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Anatomical features of the stem in Egyptian species of *Fagonia* L.

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RÉSUMÉ.

Revenant sur les travaux de Boissier, qui groupe les espèces de *Fagonia* à l'aide de leur tige, quadrangulaire ou cylindrique, l'anatomie des espèces égyptiennes de ce genre a été étudiée. Trois types de tige sont ainsi apparus, soit le type de base, le cylindrique et le quadrangulaire. C'est à l'aide de la configuration de l'anneau de croissance secondaire et de la position centrale ou excentrique de la moelle que ces types ont été caractérisés. Les espèces à tige arrondie, selon Boissier, ont en effet la tige du type cylindrique; chez les espèces à tige soi-disant quadrangulaire on trouve soit le type de base, soit le type quadrangulaire. Les données anatomiques cadrent bien avec la subdivision du genre *Fagonia* en trois entités naturelles, proposée antérieurement. Les espèces-clé de ces groupes présentent une tige appartenant au type de base. Celui-ci passe par spécialisation, soit au type rond, qui caractérise les espèces évoluées dans le groupe *arabica-bruguieri*, soit au type quadrangulaire propre à celles des groupes *glutinosa* et *sinaica*.

ZUSAMMENFASSUNG.

In Hinblick auf Boissiers Vorgehen, der die Arten der Gattung *Fagonia* auf Grund ihres viereckigen oder runden Stengels gruppiert, wurden die anatomischen Verhältnisse bei den ägyptischen *Fagonia*-Arten untersucht. Anatomisch konnten drei Stengeltypen unterschieden werden: Grundform, runder Typus und viereckiger Typus. Als Grundlage für diese Einteilung dienten die Gestalt des sekundären Leitgeweberings und die zentrale oder exzentrische Lage des Marks. Die rundstengeligen Arten Boissiers besitzen den runden Stengeltypus; die Arten mit viereckigem Stengel zeigen teils die Grundform, teils den viereckigen Typus. Die anatomischen Ergebnisse stützen die früher vorgenommene Einteilung von *Fagonia* in drei natürliche Untereinheiten. Die Schlüsselarten dieser Gruppen gehören in ihrer Stengelanatomie zur Grundform. Durch Spezialisierung wandelt sich diese bei den abgeleiteten Arten der *arabica-bruguieri*-Gruppe zum runden, bei jenen der *glutinosa*- und der *sinaica*-Gruppe zum viereckigen Stengeltypus.

SUMMARY.

The anatomical features of the Egyptian species of *Fagonia* were studied in relation to Boissier's concept of classifying these species on the basis of a terete or a quadrangular stem. The investigation revealed the presence of three anatomical patterns viz. basic, terete and quadrangular, based upon the shape of the secondary growth-ring and the position

of the pith, whether centric or excentric. Species claimed by Boissier to be terete in outline have also a terete anatomical pattern, while those claimed by Boissier to have quadrangular outline, have either a basic or a quadrangular anatomical pattern. The anatomical patterns have been found to agree with the natural groups of *Fagonia*. The key species of these natural groups have the basic anatomical pattern. This gives through specialisation the terete pattern characteristic of advanced species of the *arabica-bruguieri* group, and it is also the origin of the quadrangular pattern characteristic of the advanced species of the *glutinosa* and *sinaica* groups.

In a previous study (1966), the author has revised the Egyptian material of the genus *Fagonia* which has revealed the presence of 18 distinct species in this country.

The criteria used for the above study were some morphological characters already used by several authors, in addition to some microscopical characteristics such as pollen grain and hair morphology, which were tried for the first time and proved to be of systematic value.

Boissier (1867), classified the oriental species of *Fagonia* with foveolate-punctate seeds, according to the nature of the young shoot, into two main groups: quadrangular and sulcate, or terete and striate.

Ozenda and Quézel (1956), claimed that such differentiation had little systematic value, since it was not always clear, in a taxon, whether the stem was terete or quadrangular, especially in the adult stage.

It was thought necessary, therefore, to study the anatomy of the young shoot in relation to Boissier's concept of quadrangular and terete stems in order to ascertain how far the external features coincided with the internal structure.

MATERIAL AND METHODS

Internodes belonging to younger shoots were fixed in FAA solution (formaldehyde-alcohol-acetic acid), cleared in benzol and embedded in paraffin. The anatomical structure of each species was studied in thin sections ($10\ \mu$) in young internodes having no secondary growth and in others slightly older having only one secondary growth ring. The sections were stained with saffranin and light green, cleared in xylol and mounted in canada balsam.

ANATOMICAL FEATURES

1. *Characteristics of the stem:*

The anatomical investigation of the stem in the different species has revealed the presence of a basic anatomical pattern, which is characteristic of at least half of the species, including the older ones with wide geographical distribution such as *F. arabica* and *F. bruguieri*. In addition there are two other distinct patterns characteristic of some species of limited geographical distribution and which are derived from the older, widely distributed, taxa. One pattern, referred to here as the terete pattern, has a roundish secondary growth ring and an excentric pith. The other pattern, referred to here as the quadrangular pattern has a more or less square secondary growth ring and a centric pith.

The characteristics of these anatomical patterns, with the distribution of the different tissues are shown diagrammatically in fig. 1 and will be described shortly as follows:

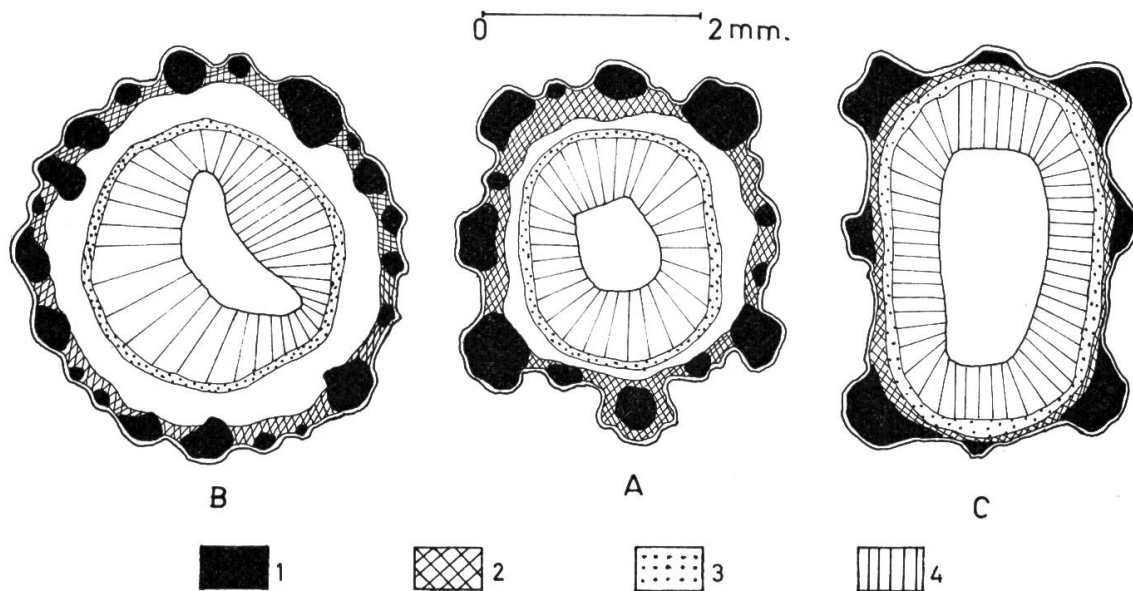


FIG. 1. — Anatomical forms of Egyptian species of *Fagonia*.

A: main form. — B: terete form. — C: quadrangular form. — 1. fibres. — 2. chlorenchyma. — 3. phloem. — 4. xylem.

A. Basic pattern:

The outline of the stem in transverse section is not clearly quadrangular or circular. It is however in some species e.g. *F. glutinosa* and *F. bruguieri*, etc., more or less quadrangular with 4 major ridges at the angles and other smaller minor ridges in between. In other species e.g. *F. arabica* and *F. myriacantha*, the outline is somewhat circular with about 5 major ridges and smaller ones between.

The epidermis is composed of cells with a relatively thick cuticle on the outer walls. It is followed by a narrow cortex composed of an outer band of chlorenchyma consisting of 2 layers of cells and an inner zone of parenchyma consisting also of about 2 layers of cells.

Patches of cortical fibres are usually subepidermal at the major and minor ridges interrupting the band of chlorenchyma. The patches are located somewhat deeper under the band of chlorenchyma in *F. glutinosa*, *F. microphylla*, *F. tristis* and *F. mollis*.

Pericycle fibre strands were observed in the young stem of several species, e.g. *F. glutinosa*, *F. mollis*, etc.

The vascular cylinder consists in the young stem of about 10 distinct vascular bundles. Later, when the secondary growth starts, a complete cylinder of primary and secondary vascular elements is formed. It consists of an outer narrow band

of phloem followed by an inner, wide, zone of xylem. This cylinder is quadrangular with a central pith in *F. bruguieri*, *F. myriacantha*, *F. kassasii*, and *F. sinaica*, while it is circular with slightly excentric pith in *F. glutinosa*, *F. microphylla*, *F. tristis* and *F. mollis*.

The cells of the pith become lignified after the beginning of secondary growth, thus the pith remains persistent.

B. *Terete pattern*:

The outline of the stem in transverse section is clearly circular, with several ridges and furrows which are identical to striations of the stem.

The epidermis is followed by a comparatively wide cortex composed of: an outer subepidermal chlorenchyma band consisting of 2-3 layers of cells and an inner parenchyma zone of at least 3 layers of cells.

Patches of cortical fibres are usually located subepidermally under the ridges interrupting the band of chlorenchyma. These patches are almost absent in *F. thebaica*, and located somewhat deeper under the band of chlorenchyma in *F. taeckholmiana*.

Strands of pericycle fibres were observed in young stems of *F. boulosii*, *F. indica* and *F. thebaica*.

The vascular cylinder is represented in the young stage by about 10 distinctly separated vascular bundles. Later, when the secondary growth takes place, a complete, clearly round cylinder of primary and secondary vascular elements is formed. It consists of an outer narrow band of phloem and an inner wide zone of xylem. The pith is excentric due to an abnormal growth of secondary xylem. Wider sectors are formed along nearly one third of the circumference of the stem.

The cells of the pith are strongly lignified (walls pitted) after the beginning of secondary growth, thus the pith remains persistent.

C. *Quadrangular pattern*:

The outline of the stem in transverse section is clearly quadrangular with 4 limbs, 4 major ridges at the angles and 4 other minor ridges half way between the limbs.

The epidermis is followed by a narrow cortex composed of: a narrow band of chlorenchyma consisting of not more than 2 layers of cells. The zone of parenchyma characteristic for the other 2 forms, is missing here.

Patches of cortical fibres are subepidermal interrupting the band of chlorenchyma at the major and the minor ridges.

The vascular cylinder is represented in the young stem by about 8 separate bundles. Later when secondary growth takes place, a quadrangular tube of primary and secondary vascular elements is formed. It consists of a narrow outer band of phloem and a wider inner zone of xylem. Due to absence of cortical parenchyma, both phloem and chlorenchyma bands come close to each other.

The pith is clearly centric. The cells remain thinwalled after the beginning of the secondary growth, and are thus subject to mechanical stress and desintegration through dessication leaving a hollow cavity.

2. Anatomical characteristics of the stem and natural groups of *Fagonia*:

Boissier (1867), included among the group of species with quadrangular stem the following species which occur in Egypt: *F. bruguieri*, *F. myriacantha*, *F. Kahirina* (= *F. sinaica* var. *kahirina*), *F. cretica*, *F. glutinosa*, *F. latifolia*, *F. mollis* (= *F. tristis* var. *boveana*) and *F. grandiflora* (= *F. mollis*).

He included in the group of species with a terete stem, the following species which were known to him to occur in Egypt: *F. arabica*, *F. thebaica* and *F. indica*.

According to Ozenda and Quézel (1956), also El Hadidid (1966), the North African species of *Fagonia* can be grouped into 3 more or less natural groups.

El Hadidi (1966), recognized 18 well defined species in Egypt, of these 9 belong to the *arabica-bruguieri* group, 6 to the *glutinosa* group and 3 to the *sinaica* group.

The following table will show the relation ship between these natural groups and the identical pattern of their species as revealed in this investigation.

Natural group	Anatomical pattern		
	Basic	Terete	Quadrangular
<i>arabica-bruguieri</i> group	<i>F. arabica</i> (type) <i>F. bruguieri</i> <i>F. kassasii</i> <i>F. myriacantha</i>	<i>F. arabica</i> (var.) <i>F. thebaica</i> <i>F. boulosii</i> <i>F. indica</i> <i>F. elba</i> <i>F. taeckholmiana</i>	
<i>glutinosa</i> group	<i>F. glutinosa</i> <i>F. microphylla</i> <i>F. tristis</i> <i>F. mollis</i>		<i>F. latifolia</i> <i>F. isotricha</i>
<i>sinaica</i> group	<i>F. sinaica</i> var. <i>kahirina</i>		<i>F. sinaica</i> var. <i>sinaica</i> <i>F. cretica</i> <i>F. bischarorum</i>

From this table, it is clear that the basic pattern is of more common occurrence than the terete and quadrangular patterns. It is also characteristic of the key species of the three natural groups viz. *F. arabica*, *F. bruguieri*, *F. glutinosa* and *F. sinaica*.

According to this investigation, there are no species with a quadrangular pattern which belong to the *arabica-bruguieri* group, and no species with a terete pattern which belong to either the *glutinosa* or *sinaica* groups.

Some of the species known to Boissier, and regarded by him as having a quadrangular stem in outline, do not show the quadrangular anatomical pattern viz. *F. bruguieri*, *F. myriacantha*, *F. glutinosa*, *F. tristis*, and *F. mollis*; whereas others viz. *F. sinaica*, *F. cretica*, and *F. latifolia* showed distinctly this pattern.

On the other hand, the Egyptian species which were described by Boissier to have a terete stem in outline, were found to have typically a terete anatomical pattern.

DISCUSSION

The anatomical characteristics of the stem in *Fagonia* species generally agree with the features of the axis in *Zygophyllaceae* as described by Metcalfe and Chalk (1957).

This investigation has shown that the basic pattern of anatomy of the stem is of common occurrence among the species of *Fagonia* in Egypt, particularly among the widely distributed key-species of the three natural groups of this genus.

Terete or quadrangular patterns are less common, and are characteristic for endemic species and taxa of limited geographical distribution which are derived from the mother key-species.

This means that such anatomical patterns are derived from the basic pattern through specialisation. Thus, the formation of excentric pith., characteristic of the terete pattern is the result of an abnormal secondary growth. Also, the narrow cortical zone of the quadrangular pattern is a reduced cortex of a wider one found in the basic pattern.

A. *The arabica-bruguieri* group :

Within this group, both the main and terete anatomical patterns are represented. It may be noticed that *F. arabica* exceptionally has the two anatomical patterns. The basic pattern, also (Montasir and Shafey 1951), is characteristic for plants that belong to the type *F. arabica* itself, whereas the terete pattern is characteristic of some specialised, less common, or endemic varieties such as var. *imamii* and var. *tilhoana*. This would agree with the author's opinion that *F. arabica* is a complex species which is only widely distributed through its numerous varieties and forms. Maire (see Ozenda and Quézel 1956 : 48) treated var. *tilhoana* as a distinct species, while other forms included among *F. arabica* need a future study on cytological and anatomical bases to settle their position.

The specialisation of the anatomical structure within the *arabica-bruguieri* group seems to take place in two distinct directions, which agree generally with interrelationships among the species of this group (compare fig. 1 : 17, in the first paper).

In one direction, *F. bruguieri*, also the closely related species *F. myriacantha* and *F. kassasii*, have retained the features of the basic pattern which is also characteristic of the type *Fagonia arabica*.

In the other direction, *F. thebaica*, *F. boulosii*, *F. indica*, *F. elba*, and *F. taeckholmiana* as well as some varieties of *Fagonia arabica* are characterised by the terete pattern.

It may be pointed out here, that *F. arabica* and *F. bruguieri* which have the basic anatomical pattern are known to be the most widely distributed taxa of this group. For comparison, those species with a terete anatomical pattern (except *F. indica*) are either endemic species or taxa of limited geographical distribution.

Anatomical characteristics may be useful to clear up the relationships between certain taxa. *F. boulosii*, an endemic taxon described from the northern parts of the Egyptian Arabic desert (see map. 1 in El Hadidi 1966) has certain morphological characters in common with *F. arabica* and *F. thebaica*. Anatomically this species has both cortical patches and strands of pericycle fibres. Such cortical patches are missing in *F. thebaica*, while pericycle fibres are present. On the other hand patches of cortical fibres are very distinct in *F. arabica*, while pericycle strands are uncommon. *F. boulosii* has been recorded in Egypt from places where both *F. arabica* and *F. thebaica* are likely to be present.

B. *The glutinosa and the sinaica groups* :

Among the two groups, the basic and quadrangular anatomical patterns are represented. Within each group, the key species viz. *F. glutinosa* and *F. sinaica* are characterised by the basic anatomical pattern. Through specialisation, within each group, other species attained the quadrangular pattern.

F. sinaica, is again and exceptionally a species which has both the basic and the quadrangular patterns. The first pattern is characteristic for the taxon growing around Cairo, and which can represent the var. *kahirina*; while the second pattern characterises the var. *sinaica*. This variety is in several respects similar to *F. bischarorum*, which has also the quadrangular pattern and represents a specialised form of the mother species *F. sinaica* var. *kahirina* in the southern regions of the Egyptian Arabic desert.

Within the *glutinosa* group nearly all the species have the anatomical features of the basic pattern except the closely related *F. latifolia* and *F. isotricha*, which have the quadrangular pattern.

It has been claimed by El Hadidi (1966), that both the *sinaica* and *glutinosa* groups have several characters which are in common between both groups. In this respect they differ from the *arabica-bruguieri* group, which may postulate that their origin is different from that of the last group.

The first two groups include usually herbaceous taxa with distinctly trifoliate leaves and spiny stipules which are shorter than or at least not exceeding the leaves in their length.

Palynologically both groups have a similar pollen type with tegillate sexine.

On the other hand, the *arabica-bruguieri* group includes usually woody taxa, with the lower leaves trifoliate (except in *F. indica* and allied taxa) and the upper ones unifoliate. The spiny stipules are usually longer than the leaves and the pollen grains have a reticulate sexine.

In addition, there are taxa among the *arabica-bruguieri* group which are widely distributed, whereas the *glutinosa* and *sinaica* groups exclusively have taxa which are either endemic to certain areas or of limited geographical distribution.

Anatomy apparently gives a support to the natural grouping. It is evident that within the *arabica-bruguieri* group, the basic anatomical pattern gave rise to the terete form, while within the *glutinosa* and *sinaica* groups, the same gave rise to the quadrangular form.

C. *Anatomical characteristics and Boissier's concept of terete and quadrangular stems:*

From the beginning, this anatomical investigation was made in order to test whether Boissier's concept of terete and quadrangular stem had any systematic value. It was intended to make a simple inspection of the young shoot of the different species in cross section. However, the investigation revealed the presence of three anatomical forms which helped in addition to several other characters to divide the *Fagonia* species into 3 more or less distinct natural groups.

Those species claimed by Boissier to have terete stem, were found to have terete anatomical pattern in addition to the circular outline.

On the other hand, the species which were claimed by Boissier to have quadrangular stem, did not always have a quadrangular anatomical pattern. Only 4 species viz. *F. cretica*, *F. bischarorum*, *F. latifolia* and *F. isotricha* (only the first and the third species were known to Boissier) have shown a typical anatomical quadrangular pattern. The other species viz. *F. sinaica* var. *kahirina*, *F. glutinosa*, *F. microphylla*, *F. tristis* and *F. mollis* (all except the third species were known to Boissier) showed anatomical features of the basic pattern, although the outline of the stem in cross section (which implies to Boissier's concept) is more or less quadrangular.

Finally it may be added that anatomical characteristics of the leaf epidermis and of the elements of the secondary xylem have also proved to be of systematic value. The result of this investigation will be left for a future treatment. May be the chemo- and cyto-taxonomical investigations of this genus, which are now undertaken will also help in giving a more accurate idea about the phylogeny of the genus.

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