

Phenological dynamics of some fruit species from the Northeastern area of Romania in the context of climate change

I. Mineață, I. Perju*, S. Sîrbu, I.E. Golache, I.V. Ungureanu and E. Iurea

Research Station for Fruit Growing, Iasi, Romania

*Corresponding author email: ionel_perju@yahoo.com

ABSTRACT

Climate change has had crucial impacts on phenological stages, such as the advancement or decline of the vegetation cycle of stone fruit trees. Vegetation phenology is an important biological indicator in understanding and predicting the behavior of ecosystems and how they respond to environmental factors. This work aims to investigate the influence of interannual climate variation (years 2023 and 2024) on the phenology of some stone fruit tree species belonging to the genus *Prunus*. The study was carried out within the fruit experimental plots of the Research Station for Fruit Growing (RSFG) Iași, North-Eastern Romania, analyzing the onset of four phenological stages from bud swelling to the end of flowering at five cultivars belonging to the species: *Prunus avium* L., *Prunus cerasus* L., *Prunus domestica* L. and *Prunus armeniaca* L. The research conducted on the climatic regime in the studied years, in relation to multiannual values (1972-2022), highlighted the variability of phenological behaviors of stone fruit species both in terms of the number of days (according to the Julian date methodology) for the start of vegetation, and in the duration of phenological stages. Thus, of the two years of study, the year 2024 was noted for an extension of the start of vegetation in cherry by 29 days, in plum by 21 days, in apricot 12 days and in sour cherry by only one day compared to 2023. The obtained results highlight the variability of the phenological behaviors of the fruit tree species but also of the cultivars and the length of the vegetation period was directly influenced by annual climatic conditions. Changes in the duration of the vegetative phases were highlighted, which can generate useful information to predict the risk of late frosts in particular, but also countermeasures to combat the effects of climate change.

Keywords: *Prunus* sp., phenology, climate change, stone fruit trees, BBCH.

INTRODUCTION

Climate change has become an observed reality, already causing an increase in average temperatures with particular intensity in certain areas, such as temperate-continental and mediterranean (Milošević and Milošević, 2023). These changes in meteorological factors lead to difficulties in covering the cold necessary to break endodormancy, the occurrence of late frost events or abnormally early maximum temperatures, with profound consequences in particular on the phenology of *Prunus* species, such as stone fruits (Salama *et al.*, 2021; Egea *et al.*, 2022).

The substantial impacts of global warming on temperate fruit crops are manifested on phenological traits, represented by the developmental stages of the species each year (Menzel *et al.*, 2006; Vanalli *et al.*, 2021). Data recorded in numerous studies (Yu *et al.*, 2010; Luedeling

et al., 2013; Egea *et al.*, 2022; Stoenescu *et al.*, 2024) highlight that the most frequent consequence of sudden temperature increases is early bud burst, thus influencing the length of the species vegetation season and advance in flowering, with a high risk of late spring frosts, if cold temperatures return. Another imbalance caused by climate change is the phenophase gap due to much too low temperatures associated with uneven precipitation by prolonging some stages of growth, such as bud breaking, flowering, fruit ripening (Vitasse *et al.*, 2018; Fadón *et al.*, 2020). Regarding stone fruit trees, they have strong environmental requirements, mainly related to temperature, being conditioned to accumulate a specific amount of cooling during winter to pass through vegetative dormancy and then require warm temperatures to finally bloom in the spring (Fadón *et al.*, 2020; López-Morales *et al.*, 2021). Understanding how species and cultivars interact and drive phenological processes in space is crucial, given the current scenario of global eco-pedoclimatic habitat change (Rumeu *et al.*, 2020; Stoenescu *et al.*, 2024). Thus, this work aims to provide additional information on the influence of interannual climate variations on the phenology of some stone fruit tree species. Knowing the temperature requirements of a cultivar can be useful to anticipate future performances and to design new strategies that take into account the predicted global warming (Luedeling *et al.*, 2009; Campoy *et al.*, 2011).

MATERIALS AND METHODS

The study was conducted in 2023 and 2024 in the experimental field of Research Station for Fruit Growing Iasi, in Northeastern Romania (Northeastern Europe, 47°20' N; 27°60' E), using as biological material five cultivars of four species of stone fruit trees belonging to the genus *Prunus*: *Prunus avium* L., *Prunus cerasus* L., *Prunus domestica* L. and *Prunus armeniaca* L. (Table 1).

Table 1. The biological material used (species and cultivars)

Species	Cultivar	Species	Cultivar
<i>Prunus avium</i> L.	'Bucium'	<i>Prunus domestica</i> L.	'Centenar'
	'Alexus'		'Carpatin'
	'Amaris'		'Prezident'
	'Cociuvas'		'Silvia'
	'Maria'		'Minerva'
<i>Prunus cerasus</i> L.	'De Botoşani'	<i>Prunus armeniaca</i> L.	'Tudor'
	'Cygany Meggy'		'Goldrich'
	'Pandy 50'		'Fortuna'
	'Erdy Botermo'		'Traian'
	'Montmorency'		'Augustin'

The region is characterized by a temperate-continental climate, located on a microrelief with a gently sloping plateau and predominantly cambic chernozem soils with good natural drainage, with a humus content of 3.7–4.3%. Regarding climatic data, the characterization of the average monthly temperature and precipitation of the study years was carried out using the *Field Climate* system within the RSFG Iaşi unit, and these values were compared with multiannual averages recorded over 50 years period (1972–2022) as a reference, using a database stored in MS Office Excel and the National Meteorological Administration Catalog. The monitoring of phenological stages was carried out through periodic visits to the experimental field and identification according to the Biologische Bundesanstalt, Bundessortenamt, and Chemical Industry (BBCH) scale (Meier, 2001): 51 BBCH (bud swelling), 53 BBCH (bud burst), 61 BBCH (beginning of flowering: about 10% of flowers open) and 69 BBCH (end of flowering). The calendar dates corresponding to each

phenophase was recorded and converted into Julian dates for a quantitative analysis of the number of days between January 1 and the evaluated phenophase (Luedeling *et al.*, 2013; Cosmulescu *et al.*, 2022).

The data obtained from the observations, as well as the relationship between the analyzed and monitored indices, were statistically processed using descriptive statistics such as: Pearson correlation coefficient (r^2) at $p \leq 0.05$, standard deviation (STDEV) and percentage coefficient of variation (CoV%).

RESULTS AND DISCUSSIONS

In order to characterize the phenological characteristics of stone fruit trees, a climatic characterization of the study area was necessary based on monitoring the average monthly temperature (Figure 1) and the amount of precipitation (Figure 2) in the studied years. The meteorological data were compared with the daily values of meteorological parameters from the last 50 years, used as multiannual reference values. Thus, the evolution of average monthly temperatures fluctuated seasonally in 2023, ranging from +1.69°C in December to a maximum of +25.5°C in August.

The average annual temperature in 2023 was +12.4°C. In 2024, the average monthly temperature had a minimum in January of +0.2°C and a maximum of +24.2°C in July. The maximum extreme temperature value was reached in August 2024, at +41.6°C. The deviation of the two-year average from the multiannual average in each month was positive, ranging between +0.1°C in May and +4.8°C in January. The deviation from the multiannual average is +2.9°C (Figure 1).

The changes highlighted in the climatic regime in the NE area of Romania fall within the context of global warming, but with particularities specific to the geographical region to which it belongs (Cheval *et al.*, 2022).

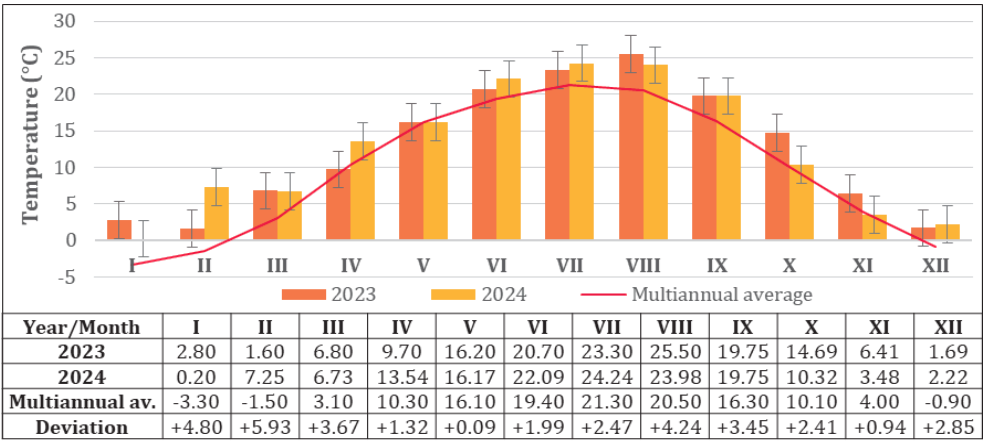


Figure 1. Average monthly temperature during the study years and multiannual reference average

Regarding the precipitation regime (Figure 2), the study years can be characterized as being highly uneven, with periods of excess precipitation followed by very dry intervals. While in 2023 the total precipitation amounted to only 284.5 mm, in 2024, a total of 611.2 mm was recorded. The deviation from the multiannual value ranged between -42.4 mm (August) and + 45.9 mm (July). Tracking phenological milestones is a simple and easy-to-apply method for monitoring flora and provides precise and useful data on how climate affects the development of each organism or species–within the ecosystem. The first phenological stages of the spring season are considered the most prone and affected by temperature

fluctuations, as well as by precipitation (Savchovska and Nesheva, 2021; Stoenescu *et al.*, 2024), with negative effects on the growth and development of fruit species. The progress through the vegetative phases of the monitored species is influenced by both climate and the biological characteristics of each cultivar.

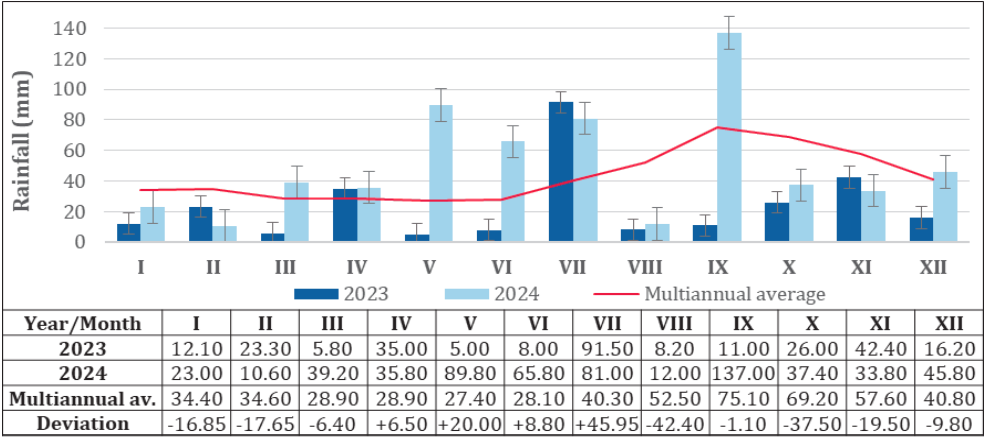


Figure 2. Total monthly precipitation amount in the study years and the multiannual reference average

Thus, following the phenological data obtained and graphically represented in Table 2, the influence of annual climatic conditions on the four stone fruit species was highlighted. The year 2023 was noted as the earliest in terms of bud swelling (51BBCH), with a difference of 29 days in *Prunus avium* L., 21 days in *Prunus domestica* L., 12 days in *Prunus armeniaca* L., with no differences in *Prunus cerasus* L.

Table 2. The phenogram of stone fruit tree species from bud swelling - end of flowering (51-69 BBCH)

Species	Month	February			March							April										May						
	Year/ Day	1	18	27	1	8	9	11	18	20	27	29	2	6	7	9	11	13	14	17	18	21	22	23	26	30	1	4
<i>Prunus avium</i> L.	2023																											
	2024																											
<i>Prunus cerasus</i> L.	2023																											
	2024																											
<i>Prunus domestica</i> L.	2023																											
	2024																											
<i>Prunus armeniaca</i> L.	2023																											
	2024																											
				51BBCH									53BBCH								61-69BBCH							

Regarding the duration of the vegetation period between the start of vegetation through bud swelling (51 BBCH) and the end of flowering (69BBCH), in 2023, although earlier, the periods between phenological stages were much shorter compared to 2024, confirming that the absence of precipitation (in 2023 being a deficit compared to the multiannual average of over 200 mm) and high daytime and nighttime temperatures lead to the occurrence of pedological, atmospheric and physiological drought, thus shortening the phenophases (Jităreanu *et al.*, 2009).To determine the changes that occurred during the phenophases, the number of days from January 1 to the stages of bud swelling, budding, beginning and end of flowering was used. Table 3 shows the statistical processing of the data obtained during the two years of

study. For the 51 BBCH phenophase, based on Julian data, the order in which this phenophase occurred in the identified species was as follows: *Prunus avium* L. (82.5 days), *Prunus domestica* L. (78.5 days), *Prunus cerasus* L. (70.5 days) and *Prunus armeniaca* L. (55.0 days). Stone fruit trees, like other woody species in temperate zones, need to accumulate a cultivar-specific amount of chilling during winter and then experience warm temperatures to overcome vegetative dormancy and trigger vegetative growth (Fadón *et al.*, 2020).

Table 3. Descriptive statistics of the number of days (Julian date) required for the development of the main phenological stages.

Species	Descriptive Statistics	51BBCH	53BBCH	61BBCH	69BBCH
<i>Prunus avium</i> L.	Average	82.50	97.00	104.50	112.50
	Variation range	68-97	92-102	97-112	104-121
	STDEV	20.51	7.07	10.61	12.02
	CoV%	24.86	7.29	10.15	10.69
<i>Prunus cerasus</i> L.	Average	70.50	93.00	109.00	116.50
	Variation range	70-71	88-98	101-117	108-125
	STDEV	0.71	7.07	11.31	12.02
	CoV%	1.00	7.60	10.38	10.32
<i>Prunus domestica</i> L.	Average	78.50	89.50	104.50	107.50
	Variation range	68-89	79-100	95-114	93-122
	STDEV	14.85	14.85	13.44	20.51
	CoV%	18.92	16.59	12.86	19.08
<i>Prunus armeniaca</i> L.	Average	55.00	69.00	88.50	97.00
	Variation range	49-61	67-71	77-100	86-108
	STDEV	8.49	2.83	16.26	15.56
	CoV%	15.43	4.10	18.38	16.04

The correlation matrix between the years of study for the number of days from bud swelling to the end of flowering (51-69 BBCH), (Table 4) revealed a non-significant correlation within the same species between the two years, except for the species *Prunus domestica* L., where a significant positive correlation coefficient was obtained (r= 0.4486). A positive correlation indicates that when one variable increases in value, the other variable also increases, following a linear pattern (Ratner, 2009).

Table 4. Correlation matrix between study years for the number of days from bud swelling - end of flowering (51-69 BBCH)

2023 2024	<i>Prunus avium</i> L.	<i>Prunus cerasus</i> L.	<i>Prunus domestica</i> L.	<i>Prunus armeniaca</i> L.
<i>Prunus avium</i> L.	0.1398^{ns}	-0.3028 ^o	-0.0158 ^{ns}	-0.1137 ^{ns}
<i>Prunus cerasus</i> L.	-0.926 ^{ooo}	0.2001^{ns}	0.1893 ^{ns}	0.7120 ^{**}
<i>Prunus domestica</i> L.	0.1414 ^{ns}	0.1893 ^{ns}	0.4486[*]	-0.0943 ^{ns}
<i>Prunus armeniaca</i> L.	-0.807 ^{oo}	0.7120 ^{oo}	0.8087 ^{**}	0.1346^{ns}

CONCLUSIONS

In conclusion, the observations and obtained results confirm the existence of variations in spring phenological stages from one year to another in the studied stone fruit species which are–strongly influenced by variations in climatic factors, including the dormancy period. These data contribute to a deeper understanding of the impact and consequences of current climate change, providing valuable information on the challenges facing the fruit-growing sector.

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