CLIMATE CHANGE EFFECTS ON APPLE AND SOUR CHERRY PHENOLOGY IN A GENE BANK PLANTATION OF HUNGARY

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ABSTRACT. – Climate Change Effects on Apple and Sour Cherry Phenology in a Gene Bank Plantation of Hungary. The trees observed were grown at Újfehértó, Eastern Hungary in a gene bank with 586 apple and 3 sour cherry cultivars. Each of the cultivars was monitored for its dates of: the beginning of bloom, main bloom and the end of bloom phenophases separately. In the present study, the interactions between the above mentioned phenomena are presented and numerically defined. Results presented proved that the dynamics of weather variables exert measurable effects on the development of fruits. We can find significant correlation between the maximum temperature of March and blooming time of the apple and sour cherry cultivars. If the temperature is increasing in the future the development stages of fruit trees will also shift to an earlier time. It is a serious problem in fruit farming, because the early climatic risk of frost occurrence is generally higher than that of in later times of a year. So, we will need to use more effective protection technologies and new extreme weather tolerant fruit varieties in the future. We should also pay more attention to the time intervals between the blooming and maturity, because the length and appearance of phenological phases have significant influences on quantitative and qualitative parameters of fruits.

Keywords: “climate change”, “absolute minima”, “frost days’ number”, “phenophases, apple”, “sour cherry”

1. INTRODUCTION

Those fruits which will allocate Hungary's production in the future can be produced with the greatest safety. According to our predictions the distribution of Hungarian fruit cultivating areas will be the following in the near future: apple 40 percent, sour cherry 15 percent, plum 10 percent, sweet cherry 10 percent, peach 8 percent, apricot 7 percent, pear 5 percent, walnut 2 percent, other fruits altogether 3 percent.. The horticultural plant cultivation is having to be considered of high value; the occurrence of extreme climatic influences may cause huge harms.

Extreme weather phenomena occurred in the past as well, but the occurrence probability has been increasing during the last decades. The influence of climate change on fruit development can be verified by only long phenological data series.

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Excessively high temperatures during blooming shorten the length of the blooming period, since pollens can be quickly released but the drying out of the stigmatic fluid lowers the probability of the pollen grains being caught thus fertilization ensured (Tőkei, 1997). The chance of pollinating bees visiting the flowers declines at the same time. As a result, the chance of flowers being pollinated and ovules being fertilized is low if there are high temperatures during bloom.

Following this tendency a research about the blooming phase of sour cherry was conducted by Lakatos et al (2010). This study showed that a significant relation can be detected between the differences of daytime and night time temperature and the length of blooming. This new-found relation indicates that the blooming phase was shorter in case of increasing temperature difference. At high temperatures, all equivalents of precipitation increase substantially (Lakatos et al. 2012.).

2. MATERIALS AND METHODS

The trees observed were grown near Újfehértó at the plantation of a gene bank of apple cultivars of the Society of Public Utility for Fruit Growing and Extension Service. We analyzed 3 sour cherry varieties called as “Debreceni bőtermő”, “Kántorjánosi”, “Ujfehértói fürtös”. This area is flat, the altitude above the sea level is about 115 meters. The soil type is acid sandy soil (the acidity is pH 5.74-5.79) the mineral content is low. Each apple cultivars are represented by two trees. We observed them at three significant points: the start of blooming, main blooming and end of blooming time between 1984 to 2016.We have the same phenological observation data base at the three sour cherry cultivars between 1983-2016.The blooming process was developed by Nyéki (1990).

Phenological observations related to the start of blooming were carried out by professionals over the past 34 years. This guarantees the reliability of data and accuracy of drawn conclusions. In case of blooming, not only the time of flower bursting, but the mature flower formation and the end of blooming were also recorded. In this study, we are only examining the dependency of blooming starts on weather factors.

The minimum and maximum temperature data derives from local weather stations, that are situated in orchards. In these stations, several other observations are concluded such as precipitation and global radiation measurements. We used the PRECIS A1B and A2 scenarios for daily weather data (maximum, minimum temperature) which is originated from the University of Eötvös Loránd at the Department of Meteorology. Using this database, we calculated the future changes of apple blooming time.

We used “frost days” as a climatic category, which is calculated from the daily minimum temperature. If the minimum temperature is less or equivalent with 0°C we call that day a “frost day”.

3. RESEARCH RESULTS

At the occurrence of spring frost we can state that during the researched period the temperature was below -17,4 ^{o}C (Table 1.). Based on the a1b scenario we can determine that between 2031-2060 the late spring frost risk will disappear from the apple and sour cherry cultivation. During the late future periods both a1b and a2 scenarios we can expect the return of slight frost during the blooming time of apple and sour cherry cultivation areas. The most severe frost was -6,2 ^{o}C during the blooming in the period between 1951-1980 (Table 1).

Table 1. ***Absolute minima and frequency of frost days' occurrences /Újfehértó 1951-2100/***

	1951-1980	1981-2010	2031-2060 a1b scenario	2071-2100 a1b scenario	2071-2100 a2 scenario
Spring frost days number	18	14	6	3	6
March frost days number	15	12	6	3	6
April frost days number	3	2	0	0	0
Spring absolute min	-17.4	-15.4	-5.5	-1.6	-3.8
March absolute min	-17.4	-15.4	-19.5	-7.8	-6.8
April absolute min	-6.2	-3.8	0.3	-0.5	-1.3

The average of "frost days" were just 2 days in April between the period 1981-2010 which will disappear from 2031. If the beginning of blooming time of apple and sour cherry varieties starts earlier in the future because of the global warming, we have to take the March frost occurrences into consideration. In March the lowest temperature was -17,4 ^{o}C in the period of 1951-1980. If we analyze the "frost days" number on the basis of two climate change scenarios (a1b, b2) we will come to the conclusion that we can expect 3 or 6 days' frost occurrence between the periods of 2031-2060 and 2071-2100 (Table 1.). So, the frost risk of apple and sour cherry cultivations will remain as a problem in the future.

3.1 Start of Blooming

We believe that it is not only the weather during the blooming period that plays an important role in the formation of blooming length, but also the meteorological conditions one month prior to the blooming. That is why we use the maximum temperature average of March for predicting the start of blooming time. We found significant correlation between the beginning of blooming and the average maximum temperature of March. We also found that blooming starts much earlier with high maximum temperatures than in case of lower values.

We can say that in case of a higher temperature in March the blooming will start earlier. If the average of daily maximum temperature increases by 1°C, it accelerates the start of blooming by two days.

We have found significant correlation between March maximum temperature and the start of blooming date for "Idared" apple cultivar. The linear regression equation can be seen in *Figure* 1.

At sour cherry varieties we can also say that the start of blooming is primarily influenced by thermic factors. If the temperature of early spring is higher, the blooming starts significantly earlier than in those years when the temperature is lower in March. In case of sour cherry cultivars, we can also state that if the average of daily maximum temperature increases by 1°C, it accelerates the start of blooming by two days. In the following figure (Figure 2.) you can see the relationship between the beginning of blooming and the average value of maximum temperature of March at "Kántorjánosi" cultivar.

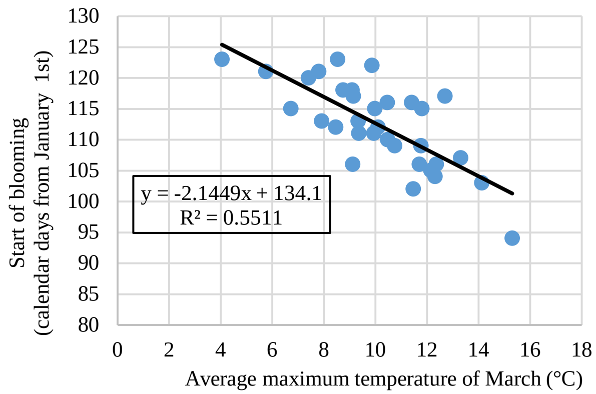

Fig. 1. ***Relationship between start of blooming of "Idared" apple cultivar and average maximum temperature of March (Újfehértó, 1984-2016)***

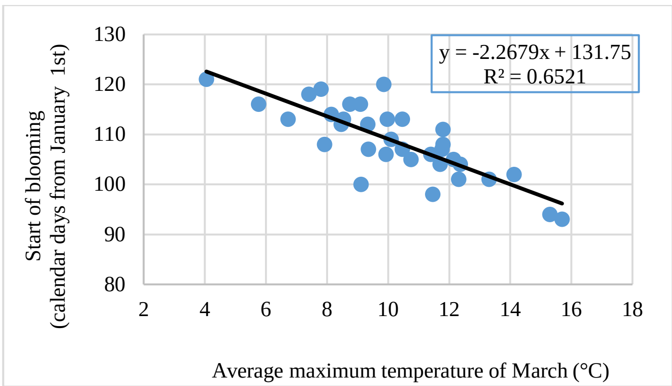

Fig. 2. ***Relationship between start of blooming of Kántorjánosi sour cherry cultivar and average maximum temperature of March (Újfehértó, 1983-2016)***

We can state that at higher spring temperature the beginning of blooming occurs in an earlier time. On the basis of predicted data base (A1B, A2 scenarios) we can state that on next 80 years the average maximum of March will be increasing significantly (*Figure 3*). It means that at the end of this century the beginning of blooming time of main cultivated apple varieties will shift 9-10 day earlier than nowadays.

In case of a mild spring, blooming starts earlier. The large differences between daytime and night time temperatures stimulate the start of blooming. The large amplitude of temperature change is associated with high daytime maxima during spring. At the most popular Hungarian varieties as (Starking, Golden R., Jonagold, Idared) we found intensive decreasing tendency at all the blooming characteristics (beginning of blooming, duration of blooming, end of blooming) of apple cultivars. The beginning of blooming shifted on earlier time *(Figure* 4).

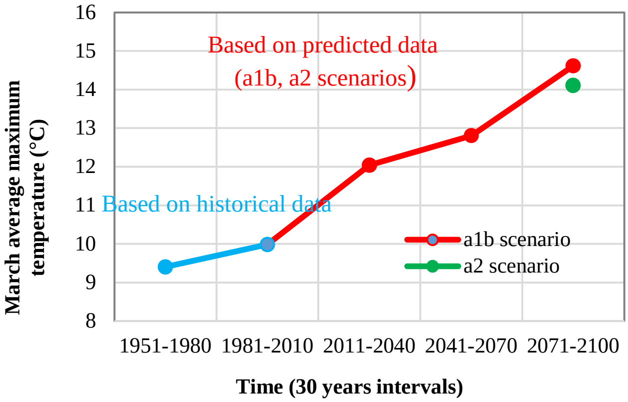

Fig. 3. ***Time series of historical and predicted average maximum temperature of March (Újfehértó, 1951-2100)***

During the observation of the most popular sour cherry varieties (“Debreceni bőtermő”, “Kántorjánosi”, “Ujfehértói fürtös”) we also found significant decreasing tendency in all the blooming characteristics (concerning the beginning of blooming, the duration of blooming and the end of blooming) of apple cultivars. The beginning of blooming shifted two weeks earlier during the observed 34 years’ period *(Figure* 5).

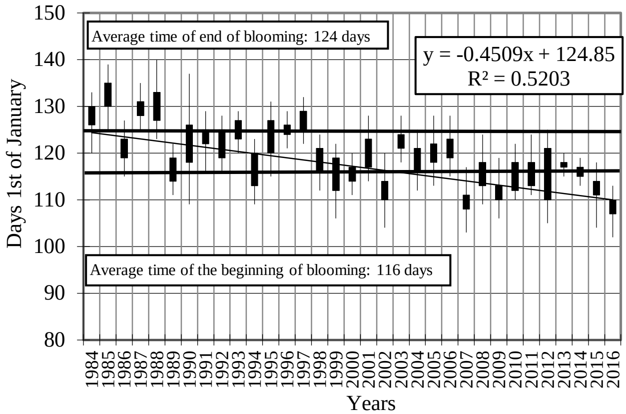

Fig. 4. ***Complex blooming time features of most popular Hungarian apple cultivars (Újfehértó, 1984-2016)***

We can say that in those years when the blooming started earlier, the period of main blooming lasted longer than in those years when the blooming started later. It is not surprising because the later blooming starts the higher the temperature is

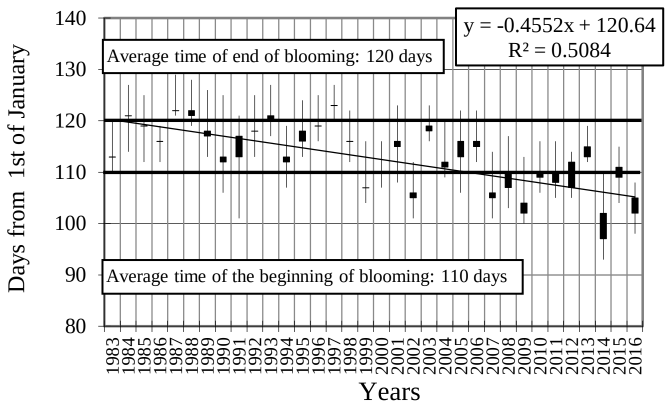

Fig. 5. ***Complex blooming time features of the three Hungarian sour cherry cultivars (Újfehértó, 1983-2016)***

3.2 Length of blooming period

The start of blooming highly depends on the weather for most fruit-producing plants. High temperature significantly accelerates the start of blooming and of course the development of its length. At the same time, cool spring weather considerably delays the starting date of blooming. Based on the provided 34-year data sequence, we can state that the period between the earliest and latest blooming can reach up to 26 days. We found significant relation between the start of blooming and length of blooming in case of apple and sour cherry cultivars as well.

The 6-8 day-long blooming periods are frequent in case of the late blooming groups, whereas in the early blooming groups it is common to find a 9-10 day-long or even longer blooming periods.

It is important to know if there are any significant correlations between the beginning of blooming and the fruit development interval.

It can be seen in *Figure 6* that there is a significant linear correlation between the two mentioned variables. We can state that the early start of blooming results in longer blooming interval while the later the blooming begins the shorter the blooming lasts.

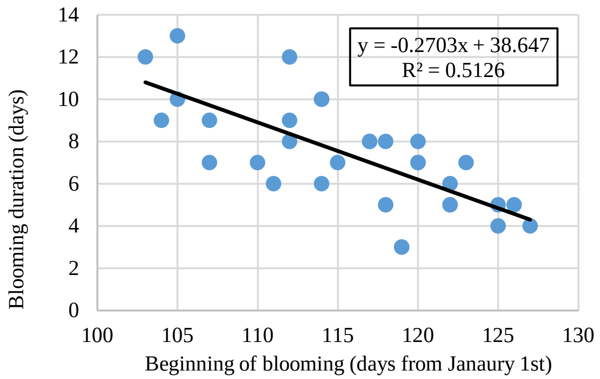

Fig. 6. ***The relationship between the beginning and duration of blooming at Fuji apple cultivar (Újfehértó, 1984-2016)***

The three sour cherry cultivars over the whole period bloomed for different lengths of time, which varied between 5 and 17 days during the observed 34 years period.

The distributions of the length of blooming periods varies, As Figure 7. depicts the “Debreceni bőtermő” has a longer blooming period than the “Újfehértói fürtös” or “Kántorjánosi” cultivars.

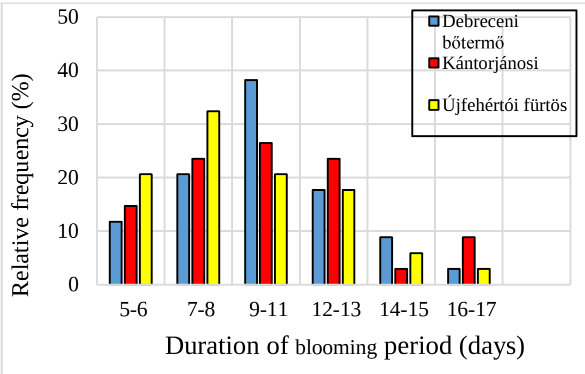

Fig. 7. ***The frequency distribution of the duration of blooming period at the three sour cherry cultivars /Újfehértó, 1983-2016/***

Based on the results we can state that, as long as blooming occurs at the beginning of April, it generally lasts for 13-14 days. If it occurs at the end of April, it usually lasts for 7-10 days only. If the beginning of blooming starts earlier because of the warmer winter or warmer early spring weather, the probability of getting a cold snap is higher. This result is different if the blooming starts relatively later in spring. In this case the blooming period is significantly shorter and the blooming process is faster than in the previous case. We can find significant correlation between the starting date and the length of blooming in case of the „Ujfehértói fürtös”' cultivar (Figure 8.).

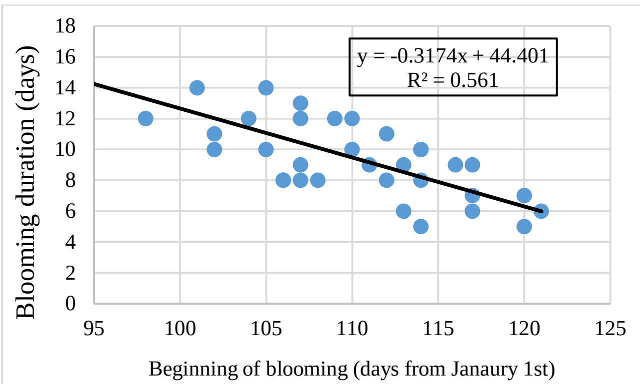

Fig. 8. ***The relationship between the beginning and duration of blooming at Ujfehertoi furtos sour cherry cultivar (Újfehértó, 1983-2016)***

The relation of developmental phases and meteorological elements should always be regarded as a complex reaction of many factors representing the whole physical environment of the climate. Thus, effects of a unique factor are always combined with the other moments of the climate. It is not recommended to evaluate the effects of a single meteorological component regardless of the complex background, as most of phenomena are the results of interactions.

4. CONCLUSIONS

The results presented above prove that the dynamics of weather variables exert measurable effects on the development of fruits. There is a significant correlation between the phenology and meteorological parameters.

After analyzing the main weather characteristics in many cultivating areas, we can determine the climatic risk of fruit growing of different species. These results help us to work out the defense strategies. Conventional growing technologies need to be updated. These methods serve the rise of ecological tolerance of fruit species, thus avoiding the extreme weather influences, and its damaging effect. As a future goal, we would pay more attention to the time interval between bloom and maturity, where several periods are to be distinguished as it is critical to improve the qualitative and quantitative characteristics of fruits.

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