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Original Research

Change of Flowering and Harvest Dates of Cherry Varieties with Air Temperature

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Abstract

Sweet cherry is a valuable fruit species that can generate high prices in both export and domestic market. The growth of this species includes the dates of flowering and harvesting for the management of natural risks and quality within important periods. It was examined interactions between full bloom and harvest dates of 23 different sweet cherry varieties and their orchard air temperatures in 2006-2011. The average change between the flowering dates and average of the mean daily temperatures (4.5-6.5 degrees C) is a 4-day difference with a degree temperature change. Similar correlation was found between harvest time and temperature. The time of harvest changed on average 8 days with a degree changing in the average temperature (between 8-11 degrees). In addition, among the varieties evaluated in the trial, Sunburst was determined to be the most stable variety for flowering and harvest time at temperature changes. Parallel to climate changes, the effect of temperatures on floral and harvest time changes will also affect the management of natural risks and quality. It is of great value to make feasibility studies by evaluating the climatic conditions in the growing for many years.

Keywords: *Prunus avium* L., cultivar, phenology, climate change, full bloom

Introduction

Global climate change has a strong impact on the living life of the planet [1-5]. It is necessary to detect and monitor this change with rapid measurable methods and to develop predictable models for its effects. Plant phenology contains very realistic data for plant response to climate change and for strong prediction modelling. Phenology is the science of repetitive events in nature [3]. Phenology also controls many aspects of vegetation by affecting different phenomena [6]. The International Biological Program (IBP) defined phenology as "the study of the timing of recurrent biological events, the causes of their timing with regard to biotic and abiotic forces, and the interrelation among phases of the same or different species" [7]. Plant phenology is one of the important climatic components in terms of the environment. In particular, climate change caused by global warming can have serious impacts on not only for plant and animal life, but also for agricultural production, human health, tourism [8]. In terrestrial ecosystems, the impact of climate change on seasonal activity is evident and manifests itself particularly in the middle and high latitudes. One of the phenomena of high impact potential of global climate change is changes in temperatures. Temperature is the main force of many

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plant growth processes and in many cases higher temperatures accelerate plant growth. Likewise, it leads to earlier the next ontogenetic stage [3]. Vegetation phenology is very sensitive to climate change [6]. In temperate climate fruit species, phenophases are highly affected by environmental conditions. In particular, the right timing during dormancy and flowering is crucial for productivity and quality. Rapidly changing, growing environment conditions will put the future temperate climate fruit species growing at risk. Within the global changes in environmental conditions, the risks of warm winters and frosts in early spring are increasing [1]. However, it was observed that the impact of climate change on phenology was very complex and, in some places, the phenological periods in the spring were later [9, 10].

Cherry has an important place among the temperate climate fruit species and is one of the important species affected by global climate change. Cherry production and consumption are increasing due to the awareness of consumers about health benefits with anthocyanins and hydroxycinamic acids [11, 12]. Global cherry production, from 1997 to 2017, with the main producers of Turkey, United States and Iran has increased from 1.64 million tons to 2.44 million tons [13]. For phenology studies, it is very important to create long-term data, and therefore, cherry orchards with a long life span provide a great opportunity [14]. One of the most important indicators of spring and in most cultures in many temperate climates, cherry blossoming is of great importance. Cherry blooming time with sensitivity to winter and spring temperatures are ideal indicators of climate change in tree phenology [15].

When the temperature changes and global climate change phenology examined were found positive temperature anomalies since 1994 in Turkey. A negative correlation was found between cherry phenological periods and February-May average temperatures with high plant growth. This shows that the cherry phenological periods have shifted early in response to increasing temperatures [16].

In present study, it was investigated the effects of temperatures on cherry blooming and harvest time with 23 different standards and important commercial cherry varieties cultivated in important regions of the world have been revealed phenological periods in Egirdir ecology and the reactions of these varieties to temperature changes between years were explained.

Methodology

Plant Materials

The data collecting was carried out in the field of Eğirdir Fruit Research Institute (37°49'12.95"N; 30°52'13.73"D; 921 m altitude) in the years 2006-2011. Sweet cherry cultivars grafted onto Mazzard (*P. avium* L.) seedling rootstock were planted spaced 6x5 m, in soil conditions characterized by loamy, calcareous (12% total lime), alkaline (pH 8.34). Trees were trained to a central leader and pruned in late winter and standard cultural practices. The orchards were irrigated with drip irrigation, fertilization applications were made with fertigation. In the study 23 standard sweet cherry cultivars were used.

Determination of Phenological Stages of Cultivars

The observations and yields in this study include data between 2006 and 2011 following juvenility. Phenological observations of the cultivars were made following the period of juvenility. The dates were recorded as full bloom and harvest date. The time of 70% of blooms opened was noted as full bloom dates. Fadon et al. [17] characterized the phenology of some sweet cherry varieties and adapted to 97 numerical BBCH codes, and framed flower development within the growth stages. According to researchers, stages (BBCH scale) were defined as follows: full bloom-stage 65. Harvest time, however, was recorded as the date when the cultivars reached harvest maturity according to stage 87 reported by Fadon et al [17].

Collecting Temperature

From 2006 to 2011, full bloom and harvest times of cherry varieties were recorded regularly. In the same period, temperatures were stored with the HOBO data logger in the trial area. In addition, validations were made with the data of the meteorology station located in the same basin as the study area and the perennial (1985-2011) temperature values of the region were obtained from this station. The daily average temperatures from the first day of each year (1 January) total and average temperatures to blooming and harvesting were calculated. The dates were digitized in the same way as the number of days of the year. Thus, it was determined that the cultivars bloomed and harvested on a given day.

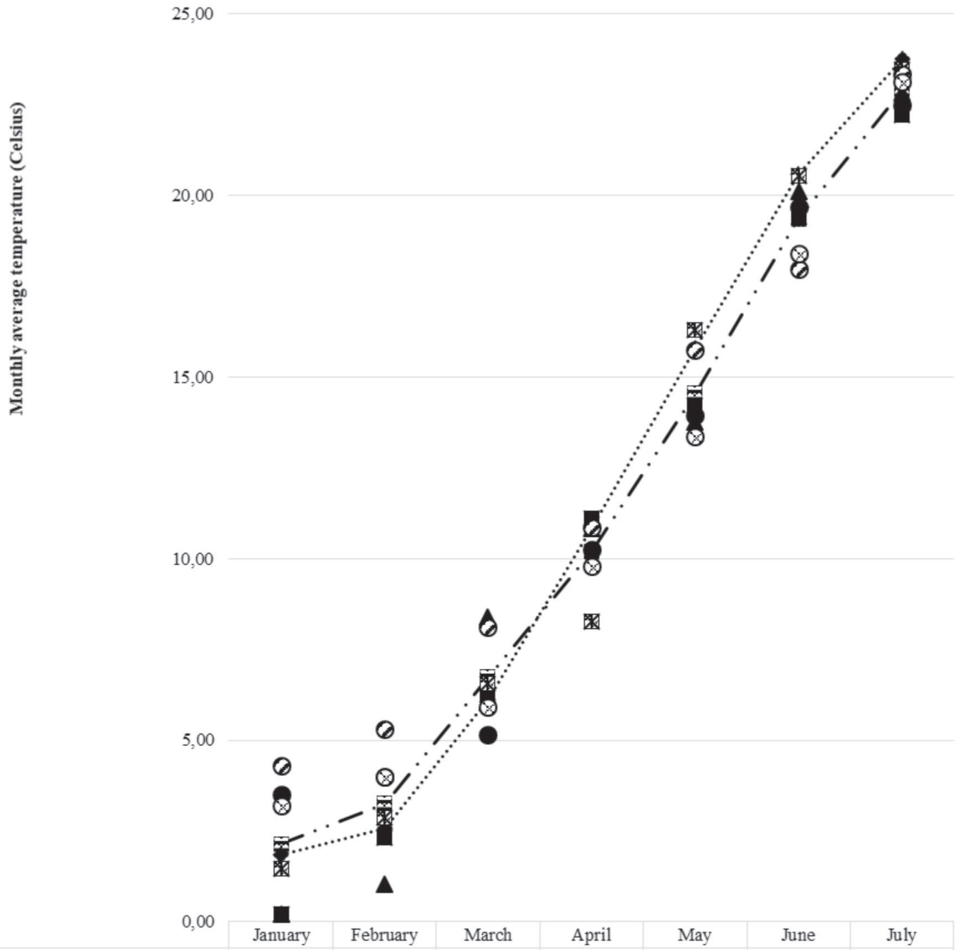
Statistical Analysis

The experimental design was a randomized blocks, 5 replicates using a single tree. Statistical analyses were performed as regression and stability using the JMP statistical software package (vers 8; SAS Inst. Inc., Cary, NC, USA).

Results and Discussion

Temperatures

The perennial climate averages were taken from the Meteorology General Directorate station located in the same basin (Egirdir lake basin, same altitude and same valley) as the study area (Fig. 1). The monthly average temperature of the trial years and average temperature of each trial year are examined in Fig. 1. When the general average of the trial years is examined, it is seen that January (2.14ºC), February (3.26ºC) and March (6.73ºC) are warmer than the perennial averages. In contrast, April (10.19ºC), May (14.55ºC), June (19.35ºC) and July (22.92ºC) produced lower temperatures than the perennial averages. The years are compared with the individual multi-year values; In January, February of 2009, 2010 and 2011, high temperatures were observed. The lowest general average temperature in January-July period was measured in 2006 and the highest average temperature was measured in 2010. In addition, temperature fluctuations were observed to occur more frequently in January, February and March. The frequency of temperature fluctuations decreases further from April (Fig. 1). When the trial area temperature data and the multi-year temperature data of the region were compared, the average of trial years in January, February and March were higher. This has had a significant impact on the dates of bud brake and flowering in the trial area, which has an interior and passage zone ecology. The trend of the temperature is to increase in the period 1971-2012 in Turkey. The upward trend is 3.3ºC/century and 1.3ºC (14.1-12.8) of this has already occurred [16]. Based on the results obtained in our study, the same researchers reported high negative correlation between temperature and harvesting periods of cherry fruit for both regional and Turkey in general.



	January	February	March	April	May	June	July
2006	0,19	2,32	6,26	11,10	14,23	19,40	22,23
2007	1,45	2,86	6,55	8,27	16,29	20,53	23,48
2008	0,19	1,04	8,39	10,83	13,77	20,10	22,84
2009	3,52	4,00	5,16	10,27	13,94	19,70	22,48
2010	4,29	5,32	8,13	10,87	15,74	17,97	23,35
2011	3,19	4,00	5,90	9,80	13,35	18,40	23,13
Average of trial years	2,14	3,26	6,73	10,19	14,55	19,35	22,92
Average for many years	1,86	2,56	6,12	10,81	15,81	20,60	23,77

2006 2007 2008
2009 2010 2011
Average of trial years Average for many years

Fig. 1. The average monthly temperatures from January to July in trail years and the perennial average (1985-2011).

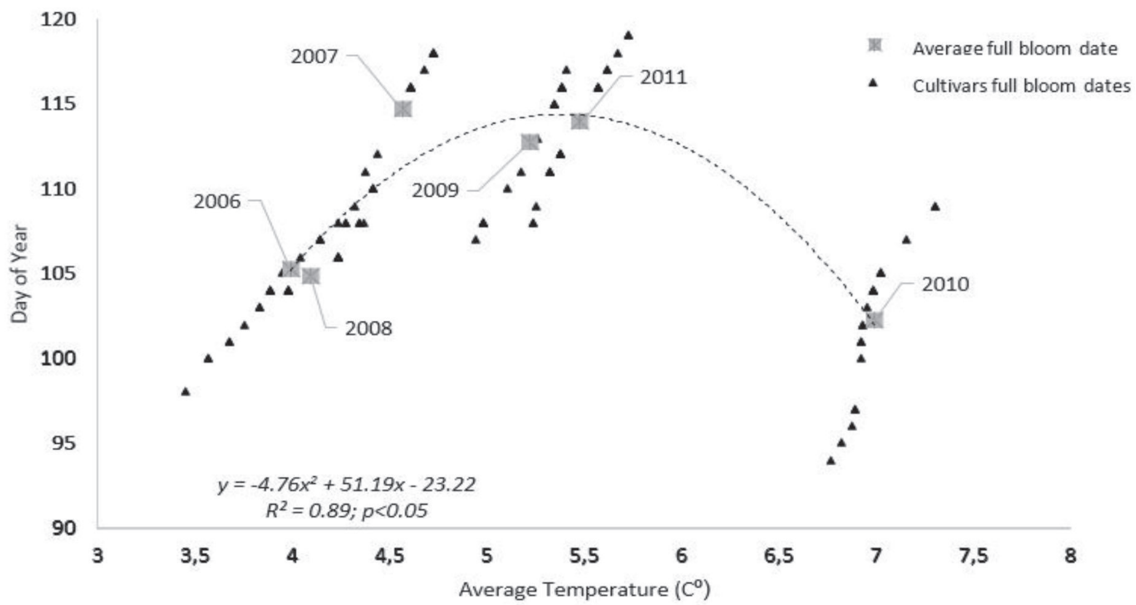


Fig. 2. Relationship between blooming dates-average and mean daily average temperatures to the dates.

Flowering Dates

The average temperature changes between 4ºC (2006) and 7ºC (2010) were correlated with approximately 4 days of phenological difference. The increase in the average temperatures up to 5.38ºC delays flowering, while the higher increases suggest rapid flowering. There was a statistically significant quadratic relationship ($P<0.05$) between flowering time and mean temperatures (Fig. 2).

In addition, the rapid fluctuation of the temperature regime close to flowering affects the flowering time. Blooming dates of the varieties were recorded for six years and digitized and compared (Table 1). Among the recorded dates, the average of the varieties was determined as 102th day in 2010 with the earliest flowering. In addition, the temperature values collected from the parcel during the observation years and the daily temperature totals that occurred until the day of the phenological period were also calculated (Table 1). The cultivars had the highest value at 715ºC in 2010

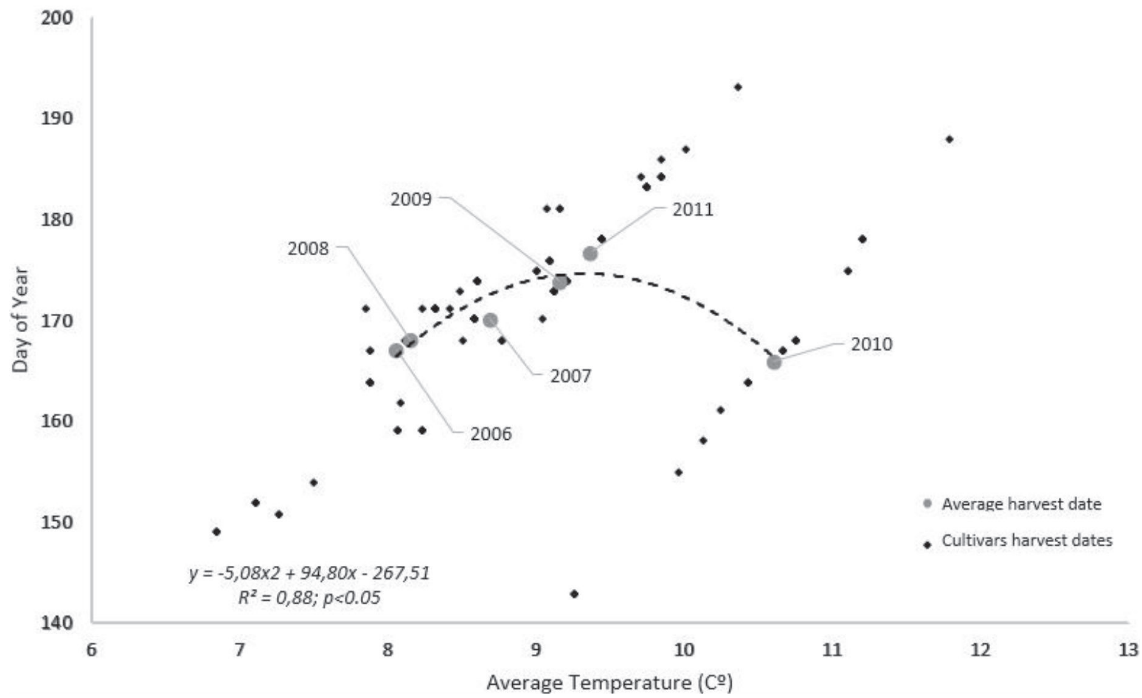


Fig. 3. Relationship between harvest dates-average and mean daily average temperatures to the dates.

Table 1. Total daily average temperature to day of the year for full bloom and cultivars blooming dates (day of the year).

	Day of the year						Av.	Total temperatures (degree)						Av.
Cultivar	2011	2010	2009	2008	2007	2006		2011	2010	2009	2008	2007	2006	
Ferbolus	116	109	116	106	108	104	**110**	646	796	625	449	462	405	**564**
Sweet Heart	108	96	107	100	106	98	**103**	565	660	529	357	449	339	**483**
Veysel	112	102	115	104	116	104	**109**	602	708	615	414	535	405	**546**
Octavia	119	104	116	104	118	108	**112**	682	727	625	414	558	471	**580**
Celeste	116	103	113	106	116	108	**110**	646	716	595	449	535	457	**566**
Rainier	112	101	108	104	109	104	**106**	602	699	539	414	471	405	**522**
Mechlain Haimer	112	105	115	106	116	107	**110**	602	738	615	449	535	443	**564**
Techlovan	111	101	111	104	116	104	**108**	591	699	575	414	535	405	**536**
Sunburst	116	105	116	104	116	107	**111**	646	738	625	414	535	443	**567**
Cultivar 7	114	102	110	106	116	104	**109**	624	708	562	449	535	405	**547**
Silvia	114	105	116	108	116	101	**110**	624	738	625	469	535	372	**561**
Cultivar 3	117	104	116	108	118	106	**112**	657	727	625	469	558	429	**578**
Venüs	109	95	108	104	111	104	**105**	573	648	539	414	486	405	**511**
Lapins	108	97	108	104	108	101	**104**	565	668	539	414	462	372	**503**
Glacier	116	104	117	106	118	110	**112**	646	727	633	449	558	405	**570**
Summit	116	104	116	104	116	107	**111**	646	727	625	414	535	443	**565**
Fercair	111	100	108	106	116	103	**107**	591	693	495	449	535	395	**526**
P.de Bernard	111	94	108	100	112	102	**105**	591	637	539	357	497	383	**501**
Belge	117	107	116	106	116	110	**112**	657	766	625	449	535	486	**586**
Kordia	118	109	116	106	118	103	**112**	669	796	625	449	558	395	**582**
0900 Ziraat	119	104	116	106	118	110	**112**	682	727	625	449	558	486	**588**
Star	112	97	108	104	116	105	**107**	602	668	539	414	535	415	**529**
N.de Meched	116	104	115	106	117	110	**111**	646	727	615	449	547	486	**578**
Average	114	102	113	105	115	105		624	715	589	429	524	420	

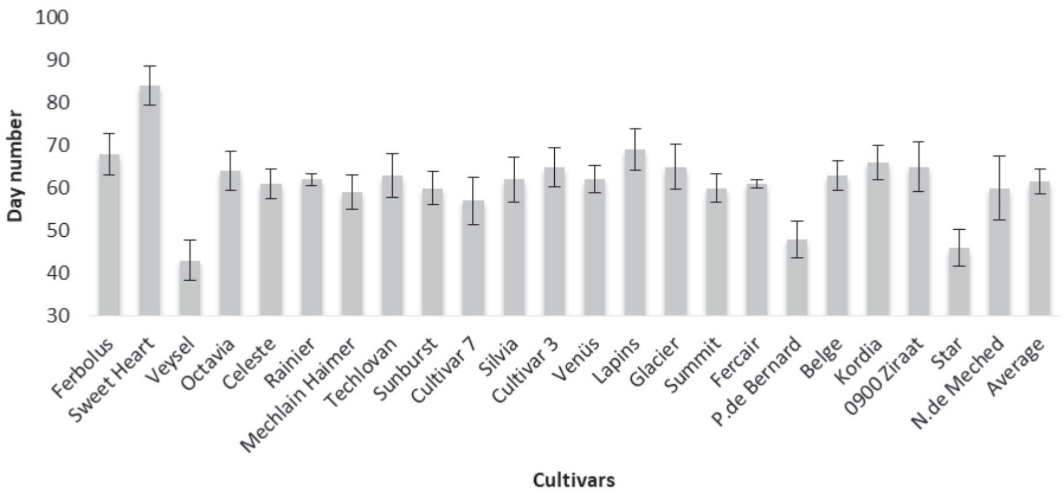


Fig. 4. The mean days numbers of cherry cultivars between blooming and harvest dates (±SD).

Table 2. Total daily average temperature to day of the year for harvest and cultivars harvest dates (day of the year).

	Day of the year						Av.	Total temperatures (degree)						Av.
Cultivar	2011	2010	2009	2008	2007	2006		2011	2010	**2009**	**2008**	**2007**	**2006**	
Ferbolus	184	178	183	181	175	164	**178**	1784	1991	1783	1656	1574	1288	**1679**
Sweet Heart	193	188	187	181	186	181	**186**	1998	2213	1868	1656	1829	1640	**1867**
Veysel	159	143	159	149	151	152	**152**	1307	1323	1282	1017	1097	1077	**1184**
Octavia	178	168	183	174	176	171	**175**	1681	1804	1783	1496	1599	1435	**1633**
Celeste	178	167	173	167	170	171	**171**	1681	1780	1574	1339	1458	1421	**1542**
Rainier	174	164	168	167	170	164	**168**	1599	1707	1471	1339	1458	1288	**1477**
Mechlain Haimer	178	164	173	167	170	164	**169**	1681	1707	1574	1339	1534	1288	**1521**
Techlovan	178	168	173	167	170	171	**171**	1680	1804	1574	1313	1458	1421	**1542**
Sunburst	178	167	173	167	170	171	**171**	1681	1780	1574	1313	1458	1421	**1538**
Cultivar 7	174	158	168	167	162	164	**166**	1599	1596	1471	1339	1309	1288	**1434**
Silvia	178	167	173	167	176	173	**172**	1681	1780	1574	1339	1599	1465	**1573**
Cultivar 3	178	175	183	174	176	171	**176**	1681	1942	1783	1496	1599	1421	**1654**
Venüs	174	155	168	167	170	171	**168**	1599	1544	1471	1339	1458	1405	**1469**
Lapins	184	168	173	174	170	171	**173**	1807	1804	1574	1496	1458	1421	**1593**
Glacier	184	175	183	174	175	171	**177**	1807	1942	1783	1496	1574	1340	**1657**
Summit	178	164	173	167	170	168	**170**	1681	1707	1574	1339	1458	1360	**1520**
Fercair	174	161	168	167	176	164	**168**	1599	1647	1427	1339	1599	1288	**1483**
P.de Bernard	159	143	159	149	151	152	**152**	1307	1323	1282	1017	1097	1077	**1184**
Belge	178	168	183	174	176	171	**175**	1681	1804	1783	1496	1599	1421	**1631**
Kordia	184	178	183	174	176	171	**178**	1807	1991	1783	1496	1599	1421	**1683**
0900 Ziraat	184	178	183	174	175	171	**178**	1807	1991	1783	1496	1574	1421	**1679**
Star	159	143	159	149	154	152	**153**	1307	1323	1282	1017	1154	1077	**1193**
N.de Meched	178	178	173	167	170	164	**172**	1681	1991	1574	1339	1458	1288	**1555**
Average	**177**	**166**	**174**	**168**	**170**	**167**		1658	1760	1593	1370	1478	1347	

at the total daily temperatures that occurred until the flowering period. In 2006 and 2008, the average of blooming at the 105th day was from the early flowering date and the temperature totals were 420ºC and 429ºC respectively (Table 1). This contrasting situation is actually the sudden high temperatures in April (11.10ºC) for 2006 and March (8.39ºC) for 2008 (Fig. 1). The low temperatures in the months of the other temperatures totalled the low overall temperature. In 2006 and 2008, before flowering, the sudden increase in temperature was thought to trigger the flowering rate.

Fluctuations up to 15 days were observed in some cultivars during the experimental years. The average temperature changes between 4ºC (2006) and 7ºC (2010) were correlated with approximately 4 days of difference and there was a statistically significant quadratic relationship between flowering time and mean temperatures. A temperature change of one degree caused an 8-day change in the average harvest dates of the varieties. According to the researchers, the predictions in foliation and flowering for forest and fruit trees were 1.9 to 7.7 days per ºC (2, 18, 19]. The flowering of early-ripening cherry varieties in Germany has improved by 4.7 days/ºC [2, 20]. In addition, due to the warmer winter, cherry production in South-West France was significantly affected and in 2007 it resulted in 30% yield [21, 22]. Sarısu [23] found, in his study that correlates temperatures and fruit set, that when the average temperature between bud burst and petal fall increased by 1ºC, it reduced fruit set by about 4% in trial years. Different researchers have reported that warmer winters may cause delayed spring phenology for some species and occasionally cause abnormal flowering phenology and low productivity [21, 22].

Table 3. The average total daily temperatures between blooming and harvest dates.

Cultivar	Total temperatures (degree; Fub to Harvest)						
	2011	**2010**	**2009**	**2008**	**2007**	**2006**	**Average**
Ferbolus	1138	1194	1158	1207	1112	883	**1115**
Sweet Heart	1433	1552	1339	1299	1380	1301	**1384**
Veysel	705	615	666	603	562	672	**637**
Octavia	999	1077	1158	1082	1041	964	**1053**
Celeste	1035	1064	979	890	923	964	**976**
Rainier	998	1007	933	925	987	883	**955**
Mechlain Haimer	1079	969	959	890	999	845	**957**
Techlovan	1089	1104	1000	899	923	1016	**1005**
Sunburst	1035	1041	949	899	923	978	**971**
Cultivar 7	976	888	910	890	774	883	**887**
Silvia	1057	1041	949	870	1064	1093	**1012**
Cultivar 3	1024	1215	1158	1027	1041	992	**1076**
Venüs	1026	895	933	925	972	1000	**958**
Lapins	1242	1135	1036	1082	996	1049	**1090**
Glacier	1161	1215	1150	1047	1016	935	**1087**
Summit	1035	980	949	925	923	917	**955**
Fercair	1009	954	933	890	1064	893	**957**
P.de Bernard	716	686	743	660	600	694	**683**
Belge	1024	1037	1158	1047	1064	935	**1044**
Kordia	1138	1194	1158	1047	1041	1026	**1101**
0900 Ziraat	1125	1264	1158	1047	1016	935	**1091**
Star	705	654	743	603	619	662	**664**
N.de Meched	1035	1264	959	890	911	802	**977**
Average	**1034**	**1046**	**1003**	**941**	**954**	**927**	

Harvest Dates

A temperature change of one degree between average temperatures until the average harvest date in 2006 (8.07ºC) and 10.60ºC in 2010 caused an 8-day change in the average harvest dates of the varieties (Fig. 3). 45-day harvest time difference was found between the earliest ripening (Star; 143th day of the year) and the latest ripening cultivar (Sweet Heart; 188th day of the year) in 2010. This difference was 29 days in 2006 with the lowest average temperature (Table 2). In general, the order of harvest time between the varieties did not change, but the difference between harvest times was highly affected by the temperature regime.

The year in which the varieties were harvested on average was 2011 with an average of 177 days. The most important factor determining this situation was thought to be the low temperatures in April and May. 2010, 2008 and 2006 were determined as the years of early ripening of varieties. It was interpreted that harvest time was prominent with the high temperature sum of 2010, high April temperatures of 2006 and high temperatures of March, April and May of 2008 (Table 2, Fig. 1).

In the study, it was concluded that the duration between the flowering and harvest were affected by the conditions of the phenophase. Usenik and Štampar [24] found that significantly higher average temperatures in April and May shortened the fruit development period for 7 days in Burlat and 11 days for Germersdorfer. These findings of the researchers support the study that the temperature conditions occurring during fruit development may affect the development process. In addition, the data obtained from our study showed that the responses of the varieties to temperature changes could be different.

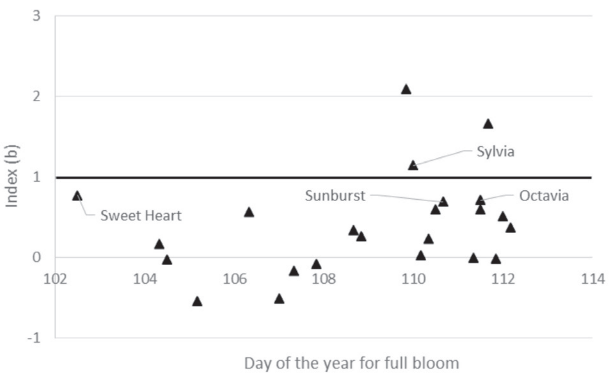


Fig. 5. Stability of varieties in terms of flowering dates.

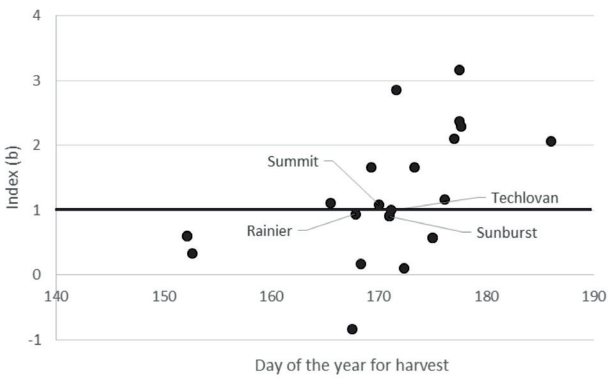


Fig. 6. Stability of varieties in terms of harvest dates.

Duration from Flowering to Harvest

The period from flowering to harvest is one of the important indicators in cherry growing. In addition, climatic events that occur to the production of the basic crop (harvest) from the start of vegetation (full bloom) are important in terms of both productivity and quality. For this reason, the temperature totals from flowering to harvest and the responses of the varieties were evaluated. The year 2010, which had the longest duration with an average of 64 days (Fig. 4), also had the highest total temperature (Table 3). There seems to be an opposite relationship, and was thought to be due to extremely low June temperatures (Fig. 1). In addition, it can be said that the harvest dates of the 2010 varieties spread over time and the gap between them was quite wide. In 2007, when flowering to harvest was the shortest (56 days; Fig. 4), the temperature total was relatively low (954ºC). It may seem that this may explain the condition exceptionally low (8.27ºC), May (16.29ºC) and June (20.53ºC) were extremely high.

Cultivar Stability

Stability analysis was applied on flowering and harvesting dates to determine how the varieties reacted to temperature differences during the trial years and to determine the least responsive varieties. Sylvia, Octavia, Sweet Heart and Sunburst are the least stable varieties that show the least variation from year to year in terms of flowering dates (Fig. 5). Summit, Techlovan, Rainier and Sunburst varieties were the most stable varieties in temperature changes at harvest times (Fig. 6).

The Sunburst cherry variety, which is common in both data analyses, was determined as the most stable cherry cultivar in terms of temperature changes from year to year in terms of both flowering and harvest date.

In this study, the stability analysis of the varieties have been revealed to give more stable reactions over the years. Wenden and Mariadassou [1], attaches importance to strategies to anticipate the changes needed in agriculture and to grow new varieties that are better adapted to future climatic conditions. In our study, the reactions of the cultivars during the experiment were analyzed for stability and it was determined that Sunburst cultivar behaved more stable than the others in terms of harvest and flowering time. For this reason, it is important to make more genetic studies on varieties such as Sunburst and to take part in breeding studies. The speed of the cherry phenological process is influenced by the temperature of the previous months. The shortening of fruit development time will likely reduce cherry fruit quality and yield, but earlier flowering after warmer winter will increase the risk of spring frosts [24]. Such changes can threaten temperate fruit production and therefore affect the global economy [1].

Conclusions

As a result, it can be said that the temperature changes occurring for long years in the temperate climate regions can have significant effects on the phenology of the species and even the varieties that will occur between the phenophases. It is thought that a 1 degree change in the average temperatures until flowering can cause 4-day flowering and 8-day harvest time shifts in species average and these changes will have negative effects on yield and quality. Therefore, more studies are needed to highlight the species and varieties that react less to change. In this study, Sunburst variety was found to be the least responsive to temperature change. It was concluded that it would be important to examine this character and use it in breeding programs.

Acknowledgements

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Conflict of Interest

The authors declare no conflict of interest.

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