

A preliminary study on arthropods as potential biological control agents for management of alien ornamental plants in Turkey

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SUMMARY

Alien ornamental plants have the potential to become invasive and biological control is considered a promising method for managing them. Global literature was searched to reveal the potential biological control agents for 56 ornamental plants which have invasion potential in Turkey. Out of the biological agents, we compiled the list of species already in Turkey which could be utilised in managing invasive species. Moreover, successful biological control agents for these plants from other parts of the world have also been listed. As a result, 128 species of arthropods were found as natural enemies and 27 of them were established in the released areas in the world. In Turkey, out of these 128 species, 58 were noted as present in Turkey, however, their impacts on plants have not been studied in detail. Potential biological agents for controlling invasive plants in Turkey are: *Carpomyia vesuviana* (Costa) for *Ziziphus mauritiana* Lam., *Rhizaspidiotus donacis* (Leonardi) for *Arundo donax* L., *Unaspis euonymi* (Comstock) for *Euonymus fortunei* (Turcz.) Hand.-Mazz., *Diaspis echinocacti* (Bouché) for *Opuntia ficus-indica* (L.) Miller, *Eulecanium ciliatum* (Douglas), *Lepidosaphes ulmi* (Linnaeus), *Melanaspis inopinata* (Leonardi) and *Phenacoccus aceris* (Signoret) for *Acer negundo* L. There is a possibility to use these biological agents for controlling the alien ornamental plants in Turkey, although there is a need for conducting further Pest Risk Assessment to assess the invasiveness of alien plants in Turkey, and studies are also required for safe release of beneficial insects.

Keywords: insect pests, Pest Risk Assessment, invasive alien plants, alien insects.

INTRODUCTION

Turkey is situated between Europe and Asia, and has an area of 783,562 km². It is surrounded by the Black Sea, Mediterranean Sea, and Aegean Sea, hence making it a country with very different altitudes, from the sea level to more than 5000 m a.s.l. These ecological characteristics result in a variation of climatic conditions in the country. Three different biogeographical regions, namely Europe Siberia (Kars-Erzurum plate), Iranian-Turan (from eastern part of Turkey to Middle Anatolia), and Mediterranean can be noted in Turkey. These biogeographic regions have different types of ecosystems, including transitions between zones. The most important ecosystems in Turkey are coastal, mountain, wetland, forest and marine ecosystems or their combinations, as well as disturbed croplands and semi-natural pastures and grasslands. The diversity of ecological characteristics provides suitable areas for thousands of species of fauna and flora, and their populations. Turkey's landscape and ecological diversity have contributed not only to a high floristic richness, but also to successful introductions of wild plants and cultivation of a great number of crops, forest trees and ornamental plants (Ercişli, 2004; Atalay et al., 2014).

Invasive alien plant species are an important issue globally due to their negative impacts on biodiversity, ecosystems and the economy (Rai and Singh, 2020; Pyšek et al., 2020; Barudanović et al., 2021). Ornamental plant species are often introduced due to their floristic elegance; however, they have a great potential of becoming invasive in the introduced areas (Niemiera and von Holle, 2009; Uludağ et al., 2013; van Kleunen et al., 2018). Some of them have the ability to spread and eventually become invasive, and consequently be a threat for the native biodiversity, meanwhile costing economies huge resources for their control.

The alien flora of Turkey has been documented within an international collaborative study and published on the Global Biodiversity Information Facility (GBIF) web site (Uludağ et al., 2017). There are 328 species listed, with 309 angiosperms, 17 gymnosperms and two ferns. Majority of the alien taxa (86%) were introduced intentionally, which highlights the importance of conducting risk assessments before plant introductions. Americas and Asia are the main origin continents of alien flora in Turkey.

Among alien species in Turkey, 60% (196 species) are ornamental wild plants according to the latest checklist (Uludağ et al., 2017). Most of them have been noted in restricted areas in Turkey, while some are already widespread. Certain species such as *Acacia mearnsii* De Wild., *Arundo donax* L., *Lantana camara* L., *Ulex europaeus* L., *Eichhornia crassipes* (Martius) Solms, and *Halophila stipulacea* (Forssk.) Asch. are among the 100 worst invasive alien species of the world. For preventing their invasions in the future and minimizing their harmful effects, quarantine measures must be taken and effective control methods should be applied in their naturalized areas in Turkey.

Biological control is one of the methods that are thought effective in controlling invasive species in some parts of the world. Insects and plant pathogens from the origin country of alien plants have been successfully used as biological control agents (Winston et al., 2014; Uludağ et

al., 2018; Hill et al., 2020). Some biological agents may provide an effective, environmentally friendly, and economic control of invasive plant species in Turkey.

In this study, the existing national and international literature was evaluated in order to reveal biological control agents that may prove efficient against the potentially invasive alien ornamental plant species in Turkey. Thus, this work will provide an insight into the possibilities for biological control agents of invasive plants in Turkey and show directions of future activities on this subject.

MATERIAL AND METHODS

Literature from various sources was searched and nearly 250 ornamental plant species with a foreign origin and currently found in Turkey were listed. Primary literature sources searched for this purpose were: Güner et al. (2012), Uludağ et al. (2017), CABI (2020a), EPPO (2020a), ISSG (2020) and TUBIVES (2020), as well as some journals: Turkish Journal of Botany, etc. Later, species in the list that were invasive in other countries (according to CABI, ISSG, EPPO) were separated into a new list (56 species given in Table 1) and information regarding their origin, location in Turkey, status, references, and distribution was added. The CABI Invasive Species Compendium (CABI, 2020a) was used as a reference to determine the origin and distribution of the species in the world, while their distribution in Turkey was determined according to Güner et al. (2012) and Turkish Plants Data Service (TUBIVES, 2020). The invasive potential of these species was determined according to a PRA prepared by EPPO or according to DS (Data Sheet) of species from different sources.

Another literature search was made on arthropods that can feed on alien species for Turkey, listed according to abovementioned literature. The literature used for this purpose included Biological Control of Weeds: A World Catalogue of Agents and Their Target Weeds (Winston et al., 2014) and the CABI and EPPO websites.. In order to find which of these natural enemies are present in Turkey, some journals were checked (Turkish Journal of Zoology and Turkish Journal of Entomology). This search resulted in 128 arthropod species that have been recorded worldwide on plants mentioned in Table 1. Only 58 of them have been recorded in Turkey so far. The host plants of these natural enemies and their distribution in Turkey was compiled (Table 2). Potential use of species as biological control agents in Turkey is classified as high, medium, or low if the agent was only aggressive and not polyphagous, neither aggressive nor polyphagous, or if only polyphagous, respectively.

RESULTS AND DISCUSSION

Among ornamental plant species recorded in Turkey, 56 have been invasive in other countries, among which 19 are trees, 13 shrubs, 10 herbs, seven aquatics, six climbers and one succulent species (Table 1). Most of them (2/3) are widespread in all continents, whereas

only three species are present in all regions of Turkey (Figure 1). Also, more than a half are naturalized in only one region of Turkey. The species listed in the Table 1 were also considered as potentially invasive for Turkey because of their invasiveness in other countries (i.e. if present in a similar biogeography). Some of these species have priority in terms of their invasiveness because they have been listed in the EPPO A2 list (*Eichhornia crassipes* (Martius) Solms), as well as EPPO invasive alien species list (*Ailanthus altissima* (Mill.) Swingle, *Amorpha fruticosa* L., *Buddleja davidii* Franch., *Carpobrotus edulis* (L.) N.E.Br., *Cortaderia selloana* (Schult. & Schult. f.) Asch. & Graebn., *Egeria densa* Planch., *Myriophyllum spicatum* L., *Solidago canadensis* L., *Sicyos angulatus* L.). Although listed in the EPPO A2 list, *Ludwigia peploides* (Kunth) P.H. Raven was ignored because of being casual in Turkey. Meanwhile, *Sicyos angulatus* L. could become invasive in Turkey.

Out of the 56 alien ornamental species (Table 1), five are already in the world's 100 worst invasive alien species: *Acacia mearnsii* De Wild., *Arundo donax* L., *Eichhornia crassipes* (Martius) Solms, *Lantana camara* L., and *Ulex europaeus* L. On the other hand, *Hydrocotyle ramiflora* Maxim. is among the seven ornamental aquatic species which has been introduced only in Turkey (CABI, 2020b), Caucasus, and Siberia (EPPO, 2020b).

Table 1. Information about ornamental plants alien in Turkey and invasive in other countries

Tabela 1. Informacije o alohtonim invazivnim ukrasnim biljnim vrstama u Turskoj i ostalim zemljama

No Br.	Alien Ornamental Plant Species in Turkey Alohtone ukrasne biljne vrste u Turskoj	Life Form ¹ Životna forma	Origin ^{2,3} Poreklo	Location in Turkey ⁴ Lokacija u Turskoj	Status ⁵ Status	World Distribution ² Raširenost u svetu
1	<i>Acacia dealbata</i> Link	T	C5	T4, NE T3	C	C1, C2, C3, C4, C5
2	<i>Acacia longifolia</i> (Andrews) Willd.	T	C5	T1	N	C1, C2, C3, C4, C5
3	<i>Acacia mearnsii</i> De Wild.	T	C5	T1	N	C1, C2, C3, C4, C5
4	<i>Acacia retinodes</i> Schldt.	T	C5	T1, T3, T4, T7	N	-
5	<i>Acacia saligna</i> (Labill.) H.L.Wendl.	T	C5	T1, T2, T3, T4, T7	N	C1, C2, C3, C4, C5
6	<i>Acer negundo</i> L.	T	C & N C3	T1, T3, T4, T7	N	C1, C2, C3, C4, C5
7	<i>Agave americana</i> L.	S	C C3	T1, T2, NE T3, T4	N	-
8	<i>Ailanthus altissima</i> (Mill.) Swingle	T	E C1 (China)	NE T3, C T4,	N	C1, C2, C3, C4, C5
9	<i>Amorpha fruticosa</i> L.	S	N C3	T1, NE T3, T4	C	C1, C3, C4
10	<i>Arundo donax</i> L.	S	C1, C2, C4	T1	N	C1, C2, C3, C4, C5
11	<i>Berberis thunbergii</i> DC.	S	C1 (Japan)	T1, T3, T4, T7	N	C1, C3, C4, C5
12	<i>Broussonetia papyrifera</i> (L.)	T	C1 (China)	T2, NE T3	N	C1, C2, C3, C4, C5
13	<i>Buddleja davidii</i> Franch.	S	C1(C & SW China)	T4	N	C1, C2, C3, C4, C5

14	<i>Carpobrotus edulis</i> (L.) N.E.Br.	H	S C2	T1	N	C1, C2, C3, C4, C5
15	<i>Citrus trifoliata</i> L.	T	C1 (China, Himalayas)	T2, E T4	N	-
16	<i>Cortaderia selloana</i> (Schult. & Schult.f.) Asch. & Graebn.	H	S C3	T3	C	C1 (Turkey), C2, C3, C4, C5.
17	<i>Dalbergia sissoo</i> DC.	T	C1	T1	C	C1, C2, C3, C4, C5
18	<i>Egeria densa</i> Planch.	A	S C3	NE T3, E T4	N	C1, C3, C4, C5
19	<i>Eichhornia crassipes</i> (Martius) Solms	A	S C3		N	C1, C2, C3, C4, C5
20	<i>Elatine ambigua</i> Wight	A	S C1	NE T3	N	C1 (Taiwan), C4 (Italy, Romania)
21	<i>Elodea canadensis</i> MICHAUX	A	N C3	NE T3	N	C1, C2, C3, C4, C5
22	<i>Elsholtzia ciliata</i> (Thunb. ex A. Murray) Hyl.	H	C & E C1	NE T3	N	C1, C3, C4
23	<i>Erigeron annuus</i> (L.) Pers	H	N C3	T4	N	C1, C3, C4
24	<i>Euonymus fortunei</i> (Turcz.) Hand.-Mazz.	S	C1 (China)	T4	N	C1, C3, C4, C5
25	<i>Ficus elastica</i> Roxb. Ex Hornem.	T	T C1, India, Malesia	T1	C	C1, C2, C3, C4, C5
26	<i>Ficus microcarpa</i> L.f.	T	C1, C5, Pacific region	T1	C	C1, C2, C3, C4, C5
27	<i>Grevillea robusta</i> A.Cunn. ex R. Br.	T	C5	T1	P	C1, C2, C3, C4, C5
28	<i>Hydrocotyle ramiflora</i> Maxim.	A	E C1 (Japan)	E T4	N	C1
29	<i>Ipomoea nil</i> (L.) Roth	C	S C3		N	C3 (Cuba)
30	<i>Ipomoea purpurea</i> (L.) Roth	C	T C3	Widespread	N	C1, C2, C3, C4, C5
31	<i>Ipomoea tricolor</i> Cav.	C	T C3	T3	N	C4 (Belgium, Romania)
32	<i>Lantana camara</i> L.	S	C & S C3	T4	C	C1, C2, C3, C4, C5
33	<i>Lonicera japonica</i> Thunb.	C	E C1 (China, Japan, Korea)	T4	C	C1, C2, C3, C4, C5
34	<i>Ludwigia peploides</i> (Kunth) P.H. Raven	A	S and C C3	T1	C	C1, C2, C3, C4, C5
35	<i>Melia azedarach</i> L.	T	S C1 (Pakistan, India)	T1, T2, , NE T3, T4, T6	N	C1, C2, C3, C4, C5
36	<i>Mesembryanthemum crystallinum</i> L.	SU	S N SW C2, W C1, S C4		N	C1, C2, C3, C4, C5
37	<i>Miscanthus sinensis</i> Andersson	H	E C1 (China, Japan, Korea)	T3	C	C1, C3, C4, C5
38	<i>Momordica charantia</i> L.	H	C2 & C5	Widespread	P	C1, C2, C3, C4, C5
39	<i>Myriophyllum spicatum</i> L.	A	C4, C1, C2		C	C1, C2, C3, C4, C5
40	<i>Nandina domestica</i> Thunb.	S	C1		C	C1, C2, C3, C4, C5

41	<i>Nicotiana glauca</i> Graham	S	S C3 (Argentina, Bolivia)	T1, T2	N	C1, C2, C3, C4, C5
42	<i>Opuntia ficus-indica</i> (L.) Miller	T	N C3 (Mexico)	T1, T4		C1, C2, C3, C4, C5
43	<i>Paulownia tomentosa</i> Steud.	T	E C1 (China)		C	C1, C3, C4, C5
44	<i>Ricinus communis</i> L.	S	N and E C2	T1, T2, NE & S T3, T4	N	C1, C2, C3, C4, C5
45	<i>Robinia pseudoacacia</i> L.	T	EN C3	T3, T4	N	C1, C2, C3, C4, C5
46	<i>Schefflera actinophylla</i> (Endl.) Harms	T	N C5	T1, T4, T3, T7	P	C1, C2, C3, C4, C5
47	<i>Solanum sisymbriifolium</i> Lam.	S	C3		N	C1, C2, C3, C4, C5
48	<i>Ulex europaeus</i> L.	S	W C4 (Atlantic maritime)	T3, NE T4	N	C1, C2, C3, C4, C5
49	<i>Phormium tenax</i> J.R.Forst. & G.Forst.	H	C5 (New Zealand)	T1	P	C1, C2, C3, C4, C5
50	<i>Solidago canadensis</i> L.	H	ES C3 (Mexico)	W T4	N	C1, C3, C4, C5
51	<i>Sicyos angulatus</i> L.	C	E C3	E T4	N	C1, C3, C4
52	<i>Tagetes minuta</i> L.	H	C C3	Widespread	N	C1, C2, C3, C4, C5
53	<i>Tradescantia fluminensis</i> Vell	H	S C3	NE T3, T4	N	C1, C2, C3, C4, C5
54	<i>Tecoma capensis</i> (Thunb.) Lindl.	C	C2	T4	C	C3
55	<i>Wisteria sinensis</i> (Sims) Sweet	C	E C1 (China)	T4	N	C1, C2, C3, C4, C5
56	<i>Ziziphus mauritiana</i> Lam.	T	S C C1 & E C1 (China)	T3, T4	N	C1, C2, C3, C4, C5

¹Plant form, A: Aquatic, C: Climber, H: Herb, S: Shrub, SU: Succulent, T: Tree

²Continents, C1: Asia, C2: Africa, C3: America, C4: Europe, C5: Australia (Oceania)

³Direction, N: North, S: South, E: East, W: West, C: Center T: Tropical

⁴Location, T1: Mediterranean, T2: Aegean, T3: Marmara, T4: Black Sea, T5: Eastern Anatolia, T6: South-East Anatolia, and T7: Central Anatolia.

⁵Status, C: Casual, N: Naturalized, P: Planted



Figure 1. Geographical regions of Turkey
Slika 1. Geografski regioni Turske

The number of natural enemies which have been recorded on ornamental plants that may act as their biological control agent in Turkey is 58 (Table 2). Some of these species were found on ornamental plants, while others were noted on other host plants. Most of these species belong to the order Hemiptera (48), followed by Hymenoptera (Güner et al., 2012). Two natural enemies were found from Diptera and Acari: Mesostigmata, while just one from Gastropoda. Out of the 58 recorded natural enemies, 23 were noted in only one geographical region of Turkey. Most of the recorded species (39) were found in the same region as the likely-invasive ornamental plants (Table 2).

Table 2. Arthropods recorded in Turkey and their current and/or possible relationship with ornamental alien plants in Turkey

Tabela 2. Evidentirane artropode u Turskoj i njihova trenutna i/ili moguća povezanost sa alohtonim ukrasnim biljkama u Turskoj

No Br.	Species and Ordo Vrsta i Red	Arthropods Artropode		Current Plant Host recorded in Turkey Trenutni biljni domaćini utvrđeni u Turskoj	Associated Ornamental Alien Plant in Table 1 Povezanost alohtonih ukrasnih biljaka u Tabeli 1
		Distribution in Turkey ¹ Raširenost u Turskoj	Use Potential Potencijalna upotreba		
1	DIPTERA (AGROMYZIDAE): <i>Agromyzinae Ophiomyia maura</i> (Meigen, 1838) DIPTERA: Tephritidae	T3	Low	olive	<i>Solidago canadensis</i> L.
2	<i>Carpomyia vesuviana</i> Costa GASTROPODA: Bithyniidae	T2	High	<i>Ziziphus sativa</i> L.	<i>Ziziphus mauritiana</i> Lam.
3	<i>Bithynia</i> spp. HEMIPTERA: Asterolecaniidae	T1, T2, T7	Medium	Recorded in swamp area	<i>Elodea canadensis</i> Michaux
4	<i>Asterolecanium pustulans</i> Cockerell HEMIPTERA: Aleyrodidae	T1	Medium	<i>Nerium olender</i>	<i>Grevillea robusta</i> A.Cunn. ex R.Br.
5	<i>Paraleyrodes minei</i> Laccarino 1990 HEMIPTERA: Coccidae	T1	Low	Citrus	<i>Miscanthus sinensis</i> Andersson
6	<i>Abgrallaspis cyanophylli</i> (Signoret)	T2	Medium	<i>Opuntia</i> sp.	<i>Opuntia ficus indica</i>
7	<i>Ceroplastes floridensis</i> Comstock	T1, T2, T5	Low	Polyphagous	<i>Acer negundo</i> L. <i>Ficus elastica</i> Roxb & <i>F. microcarpa</i> L.f. (recorded in <i>Ficus benjamina</i>)
8	<i>C. rusci</i> Linnaeus	T1, T2, T4	Low	Polyphagous	
9	<i>C. japonicus</i> Green	T3	Medium	<i>Acer negundo</i> L	<i>Acer negundo</i> L
10	<i>C. sinensis</i> Del Guercio	T4	Low	Polyfag on ornamentals and fruits	Polyfag on ornamentals and fruits
11	<i>Coccus hesperidum</i> Linnaeus	T1, T3, T4, T7	Low	Polyfag on ornamentals and fruits	Polyfag on ornamentals and fruits

12	<i>C. pseudomagnoliarum</i> (Kuwana)	T1, T2, T3, T5, T7	Low	Polyfag on ornamentals and fruits	Polyfag on ornamentals and fruits
13	<i>Eulecanium ciliatum</i> (Douglas)	T7	High	<i>Acer</i> sp.	<i>Acer negundo</i> L.
14	<i>E. ficiphilum</i> Borchsenius	T2	Medium	<i>Ficus carica</i> L.	<i>Ficus elastica</i> Roxb & <i>F. microcarpa</i> L.f.
15	<i>E. transvittatum</i> (Green)	T7	Medium	<i>Acer negundo</i> L.	<i>Acer negundo</i> L.
16	<i>E. transvittatum</i> sp. nov.	T7	Medium	<i>Acer negundo</i> L.	<i>Acer negundo</i> L.
17	<i>Neopulvinaria innumerabilis</i> (Rathvon)	T3, T7	Medium	<i>Acer negundo</i> L.	<i>Acer negundo</i> L.
18	<i>Pulvinaria floccifera</i> (Westwood)	T1, T3, T4	Low	Polyfag on ornamentals and fruits	Polyfag on ornamentals and fruits
19	<i>Pulvinariella mesembryanthemi</i> (Vallot)	T2	Medium	<i>C. aciniformis</i> (L.) L. Bolus	<i>Carpobrotus edulis</i> (L.) N.E.Br.
20	<i>Saissetia coffeae</i> (Walker)	T2, T3, T4, T7	Low	Polyfag on ornamentals and fruits	<i>Schefflera actinophylla</i> (Endl.) Harms
HEMIPTERA: Dactylopiidae					
21	<i>Dactylopius coccus</i> Costa 1839	T1	Medium	<i>Opuntia ficus-indica</i>	<i>Opuntia ficus-indica</i>
HEMIPTERA: Diaspididae					
22	<i>Aonidiella aurantii</i> (Maskell)*	T1, T2	Medium	<i>Acacia</i> spp.	<i>Acacia</i> spp.
23	<i>A. citrina</i> (Coquillett)*	T1, T2, T4	Medium	<i>Acacia</i> spp.	<i>Acacia</i> spp.
24	<i>Diaspidiotus perniciosus</i> (Comstock)	All regions	Low	<i>Citrus</i> spp	<i>Citrus trifoliata</i> L.
25	<i>Diaspidiotus ostraeformis</i> (Curtis)	T2	Medium	<i>Acer negundo</i> L.	<i>Acer negundo</i> L.
26	<i>Diaspis echinocacti</i> (Bouché)*	T1, T7	High	<i>Opuntia ficus-indica</i> (L.) Miller	<i>Opuntia ficus-indica</i> (L.) Miller
27	<i>Lepidosaphes beckii</i> (Newman)*	T1, T2, T7	Low	<i>Citrus</i> spp	<i>Citrus trifoliata</i> L.
28	<i>L. granati</i> Koroneos	T1, T2, T4	Medium	<i>Ficus carica</i> L.	<i>Ficus carica</i> L.
29	<i>L. malicola</i> Borchsenius	T5, T7	Medium	<i>Acer negundo</i> L.	<i>Acer negundo</i> L.
30	<i>L. pinnaeformis</i> (Bouché)*	T1, T6	Low	Polyfag on ornamentals and fruits	Polyfag on ornamentals and fruits
31	<i>L. ulmi</i> (Linnaeus)*	All regions	High	<i>Acer negundo</i> L.	<i>Acer negundo</i> L.
32	<i>Melanaspis inopinata</i> (Leonardi)	T2, T3, T7	High	<i>Acer</i> spp	<i>Acer negundo</i> L.
33	<i>Parlatoresopsis longispina</i> (Newstead)	T1	Medium	<i>Acacia cultiformis</i> A. Cunn. ex G. Don	<i>Acacia cultiformis</i> A. Cunn. ex G. Don
34	<i>Parlatoria crotonis</i> Douglas*	T1, T5, T7	Low	<i>Citrus</i> spp	<i>Citrus trifoliata</i> L.
35	<i>P. pergandii</i> Comstock*	T1, T5	Low	<i>Citrus</i> spp	<i>Citrus trifoliata</i> L.
36	<i>P. ziziphi</i> (Lucas)*	T1, T5	Low	<i>Citrus</i> spp	<i>Citrus trifoliata</i> L.
37	<i>Pseudaulacaspis pentagona</i> (Targioni-Tozzetti)*	T1, T2, T3, T4, T5, T7	Low	Polyfag on ornamentals and fruits	<i>Ailanthus altissima</i> (Mill.) Swingle <i>Robinia pseudoacacia</i> L.
38	<i>Rhizaspidiotus donacis</i> Leonardi	T1	High	<i>Phragmites australis</i>	<i>Arundo donax</i> L.
39	<i>Unaspis euonymi</i> (Comstock)	T1, T2, T3, T4, T5, T7	High	<i>Euonymus japonica</i> and <i>E. argentata</i>	<i>Euonymus fortunei</i> (Turcz.) Hand.-Mazz.
HEMIPTERA: Monophlebidae					
40	<i>Icerya purchasi</i> Maskell*	T1, T2, T3, T4	Low	<i>Citrus</i> spp Polyfag on ornamentals and fruits	<i>Robinia pseudoacacia</i> L. <i>Citrus trifoliata</i> L.
HEMIPTERA: Pseudococcidae					

41	<i>Nipaecoccus filamentosus</i> (Cockerell)	T3	Medium	<i>Robinia pseudacacia</i> L.	<i>Robinia pseudacacia</i> L.
42	<i>N. viridis</i> (Newstead)*	T3		<i>Robinia pseudacacia</i> L.	<i>Robinia pseudacacia</i> L.
43	<i>Phenacoccus aceris</i> (Signoret)	T1, T7	High	<i>Acer negundo</i> L. <i>Robinia pseudacacia</i> L.	<i>Acer negundo</i> L. <i>Robinia pseudacacia</i> L.
44	<i>P. madeirensis</i> Green*	T1, T3	Medium	<i>Lantana camara</i> L.	<i>Lantana camara</i> L.
45	<i>Pseudococcus adonidum</i> (Linnaeus)	T1, T4	Medium	<i>Robinia pseudacacia</i> L.	<i>Robinia pseudacacia</i> L.
46	<i>P. cryptus</i> Hempel	T1, T3, T4, T7	Low	<i>Citrus</i> spp Polyfag on ornamentals and fruits	<i>Citrus trifoliata</i> L.
47	<i>P. longispinus</i> (Targioni-Tozzetti)*	T1, T3, T4, T7	Low	Polyfag on ornamentals and fruits	<i>Citrus</i> spp.
48	<i>P. viburni</i> (Signoret)*	T1, T3, T4, T7	Low	Polyfag on ornamentals and fruits	<i>Citrus</i> spp.
49	<i>Planococcus citri</i> (Risso)	T1, T2, T3	Low	<i>Citrus</i> sp	<i>Citrus trifoliata</i> L.
50	<i>P. ficus</i> (Signoret)	T2, T3, T5, T7	Low	Polyfag on ornamentals and fruits	Polyfag on ornamentals and fruits
HYMENOPTERA: Chalcidoidea					
51	<i>Odontofroggata ishii</i> Wiebes	T1	Medium	<i>Ficus microcarpa</i> L.f.	<i>Ficus microcarpa</i> L.f.
52	<i>Philotrypsis emeryi</i> Grandi	T1	Medium	<i>Ficus microcarpa</i> L.f.	<i>Ficus microcarpa</i> L.f.
53	<i>P. taiwanensis</i> Chen	T1	Medium	<i>Ficus microcarpa</i> L.f.	<i>Ficus microcarpa</i> L.f.
54	<i>Walkerella microcarpae</i> Bouček	T1	Medium	<i>Ficus microcarpa</i> L.f.	<i>Ficus microcarpa</i> L.f.
HYMENOPTERA: Eurytomidae					
55	<i>Tetramesa romana</i> Walker	?	Medium	<i>Arundo donax</i> L.	<i>Arundo donax</i> L.
HYMENOPTERA: Symphyta					
56	<i>Arge berberidis</i> Schrank, 1802	T1, T4, T5, T7	Medium	<i>Berberis thunbergii</i> DC.	<i>Berberis thunbergii</i> DC.
MESOSTIGMATA: Phytoseiidae					
57	<i>Euseius stipulatus</i> (Athias-Henriot)	T1, T2	Low	<i>Citrus</i> and <i>Cucumis</i>	<i>Carpobrotus edulis</i> (L.) N.E.Br
58	<i>Typhlodromus phialatus</i> Corpuz-Raros, 1966	T1	Low	different plants	<i>Carpobrotus edulis</i> (L.) N.E.Br

*Cosmopolite species.

T1: Mediterranean, T2: Aegean, T3: Marmara, T4: Black Sea, T5: Eastern Anatolia, T6: South-East Anatolia, T7: Central Anatolia. Regarding ornamental host plants in column 4, pests for *Acacia* spp. could be potential to *A. dealbata*, *A. longifolia*, *A. mearnsii*, *A. retinodes* and *A. saligna*; for *Citrus* spp. to *C. trifoliata*; for *Ficus carica* and *F. benjamina* to *F. elastica* and *F. microcarpa*; for *Carpobrotus aciniformis* to *C. edulis*; and *Opuntia* sp to *Opuntia ficus indica*.

The potential biological control agents for the management of alien ornamental plants that are considered as invasive in Turkey are: *Carpomyia vesuviana* Costa for *Ziziphus mauritiana* Lam., *Rhizaspidiotus donacis* Leonardi for *Arundo donax* L., *Unaspis euonymi* (Comstock) for *Euonymus fortunei* (Turcz.) Hand.-Mazz., *Diaspis echinocacti* (Bouché) for *Opuntia ficus-indica* (L.) Miller, *Eulecanium ciliatum* (Douglas), *Lepidosaphes ulmi* (Linnaeus), *Melanaspis inopinata* (Leonardi) and *Phenacoccus aceris* (Signoret) for *Acer negundo* L. (Table 2). Some information such as regions of these natural enemies and ornamental host plants in Turkey, their introduction, effects, and potential for biological control are given briefly in the following text.

Carpomyia vesuviana (Diptera, Tephritidae) for *Ziziphus mauritiana*: *C. vesuviana* was recorded on *Zizyphus sativa* (syn: *Z. jujuba*) in the Aegean region. This is a harmful pest which damages fruits (Giray, 1979). Cultivation of *Z. sativa* is increasing in the Aegean region. This pest could be a potential biological agent for *Z. mauritiana* in the Marmara and the Black Sea Regions of Turkey, where *Z. sativa* is not grown.

Rhizaspidotus donacis (Hemiptera: Diaspididae) for *Arundo donax*: The species was regarded as a potential biological control agent for *A. donax* in North America (Goolsby et al., 2009). This insect occurs beneath the leaf sheaths, especially at the nodes. It was recorded on *Phragmites australis* (Cav.) Trin. ex Steud. in the Mediterranean region (Kaydan et al., 2007; 2014). It is predicted that its potential is quite high when existing in the same region with *A. donax* (Karakuş and Türkmen, 2014).

Unaspis euonymi (Hemiptera: Sternorrhyncha, Diaspididae) for *Euonymus fortunei*: *U. euonymi* is a major pest of *Euonymus* and is common on euonymus trees in large Turkish cities in the Mediterranean, Aegean, Marmara, and Central Anatolia regions (Erler et al., 1996; Ülgentürk and Toros, 1996; Kaydan et al., 2013). This pest is among the most important harmful insects in Turkey (Ülgentürk and Çanakçıoğlu, 2004) and infests the leaves, branches and trunks, causing the destruction of euonymus trees (Kaydan et al., 2013). This agent has potential for biological control of *E. fortunei* if present in the same region, Black Sea (Acar et al., 2007). This insect should be studied/checked if it can be considered as a biological control agent for non-native *Euonymus* spp. in Turkey, because there are 10 *Euonymus* species native to Turkey, and one of them is endemic, *E. latifolius* subsp. *cauconis* Coode & Cullen (Uludag et al., 2017; Bizim Bitkiler, 2021)

Diaspis echinocacti (Hemiptera: Sternorrhyncha, Diaspididae) for *Opuntia ficus-indica*: *O. ficus-indica* is present in the Mediterranean and the Black Sea regions (Altay et al., 2010), while *D. echinocacti* is in the Mediterranean and Central Anatolia regions (Kaydan et al., 2013), so this agent has a potential primarily in the Mediterranean region.

Eulecanium ciliatum (Hemiptera, Sternorrhyncha, Coccidae), *Lepidosaphes ulmi*, (Hemiptera, Sternorrhyncha, Diaspididae), *Melanaspis inopinata* (Hemiptera, Sternorrhyncha, Diaspididae), and *Phenacoccus aceris* (Hemiptera: Sternorrhyncha, Pseudococcidae) for *Acer negundo*: *A. negundo* is a widespread tree present in the Mediterranean, Black Sea, Marmara, and Central Anatolia regions (Acar et al., 2007). *E. ciliatum* and *M. inopinata* are common and serious pests of deciduous trees including *Acer* spp. Both are among the most important harmful insects on ornamental plants in urban habitats in Turkey. *M. inopinata* is the most common species found on deciduous trees and lives on trunks and branches (Altay et al., 2010). Its biology is unknown in Turkey. *E. ciliatum* is an important pest of *Acer campestre* and *A. pseudoplatanus* in Central Anatolia (Ülgentürk and Toros, 1999). *L. ulmi* is a polyphagous species, and an important pest on ornamental plants especially in urban areas. It is among common serious pests of shrubs, flowering trees, and deciduous trees including *Acer* spp. *P. aceris* is another important species infesting *Acer* spp. and some other deciduous trees. *P. aceris* develops large populations on *Acer* spp. and causes reduced growth as well as dying of trees (Düzgüneş, 1982). Those species have polyphagous nature and do not seem to be potential

biological control agents to be used in Turkey. Nevertheless, despite not being recommended, they can play a role of biological control agents with their current distributions as a limiting factor, given the further spread of some invasive alien plants.

According to the results of work conducted in other countries, the most successful classical biological control agent arthropods are: *Melanterius ventralis* and *Trichilogaster acaciaelongifoliae* for *Acacia longifolia*; *Neochetina eichhorniae* for *E. crassipes*; *Cactoblastis cactorum* and *Dactylopius opuntiae* for *O. ficus-indica* (Table 3). These biological agents are successful in Americas and Africa, but have not been recorded in Turkey yet, and it will be useful to investigate their effectiveness on ornamental plants in the Mediterranean region of Turkey.

Table 3. Successful biocontrol agents established in released countries, that can be considered for use in Turkey
Tabela 3. Uspješnost uspostavljene biokontrole realizovane u nekim zemljama, što može biti osnov za primenu u Turskoj

Ornamental Host Plant in Figure 1 Ukrasne biljke domaćini na Slici 1	Agent Prirodni neprijatelj	Family/Order Familija/ Red	Release Information [Winston et al., 2014] Utvrđene informacije [Winston et al., 2014]		
			Country Zemlja	Year of Release Godina realizacije	General Impact Generalni uticaj
<i>Acacia dealbata</i> Link	<i>Melanterius maculatus</i>	Coleoptera: Curculionidae	Republic of S.Africa	1994	Medium
<i>Acacia longifolia</i> (Andrews) Willd.	<i>Melanterius ventralis</i> Lea	Coleoptera: Curculionidae	Republic of S.Africa	1985	High
<i>Acacia longifolia</i> (Andrews) Willd.	<i>Trichilogaster acaciaelongifoliae</i> (Froggatt)	Hymenoptera: Pteromalidae	Republic of S.Africa	1982	High
<i>Acacia mearnsii</i> De Wild.	<i>Melanterius maculatus</i> Lea	Coleoptera: Curculionidae	Republic of S.Africa	1993	Variable
<i>Acacia saligna</i> (Labill.) H.L.Wendl.	<i>Melanterius compactus</i> Lea	Coleoptera: Curculionidae	Ex. Australia	2001	Variable
<i>Arundo donax</i> L.	<i>Rhizaspidiotus donacis</i> Leonardi	Hemiptera: Diaspididae	US	2010	Too early post release
			Mexico	2011	Too early post release
<i>Buddleja davidii</i> Franch.	<i>Cleopus japonicus</i> Wingelmüller	Coleoptera: Curculionidae	New Zeland	2006	Too early post release
<i>Lantana camara</i> L.	<i>Aceria lantanae</i> (Cook)	Acari: Eriophyidae	Republic of S.Africa	2007	Variable
<i>Lantana camara</i> L.	<i>Aconophora compressa</i> Walker	Hemiptera: Membracidae	Australia	1995	Variable
<i>Lantana camara</i> L.	<i>Calycomyza lantanae</i> (Frick)	Diptera: Agromyzidae	Australia	1974	Slight
			Fiji	1996	Unknown
			Republic of S. Africa	1982	Slight

<i>Lantana camara</i> L.	<i>Coelocephalopion camarae</i> Kissinger	Coleoptera: Brentidae	Republic of S Africa	2007	Too early post release
<i>Lantana camara</i> L.	<i>Cremastobombycia lantanelle</i> Busck	Lepidoptera: Gracillariidae	Hawaii USA	1902	Slight
<i>Lantana camara</i> L.	<i>Crociosema lantana</i> Busck	Lepidoptera: Tortricidae	Federated Micronesia	1948	Medium
			Hawaii USA	1902	Medium
			Republic of S.Africa	1984	Slight
<i>Solanum sisymbriifolium</i> Lam.	<i>Gratiana spadicea</i> (Klug)	Coleoptera: Chrysomelidae	Republic of S.Africa	1994	Medium
<i>Ulex europaeus</i> L.	<i>Aceria genistae</i> (Nalepa)	Acari: Eriophyidae	New Zealand	1985	Slight
<i>Eichhornia crassipes</i> (Martius) Solms	<i>Ecclitotarsus catarinensis</i> (Carvalho)	Hemiptera: Miridae	Republic of S. Africa	1996	Variable
<i>Eichhornia crassipes</i> (Martius) Solms	<i>Neochetina bruchi</i> Hustache	Coleoptera: Eirrhinidae	Nigeria	1994	Unknown
			Cote d'Ivoire	1997	Heavy
<i>Eichhornia crassipes</i> (Martius) Solms	<i>Neochetina eichhorniae</i> Warner	Coleoptera: Eirrhinidae	Cuba	1976	Unknown
			Nigeria	1994	Variable
			Republic of S Africa	1996	Variable
<i>Eichhornia crassipes</i> (Martius) Solms	<i>Niphograpta albivittalis</i> (Warren)	Lepidoptera: Crambidae	Cuba	1995	Unknown
<i>Eichhornia crassipes</i> (Martius) Solms	<i>Orthogalumna terebrantis</i> Wallwork	Acari: Galumnidae	Cuba	1977	Unknown
			Malawi	1991	Medium
<i>Eichhornia crassipes</i> (Martius) Solms	<i>Xubida infusella</i> (Walker)	Lepidoptera: Crambidae	Thailand	1997	Unknown
<i>Ludwigia peploides</i> (Kunth) P.H. Raven	<i>Altica foveicollis</i> (for <i>L. adscendens</i>)	Coleoptera: Chrysomelidae	Thailand	pre 1989	High
<i>Myriophyllum spicatum</i> L.	<i>Acentria ephemerella</i> (Denis & Schiffermüller)	Lepidoptera: Crambidae	Canada	1927	Variable
<i>Opuntia ficus-indica</i>	<i>Cactoblastis cactorum</i> (Berg)	Lepidoptera: Pylalidae	Hawaii USA	1950	High
<i>Opuntia ficus-indica</i>	<i>Dactylopius opuntiae</i> (Cockerell)	Hemiptera: Dactylopiidae	Hawaii USA	1949	High
			Republic of S. Africa	1938	High
<i>Opuntia ficus-indica</i>	<i>Lagocheirus funestus</i> Thomson	Coleoptera: Cerambycidae	Hawaii USA	1951	High
			Republic of S. Africa	1943	Slight
<i>Opuntia ficus-indica</i>	<i>Metamasius spinolae</i> (Gyllenhal)	Coleoptera: Dryophthoridae	Republic of S Africa	1948	High

CONCLUSION

Turkey has the smaller number of alien species compared to many other countries (Uludağ et al., 2017). One of the reasons might be less introductions of ornamental alien species (Uludağ and Ertürk, 2012; van Valkenburg et al., 2014). However, it has been predicted that more alien species will be introduced due to changing lifestyles, owing to urbanization and more aggregated urban areas which might increase the demand for ornamental species (Uludağ and Ertürk, 2012), which have been most of the alien plant species in Turkey and worldwide (Uludağ et al., 2017; van Kleunen et al., 2018, 2019; Arianoutsou et al., 2021). First of all, there is a need to investigate the invasiveness of introduced plant species in Turkey via prioritisation and PRAs (Brunel et al., 2010). It is suggested that using alien insect species can be a good choice to combat invasive alien plants (Sun et al., 2021). Despite many successful examples of biological control of weeds worldwide (Winston et al., 2014; Uludağ et al., 2018), it is still rare in Europe and Turkey (Shaw et al., 2018). It is a promising situation that possible biological control agents exist, although some of them were recorded on crop species, and further studies are required to reveal the effects of those (mostly) alien insects on the flora of Turkey. If such potential agents are to be used to control invasive alien ornamental plants in Turkey, there is a need for further studies of their safe release, as shown in decision-support systems (EPPO, 2018).

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Preliminarna istraživanja artropoda kao potencijalnih bioagenasa u kontroli alohtonih ukrasnih invazivnih biljaka u Turskoj

REZIME

Ukrasne (ornamentalne) alohtone biljke potencijalno mogu postati invazivne i smatra se da ih je moguće staviti pod biološku kontrolu. U vezi sa tim urađen je sveobuhvatni pregled literature da bi se procenila moguća biološka kontrola 56 ukrasnih biljaka koje pokazuju invazivni potencijal u Turskoj. Od mogućih bioloških agenasa napravljena je lista vrsta koje se nalaze u Turskoj i koje bi se mogle koristiti u kontroli invazivnih vrsta. Osim toga, date je i pregled bioloških agenasa koji su se uspešno koristili u svetu u kontroli ovih biljnih vrsta. Kao rezultat toga, evidentirano je 128 vrsta artropoda (zglavkara) kao prirodnih neprijatelja, a njih 27 je korišćeno u svetu biološkoj kontroli. Od ukupno 128 vrsta, 58 je evidentirano i na području Turske, međutim njihov uticaj na biljke nije dovoljno proučavan. Potencijalni biološki agensi za

kontrolu invazivnih biljaka u Turskoj su : *Carpomyia vesuviana* (Costa) za *Ziziphus mauritiana* Lam., *Rhizaspidiotus donacis* (Leonardi) za *Arundo donax* L., *Unaspis euonymi* (Comstock) za *Euonymus fortunei* (Turcz.) Hand.-Mazz., *Diaspis echinocacti* (Bouché) za *Opuntia ficus-indica* (L.) Miller, *Eulecanium ciliatum* (Douglas), *Lepidosaphes ulmi* (Linnaeus), *Melanaspis inopinata* (Leonardi) i *Phenacoccus aceris* (Signoret) za *Acer negundo* L. Postoji mogućnost upotrebe ovih bioloških agenasa u kontroli invazivnih ukrasnih biljaka u Turskoj, iako postoji potreba za daljom procenom rizika od štetočina kako bi se procenila invazivnost alohtonih biljak u Turskoj, a neophodne su i studije za očuvanje korisnih insekata.

Ključne reči: štetočine, insekti, procena rizika od štetočina, alohtone invazivne biljke, alohtoni insekti.