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Original Research

Estimating Plant Macronutrients Using VNIR Spectroradiometry

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Abstract

Leaf nutrient levels are traditionally quantified by laboratory chemical analysis, which is time consuming and requires huge investment. The objective of this research is to estimate the nutrient content of groundnut leaves using an assembled visible near-infrared spectroradiometer (650-900 nm). This method is faster and requires less time and investment compared to conventional chemical analysis. Different fertilizer was applied for different conditions along with one control of groundnut plants. The nutrient deficiency in the groundnut plants was created artificially. The leaf samples were collected in the growth of different days. The samples were analyzed for major nutrient concentrations, which are acquired by field conditions. This research provides the guidelines on the nutrient estimation of the groundnut leaves.

The peak reflectance esteem was seen in the infrared range (650-900 nm) and the reflectance value was observed for nitrogen (716 nm), phosphorus (737 nm), and potassium (720 nm). This study may provide guidelines for estimating macronutrients and yield estimation of groundnut plants.

Keywords: spectroradiometer, groundnut plant, VNIR, leaf nutrient, fertilization

Introduction

India ranks second in groundnut production of worldwide farmer output [1-2]. The production of agriculture is steadily declining because of drought, lack of rain, irrigation, and fertilization problems. The growth of agriculture is directly affected by polluted air. The morphological properties of crops change due to air pollution, which affects crop tissues and cells [3]. So the pollutants from the air should be reduced in order to improve crop growth [4]. For crop cultivation, the properties of the land have to be determined. The development of agricultural activities was based on field balance, sustainability, and landscape design. A survey of the cropland analysis is used to pre-determine land strengths and weaknesses [5-7]. The agronomic characteristics depend on the soil's water-holding capacity. Soil that holds liberal amounts of water is less subject to draining losses of nutrients and soil-connected pesticides [8]. Water stress plays an important role in the germination of seeds [9-10]. In southern India groundnut production is seriously affected due to the serious problem of nutrient deficiency. The environmental cycle gets affected due to over/under fertilization. Farmers use approximate methods of fertilization treatment [11-12]. By recommending the nutrient at the correct level, yield estimation, the rate consumption, and fertilizer consumption can be saved. Numerous studies involving

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rapid estimation of crop nutrient requirements have been carried out with non-invasive technologies [13]. Various spectroscopic techniques for rapid and non-destructive estimation of plant nutrients have been investigated [14-15]. Visible and near infrared (VIS-NIR) spectrum analysis is one of the most important and commonly used methods [16-17].

For predicting fertilizer consumption, different types of assembled spectroradiometers are used but it can be costly. The research mainly focuses on developing low cost and handiness for easy field use. The newly assembled spectroradiometer was analyzed with the existing system and efficiency was found. The existing system mainly focused on the VNIR spectroradiometer for estimating nutrient substance in groundnut leaves. The produced transmittance and absorbance sorted meters were also used for the reliability of remotely detected nondestructive plant nutrient estimation of the earlier studies. Different varieties of groundnut series (approximately) is cultivated in India. Based on the local soil type, the Tindivanam 07 (TMV07) variety of groundnut series was used in this study.

Materials and Methods

Soil Sampling and Chemical Analysis

The soil sample was collected from the rangeland of Kandampakkam village, Villupuram District, Tamilnadu, India. The surface litter of the sampling spot was removed and the soil collection was done by the following procedure: Using an auger, a plough depth of 15 cm and a V-shaped sample cut was collected from the sampling spot using spade [18]. 10 to 15 samples were collected from each sampling unit and placed in a bucket. The chemical analysis was carried out for the collected soil to evaluate the nutrients in the soil [19]. As per the content of nutrients in the soil acquired by chemical analysis, it is simpler to determine the amount of fertilizer required for the plant.

Soil Preparation

The collected soil was filled in a jute sack and placed in flowing water until the nutrient concentration of the soil was reduced to 20% from its original nutrient concentration. The washed soil was filled in a 25 kg pack for seeding.

Seed Recommendation and Procedure for Cultivation

Fourteen varieties of groundnut series are cultivated in Tamilnadu. Among them, TMV07 (Tindivanam 07) groundnut series is highly recommended for the selected soil. Each seed was placed at a depth of 5 to 6 cm with a breadth of 10 cm. The germination of groundnut seed is found to be good if the soil temperature is maintained between 25ºC and 30ºC [20]. If the temperature is low there is a delay in germination, leading to seedling disease. So the average atmospheric temperature (28ºC±2ºC) is maintained for 100-105 days for better growth.

Table 1. Combination of fertilizer applied.

Fertilizer treatment	N (%)	P (%)	K (%)
N treatment	50	100	100
	75	100	100
P treatment	100	50	100
	100	75	100
K treatment	100	100	50
	100	100	75
NPK	100	100	100

Fig. 1. Combination of fertilizer applied in triplet method.

Fertilizer Treatment

The growth of the plant mainly depends on the nutrient content available in the soil. The insufficient nutrient content of the soil drastically affects plant growth and yield [21]. Hence the fertilizer should be mixed with the soil for healthy growth and yield. The N fertilizer treatment was carried out in two different conditions, consisting of 50% and 75% with sufficient nutrient content for P and K. The same procedure was repeated for P and K fertilizer treatment. One control (100% NPK) condition was also planted for comparison (Table 1). The fertilizer was applied by triplet method, which is shown in Fig. 1.

Spectral Measurement

The spectral data was collected using the assembled handheld spectroradiometer (Fig. 2), which consists of a transmitter and a receiver. The red and infrared light source was chosen as the transmitter runs between 650 to 900 nm [22-25]. The TSL235R silicon photo diode (320-1050 nm) light to frequency converter was used as the receiver. An Atmega 328 microcontroller commonly uses an autonomous system which is a simple, user friendly, and low-powered device. The microcontroller consists of an built-in analog-to-digital converter and the output is viewed on an LCD display. The Spectroradiometer is connected to a laptop by means of a probe placed above the leaf surface. The most extreme separation between the leaf and

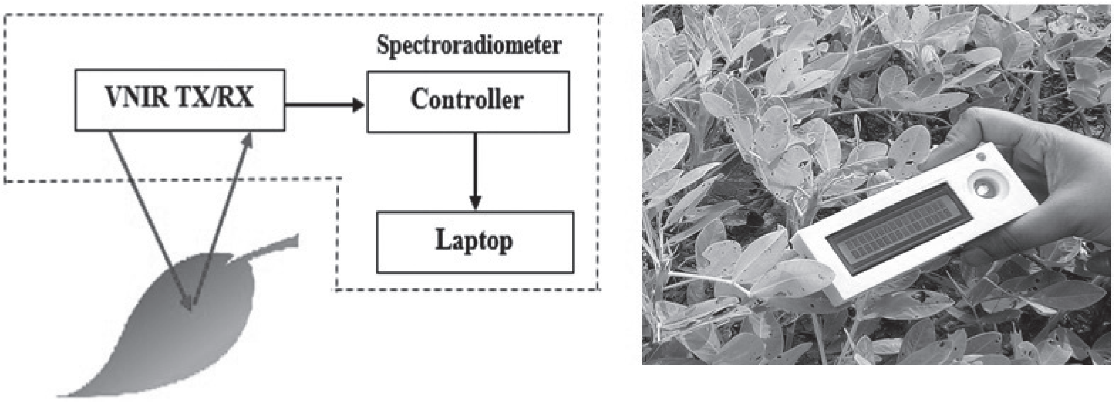

Fig. 2. Spectroradiometer.

spectroradiometer is less than 1 cm in order to obtain accurate results. If the distance between the leaf and the spectroradiometer varies more than 1 cm, it results in poor accuracy. The lights discharged from the LED were centered and focused on the leaf surface and the reflected light was observed by the receiver. The light from the LED focused on the leaf surface covers an area of 1x2 mm.

Spectra Collection

The growth of the plant was monitored continuously. In the experiment the deficiency symptoms of plant growth were seen after 30 days. The deficiency symptoms linearly increase to the following days. The symptoms can be found by means of colour variation in leaves [26-30]. The spectral measurement was carried out on four different days: 30, 40, 50, and 60. During the measurement, five different leaves were selected from each plant. The leaf colour variation was performed by the following method such as 1-5 scale, where: 1) 1-10% colour variation; 2) 11-20% colour variation; 3) 21-50% colour variation; 4) 51-75% colour variation; and 5: >75% colour variation was selected. The colour variation was not evenly spread over the leaf surface and hence the three different measurements were taken in different locations of a leaf, which is shown in Fig. 3. In total 15 readings were taken for each plant. Leaf reflectance deficiency was estimated based on the average of the 15 readings.

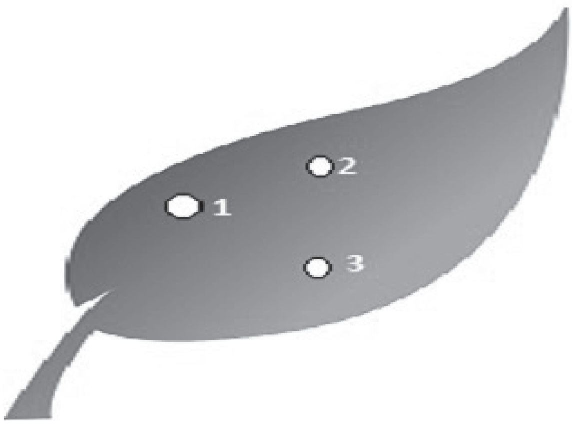

Fig. 3. Location for reflectance measurement of leaf surface.

Results and Discussion

From the laboratory analysis, the collected soil sample is found to be sandy loam, which is well suited for groundnut cultivation. From the analysis, the available soil nutrient and deficiency of nutrients in soil was estimated. Table 2 shows that the nutrient deficiency of phosphorus (P) and potassium (K) shows a higher rate [31] when compared with nitrogen (N).

The nutrient content in the soil determines plant growth. The correct proportion of fertilizer is required for healthy plant growth. After cultivation the deficiency of the nutrient in groundnut leaves was evaluated by the spectral reflectance of the assembled spectroradiometer. Spectral reflectance (650-900 nm) was measured for all treatments on various days. The leaves with nitrogen deficiency show yellow and pale appearance [32-35]. Fig. 4(a, b) shows the percentage reflectance of 25% and 50% plant deficiency in nitrogen relative to the wavelength. The slope of the red shift shows the peak reflectance in the wavelength of 716 nm [36]. The spectral reflectance measurement was observed in various days such as 30, 40, 50, and 60. It was found that the percentage of spectral reflectance varies accordingly.

Table 2. Available nutrient content and deficiency of nutrients in soil.

Macro Nutrient (Kg/acre)	N	P	K
Available soil Nutrient	77	5	18
Required Nutrient for Groundnut	99	143	75
Deficiency of Nutrient in soil	22	138	57

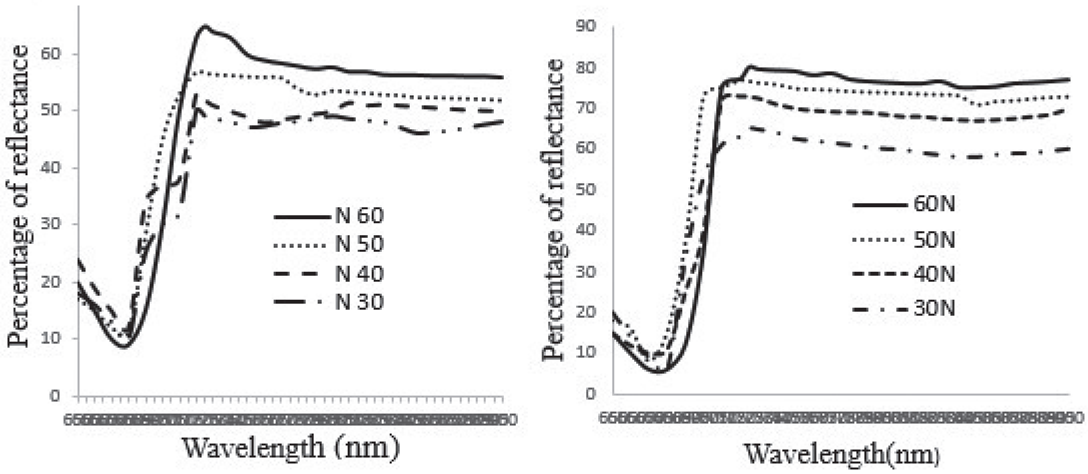

Fig. 4. Nitrogen deficiency on groundnut leaf reflectance property: a) 25% Deficiency leaf spectral reflectance b) 50% Deficiency leaf spectral reflectance.

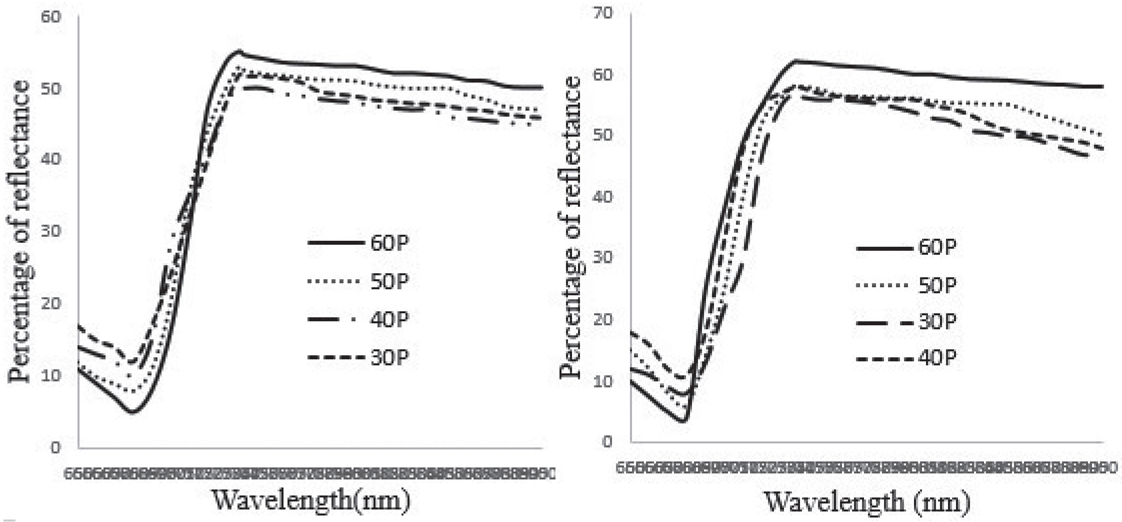

Fig. 5. Phosphorus deficiency on groundnut leaf reflectance property: a) 25% Deficiency leaf spectral reflectance b) 50% Deficiency leaf spectral reflectance.

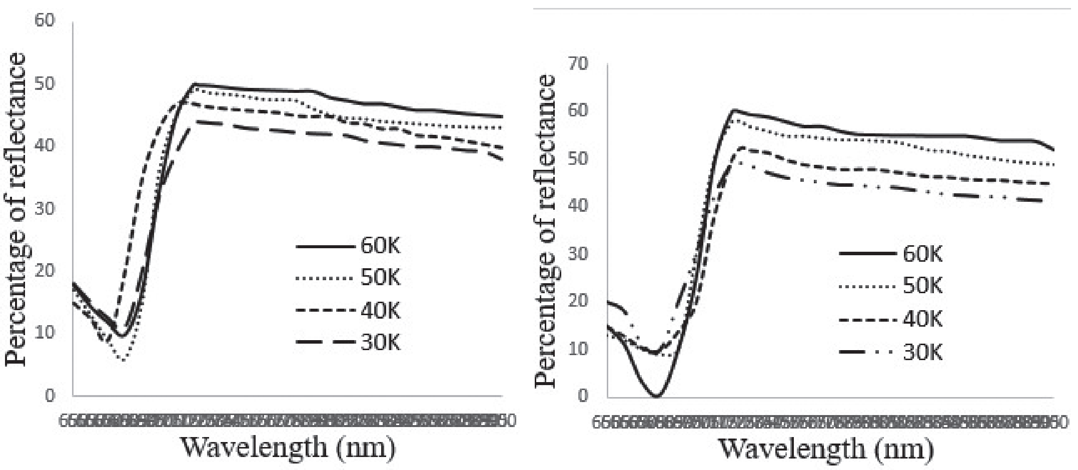

Fig. 6. Potassium deficiency on groundnut leaf reflectance property: a) 25% Deficiency leaf spectral reflectance b) 50% Deficiency leaf spectral reflectance.

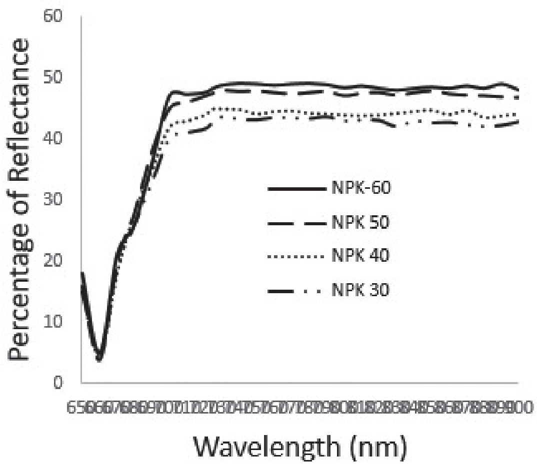

Fig. 7. Different days of controlled (NPK) groundnut leaf reflectance property.

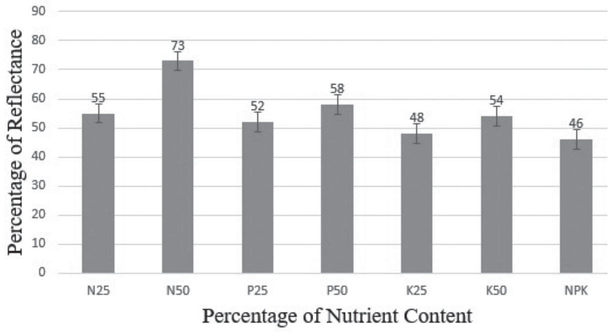

Fig. 8. Relationship between percentage of reflectance and nutrient content.

To analyze the percentage of reflectance and nitrogen deficiency, the measurement was done on the 40th day. Fig. 7 shows the spectral reflectance of healthy leaves, i.e., controlled condition on various days. As the percentage of deficiency increases, the percentage of reflectance also increases. It was found that a plant with 25% nitrogen deficiency produces 53% reflectance and a plant with 50% nitrogen deficiency produces 73% reflectance. The phosphorus deficiency results were in dark green with a leathery texture and reddish purple. Phosphorus deficiency is more difficult to analyze when compared with nitrogen and potassium deficiency because it does not show obvious symptoms in early growth. Fig. 5(a, b) shows the percentage reflectance of 25% and 50% plant deficiency in phosphorus relative to the wavelength.

Peak reflectance was observed at the wavelength of 737 nm [37]. It was found that a plant with 25% phosphorus deficiency produces 52% reflectance and a plant with 50% phosphorus deficiency produces 58% reflectance.

The potassium-deficient leaf exhibits yellow colour in the margins of the leaves. Potassium (K) deficiency symptoms first appear on older (lower) leaves.

Fig. 6(a, b) shows the percentage reflectance of 25% and 50% plant deficiency in potassium relative to the wavelength. The peak reflectance was observed in the wavelength of 720 nm [38]. It was found that a plant with 25% potassium deficiency produces 48% reflectance and a plant with 50% potassium deficiency produces 54% reflectance. Fig. 7 shows the healthy leaf condition between wavelength and percentage of reflectance. Reflectance was observed for various days.

Fig. 8 shows the relationship between the percentage of reflectance and nutrient content. The percentage of nutrient deficiency is estimated by the percentage of reflectance. From the analysis it has been concluded that, with a wavelength of 716 nm, the percentage of reflectance ranges from 50-55 and the available nitrogen content is found to have 75%. For the remaining 25% of deficiency, nitrogen fertilizer is recommended. Similar to the wavelength of 715 nm if the percentage of reflectance is about 65-75 and the available nitrogen content is 50%. So the remaining 50% of deficiency can be compensated by nitrogen fertilizer. In the wavelength of 720 nm, if the percentage of reflectance is about 48-52 then the available potassium content is 75%. For the remaining 25% deficiency, the potassium fertilizer is recommended. Similar to the wavelength of 720 nm, if the percentage of reflectance is about 53-58, the available potassium content is 50%. So the remaining 50% of deficiency can be compensated by potassium fertilizer. In the wavelength of 737 nm if the percentage of reflectance is about 47-53 then the available phosphorous content is 75%. For the remaining 25% of deficiency, phosphorous fertilizer can be administrated. Similarly, in the wavelength of 720 nm, if the percentage of reflectance is about 56-62%, the available phosphorous content is 50%. For the remaining 50% of deficiency the phosphorous fertilizer is recommended.

Yield Estimation

Yield was estimated after harvesting. Above 95%, NPK fertilizer demonstrates a higher yield when contrasted with N, P, and K. The blend of NPK

Table 3. Yield estimation of TMV07 series groundnut.

Nutrient	Percentage nutrient treated	Yield estimation (gm)/plant
N	50	62
	25	20
P	50	55
	25	15
K	50	50
	25	18
NPK	100	100-150

compost indicates a higher yield than applying manure exclusively as N, P, and K.

Table 3 shows that NPK-treated plants have higher yield estimation when compared with other nutrients such as N, P, and K. After cultivation based on the percentage of reflectance the amount of yield will be predicted.

Conclusions

The nutrient content of groundnut leaves using visible near infrared spectroradiometry (650-900 nm) was estimated. The percentage of leaf reflectance was gathered in field conditions using a developed VNIR spectroradiometer. When compared with other devices, 5-10% deviation was observed. The percentage of spectral reflectance depends on the deficiency of plant nutrients. From the research we found that peak reflectance was determined for N (716nm), P (737nm), and K (720nm). The fertilizer treatment of N, P, and K was performed in two different states such as 25% and 50%. It was observed that a plant with 25% N deficiency shows 53% reflectance and a plant with 50% N deficiency shows 73% reflectance. Likewise, a plant with 25% P deficiency shows 52% reflectance and a plant with 50% P deficiency shows 58% reflectance. In the same way, a plant with 25% K deficiency shows 48% reflectance and a plant with 50% K deficiency shows 54% reflectance. The NPK compost shows higher yield. The NPK yield estimation ranges about 100-150 gm/plant.

Units and Nomenclature

Symbols	Abbreviations
cm	centimeter
gm	gram
K	Potassium
kg	Kilo gram
LCD	Liquid crystal display
LED	Light emitting diode
N	Nitrogen
nm	Nano meter
NIR	Near infrared
P	Phosphorus
Rx	Receiver
TMV	Tindivanam Variety
Tx	Transmitter
VNIR	Visible near infrared
VIS	Visible

Conflict of Interest

The authors declare no conflict of interest.

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