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Research Article

ELECTRICAL CONDUCTIVITY AND DIELECTRIC CONSTANT AS INDICATORS OF AVAILABLE TOTAL MACRO AND MICRO NUTRIENTS IN THE SOIL

P. R. Chaudhari* and D. V. Ahire
Microwave Research Laboratory, Z. B. Patil College, Dhule-424002, INDIA
**Author for Correspondence*

ABSTRACT
The aim of this study was to evaluate the status of available total primary macronutrients (N+ P+ K), total secondary macronutrients (Ca +Mg) and total micronutrients (Cu+ Fe+ Mn+ Zn) in the soil from its electrical conductivity and dielectric constant. We have collected 8 samples (depth 0 - 15 cm) from different locations in North Maharashtra region. The soils were categorized as loamy sand, sandy loam and clay loam. The soils were analyzed for the status of available nutrients. A pH and Electrical Conductivity of soil samples were measured by Soil Testing Kit. The dielectric constant was measured at X- band microwave frequency 10 GHz by using waveguide cell method. The statistical analysis of result shows high degree positive correlation of electrical conductivity and dielectric constant of soil samples with available nutrients in soil samples while negative correlation with pH of soil samples. Regression equations are obtained to evaluate status of available total Macro and Micro nutrients from electrical conductivity and dielectric constant of soil.

Key Words: *Electrical conductivity, dielectric constant, nutrients, X- band microwave frequency*

INTRODUCTION

Soil is an extraordinarily complex medium made up of a heterogeneous mixture of solid, liquid and gaseous materials and is composed of layers. It is an important natural resource and plays a crucial role in maintaining environmental balance. Soil fertility is one of the important factors controlling yields of the crops. It also plays major role in determining the sustainable productivity of an agro-eco system. The sustainable productivity of a soil mainly depends upon its ability to supply essential nutrients to the growing plants. Proper nutrition is essential for satisfactory crop growth and production.

The mineral fraction of soil contains particles of widely varying sizes, shapes and chemical compositions. The properties of soil are mainly classified into three groups i) Physical ii) Chemical & iii) Electrical. The electrical properties of material are mainly the permittivity and permeability. The electrical characteristic of every material is dependent on its dielectric properties. Measurements of these dielectric properties can provide valuable information of material characteristics, design parameters for many electronic applications, and remote sensing applications. The permittivity and permeability of a material are not constant, but can change with frequency, temperature, orientation, mixture, pressure and molecular structure of the material. Conductivity is also another important electrical property of the material, which may depend on the salinity and chemical composition of material.

Laboratory soil test is usually time consuming and laborious. Since farmers cultivate annual crops more than once a year, this leads to delay in remedial action for the coming season. Hence, rapid measurement and monitoring of soil nutrient variability is needed to satisfy the precision farming requirements. These problems can be solved by measuring electrical conductivity (EC) of soil. Papendick and Parr (1992) reported that soil test can help in determining the status of available nutrients to develop fertilizer recommendations for optimum crop production. Kumar and Babel (2011) showed that the amount and availability of nutrients is controlled by physico-chemical and electrical properties of soil. The particle shape of soils, soil moisture contents and presence of chemical properties influence electrical conductivity of soil (Chik and Islam, 2011). Electrical conductivity has generally been associated with determining soil salinity; however, EC also can serve as a measure of soluble nutrients (Smith and Doran, 1996). In general, EC can be influenced by a number of different soil properties, including clay content and soil water content (Kachanoski *et al.*, 1990).

The dielectric constant is a complex number and is a function of frequency. The real part of the dielectric constant of soil particles is between 3 and 6 depending on the orientation of the particles. Calla *et al.* (1999) have carried out extensive and systematic studies on the dielectric behavior of soils of Rajasthan and also from many parts of northern India.

In the present work our aim is to measure electrical conductivity and dielectric constant of soil samples from North Maharashtra Region and use them to evaluate status of available total primary macronutrients, total secondary macronutrients and total micronutrients in the soil.

MATERIAL AND METHODS

Soil samples (0-15cm) were collected from 8 sites covering North Maharashtra Region, keeping in view the physiographic characteristic in different cross sections of the area as well as variation in soil texture. Soils were completely air dried and passed through 2mm sieve and stored in properly labeled plastic bags for analysis. The sieved out fine particles are then oven dried to a temperature around 110^0 C for several hours in order to completely remove any trace of moisture.

The samples were analyzed for the status of available nutrients by standard analytical methods from Govt. College of Agriculture, Dhule. The nutrient concentrations of soil samples are represented in Table1.

Table 1: Nutrients and Chemical Properties of Soil Samples

Sample No. (Location)	(N+P+K)	(Ca+Mg)	(Fe+Mn+ Zn+Cu)	OC	CaCO3	pH
1. Amalner	864.9	247	22.90	0.65	4	7.2
2. Erandol	817.2	241	20.74	0.7	4.2	7.6
3.Shirpur	765.0	217	15.36	0.42	4.9	8
4.Dhule	693.4	216	16.20	0.5	5.5	8
5. Shahada	714.3	155	16.24	0.43	5.8	7.9
6. Kalwan	664.8	166	13.44	0.3	5.7	8.4
7.Satana	678.0	143	09.41	0.4	3.9	7.8
8.Nandurbar	581.2	116	08.87	0.23	6.4	8.25

EXPERIMENTAL

Measurement of Electrical Conductivity and pH of Soil Samples: A pH and Electrical Conductivity of soil samples were measured by Soil Testing Kit Model 161E. A 20 gm of collected soil was weighed out into a 150 ml plastic jar and 100 ml distill water was added to it. Lid of jar was packed tightly and stirred continuously for 5 minutes. Then it was kept overnight and stirred again. Allowed to set for 15 minutes and strained sample into clean measuring cup. A pH and Electrical conductivity readings were taken.

Measurement of Dielectric Constant of dry Soil Samples: The waveguide cell method (Chaudhari *et al.*, 2012; Gadani and Vyas, 2008) is used to determine the dielectric properties of the dry soil samples. An automated C-band microwave set-up in the TE10 mode with Gunn source operating at frequency 10 GHz, PC-based slotted line control and data acquisition system is used for this purpose. The solid dielectric cell with soil sample is connected to the opposite end of the source. The signal generated from the microwave source is allowed to incident on the soil sample. The sample reflects part of the incident signal from its front surface. The reflected wave combined with incident wave to give a standing wave pattern. These standing wave patterns are then used in determining the values of shift in minima resulted due to before and after inserting the sample. Experiments were performed at room temperatures ranged between 25^o-35^o C. Other details of dielectric constant measurement with X-band microwave bench set-up can also be seen from Fig.1

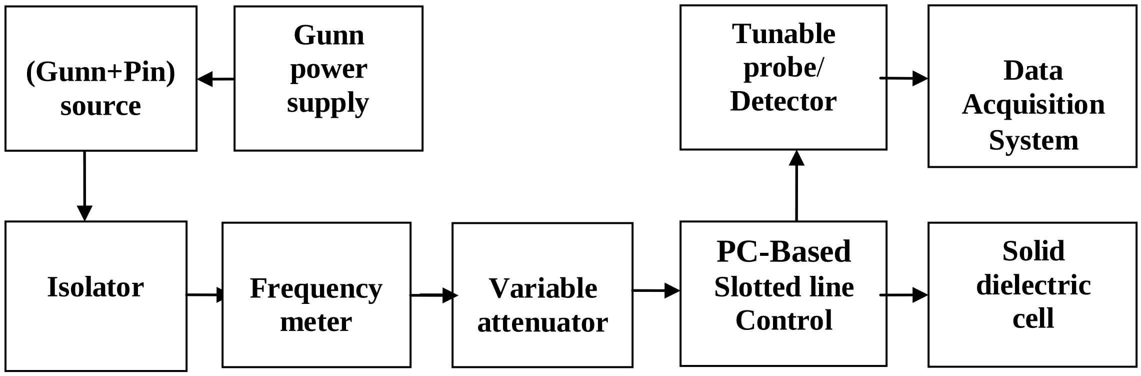

Figure 1: Block diagram of microwave bench setup for measurement of dielectric constant of Soils

Dielectric constant (ε'): The dielectric constant ε' of the soils is determined from equation 1.

$$\varepsilon' = \frac{g_{\varepsilon} + (\lambda_{gs}/2a)^2}{1 + (\lambda_{gs}/2a)^2} \qquad \text{………… 1}$$

Where, a = Inner width of rectangular waveguide

λ_{gs} = wavelength in the air-filled guide, g_{ε} = real part of the admittance

The values of electrical conductivity and dielectric constant are listed in **Table 2**.

Table 2: Electrical Conductivity (EC) and Dielectric (DC) of Soil Samples

Sample No.→	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
E C(dSm-1)	0.33	0.30	0.26	0.17	0.20	0.18	0.15	0.10
DC	3.5	3.00	3.4	3.3	3.2	3.1	3.0	2.75

Statistical analysis: The correlation coefficient ‘r’ of dielectric constant with soil parameters and nutrient concentration is obtained by using equation 2.

$$r = \frac{n\sum xy - \left(\sum x\right)\left(\sum y\right)}{\sqrt{n\left(\sum x^2\right) - \left(\sum x\right)^2}\sqrt{n\left(\sum y^2\right) - \left(\sum y\right)^2}} \qquad \text{……..… 2}$$

Where n is the number of pairs of data (x, y).

Table 3: Correlation Coefficients and Regression Equations

Soil Parameters (y)	**Correlation Coefficient (r)**		**Regression Equations**	
	with EC	**with DC**	**with EC**	**with DC**
(N+P+K)	0.9829	0.6957	y = 1130* EC + 483.5	y = 257.8* DC -91.49
(Ca+Mg)	0.8849	0.7085	y = 549.6* EC + 71.50	y = 141.8* DC -260.0
(Fe+Mn+Zn+Cu)	0.9160	0.6656	y = 57.17* EC + 3.317	y = 13.38* DC-26.85
pH	-0.7635	-0.4837	y= -3.637* EC+ 8.662	y=-0.742* DC + 10.23
OC	0.8485	0.4899	y = 1.729* EC+ 0.088	y=0.321* DC - 0.562
CaCO3	-0.6465	-0.3563	y = -7.727*EC+ 6.682	y=-1.372* DC + 9.381

The correlation coefficients (r) of dielectric constant with nutrient concentration and chemical parameters of soil samples and corresponding regression equations are given in Table 3.

RESULTS AND DISCUSSION

Soils were categorized as Clay, Silty Clay Loam, Clay Loam, Loamy, Sandy Clay Loam and Sandy Loam. All eight soil samples were found to be moderately calcareous (3.9 – 6.4 %) in nature. The pH (7.2 - 8.4) values and electrical conductivity values (0.10 – 0.33 dS/ m) indicated that all soil samples were found to be slightly to moderately alkaline and non saline in nature.

According to Methods Manual , Soil Testing in India (2011) the critical limits of Nitrogen (N), Phosphorus (P) and Potassium (K) for normal growth of plant were 280 kg/ha, 10 kg/ha and 108 kg/ha respectively. Consideration of these the available N (160 - 238 kg/ha) was low, P (6.2 - 16.9 kg/ha) of soils was ranging from low to high, while the available K (412 - 610 kg/ha) was very high. All soil samples were containing adequate amount of available Calcium (Ca) (98 - 200 meq/100 gm) and Magnesium (Mg) (18 – 49 meq/100 gm).

The critical limit of Fe is considered as 4.5 ppm for normal growth. Considering this limit only two soil samples 1 and 2 were containing sufficient amount (4.6 and 4.8 ppm) while the remaining soil samples were found to be deficient in available Fe (2.0 – 3.9 ppm).

The critical limit for available Mn is reported as 4.7 ppm. All soil samples were appeared to be high in available Mn (5.6 - 15 ppm).

The critical limit suggested for Zn is 0.5 to 1.00 ppm, according to which all soil samples are quite sufficient in available Zn (0.52 – 1.34 ppm) except sample 8 (0.32ppm).

Considering 0.66 ppm as critical limit of Cu for normal growth of plant, it may be inferred that all soil samples were contain adequate amount of available Cu (0.65 - 2.1 ppm).

For statistical analysis instead of individual content of nutrients we considered the total primary macronutrients (N +P +K) ranging from 581.2 to 864.9 kg/ha, total secondary macronutrients (Ca +Mg) ranging from 116 to 247 kg/ha and total micronutrients (Fe + Mn+ Zn+ Cu) ranging from 8.87 to 22.9 kg/ha.

Relationship of Electrical Conductivity and Dielectric Constant with total Macronutrient status of soil

High degree Positive correlation of electrical conductivity was found with available total primary macronutrients (N+ P+ K) (r = 0.9829). While there was Significant Positive correlation between dielectric constant and available total primary macronutrients (N+ P+ K) (r = 0.6957) of soil.

As that of total primary macronutrients, electrical conductivity has Strong Positive correlation with available secondary macronutrients (Ca+ Mg) (r = 0.8849) while dielectric constant has Significant Positive correlation with available secondary macronutrients (Ca+ Mg) (r = 0.7085) of soil.

Relationship of Electrical Conductivity and Dielectric Constant with total Micronutrient status of soil

High degree Positive correlation was observed between electrical conductivity and total micronutrients (Fe +Mn +Zn +Cu) (r = 0.9160) of soil. While there was significant positive correlation between dielectric constant and total micronutrients (Fe +Mn +Zn +Cu) (r = 0.6656) of soil.

Thus it was inferred that electrical conductivity and dielectric constant of soil are positively correlated with total macronutrient and total micronutrient concentrations of soil but correlations with electrical conductivity were found to be more significant than with dielectric constant.

Relationship of Electrical Conductivity and Dielectric Constant with pH, Organic Carbon and CaCO3 of soil

Strong negative and strong positive correlations of electrical conductivity respectively with pH (r = - 0.7635**)** and organic carbon (r = 0.8485) of soil were observed. While significant negative correlation was found between electrical conductivity and $CaCO_3$ (r = - 0.6465) of soil.

On the other hand it was found that dielectric constant has significant negative and significant positive correlations respectively with pH (r = -0.4837) and organic carbon (r = 0.4899) of soil. While there was negative but not significant correlation with $CaCO_3$(r = -0.3563) of soil.

Similar findings about relationship between available micronutrients, pH and electrical conductivity of soil were reported by Kumar and Babel (2011), Gadani and Vyas (2008) and Heiniger *et al.* (2003).

Conclusions

Electrical conductivity of soil samples has high degree positive correlation with available total primary macronutrients (N+P+K), total secondary macronutrients (Ca+ Mg) and total micronutrients (Fe +Mn+ Zn +Cu). However with dielectric constant they do not have so strong correlations.

High degree positive correlation of electrical conductivity and significant positive correlation of dielectric constant with organic carbon content of soil are observed.

High degree negative correlation of electrical conductivity of soil samples with pH and significant negative with $CaCO_3$ content of soil is obtained.

Dielectric constant has significant negative correlation with pH while it has negative but not so significant correlation with CaCO3.

The values of chemical parameters and status of available nutrients can be obtained from measured electrical conductivity and/or dielectric constant of soil with the use of regression equations in Table 3.

As compared to dielectric constant, electrical conductivity has more significant correlations with total nutrient concentrations and chemical parameters of soil samples.

This study helps in determining the values of different chemical parameters and the nutrient concentrations of soil from North Maharashtra region by using known electrical conductivity and/or dielectric constant (at Microwave Frequency in X band region) of soil.

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