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Climate change effects on cherry production in Northern Greece and Bonn, Germany – adaptation strategies

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Abstract

Collaboration was started between DDFT, HAO-Demeter, Naoussa, in Northern Greece (40°N; 15.7°C; med climate) and INRES, University of Bonn (50°N; temperate zone), Germany to identify climate resilient growing strategies, varieties and/or locations. Cherry was chosen as most sensitive fruit crop to changes in phenology, lack of chilling (cold period during winter), early flowering and sensitivity to frost. The work is based on long term records of both phenological (flowering) data and weather records (frost) at both locations. Whereas initial predictions suggested the med fruit growing as particularly sensitive to climate change, our comparison has shown the opposite result: The annual mean temperature of 15.7°C in Naoussa (Imathia) increased by 1.3°C since 1984 in comparison with an increase by 1.5°C to 9.8°C since 1958 at Bonn. In Naoussa, cherry flowering was advanced by 5.4 days in the late flowering ‘Tragana Edessis’, but only 2.3 days in ‘B. Burlat’, 1.3 days in ‘Vogue’ and 0.8 days in early flowering ‘Larian’ in the last 31 years (1984-2015). This suggests a trend of more advanced flowering with later and less advanced flowering with earlier flowering cherry cultivars. In the temperate zone cool climate of the Meckenheim cherry growing area, flowering was advanced by ca. 7 days, a 3-fold value / effect compared with Naoussa, in the early flowering and early maturing cherry cv. ‘B. Burlat’, which now coincides with the late spring frost. It can be concluded that due to the unique frost free climate during or after cherry flowering, and sufficient chilling accumulation, but rain during fruit maturation, Imathia with its EU protected ‘Tragana Rodochoriou’ cherry, may be climate resilient and able to export cherries in June, i.e. a time when their regional fruit is not yet available, whereas cherry production at Bonn is more prone to flower advancement, frost and less climate resilient and requires intense frost protection technology.

Keywords: Cherry (*Prunus avium* L), Adaptation strategy, Chilling, Climate resilience; Flower; Frost; Phenology.

Introduction

In horticulture, the four major effects of recent climate change, particularly for the med region, include flower advancement, lack of chilling (cold period during the winter as a pre-requisite for flowering), both as a result of warmer winters, as well as heat and drought during summer.

Table 1 Mitigation strategies to climate change in cherry production.

Season	Weather pattern	Physiological disorder	Adaptation strategy
Winter	Warm winter	Lack of chilling (cool winter temps)	Relocate to high altitude
Spring	Late frost	Flower damage	Sprinkler, turbine
Summer	Heat & drought	Soft fruit and fruit fall	Evaporative cooling

Flowering advancement is one of these five major effects of recent climate change of most fruit crops (Table 1). Therein, one of the most affected regions is Greece and generally the Mediterranean area, which has experienced the combination of increasing temperatures and declining precipitation in contrast to Germany with a milder winter but the same precipitation (Blanke and Kunz, 2009b [2].

Plant phenological events fluctuate between years and 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 (Blanke and Kunz, 2009a [1]). Advancing trends in bloom dates of temperate zone trees have been documented from historical records (Blanke and Kunz, 2009b [2]). This may be induced due to reduced chilling accumulation, as originally postulated for cherries in the continental climate of Germany (Luedeling et al., 2013 [3]), and increases in heat units (Kaufmann and Blanke, 2018 [3]). Climate data and flowering dates from four commercially cultivated cherry cultivars in Imathia, 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 for the Meckenheim growing region in Klein-Altendorf, University of Bonn, Germany.

Materials and methods

Data source

Weather data and flower opening (F1) were recorded for the cherry cultivars ‘Tragana Edessis’, ‘B. Burlat’, ‘Larian’ and ‘Van’ in fully-grown bearing trees in Naoussa, Imathia, Greece (37’N, 119 m altitude) between 1984 and 2018 and for cv. ‘Burlat’ at Klein-Altendorf experimental station (50°N, 170 m altitude) of the

University of Bonn, Germany (Blanke and Kunz, 2009b). At both locations, phenological records were taken from fully-grown bearing trees, in Naoussa from trees maintained at the cherry germplasm collection.

Regions

Table 2: Comparison of the climate in the two cherry growing regions.

Parameter	Naoussa, Imathia, Greece	Meckenheim, Bonn, Germany
Latitude	37-40°N	50°N
Precipitation	690 mm	600 mm
Altitude	119 m	170 m
Temp (annual mean)	15.7°C	9.8°C
Cherry cv. ‘Burlat’ typically starts flowering	30 March	12 April
Chilling (CH) until 1 Feb	1100-1300 CH	950- 1350 CH

The Meckenheim fruit /cherry growing region at 50°N and ca. 170 m altitude. near Bonn, Germany, is exposed to strong cold Atlantic winds, but benefits from the buffering Rhine valley. The temperate climate is Continental but mild with an average annual temperature is 9.8°C with ca. 600 mm precipitation almost evenly distributed over the year (Blanke and Kunz, 2009b [1].

At Naoussa, Imathia, Greece, the Department of Deciduous Fruit Trees (previously known as Pomology Institute) is located at 37’N, 220 06’ E at 119 m altitude with an annual mean temperature of 15.7°C (Table 2). The climate is Mediterranean with less rain allocated during the summer months.

Results

Cherry flowering and cultivation system

Fig. 1 shows the type of cherry cultivation in Imathia without crop cover with snow-capped mount Vermio in the background (top left) and in Naoussa (bottom left, P. Drogoudi) without frost protection in comparison with that in Bonn under crop cover (top right at flower and bottom right during fruit maturation; M. Blanke)

In Imathia in recent years including 2019, rain damages during fruit maturation induce fruit cracking, suggesting the need for rain shelters as in Bonn (Fig 1b- right).

Flowering advancement

In all analyses, flowering was the most critical stage affected by recent climate change. The major effect in Imathia appears unfavourable conditions for pollination during flowering, while frost is a lesser problem. Flowering advancement ranged from 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' during 1984-2015 (Fig. 2; Table 1).

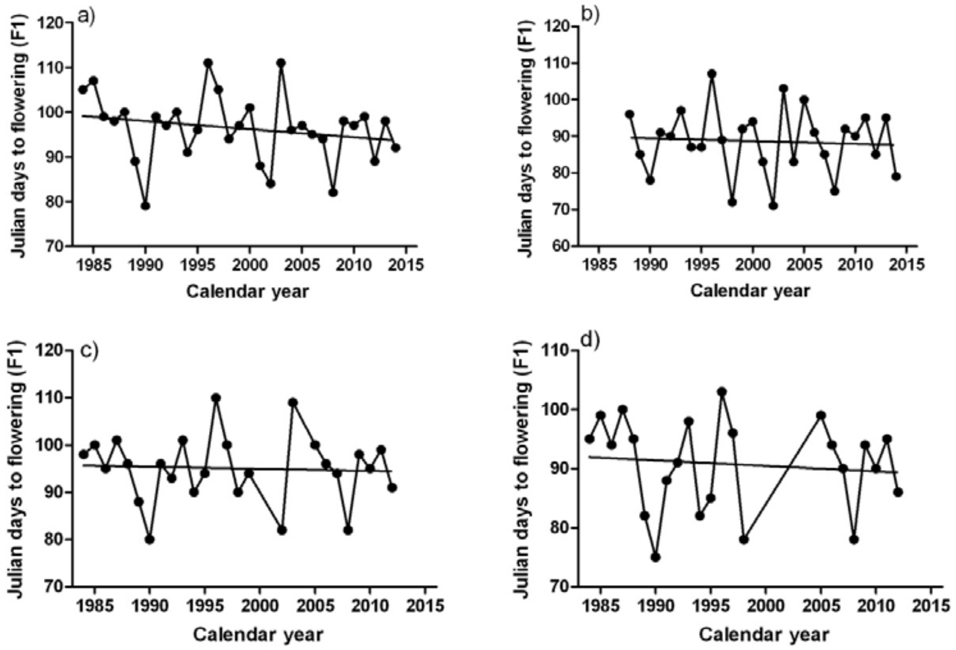

Fig. 2 Dates of beginning of flowering dates (F1) in cherry cvs a) 'Tragana Edessis', b) 'B. Burlat', c) 'Vogue', and d) 'Larian' in Naoussa since 1984, with linear curve fitting.

Table 3: Advancement of cherry flowering since 1984 in Naoussa, Northern Greece.

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

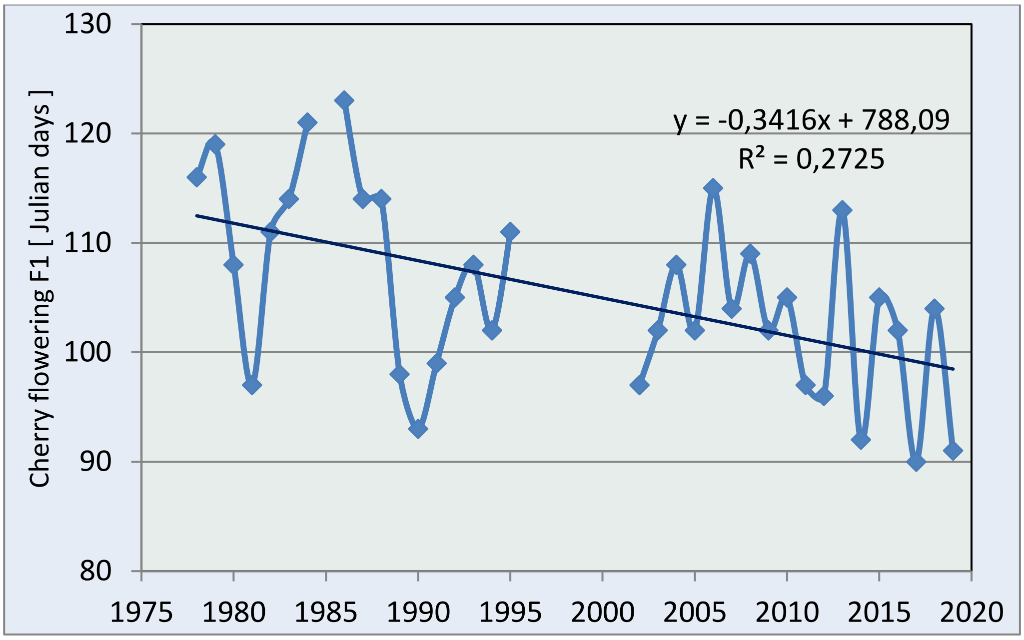

Fig. 3 Dates of flower opening (BBCH 61; F1) of cherry cv. 'Burlat' at Klein-Altendorf (50°N, 170 m asl) since 1978 with linear curve fitting (1 April = 91 Julian days; 15 April= 105 Julian days)

Flowering dates of cv. 'Burlat' in the earlier years (1978-1995) were compared with the later years (2002-2019) at Klein-Altendorf. The largest effect was a ca. 7 days earlier flowering in recent years despite a short 6 year intermediate data gap between 1996- 2001 at the beginning of climate change. This flower advancement is similar to the 10 days observed at the same site in various apple cvs , when comparing the last 20 years with the previous 30 years (Table 4) (Blanke and Kunz, 2009b [2]).

In Naoussa, the range of flowering advancement for the early cherry cv. 'B. Burlat' of 2.3 days is significantly less than the 7 days over a similar timeline (30 years, 1985-2019) in the temperate zone cherry growing region of Meckenheim (50°N) documented at Klein-Altendorf, Germany.

Table 4: Phenological data of cherry cv. 'Burlat' flower opening (BBCH 61; F1) over the last 40 years at Klein-Altendorf.

Period (years)	F1 Cherry flowering	F1 Cherry flowering
1978-1995	19 April	109(Julian days)
2002-2019	12 April	102 (Julian days)
Days earlier flowering	7 days	7 days

Risk of frost, precipitation and change in Tmean

The analysis of the recent 34-year climatic and phenological data in Northern Greece for the cherry cultivars 'Tragana Edessis', 'B. Burlat', 'Vogue', and 'Larian' in Naoussa, Greece showed a 0.8-5.4 days flowering advancement, and an increase in the annual Tmean of 1.3°C, whereas there was no effect on annual precipitation levels. A first analysis of the recent 38-year climatic and phenological data in the Bonn-Meckenheim growing region of Germany for the cherry cultivar 'Burlat' showed a ca. 7 days flowering advancement, and an increase in the annual Tmean of 1.5°C, whereas there was also no effect on annual precipitation levels.

Table 5. Frost incidence as number of frost days (0°C to -2°C) at Klein-Altendorf updated from Kunz and Blanke (2009b [2]) based on 60 years of weather data

Period	March	April	May
1958 - 2019	4.4	2.5	0.4
1958 - 1987	5.0	2.5	0.5

1988 - 2019	3.8	2.8	0.3

Table 6. Frost incidence as an average number of frost days (0°C to -2°C) at Naoussa from 1984 until 2019

Period	March	April	May
1984-2000	4.8	0.5	0
2001-2019	1.3	0.3	0

The risk of frost remains at Klein-Altendorf and now coincides with the cherry flowering at the end of March to April (Table 5) and posing a high risk to cherry production. However in Naoussa, frost decreased dramatically during March (from 4.8 days to 1.3 days) and is scarce during April in the last 30 years. Hence, this region of Naoussa in Northern Greece qualifies as climate-resilient.

Fulfilment of the chilling requirement

Predictions for med countries in general (Luedeling et al., 2013) [4] and Greece in particular included lack of chilling and hence problems with flowering for high chill fruit crops such as sweet cherry, and to a lesser extent, European plum and apple. In the hills of Imathia, chilling requirements of the cherry cultivars are satisfied in most years, 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.

Similarly, chilling was satisfied in the temperate Continental climate of Bonn-Meckenheim fruit growing region in most years (Table 7) for even the high chill cultivars like 'Schneiders späte Knorpelkirsche' (Kaufmann and Blanke, 2018 [3].

Table 7. Chilling available at Meckenheim after Luedeling, Kunz and Blanke (2011) based on 60 years of weather data at Klein-Altendorf.

Period	Chilling hours (CH)	Chilling units (CU)	Chilling portions (CP)
Up to 1st January	955 CH	1160 CU	58.0 CP
Up to 1st February	1356 CH	1527 CU	77.3 CP
Up to 1 March	1727 CH	1883 CU	96.1 CP

Mitigation strategies

Table 8: Mitigation strategies in Imathia (Greece) compared to Meckenheim (Germany)

Climate change effect	Imathia Greece	Meckenheim, Bonn/Germany
Drosophila suzukii	Insect net	Insect net
Lack of chilling	n.a.	n.a.
Frost	n.a.	Frost protection
Pollination problems	Bumble bee hive	Bumble bee hive
Rain during fruit maturation	Rain shelter	Rain shelter

Conclusions

This collaborative research has shown that

1) flowering is the most sensitive stage in fruit cultivation, since it is affected in triplicate by climate change through a) lack/loss of chilling, b) flowering advancement and c) risk of late frost at flowering, where the earlier flowering now coincides with the frost at Bonn (Germany) and d) unfavourable pollination conditions such as temperatures below 11°C and rain, which don't allow the honey bees to fly in Imathia (Greece) (Tab. 8)
2) mountainous regions like Naoussa in Northern Greece appear climate resilient due to a) fulfilment of chilling in most years; and b) lack of late frost during/after flowering.
3) The invasion of the cherry fly *Drosophila suzukii* requires insect netting where applicable

Based on this example, fruit growing regions in Greece or beyond in the med, with mountains (which provide the cool winters with sufficient chilling) like the mountainous Pilion area (central Greece) may be on the list of potentially climate resilient fruit growing areas.

Adaptation strategies may n o t be necessary for such regions, or choice of medium chill varieties (and frost protection only, if its frequency increases), whereas frost protection will be a pre-requisite in the Meckenheim fruit growing region. There, in Klein-Altendorf, the risk of a severe late frost remains or even slightly increases, but not in Northern Greece, where frost was scarce in the last 30 years. Hence, this region Naoussa in Northern Greece qualifies as climate-resilient.

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