

Review

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Review

Green Legacy: Plant Introduction and Dendrological Collections in Yerevan Botanical Gardens: From the Past to the Future

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Abstract: Botanical living collections within botanical gardens represent a crucial global asset for plant diversity. Particular emphasis should be given to dendrological collections, considering their key role in contribution to biodiversity conservation, support scientific inquiry, enhance educational initiatives and support on involvement of the public. The introduction of plants, especially woody plants, is one of the important problems in botanical science, solved in botanical gardens and arboreta. Establishment and development of the Dendrological collections in Botanical gardens is a way to have a comprehensive representation of diverse plant species from different biogeographical regions and continents. Current paper first time presents establishment, development, current status and future perspective of dendrological collections of Yerevan Botanical Garden in the linkage to introduction of woody plants in Armenia.

Keywords: botanical garden; plant introduction; dendrological collection; trees and shrubs; adaptation

Introduction

Establishment of Yerevan botanical Garden and dendrological collection

Introduction of woody plants in Armenia is connected with the activity of botanical gardens (Yerevan, Vanadzor an Sevan) and a few dendrological parks of the Republic (Ijevan, Stepanavan etc.). Tremendous role in the development of actual theoretical and practical issues of introduction and acclimatization of woody plants, as well as in creation of scientific and expositional collections was played by the Botanical garden of the Institute of Botany after A. Takhtajyan NAS of Armenia, founded in Yerevan in 1935, with an area of about 80 hectares.

The soil and climatic conditions of the Yerevan Botanical Garden, located in a semi-desert zone, are rather favorable for cultivation of many native and introduced plants, primarily xerophilic and xero-mesophilic. The climate is continental, the average annual temperature is +11°C, the absolute maximum is +40 °C, the absolute minimum is -25 °C, the frost-free period is on the average 205 days, the amount of average annual precipitations is 350-360 mm, which mainly fall in the spring. In addition, the garden, being located in a basin that does not have a flow of cold air mass, and being situated at 200-250m (1200-1250m above the sea level) above the average hypsometric marks of Yerevan city, is distinguished by more severe weather conditions than Yerevan and Ararat Valley. From this viewpoint, the choice of the botanical garden area is not very successful, so it is difficult to attract more heat-loving and mesophilic highly ornamental plants: Albizzia julibrissin, Lonicera

japonica, *Euonymus japonica*, *Ginkgo biloba*, *Diospyrus lotus*, *Chamaecyparis lawsoniana*, *Cupressus arizonica* etc. which grow well in Yerevan.

In the first years after the opening of the Botanical Garden of the AS of Armenia, active work began on the creation of scientific and expositional dendrocollections. Within the period of creation of dendrological collections, the target was set to represent as much as possible the diversity of dendrological composition of various botanical and geographical regions in the Northern Hemisphere temperate zone.

Due to the efforts and thorough work of several generations of specialists, a rich and diverse dendro collection has been created in the Yerevan Botanical Garden and in its two mountain departments, experience has been accumulated in the introduction and cultivation of plants, numerous valuable publications have been issued: "Scientific bases of afforestation and landscape greening of the Armenian SSR" [1]; Annotated catalog of trees and shrubs of botanical gardens and arboreta of the Armenian SSR, 1985 [2]; "Scientific bases for the introduction of woody plants in Armenia" [3] and etc.

Currently, in the botanical gardens multiple ways to increase the resistance of introduced species are being developed. At the same time, great opportunities open up for the introduction of new economically valuable and highly ornamental species, for replenishing the local flora with new foreign plants. There are 3 types of introduction: folk, spontaneous and scientific (planned).

Theoretical aspects of introduction of woody plants in Armenia

Folk introduction accompanies humans throughout the history of their existence.

In spontaneous introductions, plants are transported to new countries as a result of human activity. By this method weeds are primarily spread. Their seeds are introduced with various cargoes, seed material of cultivated plants, etc. Being extremely active, they are able to displace native endemic According to the data of A.M. Barseghyan and A.G. Abrahamyan [4]; only in the area of Yerevan Botanical Garden there are 78 species of alien plants that were not previously found in the flora of Yerevan. Among woody plants, this species is *Ailanthus altissima*, which, together with various cargoes from the Kazakh and Tovuz regions of Azerbaijan, was brought to the dry subtropical zone of Northern Armenia and spread throughout the republic.

During scientific introduction, the attraction of valuable and useful plants is carried out by using theoretically substantiated methods, based upon the developed special technical methods. This work is intended to be carried out by botanical gardens, arboreta and other specialized support points and stations.

Currently, folk and spontaneous introductions have an insignificant specific weight in the overall introduction process. Therefore, the term "introduction" as a rule, is comprehended as scientific planned introduction, which makes it possible to purposefully attract and introduce valuable plant species.

The purposeful process of scientific introduction in the botanical garden is carried out in the following stages:

- preliminary study and selection of source material for introduction;
- mobilization of source material for introduction;
- development of plants during introduction;
- summing up the introduction.

Based on the primary test analysis, it becomes possible to judge the prospects of the species. If the attracted species, growing in new conditions for several generations, has withstood the competition of native species and is normally replenished, this means its naturalization - it has become a "local resident". Vivid examples are *Acer negundo*, *Ailanthus altissima*, *Amorpha fruticosa* and *Robinia pseudoacacia*, which in many arid forest conditions of the South Caucasus grow and renew themselves without human intervention, gradually expanding their area. The same can be noted concerning *Cryptomeria japonica* in Adjara, *Fraxinus pennsylvanica*, *Quercus robur*, *Pinus pallasiana*, *Caragana arborescens* for many regions of Armenia. *Acer negundo*, *Ailanthus altissima*, *Amorpha fruticosa* и *Robinia pseudoacacia*.

The acclimatization process is very durable and in order to reveal the completion period for the ancient plants several generations are necessary. Despite this, we often witness the acclimatization changes- formation of new botanical forms within the limits of the given population.

Materials and Methods

Principles and methods used for introduction of woody plants in Yerevan Botanical Garden

Aimed at creation of scientific collections of woody plants, local specialists of different generations took as a basis and followed the methodical recommendations and criteria for assessing the results of work on the introduction of plants [3, 5].

During the preliminary study and selection of source material, based on the target value and feasibility, the methods of climatic and agro-climatic analogues were used [6-10], ecological and historical study of floras [11], floro-genetic [12], introduction by generic complexes [13, 14], etc.

Each of these methods has its own advantages and limitations and, depending on the circumstances, all of them were successfully used in the introduction of woody plants into the botanical gardens of Armenia. At the same time, the preliminary study and selection of plants for introduction necessarily includes a thorough analysis of literary data on the taxonomy, geography and ecology of all the species of the generic complex.

The mobilization of source material for the introduction of plants is: collecting material on expeditions, issuing seeds through "Delectus seminum" - seed exchange lists, as well as purchasing material from trading companies and nurseries, etc.

The development of introduced species includes: growing plants in open ground, taking into account their environmental properties; artificial change in biomorph (grafting on resistant rootstocks, grafting to accelerate the transition to the generative phase of development, etc.); influence on the development of plants at different stages of ontogenesis in order to increase their stability and productivity; agrotechnical methods of influence, microbiological, physiological and biochemical (growth stimulants, hormones, etc.), etc.

Summing up the results of introduction involves establishing for a given species the degree of its viability. Some plants run wild and can reproduce without human help, others complete the full development cycle and produce full-fledged offspring only under cultivated conditions. Fruiting can be annual, almost annual, irregular, single. Often, they do not produce normal flowers or fruits.

The main principle of creating the expositional dendro collections at the initial stage of the botanical garden is traditionally eco-geographical. By the same principle, expositional collections of dendroflora of the Caucasus and Crimea, Euro-Siberia, North America and East Asia (with a total area of about 16 hectares) were created in the Yerevan Botanical Garden, in which the main dendro collection of the garden is concentrated - about 1000 species and varieties of 135 genera from 59 families.

Subsequently, after the 1970s, scientific collections were created on completely different principles: conifers, beautifully flowering shrubs and garden forms, woody lianes, as well as a number of highly-ornamental and species-rich genera - *Syringa*, *Sorbus*, *Lonicera*, *Spiraea*, etc. [13].

Results and Discussions

Past and current status of Dendrological collections in Yerevan Botanical Garden

Long-term research works have shown that representatives of different dendro-floristic regions, having different floristic genesis, behave completely differently in conditions of Yerevan Botanical Garden. Trees and shrubs of dry subtropical regions, especially evergreen species, suffer from frost, alkaline soil reaction, low relative air humidity (especially winter drying) and heat. Representatives of mesophilic forests of some regions of the South Caucasus poorly withstand heat and relative air humidity [15, 16].

In Yerevan Botanical Garden, xerophilous plants and species of desert origin are almost not affected. Plants of boreal and Caucasian origin are also quite resistant, in particular, representatives of the genera *Acer*, *Ulmus*, *Sorbus*, *Lonicera*, *Betula*, *Berberis*, *Viburnum*, etc.

Representatives of some genera, especially those of boreal origin, suffer from summer dry air and heat in conditions of Yerevan. For example, in *Fagus orientalis*, *Carpinus betulus*, *Corylus colurna*, *Tilia Caucasia* and *T. cordata*, *Sambucus nigra*, *Populus tremula*, due to dry air and heat, early leaf falling often begins in August.

Thus, the main factors affecting the plant introduction in Yerevan Botanical Garden are low negative temperatures in winter and high positive temperatures in summer, low relative air humidity and alkaline soil reaction.

Aimed at elimination or mitigation of the influence of unfavorable, limiting conditions, a number of measures were taken, directed to improve the conditions for the growth and development of various plant species - selection of ecotypes, hardening of seeds and seedlings, seedling density, shading, irrigation, etc.

Long-term studies have confirmed that the ecological plasticity and adaptability of woody plants is significantly lower than that of herbaceous plants. In the evolutionary series of trees- shrubs- subshrubs-shrubs-perennials the adaptive response to unfavorable environmental factors consistently increases. In the introduction of trees and shrubs, an important role is played by photoperiodism, the coincidence of the seasonal rhythm of development of the introduced species with the climatic rhythms of the new habitat. Woody plants, as a rule, are relatively more difficult to reproduce than herbaceous ones. In the vast majority of species, difficult-to-germinate seeds require special pre-sowing preparation: stratification, hydrothermal treatment, treatment with various acids, stimulators, ultra-sonic [17]. Representatives of individual genera (*Salix*, *Populus*, etc.) and garden forms almost all reproduce well vegetatively. Woody plants enter the fruiting period late, often in new habitats - under the conditions of introduction they form non-germinating seeds, which significantly complicates their reproduction and introduction into practice. (*Salix*, *Populus* etc.)

It was revealed that woody plants of southern origin grow intensively in the conditions of Yerevan. Representatives of the dendroflora of North America usually begin their growing season later in the spring, and finish earlier in the fall than the introduced species from East Asia and especially the Caucasus, due to which they very rarely suffer from late spring and early autumn frosts. Unlike previous groups, representatives of ancient floras are distinguished by a more constant seasonal rhythm of growth and development.

The introduced plants of Northern and high-mountainous origin (*Betula litwinovi*, *Padus racemosa*, *Ulmus laevis*, etc.) in Yerevan begin to bear fruit at a younger age than in natural conditions. The fruiting productivity of boreal species in Yerevan is significantly higher than that of species of more southern origin. Many of the latter (*Vitex agnus-castus*, *Campsis radicans*, *Catalpa ovata* and many others) due to the short growing season do not have time to form fully ripe seeds, and boreal mesophilic species (*Tilia cordata*, *Aesculus hippocastanum*, *Quercus robur*, etc.) in Yerevan suffer from dry air and soil conditions, which also negatively affects the quality of seeds.

In the complex of climatic factors which negatively affect the introduced woody species, the decisive role is played by the lowered temperatures, low relative air humidity, unstable snow cover, warm southern winds, alkaline soil reaction, late spring and early autumn frosts, etc.

It was revealed that in winter-resistant species the vegetative period usually the complex of climatic factors that negatively affect tree introduced species, the decisive role is played by low temperatures, low relative air humidity, unstable snow cover, warm southern winds, alkaline soil reaction, late spring and early autumn frosts, etc. ends 10-60 days before the onset of frost (*Quercus robur*, *Tilia cordata*, *Ulmus laevis*, *Acer tataricum*, *Padus racemosa*, etc.). In heat-loving introduced plants, the vegetative period usually ends very late, the leaves are often damaged by early autumn frosts and carbohydrates make up a higher percentage of the fallen leaves (*Quercus castaneifolia*, *Diospyros lotus*, *Parrotia persica*, *Punica granatum*, etc.). Regulated watering under introduction conditions allows to increase the degree of lignification of shoots and reduce the amount of carbohydrates in the leaves. The winter resistance of the introduced species can also be significantly increased by agri-technical practices.

While discussing the botanical-geographical regions of (Euro-Sibiria, Caucasus, Eastern Asia and Northern America) from the viewpoint of assessment of tier dendrofloras as a source of woody plants introduction into Yerevan Botanical Garden it was revealed (Table 1) that:

- Out of almost 2100 species of dendroflora of Eurosiberia, about 560 species are prospective for introduction into the botanical gardens of Armenia. Of special interest are the families Betulaceae, Caprifoliaceae, Fagaceae, Fabaceae, Pinaceae, Rosaceae, Salicaceae.
- Regarding floristically, the Caucasus is one of the richest and most unique hearths on the globe. More than 840 species of woody plants grow here. From the viewpoint of introduction, almost 350 species are considered prospective. The families Sypressaceae, Aceraceae, Fagaceae, Rosaceae, Salicaceae, Oleaceae, etc. are the richest in the introduced valuable species.
- The Chinese-Japanese floristic region is one of the main large centers for the introduction and replenishment of the cultural dendroflora collection. Prospective for further introduction are about 370 representatives of dendroflora of continental and temperate enough provinces of this region, as well as inhabitants of high-mountainous regions of subtropical provinces. The most prospective source of the introduced species are the families Pinaceae, Celastraceae, Betulaceae, Rosaceae, Salicaceae, Aceraceae, Fabaceae, Caprifoliaceae, Tiliaceae.

Table 1. Assessment of various foreign dendroflora prospectiveness according to the presence of taxons: families, genera and species.

Names of the foreign dendroflora	Number of taxons subject for introduction					Bigger taxons		Prospectiveness by region		
	Number of introduced species	Family	Genus	Species	Family	Genus	Number of species	Region	Grade	
1	2	3	4	5	6	7	8	9	10	
Eurosiberian	179	37	85	560	Pinaceaea	Pinus	14	Eurasian-Arctic	III	
						Betula	9	European	I	
						Lonicera	15	Atlantic-European	III	
						Cotoneaster	8	Pontiac	II	
						Crataegus	6	Russian	II	
						Rosa	15	Eastern-Siberian	III	
						Sorbus	5	Eastern-Siberian	III	
						Spiraea	5	Atlantic-Sayansk	I	
						Rhamnaceae	8	Daurik	II	
						Salicaceae	15	Chukotskaya	III	
Caucasus and Crimea	208	50	112	350	Cupressaceae	Juniperus	7	Pre Caucasian	II	
						Aceraceae	9	Pre Caucasian	II	
						Betulaceae	5	Pre Caucasian	II	
						Caprifoliaceae	6	Dagestanian	I	
						Fagaceae	13	Dagestanian	I	
						Oleaceae	5	Western Transcaucasus	II	
						Rhamnaceae	5	Western Transcaucasus	II	
						Crataegus	11	Eastern Transcaucasus	I	
						Rosaceae	14	Eastern Transcaucasus	I	
						Pyrus	17	Eastern Transcaucasus	I	
Eastern Asia	156	38	78	370	Salicaceae	Rosa	11	Eastern Transcaucasus	I	
						Sorbus	7	Eastern Transcaucasus	I	
						Populus	21	Eastern Transcaucasus	I	
						Salix	5	Talish	II	
						Tiliaceae	5	Talish	II	
						Ulmaceae	9	Northern Chinese	II	
						Celastraceae	Euonymus			

		Province of North coastal zone of China			I
	Betulaceae	Betula	18		
	Rosaceae	Spiraea	10	Northern Japanese	I
		Sorbus	7	Northern Japanese	I
	Salicaceae	Salix	14	Central Chinese	II
	Aceraceae	Acer	19	Eastern Chinese	II
	Fabaceae	Caragana	8	Nagorno-Yunnan	II
	Caprifoliaceae	Lonicera	10	Southern Chinese	III
		Sambucus	5	Southern Chinese	III
	Saxifragaceae	Ribes	8	Southern Japanese	III
	Tiliaceae	Tilia	8	Himalayan	III
	Pinaceae	Picea	5	Canadian	II
	Cupressaceae	Juniperus	11	Canadian	II
		Thuja	11	Canadian	II
	Aceraceae	Acer	15	Canadian	II
	Anacardiaceae	Rhus	15	Appalachian	I
		Lonicera	8	Atlantic Lowland	I
	Caprifoliaceae	Sambucus	5	Atlantic Lowland	I
		Symporicarpos	7	Atlantic Lowland	I
Northern America	Fabaceae	Amorpha	10	North American prairie	II
		Robinia	12	North American prairie	II
	Fagaceae	Quercus	9	North American prairie	II
	Juglandaceae	Juglans	5	Sitka-Oregon	III
	Oleaceae	Fraxinus	10	Sitka-Oregon	III
		Crataegus	14	Rocky mountains	II
	Rosaceae	Rosa	9	Rocky mountains	II
		Spiraea	14	Rocky mountains	II
	Saxifragaceae	Philadendron	19	Californian	II
		Ribes	10	Californian	II
	Ulmaceae	Celtis	10	Nagorno-Mexican	III
	Vitaceae	Vitis	12	Nagorno-Mexican	III

The assessment of the perspectives of regions is given on a 3-point scale:

- I. – high prospects;
- II. – average prospects;
- III. – low prospects.

- The dendroflora of North America is distinguished by a rich and diverse species composition (about 845 species). For Armenia the most prospective are almost 500 species of woody plants: representatives of the families Cupressaceae, Aceraceae, Anacardiaceae, Betulaceae, Fabaceae, Fagaceae, Oleaceae, Rosaceae, Salicaceae, etc.

We also conducted assessment of the perspectives for the introduction of some valuable and rich genera representatives introduced in the dendrological collections of Yerevan Botanical Garden, the data of which are presented in figure 1.

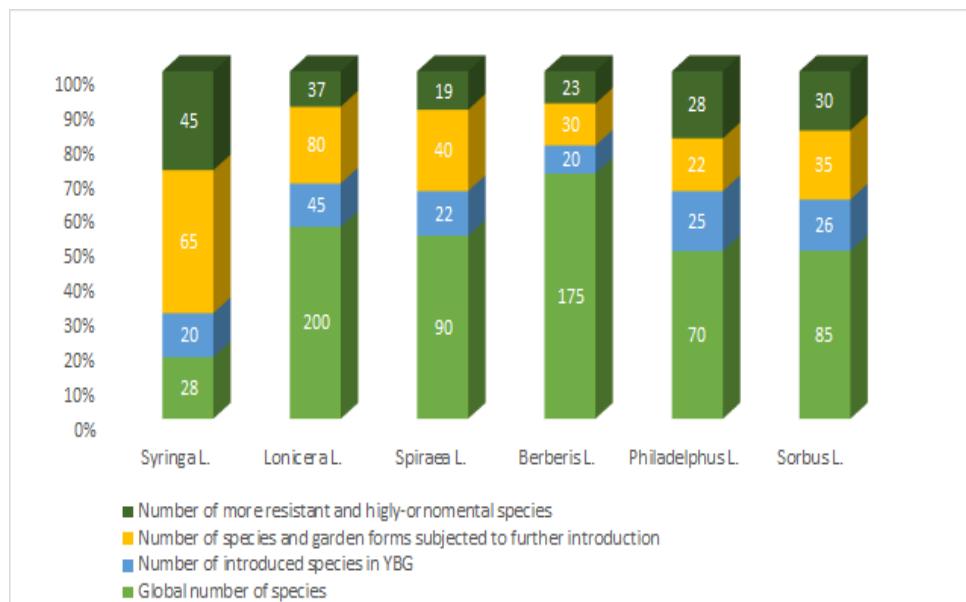


Figure 1. Assessment of prospectiveness of some highly-decorative genus representatives (* Syringa genus has more forms than species).

In addition, the analysis of the taxonomic composition of the dendrological collection of the Yerevan Botanical Garden over the last 40 years was carried out.

According to the data, the collection had the richest composition in the 1980s. Subsequently, during the years of the power default (1990-1995) and the economic blockade of Armenia, along with other dendro-cenoses, great damage was also caused to the dendrological collection of the botanical gardens of the republic, primarily Yerevan, as a result of which the dendrological composition sharply (by 25-30%) decreased. This reduction (change) at the level of families and genera is presented in Table 2. At the same time, the main composition of the most valuable and highly decorative introduced species lost - representatives of the dendroflora of North America and East Asia, which during the years of the energy crisis of the Republic due to unsatisfactory waste and low ecological relevance to new conditions of existence are shown in Table 3.

Table 2. The Change (reduction) in the taxonomic composition of the dendrological collections of the Yerevan Botanical Garden over the last 40 years (1980-2020) according to the data leading families and genera.

Large families containing more than 10 species and garden forms	By 1980		By 2020		General	Including the specified families	Genera, that are totally missing	Reduction of species in genera	General	Number of species						
	Number of species		Number of species													
	Genera	General	Genera	General												
Conifers																
Cupressaceae	Biota, Cupressus, Juniperus, Thuja	72	42	Cupressus	Juniperus	40	26									
Pinaceae	Abies, Cedrus, Larix, Pinus		24	Cedrus	Abies, Larix, Pinus		10									
Deciduous																

В том числе по семействам

Aceraceae	Acer	22	-	Acer	10
Berberidaceae	Berberis, Mahonia	13	-	Berberis	7
Betulaceae	Alnus, Betula	11	-	Alnus, Betula	6
Caprifoliaceae	Diervilla, Lonicera, Sambucus, Syphoricarpos, Viburnum, Weigela	45	-	Lonicera, Sambucus, Weigela	27
Cornaceae	Cornus, Swida	15	-	Cornus	6
Fabaceae	Albizzia, Amorpha, Astragalus, Caragana, Cercis, Colutea, Genista, Gleditsia, Gymnocladus, Halimodendron, Laburnum, Onobrychis, Robinia, Sophora, Spartium, Wisteria	47	Albizzia, Colutea, Genista	Robinia, Amorpha	23
Fagaceae	Fagus, Quercus	13	-	Fagus, Quercus	8
Hydrangaceae	Deutzia, Philadelphus	35	-	Deutzia, Philadelphus	18
Oleaceae	Fontanesia, Forresteria, Fraxinus, Jasminum, Ligustrina, Ligustrum, Syringa	615	52	Fraxinus, Ligustrum, Syringa	363
Ranunculaceae	Atragene, Clematis Amelanchier, Amygdalus, Armeniaca, Aronia, Cerasus, Chaenomeles, Cotoneaster, Crataegus, Cydonia, Exochorda, Malus, Mespilus, Padus, Persica, Physocarpus, Prunus, Pyracantha, Pyrus, Rosa, Rubus, Sorbaria, Sorbus, Spiraea	27	Atragene	Clematis	27
Rosaceae	Populus, Salix	143	-	Crataegus, Pyrus, Rosa, Sorbaria, Sorbus	107
Salicaceae	Celtis, Ulmus, Zelkova	23	-	Populus, Salix	16
Ulmaceae	Celtis, Ulmus	18	-	Celtis, Ulmus	9
Vitaceae	Ampelopsis, Parthenocissus, Vitis	16	-	Ampelopsis, Vitis	9

Table 3. Dendrological composition of more valuable and highly-decorative woody plants lost for different causes.

Families	Genera	Number of species and garden forms	Names of eliminated species and garden forms	Causes elimination	
				in adaptability to ecological conditions	Unsatisfactory care
			Conifers		
Cupressaceae	Cupressus	1	Cupressus arizonica	+	+
			Juniperus chinensis,		
	Juniperus	8	J. turkestanica, J. virginiana "Aureo-spicata", J. Virginiana "Glauca" и др.	+	+
Pinaceae	Cedrus	1	Cedrus deodara	+	-

	Abies	2	Abies cilicica, A. pinsapo	+	-
	Larix	4	Larix decidua, L. laricina, L. leptolepis, L. polonica	+	-
	Pinus	4	Pinus banksiana, P. excelsa, P. jeffreyi, P. ponderosa	+	-
	Picea	4	P. abies "Pyramidata", P. engelmannii, P. engelmannii "Glaucia", P. glauca	+	-
			Deciduous		
Aceraceae	Acer	12	A. ginnala, A. saccharinum, A. saccharum, A. Saccharinum "Laciniatum", A. velutinum и др.	-	+
Berberidaceae	Berberis	5	Berberis aggregate, B. canadensis, B. densiflora, B. integerrima, B. orientalis	-	+
Betulaceae	Alnus	1	Alnus sinuata	-	+
	Betula	4	Betula ermanii, B. lutea, B. populifolia, B. pubescens	+	+
Caprifoliaceae	Lonicera	12	Lonicera canadensis, L. dioica, L. etrusca, L. sempervirens и др.	-	+
	Sambucus	1	Sambucus canadensis	-	+
	Weigela	2	W. hortensis "Albiflora", W. praecox "Florea"	-	+
Cornaceae	Cornus	9	Cornus amomum, C. baileyi, C. foemina, C. glabrata, C. pubescens, C. stolonifera и др.	-	+
	Albizia	1	Albizia julibrissin	+	-
	Genista	1	Genista germanica	-	+
	Robinia	5	Robinia pseudoacacia "Bella-rosea", R. pseudoacacia "Inermis", R. pseudoacacia "Pyramidalis" и др.	-	+
Fabaceae	Amorpha	4	Amorpha croceolanata, A. fruticosa var. angustifolia, A. glabra, A. paniculata	-	+
	Quercus	6	Quercus ilex, Q. imeretina, Q. rubra и др.	-	+
	Deutzia	8	Deutzia discolor, D. grandifloras, D. x lemoinei, D. scabra "Rubra", D. x rosea и др.	-	+
Hydrangeaceae	Philadelphus	10	Philadelphus californicus, Ph. cordifolius, Ph. hirsutus, Ph. microphyllus, Ph. verrucosus и др.	-	+
	Fraxinus	9	Fraxinus americana, F. Lanceolata, F. Sogdiana, F. syriaca, F. velutina и др.	-	+
Oleaceae	Ligustrum	6	Ligustrum acutissimum, L. ibota, L. quihoui, L. vulgare L. "Clorocarpum" и др.	-	+
	Syringa	11	S. emodi, S. japonica, S. microphylla, S. villosa, S. wolfi, S. yunnanensis и др.	-	+
Ranunculaceae	Clematis	22	Clematis apiifolia, C. ligusticifolia, C. Montana, C. songarica, C. viorna, C. virginiana и др.	+	+
Rosaceae	Crataegus	10	Crataegus armena, C. arnoldiana, C. crus-galli, C. nigra, C. turkestanica и др.	-	+
	Pyrus	2	Pyrus regelii, P. ussuriensis	-	+
	Rosa	6	Rosa acicularis, R. arvensis, R. Blanda, R. multiflora и др.	-	+
	Sorbaria	1	Sorbaria olgae	+	-
	Sorbus	10	S. hybrida, S. intermedia, S. mougeotii, S. pohuaschanensis, S. tamamshjanae и др.	-	+
Salicaceae	Populus	5	Populus balsamifera, P. candicans, P. deltoides "Eugenii" и др.	-	+
Ulmaceae	Celtis	3	Celtis mississippiensis, C. occidentalis, C. reticulata	-	+
	Ulmus	6	U. Americana, U. foliacea, U. Scabra и др.	-	+
Vitaceae	Ampelopsis	2	Ampelopsis megalophylla, A. vitifolia	-	+
	Vitis	5	Vitis candicans, V. champinii, V. riparia и др.	-	+

Ever since 2000-s the scientific inventory of all the collections in Yerevan Botanical Garden have been carried out and purposeful works on restoration of especially valuable dendrological collections have been started (Table 4).

Table 4. The introduced species for restoration of dendrological collection

Families	Genera	Species
Araliaceae	Aralia	mandshurica
Betulaceae	Betula	platyphylla
Caprifoliaceae	Weigela	praecox

	Viburnum	alnifolium
Celastraceae	Celastrus	loesenerii
	Euonymus	Alata, nana, verrucosa
Corylaceae	Carpinus	caroliniana
Fabaceae	Caragana	pygmaea
	Laburnum	alpinum
Hydrangeaceae	Deutzia	Glabrata, gracilis
	Philadelphus	Pekinensis
Oleaceae	Fontanesia	fortunei
	Forsythia	suspensa
Rosaceae	Aronia	melanocarpa
	Malus	floribunda
	Spiraea	Alba, betulifolia, media, sargentiana, salicifolia, tomentosa, trichocarpa
Thymelaeaceae	Daphne	transcaucasica
Families 10	Genera 17	Species 26

As can be seen from Table 5, representatives of 17 genera from 10 families were used to restore separate groups of the introduced woody species.

It is note-worthy, that in parallel with the restoration of the collection, over 40 completely new representatives from 22 genera and 15 families were also introduced to enrich the dendrocollection of the botanical garden (Table 5).

Table 5. Introduced new species to enrich the arboretum collection.

Family	Genera	Species
Pinaceae	Abies	nordmanniana
Araliaceae	Acanthopanax	sesiliflorus
	Eleutherococcus	senticosus
	Kalopanax	septemlobus
Betulaceae	Ostrya	virginiana
Caprifoliaceae	Viburnum	Corylifolium, mongolicum
Celastraceae	Euonymus	japonica, japonica "Aureo-variegata"
Fabaceae	Maakia	amurensis
Hydrangeaceae	Philadelphus	schrenkii
Loganiaceae	Buddleia	japonica
Oleaceae	Forsythia	giraldiana
	Fontanesia	phillyreoides
	Ligustrum	vulgare "Aureum"
Rutaceae	Phellodendron	sachalinense
Rosaceae	Pyrus	browiczii, daralaghezi, demetrii, gergerana, megrica, elata и др.
	Rosa	foetida, sjuniki

	Sorbus	orbicularis
	Spiraea	alpina, blumei, pubescens, rosthornii, virgata и др.
Salicaceae	Salix	fragilis
Tamaricaceae	Tamarix	octandra
Tiliaceae	Tilia	platyphyllos
Lamiaceae	Caryopteris	incana
Family 15	Genera 22	Species 41

Current development and future prospective of dendrological collections at the Yerevan Botanical Garden

In the 1980s, plans were made to transform a 30-35-hectare section of the garden into a large recreational space, planting drought-resistant and other tree species. However, during the 1990s energy crisis, this area suffered greatly from anthropogenic pressures, including illegal logging and poor maintenance.

In response, the RA government initiated a recovery and development program of the Yerevan Botanical Garden in 2021, aiming to establish an urban forest grove/park (Figure 2) in this section with recreational and public benefits, while enhancing nature-based solutions in the local semi-desert ecosystem and ensuring favorable microclimate. The first phase of restoration program involves planting 34 species of woody plants (Figure 3), according to an approved construction project design, and aims to restore the rich and valuable diversity of trees lost over the decades. In addition, drip irrigation system and other infrastructures are also planned. Future plans include restoration of the remaining areas of the Botanical Garden including the existing dendrological collections.

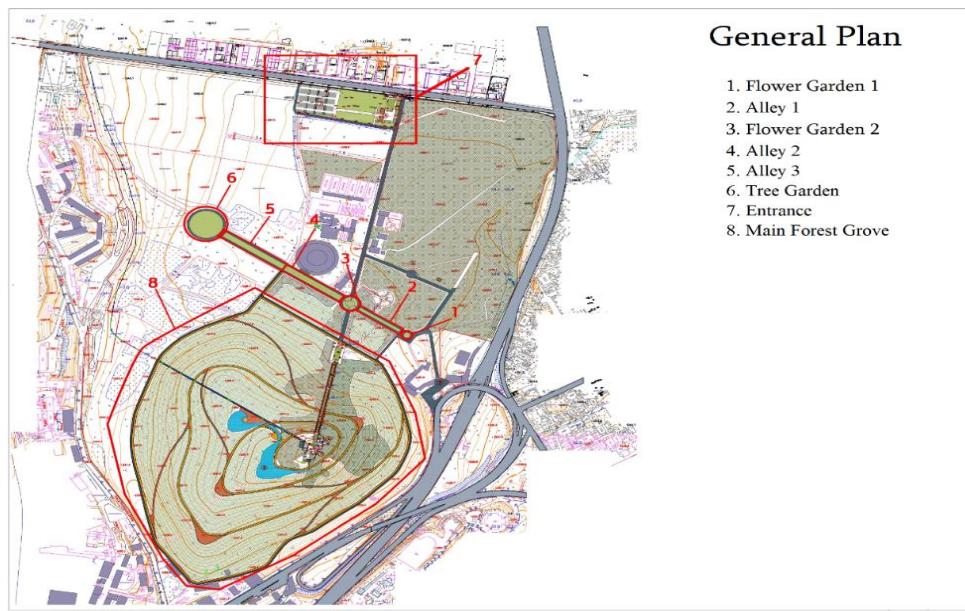


Figure 2. Scheme of Newly Planned Collections in Yerevan Botanical Garden.

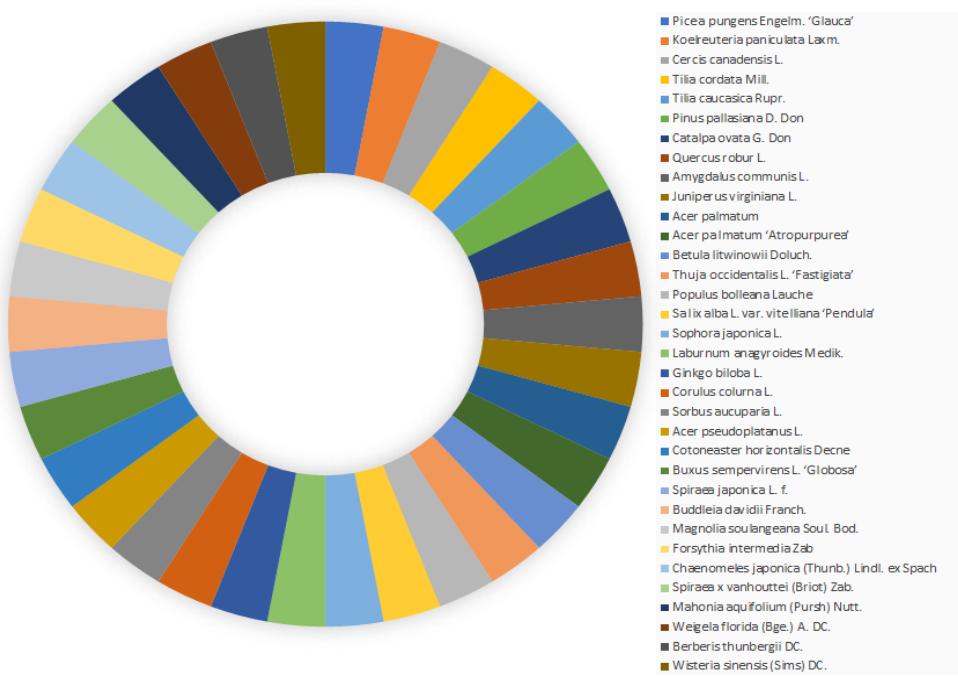


Figure 3. Collection of woody plants for Newly Planned Collections in Yerevan Botanical Garden.

A number of projects, supported financially by BGCI and ArbNet, are being implemented with international partners (Tajikistan, Ukraine, etc.) and are aiming the ex-situ conservation of tree species of conservation importance, including ornamental tree species, species of Armenian flora, etc. There are also a number of small-scale local initiatives, such as establishment of an Armenian-Lithuanian friendship birch (*Betula litwinowii*) alley.

5. Conclusions

In conclusion, the Yerevan Botanical Garden is currently in an active process of restoration and development. Efforts are underway to align the Botanical Garden's restoration initiatives with international standards through collaborations with leading botanical institutions worldwide such as the Kunming Institute of Botany of the Chinese Academy of Sciences, the Korea Institute of Arboretum and Botanical Gardens, the Singapore Botanic Garden, the Berlin Botanical Garden and Museum, etc. Design of new master plan of high-quality standards is priority for further strategic development and improvement of the infrastructure at the Yerevan Botanical Garden.

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