Seasonal changes in the woody plants development in an urbanized environment

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Abstract. The features of the phenological development of woody plants in green urban plantations in the dry steppe zone have been studied. The phenological phases of woody plants and shrubs are described and analysed: the beginning of bud swelling, the beginning of bud opening, the beginning of leaf opening, the beginning of flowering, the end of flowering, the beginning of fruit ripening, and mass loss of mature fruits. The onset of phenological seasons for the steppe zone has been determined. Formed groups of plants according to the terms of leafing and flowering. The calendar dates of the onset of phenological phases of trees and shrubs in an industrial urban environment are analysed. The sum of effective temperatures for the main phenological phases of woody plants in the steppe zone has been determined. Decorative dendrological groups have been developed for phenological phases of leafing and flowering of woody plants for urban landscaping in the dry steppe zone. Practical recommendations are given for grouping plants by flowering time for landscape construction.

1. Introduction
The study of the dynamics of the seasonal development of plants is necessary when selecting them for practical activities in landscape construction, to assess the aesthetic and sanitary-hygienic properties of plants. The materials of phenological observations are valuable in drawing up calendars of plant flowering, ripening and collecting fruits and seeds, when establishing the optimal timing of sowing and planting, as well as in the development and implementation of measures to increase the biological stability of urban green spaces, their protection from pests and diseases. When studying the state of tree and shrub vegetation, observations were made of seasonal changes in the development of woody plants in the urban environment [1].

The purpose of the work was to study the features of the phenological development of woody plants in urban green spaces in the steppe zone. The tasks set in the study were as follows: to describe and analyze the phenological phases in woody plants in urban green spaces, to determine the phenological dates of the indicators of the seasons, to determine the sum of effective temperatures for the main phenological phases, to combine the assortment of trees and shrubs into dendrological groups according to the phases of leafing, flowering.

Phenological observations were carried out according to the generally accepted method [2]. The following phenological phases were determined: beginning of bud swelling, beginning of bud opening,
beginning of leaf opening, beginning of flowering, end of flowering, beginning of fruit ripening, mass falling of ripe fruits, etc. [3].

The period of phenological observations was from 2013 to 2019.

2. Objects and results of research
Phenological observations were carried out on 40 species of woody plants growing in urban green spaces of an industrial city. The article presents some of the most common types of urban landscaping [4]. Phenological observations were carried out at 9 objects of landscape construction in Volgograd, which were selected according to the following principles: the objects of observation had characteristics that did not differ from the surrounding area in terms of relief and vegetation. Among them are general purpose objects: public garden, boulevard; roadside areas, streets; in-yard plantings of a residential neighbourhood.

The observations were carried out along route running routes.

The timing of the phenological seasons is of great practical importance. The onset of the phenological season does not coincide with the calendar season and is determined by the phenological phase of the dendrological indicator. Plants of local flora are used as the latter, such as smooth elm, common mountain ash, common lilac (table 1).

Table 1. Dates of the phenological seasons onset in the conditions of Volgograd.

| Species of woody plants | Phenological phase | Phenological subseason of the year | Calendar date |
|-------------------------|--------------------|----------------------------------|--------------|
| Common lilac            | The beginning of flowering | The height of spring | 9.05          |
| European white elm, Hungarian lilac | The beginning of fruit ripening, the beginning of flowering | Early summer | 23.05         |
| Small-leaved linden     | The beginning of flowering | Full summer | 13.06          |
| Mountain ash            | The beginning of fruit ripening | Summer recession | 21.08         |
| Silver birch            | The beginning of leaves yellowing | Early autumn | 12.09          |
| Norway maple            | The beginning of leaves colouring | | 26.09          |
| Small-leaved linden     | Complete coloring of leaves | Mellow autumn | 14.10          |
| Goat willow             | Bulk leaf coloring | | 21.10          |
| Common lilac            | Completion of leaf fall | Late autumn | 20.11          |

In the conditions of the city of Volgograd, which is located in the zone of dry steppes, phenological spring is short and early, but long phenological summer and autumn. The height of spring falls on the beginning of May, and the first flight falls on the end of May - beginning of June. All this leaves its mark on landscape construction (table 1).

Early spring flowering species have a very short flowering period. In this regard, species with long summer flowering are of particular importance. These are late spring and early summer flowering trees and shrubs [5].

Warm, dry, long-lasting autumn allows you to use the autumn colours of the colorization of the leaves of woody plants to create a rich colour in urban plantings.

The timing of the onset of various phenophases is set depending on phenological observations. This article investigated individual phenological phases - indicators of seasonal development and the most
economically important phases, such as bud and leaf blooming, flowering, fruit ripening. The duration of phenological phases and the timing of their onset are influenced by many factors, the main of which is the temperature regime of the natural zone [6]. Calendar dates of the main phenological phases of woody plants in dry steppe conditions are presented in table 2.

Table 2. Calendar time of the onset of phenological phases in the steppe zone.

| Plant species name                  | Pb1 | Pb2 | L1  | C4  | C5  | Pl3 | 3Pl4 |
|-------------------------------------|-----|-----|-----|-----|-----|-----|------|
| **Trees**                           |     |     |     |     |     |     |      |
| Common apricot                      | 28.04 | 02.05 | 07.05 | 03.05 | 16.05 | 01.08 | 15.08 |
| Armeniaca vulgaris                  |     |     |     |     |     |     |      |
| Warty birch                         | 14.04 | 24.04 | 28.04 | 08.05 | 22.05 | 13.07 | 14.08 |
| Betula pendula                      |     |     |     |     |     |     |      |
| Hawthorn                            | 09.04 | 16.04 | 22.04 | 12.05 | 01.06 | 15.09 | 20.09 |
| Crataegus monógyna                  |     |     |     |     |     |     |      |
| Siberian elm                        | 01.04 | 23.04 | 29.04 | 11.04 | 22.04 | 05.06 | 25.06 |
| Ulmus pumila                        |     |     |     |     |     |     |      |
| White willow                        | 04.05 | 07.05 | 16.05 | 06.05 | 30.05 | 05.06 | 20.06 |
| Salix alba                          |     |     |     |     |     |     |      |
| Horse chestnut                      | 22.04 | 02.05 | 11.05 | 23.05 | 02.06 | 15.09 | 08.10 |
| Aésculus hippocastanum              |     |     |     |     |     |     |      |
| Ash-leaved maple                    | 08.04 | 22.04 | 30.04 | 26.04 | 12.05 | 10.09 | 28.10 |
| Acer negundo                        |     |     |     |     |     |     |      |
| Norway maple                        | 02.04 | 30.04 | 05.05 | 01.05 | 26.05 | 02.09 | 04.10 |
| Aser platanoides                    |     |     |     |     |     |     |      |
| Small-leaved linden                 | 12.04 | 06.05 | 13.05 | 13.06 | 25.06 | 05.09 | 30.10 |
| Tilia cordata                       |     |     |     |     |     |     |      |
| Robinia                            | 21.04 | 01.05 | 05.05 | 16.05 | 29.05 | 29.09 | 19.10 |
| Robinia pseudoacacia                |     |     |     |     |     |     |      |
| Mountain ash                        | 23.04 | 26.04 | 01.05 | 18.05 | 30.05 | 21.08 | 12.10 |
| Sorbus aucuparia                    |     |     |     |     |     |     |      |
| Bird cherry                         | 05.04 | 12.04 | 17.04 | 13.05 | 19.05 | 06.08 | 28.09 |
| Prünus pádus                        |     |     |     |     |     |     |      |
| Poplar black                        | 14.04 | 17.04 | 24.04 | 05.05 | 12.05 | 09.06 | 28.06 |
| Populus nigra                       |     |     |     |     |     |     |      |
| Ash green                           | 20.04 | 15.05 | 20.05 | 16.05 | 30.05 | 15.09 | 02.10 |
| Fraxinus lanceolata                 |     |     |     |     |     |     |      |
| **Shrubs**                          |     |     |     |     |     |     |      |
| Nanking cherry                      | 29.04 | 02.05 | 08.05 | 02.05 | 20.05 | 06.07 | 17.07 |
| Prunus tomentosa                    |     |     |     |     |     |     |      |
| Serviceberry                        | 04.05 | 10.05 | 14.05 | 20.05 | 27.05 | 27.06 | 24.08 |
| Améláncier ovális                   |     |     |     |     |     |     |      |
| Common lilac                        | 22.04 | 28.04 | 30.04 | 09.05 | 19.05 | 21.08 | 29.09 |
| Syringa vulgaris                    |     |     |     |     |     |     |      |
| Golden currant                      | 17.04 | 23.04 | 28.04 | 03.05 | 16.05 | 27.07 | 18.08 |
As a result of the analysis, it can be seen that the onset of phenological phases in the dry-steppe zone occurs earlier than in the forest and forest-steppe zones. In dry steppe conditions, the vegetation period shifts in comparison with the forest zone by 2-4 weeks [7].

Early vegetation is observed in tree species: Norway maple, American maple, bird cherry, small-leaved elm, warty birch.

The earliest flowering is observed in small-leaved elm (late March - early April), European forsythia (early - late April). Due to the fact that spring is short and hot, the main number of spring flowering plants is observed in early - late May. These are common apricot, common hawthorn, common lilac, etc. (table 2).

The spring flowering is completed by the horse chestnut, common mountain ash, round-leaved irga.

Early fruit ripening is observed in small-leaved elm. Elm, willow and poplar ripen in early summer, approximately 3-5 weeks after flowering. The fruits of Norway maple begin to ripen in early autumn, robinia pseudoacacia - in late autumn. The ripening of the fruits of most of the species presented occurs mainly in the second half of summer - early autumn (table 2).

3. Discussion and recommendations

The development of plants is largely determined by the temperature regime. Depending on how heat is distributed over time, development can accelerate or slow down. The active processes of development of woody and shrub plants begin only when a certain threshold of positive temperatures is reached.

In this study, the characteristic of the thermal regime for a specific period, called the sum of effective temperatures, was calculated as the sum of positive (above 5°C) average daily air temperatures for the period under consideration for the onset of a particular plant phenophase. For each phenological phase, the sum of effective temperatures was calculated (table 3).

Table 3. Sum of effective temperatures for woody plants phenophases.

| Plant species name       | Pb1  | Pb2  | L1   | C4   | C5   | Pl1  | 3Pl4 |
|-------------------------|------|------|------|------|------|------|------|
| **Trees**               |      |      |      |      |      |      |      |
| Warty birch             | 215.5| 395.5| 403.1| 702.4| 873.9| 2081.5| 3024.8|
| Siberian elm            | 129.9| 358.9| 423.4| 229.9| 372.9| 1208.8| 3477.5|
| White willow            | 515.9| 568.9| 730.9| 553.6| 974.9| 1208.8| 1546.0|
| Norway maple            | 322.1| 420.9| 558.9| 504.9| 988.9| 3185.5| 3800.4|
| Robinia                 | 309.3| 430.9| 504.9| 773.9| 1053.4| 3623.5| 3770.3|
| Ash green               | 202.1| 242.3| 316.5| 263.9| 687.9| 3266.6| 3837.0|
| **Shrubs**              |      |      |      |      |      |      |      |
| Common lilac            | 222.7| 322.7| 443.1| 429.9| 1074.9| 2960.7| 3623.5|
| Albanian forsythia      | 203.1| 322.7| 573.9| 394.4| 459.8| 2939.3| 3668.0|

When the sum of effective temperatures is reached, the plant goes through vegetative or generative phases. For each plant species, there is its own sum of effective temperatures (SET), at which one or another phenological phase occurs (the beginning and end of flowering, ripening and falling of fruits, etc.).
SET is a universal indicator of the timing of the onset of phenophases in any natural zone. SET allows you to determine the duration of the growing season, the timing of flowering, fruiting, and other phenophases, which is extremely important for landscape construction [8]. Table 3 shows the values of the sum of effective temperatures of the most common trees and shrubs in urban landscaping.

Plants of the same dates of the onset of phenophases were combined into dendrological groups for practical activities. As a result of the study of the seasonal development of woody plants in the dry steppe zone, recommendations were formed for the creation of dendrogroups. The studied plant species are combined into dendrogroups according to the phenophase of foliage and flowering.

The group of early-growing plants includes: small-leaved elm, bird cherry, black poplar. The group of late-growing plants are: common apricot, horse chestnut, small-leaved linden.

Ornamental dendrological groups were developed by flowering time: early spring flowering, medium spring flowering, late spring flowering for dry steppe conditions. The group of early spring flowering (March - end of April) includes: European forsythia, small-leaved elm. The mid-spring bloom group (early May - mid-May) consists of: common apricot, warty birch, bird cherry, black poplar, American maple, Norway maple, hawthorn, common lilac, golden currant. The group of late spring flowering (mid-May - late May) includes: horse chestnut, pseudoacacia robinia, mountain ash, green ash, round-leaved irga. The early summer flowering group (early June - July) includes small-leaved linden.

4. Conclusion
When studying the phenological characteristics of woody plants, one obtains valuable information about the biological properties of species and their ecological requirements, which makes it possible to create sustainable and durable plantations. Through the study of phenological observations, a database is created for the practical activities of landscape architects.

In the practical activities of urban greening, the study of the dynamics of the seasonal development of plants allows you to select plants in dendrological groups that are most valuable from aesthetic points of view and in terms of sanitary and hygienic qualities, to create spectacular simultaneously blooming or continuously flowering dendrological compositions on landscape objects in urban gardening.

References
[1] Tokareva T G, Litvinov E A and Voronina V P 2014 The Development of Woody Plants in an Industrial City (Volgograd: Publishing house “Peremena”)
[2] Bulygin N E and Yarmishko V T 2003 Dendrology (Moscow: MSFU)
[3] Bulygin N E 1997 Phenological calendar of the Lisinsky training and experimental forestry enterprise 200 Years of Forestry and Experimental Work in the Lisinsky Training and Experimental Forestry (St.Petersburg) pp 113-25
[4] Semenyutina A V 2013 Dendroflora of Forest Reclamation Complexes ed I P Svintsova (Volgograd: VNIALMI)
[5] Tokareva T G 2019 Features of the phytocenosis structure in the urban ecosystem of the southern industrial centre IOP Conf. Series: Earth and Environmental Science 315 072012
[6] McCune B and Grace J B 2002 Analysis of Ecological Communities MJM Soft Ware Design 300
[7] Valyagina - Maluyutina E T 1998 Trees and Shrubs in the Middle Zone of the European Part of Russia (St Petersburg)
[8] Semenyutina A V 2002 Assortment of Trees and Shrubs for Reclamation of Agro - and Urban Landscapes of Arid Steppe (Moscow: Publishing house of RAAS)