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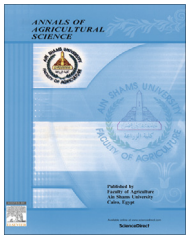

Computer-generated keys to the flora of Egypt. 6. The Boraginaceae

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Abstract Manually-constructed keys to many groups of the Egyptian flora are in urgent need of improvement and updating. To construct a conventional substitute of the key to representatives of the Boraginaceae, a data matrix was compiled to accommodate 54 characters recorded comparatively for the 49 species belonging to 14 genera which represent this family in the flora of Egypt. The 54 characters were accurately and lucidly defined to cover as much of the easily observable aspects of vegetative and floral variation in the plants as possible. The data matrix was analyzed using the key-generating package of programs DELTA. The analysis produced a conventional key with a detailed description of every species in terms of the 54 characters. The key is decidedly a marked improvement over its predecessors in that it is strictly comparative and leads directly to the full scientific name of any taxon, instead of having to use a key to the genera followed by a second key to the infra-generic taxa.

Introduction

The Boraginaceae Jussieu comprises 110 genera and 1595 species (Angiosperm Phylogeny Group; APG III, 2014), but the numbers reach 130–135 genera with 2400–2600 species in Bergianska website (2014). The plants are perennial, biennial, or annual herbs, less often lianas, shrubs, or trees, usually bristly or pubescent and scabrid. Leaves are simple, alternate, rarely opposite, with serrate or entire margin. Inflorescences often scorpioid cymes, sometimes solitary; bracts present or absent. Flowers are bisexual, actinomorphic or, rarely, slightly zygomorphic. Calyx is usually 5-parted or lobed, mostly persistent. Corolla tubular, funnel-shaped, campanulate or rotate; tube with 5 appendages, rarely more, mostly trapeziform, rarely absent, a ring of hairs present sometimes; limb usually 5-parted; lobes overlapping, rarely twisted in bud. Stamens 5, inserted on corolla tube, included or rarely exserted; anthers introrse, 2-loculed, usually dorsifixed at base, less usually medifixed, dehiscence longitudinal. Nectaries present on disk below ovary or at base of corolla tube. Ovary is superior, 2-carpels; locules 2 and each with 2 ovules, or divided by secondary septa

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into 4 locules each with 1 ovule; ovules nearly anatropous, semi-anatropous, or atropous. Style gynobasic or, rarely, terminal, branched or not. Fruit 1–4-seeded drupe or 4 nutlets (mericarps); nutlets mostly dry, often ornamented with wings, prickles and/or glochids (stiff bristles with barbed or anchor-like tips). Seeds vertical or oblique, with basal attachment; endosperm oily or absent; embryo straight, less often curved; cotyledons flat, fleshy; coat membranous (Barroso, 1986; Al-Shehbaz, 1991; Watson and Dallwitz, 1992 onwards; APG III, 2014).

The map shown in the APG III (2014) account of the Boraginaceae indicates that members of this family are widely distributed in the world. They cover the whole of N. America, Europe, Asia (except most of India and the Indonesian Archipelago), Australia, New Zealand, North Africa, East Africa, Madagascar, the Cape Province, and western South America. Detailed accounts of the geographical distribution of the Boraginaceae are given by Al-Shehbaz (1991) and Thorne (1992). According to Retief and Vanwyk (1997) members of this family grow mainly in dry, cliffy and sunny habitats.

Anatomical studies on members of the Boraginaceae are numerous and only a representative selection of the more recent studies is presented here. Selvi and Bigazzi (2001) studied leaf surface and anatomy in tribe Boragineae. Foliar anatomy of *Heliotropium* was also the subject of study by Abbasi et al. (2011), Ahmed and Kordofani (2012), and Alwahibi and Bukhary (2013). Similarly, foliar anatomy was studied by Akçin and Baki (2007) in three *Symphytum* species, by Akçin et al. (2012) in four *Cynoglossum* species, and by Güven et al. (2013) in six *Onosma* species. Stomatal profile in the foliar epidermis was studied by Dasti et al. (2003) in 31 species belonging to 15 genera, while foliar trichomes were extensively surveyed by Al-Nowaihi et al. (1987), Selvi and Bigazzi (2001), Diane et al. (2003), Taia (2006), Ventrella and Marinho (2008), Perveen (2009), and Mehrabian et al. (2014). Ovchinnikova (2009) used details of nutlet surface sculpture to determine the position of tribe Eritrichieae in the Boraginaceae, while Keshavarzi et al. (2013) used 23 characters of stem and fruit anatomy to evaluate the relationships of four *Anchusa* species. Nodal anatomy is rarely studied in angiosperms and it seems that the only study concerning members of the Boraginaceae is that of Trivedi et al. (1976) on certain representatives of the family in India. According to the account of Boraginaceae in the Bergianska website (2014), the nodes are usually unilacunar with one or three leaf traces, or trilacunar with three leaf traces. Using scanning electron microscopy, Rabaey et al. (2010) were able to elucidate the phylogenetic significance of the distribution of bordered pits in the secondary xylem of 105 species representing the major groups of the Boraginaceae.

Pollen morphology of the Boraginaceae was studied extensively. Thus, Clarke (1977) maintained that the Boraginaceae is one of the most eurypalynous families. Diez and Valdes (1991) studied the pollen morphology of 33 species of Boraginaceae from the Iberian Peninsula belonging to the tribes Cynoglosseae and Eritrichieae and they confirm the eurypalinous character of this family. Scheel et al. (1996) studied the pollen morphology of 30 taxa and classified them into nine pollen types based on aperture characteristics and surface ornamentation. Other palynological studies of different members of the Boraginaceae from various parts of the world include those by Nowicke and Miller (1990), El-Ghazaly (1995), Qureshi (1997), Bigazzi and Selvi (1998), Liu et al. (2001a,b), Khatamsaz (2001), Hargrove and Simpson (2003), Bigazzi et al. (2006), Melo et al. (2006), Binzet et al. (2010), Binzet (2011), Falatoury et al. (2011), Mehrabian et al. (2012), Coutinho et al. (2012) and Fukuda and Ikeda (2012).

Members of the Boraginaceae are of little economic importance. Only a few species are used in traditional medicine for treating wounds, fever, chest pain, and skin diseases (Neuwinger, 2000). Some species are grown as ornamentals, sources of timber or dye producers. The family is generally regarded as closely related to the Hydrophyllaceae (with similar coiled inflorescence), and the Lamiaceae (with gynobasic style); Watson and Dallwitz (1992 onwards), APG III (2014).

Boulos (2002) maintained that the Boraginaceae is represented in the flora of Egypt by 19 genera and 58 species and provided identification keys to these taxa. However, there is plenty of room for improvement in these keys. The present study has been undertaken to benefit from the inherent facilities of the program package DELTA in producing much improved keys for the identification of the genera and species representing the Boraginaceae in the flora of Egypt. Reference to previous applications of this package to other groups in the Egyptian flora with successful results can be found in El-Gazzar et al. (2013).

Material and methods

It was possible to collect herbarium specimens of only 49 species representing 14 genera of this family from the two major herbaria in Egypt: the herbarium of Botany Department, Faculty of science, Cairo University (CAI) and the herbarium of Flora and Phytotaxonomy Researches Unit at the Agricultural Museum, Ministry of Agriculture, Dokki, Giza (CAIM); acronyms are according to the *Index Herbariorum* (Holmgren et al., 1990). The number of specimens representing each taxon ranged between one and eight. The identity of available specimens was verified by re-identifying them with the aid of the local flora (Boulos, 2002) and the floras of neighboring countries (e.g. Andrews, 1956; Feinbrun-Dothan, 1977, 1978). Nomenclature was updated from the two websites (http://www.theplantlist.org/), and (http://www.tropicos.org), where full lists of synonyms and author citations can be found. Full names with author citations of taxa and collection data of most of the specimens are given in Appendix A.

As many aspects of variation in vegetative and floral morphology as can be found in the available specimens were recorded comparatively in a data matrix. The wide range of anatomical, cytological, palynological and chemical variation in members of this family was deliberately avoided so that only the easily observable features were recorded. For uniformity in the usage of the descriptive terminology to define the characters and their states, reference was made to the standard comprehensive dictionary compiled by Stearn (1966).

The data matrix was subjected to analysis under the program suit DELTA which is a multi-purpose format for generating conventional (i.e. printable) and interactive (i.e. online) identification keys (Dallwitz et al., 1993 onwards; Dallwitz and Paine, 2005; Dallwitz, 2010; http://delta-intkey.com; www.sourceforge.net). Being essentially a format for translating taxonomic data, DELTA produces descriptions of taxa in natural language (detailed descriptions) and in serial numbers of characters and character-states (item descriptions).