Climate change effects on cherry flowering in northern Greece

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Abstract

Changes in phenology due to a changing environment are of interest because of their impact on fruit set, frost occurrence and final harvest. Bloom dates of sweet cherry cultivars 'Tragana Edessis' (from the local germplasm collection), 'B. Burlat', 'Larian' and 'Vogue' were examined taking climatic parameters in Naoussa (northern Greece, 40°N), spanning the last 31 years (1984-2015). The annual mean temperature of 15.7°C in Naoussa increased by 1.3°C since 1984, confirming the hypothesis of climatic alterations during the last three decades. Cherry flowering was advanced by 5.4 days in 'Tragana Edessis', but only 2.3 days in 'B. Burlat', 1.3 days in 'Vogue' and 0.8 days in 'Larian'. This suggests a trend of more advanced flowering with later and less advanced flowering with earlier flowering cherry cultivars. This confirms results from a temperate zone cool climate cherry growing area in Klein-Altendorf, Germany exhibiting a 4-5 day advancement of flowering in the early flowering and maturing 'B. Burlat'. Due to the unique frost free climate during and after cherry flowering, sufficient chilling accumulation, and reduced cracking incidence, it appears that Imathia and its EU protected origin Rodochori-producing the cherries named 'Tragana Rodochoriou', will be able to provide many parts of Europe with cherries in June, i.e., a time when their regional fruit is not yet available.

Keywords: cherry (*Prunus avium* L.), chilling, climate change, flowering, global warming, phenology

INTRODUCTION

Climate change has been documented worldwide and one of the most affected regions is the Mediterranean area, which has experienced the combination of increasing temperatures and declining precipitation (Hillel and Rosenzweig, 2013). Plant phenological events fluctuated between years and these are strongly influenced by variations in environmental factors such as temperature. Long-term records of phenological data are valuable to estimate the influence of climate variations on plant development and the timing of life cycles (Defila and Clot, 2001).

Advancing trends in bloom dates of temperate zone trees have been documented from historical records. This may be induced due to reduced chilling accumulation (as originally postulated for cherries in the continental climate of Germany), increases in heat unit accumulation (chestnuts in the continental climate in the summer palace in Beijing, China) or changes in both cold (chilling) and heat (forcing) accumulation rates (walnuts in the med climate of the Central valley of California) (Luedeling et al., 2013a, b). Adverse impacts of climate change on fruit production may also result from increased incidence of hail, heavy rain and frost incidence (Bergamaschi et al., 2008).

The present study was undertaken in Imathia (northern Greece, west of Thessaloniki), where together with the nearby prefecture of Pella, are the epicentre (ca. 60%) of Greek cherry production with 11,000 ha (Hellenic Statistical Authority). The cherry growing areas are on the hillsides of mountains Vermio (such as Rodochori, 500 m altitude, producing the EU protected cherries 'Tragana Rodochoriou') and Voras (such as Arnissa, 650 m altitude),

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as well as in low altitude areas (Faniadis et al., 2010). In the present study, the experimental site is characterized by a) a low altitude of 119 m, b) a southerly Mediterranean latitude (40°N), c) a high long-term averaged temperature of 15.7°C, d) annual (mostly winter) precipitation of 724 mm, e) lack of late frost, and f) relatively low incidence of rain during fruit growth resulting in a unique microclimate and enabling cherry cultivation without rain covers, at least for the middle and late maturing cultivars, or frost protection. It is one of the earliest cherry producing regions in Europe that may hence be most at risk from climate change effects.

Although, a number of studies have addressed the occurrence and effects of climate change on forest species (Papadopoulos, 2016; Chrysopolitou et al., 2013), little information has been published on historical changes in the phenological stages of fruit tree or other species in Greece. Climate data and flowering dates from four commercially cultivated cherry cultivars in northern Greece were examined to determine how this particular region in northern Greece is affected by climate change and compare the results to those obtained in other European cherry growing areas.

MATERIALS AND METHODS

Cherry flowering phenology

The beginning of flowering (first bloom) was recorded for the cherry cultivars 'Tragana Edessis', 'B. Burlat', 'Larian' and 'Van' in fully-grown bearing trees maintained at the cherry germplasm collection at the Institute of Plant Breeding and Genetic Resources, Department of Deciduous Fruit Trees (previously known as Pomology Institute) in Naoussa, Imathia, Greece (40°37' N; 22°06' E, 119 m altitude). Flower opening (F1) was recorded between 1984 and 2014, based originally on the Baggiolini scale (Lichou et al., 1990; Baggiolini, 1952), later modified as BBCH scale (Meier et al., 1994). New cherry trees were planted successively to ensure that trees of appropriate age were available at all times.

Climatic data and statistical analyses

Full time series of daily precipitation and mean (T_{mean}), maximum (T_{max}) and minimum (T_{min}) temperatures for the period 1984-2015 were available from an on-site meteorological station (46703 portable hygrothergraph, Turoni, Forli, Italy). Pearson correlation analysis was performed between annual temperature changes in the long-term mean and year, and between flowering date and temperatures using SPSS (SPSS Inc., Chicago, Illinois, USA).

RESULTS AND DISCUSSION

Climate analysis

Greece in south-eastern Europe is classified as having a Mediterranean type of climate, with mild winters and long sunny dry summers associated with maritime coastal influence. The experimental site, however, is located in the northern part of Greece on the foothills of mountain Vermio, characterized by a mild damp climate. The annual T_{mean} from 1984 until 2015 (31-years) was 15.7°C (Table 1; Figure 1). Significant linear regression between temperature and cherry flowering was found (r=0.583, p<0.001), with a temperature change during the year 2001. Nevertheless, when comparing changes in the meteorological data in the last 52 years, between 1963 and 2015 results exhibited a shift in temperature in 1989, which is similar to 1988 documented at Klein-Altendorf, research station of the University of Bonn, in Germany, when comparing 50-year climatic data (1958-2007) (Blanke and Kunz, 2009).

In the present study, the increase in annual T_{mean} was 1.3°C, when comparing the periods 2007-2015 with the 1984-1989 (Table 1). A significant increase of 1.2°C in the annual T_{max} (1.2) (r=0.486; p<0.001) and of 1.7°C in the T_{min} (r=0.687, p<0.001) was also observed, which both compare favourably with the 1.45°C increase in annual temperature over 50 years at Klein-Altendorf, Germany (Blanke and Kunz, 2009).

Table 1. Mean (range) values of annual mean (T_{mean}), maximum (T_{max}) and minimum (T_{min}) temperatures (°C), and precipitation (mm), during the periods 1984-2015, 1984-1989, and 2007-2015 in Naoussa.

Parameter	1984-2015	1984-1989	2007-2015
Precipitation (mm)	690 (418-1131)	615 (418-786)	742.3 (560-1090)
T_{mean} (°C)	15.7 (14.4-17.4)	15.1 (14.9-15.2)	16.4 (14.9-17.4)
T_{max} (°C)	20.4 (18.8-22.1)	19.6 (19.1-20.0)	20.8 (18.9-22.1)
T_{min} (°C)	9.5 (7.7-11.5)	8.9 (8.4-9.3)	10.6 (9.6-11.5)

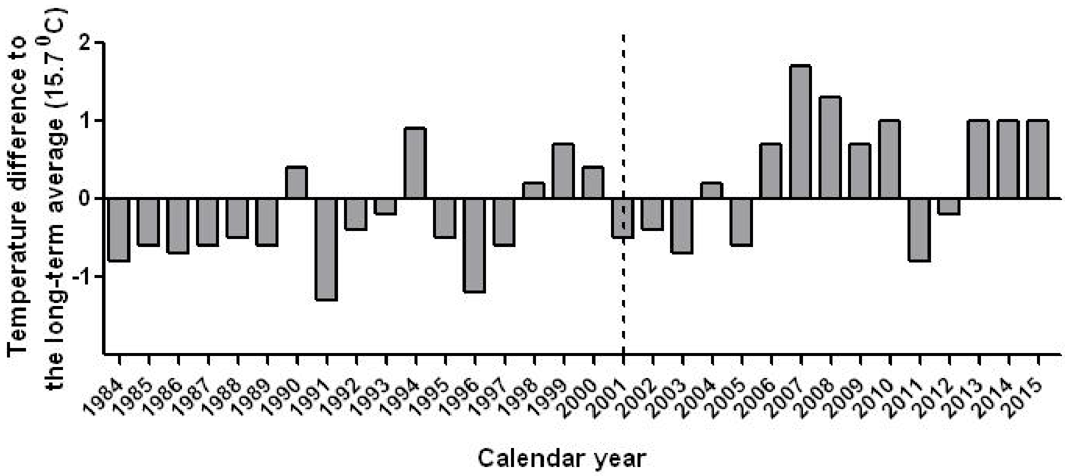

Figure 1. Temperature difference relative to the long-term 31-year (from 1984 to 2015) average temperature of 15.7°C in Naoussa, Greece. The vertical dotted line shows the deflection point or year before and after climate change.

Similar to Klein-Altendorf with its 606 mm over 30 years, there was no significant change in the precipitation during the 31-year period with a long-term average value of 690 mm in Naoussa.

Flowering trends

The changes in flowering initiation of cherry cultivars 'Tragana Edessis', 'B. Burlat', 'Vogue', and 'Larian' during the years 1984- 2015 are presented in Table 2 and Figure 2. Flowering took place 5.4 days earlier for 'Tragana Edessis', but only 2.3 days earlier for 'B. Burlat', 1.3 days earlier for 'Vogue' and 0.8 days earlier for 'Larian'. This range of flowering advancement is within the same range of flower advancement of 4-5 days documented over a similar timeline (30 years, 1985-2015) in the early cherry cv. 'B. Burlat' in the temperate zone cherry growing region (50°N) at Klein-Altendorf, Germany (Luedeling et al., 2013a; Blanke and Kunz, 2017).

Table 2. Advancement of cherry flowering since 1984 in Naoussa, northern Greece.

Cultivar	Flowering	Calendar	Julian days was	Julian days now	Difference (days)
Tragana E.	Late	April 9	99.0	93.6	5.4
Vogue	Medium	April 5	95.6	94.3	1.3
B. Burlat	Early	March 30	89.9	87.6	2.3
Larian	Early	March 30	90.0	89.2	0.8

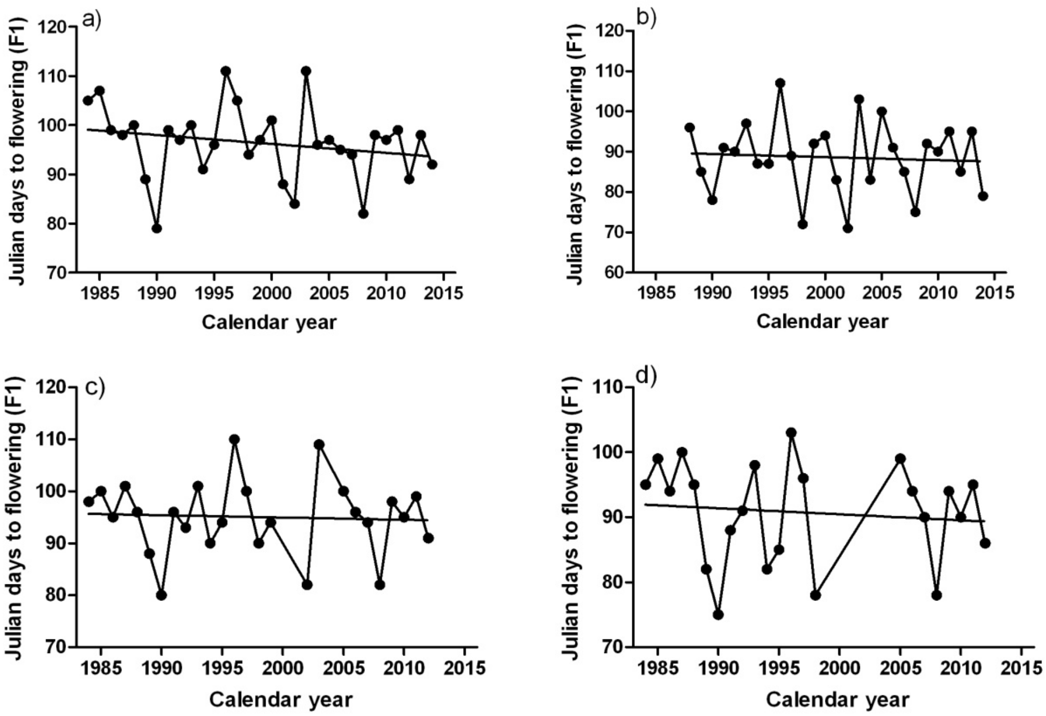

Figure 2. Dates of beginning of flowering dates (F1) in cherry cultivars: a) ‘Tragana Edessis’, b) ‘B. Burlat’, c) ‘Vogue’, and d) ‘Larian’ in Naoussa since 1984, with linear curve fitting.

Table 3 shows a negative correlation between all four cherry cultivars and the T_{mean} in February and March; similar results were also documented by PLS regression in the studies by Luedeling et al. (2013a, b) and Legave et al. (2013). In Naoussa, January is the coldest month of the year and trees are already at the end of their dormancy period, which may be related to the absence of a significant correlation between the T_{mean} in January and flowering.

Table 3. Pearson’s correlation (*r*) coefficients between mean temperatures (T_{mean}) in January, February, March and April and flowering dates (F1) in cherry cultivars ‘Tragana Edessis’, ‘Vogue’, ‘Larian’ and ‘B. Burlat’[1].

	T_{mean}-January	T_{mean}-Febuary	T_{mean}-March	T_{mean}-April
T_{mean}-January	1			
T_{mean}-February	ns	1		
T_{mean}-March	ns	.466**	1	
T_{mean}-April	ns	ns	ns	1
F1-Tragana Edessis	ns	-.582**	-.745**	ns
F1-Vogue	ns	-.671**	-.786**	-.437*
F1-Larian	ns	-.610**	-.702**	-.452*
F1-B. Burlat	ns	-.704**	-.526**	ns

[1]ns, non-significant; * $P<0.05$; ** $P<0.01$.

Chilling requirements of the cherry cultivars were probably satisfied at this time, since abnormalities in flowering have not been documented in Naoussa in any cultivar. Moreover, ‘Ferovia’, a high chill cultivar, regularly bears flowers and fruit in northern Greece.

CONCLUSIONS

A first analysis of the recent 31-year climatic and phenological data for the cherry cultivars 'Tragana Edessis', 'B. Burlat', 'Vogue', and 'Larian' in Naoussa showed a 0.8-5.4 days flowering advancement, and an increase in the annual T_{mean} of 1.3°C, whereas there was no effect on annual precipitation levels.

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