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Invasive plants in North America: a view from Ukraine

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Abstract: A biogeographical approach requires studying invasive plants within their native and synanthropic ranges, which has implications for the general theory of invasiveness and prediction/prevention of invasions. Many plant species native to Eastern Europe, and Ukraine in particular, are currently invasive elsewhere, including North America. However, 'weed exchange' between North America and Eastern Europe remains insufficiently studied, as well as its ecological factors. A preliminary assessment and analysis have been made of lists of plant species officially recognized as invasive in the US and Canada (national and state/province levels) and native to Ukraine. There are at least 120 such species, including 84 most important taxa shortlisted for the analysis. Some of them belong to taxonomically complicated groups (species of *Euphorbia, Centaurea, Vincetoxicum* etc.) and are among worst invaders (species of *Centaurea, Lepidium, Euphorbia, Lythrum* etc.). Families Asteraceae and Poaceae are most numerously represented (16.7% and 10.7%, respectively). A research overview for a comprehensive analysis of native Ukrainian plants considered invasive in North America is outlined, including aspects of their ecology, taxonomy, geography, patterns of invasions and invasiveness factors (based on phytoindication approaches and climatic models), and possible implications for biocontrol.

Key words: invasive plants, North America, Eastern Europe, invasiveness, biogeography

1. Introduction

Biotic invasions are considered among the highest global priorities in biodiversity conservation, agriculture, forestry and other sectors (Chornesky & Randall 2003; McNeely *et al*. 2001; Olden *et al*. 2004). Invasive species are probably the second most important threat to biodiversity, following only the loss of habitats (Convention on Biological Diversity, 1994). Strategies to combat and control invasive alien species (IAS) of plants have been developed at the global scale (Global Strategy on Invasive Alien Species: McNeely *et al*. 2001), in Europe (European Strategy on Invasive Alien Species: Genovesi & Shine 2003) and in many countries.

In North America such strategies, programs and approaches were developed and partly implemented in the United States and Canada nationwide, and also in various states, provinces, territories, sectors and agencies (USDA, Forest Service, Department of Interior, National Invasive Plants Council, The Nature Conservancy, etc.). Such interest to invasive species in North America is caused by their considerable economic and environmental impact (Pimentel *et al*. 2000; U.S. Congress, Office of Technology Assessment 1993; Stohlgren *et al*. 2003; Simberloff 2005).

Ukraine is the second largest European country (following the European part of Russia), which stretches 1 316 km from west to east (22° to 40° E) and about 900 km from north to south (44° to 52° N), with the total land area of 603,550 square km and population of about 47 million people. The country is subdivided into 26 administrative regions (in Ukrainian: 'oblasts'), 2 cities of special status (Kiev and Sevastopol) and the Autonomous Republic of Crimea (Protopopova *et al*. 2006). Estimations of the number of vascular plant species of Ukraine vary greatly, depending on the species concepts and circumscriptions applied by various authors, inclusion/exclusion of native, cultivated and escaped, and other categories of species, and due to other factors. The recent checklist of vascular plants of Ukraine (Mosyakin & Fedoronchuk 1999) lists about 6,000 species (including native, introduced, escaped and most commonly cultivated taxa). The total number of alien species of vascular plants was estimated by Protopopova *et al*. (2002, 2003, 2006) at 830 species (data of the end of 2001). Thus, this territory is rather rich and diverse

in terms of its flora, vegetation, climatic and physiographic conditions.

Because of that it is not surprising that many plant species native to Eastern Europe, and Ukraine in particular, are currently invasive elsewhere, including North America. Successful invasions of native Ukrainian (and East European) plants are possible due to many factors, but mainly because of the ecoclimatic matches, or similar climatic and physiographical conditions of the source areas (native ranges) and the secondary (anthropic) ranges. Several vast ecoclimatic, regions and vegetation zones of North America (Bailey 1978; Brouillet & Whetstone 1993; Barbour & Christensen 1993; Ecological regions of North America 1997) closely resemble various physiographic and vegetational zones of Ukraine (Didukh *et al*. 2000), from boreal and mixed forests in the north to forest-steppe and steppe zones, mountain areas of the Carpathians and Crimea and down south to the sub-Mediterranean Crimean South Coast.

However, the patterns and processes of 'weed exchange' between North America and Eastern Europe remain insufficiently studied, as well as ecological factors facilitating the invasions. In particular, Ukrainian botanists paid much attention to invasions of North American plants in Ukraine (Protopopova 1973, 1991; Protopopova *et al*. 2006 and references therein), there are also relevant publications by Polish researchers (e.g., Sowa & Warcholińska 1992) and authors from other countries adjacent to Ukraine, as well as others (Brock *et al*. 1997; Lambdon *et al*. 2008 and references therein). However, much less attention was given by European, and particularly Ukrainian, botanists to the reverse process of invasions of plants native to Ukraine in North America, especially from the viewpoint of the biogeographical approach and studies of the relevant taxa within their native ranges. In many cases the invasive plants causing problems in North America are rather common in Ukraine, but their exact distribution patterns, abundance, participation and a role in native, altered and man-made plant communities as well as the range of habitats and ecological conditions are often insufficiently known. Paradoxically, sometimes we observe evident lack of data even for common and widespread species, probably partly because of their seeming triviality. The proposed research plan will, hopefully, partially close this gap for some invasive plants native to Ukraine.

A biogeographical approach to the problem of plant invasions definitely requires studying invasive plants within both their native and synanthropic ranges. Hierro *et al*. (2005) emphasized that *"...the overwhelming majority of studies on exotic plants have been conducted solely within the introduced range. With few exceptions, ecologists know surprisingly little about the abundance, interaction strengths and ecosystems impacts of even the best-studied exotics in their native range*". Consequently, comparative biogeographical approaches are required for testing the main hypotheses of invasiveness. Other authors also consider parallel and comparative ecological studies on invasive plants within their native and introduced ranges among priorities in invasion ecology and biological control, as well as for predicting invasions and potential ranges of invasive plants (Jäger 1988; National Research Council 2002; Pyšek *et al*. 2004). Search for efficient biocontrol agents is also impossible without surveys within the native ranges.

Here I provide results of a preliminary assessment and analysis of lists of plant species officially recognized as invasive in the US and Canada (national and state/province levels) and native to Ukraine.

2. Material and methods

Data on lists of invasive plant species of the United States were taken from the PLANTS Database of the United States Department of Agriculture (USDA) available at http://plants.usda.gov/index.html. Relevant lists of Canadian invasives were obtained from the web site of the Canadian Botanical Conservation Network at http://www.rbg.ca/cbcn/en/projects/invasives/i_list.html. Other published and web sources were consulted as well. The preliminary list of native Ukrainian species considered invasive in North America included at least 120 such species, which were then shortlisted for the present analysis.

The principles of and criteria for selecting taxa for the analysis were as follows:

- Plants native to Ukraine; some taxa, however, are suspected archaeophytes in our area. I excluded from the list all proven archaeophytes, widely cultivated and escaped plants, species with rare or limited distribution in Ukraine and taxa with limited invasion success in North America.
- Plants officially recognized as invasive in North America
  - at the national/federal/regional level
  - at the state/province/territory level (at least in one geographical unit, with some exceptions)
  - with proven invasion success and/or current invasion trend
- Special attention was given to taxonomically complicated groups and priority taxa for biocontrol.

Nomenclature and circumscription of taxa mostly follow the checklist by Mosyakin & Fedoronchuk (1999).

3. Results

3.1. General patterns of the most important plants native to Ukraine and considered invasive in North America

The resulting shortlist of taxa for the analysis includes 84 plant species belonging to 66 genera and 38 families.

Among these plants there are such important invasives as: *Lythrum salicaria*, several species of *Centaurea* L. *sensu lato* (e.g. *C. stoebe* sensu lato, *C. diffusa*), *Carduus* L., *Chondrilla* L., *Hieracium* L. *sensu lato* (incl. *Pilosella* Hill), *Vincetoxicum* Wolf, *Lepidium* L. sensu lato (incl. *Cardaria* Desv.), *Euphorbia* L. and many other genera. Some of these species belong to taxonomically complicated groups (species of *Euphorbia, Centaurea, Vincetoxicum,* etc.), which can be also seen as an indirect factor of their invasiveness. Taxonomic problems within a group can reflect active microevolutionary processes, high variability and flexible adaptability of plants to various environmental factors, which is especially well seen in the genus *Euphorbia* (Best *et al*. 1980; Radcliffe-Smith 1985; Crompton *et al*. 1988; 1990), where the vast synonymy of invasive species greatly outnumbers the synonymy of alien but non-invasive taxa.

The considered plant species native to Ukraine rarely behave expansively in native plant communities, in contrast to their clearly invasive behavior in North America. Thus, a question arises: Which ecological and other factors explain such patterns? Evidently, biogeographical and ecological approaches are closely related to the general theory of invasiveness and prediction/ prevention of invasions, which is extensively discussed in modern publications in plant invasions (Williamson & Fitter 1996; Rejmánek & Richardson 1996; Sax & Brown 2000; Prinzing *et al*. 2002; Hierro *et al*. 2005; Richardson & Pyšek 2006; Pyšek & Richardson 2007 and many others).

Table. 1. Distribution of the analyzed taxa by families (percentage and number of species)

Family	No. of species	%
Asteraceae	14	16.7
Poaceae	9	10.7
Brassicaceae	6	7.0
Scrophulariaceae	4	4.8
Ranunculaceae	3	3.6
Lamiaceae	3	3.6
Apocynaceae	3	3.6
Other families	42	50.0
Total	84	100.0

Families Asteraceae (14 highly invasive species) and Poaceae (9 species) are best represented (16.7% and 10.7%, respectively), followed by Brassicaceae (6 species or 7%) and Scrophulariaceae sensu lato (3 species, 3.6%), see Table 1. The leading position of Asteraceae is well expected, because representatives of this family are considered among worst invaders in many regions of the Globe (see an overview in: Pyšek 1997). This family is represented in the list by such taxa highly invasive in North America as *Carduus crispus*, *C. nutans sensu lato* (including related 'microspecies' or forms: *C. thoermeri*, *C. kondratjukii*, *C. attenuatus* etc.), *Centaurea diffusa*, *C. stoebe* ssp. *australis* (*C. maculosa* auct., *C. biebersteinii*, *C. micranthos*), *Chondrilla juncea sensu lato*, *Jacobaea vulgaris* (*Senecio jacobaea*), *Pilosella caespitosa* group (*Hieracium caespitosum*, *H. pratense* and related 'microspecies'), *Tanacetum vulgare* and others. Poaceae are represented in the list by *Anisantha tectorum* (*Bromus tectorum*), *Elytrigia repens*, *Phragmites australis* (Eurasian taxa alien in North America), etc.

Distribution of the analyzed taxa by main life forms is shown on Fig. 1. The low percentage of annuals (5 species or 6%) in the shortlist may look surprising, especially considering usually high figures for this group among other groups in many alien fractions of floras elsewhere, and especially among ephemerophytes. However, the reported data reflect, in my opinion, the higher invasive ability of herbaceous perennials and biennials, their higher persistence in various habitats and their ability to transform plant communities, which is usually higher than that of annuals. All these factors make herbaceous perennials and biennials more stubborn and noxious agricultural and environmental weeds, which is properly reflected in official lists of invasive species (the main sources of taxa for our list) and attention given to such species in biocontrol programs. It is worth mentioning that many target taxa actively surveyed for biocontrol programs in North America are either herbaceous perennials or biennials (e.g. *Vincetoxicum rossicum*, *Tanacetum vulgare*, *Leucanthemum vulgare sensu lato*, *Conium maculatum*, *Convolvulus arvensis*, *Echium vulgare*, *Verbascum* spp., *Rorippa* spp., etc.).

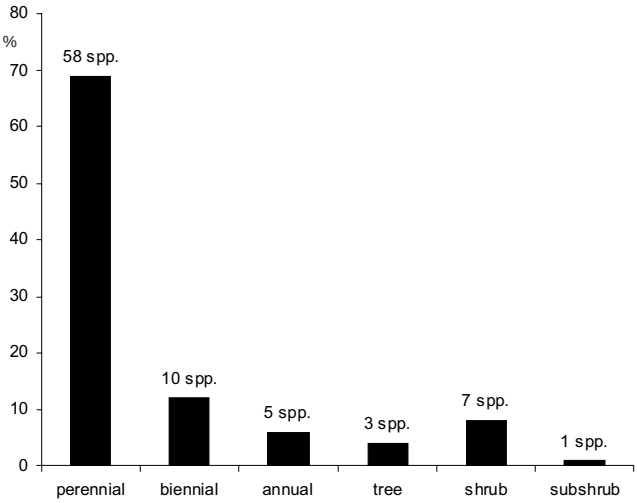

Fig. 1. Distribution of the analyzed taxa by main life forms (percentage and number of species)

The evident presence of aquatics in the list (6 species or 7%), including *Hydrocharis morsus-ranae*, *Myriophyllum spicatum*, *Nymphoides peltata* etc., is

rather expected because water plants easily adapt to conditions of various geographical areas due to essential similarity of the aquatic environment elsewhere. However, aquatic invasions are rather specific phenomena, and thus they mainly come beyond the scope of the present research.

Taxa with rather wide geographical ranges clearly dominate in the list. Moreover, at least 44 of the 84 analyzed taxa (or 52%) are considered synanthropic in Ukraine (listed in Protopopova 1991, with some corrections and additions), i.e., within their native ranges. It also reflects the concept that synanthropic behaviour of a species in its native range is a prerequisite for its invasive ability in the secondary range. However, many species considered non-synanthropic or occasionally synanthropic in Ukraine may behave as environmental weeds in North America, becoming completely naturalized in natural or semi-natural plant communities (apophytes). Consequently, the worst environmentally invasive species invading natural habitats may be considered non-synanthropic in their source areas; good examples are aquatic species.

3.2 Research needs and priorities

In the course of the preliminary assessment, a research overview was outlined for a comprehensive analysis of native Ukrainian plants considered invasive in North America, including aspects of their ecology and phytosociology, taxonomy, geography, patterns of invasions and invasiveness factors (based on phytoindication approaches and climatic models) and possible implications for biocontrol.

The main goal of the ongoing PhD research projects is to provide a comprehensive analysis of native Ukrainian plants considered invasive in North America, including aspects of their ecology and phytosociology, taxonomy, geography, patterns of invasions and invasiveness factors (based on phytoindication approaches and climatic models), and possible implications for biocontrol.

Research needs, priorities and objectives were formulated as follows:

- Compiling a comprehensive annotated checklist of taxa, with generalized data on their taxonomy, distribution and ecology;
- Mapping of target taxa (distribution in Ukraine and adjacent areas);
- Identification of most important invasive species;
- Detailed research of selected target taxa (not more than 10 species) using methods of taxonomy, ecology, plant geography in cooperation with researchers of other countries;
- Assessment of ecological requirements and participation in plant communities of target plants within the native distribution range in Ukraine and adjacent areas; comparative analysis of distribution in Ukraine (and within the native range in general) and in North America;
- Predicting potential ranges and the scope of actually and potentially invasible plant communities within the secondary range;
- Identification of additional plants native to Ukraine having invasive potential in North America but not reported as invasive yet (potential threats).

The main data sources for the research project are: (*i*) field research that started in 2007; (*ii*) herbarium material of Ukrainian herbaria: the National Herbarium of Ukraine (KW) at the Kholodny Institute of Botany, other herbaria in Kiev (National Botanical Garden & Kiev University), Lviv (Institute of Ecology of the Carpathians and Lviv University), Donetsk (Donetsk Botanical Garden), Kherson (Kherson University), Odessa (Odessa University), Crimea (Nikita Botanical Garden & Agricultural University), as well as international herbaria; (*iii*) relevant literature, including East European sources almost unknown or unavailable in the West, and (*iv*) phytosociological and other databases maintained at the Kholodny Institute of Botany.

4. Conclusions

At least 120 plant species native to Ukraine and adjacent areas of Eastern Europe are officially considered invasive in North America north of Mexico (the US and Canada). Out of these plants, 84 highly invasive taxa belonging to 66 genera and 38 families were selected for the present analysis.

The pattern of their distribution by families clearly demonstrated the dominant role of representatives of Asteraceae, which is also observed in many other regions of the world. They are followed by Poaceae, which also belong to the worst invasives.

The dominant role of herbaceous perennials and biennials over annuals is probably explained by the higher invasive ability of herbaceous perennials and biennials, their higher persistence in various habitats and their ability to transform plant communities, which is usually higher than that of annuals.

Research needs and priorities for comprehensive studies of alien plants native to Ukraine and adjacent countries and invasive in North America are outlined.

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Appendix 1. A list of species native to Ukraine and considered invasive in North America

Name of species	Synonym	Family name	Life forms
Acer platanoides L.	-	Aceraceae	t
Acer pseudoplatanus L.	-	Aceraceae	t
Aegopodium podagraria L.	-	Apiaceae	p
Angelica sylvestris L.	-	Apiaceae	p
Anthriscus sylvestris (L.) Hoffmann	*Chaerophyllum sylvestre* L.	Apiaceae	a
Vincetoxicum rossicum (Kleopow) Barbar.	*Antitoxicum rossicum* (Kleopow) Pobed., *Cynanchun rossicum* (Kleopow) Borhidi	Apocynaceae (incl. Asclepiadaceae)	p
Vincetoxicum hirundinaria Medik	*Asclepias vincetoxicum* L., *Cynanchum vincetoxicum* (L.) Pers.	Apocynaceae (incl. Asclepiadaceae)	p
Vinca minor L.	-	Apocynaceae (incl. Asclepiadaceae)	p
Carduus acanthoides L.	-	Asteraceae	b
Carduus crispus L.	-	Asteraceae	b
Carduus nutans L. sensu lato	-	Asteraceae	b
Centaurea diffusa Lam.	-	Asteraceae	b
Centaurea jacea L.	-	Asteraceae	p
Centaurea stoebe L. subsp. *australis*	*Centaurea biebersteinii* D C., C. *stoebe* L. subsp. *micranthos* (Gugler) Hayek, Centaurea *maculosa* auct. non Lam.	Asteraceae	p
Chondrilla juncea L.	-	Asteraceae	p or b
Jacobaea vulgaris Gaertn.	*Senecio jacobaea* L.	Asteraceae	p
Onopordum acanthium L.	-	Asteraceae	b
Pilosella aurantiaca (L.) F. Schultz & Sch. Bip.	*Hieracium aurantiacum* L.	Asteraceae	p
Pilosella caespitosa (Dumort.) P. D. Sell & C. West group	*Hieracium caespitosum* Dumort., *H. pratense* Tausch	Asteraceae	p
Pilosella officinarum F. Schultz & Sch. Bip. group	*Hieracium pilosella* L. agg.	Asteraceae	p
Tanacetum vulgare L.	*Chrisanthemum tanacetum* Vis.	Asteraceae	p
Tussilago farfara L.	-	Asteraceae	p
Berberis vulgaris L.	-	Berberidaceae	s
Echium vulgare L.	-	Boraginaceae	b
Alliaria petiolata (Bieb.) Cavara & Grande	-	Brassicaceae	b
Berteroa incana (L.) DC.	-	Brassicaceae	a
Isatis tinctoria L. group	-	Brassicaceae	b
Lepidium latifolium L.	-	Brassicaceae	p
Rorippa amphibia (L.) Besser	-	Brassicaceae	p
Rorippa austriaca (Crantz) Besser		Brassicaceae	p
Butomus umbellatus L. (US + Canada)	-	Butomaceae	p
Campanula rapunculoides L. (incl. C. *neglecta* Besser, C. trachelioides M. Bieb.)	-	Campanulaceae	p
Gypsophila paniculata L.	-	Caryophyllaceae	p
Kali tragus (L.) Scop.	*Salsola tragus* L.; *S. iberica* (Sennen & Pau) Botsch., *S. ruthenic*a Iljin; *S. australis* auct., *S. kali* auct.	Chenopodiaceae	?
Convallaria majalis L.	-	Convallariaceae	p
Euphorbia cyparissias L.	-	Euphorbiaceae	p
Euphorbia esula L. species complex	*Euphorbia virgultosa* Klokov, *E. pseudovirgata* (Schur) Soó, etc.	Euphorbiaceae	p
Securigera varia (L.) Lassen	*Coronilla varia* L.	Fabaceae	ss
Sarothamnus scoparius (L.) Koch	*Cytisus scoparius* (L.) Link	Fabaceae	s
Hydrocharis morsus-ranae L.	-	Hydrocharitaceae	p
Hypericum perforatum L.	-	Hypericaceae	p
Iris pseudacorus L.	-	Iridaceae	p
Myriophyllum spicatum L.	-	Haloragaceae	p
Acinos arvensis (Schur) Dandy	*Clinopodium acinos* (L.) Kuntze	Lamiaceae	b
Ajuga reptans L.	-	Lamiaceae	p
Origanum vulgare L. sensu lato	-	Lamiaceae	p
Salvia pratensis L.	-	Lamiaceae	p
Lythrum salicaria L.	-	Lythraceae	p
Lythrum virgatum L.	-	Lythraceae	p
Nymphoides peltata (S. G.Gmel.) Kuntze	-	Menyanthaceae	p
Najas minor All.	*Caulinia minor* (All.) Coss. & Germ.	Najadaceae	a
Epilobium hirsutum L.	-	Onagraceae	p
Chelidonium majus L.	-	Papaveraceae	p

Plantago lanceolata L.	-	Plantaginaceae sensu stricto	p
Peganum harmala L.	-	Peganaceae	p
Aegilops cylindrica Host	-	Poaceae	a
Anisantha tectorum (L.) Nevsky	*Bromus tectorum* L.	Poaceae	a
Cynodon dactylon (L.) Pers.	-	Poaceae	p
Elytrigia repens (L.) Desv. ex Nevski	*Elymus repens* (L.) Gould, *Agropyron repens* (L.) Beauv.	Poaceae	p
Glyceria maxima (C. Hartm.) Holmb.	*G. aquatica* (L.) Wahlenb.	Poaceae	p
Nardus stricta L.	-	Poaceae	p
Phalaroides arundinacea (L.) Rausch.	*Phalaris arundinacea* L.	Poaceae	p
Phragmites australis (Cav.) Trin. ex Steud.	*Phragmites communis* Trin	Poaceae	p
Poa compressa L.	-	Poaceae	p
Rumex acetosella L.	-	Polygonaceae	p
Rumex crispus L.	-	Polygonaceae	p
Potamogeton crispus L.	-	Potamogetonaceae	p
Lysimachia nummularia L.	-	Primulaceae sensu lato (Myrsinaceae sensu stricto)	p
Lysimachia vulgaris L.	-	Primulaceae sensu lato (Myrsinaceae sensu stricto)	p
Ranunculus acris L.	-	Ranunculaceae	p
Ranunculus ficaria L.	*Ficaria verna* Huds	Ranunculaceae	p
Ranunculus repens L.	-	Ranunculaceae	p
Frangula alnus Mill.	*Rhamnus frangula* L.	Rhamnaceae	s
Rhamnus cathartica L.	-	Rhamnaceae	ss or t
Galium odoratum (L.) Scop.	*Asperula odorata* L.	Rubiaceae	p
Galium mollugo L.	-	Rubiaceae	p
Linaria genistifolia (L.) Mill.	-	Scrophulariaceae sensu lato	p
Linaria vulgaris Mill.	*Antirrhinum linaria* L.	Scrophulariaceae sensu lato	p
Verbascum thapsus L.	-	Scrophulariaceae sensu lato	b
Sparganium erectum L.	-	Sparganiaceae	p
Tamarix ramosissima L.	*Tamarix. odessana* Steven ex Bunge	Tamaricaceae	s or t
Viburnum lantana L.	-	Viburnaceae (Adoxaceae sensu lato)	s
Viburnum opulus L.	-	Viburnaceae (Adoxaceae sensu lato)	s
Zygophyllum fabago L.	-	Zygophyllaceae	p

Explanations: *taxa selected according to criteria discussed in the text of the article, a – annual, b – biennial, p – perennial, s – shrub, ss – subshrub, t – tree