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Influence of Climate Change on the Phenological Stages at the Sour Cherry Genotypes

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RESEARCH ARTICLE

Abstract

The present study establishes the influence of changes in climatic conditions on the development of ten sour cherry cultivars existing in the sour cherry germplasm fund from Research Station for Fruit Growing Iași, Romania. The first four phenological stages were taken in account: bud swelling (code 51 BBCH), bud burst (code 53), beginning of flowering (code 61) and end of flowering (code 69) over three different periods of time (2006-2008, 2009-2011 and 2019-2021). Were registered the number of days, the sum of active temperature (SAT), growing degree-days (GDD) as well as the correlation coefficient between the number of days and the sum of active temperature between phenological developmental stages, buds swelling and bud burst, bud burst and beginning of flowering and from beginning of flowering to the end of flowering. The results obtained in the three time periods (from 2006 to 2021) have statistically significant differences and were recorded especially at the phenophases of flowering. The study determined that the higher annual average temperature was (from 10.45°C to 11.69°C), the more significant were the statistically differences. Thereby, phenological changes were a reaction to temperature what can be assumed also with the results of the present study.

Keywords: climate change, cultivar, phenophases, sour cherry tree, temperature

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INTRODUCTION

Sour cherry is a fruit species with a special importance in the countries of Eastern Europe. In Romania, sour cherry tree found favourable culture conditions, due to the high ecological plasticity. In this area of Europe, the sour cherry orchards occupy 1.5% (4.700 ha) of the total surface of 311.300 ha orchards of Romania (RSY, 2020). The sour cherry tree is widespread in most areas of the country, but especially in the hilly and in the forest-steppe areas (Ghena et al., 2010). Yearly, in Europe, commercial sour cherry orchards produce about 981.916 t (FAO, 2020) and 90% is processed in the production of juice, compote, jam or alcohol beverages such as wine, brandy and fruit beers (Quero-Garcia et al., 2017). In Romania, the largest commercial orchards are in the north-east part of the country, in Iași county (Ghena et al., 2010). Here, sour cherry and sweet cherry plantation occupy an area of 1.275 ha with an average annual production of 8.175 tonnes (RSY, 2020). Production and survival of fruit trees in temperate zones depends by phenophases and time of growth in synchrony with temperature of seasonal changes. Recent research shows that global climatic changes have influenced plants especially in the development of phenological stages (Sîrbu et al., 2016). Generally, temperature change risk in crops includes: modified phenology (timing) of leafing, flowering, harvest and fruit production; reduced winter chill; asynchrony between flowering and pollinators (Baldocchi, 2012; Mathos et al., 2014). The phenology of perennial fruit crops, such as sweet and sour cherries, is an ideal bio-indicator of climate change due to their long-lasting characteristics, in particular, flower opening data and full flowering. This involves the use of several generations of cherries and sour cherries in collections and the use of the same varieties that existed as carrier trees and were replanted after deforestation of the orchards (Wenden et al., 2017).

Many results showed that climate change could induce significant effects on different crops in Romania, on declining production. Also, the requirements towards the ecological factors of the orchards, especially of the water resources is a worrying thing because the demands could exceed their availability (Cuculeanu et al., 2002). Although, during ontogenesis sour cherry tree developed strong root systems with high water absorption in order to survive the drought, a good choice of rootstock and place of plantation can meet the water requirements of the plant (Nemeskéri, 2007; Mézes, 2012).

Sour cherry is tolerant to winter frost, buds damage occurred at winter temperature of –12°C (Dencker & Toldam-Andersen, 2005). A study conducted in the continental temperate area on sweet and sour cherry orchards between 1970-2018 showed a warming of the air in January-May, with a significant increase in March and April. This allows the existence of an advance in the first phenological stages from BBCH: bud sweeling (51), bud bust (53) and flowering period (61-63) (Păltineanu & Chițu, 2020).

Therefore, the risk of spring freeze damage on buds can have an impact for growth and fruit development (Guo et al., 2014). Although it is considered a resistant species of *Prunus*, there are studies that show various associated tolerance mechanisms involving biophysical processes on xylem tissues and the existence of preferred sites for ice formation (Gusta & Wisniewski, 2013).

This paper will focus on study of the phenological stages of some sour cherry cultivars under the long-term influence of climate change.

MATERIALS AND METHODS

The experiments were performed on ten sour cherry genotypes existing in the sour cherry germplasm fund from Research Station for Fruit Growing (RSFG) Iaşi: 'Vladimirskaia', 'Erdy Botermo', 'Montmorency', 'Mocănești 16', 'Oblacinska', 'Olivet', 'Cigany Meggy', 'Ilva', 'Kelleris', 'Pandy 14'.

Located in Northeastern Romania, in Iași county, the experimental fields benefit from an annual temperature of 10.5°C and from recorded rainfall values of 562.6 mm (Corneanu et al., 2021). The selected genotypes were grafted on *Prunus mahaleb* L. seedlings. The sour cherry germplasm fund was established in 2000 with trees planted at 5×4 m with free palmette crown on the direction of the trees row, without sustaining or irrigation system.

On the rows the soil was worked with the lateral disk with feeler and between the trees rows the grassy soil was kept.

In order to obtain conclusive results regarding the influence of climate change on sour cherry genotypes, the observation, recording and statistical processing of data were used as research methods.

Phenological observations followed the development of phenophases organs of growth and flowering by recording data according to milestones (Meier et al., 1994): bud swelling (51), bud burst (53), beginning of flowering (61) and end of flowering (69). The climatic data were recorded with the AgroExpert system by the station located on the experimental plot of the RSFG Iași – Romania.

Based on the data taken from the experimental field the sum of active temperatures (SAT) and the growing degree-days (GDD) was calculated for each variant (period of thre consecutive years) and each repetition (genotypes). The sum of active temperature (Σt°a) was provided by the sum of average daily temperature degree, which exceeds the biological limit characteristic to the sour cherry tree, considered to be 7°C (Cociu & Gozob, 1961).

$\Sigma t°a = \Sigma T\ atd - BL$, in which:

$\Sigma T\ atd$ = sum of average temperature of days between two subsequent phenological stages;

BL = the biological limit of fruit tree species.

The growing degree-days (GDD) from bud swelling to the bud burst and beginning and ending of flowering were calculated according to equation (McMaster, Wilhelm, 1997).

$GDD = (T_{max}+T_{min})/2 - T_{base}$,

where Tmax and Tmin were daily max and minim temperatures,

Tbase was base temperature or the biological limit of fruit tree species.

Also, based on the number of days and the active thermal balance, was calculated on the long-term the correlation coefficient (r).

The results obtained were interpreted statistically and the differences were determined by Duncan's test ($p \leq 0.05$). Pearson correlation coefficient was calculated between variables measured ($p \leq 0.05$).

RESULTS AND DISCUSSIONS

To determine the influence of climatic conditions on the development of phenological stages were shown in Table 1 the differences of the annual averages of the three periods, as well as the deviation from the thermal multiannual average.

Thus, in the period 2019-2021 was registered an annual average of 11.69°C, with a deviation from thermal multiannual average of 2.09°C, a temperature comparatively higher than the previous periods. The lowest annual average was recorded in the period 2009-2011, with a value of 10.45°C and a deviation from multiannual average of only 0.85°C.

The months of interest for the development of phenophases were March, April and May. According to the studies of the National Meteorological Administration, in the last 50 years, the average air temperature showed exclusively increasing trends, statistically significant throughout Romania, in general, during spring and summer (Moale, 2017).

Table 1. Monthly and annual average temperature over the three time periods (RSFG Iași, 2006-2021)

Month	Average annual temperature (°C)								
	2006-2008			**2009-2011**			**2019-2021**		
	Monthly av.	Normal	Deviation	Monthly av.	Normal	Deviation	Monthly av.	Normal	Deviation
I	-1.55	-3.30	1.75	-3.40	-3.30	-0.10	-0.67	-3.30	2.63
II	0.08	-1.50	1.58	-0.97	-1.50	0.53	1.83	-1.50	3.33
III	5.57	3.10	2.47	3.87	3.10	0.77	6.12	3.10	3.02
IV	11.00	10.30	0.70	11.57	10.30	1.27	10.07	10.30	-0.23
V	16.89	16.10	0.79	16.37	16.10	0.27	14.97	16.10	-1.13
VI	21.08	19.40	1.68	19.87	19.40	0.47	20.70	19.40	1.30
VII	22.75	21.30	1.45	22.00	21.30	0.70	22.23	21.30	0.93
VIII	21.81	20.50	1.31	21.53	20.50	1.03	22.10	20.50	1.60
IX	15.67	16.30	-0.63	16.53	16.30	0.23	17.00	16.30	0.70
X	11.29	10.10	1.19	12.47	10.10	2.37	12.70	10.10	2.60
XI	4.92	4.00	0.92	6.27	4.00	2.27	6.40	4.00	2.40
XII	1.20	-0.90	2.10	-0.70	-0.90	0.20	2.35	-0.90	3.25
Annual av.	**10.89**	9.60	1.29	**10.45**	9.60	0.85	**11.69**	9.60	2.09

To study the ten sour cherry cultivars, was calculated and interpreted statistically the number of days, sum of active temperature (SAT) and the growing degree-days (GDD) between phenophases, bud swelling (51 BBCH) - budding (53 BBCH) - beginning of flowering (61 BBCH) and the end of flowering (69 BBCH) (Meier et al., 1994), presented in Table 2. The main phenological steps according to BBCH in the sour cherry species are represented in Figure 1.

In the evolution of growth and fructification phenophases, the observations made during the three time periods of study highlighted the fact that besides the genetic determinant of the cultivar, climatic conditions had a different influence.

Thus, the mean values have significant differences between the three time periods on the phenophases BBCH 51-53 with values between 11.93 days (V1) and 19.26 days (V3) and BBCH 61-69, with differences between variants of 3.34 days. On the BBCH 53-61, differences between the three time periods were insignificant.

The number of days between initiation of vegetation and the beginning of flowering increased with the constant increase of the annual temperatures, but it seems that the period from the beginning to the end of flowering decreased from 13.70 to 10.36 days.

Regarding the SAT, significant values were recorded in the case of the flowering phenophase, 61-69 BBCH, the average values varying between 97.24°C at V_3 and 153.05°C at V_2. Between phenophases BBCH 51-53 and BBCH 53-61, there were insignificant differences between the analyzed temporal values. The constant increase in temperatures in recent years (2019-2021) has led to a shorter flowering period. Which leads to the need for self-fertile sour cherry varieties as much as possible, as described in Schuster's (2017) reviews.

Withal, the phenological stages of plants are more clearly determined in degrees-days of growth (GDD, ^{0}C), depending on the number of days, compared to other approaches of this kind such as the time of year (McMaster & Wilhelm, 1997). So, between BBCH 51 and 53, the GDD recorded insignificant average values between periods V_1 and V_2, while in period V_3 there were significant differences from the others. Among phenophases BBCH 53-61, the significant differences were between V_2 with an average value of 73.14 days and variants V_1 and V_3 with average values close to 63.92 days, respectively 63.59 days. During the flowering period (BBCH 61-69), the average values of GDD varied between 50.07 days (V_3) and 69.83 days (V_2), with statistically significant differences between all three time periods.

The number of days passed between phenophases on the sour cherry cultivars studied varies over the three time periods (V_1, V_2, V_3).

Table 2. The growing degree-days (GDD), sum of active temperatures (SAT) (≥7°C) and number of days required for the beginning of sour cherry phenophases (n=10) (RSFG Iași, 2006-2021)

Phenophases/ Period	51÷53[1]			53÷61			61÷69		
	No. days	Σ T	GDD	No. days	Σ T	GDD	No. days	Σ T	GDD
	(days)[2]	(°C)[2]	(days)[2]	(days)	(°C)	(days)	(days)	(°C)	(days)
V_1 (2006-2008)	11.93[c]	76.67[a]	43.48[b]	15.50[a]	124.92[a]	63.92[b]	13.70[a]	121.39[b]	60.35[b]
V_2 (2009-2011)	13.60[b]	76.86[a]	40.80[b]	15.13[a]	121.81[a]	73.14[a]	12.06[b]	153.05[a]	69.83[a]
V_3 (2019-2021)	19.26[a]	83.03[a]	50.11[a]	16.13[a]	123.93[a]	63.59[b]	10.36[c]	97.24[c]	50.07[c]

Note: [1]-BBCH-Phenological growth stages (Meier et al., 1994): 51 (buds swelling); 53 (bud burst); 61 (beginning of flowering: about 10% of flowers open); 69 (end of flowering); [2] -Different letters after the number corresponds with statistically significant differences for P 5% - Duncan test.

In correlation with the environmental factors, we can find significant correlation between the increase of the temperature of March and unfolding of phenophases time of the sour cherry cultivars. If the temperature is increasing in the future the development stages of fruit trees will also shift to an earlier time.

Figure 1. Phenological stages in sour cherry **-** 'Ilva'cultivar
(a) Bud swelling (51 BBCH); (b) Budding (53 BBCH); (c) Full flowering (61-69 BBCH)

The correlation of the number of days between phenophases and the sum of active temperature (Table 3) registered predominantly values positively correlated, but there are some exceptions. Thus, in the phenological periods BBCH 51-53 in the periods V_2 and V_3 respectively BBCH 53-61 in V_3, the variables were negatively correlated, and statistically insignificant. The lowest correlation coefficient was recorded during BBCH 51-63 periods over the years 2019-2021 with a value of 0.56 days/^{0}C.

Table 3. Correlation coefficient (r) between number days and active thermal balance for long term study (2006-2021)

Phenophases	Period	r[1]
I - During BBCH 51-53	2006-2008	0.86*
	2009-2011	0.61 [ns]
	2019-2021	0.56 [ns]
II - During BBCH 53-61	2006-2008	0.8*
	2009-2011	0.9**
	2019-2021	0.7 [ns]
III - During BBCH 61-69	2006-2008	0.92**
	2009-2011	0.9**
	2019-2021	0.86*

Note: [1]-*-significant correlation; **- distinct significant correlation; ns-non-significant correlation.

Thereby, it was observed that in the years with low temperatures during March- May, when the phenological phases have taken place, the period between the BBCH 61 and the BBCH 69 is greater compared to the normal years according to the climate conditions. For these phenological interval, it can be observed that it is positively correlated, which implies an increase of the active thermal balance during the flowering period.

The statistical differences from the phenological flowering period (61-69 BBCH) in the three time periods are significant and are represented graphically in Figure 2.

Based on several years of phenological observations, the average of blossom date is determined, thus the application of the normal distribution function was also determined by the probability of frost of a lower intensity at the time of full flowering.

Similar studies took place in countries near Romania, Serbia and Hungary, in which it was highlighted that we will need to use more effective protection technologies and new extreme weather tolerant fruit cultivars in the future and the expansion and successful cultivation of sour cherry culture depends to a large extent on climatic conditions. (Szabo et al., 2017; Radičević et al., 2011; Zavalloni et al., 2006). Also, it is required 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 (Pfeiffer, 2010).

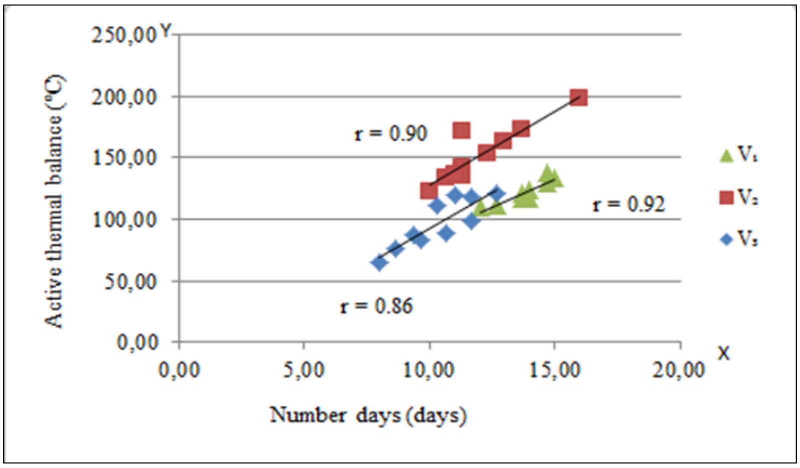

Figure 2. Correlation coefficient (r) between number days and active thermal balance from beginning to the end of flowering at sour cherry tree (RSFG Iași, 2006-2021)

CONCLUSIONS

Phenological period of the same sour cherry genotypes are variable, depending on the climate year conditions and the cultivation area. During the differences of the time periods, an increase of the average annual temperature was observed, thus influencing the onset of the phenophases, the number of days between them and the sum of the active temperature required.

The evaluation of sour cherry genotypes for different periods of time makes up the characterization of the phenological response to climate change and the plasticity of the behavior of different cultivars under different environmental conditions. This will enable the development of predictive models for sour cherry phenology and help anticipate breeding strategies to maintain and improve sour cherry production.

The number of days between bud swelling, bud burst, the beginning and end of flowering is positively correlated with the recorded temperature and sum of active temperatures.

These simulation models have potential applicability in improving the timing and efficiency of management decisions related to crop phenology, such as pest control, fertilization, and irrigation.

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