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Dielectric Technique for Measuring Soil Water Content

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ABSTRACT

The water content present in soil samples collected from the agricultural field has been reported in this work. The amount of water content present in the soil samples has been evaluated from the dielectric data. The dielectric data that is dielectric constant of the soil samples is confirmed from microwave X- band set up. The amount of moisture present in the soil has been evaluated using Topp calibration equation. The physical – chemical properties of the said soil samples have been calculated and reported. The results show that the dielectric constant of the black soil is higher than that of red soil indicates presence of higher water content in that particular soil sample.

Keywords*:* Dielectric constant; Water content; Soil samples; Soil texture; Physical- Chemical properties

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INTRODUCTION

Water is required in some way by all living things; it is a fundamental constituent of life on our planet. Our survival as well as that of other organisms depends on a supply of water both to our own bodies best ways to regulate water consumption is to know the quantity available and to manage the resource with prudence and stewardship. To achieve this aim, techniques are preferred that can be used to measure a physical quantity closely related to the amount of water contained in a porous material, be it rock, soil, or an artificial medium [1].
There are lots of development in the agricultural such as equipments, knowledge, and number of things that affect crop productivity. Farmers involved in precision agriculture can now get more detailed information about their farming options than ever before. In addition to yield boundary and field attribute maps, new electronic, mechanical and chemical sensors have been developed to study soil and plant properties [2, 3].
The real part of complex dielectric constant is an important parameter through which soil water content can be determined. The knowledge of the behavior of soil water is useful since it affects intensively many physical and chemical reactions of the soil as well as plant growth. The soil water content plays an important role in many agronomic, ecological and hydrological investigations to understand the soils chemical, mechanical, hydrological and biological relationships. The theoretical basis for soil moisture measurement is based on large contrast between dielectric constant of water (80) and that of dry soil [4, 5]. The dependence of dielectric constant on moisture can be measured with time domain reflectometry (TDR), frequency domain reflectometry (FDR) or number of sensors available in the market [6-12].
The soil water content is most important physical property of the soil which is used to characterize the availability of water for plants. Large range of approaches is available to measure this. The aim of these methods is either to provide fast measurement value or to provide value for continuous measurements over large periods. All approaches need calibrations for individual soil if absolute values are actually needed and they can have a restricted linearity at high or low moisture ranges. Most alternative methods describe the physical properties of a very restricted solid volume, which then becomes the representative for a large bulk volume. Several reviews of soil water content measurement have been published in the past, notably those by [13]. More recently, another review has been published by [14, 15] has provided very useful summaries of theory and practice of many of the techniques available, and the contribution of the Gardener has been revised and updated [16-21].
The aim of this work is to determine soil water content from dielectric data. Black and red color soil samples have been used for the study. The physical – chemical properties of the soils have been measured and reported which is useful for agricultural productivity.

MATERIALS AND METHODS

Measurement of dielectric constant

The dielectric constant of the soil samples is measured using transmission line waveguide set up which is reported in our previous work [22, 23]. The soil samples were collected from the agricultural land and brought to laboratory for further study. Dielectric constant of the soils was determined at 9-GHz frequency and at room temperature. Measurement of each sample was repeated at least for three different lengths. The dielectric constant was evaluated for each length and an average value of the three was taken as dielectric constant of that soil sample. The accuracy in dielectric constant measurement was ± 0.3 %. From the experimental dielectric data the water content present in the soil was evaluated by using following Topp calibration formula [24].

$$(\theta = 5.3 \times 10^{-2} + 2.92 \times 10^{-2} K - 5.5 \times 10^{-4} K^2 + 4.3 \times 10^{-6} K^3)$$

Where θ volumetric water content and K is is the dielectric constant of the soil sample.

Soil sampling

Soil samples were collected from 10 to 15 cm depth at different points on the agricultural field. Around 10 to 12 samples were taken from each site. After removing surface organic materials and fine roots all samples mixed thoroughly to make one composite sample. The soil samples then brought to laboratory in rigid containers to avoid atmospheric changes and breaking the soil aggregates. After air drying for a week, the soil sample was divided into two groups for analysis. Prior to the analysis, each soil sample was passed through a 5 mm sieve.

Soil Characterization

Soil P^H was measured in distilled water at the soil: water ratio as 1:5 with a PH meter after shaking the suspension for 30 min and equilibration for 30 min. The same suspension was used to determine the electrical conductivity (EC) after allowing them to settle for half an hour. Particle size distribution was determined using mechanical sieves. The other physical-chemical properties like TDS, gravimetric water content, volumetric water content, soil melting capacity, bulk density, porosity, water holding capacity and fertility were measured in laboratory.

RESULTS AND DISCUSSION

The experimental dielectric data of the two soil samples is given in Table 1. The dielectric constant of black soil is higher than that of red soil. This may be due to the soil texture, the black soil has higher percentage of clay and silt than that of red soil therefore its water holding capacity is more than that of red soil.

Table 1: Experimental values of dielectric constant

S. No.	Soil color	Frequency	Dielectric constant	Volumetric water content (cm.cm-3)
1	Black	9.0 GHz	6.97	0.125
2	Red	9.0 GHz	6.23	0.1

From Table 1 it is also observed that the experimental dielectric constant values are higher than the expected values at the studied frequency. Because, both the soil samples contain some amount of water content that will directly affect the dielectric constant. Since the observations were noted by considering the soil samples as dry. Even though the soil samples were air dried, they still content an unknown and unspecified amount of water like hygroscopic and crystal-bound. Dielectric constant is, therefore, very nearly proportional to the square of the water content [25, 26].

The soil texture data of both the soil samples is noted in Table 2. The soil texture decides the quality of land and water holding capacity of the soil. According to the data obtained, the black soil has higher percentage of clay and silt than that of red soil. Therefore the black soil has higher water holding capacity than that of red soil and it is better for more agricultural productivity than that of red soil.

Table 2: Soil texture

S. No.	Soil texture	Black soil	Red soil
1	Coarse Sand (Percentage)	6.07	27.56
2	Fine sand (Percentage)	7.56	18.93
3	Silt (Percentage)	39.21	23.24
4	Clay (Percentage)	47.16	30.27

The soil physical properties of studied soil samples are illustrated in Table 3. Amongst the physical properties, the water holding capacity and soil melting capacity of the black soil is higher than that of red soil.

Table 3: Soil physical properties

S. No.	Physical properties	Black soil	Red soil
1	Gravimetric water content (θg)	0.12 $g.g^{-1}$	0.10 $g.g^{-1}$
2	Volumetric water content(θv)	0.13 $cm.cm^{-3}$	0.11 $cm.cm^{-3}$
3	Soil melting capacity	0.48%	0.32%
4	Water holding capacity	44.83%	32.21%
5	Bulk density	1.26 g/cm^3	1.32 g/cm^3
6	Soil porosity	0.54	0.5

The soil chemical analysis or fertility of both the soil samples is given in Table 4. The data shows both the soil samples have around equal amount of available organic carbon. The black soil has higher percent of phosphate and potassium than that of red soil.

Table 4: Soil chemical properties

S. No.	Chemical Composition	Black soil	Remark	Red soil	Remark
1	Organic carbon (% by wt)	Below 0.5 %	Low	Below 0.5%	Low
2	Nitrate (Kg/hectare as N)	20.41	High	20.41	High
3	Available phosphate (Kg/ hectare as P_2O_5)	Above 29.48	High	0	Low
4	Available potassium (Kg/hectare as K)	158.76	Very high	45.36- 113.40	Medium
5	Ammoniacal Nitrogen(Kg/hectare as N)	5.89	Low	29.48	Medium
6	Conductivity	1410 μ/cm	Non-saline	225 μ/cm	Non-saline
7	Total dissolved solids (TDS)	775-1057 ppm	Medium	123-168 ppm	less
8	pH	7.7	Slightly basic	7.9	Slightly basic

CONCLUSION

The dielectric constant of both the soil samples is higher than the excepted values indicate the presence of water content even though the soil samples are dry.

The results of soil texture show that, the black soil has higher percent of clay and silt, which are useful to improve the water holding capacity. This shows that land with black soil is better for agricultural production than that of red soil and the same thing has been confirmed from the physical properties.

The PH and conductivity of both the soils is slightly basic and non-saline respectively.

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