

***Solidago canadensis* impacts on tillable land withdrawn from the farming turnover**

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Abstract. *Solidago canadensis* is the extremely aggressive alien species. Our study aimed to monitor the invasiveness of *S. canadensis* in the abandoned lands. The parameters characterizing its invasiveness (average shoot length, foliage projective cover, average number of vegetative shoots, average number of generative shoots in *S. canadensis* and the average number of associated species at the plots) were measured at two plant communities of the abandoned lands. According to our results, the invasion reduced the native plant species richness throughout 2016 and 2018. Therefore, the invasion of this species diverts of the vegetation succession, alters the mutual links between the native elements of these old fields.

1 Introduction

In latest decade, various economic changes have led to the abandonment of vast areas of previously tillable land in the countries of the Commonwealth of Independent States (CIS). At the beginning of secondary succession, former tillable land can support agricultural biodiversity and provide valuable ecosystem services (such as pollination) [1]. Frequently old fields are most vulnerable to native and alien species invasion because resource availability is elevated, increasing the probability of successful colonization and recruitment. Conditions following disturbance are particularly amenable to colonization by both native and alien species, but there are several reasons why alien species are especially successful in these areas. Even if some native species can tolerate modified disturbance regimes, alien species may greatly outnumber them and therefore dominate early successional systems [2]. It is likely that the alien species will be better adapted to anthropogenic disturbance. They can populate recently abandoned tillable land due to the increased availability of nutrients in the soil associated with previous fertilizer applications [3].

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Solidago canadensis L. (Canada goldenrod) an exceptionally successful worldwide invader as the invasive species [4]. Thus it is the most successful invasive colonizer of old fields. *S. canadensis* is a highly aggressive alien plant native to North America. Nowadays it is widely spread in China, Russia (from Kaliningrad to the Far East), Japan, Taiwan, Europe and Australia [5]. However, the actual cause underlying its invasive success remains unknown. For example, it was often cited as superior competitor over native species due to its prolific vegetative growth [6]. However, it colonizes disturbed areas such as abandoned fields and succession habitats [7], and it has the ability to capitalize on disturbance, thus weak biotic interaction exists between the native and invasive species due to the invasive species' competitive superiority, irrespective of disturbance, with competitive exclusion as the main cause of native species decline [8]. Its impact on the species richness has already been studied in other countries [9-11]. The results observed that growth conditions may be optimal for seed production (and therefore seed bank input) in former arable lands. And although *Solidago canadensis* has a limited impact on the native seed bank community, degraded old fields, driven by *S. canadensis*, instead of valuable secondary grasslands, might dominate the landscape for decades (this invasive species can persist in the fields for up to 50–75 years [9])

In this paper, we consider to estimate the impact of the invasion of *S. canadensis* on the composition and diversity of plant communities over the course of secondary succession of old fields.

2 The Materials and methods

Monitoring studies were carried out in two key areas of Belarus representing tillable land withdrawn from farming turnover. From 2016 to 2018, we surveyed a site at the village of Kosmovichi, (Nesvizh district): N 53 ° 06'53 "E 26 ° 39'50" (plot 1) and the meadow near a large-cranberry plantation in the vicinity of the village Gantsevichi (Brest region): N 52 ° 44'42 "E 26 ° 22'33" (plot2). The surveys were conducted once per site in 2016 and 2018. Five parameters were measured per study plot (1 × 1 m): average length of *S. canadensis* shoots, projective plant cover, average number of vegetative shoots, average number of reproductive shoots, and average number of associated species. Basic statistical analyses were performed using PAST 3.0; all species of vascular plants were recorded, their covers were estimated and used as importance values for calculating the Shannon diversity index of similarity between plots in 2016 and 2018.

3 The results and discussion

Solidago canadensis L. is a perennial plant, its height is 70–210 cm. It is pollinated by insects. Fecundity is more than 10000 seeds per one generative stem. *Solidago canadensis* L. is a transformer; it is capable of converting natural ecosystems. The plant can form thickets with a density of more than 300 shoots per 1 m².

To visualize the results, we used radar maps that represent the five parameters studied (Fig. 1). Plot 1: over the three years of observation, the average height of *S. canadensis* increased from 163 to 180 cm, the average projection cover increased from 95 to 100%, the average number of reproductive processes in the plot increased from 92 to 123, and simultaneously the change in the average number of vegetative shoots ranged from 9 up to 18 shoots. The number of related species decreased from 8 to 4. Plot 2: over the three years of observation, the average height of *S. canadensis* increased from 113 to 147 cm, average projective cover statistically significantly increased from 60 to 82% ($p < 0.01$) the average number of reproductive processes in the plot increased from 41 to 94, the variation of the average number of vegetative shoots from 90 to 15 shoots was statistically significant. The number

of related species decreased from 9 to 3. The number of *S. canadensis* in two sites (1 and 2) has increased significantly. Here, the height of plants of *S. canadensis* increases every year, the projective cover of this species increases up to 100%, the number of shoots increases (in plot 1 both generative and vegetative; in plot 2, a decrease in the number of vegetative shoots is compensated by an increase in the number of generative shoots)

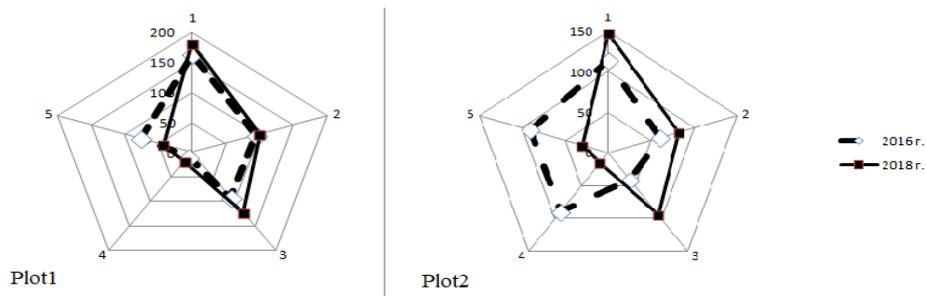


Fig. 1. Population characteristics of *S. canadensis* in various communities of the tillable land withdrawn from farming turnover (Plot 1-2): 1 – average height, cm; 2 – projective cover, %; 3 – number of generative shoots; units; 4 – number of vegetative shoots, units; 5 – average number of associated species, units.

On the abandoned lands (plot 1 and plot 2), no invasion control measures have been taken over the past 5-6 years and the abundance of *S. canadensis* in two sites has increased significantly (Fig. 2.). Here, the height of plants of *S. canadensis* increases every year (by 10% for the plot 1 and by 30% for the plot 2), the projective cover of this species increases up to 100% (by 5% for the plot 1 and by 22% for the plot 2, the number of shoots increases (in plot 1 both generative (by 34%) and vegetative (by 100%); in plot 2, a decrease in the number of vegetative shoots (by 83%) is compensated by an increase in the number of generative shoots (by 129%).

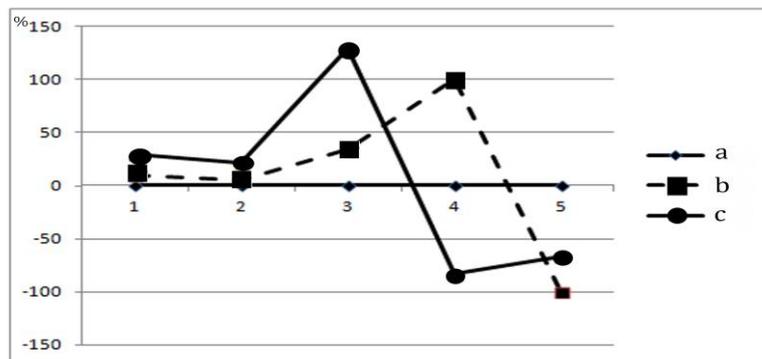


Fig. 2. The variability in the studied characteristics of *S. canadensis* as a percentage. a – data in 2016; b – plot 1, 2018; c plot 2, 2018. 1 – average height, cm; 2 – projective cover, %; 3 – number of generative shoots; units; 4 – number of vegetative shoots, units; 5 – average number of associated species, units.

The species composition of community was typical of the beginning of secondary succession on an old field and the number of related species (both native and alien) is significantly reduced. There are progressive populations of the invasive species, actively invading semi-natural communities with the displacement of indigenous species. The composition of associated species changed considerably (table1).

Table 1. Changing the set of related species and their projective cover on the studied test sites

	2016	2018
Plot 1	<i>Elytrigia repens</i> (L.) Nevski 60% <i>Artemisia vulgaris</i> L. 25% <i>Equisetum arvense</i> L. 5%; <i>Glechoma hederacea</i> L. 5%; <i>Festuca arundinacea</i> Schreb. 3%; <i>Dactylis glomerata</i> L. 2%; <i>Agrostis gigantea</i> Roth 1%; <i>Achillea millefolium</i> L. < 1%; <i>Chenopodium album</i> L. < 1%; <i>Cirsium arvense</i> (L.) Scop. < 1%; <i>Lactuca serriola</i> L. < 1%; <i>Stenactis annua</i> (L.) Cass. < 1%; <i>Taraxacum officinale</i> F.H. Wigg. < 1%; <i>Veronica chamaedrys</i> L. < 1%; <i>Vicia hirsuta</i> (L.) Gray < 1%	<i>Elytrigia repens</i> 10% <i>Agrostis gigantea</i> 5% <i>Armoracia rusticana</i> P.G. Gaertn., B. Mey. & Scherb. 2% <i>Artemisia vulgaris</i> 2% <i>Prunus divaricata</i> Ledeb. 1% <i>Urtica dioica</i> 1% <i>Chamerion angustifolius</i> < 1%; <i>Dactylis glomerata</i> < 1%; <i>Glechoma hederaceae</i> < 1%; <i>Stenactis annua</i> < 1%
Plot 2	<i>Elytrigia repens</i> 20-80% <i>Potentilla norvegica</i> L. 30% <i>Bidens frondosa</i> L. 10%; <i>Cirsium arvense</i> 8%; <i>Erigeron canadensis</i> L. 8%; <i>Chamerion angustifolium</i> (L.) Holub 3%; <i>Urtica dioica</i> L. 3%; <i>Stellaria graminea</i> L. 2% <i>Calamagrostis epigeios</i> (L.) Roth < 1%; <i>Echinochloa crusgalli</i> (L.) P. Beauv. < 1%; <i>Hypericum perforatum</i> L. < 1%; <i>Lysimachia vulgaris</i> L. < 1%; <i>Melandrium album</i> (Mill.) Garcke < 1%; <i>Myosoton aquaticum</i> (L.) Moench < 1%; <i>Polygonum scabrum</i> Moench < 1%; <i>Vicia cracca</i> L. < 1%	<i>Elytrigia repens</i> 70% <i>Calamagrostis epigeios</i> 10% <i>Cirsium arvense</i> 10% <i>Artemisia vulgaris</i> 3% <i>Chamerion angustifolium</i> 2%

In general, 30 plant species were registered at the two plots (Fig.3). In plot 1, the projective cover decreases even for such resistant species as *Elytrigia repens* and *Artemisia vulgaris*, and 9 species have practically disappeared over the past three years. In plot 2, the projective cover practically unchanged for *Elytrigia repens* and cover increased for both, *Calamagrostis epigeios* and *Cirsium arvense*, 15 species have practically disappeared over the past three years.



Our data do not differ from the results obtained in other regions of Belarus [12, 13]. For example, at abandoned agricultural lands in the southeast of the country *S. canadensis* penetrates the communities of the primary stages of progressive succession and may cause its inhibition. The occurrence of *S. canadensis* in this region is 15.5% for abandoned lands. During 10 years, the projective cover of *S. canadensis* at the key plots increased in ten and hundred times. During last 5 years, the projective cover of this species increased from 8% to 60%, while the projective cover of other species respectively reduced as follows: *Calamagrostis epigeios* – in 3.8 times; *Artemisia vulgaris* – in 1.8 times; *Urtica dioica* L. – in twice, etc. Also the species richness reduced by 10.8 species per 100 m². The increase in the projective cover is accompanied by the reduction of biodiversity: the overall number of species reduced in 2.8 times, and the number of species on 100 m² reduced in 3 times [13].

4 Conclusion

The number of native species in the abandoned lands declines in the absence of control measures. The native plants are outcompeted rapidly with alien species. Without management interventions instead of valuable secondary grasslands, *S. canadensis* might dominate the abandoned lands for decades. Active management actions are needed to reduce pressure on native plant communities. The new scientific results obtained as a result of our studies are in good agreement with the data of various scientific studies that have been obtained by other scientists [14-16].

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