NOBANIS – Invasive Alien Species Fact Sheet

Solidago canadensis

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Species description

Scientific names: *Solidago canadensis* L., Asteraceae (Compositae)
Synonyms: *S. altissima* L., *S. canadensis* ssp. *altissima* (L.) Bolos & Vigo, *S. canadensis* var. *scabra* Torr. & A.Gray.
Solidago canadensis is a highly variable species. The taxonomic status is not clear and difficult to assess. In its native range in North America several different taxonomic subunits have been recognised within the *S. canadensis* complex, which are granted species status by some authors (Weber 2000). In a strict sense this complex species in Europe is *S. altissima* (Priedītis 2002).

Common names: Canadian goldenrod (GB), Kanadische Goldrute (DE), kanadisk gyldenris (DK), Kanada kuldvits (EE), kanadanpiisku (FI), kanadagullhrís (IS), kanadinė rykštenė (LT), Kanādas zeltgalvīte (LV), Canadese guldenroede (NL), kanadagullris (NO), Nawłoć kanadyjska (PL), золотарник канадский (RU), kanadensiskt gullris (SE), zlatobýl kanadský (CZ).

Fig. 1 and 2. Close-ups of *Solidago canadensis* inflorescence and stem, photo by Normunds Rustanovičs.

Fig. 3. Stand of *Solidago canadensis,* photo by Normunds Rustanovičs.

Species identification

In Europe *S. canadensis* shoot height is 70 - 210 cm, glabrous at the base, pubescent at least in the upper half, with 40-110 leaves scarcely decreasing in size upwards (Fig. 3). Leaves are produced along the stem - lanceolate, long attenuate, pubescent beneath, with margins mostly serrate, with 2 prominent lateral veins (Fig. 2). The inflorescences form a broad pyramidal panicle with a central axis and recurving branches (Fig. 1). The bracts of the involucre are linear, obtuse or acutish. Flowers are yellow, borne on numerous small flower heads (capitula). The number of flower heads per shoots ranges from 41 – 4600 (mean 1443). Disc florets are usually fewer than ray florets, the corolla is 2.4-2.8 mm long. Fruit is an achene 0.9-1.2 mm, shortly pubescent, with a pappus of 2-2.5 mm.

The basic chromosome number of *S. canadensis* is 9, and in its native range it is most often hexaploid (2n = 54), but triploid (2n = 27) and tetraploid (2n = 36) cytotypes also occur. In Europe, only diploid plants have been found (2n = 18) (Tutin *et al.* 1976, Weber 2000).

Native range

S. canadensis is native to North America (Galenieks 1959, Hegi 1979). In the USA it is found from North Dakota southwards to Florida, Texas and Arizona and in Canada from Nova Scotia to Ontario (Weber 2000). It occurs almost throughout the USA and Canada between 26^{o} N and 45^{o} N latitude, reaching 65^{o} latitude in western Canada and Alaska (Weber 1998).

Alien distribution

History of introduction and geographical spread

S. canadensis represents one of the earliest ornamental introductions from North America to Europe. In England it is known from 1645 (Kowarik 2003). The species was first cultivated in botanical gardens and distributed by nurseries. Because the species is attractive and easy to grow, it was widely used by gardeners. The species soon extended its range in Europe (Weber 2000). In most of Central and West European countries *S. canadensis* was present in the 19th century, *e.g.* in Austria the species was first recorded in 1838 (Essl, Rabitsch 2002), in Germany in 1853, in

Belgium in 1863 (Harmonia database 2009). The first records of *S. canadensis* as an established non-native plant in the North European and Baltic regions are from Germany in 1857, in Sweden in 1864, in Denmark in 1866 (Weber 1998), in Poland in 1872 (Tokarska-Guzik 2003), in Norway in 1887 (Weber 1998), in Latvia in 1805 (Priede 2008), in Finland in 1910 (Jalas 1980), in Estonia in 1807, and in Lithuania in 1983 (Gudžinskas 1997). In Russia it was known at the end of 18th century, but the first record of a naturalised population is known from 1885 (Цингер 1885).
Nowadays the species is present over most of Europe from southern Scandinavia to northern Italy. Besides Europe *S. canadensis* is naturalised in Australia, New Zealand, Japan, China, Taiwan, and Trans-Caucasia and Siberia (Weber 2000).

Pathways of introduction
S. canadensis was introduced from North America to Europe as an ornamental plant (Weber 1998) and it was often cultivated in botanical gardens and common gardens. For example in Finland many of the naturalized occurrences of *S. canadensis* are clearly traceable as escapes from nearby or more remote allotment gardens, from special areas of parcels with ornamental plants and vegetables or from old manors (Kurtto and Helynranta 1998). In Russia *S. canadensis* was often cultivated in parks where it has been recorded as established (Сырейщиков 1910).

Alien status in the region
The species is present and abundant in many North, Central and West European countries (see Table 1). In many European countries the species is considered as common and invasive. In Norway, *S. canadensis* has been found once in Nordland County (about 65’5° N), but the species has scattered occurrences north to Central Norway (about 63^{o} N). It is, however, common only in the southern part of southeastern Norway where it is spreading rapidly. It has sometimes been confused with *S. gigantea* (Sunding 1989). *S. canadensis* is abundant throughout Poland, but most commonly distributed in southern and central Poland (Weber 2000; Solarz *et al.* 2005). The species is found as naturalised in Sweden (Karlsson 1997). In Finland the species is naturalised north to almost 63° N, but is more or less common only in the southern, densely populated areas, such as the metropolitan area of Hämeenlinna (Kurtto and Helynranta 1998, A. Kurtto, pers. comm.). In Estonia *S. canadensis* is distributed sporadically being abundant in some areas in the vicinity of cities. In Latvia and Lithuania *S. canadensis* is common species, particularly in urbanized areas, less abundant in the countryside (Gudžinskas 1997, Kuusk *et al.* 2003, Priede 2008). In the European part of Russia it is naturalised in most of districts except the north where occupies ruderal and human-created habitats in cities and villages, occurs on roadsides preferring soils with well-developed humus horizon (Игнатов и др. 1990). In Iceland *S. canadensis* has been cultivated as an ornamental since the early 1900s. It has been grown in the Reykjavik Botanic Garden since 1967. It is a late bloomer and is not known to have produced fertile seeds in Iceland (D. Jakobsdottir, pers. comm.).

Country	Not found	Not established	Rare	Local	Common	Very common	Not known
Austria						X	
Belgium						X	
Czech republic					X		
Denmark					X		
Estonia				X			
European part of Russia					X		
Finland				X			
Faroe Islands	X						
Germany						X	
Greenland	X						
Iceland		X					
Ireland				X			
Latvia					X		
Lithuania					X		
Netherlands					X		
Norway				X			
Poland					X		
Slovakia							
Sweden					X		

Table 1. The frequency and establishment of *Solidago canadensis*, please refer also to the information provided for this species at www.nobanis.org/search.asp. Legend for this table: **Not found** - The species is not found in the country; **Not established** - The species has not formed self-reproducing populations (but is found as a casual or incidental species); **Rare** - Few sites where it is found in the country; **Local** - Locally abundant, many individuals in some areas of the country; **Common** - Many sites in the country; **Very common** - Many sites and many individuals; **Not known** - No information was available.

Ecology

Habitat description

In its native range in North America *S. canadensis* is often a weedy component of vegetation in abandoned pastures and roadsides, in abandoned fields, grasslands, forest edges and human-disturbed habitats in urban areas and settlements (Walck *et al*. 1999). Often the abandoned sites are colonised rapidly after abandonment. *S. canadensis* can occur in any crop, but it is not a serious weed in annual crops since it can be controlled by tilling. However, it invades poorly managed pastures and can be a considerable weed in forest nurseries and among perennial gardens plants and crops (Werner *et al.* 1980 in CABI 2004), because *S. canadensis* is spreading very quickly and it occurs over a wide range of soil fertility and texture conditions (Weber 2000).

In its alien range *S. canadensis* is found in many disturbed sites particularly on roadsides, along railways, in urban areas, on abandoned fields, allotments and grasslands as well as in forest edges, open forests and on banks of rivers (Weber 2000, Priedītis 2002, Priede 2008). Disturbed and human-created habitats prevail, however, the species is present also in natural coastal communities (A. Kurtto, pers. comm.). Rarely the species occurs, though not being abundant, in semi-natural grassland and spring fen communities (A. Priede, pers. com.).

Reproduction and life cycle
S. canadensis is a rhizomatous hemicryptophyte and has a complex life cycle with rhizome and seed generation. Individual clones are long lived and can reach an age of 100 years. Reproduction occurs every year, but individual shoots remain vegetative if too small. Plants are able to reproduce in their first year under good conditions (Weber 2000).
Flowering may start as early as the end of July, but peak flowering time is between mid-August and the end of September, it can even continue through October (Weber 2000).
S. canadensis is insect-pollinated. Inflorescences are very attractive to pollinators due to their dark yellow colour and sweet odour; they provide high amounts of pollen and nectar. Frequent visitors of goldenrods in Europe are members of Phalacridae, Muscidae, Syrphidae, Apidae, Formicidae, Sphecidae, and Panorpidae (Weber 2000). The success of cross-pollination is crucial to the species due to its self-incompatibility (A. Kurtto, pers. comm.).

Dispersal and spread
S. canadensis is propagated by seeds and rhizomes. Seeds are produced in large numbers; in Europe an individual shoot may produce more than 10 000 seeds (Voser-Huber 1983 in Weber 2000, Meyer and Schmid 1991, Weber 2000). The small-size seeds are essential for long-distance dispersal and colonisation. Achenes released 1 m above the ground in winds of up to 5 m/s had a peak modal dispersal distance of 0.3 m, a mean of 0.6 m and a maximum of 2.4 m. Short-distance dispersal is possible by rhizomes (Werner *et al.* 1980 in CABI 2004). Locally the population increase is mainly a result of clonal growth (Weber 2000).
Accidental introduction is possible through human activity, such as collecting fruiting shoots as an ornament and then disposing of them on rubbish heaps. In autumn it is customary to cut down the fruiting shoots and dump them on rubbish heaps, often outside the gardens on riversides or brook shores, from which floods can carry shoots downstream. In the same way rhizome fragments may generate new populations along rivers and brooks (A. Kurtto, pers. comm.).
Seeds and rhizomes may also be dispersed as a result of movement of soil in the course of construction works, and by attachment to vehicles or in the air turbulence created by vehicles (CABI 2004).

Impact

Affected habitats and indigenous organisms
Large areas infested by *S. canadensis* are the result of inappropriate land use management allowing *S. canadensis* becoming established and to out-compete native plants. Species-poor communities of *S. canadensis* homogenize the landscape (CABI 2004). Since *S. canadensis* is a tall, highly competitive herbaceous perennial plant, once established, *S. canadensis* can remain dominant for a long time. Due to its clonal growth, *S. canadensis* can develop dense stands. Shoot density in well established stands could reach 309 shoots/m^2 (Weber 2000, Kowarik 2003). Overall, in its alien range the species rarely invades natural plant communities, though can be found in coastal habitats, semi-natural grassland and spring fen communities. Due to abandonment and lack of appropriate habitat management *S. canadensis* may overwhelm the (semi)natural communities outcompeting the native plant communities and locally reducing the species diversity (A. Priede, pers. comm.).
The invasion success might be related to allelopathic compounds released by *S. canadensis* and subsequent effects on native vegetation, however, since some native plants are able to persist in *S. canadensis* stands, further studies are needed (Sun *et al*. 2006, Abhilasha *et al*. 2008). The allelopathic compounds suppress also the local soil pathogens (Zhung *et al*. 2009). A study in Hungary suggested that acetone extracts of *S. canadensis* could have useful allelopathic effects on

other weeds (Solymosi 1994 in CABI 2004). It is also suggested that allelopathic agents produced by the roots of the goldenrods may inhibit the growth of other, indigenous plant species.
Studies on insect communities in sites invaded by *S. canadensis* suggest that insect species that are closely related to plant species composition are more vulnerable to the effects of the invasive plant than those that are loosely or only indirectly related to plant species composition (De Groot *et al*. 2007).

Genetic effects
In its native range genetic variations in resistance to herbivores can exist within a population. In Europe high genetic variation was found both within and among populations in phenology and morphological characters (Weber 2000). *S. canadens*is occasionally hybridise with the native *S. virgaurea* at least in Fennoscandia (Nilsson 1976, Sunding 1989, Mossberg and Stenberg 2003). However, these two species differ in flowering period. *S. canadensis* is flowering considerably later, so that detrimental large-scale hybridisation is highly improbable to occur (A. Kurtto, pers. comm.).

Human health effects
Goldenrods, in contrary to the opinion frequently held, play a very unimportant part in hay fever. The flowering period of these plants coincides with the season of greatest suffering from hay fever and as conspicuous plants they are often suspected. Pollen of the goldenrods can certainly produce hay fever symptoms but normally the heavy, sticky pollen is carried by insects or drops to the ground close to the plant. Only occasionally, in dry, very windy weather, would sufficient goldenrod pollen be blown into the air to disturb sensitive individuals (Frankton 1963).
No other negative human health effects are known.

Economic and societal effects (positive/negative)
S. canadensis is an alternative host of insects that can be vectors of crop pathogens. However, no quantitative studies on the economic impact are available (CABI 2004).
S. canadensis is cultivated as an ornamental plant in Europe. Areas dominated by *S. canadensis* are also suitable for honey production. *S. canadensis* is a medicinal plant, and it has been used in European phytotheraphy for a very long time as a urological and antiphlogistical medicament (Apáti *et al.* 2003).

Management approaches

Prevention methods
S. canadensis is listed in the EPPO List of invasive alien plants which lists the plants that have been identified to pose an important threat to plant health, environment and biodiversity in the EPPO region. Countries invaded by these species are recommended to take measures to prevent their further introduction and spread.
S. canadensis is listed in so called black lists of several European countries as highly invasive plant, e.g. in Switzerland (CPS/SKEW), Belgium (AlterIAS), Estonia (List of invasive alien species), Denmark (List of invasive alien species) and numerous other countries.

Eradication, control and monitoring efforts
Biological control presents a method to manage *S. canadensis*, since it is known that biomass allocation and physiology of the plant in its native range are influenced by herbivores. In Europe the herbivore pressure is low. Snails and small rodents rarely feed on stems and leaves. In Switzerland

18 phytophagous insects feeding on the *S. canadensis* are known (Weber 2000). There are no data on grazing, but this could be a good solution to control *S. canadensis* after mechanical control.
There are several mechanical control methods to combat *S. canadensis* stands. One effective method against *Solidago* species is mowing twice per year (May and August) for several years, or a soil rotation during summer at dry weather conditions. After mowing, sowing of a grass/forbs mixture can control growth of *S. canadensis* stands, resulting in the shoot density of plants to decrease strongly (Voser-Huber 1983 in Weber 2000). Covering goldenrods after mowing with light impenetrable plastic sheet can also reduce growth. This method, however, destroys all vegetation. The suitability of the different measures depends on the site condition (wet, dry), the infested area, and the other species present, *e.g*. the presence of rare species with high conservation values (Weber 2000).
Young plants could be controlled with chemical methods, because they are sensitive to soil herbicides, but later, during the vegetative period, soil herbicides are less effective. At heights of 10-15 cm glyphosate and several contact herbicides are suitable for the control of *S. canadensis* (CABI 2004).

Information and awareness
S. canadensis has become established in the wild in a number of European countries. It continues to be available as an ornamental from mail order catalogues and web sites of commercial nurseries and botanical gardens, and as such further introductions are likely. The Directorate for Nature Management in Norway issued in 2008 a recommendation to stop growing, importing, marketing and exchanging specimens of 10 selected alien invasive plant species including *S. canadensis*. There are several information sheets about *S. canadensis* biology, ecology and distribution, e.g. NeoFlora and Crop Protection Compendium Web page.

Knowledge and research
Alien species of *Solidago* have been intensively studied for chemical compounds. Diterpenes are common in *Solidago*. Diterpenoids of *Solidago* can act as insect antifeedants and growth inhibitors (Weber 2000). To identify the optimal date for one cutting a year experiments are made with three different dates for cutting (early June, late June and in September) at the National Environmental Research Institute, Denmark. Results show that late June is the best time to cut to control *Solidago* and at the same time to promote future vegetation. Late cutting (September) on the other hand may favour the establishment and growth of *S. canadensis* (A.B. Hald, pers. comm..).

Recommendations or comments from experts and local communities
S. canadensis has for several years been combated in areas around Oslo in Norway including within nature reserves. The most efficient methods to control the species seem to be digging up specimens or mowing the stands repeatedly before the fruits mature. Additional methods have involved soil tilling, physical removal of fruiting shoots as well as chemical treatments with Roundup (glyphosate) and/or Starane (fluoroxypyre).

References and other resources

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Links

NeoFlora fact sheet on *Solidago canadensis*
Den virtuella floran (Virtual Flora of Sweden)
EPPO list of pests recommended as quarantine pests
Crop Protection Compendium Web page

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