Diversity and Taxonomic Implication of Angiosperms in Sinai Peninsula as Revealed by Hyperspectral Remote Sensing

Ghada A. Khdery¹, Usama K. Abdel-Hameed², Mohamed A. Aboelghar¹ and Sayed M. Arafat¹

¹Agricultural Applications Department, National Authority for Remote Sensing and Space Sciences, Cairo, Egypt
²Botany Department, Ain Shams University, Khalifa El-Maamon St. Cairo, Egypt

Correspondence should be addressed to ghadabotany@yahoo.com

Publication Date: 27 November 2014


Abstract Monitoring natural vegetation through remote sensing data in Egypt is just beginning. Only few studies were carried out to monitor Mangrove communities along Red Sea coast. ASD field spectroradiometer was used to measure spectral reflectance in the wavelength ranged from 350 to 2500 nm for 20 species belonging to the following genera Achillea (one species), Aerva (one species), Alkanna (one species), Asclepias (one species), Astragalus (one species), Ballota (one species), Echinops (one species), Fagonia (one species), Hyoscyamus (one species), Matthiola (two species), Origanum (one species), Peganum (one species), Phlomis (one species), Pyrethrum (one species), Stachys (one species), Teucrium (one species), Verbascum (one species), Zilla (one species), Zygophllum (one species). Then, hyperspectral reflectance characteristics and Macro/micro-morphological features were investigated. One Way ANOVA (Tukey's HSD Post Hoc Analysis) and Linear Discriminate Analysis were carried out to identify the optimal wavebands and wavelengths to classify the different genera with high pharmaceutical values. It was found that red (550 - 750 nm) and NIR (760 - 1000 nm) spectral zones were the optimal to discriminate the different genera. The specific wavelengths that could be used to isolate each genera were identified. It was found that Asclepias sinaic, Stachys aegyptiaca and Verbascum sinaticum could be clearly isolated from the rest of the genera with unique spectral characteristics. At the same time, no specific wavelengths were investigated for Alkanna orientalis and Fagonia glutinosa.

Keywords Hyper Spectral; Natural Vegetation; Anatomy; Sinai Peninsula

1. Introduction

Unique geomorphological formations of south Sinai lead to a wide variation in its climate and vegetation than elsewhere. The most obvious and universal characteristic of desert vegetation is scarcity of plant growth and near lack of trees [1; 2]. The Sinai Peninsula is one of Egypt's most floristically diverse and phytogeographically interesting regions. Many of the plants growing the desert in Sinai are utilized by Bedouin for medicine, food and fodder [3].
The number of species recorded from Sinai was subjected to many changes by various authors viz El-Hadidi, [4] who recorded two new species to Egypt, thirty new to Sinai, making a total of 298 species belonging to 53 families; Abdallah et al. [5] stated that the flora of the Sinai region preserved in the Flora & Phytotaxonomy & Agriculture Research Center (CAIM) herbarium represented 88 families, 404 genera, 732 species, 16 subspecies and seventy varieties of the native flora of Egypt; A total of 886 species were recorded from Sinai by Danin et al. [6]; forty species were recorded for the first time from Sinai in this publication; Danin, [7] stated that there were 28 endemic species in Sinai, of which 25 occurred in the mountainous districts. El-Hadidi, [8] suggested that Sinai has 984 plant species belonging to 465 genera of vascular Cryptogams and flowering plants; he counted 108 species belonging to the Rosales families, with four species new to Sinai: Astragalus asterias (Leguminosae), Lotus halophilus, Medicago lupulina and Tephrosia purpurea. Gamal El-Din, [9] collected a total of 114 species of seed plants from Gebel El-Halal in northern Sinai during one season, of which 12 were new records; In his synthesis of the Egyptian flora, Boulos, [10] noted that 1285 taxa had been recorded from Sinai, of which 23 are doubtful records, leaving 1262 including infra specific taxa. There were 33 taxa endemic to Sinai and another four endemic to Sinai and other mainland regions of Egypt; Moustafa & Kamel, [11] listed the species growing in the Saint Katherine Mountains, identifying 221 plant species during their study. Abdou, [12] identified 107 species belonging to 31 families from South Sinai; 12% were considered to be endemic; Aayed et al. [13] suggested that Sinai contains approximately 1285 species, with South Sinai supporting 800, including 34 endemics; 62% were estimated as being rare or very rare; Gazara et al. [14] recorded 154 species from Sinai representing 32 families, with 48 rare, four endemic and 13 medicinal species contributing about 8.4% of the total recorded from Gebel El-Halal. Sinai Peninsula represents one of the most important centers of medicinal plants in the Arabian deserts [15]. Environmental conditions and human impacts have a significant influence on diversity and distribution of threatened, endemic, and medicinal plants in Sinai [16-18].

Remote sensing is an essential tool in the real-time identification of crops [19-22]. The tools for vegetation remote sensing have developed considerably in the past decades [23]. Developments in hyperspectral remote sensing have provided more accurate information on structural, biochemical and physiological properties of vegetation [24]. Most of the work on hyperspectral remote sensing of biophysical and biochemical parameters has been achieved through the development of new hyperspectral indices [25-28]. Hyperspectral data can provide significant improvements in spectral information content when compared with broad bands for detecting plant stress [27-29]; measuring chlorophyll content of plants [30]; identifying small differences in percent green vegetation cover [31]; extracting biochemical variables such as nitrogen and lignin [32]; discriminating land cover (LC) types [33], crop moisture variations [34-35], and leaf pigment concentrations (30); modeling quantitative biophysical and yield characteristics of agricultural crops [36]; improving detection changes in sparse vegetation [37; 38]; and assessing absolute water content in plant leaves [39]. In recent years, advances have been made in classifying vegetation using optimal spatial resolutions [40], red-edge first derivatives and green peak statistical indices [41]. The spectral signatures of features obtained are used as end members in hyperspectral classifications [42]. Also, it may help to improve the accuracy of supervised classification through machine learning process. [43].

2. Study Area

The Sinai lies in the arid belt of North Africa and belongs to the Saharan Mediterranean area with a true desert climate [44; 45]. The Saint Katherine region is situated in the southern Sinai and is part of the upper Sinai massif [45]. It is located between 33°55′ to 34°30′ East and 28°30′ to 28°35′ North (Figure 1). Elevation ranges from 1300 to 8530 ft. This region is characterized by outcrops of smooth granite uplifted to form several mountain peaks (e.g.; Gebel Katherine 2642 m and Gebel Musa 2285 m) [48]. The study area includes Wadi Al Arbaeen that is located between 33°56′60″ East and 28°33′5″ North and Wadi EL Sal that is located between 34°12′0″ East and 28°44′0″ North (Figure 1).
The Saint Katherine region contains a wide range of habitats and landscapes that are a consequence of varying climatic conditions, a wide range of altitudes, and variable topography. This region is characterized by outcrops of smooth granite uplifted to form several mountain peaks [46]. Because of these different conditions of temperature and humidity, there is a high level of biodiversity, particularly in the high altitude mountain area, which has the highest proportion of endemism in Egypt [47].

![Figure 1: Location of Study Area](image)

2.1. Material and Methods

The present study comprised 20 taxa grown in South Sinai, Sinai Peninsula, Egypt, representing 20 species belonging to 19 genus. Plant materials were kindly supplied by two wadies of Saint Catherine as indicated in Table 1.

Identification and nomenclature of the wild Egyptian species follows Täckholm, [48] and Boulos, [49], Voucher specimens were kept at (CAIA) Herbarium of Botany Department, Faculty of Science, Ain Shams University, Cairo, Egypt.

### Table 1: The Studied Taxa and Their Sources

<table>
<thead>
<tr>
<th>No.</th>
<th>Taxa</th>
<th>Source</th>
<th>Date of Collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>Name (Author)</td>
<td>Remarks (Reference)</td>
<td>Wadi</td>
</tr>
<tr>
<td>-----</td>
<td>--------------</td>
<td>---------------------</td>
<td>------</td>
</tr>
</tbody>
</table>

### 2.2. Macro & Micromorphological Attributes

Morphological description of the whole plant was made from the investigated living specimens or compiled from literature. Stem parts were collected and a portion of the middle lamina; including the midrib was cut from the mid. Cuttings were fixed in FAA and stored in 70% ethanol until use. Stems and lamina sections were prepared using hand microtome at 10-20µm; double stained using safranine and light green; mounted in Canada Balsam [50]; inspected by light microscope; photographed using a Reichert Microstar IV microscope at the Plant Taxonomy Research Laboratory, Botany Department, Faculty of Science, Ain Shams University, Cairo, Egypt. Cumulative plates and tables were prepared
to investigate the collected data. Terminology of Eames, [51] and Koller & Rost, [52] was used to describe the anatomical features.

2.3. Statistical Analysis of Hyperspectral Data

2.3.1. One Way ANOVA and Tukey’s HSD Post Hoc Analysis

Spectral zones that represent the atmospheric windows (portions of the electromagnetic reflectance that include data noise because of the relative air humidity) were removed. Spectral pattern of each measured sample was identified. Generally, spectral reflectance could be divided into six different spectral portions as follows: blue (350 - 440 nm), green (450 - 540 nm), red (550 - 750 nm), NIR (760 - 1000 nm), SWIR I (1010 - 1775 nm) and SWIR II (2055 - 2315 nm).

Table 2: The ASD Field Spec 3 Specifications

<table>
<thead>
<tr>
<th>Spectral Range</th>
<th>350 - 2500 nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectral Resolution</td>
<td>3:700 nm</td>
</tr>
<tr>
<td></td>
<td>8.5:1400 nm</td>
</tr>
<tr>
<td>Sampling Interval</td>
<td>6.5:2100 nm</td>
</tr>
<tr>
<td></td>
<td>1.4:350 - 1050 nm</td>
</tr>
<tr>
<td></td>
<td>2:1000 - 2500 nm</td>
</tr>
</tbody>
</table>

2.3.2. Comparing Standard Deviations from Several Populations

Analysis of variance (ANOVA) methods are presented throughout this text, for comparing means from several populations or processes. While similar methods are occasionally used for comparing several standard deviations, often using the natural logarithm of sample variances as the response variable, they are not a main focal point of this text. There are also a number of alternative procedures that are not based on ANOVA methods that can be used to compare standard deviations. Two of these are described below. Both are highly sensitive to departures from the assumption of normality; consequently, they should be used only after verification that the assumption of normally distributed errors is reasonable. When using ANOVA models with data from designed experiments, a valuable assessment of the assumption of constant standard deviations across k factor-level combinations is given by the F-max test. The F-max test is used to test the hypotheses [53] (Equation (1)).

\[
F_{\text{max}} = \left( \frac{\max \{ s_i \}}{\min \{ s_i \}} \right)^2
\]

(1)

2.3.3. Multiple Comparisons

The F-statistics in an ANOVA table provide the primary source of information on statistically significant factor effects. However, after an F-test in an ANOVA table has shown significance, an experiment usually desires to conduct further analyses to determine which pairs or groups of means are significantly different from one another [53].

2.3.4. Tukey’s Significant Difference Procedure

Tukey’s procedure controls the experiment wise error rate for multiple comparisons when all averages are based on the same number of observations. The stated experiment wise error rate is very close to the correct value even when the sample sizes are not equal. The technique is similar to Fisher’s LSD procedure. It differs in that the critical value used in the TSD formula is the upper 100α% point for the difference between the large and smallest of k averages. This difference is the range of the k
averages, and the critical point is obtained from the distribution of the range statistic, not from the \( t \)-distribution (Equation (2)).

Two averages \( y_i \) and \( y_j \), based on \( i \) and \( n_i \) observations respectively, are significantly different if

\[
\left| \bar{y}_i - \bar{y}_j \right| > TSD
\]

Where

\[
TSD = q(a; k, v) \left( MS_e \frac{n_i^{-1} + n_j^{-1}}{2} \right)^{V2}
\]  

(2)

2.3.5. Linear Discriminate Analysis

Linear Discriminate Analysis (LDA) is a method to discriminate between two or more groups of samples. The groups to be discriminated can be defined either naturally by the problem under investigation, or by some preceding analysis, such as a cluster analysis. The number of groups is not restricted to two, although the discrimination between two groups is the most common approach. Linear Discrimination Analysis (LDA) is a commonly used technique for data classification. LDA approach is explained by [21]. It easily handles the case where the within-class frequencies are unequal and their performance has been examined on randomly generated test data. This method maximizes the ratio of between-class variance to the within-class variance in any particular data set thereby guaranteeing maximal separability. LDA doesn’t change the location but only tries to provide more class separability and draw a decision region between the given classes. This method also helps to better understand the distribution of the feature data. In the current study, Class-independent transformation type of LDA was performed. This approach involves maximizing the ratio of overall variance to within class variance. It uses only one optimizing criterion to transform the data sets and hence all data points irrespective of their class identity are transformed using this transform. In this type of LDA, each class is considered as a separate class against other classes. In LDA, within-class and between-class scatter are used to formulate criteria for class separability. Within-class scatter is the expected covariance of each of the classes. The scatter measures are computed using Equations (3) and (4).

\[
S_W = \sum_j P_j \times (\text{cov}_j)
\]  

(3)

Therefore, for the two-class problem,

\[
S_W = 0.5 \times \text{cov}_1 + 0.5 \times \text{cov}_2
\]  

(4)

All the covariance matrices are symmetric. Let be the covariance of set 1 and set 2 respectively.

Covariance matrix is computed using the following Equation (5).

\[
\text{cov}_j = (x_j - \mu_j)(x_j - \mu_j)^T
\]  

(5)

Then, the between-class scatters computes using the following Equation (6).

\[
S_B = \sum_j (\mu_j - \mu_i)(\mu_j - \mu_i)^T
\]  

(6)
Sb can be thought of as the covariance of data set whose members are the mean vectors of each class. As defined earlier, the optimizing criterion in LDA is the ratio of between-class scatter to the within-class scatter. The solution obtained by maximizing this criterion defines the axes of the transformed space. As LDA is a class independent type in this study, the optimizing criterion is computed as Equation (7)

\[
\text{criterion} = \text{inv}(S_W) \times S_b
\]  

(7)

Finally, transforming the entire data set to one axis provides definite boundaries to classify the data. The decision region in the transformed space is a solid line separating the transformed data sets thus Equation (8)

\[
\text{transformed set} = \text{transform spec}^T \times \text{data set}^T
\]  

(8)

This analysis was carried out to discriminate between twenty species of plant.

3. Results and Discussion

3.1. Morphological Characters

In the present part, the different macromorphological characters of the studied taxa are presented in cumulative tables in order to facilitate deducing the most important diagnostic characters. Habit shrub in nine taxa, Sub shrubs in Ballota kaiseri, Origanum syriacum and Teucrium polium, or herb in the remaining studied taxa; Stem branching unbranched in Hyoscyamus muticus & Pyrethrum santolinoides or branched in eighteen taxa; Leaf arrangement alternate in nine taxa, alternate/spirally rosette in Hyoscyamus muticus & Verbascum sinaticum or opposite in the remainings; Leaf composition simple in thirteen taxa, pinnately compound in Astragalus sieberi, Echinops spinosus, Matthiola longipetala & Pyrethrum santolinoides & Origanum syriacum, trifoliolate in Fagonia glutinosa or dissected twice or more in Peganum harmala; shape of blade oblong-lanceolate in Achillea fragrantissima & Alkanna orientalis, linear to narrow-ovate in Aerva tomentosa, linear-lanceolate in Asclepias sinaica, Matthiola longipetala, Matthiola arabica & Peganum harmala, lanceolate in Astragalus sieberi, crenate-denate in Ballota kaiseri, ovate in Echinops spinosus, oblong-ovate to rhombic in Fagonia glutinosa, elliptical to ovate Hyoscyamus muticus, oblong-ovate in Origanum syriacum, linear in Phlomis aurea, oblong – elliptic in Pyrethrum santolinoides, oblong-lanceolate to elliptic in Stachys aegyptiaca, oblong – linear in Teucrium polium, elliptic in Verbascum sinaticum, oblanceolate in Zilla spinosa or oblong- cylindrical in Zygophyllum simplex; Apex of blade rounded in Achillea fragrantissima, acute in eight taxa, acuminate in Astragalus sieberi, Astragalus sieberi, Fagonia glutinosa and Hyoscyamus muticus, obtuse in Matthiola arabica, Origanum syriacum and Pyrethrum santolinoides and Stachys aegyptiaca, subacute to obtuse in Matthiola longipetala, cuspidate in Verbascum sinaticum or Subacute in Teucrium polium; Colour of blade white to greyish-green in Achillea fragrantissima, bluish-green to whitish-hairy in Aerva tomentosa, grey–green in Alkanna orientalis, greenish-yellow in Asclepias sinaica, green in six taxa, grayish green in Astragalus sieberi, pale green in Fagonia glutinosa, greyish-white in Matthiola arabica bright green in peganum harmala, olive or silver-green in Phlomis aurea, Mid-green in Stachys aegyptiaca, white in Teucrium polium, yellowish-green in Verbascum sinaticum, gray-green in Zilla spinosa or yellowish-green in Zygophyllum simplex; Margin of blade dentate in Achillea fragrantissima, entire in thirteen taxa, undulate in Alkanna orientalis & Matthiola longipetala, revolute in Asclepias sinaica, serrate in Astragalus sieberi or scarious in Matthiola arabica & Pyrethrum santolinoides; Petiole detection peltiolate in all taxa. This is in agreement with [54; 55; 44; 56-70].

Inflorescence position terminal in fourteen taxa, solitary axillary in Fagonia glutinosa, Hyoscyamus muticus, Pyrethrum santolinoides & Teucrium polium & Zygophyllum simplex or Solitary in Zilla spinosa; Panicle in five taxa, cyme umbellate in Asclepias sinaica, raceme in six taxa, spike in Ballota kaiseri &
Stachys aegyptiaca, cymose in Fagonia glutinosa, Peganum harmala & Zygophyllum simplex, paniculate in Matthiola arabica, Matthiola & longipetala or corymbose in Pyrethrum santolinoides; Number of flowers / inflorescence few in ten taxa or many in the rest of the studied taxa; Flower unisexual in Achillea fragrantissima & Aerva tomentosa or bisexual in the remaining studied taxa; Subsessile in Matthiola longipetala or sessile in the remaining studied taxa; Zygomorphic in nine taxa or actinomorphic in remaining studied taxa; sepal four in Matthiola arabica, Matthiola longipetala, Origanum syriacum, Peganum harmala & Zilla spinosa or five in the remaining taxa under investigation; Sepal shape tubular in six taxa, ovate in Aerva tomentosa & Asclepias sinaica, funnel in Alkanna orientalis, oblong–oblong in Fagonia glutinosa & Matthiola arabica, white to pink with dark violet veins or spots in Hyoscyamus muticus, Purple to white in Matthiola longipetala, yellowish white in Peganum harmala, Light violet in Zilla spinosa or yellowish in Zygophyllum simplex; Petal shape tubular in 6 taxa, oblong-obovate in Aerva tomentosa and Peganum harmala, funnel in Alkanna orientalis & Hyoscyamus muticus, valvate in Asclepias sinaica, papilionaceous in Astragalus sieberi, limb in Echinops spinosus & Phlomis aurea, spathulate in Fagonia glutinosa, linear to oblong-obovate in Matthiola arabica, oblong to linear in Matthiola longipetala, cylindric in Pyrethrum santolinoides, Cupulate in Verbascum sinaiticum or elliptic or pathulate in Zygophyllum simplex; number of petals are five in all the taxa under investigation except Aerva tomentosa (two petals) or Matthiola longipetala & Zilla spinosa (4 tepals); Cohesion of petals polysepalous in seven taxa or gamosepalous in remaining taxa under investigation; number of stamens five in seven taxa, ten in Astragalus sieberi, Zygophyllum simplex & Fagonia glutinosa, four stamens in six taxa, two stamens in Echinops spinosus, six stamens in Matthiola arabica & Zilla spinosa or fifteen in Peganum harmala; Direction of anther absent in Aerva tomentosa, introrse in nine taxa or extorse in remaining taxa under investigation; Ovary position inferior in seven taxa or superior in remaining taxa under investigation; Ovary setting subsessile in Achillea fragrantissima, Matthiola arabica & Matthiola longipetala or sessile in the rest of the studied taxa; Ovules (no/locule) one ovules in eight taxa, five ovules in Asclepias sinaica, Ballota kaiser & Fagonia glutinosa, two ovules in seven taxa, three ovules in Matthiola arabica or four ovules in Zygophyllum simplex; Stigma form capitulate in seven taxa, filiform in Aerva tomentosa & Teucrium polium, Papillate in Alkanna orientalis, Asclepias sinaica, Ballota kaiser, Origanum syriacum, Phlomis aurea & Teucrium polium, terminal or penicillate in Astragalus sieberi, subcapitate in Hyoscyamus muticus, obconical in Pyrethrum santolinoides, spherical in Verbascum sinaiticum or globose in Zygophyllum simplex; Fruit type achene in Achillea fragrantissima, Alkanna orientalis, Echinops spinosus & Pyrethrum santolinoides, capsule in eight taxa, berry Asclepias sinaica, legume Astragalus sieberi or schizocarp in six taxa; colour yellow in six taxa; white in Aerva tomentosa, Echinops spinosus, bright red in Alkanna orientalis, black or brown in Astragalus sieberi; viola in Ballota kaiser, brownish in Hyoscyamus muticus, purple to pink in Matthiola arabica, purple to white in Matthiola longipetala; Pale green in Origanum syriacum, orange-brown in Peganum harmala, violet in Phlomis aurea, brown to black in Stachys aegyptiaca, light-brown to dark brown in Teucrium polium or green in Zilla spinosa; dehiscence indehiscent in six taxa or dehiscent in remaining taxa under investigation; Shape of fruit oblong to ovoid in Achillea fragrantissima, Ballota kaiser, Origanum syriacum, Stachys aegyptiaca & Teucrium polium, subglobose in Aerva tomentosa & Zilla spinosa, ovoid in Alkanna orientalis & Zygophyllum simplex, spherical in Asclepias sinaica, ovoid-elliptic in Astragalus sieberi, elongate in Echinops spinosus, globose in Fagonia glutinosa, Hyoscyamus muticus & Peganum harmala, glabrous in Matthiola arabica, Matthiola longipetala & Phlomis aurea, elliptic to subglobose in Verbascum sinaiticum or subglobose in Zilla spinosa. This is in agreement with [70; 44; 61; 58-60, 62-64; 54-55; 65-67; 56].
3.2. Anatomical Characters

Stem out-line terete in 10 taxa, quadrangular in Ballota kaiseri, angular in Echinops spinosus, Fagonia glutinosa, Hyoscyamus muticus, Matthiola arabica & Matthiola longipetala or square in Origanum syriacum, Phlomis aurea, Pyrethrum santolinoides & Stachys aegyptiaca; Eglandular trichomes uncellular, unbranched in nine taxa, multicellular- branched in Aerva tomentosa, Matthiola longipetala, Phlomis aurea, Pyrethrum santolinoides & Stachys aegyptiaca, unicellular & multicellular- unbranched in Astragalus sieberi & Zilla spinosa, unicellular – unbranched & multicellular - branched in Ballota kaiser & Matthiola arabica or absent in the Echinops spinosus & Peganum harmala; Glandular trichomes are unicellular head & unicellular stalk in seven taxa, unicellular head & multicellular stalk in Matthiola longipetala, Phlomis aurea and Teucrium polium or absent in the rest of the studied taxa; Cuticle thick in eight taxa or thin in the rest of the studied taxa; subepidermal periderm present in Aerva tomentosa or absent in the rest of the studied taxa; Hypodermis present in Ballota kaiser, Echinops spinosus & Peganum harmala or absent the rest of the studied taxa; Epidermal cells shape barrel to papillose in Achillea fragrantissima, tangentially in Aerva tomentosa, Matthiola longipetala & Origanum syriacum, radially in six taxa, barrel in Asclepias sinaica, Phlomis aurea, Pyrethrum santolinoides & Verbascum sinaicicum, tangentially elongated in Ballota kaiser, Fagonia glutinosa & Zygophyllum simplex, papillose in Echinops spinosus and Stachys aegyptiaca or rectangular in Teucrium polium; Parenchyma rows in ground tissue one row in Achillea fragrantissima, two rows in Aerva tomentosa & Matthiola arabica, 2-3 rows in Alkanna orientalis & Asclepias sinaica, 4-5 rows in eight taxa, 1-2 rows in Ballota kaiser & Matthiola longipetala, 3-4 rows in Echinops spinosus, Stachys aegyptiaca & Zilla spinosa, 5-6 rows in Peganum harmala & Hyoscyamus muticus; Chlorenychyma tissue 3-4 rows in Achillea fragrantissima, Stachys aegyptiaca & Zilla spinosa; absent in Aerva tomentosa, Alkanna orientalis & Origanum syriacum, 2-3 rows in six taxa; 4-5 in Echinops spinosus & Matthiola arabica, 2 rows in Fagonia glutinosa, Pyrethrum santolinoides, 3 rows in Hyoscyamus muticus, 1-2 in Matthiola longipetala or 5-6 in Zygophyllum simplex; Collechyma tissue angular & Lamellar in Achillea fragrantissima, Phlomis aurea & Stachys aegyptiaca; absent in Aerva tomentosa, Astragalus sieberi, Matthiola longipetala, Zilla spinosa & Zygophyllum simplex or angular in the remaining studied taxa; Sclerenchyma tissue absent in Matthiola longipetala & Origanum syriacum or present in the remaining studied taxa; Pith width narrow in six taxa and wide in the remaining studied taxa; type of cells in pith lignified in ten taxa or thin in the remaining studied taxa; Aspect in fascicular region are separated strands in Aerva tomentosa or continuous strands in the remaining taxa under investigation; Rays in fascicular region, uniseriate in Asclepias sinaica or absent in the remaining studied taxa; Xylem contents in inter fascicular region fibers & vessels in fourteen taxa or fibers in six taxa; Rays in inter fascicular region uniseriate in Achillea fragrantissima, Aerva tomentosa, Asclepias sinaica, Hyoscyamus muticus & Zygophyllum simplex or absent in the remaining studied taxa; Cambium absent in Peganum harmala or present in the remaining studied taxa; Crystals druces in 12 taxa; Raphides in six taxa, absent in Matthiola arabica or raphides & druses in Origanum syriacum.

Leaf outline in T.S flattened adaxially in Achillea fragrantissima, Fagonia glutinosa & Matthiola longipetala, raised adaxially in six taxa, depressed adaxially in nine taxa or v shape in Echinops spinosus; Eglandular trichomes absent in five taxa, multicellular-unbranched in Aerva tomentosa, Asclepias sinaica & Teucrium polium, uni & multicellular, unbranched in Alkanna orientalis & Astragalus sieberi, unicellular-unbranched & multicellular-branched in Ballota kaiser, unicellular & unbranched in Matthiola arabica, Fagonia glutinosa, Zygophyllum simplex & Origanum syriacum or multicellular-branched in Hyoscyamus muticus, Phlomis aurea, Stachys aegyptiaca & Verbascum sinaicum; Glandular trichomes absent in ten taxa, unicellular head & multicellular stalk in Alkanna orientalis, Matthiola longipetala, Phlomis aurea & Teucrium polium, multicellular head with uni & biseriate stalk in fagonia glutinosa, multicellular head & multicellular stalk in Hyoscyamus muticus & Matthiola arabica, unicellular head & unicellular stalk in Origanum syriacum or unicellular head-unicellular stalk & unicellular head, bi cellular stalk in Stachys aegyptiaca; Cuticle thin in twelve taxa and thick in seven taxa; Shape of epidermal cells tangentially in Achillea fragrantissima, Origanum...
syriacum & Peganum harmala, barrel in Aerva tomentosa, Alkanna orientalis, Matthiola longipetala & Teucrum polium, tangentially radially in Asclepias sinaica, tangentially elongated Astragalus sieberi & Fagonia glutinosa, papillose in Ballota kaiseri, tangentially elongated to papillose in Echinops spinosus, radially in Hyoscyamus muticus, Verbascum sinaiticum & Zilla spinosa, oblong-ovoid in Matthiola Arabica & Zygophyllum simplex or radially elongated in Phlomis aurea & Stachys aegyptiaca; Type of mesophyll tissue isobilateral in ten taxa or dorsiventral in nine taxa; Palisade rows number two rows in six taxa or one rows in the remaining studied taxa; Palisade extended at mid rib region present in seven taxa or absent in the remaining studied taxa; Collenchyma in ground tissue absent in Aerva tomentosa, Matthiola longipetala, Matthiola arabica & Fagonia glutinosa, angular in Hyoscyamus muticus, lamellar in Stachys aegyptiaca or annular in the remaining studied taxa; parenchyma in ground tissue 4-5 rows in Achillea fragrantissima, Asclepias sinaica, Astragalus sieberi, Peganum harmala & Phlomis aurea; 3-4 rows in Aerva tomentosa, Alkanna orientalis & Ballota kaiseri, 1-2 rows in Echinops spinosus, Matthiola arabica & Matthiola longipetala, 2 rows in Origanum syriacum, 2-3 rows in six taxa, 5-6 rows in Hyoscyamus muticus; Aspect shape in vascular tissue centric single in nine taxa or crescent form in ten taxa; Crystal raphides in Ballota kaiseri; absent in Astragalus sieberi or druces in eighteen taxa; stomata present in lower epidermis in six taxa, stomata absent in Pyrethrum santolinoides, Stachys aegyptiaca & Zygophyllum simplex or present in lower and upper epidermis in ten taxa. This is in accordance with [71-75; 70; 76] (Figure 2a and b).
**Figure 2a: Macro and Microphotographs Analysis**

Stem Anatomy (A) Achillea Fragrantissima (B) Aerva Tomentosa (C) Alkanna Orientalis (D) Asclepias Sinaica (E) Astragalus Sieberi (F) Ballota Kaiseri (F) Echinops Spinosus (G) Fagonia Glutinosa (H) Hyoscyamus Muticus (I) Matthiola Arabica (J) Matthiola Longipetala (K) Origanum Syriacum (L) Peganum Harmala (M) Phlomis Aurea (N) Pyrethrum Santolinoides (O) Pyrethrum Santolinoides (P) Stachys Aegyptiac (Q) Teucrium Polium (R) Verbasum Sinalicum (S) Zilla Spinosa (T) Zygophyllum Simplex
3.3. Spectral Reflectance Pattern and Spectral Discrimination

Spectral reflectance of plant leaves could be characterized as absorption centered at about 0.65 µm (visible red) by chlorophyll pigment in green-leaf chloroplasts that reside in the outer of Palisade leaf, and to a similar extent in the blue, removes these colors from white light, leaving the predominant but diminished reflectance for visible wavelengths concentrated in the green. Strong reflectance between 0.7 and 1.0 µm (near IR) in the spongy mesophyll cells located in the interior or back of a leaf, within which light reflects mainly at cell wall/air space interfaces, much of which emerges as strong reflection rays.
It was found that all plants (measured samples) gave the general form of the spectral signature matched to a large extent in different spectral zones in the field of visible light and infrared. It was found that SWIR1 spectral zone was generally similar to the reflectance in the field of visible spectral zone and that was more memorable and less overlap between the various plants. The spectral Reflectance in SWIR1 was higher than the spectral reflectance in SWIRII. It was found that spectral reflectance of Verbascum sinaliticum, Phlomis aurea; Stachys aegyptiaca was higher than the rest of the plants in all spectral zones except the spectral zone SWIR2, where Achillea fragrantissima showed close spectral reflectance with Verbascum sinaliticum. Hyoscyamus muticus showed the lowest reflectance in SWIR2 while Asclepias sinalica showed the lowest reflectance in Infrared. In visible zone, reflectance was largely convergent except Verbascum sinaliticum and Stachys aegyptiaca (Figure 3).

In visible zone, Achillea fragrantissima showed relatively different reflectance pattern.

![Figure 3: The Spectral Reflectance Pattern for the Different Species](image)

Blue spectral zone showed significant reflectance for species Stachys aegyptiaca, Astragalus sieberi and Achillea fragrantissima. Green spectral zone showed significantly different reflectance pattern with Stachys aegyptiaca and Verbascum sinaliticum. NIR spectral zone showed significantly different reflectance with Stachys aegyptiaca, Verbascum sinaliticum, Phlomis aurea, Matthiola arabica, Ballota kaiseri, Asclepias sinalica and Pyrethrum santolinoides. Red spectral zone showed significantly different reflectance with ten samples (Verbascum sinaliticum, Stachys aegyptiaca, Achillea fragrantissima, Zilla spinosa, Hyoscyamus muticus, Peganum harmala, Ballota kaiseri, Echinops spinosus, Alkanna orientalis and Pyrethrum santolinoides). SWIR1 spectral zone showed significantly different reflectance with Phlomis aurea. SWIRII spectral zone showed significantly different reflectance with Phlomis aurea, Stachys aegyptiaca, Ballota kaiseri and Hyoscyamus muticus. Generally, the results of Tukey's HSD showed that Red was the best spectral zone for the discrimination between the most of the samples. Also, it was found that SWIR1 was not sufficient to discriminate the spectral reflectance of the different samples. The other four spectral zones showed acceptable results to for discrimination different samples. The results explained the optimal wavebands that could be used to identify each plant species (Figure 4). It was found that (Fagonia glutinosa and Alkanna orientalis) did not show any unique spectral zone. The three plants Verbascum...
sinaiticum, Stachys aegyptiaca and Asclepias sinaica showed relatively wide unique spectral zones as shown in table. It was found that seven of the samples (Zilla spinosa, Astragalus sieberi, Echinops cornigerus, Matthiola arabica, Matthiola longipetala, Origanum syriacum, Teucrium polium and Aerva tomentosa) have only one unique spectral zone. Following the spectral signature of all samples showed that the three plants Verbascum sinaiticum, Stachys aegyptiaca and Asclepias sinaica are the most vulnerable for discrimination and segregation through different sensors. These samples are characterized by unique and quite separable wavelengths and high values of reflection. This could be the core of future studies to survey, monitor and produce maps for the distribution of these plants in Sinai. It was also found that red spectral zone showed compatible results with morphological and anatomical studies as ten samples were quietly spectrally, anatomically and morphologically separable. Spectral reflectance characteristics of other species were observed to identify the optimal waveband and wavelength Viz [77-83].

Table 3: The Optimal Waveband to Differentiate Between the Different Species

<table>
<thead>
<tr>
<th>Species</th>
<th>Optimal Wavelength Zones (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Achillea fragrantissima</td>
<td>719: 725</td>
</tr>
<tr>
<td>Aerva tomentosa</td>
<td>718</td>
</tr>
<tr>
<td>Alkanna orientalis</td>
<td>----</td>
</tr>
<tr>
<td>Astragalus sieberi</td>
<td>713</td>
</tr>
<tr>
<td>Ballota kaiser</td>
<td>715: 716</td>
</tr>
<tr>
<td>Echinops spinosus</td>
<td>712</td>
</tr>
<tr>
<td>Fagonia glutinosa</td>
<td>----</td>
</tr>
<tr>
<td>Hyoscyamus muticus</td>
<td>715:716, 1313:1320</td>
</tr>
<tr>
<td>Matthiola arabica</td>
<td>719</td>
</tr>
<tr>
<td>Matthiola longipetala</td>
<td>714</td>
</tr>
<tr>
<td>Origanum syriacum</td>
<td>716</td>
</tr>
<tr>
<td>Peganum harmala</td>
<td>721, 1343: 1349</td>
</tr>
<tr>
<td>Phlomis aurea</td>
<td>719: 725</td>
</tr>
<tr>
<td>Pyrethrum santolinoides</td>
<td>716:718</td>
</tr>
<tr>
<td>Stachys aegyptiaca</td>
<td>702:719, 1562 :1799</td>
</tr>
<tr>
<td>Teucrium polium</td>
<td>720</td>
</tr>
<tr>
<td>Verbascum sinaiticum</td>
<td>718: 1349</td>
</tr>
<tr>
<td>Zilla spinosa</td>
<td>711</td>
</tr>
<tr>
<td>Zygophillum simplex</td>
<td>708: 709, 1330:1336</td>
</tr>
</tbody>
</table>
4. Conclusion

In the current study, ASD field spectroradiometer was used to measure spectral reflectance in the wavelength ranged from 350 to 2500 nm for twenty (20) species belonging to nineteen (19) genera. Hyperspectral reflectance characteristics and Macro/micro-morphological features were investigated.

**Figure 4:** The Spectral Reflectance Pattern for the Different Plant Species
One Way ANOVA (Tukey's HSD Post Hoc Analysis) showed that red (550-750 nm) and NIR (760-1000 nm) spectral zones were the optimal to discriminate the different genera. These results were consistent with morphological and anatomical studies as ten samples were quietly spectrally, anatomically and morphologically separable. Linear Discriminate Analysis identified the optimal wavebands and wavelengths to classify the different genera with high pharmaceutical values. Three species (Asclepias sinaic, Stachys aegyptiaca and Verbascum sinalicicum) could be clearly isolated from the rest of the genera with unique spectral characteristics. No specific wavelengths were investigated for Alkanna orientalis and Fagonia glutinosa. The results of the current study could be the basis for accurate mapping, monitoring and surveying three plant species with highly pharmaceutical value.

Acknowledgments

The authors are very thankful to Prof. Tantawy M.E. and Abou-El-Enain M.M. for their suggestions, expert advice and support. Authors also thank the research staff of the Agricultural applications department at the Egyptian National Authority for Remote Sensing and Space Sciences.

References


[55] Barry, J.C. *Teucrium Pilbaranum (Labiatae), a New Species from the Pilbara, Western Australia Australia.* Telopea. 8 (3) 299-303.

[56] Batanouny, K.H. 1999: *Wild Medicinal Plants in Egypt.* Academy of Scientific Research and Technology, Egypt. The World Conservation Union (IUCN), Switzerland. 60-64.


Hepper, F.N. and Friis, I., 1994: The Plants of Pehr Forsskal's "Flora Agyptiaco-Arabica". Kew: K.


