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# Peculiarities of seasonal growth of *Pinus nigra* J.F. Arnold under the conditions of introduction in the Right-Bank Forest-Steppe of Ukraine

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**Abstract**

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Generalization of scientific studies and analysis of experimental data on the peculiarities of seasonal growth of vegetative organs of *Pinus nigra* J.F. Arnold, their compliance with the climatic conditions of the Right-Bank Forest-Steppe of Ukraine are reported. Studies showed that the mechanisms of regulating growth processes are directly affected by the air temperature. *P. nigra* belongs to the species that begin their vegetation early in spring. The first shoots to start growing are the ones which require a small amount of heat. Studies showed that the needle growth begins on the 30th–35th day after the onset of shoot growth. During the study period it was also noted that the growth intensity of shoots is gradually increasing from the base of the crown to its top.

**Keywords**: invasive plants; temperature; phenological development; temperature; shoots; needles

Green spaces continue to play an essential role in improvement and enhancement of the human habitat. Today, it is difficult to imagine the functioning of city plantations and parks without invasive plants. The process of plant introduction is preceded by a detailed study of their peculiarities, through which the prospects of specific use are found (Kischenko 2011). *Pinus nigra* J.F. Arnold is one of these invasive plants, which is effectively used for forest cultures, afforestation of slopes, ravines, quarries, lands unsuitable for further agricultural use and in green construction.

An objective prospective assessment of the introduced species is possible only on the basis of comprehensive studies, in particular on the degree of compliance of the rhythm of plant growth and development with the variability of environmental factors, which leads to the corresponding state of adaptation (Rehder 1940; Bollmann 1986; Van Haverbeke 1990; Makarynska 2012a). In order to characterize any species of tree plants under the conditions of introduction, study of the peculiarities of going through certain biological processes, the intensity and duration of growth of vegetative organs in particular is important, as the biological productivity of plants depends on them (Kischenko 2011).

The change of ecological conditions affects the seasonal rhythm of growth and development, duration of certain phenological phases, as well as the morphological features of plants (Wachowiak et al. 2018). Evergreen species have less pronounced signs of the onset and the end of vegetation and are described by different scientists differently (Elagin 1976; Wheeler et al. 1976; Bollmann 1986; Makarynska 2012b).

## MATERIAL AND METHODS

Immediate objects of the study are introduced *P. nigra* trees of Uman, the Cherkaska region, and Holovanivsk, the Kirovogradska region, where measurements of annual shoots and needles were made.

The climate of the studied regions is moderately continental with relatively warm and mild winters. Analysis of Table 1 shows that the 2010 and 2011 studies are characterized by somewhat higher temperature indices than long-term average data.

The spring-summer period was accompanied by long dry periods with the air temperature over 35°C in the shade. The growing season lasts from April to September and its duration is 175 days. The average temperature during this period was in the range of 16.7–18.7°C.

Peculiarities of the growth of *P. nigra* shoots and needles of plants of different ages during the vegetative season were specified by the method of Molchanov and Smyrnov (1967).

The length of the shoots was measured with a metal ruler three days after the onset of the state of "linear growth of shoots". The records were kept from the place of attachment of the bud that is unfolding to the last year shoot. The total number of shoots in each model group was 20. After the growth of shoots was stopped, daily increment was calculated, which was defined as the difference in length between the next and the previous value of each measurement period, divided by the number of days of this period.

Observations of the growth of needles in length were carried out on the same shoots, which were studied for growth. On each shoot the length of 5 needles, located in the middle part of the shoots, was measured with a ruler. Thus, 100 needles were measured at a time. By analogy with the shoots daily increments were also calculated and basic statistics were received. Measurements were carried out in the period of intense growth for next three days, and in periods of its decline – for next five days. All the while, average daily air temperature was recorded. According to the results of the study, schedules of the shoot growth during the vegetative season and of growth dynamics were drawn up and dependence of the intensity of shoot growth on the air temperature was determined.

## RESULTS AND DISCUSSION

### Linear growth of shoots

The studies of Isik (1990) in Central Anatolia showed that the growth rate of P. nigra was slow in the first decade of April, while it accelerated during the second half of April, and peaked in late May. According to our research, the appearance of a gap between the bud scales is considered to be the beginning of growth. The beginning of growth of *P. nigra* shoots is considered to be the appearance of lumens between kidney scales. This usually happens in the first decade of April. Regardless of forest conditions, the indicated phenophase begins with an increase in the air temperature to 8.5°C (Table 2).

Table 2. Air temperature – *T* (°C) during the growth of *Pinus nigra* J.F. Arnold shoots and needles

| Year | Growth | | | | | |
|---|---|---|---|---|---|---|
| | beginning | | climax | | ending | |
| | date | *T* | date | *T* | date | *T* |
| **Shoots** | | | | | | |
| 2010 | 03.04 | 8.9 | 15–24.06 | 21.7 | 15.09 | 15.7 |
| 2011 | 09.04 | 8.2 | 05–15.06 | 20.8 | 19.09 | 16.1 |
| 2012 | 08.04 | 8.5 | 17–26.06 | 21.9 | 21.09 | 16.5 |
| **Needles** | | | | | | |
| 2010 | 05.05 | 16.8 | 08–16.07 | 24.1 | 07.09 | 18.4 |
| 2011 | 16.05 | 16.4 | 15–20.07 | 24.7 | 05.09 | 18.9 |
| 2012 | 08.05 | 17.1 | 05–11.07 | 24.7 | 05.09 | 17.4 |

Table 1. Average monthly temperatures (°C) for 2010–2012 years of researches (by the data of Uman weather-station)

| Year | Month | | | | | | | | | | | | Average for a year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | |
| 2010 | –7.8 | –3.0 | 0.7 | 9.3 | 16.4 | 20.6 | 23.0 | 23.6 | 14.5 | 5.9 | 8.8 | –3.8 | 9.0 |
| 2011 | –3.1 | –5.2 | 1.4 | 9.5 | 15.7 | 19.7 | 21.7 | 18.9 | 15.0 | 7.0 | 1.8 | 1.9 | 8.7 |
| 2012 | –4.2 | –10.2 | 2.2 | 12.1 | 18.0 | 21.3 | 23.4 | 20.8 | 16.4 | 10.8 | 4.5 | –5.3 | 9.2 |
| Average for 3 years | –5.0 | –6.1 | 1.4 | 10.3 | 16.7 | 20.5 | 22.7 | 21.1 | 15.3 | 7.9 | 5.0 | –2.4 | 8.9 |
| Long-term annual average | –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 vegetation period from April to September

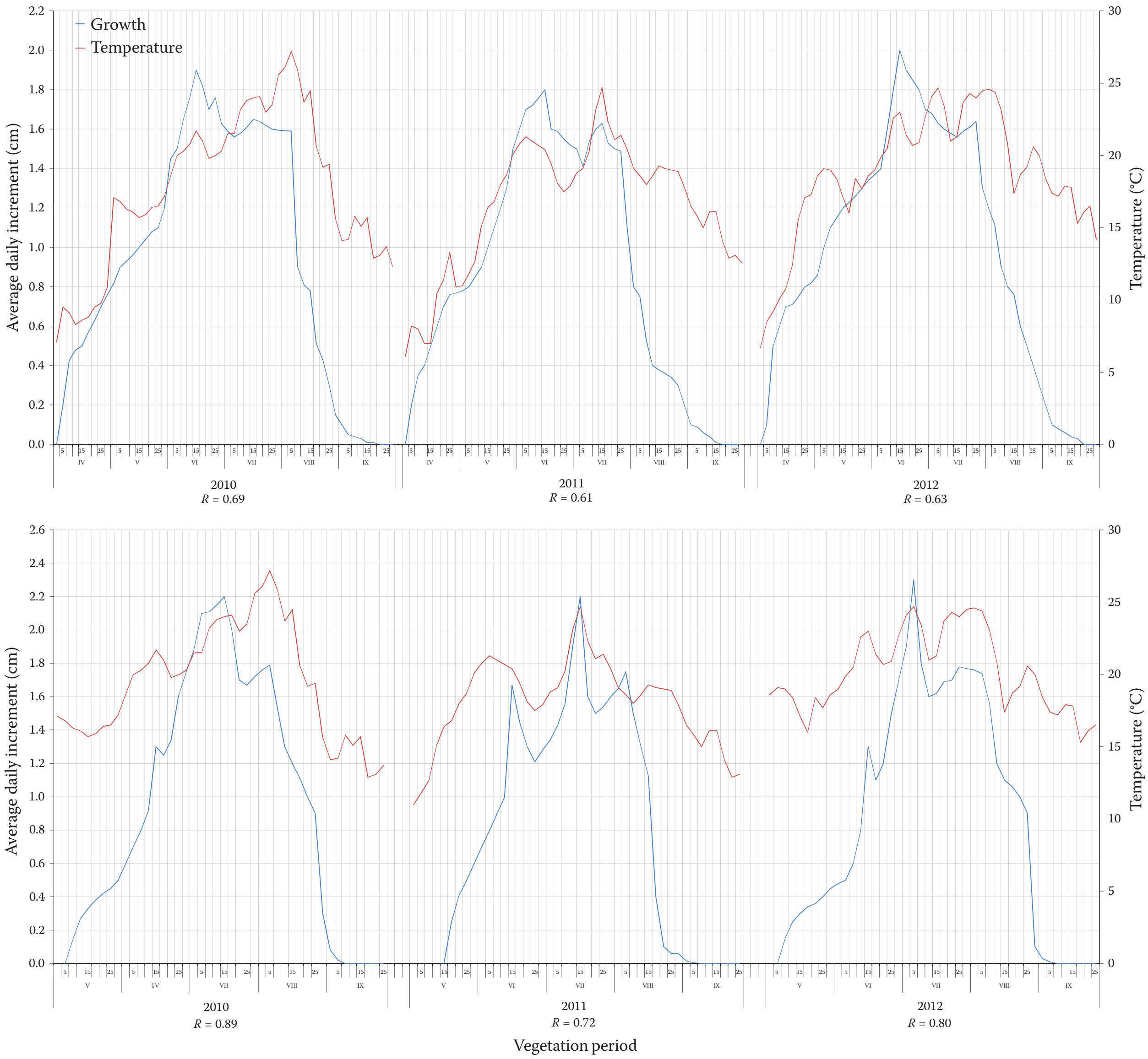


Fig. 1. Dependence of seasonal growth of *Pinus nigra* J.F. Arnold shoots (a), needles (b) on the air temperature

Climax of the first wave of growth was observed in June, when the daily average air temperature rose over 20.0°C. At that time, the length of the shoots was 8.5 cm. Starting from the first decade of August, growth gradually decreased and by the end of the second decade of September shoots completely stopped growing. It was found (Bollmann et al. 1986; Kischenko, Vantenkova 2011) that duration and intensity of shoot growth are related to the peculiarities of temperature regime during the growing season. The graphic data shown in Fig. 1a indicate a relationship between temperature fluctuations and shoot growth.

The correlation coefficient ranged from 0.61 to 0.69. This means that there is a correlation between the beginning of growth and increase in the average daily air temperature to 8–9°C. In future, the intensity of shoot growth will also be related to the air temperature. With its increase there is an increase in average daily increments.

The onset of the growth process climax is also related to the air temperature. The maximum increment over the years of study was observed in the first or second decade of June, when the temperature rose above 20°C. At this time, it was about 2 cm per day. An especially notable dependence of increments on the air temperature is observed in the period between the climaxes of the first and second wave of growth. Thus, after lowering the temperature in the 2nd–3rd decade of June, the intensity of increments sharply decreases, and after its increase in July, there is a second wave of growth, which is accompanied by an increase in daily increments. The attenuation of growth is not closely related to subsequent changes in the air temperature. After climax, growth still remains high, but it is falling rather quickly.

Table 3. Duration of shoot growth in different parts of the crown

| Growth | Part of the crown | | | | $LSD_{0.05}$ |
|---|---|---|---|---|---|
| | top | upper | middle | lower | |
| **Phase** | | | | | |
| Beginning | 05.04 | 05.04 | 05.04 | 05.04 | |
| Ending | 18.09 | 14.09 | 05.09 | 28.08 | |
| **Duration (day)** | 160 | 156 | 147 | 139 | 2.06 |

LSD – least significant difference

During the period of increased shoot growth and the onset of climax of the second wave of growth, 76% of annual growth is formed. Consequently, the greatest effect of forest management measures aimed at increasing the productivity of the tree stands can be achieved by conducting them prior to the extinction of growth processes.

During the study period it was also noted that the intensity of shoot growth from the base of the crown to its top is gradually increasing. Thus, the maximum increase was observed in the upper part of the crown, in the middle it was slightly lower and the lowest – at the base of the crown.

Nesterovich et al. (1972) found that the average daily increment of *Pinus sylvestris* Linnaeus shoots in the middle and lower parts of the crown is 39 and 56% lower, respectively, than in the upper part. Instead, the length of the apical shoots is higher than in the upper, middle and lower parts of the crown, respectively, in 2.5, 4.5 and 11.5 times.

After conducting research on the growth intensity of *P. nigra* shoots, it was found that the length of its apical shoot is 1.8 times higher than that of the others. Duration of the shoot growth in different parts of the crown is also different (Table 3).

It takes the shoots of the top and the upper part of the tree to grow the longest, 160 and 156 days, respectively. Shoots of the middle part stop growing somewhat sooner. Shoots of the lower part grow for the shortest period – 147 days. A difference in the duration of growth of the top and the lower part is 21 days.

## Linear growth of needles

The length of the needles under the same conditions of location is considered to be a variable feature (Pensa, Jalkanen 2005; Meicenheimer et al. 2008). Studies on *P. nigra* in Central Anatolia showed that needle tips emerged on about 15 May (Isik 1990). Our studies showed that growth of the needles begins on the 35th–40th day after the onset of shoot growth. Differences in terms of the onset of this phase also depend on the air temperature (Fig. 1b).

It is known that the features of needle growth are influenced by many factors, such as reduction of light regime, technogenic contamination, radiation, which can reduce or increase their length in particular (Junttila, Heide 1981; Fedotov 1983; Dougherty et al. 1994; Salminen, Jalkanen 2006; Chudzińska et al. 2014).

According to the results of the study, the growth of the needles was observed at an average daily temperature of 16°C in the 1st–2nd decade of May. Further, with increasing temperature growth increased.

It is seen from the graphic that the intensity of needle growth varies depending on the temperature fluctuation. This is evidenced by the correlation coefficient, which is in the range of 0.72–0.89. For example, in the second decade of June, a sharp, short-term rise in temperature above 21°C was accompanied by an increase in growth to 1.3–1.6 cm per day. Further, the temperature dropped to 20°C and, with this, the intensity of growth decreased to 1.1 cm per day. A similar dependence was observed throughout the period of needle growth.

The growth climax also coincides with the climax of the air temperature and falls in the 1st–2nd decade of July. The largest daily increment at this time is 2.1–2.3 mm. Unlike shoots, the intensity of needle growth depends on the air temperature throughout the period.

The end of needle growth is observed in the 3rd decade of August–the 1st decade of September, when the air temperature is lower than 18°C. In the period of the needle growth decline, which lasts for 45 days, 28% of the annual growth is formed. The total duration of the needle growth is 105 days. The period of increased needle growth is almost 1.5 times longer than the period of decline and is equal to 60% of the total duration of its formation. During this time, up to 72% of the annual growth is formed.

Thus, the selected study objects corresponded to the aim and tasks of the work. As a result of the analysis of natural conditions of the Right-Bank Forest-Steppe of Ukraine, it can be concluded that they partially comply with the natural habitat of *P. nigra*. This research gave concrete ways of increasing the phytoremediation efficiency of forest stands with the participation of *P. nigra*. The generalized knowledge of the growth of this species gives an assessment of its introduction and possible use in green construction of the Right-Bank Forest-Steppe of Ukraine.

## CONCLUSIONS

Growth of shoots begins in April when the average daily air temperature reaches 8.5°C. At first, the top and the upper part shoots grow, then in 10 to 15 days the shoots of the middle part begin to grow, and after 21 days, the shoots of the lower one.

The growth climax is observed in June, after 65 days after swelling of the buds. During this time 76% of the annual growth is formed. The maximum daily increment is 2 cm. The growth of shoots ends in the $2^{nd}$–$3^{rd}$ decade of September. The total duration of shoot growth is 175 days.

Growth of the needles also depends on the air temperature and begins after 35–40 days after the beginning of shoot growth. The climax of daily increment is observed in the $1^{st}$–$2^{nd}$ decade of July. By this time, which occurs 60 days after the beginning of growth, 72% of the annual growth is formed. The period of growth extinction lasts 45 days.

### References


Bollmann M.P., Sweet G.B., Rook D.A., Halligan E.A. (1986): The influence of temperature, nutrient status, and a short drought on seasonal initiation of primordia and shoot elongation in *Pinus radiata*. Canadian Journal of Forest Research, 16: 1019–1029.

Chudzińska E., Diatta J.B., Wojnicka-Półtorak A. (2014): Adaptation strategies and referencing trial of Scots and black pine populations subjected to heavy metal pollution. Environmental Science and Pollution Research International, 21: 2165–2177.

Dougherty P.M., Whitehead D., Vose J.M. (1994): Environmental influences on the phenology of pine. Ecological Bulletins, 43: 64–75.

Elagin I.N. (1976): Seasonal Development of Pine Forests. Novosibirsk, Nauka: 230. (in Russian)

Fedotov I.S. (1983): Pine as a bioindicator of chemical and radioactive contamination. In: Permyakov E.A., Lahno V.D. (eds): The Influence of Industrial Enterprises on the Environment, Puschino, Dec 4–8, 1983: 201–202. (in Russian)

Isik K. (1990): Seasonal course of height and needle growth in *Pinus nigra* grown in summer-dry Central Anatolia. Forest Ecology and Management, 35: 261–270.

Junttila O., Heide O.M. (1981): Shoot and needle growth in *Pinus sylvestris* as related to temperature in Northern Fennoscandia. Forest Science, 27: 423–430.

Kischenko I.T. (2011): Seasonal Growth and Development of Native and Introduced Conifers in the Taiga Zone of Russia. Petrozavodsk, Petersburg State University: 372. (in Russian)

Kischenko I.T., Vantenkova I.V. (2011): Seasonal Growth of Forest-forming Species in the Taiga Zone of Russia. Petrozavodsk, Petersburg State University: 321. (in Russian)

Makarynska S.A. (2012a): Features of seasonal development *Pinus nigra* Arn. in terms of introduction. In: Nepochatenko O.O. (ed.): The Prospects of Development of Forestry and Landscape Gardening, Uman, Apr 22, 2012: 114. (in Ukrainian)

Makarynska S.A. (2012b): Seasonal growth of vegetative organs of three-year-old seedlings of *Pinus nigra* Arn. in the conditions of the right-bank forest steppe eco-zone of Ukraine. In: Cherevchenko T.M. (ed.): The International Reading, Dedicated to the 110th Anniversary of the Birth of Doctor of Biological Sciences, Professor L.I. Rubtsov, Kyiv, May 15–18, 2012: 323–325. (in Ukrainian)

Meicenheimer R.D., Coffin D.W., Chapman E.M. (2008): Anatomical basis for biophysical differences between *Pinus nigra* and *P. resinosa* (Pinaceae) leaves. American Journal of Botany, 95: 1191–1198.

Molchanov A.A., Smirnov V.V. (1967): Technique of Studying the Growth of Woody Plants. Moskva, Nauka: 95. (in Russian)

Nesterovich N.D., Derugina T.F., Oliker B.S. (1972): Rhythm of growth of annual shoots depending on their location in the crown of a tree. Bulletin of the Academy of Sciences of Belarusian Soviet Socialist Republic. Series of Biological Science, 4: 5–10. (in Belarusian)

Pensa M., Jalkanen R. (2005): Variation in needle longevity is related to needle-fascicle production rate in *Pinus sylvestris*. Tree Physiology, 25: 1265–1271.

Rehder A. (1940): Manual of Cultivated Trees and Shrubs in North America. New York, Macmillan: 996.

Salminen H., Jalkanen R. (2006): Modelling variation of needle density of Scots pine at high latitudes. Silva Fennica, 40: 183–194.

Van Haverbeke D.F. (1990): *Pinus nigra* Arnold (European Black Pine). In: Burns R.M., Honkala B.H. (eds): Silvics of North America. Volume 1. Conifers. Agriculture Handbook No. 654. Washington, D.C., USDA Forest Service: 797–818.

Wachowiak W., Perry A., Donnelly K., Cavers S. (2018): Early phenology and growth trait variation in closely related European pine species. Ecology and Evolution, 8: 655–666.

Wheeler N.C., Kriebel H.B., Lee C.H. (1976): 15-year performance of European black pine in provenance tests in North Central United States. Silvae Genetica, 25: 1–6.



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