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The influence of changing some climatic conditions on the phenological phases of the development of native bush of Forest-Steppe zone plants

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Abstract

It was studied that the dynamics of phenophases, the dates of the beginning and duration of phenological cycles in plants are under the constant influence of seasonal changes in climatic conditions (regular alternation of seasons with different durations of day and night, warm or cold and rainy or dry seasons). Together with the study of the shoot growth duration, it is worth conducting a study of the dynamics of their growth. This is also important for determining the tolerance for winter conditions, since it is known, that not only those shoots that finish growing early but also those that grow for a long time, but rather slowly, can be winter resistant.

The intensive growth of shoots of all studied species occurs in May to mid-June. Almost all of them have two peaks of shoot growth: June and mid-July. The growth of shoots has a certain dependence on air temperature.

The conducted long-term phenological observations made it possible to establish the periods of phenophases in five species of shrubs and show that in the conditions of the Right-Bank Forest-Steppe, all of them manage to complete their vegetation in time, before the beginning of frost.

Among the studied species, *Lonicera tatarica* L. and *Viburnum lantana* L. were the first to start their shoot growth in the first decade of May. Then, in the third decade of May, shoots of *E. europaeus* began to grow. *P. spinosa* and *R. canina* were the last to start their shoot growth.

The conducted research has a certain significance for forest reclamation work as these types of shrubs are used to create protective plantings. Establishing a certain dependence on air temperature will allow to adjust the species composition and their number when creating this type of plantation.

Key words

temperature, dynamics of shoot growth, shrub species, seasonal development

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Introduction

Phenology solves a wide range of scientific problems. In forestry, based on the materials of long-term phenological observations, a natural connection is determined between the time of certain phenomenal occurrence and optimal periods of work during the planting of forest crops, maintenance felling, protection of forests from fires and harvesting of fruits and seeds. The phenological state of forest stands is also taken into account during forest inventory (Chapin et al. 1995; Myers-Smith et al. 2011).

The phenological development of plants is understood as the regular alternation and annual repetition of the same phenocycles (vegetation and dormancy, shoot growth and its completion, appearance and fall of leaves, flowering, ripening of fruits and seeds), and within the limits of the cycles, the sequential course of the onset and passing of the phenological phases of growth and development. The phenological phase is a stage in the annual cycle of the development of a plant and its individual organs, which is characterized by clearly expressed external morphological changes (swelling and opening of buds, unfolding of leaves, growth of shoots, flowering, fruiting, etc.) (Cosmulescu and Calusaru 2020; Gyan nd Woodell 1987; Hayesand and Peterson 2020).

The dynamics of phenophases, the dates of the beginning and duration of phenological cycles in plants are under the constant influence of seasonal changes in climatic conditions (regular alternation of seasons with different durations of day and night, warm or cold, and rainy or dry seasons). Adapting to it, plants significantly change the rhythm of processes growth and development as well as its phenological state. Under the influence of seasonal changes in woody plants, the dynamics of their growth processes changes rapidly. Therefore, their phenological development is understood as seasonal development. Each territory has its own seasonal phenomena and calendar dates for their onset. These terms are not constant over the years (Pawłowski et al. 2020; Peterson et al. 2018; Santiago et al. 2015).

Shrub species are constant components of forest ecosystems and form the understory layer. Many researchers inform about their increase with climate change. Shrub species help retain snow in the forest, accelerate mineralization of the litter of forest-forming species and enrich it, enrich biodiversity and fodder base for fauna and prevent soil erosion (Chapin et al. 1995; Myers-Smith et al. 2011; Demchenko 2013).

The importance of conducting research on certain phenological phases of shrub species in forest stands growing in Right-Bank region of Ukraine is due to the partial absence of such data in literary sources.

Thus, studies on the seasonal growth and the development of species of shrubs of the Rosaceae family were carried out in different periods and in different regions by Mysnyk (1976), Litvinenko (2004) and Kolisnichenko (2004). There are also brief reports that the species of the genus *Viburnum* L. bloom in May–June and the fruits ripen in September–October (Farall et al. 2021). The works by Zayachuk (2013) and Demchenko (2013) comprise some phenological data. Seasonal growth and development of introduced snowball tree in the conditions of Kyiv city was studied by Mamushkina (1985). A number of foreign scientists studied *Lonicera tatarica* L., *Prunus spinosa* L. and *Rosa canina* L. (Cosmulescu and Calusaru 2020; Gyan and Woodell 1987; Hayes and Peterson 2020; Kollmann and Grubb 2002; Mammadov and Seyidli 2021; Novak et al. 2008; Palacios et al. 2002; Pawłowski et al. 2020; Peterson et al. 2018; Santiago et al. 2015; Vander et al.2022; Yörük et al. 2005).

Similar studies have not been conducted in the conditions of the Right-Bank Forest-Steppe, Ukraine. Knowledge of individual phenological phases in shrub species and their correspondence to temperature data will help to optimize the maintenance of forest plantations. It will also help to optimize the species composition of shrub species and their number in plantations of various types.

Material and methods

The shrub species of fresh hornbeam Bilogrudivskyi forest which is situated in Uman, Cherkasy region, became the objects of the research. In general, five species of shrubs from four families were studied: *Euonymus europaeus* L. from the Celastraceae family, Tatarian honeysuckle *Lonicera tatarica* L. from the Caprifoliaceae, *Prunus spinosa* L. and *Rosa canina* L. from the Rosaceae family and *Viburnum lantana* L. from the Adoxaceae family. The dominant forest species in the stands are *Quercus robur and Fraxinus excelsior*, which form the bulk of the forest fund and form the first storey. The *Carpinus betulus*, with the admixtures of *Acer platanoides, Acer campestre, Ulmus campestris, Ulmus glabra* and *Cerasus avium* dominate in the second storey. The derived types of plantations are represented by the forest stand with the *Carpinus betulus* preference. Phenological observations of the formation of generative and vegetative organs were carried out during 2020–2022 according to the method of Kalinichenko (2000).

In 2019–2021, 11 permanent sample plots approximately 0.5 ha each were laid in the forest of Uman husbandry. Research was conducted during the growing season. For this purpose, the plots were inspected every 2–4 days. The dates of the certain phenophase onset of each of the studied species were recorded.

The peculiarities of shoot growth during the vegetation period were determined according to the method of Smirnov and Molchanov (1967). The record was kept from the place of attachment of the blooming bud to the previous year shoot. The total number of shoots in each model group was 20 pieces. After the growth of the shoots stopped, the calculation of daily growth was carried out, which was defined as the difference in length between the next and previous value of each measurement period divided by the number of days of this period.

Measurements were carried out during the period of intensive growth after 3 days, and during periods of its decline, measurements were done after 5 days. At the same time, the average daily air temperature was recorded. According to the research results, the diagrams of the shoots growth during the vegetation period and the dynamics of growth were developed, and the dependence of the shoot growth intensity on the air temperature was established.

In the phenological observations, the following main phases in the seasonal rhythm of plant development are highlighted: the vegetation beginning, the unfolding of leaves, the beginning of flowering, the end of flowering, the fruit ripening, the fall of leaves and the growth of shoots.

Observations were made on shrubs of various ages that had reached reproductive capacity. A total of 20 bushes of each species were searched for in each plot. Phenological observations were made daily during the period of physiological activity. In the summer time, when development slows down, observations were made one to two times a week.

The research region is characterized by a moderately continental climate with relatively warm and mild winters.

According to Uman weather station, the average long-term air temperature is 7.2°C, for the coldest month (January), it is -5.8°C, and for the hottest month (July), it is 19.7°C. The average of the absolute minimum air temperatures is -21°C. Severe frosts are rare. A stable transition of the average daily temperature through 5°C is in the first decade of April, through 10°C in the third decade of April. The period with an average daily temperature above 10°C lasts 160–165 days. The duration of sunshine per year is 840 hours, and during the growing season, it is 460–520 hours. The sum of average daily air temperatures above 0°C was 3155°C, above 5°C was 3040°C, above 10°C was 2710°C. In the summer period, warm weather is observed at first, and in July and August, hot weather is observed.

Table 1. Average monthly temperature (°C) for 2019–2021 (according to Uman weather station)

Years	Months												Yearly average
	1	2	3	4	5	6	7	8	9	10	11	12	
2019	–4.7	0.5	4.5	9.6	17.0	23.4	20.0	20.7	15.6	10.0	5.5	2.2	10.4
2020	0.4	2.2	6.3	9.2	12.5	20.9	21.6	21.2	17.8	12.7	3.7	0.0	10.7
2021	–2.3	–3.8	2.0	7.4	14.0	19.8	23.2	20.3	13.0	7.2	4.7	1.3	8.9
Average for 3 years	–2.5	–0.4	4.3	8.7	14.5	21.3	21.6	20.7	15.4	9.9	4.6	1.2	9.9
Average many-year	–5.7	–4.2	0.4	8.5	14.6	17.6	19.0	18.2	13.6	7.6	2.1	–2.4	7.4

The beginning of spring (stable transition of the average daily air temperature through 0°C) occurs in March 15–20 (Tab. 1). However, there are also late and early springs.

According to Table 1, for the research years, certain months have higher temperature indices compared to the average many-year data. The spring–summer period is characterized by frequent dry periods with air temperature above 35°C in the shade.

Statistical processing of research results was carried out using the Excel program. At the same time, the regression equation and the coefficient of determination were calculated.

Results

Since the studied shrub species belong to different genera with various morphological features, the certain phases of their vegetation had significant differences (Tab. 2).

Thus, *E. europaeus* and *L. tatarica* started their vegetation earlier – in the second or third decade of March, while *V. lantana* started its vegetation in the first decade of April. The representatives of the Rosaceae family (*P. spinosa* and *R. canina)* started their growing season last – in the second and third decades of April.

The budding stage of leaves in *L. tatarica* and wayfaring tree begins almost at the same time during the years of research, on average at the end of the first decade of April. *E. europaeus* starts it a little later – in the second decade of April. In *R. canina*, the leaves are coming out at the end of the second decade of April and in *P. spinosa* – in the third decade of April. *P. spinosa* is the first of the studied species to start flowering – at the end of the third decade of April. The flowering of *E. europaeus* and *L. tatarica* was recorded in mid-May. *R. canina* and *V. lantana* begin to bloom in the third decade of May.

Since *P. spinosa* began to bloom earlier than all the studied species, accordingly, the end of flowering is observed the earliest – the first decade of May. *E. europaeus* and *L. tatarica* finish flowering in the first decade of June and *V. lantana* and *R. canina* – in the second decade of June (Tab. 2).

The period of fruit ripening is also different for each species. First, it begins in *V. lantana*. Its fruits begin to ripen in the third decade of July and until the middle of August. Also, at the end of the third decade of July, the fruits of *L. tatarica* begin to ripen and finish their ripening by the second decade of August. The fruits of *R. canina* and *P. spinosa* begin to ripen in mid-August, and this process continues until the third decade of September. The fruits of *E. europaeus* begin to ripen at the latest – from the second to the third decade of September.

The fall of the leaves indicates the beginning of the plant's preparation for winter and the complete end of vegetation and entry into a rest.

In all the studied species, this happens in the middle of autumn. The earliest average leaf fall over the years of research was recorded in *L. tatarica* – from the third decade of September to mid-October. From the first to the third decade of October, the leaves of

Table 2. Peculiarities of the seasonal development of shrub species of fresh hornbeam stand (average for 2019–2021**)**

Species	Beginning of vegetation	Budding of leaves	Beginning of flowering	End of flowering	Fruit ripening	Leaf fall	End of vegetation	Duration	Shoot growth
E. europaeus	20.03±2	11.04±1	17.05±2	01.06±2	11.09±2 + – 27.09±1	05.10±2 + – 30.10±1	03.11±2	227±3	19.04±2 + – 24.06±2
L. tatarica	16.03±3	09.04±3	16.05±3	03.06±3	28.07±3 + – 09.08±1	20.09±3 + – 19.10±2	22.10±3	223±4	11.04±1 + – 23.06±2
P. spinosa	21.04±3	28.04±2	23.04±4	08.05±2	18.08±2 + – 20.09±4	17.10±2 + – 04.11±3	09.11±3	184±5	05.05±1 + – 25.06±2
R. canina	14.04±1	19.04±1	27.05±1	09.06±1	18.08±3 + – 15.09±4	16.10±1 + – 27.10±1	05.11±3	185±3	01.05±1 + – 30.06±2
V. lantana	01.04±3	08.04±3	27.05±5	10.06±3	20.07±4 + – 13.08±2	26.10±1 + – 03.11±1	12.10±3	190±3	12.04±1 + – 30.06±2

E. europaeus fall and the leaves of *R. canina* fall in the second or third decade of October. And from the third decade of October to the beginning of November, the leaves of *P. spinosa* and *V. lantana* fall. The end of vegetation of all species occurs at the end of October to the beginning of November.

The study of the shoot growing stage is of particular importance. After all, the degree of their lignification, frost resistance and tolerance for winter conditions depend on how long they grow. Together with the study of the shoot growth duration, it is worth conducting a study of the dynamics of their growth. This is also important for determining the tolerance for winter conditions, since it is known that not only those shoots that finish growing early but also those that grow for a long time, but rather slowly, can be winter resistant.

The intensive growth of shoots of all studied species occurs in May and mid-June. Almost all of them have two peaks of shoot growth: June and mid-July. The growth of shoots has a certain dependence on air temperature.

Among the studied species, *L. tatarica* and *V. lantana* were the first to start their shoot growth in the first decade of May. In 2020 and 2021, this stage began with

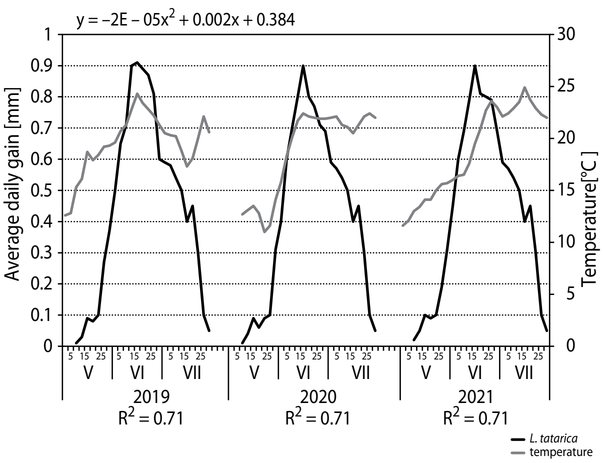

Figure 1. Dynamics of the shoot growth of *L. tatarica* (2019–2021)

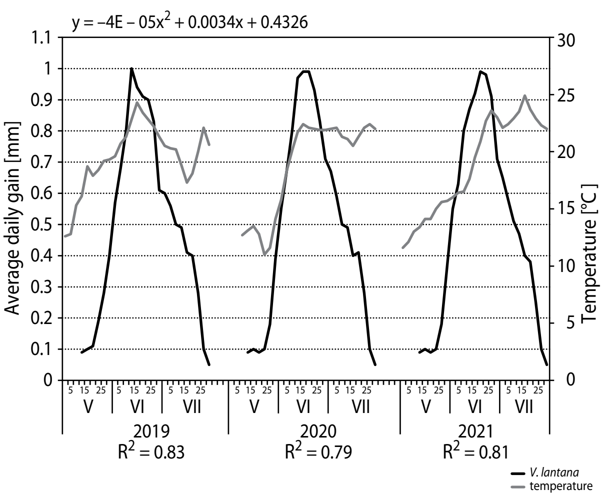

Figure 2. Dynamics of the shoot growth of *V. lantana* (2019–2021)

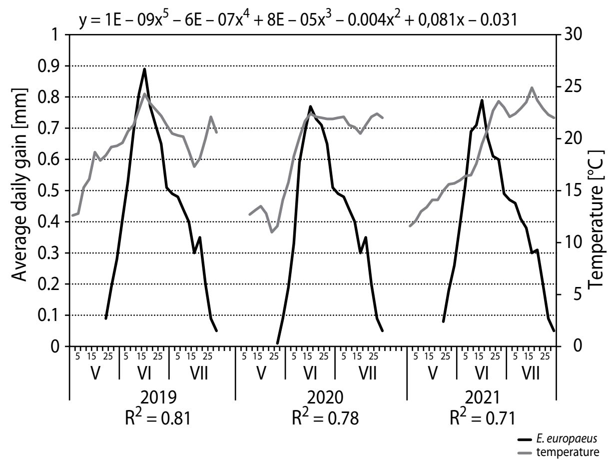

Figure 3. Dynamics of the shoot growth of *E. europaeus* (2019–2021)

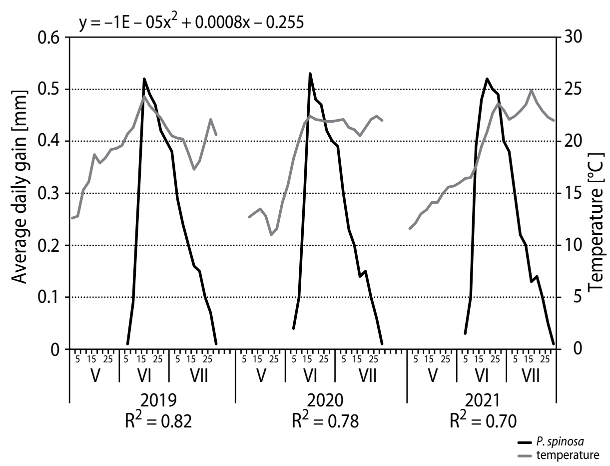

Figure 4. Dynamics of the shoot growth of *P. spinosa* (2019–2021)

a temperature of 12–13°C and in 2019 – when the temperature rose above 15°C (Fig. 1 and Fig. 2). Then, in the third decade of May, shoots of *E. europaeus* began to grow (Fig. 3). *P. spinosa* and *R. canina* were the last to start their shoot growth (Fig. 4 and Fig. 5).

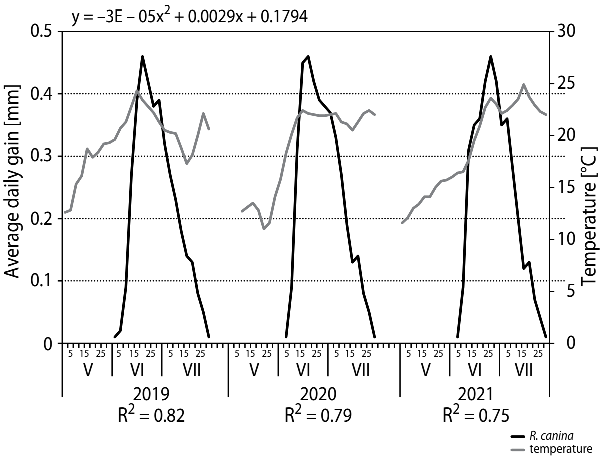

Figure 5. Dynamics of the shoot growth of *R. canina* (2019–2021)

As the growing season progressed and the average daily temperature increased, the increment rate also increased. The peak of growth of all studied species occurred at the same time – the end of the second decade to the beginning of the third decade of June and almost coincided with the peak of air temperature in 2019 and 2020. In 2021, due to the peculiarities of the temperature indices of the growing season, these two indices did not coincide.

After the culmination of the first wave, further shoot growth had a weaker dependence on air temperature fluctuations. Thus, the culmination of the second wave, which occurred in mid-July, did not always coincide with the temperature rise at that time. It is obvious that during this period, the shoots have almost completed their growth and started preparing for the autumn period. In addition, the air temperature in this period during the research years was slightly different. Thus, in 2019, it was within 17–19°C, and in 2020 and 2021, it is -21°C.

After the culmination of the second wave of growth, despite the air temperature fluctuation, the increment intensity decreases sharply, and by the end of July, the growth is completed.

Discussion

By comparing the results of phenological observations with the corresponding meteorological data, it is possible to trace the relationship between the development stages and air temperature. It has been established that plant growth begins in spring, when the sum of positive temperatures reaches the required level for plants. This temperature threshold for the beginning of development is slightly different for all studied species. This is due to the biology peculiarities of all studied species. In the future, the onset of phenological phases in all species also varies slightly in time.

Studies of the relationship between air temperature and the shoot growth showed that at the beginning of growth, the average daily temperature fluctuated within 12–15°C, during the years of research. Such variability of this factor value indicates its weak influence on the period of start of meristematic tissues activity (Schieber 2014; Wanjiku and Bohne 2021). This phenomenon can be explained by the fact that in the initial period, growth processes take place at the expense of reserve nutrients. In the future, the role of assimilants of the current year begins to increase and fluctuations in air temperature begin to be reflected in the intensity of growth processes.

Thus, for example, during all the years of research at the end of the first decade of April, a sharp increase in air temperature by 0.5–1°C caused a jump in growth in *V. lantana* and *L. tatarica*. The rest of the species is not monitored here due to the later start of their vegetation. Then, as the average daily temperature increases, the intensity of increments gradually increases. However, the maximum air temperature during the active growth of shoots does not always coincide with the increment culmination. This was especially clearly visible in 2021. At that time, the culmination of almost all studied species was in the middle of June, while the maximum air temperature was in the middle of the third decade of June. Only in *R. canina*, these two indices almost coincided in time, but comparing with past years, this cannot be considered a regularity as the culmination of increments in this species falls on this period in all years of research.

After the culmination, there is a gradual attenuation of the increment intensity, which does not have a clear dependence on air temperature. This is clearly seen in 2020. At that time, the onset of the culmination of growth of increments and temperature approximately coincided in time (the second decade of June); however, in the following days, the temperature indices continued to remain at the same level, and the intensity of increments began to decrease.

A certain dependence of increments on temperature fluctuations can still be observed in July, when the second wave of growth passes. It is already quite weak, but coincides in time with a slight jump in temperature. This pattern was observed in all species in all years of research. But it was especially interesting in 2021. Then, the culmination came before the culmination of the air temperature. Then, the intensity of increments, despite temperature fluctuations, began to decrease, but already the second wave of growth coincided with the maximum temperature during the growing season.

Such a discrepancy between certain stages of temperature and increments can be explained by the peculiarities of certain physiological processes during the period of growth and development of shoots (Ryabchuk at al. 1996; Ryabchuk et al. 2000; Wanjiku and Bohne 2021). Thus, from the beginning of its growth until the culmination, most of the nutrients go to support growth processes. At this time, the shoots are already almost at their maximum length. After the culmination, the processes of lignification and accumulation of nutrients necessary for successful overwintering begin in the shoots. Therefore, at this time, the growth activity is minimal and high temperatures no longer affect the growth.

Conclusions

The conducted long-term phenological observations made it possible to establish the periods of phenophases in five species of shrubs and show that in the conditions of the Right-Bank Forest-Steppe, all of them manage to complete their vegetation in time, before the beginning of frost.

Among the studied species, *L. tatarica* and *V. lantana* were the first to start their shoot growth in the first decade of May. Then, in the third decade of May, shoots of *E. europaeus* began to grow. *P. spinosa* and *R. canina* were the last to start their shoot growth.

The intensive growth of shoots of all studied species occurs in May and mid-June. Almost all of them have two peaks of shoot growth: June and mid-July. The growth of shoots has a certain dependence on air temperature.

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