Relationship beetwen the phenological features of pear cultivars and the main meteorological parameters in a gene bank with 555 pear

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Summary: The trees observed are grown at Újfehértó, Eastern Hungary in a gene bank with 555 pear cultivars. Each of the cultivars was monitored for its dates of: the beginning of bloom, main bloom and the end of bloom and ripe phenophasis separately between 1984 and 2002. We analyzed the statistical features, frequency, distribution of these phenophasis and its' correlation the meteorological variables between the interval. During this period the meteorological database recorded the following variables: daily mean temperature (°C), daily maximum temperature (°C), daily minimum temperature (°C), daily precipitation (mm), daily hours of bright sunshine, daily means of the differences between the day-time and night-time temperatures (°C). For the analysis of data the cultivars have been grouped according to dates of maturity, blooming period as well as types of the seasons. Groups of maturity dates: summer ripe, autumnal ripening, winter ripe cultivars. Groups of blooming dates: early blooming, intermediate blooming, late blooming cultivars. At all the separated groups we analyzed the relationship between phenophasis and meteorological variables. During the 18 years of observation, the early blooming cultivars started blooming on 10–21 April, those of intermediate bloom date started flowering between 20 April and 3 May, whereas the late blooming group started on 2–10 May. Among the meteorological variables of the former autumn and winter periods, the winter maxima were the most active factor influencing the start dates of bloom in the subsequent spring. For the research of fruit growing-weather relationships we used simple, well known statistical methods, correlation and regression analysis. We used the SPSS 11.0 software for the linear regression fitting and for calculation of dispersions as well. The tables made by Excel programme.

Key words: pear, cultivar, meteorological data

Introduction

Growth and development of plants is fundamentally coded in their inherited genetic constitution, but manifestation of the expression of the particular genes depends on the complex effects of the immediate environment. This environment is subject within wide limits to periodically repeated changes, especially through the repeating seasons of the successive years. The seasonal life cycle of plants is divided into distinct phases recognized easily by their appearance (phenophases), which are often closely related. Most of weather adversities in Hungarian fruit growing are due to the temperature minima during the winter and spring, although excessive heat may become deleterious as well (*Szabó*, 1997). The effect of temperature on the development of buds has been studied by *Szabó* (1997), and he stated that during the period of endodormancy, buds and aerial, lignified parts of fruit trees are practically undamaged by low temperatures of –20 °C in Hungary (*Szász & Tőkei*, 1997). As endodormancy finishes, any temperature above 0 °C stimulates the life processes of the trees (*Holdefleiss*, 1930) and abolishes, gradually, the frost resistance experienced during endodormancy. The regression of frost resistance in the flower buds and flowers continues until the end of bloom and fruit set, which is the most frost susceptible period of the fruit trees (*Soltész*, 1997). The relation of phenophases and meteorological phenomena, especially temperature, has been mostly explored around the bloom time of fruit trees. The blooming process has been analyzed meticulously by *Nyéki* (1980, 1989, 1990) and divided into the following sub-periods 1. Start of bloom (1–5% of flowers opened on the tree), 2. Main bloom (the ratio of open flowers is 50% or more), 3. The day of full bloom (the ratio of open florets achieves a maximum), 4. End of bloom (when 95–100% of flowers shed their petals).

The length of endodormancy (a phenophase) of apple cultivars is determined by the demand of a set number of chilling hours, i.e. until that demand is fulfilled, the rising temperature does not trigger the process of flower development. Mild winters may cause reversion of the customary blooming order of cultivars in the following spring because endodormancy of some cultivars is still not completed (*Nyéki* et al., 2004). If in all cultivars the endodormancy expired regularly (which would be the case in normal or rather long winters), the blooming order would not be disturbed (*Soltész*, 1992)

Excessively high temperatures during bloom shorten the length of the blooming period, pollen is quickly released but the drying out of the stigmatic fluid lowers the probability of pollen grains being caught and fertilization ensured. The chance of the flowers being visited by pollinating bees declines at the same time (*Brózik & Nyéki*, 1975). Summing up, the chance of flowers being pollinated and of ovules being fertilized is low with high temperatures during bloom (*Szabó*, 1997).

Ripening, as the last phase of fruit development, is associated with changes of the ground colour and/or covering colour of the fruit skin, the force needed to pick the fruit, the firmness of the fruit flesh, accumulating of sugar, regression of acidity, etc) (*Brózik & Nyéki*, 1974).

Materials and methods

The trees observed were grown at Újfehértó in the plantation of a gene bank of apple cultivars of the Society of Public Utility for Fruit Growing and Extension Service. This area is a flat place, the altitude above the see level is about 115 meter. The soil type is acid sandy soil (the acidity is pH 5.74–5.79) the mineral content is low.

Each of the 555 cultivars is represented by two trees, which have been observed for their dates of the start of bloom, the main bloom and the end of bloom from 1984 to 2002.

In the course of the examinations 2 trees/cultivars in a repetition system 555 pear cultivars phenology we noted the occurrence time of his phases, and we studied the effect of the meteorological factors on these stages. We examined altogether 1172 trees. All the pear cultivars planted in 1981. The plantation is a wild pear seedling, the row and stem distance 8 × 2 m.

The developmental cycles, such as the physiological processes of the trees, are influenced not only by the actual weather but also by the meteorological events of the past years. The previous year, is also considered in the exploration of causes manifested in varying blooming dates, especially the start of bloom.

Between 1983 and 2001 the meteorological data-base keeps the following variables:
- daily means of temperature (°C)
- daily maximum temperature (°C)
- daily minimum temperature (°C)
- daily precipitation sums (mm)
- daily sums of sunny hours
- daily means of the differences between the day-time and night-time temperatures (°C)

These variables served to calculate means of the respective growing seasons, which in turn are the base of computing correlation and regression coefficients characterizing the start of blooming of apple cultivars.

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The examined phenological phases were the following:
- the calendar time of beginning of blooming
- the calendar time of main blooming
- the calendar time of the end of blooming
- the calendar time of fruit ripening

We also calculated the length of beginning of blooming to end of blooming as a blooming duration and from the end of blooming to the fruit ripening as fruit development.

The occurrence times of phenological stages were the following:
- The beginning of blooming when 1–5 percent of all the flowers on the tree is opening
- During the main blooming 50% you are more of the flower was opening
- At the end of the blooming all the flowers opened, the pollen dispersion ended, the pistils lost their function ability, the flower made his petals fall down. For the expression of the occurrence time of phenological phases we used sum calendar time from January 1st Blooming duration: the number of days filled up with his blooming beginning until the end of the blooming
- Ripening time: This value is equal to the picking time practically.
- The time span of fruit development: This value is from the end of the blooming (following the full petal carcass one) until the fruit ripening (until vintage) filled up with time we characterize it, and we granted it in days.

We separated 3–3 groups based on the blooming beginning and the frequency distributions of the fruit development time span. Based on blooming we can speak about:
- early blooming
- intermediate blooming
- late blooming fruit cultivars

Based on the time span of the fruit development:
- summer ripe
- autumnal ripening
- winter ripe cultivars

At the above mentioned groups we researched separately the correlation between fruit stages and meteorological parameters. We used SPSS 11 software for the statistical evaluation (relative frequency correlation, regression fitting, significances) and Excel program for making tables and figures.

Results and discussion

At the occurrence of winter and spring frost we can stated that during the researched period there was below minus 25 °C. During the blooming period the lowest temperature value was minus 5,8 °C. Between the 1984–2002 interval there were 47 days when the temperature was below 0 and higher than minus 5 °C in March the lowest temperature was minus 16,7 °C during the research period. We have found that 11 days was the temperature below minus 10 in March during 1984–2002 (*Table 1.*).

Table 1. Absolute minima and frequency of frost occurrence (Újfehértó 1984–2002)

1984–2002	abs min	Below –20 °C	Between –10 –20 °C	Between –5 –10 °C	Between 0 –5°C
November–March	–26.1	7	178	350	909
November	–17.9	0	7	40	170
December	–18.1	0	78	88	198
January	–26.4	5	51	114	196
February	–25.3	2	31	78	187
March	–16.7	0	11	30	158
April	–5.8	0	0	1	47
May	0.4	0	0	0	0

Start of Blooming. The temporal distribution of the start blooming in the population of 555 pear cultivars which started blooming between 79–136 day of the year over the 18 sears observation. The histogram of distribution is shifted to right which means that later blooming cultivars are in majority (*Figure 1*).
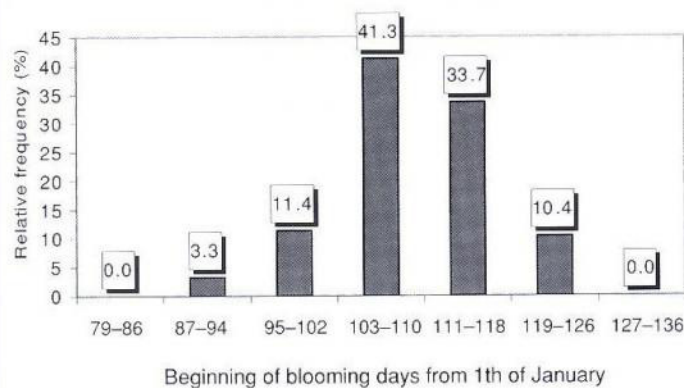
Figure 1. Distribution of start of blooming at 555 pear cultivars

Approximately the half of the cultivars examined (41,3%) started blooming between the 103rd and 110th day, i.e. between April 13 and April 20. After May 5 and before March 15 blooming occurs very rarely.

Considering the ripening dates, i.e. the elapsed until fruit maturity, it turned out that start of blooming not necessarily associated with the time of maturity (*Figure 2*). However a slight tendency of covariation is detected in two intervals, namely between the 103th and 110th day, i.e. April 13–20. The early ripening cultivars represent earlier blooming at a rate of 6–8% more than late blooming one.

Very important to know are there any significant correlation between beginning of blooming and fruit development interval. It can be seen in the *Figure 3*. that there is a significant linear correlation between the two mentioned variables. We can stated that earlier start of blooming results longer blooming interval, at later beginning of blooming the time of flowering is shorter. It is not surprising because at later flowering the temperature generally higher than earlier one.
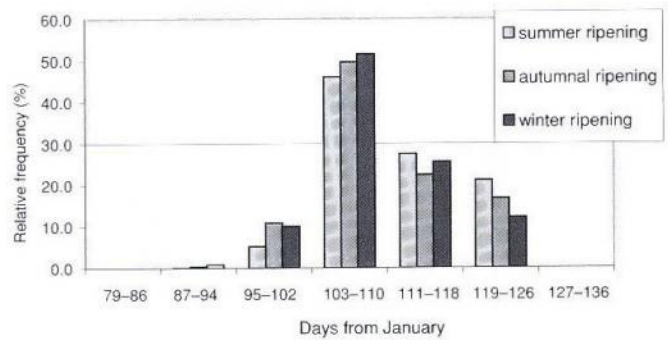

Figure 2. Distribution of the beginning of flowering at different maturity groups pear cultivars (1984–2002)
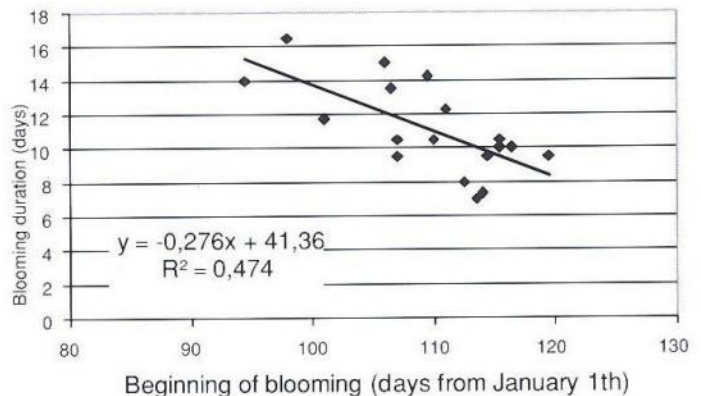

$$y = -0,276x + 41,36$$
$$R^2 = 0,474$$

Figure 3. The relationship between the beginning and duration of blooming at pear cultivars (Újfehértó, 1984–2002)

The closest correlation we have found between spring maximum temperature and start of blooming. The linear regression equation you can see in the *Figure 4*. We can stated that at higher spring temperature the beginning of blooming occurs in earlier time.

The general statements concerning the relationships between the spring weather of the current year and the date of bloom in different groups of cultivars, regarding start of bloom and length of fruiting period are the following:

The date of starting blooming is less influenced by the spring weather of the current year in the early blooming group of cultivars. For all the 7 meteorological variables, an influence could not be proved on the date of starting bloom. In the early blooming group of cultivars, the thermal conditions of spring and summer of the previous year were
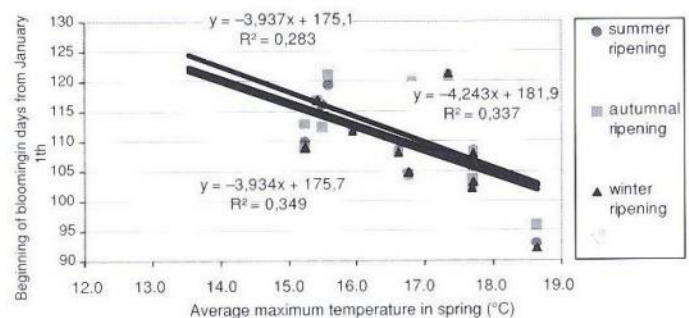

Figure 4. Relationship between beginning of blooming at different maturity groups and average maximum temperature in spring time at 555 pear cultivars (1984–2002)

more decisive. In the intermediate blooming time group of cultivars, the spring temperature and the mean differences between daytime and night time temperatures proved to be significant in influencing the start of bloom.

Similarly, in the late blooming group of cultivars, the mean differences between daytime and night time was decisive in influencing the start of blooming (*Figure 5*).
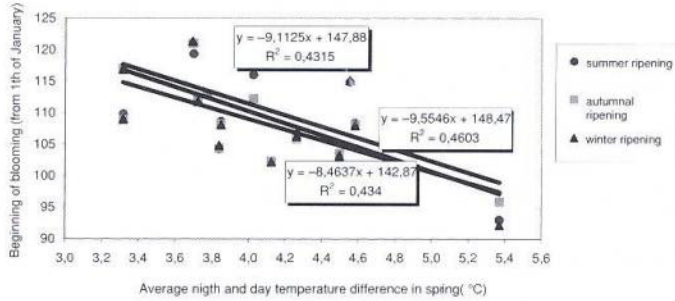

Figure 5. Relationship between different maturity groups of pear cultivars and the differences of night and day temperature (1984–2002)

In a mild spring, blooming starts earlier. The larger differences between daytime and night time temperatures stimulate the start of blooming. The large amplitude of temperature changes is associated with high daytime maxima during the spring. In the other cultivar groups too, the two mentioned meteorological variables are decisive in influencing the start of bloom.

In addition, cultivars of intermediate blooming date are significantly influenced by the minimum temperatures of the spring. The surprising fact is that with early blooming cultivars none of the meteorological variables altered significantly the start of bloom. However, weather conditions of the previous year proved to be decisive in determining the blooming dates.

At summer ripening cultivars we could find most intensive decreasing tendency. The beginning of blooming shifted on earlier time (*Figure 6*). At autumnal ripening cultivars also we can see the decreasing tendency but the intensity is lower than at summer ripening cultivars. At winter ripening cultivars we haven't got any significant changes.
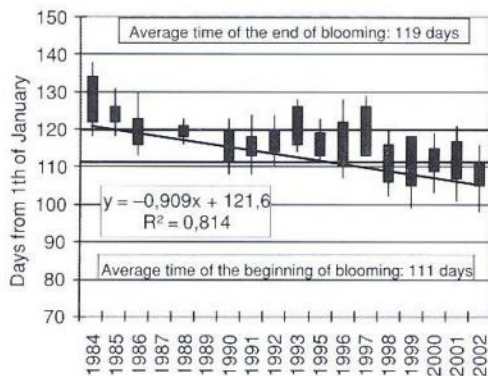

Figure 6. Blooming times of pear cultivars at summer ripening cultivars (Újfehértó, 1984–2002)

Length of blooming period. The variation of the relative lengths of blooming periods in the whole population of cultivars is shown in *Figure 7*. The 555 cultivars over the whole period bloomed for very different lengths of time, which varied between 3 and 30 days during the 18 years. The density of the distribution is skewed to the left, which means that cases with shorter blooming periods are in majority.
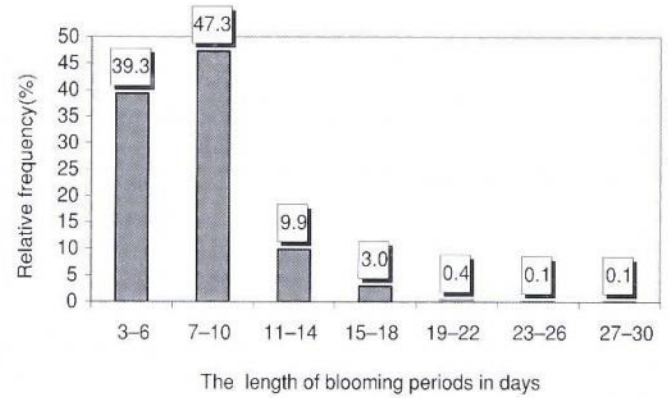

Figure 7. Frequency distribution of the length of blooming periods 555 pear cultivars

If the groups of blooming date are separated, the distributions of the length of blooming periods in suggestive (*Figure 8*) of that the early blooming cultivars tend to bloom for a longer period than the later blooming ones. The 12–14-day-long blooming periods are much more frequent in the early blooming group, whereas in the late blooming group the emphasis is on the less than 3–8 day-long blooming periods. But the difference is not so significant (less tha 5–6%).
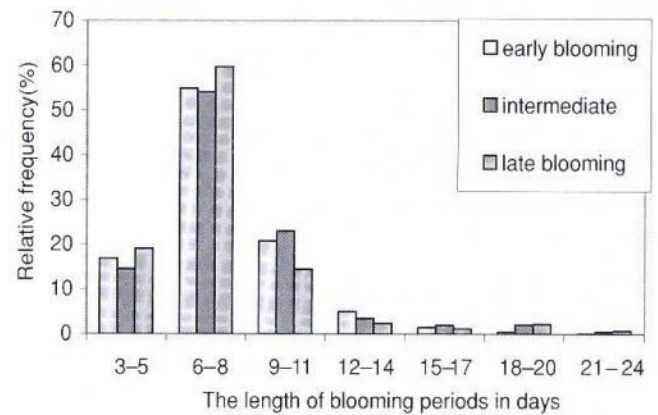

Figure 8. The frequency distribution of the length of blooming period in the groups of pear cultivars (1984–2002)

The best regression fitting we could find between maximum temperature of spring and length of blooming. As you can see in the *Figure 9*. at early blooming cultivars the increasing maximum temperature in spring time results shorter length of blooming periods. At dry, sunny weather the effect is similar, but only early blooming cultivars we could find significant fitting.
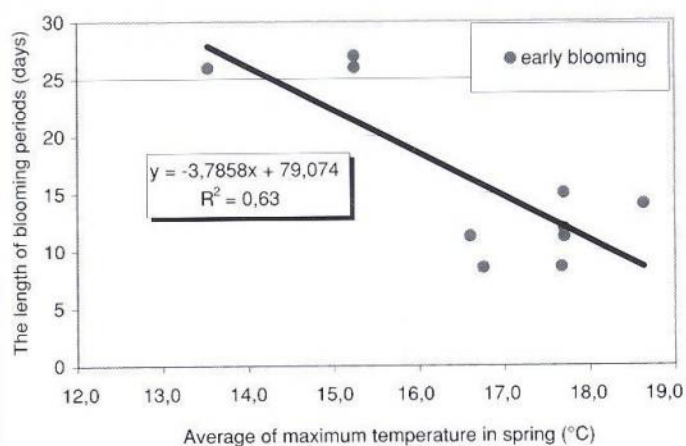
Figure 9. Relationship between early blooming cultivars of pears and average maximum temperature in spring time (1984–2002)

Ripening (picking) time. We can see the frequency distribution of ripening time (*Figure 10*).

The 555 cultivars ripening time varied between 174 and 303 days during the 18 years. The density of the distribution is skewed to the right, which means that cases with longer ripening periods, or winter ripening cultivars are in majority.
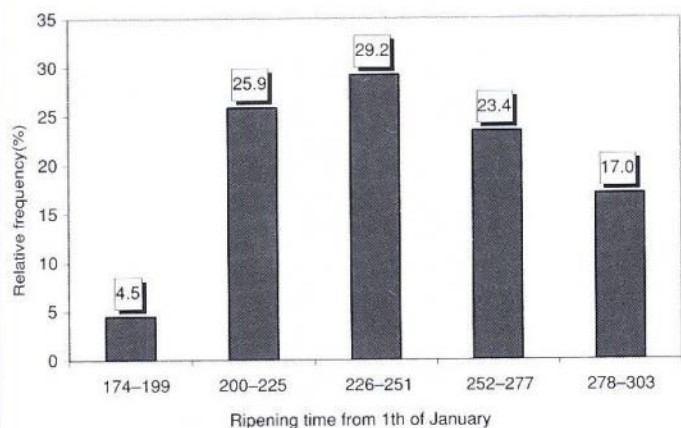

Figure 10. Distribution of ripening time at 555 pear cultivars

If we want to find significant correlation between the weather parameters and the ripening time of pear cultivars can be stated the following:

At early blooming cultivars the minimum, maximum, average spring temperature, sunshine duration and summer average and maximum temperature, and the whole development period's minimum and average temperature has a significant correlation between ripening time.

In intermediate blooming cultivars cases the summer sunshine duration, the whole development period's sunshine duration while at late blooming cultivars the spring and summer sunshine duration, autumnal precipitation and autumnal average difference of night and day temperature has a strong correlation between the ripening time.

At maturity groups of pear cultivars at summer ripening cultivars we could find significant correlation between ripening time and spring average and maximum temperature. At autumnal ripening cultivars the summer sunshine duration, and summer average difference of night and day temperature parameters shows significant correlation with the ripening time.

Winter ripening cultivars only summer average difference of night and day temperature and autumnal maximum temperature has a strong correlation with the ripening time.

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