

MACRO- AND MICRO-MORPHOLOGICAL CHARACTERISTICS OF *KICKXIA* DUMORT. AND SOME RELATED TAXA IN SAUDI ARABIA

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Abstract

The morphological and anatomical aspects of 13 species belonging to genera *Kickxia*, *Scrophularia*, and *Plantago* of Saudi Arabia reveal that the species of *Kickxia* and *Scrophularia* are distinct from *Plantago major*. The most notable morphological differences are the absence of adventitious roots and the presence of acaulescent stem in the species of *Kickxia* and *Scrophularia* and the existence of adventitious roots and the absence of acaulescent stem in *P. major*. The species of *Plantago* possessed rose-shaped radical leaves, whereas the rest of the species studied had cauline leaves or both. The species of *Kickxia* and *Scrophularia* have pentamerous flowers with bilabiate corollas, whereas, *P. major* has tetramerous flowers with tubular corollas. The separation of *P. major* from the rest of the studied species is the most obvious result obtained from the dendrogram, and this result is consistent with some traditional taxonomic studies that placed *Kickxia* in the Scrophulariaceae species while separating *P. major* into an independent family Plantaginaceae. The anatomical findings revealed that the upper and lower epidermal cells of the leaves were irregular with undulate walls in all analyzed species, except in *P. major*, where they were polygonal with straight walls. Only *P. major* had amphianisocytic paracytic stomata, but eight *Kickxia* species had anomocytic stomata and *K. hastata* and *K. abhaica*, and the two *Scrophularia* species had anisocytic stomata. Therefore, this study suggests the retention of the *Kickxia* in Scrophulariaceae s.l. and maintaining *Plantago* in Plantaginaceae s.s.

Introduction

Kickxia Dumort. is represented in Saudi Arabia by nine species under one subspecies (Collenette, 1998 - 1999), which are *Kickxia abhaica*, *K. acerbiana*, *K. aegyptiaca*, *K. collenetteana*, *K. corallicola*, *K. elating* subs. *crinita*, *K. hastata*, *K. petiolata*, *K. pseudoscoparia*, and *K. scalarum*, while (Migahid, 1996) added two more species, which are *K. heterophylla* and *K. spartioides*. In broad concept, *Kickxia* s.l. includes 46 species (Mabberley, 1997; El-Hadidi *et al.*, 1999; Ghebrehiwet, 2000), or 50 cosmopolitan species (Chaudhary, 2001), While (APG, 2009) listed 25 acceptable species of *Kickxia*.

The species of this genus were divided based on the Morphological differences in the way of seed capsule opening (Jagel and Unterladstetter, 2018). (Chaudhary, 2001) Mentioned that some species of *Kickxia* are endemic plants in Saudi Arabia, for instance (*K. abhaica*, *K. collenetteana*, *K. corallicola*, and *K. pseudoscoparia*).

Concerning the taxonomic position of *Kickxia*, it was included in Scrophulariaceae according to the traditional taxonomic systems (Bentham and Hooker, 1876; Cronquist, 1981; Engler and Prantl, 1895) and others. However, the recent studies (APG, 2009, 2016) transferred it to

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Plantaginaceae along with other species that were belonging to Scrophulariaceae, due to the molecular characteristics. In studying the relationship between plants and animals, (Knerl and Bowers, 2013) found that the species *Kickxia spuria* is of the preferred families for the Buckeye Butterfly. (Jeddi and Chaieb, 2010; Tarhouni *et al.*, 2010) considered the species *Kickxia aegyptiaca* as pastoral plants. *Kickxia elatine* was also considered a pastoral plant by (Parlak *et al.*, 2011).

The study of (Eraud *et al.*, 2015) included the species *Kickxia elatine* in the plants of importance in bird feeding. (Adeux *et al.*, 2017) considered *Kickxia* as an agricultural crop and can be used as an alternative to corn.

This research aims mainly to study the *Kickxia* species in Saudi Arabia due to the lack of taxonomic studies on this genus and compare these with the two species of the genus *Scrophularia* L. of Scrophulariaceae *viz.*: *Scrophularia deserti*, *Scrophularia peyronii*, and the species *Plantago major* as the typical representative of Plantaginaceae family, by using the morphological and anatomical taxonomic evidence and then analyzing these results statistically to obtain evidence to either endorse or reject the transferring of the species of *Kickxia* from Plantaginaceae to Scrophulariaceae.

Materials and Methods

In the present study, 13 species were collected from different localities in Saudi Arabia (Table 1). The studied taxa include 10 species belonging to *Kickxia*, two *Scrophularia* species in addition to one species from Plantaginaceae (*Plantago major*).

For recording the morphological characteristics of vegetative and floral organs, the phenotype of both stem and leaves in each species was examined in terms of shape, margin, base, and apex of the blade, the dimensions of the lamina, the distribution of leaves on the stem and leaf veining were also measured, and the floral characteristics were examined using different optical microscopes. Photos were taken by camera Hawaii mate 20 pro. All results, observations, and measurements have been recorded.

For recording the micro-morphological (anatomical) characteristics, the method of Al-Duaiji *et al.* (1997) was used to prepare skinned leaves from plant species studied as follows:

(i) Numbers were given to the samples to be stripped, then the dry leaves were cut and washed with running water to remove the dirt stuck, and then they were washed with distilled water. (ii) The dry leaves taken from the herbarium samples were soaked in distilled water for 24 hours; until the leaves became soft and easy to make a thin strip. (iii) A simple portion was made from the surface of the paper with a sharp mouse, and then, using pointed forceps and very carefully, a thin skin was prepared from the leaf skin. (iv) The stripes were placed on a glass slide making sure that the top was on the outside. (v) the strip was covered with drops of ethyl alcohol for 3-5 minutes to thicken the stripes and make them as transparent as possible. (vi) the stripes were stained with light green or saffron for several seconds, then the stripes were loaded with a drop of glycerin and covered with the slide cover, then placed into a 40 ° C oven for several hours. (vii) The slides were examined by light microscopy and imaged at force (40 ×) by the camera device installed with a light microscope.

The relevant terms of Metcalfe and Chalk (1950) were used to define the cell shapes, while stomatal types were determined from Stace (1989). The types of hairs (Trichomes) were also determined following Prabhakar (2004).

Table 1. List of the species studied and their varied localities.

S/N	Taxa	Collection site
1	<i>Kickxia abhaica</i> D. A. Sutton	Wadi Alus, Rejal Almaa, Abha, Collected by the PI during March 2018 18°16'07.4"N 42°19'46.4"E
2	<i>K. acerbiana</i> (Boiss.) Tackh. & Boulos	Yanbu-Umluj Road, Collected by the PI during March 2018 24°43'38.9"N 37°20'01.7"E
3	<i>K. aegyptiaca</i> (L.) Nab.	Al sheheia, Alqassim, Collected by the PI during April 2018 26°18'58.0"N 43°37'26.5"E
4	<i>K. corallicola</i> D. A. Sutton	Farasan Island, Jizan, Collected by the PI during April 2018 16°50'32.7"N 41°55'09.5"E
5	<i>K. elatine</i> (L.) Dumort.	Ministry of Environment, Water & Agriculture Herbarium No. 5659, 5660
6	<i>K. hastata</i> (R. Br. ex. Benth.) Dandy	Ministry of Environment Water, & Agriculture Herbarium No., 5957, 8942
7	<i>K. petiolate</i> D. A Sutton	Ministry of Environment, Water & Agriculture Herbarium No., 3286, 14476 and Herbarium of Botany & Microbiology Department, Collage of Science, King Saud University, No. 9129
8	<i>K. pseudoscoparia</i> v. w. Smith & D. A. Sutton	Al sail Alsageer, Taif, Collected by the PI during March 2018 21°30'14.9"N 40°31'01.9"E
9	<i>K. scalarum</i> D. A. Sutton	Ministry of Environment water & Agriculture Herbarium No., 9072, 959
10	<i>K. spartioides</i> (Brouss. ex. Bush Janch.)	Herbarium of Botany & Microbiology Department, Collage of Science, King Saud University, No 1458
11	<i>Plantago major</i> L.	Wadi Darak, Al Mandaq, Collected by the PI during May 2018 20°11'08.9"N 41°17'05.3"E
12	<i>Scrophularia deserti</i> Del.	Bani Saad, Taif-Albaha Road, Collected by the PI during April 2018 20°59'23.7"N 40°44'11.1"E
13	<i>S. peyronii</i> Post	Ministry of Environment. water & Agriculture Herbarium No., 13402

Numerical analysis

A dendrogram was constructed based on a data matrix using the NTSYS-pc 2.2 software package (Rohlf, 2009) by using both morphological and anatomical characteristics of the studied species.

Results and Discussion

Morphological Characteristics of Vegetative and Floral Organs

The morphological analysis of vegetative, floral, and anatomical aspects of 13 species belonging to genera *Kickxia*, *Scrophularia*, and *Plantago* L. of Saudi Arabia was carried out. The morphological characteristics of vegetative and floral organs of these species are described below.

Lifeform: Through field trips, it was found that *Kickxia* (Table 2) and *Scrophularia* are spread in their environments as distant individuals while *Plantago major* in groups. The plant species differ in their lifeform. There are ephemeral annuals represented by *K. elatine* and *K. hastata*, as they are characterized by being small and their roots are shallow and spread horizontally to exploit rainwater and dew drops on the soil surface, and this observation is consistent with the study of Wood (1997) and Chaudhary (2001). There are Sclerophytes, which are shrubs or perennial herbs in most of the species under study, which have adaptations to withstand or avoid the dry season, and among these adaptations observed in some species are the reduction of their vegetative total and the epiphysis surface, rapid leaf fall, and the presence of dense hairs on the plant and leaves which reflect part of the sun's rays and form a moist medium around the leaves so, reduce the process of transpiration. The results of this study agree with Fischer (2004) and Hamed *et al.* (2014).

Habit: On the Habit side, the subshrub was found in the two species of *Scrophularia*, which corresponded to the result of Issa and Al-Ali (2018), while we found woody herb in five species of *Kickxia* (*K. acerbiana*, *K. aegyptiaca*, *K. elatine*, *K. pseudoscoparia* and *K. spartioides*). The herb appeared in *Plantago major*, as well as in the other five species of *Kickxia*, and this result was consistent with the results of Ghebrehiwet *et al.* (2000).

Stem: Some species were distinguished by being hairy as in *Kickxia abhaica*, and three species were sparsely hairy, which are: *K. elatine*, *K. acerbiana*, *K. aegyptiaca*, and the species *Plantago major*, while in other species the appearance of the plant was glabrous, and this result was consistent with Hamed *et al.* (2014). All the studied species were distinguished by the caulescent market except for *Plantago major*, the stem was a caulescent (stemless - dwarf), this result agreed with Bukari (2009), Zubair (2010), and Hamed *et al.* (2014). The stem erects also appeared in four species of *Kickxia*: *K. acerbiana*, *K. aegyptiaca*, *K. pseudoscoparia*, *K. spartioides* and two species of *Scrophularia*, while a weak was extended or climbing in other species of *Kickxia*, and this is consistent with what was stated in the study of Chaudhary (2001). All the studied species were branched except for the *Kickxia hastata*, which was unbranched this matches what was stated in the study of Chaudhary (2001) and Hamed *et al.* (2014). The branching was monopodial for all species except for *Scrophularia peyronii* which was sympodial (limited growth), and this is consistent with a study by Issa and Al-Ali (2018).

Leaves: The leaves of *Kickxia* species were distinguished by the heterophylly, while this variation was not recorded in *P. major* and the two *Scrophularia* species which were characterized by identical leaves. This result is consistent with Chaudhary (2001) and Hamed *et al.* (2014). Also, the leaves of all *Kickxia* species were simple, entire, with reticulate veins, whereas in the two species of *Scrophularia* it was pinnately lobed with reticulate veins. The leaves of the studied species were organized alternate except for the leaves of the *Scrophularia deserti*, which were opposite (Issa and Al-Ali, 2018), while *Plantago major* leaves are broad, clustered at the base of the plant in the form of the rosette and prominent parallel veins, and this result is consistent with Weryszko-Chmielewska (2012) and Haddadian *et al.* (2014).

Flowers: In all *Kickxia* species, flowers were solitary, while in *Plantago major* they were regular on one axis in the form of spike inflorescence, and flowers of the two *Scrophularia* species were regular in racemose inflorescence. All the flowers of the studied species were pentamerous and zygomorphic, except for *Plantago major*, which was tetramerous and Actinomorphic. The results are consistent with the study of Bukari (2009), Ianovici *et al.* (2010) and Hamed *et al.* (2014). Hairy flowers appeared in all *Kickxia* species, while they had a glabrous appearance in *Plantago major* and *Scrophularia*. All the flowers of the *Kickxia* species were yellow, while *Scrophularia* species were characterized by a dark red colour, and *Plantago major* flowers were membrane brownish as in Bukari (2009), Ahmad *et al.* (2009) and Hamed *et al.* (2014).

All the studied samples were distinguished by a continuous calyx with the fruit and free sepals, as well as by transparent membranous edges, which varied in their shapes between filiform and lanceolate. All species of *Kickxia* and *Scrophularia* were distinguished by a corolla with fused petals of a five-bilabiate shape and differed by the presence of a spur in the petals of the species belonging to *Kickxia*, which resulted from the mutation of the front petal and it differs in length according to the species. This result agreed with a study by Chaudhary (2001) and Hamed *et al.* (2014).

All the studied species contained four fertile stamens, and all the stamens were epipetalous and didynamous except for *Plantago major*, the stamens were equal. This result was consistent with the study of Hamed *et al.* (2014). Pollen in the two species of *Scrophularia* was distinguished by the presence of a sterile stamen, and this result agrees with the study of Uzunhisarcikli *et al.*

(2015), Ranjbar and Rahchamani (2018). The stamens are found in all *Kickxia* species inside the corolla tube while they are exerted in the two *Scrophularia* species and *Plantago major*. This result agreed with the study of Bukari (2009) and Hamed *et al.* (2014).

Fruits: All fruits of the studied species were globose, except for *Kickxia acerbiana* and *Plantago major* the fruits were elongated. All the fruits of the studied species were dehiscence, multi-seeded capsule, but they differed in the method of blooming as the fruits of the *Kickxia* species opened with two apical pores, while in *Plantago major* they opened with a cover and with two valves in *Scrophularia* species as in Hamed *et al.* (2014).

The results obtained from the dendrogram (Fig. 1) and (Table 2) separated *Plantago major* in an independent series (SI), while the rest of the other species are combined in (SII) due to their similarity in many of the phenotypic characteristics and this result is consistent with many traditional taxonomic systems that include *Kickxia* within the Scrophulariaceae (Bentham and Hooker, 1876; Cronquist, 1981; Engler and Prantl, 1895). This result also matches the opinion of some studies in maintain *Kickxia* and keeping it within Scrophulariaceae *s.l.* (Hamed *et al.*, 2014).

Table 2. Data matrix of the morphological characters of the studied taxa and their codes, (0 = absent, 1 = present).

Morphological characters		<i>Kickxia abhaica</i>	<i>K. acerbiana</i>	<i>K. aegyptiaca</i>	<i>K. corallicola</i>	<i>K. elatine</i>	<i>K. hastata</i>	<i>K. petiolate</i>	<i>K. pseudoscopia</i>	<i>K. scalarum</i>	<i>K. spartioides</i>	<i>Plantago major</i>	<i>Scrophularia deserti</i>	<i>S. peyronii</i>
Whole plant	Life form	Annual	0	0	0	0	1	1	0	0	0	0	0	0
		Perennial	1	1	1	1	0	0	1	1	1	1	1	1
	Habit	Herb	1	0	0	1	0	1	1	0	1	0	1	0
		Woody herb	0	1	1	0	1	0	0	1	0	1	0	0
Texture	Subshrub	0	0	0	0	0	0	0	0	0	0	0	1	1
	Glabrous	1	0	0	1	0	1	1	1	1	1	0	0	1
	Hairy	0	1	1	0	1	0	0	0	0	0	1	1	0
Adventitious roots		0	0	0	0	0	0	0	0	0	0	1	0	0
Length	Long	1	1	1	1	1	1	1	1	1	1	0	1	1
	Dwarf	0	0	0	0	0	0	0	0	0	0	1	0	0
Branching		1	1	1	1	1	1	1	1	1	1	0	1	1
	Strength													
	Erect	0	1	1	0	0	0	1	1	0	1	1	1	1
	Weak	1	0	0	1	1	1	0	0	1	0	0	0	0
Heterophylly		1	1	1	1	1	1	1	1	1	1	0	0	0
Arrangement	Alternate	1	1	1	1	1	1	1	1	1	1	0	0	1
	Opposite	0	0	0	0	0	0	0	0	0	0	0	1	0
	Verticillate	0	0	0	0	0	0	0	0	0	0	1	0	0
Composition	Simple	1	1	1	1	1	1	1	1	1	1	1	0	0
	Lobed	0	0	0	0	0	0	0	0	0	0	0	1	1
Venation	Reticulate	1	1	1	1	1	1	1	1	1	1	0	1	1
	Parallel	0	0	0	0	0	0	0	0	0	0	1	0	0
Leaf Shape	Linear	0	0	0	0	0	0	0	1	0	1	0	0	0
	Lanceolate	0	0	0	0	0	1	0	0	0	0	1	0	0
Basal leaves	Ovate	1	0	0	0	0	0	0	0	0	0	1	0	0
	Elliptic-ovate	0	0	0	0	0	1	0	0	0	0	0	0	0
	Hastate	0	1	1	0	1	0	0	0	1	0	0	0	0
	Cordate	0	1	0	0	0	0	0	0	0	0	0	0	0
	Sagittate	0	1	0	1	1	0	1	0	1	0	0	0	0
Texture	Glabrous	0	0	0	1	0	1	1	1	1	1	0	1	1
	Hairy	1	1	1	0	1	0	0	0	0	0	1	0	0

Upper leaves	Petiole	Petiolate	0	1	0	1	1	1	1	1	1	0	0	0		
	Shape	Sessile	1	0	1	0	0	0	0	0	0	0	0	0	1	
		Linear	1	0	0	0	0	0	0	0	0	0	0	0	0	
		Lanceolate	0	0	0	1	0	0	1	1	1	1	0	0	0	
		Ovate	0	1	0	0	1	0	0	0	0	0	0	0	0	
		Hastate	0	0	0	0	0	1	0	0	0	0	0	0	0	
		Cordate	0	1	1	0	0	0	0	0	0	0	0	0	0	
		Sagittate	0	0	0	0	0	1	0	0	0	0	0	0	0	
	Texture	Elliptic	0	0	0	0	0	0	0	1	1	1	0	0	0	
		Glabrous	1	0	0	1	0	1	1	1	1	1	0	0	1	
Aggregation	Hairy	0	1	1	0	1	0	0	0	0	0	0	0	0		
	Solarity	1	1	1	1	1	1	1	1	1	1	0	0	0		
Inflorescence	Pedicele	0	0	0	0	0	0	0	0	0	0	1	1	1		
	Petiolate	1	1	1	1	1	1	1	1	1	1	0	1	1		
Number of floral parts	Sessile	0	0	0	0	0	0	0	0	0	0	1	0	0		
	Tetramerous	0	0	0	0	0	0	0	0	0	0	1	0	0		
Symmetry	Pentamerous	1	1	1	1	1	1	1	1	1	1	0	1	1		
	Actinomorphic	0	0	0	0	0	0	0	0	0	0	1	0	0		
Bract	Zygomorphic	1	1	1	1	1	1	1	1	1	1	0	1	1		
	Pedicele	0	1	1	1	1	1	1	1	1	1	0	0	0		
Flower	Sepals	Sessile	1	0	0	0	0	0	0	0	0	0	1	1	1	
		Shape	Linear	1	0	0	0	0	0	0	0	0	0	1	1	
	Corolla	Lanceolate	0	0	0	0	0	0	1	1	0	1	0	0	0	
		Ovate	0	0	0	0	1	0	0	0	0	0	0	0	0	
		Hastate	0	0	1	0	0	0	0	0	0	0	0	0	0	
		Cordate	0	1	1	0	0	0	0	0	0	0	0	0	0	
		Elliptic	0	0	0	1	0	1	0	0	1	1	1	0	0	
		Texture	Glabrous	1	0	0	1	0	1	1	1	1	1	1	1	1
			Hairy	0	1	1	0	1	0	0	0	0	0	0	0	0
		Spur	Glabrous	1	0	0	1	0	1	1	1	1	1	0	1	1
Hairy			0	1	1	0	1	0	0	0	0	0	1	0	0	
Shape		Linear	1	1	0	0	0	1	0	0	0	0	0	0	0	
	Lanceolate	1	0	1	1	1	0	1	1	1	1	1	0	0		
Colour	Ovate	0	0	0	0	0	0	0	1	0	0	0	1	1		
	White-margined	1	1	1	0	0	0	0	1	1	0	1	1	1		
Membrane-brownish	Green	1	1	1	1	1	1	1	1	1	1	0	1	1		
	Membrane-brownish	0	0	0	0	0	0	0	0	0	0	1	0	0		
Shape	Bilabiate	1	1	1	1	1	1	1	1	1	1	0	1	1		
	Rotate	0	0	0	0	0	0	0	0	0	0	1	0	0		
Texture	Glabrous	0	0	0	1	0	1	1	1	1	1	1	1	1		
	Hairy	1	1	1	0	1	0	0	0	0	0	0	0	0		
Spur	Presence	1	1	1	1	1	1	1	1	1	1	0	0	0		
	Absence	0	0	0	0	0	0	0	0	0	0	1	1	1		
Colour	Yellow	1	1	1	1	1	1	1	1	1	1	0	0	0		
	Red	0	0	0	0	0	0	0	0	0	0	0	1	1		
Androecium	Colourless	0	0	0	0	0	0	0	0	0	0	0	1	0		
	Length of stamens (Didynamous)	1	1	1	1	1	1	1	1	1	1	0	1	1		
Stamens inclusion	Equal	0	0	0	0	0	0	0	0	0	0	1	0	0		
	Included in the corolla tube	1	1	1	1	1	1	1	1	1	1	0	0	0		
Staminode	Exerted from corolla tube	0	0	0	0	0	0	0	0	0	0	1	1	1		
	Presence	0	0	0	0	0	0	0	0	0	0	0	1	1		
Gynoecium	Absence	1	1	1	1	1	1	1	1	1	1	1	0	0		
	Shape	Globose	1	0	1	1	1	1	1	1	1	0	1	0		

Fruit	Shape	Elliptic	0	1	0	0	0	0	0	0	0	1	0	0	
		Stigma	Simple	1	1	1	1	1	1	1	1	1	1	0	0
		Capitate	0	0	0	0	0	0	0	0	0	0	0	1	1
	Dehiscent	Globose	1	0	1	1	1	1	1	1	1	1	0	1	1
		Elliptic	0	0	0	0	0	0	0	0	0	0	1	0	0
	Lid	Elliptic-ovate	0	1	0	0	0	0	0	0	0	0	0	0	0
		Two apical pores	1	1	1	1	1	1	1	1	1	1	1	0	0
		Lid	0	0	0	0	0	0	0	0	0	0	0	1	0
		Two valves	0	0	0	0	0	0	0	0	0	0	0	1	1

Table 3. Data Matrix of the Lamina Anatomical Characters of the Studied Taxa and Their Codes (0 = absent, 1 = present).

Lamina anatomical characters			<i>Kickxia abhaica</i>	<i>K. acerbiana</i>	<i>K. aegyptiaca</i>	<i>K. corallicola</i>	<i>K. elatine</i>	<i>K. hastata</i>	<i>K. petiolate</i>	<i>K. pseudoscoparia</i>	<i>K. scalarum</i>	<i>K. spartioides</i>	<i>Plantago major</i>	<i>Scrophularia deserti</i>	<i>S. peyronii</i>	
Epidermis cells	Shape	Irregular	1	1	1	1	1	1	1	1	1	1	0	1	1	
		Polygonal	0	0	0	0	0	0	0	0	0	0	0	1	0	0
	Wall	Undulate	1	1	1	1	1	1	1	1	1	1	1	0	1	1
		Straight	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Stomata	Type	Anisocytic	1	0	0	0	0	1	0	0	0	0	0	0	1	1
		Anomocytic	0	1	1	1	1	0	1	1	1	1	1	0	0	0
	Subsidiary cells	Paracytic	0	0	0	0	0	0	0	0	0	0	0	1	0	0
		Irregular	1	1	1	1	1	0	1	1	1	1	1	0	1	1
		Straight	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Presence	Number	3	1	0	0	0	1	0	0	0	0	0	1	1	1	
Unbranching	3-4	0	1	1	1	1	0	1	1	1	1	1	0	0	0	
Trichomes	Type	Glandular	1	1	1	0	1	0	0	0	0	0	0	0	0	0
		Non-glandular	0	0	0	0	0	0	0	0	0	0	0	1	0	0
	No. of cells	Bicellular	0	1	0	0	0	0	0	0	0	0	0	0	0	0
		Multicellular	1	0	1	0	1	0	0	0	0	0	0	1	0	0
	Terminal cell	Acute	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Spherical head	Spherical head	0	1	1	0	1	0	0	0	0	0	0	0	0	0	

Micro-Morphological (Anatomical) Characteristics

Data Matrix was constructed from the obtained results (Table 3) of the anatomical features of the studied species so that the presence of the trait was expressed by the number (1) and in the absence of the trait by (0) to be used in the numerical analysis, and a dendrogram was created between the plant samples using NTSYS-pc 2.2 software package according to the method of (Rohlf, 2009), cluster analysis of a matrix of similarity and dissimilarity was implemented among the species under study. It is from the results obtained from the dendrogram (Fig. 2) the number of Series, Clusters and Groups between the studied species.

The results showed the upper and lower epidermal cells of the leaves are identical on both isodiametric surfaces. They appeared irregular with the undulate surface in all studied species except for *Plantago major*. The results of this study agree with the results of Bahadar *et al.* (2018).

The results also showed the presence of the amphistomatic leaves i.e., the stomata are located on both lower and upper surfaces of the leaves alike, and they were distinguished by three types:

The first type: Anomocytic (Ranunculaceous) stomata observed in eight species of *Kickxia*, and this result is consistent with the results of Lahari and Rao (2018).

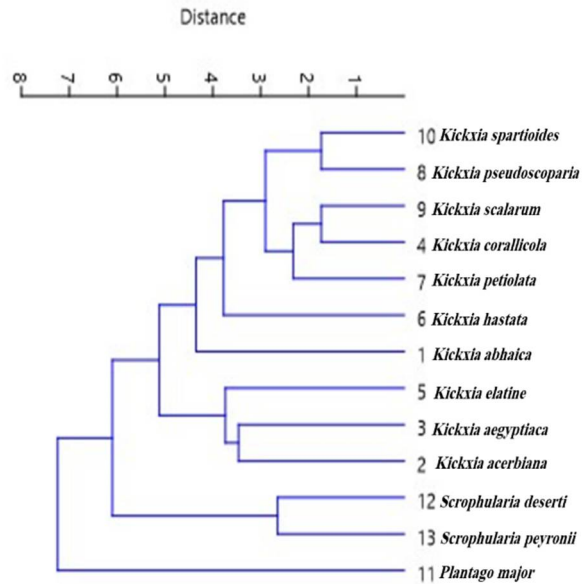


Fig. 1. Dendrogram for the species under study Based on the results of the phenotypes.

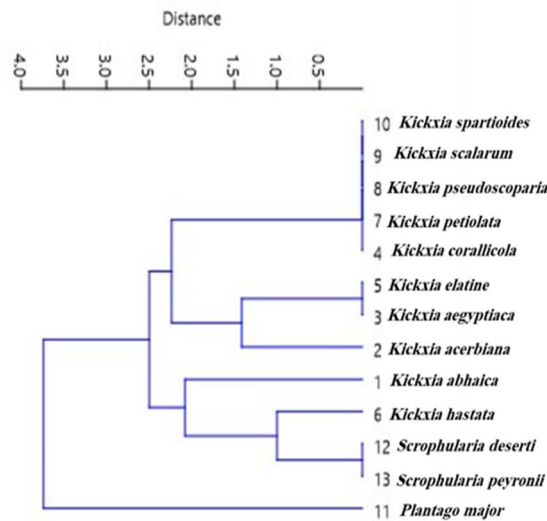


Fig. 2. Dendrogram for the studied species based on minor anatomical features.

The second type: Anisocytic (Cruciferous) stoma, surrounded by three cells. It was observed in only two species: *Kickxia abhaica* and *K. hastata*. It was also observed in two species of *Scrophularia*. This result agreed with the results of Ranjbar and Rahchamani (2018).

The third type: Amphianisocytic-Paracytic. This type was seen only in *Plantago major*, and this result agrees with the results of Bahadar *et al.* (2018) but disagrees with Mesquita *et al.* (2017), where it was mentioned that the stomata in *Plantago major* are anomocytic.

Most of the studied species were characterised by the absence of hairs on the epidermal leaf surface while the others were distinguished by the presence of non-branching glandular hairs with two and multiple cells arranged in one row and differed in the shape of the terminal cell, so it took the glandular spherical shape in the species *K. abhaica*, *K. acerbiana*, *K. aegyptiaca*, *K. elatine*, acute while non-glandular in *Plantago major*.

Thus, it is evident from the anatomical study of the leaves of the studied species that there are some characteristics which distinguish *Plantago major* from the rest of the studied species in terms of the shapes of the polygonal epidermal cells from 4-5 while the rest of the species are irregular in shape, as well as the type of stomata in the *Plantago major* amphianisocytic - paracytic, unlike other species. Also, by a special type of non-glandular, multicellular, unbranched acute hairs.

Thus, this study demonstrates that *Plantago* is unique in its anatomical characteristics from the rest of the species under study, which confirms that *Plantago* is kept in a separate family (Plantaginaceae) and not included in the Scrophulariaceae family, which includes *Kickxia* and *Scrophularia*.

This result agreed with the anatomical and morphological study (Hamed *et al.*, 2014) on some genera of the Scrophulariaceae family with *Plantago* and emphasized the need to keep *Plantago* within a separate family (Plantaginaceae) and for more accuracy in separating the species, many studies must be conducted. The other is to create new taxonomic indications that support the separation or not.

Also, the results obtained from the dendrogram (Fig. 2) and (Table 3) separated *Plantago major* into an independent series, while the rest of the other species are grouped in another series due to their similarity in many anatomical features; the shape of epidermal cells, the type of stomata, the terminal cell shape of the hair, and this result is consistent with many traditional taxonomic systems that include *Kickxia* within Scrophulariaceae (Bentham and Hooker, 1876; Cronquist, 1981; Engler and Prantl, 1895). Also, agree with the opinion of some studies that suggest that *Kickxia* should not be separated and kept within the Scrophulariaceae *s.l.* (Hamed *et al.*, 2014).

The Macro and Micro-Morphological characteristics of species under study are important in defining, separating, and studying the evolutionary relationships between taxa. This observation gives extra support to the taxonomic views that suggest the retention of the *Kickxia* in the family of Scrophulariaceae *s.l.* and maintaining *Plantago* in a separate monogenetic family of Plantaginaceae *s.s.*

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