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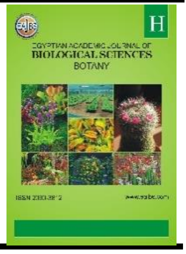

# Remotely Identification and Differentiate of Some Family Fabaceae Species in Antoniadis Garden Using Spectral Reflectance Measurements

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**ABSTRACT**

This research was carried out in Antoniadis Garden, Alexandria city, Egypt, on trees of fourteen genera belong to family fabaceae, to study the differences on their leaves spectral properties, using some vegetation indices "NDVI, SR, IR/R, IR/G, RE, REP and DN". Also, spectral reflectance curve of each tree species and for each and both leaf surface was drawn to examine the ability of spectral measurements and vegetation indices to differentiate among tree species. Moreover, leaves content of total chlorophyll was determined and it's correlation to studied indices was examined. Results showed that all studied indices can successfully differentiate among trees species and showed a highly significant differences between species. Moreover, spectral curve of each plant species were obviously separated for each and both leaf surface. It is manifested that Green and NIR regions are clearly separated between spectral curves of leaves according to their color, thickness and internal structure, so this electro-magnetic radiation of light can be used successfully to classify plant species. Also, a highly correlation was found between total chlorophyll content and studied vegetation indices.

## INTRODUCTION

Floristic diversity is essential for life on Earth, especially in providing stability in ecological crucial (Cunningham *et al*., 2015). According to (Boulos 2005, 2009, Shaltout and Eid 2010 and Ahmed *et al*., 2020), Egypt had an important area of plant diversity and contains about 28.8% of the threatened plants of North Africa where it has more than 2145 species and approximately 220 subspecies. One of the most important and widespread plant groups in Egypt belongs to family Leguminosae (Fabaceae), where it is the third-largest family of angiosperms (flowering plants) with 770 genera and 19500 species (LEWIS *et al*., 2005 and LPWG, 2017). Fabaceae family is divided into six subfamilies (Caesalpinioideae, Cercidoideae, Detarioideae, Dialioideae, Duparquetioideae, and Papilionoideae) (LPWG, 2017). Fabaceae is a family of great economic importance (Cai *et al*., 2014) being nourishing cultures important was provides high nourish sources of proteins and micronutrients that can profit the health and ways of subsistence, especially the developing countries. (Yahara *et al*., 2013). Moreover, it is the main source of gums, dyes, fuel, timber, medicinals, and pulses (Everitt *et al*., 2007and Abd El-Ghani *et al*., 2021). Because, plant species are required a main element of all ecosystems, so, ecosystem sustainable management needs clear data to understand species composition and distribution (Nagendra, 2002). For that reason, remote sensing is considered an important tool for collecting qualitative and quantitative information to study vegetation cover activity and land use, especially in large areas. Estimation of biophysical variables of the canopy is very important in different studies such as meteorology, agriculture and ecology (Susan *et al*., 2011). The spectral properties of plant species depend on plant physiology, morphology, or anatomy (Kycko *et al*.,2014; Jarocinska *et al*., 2016). Spectral behavior of leaves in regions from visible-infrared (VNIR) to shortwave infrared (SWIR), differs according to the content of dry matter, pigments, e.g. chlorophyll, carotenoid, and water (Jean-Baptiste *et al*., 2008). Moreover, variations in plant canopy and leaf structure, pigment and water content cause changes in vegetation reflectance properties, even between closely related species. So, species identification is possible from these unique spectral properties (Thenkabail *et al*., 2000). Where, absorption, transmission, or reflection of the electromagnetic spectrum by plants can play a significant role in the monitoring of ecosystem changes. Spectral vegetation indices are useful in discriminating differences between vegetation types. Spectral vegetation indices (SVIs) are usually ratios of reflectance values at different wavelengths (Gumz and Weller,2005). Near, middle and thermal infrared bands have been strongly suggested for species diversity differentiation. Their combinations are strong stable indicators of plant diversity (Muldavin *et al*., 2001; Everitt *et al*., 2007 and Cai *et al*., 2014). Vegetation indices are mathematical transformations that are designed for analyzing and evaluating plants in multispectral satellite observations. Fundamental of the function of each index is the difference between red and near-infrared bands, where, red light absorbed by pigments in the chlorophyll, causes low plants reflectance in this band and denser in the near-infrared band reflectance, (Hashemi *et al*.,2013).

Vegetation indices were designed to estimate vegetation status, classify land cover, and phenology, detect land use and drought monitoring (Padilla *et al*., 2011), however, selecting the best indices for forest biodiversity and vegetation is one of the serious problems faced by users (Hashemi *et al*.,2013). The remote sensing method has many vegetation indices, such as the Normalized Difference Vegetation Index (NDVI) which is an important, common and widely used index in research on global environmental and climatic change (Bhandari and Kumar, 2012). NDVI is calculated as a ratio between measured canopy or leaves reflectance in the red and near-infrared bands, respectively (Nageswara *et al*., 2005).

The red edge is a special index of green vegetation related to two optical properties of plants (chlorophyll absorption caused low red reflectance, and internal leaf scattering gave high near-infrared reflectance), Within the red edge region, the maximum point of slope (or inflection point) is referred to red edge position, that occurs between 680 – 780 nm. Which, is fundamentally sensitive to chlorophyll, water, foliage mass and leaf area index (Ganapol *et al*., 1998, Baranoski and Rokne 2005; Cho and Skidmore, 2006). This index is used as an Indicator of sharp change in leaf reflectance.

Urban vegetation cover has a lot of tree species to define, monitor and survey. Little is known about the leaf optical properties of tropical tree species and about using remote sensing in tree species identification. So, (Lee *et al*. 1990) studied leaf optical properties of tropical species, as well as (Avalos *et al*., 1999) worked on leaf optical properties of tropical dry forest trees and lianas. Moreover, (Cochrane, 2000) estimated the reflectance of leaves or branches to differentiate tropical tree species. When, (Clark *et al*. 2005) succeeded to determine seven tropical tree species at the leaf, pixel, and crown levels. No doubt that species classification has several applications, such as monitoring endangered or commercial tree species, characterizing biodiversity, monitoring changes in species composition over time and changes in tree demography associated with global environmental changes so, one of the important goals of using spectral reflectance curve in plant classification is to generate spectral libraries of earth's surfaces or materials to map human activities, (Manakos *et al*., 2010, Jiménez and Díaz-Delgado, 2015). Even so, the studies of remote sensing and vegetation mapping have focused on grasslands, shrublands, marshlands, forests, and sub-aquatic (Kalacska, 2007; Manevski *et al*., 2011; Somers and Asner,2012).

So, the purpose of this research is to define and record the differences among some tree species wildly used and separated in Egypt that, belong to family fabaceae using the smallest element in trees crown" leaf". Moreover, to express the differences in plant leaf optical properties and found the best vegetation indices to differentiate among vegetation species to collect data about our urban vegetation for building our spectral library in Egypt.

## MATERIALS AND METHODS

### Study Area and Tree Species:

This study was carried out in August 2021 in Antoniadis Garden, Alexandria city, Egypt. Leaves samples of fourteen genera belonging to the family Fabaceae were collected randomly all over fully sun faces trees crowns, from big and mature trees. (Fig.1) showed the location, and Tables (1 & 2) summarized the phonological properties of the studied species.

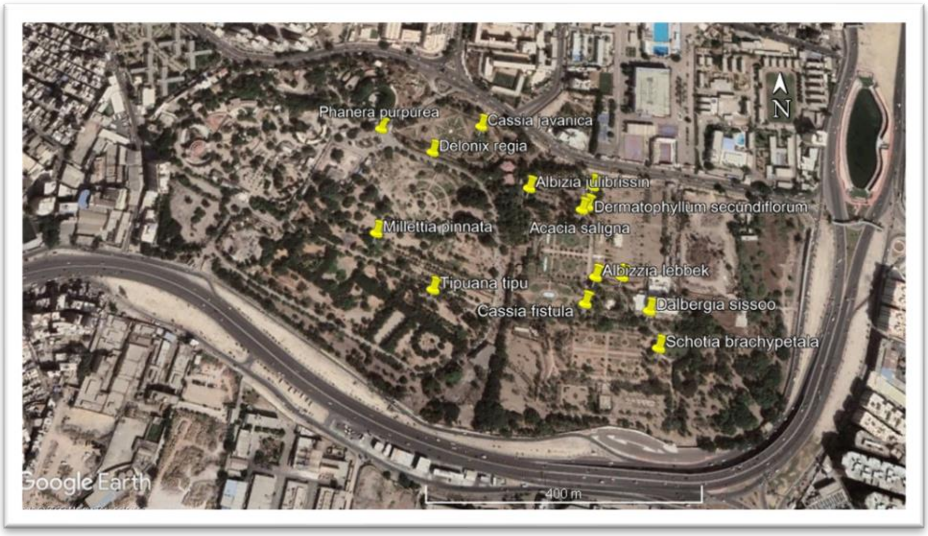



**Fig (1):** The location of studied species in Antoniadis Garden.

**Table 1:** Phonological properties of the studied species.

| No | Species | Tree height average (m) | leaves | | | Flower | | | Fruit | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Shape | Length (cm) | Broad (cm) | Blooming Time | color | Diameter (cm) | Type | Length (cm) | Broad (cm) |
| 1 | *Acacia saligna* (Labill.) H.L.Wendl. | up to 6 | simple | 15 – 30 | 1 -3 | Early summer | Yellow | 7.5 | legume | 12.5 | 0.5 |
| 2 | *Albizia lebbeck* L. Benth. | 18 - 30 | pinnate | 7.5 -15 | 9 - 11 | March - April | White | 5- 8 | legume | 15 - 30 | 2.5 – 5.0 |
| 3 | *Albizia julibrissin* Durazz. | Up to 6 | pinnate | 20 - 45 | Up to 20 | summer | Pink | 4- 6 | legume | 15 - 30 | 2.5 - 5 |
| 4 | *Phanera purpurea* (L.) Benth. | 10 -20 | simple | 10 - 20 | 20 - 22 | winter | Pink | 20 | legume | 30 | 2.5 |
| 5 | *Cassia fistula* L. | 10 - 20 | pinnate | 30 - 40 | 4 - 9 | Early summer | Yellow | 4 - 7 | legume | 30 - 60 | 1.5 – 2.5 |
| 6 | *Cassia javanica* subsp. Nodosa (Bush. -Ham. Ex Roxb) K. Larsen &S.S. Larsen. | 25 - 40 | pinnate | Up to 20 | 25 - 18 | summer | Pink | 4 - 7 | legume | 30 - 60 | 1.5 – 2.5 |
| 7 | *Dalbergia sisso* Roxb. ex DC. | up to 25 | pinnate | 18 | 4 - 6 | July | White | up to 1.5 | legume | 4 - 8 | 1.0 |
| 8 | *Delonix regia* (Bojer ex Hook.) Raf. | up to 8 | pinnate | 30 - 50 | 10 - 15 | summer | Red | 7 - 10 | legume | up to 60 | 5 – 6.5 |
| 9 | *Erythrina caffra* Thunb. | 10 | trifoliate | 6 - 8 | 13 – 15 | Three times per year | Red | 5 - 7 | legume | 10 - 12 | 0.5 – 1.0 |
| 10 | *Parkinsonia aculeata* L. | 2 - 8 | pinnate | 0.5 | 10- 12 | summer | Yellow | 2 - 3 | legume | Up to 7 | 0.5 |
| 11 | *Millettia pinnata* (L.) Panigrahi. | Up to 7 | simple | 10 | 12- 15 | April - May | White | 2 - 3 | legume | 5 - 7 | 2 - 3 |
| 12 | *Schotia brachypetala* Sonder. | up to 5 | pinnate | 8 – 9 | 5 – 7 | May | Red | 4 - 7 | legume | 10 | 2 - 3 |
| 13 | *Dermatophyllum secundiflorum* (Ortega) Gandhi & Reveal. | Up to 10 | 3-5 leaflet | 7 - 9 | 4 - 6 | summer | blue | 2 - 4 | legume | 14 - 16 | 7 - 10 |
| 14 | *Tipuana tipu* (Benth.) O. kuntze | up to 15 | pinnate | 6 - 11 | 3 – 5 | **April - May** | Yellow | **5 - 7** | legume | 6 - 8 | 2 - 3 |

Badr (2003) , Heneidy (2010) and Mohamed (2018).

**Table 2:** Photos of Leaves, Flower and Fruit of studied species.

| No | Species | leaves | Flower | Fruit |
|---|---|---|---|---|
| 1 | *Acacia saligna* (Labill.) H.L.Wendl. |  |  |  |
| 2 | *Albizia lebbeck* L. Benth. |  |  |  |
| 3 | *Albizia julibrissin* Durazz.. |  |  |  |
| 4 | *Phanera purpurea* (L.) Benth. |  |  |  |
| 5 | *Cassia fistula* L. |  |  |  |
| 6 | *Cassia javanica* subsp. Nodosa (Bush. -Ham. Ex Roxb) K. Larsen &S.S. Larsen. |  |  |  |

| | | | | |
|---|---|---|---|---|
| 7 | *Dalbergia sisso* Roxb. ex DC. |  |  |  |
| 8 | *Delonix regia* (Bojer ex Hook.) Raf. |  |  |  |
| 9 | *Erythrina caffra* Thunb. |  |  |  |
| 10 | *Parkinsonia aculeate* L. |  |  |  |
| 11 | *Millettia pinnata* (L.) Panigrahi. |  |  |  |
| 12 | *Schotia brachypetala* Sond. |  |  |  |
| 13 | *Dermatophyllum secundiflorum* (Ortega) Gandhi & Reveal. |  |  |  |
| 14 | *Tipuana tipu* (Benth.) O. kuntze |  |  |  |

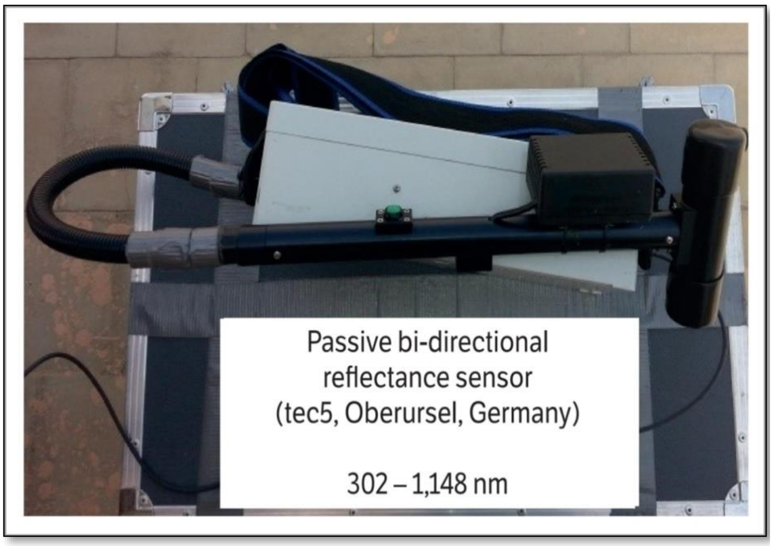
Badr (2003) , Heneidy (2010) and Mohamed (2018)

**Experimental Design:**

Leaves sample of each tree was collected from mature trees representative of their species. Two trees were selected from each species. A sample of four leaves was collected randomly from the crown of each tree, at the four-crown direction from each orientation. Samples of fully exposed to sunlight leaves from the upper part of the crown were selected randomly. Then leaves samples were washed and prepared for spectral reflectance measurements.

**Equipments and Measurements:**

Spectral reflectance was measured by the passive reflectance sensor that contains two units, one unit to detect the solar radiation as a reference signal, and the second unit measures the reflectance of leaves with an angle of view of 12°,(tec5, Oberursel, Germany). Leaf spectral reflectance was taken from a 0.25m distance and the field of view is 0.05 $m^2$. The spectral range of the passive sensor is 302−1148 nm, with a spectral bandwidth of 2 nm, (Fig. 2a), (El-Sayed *et al*., 2015).





a b

**Fig 2: a-** The Field Spectral Radiometer Hand-Held instrument
**b-** A hand-held chlorophyll meter

**Measurements and Calculations:**

**-Spectral Reflectance Curve**.

The digital numbers (DN) of each different tree species were extracted from the 302 -1148 nm wave-length range and plotted to illustrate leaves behavior of each tree species to different wavelength bands of the spectrum.

**-Digital Number (D.N.).**

The average digital numbers (DN) of each different tree species were extracted from visible bands and plotted to show the behavior of leaves of each tree species in different wavelengths of the spectrum.

**-Vegetation Indices:**

**1-Normalized difference vegetation index. (NDVI).**

$$NDVI = (NIR - R)/(NIR + R)$$

Where: NIR is a Near-infrared wave band
R is Red wave band

NDVI is related to changes in the amount of green biomass, pigment content and concentration and leaf water stress, etc. (Tucker and Sellers, 1986; Fassnacht *et al*., 1997). The value of NDVI ranges between (-1 to 1), NDVI value close to 1 indicates very dense vegetation, while a value near 0 indicates bare soil or very sparse vegetation.

**2-Simple Ratio (SR).**

$SR = NIR/R$ …………

Near-infrared / Red reflectance ratio Related to changes in the amount of green biomass, pigment content and concentration and leaf water stress, etc. (Tucker, 1979; Baret and Guyot, 1991).

**3- Infrared to the red ratio (IR/R)**

$\frac{IR}{R} = \frac{R780}{R670}$ **Pearson and Miller (1972)**

**4 -Infrared to the green ratio (IR/G)**

$IR/G = \frac{R780}{R550}$ **Takebe *et al*. (1990)**

**5- Red-edge (RE)**

Calculation of the reflectance at the inflection point.(R red-edge ).

$$Rre = \frac{(R670 + R780)}{2}$$

where R is the reflectance**. (Guyot and Baret, 1988 and Curran *et al*., 1995)**.

**6- Red-Edge Position (REP)**

Calculation of the red edge position.

$$REP = 700 + 40\left(\frac{Rre - R700}{R740 - R700}\right)$$

where 700 and 40 are constants resulting from interpolation in the 700–740 nm interval (Guyot and Baret 1988 and Curran *et al.*, 1995).

- **Total chlorophyll content**

Total Chlorophyll content of the leaves of each tree species was measured using A hand-held chlorophyll meter (Fig. 2 b).

**Statistical Analysis**:

The layout of the experiment was a complete randomized design (CRD) with 4 replicates, Means were compared by L.S.D. test at a 5% level of probability according to (Snedecor and Cochran, 1989). The correlation between leaves' chlorophyll content and vegetation indices was calculated according to Federer, (1955).

## RESULTS

**Spectral Reflectance Curve:**

Data of spectral reflectance of each wave-length band within 302-1148nm, with a spectral bandwidth interval of 2 nm from both and each side of leaf surface for each tree species were measured and plotted in a curve to show the behavior of different wavelengths reflect from each tree species leaves. (Figs. 3 & 4) clarified that extracted spectral curves of both and each leaf surface showed clear differences among tree species and can be used successfully for species classification. Spectral curves are formed of bottoms (absorption regions) and peaks (reflectance regions). Results showed that Spectral curves are clearly separated for all species at Green (520-580nm), Red edge (670 nm) and near-infrared (NIR) (780-1080 nm) regions, (Figs.3 &4). Moreover, spectral curves of the upper and both leaf surfaces are similar where, *Cassia fistula* gave the highest reflectance value in (NIR) region, and at the same time, *Phanera purpurea* gave the highest reflectance value in the green region. When at leaf lower side curve *Phanera purpurea* gave the highest reflectance value for both NIR and Green region.

**Digital Number (D.N.):**

Reflected spectrum averages of 302-1148 nm wavelength from both and each side of the leaf surface for each tree species were calculated and statistically analyzed. Results of Statistical analysis showed highly significant differences between digital numbers (DN) among tree species and these results have been obtained from upper, lower and both leaf surface sides, as presented in (Tables 3,4 and 5).

*Phanera purpurea* and *Cassia fistula* recorded the highest value of (DN) (32.70, 31.66),(31.71, 23.04) and (33.68, 31.28) when, *Albizia julibrissin* gave the lowest value of (DN) (16.84, 17.73 and15.26) for both and each side of leaf surface, respectively.

**Vegetation Indices (V.I.)**:

Six vegetation indices [Normalized Difference Vegetation Index (NDVI), Simple Ratio (SR), Infrared to Red ratio (IR/R), Infrared to Green ratio (IR/G), Red-Edge (RE) and Red-Edge Position (REP)] were calculated for upper, lower and both leaf surface sides to examine their ability to differentiate trees species. According to statistical analysis, all studied indices gave highly significant differences between species and the means of these indices were presented in (Tables 3,4 and 5). For both leaf sides the highest values of NDVI, were recorded in *Parkinsonia aculeate*, *Delonix regia*, and *Millettia pinnata* species (82,82,82) and the highest values (84,82,82) were found in *Millettia pinnata*, *Parkinsonia aculeate* and *Delonix regia*, respectively. when, the highest NDVI values (83, 82, 80) were, recorded in *Delonix regia*, *Parkinsonia aculeate* and *Millettia pinnata*, in order for the lower leaf surface. While, *Parkinsonia aculeate* recorded the highest value for SR, IR/G and REP for both and each leaf side (4.5, 4.4, 718.75; 4.4, 4.3, 718.67 and 4.58, 4.44, 718.84), respectively.

At the same time, *Delonix regia* gave the highest value of IR/R index (11.7 and 12.38) for both and lower leaf surfaces, respectively. When *Millettia pinnata* had the highest value on the leaf's upper surface 11.7.When the highest value of RE (24.9 and 34.18) was obtained from both and upper sides of *Cassia fistula* leaf surface, compared to *Phanera purpurea* lower leaf surface that recorded the highest value of RE 35.34.

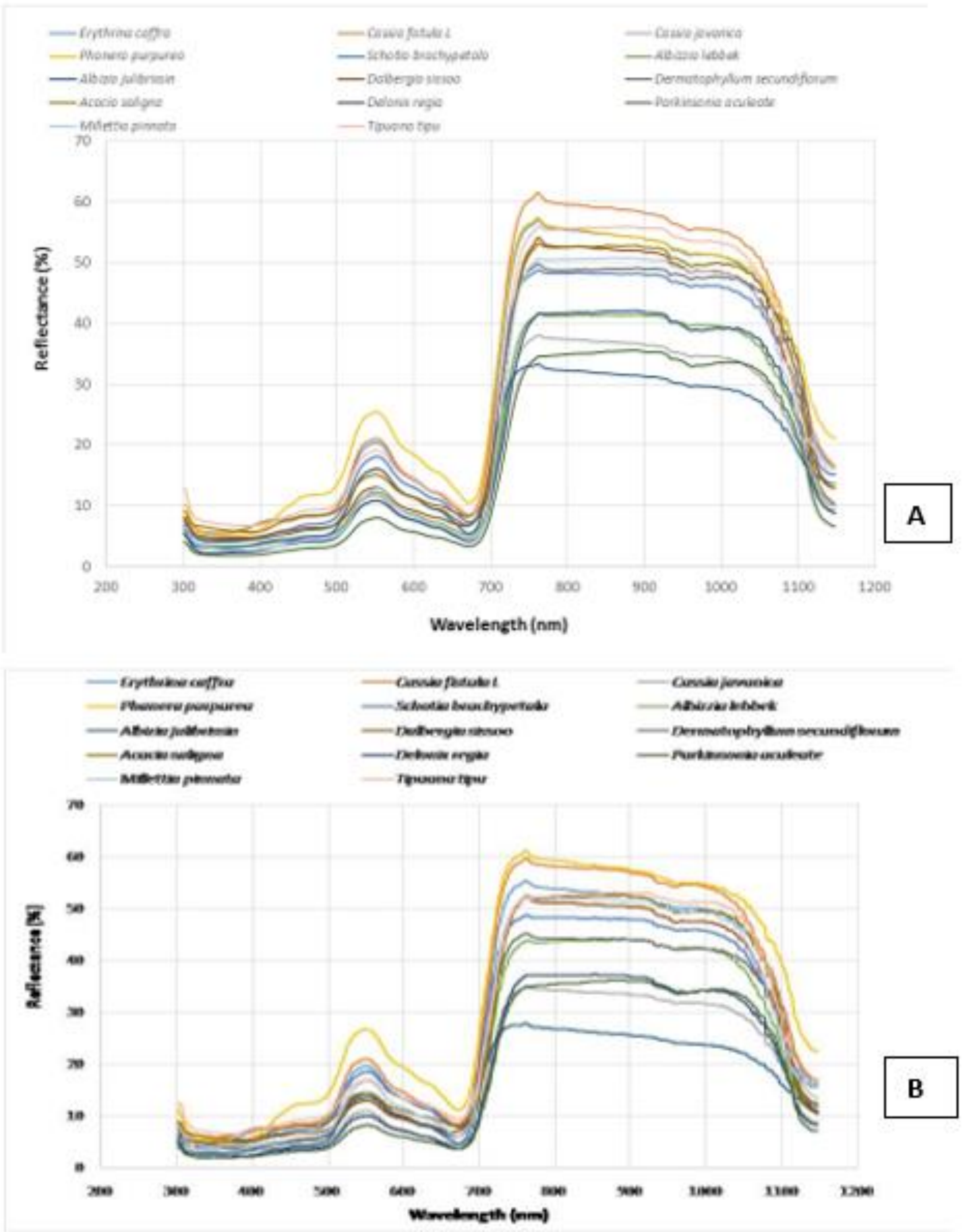



**Fig. 3: A** ) Leaf upper Side spectral curve **B**) Leaf lower side spectral curve of different tree species

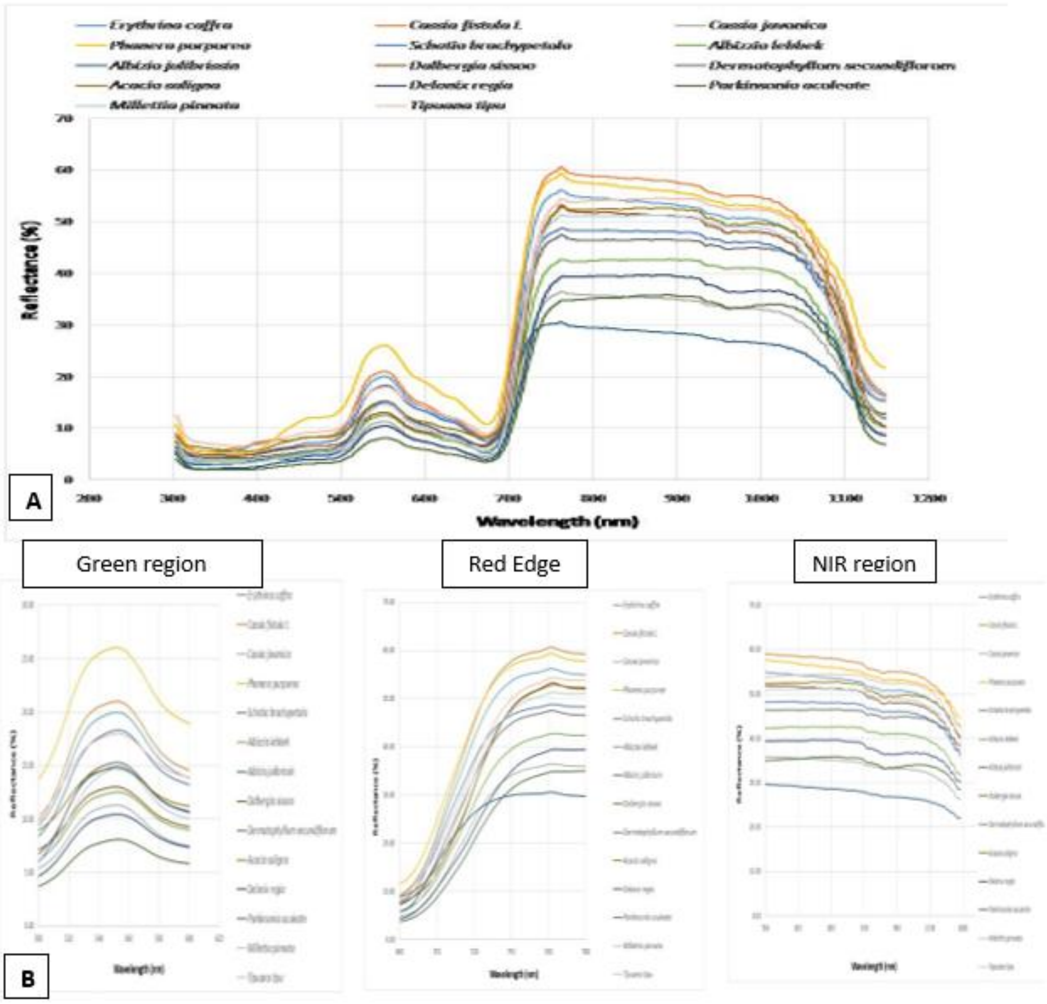



**Fig. 4**: A- the spectral curve of both the upper and lower sides of leaf surface
B- regions of differences and separated bands on green, red edge and NIR regions.

**Table 3:** Means of vegetation indices for upper and lower leave surface for plant species

| **Indecies** / **Species** | **NDVI**** | **SR**** | **IR/R**** | **IR/G**** | **$R_{re}$ (red edge) *** | **REP**** | **DN**** |
|---|---|---|---|---|---|---|---|
| ***Erythrina caffra*** | 0.74 | 2.9 | 6.8 | 2.9 | 23.9 | 712.94 | 29.57 |
| ***Cassia fistula* L** | 0.75 | 3.0 | 7.5 | 2.9 | 24.9 | 712.91 | 31.66 |
| ***Cassia javanica subsp. Nodosa*** | 0.77 | 3.3 | 8.2 | 3.2 | 16.2 | 716.14 | 18.70 |
| ***Phanera purpurea*** | 0.68 | 2.3 | 5.4 | 2.2 | 24.6 | 711.91 | 32.70 |
| ***Schotia brachypetala*** | 0.74 | 2.7 | 6.9 | 2.7 | 20.8 | 712.61 | 26.49 |
| ***Albizzia lebbek*** | 0.77 | 3.5 | 8.1 | 3.4 | 18.6 | 716.57 | 22.33 |
| ***Albizia julibrissin*** | 0.71 | 2.0 | 5.9 | 2.0 | 13.4 | 704.11 | 16.84 |
| ***Dalbergia sissoo*** | 0.77 | 4.4 | 8.4 | 4.3 | 22.3 | 717.95 | 26.37 |
| ***Dermatophyllum secundiflorum*** | 0.77 | 3.3 | 7.7 | 3.2 | 20.1 | 714.26 | 25.18 |
| ***Acacia saligna*** | 0.73 | 3.7 | 6.5 | 3.6 | 22.2 | 718.51 | 27.81 |
| ***Delonix regia*** | 0.82 | 4.2 | 11.7 | 4.1 | 17.9 | 718.20 | 19.94 |
| ***Parkinsonia aculeate*** | 0.82 | 4.5 | 10.3 | 4.4 | 16.0 | 718.75 | 17.87 |
| ***Millettia pinnata*** | 0.82 | 3.7 | 10.8 | 3.6 | 22.4 | 716.35 | 26.09 |
| ***Tipuana tipu*** | 0.71 | 3.2 | 6.3 | 3.1 | 23.1 | 716.50 | 29.6 |
| **LSD** | LSD 0.05 = 0.039 | LSD 0.05 = 0.55 | LSD 0.05 = 1.77 | LSD 0.05 = 0.52 | LSD 0.05 = 6.79 | LSD 0.05 = 1.49 | LSD 0.05 = 3.13 |

**Table 4 :** Means of vegetation indices for upper surface of plant species leaves

| Indecies / Species | NDVI** | SR** | IR/R** | IR/G** | $R_{re}$ (red edge) ** | REP** | DN** |
|---|---|---|---|---|---|---|---|
| *Erythrina caffra* | 0.73 | 2.9 | 6.6 | 2.8 | 32.17 | 712.85 | 30.01 |
| *Cassia fistula* L | 0.75 | 3.0 | 7.3 | 2.9 | 34.18 | 712.81 | 32.04 |
| *Cassia javanica subsp. Nodosa* | 0.78 | 3.3 | 8.2 | 3.2 | 21.15 | 716.26 | 19.45 |
| *Phanera purpurea* | 0.68 | 2.3 | 5.3 | 2.2 | 33.32 | 711.95 | 31.71 |
| *Schotia brachypetala* | 0.74 | 2.7 | 6.9 | 2.7 | 27.9 | 712.76 | 26.49 |
| *Albizzia lebbek* | 0.78 | 3.5 | 8.3 | 3.4 | 23.23 | 716.44 | 21.66 |
| *Albizia julibrissin* | 0.71 | 2.0 | 5.9 | 2.0 | 19.00 | 704.56 | 17.73 |
| *Dalbergia sissoo* | 0.77 | 4.3 | 8.2 | 4.2 | 29.71 | 717.95 | 26.64 |
| *Dermatophyllum secundiflorum* | 0.76 | 3.3 | 7.5 | 3.2 | 27.83 | 714.24 | 26.66 |
| *Acacia saligna* | 0.73 | 3.6 | 6.4 | 3.5 | 30.37 | 718.33 | 28.00 |
| *Delonix regia* | 0.82 | 4.1 | 11.0 | 4.0 | 22.96 | 718.36 | 21.22 |
| *Parkinsonia aculeate* | 0.82 | 4.4 | 10.2 | 4.3 | 19.08 | 718.67 | 18.41 |
| *Millettia pinnata* | 0.84 | 4.0 | 11.7 | 3.9 | 27.61 | 717.24 | 25.44 |
| *Tipuana tipu* | 0.73 | 3.2 | 6.8 | 3.1 | 32.11 | 715.66 | 30.27 |
| **LSD** | LSD 0.05 = 0.05 | LSD 0.05 = 0.67 | LSD 0.05 = 2.21 | LSD 0.05 = 0.63 | LSD 0.05 = 4.4 | LSD 0.05 = 2.2 | LSD 0.05 = 4.46 |

**Table 5:** means of vegetation indices for lower surface of plant species leaves.

| Indices / Species | NDVI** | SR** | IR/R** | IR/G** | $R_{re}$ (red edge) ** | REP** | DN** |
|---|---|---|---|---|---|---|---|
| *Erythrina caffra* | 0.74 | 2.94 | 6.88 | 2.88 | 31.04 | 713.04 | 29.13 |
| *Cassia fistula* L | 0.75 | 2.99 | 7.60 | 2.94 | 33.35 | 713.01 | 31.28 |
| *Cassia javanica subsp. Nodosa* | 0.76 | 3.24 | 8.21 | 3.15 | 19.34 | 716.01 | 17.95 |
| *Phanera purpurea* | 0.68 | 2.29 | 5.42 | 2.25 | 35.34 | 711.87 | 33.68 |
| *Schotia brachypetala* | 0.73 | 2.69 | 6.87 | 2.64 | 27.93 | 712.47 | 26.48 |
| *Albizzia lebbek* | 0.76 | 3.49 | 7.84 | 3.40 | 24.66 | 716.69 | 22.99 |
| *Albizia julibrissin* | 0.70 | 1.97 | 5.94 | 1.96 | 15.81 | 703.67 | 15.26 |
| *Dalbergia sissoo* | 0.76 | 4.49 | 8.57 | 4.34 | 28.98 | 717.95 | 26.11 |
| *Dermatophyllum secundiflorum* | 0.77 | 3.32 | 7.95 | 3.24 | 25.02 | 714.27 | 23.70 |
| *Acacia saligna* | 0.73 | 3.71 | 6.57 | 3.61 | 29.98 | 718.70 | 27.62 |
| *Delonix regia* | 0.83 | 4.28 | 12.38 | 4.17 | 20.37 | 718.04 | 18.66 |
| *Parkinsonia aculeate* | 0.82 | 4.58 | 10.34 | 4.44 | 19.31 | 718.84 | 18.00 |
| *Millettia pinnata* | 0.80 | 3.38 | 9.90 | 3.32 | 28.74 | 715.46 | 26.74 |
| *Tipuana tipu* | 0.70 | 3.19 | 5.82 | 3.12 | 30.70 | 717.34 | 28.94 |
| **LSD** | LSD 0.05 = 0.07 | LSD 0.05 = 0.93 | LSD 0.05 = 2.98 | LSD 0.05 = 0.89 | LSD 0.05 = 4.74 | LSD 0.05 = 2.18 | LSD 0.05 = 4.69 |

**Chlorophyll Content:**

Total chlorophyll content for each tree species was measured and statistically analyzed. Results displayed in (Fig. 5) illustrated highly significant differences among tree species in their chlorophyll content which is principally responsible for light absorption and reflection.

The highest chlorophyll content was recorded in *Tipuana tipu* 81.7 followed by *Millettia pinnata* 66.45 while *Erythrina caffra* had the lowest value 26.84.

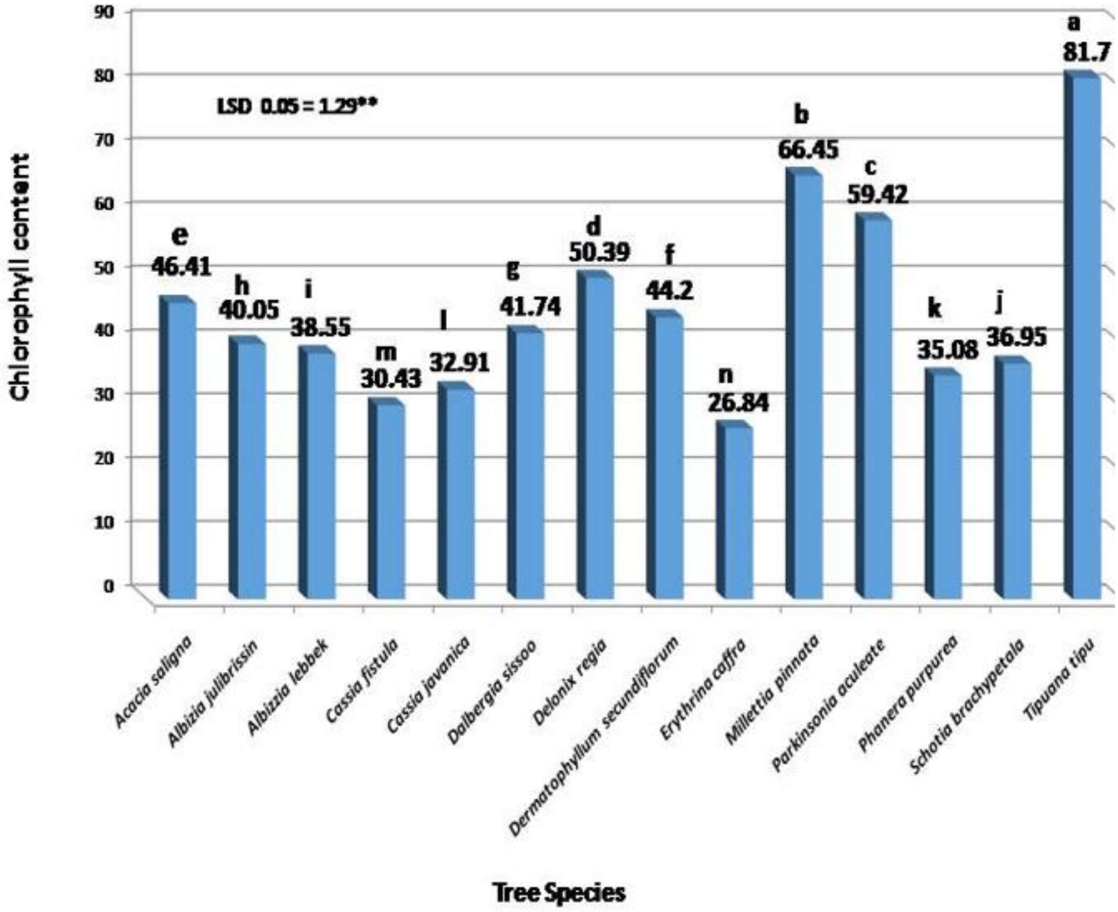



Fig. 5: Differences between chlorophyll content means of studied species.

**Correlation between Vegetation Indices and Chlorophyll Content.**

Correlation between chlorophyll content as a main factor of spectral behavior inside plant leaves, and studied vegetation indices were examined.

According to correlation analysis results presented in (Fig.6), there was a highly significant correlation at 0.01 probability between the total chlorophyll content of studied species leaves and tested vegetation indices NDVI, SR, IR/R, IR/G, RE, REP and DN with (R = 94, 97, 97, 97,88, 80 and 90 , respectively).

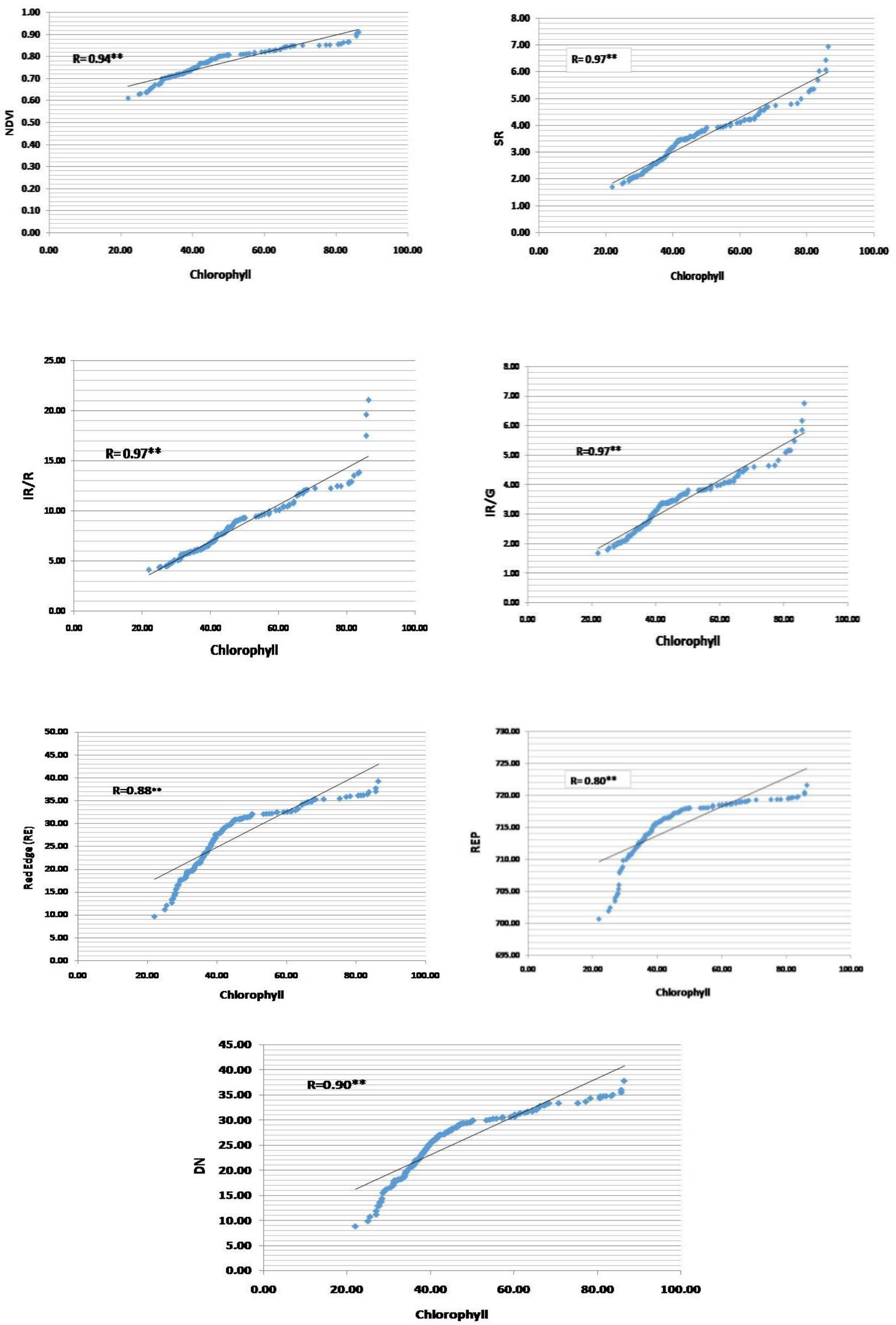



**Fig. 6:** Correlation between Chlorophyll content and different vegetation indices.

## DISCUSSION

There were obvious variations and differences in spectral curves for the upper, lower and both leaf surfaces of the studied species. It's noticeable that the spectral curve is formed of bottoms at blue, and red wavebands and peaks at Green and NIR wavebands. The result is matched with the fact of "all species had unified manner of the spectral response of lower reflectance in blue and red wavebands, and high reflectance in green and NIR regions". According to studies by (Ismail *et al*.,2016 and Matongera *et al*., 2017) each plant species, has unique spectral reflectance because of its physical and biochemical characteristics that essentially facilitate species identification. Therefore, it is often possible to differentiate plant species using their spectral diversity (Ustin and Gamon, 2010, He *et al*., 2011).

Data from narrow spectral bands have led to the successful spectral separation (Samiappan *et al*., 2017; Mohamed *et al*., 2018; Martin *et al*., 2018 and Kattenborn *et al*., 2019) on native and invasive species, even by satellite images or field-based instruments Tesfamichael *et al*., (2018). Also, Cochrane (2000) studied the differences among tropical forests species using ASD spectroradiometer (350–1050 nm) as well as, tropical mangrove species Vaiphasa *et al*., (2005) and tropical plant species Ullah, *et al.*, (2012). Spectral curves are formed from bottoms and tops that refer to absorption and reflectance regions. Where, wavelengths 670 nm and above near-infrared (NIR) regions gave the greater reflectance, plus an upright slope from 640 to 740 nm on the red edge. So, NIR reflectance was useful in differentiating the mint crop from monoculture weed, Apan *et al*., (2003) moreover, they suggested a technique for site-specific herbicide building on differences in NIR reflectance between plant species with different leaf morphology. The position of the red edge is consistent among different species and generally ranges from 680 to 750 nm. Mohammed *et al*., (2000).

Also, the results are matched with Middleton *et al*. (1998) that found significant differences in adaxial versus abaxial leaf surfaces of *Pinus banksiana*, *Picea mariana*, and *Populus tremuloides*. *Adaxial surfaces* of foliage were suggested to be likely the most important because they dominate the view from above. In general, *Abaxial surfaces* of evergreen foliar produced higher reflectance in the visible (VIS) wavebands than the adaxial surfaces. This result was obtained from broadleaved species compared to conifers, and in species, foliage had clear color differences between the abaxial and adaxial sides, e.g., *Acer rubrum* and *A. saccharinum*. Results illustrated that tree species can be differentiated in NIR region, Mohammed *et al*., (2000), related these differences to leaf biochemical "such as pigments, lignin, cellulose, proteins, nitrogen, and water content" and anatomical properties, according to Ouqrcival *et al*., (1999) on their research on *Quercus ilex* leaves, they studied the thickness of tissues, cuticle, upper epidermis, palisade mesophyll, and spongy mesophyll that tell us, how plants work. So, because of the internal leaf cell structure differences Plants vary greatly in near-infrared reflectance. Moreover, variation in NIR reflectance depends on plant leaves' shape and orientation (Williams, 1991). Therefore, near-infrared reflectance values are often more useful than visible reflectance values in distinguishing forest types. Moreover, determining the absolute peak reflectance in near-infra-red (NIR) (750 – 800 nm) is conceder an indicator of the volume of intercellular space in leaves.

We can estimate the unique spectral response of every plant species by comparing spectral signatures between and within species and detecting differences and distances in their spectral curve. Marcos and Díaz-Delgado (2015) and Mohamed *et al*, (2018). Optical properties of plant leaves are affected by chlorophyll concentration and other biochemicals, and water content which varies within species (Gausman and Allen,1973, Gausman 1985, De Boer and Tjin 1993, and Verdebout 2000) explained in their research that 680, 850, 1650, and 2200 nm wavelength are the most useful wavelength for leaves discrimination and these wavelengths are correlated to chlorophyll and water content. Where, vegetation has low reflectance and transmittance related to strong absorptions by foliar pigments such as chlorophyll pigments that absorb violet-blue and red light for photosynthesis and don’t absorb green light so, plants appear green. Furthermore, chlorophyll tends to control the spectral response because it is 5 to 10 times much than carotenoid pigments (Belward, 1991).

A high chlorophyll concentration guarantees a high light absorption; hence plant pigments absorb light strongly at some wavelengths and not at all others. Different plants and even different leaves from the same plant are known to be characterized by different efficiency of photosynthesis and plant growth Buschmann and Nagel (1993), El-Shanhorey, (2021) and El-Shanhorey, (2022). The plant leaf consists of an outer cuticle, cells and intercellular air spaces. Though the basic elements of plant leaves' anatomical structures are the same, the variability of the leaf's optical properties results from their arrangement inside the leaf (Verdebout *et al.*, 1994). All the above results are counter to, Smith, (2000), and Shimada *et al*., (2012), who mentioned that Poaceae grass leaves may have special carotenoid, and phytochrome, that absorbed blue and red, blue to green, and, red to NIR bands. When vegetation indices result corresponded with Cabacinha and Castro (2009) who found a strong correlation between plant diversity and Modified Vegetation Index (MVI), NDVI, and SAVI. As well as Bawa *et al*., (2002) found a positive correlation between NDVI and tree species diversity. Also, Walker *et al*., (1992) confirmed a correlation between plant species richness and the NDVI vegetation index. Also, Gillespie (2005) and Gillespie *et al*., (2009) found that NDVI index is the best vegetation index in the assessment of forest tree species diversity. According to, Broge and Leblanc, (2000) Thenkabail *et al*., (2002) vegetation indices extracted from narrow-band spectra are more sensitive to chlorophyll and other pigments. Also, results illuminated the correlation between vegetation indices and total chlorophyll content as agreed with (Slaton *et al.*, 2001 and Chen and Chen 2008) they found a clear correlation between chlorophyll content and SR and NDVI and they recognize these two indices to estimate the change of pigment content of each species moreover, they able to define the differences of leaves structural of different species. They mentioned that REP has an effective application to estimate chlorophyll content, and showed a more constant correlation for a single species. It's noticeable that VIS region indices, especially the red and green wavebands (FR/G, R/FR, FR/R), could differentiate abaxial and adaxial surfaces of broadleaved species, moreover, NIR reflectance declined according to chlorophyll decreasing, (Slaton *et al*., 2001; Read *et al*., 2002). Pointed out that the reflectance of NIR is influenced by spongy tissue inside the mesophyll and intercellular air spaces, and reflectance increased by increasing spongy tissue inside the mesophyll. Furthermore, NIR is influenced by the number of photosynthetic pigments (Carter and Knapp, 2001; Gitelson *et al*., 2003 and Muller *et al*., 2008). Rationally, to obtain an accurate determination of vegetation types we need to use several indices side by side Hashemi *et al*., (2013). NDVI is mainly used to improve the analysis of vegetation data. Where, Pettorelli *et al*. (2005) mentioned that NDVI is efficient to differentiate savannah, dense, evergreen forest, non-forest species and agricultural fields and estimating vegetation properties like LAI, biomass, chlorophyll and plant stress (Dutrieux *et al*., 2015; Pastor-Guzman *et al*., 2015; Zhu and Liu 2015; Chavez *et al*., 2016; Vicente-Serrano *et al*., 2016 and Tian *et al*., 2017).

**Conclusion**

In this research, the possibility of some vegetation indices to differentiate among some tree species belonging to the family fabaceae and widely separated in Egypt was examined on the leaf level. According to the results, the used indices " NDVI, SR, IR/R, IR/G, RE, REP and DN" plus spectral curve significantly succeeded to differentiate among studied species. Moreover, the spectral properties of each leaf surface were examined. The spectral of the plant leaf's upper surface is compatible with the measured spectral from both the upper and lower leaf surface together, that because most crown leaves are faced sun on their upper surface. With that, there were significant differences among tree species in leaf upper, lower and both surfaces. Variations in plant leaf structure as well as pigment and water content result in changing reflectance properties, even between closely related species. It is noticeable that the NIR region is varied between leaves according to their color, size, thickness and internal structure, Thus, species identification is possible from these unique spectral properties. Moreover, even small changes in reflectance can be measured, recorded and assigned to a specific species, which helps in collecting more and accurate spectral data about our trees and other vegetation covers, for more studies on vegetation biodiversity, phonological differences and health condition.

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## ARABIC SUMMARY

**التعريف والتفريق الإستشعارى لبعض أنواع العائلة البقولية فى حديقة أنطونيادس بإستخدام قياسات الإنعكاس الطيفى**

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تم إجراء هذا البحث فى حديقة أنطونياس , مدينة الإسكندرية, مصر على أشجار من أربعة عشر جنس يتبع العائلة البقولية لدراسة الإختلافات فى الخصائص الطيفية لأوراقها وإستخدام بعض الدلائل الخضرية مثل (دليل الإختلاف الخضرى الطبيعى (NDVI)- دليل النسبة البسيطة (SR) - دليل الأشعة تحت الحمراء إلى الأشعة الحمراء (IR/R) - دليل الأشعة تحت الحمراء إلى الأشعة الخضراء (IR/G) – دليل حافة الأشعة الحمراء (RE) - دليل موضع حافة الأشعة الحمراء (REP) هذا كله بالإضافة الى الرقم الطيفى (DN) , كما تم رسم المنحنى الطيفى Spectral curve لكل من السطح العلوى والسفلى للورقة وكذلك منحنى السطحين معا للورقة لكل نوع نباتى لإختبار قدرة إستخدام القياسات الطيفية وكذلك الدلائل الخضرية المستخدمة فى التفريق بين هذه الأنواع النباتية .هذا بالإضافة لتقدير الكلوروفيل الكلى فى الأوراق ودراسة مدى إرتباطه بهذه الأدلة فى التفريق بين الأنواع المستخدمة. وقد أظهرت النتائج أنه يمكن إستخدام القياسات الطيفية فى التفريق بين الأنواع النباتية المستخدمة بنجاح , حيث ان كل من الأدلة المستخدمة أظهرت معنوية عالية فى التفريق بين الأنواع النباتية المستخدمة وكذلك كان يوجد فروق واضحة فى المنحنيات الطيفية لكل نوع خاصة فى منطقة الضوء الأخضر ومنطقة الأشعة تحت الحمراء تبعا للون وسمك والتركيب الداخلى لكل نوع . كما أظهرت النتائج أيضا وجود إرتباط قوى بين محتوى الأوراق من الكلوروفيل الكلى والدلائل النباتية المستخدمة فى الدراسة. وعليه فإن القياسات الطيفية للموجات الضوئية لها القدرة على الفريق بين الأنواع النباتية بنجاح.