

Rapid Communication**Expansion of invasive *Adenocaulon adhaerescens* Maxim. (Asteraceae) in Moscow Region**Sergey Mayorov¹, Mikhail Serebryanyi² and Yulia Vinogradova^{2,*}¹Lomonosov Moscow State University, GSP-1, Leninskie Gory, Moscow, 119234, Russia²NV Tsitsin Main Botanical Garden, Russian Academy of Sciences, ul. Botanicheskaya 4, Moscow, 127276, RussiaAuthor e-mails: saxifraga@mail.ru (SM), misha@florin.ru (MS), gbsad@mail.ru (YV)

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OPEN ACCESS**Abstract**

Adenocaulon adhaerescens (Asteraceae), a native species from the Russian Far East, has escaped from cultivation in N.V. Tsitsin Main Botanical Garden of the Russian Academy of Sciences, Moscow. Herewith, we record it as a new invasive alien plant species: recently it has been recorded in 13 localities in Moscow and the surrounding area and we revisited 12 sites and confirmed its distribution at 8 localities. In populations of *Adenocaulon adhaerescens* along trails in parks and recreational forests its covering could reach 100% (recorded in Moscow and Moscow Region). The biggest plants produce more than 5000 seeds per season and these are equipped with viscid glands. Those glands make seed distribution over great distances (both via anthropo- and zoochory) very effective. Unaided or unintentional introduction of this species in East European countries and its further invasion in natural plant communities is likely to occur, so monitoring of the initial populations of this species and implementing measures intended to prevent its spread are necessary.

Key words: alien plants, dispersal, naturalization, botanical garden, escape from cultivation, population

Introduction

Horticulture is a renowned major source of propagule pressure and plant invasions, and there is clear and continuous evidence of new alien plants escaping into the wild (Reichard and White 2001; Pergl et al. 2016). Quite often the escaped species become invasive and penetrate in the natural plant communities which could result in significant economic and ecological harm (Richardson et al. 2000), e.g., 19 of 34 most aggressive invasive alien species worldwide escaped from botanical gardens (Hulme 2011).

The accelerating rates of plant invasions encouraged EuroGard V, the Congress of European Botanical Gardens (Helsinki, 2009), to determine new goals for botanical gardens: to recognize the risk of cultivation of alien plant species, to inform other botanical gardens about each case of plant escape from cultivation, and to follow the Code of conduct for botanic gardens on invasive alien species. This Code was adopted in Russia at the Conference on Preservation of Biodiversity (Yaroslavl, 2011) and approved

at the First Organizational Congress of the Council of Botanical Gardens of the CIS Countries of the International Association of the Russian Academy of Sciences (Moscow, 2013). That is why our research focuses on the only species that escaped from cultivation in N.V. Tsitsin Main Botanical Garden RAS (further in the text – MBG) in more than 70 years – *Adenocaulon adhaerescens* Maxim. Recently it has been recorded far from the territory of MBG.

Less than a decade ago the third author proposed a list of urgent actions for invasion biology in Russia, including task 9 (translated from Russian by the authors): “the most important but far-off task – implementation of online system for monitoring the invasive species (their introduction and spread and expansion) based on herbarium material, not on the bibliographical data” (Vinogradova 2012). That initiative seemed to be almost hopeless back in 2012, but with the development of powerful Internet resources such as iNaturalist that goal became manageable e.g., in the Moscow region, 32 iNaturalist observers made 70 records of *A. adhaerescens* in 3 years. A total of 1966867 plant observations have been recorded on iNaturalist for Russia, 920660 of them have been confirmed. For *Adenocaulon*, there are 96 observations registered on iNaturalist: 2 for Japan and 94 for Russia. There are 70 observations in 12 locations in the Moscow region (all of them are shown in Figure 1), 1 – for South Urals and the rest given for 17 locations in the natural range of the species in the in Russia, invasive populations of Far East. Thus, *Adenocaulon* have so far been found only in the Moscow region. In this paper, we describe the recent distribution of *A. adhaerescens* in Moscow and Moscow Region.

Species studied

The genus *Adenocaulon* Hook. (Asteraceae – Mutisieae) comprises 5–6 species with circumpacific range: North and South America – East of Eurasia (Deng et al. 2018). The only species of the genus in Russia, *Adenocaulon adhaerescens* Maxim., is recorded for Trans-Baikal Territory; Amur Region; Sakhalin Region, Kunashir Island (Kurilskii State Nature Reserve); Khabarovsk Territory; Primorye Territory (Barkalov et al. 1992). The species was described by Karl Ivanovich Maximovich, in 1859 at page 152 of *Primitiae Florae Amurensis* (Maximowicz 1859; Komarov 1905; Golubkova 1959). In the latest taxonomic revision of the genus (Bittmann 1990 a, b) *Adenocaulon adhaerescens* was synonymized with *A. himalaicum* Edgew. That point of view was also followed in *Flora of China* (Chen and Hind 2011) and considered to merely represent an isolated marginal population of the latter species. Bittmann (1990a, b) pointed out that no unique diagnostic characters to distinguish *A. adhaerescens* from *A. himalaicum* could be found, so variation in *A. himalaicum* comprises morphological description of *A. adhaerescens*. According to the protologue of *A. himalaicum*, the lower leaf surface is characterized as “niveo-tomentosa”, the upper as “... glabra,

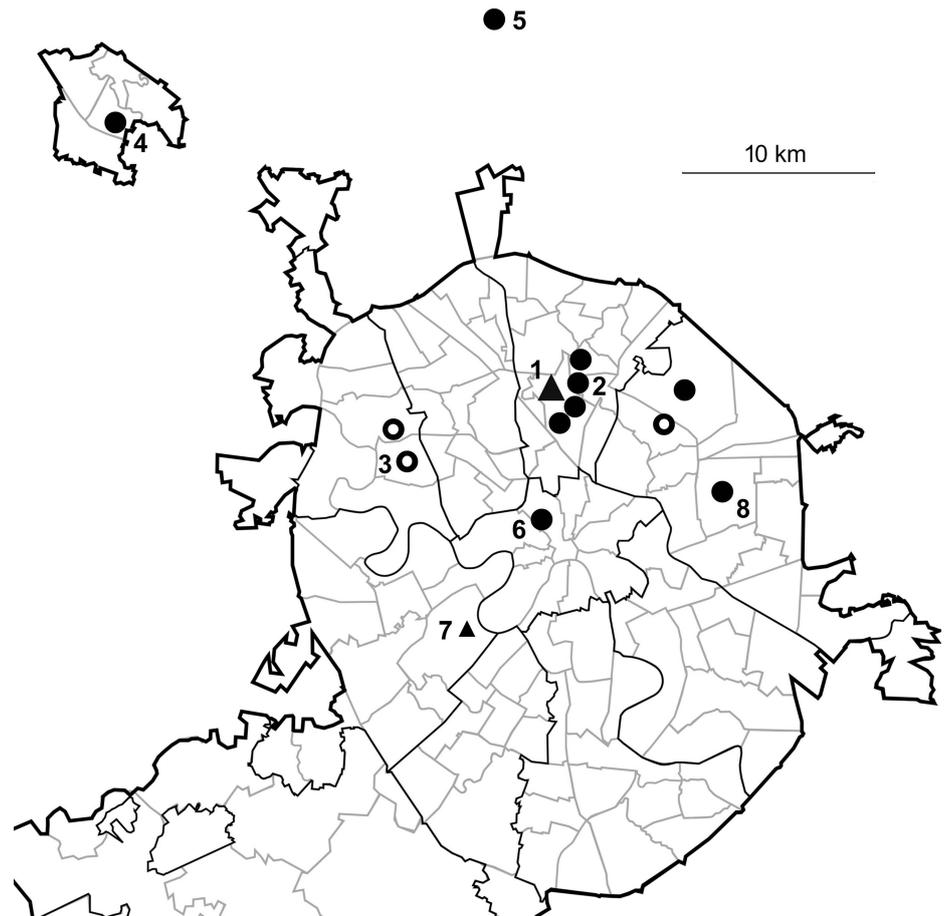


Figure 1. Up-to-date distribution for *A. adhaerescens* in the Moscow Region (2020), based on data from iNaturalist, MHA and MW. Localities that were visited during our study are numbered. The larger triangle indicates the MBG territory – the source and starting point of the distribution; the smaller triangle indicates the Moscow State University Botanic Garden. Unfilled circles stand for unconfirmed records.

ad nervos tantum glanduloso-puberula...” (Edgeworth 1846, Maximowicz 1859) whereas the plants from the Russian Far East have greyish-pubescent lower and almost glabrous upper leaf surfaces. The same characters are found in the plants collected in Moscow: upper leaf surfaces are glabrous, with a few glands only. According to the protologue of *A. himalaicum* the marginal female flowers are “... campanulati, 4-fidi ...”, whereas almost all pistillate flowers in the plants from Moscow are pentamerous. Therefore, we are treating *A. adhaerescens* as a separate species, keeping in mind that the group *A. himalaicum* — *A. adhaerescens* demands additional in-depth taxonomic study. Data on the distribution of *A. himalaicum* in China, Korea and Japan are scanty and contradictory; the morphological descriptions from the regional floras (e.g. Ohwi 1965) are not detailed enough. Therefore, assessing the genuine distribution range of the species beyond the Russian borders is difficult.

Adenocaulon adhaerescens was introduced in the living plants collection of MBG from seeds collected in 1953 in Vladivostok (near Okeanskaya railway station). After 30 years several plants, spontaneously developed from seeds, beyond the exposition of the Russian Far East were recorded

(Skvortsov et al. 1979). In the 1980s plants of *A. adhaerescens* were found in large numbers in MBG along the Likhoborka river valley (Ignatov et al. 1988; 1990). In 1997, *A. adhaerescens* was recorded for the first time beyond the limits of the MBG, i.e. between the MBG territory and the metro station “Botanical Garden” (MW0538552!; Sorokin and Seregin 2011).

Towards the end of the XX century *A. adhaerescens* became a weed within the MBG territory. In 2005 *A. adhaerescens* was recorded in the Ostankino Park and VDNKh (Exhibition of Achievements of the National Economy), territories adjacent to the MBG. Finally, in 2007, the species was also reported in the West of Moscow, very far from the MBG territory, in a recreational forest near the metro station “Schukinskaya” (Vinogradova 2013).

It is worth mentioning that *A. adhaerescens* was planted in the Botanic Garden of Moscow State University, but it has not been recorded outside the garden’s territory. Elsewhere in Russia, there is also a record of *A. adhaerescens* in Nizhniy Tagil, South Urals (population within Rogozhinskoye Sanctuary). Unfortunately, that record is documented only by a few photos (not confirmed by herbarium specimens) on the Internet (molbiol.ru 2020). Finally, *A. adhaerescens* was recorded in the Botanical Garden of Vitebsk, Belarus in 2013 (Dzhus et al. 2013). Apparently, it was unintentionally imported there from MBG with other living plants.

Materials and methods

We used iNaturalist for studying the secondary distribution ranges of alien species and their distribution dynamics. iNaturalist is a joint initiative of the California Academy of Sciences and the National Geographic Society supported by dedicated personnel and developed by a scientific and civil community. Photos of plants with coordinates of the localities are being permanently published on the platform which supports both mapping distribution ranges of native and invasive species. Data on iNaturalist (2021) revealed new localities/populations of *A. adhaerescens* in Moscow and the Moscow Region (Figure 1). We visited some of the localities distant from the MBG territory and collected herbarium specimens there (MHA, MW– according to Index Herbariorum 2021).

Results

The following eight locations/populations were visited:

1. Moscow, N.V. Tsitsin Main Botanical Garden (MBG RAS) (55°50'N; 37°35'E);
2. Moscow, Leonovskaya Roshcha (55°50'N; 37°38'E);
3. Moscow, Schukinskiy recreational forest (55°48'N; 37°28'E);
4. Zelenograd, Kryukovo recreational forest (55°59'N; 37°12'E);

5. Moscow district, Depo railway station, Lobnya vicinity (56°02'N; 37°31'E);
6. Moscow, Fadeyeva str., settlement gardening (55°46'N; 37°36'E);
7. Moscow State University Botanic Garden (55°71'N; 37°53'E);
8. Izmailovo Urban Forest (55°78'N; 37°78'E).

Not all the iNaturalist localities were confirmed by our field excursions: not a single plant has been found neither in National Park «Elk Islands» near the Belokamennaya station, nor in the city park Pokrovskoye-Streshnevo. The number of fertile plants and their seed production (of the biggest plants) were calculated in the populations studied. The descriptions of plant communities with *A. adhaerescens* are as follows.

Locality/population no. 1

Oak forest (with birch in tree-layer), scanty shrub layer and anthropogenically disturbed herbaceous layer. Dominant species (by layers; dominant species of strata within tree-layer and herbaceous layer are divided by “– –”, between layers – by “ – ”): *Quercus robur*, *Betula pendula* – *Corylus avellana* – *Aegopodium podagraria*, *Impatiens parviflora*, *Urtica dioica* – – *Ranunculus repens* (Supplementary material Table S1). Several invasive herbaceous species were recorded in the relevé plots (*Geum macrophyllum*, *Poa supina*, etc.).

Adenocaulon adhaerescens is an abundant weed in the MBG territory: it occurs along the trails and pathways throughout the Garden, penetrates in the natural plant communities and forms local dense micro-populations (50 plants per m²). According to our data, in 2018 there were 5891 plants in the MBG territory (360 hectares). The most common groups/micro-populations of *A. adhaerescens* are represented by single fertile plants with surrounding seedlings. Average density of the fertile plants for the MBG territory was estimated as 0,0016 per m² (Ganina and Vinogradova 2019). Sexual reproduction by seeds is prevalent, only 5% of plants can flower during the first year, mass flowering occurs during the 2nd year. Each plant produces 1500 seeds (on average), therefore an annual seed bank for the MBG territory could be estimated as 1.5 million. Cypselas of *A. adhaerescens* are covered with long multicellular glands, abundantly producing a viscid secret (Figure 2). That is why its propagules easily stick to clothes and footwear, as well as to dogs' paws. *A. adhaerescens* populations hardly spread vegetatively, forming 1-2 wintering buds per plant (Mayorov et al. 2013).

Locality/population no. 2

Oak forest (with birch participation in the 1st tree-layer and five species in the 2nd tree-layer), scanty shrub layer and anthropogenically disturbed herbaceous layer. Dominant species (by layers): *Quercus robur*, *Betula pendula* – – *Acer platanoides*, *Acer negundo*, *Populus tremula*, *Tilia cordata*, *Ulmus glabra* – *Aegopodium podagraria*, *Impatiens parviflora*, *Urtica dioica* – – *Ajuga reptans* (Table S1).

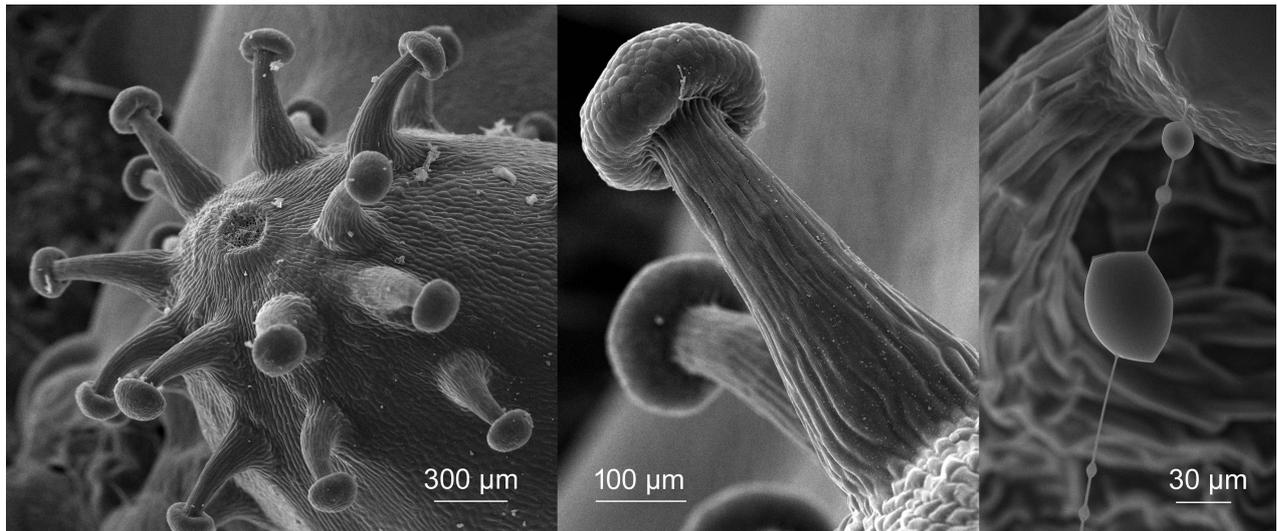


Figure 2. Details of cypselas of *Adenocaulon adhaerescens* (SEM JSM-6380LA): top of cypselum (left), multicellular glands (center), viscid secret (right). Photo by S. Polevova.

Although several invasive herbaceous species were recorded in the relevé plots (*Dipsacus pilosus*, *Heracleum sosnowskyi*, *Impatiens parviflora*, *Impatiens glandulifera*, *Lunaria rediviva*), their abundance and cover were low. About 1000 plants of *A. adhaerescens* are recorded for Leonovskaya Roshcha. They grow mainly along the asphalt trails and pathways. Less than 10 micro-populations occur in small openings in the midst of the recreational forest.

Locality/population no. 3

The territory of the Schukinskiy recreational forest (NW of Moscow) covers 22 hectares with almost no herbaceous layer. Mixed forest derived from planted forest with scanty shrub layer and needle litter layer. Dominant species (by layers): *Betula pendula*, *Larix sibirica*, *Pinus sylvestris*–*Acer platanoides*, *Tilia cordata*–*Corylus avellana*–*Aegopodium podagraria*, *Impatiens parviflora*, *Geum urbanum* (Table S1). Only *Impatiens parviflora*, *Geum macrophyllum* and *Poa supina* are recorded in the relevé plot as invasive alien species. Forty-seven micro-populations of *A. adhaerescens* (2nd year) were recorded with a total number of plants of about 500. Each capitulum consists of 5-7 cypselas, each plant forms 25-30 capitula and at least 250 seeds, respectively. Thus, the *A. adhaerescens* population forms an annual seed bank for the territory estimated as 127,000 (Ganina and Vinogradova 2019).

Locality/population no. 4

Spruce planted forest with a shrub layer (*Corylus avellana*) and an anthropogenically disturbed herbaceous layer. Dominant species (by layers): *Picea abies*–*Corylus avellana*–*Urtica dioica*, *Dryopteris carthusiana*, *Festuca gigantea*–*Poa supina* (Table S1).



Figure 3. Dense thickets of *A. adhaerescens* in Zelenograd outskirts with an estimated 100% covering. Foto S. Mayorov, Yu. Vinogradova, August 2020.

The largest population of *A. adhaerescens* is recorded in Zelenograd: at least 10,000 plants grow there, particularly in thickets of 100% cover (Figure 3). These monospecific thickets form an uninterrupted cover along the trails in the recreational forest for a few hundred meters distance. The biggest plants produce 400-500 capitula per plant, each of those containing 6-12 cypselas.

Locality/population no. 5 (close to Lobnya)

Planted pine forest with shrub layer of *Corylus avellana* and *Lonicera xylosteum* and anthropogenically disturbed herbaceous layer. Dominant species (by layers): *Pinus sylvestris*–*Corylus avellana*, *Lonicera xylosteum*–*Aegopodium podagraria*, *Impatiens parviflora*–*Oxalis acetosella*, *Carex digitata* (Table S1).

Only 4 plants of *A. adhaerescens* were found near the Depo railway station; all of them are located along the forest road that separates forestry sections (compartments). There was only one fertile plant with 2 capitula, containing, respectively, 7 and 3 cypselas.

Locality/population no. 6

Within Moscow City Centre (just outside the Garden Ring), on Fadeeva street, *A. adhaerescens* is cultivated as an ornamental plant in a front yard.

About 20 fertile plants were recorded. In the back of the yard, under the windows of the neighboring house, we found about 50 plants. It is not clear, whether these plants were cultivated or they had escaped from the front yard. There is a significant alien component in plant communities with *A. adhaerescens*. It comprises *Acer negundo* (both in the tree-layer and as seedlings), *Bidens frondosa*, *Dipsacus pilosus*, *Geum macrophyllum*, *Heracleum sosnowskyi*, *Impatiens glandulifera*, *Impatiens parviflora*, *Lunaria rediviva*, *Poa supina*.

Locality/population no. 7

Territory of Moscow State University Botanic Garden. Only cultivated populations of *A. adhaerescens*. No plants outside the garden.

Locality/population no. 8 (Izmailovo Urban Forest)

Linden forest on a gradual North-facing slope to the stream effluent from the Krasnyi pond. *Tilia cordata* (*Betula pendula*, *Quercus robur*, *Ulmus laevis*)–*Corylus avellana* (*Sorbus aucuparia*, *Lonicera xylosteum*)–*Aegopodium podagraria*, *Carex pilosa*, *Lamium galeobdolon*, *Asarum europaeum*. No more than 10 juvenile plants of *Adenocaulon* were found.

Conclusions

Adenocaulon adhaerescens—a native species from the Russian Far East—escaped from cultivation back in 1997 and began to expand its secondary distribution range in the Moscow Region, where is therefore considered as an invasive species. Up to 2019 only 3 invasive populations were recorded but later the expansion accelerated. In 2020 eight new localities/populations were recorded for the Moscow Region, four of them were later confirmed by the authors; herbarium material was collected and studied, descriptions of plant communities with *A. adhaerescens* were made. *Adenocaulon adhaerescens* occurs under the tree cover of all the dominant species in Moscow botanical-geographic region. In some localities it can be dominant in the herbaceous layer, especially along trails and paths, where its cover can reach 100%; at a distance of 3-5-meters from the local/forest roads and foot-paths *A. adhaerescens* is accompanied both by local/native weeds, e.g., *Aegopodium podagraria*, *Urtica dioica*, *Ajuga reptans*, *Glechoma hederacea*, *Plantago major*, and by alien species, e.g. *Geum macrophyllum*, *Impatiens parviflora*. The largest plants can produce up to 5000 cypselas per year; cypselas are equipped by viscid glands which enhance the species' spread over great distances. Therefore, we expect a further spread of *A. adhaerescens* along forest roads, trails, paths, particularly in old spruce plantations.

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Authors' contribution

Research conceptualization – MS; sample design and methodology – MS, VY; investigation and data collection – MS, VY; data analysis and interpretation – MS, SM, VY; funding provision – VY; writing original draft – VY; review and editing – MS, SM, VY.

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Supplementary material

The following supplementary material is available for this article:

Table S1. Floristical relevés of *Adenocaulon adhaerescens* stands in Moscow and Moscow district.

This material is available as part of online article from:

http://www.reabic.net/journals/bir/2021/Supplements/BIR_2021_Mayorov_etal_SupplementaryMaterial.xlsx