PLANTS
IN URBAN AREAS AND LANDSCAPE

INTRODUCTIONAL POSSIBILITIES OF WOODY PLANTS USED FOR LANDSCAPING IN CENTRAL YAKUTIA

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The analysis of the species composition of plantations of trees in the city of Yakutsk and its surroundings showed that introduced, mainly natural species of flora of Yakutia (50%). In 40 years of work of employees of the Yakut Botanical garden culture there were introduced 180 species of trees and shrubs, including 55 species of local flora. All kinds are divided into groups with different rhythms of growth. The plants with early rhythm the beginning of the growing season and the early end of the growing season are the most promising ones for implementation in the conditions of Yakutia.

Keywords: dendroflora, introduction of ornamental woody species, rhythmotypes

1 Introduction

One of the main problems of plant introduction is the preliminary selection of plant species from other climate zones, with sufficient stability in the new conditions of growth. There have been developed many methods for the selection of species. The method of climate analogues X. Myra (the international Association of genocide scholars, 1890, 1909) – one of the first introductions of plants – implied the transfer of plants to identical climatic conditions. In the United States, the dendrologist A. Render (Render, 1947) developed the introduction zonation based on one factor – absolute minimum of air temperature. Followers of the method of climate applied analogical methods with some modifications – A. Pavari (Pavari, 1916), F. Koeppen (Corep, 1923), A. Cajander (Cajander, 1924), G. T. Selyaninov (1937), E. E. Kern (1925, 1934), V. P. Alekseev (1960), I. I. Galaktionov, A. V. By (1963) and others. In the 1980s B. N. Golovkin attempted to introduce the territory of the USSR on the same principle and to evaluate the winter hardiness of woody plants on the American scale of Reader-Women (1986). The ecological-historical method by M. V. Kultiasov (1953), based on the ecological potential of plants, acquired in the course of historical evolution. According to the method of determining selection of species according to the identity of climates (Maleev, 1933; Shlykov, 1963; Vavilov, 1965), Yakutia, having no climatic analogues, is considered as an unpromising region to tap into the culture of an alien plant. The choice of sources of introductions to Yakutia with its unfavourable climate is very difficult.

The Yakut Botanical Garden of Institute for Biological Problems of Cryolithozone SD RAS (IBPC SD RAS) develops theoretical and practical issues of planting and ornamental gardening in the Far North since the 1960s. It was recommended to 150 species of ornamental herbaceous annuals and perennials and 35 species of woody plants (Krotova, 1980). Nowadays, 222 species of rees and shrubs, with various geographical origins, pass the test with the introduction of culture (Petrova, Romanova and Nazarova, 2000).

However, even after 50 years of preparation of area-based assortments is focused to representatives of local wild flora. According to the current data, the flora of Yakutia has 1,970 species of vascular plants, where dendroflora includes 189 species (Variety..., 2005). Yakutian tree species have one advantage – all kinds of Yakutian trees are very winter-hardy. Therefore, the duration of the selection among them for decorative qualities is reduced by eliminating the need to select frost forms. At the same time, the high polymorphism of features allows you to select the most decorative forms.

2 Materials and Methods

Yakutia is the coldest region of Russia with continuous permafrost; its thickness is about 100–150 m. The Central Yakutian floristic region is the driest area with sharply continental climate. The total precipitation is

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Plants in Urban areas and Landscape | 2018 | pp. 45–50 |
https://doi.org/10.15414/PUAL/2018.45-50

200–250 mm per year. The period with negative daily temperature lasts 7–8 months, the average January temperature reaches -41 ... -43 °C and the minimum is below -60 °C. At the same time, the average temperature in July (the hottest month) is 18.8 °C, with an absolute maximum of 38 °C. High summer temperatures are associated with the peculiarities of the radiation regime. The annual rate of direct radiation reaches 48.4 kcal/cm^2 and diffused – 40.2 kcal/cm^2 (Agroclimatic Resources of YASSR, 1973; Gavrilova, 1973). Yakutia is represented by seven floristic regions. We allocated points of input materials for the introduction in central Yakutia and held their evaluation (Table 1).

The division into zones was developed in the United States Department of Agriculture (USDA), but then became universal for gardeners in other countries (Table 2). Russia also sticks to it, because many plants are exported from foreign nurseries, and we should focus on the conditions of their cultivation. The map of climatic zones based on the minimum temperature in winter is in fact a map of hardiness or hardiness of plants. The scale has 12 climatic zones (0 to 12), from northern latitudes (zero zone, the cold) to the equator. The description of winter hardiness of species of plants and new varieties is based on this scale. In Russia there are 10 hardiness zones, from zero to nine.

Winter hardiness was determined using a scale developed in the Main Botanical garden of Academy of Sciences of Russia (Lapin and Sidneva, 1973). According

Table 1 Climatic characteristics of the regions under of woody plants species growing.

Location	Days within year with t° >		Sum of t° for year >10°C	Frost-free period, days	Average absolute annual, min t°	Coefficient*	
	5°C	10°C				C_1	C_2
Olekminsk	135	100	1600	95	54	100.1	0.49
Aldan	120	87	1300	75	53	99.5	0.89
V. Viliuysk	124	92	1400	75	57	112.2	0.33
Verkhoyansk	110	83	1200	65	67	123.7	0.26
Yakutsk	130	97	1500	90	57	110.3	0.38

`* C_1 – conrod continentality; C_2 – Mezentcev moistening

Table 2 Data on the winter hardiness zones of the plants

Zone	Temperature (C°)		Examples of areas with similar climate
	min	max	
1	below -45		Central Siberia
2	-45.5	-40.1	Southern Siberia
3	-40.0	-34.5	Lapland
4	-34.4	-28.9	A large part of Russia, Northern and mountainous areas of Scandinavia
5a	-28.9	-26.1	Average Russia, the Baltic countries
5b	-26.0	-23.4	North-Eastern Poland, Western Ukraine, southern Sweden, southern Finland
6a	-23.3	-20.6	Eastern Poland, Slovakia, Central Sweden, southern Norway
6b	-20.5	-17.8	Central Poland, Eastern Hungary, the Czech Republic
7a	-17.7	-15.0	Eastern Germany, Western Poland
7b	-14.9	-12.3	Eastern Holland, Denmark
8a	-12.2	-9.5	Central Holland, Belgium, Northern and Central France, Northern England
8b	-9.4	-6.7	Seaside the Netherlands, Western France, Northern Italy, Central England
9	-6.6	-1.2	Southern France, Central Italy, Portugal, South England
10	-1.1	4.4	Southern Italy, southern Spain, Central Greece
11	4.4	10.6	North Africa
12	more than 10.6		South Africa

Source: Hofman H.A. 1998. Raveslot "Winterhardheid van boornkwekeriioewassen"

to this scale, the points of stability are defined as follows:

I – plants are not frosted over,
II – frosting not more than 50% of the length of annual shoots,
III – frosting from 50 to 100% of the length of annual shoots,
IV – freeze with older shoots,
V – frosting the aboveground part to the snow cover,
VI – frosting the whole aboveground part,
VII – the plant dies entirely.

Trulevich N. allocates 4 groups of introduction of plant resistance and gives the following justification.

I – Unstable plants. They do not undergo a complete annual cycle of development of shoots, rhythmic processes are damaged, life as year after year, often dying in the early stages of ontogenesis (obtained from a seed) or in the first years of planting (transplanted).

Their life expectancy is up to 5 years.

II – weakly stable plants. Plants are one-year development cycle shoots irregularly, life as compared to the plants natural habitats weakened, the life form often varies considerably, not independently resume the pace of ontogeny often less accelerated or slowed. In the collection of live 5-10 years.

III – Resistant plants. They have a full cycle of development of shoots, rhythmic processes are stable, adapted to local climatic conditions, life as high on productivity, the size of these plants meets or exceeds their natural life form is preserved, self-seeding, not form, but successfully reproduce by artificial means. Held in the collection of up to 20 years.

IV – highly resistant plants. They develop fully as the previous ones, but multiply rapidly, often form a self-seeding or able to vegetatively samboteanu, expanding footprint and stored in a collection after 20 years.

Phenological observations of woody plants were carried out according to the "Guidelines for phenological observations in the botanical gardens of the USSR ", developed in 1975 at the Main Botanical Garden of Academy of Sciences. The degree of adaptation of the form was determined as the ratio of the actual amount of points to the maximum amount of possible points. This ratio is called the adaptation coefficient and expressed by the equation: $Ka = S1 / S^* \times 100$, where *Ka* – adaptation coefficient; *S*1 – actual points sum; *S** – fully adapted plants points sum. All figures are determined on 5 score-scale where the highest score means a high degree of feature.

Taxa in the rank of families and genera are given by A.L. Takhtadzhyan (1987), generic and specific names are given by S.K. Cherepanov (1995), in some cases the names are used from different reports (Trees and shrubs of the USSR, 1949-1962).

Life forms of plants were identified by I.G. Serebriakova's system (1964) and assigned to two divisions:

1. woody (trees, shrubs, bushes, tree and bush vines, cushion plants),
2. subwoody plants (shrubs, dwarf shrubs, semi-shrubs and creepers subshrubs).

Data on plant phenology was processed by mathematical statistics methods using the software STATGRAPHICS Plus-Printing, NIRSMAIN and EXCEL.

3 Results and Discussion

About 5,000 samples of seeds were tested in Central Yakutia for 40 years. The choice of plant assortment was carried out using species of both local flora and from various botanical and geographical regions of Russia.

The majority of the species studied in the culture refer to latitudinal boreal (96/50, 8%), steppe and alpine latitudinal elements (28/14, 8% and 27/14, 3%, respectively).

The species of the Yakut flora make up more than 50% (94 species, about 22 families). This group includes various uses: food, medical, technical. Many types in addition to these qualities are also decorative.

One of the criteria of introductory stability of plants is the fullness of plants' phenological phases. In conditions of culture, all woody species bloom and bear fruit annually, form the seeds, and their biological productivity increases. All this testifies their high ductility and high capacity of introduction.

Comparative analysis of phenological biorhythms allowed dividing plants into groups with different rhythmotypes. The fenorhythmotype concept combines plants with similar duration and timing of the beginning and end of the growing season, and with the same direction of the main phenological shifts states: vegetation and quiet. Timing of flowering and fruiting are considered. The growing season is determined by the number of days between the dates of onset and termination of average daily temperatures above 5 °C. Species, vegetation completed before the end of the growing season, attributed to the early growing season -ending (Ee), after the end of the growing season to late (Le)-ending vegetation.

Early rhythmotype is when vegetation starts in the first half of May, with accumulation of amount of active

temperatures is 97.8°; noted bloom in late May – early June, the amount of active temperatures is 463.6°; fruition in the first or second decade of June. This group includes *Ribes triste*, *R. procumbes*, *R. nigrum*, local varieties of currants (Yakut), *Spiraea betulifolia*, *S. dahurica*, *Sorbaria sorbifolia*, *Lonicera edulis*, *Atragene sibirica*.

The average rhythmotype means the beginning of vegetation occurs in the second decade of May, the amount of active temperatures is 170.5 °C. This group includes species: *Ribes glabellum*, *R. palczewskii*, *R. pauciflorum*, local varieties of black currants Myuryucheene, Sardana, Khara Kytalyk, all species of the genera *Crataegus*, *Rosa*, *Lonicera*, *Betula*, *Cotoneaster*, *Spiraea*, *Padus*, *Sorbus*, *Sambucus*, *Sorbocotoneaster*, *Caragana*, *Populis*. Among the species beginning vegetation at this time, you can select a group by timing of flowering and fruiting: with early flowering and fruiting ($A_vE_{fl}E_{fr}$), with an average flowering and fruiting ($A_vA_{fl}A_{fr}$), and late flowering and fruiting ($A_vL_{fl}L_{fr}$).

The types with late rhythmotype (L_v): the beginning of vegetation is observed in the third decade of May, the amount of active temperature is 284.8 degrees, for bloom is 613 ˚C for native species are not represented.

The plants of the phenogroups $E_vE_{fl}E_e$, $A_vE_{fl}A_e$, $A_vA_{fl}E_e$ are most adapted to local climatic rhythm and therefore more perspective for introduction in Yakutia. The distribution of native species of vegetation on top as follows: 74 of them (80%) begin vegetation, bloom in the early stages, 11 species start growing season, flowering takes place in the medium term, 8 species are characterized by average vegetation period (*Ribes glabellum*, *R. palczewskii*, *Betula fruticosa*, *Sorbocotoneaster* pozdnjakowii). All 93 species (100%) complete vegetation before the end of the vegetation growing season. Phenological biorhythm of woody plants can be regarded as an integral indicator of the level of adaptation of exotic species, if we consider the beginning of the growing season and total duration of the growing season (Bulygin and Firsov, 1995).

In a "green building", it is important to know decorative properties of woody plants, the conditions of their maximum development. During the observation, 168 exotic species bloomed and fruited (Korobkova, Sabaraykina, Pavlova and Ushnitskaya, 2001). The investigated types are divided into three phenological groups by time and duration of flowering (Table 3).

The largest group with the early onset and the end of flowering (PP) has 133 species of plants, while 53 species of them are local. Most of the observed species bloom in May and June. The phenogroup PP includes species in the collection of genera: *Berberis*, *Lonicera*, *Viburnum*, *Hippophae*, *Caragana*, *Physocarpus*, *Cerasus*, *Padus*, *Amygdalus*, *Prunus*, *Pentaphylloides*, *Crataegus*, *Pyrus*, *Malus*, *Sorbus*, *Sorbocotoneaster*, *Aronia*, *Grossularia*, *Ribes*, *Syringa*, *Euonimus*, *Celastrus*, *Securinega*, *Salix*, *Populus*, *Acer*, *Alnus*, *Betula*, *Ulmus*, *Vitis*. The earliest flowering was observed in 2004–2005 during the period from May 2 to May 24 among many plants (*Hippophae rhamnoides* L., *Cerasus avium* Moench, *Cerasus vulgaris* Mill., *Salix aegyptiaca* L., *Salix dasyclados* Wimm., *Ribes rubrum* L., *Ribes alpinum* L., *Ribes nigrum* L., *Grossularia reclinata* (L.) Mill.).

The plants of the average phenogroup (CP) bloom in June and July. These include species of genera Colutea, Ligustrum, Deutzia. The late blooming group PP includes the following observed species: *Symphoricarpus*, *Lespedeza*, *Sorbaria*, *Rubus*, *Parthenocissus*, *Aralia*, *Eleutherococcus*, *Lycium* and *Hibiscus*.

Siberian species dominate over exotic species. Their hardiness is estimated at 1.2 points (on the scale of GBS). The analysis of the causes of unsuccessful introductions showed that for berry species migrating from Siberia (Berdsk, Novosibirsk, Barnaul) and the Northern European part of Russia (Ufa, Syktyvkar, Petrozavodsk, Michurinsk), the most important is the minimum winter temperature and the amount of average daily temperatures above 10 °C. The main type of damage is freezing off. When this value is not only the extreme minimum temperatures, but also the duration of their exposure. There is repeatability of extremely cold

Table 3 Number of species with different duration of flowering

Phenogroups	Terms		Average duration (days)	Number of species
	start	finish		
EE	before 06.06	before 23.06	11	133
AE	before 06.06	after 23.06	20	5
LL	after 06.06	after 23.06	12	33

E – early; L – late; A – average

weather (average daily temperature is below minus 45.2 °C) and hard-freezing weather (-32.5–42.4 °C) in November in Central Yakutia is 40-45%. In December and January, it is 60–70% and 25–30%.

Far Eastern species have significantly lower hardiness. Species having 1–3 points are perspective.

1 point – *Crataegus maximowiczii* Schneid (Barnaul, Irkutsk)

2 points – *Lonicera maximowiczii* (Rupr.) Regel. (Altai)
Malus baccata (L.) Borkh. (Kirovsk, Lithuania)

3 points – *Crataegus pinnatifida* Bunge. (Khabarovsk)
Lonicera chrysantha Turcz. (Saint Petersburg)
Lonicera ruprechtiana Regel (Kirovsk, Moscow, Novosibirsk)
Malus mandschurica (Maxim) Kom. (Barnaul, Vladivostok)
Ribes mandschuricum (Maxim) Kom. (Amur oblast)
Rosa rugosa Thunb. (Moscow, Novosibirsk, Lithuania)
Sorbus sambucifolia M. Roem. (Kirovsk)
Cerasus besseyi Bailey (Vladivostok, Rostov)

4 points – *Berberis amurensis* Maxim. (Moscow, Novosibirsk)
Padus maackii (Rupr.) Kom. (Moscow, Barnaul, Irkutsk, Latvia)

5 points – *Pyrus ussuriensis* Maxim (Khabarovsk)

6 points – *Armeniaca manschurica* (Maxim) Skvorts. (Khabarovsk, Kazakhstan)
Cerasus glandulosa (Thunb.) Loisel. (Kazakhstan, Barnaul, Irkutsk, Vladivostok)
Prunus ussuriensis Koval. (Kazakhstan, Khabarovsk)
Ribes komarovii Pojark. (Slovakia, Altai)

7 points – *Actinidia arguta* Planch (Moscow, Poland)
A. kolomikta Maxim. (Moscow, Slovakia)
Cerasus maximowiczii Rupr. (Minsk, Ukraine, Tajikistan)
Pyrus japonica Thumb. (Moscow, Tajikistan)
Ribes ussuriense Jancz. (Moscow, Tajikistan)
Sorbus amurensis Koehne. (Moscow, France)
Vitis amurensis Rupr. (Moscow, Poland)

Table 4 Comprehensive Evaluation of Introduction of Woody Plants in the Yakut Botanical Garden (2007–2009)

Species	Σ (+) temperature(°C)		Index of thermophilia (Fjw)	Coefficient of phenological adaptation (Kpha)	Winter-hardiness, score
	beginning of vegetation	during vegetation			
Sorbaria sorbifolia	88.8	2145.4	0.041	3.82	I
Crataegus daurica	147.6	2060.9	0.072	6.47	I
Rosa ***majalis***	88.8	2057.0	0.083	13.31	II
Rosa ***jacutica***	147.6	2068.8	0.071	8.31	I
Lonicera edulis	74.5	2101.2	0.035	5.6	I
Betula dahurica	172.1	2070.6	0.083	12	III
Betula exelis	120.2	2058.7	0.058	7	I
Betula fruticosa	120.2	1978.2	0.061	8	I
Cotoneaster melanocarpus	120.2	2044.8	0.059	7.11	I
Ribes procumbens	74.5	2120.4	0.047	4.97	I
Ribes nigrum ssp. sibiricum	74.5	2133.5	0.035	4.64	II
Ribes pauciflorum	74.5	2005.1	0.037	2.31	I
Ribes glabellum	147.6	2040.6	0.072	2.56	I
Spiraea betulifolia	88.8	2091.3	0.042	5	III
Spiraea dahurica	109.0	2104.4	0.052	9.39	I
Padus avium	100.6	2114.9	0.047	6.16	I
Sorbus sibirica	100.6	2140.2	0.047	5.91	II
Sambucus racemosa	187.0	2076.9	0.090	3.83	II
Sorbocotoneaster pozdnjakowii	147.6	2010.0	0.073	7.96	I

A comprehensive assessment of the results of the introduction of 19 species of woody plants (Table 3) showed that in the conditions of Central Yakutia, floristic area indicators of successful introduction of different types in Yakutia are various. Winter hardiness varies from I to III points, phenological adaptation coefficient from 2.31 (*Ribes pauciflorum*) to 13.31 (*Rosa majalis*). Such differences may be explained by the environmental characteristics of plants in places of mobilizing culture, exposure to disease and pest species.

We can conclude that the prospects for the introduction of woody species are large enough in Yakutia. And although the main species representing economic interests are defined and used, new species may enrich the cultural flora of Yakutia or can be used for breeding and scientific purposes.

4 Conclusions

The most resistant species to adverse abiotic and biotic factors include species belonging to the type of sustainable and dynamic development. The plants of transition and development of indeterminate types with a long growing season are less stable, but despite weak frost hardiness, they can normally grow and evolve due to high bine formation ability, resistance to air drought and resistance to pests and diseases.

During introduction of woody plants into Central Yakutia, changes in terms of vegetation, nature and strength of growth are noticed, and coming into fruition is slowing. The main factors that should be considered when introducing species from other regions of Russia are the minimum winter temperature and the amount of average daily temperatures above 10 °C. During the introduction of Yakut species, moisture content of the territory and duration of period with a temperature higher than 5 °C are very important.

The largest group with the early onset and the end of flowering has 133 species of plants, 53 species of them are local, which allows using native species in landscaping. During the summer season, the emphasis falls on the flowering Siberian and Far Eastern species.

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