a; b; Carter, 1993; Jaynes, Colvin, & Ambuel, 1993; Kitchen, Sudduth, & Drummond, 1996) and mobile electrical resistivity equipment (Rhoades, 1992a; b; Carter, 1993). In instances

Abbreviations: D1, *Discorea alata* L. (TDa 00/00194); D2, *Discorea alata* L. (TDa 00/00006)

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where yield correlates with ECa, spatial measurements of ECa can be used in a precision agriculture context (Corwin & Lesch, 2003).

Yam (*Dioscorea spp.*) is an important tuber crop produced both as food and cash crop in Nigeria (Asumugha et al., 2009). No other crop in Africa is associated with a great amount of social and cultural activities than yam (Ikeh et al., 2012). Nigeria produces 26.587 million metric tonnes of yam annually making it the largest world producer of yam (FAO, 2006). Yam is a high nutrient demanding crop that requires large amounts of nutrients and good soil condition to maintain its optimal yield (Orkwor & Asadu, 1998). Low crop yield has been attributed to soil degradation (Oshunsanya & Akinrinola, 2013). High yield of yam could be obtained through good management of the soil using ECa. Also, there is little or no information on the estimation of yam growth and yield using electrical resistivity which offers the most veritable techniques to determine soil properties influencing yield under various agronomic conditions (Kearey, Brooks, & Hill, 2002). Hence, the objectives of this study are to: (i) identify soil properties that are highly influencing yam yield using ECa, (ii) determine the correlation between yam yield and ECa and (iii) Predict yam yield based model using soil properties.

2. Materials and methods

2.1. Study area

The experiment was carried out at the Teaching and Research Farm of the Department of Agronomy in the Faculty of Agriculture and Forestry, University of Ibadan Nigeria (latitude 7° 24' 02.9"N, longitude 3° 54' 26.25"E). The site is located in a forest savannah transition zone on a gravelly Oxic Kandiustalf with an annual rainfall of 1300 mm and average daily temperature 26 °C with a range between 18 °C and 35 °C.

2.2. Experimental layout and planting of yam setts

The two cultivars of yam planted (D1 and D2) were sourced from International Institute of Tropical Agriculture. Yam were cut into setts and air dry overnight before planting. Yam setts were planted (5 April 2015) on mounds arranged in blocks. Each cultivar occupied twelve plots with a total number of 24 plots. Each plot has an area of 6 m by 4 m occupying a total area of 576 m^2. Staking was carried out at 2 month after planting when vines were fully grown for twisting round the stake without damage.

2.3. Soil sampling and analysis

Soil samples at 0–15 cm, 15–30 cm and 30–45c m depths were collected and prepared for soil physical and chemical analysis.

Particle size distribution of the soil samples (< 2 mm) was determined using hydrometer method as described by Gee (2002), and the textural class was determined using the textural triangle. Saturated hydraulic conductivity was determined using the constant head method as described by Klute (1986). Core samples taken were used to determine bulk density using core method (Grossman & Reinsch, 2002). Total porosity was estimated from bulk density values by the formula:

$$TP = \left(1 - \frac{\rho b}{\rho s}\right) \times 100 \quad (1)$$

Where, TP = total porosity, ρb = bulk density and ρs = particle density (2.65 g cm^{-3}).

Soil total nitrogen (N) was determined using the Kjeldahl digestion procedure described by Bremner and Mulvaney (1982). While available phosphorus (P) was determined by the Bray II method (Bray & Kurtz, 1945). Exchangeable bases (Na, Mg, K and Ca) were extracted using DTPA method. Na and K were read on the Flame Photometer while Atomic Absorption Spectrophotometer is used for Ca and Mg. Soil organic carbon was determine by the Walkley-Black wet oxidation method (Allison & Moodie, 1965) and later converted to soil organic matter (SOM) by multiplying with the factor 1.724. Soil pH was adopted using pH meter. Micro nutrients (Zn, Fe, Cu, and Mn) were extracted using DTPA method and were determined by atomic absorption spectrophotometer.

2.4. Apparent soil electrical resistivity

Soil ECa is the ability of soil to transmit an electrical current. The soil ECa is a good indication of the amount of nutrients available for crops to absorb due to the fact that all the major and minor nutrients important for plant growth take the form of either cations (positively charged ions) or anions (negatively charged ions) in solution. These ions that are dissolved in the soil water carry electrical charge and thus determine the ECa level of the soil and how many nutrients are available for crops to take in.

Soil ECa measurements were taken using soil digital resistance meter with 4 electrodes (MILLER 400D) on each plot. Resistivity readings were taken very early in the morning at field capacity (soil water content). The electrodes were equally spaced while taking the reading depending on the depth of the soil being considered. For example, for 15 cm soil depth measurement, the electrodes were 15 cm spaced.

The electrical resistivity is further converted to electrical conductivity using Eq. (2):

$$ECa = \frac{1}{ERa} \quad (2)$$

$$ERa = 2\pi.\ s.\ Rw \quad (3)$$

Where ERa = measured apparent soil resistivity (Ω m), ECa = Apparent soil electrical conductivity (dS/m), s = electrode spacing (m) and R_W = resistance measured as "V/I" (Ω) according to ohm's law.

2.5. Harvesting and collection of yam tuber yield

Harvesting of yam tubers was carried out on 17 November 2015 which is about 7 months after planting. Freshly harvested tubers were weighed and recorded using weighing balance.

2.6. Data analysis

Data collected were subjected to correlation and regression analysis using ORIGIN PRO software version 8.1. Simple correlations were determined between yield and soil properties, soil properties and soil ECa, and between yam yield and ECa. Through a stepwise regression analysis, best curve fit were established for yields and ECa. Models for yields and ECa were generated using multiple linear regression analysis.

3. Results and discussion

3.1. Physical and chemical properties of soil under yam cultivation

Table 1 is a summary of the soil physical properties grown to yam. According to the texture, the experimental soil is generally a sandy loam soil, though the clay, silt and sand content vary from

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