Documenting the collections of the Botanical Garden of the Saint Petersburg Forest Technical University for the purpose of international standardization of education

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Abstracts. The Botanical Garden of the Saint Petersburg Forest Technical University was established in 1827. It is one of the oldest botanical gardens in Russia. It is also the first botanical garden in the country, which was created for educational purposes. The collection of woody plants includes over 1600 taxonomic units, about 4000 open-field flower crops, some 1300 tropical and subtropical plants. Cataloging of the collection since 2018 is based on modern classifications based on molecular studies (APG, PPG, etc.). This internationally recognized plant classification approach is necessary to organize collections, publications, and enhance standardization of the university education.

1. Introduction

The Botanical Garden of St. Petersburg Forestry University is one of the oldest botanical gardens of Russia and the first garden in the country, which was initially created for the educational purposes. The garden was founded on May 5 (April 22), 1827. On this day, His Imperial Majesty Nicholas I has approved the note of Minister of Finance, Lieutenant-General Count E F Kankrin on arrangement of the Forest Park of St. Petersburg Forest Institute for training of students in sowing and planting of forests.

The Botanical Garden is a specially protected natural reservation consisting of three dendro-gardens, an open park, a greenhouse, collection areas of ornamental herbaceous plants, and nurseries. The collection of woody plants comprises over 1 600 taxa, about 4 000 open-field flower crops, 1 300 tropical and subtropical plants. The park (in 1827 - 1830s garden masters were P Buck, G Bush and M Call) has valuable collection of trees and shrubs, ponds, canals, an English garden with a pattern bed in a formal setting. It is a monument of landscape gardening art of the early 19th century, and is a national treasure of Russia. Today, the Botanical Garden of St. Petersburg SFU is research, cultural and educational unit of the University. It is a part of the system of botanical gardens of the Russian Federation. The work is underway to preserve, study and enrich the gene pool of plants of natural and cultivated flora, provide educational programs of graduate and post-graduate professional education [1].

At the beginning of the XXI century, more than 2,200 botanical gardens were known in the world, with hundreds of thousands of taxa in their collections, of which over 400 are in Europe and about 200 are in the United States. There were 150 botanical gardens in the former USSR. The database of the Council of
Botanical Gardens of Russia contained 111 botanical gardens and arboretums, including 40 in the system of the Ministry of Science and Higher Education of the Russian Federation. Each country has its own definitions of the concept of botanical gardens and their functions related to ethnic characteristics of cultural and economic development [2].

Living collections are not only tools for attracting and reaching the public, for conserving the ex situ plants; it is a source of plant material (complementing the field studies and herbarium specimens) to study phylogeny, flower biology, etc. The main areas of work of the Botanical Gardens of the world, such as biodiversity conservation, education and research, make up international field of activities. They require reliable interaction of the network of botanical organizations with agreed collections and goals, which will ensure fruitful research and allow effective use of the results [3].

For the recent three centuries, the Botanical Gardens of different countries were developing quite on their own and independently from each other in accordance with their goals and tasks: They formed collections, created exhibitions, kept records of their collection funds using various classifications. Only recently the importance of integration has been fully understood and appreciated.

Today there are several most widely used systems, and collections around the world are arranged according to these classifications. The most widely used classification is the classification of A Engler [4]. Many world herbariums and collections are organized according to the Engler classification, especially in North America and in Europe, except Great Britain. The system of the English botanists of XIX century J Bentham and J Hooker was used in Great Britain and had great influence because it was applied in the Kew Botanic Gardens [5]. The taxonomic classification system of flowering plants of American botanist A Cronquist [6, 7] is still used in the world, both in its original and more adapted form. Phylogenetic classification system of flowering plants of Soviet botanist A L Takhtajyan was widely used in the Soviet Union [8, 9] and is still in use in Russia and in the former Soviet Republics.

In late 1990ies Angiosperm Phylogeny Group (APG) was formed to develop a single stable classification of angiosperms. The system is based on the cladistic analysis of the DNA sequences of three genes, two chloroplast genes and one gene encoding ribosomes. The first APG system [10] has since been updated three times APG II - 2003 [11]; APG II I- 2009 [12]; APG IV - 2016 [13]. The APG classification is not completed, but many botanical gardens and herbaria, including the Royal Kew Botanic Gardens, have adopted this system [3]. The Plant List [14] and Tropicos [15] botanical online resources are updated according to the APG III system. To achieve an international consensus on the single classification, the descriptions of other groups have been revised: for ferns and lycophits [16] and gymnosperms [17], which provide related classifications for the rest of the vascular plants.

Reformatting of the collections in accordance with the modern system requires attraction of significant resources, especially in the short term, but allows for coordinated work with other leading botanical institutions of the world. The adoption of and work on a single unified classification is very important in educational institutions for the purpose of international standardization of education.

2. Methods and Materials
The creation of the collections of the Botanical Garden of St. Petersburg SFU began in the first half of the XIX century with the park establishment and formation of a landscape composition involving large number of introduced species. Then the nurseries of woody plants and arboretums were laid down, and a greenhouse was built. The first exhibition, which was organized according to the ecological-geographical principle, was arranged in the North American sector. Due to the great loss of plants during the World War II and the siege of Leningrad, the followed up mortality of old-aged trees and shrubs, as well as limits of the city’s borders, the plants were additionally planted into vacant spaces. The planting proceeded mainly on the basis of the plants ecological (sensitiveness to light and soil moisture) and decorative features. The collection of herbaceous plants is represented by generic complexes of the main ornamental
groups of garden plants, and areas of natural floras organized according to the ecological-geographical principle. The collection of tropical and subtropical plants is also arranged according to generic features educational targets.

Thus, the physical arrangement of plants in the collections and exhibitions of the Botanical Garden of St. Petersburg SFU on a systematic basis has not been used, and no actual relocation of plants both from the historical point of view and the modern requirements of the educational process is supposed. This greatly simplifies the reformatting of collections in accordance with the new system. However, even translation of the collection documentation required large resources. The work has not been completed yet. Contemporary description of the collections, including their new classifications, is discussed below.

The collection of woody plants contains about 1,600 taxa located on the territory of three dendro-gardens, in the park, on the introduction nursery and other collection sites. More than 52 thousand woody plants grow in the park: 24 thousand trees, of which about a thousand are over 150 years old, and 28 thousand shrubs. These are 215 species and 26 varieties and kinds included in 29 families and 69 genera. In the dendro-garden the collection of woody plants comprises about 1,200 taxa (957 species and 234 kinds and varieties) of 51 families and 146 genera. 936 taxa are grown in the Upper Dendro-garden, 580 in the Lower Dendro-garden, 166 in the Western Dendro-garden, 51 on the Exposition section. Coniferous plants are included in 2 subclasses, 3 orders, 4 families and 14 genera. The most widely represented genera are: *Picea* (22 species, 7 cultivars), *Pinus* (20, 1), *Abies* 17, *Thuja* (3, 31). The most widely represented deciduous families include: *Rosaceae* - 33 genera, *Ericaceae* - 8, *Fabaceae* - 8, *Caprifoliaceae* - 6, *Hydrangeaceae* - 5, *Oleaceae*, *Betulaceae* and generic complexes *Lonicera* (46, 10), *Acer* (37, 18), *Sorbus* (45, 6), *Crataegus* (41, 1), *Betula* (46, 3), *Spiraea* (32, 7), *Rhododendron* (27, 5) etc. The represented live forms are: trees - about 600 taxa, shrubs - 500, semi-shrubs and little shrubs - 15. More than 2,000 specimens of woody plants from 70 families, 189 genera, 965 species are tested on the introduction woody nursery, many of them being tested for the first time. In accordance with the modern classification, grown and cultivated in the Upper Dendro-garden are 110 species and forms, 70 cultivars relating to 4 families and 14 genera, angiosperms - 550 species and forms, 104 cultivars relating to 18 orders, 41 families and 120 genera. The collection of the Lower Dendro-garden has 9 genera of gymnosperms, 18 orders, 34 families, 68 genera of angiosperms.

The collection of open-field flowercrops has more than 4,000 taxa. According to the new system, 3,883 taxa (2,104 species, 121 forms, 1,658 varieties) relating to 108 families and 698 genera have been cataloged. Plants are grown on collection plots and open-field flower beds, some part naturally grows in the park and dendro-gardens. Collections of generic complexes are widely represented: *Astilbe* (10 species, 50 varieties), *Iris* (36, 72), *Hemerocallis* (10, 70), *Phlox* (9, 52), *Rosa* (8, 55), *Clematis* (22, 16) etc. Collections and exhibition areas have been created: plants for shady areas, alpine scree gardens, water reservoirs, spring-flowering perennials, a group of tall plants, a garden of continuous flowering, and others. Plants from natural habitats have been collected: from Siberia, the Caucasus, the Far East, North-West Russia. More than 80 taxa of herbaceous plants have been planted on the exhibition area of the American flora, more than 50 on the area of the East Asian flora.

The collection of tropical and subtropical plants comprises 1,344 taxa (996 species, 65 varieties and 283 cultivars) included in 7 subclasses, 53 orders, 124 families 428 genera. The collection has 11 families of higher spore plants and 10 families of gymnosperms. The following families are most fully represented: *Araceae* (17 genera, 59 taxa), *Bromeliaceae* (16, 42), *Arecaceae* (12, 27), *Commelinaceae* (10, 35) etc. A significant place in the collection is occupied by plants of arid regions of the world: *Crassulaceae* family (24, 187), *Cactaceae* (27, 82), *Agavaceae* (7, 34), *Aizoaceae* (11, 24).

The collection funds were initially cataloged according to A Engler’s system which was widely used by botanical institutions all over the world [4], and since the 1980ies according to the system of A L Takhtajan [8,9]. The modern classification is introduced by the basis of the following sources.
Pteridophytes are classified on the basis of the PPG I consensus classification [16]. Gymnosperms are classified according to the paper «A new classification and linear sequence of extant gymnosperms» [17]. Angiosperms are classified according to the APG IV system [13]. The overall classification of the plant collection of the Botanical garden of St. Petersburg SFU is presented based on the paper by Mark W Chase и James L Reveal «A phylogenetic classification of the land plants to accompany APG III» [18]. The nomenclature of taxa has been verified according to Plant List [14] and Tropicos [15] online resources.

The work was based on the inventory of 2017-18. The cataloging of the collections according to the new system was carried out on electronic media by several stages:
- adjustment of the taxon nomenclature
- introduction of new information into the electronic database of the garden collections, with preservation of all previously accumulated information, including based on the system of A L Takhtajan

3. Results and Discussion

The use of a modern, molecular-based, internationally unified classification of living plant and herbaria collections in botanical gardens is undoubtedly reasonable and necessary step to ensure fruitful cooperation of the world botanical community in the field of biodiversity conservation, scientific and educational activities. This is especially true for the university botanical gardens, where a common approach to systematization of collections and work on the basis of uniform classifications will contribute to the international standardization of training.

Systematic work on the introduction of a new classification in the Botanical Garden of St. Petersburg SFU started in 2018. Prior to this, the collections were recorded according to the system of A Engler [4] and then A L Takhtajan [8, 9]. However, the reconciliation of the nomenclature of the taxa re-entering the collection based on Plant List and Tropicos online resources began in 2013–14. In fact it meant working in accordance with the APG III. This system was widely used by the students and university teachers. The previous systems do not have such a strong and accessible online support. Thus, the expediency of international standardization and the actual use of this system have led to the system introduction in the Botanical Garden of St. Petersburg SFU. This does not mean that the classification of the collection according to A L Takhtajan’s system has been cancelled; it was preserved and will be used in the future. No physical reorganization of the collections and exhibition areas of the garden are foreseen because, due to the historical traditions and specificity the university traditions, the collections were not arranged according to a systematic principle. The living plant collections were arranged according to the ecological-geographical principle and decorative features of plants; the generic compositions were also arranged with the view of terrain microclimatic characteristics, while the plants were referenced and recorded based on the planting place.

At present the work is underway to introduce modern classification. Nomenclature of the main collections has been verified and documented on electronic media. The next stage is creation of a common base uniting all the collections, which will allow management of the collection funds based on a single system. Then transition from work on electronic media to practical use presumes namely:
- creation of working inventory logs;
- labeling of the collection plants;
- publication of textbooks based on this system;
- introduction into training programs;
- promotion of of the new system.

Adoption and maintenance of the modern system of plant classification in the botanical gardens of universities is undoubtedly a strategically substantiated approach and is international and interdisciplinary.
This internationally unified approach to the classification of plants is necessary for organizing collections, publications, and enhancing the standardization of training.

References
[1] Adonina N P 2016 Botanicheskiy sad Sankt-Peterburgskogo lesotekhnicheskogo universiteta - 190 let introdutsii. // Lesa Rossi: politika, promyshlennost', nauka, obrazovaniye. / materialy nauchno-tekhnikheskoy konferentsii (Saint-Petersburg:SPbGLTU) I p 7-9
[2] Andreev L N, Ber M N, Êgorov A A, Kamelin R V, Lurie E A, Prokhorov A A, Strikhanov M N, Selikhovkin A V 2006 Botanicheskiye sady i dendrologicheskiye parki Vysshikh uchebnikh zavedeniy. Hortus Botanicus 3 p. 5-27 http://hb.karelia.ru/files/redaktor_pdf/1362935722.pdf
[3] Wearn J A, Chase M W, Mabberley D J and Couch C 2013 Utilizing a phylogenetic plant classification for systematic arrangements in botanic gardens and herbaria. Botanical Journal of the Linnean Society Vol. 172 pp. 127–141. https://doi.org/10.1111/bot.12031
[4] Engler A and Prantl K 1887-1909 Die Naturlichen Pflanzen familien nebst ihren Gattungen und wichtigeren Arten, insbesondere den Nutzpflanzen, unter Mitwirkung zahlreicher hervorragender Fachgelehrten. 33 parts (Abteilungen) in 23 volumes. (Leipzig: W. Engelmann), https://doi.org/10.5962/bhl.title.4635
[5] Bentham G and Hooker J 1862–1883 Genera plantarum: ad exemplaria imprimis in Herberiis Kewensibus servata definita / Londini: A. Black, https://doi.org/10.5962/bhl.title.747
[6] Cronquist A 1981 An Integrated System of Classification of Flowering Plants (New York: Columbia University Press) pp 1262
[7] Cronquist A 1988 The evolution and classification of flowering plants. (New York Botanical Garden) pp 555
[8] Tahtadzhyan A L 1987 Sistema magnoliofitov (Leningrad: Nauka) p 440
[9] Takhtajan A L 1997 Diversity and Classification of Flowering Plants. (New York, Columbia University Press) p 663
[10] Angiosperm Phylogeny Group, APG. 1998 An ordinal classification for the families of flowering plants. Annals of the Missouri Botanical Garden. Vol. 85, 4 pp 531-553
[11] APG II. 2003 An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG II. Botanical Journal of the Linnean Society. Vol. 141, 4 pp 399-436 https://doi.org/10.1046/j.1095-8339.2003.t01-1-00158.x
[12] APG III. 2009 An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III. Botanical Journal of the Linnean Society. Vol. 161, 2 pp 105-121 https://doi.org/10.1111/j.1095-8339.2009.00996.x
[13] APG IV. 2016 An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV. Botanical Journal of the Linnean Society. Vol. 181, 1 pp 1-20. https://doi.org/10.1111/bot.12385
[14] The Plant List 2013 Version 1.1. Published on the Internet; http://www.theplantlist.org
[15] Tropicos.org Missouri Botanical Garden. http://www.tropicos.org
[16] Pteridophyte Phylogeny Group. 2016. Schuettpelz E, Schneider H and Smith A R. A community-derived classification for extant lycophytes and ferns. Journal of Systematics and Evolution. Vol. 54 (6). pp. 563 - 603. https://doi.org/10.1111/jse.12229
[17] Christenhusz M J M, Revel J L, Farjon A, Gardner M F, Mill R R and Chase M W. 2011. A new classification and linear sequence of extant gymnosperms. Phytotaxa. Vol. 19. pp. 55 - 70. http://dx.doi.org/10.11646/phytotaxa.19.1.3
[18] Chase M W and Reve J L 2009 A phylogenetic classification of the land plants to accompany
APG III. Botanical Journal of the Linnean Society. Vol. 161 pp 122-127. https://doi.org/10.1111/j.1095-8339.2009.01002.x