Groundnut spectral indices and characterization in relation to crop nutrient status

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ABSTRACT
The spectral indices such as NDVI and RVI were calculated by using spectral signatures obtained through spectro-photo-sensor. The mean NDVI and RVI values were 0.71 and 6.46, respectively. Wide variation in the NDVI and RVI values were observed across the farmers’ fields revealing that crop was exposed to varied levels of nutrient deficiency. The SPAD (Indicator of chlorophyll activity) readings ranged between 25.8 and 46.8. The SPAD and the index leaf N, P, K, Ca and Fe content had positive and strong relation with both NDVI and RVI. However, NDVI registered stronger relation than RVI. Co-efficient of determination ($R^2$) value of the multiple regressions between NDVI and index leaf nutrient content was 0.52. The mean N, P, K, Ca and S content in the index leaf were 3.9, 0.43, 3.45, 1.77 and 0.43 per cent, respectively. Similarly, Zn, Fe, Mn and Cu content in the crop index leaf tissue were 21.9, 40.6, 53.2 and 19.3 mg kg$^{-1}$.

Key words: Groundnut, Nutrient content, NDVI, RVI, Spectral indices.

INTRODUCTION
Though India is the second largest producer of groundnut, average crop productivity is only 1 t ha$^{-1}$ and it is 74 per cent of the world average productivity. The states like Karnataka have registered a very low productivity of 0.63 t ha$^{-1}$ (Anonymous, 2013). Yield reduction due to malnutrition/deficient nutrition of the crop is estimated to be around 30-70 per cent. Among many crop management interventions, balanced nutrition of the crop is very critical in enhancing productivity and profitability. A healthy crop of groundnut yielding 1.9 t ha$^{-1}$ is known to remove 170 kg N, 30 kg P, 110 kg K, 39 kg Ca and 15 kg S from the soil (Aulakh et al., 1985). Therefore, crop cultivation rapidly depletes nutrient reserve status and leads to low productivity unless land is sufficiently fertilized and manured. India is the net importer of the edible oil and spent 15 billion dollars on edible oil import during 2014-15 (ASSOCHAM, 2014). Therefore, it is high time to look into mineral nutrition of the crop for achieving higher and profitable production.

The present study was conducted during kharif crop season in Dharwad taluk (Karnataka) farmers’ fields and it discusses about the crop spectral characterization and suitability of spectral indices for assessing nutrient stress level of the crop.

MATERIALS AND METHODS
One hundred groundnut growing farmers in Dharwad taluk were chosen to record the field observations and to collect the samples for laboratory analysis. All the chosen farmers grew GPBD-4 cultivar and dibbled the seeds either on same day or within an interval of 5 days. This ensured uniform growth stages of the crop for spectral observation and sampling. Location of the chosen fields were recorded using GPS meter. Sufficient number fully opened top most leaves were collected from each of the 100 fields.

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at peak flowering stage. Collected samples were thoroughly washed with tap and distilled water and dried at 65 °C for 8 hours. These samples were powdered and digested with di-acid mixture (HNO₃:HClO₄ at 10:4). Aqueous extract of the acid digest was used to estimate leaf content of P, K, Ca, Mg, S, Zn, Fe, Mn and Cu. Nitrogen content in the leaf tissue was estimated by digesting sample in strong H₂SO₄ in presence of CuSO₄, K₂SO₄ and Selenium powder (Tandon, 1998). Plant chlorophyll content was estimated in the field on five plants by using SPAD meter and the average value was recorded.

Spectral observations were recorded from the height of 1 m above the crop canopy using portable spectrophotosensor during flowering stage of the crop on cloud free days between 10:30 AM and 12:30 PM. Spectral reflectance capturing and plant sample collection were done on same day and in the same field.

The selected spectral bands were:
1. Visible blue 450-520nm
2. Visible green 520-590nm
3. Visible red 620-680nm
4. Near infra red 770-860nm

By using the reflectance values recorded at above band width following indices were calculated

\[
\text{NDVI} = \frac{\text{NIR} - \text{Red}}{\text{NIR} + \text{Red}}
\]

\[
\text{RVI} = \frac{\text{NIR}}{\text{Red}}
\]

The leaf tissue nutrient content and the spectral values and indices were subjected to regression and correlation analysis (Gomez and Gomez, 1984) to understand the relation between spectral values and leaf nutrient content.

**RESULTS AND DISCUSSION**

**Spectral indices:** The NDVI values of groundnut crop ranged from 0.53 to 0.80 whereas, RVI values of groundnut crop varied from 3.69 to 8.80 (Table 1). The mean NDVI and RVI values of groundnut canopy were 0.71 and 6.46, respectively. Higher mean NDVI and RVI values in groundnut leaves were mainly attributed to better crop stand, higher chlorophyll development, and high leaf area index (LAI) and total biomass. Active chlorophyll absorbs 0.45-0.66 mm (blue and red bands) for photo-synthetic process under stress free healthy crop condition. On the other hand, EM (electromagnetic) radiation in IR (infrared) spectrum gets reflected and this would register the higher NDVI values.

**Correlation coefficients (“r” values) were worked out to determine the relationship between Ratio Vegetation Index (RVI) and Normalized Difference Vegetation Index (NDVI) with groundnut leaf nutrient concentrations. It was observed that SPAD, nitrogen, phosphorus, potassium, sulphur, calcium, iron and ferrous

and it is reverse in case of the plant which is under stressed situation (Patil et al., 2007 and Gole et al., 2008). Further, nutrient deficient groundnut crop had lower NDVI and RVI values compared to nutrient sufficient groundnut samples. Nutrient deficient samples had much lower IR/red ratio. This may be because of higher red reflectance and lower reflectance in NIR for nutrient deficient crop.

Among the abiotic factors that influence growth and development of the crops, nutrient stress is one of the important growth and yield limiting factor (Gole et al., 2008). A very wide range of NDVI and RVI values were recorded revealing that the crop under different fields might have been exposed to varying level of nutrient deficiency. In a nutrient deficient crop, because of the low chlorophyll content, the red reflectance would be much higher compared to that in the infra red region. Patil et al., (2007) reported that these derived spectral indices were in agreement with the important biophysical parameters of the plant like leaf area, leaf area index, leaf area duration, chlorophyll content, dry matter production and these attributes were positively correlated with ultimate economic part of crop production. Similar variation was observed for the NDVI and RVI and also for the SPAD reading.

In the present investigation the SPAD meter value (indicator of chlorophyll content) of groundnut ranged from 25.80 to 46.82. Adequate supply of soil N might contribute to vigorous vegetative growth leading to increased in chlorophyll content in the leaves. Groundnut leaf content of N was sufficient. Dwivedi (1988) reported that chlorophyll content of leaves is a direct function of the nutrient supply by soil. Further, sufficiency of iron availability might have helped in formation and activation of chlorophyll. Paliwal et al. (2004) opined that iron serves as catalyst in the formation and functioning of chlorophyll. Importance of zinc and iron in increasing chlorophyll content in leaves was reported by Wu and Xiao (1995).

**Relationship between spectral indices and groundnut leaf nutrient concentration:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>NDVI</th>
<th>RVI</th>
<th>SPAD Nutrient</th>
<th>P</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>S</th>
<th>Zn</th>
<th>Fe</th>
<th>Mn</th>
<th>Cu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>0.53</td>
<td>3.69</td>
<td>25.8</td>
<td>2.99</td>
<td>0.22</td>
<td>2.14</td>
<td>0.98</td>
<td>0.10</td>
<td>0.28</td>
<td>14.6</td>
<td>29.4</td>
<td>32.6</td>
</tr>
<tr>
<td>Maximum</td>
<td>0.80</td>
<td>8.80</td>
<td>46.8</td>
<td>5.03</td>
<td>0.69</td>
<td>4.24</td>
<td>3.08</td>
<td>0.93</td>
<td>0.65</td>
<td>33.0</td>
<td>56.4</td>
<td>70.7</td>
</tr>
<tr>
<td>Average</td>
<td>0.71</td>
<td>6.46</td>
<td>39.9</td>
<td>3.90</td>
<td>0.43</td>
<td>3.45</td>
<td>1.77</td>
<td>0.52</td>
<td>0.43</td>
<td>21.9</td>
<td>40.6</td>
<td>53.2</td>
</tr>
<tr>
<td>SD</td>
<td>0.06</td>
<td>1.33</td>
<td>3.49</td>
<td>0.41</td>
<td>0.10</td>
<td>0.44</td>
<td>0.51</td>
<td>0.18</td>
<td>0.09</td>
<td>3.4</td>
<td>4.3</td>
<td>7.8</td>
</tr>
<tr>
<td>CV (%)</td>
<td>7</td>
<td>21</td>
<td>9</td>
<td>11</td>
<td>24</td>
<td>13</td>
<td>29</td>
<td>35</td>
<td>20</td>
<td>16</td>
<td>11</td>
<td>15</td>
</tr>
</tbody>
</table>

Table-1: Groundnut NDVI, RVI, chlorophyll content and leaf nutrient status
Table 2: Relationship between spectral indices and groundnut leaf nutrient content

<table>
<thead>
<tr>
<th>Spectral Indices</th>
<th>Leaf nutrient content (“r”)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
</tr>
<tr>
<td>NDVI</td>
<td>0.568**</td>
</tr>
<tr>
<td>RVI</td>
<td>0.624**</td>
</tr>
</tbody>
</table>

** Significant at 0.01 level
* Significant at 0.05 level

Table 3: Regression between groundnut leaf nutrient content and spectral indices

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Regression equation</th>
<th>R² value</th>
</tr>
</thead>
<tbody>
<tr>
<td>NDVI</td>
<td>1.221 +1.086 SPAD* + 0.110 N** + 0.162 P* + 0.022 K* + 0.070 S + 0.003 Zn + 0.016 Fe* + 0.002 Cu + 0.004 Mn* + 0.002 Fe²⁺ + 0.856 Ca* + 0.047 Mg</td>
<td>0.520</td>
</tr>
<tr>
<td>RVI</td>
<td>1.108 +4.192 SPAD* + 1.569 N** + 0.552 P* + 0.127 K** + 0.782 S* + 0.022 Zn + 0.082 Fe** – 0.037 Cu – 0.013 Mn + 0.642 Fe²⁺ + 0.260 Ca* + 0.096 Mg</td>
<td>0.591</td>
</tr>
</tbody>
</table>
action of various organic acids liberated during the decomposition of organic matter. This process contributes to higher P availability and subsequent uptake as reported by Subbiah et al. (1982). Variation in P concentration in groundnut plants of different fields was attributed to variation in soil depth, available moisture, available P status and organic matter content. Further, cultivation practices particularly the quantum of fertilizers and manures applied by the farmers also influenced the P uptake. Bidari (2000) reported that uptake of P varied with location, cultivation practices followed by farmers particularly fertilizers and manures management practices.

Potassium content in groundnut leaves recorded a higher mean K (3.45 per cent) values (Table 1). The soils of sampled fields were medium to high in available K status (Table 4). Higher potassium uptake by groundnut plants might be due to sufficient K and P availability from the soil and applied fertilizers. Interaction between phosphorous and potassium is synergistic. Higher available soil phosphorous and potassium increases the uptake of potassium at all stages of plant growth (Jain and Dixit, 1987).

Sulphur concentration in groundnut leaves showed above the critical level of 0.20 to 0.35 per cent (Table 1). This could be attributed to sufficient level of available sulphur content in the soils as presented in Table 4. Chandrasekhar Reddy and Krishna Murthy (1985) reported that higher amount of native sulphur contributed to higher concentration in groundnut plants. Similar findings were also reported by Mahapatra and Sahu (1996) who noticed significant and positive relationship between available sulphur content of soil and sulphur concentration in groundnut plant at peg initiation stage.

The concentration of Ca and Mg ranged from 0.98 to 3.08 per cent and from 0.10 to 0.93 per cent respectively (Table 1). Groundnut plant recorded higher mean Ca (1.77 per cent) and Mg (0.52 per cent) leaf tissue concentration. This might be due to higher mean exchangeable Ca and Mg content of soils (Table 4). This is attributed to better root growth and root branching that favored the uptake of Ca and Mg by plants. Sharma et al. (1996) reported that root growth and branching were important in providing sites for Ca and Mg uptake where casparian strip is not fully developed at the tip of root.

The content of zinc in groundnut leaves ranged between 14.6 to 33.0 mg kg⁻¹. In the present study, 36 per cent of the samples were below the critical level of less than 21 mg kg⁻¹ and 64 per cent were above critical range 21 – 60 mg kg⁻¹. The mean zinc concentrations in groundnut plants was above the critical level. The increased uptake of zinc was also due to mobility and possible chelation with decomposed organic matter which might have enhanced the supply of zinc in the entire growth period of the crop (Singh, 2004). The synergetic effect of Zn and Fe in plant might be the reason for the higher uptake of zinc. Ramaprasad et al. (2011) revealed that the increased zinc uptake could also be attributed to the sulphur and zinc application at higher level through zinc sulphate by most of the groundnut growing farmers.

Further, it was noticed that total iron and ferrous iron concentration in groundnut leaves were in sufficient range. Groundnut plant recorded higher mean total Fe (394 mg kg⁻¹) and Fe²⁺ (40.6 mg kg⁻¹) content. This is attributed to high organic matter that forms stable complex with native Fe and make iron more soluble and available to the crops (Bidari 2000). There was a steep increase in uptake of nutrients at 45 DAS (days after sowing). This might be due to the role of Fe in the synthesis of chlorophyll in leaves which are very active at 45 DAS. It is generally known that under iron stress conditions plants have the tendency to accumulate more of Fe³⁺ and it was not observed in case of GPBD-4 cultivar which had been reported as Fe-efficient plant (Nagarathnamma, 2006).

The mean copper content in groundnut leaves was higher. Generally, uptake of Cu increases significantly with the advancement in age of the crop. An increased Cu uptake in latter stage was attributed to its role in relation of flowering in plants. Higher organic matter content in soils had enhanced availability of native micronutrient cations through the transformation of precipitations to soluble metal-organic complexes. Further, the extensive root system enhanced the copper uptake. Bidari (2000) reported higher Cu uptake by plants grown on soils with high organic matter content similar to the present investigation.

The manganese content in groundnut leaves ranged from 32.6 to 70.4 mg kg⁻¹. The mean (53.2 mg kg⁻¹) as well as entire samples had Mn content above the critical limit. This might be due to medium and higher organic matter content of soils. Soil organic matter increased the availability of native manganese by mobilization through chelation. Thus, increasing the available manganese status in soil for

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**Table 4:** Available nutrient status of groundnut growing fields

<table>
<thead>
<tr>
<th>Particulars</th>
<th>N</th>
<th>P₂O₅ (kg ha⁻¹)</th>
<th>K₂O</th>
<th>Ex.Ca (cmol (p+)) kg⁻¹</th>
<th>Ex. Mg</th>
<th>S (kg ha⁻¹)</th>
<th>Zn (mg kg⁻¹)</th>
<th>Fe (mg kg⁻¹)</th>
<th>Cu (mg kg⁻¹)</th>
<th>Mn (mg kg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>189 - 290</td>
<td>14 - 34</td>
<td>299 - 612</td>
<td>12.6 - 40.2</td>
<td>4.2 - 16.4</td>
<td>14.1 - 28.3</td>
<td>0.26 - 0.64</td>
<td>0.89 - 5.32</td>
<td>0.16 - 0.63</td>
<td>2.34 - 9.41</td>
</tr>
<tr>
<td>Mean</td>
<td>249</td>
<td>23</td>
<td>401</td>
<td>25.5</td>
<td>9.5</td>
<td>20.3</td>
<td>0.47</td>
<td>3.14</td>
<td>0.40</td>
<td>4.91</td>
</tr>
<tr>
<td>SD</td>
<td>27</td>
<td>4</td>
<td>77</td>
<td>5.4</td>
<td>2.7</td>
<td>3.1</td>
<td>0.09</td>
<td>0.94</td>
<td>0.11</td>
<td>1.37</td>
</tr>
<tr>
<td>CV (%)</td>
<td>11</td>
<td>19</td>
<td>19</td>
<td>21.4</td>
<td>28.6</td>
<td>15.2</td>
<td>19.29</td>
<td>29.99</td>
<td>28.55</td>
<td>27.84</td>
</tr>
</tbody>
</table>
groundnut crop resulted in its increased tissue content as well as uptake by the plant. Further, synergistic effects of other micronutrients with Mn might have significantly increased the availability and uptake of manganese by the groundnut crop.

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