The effect of altitude and latitude on the phenology of the plum cv. Požegača in Serbia

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Abstract

Several phenological stages of the plum cv. Požegača at 60 locations in Serbia in a 35-year period were examined: leaf unfolding, beginning of flowering, full flowering, harvest and general leaf colouring. All examined phenophases, except general leaf colouring, are strongly influenced by altitude, while the latitude has a significant influence on flowering phenophases and harvest. These climatic controls also affect an interrelation of phenophases onset. A difference between the mean dates of general leaf colouring and harvest gets smaller with increased altitude and latitude. Požegača generally flowers before leafing at lower elevation, while at higher locations the beginning of flowering could be more than 15 days after leaf unfolding.

Key words: plum, Požegača, phenology, altitude, latitude

Introduction

Many phenological studies of larger regions confirm that the latitude, altitude and the degree of oceanity - continentality are important to the timing of plant phenophases (Menzel, 1997; Roetzer and Chmielewski, 2001). The responses of species to existing climate gradients along altitudinal and latitudinal gradients can be used to predict the likely effects of future climate change.

The altitude in Serbia is the most influential control of thermal conditions which regulate phenological dynamics to a great extent. According to Mišić (1994), temperature decreases by 0.5-0.6°C for every 100 m increase in altitude. Vulić (1998) reported that decrease of temperature with altitude in Serbia is not the same at all latitudes. Between 44 and 45°N is 0.5°C/100m, while between 42 and 43°N varies from 0.3 to 0.4°C/100m.

This work has aimed at determining the effect of altitude and latitude on the phenology of the plum cv. Požegača in Serbia. Plum (Prunus domestica L.) is still, according to its participation in total fruit production, among most important fruits in Serbia, despite the decline of total tree number in last few decades, aggravation of age tree structure, unfavourable assortment, poor health condition caused by virus Sharka (Plum Pox) and smaller price competitiveness comparing to other fruit species. Požegača has been chosen for analysis, because it is the only plum cultivar which has a representative data set (long enough for sufficient number of stations). Since, there is no data for other varieties of this fruit, spatial distribution of cv. Požegača may serve as indicator of regional influence on phenology of other varieties as well.

Materials and methods

The phenological data were collected within phenological network organized by Republic Hydrometeorological Service of Serbia. Records were taken at 60 locations throughout the state representing an altitude range from 39 m to 1030 m and a latitude range from 42° 14′ to 46° 06′ N. Data were available for the 35 years from 1961 to 1995.
Following phenological events were considered: leaf unfolding, beginning of flowering, full flowering, harvest and general leaf colouring. Growing period is defined in a narrower sense as active period of photosynthesis, as it was done, for example, by Menzel (2003) in her studies. This period begins with leaf unfolding and ends with general leaf colouring.

Since in Serbia the higher mountains are mostly in the southern part of the country and there is a correlation between the altitude and latitude of the examined locations \((r=-0.64, p<0.001)\), we used partial correlations to examine the relationship between the phenological events and geographical location of observation sites. The partial correlation is a measure of the linear dependency between two variables, where the influence of a third variable is eliminated. Multiple regression equations for all examined phenophases were determined to enable estimation of joint importance of the latitude and altitude on plum phenological dynamics.

**Results and discussion**

Partial correlation of different phenological phases with altitude and latitude is given in Table 1. The values of Pearson correlation coefficient are given in parenthesis in order to illustrate how the correlation results of two variables could be clouded because they are both related to a third variable in cases when simple correlation is used.

<table>
<thead>
<tr>
<th>Leaf unfolding</th>
<th>Beginning of flowering</th>
<th>Full flowering</th>
<th>Harvest</th>
<th>Leaf colouring</th>
<th>Development period</th>
<th>Diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altitude</td>
<td>0.68***</td>
<td>0.88***</td>
<td>0.89***</td>
<td>0.79***</td>
<td>-0.11 n.s.</td>
<td>-0.47***</td>
</tr>
<tr>
<td>(0.71***</td>
<td>(0.86***</td>
<td>(0.87***</td>
<td>(0.79***</td>
<td>(-0.02 n.s.)</td>
<td>(-0.41***</td>
<td>(-0.56***</td>
</tr>
<tr>
<td>Latitude</td>
<td>0.20 n.s.</td>
<td>0.51***</td>
<td>0.48***</td>
<td>0.34***</td>
<td>-0.19 n.s.</td>
<td>0.26*</td>
</tr>
<tr>
<td>(-0.34**)</td>
<td>(-0.35**)</td>
<td>(-0.38**)</td>
<td>(-0.35**)</td>
<td>(-0.16 n.s.)</td>
<td>(0.08 n.s.)</td>
<td>(0.16 n.s)</td>
</tr>
</tbody>
</table>

Diff - difference between the mean date of general leaf colouring and harvest

\* \(P<0.05\)

\** \(P<0.01\)

\*** \(P<0.001\)

n.s. Non significant

Altitude is better correlated with phenological timing than latitude. The effect of intercorrelations among selected variables is more pronounced in case of latitude. The partial and simple correlation coefficients even have an opposite signs as a consequence of the stronger influence of altitude than latitude and negative correlation between them. Compared to spring phenophases and harvesting, correlation between the mean date of general leaf colouring and geographical location was much weaker. The same findings about influence of thermal conditions on the spring and autumn phenological events were reported by other authors (Walther et al., 2002; Chmielewski et al., 2004.). Also, result that flowering appears to be more sensitive to geographical location than leaf unfolding agrees with results of other studies dealing with influence of air temperature on these spring phenophases (Chmielewski and Rotzer, 2001; Črepinšek et al, 2006).

Regression equations with day of the year (for phenological stage onset) or number of days (for growing period length) as the dependent variables \((y)\) and altitude \((x1)\) and latitude \((x2)\) as the independent variables are as follows:

- \(y = 0.0185 x_1 + 1.002 x_2 + 55.99 (R^2 = 0.52)\) for leaf unfolding;
- \(y = 0.0270 x_1 + 2.038 x_2 + 8.29 (R^2 = 0.81)\) for beginning of flowering;
- \(y = 0.0292 x_1 + 1.995 x_2 + 13.91 (R^2 = 0.82)\) for full flowering;
- \(y = 0.0348 x_1 + 2.345 x_2 + 134.99 (R^2 = 0.67)\) for harvest;
- \(y = -0.0224 x_1 - 2.723 x_2 + 308.96 (R^2 = 0.22)\) for length of the growing period;

where \(R^2\) is the coefficient of determination.

The regression equation for general leaf colouring is not presented, because the correlation analysis showed weak correlation with altitude and latitude. According to given regression equations, leaf unfolding is delayed by 1 day per degree of latitude and by nearly 2 days per 100 m of altitude, flowering by 2 days per degree of latitude and by nearly 3 days per 100 m of altitude. These results are close to those obtained by Menzel (1997), who analyzing European phenological data found that early phenophases were delayed by
2.5-3 days per degree of latitude and 2-4 days per 100 m of increased elevation. When harvest is considered, our data show 2.3-day delay per degree of latitude and 4.5-day delay per 100 m of altitude. Length of the growing period is shortened by 2.7 days for each degree of latitude and 2.2 for each 100 m of increased elevation.

As it can be seen from Table 1, the number of days between general leaf colouring and harvest decreases with altitude. Using the relationship between the difference in the mean dates of these phenophases and altitude (Fig.1), theoretical elevation, where these two phenological events overlap, could be estimated. According to our data, this elevation line lies around 1200 m for the plum cv. Požegača in climatic condition of Serbia.

Another interesting result that we came up with was that Požegača generally flowers before leafing at lower elevation, while at higher locations the beginning of flowering could be more than 15 days after leaf unfolding. According to regression equations for these two phenological stages (Fig. 2), estimated elevation at which the alternation occurs is 500 m.

\[ y = -3E-05x^2 + 0.0021x + 43.927 \]
\[ R^2 = 0.3502 \]

\[ BF = 2E-05x^2 + 0.0044x + 101.82 \]
\[ R^2 = 0.7818 \]
\[ LU = -2E-06x^2 + 0.0181x + 100.44 \]
\[ R^2 = 0.5039 \]

**Figure 1.** Difference between the mean date of general leaf colouring and harvest (Diff) of the plum cv. Požegača as a function of altitude

**Figure 2.** Relationships between the beginning of flowering and leaf unfolding of the plum cv. Požegača and altitude

**Conclusion**

Our analysis of 60 sites in Serbia demonstrates that phenology of Požegača is strongly influenced by altitude and to a lesser extent by latitude. The only phenological stage that does not show significant correlation with altitude is general leaf colouring. A delay in the developmental rate and shortening of development period was found in partial correlations with altitude and latitude. The synchronization of phenological events is also affected by geographical location. The mean dates of harvesting and leaf colouring get closer with increased altitude and latitude. In the case of leaf unfolding and beginning of flowering even inversion of phenological timing occurs with increased altitude.
The results obtained from this work should provide better understanding of plum phenology, which could be very useful for improving plum cultivation in the studied region. Also, they can be helpful in estimation of possible global warming impact on plum growing in climate change studies.

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References


