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PHENOLOGICAL CALENDAR OF PLUM CULTIVARS, DEPENDING ON THE CHANGES OF CLIMATIC CONDITIONS FOR THE TROYAN REGION, BULGARIA

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Abstract

The purpose of this paper was to analyze the influence of climatic factors and their impact on the phenology of some plum varieties grown in RIMSA Troyan during the period 2019-2021. The phenophases of the beginning of flowering, the end of flowering and the period of fruit ripening were observed and analyzed. Regarding the flowering phenophase, it was found that earliest blossoming of plum cultivars occurred at the beginning of April in 2019. The blossoming period for 'Kyustendilska' both began and ended at the latest time. Every year, within 10-11 days, there was a complete overlap of the blossoming of all the studied cultivars.
Regarding the fruit ripening, higher temperatures combined with low amounts of precipitation, cause an earlier onset of the ripening phase.

Key words*: plum, cultivars, phenology, climate change.*

INTRODUCTION

Agro-climatic adaptability and ecological plasticity of plum cultivars are key elements for research in agriculture and the information is essential for the creation of sustainable and competitive plantations. Jakab-Ilyefalvi et al. (2021) believe that data on the occurrence and duration of phenophases are bioindicators of climate change events and are key elements in fruit crop technology. The large variation in spring temperatures mainly affects early cultivars, which affects the technology, market, prices and investment costs of farmers (Jakab-Ilyefalvi et al., 2021). Temperature factors cannot be controlled directly, therefore suitable cultivars are selected for the establishment of orchards, according to the period of blossoming. Modeling detailed phenology is the key to the correct selection of optimal cultivars in a specific geographic area (Ganji Moghaddam et al., 2011).
Tree fruit species synchronize their physiology, including blossoming and annual development patterns, according to environmental conditions, as temperature is a major factor. Stone fruit species are the earliest to enter the blossoming process. Fadón et al. (2021) reported that the earliest blossoming dates were associated with a large amount of heat following a prolonged cold spell. These findings may support the development of new modeling frameworks that can help predict the impacts of climate change on tree dormancy.
Potential yields of fruit species are also strongly influenced by climate conditions that regulate dormancy and subsequent blossoming. Yield fulfillment at the end of the vegetation season depends on several additional factors, including environmental conditions and cultivation technologies. Information on how the reduction of cold (i.e., global warming) affects crop yield is crucial for farmer decision-makers, especially in warm fruit growing regions (Whitney, 2021).
The date of mass swelling of flower buds occurs after an increase in the average day and night air temperatures above 5ºC and is taken as a sign of the termination of the "forced dormancy" in fruit species. An increase in the average daily temperature above 10.5ºC leads to a sharp increase in the temperature sum. Broad limits for the beginning and end of fruit bud break were found by Kazandzhiev &

Malasheva (2016). Cool and rainy weather prolongs the blossoming phase, and dry and warm weather shortens it. Very rapid overblooming is not favorable, because most of the flowers are not pollinated by insects.

Milatovic et al. (2019) for the conditions of Belgrade, The average flowering time of the tested cultivars was in the first half of April, and the average duration of flowering varied from 7.4 to 10.4 days. Glišić et al. (2016) investigate phenological, pomological and productive properties of three new plum cultivars ('Zlatka', 'Mildora', 'Krina') and one standard ('Čačanska Rodna') developed at Fruit Research Institute, Čačak. Maghlakelidze et al. 2017 defines the cultivars a collection plot of the Scientific-Research Center of Agriculture, in village Jighaura of Georgia, according to flowering time: Early ('Amers', 'Bluefree'), Middle ('Stanley', 'President', 'Empress') and late ('Chanchuri', 'Tophit') cultivars during flowering. there were 12- daily difference between early and late cultivars during flowering.

Dimitrova & Sotirov (2020) found a strong correlation dependence between the temperature sums above 5 and 10°C and the number of days for blossoming and fruit ripening.

The objective of the present study was to determine the phenological response to climate change and the behavior of some plum cultivars in the Central Balkan region for the period 2019-2021.

MATERIALS AND METHODS

Materials

The 'Rutgerstetter', 'Top First', 'Katinka', 'Tegera', 'Hanita', 'Strinava', 'Gabrovska', 'Mirabelle de Nancy', 'Stanley', 'Kystendilska', 'Jojo', 'Elena' plum cultivars have been studied at the RIMSA-Troyan (42°53′N 24°43′E). The trees are grown on light gray forest soil, under nonirrigated conditions, with tillage in the row-spacings.

The investigated plum cultivars find suitable conditions for good growth and development in the Troyan region. Crowns typical for the respective cultivar are formed, with sizes corresponding to the age.

Methods

Observations were made throughout the year for each phenophase. The phenophases - beginning of blossoming, end of blossoming and fruit ripening periods - were established and the number of days was determined according to the generally accepted methodology for studying plant resources in fruit plants (Nedev et al., 1979).

Based on data from the Meteorological Station on the territory of RIMSA, the meteorological factors were analyzed, such as average monthly temperatures and total amounts of precipitation for 2019-2020 compared with a 20-year base period (Figure 1); temperatures, precipitation and atmospheric humidity by ten days in March and April (2019-2020) (Table 1).

RESULTS AND DISCUSSIONS

Climate conditions for the Troyan region are characterized by warm and dry summers and not very cold winters. For the study period, warmer winter months (January and February) were recorded in 2020 (with 1.5-2°C) and 2021 (with 1.5°C) compared to the average for a 20-year base period (Figure 1). In 2021, March and April were very cold, which is a prerequisite for delaying the onset of vegetation.

For the summer months of 2021 (May and June), a complete coincidence of temperatures compared to the base period was reported, while July, August and September were each 2 degrees warmer and without significant amounts of precipitation (only 12 mm), i.e. this period is characterized as drought.

It was found that after mid-summer, during fruit ripening, autumn rainfall was scarce (from 16 to 30mm), except for October 2020 (114 mm). The temperatures in August, September, October in all three years were higher than the basic average, which is a sign of a tendentious global climate warming and changes that will seriously affect the factors on which the favourable cultivation of plums in our area depends.

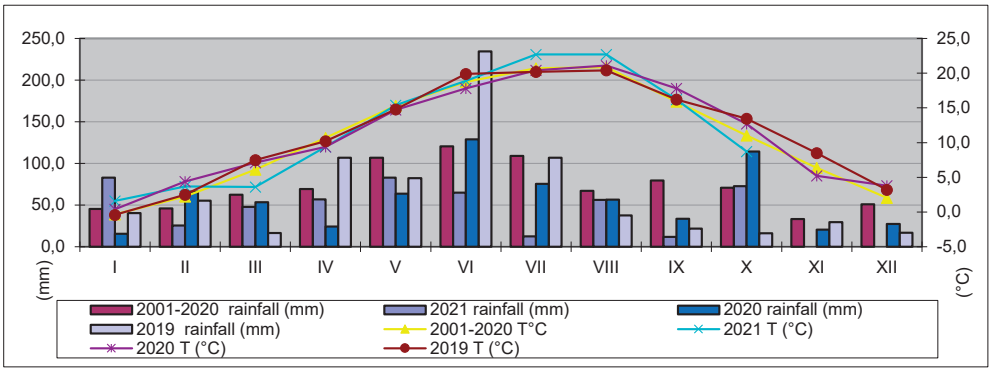

Figure 1. Average monthly temperatures and total precipitation (2019-2021) and 20-year base period (2001-2020)

During the period of the beginning of blossoming, the changes in the factors, such as temperature, humidity and the amount of precipitation for 2019-2021 were different as the difference in precipitation during the first 2 ten days of April 2019 (50.4 mm) and 2020 (10.6-9.2 mm) was distinct. In 2021, very low temperatures (from 3.3 to 6.3°C) were registered in March and the beginning of April, which is the reason that blossoming began in the third ten days of April, when they reached 11.3°C. In 2020, temperatures above 10°C were recorded in the second ten-day period, and then the blossoming begins, because at the beginning of the vegetation season, they are from 5.3 to 5.9°C, and in 2019, even at the beginning of April, the average temperature for the first ten-day period was 9.8°C, which is a prerequisite for early blossoming (Table 1).

Table 1. Meteorological factors in March and April in ten-day period (2019-2021)

	March			April		
2019	1-10	10-20	21-31	1-10	10-20	21-30
Relative humidity (%)	61.0	69.0	62.0	68.0	79.0	70.0
Rainfall (mm)	1.6	14.3	0.6	50.4	45.1	11.4
Temperature (°C)	8.0	7.9	6.8	**9.8**	8.1	12.0
2020						
Relative humidity (%)	72.9	69.2	77.6	70.7	66.4	69.0
Rainfall (mm)	39.0	5.6	8.8	10.6	9.2	4.6
Temperature (°C)	8.9	7.2	5.3	5.9	**11.3**	11.1
2021						
Relative humidity (%)	69.1	83.1	75.2	72.7	75.1	73.3
Rainfall (mm)	5.1	20.0	22.6	26.0	20.6	10.4
Temperature (°C)	3.6	3.3	3.9	6.3	7.3	**11.3**

For these reasons, in the first year of the study (2019), the earliest blossoming started for 'Jojo' cultivar on 28 March, followed by 'Tegera' and 'Elena' (29 March), and the latest (5 April) for 'Kystendilska'. The end of full blossoming was from April 13 to 19 for 'Stanley', 'Hanita' and 'Kyustendilska' plum cultivars (Figure 2).

In 2020, the earliest blossoming period began for 'Jojo' (7 April.) and the latest (15 April) for 'Kystendilska', but this is 10 days later than in 2019. The latest date for the end of blossoming period for 'Kyustendilska', 'Katinka' and 'Hanita' cultivars was reported on 30 April.

In 2021, blossoming period began for 'Jojo' and 'Tegera' (9 April), whereas the latest date for the beginning was registered for 'Kystendilska' (23 April). The latest date for the end of blossoming was registered for 'Kystendilska' (06 May) and 'Katinka' (02 May) reaching the month of May. In 2020, the duration of blossoming stage was about 3 days

shorter than 2019. On average, the blossoming period is about 15 days, ac the longest blossoming period was registered for ‘Mirabelle de Nancy’. The high temperature of spring causes a shorter flowering period and the "full flowering" phenophase lasts only a few days.

‘Jojo’ is defined as the earliest blossoming of the group of German cultivars, followed by ‘Tegera’ and ‘Hanita’. ‘Kyutendilska’ completed its blossoming phase in 2019 – 05 April; in 2020 - 15 April; 2021 - 06 May. This has been investigated and confirmed in our other studies as well (Stefanova et al., 2017; Stefanova, 2019).

Milatovic et al. (2017), the average time of flowering of tested cultivars was in the first half of April, and the average duration of flowering varied from 7.8 to 11.3 days. The average time of maturation ranged from July, 17 (‘Valerija’) to July, 31 (‘Hanita’).

For each year, within 10-11 days, there was a complete overlap of the blossoming of all investigated cultivars. In 2019, this was the period from 02 to 13 April; in 2020 from 10 to 20 April; in 2021 from 16 to 26 April. This indicator ensures good mutual pollination of the cultivars and favours the harvest.

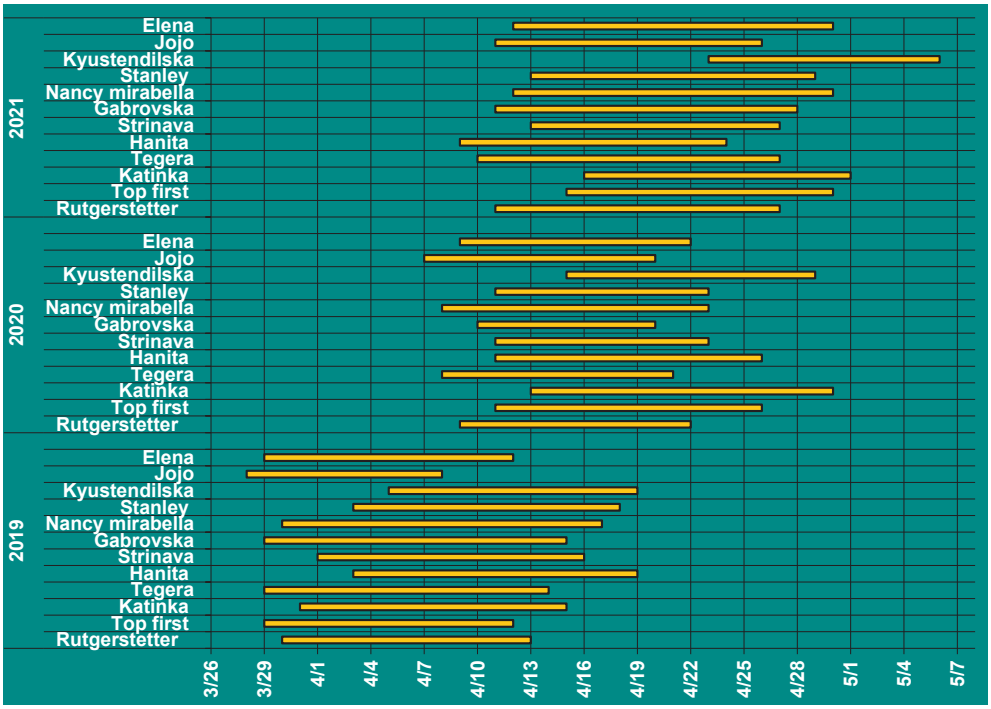

Figure 2. Blossoming phenogram (2019-2021)

The studied plum cultivars cover a harvest period from mid-July (‘Rutgerstetter’) to the end of September (‘Elena’ and ‘Kyustendilska’ cultivars). For the ‘Stanley’ cultivar, in most cases the fruits reach ripening stage at the end of August, beginning of September. In the second half of August and the beginning of September, the average daily temperatures in 2021 were higher and the low amounts of precipitation, compared to the base 20 year period, caused an earlier onset of ripening stage by about 5-6 days, compared to previous years (Figure 3).

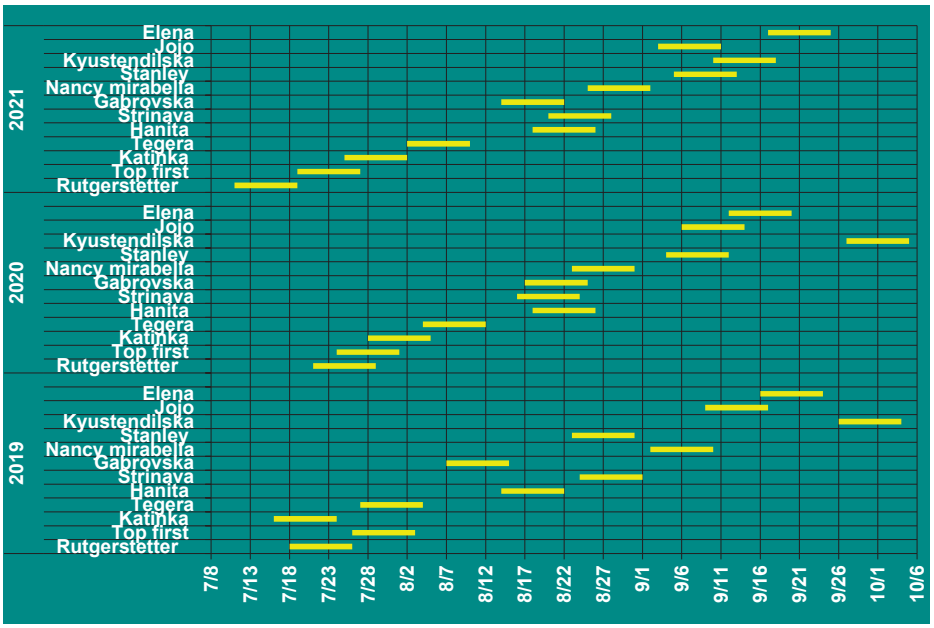

Figure 3. Ripening Phenogram (2019-2021)

Directly related to the power of flowering and the duration of flowering is the realized yield. Agro-ecological factors and their variability affected flowering, by later onset of phenophases, but posed a risk of late spring frosts. They are most sensitive in the fruit set phase. Certain climatic conditions also affect the attack of diseases. Early brown rot compromised the harvest in 2019, yields (measured real and objective) were the lowest for the study period. The highest yields were registered in 2021, as a result of the favourable course of blossoming, good pollination and the formation of a large percentage of fruit-set. Heavy rains in June and July (Figure 1) allowed the fruits of most cultivars to ripen. The highest yields were gathered from 'Kyustendilska' (31 kg), 'Stanley' (26 kg), 'Tegera' (26 kg). These conditions, without prerequisites for the development of economically important fungal diseases, allowed the cultivars to reach their biological potential, with the exception of 'Strinava' and 'Jojo', which are susceptible to drought and remain with the lowest yields in 2021 (Table 2).

Table 2. Average yield per a tree by cultivars (2019-2021)

Average yield per a tree (kg)	2019	2020	2021
Rutgerstetter	3.0	4.2	7.0
Top first	4.3	3.0	5.0
Katinka	17.0	13.5	19.0
Tegera	12.0	14.3	26.0
Hanita	7.5	8.0	19.0
Strinava	19.5	23.4	8.0
Gabrovska	13.0	19.2	17.0
Nancy mirabella	22.5	26.5	32.0
Stanley	14.0	22.3	26.0
Kyustendilska	5.3	11.0	31.0
Jojo	24.0	25.0	6.0
Elena	14.5	12.7	17.0
St. Dev.	*7.000*	*8.015*	*9.678*
CV (%)	*53.64*	*52.53*	*54.52*

CONCLUSIONS

The earliest blossoming of plum cultivars for the conditions of the Troyan region occurred at the beginning of April in 2019. Each subsequent year, the permanent increase in temperatures above 10°C was delayed by 10 days.

The 'Jojo' cultivar is determined as the earliest blossoming of the German cultivar group, followed by 'Tegera'. 'Kyustendilska', 'Katinka' and 'Hanita' cultivars had later blossoming period. The blossoming period for 'Kyustendilska' both began and ended at the latest time.

Every year, within 10-11 days, there was a complete overlap of the blossoming of all the studied cultivars. It is the longest for the 'Mirabella du Nancy' cultivar (17-18 days).

In 2020, the average blossoming period for all cultivars was about 3 days shorter than in 2019 and 2021.

The drier conditions in 2021 caused an earlier ripening of the fruits by about 5-6 days, compared to the previous years.

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