

REVIEW PAPER

Twinflower (*Linnaea borealis* L.) – plant species of potential medicinal properties

BARBARA THIEM^{1*} ELISABETH BUK-BERGE²

¹Department of Pharmaceutical Botany and Plant Biotechnology
Poznań University of Medical Sciences
Św. Marii Magdaleny 14
61-861 Poznań, Poland

²The Norwegian Ministry of Education and Research**
Postbox 8119
Dep. 0032 Oslo, Norway

*corresponding author: phone: +4861 6687851, e-mail: bthiem@ump.edu.pl

Summary

Twinflower (*Linnaea borealis* L.) is a widespread circumboreal plant species belonging to *Linnaeaceae* family (previously *Caprifoliaceae*). *L. borealis* commonly grows in taiga and tundra. In some countries in Europe, including Poland, twinflower is protected as a glacial relict. Chemical composition of this species is not well known, however in folk medicine of Scandinavian countries, *L. borealis* has a long tradition as a cure for skin diseases and rheumatism. It is suggested that twinflower has potential medicinal properties. The new study on lead secondary metabolites responsible for biological activity are necessary. This short review summarizes very sparse knowledge on twinflower: its biology, distribution, conservation status, chemical constituents, and describes the role of this plant in folk tradition of Scandinavian countries.

Key words: *Linnaea borealis*, botanical description, distribution, secondary metabolites, folk medicine

INTRODUCTION

Linnaea borealis L. (eng. twinflower; pol. zimoziół północny, Linnea północna; nor. Nârislegras, Flis-megras) belongs to *Linnaeaceae* family, formerly to *Caprifoliaceae* [1, 2]. An updated description

of the *Linnaea* genus was provided by Christenhusz in 2013 [3]. The genus *Linnaea* was reviewed and expanded to include the genera: *Abelia*, *Dipelta*, *Diabelia*, *Kolkwitzia* and *Vesalea*. In general, in the new depiction this taxon consist of 16 species.

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L. borealis, a plant with beautiful and delicate flower of native pinewoods, is a relict of Late Glacial period. The twinflower's range includes North Europe, Asia and a part of North America [4]. In Poland, it reaches the southern extent of its range [5]. In Norway, *L. borealis* is a common species throughout the country [6, 7]. In Sweden, it is also a common taxon from the region of Småland in South and northwards [7].

Twinflower's specific name 'borealis' reflects its northern distribution, while the other part of its binomial scientific name honors Carolus Linnaeus, the Swedish botanist who developed the modern system of taxonomic classification. The naming history of this plant is very interesting. Carl Linnaeus described the plant on his journey to Lapland in 1732. *Campanula serpyllifolia*, as this plant was first called, was renamed as suggested by Jan Frederik Gronovius in honor of Linnaeus who was his close friend [8, 9]. *L. borealis* was reported to be Linnaeus favorite plant and became Linnaeus' symbol, called 'Herba nostra' (my flower) also depicted in Linnaeus coat of arms.

This paper provides a short review related to botany, distribution, chemical compounds, folk medicinal uses and the role, which twinflower plays in Scandinavian culture.

Botanical description and taxonomy

L. borealis is a small, creeping, perennial plant (fig. 1). It is an evergreen, stoloniferous dwarf shrub characterized by the above-ground runners. The main stems are slender but woody, elongate, creeping, slightly hairy when young, and often also glandular. Long runners producing numerous short, erect, leafy stems (less than 10 cm tall). From these stolons grow numerous short lateral shoots. They bear small elliptic or round leaves which are opposite to each other. The shoots are of three different kinds: horizontal shoots, vertical sexually reproductive shoots (the flowering shoots have inflorescences up to 15 cm tall) and the non-sexually reproductive ones (with only leaves on them). The stolons are first produced when the plant is 5–10 years old, and they grow in annual segments which can be as much as ca. 50 cm long. The roots are formed along the stolons and are initiated at the nodes of previous year segment. The stolons also produce branches, and when a branch becomes separated from the main stolon, it grows on to form a new plant [7, 10]. Cytogenetic study of Packer [11] revealed that the number of chromosomes in cells of *L. borealis* is $2n=32$.

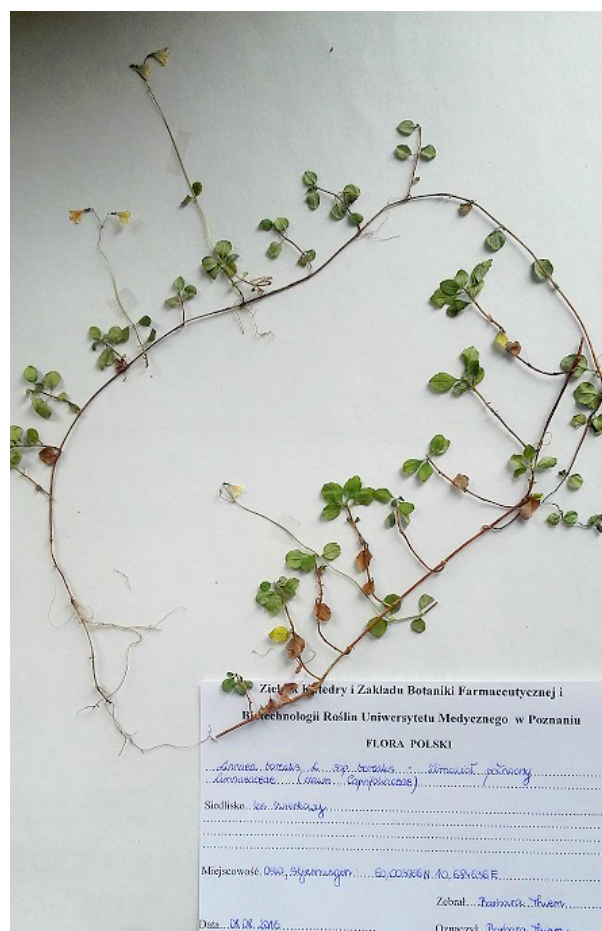


Figure 1.

Linnaea borealis L. from herbarium [fot. B. Thiem]

Twinflower's common name arises from its distinctive and unique inflorescence which is composed of two bell-shaped flowers growing on a forked stem of letter Y shape (fig. 2). The flowers, white or pinkish-white in color, downward facing and sweetly scented, produce nectar which attracts pollinating insects. Blossom time is typically June or early July in Europe,



Figure 2.

L. borealis in coniferous forest Skjennungen near Oslo (Norway) [fot. E. Buk-Berge]

however elsewhere in its range it can flower as late as in September. Individual blossoms persist for about 7 days, and after pollination the flower develops into a fruit in the form of a small, dry, one-seeded capsule, which ripens after 36 days. Twinflower spreads by zoochory – its seeds are dispersed by birds or by small animals, and are partially covered in small, hairy bracts which stick to the fur of wildlife and are thereby transported to new sites [4, 12]. Although seed production is plentiful, only a small percentage of seeds has been found viable. Seedlings are rarely observed, mainly growing on disturbed ground. As a shallow-rooted species, twinflower is susceptible to drought. Populations of *L. borealis* are decreasing in some sites due to the loss of its pinewood habitat, so twinflower is a rare plant in several areas. However, in some countries, like in Norway, twinflower is occurring in abundance.

Three subspecies of twinflower are recognized: *Linnaea borealis* L. ssp. *borealis*, *L. borealis* L. ssp. *americana* (Forbes) Hultén ex R.T. Clausen and *L. borealis* L. ssp. *longiflora* (Torr.) Hultén. The latter taxon has two synonyms: *L. americana* Forbes and *L. borealis* var. *americana* (Forbes) Rehder [12, 13].

Distribution and habitats

Twinflower has a circumboreal distribution, occurring from Scotland and northern Europe through Russia to Siberia, northern Asia to Kamchatka and Japan, northern China and Mongolia and from Alaska and Canada to Greenland. Moreover, in the USA it is found as far south as Northern California, New Mexico and West Virginia. The main distribution of twinflower in Europe is in the Nordic countries.

L. borealis ssp. *borealis* grows in Europe (including Poland), Asia and Alaska. In Greenland and North America, *L. borealis* ssp. *americana* is the widespread taxon, occurring throughout the species range, while the longtube twinflower, *L. borealis* ssp. *longiflora*, has a more restricted distribution in the Pacific Northwest region [13].

Poland marks the southern border of the reach of this species. In Poland, *L. borealis* occurs in more than 200 localities, concentrated mainly in the northern part of the country and the Lublin region [4]. The highest twinflower site found in Poland is in the West Tatra at the altitude of 1450 m [4, 14, 15]. Localities of *L. borealis* occurrence are highly non-stable since they are a result of retreating from some sites and the appearance of the another. Twinflower

is often described as ‘a relict of the wandering’ or pseudo-relict [16, 17]. Until recently there have been numerous localities of *L. borealis* in the district of Wolin National Park (WNP) and the abundance of twinflower populations in Wiselka region described by Piotrowska [18]. At present, these localities disappear gradually, which may be due to habitat changes: altered light conditions (light deficiency) and increase in canopy cover and growth of the shrub layer (processes of succession) [verbal information from WNP 2017]. *L. borealis* is a characteristic plant of the acidophilic coniferous forests. In Far North, twinflower grows in tundra and taiga, mostly in a light shadow, in a widely spaced tree stands. The species prefers sandy, poor and acidic soil. It doesn't put up with calcium in soil. Often covers tree stumps and moss covered rocks. In general, the populations show strong viability, however, slightly varying. In dry years the size of populations drastically decreases, and it increases during moist years [4].

The reason for the disappearance of twinflower stands is primarily habitat change associated with forest management and succession. One of the most important environmental factors affecting the *L. borealis* populations is the light availability [7, 10, 19–21]. As it was indicated in numerous studies, twinflower grows in the direction of moderate sunlight, but not in full sun. That is why many stations of this species are found near woody roads and tracks. Competitive undergrowth species, such as *Vaccinium myrtillus* and *V. vitis-idaea*, limit the twinflower populations. Despite of the fact that twinflower blooms at all of the stations, fruiting specimens rarely occurs in Poland and were found only in a few localities [17].

Propagation

L. borealis flowers are entomophilous; approached by many different insect species. As mentioned above, twinflower is self-incompatible and requires cross-pollination to produce viable seeds. Fructification is rare due to long distances between clonal patches. Flowers on different plants are too far away one from another to be cross-pollinated by insects which are not able to make the distance. As a result, twinflower is rarely propagated by generative methods especially on small isolated sites, where seeds are often not produced or seedling germination does not occur. *L. borealis* plants in a forest stands often intensively spread by stolons to form large

clonal patches consisting of groups of genetically identical plants. Such clonal patches of twinflower can be long-persisting, which may be hundreds of years old [7, 10, 21].

Attractive appearance during flowering makes twinflower a popular garden plant. It is used as an ornamental plant, but it is not easy to establish in cultivation. *L. borealis* can be propagated mainly by vegetative and rare by generative methods. In cultivation, generative propagation by seed gives best results when sown as soon as it is ripe in autumn in a cold frame. Seeds require a period of cold stratification. The seedlings have to be pricked out into individual pots and grow in the greenhouse for their first winter. In late spring or early summer, the sprouts may be planted out into their permanent position. Vegetative methods for garden propagation are both division of rooted runners in the spring and cuttings of half-ripe wood in summer [22].

Conservation status in Europe

Twinflower is generally quite abundant throughout its range, so it is not considered endangered at an international level. However, the situation is different in a few areas. Twinflower has been endangered in Poland, Germany and Slovenia, it is also becoming quite rare in Scotland. Scandinavian countries are different: this species is abundant there [6, 7].

In Poland, *L. borealis* is a rare, protected and designated as endangered species in many regions. This taxon was earlier strictly protected [23], but it has changed and the plant is now under partial protection [24]. In some regions, twinflower is considered to be extinct (category RE), while in others is critically endangered (CR): in the Południowopodlaska Lowland [17], Wielkopolska region [25] and Polish Carpathians [17, 26].

Bioactive compounds

The chemical composition of *L. borealis* herb is described only by few data in Colombia University dissertation on phytochemical study of *Caprifoliaceae* [27] (fig. 3). Some flavonoids and phenolic acids as secondary metabolites have been reported in ethanolic extracts from leaves of *L. borealis* ssp. *longiflora* and *L. borealis* ssp. *americana*. There are glycosides of quercetin (quercetin 3-*O*-rhamnoglucoside, quercetin 3-*O*-glucoside) and kaempferol (kaempferol 3-*O*-glucoside) as well as apigenin and luteolin

derivatives (apigenin 7-*O*-glucoside, apigenin 7-*O*-rhamnoglucoside and luteolin 7-*O*-glucoside).

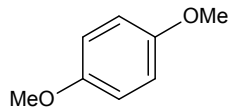
Among phenolic acids, Glennie [27] identified several compounds: *p*-coumaric acid (4-hydroxycinnamic), *p*-hydroxybenzoic acid, caffeic acid (3,4-dihydroxycinnamic), ferulic acid (3-methoxy-4-hydroxycinnamic), protocatechuic acid (3,4-dihydroxybenzoic), vanillic acid (3-methoxy-4-hydroxybenzoic), phloretic acid (4-hydroxydihydrocinnamic) and four chlorogenic acid isomers (3-caffeoylquinic, 4-caffeoylquinic, 3,4-caffeoylquinic, 4,5-caffeoylquinic).

Floral scent is described as almond-like or anise-like and consists of four benzoid compounds: 1,4-dimethoxybenzene, anisaldehyde, 2-phenylethanol, and benzaldehyde, and one nitrogen-containing compound, nicotinaldehyde [7].

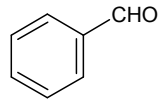
Folk medicinal and other usages

In Norwegian folk medicine, *L. borealis* has a long tradition as a cure for shingles (herpes zoster). In the past, this species was also used to treat other kinds of rash, eczema, measles, hives, ringworm, scabies, water blisters, rheumatism and finger infections. Numerous vernacular names reflect this use, e.g. 'nårislegras', 'flismegras' [28]. The plant was applied either internally (as a decoction) or externally (as an ointment, in compresses or by exposing the patient to smoke). According to Alm [6], the plant was usually boiled in water, but sometimes in milk or cream and the decoction was usually drunk in the morning, before breakfast. In most cases, it is likely (but not specified) that the whole plant was used. Tea has been prepared from the flowers. The plant has been boiled in beer or extracted with alcohol. It has also been used fresh, simply by placing it around the waist [6].

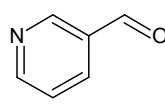
The use of *L. borealis* to treat shingles and skin diseases is almost entirely restricted to Norway. In older tradition, twinflower was often used in combination with other remedies, e.g. with a lichen called 'elvenmver' (probably *Lobaria pulmonaria* /L./ Hoffm.) to smoke the body every evening. The leaves were placed in a dry coffeepot and heated. In Sweden, Finland and Russia, *L. borealis* is widely known as a remedy for treatment of rheumatism [6]. Similar uses in folk medicine were observed in Scotland, North England and more sporadic in Denmark, Poland, Caucasus, Grenland [28]. In North America, twinflower was also used in folk medicine. According to Moerman [29] the entire



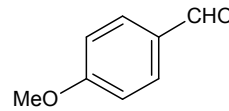
1,4-dimethoxybenzene



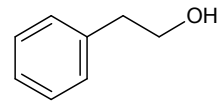
benzaldehyde



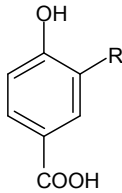
nicotinaldehyde



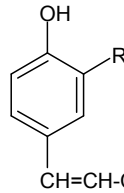
anisaldehyde



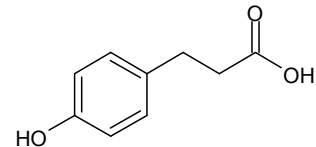
2-phenylethanol



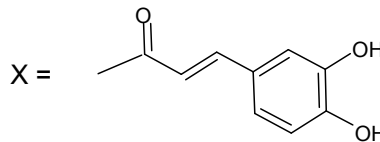
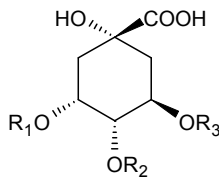
R = H - *p*-hydroxybenzoic acid
 R = OH - protocatechuic acid
 R = OMe - vanillic acid



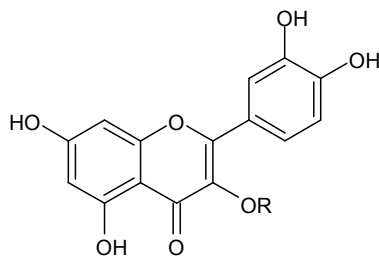
R = H - *p*-coumaric acid
 R = OH - caffeic acid
 R = OMe - ferulic acid



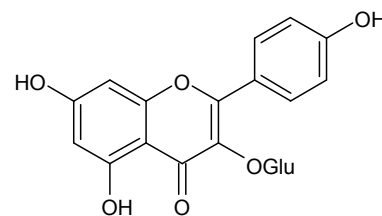
p-hydroxyphenylpropionic acid
 (phloretic acid)



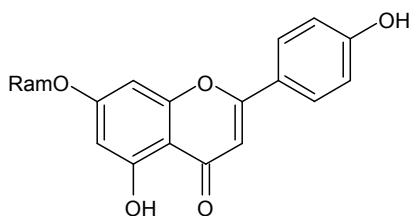
$R_1 = R_2 = H, R_3 = X$ - 5-caffeoylquinic acid
 $R_1, R_3 = H, R_2 = X$ - 4-caffeoylquinic acid
 $R_1 = H, R_2 = R_3 = X$ - 4,5-dicaffeoylquinic acid
 $R_1 = R_2 = X, R_3 = H$ - 3,4-dicaffeoylquinic acid



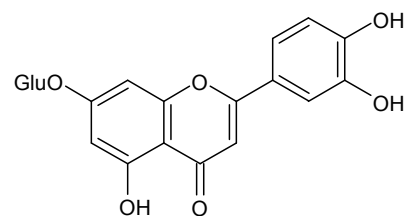
R = rhamnoglucosyl (quercetin 3-*O*-rhamnoglucoside)
 R = glucosyl (quercetin 3-*O*-glucoside)



Glu = glucosyl
 kaempferol 3-*O*-glucoside



Ram = rhamnosyl
 apigenin 7-*O*-rhamnoside



Glu = glucosyl
 luteolin 7-*O*-glucoside

Figure 3.

The chemical structures of components of *Linnaea borealis* – floral scent compounds, phenolic acids and flavonoids.

plant of *L. borealis* var. *americana* was used as a squaw medicine and food plant by the Carrier Indians. Among the white men, the plant has been used as a bitter, a sub-astringent and an antirheumatic. Several Indian tribes used the plant for medicinal purposes as a tonic in pregnancy and also in the treatment of painful or difficult menstruation. A decoction of twigs was given to children with cramps, fever or for crying and a decoction of leaves was taken for colds. The mashed plant was used as a poultice on inflamed limbs and was also applied to ease the headaches [29].

At present, dietary supplement from flowers of *L. borealis* is obtained as a part of New Essences Research Program carried out by Alaskan Essence Inc. According to the recommendation, this product: 'Assists the body/mind to more easily take in and integrate sensory stimuli in [the consumer's] surroundings. Calms mental confusion and the sense of being overwhelmed from sensory overload' [30].

As Polish name of twinflower 'zimoziół' indicates, this plant was also used in folk medicine in Poland. Liquid was made for building up the strength in pregnancy or for soothing menstrual complaint, as it was also the case with some Indian tribes mentioned above. Pap of raw plant was used as remedy for painful limbs and headache.

Recently, this species is used in cosmetology. The extract of the whole plant of *L. borealis* is listed in International Nomenclature of Cosmetic Ingredients as cosmetic ingredient and used in cosmetic preparations with skin conditioning properties.

This beautiful plant with delicate flowers is used as an ornamental plant for ground cover in woodland and rock gardens. *L. borealis* ssp. *americana* is especially well fitted for gardening as this subspecies forms an extensive twiggy mat and is useful as a ground cover on peat beds. However, plants can be rather difficult to establish. They require an acid soil and prefers a shaded position in a moist peaty soil. The subspecies *L. borealis* ssp. *americana* grows more freely than the European form.

Linnaea borealis in Scandinavian culture

Twinflower is one of the favorite decorative plant motifs in Sweden that can be found on postcards, tableware and tableclothes, and in painting (fig. 4, 5). Twinflower is also a plant symbol of Smaland, the region in Sweden, where Linnaeus comes from. Not surprising, this little plant is often depicted on portraits of this great botanist. From 2015, twinflower is

to be found on Swedish twenty-crowns note (back side). *L. borealis* is also used as a motif on postcards and post stamps in Sweden, Finland and USA. For many people the word 'Linnaea' is mostly associated with female names 'Linnèa' or 'Linnea', which are very common in Sweden and Norway.



Figure 4.

L. borealis postcard with illustration from Carl Linnaeus „Flora Svecica”



Figure 5.

L. borealis as a decorative motif on tableware [fot. E. Buk-Berge]

CONCLUSIONS

Traditional medicinal use of *L. borealis* needs further scientific exploration. Ethnobotanical data, mainly from Norway, indicate that *L. borealis* may have potential health promoting activity. Due to high demand for herbal products for treatment of skin disease, new phytochemical and pharmaceutical investigation of twinflower is needed for confirmation of their potential biological and

medicinal properties. Local knowledge of *L. borealis* used by the people of South Norway and North America for medicinal and food purposes seems to be well known to its culture and tradition. The evidence on chemical composition of twinflowers, from only two American subspecies, is very scarce and based on data from 1969. *L. borealis* ssp. *borealis* could have different chemical profile and new studies on lead secondary metabolites responsible for potential medicinal activity are necessary. Phytochemical investigation of European subspecies (from Norway) is currently carried out in Department of Pharmaceutical Botany and Plant Biotechnology of Poznań University of Medical Sciences (Poland).

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Zimozioł północny (*Linnaea borealis* L.) – gatunek rośliny o potencjalnych właściwościach leczniczych

BARBARA THIEM^{1*}, ELISABETH BUK-BERGE²

¹Katedra i Zakład Botaniki Farmaceutycznej i Biotechnologii Roślin
Uniwersytet Medyczny im. Karola Marcinkowskiego w Poznaniu
ul. Św. Marii Magdaleny 14
61-861 Poznań

²The Norwegian Ministry of Education and Research
Postbox 8119
Dep. 0032 Oslo, Norway

*autor, do którego należy kierować korespondencję: tel.: +48 61 668 7851, faks: +48 61 668 7861,
e-mail: bthiem@ump.edu.pl

Streszczenie

Zimoziół północny (*Linnaea borealis* L.) jest szeroko rozpowszechnionym gatunkiem cyrkumborealnym, należącym do rodziny *Linnaeaceae* (wcześniej *Caprifoliaceae*). Licznie rośnie w tajdze i tundrze. W kilku krajach Europy, także w Polsce, zimoziół został objęty ochroną gatunkową jako relikw glacialny. W medycynie ludowej krajów skandynawskich *L. borealis* cieszy się długą tradycją stosowania w chorobach skórnych i reumatycznych, co wskazuje na potencjalne właściwości lecznicze omawianego gatunku. Jego profil chemiczny jest słabo poznany, dlatego wskazane są nowe badania głównych metabolitów wtórnych, które mogą być odpowiedzialne za aktywność biologiczną surowca. Niniejszy artykuł stanowi krótki przegląd dostępnej literatury, podsumowując skromną wiedzę na temat *L. borealis* z zakresu biologii, występowania, ochrony gatunku, obecności związków czynnych, stosowania w medycynie tradycyjnej i miejsca tego gatunku w kulturze krajów skandynawskich.

Słowa kluczowe: *Linnaea borealis*, opis botaniczny, rozmieszczenie, wtórne metabolity, medycyna ludowa