Invasive plant species in the forest parks of Yekaterinburg

Invasive plant species in the forest parks of Yekaterinburg

T B Srodnykh, S V Vishnyakova*, S N Luganskaya

Ural State Forestry Engineering University, Yekaterinburg, Russia

*Corresponding email: svvish@rambler.ru

Abstract. Invasive species – introduced species, spontaneously settled outside their natural range, and successfully adapted to the new growing conditions. The problem of invasive species penetration, both herbaceous and woody, has long been a concern of scientists, their views on this issue being contradictory. In the forest parks of Yekaterinburg there is a significant number of introduced species – invasive species. The occurrence of invasive species was considered in three forest parks of the city. The article shows invasive species high occurrence, wide amplitude of ecological plasticity, lack of response to shade density conditions in forest parks and urban plantations. They easily adapt to the conditions of different shade density and increased recreational load, both in urban areas plantations and in the conditions of a forest park. The studied species can be recommended for use in urban parks and forest parks. *Cotoneaster lucidus* Schlecht. and *Amelanchier spicata* (Lam.) K. Koch. are quite decorative and can be used both in the formation of edges, landscape groups and as undergrowth species.

1. Introduction

Yekaterinburg is located in the subzone of the southern taiga and is surrounded along its whole perimeter by a ring of 15 forest parks, most of which were created in the 60s of the last century. Their total area is 12.15 thousand hectares. The city is growing rapidly going beyond this ring. During the period from 2004 to 2013 the total area of forest parks decreased by 3.8% [1]. In this regard, it is very important to maintain the forest environment in parks surrounded by buildings. And one of the key issues is the composition of the plantations, which is changing under the expansion of species that came from the city streets, gardens, public gardens and parks. The problem of invasive species penetration, both herbaceous and woody, has long been a concern of scientists, their views on this issue being contradictory. The study of these species will help to deliver a verdict – "for" or "against" their introduction into forest plantations.

The objectives of the study included a survey and analysis of the growth and condition of some introduced species of trees and shrubs in forest parks and in the streets of Yekaterinburg.

The work program was to include: – determining the occurrence of arboreal and shrubby introduced species in the forest parks and urban landscape gardening spaces; – the measurement of biometric indicators of introduced arboreal species on the selected spaces; – determination of the studied plants ecomorphs with the help of tolerance amplitude according to D N Tzyganov; – determination of fluctuating asymmetry of the leaf blade [2].

2. Materials and methods

In the course of the work the following methods were used:

1. occurrence of species in forest parks was determined by the route method;

2. biometric measurements were carried out on temporary test areas (TTA) in forest parks and in urban conditions on the plots with different types of spatial structure;

3. sanitary condition was determined by the scale of assessment of the state of green plantations and living conditions improvement elements [3];

4. determination of ecomorphs of the introduced species was carried out via the amplitudes of tolerance in relation to the regimes of 7 factors according to D N Tzyganov [4].

3. Results and discussion

Invasive species – introduced species, spontaneously settled outside their natural range, and successfully adapted to the new growing conditions.

The occurrence of invasive species was considered in three forest parks of the city: Southwest (575.45 ha), Uktussky (414.41 ha) and in the forest park named after Foresters of Russia (906.75 ha). The forest parks area makes up 15.6% of the total area of the forest park ring. These are medium-sized forest parks located in the southern sector of Yekaterinburg. The terrain of both the forest park named after Foresters of Russia and South-West forest park is relatively flat with small hills. Pure pine plantations of high quality classes and the average age of 130-150 years predominate there, sometimes with a small admixture of birch. The terrain of Uktussky forest park is mountainous. The soils of the forest park are gravelly. On the territory outcrops of bedrocks frequently occur. The bedrocks are rich in magnesium and calcium (gabbro, serpentine, peridotite, dunite), creating dryness of substrate of shallow mountain soils [5]. In the Uktussky forest park, there is a natural monument to rare plants' nature – virgin steppes with a complex of steppe flora.

In the process of these forest parks inspection there were identified 11 species of introduced plants. The list of predominant species is presented in Table 1.

Table 1. The most common types of introduced species in the forest parks.

Forest park	Species	Occurrence, %
Uktussky	*Malus baccata* (L.) Borkh.	86.7
	Cotoneaster lucidus Schlecht.	66.7
	Amelanchier spicata (Lam.) K. Koch.	60.0
Southwest	*Malus baccata* (L.) Borkh.	53.8
	Acer negundo L.	53.8
	Cotoneaster lucidus Schlecht.	38.5
	Padus maackii (Rupr.) Kom.	38.5
Named after Foresters of Russia	*Malus baccata* (L.) Borkh.	58.3
	Acer negundo L.	41.7
	Cotoneaster lucidus Schlecht.	41.7

The data in Table 1 indicate that the following species are characterized by the highest occurrence observed in all the forest parks: *Malus baccata* (L.) Borkh. – 86.7% Uktusskaya to 53.8% in the South West. The second place was taken by *Cotoneaster lucidus* Schlecht. – from 66.7% in Uktussky forest park to 38.5% in the South-West one. *Amelanchier spicata* (Lam.) K. Koch. is characterized by high percentage of occurrence in Uktussky forest park– 60%. In the South West forest park *Acer negundo* L. – 53.8% and *Padus maackii* (Rupr.) Kom. – 38.5% are also characterized by high percentage of occurrence.

Uktussky forest park was chosen for further research. All in all there were found 11 introduced species, but only three of them were characterized by a high percentage of occurrence. Two species – *Cotoneaster lucidus* Schlecht. and *Amelanchier spicata* (Lam.) K. Koch. - were chosen as the object of research. *Malus baccata* (L.) Borkh. was excluded from the study because this species had been studied rather well in both urban and forest park plantations of Yekaterinburg [6].

Cotoneaster lucidus Schlecht. is used quite often for urban objects, mainly in the form of hedges. According to L A Semkina, the occurrence of *Cotoneaster lucidus* Schlecht. in the central part of the city in the yard and street areas is 62.5% [7]. In parks, the occurrence of this species reaches 100% due to artificial planting and natural propagation. While *Amelanchier spicata* (Lam.) K. Koch., according to L A Semkina, does not occur on the yard and street areas of the central part. However, according to our data, in the public gardens of the central part of the city, in the streets and parks it occurs in the form of single plantings in a small amount (up to 1% of the share in the composition of plantations) [8].

Both species are recommended for urban landscape gardening in the cities of the Urals in a wide range: *Amelanchier spicata* (Lam.) K. Koch. – everywhere, excluding only the northernmost area (further than 60° N l); *Cotoneaster lucidus* Schlecht.– everywhere, excluding mountain spurs in the steppe zone of the Urals [9].

For the study of biometric indicators, the values of linear annual increment and sanitary condition of introduced species (Table. 2) 5 TTA with different types of spatial structure (TSS) were laid in Uktussky forest park. All TTA were represented by pine plantations sometimes with the admixture of *Betula pendula* Roth. and *Populus tremula* L. Type of the forest was predominantly pine mixed herb- and -grass plant forest. 3 and 4 stages of digression were marked on all sample areas, which was caused by high attendance due to the proximity of collective gardens along the border of the forest park.

To study the same parameters in the conditions of public gardens and city streets, another 3 TTA were laid.

As a result of comparison of the average biometric indicators with the help of the criterion of reliability Student at 95% significance level it was found that *Cotoneaster lucidus* Schlecht. in the forest park was characterized by unreliable differences for all indicators considered ($t<2.0$). For *Amelanchier spicata* (Lam.) K. Koch. significant differences were marked concerning only the height of the plant. On shaded areas in the forest park plant height was significantly higher, this difference being 1.3 m, which was natural for the growth and development of plants under the canopy.

For the remaining indicators, the differences are random. Thus, a preliminary conclusion can be made that the shade density factor does not affect the growth rate and development of these species.

Table 2 shows that the same-aged plants *Amelanchier spicata* (Lam.) K. Koch. in urban plantations under the same shade density conditions (semi-open TSS), but with different planting density (0.75 m and 1.5 m) differ significantly in plant height and crown diameter. Other indicators and even linear growth have no significant differences.

The category of sanitary condition of the studied introduced species in the conditions of the city and forest parks is estimated as excellent and good.

For more accurate determination of the potential possibility of growth of the studied species, phytoindication tables of D N Tzyganov were used. Tsyganov tables are often used in works on ecological survey of territories [10]. For ease of use, the average score of the conditionally optimum type of regime was determined. It was found with the help of the scales of factors as the average of the minimum and maximum of the tolerance amplitude of the species, which is reflected in Table 3.

Table 2. Biometrics indicators and sanitary condition of *Cotoneaster lucidus* Schlecht. and *Amelanchier spicata* (Lam.) K Koch.

Species	Criteria	Bush height, m	Diameter at a height of 1.3 m, cm	Crown diameter, m	Average annual increment, cm	Condition category, point
Uktussky forest park						
Cotoneaster lucidus Schlecht.,	x±m	1.41±0.072	1.85±0.110	1.43±0.098	17.04±0.103	1.35±0.110

closed TSS						
Cotoneaster lucidus Schlecht., open TSS	x±m t (t_{tab}=2.0)	1.25±0.073 1.56	2.13±0.166 1.38	1.3±0.095 0.93	15.97±0.757 1.40	1.35±0.109 0
Amelanchier spicata (Lam.) K. Koch., open TSS	x±m	3.2±0.138	3.9±0.108	2.5±0.106	15.93±0.945	1.65±0.131
Amelanchier spicata (Lam.) K Koch., closed TSS	x±m t (t_{tab}=2.0)	4.5±0.225 5.00	3.9±0.122 0	2.5±0.096 0	16±0.917 0.05	1.85±0.167 0.95
			City objects			
Cotoneaster lucidus Schlecht., public garden in Mira str., closed TSS	x±m	2.14±0.111	2.38±0.102	2.03±0.186	22.12±1.206	1.83±0.222
Amelanchier spicata (Lam.) K Koch., Sibirsky trakt str. semiopen TSS, Thinned out plantations	x±m	5.36±0.259	4.98±0.289	1.91±0.125	21.29±1.893	1.73±0.216
Amelanchier spicata (Lam.) K Koch., Sibirsky trakt str. semiopen TSS, Dense plantations	x±m t (t_{tab}=2.0)	6.12±0.146 2.5	4.90±0.260 0.21	2.56±0.254 2.32	18.68±0.956 1.23	1.88±0.189 0.53

Table 3. The average score of the tolerance amplitude of species by factors. Tm – thermo morph, Om –ombro morph, Cr – cro morph, Hd – hydro morph, Tr – tro fomorph, Rc acido morph, Lc – helio morph.

Species	Factors						
	Tm	Om	Cr	Hd	Tr	Rc	Lc
Amelanchier spicata (Lam.) K Koch.	9	8	10	12	6	6	3
Cotoneaster lucidus Schlecht.	8	7	6	9	7	9	3

The data presented in the table show the following:

– by the temperature regime of climate (Tm) *Amelanchier spicata* (Lam.) K Koch. ranges from boreal to Mediterranean, while *Cotoneaster lucidus* Schlecht.– from intermediate type between subarctic and boreal to sub-Mediterranean, that is *Cotoneaster lucidus* Schlecht. is more frost-resistant, and *Amelanchier spicata* (Lam.) K. Koch. is more heat-loving;

– by climate humidity (Om) the species are rated in an intermediate regime between semi-arid and sub-humid types;

– by the frosts frequency of climate (Cr) according to the average indexes the species belong to the intermediate type between moderate and mild winters, but *Cotoneaster lucidus* Schlecht. range is shifted towards the "harsh" and "very harsh", while *Amelanchier spicata* (Lam.) K. Koch. towards "soft" and "warm»;

– by soil moisture (Hd) *Amelanchier spicata* (Lam.) K. Koch. can be attributed to the dry-forest - meadow type, and *Cotoneaster lucidus* Schlecht. – to the meadow-steppe regime type;

– by salt regime (Tr), both species have the same upper limit – soils rich in salts, but *Amelanchier spicata* (Lam.) K. Koch. has a wider amplitude – it grows on poor soils as well;

– by soil acidity (Rc) *Amelanchier spicata* (Lam.) K. Koch. has a very wide amplitude of tolerance from 1 to 11, that is, from very acidic soils to slightly alkaline, and *Cotoneaster lucidus* Schlecht. only from acidic to slightly alkaline;

– by shade density (Lc) *Amelanchier spicata* (Lam.) K. Koch. has a wider amplitude from 1 – open space to 5 – low shade density forests. On average, both species can be attributed to the regime of semi-open spaces.

Thus, these species are very plastic in ecological terms and can occupy various niches in forest phytocenosis, including various degrees of shade density, high frost resistance, on poor soils, on soils with high acidity. Moreover, by almost all factors *Amelanchier spicata* (Lam.) K. Koch. has a wider range for optimum growing conditions.

Cotoneaster lucidus Schlecht. leaf blades were used to study fluctuating asymmetry. *Cotoneaster lucidus* Schlecht. grows in conditions with different degrees of shade density and anthropogenic influence in both forest park and urban plantations. The data are presented in Table 4.

Table 4. The degree of asymmetry of *Cotoneaster lucidus* Schlecht. leaf blades.

Object	The degree of asymmetry in the sample
Public garden in Mira str., shaded areas	0.079
Public garden in Lenin str., low shade density areas	0.068
Uktussky forest park, shaded areas	0.061
Uktussky forest park, low shade density areas	0.079

It is well known that the degree of fluctuating asymmetry of a leaf increases when impact degree of one or another adverse factor increases. Indicators of asymmetry of *Cotoneaster lucidus* Schlecht. leaf blades (table 4) indicate that shade density conditions do not have a significant effect on the increase in leaf asymmetry. In urban conditions, the highest level of asymmetry is observed in the public garden in Mira street, on a shaded area located near the highway of district importance and a vehicles stop, that is, in conditions of increased gas pollution. In a forest park conditions the highest index of asymmetry was marked on low shade density area of large-herb-and- grass plant cutting of the 4th stage of digression, that is, on the area with high anthropogenic load.

4. Conclusion

The conducted research made it possible to establish the following:

1. In the forest parks of Yekaterinburg there is a significant number of introduced species – invasive species. Three forest parks of the southern sector taken as a sample demonstrated that the number of such species with high occurrence (more than 80%) did not exceed five species.

2. *Cotoneaster lucidus* Schlecht. and *Amelanchier spicata* (Lam.) K. Koch. were taken for a detailed study. Both species are plastic in ecological terms. They easily adapt to the conditions of different shade density and increased recreational load, having a high score of sanitary condition – from 1.3 to 1.8, both in urban areas plantations and in the conditions of a forest park. Shade density and anthropogenic load factors also do not have a significant impact on the value of biometric indicators.

3. The data of tolerance according to 7 factors showed that both species have wide amplitudes of growth, *Amelanchier spicata* (Lam.) K. Koch. having especially high plasticity and adaptability to environmental conditions.

References

[1] Zaitsev O B and Polyakov V E 2015 *Specially protected natural areas of Yekaterinburg* [InRussian – Osobo ohranyaemye prirodnye territorii goroda Ekaterinburga] (Yekaterinburg: Izdatelskyi dom “Azhur”) p 51

[2] Zakharov V M, Baranov A S, Borisov V I, Valetsky A V, Kryazheva N D, Chistyakova E Kand Chubinishvili A T 2000 *Health of environment: methods of assessment* [In Russian – Zdorov'e sredy: metodika ocenki] (Moscow: Centr ekologicheskoj politiki Rossii) p 68

[3] FSAD "Institute of organizational technologies for housing and communal services" [In Russian – FGUP – Institut organizacionnyh tekhnologij v zhilishchno-kommunal'nom hozyajstve] 2007 *Regulations on works on inventory and certification of objects of landscape gardened areas of the 1st category* [In Russian – Reglament na raboty po inventarizacii i pasportizacii ob"ektov ozelenennyh territorij 1-j kategorii g. Moskvy] (Moscow: Moszelenhoz) p 54

[4] Zhukova L A, Dorogova Y A, Turmuhametova N V et al. 2010 *Ecological scales and methodsof analysis of ecological diversity of plants* [In Russian – Ekologicheskie shkaly i metody analiza ekologicheskogo raznoobraziya rastenij] (Yoshkar-Ola: Marijskijgosudarstvenny`j universitet) p 368

[5] Arkhipova N P 2001 *Natural Attractions of Yekaterinburg and its Surroundings* [In Russian – Prirodnye dostoprimechatel'nosti Ekaterinburga i ego okrestnostej] (Yekaterinburg: AKVA-PRESS) p 226

[6] Lisina E I 2013 *Characteristics of boulevards growing stock in the cities of the Middle Urals* [In Russian – Harakteristika nasazhdenij bul'varov v gorodah Srednego Urala], PhD thesis Yekaterinburg: The Ural State Forest Technical University p 23

[7] Zubova S S, Suslova N G and Vorozhnin V S 2014 Study of the role of *Malus Baccata* in the improvement of the urban area [In Russian – Izuchenie roli *Malus Baccata* v blagoustrojstve gorodskoj territorii] *Sovremennye problemy nauki i obrazovaniya* **2** pp 6–12

[8] Semkina L A, Makarova O B and Yakovleva S V 1991 The condition of green plantations in Sverdlovsk and at some industrial enterprises [In Russian – Sostoyanie zelenyh nasazhdenij v g. Sverdlovske i na nekotoryh promyshlennyh predpriyatiyah] *Ecology and Introduction in the Urals* [In Russian – Ekologiya i introdukciya na Urale.] (Sverdlovsk: USSR Academy of Sciences, The Ural Branch [In Russian – AN SSSR. Ural'skoe otdelenie]) pp 81–94

[9] Vishnyakova S V, Luganskaya S V, Mezenina O B and Frolova T I 2018 Results of the reconstruction of the park named after Pavlik Morozov in Yekaterinburg [In Russian – Itogirekonstrukcii parka im. Pavlika Morozova v gorode Ekaterinburge] *Prirodoobustrojstvo* **4** pp 121–129

[10] Konovalov N A, Lugansky N A and Srodnykh T B 2010 *Trees and shrubs for landscape gardening in the cities of the Urals* [In Russian – Derev'ya i kustarniki dlya ozeleneniya gorodov Urala] (Yekaterinburg: Ural'skij gosudarstvennyj lesotekhnicheskij universitet) p 181

[11] Zubkova E V 2011 On some characteristics of D. N. Tzyganov range ecological scales of plants [In Russian – O nekotoryh osobennostyah diapazonnyh ekologicheskih shkal rastenij D.N. Cyganova] *Izvestiya Samarskogo nauchnogo centra Rossijskoj akademii nauk* **5** pp 48–53

[12] Zolotova E S and Ivanova N S 2015 Use of D. N. Tzyganov scales for the analysis of ecological space of forest types in the Middle Urals [In Russian – Ispol'zovanie shkal D.N. Cyganova dlya analiza ekologicheskogo prostranstva tipov lesa Srednego Urala] *Fundamental'nye issledovaniya* **23** pp 5114–5119