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Review

Phytochemistry of European *Primula* species

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ABSTRACT

The genus *Primula* is the largest among the Primulaceae and is widespread mainly in the cold and temperate regions of the Northern Hemisphere.

Since the beginning of the Twentieth century, several studies on the phytochemical composition of different species of *Primula* have been carried out. The main constituents examined were tissue and epicuticular flavonoids and saponins, which are of therapeutic significance. Only in recent years studies of the volatiles emitted by leaves and flowers have been carried out as well, but they are restricted to a small number of species. Only a few authors have documented the morphology and function of glandular trichomes in relation to the production of flavonoids and volatile organic compounds (VOCs).

The use of *Primula* in folk medicine is described in the literature. Investigation of the biological and pharmacological activities of *Primula* are reported.

This study aims at providing a collection of publications on the genus *Primula* along with a critical revision of literature data. It focuses on the possible taxonomic significance of the secondary metabolites and on their ecological role as attractors for pollinators and deterrents against herbivores and parasites, in order to build the base for further studies.

1. Introduction

The genus *Primula* is the most widespread among the Primulaceae family, accounting for 430 species classified in 7 subgenera and 38 sections (Richards, 2003). It is chiefly distributed in the temperate and cold regions of the Northern Hemisphere, where it is particularly concentrated in the Himalayan area.

Europe accounts for 33 species (Table 1) subdivided into 3 subgenera [*Primula*, *Aleuritia* (Duby) Wendelbo, *Auriculastrum* Schott - Tutin et al., 1993]. Here the genus is concentrated mainly in the Alps. Italy houses almost two thirds of the whole European *Primula* spp.: Pignatti (1982) recognised 20 species, and three further species endemic to the Alps, *P. albenensis*, *P. grignensis* and *P. recubariensis*, were recently discovered (Aeschimann et al., 2004), while on the Apennines two endemic species were identified: *P. apennina* and *P. palinuri* (Pignatti, 1982).

The genus is composed of herbaceous plants with a basal rosette of leaves and flowers on top of a naked scape (sometimes absent, as in *P. vulgaris*) gathered in lateral or perpendicular to the axis umbels.

The classification is traditionally based on morphological characteristics: flower colour, bract and calyx size and shape, seed appearance, leaf shape, consistency and, if present, scent, glandular hairs, exudates and farina disposition and morphology.

The interest in the genus *Primula* is evidenced by the publication, starting from the beginning of the nineteenth century, of extended monographs -Duby (1844), Lehmann (1817), Lüdi (1926), Pax (1889), Pax and Knuth (1905), Richards (1993, 2003), Schott (1851), Wendelbo (1961), Wright Smith and Fletcher

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Table 1
Primula genus - Taxonomy of the European species.

Species	Subgenus	Section	Subsection
❋ *P. albenensis* Banfi et Ferlinghetti	*Auriculastrum* Schott	*Auricula* Duby	*Brevibracteata* Widmer
❋ *P. allionii* Loisel. in Desv.	*Auriculastrum* Schott	*Auricula* Duby	*Rhopsidium* Schott
❋ *P. apennina* Widmer	*Auriculastrum* Schott	*Auricula* Duby	*Erythrodosum* Schott
❋ *P. auricula* L.	*Auriculastrum* Schott	*Auricula* Duby	*Auricula*
❋ *P. carniolica* Jacq.	*Auriculastrum* Schott	*Auricula* Duby	*Brevibracteata* Widmer
✦*P. clusiana* Tausch	*Auriculastrum* Schott	*Auricula* Duby	*Arthritica* Schott
❋ *P. daonensis* (Leybold) Leybold	*Auriculastrum* Schott	*Auricula* Duby	*Erythrodosum* Schott
✦*P. deorum* Velen.	*Auriculastrum* Schott	*Auricula* Duby	*Cyanopsis* Schott
✦*P. glaucescens* Moretti	*Auriculastrum* Schott	*Auricula* Duby	*Arthritica* Schott
P. grignensis D. M. Moser	*Auriculastrum* Schott	*Auricula* Duby	*Erythrodosum* Schott
✦*P. glutinosa* Wulfen in Jacq.	*Auriculastrum* Schott	*Auricula* Duby	*Cyanopsis* Schott
❋ *P. hirsuta* All.	*Auriculastrum* Schott	*Auricula* Duby	*Erythrodosum* Schott
✦*P. kitaibeliana* Schott	*Auriculastrum* Schott	*Auricula* Duby	-
✦*P. integrifolia* L.	*Auriculastrum* Schott	*Auricula* Duby	*Rhopsidium* Schott
❋ *P. latifolia* Lapeyr.	*Auriculastrum* Schott	*Auricula* Duby	*Brevibracteata* Widmer
❋ *P. marginata* Curtis	*Auriculastrum* Schott	*Auricula* Duby	*Brevibracteata* Widmer
✦*P. minima* L.	*Auriculastrum* Schott	*Auricula* Duby	*Chamaecallis* Schott
❋ *P. palinuri* Petagna	*Auriculastrum* Schott	*Auricula* Duby	*Auricula*
❋ *P. pedemontana* Thomas ex Gaudin	*Auriculastrum* Schott	*Auricula* Duby	*Erythrodosum* Schott
❋ *P. recubariensis* Prosser et Scortegagna	*Auriculastrum* Schott	*Auricula* Duby	*Erythrodosum* Schott
✦*P. spectabilis* Tratt.	*Auriculastrum* Schott	*Auricula* Duby	*Arthritica* Schott
✦*P. tyrolensis* Schott	*Auriculastrum* Schott	*Auricula* Duby	*Rhopsidium* Schott
❋ *P. villosa* Wulfen in Jacq.	*Auriculastrum* Schott	*Auricula* Duby	*Erythrodosum* Schott
✦*P. wulfeniana* Schott	*Auriculastrum* Schott	*Auricula* Duby	*Arthritica* Schott
P. egaliksensis Wormsk. in Hornem.	*Aleuritia* (Duby) Wendelbo	*Armerina* Lindley	–
P. farinosa L.	*Aleuritia* (Duby) Wendelbo	*Aleuritia* Duby	*Aleuritia*
P. frondosa Janka	*Aleur itia* (Duby) Wendelbo	*Aleuritia* Duby	*Aleuritia*
P. halleri G. F. Gmelin	*Aleuritia* (Duby) Wendelbo	*Aleuritia* Duby	*Aleuritia*
P. longiscapa Ledeb.	*Aleuritia* (Duby) Wendelbo	*Aleuritia* Duby	*Algida* A. J. Richards
P. nutans Georgi	*Aleuritia* (Duby) Wendelbo	*Armerina* Lindley	–
P. scandinavica Bruun	*Aleuritia* (Duby) Wendelbo	*Aleuritia*	*Aleuritia*
P. scotica Hooker in Curtis	*Aleuritia* (Duby) Wendelbo	*Aleuritia*	*Aleuritia*
P. stricta Hornem.	*Aleuritia* (Duby) Wendelbo	*Aleuritia*	*Aleuritia*
P. elatior (L.) Hill	*Primula*	*Primula*	–
P. veris L.[a]	*Primula*	*Primula*	–
P. vulgaris Hudson	*Primula*	*Primula*	–

Notes: with reference to the classification introduced by Zhang and Kadereit, 2004: ❋ Subsection *Euauricula*; ✦ Subsection *Cyanopsis*. For recent reference to further biomolecular studies, see Boucher et al., 2016. *P. grignensis* was not mentioned in the work by Zhang and Kadereit, 2004.
Refs.: Pignatti, 1982; Richards, 2003; Tutin et al., 1993.
Shades are used to separate the different taxonomic groups.
[a] *P. veris* L. syn. *P. officinalis* (L.) Hill (Karl et al., 1981).

(1941–1950), Wright Smith and Forrest (1928)-, an interest which is still active, as shown by the great number of works published on this topic in the past few years (Aronne et al., 2015; Boucher et al., 2016; Brys and Jacquemyn, 2015; Elser et al., 2016; Hashimoto et al., 2015; Nowak et al., 2015; Triest et al., 2015). These studies bear witness to the attention towards several aspects of scientific relevance: phytogeography, phytochemistry, biochemistry, phytotherapy, etc.

The current work presents an up-to-date critical review of publications on the genus *Primula* with the aim of laying the groundwork for further scientific investigations.

2. Chemical constituents

2.1. Flavonoids - a historical overview

Flavonoids are among the most studied plant secondary metabolites. These compounds may be accumulated both into the various organ tissues and on the aerial parts as epicuticular secretion, where they exert a number of useful functions for the plant.

Several phytochemical studies on the flavonoid composition have been carried out on the genus *Primula*.

The first studies on the flavonoids from genus *Primula* can be traced back to the beginning of the Twentieth century (Blasdale, 1945, 1947; Brunswik, 1922; Müller, 1915). In particular, we mention the work by Harborne (1968) on the correlation between the pigment content and the systematics of the Primulaceae family and the numerous studies by Ekhard Wollenweber and colleagues on the flavonoid composition of the farina in *Primula* species. (Wollenweber, 1974; Wollenweber and Mann, 1986; Wollenweber and Schnepf, 1970; Wollenweber et al., 1988a, 1988b; 1989, 1990).

Furthermore, we cite the work by Schöpker et al. (1995), who localised PAL (phenylalanine ammonia-lyase) and CHS (calchone synthase) in the glandular trichomes of *P. kewensis*, and thus