Primary Nutrient Determination in the Cultivated Soil

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Abstract: **The goal of accurately mapping of soil properties is to analyze various primary nutrients (NPK) in the soil. In this paper we discussed spectroscopy and conductivity measurement technique for primary nutrients determination. In the conductivity measurement, we observed that conductivity of the soil depends on the concentration of primary nutrients. The results are verified for Potassium nutrient by conductivity setup. In spectroscopy method, results are tested for potassium nutrient. Experimentally it has been found that maximum absorbance is at 260 nm and as concentration of the Potassium increases the absolute value of absorbance also increases. The results are helpful in analyzing primary nutrients in the soil.**

Keywords: **NPK, Spectroscopy, Absorbance, Conductivity measurement, Conductance.**

I.   INTRODUCTION

It is known that agricultural yield is an outcome of complex interaction of seed, water, soil and agro chemicals (including fertilizers).Precision Agriculture (PA) brings judicious management of all inputs essential for better outcome [1].Technology plays a catalytic role in striking a common ground between environmental and economic goals. The most used techniques in precision agriculture are Global Positioning System (GPS) receivers, yield monitoring, grid soil sampling & mapping, Variable rate fertilizer (VRT) application, Remote Sensing (RS) and Crop scouting [2].

To optimize the management of PA inputs according to site-specific needs, large data collection of geo-referenced information about the site is required. This database mainly includes real time information about soil and crop properties like texture, pH, moisture and nutrients contain etc [3].

Qualitative and quantitative yield of crop is greatly depend on primary nutrients in the soil. Primary nutrients in the soil are Nitrogen (N), Phosphorus (P), and Potassium (K). The application of N, P, and K fertilizers has contributed to a tremendous increase in yields of agricultural crops. However, excessive use of these fertilizers has been cited as a largest source of contamination of surface and groundwater. Ideally, application rates should be adjusted based on estimates of the requirements of crops at each location because of high spatial variability of N, P, and K within individual agricultural fields [4]. Thus on field portable soil sensor is required to determine nutrient in the soil. On field sensors are of two types, on- the- go soil sample and intensive grid sampling. On-the-go soil sensor technologies can serve as a rapid method for measuring soil properties. Intensive grid sampling is laborious, time consuming expensive and thus impractical for implementation in large scale [4].

Table 1 shows different types of on the go sensor that can be used to real time information of soil.

TABLE I: On-the-go soil sensor types and their applications [4-6].

Sensor type	Example and applications
Electrochemical	Soil pH, nitrate, potassium
Electrical and electromagnetic	Soil texture (sand, silt, clay), soil moisture content soil depth, cation exchange capacity
Optical and radiometric	Soil organic matter, soil moisture
Acoustic	Soil texture (sand, silt, clay), soil bulk density soil depth variability (depth of top soil)
Mechanical	Soil compaction, compacted soil

From the Table 1, it can be seen that there are three methods to sense primary nutrients (NPK) in the soil.

These methods are conductivity measurement, optical method and electrochemical methods to analyze concentration of primary nutrients.

Conductivity can be measured using various electrodes as Steel, Silver, Platinum, Graphit and Copper. To measure electrical conductivity two or three electrodes of same material are immersed in samples. AC voltage is applied to one electrode; another electrode is connected to multimeter to measure the current changes. Varying current gives varying conductivity. Electrical conductivity varies with concentration Nitrogen (N), Phosphorus (P) and Potassium (K) [7]. ISE and ISFET selects particular ion from samples using sensor cocktail. ISEs/ISFETs uses different membranes, extraction solutions and a multi-target system with coated wire field-effect transistor [8].

The last type for soil sensor technology is optical sensor. Principal of optical techniques is based on the interaction between incident light and soil surface properties, such that the characteristics of the reflected light vary due to the soil physical and chemical properties. Laser Induced Florescence Spectroscopy (LIFS) and Near InfraRed spectroscopy (NIR) are main optical techniques. In LIFS technique analyte in the molecule absorbs radiation at a certain wavelength (usually UV and visible regions) and emits photon.[9-10]. NIR experimental setup was prepared by Burns,D.A, and Ciurczak E.W [8]was then modified by Alanso [9], C.D. Christy, P. Drummond, and E. Lund [11] and Peter Scharf [12-13]. The setup is as shown in Fig 1.
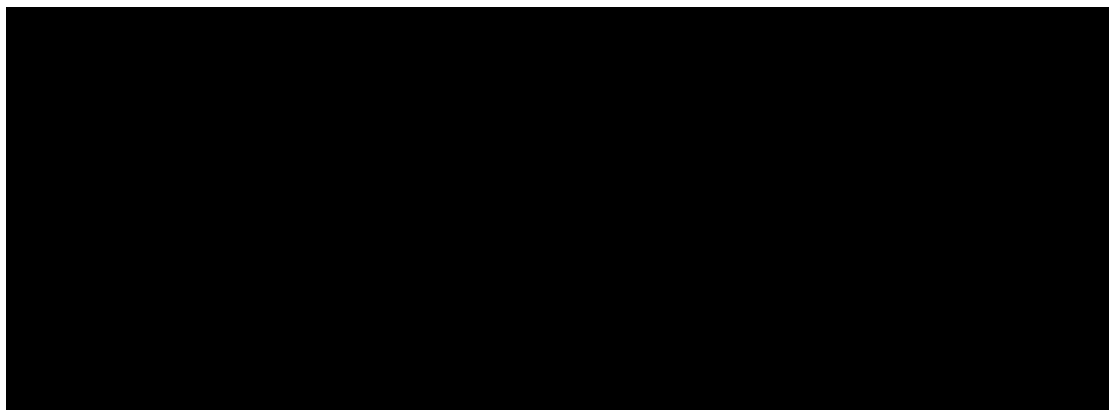

Fig 1: NIR Spectroscopy [11]

In the setup, Tungsten-halogen lamps are the most common light sources with quartz windows monochromator which selects required wavelength. This light is incident on samples whose concentration is to be measured. As per the primary nutrients concentration, reflectance spectra of sample varies at predefine wavelength.

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II.   METHODOLOGY

It is known that agricultural yield is an outcome of many components like seed, water, soil and agro chemicals (including fertilizers). Soil contains micro nutrients like Nitrogen (N), Phosphors (P) and Potassium (K). These micro nutrients decides qualitative and quantitative yield of crop. As the time progresses amount of these micronutrients changes bringing down the yield of crop. It is advisable to collect real time soil characteristics which determine concentration of NPK in the soil. In this paper, experimental setup and results of UV spectroscopic methods and conductivity measurement method for NPK determination are discussed.

III.   UV SPECTROSCOPY METHOD FOR NPK DETERMINATION

In optical method UV spectroscopy module is used. This deals with the interactions of ultraviolet radiation with the sample under investigation. It is based on the absorption of electromagnetic radiation at wavelengths in the range of 200-400 nm. Non-bonding electrons (n-electrons) in the molecules can absorb the energy in the form of ultraviolet or visible light. To excite these electrons to higher anti-bonding molecular orbitals UV light Provides energy. Lower is the energy gap between the HOMO and the LUMO, longer the wavelength of light it can absorb. UV spectroscopy follows Beer-Lamberts law. The Beer- Lambert law states that the absorbance of a solution is directly proportional to the concentration of the absorbing species in the solution and the path length. Thus concentration of the particular element in a solution can be determine by using UV spectroscopy at its fixed path length. It is necessary to know how quickly the absorbance changes with concentration. This can be taken from references (tables of molar extinction coefficients), or more accurately, determined from a calibration curve. Spectrum is a plot of energy (reflectance, absorption or transmittance) versus wavelength, for measuring energy transmission [14].

A.UV reflectance analysis

The instrument used in ultraviolet-visible spectroscopy is called a UV spectrophotometer. It measures the intensity of light passing through a sample (I), and compares it to the intensity of light before it passes through the sample (I0). The ratio (I/I0) is called the transmittance; it is expressed as a percentage (%T). The absorbance can be given as A= (-log T)
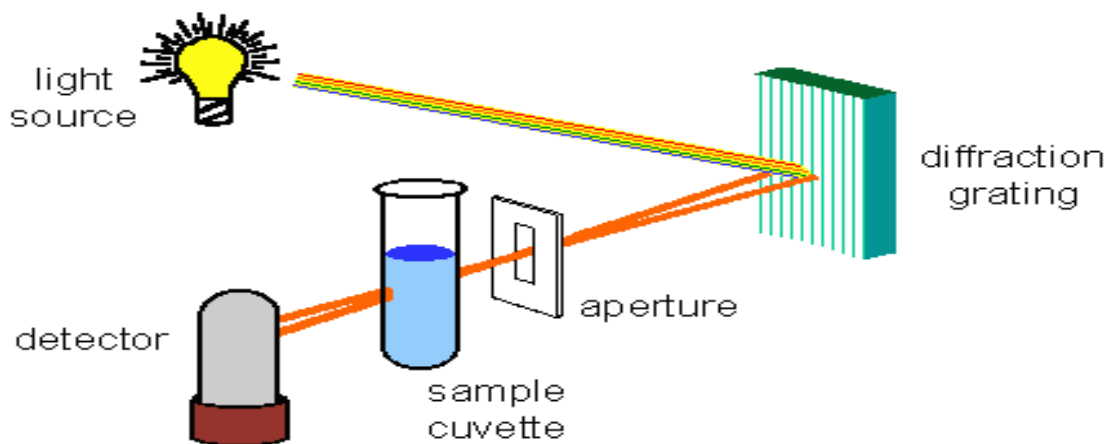

Figure 2: UV Spectroscopy [15]

B. Preparation of soil samples and experimentation

Soil samples were collected from Mahatma Phule Agriculture College, Pune, and Maharashtra. Seven samples were collected from different agricultural plot which are already ploughed up. Soil samples were transferred to plastic bags and were labeled as sample number 1, 2, 3 respectively. In the lab, the samples were air-dried, external objects were removed by sieving. For experimentation aqueous solution of soil residue with varying ion concentration were prepared. For each sample of soil is added with distilled water in the ratio 1:2.5. various chemical solutions were prepared by adding Potassium Iodide UV spectroscopic analysis was performed in two stages as initial analysis and detailed analysis.

C. Initial analysis of soil samples

In the first stage four different soil samples were mixed with distilled water in 2.5:1 ratio to the soil. These samples are then filtered using whatman filter paper. The samples are then analyze using Varian 100 carry spectrophotometer. The soil sample spectrum for soil sample 1, soil sample 2, soil sample 3, and soil sample 4, are shown in Fig 3, fig 4, Fig 5 and Fig 6 respectively
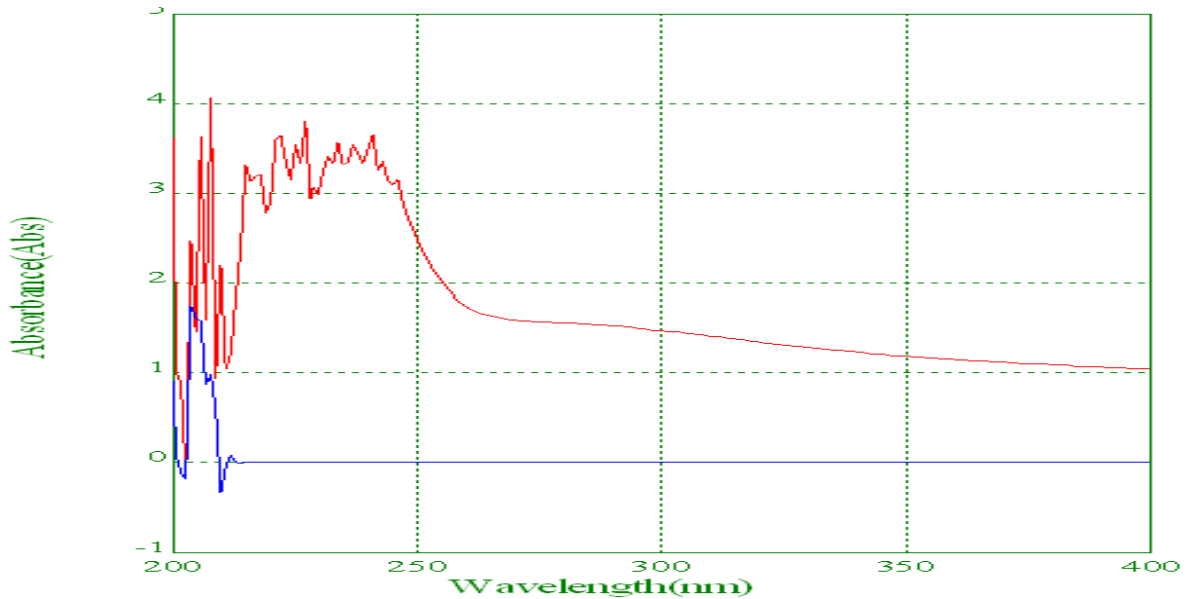

Fig 3: Absorbance spectrum for soil sample 1

Soil for sample 1 is collected from corn farm. Soil consists of high potassium. Blue curve is spectrum of distilled water and red curve is spectrum of soil sample 1.wavelength is shown on X axis and absorbance is shown on y axis.

Fig 4: Absorbance spectrum for soil sample 2

Soil for sample 2 is collected from sugarcane farm. Soil consists of high potassium. Blue curve is spectrum of distilled water and red curve is spectrum of soil sample 1.wavelength is shown on X axis and absorbance is shown on y axis.
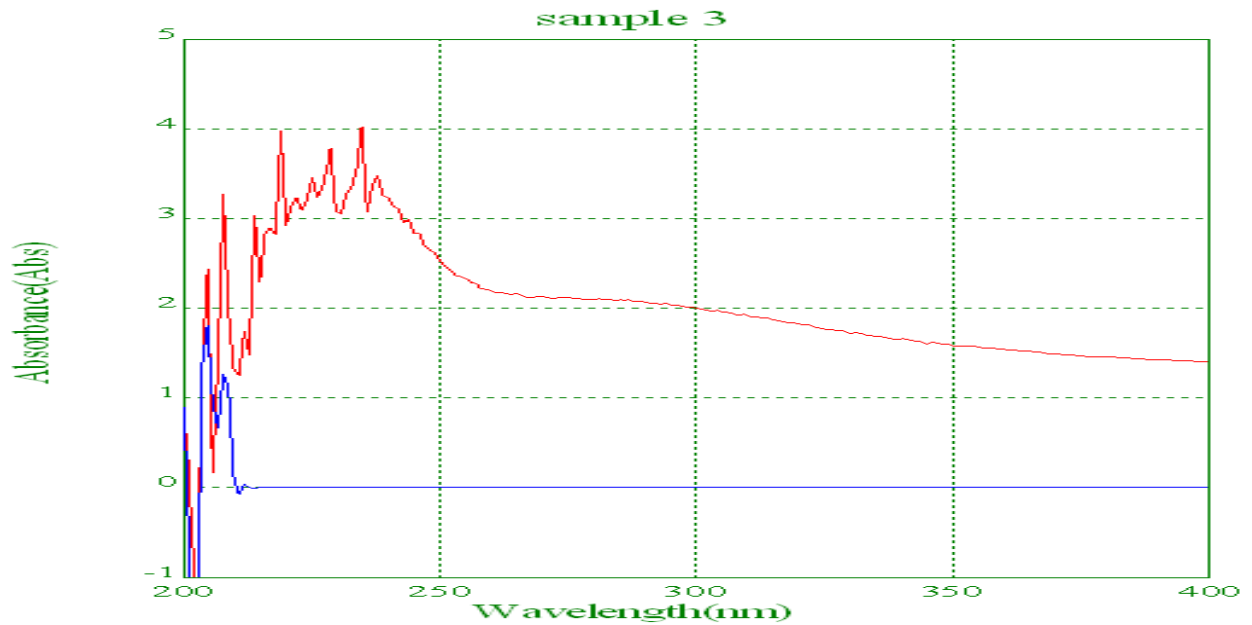
Fig 5: Absorbance spectrum for soil sample 3

Soil for sample3 is collected from wheat farm. Soil consists of high potassium. Blue curve is spectrum of distilled water and red curve is spectrum of soil sample 1.wavelength is shown on X axis and absorbance is shown on y axis.

Fig 6: Absorbance spectrum for soil sample 4

Soil for sample 4 is collected from spinach farm. Soil consists of high potassium. Blue curve is spectrum of distilled water and red curve is spectrum of soil sample 1.wavelength is shown on X axi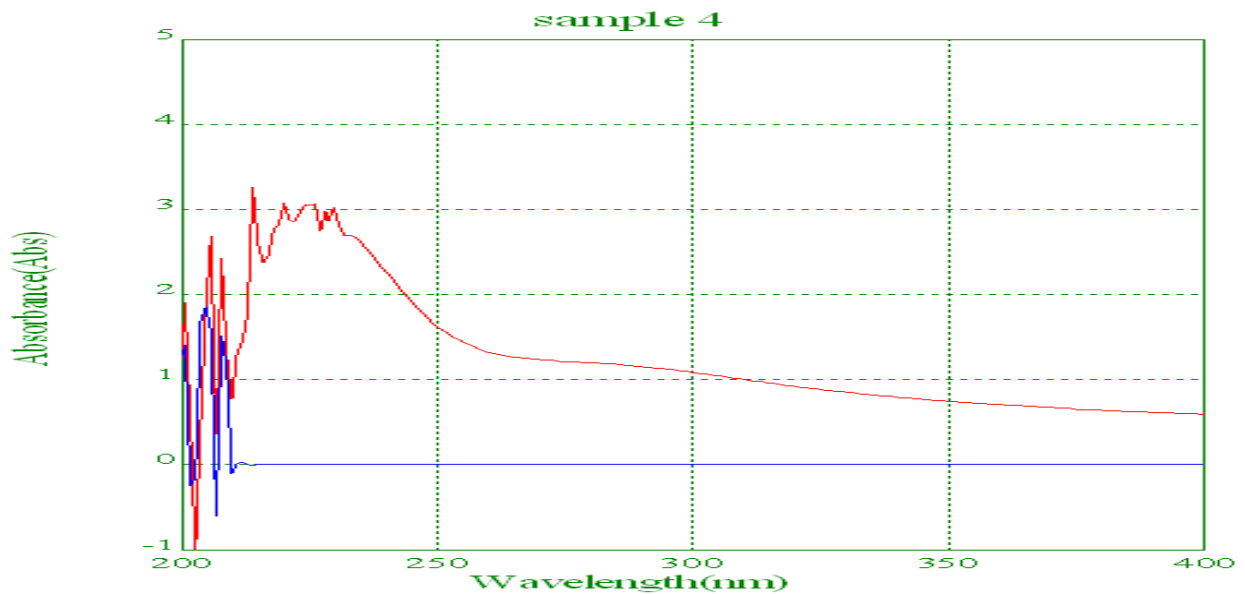s and absorbance is shown on y axis. These results shows that soil nutrient sensing can be done using UV spectrophotometer in the range of 200nm to 400nm. In each graph blue line represents spectrum of distilled water which is used as reference and red curve shows spectrum of soil. It has been observe that various nutrients shows sensitivity to UV rays in the range of 210 nm to 270 nm.

D. Detailed investigations determine Potassium in the soil sample

In the standard measuring flask of 25 ml, 10 mg of soil is added with 25 ml of distilled water. This makes the total contained of flask equal to 35 ml. To make standard stock solution of 1000 ppm, it is necessary to add 35 mg of ion into the solution.

Potassium Iodide (KI) is used to increase concentration of potassium ion. 35 mg of KI is calculated from total molecular weight. Total molecular weight of KI is 166.0028 mol/gm. It contains 39.0983 gm of potassium thus calculating for 35 mg of potassium we required 148.603 mg of KI.

This amount is measured using weighing machine and added to soil sample of 35 ml. Thus for 1 ml of soil sample 1mg of potassium is added. This results 1000ppm solution also called as stock solution.

From stock 0.1 ml is pippet out and diluted to 10ml in standard measuring flask. This results in 10ppm soil sample solution. Similar from stock 0.2 ml is pippet out and diluted to 10ml in standard measuring flask. This results in 20ppm soil sample solution. This procedure is repeated till 100 ppm solution.
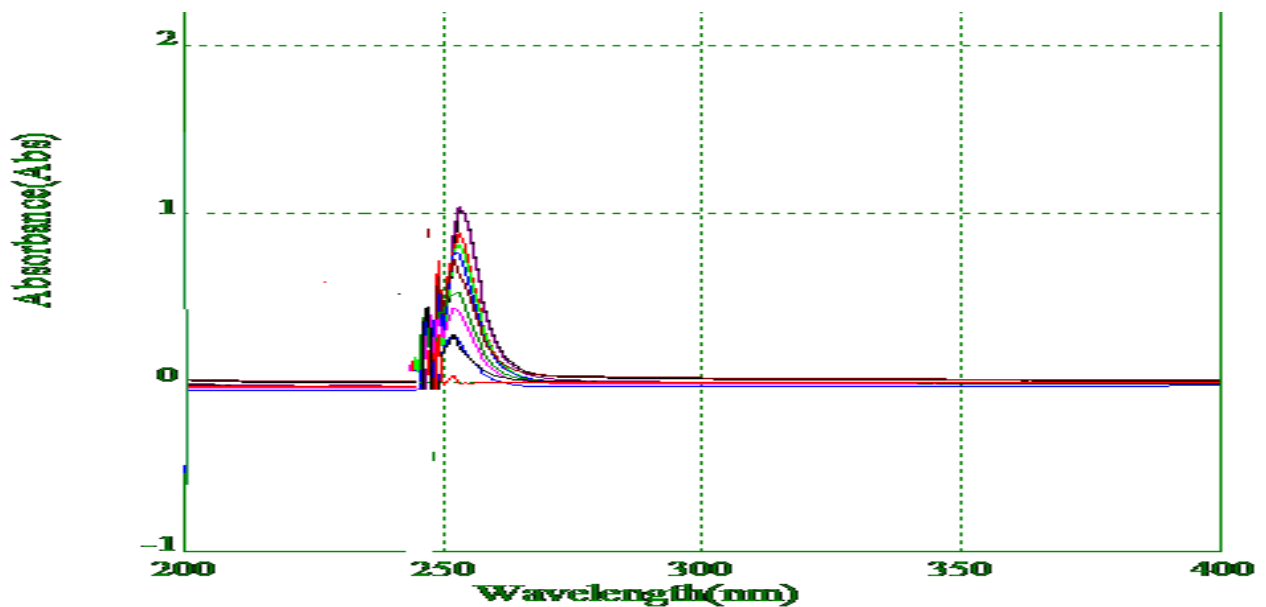
These solutions are filtered using whatman filter paper to obtained crystal clear solution. This will avoid noise reflectance due to visible particles.

The samples are scanned using Varian 100 carry UV spectrophotometer. Resultant spectrum is as shown in Fig 7

It can be seen from the fig 7 that at 260 nm we can observe change in reflectance. This change is proportional to concentration of potassium in the soil sample.

To obtain potassium calibration curve. 10 mg of Potassium ion is added to 10 ml of distilled water. To get 10 mg of potassium ion from KI 42.458 mg of KI is required. This results in 1000 ppm solution of distilled water and potassium as stock solution.

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Color Notation

Ref –Red	10ppm -Black	20ppm -Blue
30ppm –Pink	40ppm -Bottle Green	
50ppm-Brown	60ppm-Blue	70ppm-Green
80ppm-Red	90ppm-Purple	100ppm -Black

Fig 7: Resultant spectra for potassium

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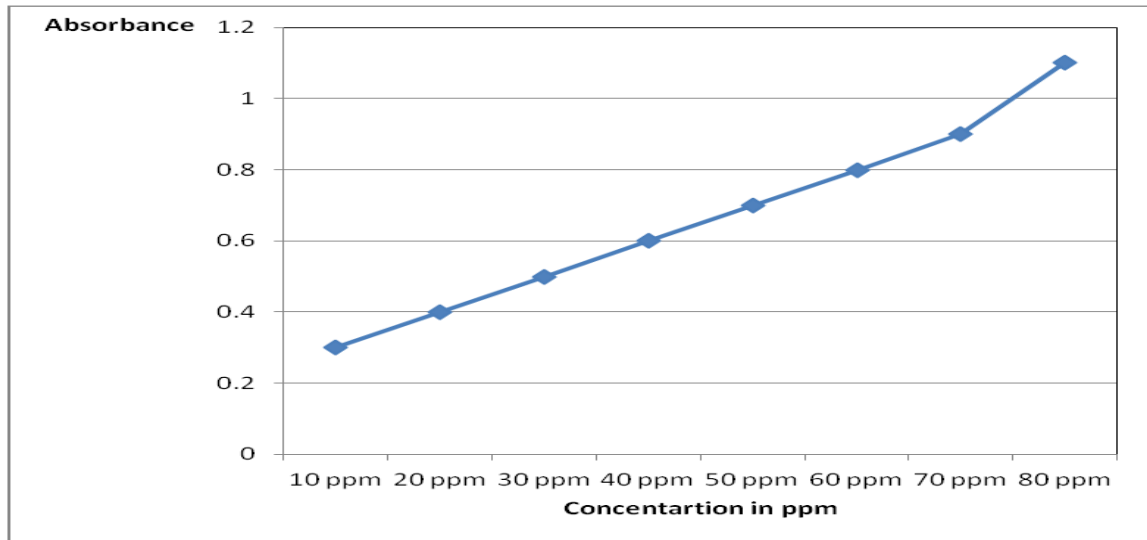

Fig 8: Calibration curve for Potassium

From calibration curve formed using UV spectrophotometer, the concentration of potassium ion can be determine

IV.   CONDUTIVITY MEASURMENT

Under field conditions measuring electrical conductivity is a simpler procedure and it can give reliable results. Variability between electrical conductivity and concentration N, P, and K (raw data) are observed. As concentrations got higher, variability in electrical conductivity is observed, based on the theory of relation between micronutrient concentration and electrical conductivity. We conducted various experiments on soil samples collected from three different fields. These samples are dried and soaked for 24 hrs. We have mixed 150 gm of soil with 350 ml of tap water. To measure electrical conductivity two electrodes of Steel material are immersed in samples. An A.C. voltage of 1 vpp and 1 Khz is applied to one electrode. This A.C. voltage results in movements of ion which in turn results in variability of conductivity of soil sample. Use of A.C. voltage avoids neutralization of ions. Other electrode is connected to Multimeter to measure the current changes.

Table 2 shows the results of experiment conducted on soil samples for detecting the presence Primary nutrient

TABLE II: Earlier results for soil and tap water

Initial	10.2μS
After 24hrs	16.6μS
After 48 hrs	59.63μS

It can be seen from Table 2 that sample with addition of KI shows higher conductivity due to more potassium ions.
The earlier results were very unstable which was mainly due to water impurities. To avoid instability in the results soil samples are prepared using distilled water. In the 150 mg of soil 350 ml of distilled water is added and results are checked

using conductivity measurement method. For the same sample results are checked after 24 hrs and 48 hrs. These results are shown in table 3.

TABLE III: Results using distilled water + Soil +KI

	Distilled water	Distilled water +Soil	Distilled water+ Soil+ KI
Initial	0.01 μS	1.2 μS	9μS
After 24 hrs	0 .01μS	4.5 μS	14.7μS
After 48 hrs	0 .01μS	1.2 μS	5 μS

It can be observed from table that distilled water shows almost zero conductivity. In the soil shows little conductivity. Addition of potassium ion increases conductivity of soil. Conductivity is increasing after 24 hrs as more ions are taking part in conduction. After some time neutralization process begins resulting significant decrease in conductivity of soil.

As the conductivity is greatly depend on distance between electrodes, various experiments were performed in which distance between electrodes these results are monitored. Results were expected in the range of micro Siemens. Results are as shown in table 4. In the table 4 it can be seen that as the distance between electrodes increases conductivity decreases.

These results once tested for large number of samples, will be calibrated and displayed in ppm as per the conventional standard. These values will be useful to find out the deficiencies of primary nutrient in the soil and accordingly suggestion will be given to farmer for optimum use of fertilizers.

TABLE IV: Relation between electrical conductivity and Concentration

	1 cm	1.5cm	2cm	3cm	Conductometer
Initial	0.463 mS	0.441 mS	0.442 mS	0.413mS	0.47 8mS
After 24hrs	0.468 mS	0.442 mS	0.447 mS	0.430mS	0.541mS
After 48 hrs	0.468 mS	0.442 mS	0.448 mS	0.423 mS	0.541mS

V. CONCLUSION

In this paper, two methodologies for primary nutrient determination as spectroscopy and conductivity measurement are described. In the Optical method i.e. spectroscopic method it can be seen that Potassium shows reflectance changes at 260nm. At 260 nm we can plot graph of concentration and absorbance .This method is laborious, time consuming expensive. On the other hand measuring variability in conductivity of the soil is low cost method. It can be concluded from various experiments that electrical conductivity varies with concentration of primary nutrients in the soil.

In the future large number of samples will be tested to detect primary nutrients in the soil leading to efficient portable sensor for primary nutrients determination in the soil.

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