

INTRODUCTION

Geranium L., with 307 species, is the largest genus of the Geraniaceae, a family that according to Stevens (2001), also contains the genera *Pelargonium* L'Hér. (280 species), *Erodium* L'Hér. (80 species, including *California* Aldasoro & al.), *Monsonia* L. (40 species, including *Sarcocaulon* Sweet) and *Hypseocharis* Remy (2 species; Lozada-Gobilard & al. 2020). *Hypseocharis*, however, differs from the other genera by its estipulate leaves, capitate stigma, ovaries with many ovules per loculus, and unbeaked fruits. This set of characters may support assignment to a monotypic family sister of the Geraniaceae core (Aedo 2012, Palazzesi & al. 2012). Retaining *Hypseocharis* would result in the Geraniaceae losing the main characters (stipulate leaves, style with 3-5 stigmatic branches, one or two ovules per loculus, beaked fruits) that define the family. Regarding the generic division of the family, the synonymization of *California*, and especially those of *Sarcocaulon* seems controversial (Albers 1996, Dreyer & al. 1997, Moffett 1979, 1997).

After the segregation of *Erodium*, *Monsonia*, *Pelargonium* (see *Historical overview*) from *Geranium*, the circumscription of the genus has been stable throughout its recent history. Three attempts to separate some species into independent genera have not been followed by most of the authors: *Robertium* to accommodate some species of sect. *Ruberta* (Picard 1837), *Neurophyllodes* to accommodate the species of sect. *Neurophyllodes* (Degener & Greenwell 1937), and *Geraniopsis* to accommodate two species of sect. *Trilopha* (Chrtek 1968).

The genus *Geranium* is easily differentiated from the other genera of the family by its usually actinomorphic flowers with five free petals, without hypanthium nor nectariferous tube, and with ten free stamens arranged in two whorls, very rarely the outer lacking the anthers. *Geranium* is distributed throughout most of the world except in lowland tropical areas, but it has diversified more in certain regions. The mountains around the Mediterranean Basin, the Caucasus and the Himalayas constitute some of these regions. Regarding the Old World, also South Africa and the mountains of New Guinea are very rich in endemic species. In the New World, the two areas particularly diverse in species are Mexico and adjacent regions of western U.S.A., and the north of the Andes, from Venezuela to northern Peru.

Knuth's (1912) worldwide monograph of *Geranium* was the most complete treatment of the genus during several decades, and a good starting point for an overview of the genus. This author accepted 269 species plus 72 more species in subsequent papers (Knuth 1913, 1915, 1916, 1922, 1923, 1930a, 1930b, 1931, 1933, 1934, 1936, 1937a, 1937b, 1938, 1939). This impressive monograph causes even more astonishment when we consider that it covers the whole Geraniaceae, in a broad sense, including small related families.

According to Melchior (1957: 185), Reinhard Knuth received his doctorate in 1902 with the dissertation entitled *Über die geographische Verbreitung und die Anpassungs-*

scheinungen der Gattung Geranium im Verhältnis zu ihrer systematischen Gliederung (Knuth 1903, 1904). He collaborated with F. Pax in the monograph treating Primulaceae published in 1905 in the Engler's *Pflanzenreich*. Subsequently he wrote monographs on Geraniaceae for the same series directed by A. Engler. The main work seems to have been carried out in a relatively short period, perhaps less than ten years, taking into account that his first taxonomic publication on the genus is from 1904 (Knuth 1904). This monograph should be seen in the context of its time, in which many areas were still unexplored or undercollected and loans between herbaria were not routinely done. This resulted, as an unavoidable consequence, in the scarcity of material for preparing full descriptions and keys, and for obtaining detailed distributions of the species. These limitations led to the description of some species that are now seen as synonyms. This however does not diminish the value of Knuth's work (Fig. 1).

Among the relevant contributions after Knuth's monograph, many floras can be mentioned. The list is, however, lengthy and it would be difficult to do justice to all the efforts of the authors of these works. One relevant example would be *Flora of the U.R.S.S.* (Bobrov 1949), that covers more than 22 million km², and presents a valuable taxonomic treatment of *Geranium* (55 species). Other important works that cover areas poorly known are those of Moore (1943) for species of Mexico and Central America, Jones & Jones (1943) for United States and Canada, Carolin (1965) for the southwestern Pacific area, Veldkamp & Moerman (1978) for the Malesian species, and Hilliard & Burtt (1985) for South African species.

A considerable advance in the knowledge of *Geranium* occurred with the works of P. Yeo, some focused on classification and others that studied various groups in particular. Among works on classification, it should be mentioned the new proposal for an infrageneric classification by Yeo



Fig. 1. Reinhard Knuth's handwritten label used to identify the plants studied in his monograph. Specimen preserved in the herbarium of University of Zurich (Z-000064950).

(1982, 1984, 1990), inspired in Tokarski (1972), and among group studies Yeo (1970, 1973a, 1973b, 1975, 1983, 1992, 2003, 2004).

The difficulty of preparing monographic treatments of large genera is well known (Frodin 2004) and applies to medium-sized genera as *Geranium* as well. The initial strategy for preparing an updated monograph of the genus was to review sections or subgenera that were well-characterized morphologically (Aedo 1996, 2001a, 2003, 2017b; Aedo & al. 1998, 2002, 2003, 2005a, 2005b, 2007, 2009, 2016; Aedo & Estrella 2006). However, these well-defined subgroups cover only a minor part of the genus. Consequently, to move forward, a change of approach was needed. For this reason the study of well-defined groups was combined with the study of species from little or poorly known areas. The species of China (Xu & Aedo 2008), the New World (Aedo 2012), the Iberian Peninsula (Aedo 2015), and the Pacific area (Aedo 2017a), have been revised in this way. Despite all this work, a part of the species of Eurasia and Africa requiring detailed study still remains. They are now here presented with the remaining of the genus.

For the present monograph, these previous accounts were amended as necessary. The descriptions were harmonized as much as possible, but in some cases it was not possible to complete some characters of species because the loans had been returned. The nomenclature was revisited and some new types were found. The delimitation of the species, as well as keys and distribution ranges, have sometimes been refined in light of the study of new collections.

HISTORICAL OVERVIEW

In early manuscripts about plants of Western culture, geraniums are occasionally mentioned. Dioscorides in his *De Materia Medica*, written between AD 50 and 70, provided a reference and a drawing (3.116) of a species of this genus difficult to identify but probably *Geranium rotundifolium* or *G. molle* (Estrella 2006). Pliny the Elder in his *Historiae Naturalis* (AD 77) refers to what seem to be two geraniums. He describes the first as a herb similar to hemlock, with smaller leaves and shorter stem and bearing at the top of the branches heads of cranes, which strongly suggest that it is an *Erodium*. The second plant is described as having leaves like those of anemone and a round root like an apple, which could indicate that it is *G. tuberosum* or other species of the section *Tuberosa* (Huerta 1629: 415; Jones 1966: 344). According to Sharples & Minter (1983) there is, however, some controversy about the use of the term geranium in the botanical writings by Theophrastus and Pliny the Elder.

After the medieval period which contributed little to the botanical knowledge from the Greek and Latin classics, a new current developed in central Europe. The herbalist Leonhart Fuchs is one of its main representatives. Fuchs (1542: 204-211) provided six drawings of European *Geranium*, some identifiable as *G. robertianum* and *G. sylvaticum*, one *Erodium* sp. and some *Geranium* sp. Unfortunately, these authors did not conserve the plants in herbaria and therefore the identification of their species cannot be confirmed.

It is more difficult to find ancient references outside the scope of Western culture. An interesting case are the manuscripts of Francisco Hernández who traveled through Mexico between 1572 to 1577 and collected information on the natural history of Mexican pre-Hispanic cultures. His manuscripts were published abbreviately from 1629 by Nardi Antonio Reccho in different editions. In one edition two drawings of Mexican taxa of *Geranium* are found but they cannot be assigned to any known species (Hernández 1649: 293). No herbarium testimonies are known to clarify the identity of these species.

In the Cinquecento the technique of pressing plants and preserving them in bound volumes was developed in northern Italy. Over time this gave rise to herbaria as we know them today. The oldest known pressed specimens of *Geranium* date from this time. According to Chiovenda (1928: 130), specimens of *Geranium nodosum* and *G. san-*



Fig. 2. Specimens of *Geranium nodosum* (FI-060876) and *G. sanguineum* (FI-060877) from Anonimo Toscano herbarium (formerly attributed to Michelle Merini), dated ca. 1544, and kept at the *Museo di Storia Naturale*, University of Florence (FI) [photo: the staff of the herbarium].