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Spectroscopic and morphological characteristics of genus *Jatropha* (Euphorbiaceae) and genus *Jojoba* (Simmondsiaceae)

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Abstract

Using second generation of biofuel that does not affect food crop production is an issue of global concern. Remote sensing (RS) proved to be efficient technique for inventory and monitoring the spatial distribution of biofuel plants at both local and regional scales. It is used also for site selection of the most suitable sites for the plantation of these plants through the integration of multi spatial layers. Spectral identification of these plants and the relationship between spectral and morphological parameters were not observed.

This work is considered the first step of a series of studies deals with the identification of the spectroscopic parameters and their relation with morphological parameters of the most common Egyptian natural vegetation. At this stage, two sources of fossil oil plants Jatropha and Jojoba were investigated. Spectral reflectance was measured using ASD spectroradiometer device and the spectral signature was identified for the two taxa. Secondly, optimal spectral zone and wavelength/s were identified for each sample. A Strong relation was found between chlorophyll content and spectral reflectance at visible spectral region. Normalized difference vegetation index (NDVI) was found to be highly correlated with chlorophyll content. Further work will be carried out to quantitatively relate the amount of ingredient fossil oil of these plants with spectroscopic characteristics.

Keywords: *Jatropha*, *Jojoba*, Spectroscopic Characteristics, Morphological Characters

Introduction

World's energy demand is increasing significantly according to the development of the industrial economy and huge population growth. Fossil fuels are the source and motive for many economic and environmental crises including instability of fuel price, declining energy resources, rising air and land temperature that leads to climate change and global warming. Importance of biofuel is increasing significantly as the world is struggling to face the problems of global warming and shortage in energy sources that threaten sustainable development in many regions of the world. Increasing the usage of renewable energy will certainly reduce global warming. International Energy Agency (IEA) determined amount of produced biofuel globally by about 83 billion liters (Ndegwa and Geoffrey et al. 2011).

Researchers worldwide are working to extract liquid biofuels like biodiesel and ethanol. Generally, there are two types of biofuel; the first type depends on economically valuable food crops such as maize/corn, sugarcane, wheat, or others. This type of biofuel is inconsistent with the requirements of food security. The second type of biofuels does threaten food security since it depends on non-edible woody plants such as *Jatropha* that get strong attention since the beginning of the 21st century due to its rich non-edible oil content (around 35 to 48 percent) (Openshaw, 2000; Fei et al., 2005).

Jatropha is a genus of about (175) plants belong to family Euphorbiaceous. It is divided into two subgenera, *Jatropha* and curcas. Subgenus *Jatropha* occurs widely in Africa, India, South America, West Indies, Central America, and the Caribbean (Leal and Agra 2005). Hutchinson and Dalziel (1958) (Hutchinson and Dalziel 1958) identified eight species of *Jatropha* in West-Tropical Africa, while Ratha and Paramathma (2009) identified twelve species of *Jatropha* in India, using morphological traits. *Jojoba*, (*Simmondsia Chinensis* (Link) Schneider), belongs to the family Simmondsiaceae, is a new semi- arid oil industrial crop that recently has to get more attention.

Earlier botanists placed Jojoba in the family Buxaceae, based on anatomical studies of Buxaceae, while (Melikyan, 1968) placed Simmondsia in a separate monotypic family Simmondsiaciae. This supports the contention of Van Tieghem the Belgian botanist in 1898 who suggested on the basis of the dioecious breeding system, floral morphology, and wood anatomy that jojoba be put into the family of its own, Simmondsiaceaen (Anon, 1980) and this was later supported by (Scogin, and Brown, 1979; Sherbrook, 1976a) who reported that based on the international rules of botanical nomenclature, the only valid scientific name for jojoba is (*Simmondsia chinensis* (link) Schneider).

Jatropha genus includes many toxins including lectin, saponin, carcinogenic phorbol and a trypsin inhibitor. *Jatropha gossypifolia* is recognized as invasive and highly toxic to human when the oil of *Jatropha curcas* is a purgative ones that is toxic in large quantities (Smith, 1923).

Simmondsia Chinensis (link) Schneider) (Jojoba) is another shrub that is getting high attention because of its valuable ingredient of oil that is used as a source of energy and for cosmetic purposes. The two plant genus (*Jatropha* and *Jojoba*) are sources of biofuel as well as their importance in medical and cosmetic purposes.

The two plant genus (*Jatropha* and *JoJoba*) are resources of biofuel in addition to their importance in medical and cosmetic purposes. The two plant genus are dry tolerant and could be cultivated over large areas in an arid and semi-arid environment of Egypt with no negative effect on food security. Therefore, it has been suggested that they should be cultivated over large areas of low capability soil as there is no competition for land with food crops.

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Its ability to regularly monitor habitat and invasive species is critical for better understanding of ecosystem and climate models (Kerr, and Ostrovsky, 2003), however, ecological monitoring and modeling the dynamics of an ecosystem may require higher spectral, temporal and spatial resolutions remotely sensed data. Hyperspectral remotely sensed data improved both ecological and geologic analysis of the earth's surface because of its ability to identify and discriminate spectral reflectance patterns of mineralogy, soil, vegetation (Van der Meer, 1998; Kruse et al., 2003; Schmidt and Skidmore, 2003; Apan et al., 2004).

Hyperspectral (RS) was used to differentiate particular environmental variables that were impossible to be identified using multispectral, broadband imagery. (RS) was used to propose a method for site selection of Jatropha C. plantation (Arslan, et al., 2015). Identification of the spectroscopic parameters and spectral reflectance pattern of Jatropha and its correlation with morphological characteristics has not been searched before. Spectral reflectance characteristics of Jojoba under salinity stress were studied by (Rao, et al. 2000). It was found that reflectance in near infrared range decreases with increasing age and leaf area index (LAI).

The main objective of the current study is to use microscopic examinations of morphological characters to provide useful taxonomic data that give further insight into proper classification, delineation, and identification of the studied taxa. Another aim is to identify spectroscopic characteristics and spectral reflectance pattern for four species of *Jatropha* and *simmondsia chinensis* (link) Schneider). The study aims also to analyze the correlation between spectral reflectance pattern and morphological characteristics of the studied taxa. Furthermore, the study identifies the optimal wavelength region and the specific wavelength for each investigated sample. These optimal wavelengths could be correlated with the amount of ingredient oil and physiological conditions of the studied samples.

Materials and Methods

Experiment was performed for four species from *Jatropha* genus that are common in Egyptian environment: *Jatropha curcas* L., *Jatropha gossipifolia* L., *Jatropha integerrima* Jacq, *Jatropha multifida* L and *Simmondsia chinensis* (link) Schneider). Plant materials were collected during a field observation to Al Orman Garden from May 2016. Morphological features were described following Taxonomy of Flowering Plants (Grill, 1998).

Spectral reflectance of the different samples was measured by (FieldSpec 4 Hi-Res NG Spectroradiometer). The device measured radiance in over two thousands wavebands ranged from (0.3 – 2.5 micrometer). Radiance of white reference was saved in a sampling file that comprises ten radiance spectra. Two vegetation indices: hyperspectral normalized difference vegetation index (NDVI) and Chlorophyll index (CI) were calculated. Then, statistical analysis was performed in two main steps. Turkey's procedure was applied to define the optimal waveband region for each investigated sample. Linear discrimination analysis (LDA) was applied to identify the unique wavelength/s for each investigated taxa.

Results and Discussion

Morphological analysis

Morphological characteristics of the studied taxa are presented in table – 1. In order to facilitate deducing the most important diagnostic characters, it was found that habit shrub in *J. gosspifolia*, *J. integrima* and *Simmondsia chinensis* or shrub/small tree in *J. curcas* and *J. multifida*, or herb in the remaining studied taxa; Stem erect in *J. curcas, J. gossypifolia, J. integerrima* and *Simmondsia chinensis*, erect or somewhat succulent in *J. multifida* or branched in *Simmondsia chinensis* .

Petiole absent in *J. curcas, J. integerrima* and *Simmondsia chinensis;* petiole 3–14 cm long in *J. gossypifolia;* petiole 10–30 cm long *in J. multifida* or; Leaf composition simple in all taxa; Shape of blade broadly ovate in *J. curcas*, *J. multifida* and *gossypifolia,* obovate in *J. integerrima* or oblong in *Simmondsia chinensis*; Apex of blade acute or shortly acuminate tip in *J. curcas*, acute in *J. gossypifolia*, *J. multifida* and *Simmondsia chinensis*, acuminate in *J. integerrima*; Color of blade light green in *J. curcas*, Green in *J. gossypifolia* and *J. multifida*, dark green in *J. integerrima* and green to grey in *Simmondsia chinensis*; Margin of blade entire in *J. curcas*, *J. integerrima*, *J. multifida* and *Simmondsia chinensis* or Serrated in *J. gossypifolia*; Petiole detection petiolate in all taxa. This is in agreement with (Dehgan, and Webster, 1979; Dehgan, 2012; Ratha, and Paramathama 2009)**.**

Inflorescence position terminal in *J.curcas*, *J. multifida*, *J. gossypifolia* and *J. integerrima* or axillary in *Simmondsia chinensis*, Inflorescence type dichasial cymose in *J. curca*, Scorpioid raceme in *J. gossypifolia*, polychasial cymose in *J. multifida*, subcorymbiform in *J. integerrima* or cymose in *Simmondsia chinensis*; Number of flowers / inflorescence five in *J.curcas*, *J. multifida*, *gossypifolia* and *J. integerrima* or 2-7 in *Simmondsia chinensis*. This agreed with (Undersander, et al.. 1990).

Flower unisexual in all studied taxa; Flower color creme in *J.curcas*, red in *J. multifida*, *J. gossypifolia* and *J. integerrima* or greenish-yellow in *Simmondsia chinensis*; Cohesion of sepals polysepalous in *J.curcas*, *J. multifida*, *gossypifoli* and *Simmondsia chinensis* or gamosepalous in *J. integerrima*; Petal shape oblong-obovate in *J. curcas*; Broadly obovate to spade-like, c. 3.5 by 2 mm in *J. gossypifolia*, obovate, c. 5 by 2.5 mm in *J. multifida* or obovate, 10–13 by 4–5 mm in *J. integerrima*; Number of stamens 10, the 5 outer filaments only basally united, the 5 inner completely united in *J.curcas*, stamens 8, the 5 outer filaments united in the lower half, the 3 inner ones united for two-thirds in *J. gossypifolia*, 8, c. 5 mm long; The filaments quite free in *J. multifida* , 10, the 5 outer filaments united for three-quarters, the 5 inner ones unitd for two-thirds their length in *J. integerrima* or 10–12 stamens per flower in *Simmondsia chinensis*; Ovary position superior in all taxa under investigation; Stigma form elongate, erect, thickened, bifid in *J. curcas*, free, erect, capitate, bifid in *J. gossypifolia*, capitate, bilobed in *J. multifida*, deeply bifid in *J. integerrima* or papillate in *Simmondsia chinensis*. This agreed with Anon (2004).

Fruit dehiscent in all taxa under investigation; Shape of fruit ellipsoid to tear drop shaped in *J. curcas*, Globose capsule in *J. gossypifolia*, Ellipsoid capsule in *J. multifida*, ellipsoid to ovoid in *J. integerrima* or capsule in *Simmondsia chinensis*. Seed size c. 1.7 by 1 cm in *J. curcas*, c. 7.5 by 4.5 mm in *J. gossypifolia*, 1.5–2 by c. 1.5 cm in *J. multifida*, c. 5 mm wide in *J. integerrima* or 1(-3)-seeded-0.5-1.1 g in *Simmondsia chinensis;* Seed Shape compressed ovoid-ellipsoid in

J. curcas, ovoid to ellipsoid-ovoid in *J. gossypifolia*, Broadly ovoid- ellipsoid to subglobose in *J. multifida*, Ellipsoid to ovoid, 8–9 in *J. integerrima*, ovate in shape in *Simmondsia chinensis*. This is in agreement with (Fairless, 2007; Buchmann, 1987).

Table – 1: Macromorphological Characters of the studied taxa.

Character	***J. curcas***	***J. gossypifolia***	***J. multifida***	***J. integerrima***	***Simmondsia chinensis***
Habit	Shrub/small tree	Shrubs up to 3 m tall	Shrubs or small trees, up to 7 m high	Shrub up to 6 m tall	Shrub
Stem	Erect	Erect	Erect somewhat succulent	Erect	Erect
Petiole					
Petiole	Absent	Petiole 3–14 cm long	Petiole 10–30 cm long	Absent	Absent
Leaf					
Leaf shape	Broadly ovate	Broadly ovate	Broadly ovate	Obovate	Opposite, oval in shape
Leaf colour	Light green	Green	Green	Dark green	Green to gray in color
Leaf apex	Acute or shortly acuminate tip	Acute	Acute	Acuminate to cuspidate	Acute
Form of margin	Entire	Serrated	Entire	Entire	Entire
Inflorescence					
Position	Terminal	Terminal	Terminal	Terminal or axillary	Axillary
Inflorescence type	Dichasial cymose	Scorpioid cymose	Polychasial cymose	Sub corymbiform	Raceme
No. of flowers	5	5	5	5	2-7
Penducle	Long and smooth ending	Long and smooth ending	Long and smooth ending	Glandular teeth	Long and smooth ending
Flower					
Color	Creme	Red	Red	Red	Greenish-yellow
Sex	Unisexual	Unisexual	Unisexual	Unisexual	Bisexual
Sepal	polysepalous	polysepalous	polysepalous	Gamosepalous	Polysepalous
Petal	polypetalous	polypetalous	polypetalous		
Petal shape	Oblong-obovate	Broadly obovate to spade-like, c. 3.5 by 2 mm	Obovate, c. 5 by 2.5 mm	Obovate, 10–13 by 4–5 mm	Without petals
Stamens	10, the 5 outer filaments only basally united, the 5 inner completely united	Stamens 8, the 5 outer filaments united in the lower half, the 3 inner ones united for two-thirds	8, c. 5 mm long, the filaments quite free	10, the 5 outer filaments united for three-quarters, the 5 inner ones united for two-thirds their length	10–12 stamens per flower
Ovary	Glabrous	Hirsute especially towards the apex	Trigonous	Glabrous	Glabrous
Position of ovary	Superior	Superior	Superior	Superior	Superior
Stigmas	Elongate, erect, thickened, bifid	Free, erect, capitate, bifid	Capitate, bilobed	Deeply bifid	Papillate

Fruit					
Fruit shape	Ellipsoid to tear drop shaped	Globose capsule	Ellipsoid capsule	ellipsoid to ovoid	Ovoid capsule
Dehiscence	Dehiscing loculicidal.	Dehiscing both septicidal and partly loculicidally	Dehiscent to sub drupaceous	Dehiscing	Dehiscent
Seeds					
Size	c. 1.7 by 1 cm	c. 7.5 by 4.5 mm	1.5–2 by c. 1.5 cm	c. 5 mm wide	1(-3)-seeded 0.5-1.1 g
Shape	Compressed ovoid-ellipsoid	ovoid to ellipsoid-ovoid	Broadly ovoid-ellipsoid to subglobose	Ellipsoid to ovoid, 8–9	Ovate in shape

Figure – 1: Macrophotographs of the studied taxa. A. *Jatropha curcas*, B. *Jatropha gossipifolia*, C. *Jatropha integerrima*, D. *Jatropha multifida*, E. *simmondsia chinensis*

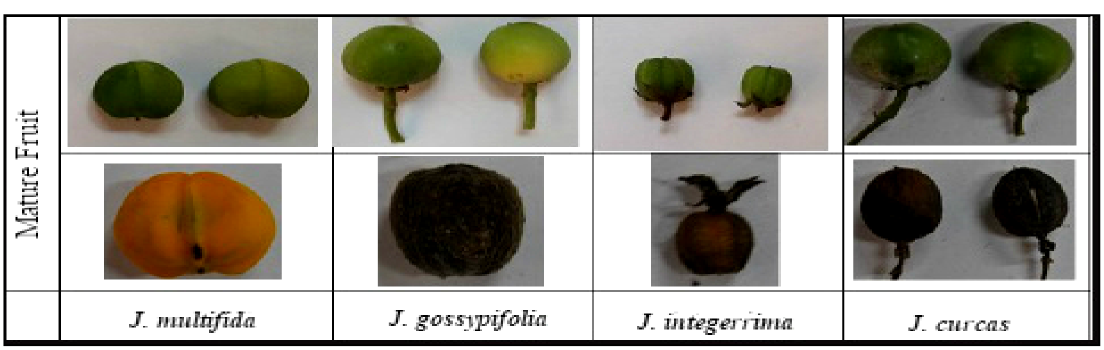

Figure – 2: Shape of fruits for four Jatropha species.

Spectroscopic characteristics

Spectral reflectance of plant leaves could be characterized as absorption centered at about 650 nm (visible red) by chlorophyll pigment in green-leaf chloroplasts in the outer of Palisade leaf, and to a similar extent in the blue, removes these spectrums from white ones, leaving the predominant reflectance for visible wavelengths concentrated in the green. Strong reflectance between (700 and 1000 nm) is from spongy cells in the interior or back of a leaf.

Spectral reflectance pattern of the investigated taxa as shown in figure (3) indicated the same trend of spectral reflectance as all samples are vegetative samples. The highest spectral reflectance was identified in near infrared spectral region; lower spectral reflectance was identified in shortwave infrared while the lowest spectral reflectance was identified in the visible spectral region (350 - 700 nm). The spectral Reflectance in SWIR1 was higher than the spectral reflectance in SWIRII with all samples. Relatively higher spectral reflectance was found for Jatropha gossypifolia and Simmondsia chinesis through the whole spectral regions, however, comparing with other plants, significantly higher spectral reflectance for the two plants over the rest of the plants was identified in the wavelength region from (350 - 700 nm).

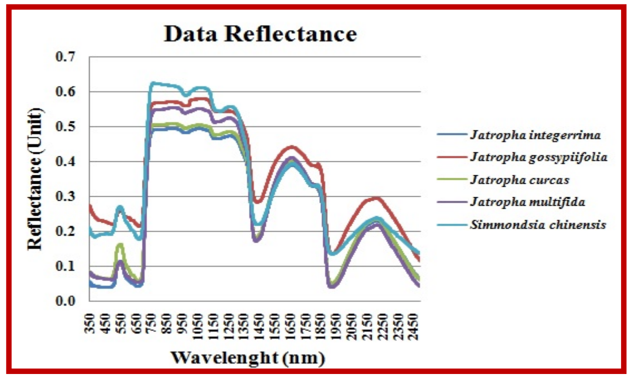

Figure – 3: The Spectral Reflectance Pattern for the Different Species

The result of Tukey's procedure as shown in figures (4, 5, 6, 7, 8 and 9) indicated that (SWIR-I) and (SWIR-II) were not sufficient for the spectral discrimination between samples. At the same time, NIR and blue spectral regions were the optimal to discriminate investigated taxa when green and red spectral regions showed acceptable results for discrimination.

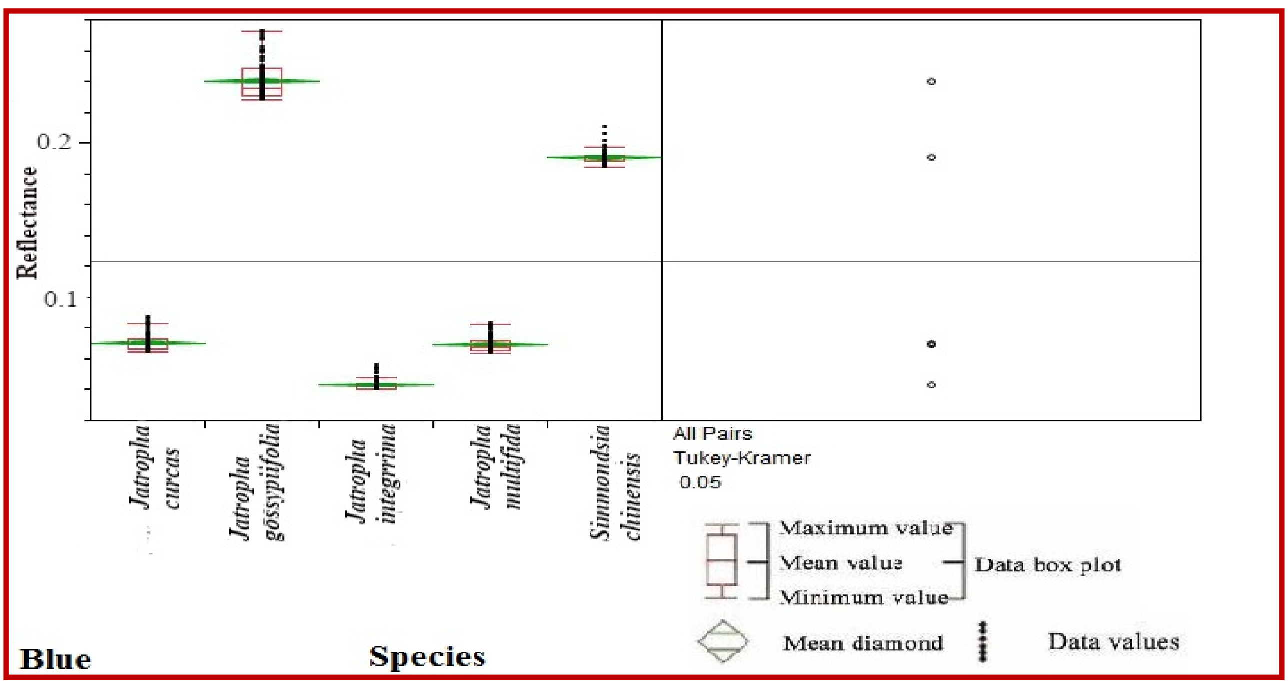

Figure – 4: ANOVA and Tukey's HSD analyses to discriminate the studied taxa in blue spectral zone

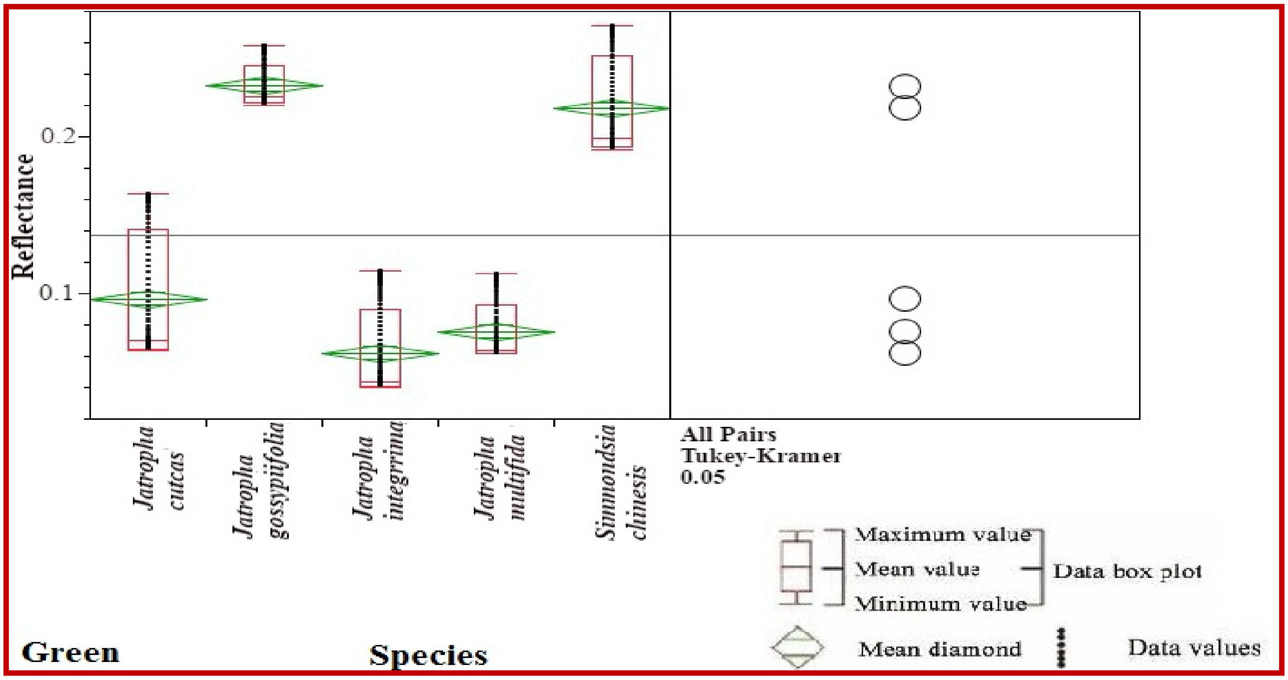

Figure – 5: ANOVA and Tukey's HSD analyses to discriminate the studied taxa in green spectral zone

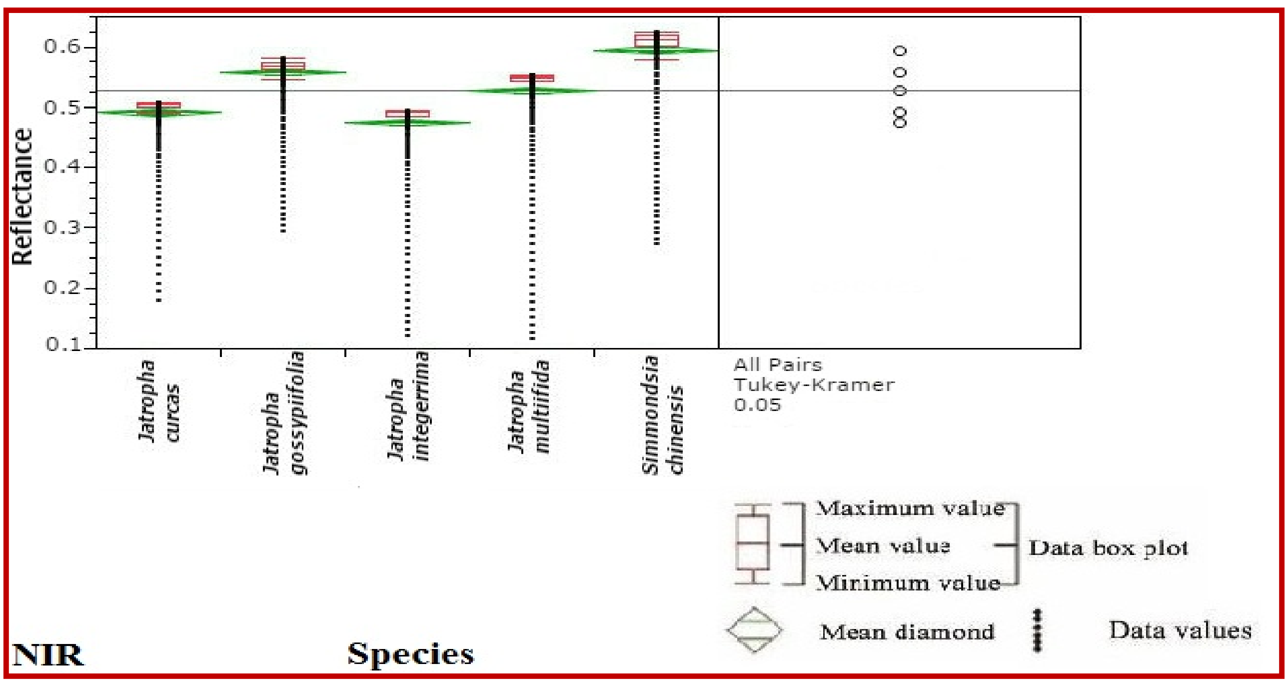

Figure – 6: ANOVA and Tukey's HSD analyses to discriminate the studied taxa in red spectral zone

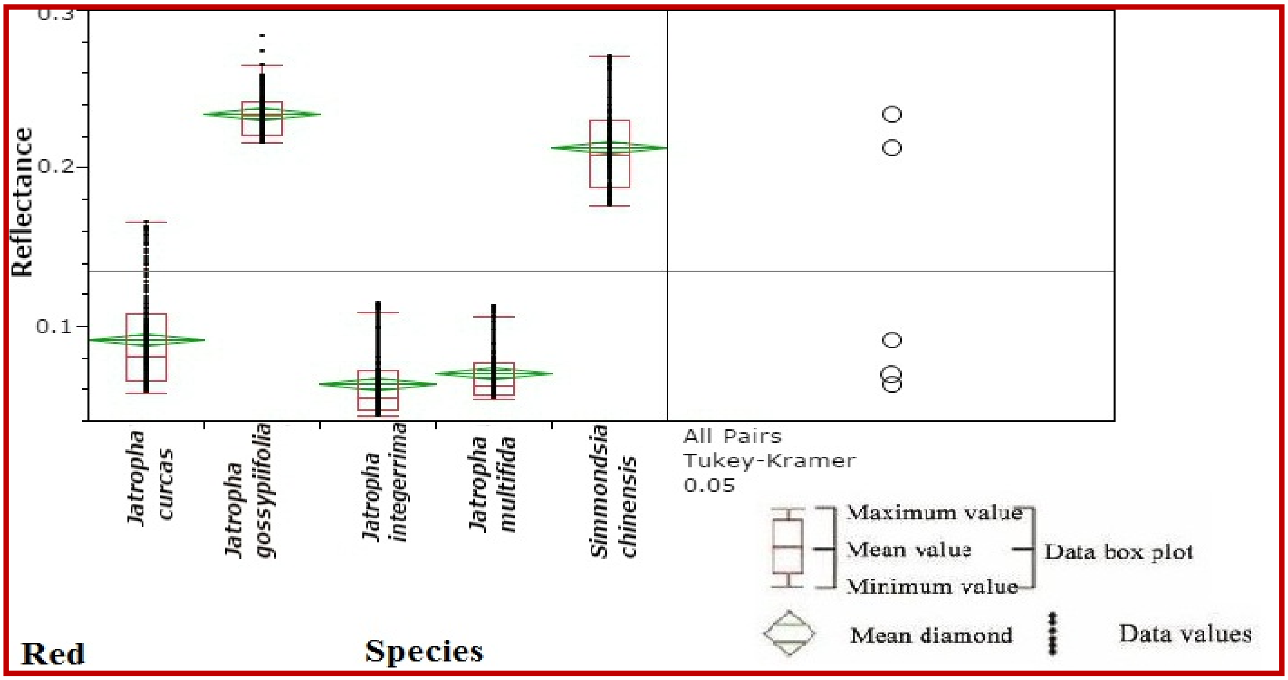

Figure – 7: ANOVA and Tukey's HSD analyses to discriminate the studied taxa in near infrared (NIR) spectral zone

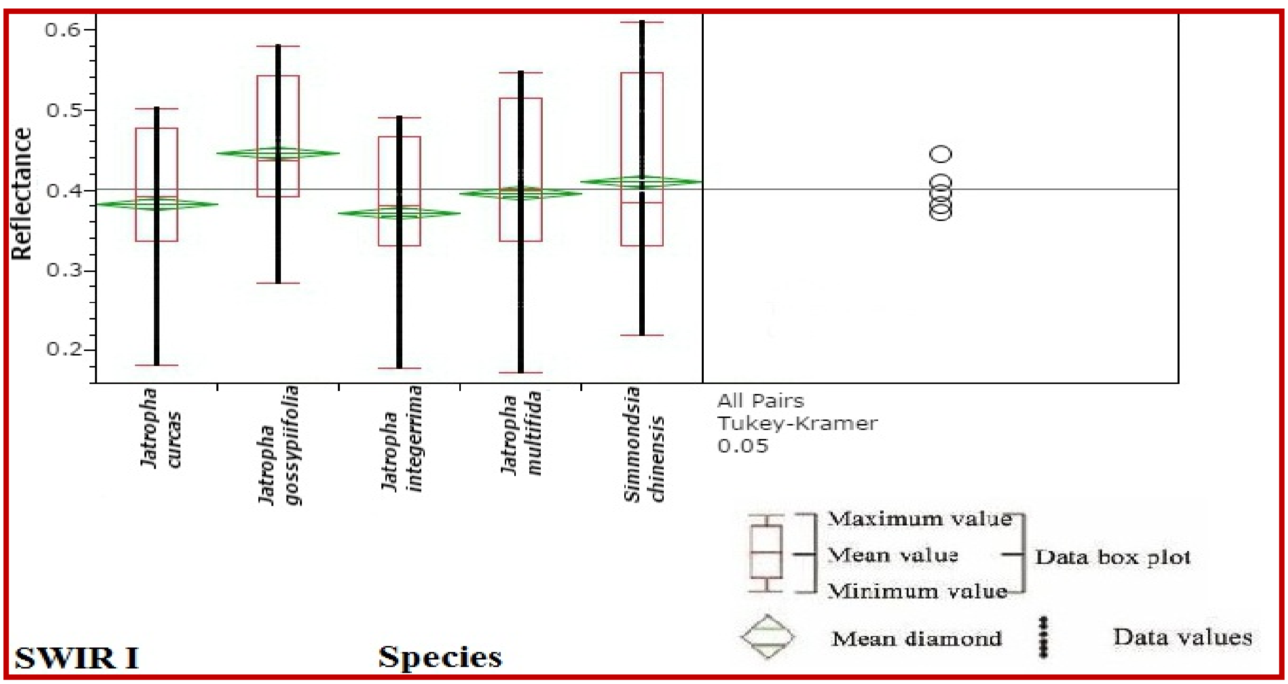

Figure – 8: ANOVA and Tukey's HSD analyses to discriminate the studied taxa in SWIRI spectral zone

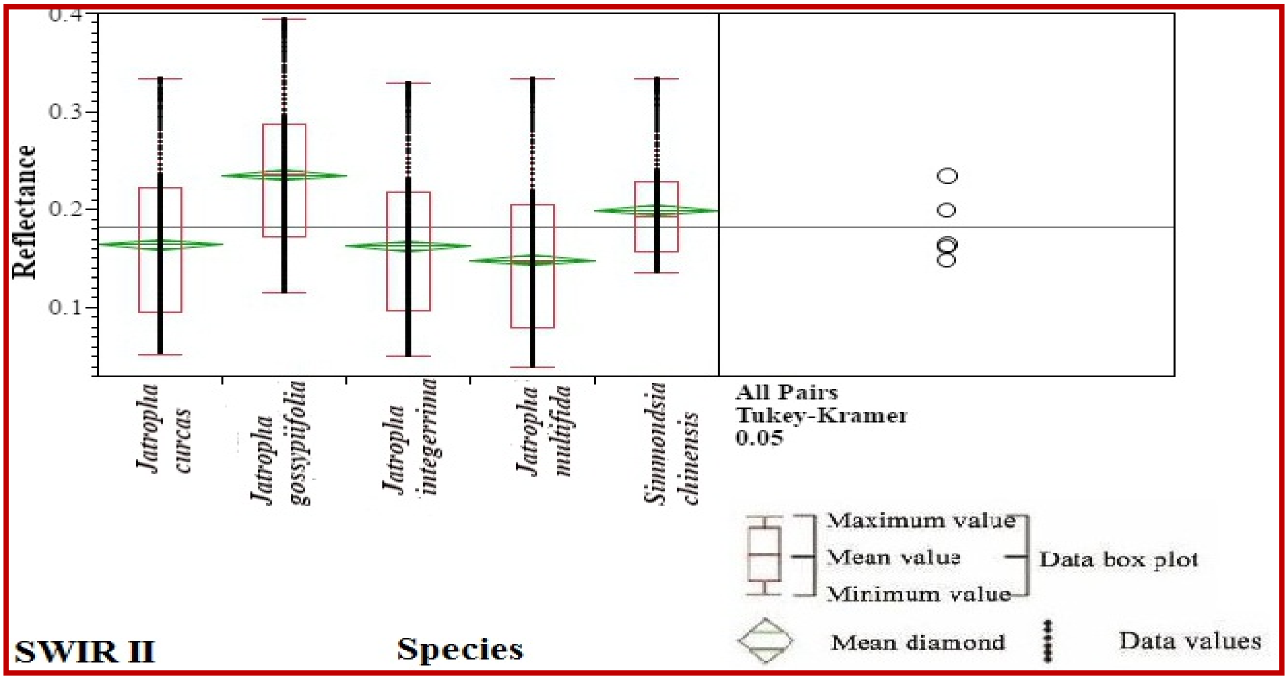

Figure – 9: **ANOVA and Tukey's HSD analyses to discriminate the studied taxa in SWIRI spectral zone**

The results of the the linear discriminate analysis are shown in the table (2). This analysis identified the specific wavelength for each taxon. Uniquely, visible spectral region (350 - 713 nm) and far SWIRII spectral region (1859 - 2500 nm) were the optimal to identify *Jatropha integerrima* although the value of spectral reflectance in the visible region was the lowest compared with reflectance values of the other taxa in the same spectral region. Since most of the visible light is used by chloroplastides for photosynthesis, the amount of reflectance is quite low and plant leaves appear in dark green color for morphological description and appear also in the value of chlorophyll index (0.43). *Jatropha gossypiifolia* and *Simmondsia chinensis* showed a higher spectral reflectance with all region, however, the unique spectral zone was different from one another. When *Jatropha gossypiifolia* showed one wide spectral range including NIR and SWIR-1, *Simmondsia chinensis* showed different narrow spectral zones for discrimination. The specific wavelengths for the rest of the samples were close to each other as an indicator for close anatomical characteristics.

Calculated values of (NDVI) and (CI) as shown in the table (3) indicated the close relation between chlorophyll and spectral reflectance of red and infrared spectral zones. High chlorophyll content in plant leaves leads to using most of the red spectrum in photosynthesis resulting in very low reflectance in the red spectral zone that is finally translated in high (NDVI). These results agree with morphological characteristics as the plants with the highest reflectance in red spectral zone appear in light green color when low red spectral reflectance appears in dark green color.

Table – 2: **The Optimal waveband to identify different taxa**

Species	Wavelength
Jatropha curcas	708, 1394, 1510, 1511, 1512, 1513, 1857, 1858
Jatropha gossypiifolia	708-1860
Jatropha integerrima	350-713, 1395-1515, 1859-2500
Jatropha multifida	714-716, 1390-1393, 1518-1534, 1844-1856
Simmondsia chinensis	706-709, 1388-1393, 1544-1582, 1751-1850

These results explain that spectroscopic parameters and spectral signature could be used for the identification of plant taxa as morphological and anatomical parameters. Further work is necessary for the establishment of the spectral library of the common natural vegetation in Egyptian environment.

Table – 3: NDVI and CI values

Plant	NDVI	CI
Jatropha curcas	0.124	0.068
Jatropha integerrima	0.986	0.580
Jatropha gossypiifolia	0.433	0.425
Jatropha multifida	0.112	0.006
Simmondsia chinensis	0.362	0.156

The water content of *Jatropha gossypiifolia* was less than the rest of the samples folled by *Simmondsia chinensis*. This appeared in high reflectance in SWIR spectral region for these two taxa.

Conclusions

This study is the first of series that observe the spectroscopic characteristics of the common economically valuable natural vegetation in Egyptian environment. The current study was carried out to identify spectroscopic characteristics of five taxa that have increasing importance as sources of fossil fuels. Observing the relationship between spectroscopic and morphological characteristics was among the objectives of this study. Morphological analysis of all samples was carried out and field spectral reflectance measurements were carried out using ASD field spectroradiometer device. The study identifies the spectral signature, the spectral zones and the specific wavelength/s for each taxon. Generally, *Jatropha gossypiifolia* and *Simmondsia chinensis* showed higher reflectance than the rest of the samples, when, *Jatropha integerrima* showed specific wavelength for identification. Morphological characteristics show a strong relation with both normalized difference vegetation index (NDVI) and chlorophyll index (CI). The study indicated that spectroscopic parameters and spectral signature could be used in parallel with morphological and anatomical characteristics for the identification and classification of plants. This study will be followed by other studies to quantitatively relate the content of fossil fuel of the pants with spectroscopic characteristics.

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