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ORIGINAL ARTICLE

The escape of alien species from botanical gardens: a new example from Ukraine

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Abstract

The spontaneous appearance of the annual plant, *Veronica cardiocarpa* Walp. (*Plantaginaceae*), from Central and Minor Asia was recorded in the O.V. Fomin Botanical Garden of the Taras Shevchenko National University of Kyiv in 1983 as a result of unintentional introduction. It was the first documented occurrence outside of its natural range. *V. cardiocarpa* has been widespread within the Botanical Garden since 2007, and the first location outside the Botanical Garden was discovered in 2010. Later, the presence of *V. cardiocarpa* was noted in Chernihiv, as well as new locations in Kyiv. This species has become a new invasive plant of the flora of Ukraine, because it occupies new areas and shows high seed productivity. Additionally, *V. cardiocarpa* has high seed germination under certain conditions that were established during our experiment, consisting of four variants and a control. The conditions of the second variant—cold stratification with low positive temperatures for two months and germination of seeds at + 18–20 °C—were the most favourable—49 ± 4.36% germinated seeds began to appear on the third day after completion of stratification. Moreover, some indirect facts show that *V. cardiocarpa*is is already deeply integrated in local urban ecosystems. Therefore, the main stages of the adaptation and spreading of *V. cardiocarpa* have been studied and described in Ukraine in this research. Information about a new location of this species in the Russian Federation significantly changed the understanding of *V. cardiocarpa* distribution in Eastern Europe. Finally, in this article, we discuss the important matter of dealing with the *V. cardiocarpa* invasion, and some approaches to prevent similar cases of the new alien species penetration through collections of botanical gardens and arboreta.

Keywords Adventive species · Eastern Europe · Invasion · Seed germination · *Veronica cardiocarpa*

Introduction

Due to its multifactor impact, the invasion of alien vascular plants is a serious challenge for natural ecosystems, the global economy and the health of the human population of all continents except Antarctica at present (Theoharides and Dukes 2007). There are many ways for non-indigenous plant species to enter new regions and areas, but one of the oldest and most "effective" is escape from botanical gardens and arboreta where they were introduced and cultivated (van Kleunen et al. 2018; Galbraith and Cavallin 2021). Over half of the 34 plants listed by the IUCN as among the 100 worst invasive species worldwide were most likely distributed first from botanic gardens (Hulme 2011). Many local examples of this phenomenon are known from various countries and regions (Guo et al. 2016; Ferus et al. 2020; Mayorov et al. 2021). A highly successful pathway for alien species spread is unintentional introduction, when a species is introduced accidentally with contaminated seeds or planting material of deliberately cultivated species – the percentage of species naturalized in this way could be significant (Reichard and White 2001; Virtue et al. 2004; Kuma et al. 2011; Pyšek et al. 2011; Lehan et al. 2013). Although most species are introduced for cultivation, accidentally introduced species may have a higher invasive capacity. For instance, in

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Australia among the unintentionally introduced plants, 76% became invasive (Virtue et al. 2004).

The territory of Ukraine is no exception: 591 out of 803 alien vascular plants were considered naturalised 15 years ago (Lambdon et al. 2008). Nevertheless, according to other data, published afterwards, the alien fraction of the flora was represented by 830 species (Protopopova et al. 2002, 2003). The processes of appearance and detection of new alien plants is ongoing in Ukraine: reports of findings for more than 15 new species for the country have been published in the last 10 years (Melnyk et al. 2013; Olshanskyi and Orlov 2013; Orlov et al. 2014, 2019; Gouz and Timoshenkova 2017; Orlov and Shevera 2020, 2021; Shevera et al. 2020; Mosyakin and Mosyakin 2021; Shynder et al. 2022). Unfortunately, it is now impossible to find accurate information on how many alien species of vascular plants began to spread from the cultivation, namely from botanical gardens and arboreta, within the country. But it has been already reported that some species escaped from botanical gardens, nurseries, and experimental stations. Unforeseen consequences were observed at spontaneous and uncontrolled introduction zones by separate persons (Protopopova et al. 2006) and was discussed in other later publications. For example, it was been established by analysis of the non-native woody species of the flora of Ukraine that nowadays there is data about the controlled spreading of 23 such species beyond collections and expositions of botanical gardens and arboreta. Additionally, there was a single described case of spontaneous escape of 2 invasive species from the Nikitsky Botanical Garden to the adjacent Nature Reserve "Mart'yan Cape" (Burda and Koniakin 2019). At the same time, it is supposed because of a lack of reliable proof that M.M.Gryshko National Botanical Garden of the National Academy of Sciences of Ukraine and O.V. Fomin Botanical Garden of the National Taras Shevchenko University of Kyiv have become centres for the spread of a number of alien plant species at least in Kyiv and neighbourhood regions (Mosyakin and Mosyakin 2021; Shynder et al. 2022).

The current study is a new example of documented escaping of an alien species from botanical gardens in Ukraine. However, it is not a typical case, because *Veronica cardiocarpa* Walp. (*Plantaginaceae*) has not been cultivated purposefully. This species came to O.V. Fomin Botanical Garden of the National Taras Shevchenko University of Kyiv accidentally with planting material brought from an expedition to Central Asia about 40 years ago (Holyachenko et al. 1992), and it began to spread within the garden and outside.

Actually, there was no information about *V. cardiocarpa* distribution outside of its natural range until this species was discovered on the territory of the O.V. Fomin Botanical Garden of the Taras Shevchenko National University of Kyiv in Ukraine (Holyachenko et al. 1992). The authors assumed *V. cardiocarpa* appeared spontaneously, probably caused by the seeds in the soil during the transplantation of various Central Asian plants. There was no evidence that someone ordered seeds of this species by a delectus or got in any other type of seed exchange. However, at that time in the former Soviet Union field expeditions were common to Central Asian countries.

In 2016, the authors of this report published the results of observations on the distribution and condition of the population of *V. cardiocarpa* in O.V. Fomin Botanical Garden (Peregrym et al. 2016). According to this data, it was confirmed that the species had already been widely distributed since 2007 within the Botanical Garden. The first location of *V. cardiocarpa* outside (though very close to its fence) was documented in 2010. Also, the first finding of the plants was noted in Chernihiv in 2014 and 2015 in a private house area, which the second author of this research often visited. His shoes could be the source of *V. cardiocarpa* seed spreading. Nevertheless, the plants were removed from time-to-time and the owners, according to a personal communication, had not seen this species during the last years in their own yard (this fact was not checked personally).

Meanwhile, new locations of *V. cardiocarpa* have been found during vegetation surveys on the territories adjacent to the Botanical Garden since 2016, as well as new findings of the species within Kyiv and Voronezh (Russian Federation). Therefore, the aim of our study is to describe the main stages of the adaptation and spreading of *V. cardiocarpa*, as well as to discuss possible ways to eradicate its invasion and prevent future similar cases.

Material and methods

Study area. This research has been carried out within O.V. Fomin Botanical Garden of the National Taras Shevchenko University of Kyiv (Ukraine) and its neighbourhoods in 2007–2021. The botanical garden is located close to downtown in the capital of Ukraine, its administrative address: Symon Petlura Str., 1; its geographic coordinates are 50°26′38.5"N, 30°30′06.1"E.

The square of the garden is 22.5 ha. It is divided into two main zones according to the type of economic activity and purpose of use: the scientific part of the garden and the park area. The altitude is 139–178 m above sea level. The topography of the Botanical Garden is heterogeneous, divided by ravines and streams into separate hills and small areas of plateaus. Its soil cover is mosaic and it is represented by grey forest and sod-podzol soil types. The initial types are alluvial sands, loess-like loams and siltstones. Depending on the relief, the thickness of the humus horizon varies from 5 to 25 cm. Reaction of the soil solution is slightly acidic

or neutral. Groundwater level for root systems is practically inaccessible (Solomakha 2007).

Climate of Kyiv is moderately continental. The average annual air temperature is + 7.2 °C, average minimum air temperature –6 °C, absolute minimum –32 °C, average maximum + 11.6 °C and absolute maximum + 39.4 °C. The average duration of the frost-free period is 182 days. The average annual humidity is 78% with average rainfall of 655 mm/year, ranging from 594.7 to 732.4 mm/year (Voloshchuk and Tokar 1995).

The research object. The main object of our investigation is *Veronica cardiocarpa* (syn. *Diplophyllum cardiocarpum* Karelin & Kirilov) (Fig. 1). It is an annual herb with erect pubescent stems. Leaves 4, below inflorescence, whorled or nearly so; petiole 2–5 mm; leaf blade ovate-oblong, 1–2.5 × 0.5–1.5 cm, widest in middle or below middle, base rounded, margin dentate. Racemes terminal; bracts alternate, much smaller than leaves, margin sparsely deltoid dentate. Pedicel 5–8 (-12) mm in fruit, as long as or longer than calyx, shorter to longer than bract in fruit, patent, straight or slightly curved below top. Calyx 4-lobed, 6–12 mm in fruit; lobes rhomboid-ovate, sparsely ciliate, apex short acuminate, veins 2 or 3. Corolla rotate, 2–4 mm in diameter. Capsule obcordate, strongly compressed, 2–4.5 × 4.5–5.5 mm, deeply notched; lobes ovate-orbicular, obtuse. Seeds 6–8 per capsule, yellow, ovoid, cupular, ca 1.2–1.8 × 0.9–1.2 mm; seed coat smooth or nearly so (Borisova 1955; Elenevskiy 1978; Deyuan and Fisher 1998).

Natural range of *Veronica cardiocarpa* is limited mainly to the mountains of Central and East Asia: the Uly Balkhan, Kopetdag, Pamir-Alai, Karatau, Tien Shan (absent in the eastern and Kashkar parts), Dzungarian Alatau (extreme eastern locations near Lake Alakol), Mugojar (Mount Great Boktubay); Kashgar and Dzungaria (Borisova 1955; Elenevskiy 1978; Deyuan and Fisher 1998). The natural habitats of this species are stony and gravelly slopes, mountain forests, thickets of shrubs and mountain meadows near snowfields up to 4000 m a.s.l. (Borisova 1955).

Plant nomenclature. All Latin names of mentioned plants are given according to Euro+Med PlantBase (https://europlusmed.org).

Herbarium data. The history of *Veronica cardiocarpa* distribution within Kyiv was studied during the processing of herbarium collections of the M.G. Kholodny Institute of Botany of the National Academy of Sciences of Ukraine (acronym – *KW*) and O.V. Fomin Botanical Garden of the National Taras Shevchenko University of Kyiv (*KWHU*). As well, our collected samples of *V. cardiocarpa* were passed to *KW* and *KWHU*. The map with its locations was produced using the geographic information system QGIS 3.22.8 (https://www.qgis.org) and also available tools at the website "Simplemappr" (https://www.simplemappr.net).

Methodology of seed germination. The experiment was carried out according to a generally accepted method of germinating dormant seeds (Nikolaeva et al. 1985) in 2015–2016 years. It consisted of four variants and one control. Each variant of the experiment was done in three replications of 100 seeds of *V. cardiocarpa.* The germination of seeds in Petri dishes on distilled water-moistened paper at + 18–20 °C was considered a control. The first and second variants of the experiment included cold stratification by low positive temperatures + 7–10 °C for one and two months respectively, after which the seeds were germinated at + 18–20 °C. The third and fourth experiments involved cold

Fig. 1 The general view of *Veronica cardiocarpa* Walp.: **a**) flowering plant, **b**) fruiting plant

stratification for one and two months at + 4–6 °C, respectively, and then the seeds were also germinated at + 18–20 °C. Statistical processing to determine the reliability of seed germination differences was done by ANOVA (Analysis of Variances) test and multiple comparisons by Tukey's HSD post hoc test. Differences between experiments were considered reliable at significance level ≤ 5%. All statistical analyses were performed in R 3.2.3 software according to the relevant recommendations (Shipunov et al. 2012).

Results

History of distribution in Eastern Europe

The first locations of *Veronica cardiocarpa* in O.V. Fomin Botanical Garden of the Taras Shevchenko National University of Kyiv were found and confirmed about 40 years ago within the collection named "Medical plants" (12.05.1983, M.M. Bortnyak, H.K. Smyk, *KW*; #018,821, *KWHU*; 11.05.1984, 16.05.1984, M.M. Bortnyak, #018,815, #018,816, *KWHU*), and 2 years later within the collection called "The system of high plants" (12.05.1985, 26.05.1986, 15.05.1987, 22.05.1988, 9.05.1990, M.M. Bortnyak, H.K. Smyk, *KW*; #018,814, #018,817, #018,818, #018,819, #018,820, *KWHU*). The data about the further spread of the species within the Botanical Garden until 2016, as well as its spontaneous appearance in Chernihiv were given in publications mentioned in Introduction. Also, relevant herbarium samples are kept in *KW* and *KWHU*. However, on May 10, 2016, new locations of *V. cardiocarpa* were found during vegetation surveys on the territories adjacent to the Botanical Garden. They are situated along the Lev Tolstoy Street in Kyiv, next to residential buildings №33, 39, and building №31, which belongs to the R. Glier Kyiv Institute of Music. These sites are at a distance of approximately 150 – 250 m from the nearest known locations of the species. This local population consisted of five fragments. The largest of them covered an area of about 14 m^2 on the lawn and along the curbs near house №, 39 (50°26′30.0"N, 30°30′07.5"E). The density of *V. cardiocarpa* plants is about 280 individuals/m^2 in this area. The second-largest fragment is on the lawn near the Institute of Music (50°26′26.4"N, 30°30′09.2"E). Its area is about 5 m^2 and the density of plants is nearly 60–80 individuals/m^2. The remaining fragments are formed by only a few individuals of *V. cardiocarpa* in flower beds in the yard near the Institute of Music (50°26′26.8"N, 30°30′08.4"E; 50°26′28.5"N, 30°30′08.2"E) and on the lawn near the playground of building №33 (50°26′29.4 "N, 30°30′09.3"E). All plots where *V. cardiocarpa* was present were situated in the shaded places. *Alliaria petiolata* (M. Bieb.) Cavara & Grande, *Chelidonium majus* L., *Geum urbanum* L., *Plantago major* L., *Erigeron annuus* (L.) Desf., *Taraxacum* F.H. Wigg. sect. *Taraxacum, Myosoton aquaticum* (L.) Moench. were noted as concomitant species.

Nevertheless, those locations were not our final findings. On May 26, 2021, it was noted that the invasion is still ongoing and spreading: about 10 individuals of *Veronica cardiocarpa* were revealed along the same street near the building #27/35 (50°26′29.4"N, 30°30′12.8"E), and, at the same time, the known locations still existed. The new point is located about 30–40 m from the closest registered one.

Information about these findings of the species was shared in the Facebook group "Flora of Ukraine" (https://www.facebook.com/media/set/?set=oa.1754931648086900&type=1) in 2016. In the discussion thread we received new data about *V. cardiocarpa* possible distribution from Dr. Olena Krasnyak, a researcher from M.G. Kholodny Institute of Botany of the National Academy of Sciences of Ukraine. She informed us about the existence of another location of *V. cardiocarpa* on the territory of the National Complex "Expocenter of Ukraine" (Kyiv, Academician Hlushkov Avenue, 1). According to the correspondence, the first observation of *V. cardiocarpa* was made there in 2003, after that it was possible to see these plants every year, without tendency to distribute. The population is located approximately 50–100 m to the left from the main entrance under the fence, near the playground. However, this report needed additional confirmation by herbarium materials or, at least, by pictures. Our search did not get positive results, since we were not able to visit all of this area due to the limitation of free access (paid attractions were built).

V. cardiocarpa spreading in Eastern Europe is not limited to Ukraine and a new recent finding of this species was mentioned in a park of Voronezh city, Russia (51°40′31.3"N, 39°12′35.7"E). This observation has been published by K.S. Ivlev on *iNaturalist*: https://www.inaturalist.org/observations/116962432. Unfortunately, we do not have any further information about this location, except the mentioned link, but it should not stay unnoticed.

All gathered data about the current distribution of *V. cardiocarpa* in Eastern Europe are presented on Fig. 2, they are given in the chronological order for O.V. Fomin Botanical Garden.

The laboratory germination of Veronica cardiocarpa seeds

Also, to assess the risks of the further spread of *V. cardiocarpa* in Eastern Europe, we determined the success of germination of its seeds in the laboratory. As was mentioned in Material and methods, we had four variants and a control (Fig. 3). Conditions of the control of experiment were not appropriate to seed germination of *V. cardiocarpa,* which was low, only 1 ± 1% and small number of shoots appeared in one of the Petri dishes. In the first variant of the experiment, seed germination had started on the fourteenth day

Fig. 2 The known localities of *Veronica cardiocarpa* Walp.: **A**) in Eastern Europe ("●" – an existing location, "○" – an extinct one), **B**) in Kyiv ("■" – an existing location, "?" – an unconfirmed one); **C**) in the O.V. Fomin Botanical Garden of the Taras Shevchenko National University of Kyiv and its neighbourhood

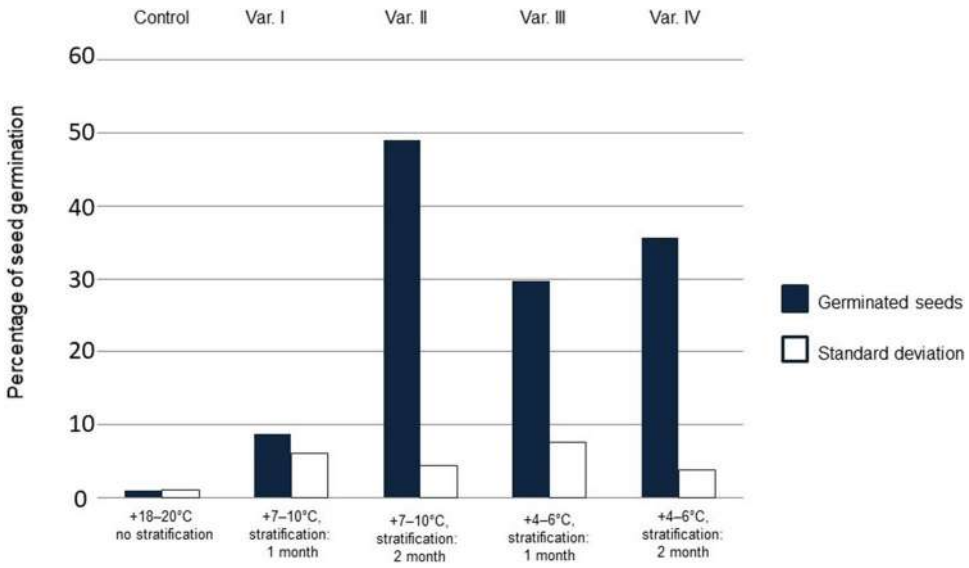

Fig. 3 Percentage of *Veronica cardiocarpa* Walp. seed germination depending on the experiment conditions

after planting on filter paper. However, it was 8.67 ± 6.03%, which did not differ significantly from the control. In the third variant of the experiment, the first seedlings were also observed on the fourteenth day and 29.67 ± 7.64% of the seeds had germinated. The most effective were the conditions of the second variant of the experiment, 49 ± 4.36% germinated seeds of *V. cardiocarpa* began to appear on the third day after completion of stratification. Conditions of the fourth variant of experiment proved to be a little worse. The appearance of the first shoots was observed on the third day, the germination rate of seeds was 35.67 ± 3,79%.

Discussion

Here we would like to consider four main questions: 1. What is the present status of *V. cardiocarpa* in Eastern Europe? 2. Is the species a real threat to native flora as well as natural or secondary plant communities? 3. How and who should act to stop this invasion? 4. What could botanical gardens do to prevent the same cases in the future?

Having the documented facts about the appearance and slow spreading of *V. cardiocarpa* in the Botanical Garden and its neighbourhoods which are described above, as well as the relevant map (Fig. 2), we would like to discuss the present status of the alien species in Ukraine. In our opinion, using terminology by Richardson et al. (Richardson et al. 2000), *V. cardiocarpa* has to be considered as a new invasive plant in the flora of Ukraine, because the species meets all formal criteria for this category, namely: naturalized plants that produce reproductive offspring, often in very large numbers (Peregrym et al. 2016), at considerable distances from parent plants (approximate scales: > 100 m; < 50 years for taxa spreading by seeds), and thus have the potential to spread over a considerable area. In particular, based on the results of the experiment on seed germination of *V. cardiocarpa*, warm and wet/snowy winters are likely to contribute to the expansion of its known locations and the emergence of new localities of the species.

One more important detail for the confirmation of our position is the direction of the invasion, i.e. we observe that the new locations of *V. cardiocarpa* appear not in low relief areas that would be predicted, because of the flushing of its seeds with rain or melt water, but mostly in the direction towards the top of slopes. There is no evidence for now, but we hypothesise their spread is related to ant activity. If our hypothesis is correct, then this may indicate the deep present integration of this species in local ecosystems, namely urban ones.

Regarding the *V. cardiocarpa* finding in Voronezh, we cannot draw any conclusions at present due to lack of data. Of course, this location needs to be studied in more detail as well as to be monitored as its origin is especially interesting. So, we need more data to determine its status there and in Eastern Europe as a whole.

It is impossible to answer for sure if *V. cardiocarpa* is a new real threat to native flora as well as natural or secondary plant communities at present, however if we remember some other cases of escaping of alien annual plants from their cultivation, then such a danger exists. Moreover, a few species with the similar origin are considered species-transformers in Ukraine, i.e. they can significantly change the structure and composition of natural communities. Probably, *Ambrosia artemisifolia* L. is the best example that demonstrates our words above. The species was introduced in the cultivation in Kudashivka village (Dnipropetrovsk region, Ukraine) in 1914, but escaped in 1925, *A. artemisifolia* has became one of the most dangerous species for the Ukrainian flora and for the local population since the last decades (Protopopova and Shevera 2019). One more vivid example, but outside of Ukraine, is *Parthenium hysterophorus* L., an annual plant originating from the Americas, which is a major invasive alien plant in almost all continents. This inconspicuous annual plant spreads using different ways, but it has been entered Pakistan and India as a soil contaminant during the transportation of ornamental plants (Brunel et al. 2014). Nevertheless, if to be objective, many annual alien species can be disappearing after a short period of their growing within new territories for them. Such examples from the flora of Ukraine are *Amsinckia calycina* (Moris) Chater which was noted in the harbor of Odesa during 1992–1998 (Vasyljeva and Kovalenko 2000), or *Potentilla virgata* Lehm. which was observed only several years on the territory of the cotton mill in Kherson (Moysienko 1998).

One more indirect fact which parallels the studied situation with the *Veronica cardiocarpa* invasion, indicating the likelihood of severe consequences for local ecosystems, has been established in the USA. Namely, a significant proportion of successful invasive forbs and grasses are the most likely to have arrived there accidentally through seed contaminants, while almost all nonnative, invasive trees were introduced deliberately (Lehan et al. 2013). Though, our situation is special, because *V. cardiocarpa* belongs to the group of ephemeral plants with short life cycles. Therefore, we predict that this species will not impact natural ecosystems in the near future, but it could become a weed for urban ecosystems in spring time, especially littering flower beds, mixborders, neglected lawns, dissipating in asphalt cracks, etc., as some alien annual plants from genera *Fumaria* L. or *Euphorbia* L. in later spring or summer time in Ukraine.

Nevertheless, there is no doubt that it is vital both to continue observations and to start eradication the *V. cardiocarpa* invasion in Ukraine. In our opinion, these actions are the responsibility of the Taras Shevchenko National University of Kyiv, since the escape of the species happened on its territory and the organisation has all the needed resources

including research and technical staff. Also, it will not be complicated for the University to invite volunteers for help from the number of its students and residents adjacent to its botanical garden territories.

Because *V. cardiocarpa* is an annual plant that reproduces only by seeds, it seems that the mowing of high density locations will prevent seed development and thus be an effective method of preventing reproduction. Probably, this action should be carried out two or three times per vegetation season. Manual removal of *V. cardiocarpa* plants will make sense in localities with low density. Also, it may also be appropriate to use some selective herbicides, if it is not dangerous and has minimal risks for local habitats and ecosystems. However, it is impossible to predict at the present how many years these actions should last to ensure the complete extermination of this alien species, because *V. cardiocarpa* has a very high level of seed productivity in Kyiv's conditions (Peregrym et al. 2016). Additionally, there is no data on how long their seeds can maintain germination. Also, O.V. Fomin Botanical Garden should not provide living plants from its own collections or nurseries directly to other botanical gardens, arboreta, other organisations, or private collectors until the proposed action is complete. This also concerns plant selling. All plants should be transplanted into flower pots, kept under quarantine observation, at least, for one year, before they might be given or sold. This measure seems essential in order to prevent future spreading of *V. cardiocarpa*. The same approach should be used by accepting organisations or people, i.e. the received plants should be isolated in special places in flower pots, at least, for one year to check on the present/absence of seedlings of the species.

Also, we should not forget prevention by educational methods. The Botanical Garden could prepare informative posters about *V. cardiocarpa* and the potential danger of its invasion to inform residents of close areas, other botanical gardens and arboreta. It is also possible to use social networks to share this information.

Certainly, botanical gardens and arboreta already implement policies intended to prevent the described or similar cases of the appearance and spreading of alien species. Ukrainian organisations are not an exception. For example, "A Code of Conduct on Invasive Alien Species for Botanical Gardens and Arboretums of Ukraine" was published 9 years ago (Burda et al. 2014). The Code outlines the main policy principles on the management of invasive alien species in botanical gardens and arboreta of Ukraine: awareness, sharing information, prevention of new invasions, control measures, outreach information and forward planning. However, these recommendations do not often work in practice, for many reasons, the main ones being: the Russian invasion since 2014 in Ukraine which significantly changed priorities in the country, including for botanical gardens and arboreta, and became the principal reason for the deep economic crisis; as well, the low responsibility of some employees and their misunderstanding of the problem of plant invasion. Moreover, nowadays Ukraine does not have a relevant legislative framework which allows control of alien species, combating of invasive species and prevention of spread. However, it is necessary to continue this work, especially using international experience and offers, for example, to create a common informational system among botanical gardens and arboreta the same way it was done in the USA (Culley et al. 2022). Ideally, such a system functions not only within one country, but becomes a European working network for informational exchange about invasive species.

Conclusions

This study contains information about the history of the appearance of *V. cardiocarpa* in the territory of the O.V. Fomin Botanical Garden of the National Taras Shevchenko University of Kyiv, and its dynamic of colonisation of new areas in Ukraine from 1983 to the present. Moreover, a new location of this species was reported in the Russian Federation that significantly changed the image of the *V. cardiocarpa* distribution in Eastern Europe. The obtained data is a basis for identification of *V. cardiocarpa* as a new invasive species, at least, in the flora of Ukraine.

Also, we discussed important questions about methods of combating the *V. cardiocarpa* invasion, as well as offering some approaches to prevent similar cases of arrival of new alien species through collections of botanical gardens and arboreta in the future.

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Author contributions All authors contributed to the study equally. It concerns the conception of the work, data collecting and analysis, the preparation of the manuscript as well as the approving its final version to be published. All authors are agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Declarations

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Informed consent not applicable, because human participants, their data or biological material have not been involved in this research

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