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SOIL WATER BALANCE APPROACH IN ROOT ZONE OF MAIZE (95 TZEE-Y) USING CAPACITANCE PROBE (*DIVINER 2000*) IN NORTHERN GUINEA SAVANNAH OF NIGERIA

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ABSTRACT
Water balance approach is the simplest method in the study of plant water consumption. The experiment was established in 4.0 x 5.0 m plots in a randomized complete block design containing six (6) treatments water application (3-days, 4-days, 5-days, 6-days, 7-days and 8-days which correspond to T_1, T_2, T_3, T_4, T_5 and T_6 respectively) using gravity methods with four replications giving a total of twenty four (24) plots. One Polyvinylchloride (PVC) access tube was installed in the centre of each plots and measurements were taken daily over the growth season of March to June. The Diviner 2000 uses the method that utilizes the high dielectric constant of water compared to soil and air to determine water content of the soil. The research result from the experimental field of maize (95-TZEEY) on measurement of soil water status using capacitance probe (Diviner 2000) for three dry seasons are presented.

Keywords: Water, Diviner, Probe, Soil

INTRODUCTION

Water balance approach is the simplest method in the study of plant water consumption. Capacitance probe (*Diviner 2000*) sensors are popular electromagnetic method for estimating soil water content (Kelleners *et al*., 2004). Capacitance Probe (*Diviner 2000*) consists of two electrodes that measure capacitance of dielectric comprising in-situ soil surrounding a vertical PVC access tube. The two electrodes are in the form of coaxial cables which usually contain self-capacitance and inductance. Some researchers (Bell et al., 1987; Dean *el al*., 1987; Evett and Stener, 1995; Evett, 2000) give C (Hz), express capacitance of the soil-access tube system as:

$$C = g\varepsilon \qquad (1)$$

where ε is the system apparent dielectric constant and g has units of Farads and a value dependant on geometry of the system.

It uses a basic principle of incorporate soil into an oscillator circuit to measure its resonant frequency. The sensor reacts to capacitance of the soil and access tube system, which is related to permittivity of the soil, and thus a function of soil water content. Measurement of the dielectric constant (ε) offers a potentially and very sensitive determination of soil moisture contents. The dielectric constant for frequencies less than 1000 MHz is about 1 for air, 3 to 5 for soil particles and about 80 for water (Dean *et al*., 1987; Evett and Stener, 1995; Evett, 2000). The relative large constant of water means that dielectric constant of bulk soil is higher when soil contains more water (Dean *et al*., 1987; Paltineanu and Starr, 1997; Fares and Alva, 1999; Fares *et al*., 2000; Heng *et al*., 2000).

Thus, frequency (Hz or s^{-1}) that is a property of the electromagnetic wave (EMW) is a function of the soil dielectric constant (if EMW interacts with soil matter). Also, the soil dielectric constant (ε) is a function of the soil water content (θ). Then, frequency is a function of the volumetric soil moisture (Dim *et al*., 2005). Thus we can write

$$f(s^{-1}) = f_\theta(\theta) \qquad (2)$$

$f(\theta)$ is function of θ

Capacitance of the soil is measured by incorporating into an oscillator circuit and the resonant frequency (f) thus measured;

$$f = \frac{1}{2\pi\sqrt{LC}} \qquad (3)$$

As soil water content increases, C also increases and f decreases. A resonant LC circuit in the probe includes ensemble of soil outside the access tube, access tube itself, plus air space between the probe and access tube, as one of the capacitative elements. Changes in resonant frequency of the circuit depend on changes in capacitance of the soil-access tube system (Evett and Stener, 1995; Evett, 2000). The total circuit capacitance in this case is made up of three components, which acts both in parallel and series (Kelleners *et al*., 2004), and equation [3] is now of the form

$$f = \frac{1}{2\pi\sqrt{L\left(C_m + \frac{C_p C_1}{C_p + C_1}\right)}} \quad (4)$$

where C_m is the capacitance of the medium, C_p is the capacitance of the plastic access tube surrounding the sensor, and C_1 is the capacitance due to stray electric fields.

Since soil is part of the resonant circuit other variables in the soil will affect resonance frequency, and therefore it is necessary to suppress effect of certain variables leaving capacitance and conductivity effects.

Dielectric constant of a material arises from its polarization or electric dipole moment per unit volume. Free water molecule has a particularly high permanent electric dipole moment, which determines the high value of dielectric constant. To contribute to dielectric constant, the dielectric dipole of whatever origin, must respond to frequency of the electric field. The freedom to respond is determined by local molecular binding forces so that overall response is a function of molecular inertia, binding forces and frequency of the electric field (Dean *et al.*, 1987).

The main components that describe the estimation of plant water requirement in the plant root zone are irrigation, rainfall, drainage, evapotranspiration, and change in soil water storage of the plant root zone (Oyediran, 1977; Kirda, 1990; Lirbadi *et al.*, 1996, Das *et. al*, 2002).

MATERIALS AND METHODS

It is usual practice to use available soil water content as a criterion for deciding when irrigation is needed. Soil water content is determined by using soil measuring techniques (capacitance probe) that describe the depletion of available soil water see fig1 and 2. The irrigation scheduling is based on the water treatment (i.e. T_1, T_2, T_3, T_4, T_5, and T_6) that decides when to irrigate and observe the behaviour of the maize plants and yields for three seasons 2003, 2004 and 2005. The maize (95 TZEE-Y) takes about 11 weeks to mature. On treatment days 480 litres (about 24 mm) of water is applied to each plot. Thus the total water applied to each plot for the maize to reach its maturity is

$$\text{Total water applied by irrigation (mm)} = \text{water applied to a plot } X \left(\frac{7}{\text{treatment days}}\right) X \text{ 11 weeks}$$

Water balance approach is the simplest method in the study of plant water consumption. The main components that describe the estimation of plant water requirement in the plant root zone is given by

$$I + P - (D + ET) = \pm \Delta S \quad (5)$$

where I, P, D, ET and ΔS represent irrigation, rainfall, drainage, evapotranspiration, and change in soil water storage of the plant root zone respectively (Oyediran, 1977; Kirda, 1990; Lirbadi *et al.*, 1996, Das *et al.*, 2002). Change in soil water storage of the plant root zone (ΔS) is determined by using capacitance probe (*Diviner 2000*) a soil moisture measurement technique. This is determined by knowing the changes of water storage in the plant root zone before and after irrigation or simply the differences which could be ± (positive or negative) between the measurements done during planting and when harvesting. Only soil water content distribution profiles within the plant root zone are needed to calculate the amount of soil water stored (S(t)). This is assessed by capacitance probe as

$$S(t) = \int_0^L \theta dz \quad (6)$$

$$S(t) = \Sigma \theta \Delta z$$

where the right hand sides of the equations (6) above are the area under the soil water profile curve.

Since it is not rain fed, drainage (D) is zero (0) and from equation (5) plant water consumption is simply

$$I + P = ET \pm \Delta S$$

RESULTS AND DISCUSSION

In an irrigation situation, this information, along with soil bulk density and soil texture, would be used to determine how many "cm" of available water a soil profile would hold. This is shown in Figure 1 in which the same treatment are applied shows the graphs with similar pattern even though they are far apart, which was as a result of soil texture and soil bulk density. Figure 2 shows water intake at each "cm" of a particular treatment in which water intake level are in the same range at 30, 40, and 50 cm. This information is also useful in determining how much water can be applied to a soil before leaching of nutrients and pesticides may occur.

From the table it is easily seen that the treatment of each season differ only in evapotranspiration which determine the water at the root zone of the plant. In addition, it gives information on the available water (AW) in the field of when to irrigate to field capacity. At developmental stages for plant growth, water intakes by the plant for all treatments is proportionate to the growth of plant. At development stages the amount of soil water storage available for plant at irrigation days continues to reduce as plant grow. Crop water requirements vary with stage of growth.

The water intake by plant after ponding has similar pattern in all stages. For treatment 6, on the 6th day after ponding, about 70% of water available for plant has been used and plant begin to have water stress.

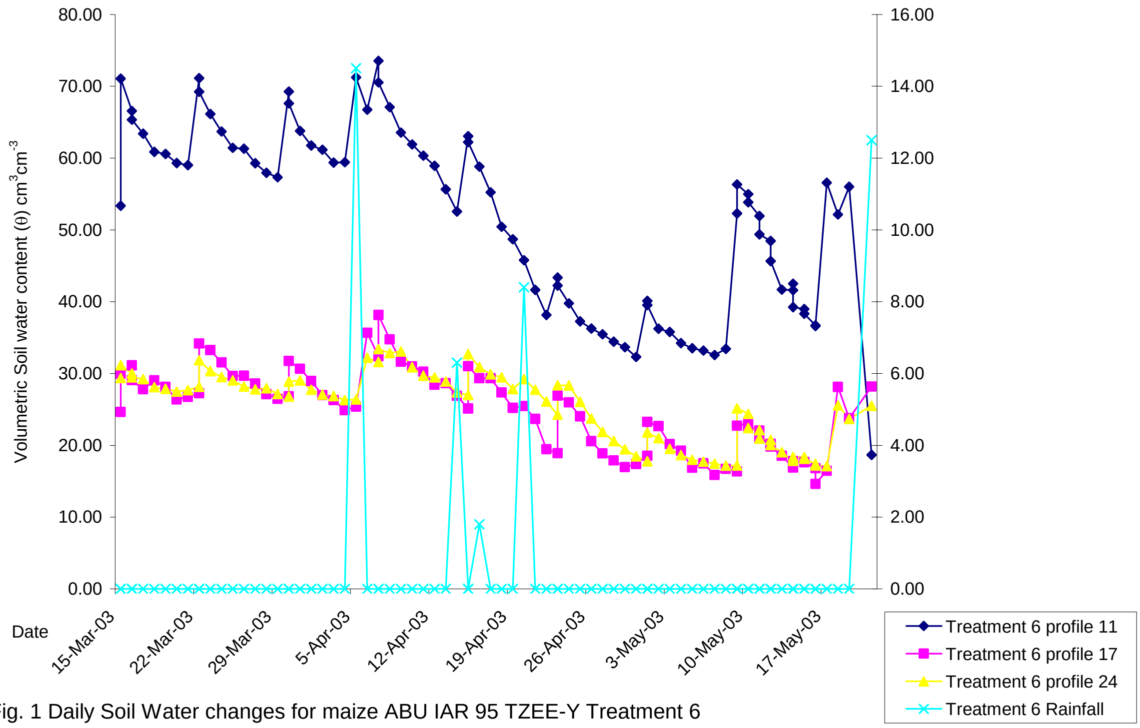

Fig. 1 Daily Soil Water changes for maize ABU IAR 95 TZEE-Y Treatment 6

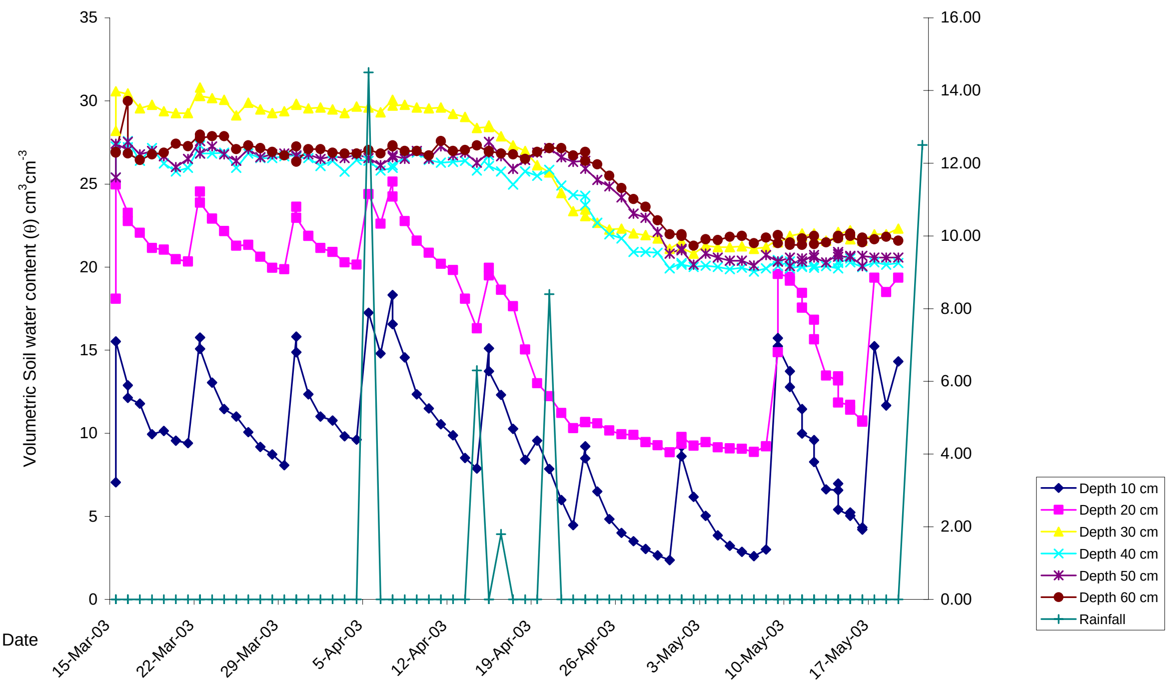

Fig. 2 Daily soil water changes for IAR ABU Maize variety 95 TZEE-Y Profile 11 Treatment 6

Table: Soil Water balance for Maize in three seasons.

	Seasons											
	2003				2004				2005			
Treatment	**I (mm)**	**P (mm)**	**ET (mm)**	**ΔS (mm)**	**I (mm)**	**P (mm)**	**ET (mm)**	**ΔS (mm)**	**I (mm)**	**P (mm)**	**ET (mm)**	**ΔS (mm)**
T_1	616	63.4	684.09	-4.69	616	121.3	750.48	-13.18	616	176	801.86	-9.86
T_2	462	63.4	526.85	-1.45	462	121.3	597.30	-14.00	462	176	648.44	-10.44
T_3	369	63.4	427.93	4.47	369	121.3	498.06	-7.76	369	176	552.99	-7.99
T_4	308	63.4	371.27	0.13	308	121.3	442.65	-13.35	308	176	482.87	1.13
T_5	264	63.4	323.07	4.33	264	121.3	391.97	-6.67	264	176	436.89	3.11
T_6	231	63.4	292.86	1.54	231	121.3	345.74	6.56	231	176	401.01	5.99

CONCLUSION

Information on water storage in the plant root zone is widely used in deciding the most suitable types of cropping system in a given region. Effective rainfalls at the end of a rainy season are easily accessed by taking measurements of changes in water storage before and after the rains. Water retention capacity of soils influencing water availability to plants and can be determined with the knowledge of the changes in water storage in the plant root zone. A number of studies have shown that water uptake from a given volume of soil depends on the rooting density and soil water properties (Kamara *et al.*, 2004). Crop water requirements vary with stages of growth.

The soil water balance equation thus helps in making estimates of parameters, which influence the amount of soil water. The periods of water stress/excesses which may have adverse affect on crop performance are easily identify from soil water balance equation. This identification will help in adopting appropriate management practices to alleviate the constraint and increase the crop yields.

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