

Ecological and biological features of the development of introduced species of the genus *Abies* Mill

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Abstract. Against the background of man-made impact on the environment, the role of landscape architecture increases. Green plantings reduce the impact of adverse factors. A special role is given to coniferous plants that perform environmental-improving functions all year round. The collection of the VNIISPK arboretum includes more than 310 species, forms and varieties of woody plants representing 31 families. The most numerous family of Pinaceae includes 5 genera, one of which is the genus *Abies* Mill. The purpose of the study is a comprehensive assessment of ecological and biological features of the genus *Abies* of different origin to justify the success of the introduction in conditions of the Central Chernozem region of Russia. All the studied species have high winter hardiness in the conditions of the central part of Russia. *A. balsamea*, *A. concolor*, *A. fraseri*, *A. lasiocarpa*, and *A. sibirica* were resistant to infectious diseases. *A. alba*, *A. concolor*, *A. fraseri*, *A. nephrolepis*, *A. sachalinensis* and *A. veitchii* showed resistance to pests. According to the results of comprehensive assessment of the ecological and biological features of 9 introduced species of the genus *Abies*, three highly decorative genotypes of North American origin, resistant to a complex of adverse environmental factors, were identified: *A. balsamea*, *A. concolor*, and *A. fraseri*.

1 Introduction

The increased anthropogenic impact on the biosphere has led not only to global environmental perturbations and decrease in the level of environment comfort, but also has created conditions that are dangerous for human health [1-5]. Against this background, the role of landscape architecture is increasing as one of the main directions of creating a harmonious human environment. Natural and artificial green plantings, including urban and suburban forests, parks and other green areas of various functional purposes, directly related to both the aesthetic properties of the living environment and the ecological ones, perform primarily environmental functions and are of vital importance for human [2-8]. Plants have a beneficial effect on the microclimate, moisturize and enrich the air with oxygen, reduce noise, serve as a natural filter that absorbs dust, and improve the radiation regime. By adsorbing a significant amount of toxic components, including heavy metals,

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from the air and neutralizing them in the tissues, and releasing phytoncides, they contribute to maintaining a healthy gas balance in the atmosphere [2, 4-6, 9-15]. However, when working on the creation of landscaping objects, it should be taken into account that woody plants differ significantly from each other in terms of stability in urban environment. Currently, specialists face two main tasks: the preservation of existing green areas and the creation of new green plantings, which must have great resistance to anthropogenic pressure and meet high aesthetic requirements [12, 16].

In central part of Russia, where all native foliaceous plants are deciduous, it is impossible to create a garden or park that performs its sanitary and hygienic functions all year round and retains its attractiveness, without coniferous plants, most of which are evergreen [11]. At the same time, the impact of negative factors of the urbanized environment contributes to the formation of an assortment with a limited species composition of woody plants, which makes it necessary to search for introduced plants to create a sustainable landscaping system [13, 14].

Green plantings are leveled by unfavorable factors of natural and man-made origin, are exposed to chemical, physical, biological and complex pollution. The high degree of influence of urbanized territories negative factors often leads to vegetation weakening, damage by diseases and pests, loss of their biological stability, decrease in decorative properties, premature aging and trees drying [5, 8, 13, 17-20].

According to L. N. Kovrigina [11] coniferous species that have low level of metabolism, long-term assimilation organs and imperfect conducting system in comparison with foliaceous ones, and are the most sensitive to urban environment pollution. O.N. Kulikova believes [6] that many species of coniferous plants, when they are transferred to new conditions (i.e., to introduction conditions), are resistant to gas contamination and smoke, are durable, decorative, fast-growing, and superior to local species in biological or technical properties. Despite the long period of study, the choice of forms and varieties introduced and promising for gardening is associated with a lack of data on their stability and prospects [11, 14, 21].

Botanical gardens and arboretums study the adaptation of woody introduced species to changing environmental conditions [22]. To this date, the collection of the arboretum of the Russian Research Institute of Fruit Crop Breeding (VNIISPK, Russia) includes more than 310 species, forms and varieties of woody plants representing 31 families. Representatives of the coniferous plants class make up 25% of the total number of taxa and are represented by three families: Pinaceae Lindl, Cupresaceae Neger and Taxaceae Lindl. The most numerous family of Pinaceae in terms of the number of species includes 5 genera [23], one of which is the genus *Abies* Mill. All species of this genus in our collection are introduced species.

Abies is a genus of evergreen forest-forming gymnosperms. These are pyramidal trees up to 60 meters high, having ringed horizontal branches. The life span is 150-200 years. Representatives of the genus *Abies* are quite cold-hardy, but are sensitive to drought and industrial air pollution [14, 24, 25].

The VNIISPK rboretum is located in the European part of Russia, 368 km to the southwest of Moscow (53°00'N, 36°00'E), one and a half kilometers from the city of Orel in the immediate vicinity of the busy Orel-Bolkhov highway, from which it is separated by a single-row planting of small-leaved linden. According to the research of L. N. Kovrigina [11] the use of coniferous trees in the protective zones of industrial enterprises and in plantings along highways with heavy traffic is impractical, since this reduces their resistance to other negative environmental factors. The presence of a highway in the experimental conditions allows to identify plants that are resistant to anthropogenic loads. The purpose of the study is a comprehensive assessment of ecological and biological

features of the genus *Abies* of different origin to justify the success of the introduction in conditions of the Central Chernozem region of Russia.

2 Materials and methods

The objects of the study were plants of 9 species of the genus *Abies* growing in different geographical zones of the genetic collection of the VNIISPK arboretum (Table 1). The research was conducted from 2012 to 2020. Annual increments were studied from 2018 to 2020. The following methods were used: determination of winter-hardiness - visually in the field conditions at the end of budding on a 7-point scale of P.I. Lapina and S.V. Sidneva [26], where 1 is the highest score of winter-hardiness; the general condition of plants on a 3-point scale of A. G. Golovach [27], where 1 is the best state; determination of resistance to diseases and pests - by visual inspection with regard to the influence of this factor on the decorativeness, in connection with this proposed 3-point scale (0 – no damage (affect), 1 – there is damage (affect) without loss of decorativeness, 2 – damage (affect) is present with loss of decorativeness). The height measurements of the studied plants were carried out with a Nikon Forest Pro altimeter.

Statistical processing of the research results was carried out by variance analysis method (ANOVA). The significant difference between the varieties (LSD) was calculated with a 5% significance level. The calculations were performed using the Microsoft Excel 2016 software package.

Table 1. Research objects

Species	Natural growth area	Year of planting in arboretum	Number of plants	General condition as of 01.10.2020
<i>Abies alba</i> Mill.	Western Europe	1974	10	2
<i>Abies balsamea</i> Mill	North America	1968	2	1
<i>Abies concolor</i> (Gord.) Engelm.	North America	1968	9	1
<i>Abies fraseri</i> (Purch)Poir.	North America	1977	16	1
<i>Abies lasiocarpa</i> (Hook.) Nutt.	North America	1977	10	2
<i>Abies nephrolepis</i> (Trautv. ex Maxim.) Maxim.	Far East	1968	1	3
<i>Abies sachalinensis</i> (F.Schmidt) Mast.	Far East	1968	5	1
<i>sibirica</i> Ledeb.	Siberia	1977	11	2
<i>Abies veitchii</i> Lindl.	Far East	1977	2	2

3 Results and discussion

The prospects of introduction largely depend on winter-hardiness, that is, on the ability of plants to withstand a complex of environmental influences during the winter and early spring periods. This factor depends on the biological characteristics of woody plants, their age and growing conditions [6, 28, 29]. According to the results of our research, all objects of the genus *Abies* have a high winter-hardiness (1 point) in the conditions of the central part of Russia.

The assessment of the general condition of plants of the genus *Abies* was carried out by us at the end of the growing season of each year of research. Deterioration of the condition of adult coniferous plants, as a rule, leads to irreversible damage, since dead needles and

dried branches are not restored. Respectively, the condition of the research objects as of 01.10.2020 reflects the total result for this indicator for the entire period of research (Table 1). It was found that *A. nephrolepis* is in poor condition and has a weak vitality, which is associated with the low resistance of this species to diseases. The plant of this species is noticeably weakened, the growth of shoots is weak, the color of the needles is pale, the cones are not formed. Satisfactory condition (medium vitality) was recorded in *A. alba*, *A. lasiocarpa*, *A. sachalinensis*, *A. sibirica*, and *A. veitchii*. The shoots growth, development and brightness of the needles color in these species did not reach the maximum. Three of the studied objects (*A. balsamea*, *A. concolor*, and *A. fraseri*) had good vitality. These species had a dense symmetrical crown, healthy appearance, good annual growth, and typical shoots and needles throughout the entire observation period. A large number of cones with full-fledged seeds were formed on the plants. The growth of *Abies* plants in the arboretum at a close distance from the highway did not affect their general condition.

One of the important indicators of plant resistance in the conditions of introduction is their resistance to pests and diseases. During the years of research, we have recorded physiological and infectious diseases of *Abies*. In individual specimens of *A. alba*, *A. concolor*, and *A. fraseri*, there was a slight physiological drying of the branches due to the thickening of individual plantings. There were pine-leaf cast, brown pine-leaf cast and needles brown streak among infectious diseases. The causative agent of pine-leaf cast is the fungus *Lophodermium nervisequium* (DC.) Rehm. On some branches of *A. nephrolepis*, *A. sachalinensis* and *A. veitchii*, the two-year-old needles became brown, with small, oblong, black fruit bodies visible on needle underside. The brown needles fell off by autumn. Fungi *Herpotrichia juniperi* (Duby) Petr. is the causative agent of brown pine-leaf cast, which was observed on *A. alba* (fig. 1, A). In the spring, the needles on some branches of individual specimens turned yellow and were covered with a gray-brown web mycelium. In the affected needles, black spherical small fruit bodies of the wintering stage of the pathogen fungus were formed. The needles turned brown and dried up, remaining on the branches. The browning of *Abies* needles is caused by the fungi *Trichosphaeria parasitica* Hart. and *Rhizosphaera pini* (Corda) Maubl. This disease in arboretum conditions was noted on *A. nephrolepis*. The needles gradually turn brown, but, supported by mycelium threads, they do not fall off immediately. On the underside of the needles, point-shaped spherical fruit bodies are formed. In wet years, individual branches of *A. nephrolepis* are strongly affected (2 points), which causes mass needles fall off and branches denudation. All diseases recorded on *Abies* species reduce the decorative effect of the affected specimens (1-2 points). *A. balsamea*, *A. concolor*, *A. fraseri*, *A. lasiocarpa*, and *A. sibirica* were resistant to infectious diseases.

The main pest of *Abies* during the research period was hermes (*Aphrastasia peclinatae* Choi.) – a small insect, aphid, black in color, abundantly covered with white pubescence, whose entire life is spent on young shoots. Aphids feed on the underside of the needles, and yellow spots appear on the upper side in these places. During the season, 3-4 generations develop. In large numbers, this type of pest in the arboretum was noted on *A. lasiocarpa* and *A. sibirica* (2 points) (fig. 1, B). Damaged needles turn yellow and fall off, which affects the decorative and general condition of plants of these species. *A. alba*, *A. balsamea*, *A. concolor*, *A. fraseri*, *A. nephrolepis*, *A. sachalinensis* and *A. veitchii* showed resistance to pests.

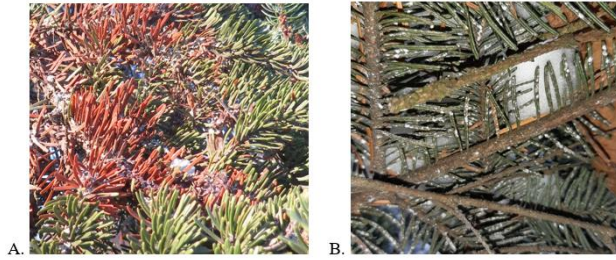


Fig. 1. A – *Herpotrichia juniperi* on *A. alba*; B – *Aphrastasia peclinatae* on *A. sibirica*

One of the defining properties when selecting an assortment of woody plants for decorative gardening is the size they achieve, growth speed and durability. Measurement of plants height of the genus *Abies* in arboretum conditions (as of 01.11.2020) showed different variability of this parameter within the species (fig. 2). Slight variation (coefficient of variation does not exceed 10 %) was observed in 3 species of *Abies* - *A. balsamea*, *A. sibirica* and *A. veitchii*. *A. alba* has the greatest variability in the value of this indicator (25.5 %). The remaining *Abies* species studied have an average variation of 10.8 to 18.5 %. Based on the measurements carried out, significant differences in height were revealed between different *Abies* species. In relation to the majority of the studied species, a significantly low value of this indicator was found in *A. alba* (13.1 m) and *A. veitchii* (13.8 m), while *A. concolor* (18.5 m) and *A. sibirica* (17.5 m) had a significantly high value.

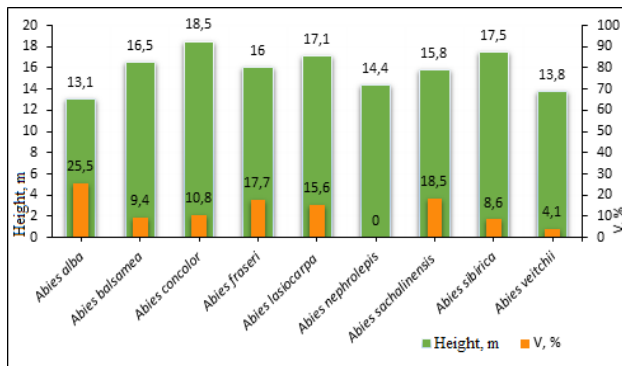


Fig. 2. The average height of plants of *Abies* species (LSD05 = 1.45) and the coefficient of variation of this trait (V).

In nature, *A. alba*, *A. concolor*, *A. sachalinensis*, *A. sibirica* and *A. veitchii* reach quite large sizes (more than 20 m) and are trees of the first range. In arboretum conditions, at the moment they are trees of the second range (Table 2), that is, they have not yet reached the typical size for the species. *A. balsamea*, *A. fraseri*, *A. nephrolepis* and *A. lasiocarpa* rarely reach a height of 20 m in natural conditions, that is, they are trees of the second range. Studies have shown that in the arboretum, these objects of study have already reached the size typical for the species. Nevertheless, it should be noted that the studied *Abies* species in the arboretum have an age young enough for representatives of this genus in natural conditions of growth, so they continue their growth and development. Based on this, further observation of these objects of research is of scientific and practical interest from the point of view of studying the dynamics of their growth in connection with longevity.

4 Conclusion

According to the results of comprehensive assessment of the ecological and biological features of nine introduced species of the genus *Abies* of the genetic collection of VNIISPK arboretum, three highly decorative genotypes of North American origin, resistant to a complex of adverse environmental factors, were identified: *A. balsamea*, *A. concolor*, and *A. fraseri*. When these species are introduced into the conditions of the Central Chernozem region of the Russian Federation, a positive result can be predicted.

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