Seasonal development of aboveground phytomass of evergreen introduced plants on the Southern Coast of the Crimea

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Abstract. For the Southern Coast of Crimea, the problem of park communities' productivity, due to the high recreational load on the environment and climate change, is of particular relevance. The aim of the research was to study the features of the introduced park communities evergreen aboveground phytomass formation and seasonal growth in the conditions of the Southern coast of the Crimea. A comparative assessment of vegetative shoots seasonal growth features of plants Laurus nobilis L., Prunus laurocerasus L., Viburnum tinus L., Aucuba japonica Thunb and Nerium oleander L. was performed. It was found that the time of renewal of shoot growth in spring after winter dormancy in V. tinus and A. japonica began at 459–462 °C, P. laurocerasus – 649 °C, and L. nobilis – 886 °C and N. oleander – 990 °C amounts of active air temperatures above 5 °C. The largest growth (49.3 cm) and the accumulation of leaf phytomass (42.3 cm³) differ in annual shoots of N. oleander. P. laurocerasus has a great potential with a phytomass volume an annual shoot of 24.5 cm³. The increase of shoots phytomass in V. tinus, A. japonica, and L. nobilis is 7-8 times less than that in N. oleander.

1. Introduction
Adaptation of plants to environmental factors during introduction can be manifested by various morphological and physiological reactions, depending on the ecological and geographical origin of individual species [1]. In the process of restructuring the seasonal development cycle, this affects their growth rhythms, the timing of the vegetation beginning and end, and the duration of deep dormancy [2]. The beginning of active life and growth of shoots in plants after winter dormancy largely requires a certain level of heat supply (thermal threshold of vegetation), which value is genetically determined and is a species trait [3]. The change in the thermal threshold of vegetation occurs in a number of generations and is the main result of acclimatization during artificial migration due to introduction [4]. Therefore, the timing of the start and end of shoot growth is a significant indicator of the success of introduction [5].
In the modern world, with its many problems of urbanized habitat, the importance of green spaces is significantly increasing, among which the leading role belongs to woody plants [6]. Especially important for the development of green construction is the use of evergreen introduced species in the structure of decorative tree and shrub compositions in the southern regions, where they provide much-needed shade and coolness during hot season [7].

For the Southern Coast of the Crimea (SCC), the problem of park communities’ productivity, due to the high recreational load on the environment and climate change, is particularly relevant for the reconstruction and restoration of green spaces [8]. Therefore, one of the main directions for optimizing the planting of garden and park plantations is to expand comprehensive research on the bioecological potential, adaptive capabilities and resistance to adverse factors of ornamental plant species cultivated in the conditions of the SCC [9]. The integral and most labile indicator of plants biological productivity, reflecting the phenotypic manifestation of a genetically determined rate of seasonal development, is the formation of the increase in aboveground phytomass. Based on the analysis of the shoots and phytomass growth rate, it is possible to quantify the tolerance of plants to environmental factors, which is important for the development of effective measures to increase productivity, stability and rational use of tree introduced species [10].

The objective of the research was to study the features of park coenoses evergreen introduced species aboveground phytomass development and seasonal growth in the conditions of the Southern Coast of the Crimea.

2. Materials and methods
The research was carried out in the Nikitsky Botanical Gardens, National Scientific Center, located on the SCC (44°31’ N, 34°15’ E). The climate is subtropical and Mediterranean, characterized by hot, dry summers and moderately humid winters. The average annual air temperature is 12.6 °C, and the average annual precipitation is 592 mm.

The objects of the study were 5 species of evergreen introduced species widely used in the development of natural and artificial systems in the SCC for 150 years or more: Laurus nobilis L. (Lauraceae), Prunus laurocerasus L. (Rosaceae), Viburnum tinus L. (Adoxaceae), Aucuba japonica Thunb. (Garryaceae), Nerium oleander L. (Apocynaceae).

Observations of shoots seasonal growth were carried out during 2016-2020. Experimental plants (seedlings 4-8 years old) grew in the open area, not shaded by each other and other plants. Regular care was carried out on the site; the level of soil moisture was maintained within 60-80% of the minimum water capacity. The soil of the experimental site is typical for the coastal zone of the SCC, dark brown, medium-clay, medium-gravelly on a gravelly-stony limestone eluvium. The minimum water capacity ranges from 21.6 to 25.2%, wilting moisture is 9.9-11.1%.

In 2016, 6 model plants of each species with the same age and size were selected to study the growth of annual shoots and the accumulation of phytomass. 5 shoots were marked on each model plant, where the length of shoots and linear dimensions (length and width) of leaf blades were recorded weekly from the moment of vegetative budding (March) to the complete cessation of growth of stems and leaves (October) [10]. Direct measurements of the shoot length, length and width of the leaf blade were carried out directly on the site by using a ruler. The thickness of the leaf blade was measured by using the device “Turgoromer-1” (Russia).

The volume of phytomass of each leaf blade (V_{Li}) was determined by the formula (1):

\[ V_{Li} = L_{Li} \times W_{Li} \times Th_{Li} \times K_{Lf}, \]

where: \( V_{Li} \) is the length of the i-th leaf blade; \( W_{Li} \) is the width of the i-th leaf blade; \( Th_{Li} \) is the average thickness of the i-th leaf blade, calculated as the arithmetic mean thickness of all the leaf blades of the shoot on which the i-th leaf blade is located; \( K_{Lf} \) is the leaf blade shape coefficient calculated for each plant species.

The \( K_{Lf} \) was determined for each species by the formula (2):
$K_{Lf} = \sum_{i=1}^{n} \frac{S_{Li}}{L_{Li} \times W_{Li}}$, 

(2)

where: $S_{Li}$ is the area of the $i$-th leaf blade measured from a digital photograph programmatically; $n$ is the number of leaf blades measured.

To determine the $K_{Lf}$ for each species, 150 leaf blades were selected (5 from each shoot).

Environmental characteristics were measured around the clock at 10-minute intervals using the DWS-11z automatic weather station installed at the test site, which includes a pyranometer (Apogee Instruments, USA), a temperature and humidity sensor, a rain gauge (Decagon Devices, USA), and an anemometer (Davis Instruments, USA).

The resulting data array was analyzed by using the MS Excel2010 program. All the calculations were performed at a given significance level $P < 0.05$.

3. Results and discussion

To assess the impact of abiotic factors on the timing and duration of shoot growth, the weather conditions of five growing periods were analyzed, which showed that 2016-2020 periods significantly differed in moisture availability and temperature regime. The warmest growing season was in 2018 with the average air temperature of 20.5 °C, and the coolest was in 2017. Maximum air temperatures in the summer period during the years of observation reached 35-37 °C. The amount of precipitation varied widely: from 170-183 mm (2020 and 2019) to 347 mm in 2016. 2016 and 2018 were particularly contrasting in terms of moisture conditions during the growing season. The growing season in 2016 was moderately wet, with 301 mm of precipitation in April-August, and the Selyaninov hydrothermal coefficient (HTC) was 0.94. 2018 was characterized as very dry, and the SCC for April – August was 0.32. In comparison with 2016, in 2018, the amount of precipitation during these months was almost three times less (120 mm). In 2017, a lot of spring and autumn precipitation fell. The beginning of the growing season in 2016 and 2018 was characterized by the increased temperature regime in April, and in 2017 – the reduced one. A distinctive feature of 2019 and 2020 was very warm, long and dry autumn. In 2020, it was observed after a significant shortage of winter precipitation and a prolonged spring drought. The driest season was the growing season in 2020, the HTC for the warm period (April – October) was the lowest in the last 5 years – only 0.44.

The growing season of 2016 when studying the rhythmic growth of aboveground phytomass of evergreen introduced plants in the SCC was characterized by very hot June, heavy rains in the first days of July, dry September, and cold wet weather in the second half of October. The highest monthly average temperature (25.8 °C) was observed in August, and the absolute maximum (35.6 °C) – in June (Figure 1). At the beginning of the growing season, the weather conditions in 2016 were characterized by a temperature regime above average and a relatively low level of humidity.

![Figure 1. Dynamics of meteorological parameters during the period of the evergreen introduced plants annual shoots phytomass growth measuring, 2016.](image-url)
When analyzing the annual growth of shoots for 2016-2020, it was found that the timing of their resumption of growth in spring after winter dormancy and ending in autumn significantly differed, both depending on the thermal threshold caused by genetics, and on the prevailing weather conditions. The study of the introduced plants requirements for heat supply and temperature regime showed that the increased temperature regime in March-April 2016 contributed to an earlier start of growth processes in evergreen species with the need for active air temperatures above 5 °C (Δt>5), which reached 459-462 °C (V. tinus and A. japonica) (Table 1).

**Table 1. Phenology of shoot growth of the evergreen introduced tree species on the Southern Coast of the Crimea.**

| Species      | Years          | Time of active growth          | Duration (day) |
|--------------|----------------|--------------------------------|----------------|
| L. nobilis   | 2016           | Beginning | Date  | SD (°C) | t (°C) | SD (°C) | Σt>5 (°C) | SD (°C) | Date  | SD (°C) | t (°C) | Σt>5 (°C) |
|              | 2016-2020      |           | 02.V  | 14.8   | 886    | 06.VII | 24.6     | 2173    | 65     |
| P. laurocerasus | 2016          |           | 12.IV | 15.0   | 625    | 16.IX  | 20.8     | 2808    | 157    |
|              | 2016-2020      |           | 19.IV | 12.4   | 649    | 20.IX  | 18.9     | 2850    | 158    |
| V. tinus     | 2016           |           | 24.III| 7.5    | 440    | 20.X   | 12.3     | 4470    | 210    |
|              | 2016-2020      |           | 01.IV | 8.5    | 459    | 104.21.X | 14.5    | 4485    | 202    |
| A. japonica  | 2016           |           | 31.III| 7.0    | 484    | 28.IX  | 15.3     | 4158    | 181    |
|              | 2016-2020      |           | 02.IV | 8.3    | 462    | 126.08.X | 16.4    | 4158    | 89     |
| N. oleander  | 2016           |           | 14..V | 15.5   | 1061   | 20.IX  | 19.5     | 4033    | 129    |
|              | 2016-2020      |           | 04.V  | 15.0   | 990    | 03.IX  | 21.9     | 3649    | 122    |

SD – standard deviation from the long-term average; t – average daily air temperature; Σt>5 – accumulated active air temperatures above 5 °C.

Shoot growth in these species begins on average on April, 1-2 at average daily air temperatures of 8.3-8.5 °C. In mid-April, when the heat supply is higher by 649 °C P. laurocerasus starts active shoot growth, and with the accumulation of another 130 °C of active air temperatures above 5 °C – L. nobilis begins to grow. The highest level of heat supply for the beginning of vegetation is necessary for N. oleander, the resumption of shoots growth is observed in the first half of May when the accumulation of about 990 °C amounts of such temperatures and the average daily temperature is above 15 °C. The range of shoot growth duration of the studied species varies from 69 days in L. nobilis to 202 days in V. tinus. Growth of N. oleander shoots stops in the first half of September, and P. laurocerasus – in the second half.

The study of leaf growth by area, length, and width of the leaf blade showed that for each species, the linear dimensions of the length and width of a fully formed leaf blade can vary from 19-25% (P. laurocerasus) to 37-41% (A. japonica), and its area is up to 64-65% (L. nobilis, N. oleander) (Table 2). Leaf area is a measure of its photosynthetic potential, and a single leaf is an elementary unit when assessing the leaf surface of the plant and coenosis. Of the evergreen species under consideration, P. laurocerasus has the largest leaf blade area (50.8 cm²), and V. tinus has the smallest one (18.7 cm²). The largest number of leaves during the growth period on an annual shoot is formed in N. oleander (on average 56 pcs). Their number on the same shoots in P. laurocerasus and V. tinus was 2-2.5 times less, and in L. nobilis and A. japonica – 6.5-7.5 times less. The average leaf surface area of an annual shoot...
at the end of the growing season in descending order was: N. oleander – 124.447 cm², P. laurocerasus – 79.901 cm², V. tinus – 25.075 cm², A. japonica – 16.192 cm² and L. nobilis – 13.634 cm².

It is known that the intensity of the current tree growth development depends on both external environmental conditions and internal hereditary traits inherent in this ecotype [10]. The analysis of the studied evergreen introduced plants growth dynamics allowed to determine the differences between the species based on their growth intensity in different periods. The intensity is indicated for each species as a percentage of the current daily growth of the shoot to the maximum daily growth recorded for the entire growing season.

Table 2. Morphometric parameters of leaf blades on annual shoots of L. nobilis, P. laurocerasus, V. tinus, A. japonica, and N. oleander.

| Species          | ThL (mm) | Ll (cm) | Wl (cm) | Sl (cm²) | KLf  | Il  | Leaves amount (pcs) |
|------------------|----------|---------|---------|----------|-------|-----|---------------------|
| L. nobilis       | 0.22±0.02| 7.6±2.4 | 3.2±0.9 | 22.2±14.5| 0.70±0.02| 2.47±0.38 | 8.75±3.10           |
| P. laurocerasus  | 0.34±0.03| 11.1±2.1| 4.8±1.2 | 50.8±19.8| 0.72±0.02| 2.53±0.32 | 22.00±23.13         |
| V. tinus         | 0.25±0.08| 5.4±1.8 | 2.9±0.9 | 18.7±10.7| 0.74±0.03| 2.04±0.25 | 23.33±1.15          |
| A. japonica      | 0.34±0.04| 7.5±3.1 | 3.0±1.1 | 40.0±20.1| 0.70±0.02| 2.57±0.18 | 7.50±2.38           |
| N. oleander      | 0.45±0.03| 13.0±3.7| 2.4±0.7 | 29.9±19.1| 0.73±0.01| 5.64±0.83 | 56.25±16.98         |

ThL – thickness, Ll – length, Wl – width, Sl – area of leaf blade; KLf – shape parameter, Il – leaf blade index.

It was found that L. nobilis and N. oleander in the conditions of the Southern Coast of the Crimea have the same growth peak (Figure 2). However, it should be noted that when the crown is cut, the continuous growth of young shoots in L. nobilis on the SCC does not stop until the end of September. The maximum daily growth of 3.6 mm was observed in L. nobilis in the second decade of May. For N. oleander, it was 8.5-8.8 mm and was observed in the second and third decades of July (Table 3).

![Figure 2. Intensity of seasonal growth of shoots of L. nobilis, P. laurocerasus, V. tinus, A. japonica, and N. oleander.](image-url)
Research results show that the dynamics of growth of deciduous phytomass of the L. nobilis annual shoot is characterized by a pronounced surge in intensity, the peak of which (0.12 cm³/day) falls on the

Table 3. Dynamics of annual shoot phytomass growth in L. nobilis, P. laurocerasus, V. tinus, A. japonica, and N. oleander in the absence of water stress.

| Date   | L. nobilis | P. laurocerasus | V. tinus | A. japonica | N. oleander | shoot length, mm | volume of biomass of leaves, cm³ |
|--------|------------|-----------------|----------|-------------|-------------|------------------|-------------------------------|
| 31.03  | 1.2        | 0.0             | 2.2      | 0.3         | 0.0         | 0.0              | 0.0                           |
| 10.04  | 4.9        | 0.1             | 2.6      | 1.8         | 0.0         | 0.0              | 0.0                           |
| 20.04  | 6.4        | 3.6             | 3.8      | 1.6         | 0.0         | 0.0              | 0.2                           |
| 30.04  | 9.0        | 9.8             | 3.3      | 2.4         | 0.0         | 0.1              | 1.0                           |
| 10.05  | 11.8       | 24.3            | 4.0      | 5.4         | 0.0         | 0.1              | 1.6                           |
| 20.05  | 35.9       | 17.7            | 15.4     | 9.6         | 4.5         | 0.8              | 1.4                           |
| 31.05  | 29.6       | 12.0            | 7.6      | 9.4         | 12.6        | 1.2              | 1.8                           |
| 10.06  | 4.7        | 5.8             | 6.6      | 2.4         | 21.0        | 0.5              | 1.0                           |
| 20.06  | 3.7        | 9.6             | 4.5      | 1.1         | 36.7        | 0.3              | 0.5                           |
| 30.06  | 1.8        | 4.7             | 14.8     | 0.0         | 56.8        | 0.0              | 0.7                           |
| 10.07  | 1.9        | 12.2            | 27.9     | 1.5         | 66.8        | 0.0              | 1.1                           |
| 20.07  | 0.7        | 14.2            | 33.2     | 9.9         | 88.1        | 0.0              | 1.9                           |
| 31.07  | 0.0        | 28.5            | 24.6     | 5.5         | 84.7        | 0.0              | 3.4                           |
| 10.08  | 0.0        | 22.5            | 12.9     | 0.5         | 49.6        | 0.0              | 2.6                           |
| 20.08  | 0.0        | 22.2            | 10.5     | 0.0         | 40.1        | 0.0              | 2.5                           |
| 31.08  | 0.0        | 12.3            | 13.0     | 0.0         | 28.6        | 0.0              | 3.5                           |
| 10.09  | 0.0        | 2.9             | 8.7      | 0.2         | 3.8         | 0.0              | 1.1                           |
| 20.09  | 0.0        | 0.0             | 9.5      | 0.0         | 0.1         | 0.0              | 0.2                           |
| 30.09  | 0.0        | 0.0             | 0.7      | 0.0         | 0.0         | 0.0              | 0.2                           |
| 10.10  | 0.0        | 0.0             | 2.6      | 0.0         | 0.0         | 0.0              | 0.0                           |
| 20.10  | 0.0        | 0.0             | 1.0      | 0.0         | 0.0         | 0.0              | 0.0                           |
| 31.10  | 0.0        | 0.0             | 0.0      | 0.0         | 0.0         | 0.0              | 0.0                           |

Two species (V. tinus and A. japonica) had two growth peaks each. It was found that V. tinus maximum growth (2.5-3.3 mm per day) was observed at the second peak of growth in July, while A. japonica has the differences between the peak values of the intensity gain at first (in May, 0.9-1.0 mm per day) and the second (in July, 1.0 mm per day) periods is insignificant (Figure 2). Analysis of the relationship between the growth dynamics of shoots with the weather conditions for 2016-2020 showed that the secondary growth of shoots in terms of the SCC in the second half of July until early October in A. japonica is observed only when there is sufficient moisture supply and optimal temperature levels. In the absence of favorable hydrothermal conditions, A. japonica has only one growth peak, which usually ends in the first half of June.

It was found that in the conditions of the SCC in the absence of water stress, P. laurocerasus has three growth peaks. The maximum growth of 2.9 mm per day was observed in the second half of the growing season with the third activation of shoot growth (end of July, Figure 2). At the beginning of the growing season, the maximum daily growth of 2.4 mm was observed in the first half of May. Subsequently, there was a significant decrease in this indicator. After some stabilization and formation of the apical bud by the end of May, in mid-June, a noticeable activation of growth processes began, but the level of their intensity was almost 2.5 times lower than in May (Figure 2 and Table 3).

Research results showed that the dynamics of growth of deciduous phytomass of the L. nobilis annual shoot is characterized by a pronounced surge in intensity, the peak of which (0.12 cm³/day) falls on the
3rd decade of May (Figure 3 and Table 3). This surge is followed by a sharp decline – over a decade, the growth of leaf phytomass decreases by 2.5 times. In the future, the growth of L. nobilis leaf phytomass reaches a plateau, there is a sharp decline in the accumulation of shoot phytomass (up to 12% of the maximum), followed by a complete cessation of leaf growth at the beginning of the 3rd decade of June.

A distinctive feature of the P. laurocerasus aboveground phytomass seasonal development is two periods of intensive leaf growth during the growing season. The first period (2nd decade of April – 1st decade of June) is characterized by a sharp increasing in the intensity of leaf phytomass growth with a peak of 0.18 cm³/day at the end of May (Figure 3 and Table 3). The beginning of the 2nd period of leaf phytomass intensive growth falls on the 2nd decade of July. The maximum increase in this period is 0.34 cm³/day and falls at the end of July. In the last days of August, the second peak of the 2nd period of active growth is recorded – 0.35 cm³/day. In the first decade of September, there is a sharp decrease in biomass growth to the level of 0.11 cm³/day, and by the end of the 3rd decade of September, the growth of P. laurocerasus leaf biomass stops.

The development of V. tinus aboveground phytomass begins in the 3rd decade of April. The growing season of V. tinus has 3 distinct peaks of active leaf biomass growth. Similarly, with L. nobilis, the 1st peak occurs in the second half of May, but a distinctive feature is a less sharp growth jump and greater stability – throughout the second half of May, biomass growth remains at the level of 80-100% from the maximum of 0.08 cm³/day (Figure 3 and Table 3). At the beginning of the 1st decade of June, the growth of biomass slows down to 0.05 cm³/day, in the 3rd decade of June it is 0.02 cm³/day. In the 1st decade of July, the growth of phytomass V. tinus is activated again, its maximum is 0.08 cm³/day – this is the 2nd peak of active growth, which occurs at the end of July. The entire August increase in biomass is 0.02-0.03 cm³/day. In early September, the growth of V. tinus phytomass sharply reaches the 3rd peak, which is 0.05 cm³/day. Subsequently, the intensity of phytomass accumulation gradually decreases. Full completion of the growth occurs in mid-October.

A. japonica has several distinctive features of the leaf phytomass growth dynamics during the growing season. The first feature is the presence of a rest period in the middle of the growing season – complete cessation of leaf growth. This period begins in the 3rd decade of June, and ends in late July-
early August. The second feature is a strong difference in the rate of accumulation of phytomass before the dormant period from the rate after this period. The peak value of leaf growth before the dormant period falls on the 2nd decade of May and is 0.21 cm³/day, while after the dormant period it does not exceed 0.02 cm³/day (Figure 3 and Table 3). From the beginning of April to the beginning of May, there is a moderate activity of leaf development at the level of 0.02-0.03 cm³/day. At the end of May, the increase is 0.14 cm³/day. Activation of leaf growth after the dormant period (2nd decade of June-3rd decade of July) depends on weather conditions of the year, it occurred in the 1st decade of August and lasted until the 3rd decade of September.

Studies have shown that the beginning of growth of N. oleander leaf phytomass is observed in the 2nd decade of May (0.03 cm³/day). In mid-June, there is a sharp increase in the accumulation of phytomass and at the end of July reaches a maximum of 0.63 cm³/day (Figure 3 and Table 3). In August, the rate of phytomass growth gradually decreases and ends to the 3rd decade of September.

4. Conclusion
A five-year study of the features of evergreen introduced species L. nobilis, P. laurocerasus, V. tinus, A. japonica and N. oleander vegetative shoots seasonal growth on the Southern Coast of the Crimea allows to note the following. When analyzing the annual growth of shoots, it was found that the terms for resuming their growth in spring after winter dormancy and ending in autumn significantly differed, both depending on the thermal threshold due to genetic factors and on the prevailing weather conditions.

Specific features of the climax of the shoots and leaf phytomass growth during the growing season were revealed. The analysis of the growth dynamics allowed to establish that L. nobilis and N. oleander on the SCC are characterized by one peak of shoot growth, V. tinus and A. japonica – by two peaks, and P. laurocerasus – by three peaks. In the absence of favorable hydrothermal conditions, A. japonica has only one growth peak, which usually ends in the first half of June. The maximum daily growth of 3.6 mm was observed in L. nobilis in the second decade of May, for N. oleander it was 8.5-8.8 mm and was observed in the second half of July, in V. tinus (2.4-3.2 mm) - in the first half of July, in A. japonica - at the end of May (0.9-1.0 mm), and in P. laurocerasus – in late July (2.9 mm).

Leaf phytomass growth culminates in L. nobilis in late May, in P. laurocerasus in late July-August, in V. tinus in late May and late July, and in N. oleander in July. The largest growth (49.3 cm) and accumulation of leaf phytomass (42.3 cm³) are distinguished by annual shoots of N. oleander. P. laurocerasus has a rather large potential, with a volume of phytomass of an annual shoot of 24.5 cm³. The annual growth of V. tinus, A. japonica, and L. nobilis shoots phytomass is 7-8 times less than that of N. oleander. To increase the growth of phytomass and activate the growth of shoots in L. nobilis and V. tinus cutting the crown can be applied.

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References
[1] Plugatar Yu V, Maksimov A P, Kovalev M S, Rabotyagov V D, Trikoz N N and Khromov A F 2018 Biological and environmental peculiarities of introduction of Washingtonia filifera (Lind. ex Andr.) H. Wendl. Ex Bary at the southern coast of Crimea South of Russia: Ecology, Development 13(1) 88–100
[2] Fadón E, Fernandez E, Behn H and Luedeling E A 2020 Conceptual framework for winter dormancy in deciduous trees Agronomy 10(2) 241
[3] Tang J, Körner C, Muraoka H, Piao S, Shen M, Thackeray S J and Yang X 2016 Emerging opportunities and challenges in phenology: a review Ecosphere 7(8) e01436
[4] Rupp L A, Anderson R M, Klett J, Love S L, Goodspeed J and Gunnell J D 2018 Native and adapted plant introduction for low-water landscaping Hort Technology 28(4) 431–435
[5] Salmond J A et al. 2016 Health and climate related ecosystem services provided by street trees in the urban environment *Environ Health* **15**(S1) 36

[6] Braubach M, Egorov A, Mudu P, Wolf T, Thompson C Ward and Martuzzi M 2017 Effects of urban green space on environmental health, equity and resilience *Nature-Based Solutions to Climate Change Adaptation in Urban Areas Theory and Practice of Urban Sustainability Transitions* pp 187-205

[7] Aram F, García E H, Solgi E and Mansournia S 2019 Urban green space cooling effect in cities *Heliyon* **5**(4) 1339

[8] Pashtetsky A, Plugatar Yu V, Ilnitsky O and Korsakova S 2019 Using of phytomonitoring data for eco-physiological evaluation of the environmental factors limiting development of ornamental plants *Acta Horticulturae* **1263** 199–206

[9] Marko N and Korsakova S 2019 Phenological response to the climate change of oil-bearing rose under subtropical conditions of the Southern coast of the Crimea *Acta Horticulturae* **1257** 175–182

[10] Kishchenko I T 2019 Seasonal formation of aboveground phytomass of middle-aged pine stands in various types of forest in middle taiga *Lesovedenie* **1** 19–28