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## INVASION OF ALIEN *Solidago* TAXA INTO URBAN HABITATS: A STUDY OF SELECTED TOWNS IN SOUTHERN POLAND

### INWAZJA OBCYCH TAKSONÓW (*Solidago* sp.) NA SIEDLISKA MIEJSKIE NA PRZYKŁADZIE WYBRANYCH MIAST W POŁUDNIOWEJ POLSCE

**Abstract:** In Poland there are three invasive species of the genus *Solidago* native to North America. In the years 2010-2015 field survey in five towns in Oswiecim Basin and its vicinity was performed which aimed to examine frequency, habitat preferences and basic parameters of populations of these species. Amongst invasive goldenrods *S. canadensis* (79 localities) and *S. gigantea* (74) prevailed in the study area and are much more frequent than *S. graminifolia* (8). Populations of goldenrods were not very abundant and did not occupy large area, however, there were populations exceeding 500 m<sup>2</sup> and that had more than 500 ramets except for *S. graminifolia* which occur at low densities. The Canadian goldenrod *S. canadensis* tended to occur more frequently in ruderal and segetal habitats than *S. gigantea* whereas *S. graminifolia* was encountered only at fallows. Both *S. gigantea* and *S. canadensis* were reported to occur in wetland habitats and sometimes formed monospecific stands what prove negative influence on biodiversity.

**Keywords:** biological invasions, neophyte, urban flora, ecological amplitude

## Introduction

In Poland the three species of the genus *Solidago* occur which are of alien origin. These are: Canadian goldenrod *Solidago canadensis* L, giant goldenrod *S. gigantea* Aiton, grass-leaved goldenrod *S. graminifolia* (L.) Elliot [1]. The taxonomic status of *S. altissima*, which is distributed in Europe, in Poland is not certain [2-4]. Apart from invasive goldenrods there is the only one native congeneric species - European goldenrod *S. virgaurea* L. All three invasive congeners belong to the most common invasive species native to North America. Since second part of 19<sup>th</sup> century they increase in range and abundance. Goldenrods were introduced into Europe as ornamental plants and at the beginning they were grown in botanical gardens which from they escaped [4]. Some plants as *S. gigantea* are larger in introduced range than in its native range [5] and they differed in many other plant traits [6-9]. There is an enormous literature body showing negative impact

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of *Solidago* taxa on native biodiversity including plants and pollinators and overall landscape [2, 3, 10-16]. Giant goldenrod can even form monospecific stands which almost no native species can occupy [17, 18].

*Solidago gigantea* was introduced in the territory of Poland in 1853. It spread in the country very fast. In the middle of 20<sup>th</sup> century the species was known from 150 localities. At the end of the century there were 5300 localities. Nowadays it is widely distributed species which occurs more densely in southern and southern-western part of Poland [1]. *Solidago canadensis* was noted in 1872 on the territory of Poland. The increase of range was also rapid. During 50 years since the half of 20<sup>th</sup> century number of localities of the species increased from 60 localities to 3500 localities. Both plants occupy similar habitats and can be encountered in anthropogenic, seminatural, natural ecosystems. They grow in moist forests and scrub, forest edges, meadows and river banks. They can be found also on roadsides, fallows, embankments, vicinities of water bodies [1, 20].

*Solidago graminifolia* is the rarest amongst alien goldenrods. The core occurrence area of *S. graminifolia* is in the central part of Opole-Silesia. During the 20th century, the area of dense distribution of *S. graminifolia* broadened from around 3 km<sup>2</sup> to about 300 km<sup>2</sup>. This species is spreading mainly in open, anthropogenic or semi-natural habitats. The highest abundance was achieved by *S. graminifolia* in abandoned pastures and meadows, in riverbank rushes, on roadsides, and in fallow fields [19, 20].

Taking into account differences in spread rate of goldenrods in the country and little knowledge about tendencies in distribution, habitat preferences of *Solidago* taxa at local and regional level the present study aimed to examine frequency of all three invasive goldenrods (i), to analyze abundance of populations (ii), and area occupied by populations by particular species (iii), as well as to assess contribution of accompanying species within populations of goldenrods (iv).

## Study area

The study was performed in the Oswiecim Basin and in the vicinity - fragment of the Little Beskids Mts (Southern Poland). The investigated area with neighbourhood is the part of Northern Subcarpathian Region. This basin of 1236 km<sup>2</sup> of an area is divided into Pszczyzna Plateau, Upper Vistula Basin and Wilamowickie Foothills. Majority of this region is agricultural land and industrial area. The forests occupy small area and are rather fragmented. Small towns usually are densely inhabited. In total five small towns which ranged from 11000 to 40000 in terms of population and occupied area from 10 to 30 km<sup>2</sup> were chosen for the purpose of the study (Table 1).

Table 1

Characteristics of studied towns

Town	Longitude	Latitude	Area [km <sup>2</sup> ]	Population
Andrychow	19°20'E	49°52'N	10.33	20848
Brzeszcze	19°09'E	49°59'N	19.04	11691
Kety	19°13'E	49°53'N	23.05	19080
Oswiecim	19°08'E	50°02'N	30	40324
Pszczyzna	18°57'E	49°59'N	22.49	26028

## Material and methods

The studied towns were searched for localities of alien *Solidago* taxa in the peak of vegetation season in the years 2010–2015. They were focused on survey (onefold visit in the locality) and not included detailed ecological research. Each locality of the particular taxon was noted on the map. Abundance and occupied area by population was recorded and some site characteristics. The following classes of abundance (density of ramets) were adopted: 1) < 10 ramets; 2) 10–50; 3) 51–100; 4) 101–250; 5) 251–500; 6) > 500. As area is concerned 6 classes were adopted as follows: 1) < 5 m<sup>2</sup>; 2) 5–20 m<sup>2</sup>; 3) 21–50 m<sup>2</sup>; 4) 51–150 m<sup>2</sup>; 5) 151–500 m<sup>2</sup>; 6) > 500 m<sup>2</sup>. The type of occupied habitat was noted. Finally habitats were classified into five main groups: forests (forest interiors and forest paths), routes (roads and railways), wetlands (river banks and vicinity of water bodies), fallows (abandoned arable fields and pastures), ruderal sites (dumping sites). Within the patch of stand of goldenrods percentage cover of accompanying species were noted in intervals: 0–10, 20–30, 40–50....90–100%.

The differences in frequency among species in terms of number of localities representing particular classes of abundance, classes of area, number of occupied types of habitats G test (log-likelihood test) was adopted. For pair-wise comparisons G-test with Bonferroni correction ( $p = 0.0167$ ) was used. The difference in mean cover of accompanying species was analysed by Wilcoxon sum rank test only for pair *S. canadensis* and *S. gigantea* due to enough large data. R language and environment was employed to calculate statistics [21].

## Results

The most frequent species was *S. canadensis* which was found on 79 localities followed by *S. gigantea* (74 localities) and *S. graminifolia* was encountered only at 8 localities (Fig. 1). The *Solidago* species differed significantly ( $G = 33.42$ ,  $df = 10$ ,  $p < 0.001$ ) in density of individuals at locality (Fig. 2a).

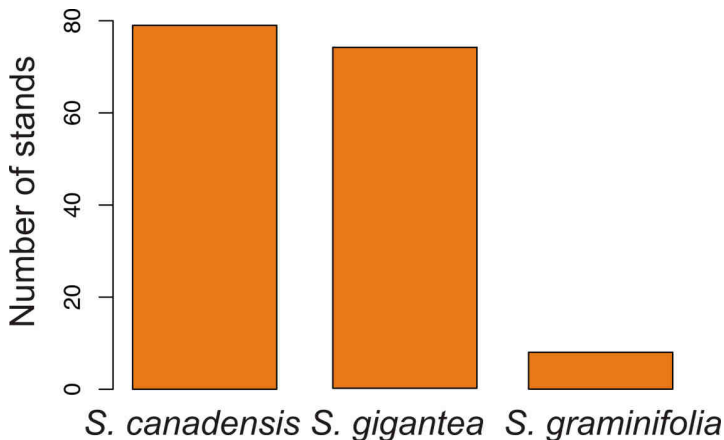


Fig. 1. Comparison of frequency of localities of *Solidago* taxa in the studied towns

Majority *ie* 87% of all stands in *S. graminifolia* were very small in size - less than 10 ramets, whereas populations larger consisted from 10-50 ramets constituted 12.5% of all stands. Distribution of classes of abundance of remaining goldenrods were similar but they differed significantly ( $G = 26.608$ ,  $df = 5$ ,  $p < 0.0001$ ). In both *S. canadensis* and *S. gigantea* taxa populations consisted 10-50 individuals were most frequent which scored 38 and 33.8% of total number of populations respectively. The largest in size populations *ie* higher than 500 ramets were more frequent in *S. gigantea* (10.8%) vs. (7.8%) in *S. canadensis*. There are no significant differences among goldenrods in occupied area by population ( $G = 12.071$ ,  $df = 10$ ,  $p = 0.2803$ ). In *S. canadensis* and *S. gigantea* populations which occupied 21-50 m<sup>2</sup> were the most frequently (26.6 and 29.7% respectively) while *S. graminifolia* occupied 37.5% populations which ranged from 151 to 500 m<sup>2</sup> (Fig. 2b).

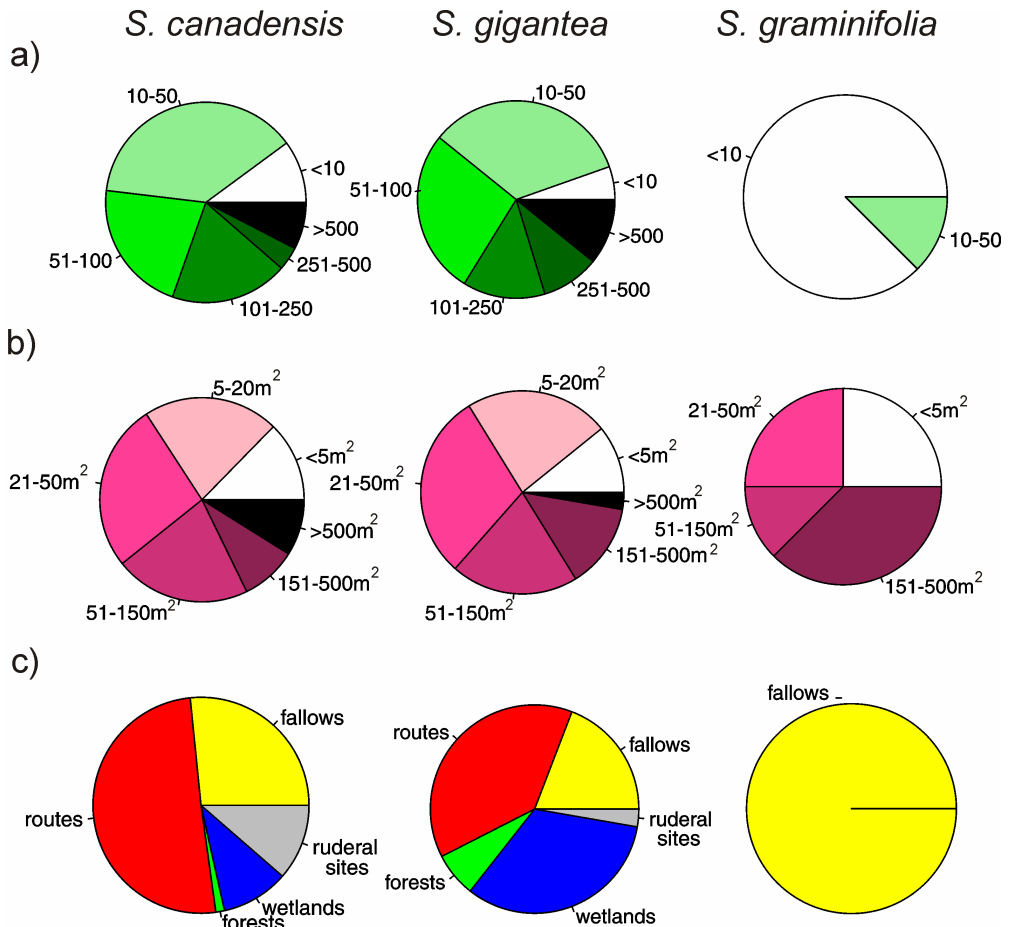


Fig. 2. Percentage of populations of *Solidago* taxa in the studied towns in terms of: a) classes of abundance, b) classes of area size, c) type of habitats

The frequency of habitats differed significantly between *S. canadensis* and *S. gigantea* ( $G = 19.403$ ,  $df = 4$ ,  $p = 0.000655$ ). *S. graminifolia* was not included in comparison due to limited occurrence in type of biotopes - fallows (Fig. 2c). There were similar mean covers of native accompanying species between *S. canadensis* and *S. gigantea* (Wilcoxon sum rank test,  $W = 1820$ ,  $p = 0.1739$ ) (Fig. 3).

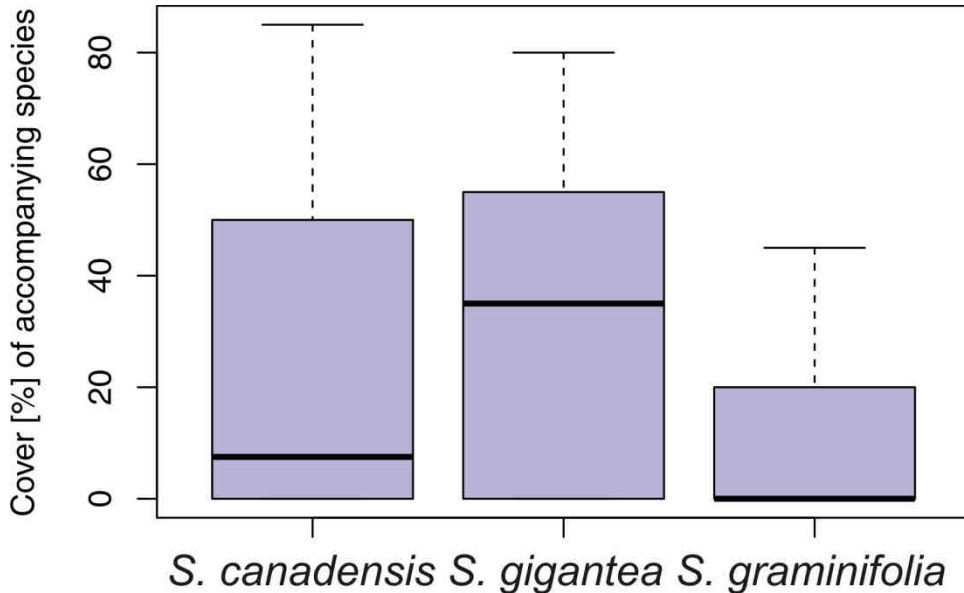


Fig. 3. Median of percentage cover ( $\pm$ IQR) of accompanying native species within a patch by *Solidago* species

## Discussion

The results of this study showing very low number of localities of *S. graminifolia* in the research area confirm its small range and low dynamics of populations in the country. In the Silesian Upland it was found only at 7 localities [22] wherein 5 localities were in southern-western part of this region [23]. This species was observed only at abandoned arable fields, whereas [20] noted this plant in open cast quarries, embankments and ditches. As remaining species are concerned as it could be expected *S. canadensis* was a little more frequent. In the adjacent region - Silesian Upland *S. canadensis* also prevailed - 636 localities vs. 561 of *S. gigantea* [22]. In northern-eastern part of Poland higher disproportion was recorded [24]. In that region, on the basis of data gathered from 9 towns it was reported 82% of localities belonging to *S. canadensis*. The remaining stands were of *S. gigantea*, whereas *S. graminifolia* was not recorded at all.

These authors demonstrated that at the majority of localities areas occupied by populations did not exceed 100 m<sup>2</sup>. Only 10 and 5.4% were found for Canadian goldenrod and giant goldenrod respectively and they were larger than 100 m<sup>2</sup>. Taking into account different adopted scale of size of the area in this study it can be concluded that surely goldenrods occupied larger areas. In case of *S. canadensis* more than 10% were large than

150 m<sup>2</sup> whereas in *S. gigantea* it was more than 20% of total localities. In general *Solidago* taxa did not occupied very large areas likewise in rural landscape, where sometimes on meadows these species grow in masses. In urban habitats conditions for development are not so favorable. Giant goldenrod was found more frequently in wetlands than Canadian goldenrod, however both species tend to grow in riparian habitats. They can occur in nitrophilous riparian communities of the *Convolvuletalia sepium* order, in floodplain forests of the *Alno-Ulmion* forests and willow scrub of the *Salicetalia purpurae* order [1, 19]. These plant communities belong to native phytocoenoses and the presence of alien species pose a threat to native biodiversity. Both taxa are characteristic species for the *Rudbeckio-Solidaginetium* association, synanthropic community. In the studies [24, 25] it was observed more and more frequent appearance of *S. canadensis* on abandoned arable fields. They even postulate to recognize arable field as fallow where massive occurrence of the species is noted. In our study higher proportion of fallows when compared to giant goldenrod was also observed. In general Canadian goldenrod was found more frequently in synanthropic habitats than the latter species. It partially be confirmed by [24] who stated that using 9-degree hemeroby scale *S. gigantea* tended to occur in more mesohemerobic biotopes than *S. canadensis* which preferred more euhemerobic sites.

The contribution of accompanying native species ranged from 0 to 85%. Despite differences in medians among species they were no significant due to very high variation of cover of species. Nevertheless, this study confirmed that monospecific stands formed by these *Solidago* taxa are not unique.

## Conclusions

1. Amongst invasive goldenrods *S. canadensis* and *S. gigantea* prevail in the study area and are much more frequent than *S. graminifolia*.
2. Populations of goldenrods are not very large in terms of density and occupied area, however, there are populations exceeding 500 m<sup>2</sup> and that had more than 500 ramets except for *S. graminifolia* which occur at low densities.
3. Contribution of habitats is typical for urban and suburban conditions thus meadows are almost absent but there are differences in frequency between *S. canadensis* and *S. gigantea*. The former tended to occur in more ruderal habitats than the latter. *S. graminifolia* was encountered only at fallows.
4. Goldenrods occur in wetland habitats and sometimes form monospecific stands what prove negative influence on biodiversity.

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## INWAZJA OBCYCH TAKSONÓW (*Solidago* sp.) NA SIEDLISKA MIEJSKIE NA PRZYKŁADZIE WYBRANYCH MIAST W POŁUDNIOWEJ POLSCE

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**Abstrakt:** W Polsce występują trzy inwazyjne gatunki z rodzaju nawłóć *Solidago* rodzime dla Ameryki Północnej. W latach 2010-2015 przeprowadzono badania pilotażowe w pięciu miastach Kotliny Oświęcimskiej i w jej sąsiedztwie. Badania miały na celu określenie częstości występowania, preferencji siedliskowych i podstawowych parametrów populacji tych taksonów. Wśród inwazyjnych nawłoci przeważały: nawłóć kanadyjska *S. canadensis* (79 stanowisk) oraz nawłóć późna (n. olbrzymia) *S. gigantea* (74) nad nawłocią trawolistną *S. graminifolia* (zaledwie 8 stanowisk). Populacje nawłoci nie były liczne i zajmowały niewielką powierzchnię, aczkolwiek występowały populacje przekraczające 500 m<sup>2</sup> i mające więcej niż 500 pędów (ramet) z wyjątkiem *S. graminifolia*, która pojawiała się tylko w małej liczbie okazów. Nawłóć kanadyjska miała tendencję do występowania na bardziej ruderalnych i segetalnych siedliskach niż *S. gigantea*, podczas gdy *S. graminifolia* została odnotowana wyłącznie na ugorach. Zarówno *S. gigantea*, jak i *S. canadensis* zostały stwierdzone na siedliskach mokradłowych i czasami tworzyły jednogatunkowe płyty, co jest przejawem negatywnego wpływu na rodzimą różnorodność biologiczną.

**Słowa kluczowe:** inwazje biologiczne, kenofit, wymagania siedliskowe