PHENOLOGICAL DEVELOPMENT INVESTIGATION OF COMMON LOCUST (*ROBINIA PSEUDOACACIA L.*) TREES IN BULGARIA

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Abstract

The beginning of phytophenological observations in Bulgaria was founded in 1891. In the National Institute of Meteorology and Hydrology all available phenological information for main trees and bushes species and collected during 1960-2000 in over 100 forest meteorological and phenological stations are kept. In this investigation phenological data for common locust trees (*Robinia pseudoacacia L.*) are processed and relationships for average dates main stages arrives such as – swelling of buds (D_1), breaking of buds (D_2), opening of leaves (D_3), flowering (D_5), ripening of seeds (D_6), autumn tint of leaves (D_8) and falling of leaves (D_9). Use the relationships (1), (2), (3), (7), (8), (9), (10), (11) and (12) it is possible to develop forest meteorological phenological forecasts for services of main technology activities.

Key words: phytophenological stages, forest-meteorology forecasts, forest-climatologically zoning

INTRODUCTION

It has long been known the influence of different phenomena from life of the plants and animals, and phenomena from not alive nature on the human life. Learn them in their succession and interaction under the characterization of environment is subject of the science Phenology. From a hoary antiquity, subsist the scientific interest to most important dates of plant development. They are the part of special phenomenology named – plant-phenology or phytophenology. On the base of phytophenological, data are created “floristic calendars” or as it is named in contemporary language – phenological calendars from the plant phenomena for more important human practical use.

The longest known record in the World from phenological observations is on the flowering of morello-trees (*Prunus suberitella L.*) in Kioto, Japan and includes the period from 812-1864 (Daigo, Suzuki, 1947). In Europe, the longest known record is in England, Norfolk from 1736 to 1925 (Margary, 1926). The longest record of phenological observations on the common locust trees (*Robinia pseudoacacia L.*) is registered in Germany, in region Rein-Main and includes the period 1841-1947 (Schnelle, 1950) and in Hungary for the period 1850-1930 (von Nagy, 1932).
The record of phytoclimatological phenomena in Bulgaria started with beginning the meteorological observations in 1891, when was founded and opened of phytoclimatological observations on the forest trees, bushes, wild herbs and agricultures (Kirov, 1936). First data from the phenological points on 68 plant species for 1901-1910 period were issued under title “Floristic calendar of Sofia” by Kirov (1936), where for the first me data for phenology of common locust trees could be found. Collected in the first years phenological data have some methodological imperfection, but they are not worse on this, collected in other countries in this time (Slavov, 1997). Unfortunately, paper phytoclimatological archives from initial years up to 1950 are destroyed.

New developments of forest-meteorological observations in Bulgaria started with foundation of Hydro-meteorological service in 1950, Institute of Hydrology and Meteorology (1954) to the Ministry of Agriculture and Forests. Thereafter started building a permanent network for forest-meteorological stations and phenological points to provide specialized observations and measurements in forest ecosystems. First results of phenological observations on the thirteen forest trees and bush species, during 1954-966 period provided in 27 points are published by Florov, Abadjieva (1966). Later, Abadjieva composed forest-meteorological annuals for 1974 and 1975 where are published data from observations in 68 forest-meteorological stations and phenological points. For the first time attempt for spatial presentation of common locust main phenoclimatological phenomena in our country was made by Slavov, Kazandziev, 2001.

The purpose of this work is to discover average dates of arriving the basic phenoclimatological stages of development of common locust (Robinia pseudoacacia L.), duration of inter-stage periods and of all vegetation cycle duration. This phenoclimatological information will be useful for forest- meteorological forecasts for dates of arriving of basic phenoclimatological stages of development and especially terms for seeds ripening, seeds collecting and organizing sapling production. Also for apiculture – to forecast dates of flowering and creating of optimal conditions for nectar collecting from swarm of bees and producing common locust honey – biologically active and with wide application in therapy. From point of view of forestry – forecasts of beginning of vegetation season to organize the technological works. For the dendrologists – will enlarge forest-climatic zoning understanding for common locust trees and spatial presentation of basic stages of phenoclimatological development etc.

MATERIAL AND METHOD

Initial information for data collection are the archives of NIMH-BAS, which is only one of this kind and contain information for phenoclimatological stages observations on the forest and bushes trees grow on the territory of our country. This information is collected according with instructions and handbooks elaborated in Hydro-Meteorological Office (HMO), according with international standards (1960, 1975, 1984). Were processed observations on the phenological development of common locust from the beginning of 1960 up to 2000 provided in more of 100 forest-meteorological stations and points with different origin (sprout and seed) plantations to 1000 m a.s.l. – Fig.1. They are equable distributed on the territory of Bulgaria and cover main soils types. Also they are considered with statistical structure of the field of phenoclimatological phenomena in our country (Hershkoich et al., 1976, 1979). According with these investigations inadmissible distance for spatial interpolation is up to 80 km to altitude of low forest zone 800-1000 m. Phenological observations are provided during the whole vegetation period on the next basic stages of development of common locust (Robinia pseudoacacia L.): swelling of buds (D.), breaking of buds (D.), opening of leaves (D.), flowering (D.), seeds ripening (D.), fall of fruits (D.), autumn leaves tint (D.) and leaves fall (D.). Two observed stages – forming of racemes (D.) and fall of fruits (D.) was passing of these examinations because time series is not homogeneous because of missing observations. Calculation of averages standards of dates observations from 1961 to 1990 were taken as 30 years homogeneous time series are composite. Data from 1991-2000 are used to estimate accuracy for predicted average dates of arriving phenological stages. The data for average dates for phenological stages arriving are presented as a time series with start 1st January, i.e. Julian days. For a day of average date of arriving of given stage are taken the first day after fixing arriving given stage on a mass scale (>75%) on the observed trees. Accuracy of calculation of average date on mass scale arriving of phenological stages for vegetable organisms depends from their changeability in the time and physiological flexibility. As much forest-meteorological element as low changeable, that much shorter time series of observations are necessary to obtain reliable and steady values. Examinations for adequate number of years of phenological observations determination are made by Witterstein (1952) and Schnelle (1950, 1955), who specify that for this is necessary 20-40 years.

Our calculations use Lebedev's method (1964) show, that minimum limit of time series duration with average dates of phenological stages arrive and sufficiently accurate estimate of average date ≤ 10% can be received from 30 years homogeneous time series row.

The data of average dates arrive of basic phenological stages development for common locust are processed by correlation and regression analysis application. Because of this, different interesting relationships were determined between average dates of examined phenomena. By application of these dependences was developed methodology for forest-meteorological prognosis for main stages arriving for a practice needs.

RESULTS AND DISCUSSION

Phenological phenomena are different from many other natural phenomena with stochastic pattern. For that reason for it investigation we use biological principle that every stage is observed only once during vegetative season, because the processes of growth and development are unidirectional, consecutive and irreversible.

The beginning of our investigations was initiate with search and bring relationship between dates of arriving first stages of phenological development of common locust (Robinia pseudoacacia L.) which indicate beginning of vegetative season, closely connected with
active grow and spring season start. First of all, connection between first three phenological stages – swelling of buds, breaking of buds and opening of leaves, which characterize forming of leaves of common locust, was investigated. Appearance of these relationships are shown in Fig. 2, 3 and 4 and analytical presentation with dependences (1), (2) and (3):

\[ D_4 = 0.87 D_3 + 23.4 \quad r=0.94 \quad Er=2.07 \]  
\[ D_5 = 0.64 D_4 + 56.2 \quad r=0.82 \quad Er=2.99 \]  
\[ D_5 = 0.78 D_4 + 34.9 \quad r=0.91 \quad Er=2.10 \]  

Where: \( D_4 \) – average date for swelling buds; \( D_5 \) – average date of breaking buds and \( D_5 \) – average date of leaves opening. By given relationships exist close dependences, which was confirmed and from graphical verification. This encourage us to propose Method for Prognosis of any stages arriving from leaves formation it is known at least average date of initial stage. Methodology for dates of breaking of buds (\( D_4 \)) and leaves opening (\( D_5 \)) prognosis is based on dependence of dates of swelling of buds and relationships (1), (2), and (3). Before forecast work up it is necessary closely analyze map with average dates of swelling of buds (Slavov, Kazandjiev, 2001). From this map we receive average values of long time periods for swelling of buds for different regions of the country. When compose the forecast for buds breaking and leaves opening of common locust stages arriving for given year we above all determine date of swelling of buds. This forecast set up the beginning of first stages of development and start of vegetative period as well as and beginning of photosynthetic potential formation of given plant ecosystem. By the relation between average long term date and the date in given year we can estimate whether forecasted date is near to normal or development goes with forestall or slow motion in concrete year. With this forecast can be supported works in the forest for different regions of Bulgaria.

Very important moment of phenological development of common locust (\( R. \ pseudoacacia L. \)) this is flowering \( D_5 \) because this is the start of reproductive period of development and it is in very close connection with organizing of nectar collecting from swarm of bees and honey producing. This way we examine relation between dates of leaves formation and flowering of common locust trees, shown on Fig. 5, 6 and 7. Dependencies (4), (5) and (6) present analytical description of these empirical relationships, as follows:

\[ D_5 = 0.26 D_4 + 114.4 \quad r=0.35 \quad Er=4.51 \]  
\[ D_5 = 0.40 D_4 + 96.8 \quad r=0.51 \quad Er=4.16 \]  
\[ D_5 = 0.54 D_4 + 76.1 \quad r=0.53 \quad Er=3.92 \]  

Where: \( D_5 \) is average date for flowering arriving.
Unfortunately these dependencies are characterized with correlation coefficient under or on the limit of statistical significance, this is confirmed and from graphical verification. Nevertheless these values can be used for approximate calculations of probable date of flowering arriving of common locust (*R. pseudocacia L*.) if the dates of leaves formation are known.

Results mentioned above give us reason to make attempt calculate average dates of flowering arrive, as investigate connection with three stages of leaves formation. Approximation relationships are multifactor and linear with and without constants and (7) and (8) present their analytical descriptions:

\[ D_3 = -0.65 D_1 + 0.71 D_2 + 0.44 D_5 + 72.7 \quad r=0.68 \quad Er=3.71 \]  
(7)

\[ D_3 = -0.69 D_1 + 0.34 D_2 + 1.44 D_5 \quad r=0.99 \quad Er=4.8 \]  
(8)

These relationships approximate one and the same phenomenon - flowering arriving (*D_3*) by the dates of swelling of buds (*D_5*), breaking of buds (*D_1*) and opening of leaves (*D_2*). Difference between equations (7) and (8) is that the first contain constant. The meaning of this constant is connected with earliest date of arriving of flowering stage i.e. least 73 days after vegetation renew.

Practically this starts later, that is why approximation by analytical relationship (8) is higher. As it is seen, these relationships have high accuracy and can be used for forest-meteorological prognosis of common locust development.

We develop methodology for prognosis of flowering dates (*D_3*) for common locust use data for leaves formation and dependencies (7) and (8). During drawing of forecast we analyze map for swelling of buds and take in mind observed dates for swelling and breaking of buds and opening of leaves while we forecast dates for flowering in different regions in conditions for given year. That forecast define beginning of reproductive period and help to apiarists to find pasture for bees swarm and honey producing.

Very important moment for the reproductive period of development of common locust (*R. pseudocacia L.*) is the seeds ripening, because arriving of this stage is connected with organize and timely collecting of them and saplings producing. We investigate connection between average date of arriving of this stage and flowering stage. Graphic presentation of this relationship is on Fig. 8, and analytical aspect is:

\[ D_0 = 306.99 - \frac{1449643}{D_3} \quad r=0.65 \quad Er=9.59 \]  
(9)

Where: *D_0* is average date of seeds ripening. Comparatively high accuracy of this connection gives us reason to develop methodology to develop of forecast of date for seeds ripening. During drawing that forecast, we analyze map of average dates for flowering (Slavov, Kazandjiev, 2001) and their distribution for the country. When compose the forecast for seeds ripening for every concrete year we define deviations between
average long period values and observed dates of flowering for given year. That forecast permit more effective organize and optimize collecting of seeds and producing of saplings in different regions of Bulgaria.

The next stage subject of examinations, which is very important for the practice, is autumn tint of leaves ($D_s$). By arriving of this stage we propose to estimate end of photosynthesis season and end of assimilates flux to the reproductive organs and other parts of the plants. At the fig. 9 is shown connection between average dates arriving of autumn tint of leaves ($D_s$) and flowering ($D_i$). This relationship is present with (10):

$$D_s = 640.41 - 0.000395 D_i^{1.55} \quad r=0.78 \quad Er=70.6 \quad (10)$$

Where: $D_s$ - autumn leaves tint.

Finally we examine average dates falling of leaves arriving ($D_s$), by which stage terminate vegetative season of common locust trees. For this purpose, investigate connection between average dates of leaves falling and average dates of flowering. Their empirical description is present on fig. 10. This connection has high level of correlation and it analytical description is present with (11):

$$D_s = \left( 1.69 + \frac{286778}{D_i^2} \right)^{0.95} \quad r=0.95 \quad Er=10.6 \quad (11)$$

Where: $D_s$ - average date for fall of leaves arriving.

We seek for relationship between average date of falling of leaves and average dates for seeds ripening, i.e. we examine the hypothesis for link between the moment of finish of reproductive period and end of vegetation period. This dependence is present on Fig. 11 and analytical description with (12):

$$D_s = 869 - 0.00977 D_i^{0.84} \quad r=0.84 \quad Er=59.78 \quad (12)$$

**Fig. 8.** Connection between average date of seeds ripening ($D_s$) and average date of flowering ($D_i$)

**Fig. 9.** Connection between average date of autumn colouring of leaves ($D_s$) and average date of flowering ($D_i$)

**Fig. 10.** Connection between average date of leaves fall ($D_s$) and average date of flowering ($D_i$)

**Fig. 11.** Connection between average date of leaves fall ($D_s$) and average date of flowering ($D_i$)

**CONCLUSIONS**

During examination of phenological development of common locust for first time in Bulgaria was determined relationships between main stages of development, such as:

- dates of breaking of buds ($D_s$) with dates of swelling of buds ($D_i$) (1);
- dates of opening of leaves ($D_s$) with dates of swelling of buds ($D_i$) (2);
- dates of opening of leaves ($D_s$) with dates of breaking of buds ($D_i$) (3);
- dates of flowering ($D_s$) with dates of breaking of buds ($D_i$) (5) and dates of opening of leaves ($D_s$) (6);
- dates of flowering ($D_s$) and dates of leaves formation ($D_s$) ($D_i$) (7, 8);
- dates of seeds ripening ($D_s$) and dates of flowering ($D_s$) (9);
- dates of autumn leaves tint ($D_s$) and dates of flowering ($D_s$) (10);
- dates of falling of leaves ($D_s$) and dates of flowering ($D_s$) (11) and finally between dates of falling of leaves ($D_s$) and dates of seeds ripening ($D_s$) (12).

With the help of received relationships we elaborate methodology for forest-meteorology forecast and prognosis of arriving dates for main stages of phenological development of common locust (*Robinia pseudoacacia* L.). By means of them may be made scientifically founded zoning and simultaneously with this start with organize of seeds collecting, insure nectar gathering from bee swarms during flowering stage and producing locust honey etc.

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