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INVASIVE ALIEN PLANTS IN GRASSLANDS FROM THE LAND OF FĂGĂRAȘ

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Abstract

Using flowing water as a transportation medium for seeds and fruit, invasive plant species can spread rapidly, making river banks an environment where they can grow prosperous populations. In the plain of the Land of Fagaras, on the fringe of water courses, are many meadows with rich plant diversity. During field research conducted in 2021 and 2022, data from grasslands near twelve towns were collected to observe the presence of invasive plant species in this area. Sixteen species from the List of invasive and potentially invasive alien plants in Romania were identified in or close to analyzed grasslands. One of them, Impatiens glandulifera Royle, is on the List of invasive alien plants of concern for the EU. In the river banks, small or extended populations are formed, and only a few of these invasive species are installed in the grassland, except for Erigeron annuus.

Key words*: grassland; invasive alien plant species; the Land of Fagaras.*

INTRODUCTION

Invasive alien species are described as non-native species that once introduced outside their natural range have the ability to establish themselves in the recent area, produce offspring, and spread exponentially, extending their range (Pyšek et al., 2004).

The effects of those species on the environment were studied, and they ranged from changes in the richness and abundance of native species and the increased risk of native species extinction to changes in the ecosystems' functioning and services by changing nutrients and contaminating cycling, hydrology, and habitat structure (Pyšek et al., 2020).

The impact of invasive alien species on biodiversity is expected to grow in the future as a result of synergies with other global changes such as climate change, habitat loss, or human pressure (Genoves & Monaco, 2013; Pyšek et al., 2020).

Appropriate management solutions can prevent or attenuate the consequences of biological invasion. Therefore, complete data on the biological features of invasive species and their dispersion in specific habitats are necessary (Anačkov et al., 2013).

The information needed to prevent, control, or limit the spread of invasive species can be provided by compiling accurate lists on local levels (McGeoch et al., 2012).

Sârbu et al. (2022) published a review of the scientific literature on adventive plants, which emphasizes a national pattern regarding plant species invasions, geographical origins, and pathways of introductions. This is an important starting point for the management and action plans for invasive alien plant species in Romania. As this paper concludes that data collection in our country was conducted opportunistically rather than systematically, it is important to sample more intensive areas away from major academic and research facilities, and outside of popular protected areas.

Recently, several scientific papers or theses have addressed the subject of invasive plants in different regions of our country: Skolka & Preda (2011) for the Black Sea coast, Szatmari (2012) for the Carei Plain, Raduțoiu & Băloniu (2021) for the Oltenia region, Gradinaru (2021) for the Agighiol Hills from Dobrogea region or Susanu (2022) for the lower course of the Siret River.

Zimmermann et al. (2015) approach the subject of invasive plant species in the central part of Romania, in the South of Transylvania, around Sighișoara town, sampling a large variety of landscape elements, from the border of the

roads to farming landscapes and abandoned lands. According to them, there are eight species of plant invaders that have the potential to expand their distribution, in connection with landscape heterogeneity, roads, agricultural areas being at the top of colonized habitats.

The Land of Fagăraş, also known as the Land of Olt, is an erosion depression of 1000 km^2 situated in the South of the Transylvania Plateau. It is traversed from east to west by the Olt River. There are extensive terraces and meadows along the Olt and its tributaries, which are occupied by secondary grasslands (Ghinea, 1996; Grecu et al., 2008; Cimpoieș, 2013) alongside oak and beech forests. Only a few scientific papers on flora and vegetation are reported in this region. In 1969, Ularu wrote about the vegetation in hay meadows in the Persani Mountains. Concerning the vegetation of Sinca Noua, there are two works, the first in 1958 (Pop & Terentiu) and the second in 2008 (Danciu et al.). A list of species and habitats was included in the last one. Two invasive alien plants are found between species. In this paper, we describe alien invasive species found in grasslands near twelve towns from the Land of Făgăras, their taxonomy, ways of introduction, and biological characteristics in order to analyze their invasivity and the potential impact on plant diversity.

MATERIALS AND METHODS

The observation was carried out in grasslands near 12 towns in the Land of Fagaras (Figure 1).

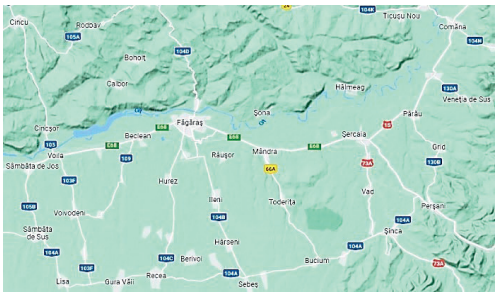

Figure 1. The area of investigation (https://www.google.com/maps/)

A layered alluvial-proluvial plain, formed by the terraces and meadows extended along the Olt valley and its tributaries, represents the relief of this territory (Ghinea, 1989).

The grasslands of the Land of Făgăras searched by us, are near the fringe of water courses, and they are classified in the association of *Molinietalia caerulaea* order such as *Agrostideto stoloniferae-Festucetum pratensis* Soo 1949, *Festuco rubrae-Agrostetum capillaris* Horvat 1951 (Pop, 2008), and *Anthoxantho-Agrostetum capillaris* Sillinger 1933 (Chifu et al., 2014).

Based on the list of alien invasive or potentially invasive plant species in Romania (Anastasiu et al., 2019), the list of plants was made through field observations, in 2021 and 2022. The information about the taxonomy and biological features of species was taken from books of Flora of Romania (Ciocârlan, 2009; Sârbu et al., 2013).

RESULTS AND DISCUSSIONS

The grasslands of the Land of Făgăras, which are abundant in mesophyllous species, are economically, biologically, and historically significant. They are used as hay meadows or as pastures. Several rare species, such as orchids, can be found, some of which are noted in the Red List of Plants of Romania (Danciu et al., 2008). Land stewardship of the local inhabitants and knowledge of the uses of plants in folk medicine, dyeing the wool, or alimentation sustain the historical dimensions of these grasslands (Drăgulescu, 1995). Anthropogenic pressure can affect the floristic composition and increase the risk of invasive species appearing.

Taxonomy, origin, and mod of introduction

We identified 16 species from the List of alien invasive or potentially invasive plant species in Romania (Anastasiu et al., 2019), which are located near or into grasslands. The majority are originally from North America, and only three of them are from Asia (*Impatiens glandulifera*) and South or Central America (*Galinsoga parviflora, Xanthium strumarium*) (Table 1).

Regarding pathways of introduction, some were introduced as ornamental plants and escaped from gardens where they were cultivated (*Oenothera biennis, Impatiens glandulifera, Echinocystis lobata, Solidago canadensis, Solidago gigantea*). Species like *Solidago canadensis* and *Impatiens glandulifera* are still found in gardens (Drăgulescu, 1995).

Acer negundo was also introduced as an ornamental plant and appears in a list of plants in The Bishop's Palace gardens at Fulham in 1692 (Brown, 2004). It was planted in many places in Romania as forestry species.
Species such as *Amaranthus powelli, Erigeron annuus, Galinsoga parviflora*, or *Matricaria discoidea* were introduced into botanical gardens as curiosities from which they emerged and spread in Europe and Asia (Mabey, 1996; Pârvu, 1997).
It is possible that *Ambrosia artemisiifolia* has been introduced accidentally with some cereals (Anastasiu & Negrean, 2007).

Table 1. Taxonomy, origin, and pathways of introduction of alien invasive species in the Land of Fagaras grasslands

Species	Family	Origin	Pathways of introduction
Amaranthus powelii	Amaranthaceae	NAm	Escaped from garden
Amorpha fruticosa	Fabaceae	NAm	Planted ornamental,
Robinia pseudoacacia	Fabaceae	NAm	Planted forestry, sand stabilization
Oenothera biennis	Onagraceae	NAm	Escaped from garden
Acer negundo	Aceraceae	NAm	Planted forestry, ornamental
Impatiens glandulifera	Balsaminaceae	As	Escaped from gardens
Echinocystis lobata	Cucurbitaceae	NAm	Escaped from gardens
Ambrosia artemisiifolia	Asteraceae	NAm	With some cereals
Erigeron annuus/ annuus	Asteraceae	NAm	Escaped from gardens
Erigeron canadensis	Asteraceae	NAm	Unknown
Galinsoga parviflora	Asteraceae	SAm	Escaped from gardens
Matricaria discoidea	Asteraceae	NAm	Escaped from gardens
Rudbeckia laciniata	Asteraceae	NAm	Escaped from gardens
Solidago canadensis	Asteraceae	NAm	Escaped from gardens
Solidago gigantea	Asteraceae	NAm	Escaped from gardens
Xanthium strumarium	Asteraceae	C, SAm	Accidentally

Legend: NAm - North America; C, SAm - Central, South America; As - Asia

After being introduced to Europe, *Robinia pseudoacacia* and *Amorpha fruticosa* were planted in Romania to stabilize sandy soils or along roads (Anastasiu & Negrean, 2007).
Xanthium strumarium, which is known in Europe since the XVI century (Săvulescu et al., 1964), was probably introduced accidentally as a contaminant.
Erigeron canadensis is known to have been introduced into Europe from North America in 1655, but there are no data on its pathways of introduction. Romania's data on the species originates from around 1814 (Săvulescu et al., 1964). Form of life and reproduction mode, pollination, and seeds dispersal type

The success of alien plants in new habitats depends on their flexibility in basic biological processes

Ten of the species are therophyte or hemitherophyte, which reproduce by seeds (Table 2). Some species include *Erigeron canadensis, Erigeron annuus, Oenothera biennis, Impatiens glanduligera, Galinsoga parviflora*, or *Matricaria discoidea* show a long period of flowering, from May to September. Other species - *Echynocystis lobata, Xanthium strumarium, Ambrosia artemisiifolia*, or *Amaranthus powelii*, have a flowering period during the second part of the summer (Sârbu et al., 2013).
The remaining species, which are six in number, are perennial. Three species - *Robinia pseudoacacia, Amorpha fruticosa,* and *Acer negundo* - are phanerophytes, and they reproduce vegetatively through root sprouts in addition to seeds.
The other species are herbaceous with rhizomes. For *Solidago* species, vegetative reproduction is more important than seed production.
Most of the species exhibit an entomophily type of pollination, without specialization on an insect or a group of insects in particular (Table 2). Furthermore, they can perform pollination with two agents, one principal and one

secondary (like wind). It's also possible the self-pollination (Wang et al., 2021).
Seed dispersal allows species to expand their range. Anemochory and zoochory are the preferred methods of dispersing the seeds (Table 2). Autochory is combined with other methods of dispersal, for example to *Galinsoga parviflora* or *Impatiens glanduligera*.
Regardless of the case, antropochory remains a major factor in the spread of invasive species, whether accidentally or intentionally (Warwick & Sweet, 1983).

Table 2. Form of life, reproduction, pollination, and seed dispersal mode of alien invasive species in the Land of Fagaras grasslands

Species	Form of life/ Reproduction mode	Pollination type	Seeds dispersal
Amaranthus powelii	T; sexual (seeds)	Anph/E	An/Aut/Z
Amorpha fruticosa	Ph; sexual (seeds) and vegetative (root sprouts)	E	Aut/ Z
Robinia pseudoacacia	Ph; sexual (seeds) and vegetative (root sprouts)	E	Aut/Z
Oenothera biennis	Th; sexual (seeds)	E	An/H
Acer negundo	Ph; sexual (seeds) and vegetative (root sprouts)	Anph	An/others
Impatiens glandulifera	T; sexual (seeds)	E	Aut/ others
Echinocystis lobata	T; sexual (seeds)	E	Aut
Ambrosia artemisiifolia	T; sexual (seeds)	Anph	Z
Erigeron annuus/ annuus	T; sexual (seeds)	E	An
Erigeron canadensis	T; sexual (seeds)	SP/E	An/ H
Galinsoga parviflora	T; sexual (seeds)	E	An/ Antrop/ Z
Matricaria discoidea	T; sexual (seeds)	E	An
Rudbeckia laciniata	H; sexual (seeds) vegetative (rhizome)	E	An
Solidago canadensis	H; vegetative (rhizome, stolon) sexual (seeds)	E	An
Solidago gigantea	H; vegetative (rhizome, stolon) sexual (seeds)	E	An
Xanthium strumarium	T; sexual (seeds)	Anph	Z

Legend: T - therophyte; Ph - phanerophyte; Th - hemitherophyte; H - hemicryptophyte; Anph - anemophily; E - entomophily; SP - self-pollinated; An - anemochory; Aut - autochory; Z - zoochory; H - hydrochory; Antrop - antropochory.

The frequency, density, and spatial distribution of populations of invasive alien species in the Land of Fagăraș grasslands

The analysis of the populations' frequency in the twelve localities reveals that there are differences between species: only *Erigeron annuus* populations are present in all the observed locations (Table 3). The next species with an obvious presence are *Impatiens glandulifera* and *Oenothera biennis*, whose populations were found in four locations. The remaining species are present in two (*Amorpha fruticosa, Robinia pseudoacacia, Erigeron canadensis, Matricaria discoidea, Xanthium strumarium*), or only one location (*Amaranthus powelii, Acer negundo, Rudbeckia laciniata, Galinsoga parviflora, Solidago canadensis, S. gigantea*).
The population sizes of the *Erigeron annuus* in different locations may comprise between 50-100 individuals, in some places even can be found populations with more than 100 individuals (in a wet grassland near Holbav we found populations made of 100-500 individuals) (Figure 2).

Figure 2. View of *Erigeron annuus* in Valea Lupului meadow

Impatiens glandulifera is the second-largest population, with 51-100 plants found in grasslands near Șinca Nouă (Figure 3).
In certain locations, large populations of *Echinocystis lobata* were found, such as at the edge of grasslands in relation to fringe water courses, like in Comăna de Jos or Grid.
Populations of over 50 plants were found for *Solidago* species, but they are in relation to farming lands that are near the grasslands, in Lisa or Comăna de Jos.
The rest of the inventoried species have small populations. They can range in size from one to 10 plants or up to 50 individuals (Figure 4).
We can talk about three situations regarding the spatial distribution of species: species that are part of grassland associations, like *Erigeron annuus* and *Impatiens glandulifera*; species that are found in disturbed places in grasslands or disarranged meadows, like *Oenothera biennis, Rudbeckia laciniata, Xanthium strumarium, Matricaria discoidea* or *Erigeron canadensis*; plants found in the vicinity of grasslands, towards roads, water courses, or crops around meadows, such as *Galinsoga parviflora, Amaranthus powelii, Ambrosia artemisiifolia, Robinia pseudoacacia, Solidago canadensis, Amorpha fruticosa, Echinocystis lobata,* or *Acer negundo*.

Figure 3. View of Impatiens glandulifera

Figure 4. View of *Oenothera biennis* in Copăcel meadow

Table 3. The frequency of populations of invasive alien species in the Land of Fagăraș grasslands

Species/Town	Șinca Nouă	Hălmeag	Vad	Toderița	Copăcel	Grid	Sebeș	Holbav	Lisa	Perșani	Șercaia	Comăna de jos
Amaranthus powelii	-	-	-	-	-	-	-	-	-	-	+	-
Amorpha fruticosa	-	-	-	-	-	+	-	-	-	-	+	-
Robinia pseudoacacia	-	-	-	-	-	+	-	-	+	-	-	-
Oenothera biennis	+	-	-	-	+	-	+	-	+	-	-	-
Acer negundo	-	+	-	-	-	-	-	-	-	-	-	-
Impatiens glandulifera	+	+	-	-	+	-	-	-	+	-	-	-
Echinocystis lobata	-	+	-	-	-	+	-	-	-	-	-	+
Ambrosia artemisifolia	-	-	-	-	-	-	-	-	-	-	+	-
Erigeron annuus subsp. *annuus*	+	+	+	+	+	+	+	+	+	+	-	+
Erigeron canadensis	-	-	-	-	-	-	-	-	+	+	-	-
Galinsoga parviflora	-	-	-	-	-	-	-	-	+	-	-	-
Matricaria discoidea	-	-	-	-	-	-	+	-	-	+	-	-
Rudbeckia laciniata	-	-	-	-	+	-	-	-	-	-	-	-
Solidago canadensis	-	-	-	-	-	-	-	-	+	-	-	-
Solidago gigantea	-	-	-	-	-	-	-	-	-	-	-	+
Xanthium strumarium	-	-	-	-	-	+	-	-	-	+	-	-

The invasivity and the potential impact of aliens' species on plant diversity from grasslands in the Land of Făgăraș

Among the possible successful causes of the invasion of *Erigeron annuus* populations in grasslands are entomophily pollination, self-, or cross-fertilization, and winged achene dispersed by wind and animals. According to Song et al. (2018), the dominance of *E. annuus* in recently reclaimed areas or disturbed zones is not due to the morphological or biological advantages of this species, such as seed germination, seedling growth, allelopathy, photosynthesis or resistance to disturbance, but to repeated mowing. They stressed the importance of finding the best timing and establishing a frequency of mowing since *E. annuus* begins to bloom earlier than other species. A risk analysis of the invasive potential of allogenic species in the South of Transylvania shows that *E. annuus* has the highest potential for distribution (Zimmermann et al., 2015). The spread of *E. annuus* is mainly due to abandoned farmlands and changes in land use. Proper management and mowing, adapted to land characteristics, can be used to prevent this species from invading the grasslands.

The increase in the distribution area of *Impatiens glandulifera* was attributed to the larger number of seeds produced by a single plant, over 4000, and the specific autochoric spread of the seeds, which reached a distance of 7 m (Helmisaari, 2010). The hydrochory and anthropochory also contributed to the massive presence of the species in the grasslands near the fringe of water courses. It is important to pay attention to the biology of the species and their spring germination.

Other species that prefer wet habitats, such as *Rudbeckia laciniata*, *Oenothera biennis*, and *Echinocystis lobata*, rely on the hydrochory. They enhanced the bank seeds, which became a source for allochthone species in nearby meadows. Monitoring the banks of water courses and occasionally removing patches of vegetation with invasive species could contribute to preventing their spread and allowing native vegetation to regenerate (Jędrzejczak et al., 2022).

Allelopathic effects (Lorenzo et al., 2011) and anthropogenic activity could contribute to the growth of distribution areas for some species such as *Xanthium strumarium, Matricaria discoidea, Galinsoga parviflora, Amaranthus powelii, Ambrosia artemisiifolia, Amorpha fruticosa, Solidago canadensis* or *Erigeron canadensis*. Some of them are related to agricultural land use and crop plants (Figure 5) but they may also extend to grasslands where traditional management is no longer applied.

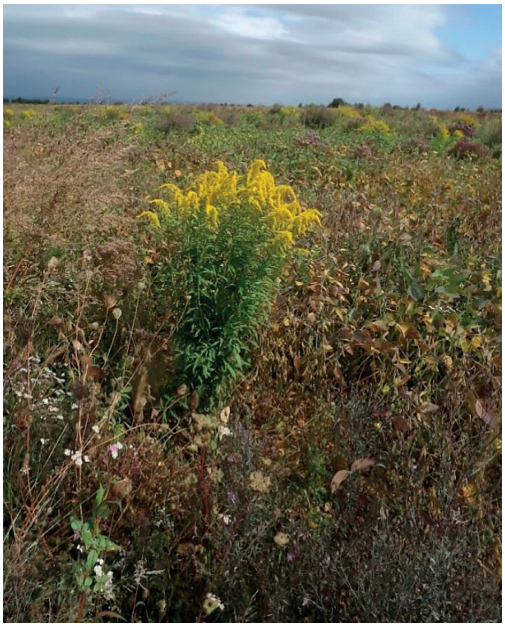

Figure 5. *Solidago canadensis*, *Xanthium strumarium*, and *Erigeron annuus* in a soibean crop in Lisa area

CONCLUSIONS

Of the sixteen species found around grasslands of the Land of Fagaras, four are found mixed with species from the original vegetal associations.

A significant source of infestation is represented by populations of alien species installed on the watercourse banks.

Besides the morphological and biological characteristics of the species, the invasion success is backed up by the anthropic activity and management of the land.

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