Research Article

Morphological and Spectral Taxonomic Study of Some *Ficus carica* L. Cultivars Growing in Northern Iraq

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Abstract | In the current research, have a comparative taxonomic study of the morphological and spectral characteristics of (6) cultivars of *Ficus carica* L. namely; (Shynik, Akrah, Benatty, Rubari, Brown Turky and Jordan) cultivated in northern Iraq. The morphological study included the characteristics of the leaves (length and width of leaf blade, length and diameter of the leaf petiole, shape of the apex, base and margin of the leaf blade, number of lobes and colour of leaf bade), and fruit characteristics (length, diameter, size, ostiole diameter, peduncle length, fruit shape, and color). It was found that most of the leaf and fruit characteristics have taxonomic importance in distinguishing and diagnosing the cultivars of the studied cultivars. Regarding the spectral study, the spectrum of absorbance of the alcoholic extract of leaf chlorophyll and the extract of pigments of the studied cultivars were examined by a U.V. spectrophotometer which divided the cultivars into groups depending on the values of λmax, which represents the highest absorption; cultivars were separated into three groups regarding the alcoholic extract of leaf chlorophyll: The first included the cultivar Akrah with a value of λmax =(468) nm, and the second group had λmax values that ranged between (434-446) nm; it included the cultivars Shynik, Benatty, and Jordan. The third group had a λmax value between (412-414) nm, and it was distinguished in the cultivars Brown Turkey, and Rubari compared to the other studied cultivars. The spectral study contributed to the separation of cultivars.

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Introduction

The taxonomic evidence for all parts of the plant during its growth and development stages is of taxonomic importance, and the morphological identifiers for characterizing the new cultivars of each plant depend on a set of traits that can distinguish cultivars from each other (Judd *et al.*, 1999).

The general morphological traits are of great importance in diagnosing the various taxonomic categories such as family, genus, species, and cultivars,

and recent taxonomic studies have proven that reproductive organs are of very important traits and characteristics due to their stability, so they have become among the most important characters used in the taxonomy of flowering plants angiosperms and gymnosperms (Abdul Wahhab and Al-Aoun, 2018).

Taxonomic studies using UV or infrared devices in conjunction with taxonomy will provide a new gate to discovering differences in the absorption values of chemical compounds that contribute to the isolation of species and cultivars within the same genus (Al-Rajab *et al*., 2014).

Sanchez *et al*. (2008) reported that ultraviolet spectroscopy studies are important in diagnosing and distinguishing closely related plants, as this technique has some advantages such as speed, low cost, simplicity, and accuracy in preparing simple samples.

Rafi *et al*. (2018) mentioned the importance of spectroscopy studies using a U.V. spectrophotometer as a fast, efficient and reliable technique for plant identification and classification when studying four species of the genus *Curcuma*.

Green plants are characterized by different characteristics due to the presence of various pigments, such as chlorophyll, carotene, and xanthophyll, as well as other pigments and water content, which constitute the spectral characteristics of the plant body (Philip and Shirly, 1978).

Spectrophotometric methods have already been used in several studies such as Al-Rajab *et al*. (2014), Abdul-Fatah *et al*. (2016), Al-Badrany and Almathidy (2020) and Shehab and Almathidy (2020) to diagnose, distinguish and plants.

The cultivated fig *Ficus carica* L. of the genus *Ficus* L. of the family *Moraceae* is one of tropical and subtropical fruits with great adaptive capabilities in different ecological zones (Valdeyran and Liody, 1979; Weiblen, 2000; Irineu *et al*., 2014). Fig trees adapt to different soils, but the most suitable soil is rich in organic matter and has a pH = of 6.0-6.8 (Irineu *et al*., 2014).

The scientific name *Ficus carica* L. is made up of two words. The first is the genus name (*Ficus*) derived from the word Fig in Latin because its small flowers are hidden in the syconium (Zhang *et al*., 2019). The species name (Carica) derived from the region of Caria in Asia Minor,that was the habitat of edible figs (Starr *et al*., 2003).

The cultivation of figs has recently gained great attention due to their high economic, nutritional, and medicinal value (Khadivi *et al*., 2018; Hssaini *et al*., 2019; Zhang *et al*., 2019).

Koka (2010) the study shed light on the stable characteristics of fig leaves and fruits and their importance in diagnosing *Ficus carica* L. cultivars, such as leaf shape, color, size, stem length, fruit shape, color, ostiole diameter and peduncle length.

Ipgri and Ciheam (2003) reported that leaf shape, fruit shape, ostiole diameter, fruit peel color, inner pulp color, and fruit peel cracks are among the highly distinguishing characteristics of the species *Ficus carica* L.

The fruite peel color of *Ficus carica* L. is mostly due to anthocyanin accumulation, with variable forms and levels in different cultivars (Dueñas *et al*., 2008).

Nowadays, the interest in cultivating fig trees and consuming fruit has increased because of its fine taste, nutritional value, and biological efficacy, and due to the economic and medical importance of cultivars of *Ficus carica* L. species. Due to the absence of morphological and spectral taxonomic studies for the cultivars in Iraq, the current research addressed the morphological and spectral characteristics of leaves and fruits of some cultivars of *Ficus carica* L. fig growing in northern Iraq.

Materials and Methods

Our research was performed on fresh specimens of the *Ficus carica* L. cultivars under study, collected from several regions in northern Iraq during a field survey in the governorates of Nineveh and Dohuk, included the Nineveh and Dohuk horticultural stations, and their nurseries and fields identified by the Ministry of Agriculture during August and September of the years 2021, the specimen of the plants were collected through fied trips from different location in Northern of Iraq (Table 1 and Figure 1). Five fig trees of each cultivar were selected as consistent as possible in terms of growth and age; The specimens were thoroughly

collected and photographed before being sent to the research unit of the Department of Biology, College of Education for Pure Sciences, University of Mosul for investigation, which included:

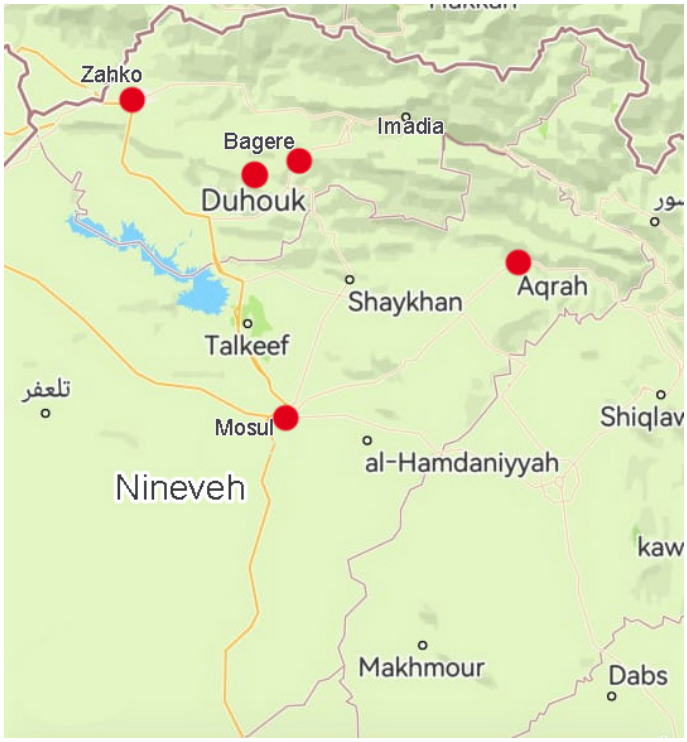

Figure 1: *A map of Northern Iraq showing localities for collecting the specimen of the plants.*

Morphological study

Leaves: (1) Leaf dimensions: Blade leaf length (cm); blade leaf width (cm) and petiole length (cm) and petiole diameter (mm) were measured with a tape measure. (2) The qualitative characteristics of the blade leaf: The apex, margin, base, the number of lobes, and color of the leaf blade.

Fruits: (1) Fruit dimensions: length, diameter and the length of the fruit peduncle the ostiole's diameter were measured by the electronic vernier in (mm). (2) The size of the fruit was measured by following the method of the graduated cylinder and the displaced distilled water. A known volume of distilled water was placed in the graduated cylinder and the fruit was immersed inside the cylinder. The volume was measured by finding the difference between the water level in the two cases and in (cm^3). (3) Fruit shape and colour: The shape and colour of the fruit were visually recorded to assess diversity using fig descriptors provided by (Ipgri and Ciheam, 2003).

Measurements were taken for 25 leaves and 25 fruits for each character, then the mean of the measurements and their standard deviation were taken, and the data were tabulated for the various morphological characteristics after converting them into quantitative and qualitative results for the purpose of comparison between Ficus carica cultivars under study on the basis on similarity and difference for the quantitative and qualitative traits.

The present study was based on the terms mentioned in each of (Ipgri and Ciheam, 2003; Gaaliche *et al.*, 2012; Mohamed *et al.*, 2017; Hassaini *et al.*, 2019; Rodrigues *et al.*, 2019).

Spectral study

Determination of the absorbance spectrum of leaf chlorophyll: The absorbance spectrum of chlorophyll for leaves of cultivars was estimated using a U.V. spectrophotometer of Japanese origin, and according to the method of (Ciser, 2010a), the alcoholic extract of chlorophyll weighing 0.3 grams was prepared from the leaves of the cultivars of the species under study, the leaves were cut into small pieces and placed in a ceramic mortar; 10 ml of absolute ethanol alcohol was added to it and crushed until what all remained were tiny pieces, then, 20 ml of absolute ethanol alcohol was added to the samples in the ceramic mortar, and the solution was filtered in a beaker through a separating funnel using filter paper. The filtrate was then put in quartz containers of the device; absorptions were plotted against wavelengths of range 400-800 nm.

Table 1: *Locations and Altitude collecting of the cultivars specimen.*

Altitude (m)	Localities	Cultivars
720	Dohuk Horticultural station / Zahko forest nusery	Shynik
660	Aqrah forest nursery (Dohuk)	Aqrah
580	Dohuk. Horticultural station	Benatty
860	Bagere fields (Dohuk)	Rubari
230	Nineveh Horticultural station	Brown Turky
860	Bagere fields (Dohuk)	Jordan

Table 2: *Quantitative morphological traits of the studied cultivars' leaves of Ficus carica L. species.*

Petiole diameter (mm)	Petiole length (cm)	L/W	Blade leaf width (cm)	Blade leaf length (cm)	Cultivars
*3.48 (3.90-2.90) **0.25	*7.62 (10.70-5.80) **1.70	1.29	*14.55 (18.20-12.30) **2.28	*18.84 (23.00-15.20) **2.78	Shynik
*3.34 (3.92-3.00) **0.34	*12.07 (15.10-9.50) **1.70	1.18	*19.59 (21.20-17.50) **1.70	*23.08 (26.00-19.00) **2.08	Aqrah
4.24 (4.71-3.74) **0.39	*8.70 (10.70-7.20) **1.06	1.16	*23.53 (26.00-20.80) **1.53	*27.40 (29.00-24.50) **1.49	Benatty
*4.04 (4.54-3.53) **0.29	*9.07 (11.20-7.30) **1.23	1.18	*17.60 (21.00-15.20) **1.52	*20.84 (25.00-18.20) **2.24	Rubari
*3.75 (4.28-3.18) **0.38	*4.31 (5.00-3.2) **0.62	1.17	*15.43 (17.7-13.4) **1.46	*18.06 (20.00-14.80) **1.59	Brown Turky
*3.65 (4.30-3.02) **0.47	*10.04 (12.50-8.80) **1.17	1.19	*19.42 (22.70-15.70) **2.57	*23.07 (25.70-19.30) **2.42	Jordan

** Average; ** Standard deviation; ( ) range.*

Table 3: *Qualitative morphological traits of leaves of the studied cultivars of the species Ficus carica L.*

Leaf blade colour	No. of Lobes	Leaf blade base	Leaf blade margin	Leaf blade Apex	Cultivars
Dark green	Undivided and three	Truncate-oblique	Crenate	Acute	Shynik
Green	Five	Cordate	Crenate	Obtuse	Aqrah
Dark green	Three	Cordate	Undulate	Acute	Benatty
Green	undivided and three	Cordate	Crenate	Obtuse	Rubari
Green yellowish	Five	Cordate	Crenate	Obtuse	Brown Turkey
Dark green	Five	Oblique	Undulate	Obtuse	Jordan

Determination of the absorbance spectrum of fruit pigments: The pigments extract of acidic cultivars of the fruits with pH=1.5 were prepared according to the method of (Syukri *et al.*, 2013) by mixing absolute ethanol with citric acid (35%) with a ratio of 3:7. 200 ml of acidic ethanol was added to a 1000 ml beaker containing 100 g of fruit, then the cultivars' pigments were extracted at room temperature for 12 hours in a dark environment, and this procedure was repeated three times to collect the extraction solution, then the extract was concentrated at room temperature until 1/3 was gone, the solution was filtered using filter papers and the filtrate was placed in quartz containers of Shimdzu UV-1800 spectrophotometer, and absorbances were plotted against wavelengths in the range of 200-800 nm.

Results and Discussion

Morphological study

Leaves: The current research showed that the leaves in all cultivars of the studied species are simple and petiolate, their arrangement on the stem is alternate and the dimensions of the leaf blade are one of the most variable characteristics, followed by the base of the leaf blade, apex, margin, , number of lobes and colour, (Tables 2 and 3) and (Plate 1). The studied cultivars of the species *Ficus carica* L. varied in the dimensions of the blade of the leaf and the cultivar Benatty recorded the highest average of 27.40 × 23.53 cm, and the lowest average of its dimensions was seen in the cultivar Shynik of 18.84 × 14.55 cm. Other studied cultivars ranged between these values, and these results are consistent with those of (Gaaliche *et al.*, 2012; Rodrigues *et al.*, 2019).

The cultivars also showed clear and important variations in the base of leaf blade, which could be adopted in isolating the cultivars of the species into three groups:

1: The first group: its blades have a truncate-oblique base, and it represents the cultivar Shynik.

2: The second group: has oblique base of the blade and it represents the cultivar Jordan.
3: The third group: of cordate-based blades and includes the cultivars Akrah, Benatty, Rubari and Brown Turky.

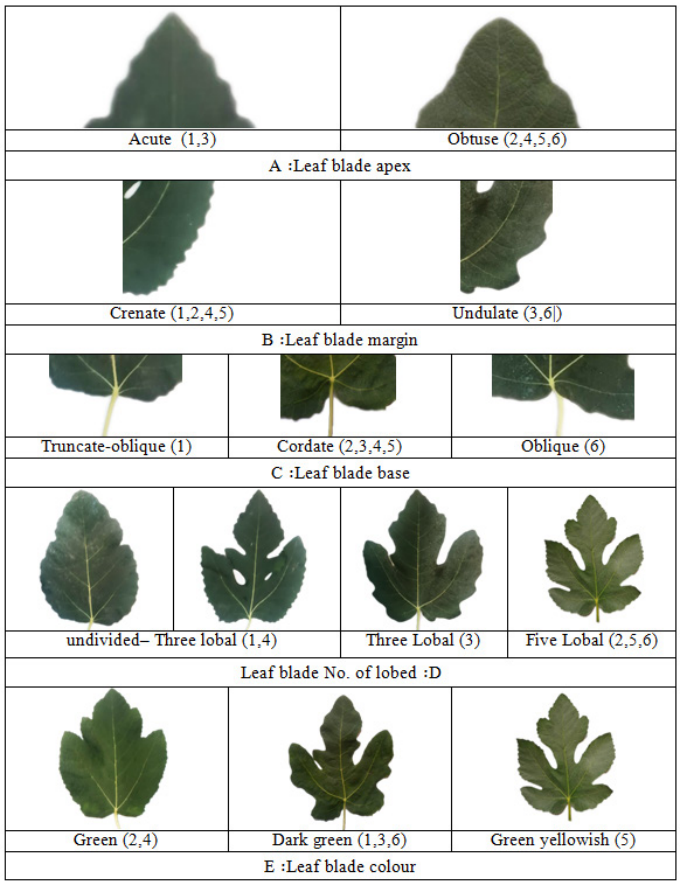

Plate 1: *Variations in the qualitative traits of leaves of the studied cultivars of the species Ficus carica. 1, Shynik; 2, Akrah; 3, Benatty; 4, Rubari; 5, Brown Turky; 6, Jordan.*

As for the leaf blade apex, the two cultivars Benatty and Shynik were distinguished by their acute blade apex from the other studied cultivar of obtuse blade apexes, this result agreement with (Mohamed *et al.*, 2017).

The leaf blade of fig was incision palmate and margin of lobes, were crenate in the cultivars Shynik, Akrah, Rubari, Brown Turky, and undulate in Other cultivars studied. These results are consistent with those reached by Gaaliche *et al.* (2012) regarding the existence of variation among cultivars of *Ficus carica* L. in the shape of the leaf's apex, base and margin.

In terms of the leaf blade number of lobes, the cultivars under study varied, and they were three lobes in the cultivar Benatty and five lobes in the cultivars Akrah, Benatty, Brown Turky and Jordan, and (undivided and 3 lobal) in other studied cultivars Rubari and Shynik. These results agreed with (Iqgri and Ciheam, 2003; Rodrigues *et al.*, 2019).

Leaf blade colour varied among cultivars, it was green in cultivars Akrah and Rubari and dark green in cultivars Shynik, Benatty and Jordan, and yellowish-green in the cultivar Brown Turky, and this results is consistent with (Mohamed *et al.*, 2017).

Also, clear differences were found between The cultivars studied in the petiole length, the cultivar Akrah showed the highest petiole length with an average of 12.07 cm, and the cultivar Brown Turky exhibited the lowest average of 4.31 cm, and the other cultivars ranged between these two values. In terms of petiole diameter, it varied between the studied cultivars, the cultivar Benatty recorded the highest average of 4.24 mm, and the cultivar Akrah recorded the lowest average of 3.34 mm, and the other cultivars ranged between them. These results agreed with the study (Koka,2010; Gaaliche *et al.*, 2012).

Fruit parts

Fruiting stalk (peduncle): The studied cultivars of the species *Ficus carica* L. were characterized by variations in the length of the fruiting stalk, can be divided into 3 groups.

The first group was average length ranged between (4.73-9.32mm) included the cultivars Benatty and Brown Turky. The second was ranged between (9.32-13.58mm) included Shynik, Aqrah, and Jordan, but the third group, average length more th (13.58mm) included Rubari cultivar (Table 4).

Fruits: The study showed that the fruits of the fig cultivars examined were multiplied fruits known as (Syconium) (Plate 2), it distinguished by their variable dimensions (Table 4). Cultivars under study were divided into three groups according to the length of the fruit: the first was of average length ranging between 33.83-33.79 mm and included the two cultivars Rubari and Shynik. The second group: The fruits with an average length between 36.56-37.51 mm, included the cultivars Rubari and Shynik. The third group the fruits average length ranging between 39.44-44.48 mm, involved the cultivars Jordan and Brown Turky.

In terms of fruit diameter, the cultivars studied were distinguished by a broad range among it. The maximum

Table 4: *Morphological traits of fruits of the studied cultivars of Ficus carica L. species.*

Fruit color	Fruit shape	Stalk fruit (mm)	Ostiole diameter (mm)	Fruit size (cm^3)	Fruit diameter (mm)	Fruit length (mm)	Cultivars
Yellow	Pyriform	*9.32 (13.8-5.39) **3.00	*5.86 (6.45-4.5) **0.68	*27.05 (37-20) **6.07	*41.77 (49.5-35.4) **5.58	*33.83 (40.2-29.6) **4.02	Shynik
Yellow greenish	Ovoid	*11.39 (15-9.6) **2.27	*5.20 (6-4.3) **0.71	*40.02 (49-31) **6.13	*45.29 (49.00-41.30) **2.85	*37.51 (40.3-33.7) **2.21	Aqrah
Green yellowish	Ovoid	*4.73 (7.1-4) **1.32	*8.34 (10.18-6.5) **1.19	*28.55 (38-25) **4.10	*45.91 (50.61-41.16) **3.62	*36.56 (46.32-32.34) **3.94	Benatty
Green	Pyriform	*26.99 (34.3-20.6) **3.35	*10.49 (11.4-9.66) **0.99	*17.41 (20-13) **2.31	*39.11 (43.5-35.44) **2.65	*33.79 (38-29.12) **2.64	Rubari
Dark brown	Pyriform	*9.07 (11-6.6) **2.02	*5.48 (6.4-4.7) **0.59	*37.9 (42.25-32.5) **3.47	*42.84 (47.00-39.40) **2.71	*44.48 (48.3-39.6) **3.02	Brown Turky
Violet darkish	Pyriform	*13.58 (22-7.44) **6.97	*12.59 (17.4-9.65) **2.92	*37.44 52-27.5) **7.06	*46.92 (54.25-40.8) **4.46	*39.44 (48.4-31.8) **4.96	Jordan

** Average; ** standard deviation; ( ) range; Pyriform (nearer to the ostiole- end); Ovoid (in the middle). Fruit shape: according to the location of the maximum width.*

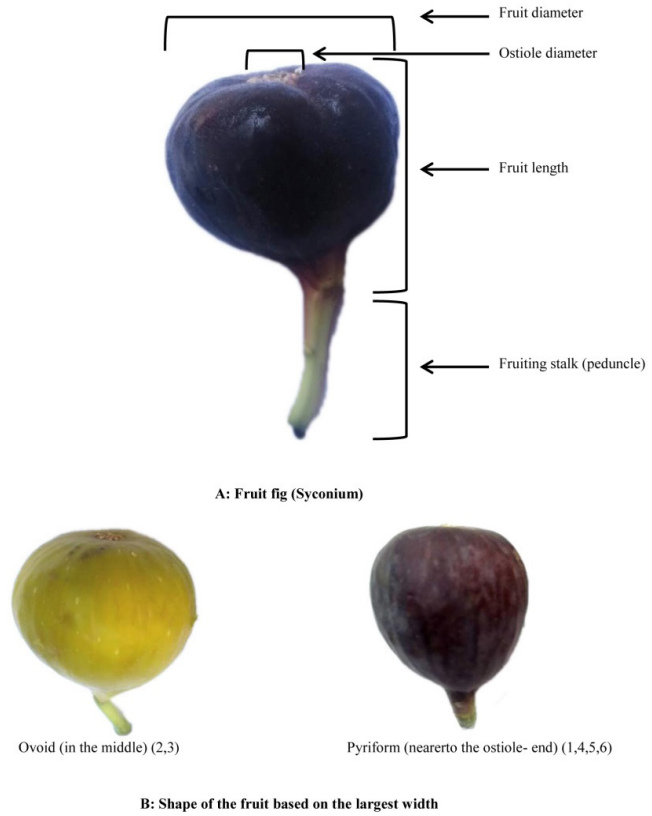

Plate 2: *parts and shape of the fig fruit.*

average diameter of the fruit was 46.92 mm in the cultivar Shynik, while the lowest average was 39.11 mm in the cultivar Rubari. Other cultivars under study ranged between them, this result consistent with (Fateh and Ali, 2009; Gaaliche *et al.*, 2012) mentioned that the characteristics of length and diameter of the fruit are the distinguishing characteristics of *Ficus carica* L. fruits.

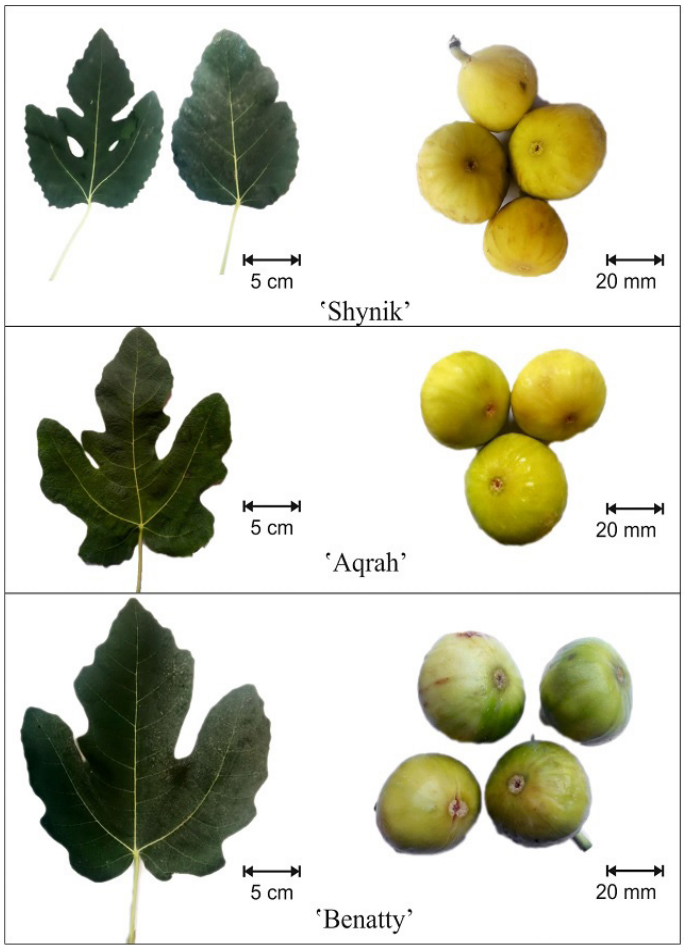

Plate 3: *Variation in the traits of leaves and fruits of the studied cultivars of Ficus carica L. species.*

Also, differences in fruit size were among the significant taxonomic characristics that allowed the cultivars studied divided into three groups:

- The first group: was small fruits; the average size at 17.41 cm^3, included the cultivar Rubari.
- The second group: medium fruits, with averaged size between 27.05-28.55 cm^3, and included the two cultivars Shynik and Benatty.
- The third group: large fruits, With average size between 37.44-40.02 $cm^{3,}$ and Involved three cultivars Jordan, Brown Turky and Akrah.

The ostiole's taxonomic significance was evident in its diameter, which demonstrated substantial variations amongst cultivars of the investigated cultivars. The Jordan cultivar had the largest average ostiole diameter of 12.59 mm, while the Akrah cultivar had the smallest at 5.20 mm (Table 4). These results agree with (Ipgri and Ciheam, 2003; Fateh and Ali, 2009; Gaaliche *et al.*, 2012), indicated that ostiole diameter is one of the highly distinguishable traits among ficus carica cultivars. It should be noted that the small ostiole opening has a role in preventing pests from entering and infecting the fruit. It is also important to determine the fruit's quality (Al- Jane *et al.*, 2018). Regarding the qualitative characteristics of the fruits, significant differences were found between the studied cultivars (Table 4) and (Plates 2 and 3), indicating an important taxonomic significance in isolating the cultivars studied, as the fruits were classified into two groups based on their shape:

- The first group: was of pyramidal shape (Pyriform) and included the cultivars Shynik, Rubari, Brown Turky, and Jordan.
- The second group: was ovoid and included the two cultivars Akrah and Benatty.

The fruits also varied in their colors between the cultivars, as the fruits of Rubari were green, Benatty appeared in green yellowish, Shynik appeared in yellow, Akrah was yellow-greenish, Brown Turky J was dark brown, and Jordan darkish violet.

These results agreed with Ipgri and Ciheam (2003) indicated: the shape and color of the fig fruit are important characteristics in the diagnosis and discrimination of cultivars of *Ficus carica* also, these results are consistent with those of Perez-Sanche *et al.* (2016) , the fruit of *Ficus carica* cultivars can acquire different colors depending on the cultivar, ranging from green to darkish violet.

Spectral study

The spectral study has an important and prominent role in assisting and supporting morphological traits, as it showed clear differences between Ficus carica cultivars; it was possible to use them taxonomically in separating and isolating Cultivars studied, based on the λmax values of the chlorophyll extract of the leaves, which represents the highest absorbance, into three groups: the first group with λmax values ranged between 412-414 nm and included Rubari and Brown Turky cultivars, and the second group had values between 434–446 nm, and included the cultivars Shynik, Benatty, Jordan, and the third group was unique to the Akrah cultivar, recorded the highest λmax of 468 nm compared to the other cultivars studied, as shown in (Table 5), (Plate 4) and (Figure 2).

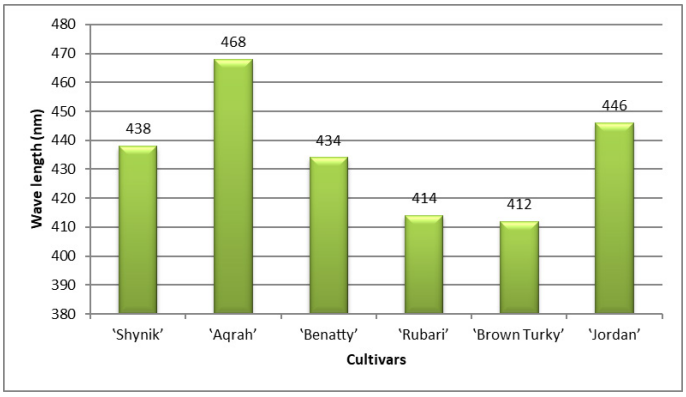

Figure 2: *λmax values for the chlorophyll leaves of the studied cultivars of Ficus carica L.*

These results were consistent with the results of study Al-Badrany and Al-Mathidy (2020) on *Morus* L.; Shehab and Al-Mathidy (2020) on *Pyrus malus* and *Pyrus communis.*

In addition, the results of the spectral study with a spectrophotometer device for pigments of the fruits of the studied cultivars showed variant spectral shapes (Table 5) and (Plate 5), and based on their λmax values; we were able to separate them into five groups:

- The first group: included the cultivar Shynik, which recorded the highest absorbance at wavelengths 237.5, 278, 306, 322, and 346 nm.
- The second group: included the two cultivars Aqrah and Benatty, recorded the highest absorbance at wavelengths 293.5 and 306 and 296.5 and 315.5 nm, respectively.
- The third group: included the cultivar Rubari' solely, with a wavelength of 259.5 nm at the highest absorbance.

- The fourth group represented the cultivar Brown Turky, showed the highest absorbance at a wavelength of values 207.5 and 306 nm.
- The fifth group: represented by the cultivar Jordan, had the highest absorbance at wavelengths of 262, 314.5, and 330 nm.

Table 5: *Absorbance spectrum of chlorophyll leaves and pigment fruit of Ficus carica L. cultivars.*

Bigments fruits		Chlorophyll leaves		Cultivars
Absor-pation	λmax (nm)	Absorpa-tion	λmax (nm)	
4.00	346, 322, 306, 278, 237.5	3.67	438	Shynik
4.00	306, 293.5	3.86	468	Aqrah
4.00	315.5, 296.5	3.37	434	Benatty
3.65	259.5	3.67	414	Rubari
4.00	306, 207.5	3.39	412	Brown Turky
4.00	330, 314.5, 262	3.88	446	Jordan

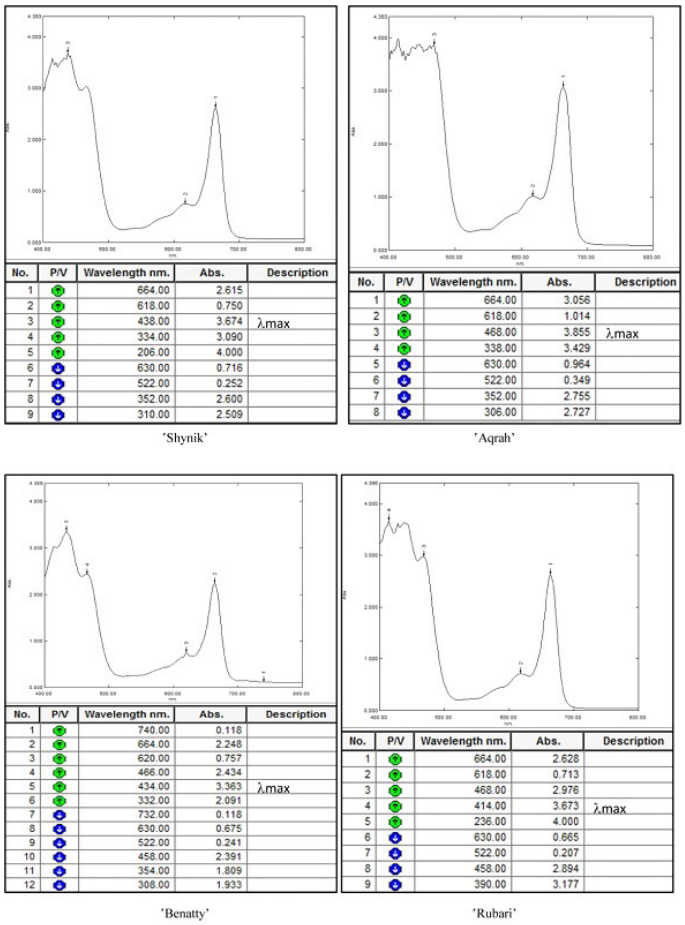

Plate 4: *Absorbance spectrum and λmax values for the chlorophyll leaves of the studied cultivars of Ficus carica L.*

These results are consistent with Al-Rajab *et al.* (2014) the values of λmax are among the physical constants that can assist and support taxonomic evidence in the classification of plants and make each value a unique identity by distinguish the different species and cultivars of plants. The relationship between spectral studies and taxonomy will create a new gate to discovering significant distinctions in separating cultivars and species. The results of the study are in line with Abdul-Fatah *et al.* (2016) the chemical composition may be used in spectral studies of plants, in dependence on the qualitative detection of certain substances in the plant and comparing with another plant, and recognizing the difference by measuring the highest wavelength, which corresponds to the highest absorbance.

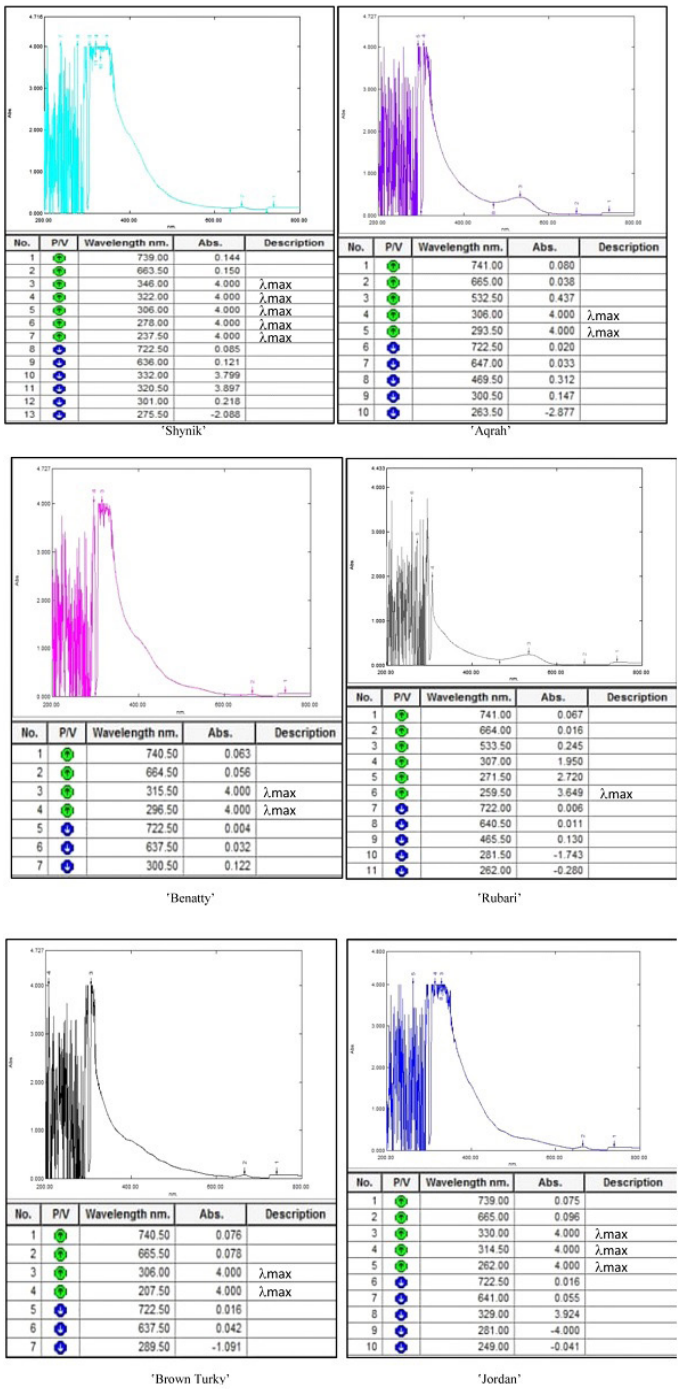

Plate 5: *Absorbance spectrum and values of λmax for pigments of fruits of the studied cultivars of Ficus carica L.*

Wavelength information of value in studing plants. Commercial plant nurseries can take advantage of this knowledge to provide necessary wavelengths and bost growth and overall production (Ciser, 2010b).

The spectral balance of solar radiation can vary greatly, affecting the performance and development of plants (Ptushenko *et al*., 2020).

Conclusions and Recommendations

1. It is possible to rely on the morphological characteristics of leaves and fruits in diagnosing and distinguishing Ficus carica cultivars. such as the dimensions of the leaf blade, apex, base, margin, nature, number of lobes, fruit dimensions, size, shape, color, ostiole diameter and length of the fruit peduncle.
2. The spectral study contributed to the differentiation and separation between the cultivars studied through the spectral variation in λmax values of the alcoholic extracts of its chlorophyll and the pigments of fruits, which consolidated the taxonomic importance of this study and adopting as taxonomic guides to isolate and separate the cultivars from each other, which turned out to be important in supporting the morphological characteristics of the studied cultivars.

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Novelty Statement

Identification cultivars and selected the economic and medical cultivars of the species *Ficus carica*.

Author's Contribution

Raad H.M. Al-Badrany: Manuscript ideas and study of phenotypic traits.
Aamer M.M. Al-Ma'thidy: Studied spectral characteristics and statistical analysis.

Conflict of interest
The authors have declared no conflict of interest.

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