

Solidago virgaurea L

Subjects: Biochemistry & Molecular Biology

Contributor: Cornelia Fursenco

Solidago virgaurea L. (European goldenrod, Woundwort), Asteraceae, is a familiar medicinal plant in Europe and other parts of the world, widely used and among the most researched species from its genus. The aerial parts of European goldenrod have long been used for urinary tract conditions and as an anti-inflammatory agent in the traditional medicine of different peoples. Its main chemical constituents are flavonoids (mainly derived from quercetin and kaempferol), C6-C1 and C6-C3 compounds, terpenes (mostly from the essential oil), and a large number of saponin molecules (mainly virgaureasaponins and solidagosaponins).

Keywords: *Solidago vigaurea* L. ; European goldenrod ; asteraceae ; ethnomedicinal ; phytochemistry ; distribution ; pharmacological activity

1. Introduction

The genus *Solidago* includes about 190 species and infraspecific taxons (subspecies and varieties) with an accepted status and about 330 species and intraspecific taxons with an ambiguous status^[1]. They are widespread throughout the world, most of them originating from North America or confined to this part of the world^[2]. Most of *Solidago* species are herbaceous flowering plants, which occur in the spontaneous flora or are cultivated as decorative plants^[3]. Raw materials of goldenrods have a long and wide use history in the traditional medicine of different parts of the world: *S. virgaurea* L. (European goldenrod) is the most used in Europe and Asia; *S. canadensis* L. (Canadian goldenrod), *S. gigantea* Aiton (Giant goldenrod), and *S. odora* Aiton—in North America; *S. chilensis* Meyen—in South America^{[4][5]}. According to the Flora Europaea, on the continent, there are 5 representatives of the genus *Solidago*: *S. virgaurea* L., *S. canadensis* L., *S. gigantea* Aiton., *S. altissima* L., and *S. graminifolia* L. Salisb.)^[6]. Today, *S. graminifolia* is considered a synonym for *Euthamia graminifolia* (L.) Nutt.^[7]. *S. canadensis* and *S. gigantea*, although of North American origin, have become widespread across Europe and are considered “serious invaders”, whereas *S. rugosa*, of the same origins, has been reported only in a few Western European countries^[8].

The aerial parts of European goldenrod have been known and used for centuries as anti-inflammatory, spasmolytic, and diuretic remedies in the traditional medicine for the treatment of numerous diseases, especially as a urological agent in kidney and bladder inflammation, urolithiasis, and cystitis^{[3][4][8][9][10][11][12]}. According to the European Medicines Agency, *S. virgaurea* is one of the most used and studied species of the *Solidago* genus in Europe^[9].

The growing interest for the species *S. virgaurea* as a medicinal plant led us to carry out this review using the most relevant and recent international research studies. The scientific community interest in *S. virgaurea* is booming. [Figure 1](#) depicts the cumulative number of articles (total of 580) published on *S. virgaurea* in the period 1944–2020. For this purpose, two well-known and worldwide applied scientific databases (MEDLINE (PubMed) and HINARI), as well as Google Scholar, were used. The number of published paper on this species has escalated in the last two decades (2000–2020).

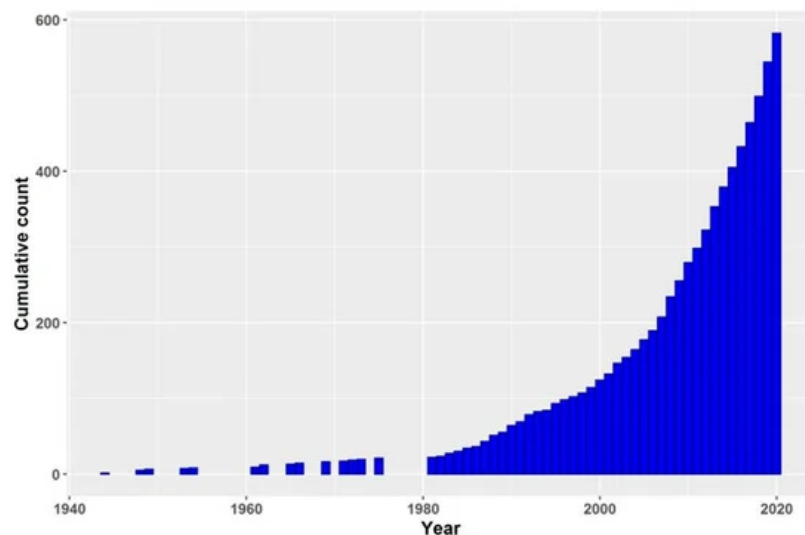


Figure 1. Cumulative number of citations on *S. virgaurea*. Source: PubMed.

2. General Description, Taxonomy, and Distribution

S. virgaurea is a perennial herb provided with an oblique, woody rhizome, of a cylindrical shape and devoid of knots, on which stem scars are visible (Figure 2A). The round, erect stem may achieve a height of up to 1 m, and is ramified and pubescent at the topside. The leaves, with an alternate arrangement, are simple, slightly pubescent on the adaxial face, and pubescent on the abaxial one. Basal leaves have ovate or ovate-elliptic blades with an acute tip and a winged petiole, whereas upper leaves have short stalks and linear-lanceolate or elliptic blades, with margins either serrated or entire (Figure 2B,C). The radiate flower heads have morphologically distinguished ray (female, tongue-like) and disc yellow florets (hermaphrodite, tubular). The flowers capitula are grouped in a simple raceme or in panicles (Figure 2D). The receptacle is glossy and flat. The fruit is a cylindrically-shaped achene, with 8–10 ribs and a pappus derived from the modified calyx^[13].

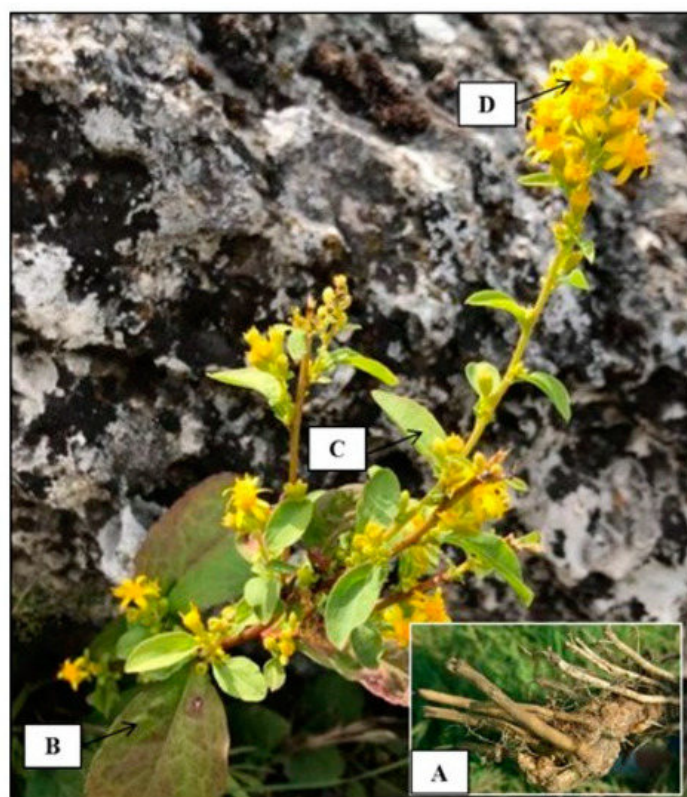


Figure 2. *S. virgaurea* (original photo): (A) oblique rhizome, (B) basal leaves, (C) cauline leaves, (D) radiate flower heads.

A recent morpho-anatomical local study focused on the morphological and anatomical investigation of *S. virgaurea* from flora of the Republic of Moldova, and its herbal product *Solidaginis virgaureae herba*, was done by Calalb T. et al.^[13]. The anatomical features of the highest interest for the exact identification of *S. virgaurea*, established in this study, include: repartition of stomata on both sides of the leaf, anomocytic arrangement of stomata, cone-shaped or fan-shaped

multicellular trichomes on both epidermises, as well as glandular trichomes, dorsiventral structure of the leaf with vascular bundles collateral and open, and secretory ducts in the stem. The anomocytic stomata reported for the leaf is consistent with the findings of Szymura M. and Wolsky K.^[14], who also established that anomotetracytic stomata were the most widespread type in other *Solidago* taxa collected from Poland. The presence of two categories of multicellular trichomes (cone-shaped and fan-shaped) on the goldenrod leaf was also reported by other sources^{[14][15]}: by Buynov MV. on *S. dahurica* leaf^[16], by Douglas M. et al. on *S. chilensis* leaf^[17], and by Fedotova VV. on *S. caucasica* leaf^[18]. Care is needed for a correct identification, because in the 19th century, a scientific paper written by a medical doctor (based on his personal experience repeated several times) drew the attention to the risks of confusing this medicinal plant with a non-effective (and likely dangerous for the health) *Senecio nemorensis* L.^[19]

According to a number of sources^{[20][21]}, *S. virgaurea* is regarded as a taxonomic group or complex, and it consists of perennial herbaceous species extensively distributed from Europe to East Asia. As a group, it is generally divided longitudinally: in Europe the genus is represented by *S. virgaurea* L., in Siberia and most of the Far East by *S. dahurica* (Kitag.) Kitag. ex Juz. Together with *S. spiraeifolia* Fisch. ex Herder, whereas in the Far East region of Russia, known as Chukotka and in North America, the genus is represented by *S. multiradiata* Ait. ^[22].

The European *S. virgaurea* L. has been described as “an exceedingly polymorphic taxon”, and a multitude of narrowly related taxa have been included within it at different levels (varieties, subspecies, and even species) ^{[22][23]}. In a European country (Czech Republic) flora, discussing the variability, S. Slavik (2004) has identified 17 taxa as belonging to the *S. virgaurea* L. group (leaving aside taxa from Japan), of which a number of six are qualified as subspecies, whereas a number of eleven as “microspecies” ^{[22][24]}. The Atlas of the British and Irish flora^[25] describes *S. virgaurea* as highly variable, with many distinct forms for distinct habitats (ecotypes). Strong correlations have been claimed between *S. virgaurea* genotypes and their geography, and a strong ability to rapidly evolve and ecologically diversify has been recognized for the species^[26].

3. Synonyms and Common Names

According to the Assessment Report on *Solidago virgaurea*, realized by the European Medicines Agency^[9] and the World Flora Online^[1], the main synonyms in use are: *Amphiraphis leiocarpa* Benth., *Amphiraphis pubescens* DC., *Aster virgaurea* (L.) Kuntze, *Dectis decurrens* Rafin. (Lour.), and *Doria virgaurea* Scop. *S. patagonica* Phil. is currently an accepted name^[1], although it was reported that one Argentine specimen identified as *S. patagonica* was in fact an escaped cultivar of *S. virgaurea*^[27].

The most often used common name for *S. virgaurea*, as well as for other *Solidago* species is goldenrod. Sometimes the “European” qualifier is added to this vernacular name and in this paper, in order to avoid confusion with other species of the genus, we will hereafter use this name (European goldenrod). According to the American Botanical Council, other common names in use are: Solidago, Virgaurea, Woundwort, Aaron's rod, and Yellowweed^[28]. The dried flowering aboveground parts are the subject of a European herbal monograph^[29].

4. Ethnomedicinal Uses

S. virgaurea has a diversity of medicinal uses in the territories where it is spread. Probably its most widely known ethnopharmacological uses are related to kidney disorders (being often found in teas intended to help pass kidney calculi), urinary tract infections, the overactive bladder syndrome, and prostatic diseases^{[30][31][32]}, the urologic uses of the plant going back at least to the writings of Arnold von Villanova (1240–1311) ^[33]. Traditionally, the aerial parts of the plant have been used for healing and antiseptic properties^[9], as well as for the treatment of diabetes, allergies, and gastro-intestinal disorders^{[8][32]}. Likewise, infusions or decoctions prepared from European goldenrod is used in the traditional medicine in many parts of the world for its antibacterial and anti-inflammatory effects^[34], including inflammation of the oral cavity and throat, when used as a mouth rinse^[32]. Further scientific studies have shown the growing importance of European goldenrod as a source for herbal drugs^[35]. In many European countries, the herbal product derived from the species has often been in combination products^[9].

4.1. Germany

Hieronymus Bock (1498–1554), one of the first modern botanists in Germany, conjectured that Germanic tribes had been using the plant for medicinal purposes, mentioning that they regarded it as a “miracle herb” (*Wunderkraut*)^[36]. It is believed that the German father of Reformation, Martin Luther (1438-1546), had a good opinion on goldenrod and used it often to care for his physical infirmities^[33]. One of the first reports on its diuretic and anti-inflammatory effects are ascribed to the “father of German botany” (1525–1590), Jacobus Theodorus Tabernaemontanus ^[37], who stated that it “also

cleanses the kidneys and urinary tract of all coarse mucus" [36]. The name *Heydnisch Wundkraut* (heathen woundwort), employed in the German territories during the Middle Ages for the plant, evokes the healing properties of the herb. Another vernacular German name, *Unsegenkraut* (curse herb), indicates belief at that time in its magic abilities, in an era where disease was often attributed to witchcraft and metaphysical causes, and indirectly the name might still point towards its potential medicinal properties[38]. In German folk medicine, goldenrod was used for the treatment of urinary retention, kidney stones, and hemorrhoids[36]. Since the middle 19th century, its use was slowly forgotten in Germany, to be revived only relatively recently with the renewed interest for the herbal therapy [36].

Currently, a well-established use is accepted in Germany for inflammatory diseases of the urinary tract collection system, urolithiasis and renal gravel. A variety of extracts are used, particularly dried extracts obtained from the aerial parts (*Solidaginis virgaureae herba*) using 30–60% ethanol as an extraction solvent[9]. A monograph of the species was introduced in DAB in 2002, which also acknowledged *S. canadensis* and *S. gigantea* as valid species, despite certain differences in the spectrum of their phytochemicals[33].

4.2. Czech Republic

The herbal drug obtained from *S. virgaurea* is included in the Czech Pharmacopoeia 2009[39]. A drink obtained from the aerial parts of the plant is used as an adjuvant treatment in inflammatory conditions of the urinary system, as well as for the prevention of kidney and bladder calculi[9]. It is not clear, though, whether such uses represent an old Czech tradition, as a Czech paper on the species only cited foreign sources when referring to the traditional medicinal use of the species[39].

4.3. Poland

Traditionally, the infusion prepared of dried aerial parts of *S. virgaurea* has been used as a diuretic and as an adjuvant in treatment of minor complaints of the urinary tract[9]. In a Polish source, it is stated that raw material of this herb is characterized by diuretic, detoxifying, anti-inflammatory, and bile secretion enhancing properties[35]. A Polish source mentions its disinfectant properties as the most important among the traditional uses, but also its useful effects in accelerating wound healing and in skin care[40].

4.4. Russian Federation

In Russian folk medicine, European goldenrod is used for a variety of conditions, from gallstone disease to indigestion, and from rheumatism to gout. For external use, fresh leaves are recommended in abscesses and boils [41]. Other Russian sources[35][42] state that most common uses of this species include prevention and treatment of various diseases of the kidneys, bladder, and prostate gland (i.e., the traditional use most widely acknowledged in Europe). In the Russian folk tradition, the European goldenrod is also known as a hemostatic and astringent agent, as well as a good remedy for respiratory diseases (tonsillitis, laryngitis, acute respiratory diseases), gallstone diseases, and pulmonary tuberculosis[41].

4.5. Ukraine

The use in tuberculosis is also well established in the Ukraine folk medicine, where the name of the plant, *zolutushnik*, alludes to its use in decoctions as "a good remedy against scrofula (*zolutukha*)", but the plant was also believed to have diuretic effects[43].

4.6. Bulgaria

According to a Bulgarian source, the aerial parts of *S. vigaurea* L. are used as a diuretic, antihypertensive, and expectorant, as well as in the therapy of renal deficiency and gout[44].

4.7. Romania and the Republic of Moldova

S. virgaurea has a long history of use in the Romanian traditional phytotherapy. The herbal product *Solidaginis virgaureae herba* has been used in herbal therapy and marketed by specialized outlets since 1990[45]. Ethnopharmacological uses of this plant are mostly related to maintaining the health of the urinary tract and the normal functioning of the digestive system. Traditionally, it is recommended as a diuretic, saluretic, anti-inflammatory, antiseptic, healing, or a sedative agent. For external use, the most common application consists in administering an infusion or decoction of the aerial parts or blooming tops in the treatment of wounds or ulcers of the oral cavity [46][47]. The external use in rickets, also acknowledged by Romanian traditional sources[48], does not seem to have great benefit, considering the current knowledge of this disease and its causes.

4.8. Korea

The root and aerial parts of *S. virgaurea* subsp. *gigantea* (Nakai) Kitam have been used as an appetite stimulant and diuretic in Korean folk medicine, whereas the immature aerial parts are used in the same area as food^{[49][50]}.

4.9. China

Decoctions obtained from the whole plant were used for their antibacterial activity, and in respiratory tract infections for its expectorant and anti-inflammatory properties^[51].

4.10. Other Uses

Besides its medicinal uses, *S. virgaurea* has been recognized as a first-class alternative source for the floriculture business, both on the old continent and in the new world^[32]. It has also been proposed to be used as a rotation crop as a means of containing noxious weeds in an organic agriculture context^[35]. *Solidago* spp., including *S. virgaurea*, have been claimed to have potential utility for phytoremediation purposes, based on their ability to transfer iron from soil to plants near iron processing industrial sites^[35]; however, studies on other oligo-elements (such as zinc) have not identified particular hyperaccumulator properties for the plant^[52], and whereas a number of papers have been published on the phytoremediation potential of *S. canadensis*^{[53][54]}, we could find none on *S. virgaurea*. The pollen of the latter is of good quality, and its availability may contribute to long-lived bees being able to survive a hard winter ^[55].

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