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THE EFFECT OF CLIMATE CHANGES ON PHENOLOGICAL PHASES IN PLUM TREE (*Prunus domestica* L.*)* IN SOUTH-WESTERN ROMANIA

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Abstract: *This paper's aim is to study phenological changes in plum tree species (Prunus domestica L.) that recently appeared in Oltenia region (Romania). It was found that in the years with early spring season and high temperatures, vegetation phenological phases have developed much earlier than in normal years. Analysis of data obtained showed that "flowering time duration" is a feature which is influenced by climatic factor and genetic factor. The influence of meteorological factor is manifested in different years, thus causing, in the same cultivar, different time durations between the beginning and the end of flowering. In general, the earlier the flowering is developing, the shorter its time duration. The studies on the environmental factors' impact on phenology in fruit-tree species are allowing making decisions on forming out suitable assortments for different culture zones, depending on local ecological conditions.*

Key words: *phenological observations, climatic variations, plum.*

INTRODUCTION

Analysis of climatological data strings for the 20th century (1901-2000) showed that the average annual temperature in Romania increased by 0.3°C, a value that is below the global average warming of 0.6°C. The effects of climate changes on agriculture made an ever increasingly main concern as the changes in regional and local climate conditions shall have influence on ecosystems.

Worldwide, according to *Intergovernmental Panel on Climate Change* (IPCC), the total increase in global temperature from 1850 to 2005 is 0.76°C, and heating rate average over the last 50 years is almost twice as in the past 100 years.

The last 25 years indicated an increase of average temperature of about 0.177±0.052 ^{0}C, as compared to the average temperature increase of about 0.074±0.018 ^{0}C in the last 100 years (source IPCC 2007).

The possible impact of global climate changes on agricultural ecosystems is the subject of numerous recent studies. Globally, the long-term analysis of climate changes and their biological effect showed that they have an impact on species' physiology, species distribution, organisms' phenology, and biocenosis composition and dynamics (Parmesan & Yohe, 2003). One of the indicators used and accepted by many scientists to monitor climate change, is phenology (Rötzer & Chmielewski, 2001). On phenology, Sparks & Menzel (2002) presented phenology as the ideal way to demonstrate the effects of global warming on the living world.

The same idea is expressed by Chmielewski & Rötzer (2001), Walther et al. (2002), who believe that phenological observations are best quantifying the plants' response to climatic conditions, ie climate changes.

Distinct changes that occurred in air temperature in the late 1980s have led to sharp reactions of plants' phenology in many regions of the world (Chmielewski et al., 2004). Temperature rise caused by the greenhouse effect is manifested by changes in the diurnal, annual and inter-annual pattern, which may cause phenological changes in plants (Peiling et al., 2006, Cosmulescu et al., 2007, 2008, Cosmulescu & Baciu, 2002). Many trees are susceptible to spring frost during flowering. Climate warming will advance both the date of the last springtime frost and flowering date, while the risk of late frost to affect floral buds remains generally unchanged (Rochette et al., 2004).

Increased interest for the influence of climate on phenology is illustrated by the following passage: *"It is required that we all take into consideration the establishment of a global network of phenological observation for monitoring the climate changes and impacts on ecosystems"* (International Conference on Climate Chnages Impact on the Environment and Society, Japan, 1991).

The plan to set up a new global network of phenological monitoring was initiated by the *„Phenology Study Group"* within the International Society of Biometeorology (ISB) in Canada in 1993. The objective of the Global Phenological Monitoring (GPM) programme is to set up a solid structure of phenological observations that can connect 'local' networks, and encourage expansion of phenological networks worldwide.

Setting out from the idea expressed by the experts showing that phenology is the ideal way to demonstrate the effects of global warming on the living world, and from the fact that phenological observations are best quantifying the plants' response to climatic conditions, this paper aims at recording the vegetation phenophases in plum-tree species, to highlight the changes occurred under the current climate conditions.

MATERIALS AND METHODS

For this study, the plum tree species *(Prunus domestica L.)* was chosen, and the town of Craiova (44°20'0"N, 23°49'0"E), in Oltenia region of Romania, with continental temperate climate regime, specific to plain areas, with Mediterranean influences.

The genetic diversity of *Prunus* genus into the Sub-Carpathian of Oltenia-Romania is quite high (Botu et al., 2002, Botu et al, 2007), and plum tree species is well-adapted to ecological conditions which are specific to this area. In this paper, phenological and climatic data were used, and they were statistically correlated and interpreted. Vegetation phenophases were recorded in plum tree cultivars *(Prunus domestica* L.*)*, during period 1995-2009.

Calendar recording of phenological phases was made by using the method developed by Gautier (1978). Observations were carried out every day in spring season (photo 1-3). The beginning of a phenophase is recorded when the plant's development stage reaches 25% of flowers.

Photo 1-3: Phenological phases of plum cultivars

Climatic data (temperature, rainfall) for the years 1960-2008 were obtained from the Meteorological Station in Craiova. For statistical analysis, Microsoft Excel was used. In studying phenology in correlation with environmental factors, the methods used were those recommended in literature.

The dates of flowering starting have been converted into number of days from the 1st of February, an approximate reference of the end of deep pause.

RESULTS AND DISCUSSIONS

Changes in air temperature

In Craiova area, according to data available in Meteorological Station in Craiova, in the last 10 years, the rising trend of air temperature was linear (the annual average), and the variation limits for this indicator were 10.4^0 C in 1999 and 12.4^{0}C in the year 2007. Over the reference period (1960-1990), the differences ranged from -0.2^0 C to 1.8^0 C (Figure 1).

During the reference period (1960 – 1990), the annual average of air temperature in Craiova area was 10.6°C. During the period 1961 - 2008 the temperature has been continuously rising, with linear trend, the confidence interval +- 0.4°C (figure 2). The most interesting characteristic during this time was the relatively strong change of the air temperature over the last 10 years. Rising trend (during 1999-2008) for the air temperature was 0.26°C (figure 3).

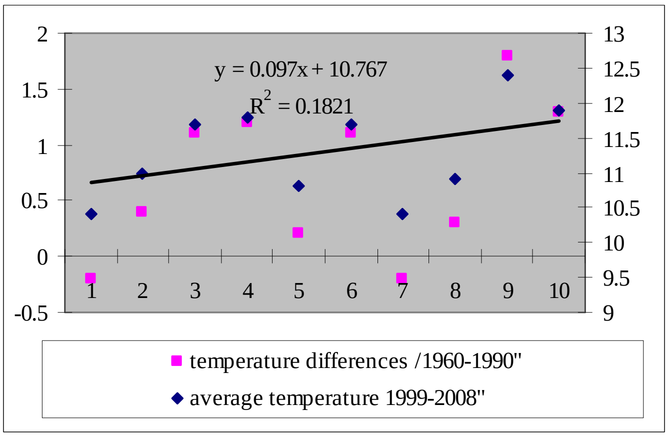

Figure 1: Rising trends in air temperature over the last 10 years

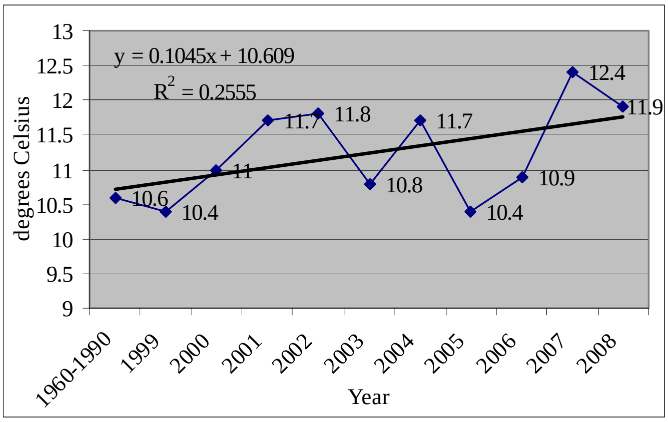

Figure 2: Air temperature (annual average) during 1960-2008

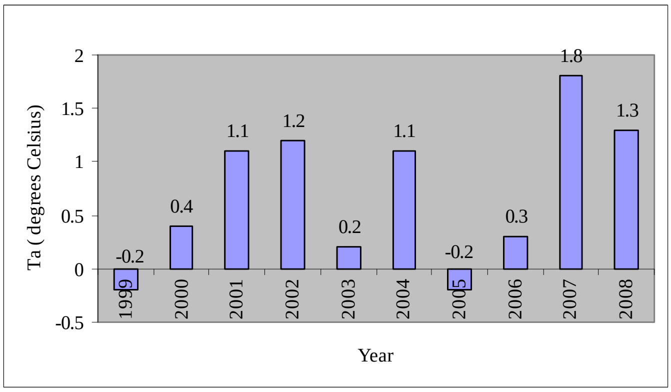

Figure 3: Difference between annual average temperature and the period 1960-1999

In fruit trees, many phenological phases are developing during April and May. April is usually the period of the year when flowering period is developing (for the most species in the area studied). Climatic conditions variability from year to year is causing some fluctuation in the yearly calendar of phenophases. Literature considers that the average air temperature from February to April makes a good climate indicator for phenophases' timing during spring season (and Rötzer Chmielewski, 2001).

The response of plants to temperature varies depending on the species and type of plant. As regards the temperature influence on phenology, according to literature, the correlation between temperature and phenology trends was highest for leaf development in deciduous trees and fruit trees (r =-0.63 and r=-0.46, respectively) (Estrella et al., 2009).

Differences in average temperature (1999-2008), over the months March to May, as compared to the reference period 1960-1990, are presented in Table 1.

Table 1

Differences in average temperature (1999-2008), over the months March to May, as compared to the reference period 1960-1990

YEAR	Months				
	II	III	IV	V	
1999	2.7	0.3	-3.7	1.6	
2000	3.6	0.1	2.3	-0.3	
2001	1.2	2.2	1.2	-0.3	
2002	6.6	4.3	-0.6	2.7	
2003	-4.4	-1.6	-1.2	3.9	
2004	1.5	2.0	1.1	-0.9	
2005	-2.9	-0.9	0	0.3	
2006	-1.2	0.1	0.9	0.2	
2007	3.9	2.8	1.7	2.2	
2008	3.0	3.5	1.2	0.6	
TREND	1.81	0.59	-0.86	1.03	0.25

In February, differences in temperature were recorded ranging from -4.4°C to 6.60°C; in March from -1.6°C to 4.3°C; in April from -3.7°C to 2.3°C; and for May between -0.9°C and 3.9°C. In calculating the rising trend of average temperature for these months, during 1999-2008, the average value found was 0.25°C while the maximum value was recorded in February (1.81°C). Climatic diagrams showed major changes from one period to another. During 1960-1990, a drought period was recorded over the months July to October (Figure 4), the average rainfall ranging from 33.4 mm to 71.2 mm.

In 1999, drought periods were more numerous and longer, from May to September; and humidity deficit was also recorded over February and November (Figure 5), the variation limits were very wide, ranging from 12.7 mm to 107.3 mm of average monthly rainfall. Meteorologically, the year 2008 was particularly different from previous years: much warmer than normally, with very dry periods, or rainfall in excess (July).

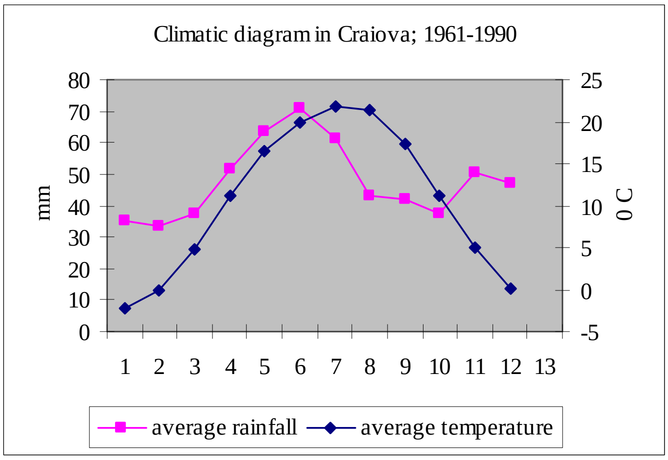

Figure 4: Climatic diagram in Craiova over the period 1961-1990

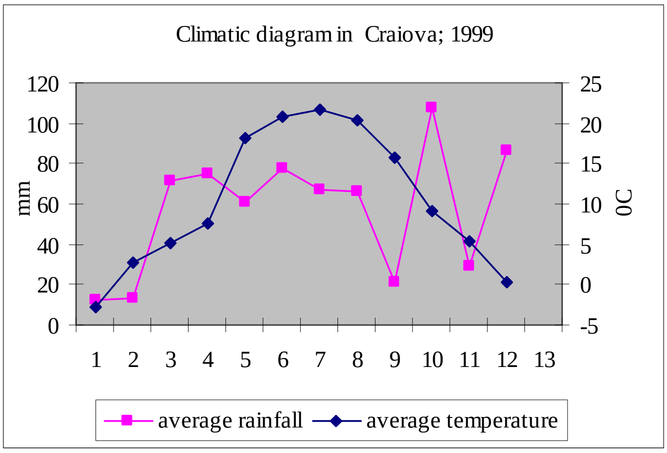

Figure 5: Climatic diagram in Craiova for year 1999

These positive deviations caused an especially warm weather during winter season and an excessively warm weather during summer; with many hot periods from June to August, when maximum temperatures have exceeded 35°C (Figure 6).

In correlation with air temperature evolution in 2008, the recorded rainfall regime has also developed in Craiova. It is noteworthy that August (0.6 mm) and February (4.5 mm) have recorded quite low amounts of rainfall.

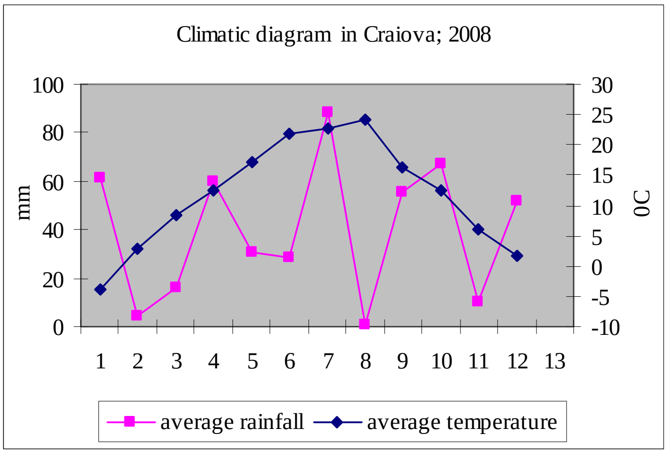

Figure 6: Climatic diagram in Craiova for year 2008

Phenological changes

Phenology is a major bio-indicator of climate change impact on ecosystems (Schleip et al. 2006). Changes in climatic conditions have the strongest impact upon the annual seasonal dynamics of perennial plants, especially at the beginning of their vegetation (Menzel, 2000; Wiegolaski, 1999).

The study is made on the impact of air temperature rise on flowering phenophase in plum tree species. The period 1995-2001 was chosen as reference time period.

Analysis of phenological data recorded over the period 1995-2009 indicated that the flowering phenophase in plum tree during 1995-2001 was conducted over a period from March the 30th ('Ialomita' cultivar) and the first part of May (May the 8th, 'Pescăruş' cultivar), differentiated depending on cultivar and combination cultivar/rootstock.

Differences occurred within cultivars, depending on rootstock, a fact that is confirmed also by other authors (Sestras et al, 2007, Botu et al, 2007).

In 2007 the flowering in plum tree cultivars occurred 12-20 days earlier than normal years. In comparing the periods under study, it was found an earlier flowering time in 2007, a fact explained by higher monthly average temperatures compared to the period under review. The results obtained are in accordance with those in literature, namely that higher temperatures hasten the phenophase development. Assessment of phenological changes in apple tree species made in Lithuania indicated that climate warming over the last decade caused the flowering starting with 4-5 days earlier than the multiannual average (Romanovskaja and Bakšiene, 2009).

In 2009 the flowering in plum cultivars examined was conducted over a period between 15 and 23 April; the flowering duration was approximately eight days. In comparing the period 1995-2001 with the year 2009, it appears that the flowering phenophase started in 2009 around the 15th of April, about two weeks later than the earliest year of period 1995-2001.

The end of flowering in 2009, as compared with the earliest year of period 1995-2001, started two weeks later and two weeks earlier than the latest year of the period 1995-2001. The start of flowering is characteristic for each cultivar or group of cultivars; it is genetically determined and is not correlated with fruit ripening period.

Depending on year's conditions - very early or very late spring season, it was found en bloc shifting of flowering start in all cultivars through time interval March - April - May. Chmielewski et al. 2003 showed that 1°C rise in average air temperature between February and April caused an early beginning of growing season and blossoming of fruit trees by about 5 days. Menzel et al., 2007, showed that the most prominent temperature driven changes in plant phenology are an earlier start of spring in the last three to five decades of, on average, 2.5 days/decade, mainly observed in midlatitudes and higher latitudes of the northern hemisphere.

To trigger the flowering, cultivars need certain amounts of active temperatures, amounts that are different from one cultivar to another. There were found differences of up to 48 days for phenophase of flowering beginning, and up to 30 days for the end of flowering. Regarding phenological changes found in different in the UK, Sparks et al., 2005, shows that response rates to temperature varied between 4 and 12 days earlier for each °C warmer. For statistical analysis, the dates of flowering triggering were transformed into number of days as from February the 1st, which is an approximate reference date for the end of deep pause.

Statistical analysis of the feature named "flowering starting", showed an average time of 71 days over the period 1995-2001, 60 days for year 2007, 59 days for year 2008, and 67 days for year 2009, respectively. The earliest value of flowering was 56 days over the years 2007-2008, while the latest value of flowering was 86 days over the period 1995-2001 (Table 2). Homogeneity of flowering phenophase starting was higher in 2009 (s% = 2.07).

Regarding the distribution of cultivars depending on "flowering starting", it was found that it starts from February 1, having 55-70 days. Given that for Craiova area, the average number of days with frost is about 127 days, and the latest frost occur May, in some years there is a danger of climatic accidents occurring during the plum tree flowering. First frost occurs in autumn, during October 20-30, while the latest frost is in February.

As regards flowering duration, it oscillated between 8 and 18 days within species due to meteorological factors, and it varied from 6 to 12 days due to cultivar. Analysis of data obtained indicated that "flowering duration" is a feature influenced by meteorological factor and genetic factor. Influence of meteorological factor is manifested in different years, causing different durations of time within the same cultivar, between the beginning and end of flowering. In general, the later the flowering develops, the shorter its time duration (year 2009).

Table 2

Statistical analysis of feature „flowering starting"

Parameter	Year			
	1995-2001	2007	2008	2009
Average (in days)	72.0	60.0	60.0	67.0
Standard Deviation	12.13	2.22	2.46	1.39
Minimum (in days) (the earliest value of flowering)	58.00	56.00	56.00	65.00
Maximum (in days) (the latest value of flowering)	86.00	65.00	65.00	69.00
Amplitude (Range)	28.00	9.00	9.00	4.00
Variation coefficient	16.9	3.7	4.1	2.07

Persistence of flowers on tree for a longer time is a positive characteristic of cultivar's adaptation to unfavourable conditions for pollination, a longer duration of flowering, including a higher number of days that are favourable to the flight of bees and securing the pollination.

In conclusion, according to the results obtained, the temperature rise caused changes on relative duration of vegetation phenophases and frequency of heat stress. Therefore, the adaptation strategies to climate changes should focus on the use of drought tolerant cultivars, as well as on matching the phenology with new environmental conditions, to avoid extreme events.

The study of phenology correlated with ecological factors can be used in several ways, namely: use in fruit growing, in making decisions on creating the cultivars able to adapt to current climate changes, to escape climate accidents that are frequent in certain areas and causing sometimes the loss of harvest; and in monitoring the climate changes, knowing that plants are those that are recording and responding to ecological factors.

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