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Journal homepage: asn.shu.bg**Invasive alien plant species distributed as weeds in arable land in Bulgaria****Dimcho Zahariev, Nina Ivanova, Aishe Nasuf***University of Shumen Bishop Konstantin Preslavski,**Faculty of Natural Sciences,**115 Universitetska Str., 9700 Shumen, Bulgaria*

Abstract: 26 species of invasive alien plant species enter the arable land in Bulgaria as weeds. Some of these species are already causing economic damage and are included in the list of the 100 most economically important weeds. For others, it is only a matter of time before they are included in this list. Possessing a complex of qualities, they spread quickly and aggressively, occupying new areas and settling permanently in them. As artificial habitats in which there is no permanent vegetation, arable land is one of the easiest terrains to invade. The study examines the biological characteristics that determine the invasive nature of this group of plants, their origin, distribution routes, weed crops and control measures that can be taken. Particular attention shall be paid to the additional effects that these species may have on human health, on cultivated crops and on natural habitats located in the neighborhood.

Keywords: invasive species, origin, distribution, reproduction, impacts, weeds, control

Introduction

Invasive alien plant species are usually distinguished from weeds. The definition of an invasive species according to the International Union for Conservation of Nature (IUCN) is as follows: a species that is found in natural and semi-natural ecosystems or habitats and causes change and a threat to natural biodiversity [1]. In this sense, such species cannot be considered invasive within arable land. Their presence in

agroecosystems leads to the same negative effects as for other weeds [2], but the degree of impact of invasive alien plant species may be higher. The negative effects of their presence in the arable land are expressed in the following:

1. Decreased productivity. Competition with weeds leads to poorer nutrition, water supply and lighting of cultivated plants. In many cases, weeds also have an allelopathic effect.

2. Quality reduction. The protein content of alfalfa in weedy areas can fall below 10%, while with effective weed control it can exceed 20%.

3. Increase in diseases and pests. Weeds often prove to be carriers of pathogens or attract insects that attack cultivated plants.

4. Increasing the cost of production. The use of herbicides inevitably leads to increased production costs. Weeding leads to an increase in the costs of agronomic activities both during the growing season and after harvest.

The presence of invasive alien plant species in arable land poses no less risk to natural habitats. In the first place, arable land is proving to be one of the **most effective ways for the rapid spread of invasive species**. On the one hand, arable land occupies a large area, is interconnected and has access to road infrastructure, which is also one of the routes for the spread of invasive species. On the other hand, the produced products are transported over long distances and thus transport the seeds of invasive species to new territories.

Second, arable land is proving to be **rapidly increasing the population of invasive species**. This is especially easy if timely or adequate measures are not taken to control their numbers.

Third, arable land is a **base from which invasive species can enter neighboring natural habitats**.

With all this in mind, we believe that the presence of invasive alien plant species such as weeds in arable land should be approached with more care than weeds that are part of the country's natural flora.

So far, an inventory of invasive and potentially invasive alien plant species in Bulgaria has been made [3], as well as of alien plant species as part of the plant composition in the periphery of arable land [4].

The purpose of this study is to make an inventory of invasive alien plant species that enter the arable land in Bulgaria as weeds. In this regard, the biological features that determine their invasive nature will be considered; the origin; the roads for entering the arable lands; weed crops; the control measures that can be taken; other negative impacts are also indicated.

Materials and methods

The objects of study are invasive alien plant species that enter the arable land in Bulgaria as weeds. The origin of the species is presented according to the USDA, Agricultural Research Service, National Plant

Germplasm System [5]. According to Petrova et al., The biological features and the transfer of fruits and seeds are. [3]. The data for the maximum amount of formed seeds and the period for preserving the viability in the soil are according to: Petrova et al. [3], Bhowmik & Bandeen [6], Clements et al. [7], Costea & Tardif [8], Crop Science [9], Invasive Species Compendium [10], Victorian Resources Online [11], Warwick & Black [12], Warwick & Sweet [13], Weaver & Warwick [14]. According to Petrova et al. [3], Bogatsevska et al. [15, 16], Stancheva et al. [17], Tonev et al. [18, 19], Harizanov et al. [20] and Invasive Species Compendium [10]. The measures for struggle are according to Petrova et al. [3, 21].

Results and discussion

Taxonomic diversity

As a result of the study, 26 species from 18 genera and 10 families of invasive alien plants were identified, which enter the arable land in Bulgaria as weeds. For comparison, in the periphery of arable land, the authors identified 20 species of invasive and potentially invasive alien plant species [4], of which only 10 species are identical to those described in our study. A complete list of species is presented in a special appendix at the end of the article.

In terms of taxonomic status, the largest number of species belongs to the family Asteraceae (12 species). With a smaller number of species are the families Poaceae (4 species) and Amaranthaceae (3 species). The other families are represented by one species.

The largest number of species belongs to the group of annual late spring weeds (19 species). Very often they cause secondary weeding of crops. Next in number of species are perennial rhizome weeds (4 species). Only one species have annual winter-spring weeds, perennial weeds with creeping stems and complete parasites (stem parasites) (see Appendix).

Qualities that cause rapid invasion

Invasive plants have a number of qualities that allow them to quickly and efficiently spread and increase populations:

Unpretentiousness of habitat conditions. Such plants usually belong to the group of pioneer species that rapidly colonize habitats with disturbed or missing vegetation cover. Such species are, for example *Erigeron annuus* (L.) Desf., *E. canadensis* L. and *Xanthium italicum* Moretti.

Lack of dormancy of seeds. The seeds of *Erigeron bonariensis* L. and *Galinsoga parviflora* Cav. are able to germinate immediately after ripening.

Lack of special requirements for seed germination. The seeds of *Galinsoga parviflora* Cav. are able to germinate and form viable individuals in a wide variety of environmental conditions [13].

Fast growth. Some species can grow very quickly after seed germination and complete their vegetative development in a very short time. Such species are, for example, *Chenopodium ambrosioides* L. and *Galinsoga parviflora* Cav. [3, 22].

Early flowering. In this case, the formation of flowers begins shortly after germination. In *Galinsoga parviflora* Cav. the first flowers appear in the period 41-60 days after germination [13].

Self-compatibility. Some plants can reproduce even in the absence of other specimens of the same species. This is the reason for their spread even in cases where only single seeds have been transferred. Examples of such species are: *Erigeron canadensis* L., *Erigeron sumatrensis* Retz. and *Xanthium italicum* Moretti.

Several generations for one growing season. As a result of rapid growth and early flowering, some species are able to form several generations in just one growing season. Such are, for example, the species of the genus *Amaranthus* L., *Chenopodium ambrosioides* L. and *Galinsoga parviflora* Cav. [3, 22].

High seed productivity per individual. Of the identified species such are: *Panicum dichotomiflorum* Michx. (up to 500,000 seeds per individual), *Amaranthus albus* L. and *Galinsoga parviflora* Cav. (up to 400,000 seeds per individual), *Erigeron sumatrensis* Retz. (up to 200,000 seeds per individual) [3, 8, 13].

Possibility for easy vegetative propagation. Weeds with underground stems modified into rhizomes, such as *Sorghum halepense* (L.) Pers. The mechanical cutting of the rhizomes during plowing leads to the activation of part of the dormant buds along their length and to the production of a large number of new stems. *Oxalis corniculata* L is propagated vegetatively by creeping stems that take root in the nodes. The detached stems are easily rooted in *Galinsoga parviflora* Cav.

Natural propagation of seeds over long distances. Most often this is done through devices for propagation by wind (anemochoria). Such are, for example, the species of the genus *Erigeron* L., genus *Galinsoga* Ruiz & Pav. and *Asclepias syriaca* L.

In addition, some other qualities can complement and even enhance the impact of those already mentioned. Such a quality is the preservation of the viability of the seeds for a long period of time. Eg. in *Ambrosia artemisiifolia* L. and *Datura stramonium* L. the seeds can remain viable in the soil for up to about 40 years, and in *Panicum capillare* L. - for up to 47 years.

Reproduction

All species reproduce by seed. Only 23.1% of invasive species can reproduce vegetatively. This includes all perennial species: *Asclepias syriaca* L., *Oxalis corniculata* L., *Paspalum distichum* L., *Phytolacca americana* L. and *Sorghum halepense* (L.) Pers. The parasitic species *Cuscuta campestris* Yunck can also reproduce vegetatively from annual plants.

Although they cannot reproduce vegetatively, the resistance of annual invasive species consists in the ability to form lateral branches when the main stem is removed. They reach a shorter length and the period of flowering and fruiting is shorter. An important device for survival in these weeds is the ability to grow new stems in a horizontal direction. Usually these stems are close to the soil surface. In *Ambrosia artemisiifolia* L., which forms unisexual flowers, in this case mainly female flowers are formed on the lateral branches, which increase seed productivity.

Origin

According to their origin, most of the invasive species come from North America (21 species). Of these, 12 species originate only from North America (Fig. 1), 7 species originate simultaneously from North and South America, 1 species originate from North and Central America and 1 species originate from North America and Northeast Asia. Approximately half of the species are native to South America (11 species). Of these, 7 species originate simultaneously from North and South America, 3 species originate only from South America and 1 species originate from Central and South America. Only one species originates outside America - *Sorghum halepense* (L.) Pers., which originates from North Africa, West, Central and Tropical Asia.

Number of species

Fig. 1. Distribution of invasive species by origin: 1. North America, 2. North and South America, 3. South America, 4. North and Central America, 5. Central and South America, 6. North America and Northeast Asia, 7. North Africa, West, Central and Tropical Asia

Ways to enter the arable land

The spread of invasive plant species in arable land is due to a number of different reasons. They are usually several for one plant species. Therefore, the values below are many times higher than 100%.

The safest way for invasive plants to enter arable land is through poorly cleaned seeds for sowing. This is also one of the most effective ways to spread invasive species in a new arable area, in a new country or even in a new continent. For 76.9% of the identified species there is data that they are distributed in this way. Such are, for example, the species of the genus *Amaranthus* L., *Cuscuta campestris* Yunck. and *Oxalis corniculata* L.

One of the most common ways to transport invasive plants in arable land is through road infrastructure. Agricultural machinery and vehicles are particularly effective in this process. Fruits and seeds adhering to them can be transported over very long distances. In this way, all invasive plant species can potentially spread. For 50.0% of the identified species there are data for their distribution through agricultural machinery.

Air currents are an effective way to propagate light fruits and seeds or those that are equipped with suitable devices. Thus, 53.8% of invasive species are distributed. Such are, for example, the species of the genus *Erigeron* L., *Asclepias syriaca* L. and *Ambrosia artemisiifolia* L.

The transport of the seeds of invasive plants through the waterways is carried out both through constantly flowing waters - rivers, irrigation canals, and through temporarily flowing waters, obtained during the melting of snow or after heavy rainfall. In this way 50.0% of the species are distributed. For example: *Galinsoga parviflora* Cav., *Sorghum halepense* (L.) Pers., *Xanthium italicum* Moretti. As a result, they can often be found on the shores of water bodies.

Animals are also one of the very effective carriers of fruits and seeds. They participate in the spread of 46.2% of the identified invasive plants. Most often the transmission is carried out by birds, mammals and ants. With the help of birds, for example, species of the genus *Amaranthus* L., *Phytolacca americana* L., *Sorghum halepense* (L.) Pers. Mammals are involved in the spread of species of the genus *Xanthium* L., *Bidens frondosus* L., *Datura stramonium* L. Ants contribute to the spread of species such as *Euphorbia maculata* L. and *Sorghum halepense* (L.) Pers.

The reasons for the establishment of invasive species in arable land are different:

1. Lack of preventive measures. This leads to the emergence and permanent establishment of invasive alien plant species in arable land.
2. Untimely or improper tillage that is ineffective or leads to increased weeding.
3. Improper application or use of inappropriate herbicides.
4. Improper crop rotation.

In our field research we found arable land with an extremely high percentage of weed cover due to lack of cultivation during the last marketing year. The most impressive example is arable land near the village of Petko Karavelovo, Veliko Tarnovo region, weeded with *Sorghum halepense* (L.) Pers. with coverage of about 90% (Fig. 2).

Fig. 2. Arable land weeded with *Sorghum halepense* (L.) Pers.

Crops that are attacked by weed

The Guidelines for Integrated Pest Management in Different Crops, issued by the National Plant Protection Service [15-20], list 8 species out of a total of 26 species of invasive alien plants that enter in the arable land in Bulgaria as weeds. The distribution of 26 invasive species as weeds, presented by crop groups [3, 10, 15-20], is as follows:

Erigeron canadensis L., *Sorghum halepense* (L.) Pers. – cereals (wheat, barley). *Matricaria discoidea* DC is also a potential species, because the native species *Matricaria chamomilla* L. is a weed.

Amaranthus albus L., *Amaranthus hybridus* L., *A. retroflexus* L., *Datura stramonium* L., *Erigeron canadensis* L., *Galinsoga parviflora* Cav., *Sorghum halepense* (L.) Pers., *Xanthium italicum* Moretti – cereals (maize).

Amaranthus retroflexus L., *Sorghum halepense* (L.) Pers. – legumes (beans, lentils).

Amaranthus albus L., *A. hybridus* L., *A. retroflexus* L., *Sorghum halepense* (L.) Pers. – legumes (peas).

Amaranthus retroflexus L., *Datura stramonium* L., *Sorghum halepense* (L.) Pers., *Xanthium italicum* Moretti – legumes (soybeans).

Amaranthus albus L., *A. retroflexus* L., *Datura stramonium* L., *Erigeron canadensis* L., *Galinsoga parviflora* Cav., *Sorghum halepense* (L.) Pers., *Xanthium italicum* Moretti – vegetable crops grown in the field.

Amaranthus retroflexus L., *Sorghum halepense* (L.) Pers. – vine and berry crops.

Amaranthus retroflexus L., *Galinsoga parviflora* Cav., *Sorghum halepense* (L.) Pers. – berry crops (strawberries, raspberries).

Amaranthus retroflexus L. – berry crops (blackcurrants).

Amaranthus retroflexus L., *Erigeron canadensis* L., *Sorghum halepense* (L.) Pers., *Xanthium italicum* Moretti – fruit crops.

Amaranthus albus L., *A. hybridus* L., *A. retroflexus* L., *Sorghum halepense* (L.) Pers., *Xanthium italicum* Moretti – technical crops (sunflower).

Amaranthus retroflexus L., *Sorghum halepense* (L.) Pers. – industrial crops (rapeseed).

Amaranthus retroflexus L., *Datura stramonium* L., *Sorghum halepense* (L.) Pers., *Xanthium spinosum* L. – technical crops (tobacco).

Amaranthus retroflexus L., *Sorghum halepense* (L.) Pers. – technical crops (beets).

Amaranthus retroflexus L., *Sorghum halepense* (L.) Pers., *Xanthium italicum* Moretti – technical crops (peanuts).

Amaranthus retroflexus L., *Erigeron canadensis* L., *Sorghum halepense* (L.) Pers. – fodder crops (alfalfa).

Of these species, two are particularly widespread as weeds in the listed groups of crops: *Amaranthus retroflexus* L. and *Sorghum halepense* (L.) Pers.

Summarizing the information from the available literature sources [3, 10, 15-20], it can be seen (Fig. 3) that the largest number of invasive alien plants enter as weeds in the arable land occupied by cereals (21 species) and vegetable crops (15 species).

Measures to combat

The most commonly applied measures to control invasive weed species belong to two groups: agrotechnical and plant protection. The agrotechnical measures for annual weeds include: basic tillage before sowing crops, soil cultivation, regular hoeing of trench crops, timely plowing of stubble, crop rotation. For perennial weeds are recommended: basic tillage before sowing crops, cultivation, disking with rhizome removal, rotation of winter and spring cereals.

The plant protection measures for all groups of weeds are recommended to be taken before the ripening of weed seeds.

The most effective results are obtained by combining measures from both groups. Special attention must be paid to preventive measures to control invasive plant species in order to prevent them from entering arable land.

Fig. 3. Distribution of invasive species by groups of weed crops

Other negative effects

On human health. Some of the invasive species can be dangerous in contact with them, and others - by inhaling volatile substances or pollen during flowering. These are 6 of the described invasive species. The whole plant, including the seeds of *Datura stramonium* L., is highly poisonous. The pollen of *Ambrosia artemisiifolia* L. has a strong allergenic effect and can cause hay fever, rhino-conjunctivitis, asthma, and less frequently contact dermatitis and urticaria. The pollen of *Iva xanthiifolia* Nutt. and contact with the plant can cause an allergic reaction. The milky juice of *Asclepias syriaca* L. in direct contact can cause contact

dermatitis. The essential oil of *Chenopodium ambrosioides* L. can cause contact dermatitis and is dangerous to inhale [3]. The contact with *Erigeron annuus* (L.) Desf. can cause contact dermatitis [23].

On the health of cultivated plants. Some invasive species (11 species) are resident hosts of viruses, bacteria or fungal phytopathogens that cause diseases on cultivated plants. The carrier of viruses in different crops is *Phytolacca americana* L., and the carrier of viruses in vegetable crops is *Erigeron canadensis* L. The carrier of bacteria in different crops is *Sorghum halepense* (L.) Pers. Carriers of both viruses and bacteria in different cultures are: *Amaranthus albus* L., *A. hybridus* L., *A. retroflexus* L., *Datura stramonium* L. and *Xanthium italicum* Moretti. *Galinsoga parviflora* Cav is a carrier of viruses and bacteria that cause diseases in vegetable crops. Intermediate hosts of fungal phytopathogens causing diseases on cultivated plants are *Chenopodium ambrosioides* L. and *Euphorbia maculata* L. [10, 15, 16].

On the natural habitats located next door. Characteristic of all described invasive species is their preference for habitats in which the vegetation does not form a dense cover. For this reason, the natural habitats in which they are housed and registered so far have the same characteristics. In them they can form dense groups and in some places completely displace the local natural flora. 12 species belong to this group. Most species prefer riparian habitats: *Ambrosia artemisiifolia* L., *Asclepias syriaca* L., *Bidens frondosus* L., *Galinsoga parviflora* Cav., *G. quadriradiata* Ruiz. & Pav., *Iva xanthiifolia* Nutt., *Panicum dichotomiflorum* Michx., *Paspalum distichum* L. and *Xanthium italicum* Moretti. On sand dunes are found: *Erigeron canadensis* L., *E. sumatrensis* Retz. and *Xanthium italicum* Moretti. Only *Sorghum halepense* (L.) Pers. can be sustainably housed in grassy habitats [3].

Conclusions

The presence of invasive alien plant species such as weeds in arable land in Bulgaria requires special treatment. Unlike other weeds, they pose a threat to natural habitats located adjacent to arable land. It is necessary to monitor both their species diversity and their numbers. Taking measures to control their numbers is best based on an integrated approach.

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Appendix

List of invasive alien plant species that enter the arable land in Bulgaria as weeds

Degree of danger: 1. In the list of the 100 most economically important weeds in Bulgaria [21]. 2. In the list of the most dangerous invasive alien species threatening biodiversity in Europe [25]. 3. In the list of invasive species of European and Mediterranean Plant Protection Organization (EPPO) [24]

Name of the species	Family	Weed group	Degree of danger		
			1	2	3
<i>Amaranthus albus</i> L.	Amaranthaceae	Annual late spring			
<i>Amaranthus hybridus</i> L.	Amaranthaceae	Annual late spring			
<i>Amaranthus retroflexus</i> L.	Amaranthaceae	Annual late spring			
<i>Ambrosia artemisiifolia</i> L.	Asteraceae	Annual late spring		*	*
<i>Asclepias syriaca</i> L.	Apocynaceae	Perennial rhizomatous			
<i>Bidens frondosus</i> L.	Asteraceae	Annual late spring		*	*
<i>Chenopodium ambrosioides</i> L.	Chenopodiaceae	Annual late spring			
<i>Cuscuta campestris</i> Yunck.	Convolvulaceae	Complete parasites (stem parasites)			
<i>Datura stramonium</i> L.	Solanaceae	Annual late spring			
<i>Erigeron annuus</i> (L.) Desf.	Asteraceae	Annual late spring			
<i>Erigeron bonariensis</i> L.	Asteraceae	Annual late spring			
<i>Erigeron canadensis</i> L.	Asteraceae	Annual late spring			
<i>Erigeron sumatrensis</i> Retz.	Asteraceae	Annual late spring			
<i>Euphorbia maculata</i> L.	Euphorbiaceae	Annual late spring			
<i>Galinsoga parviflora</i> Cav.	Asteraceae	Annual late spring			
<i>Galinsoga quadriradiata</i> Ruiz. & Pav.	Asteraceae	Annual late spring			
<i>Iva xanthiifolia</i> Nutt.	Asteraceae	Annual late spring		*	
<i>Matricaria discoidea</i> DC.	Asteraceae	Annual winter-spring			
<i>Oxalis corniculata</i> L.	Oxalidaceae	Perennials with creeping stems			
<i>Panicum capillare</i> L.	Poaceae	Annual late spring			

<i>Panicum dichotomiflorum</i> Michx.	Poaceae	Annual late spring			
<i>Paspalum distichum</i> L.	Poaceae	Perennial rhizomatous			*
<i>Phytolacca americana</i> L.	Phytolaccaceae	Perennial rhizomatous			
<i>Sorghum halepense</i> (L.) Pers.	Poaceae	Perennial rhizomatous			
<i>Xanthium italicum</i> Moretti	Asteraceae	Annual late spring			
<i>Xanthium spinosum</i> L.	Asteraceae	Annual late spring			

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