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Araştırma Makalesi/*Research Article (Original Paper)*

Fruit Characteristics, Phenology and Yield of Six Sweet Cherry Cultivars

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Abstract: Breeding programs initiated in the early 1900s accelerated the development of sweet cherry cultivars. Up to the present, hundreds of cultivars have been bred and introduced to sweet cherry farming. In the present experiment, six currently popular sweet cherry cultivars, Celeste, Lapins, Glacier, Rainier, Sunburst, and Sweetheart grafted onto mazzard (*Prunus avium* L.) seedling rootstock were compared with each other in terms of fruit quality during 2010 and 2011, phenology over the six-year period from 2006 to 2011 and yield efficiency. Blooming periods of the cultivars differed by years. Differences arising from bud breaking were prominent. Sweetheart regularly started to bloom earlier than all other cultivars. In terms of harvest time, Sunburst and Celeste reached harvest maturity +3 days, Lapins +6 days, Glacier +9 days, and Sweetheart +18 days after Rainier according to average harvest time. Sunburst and Celeste were fruits were heavier, weighing an average of 10 g. All cultivars bigger fruit size than 25 mm. In terms of yield efficiency, Sweetheart was the most efficient cultivar with 0.79 kg cm^{-2}, followed by Celeste (0.56 kg cm^{-2}) and Rainier (0.48 kg cm^{-2}). The lowest yield efficiency, was observed in Sunburst (0.21 kg cm^{-2}). Overall, it was determined that Sweetheart and Celeste cultivars had the most economic potential. These two cultivars have different harvest times, allowing for a mixed distribution of cultivars in production areas.

Keywords: Fruit quality, Performance, *Prunus avium* L., Variety

Altı Kiraz Çeşidinin Verim, Fenoloji ve Meyve Özellikleri

Özet: 1900'lü yılların başlarında oluşturulan ıslah programları ile kiraz çeşitlerinin geliştirilmesi ivmelenmiş ve günümüze kadar yüzlerce çeşit ıslah edilerek kiraz tarımına kazandırılmıştır. Denemede son zamanlarda dünya kiraz tarımında önemle bahsedilen Celeste, Lapins, Glacier, Rainier, Sunburst, Sweet Heart çeşitlerinin kuşkirazı anacına aşılı olarak 2010 ve 2011 yılına ait meyve kaliteleri, 2006-2011 yılları arası 6 yıllık fenolojileri ve verim etkinlikleri karşılaştırılmıştır. Yıllar dikkate alındığında çeşitlerin çiçeklenme periyodları farklılıklar göstermektedir. Özellikle tomurcuk patlaması aşaması ile oluşan farklılık dikkat çekmektedir. Sweet Heart düzenli olarak tüm çeşitlerden daha erken çiçeklenmeye başlarken, diğer çeşitlerde yıllara göre kısmi farklılıklar görülmektedir. Hasat zamanları kıyaslandığında Sunburst ve Celeste Rainier'den ortalama +3, Lapins +6, Glacier +9, Sweet Heart +18 gün sonra hasat olgunluğuna gelmiştir. Kalitenin en önemli belirleyicisi olan meyve iriliğinde Sunburst ve Celeste çeşitlerinin ortalama olarak 10 g ve üzerinde meyve oluşturduğu belirlenmiştir. Tüm çeşitler ortalama 25 mm ve üzeri meyve kalitesini yakalayabilmiştir. Verim etkinliğinde 0.79 kg cm^{-2} ile Sweet Heart çeşidi en verimli çeşit olmuştur. Bu çeşidi Celeste (0.56 kg cm^{-2}) ve Rainier (0.48 kg cm^{-2}) çeşitleri takip etmiştir. En düşük verim etkinliği Sunburst (0.21 kg cm^{-2}) çeşidinde elde edilmiştir. Birim alandan elde edilen kümülatif verim hesaplandığında Sweet Heart ve Celeste çeşidinin yüksek verim ile çiftçi gelirlerine katkı yapabileceği görülmüştür. Bu iki çeşidin hasat zamanlarının farklı olması da üretim bölgelerinde çeşit dağılımının oluşmasına katkı sağlayacaktır.

Anahtar kelimeler: Meyve kalitesi, Performans, *Prunus avium* L., Çeşit

Introduction

For many countries and regions, sweet cherry is a luxury fruit. Climate is the most important factor that limits sweet cherry production (Webster and Loney 1996). During almost every year, demand for sweet cherry is higher than supply. Customers are willing to pay higher prices for sweet cherry fruit (O'Rourke 2007). This factor in particular makes farming of sweet cherry more attractive than other species.

Breeding programs initiated in the early 1900s have accelerated the development of sweet cherry cultivars around the world. Up to the present, hundreds of cultivars have been bred and introduced to sweet cherry farming. Sansavini and Lugli (2005) reported that more than 140 new sweet cherry cultivars had been registered in recent years, the cultivar development aimed at creating differences in terms of quality and harvest time. Breeding programs have been maintained in many countries, taking criteria such as fruit size, fruit quality (high sugar and aroma), productivity, fruit flesh firmness, self-fertility, and dwarfing into consideration (Richards vd. 1995; Brozik 1996; Nikolic vd. 1997; Wustenberghs 1997; Christensen 1998; Claverie et. al. 2008). Self-fertility is one of the most significant criteria in sweet cherry breeding (Saunier 1996) for the last 20 years, considerable progress has been made in the development of self-fertile sweet cherry cultivars (Zhivondov 2006). In sweet cherry, incompatibility is genetically controlled. The responsible genes (such as S_1, S_2, S_3) group with different alternatives (multiple alleles) (Thompson 1996). Cultivars are classified in groups depending on their compatibility behaviors. Cultivars which carry the same two S alleles appear in the same group (Tehrani and Brown 1992).

Global sweet cherry production of the world is 2.294.455 tons. Turkey (494.325 tons), USA (301.225 tons), Iran (200.000 tons), Italy (131.175 tons) and Uzbekistan (100.000 tons) are the top sweet cherry producing countries (FAO 2013). Being the leader in world's sweet cherry production, Turkey exports approximately 10% of per production every year on average. Future plans focus on increasing export of sweet cherry. Ecological compatibility positively affects fruit quality and also provides competitive advantage.

In Turkey, export-worthy sweet cherry production is conducted with a limited number of cultivars. The majority of plantations in commercial sweet cherry production areas are based on the cultivar '0900 Ziraat'. '0900 Ziraat', which is also called "Turkish Sweet Cherry" in international markets, is the most popular local sweet cherry cultivar grown in Turkey. This cultivar produces high-quality fruits but has low productivity and self-incompatibility (Öztürk vd. 2010). Low productivity and dependence on a single cultivar have started to cause problems in competition especially in recent years. For this reason, it is of great importance to seek productive and high-quality cultivars, whether through introduction of existing cultivars or by new cultivar development. The regional performances of the cultivars developed by different breeding studies should be analyzed in order to inform introduction efforts. In this publication, the quality, yield and phenology indicators in the Turkish Lakeland of self-fertile sweet cherry cultivars Celeste, Lapins, Glacier, Sunburst, Sweetheart and self-incompatible Rainier were analyzed. The results may offer new alternatives for plans intended to eliminate the negative properties of 0900 Ziraat and the disadvantages of being dependent on a single cultivar.

Materials and Methods

The experiment was conducted in Eğirdir Fruit Research Institute's experimental area (37°49'12.95"N; 30°52'13.73"E; altitude, 921 m) between the years of 2000 and 2011. The sweet cherry cultivars grafted onto mazzard (*P. avium* L.) seedling rootstock were planted on calcareous (12% total lime), alkaline (pH 8.34) and loamy textured soil. Trees were trained to central leader system. In the plot, drip irrigation and fertigation were used. Besides, for plant protection, integrated control methods were adopted.

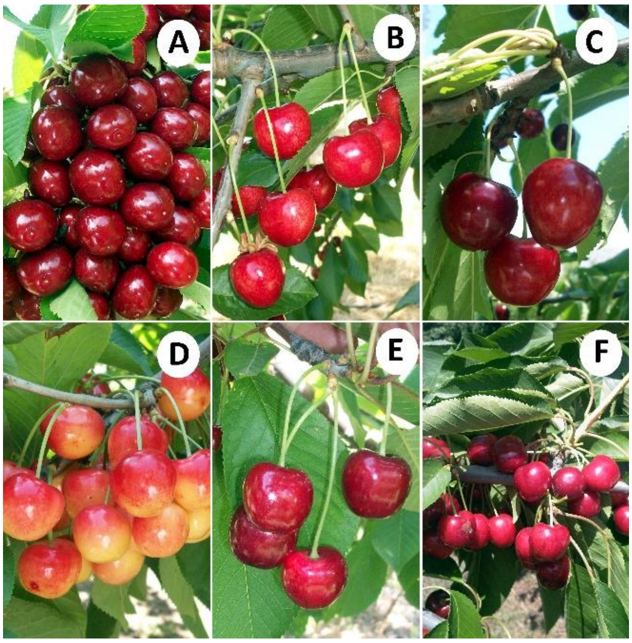

Figure 1. A) Sweetheart; B) Celeste; C) Sunburst; D) Rainier; E) Glacier; F) Lapins

Plant materials

Celeste, Lapins, Glacier, Rainier, Sunburst, Sweetheart (Figure 1, Table 1) cultivars grafted onto mazzard (*P. avium* L.) seedling rootstock were used in the experiment. Sweet cherry trees were planted 6x5m distances.

Table 1. Compatibility group, breeder and genotype of cultivars

Cultivar	Country	Breeder	References	Genotype	References
Celeste	Canada	Summerland	Kappel and Lane 1998	S_1S_4’	Wünsch and Hormaza 2004; Wiersma vd. 2001
Lapins	Canada	Summerland	Lane and Schmid 1984	S_1S_4’	Lacis vd. 2008; Wünsch and Hormaza 2004; Wiersma vd. 2001
Glacier	USA	Washington State University	Lang et al, 1998	S_4’S_9	Schuster, 2012
Rainier	USA	Washington Agric.Exp.Sta.and USDA cooperating	Lang vd. 1998	S_1S_4 (SI;Self-incompatible)	Wünsch and Hormaza 2004; Wiersma vd. 2001; Boskovic and Tobutt, 2001
Sunburst	Canada	Summerland	Lane and Schmid 1984	S_3S_4’	Lacis vd. 2008; Wünsch and Hormaza 2004; Wiersma vd. 2001
Sweetheart	Canada	Summerland	Lane and MacDonald 1996.	S_3S_4’	Wünsch and Hormaza 2004; Wiersma vd. 2001

Phenological observations

The phenological observations in this study cover the data between 2006 and 2011 following juvenile period. Phenological observations were made on the cultivars after juvenile period, and phenological observation dates were recorded as bud burst, first bloom, full bloom, petal fall, and harvest dates. Bud burst and petal fall dates were noted according to Chapman and Catlin (1976). The time of 5% and 70% of blossoms opened was noted as respectively first and full bloom dates. According to Fadon vd. (2015), phenological stages (BBCH scale) were defined as follows: bud burst - stage 53; first bloom - stage 61; full bloom - stage 65; and petal fall - stage 69. Harvest time, however, was recorded as the date when the cultivars reached harvest maturity according to stage 87 reported by Fadon vd. (2015).

Determination of fruit properties

Pomological analyses were performed for the purpose of identifying the differences between cultivars in the last two years of the experiment, 2010-2011. 20 fruits sampled from each replicate were used for analyses. Using standard morphometric methods, fruit weight (*fw*), fruit width (*wf*), fruit length (*lf*), fruit thickness (*tf*), stone weight (*sw*), stalk length and stalk weight (*ws*) were measured, and fruit shape factor (with $lf^2/wf.tf$), stone share (with $ws.100/fw$), and percent of flesh of fruit weight (PFFW; with $[fw-(sw+ws)].100/fw$)) were calculated. Besides, in fruits, soluble solids content (by refractometer, %), total acidity (by titration with 0.1N NaOH; %), fruit juice pH, and fruit flesh firmness (by penetrometer with the tip of 4.5 mm; N) were measured.

Yield

Yield was taken as yield per tree (kg) every year following juvenile period. Average yield per tree, cumulative yield, and cumulative yield per unit area ($kg.ha^{-1}$) were calculated. In the last year of the experiment, cumulative yield per trunk section area ($kg.cm^{-2}$) was determined.

Experimental Design and Statistical analysis

The experiment was designed as randomized blocks with five replications, each replicate having 1 tree. A variance analysis was conducted with the data obtained. Differences between cultivars were tested by means of LSD’s Multiple Range Test.

Results and Discussion

Fruit properties

Fruit size is not only a determinant in the perception of quality (Öztürk vd. 2010) but also the most important quality criterion for sweet cherries, (Milošević vd. 2015). The optimum size for sweet cherry cultivars is considered as 11-12 g (fruit weight) and 29-30 mm (fruit diameter) (Kappel vd. 1996). However, international markets demand a 9 g fruit weight. The difference here is related both to market structure and partially to the fruit shape characteristic of 0900 Ziraat, which is the main sweet cherry cultivar exported by Turkey.

As a result of the pomological analyses, Glacier cultivar had the smallest fruit weight. Compared to other cultivars, Sunburst (11.83 g) formed the biggest fruits in 2010. Sunburst (10.61 g) and Celeste (11.06 g) had heavier fruits than 10 g in 2011. Similar results were obtained in fruit diameter except for Rainier (26.95 mm) fruit diameter that it placed the first statistical group with Celeste (28.06 mm) and Sunburst (27.68 mm) in 2011 (Table 2). But fruit size partially varied by years. Kappel vd. (1998) reported that sweet cherry cultivars could have different sizes in different regions. For example, Sumpaca Celeste was 10.3 g in Canada, 8.7 g in Belgium, 8.2 g in Denmark (Kappel vd. 1998), and 7.8 g in Serbia (Milošević vd. 2015); Lapins was 6.1-7.7 g in Lithuania (Lanauskas vd. 2012) and 11.53 g in Canada (Lane and Schmid 1984); Sunburst was 11.4 g in Serbia (Milošević vd. 2015) and 13.12 g in Canada (Lane and Schmid 1984). In both years of this experiment, the average fruit size of all cultivars except Glacier was found to be suitable for market demand.

Table 2. Fruit properties of sweet cherry cultivars

Cultivar	Fruit weight (g)		Fruit diameter (mm)	
	2010	2011	2010	2011
Celeste	9.79 b**	11.06 a**	27.06 bc**	28.06 a**
Lapins	9.32 b	8.77 b	26.40 c	25.08 c
Glacier	8.45 c	8.43 b	25.06 d	25.50 bc
Rainier	9.54 b	8.96 b	27.84 b	26.95 ab
Sunburst	11.83 a	10.61 a	29.18 a	27.68 a
Sweetheart	9.79 b	8.50 b	26.86 c	25.64 bc

**Means within column with the same letter are not significantly different by LSD’s Multiple Range Test at $P \leq 0.01$.

Having importance in terms of ease of easy harvest, cracking and storage life (Stojanovic vd. 2012), cultivars’ stalk lengths were statistically different that longer stalks were preferred by consumers

(Gjamovski vd. 2016). Celeste, Sunburst and Sweetheart cultivar had longer stalk than other cultivars in both years. Stalk length closely related to genetic structure (Stojanovic vd. 2012). Consumers prefer sweet cherries with large fruit flesh ratio (Gjamovski vd. 2016). There is a statistical difference between cultivars in terms of percent fruit flesh weight and, compared to other cultivars, Sunburst and Celeste offer the opportunity of more fruit flesh consumption. Stone size is one of the most important effects on this percentage. Celeste and Sunburst had also the lowest stone shares (Table 3). Gjamovski vd. (2016) reported that statistical differences were found among sweet cherry varieties' stalk length and indifferences were found among stone sizes of cultivars.

Table 3. Fruit stalk and stone properties and percent of flesh of fruit weight

Cultivar	Stalk Length (mm)		Stone				PFFW (%)	
			Weight (g)		Share (%)			
	2010	2011	2010	2011	2010	2011	2010	2011
Celeste	48.84 a**	43.52 ab*	0.402 cd**	0.396	4.11 d**	3.62 c**	94.51 b**	95.17 a**
Lapins	39.52 c	41.04 bc	0.468 b	0.434	5.05 c	5.00 ab	93.85 c	93.73 b
Glacier	43.48 bc	41.24 bc	0.536 a	0.482	6.35 a	5.71 a	91.87 e	92.59 c
Rainier	40.60 c	38.40 c	0.427 c	0.412	4.49 d	4.66 b	94.34 b	93.81 b
Sunburst	46.40 ab	42.96 ab	0.373 d	0.405	3.15 e	3.85 c	95.52 a	95.14 a
Sweetheart	44.40 abc	45.80 a	0.545 a	0.451	5.57 b	5.28 ab	92.81 d	93.40 bc

PFFW: Percent of Flesh of Fruit Weight *Means within column with the same letter are not significantly different by LSD's Multiple Range Test at $P \leq 0.05$; **Means within column with the same letter are not significantly different by LSD's Multiple Range Test at $P \leq 0.01$.

In this study, sweet cherries were harvested when they acquired the color common to their respective cultivar. The soluble solids contents of the cultivars were between 13% and 17%. No difference was obtained between their fruit juice pHs, but their total acid contents differed (Table 4). Kappel vd. (1996) reported that minimum SSC values were between 17% and 19% in sweet cherries and that fruit juice pH was 3.8. In another study on sweet cherry cultivars, however, SSCs were stated to be between 15% and 17% (Predieri vd. 2004).

Fruit firmness, an important quality parameter is related the storability and resistance to fruit pitting. Fruit firmness is different in sweet cherry cultivars (Wani vd. 2014). It was determined that Lapins (12.19 N) and Sunburst (10.85 N) had firmer fruit flesh than others 2010 and Lapins (12.54 N) was the firmest in 2011. San Martino vd. (2008) reported that Sweetheart and Lapins had firmer fruits although Sunburst and Rainier had low value than standard firmness level.

Table 4. Fruit chemical composition

Cultivar	Soluble solids content (%)		pH		Total acids (%)		Firmness (N)	
	2010	2011	2010	2011	2010	2011	2010	2011
Celeste	13.22^{ns}	16.08^{ns}	3.84^{ns}	3.52^{ns}	0.69 cd**	0.57 bc**	9.30 b**	9.47 bc**
Lapins	14.52	15.44	3.90	3.53	0.76 bc	0.55 c	12.19 a	12.54 a
Glacier	15.30	15.38	3.95	3.74	0.81 b	0.70 a	7.65 cd	7.74 c
Rainier	13.16	16.58	3.79	3.57	0.90 a	0.69 ab	6.67 d	7.74 c
Sunburst	16.34	16.36	3.91	3.66	0.66 d	0.82 a	10.85 a	10.32 b
Sweetheart	17.12	15.04	3.67	3.75	0.88 a	0.73 a	8.23 bc	8.67 bc

ns not significant; **Means within column with the same letter are not significantly different by LSD's Multiple Range Test at $P \leq 0.01$.

Yields

Subsequent to juvenile period, cultivars' tree yields were recorded. There were significant differences between cultivars' yields at the end of the experiment. Compared to other cultivars, Celeste and Sweetheart had higher cumulative yield (kg.tree^{-1}) (Figure 2D). Of all cultivars, statistically two groups emerged in terms of trunk section area. Glacier and Celeste had the widest trunk, while other cultivars statistically fell into the second group (Figure 2A).

Sweetheart cultivar had the highest yield efficiency with 0.79 $kg.cm^{-2}$, followed by Rainier (0.48 $kg.cm^{-2}$) and Celeste (0.56 $kg.cm^{-2}$). The lowest yield efficiency was obtained in Sunburst (0.21 $kg.cm^{-2}$) (Figure 2B). Upon the calculation of cumulative yield per unit area, Sweetheart (72.21 $t.ha^{-1}$) and Celeste (66.92 $t.ha^{-1}$) were obtained to have the potential of contributing to farmers' income with high yield (Figure 2B). These two cultivars have different harvest times, allowing for the distribution of cultivars in production areas.

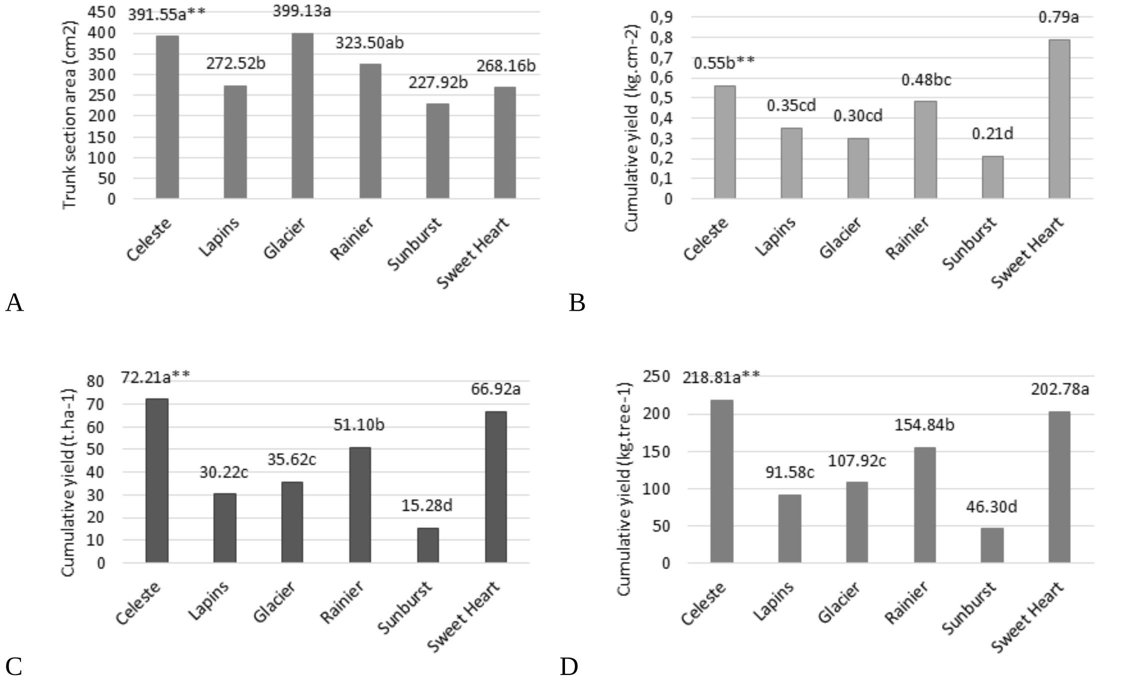

Figure 2. Yield efficiencies of cultivars; **Means within cultivars with the same letter are not significantly different by LSD's Multiple Range Test at $P \leq 0.01$.

Phenological properties

The average duration from bud burst to petal fall was generally close to each other for all cultivars, but Lapins (27.50 days) stood out as the one having a shorter blooming period than other cultivars. Given the six-year averages, it is possible to state that the blooming period of sweet cherry cultivars is approximately one month (Table 6). Sunburst and Celeste bloomed and matured almost at the same date. When full bloom dates are compared according to six-year averages, it is seen that Sweetheart bloomed earlier but Glacier bloomed partially later than others (Table 5).

Table 5. Phenological observations (average, 2006-2011)

Cultivar	Duration from bud burst to petal fall (days)	Duration from full bloom to maturation (days)	Phenological dates				
			Maturation	Bud burst	First bloom	Full bloom	Petal fall
Celeste	30.83	60.67	20 June	31 March	16 April	21 April	1 May
Lapins	27.50	69.00	23 June	29 March	10 April	15 April	26 April
Glacier	31.33	65.17	26 June	1 April	16 April	22 April	2 May
Rainier	30.17	61.50	17 June	29 March	11 April	17 April	28 April
Sunburst	30.33	60.33	20 June	1 April	16 April	21 April	1 May
Sweetheart	31.00	83.50	5 July	24 March	9 April	13 April	24 April

Sweetheart (83.50 days) was found to have the longest duration according to six-year averages. In terms of harvest time, Sunburst and Celeste reached harvest maturity +3 days, Lapins +6 days, Glacier +9 days, and Sweetheart +18 days after Rainier on the average (Table 5).

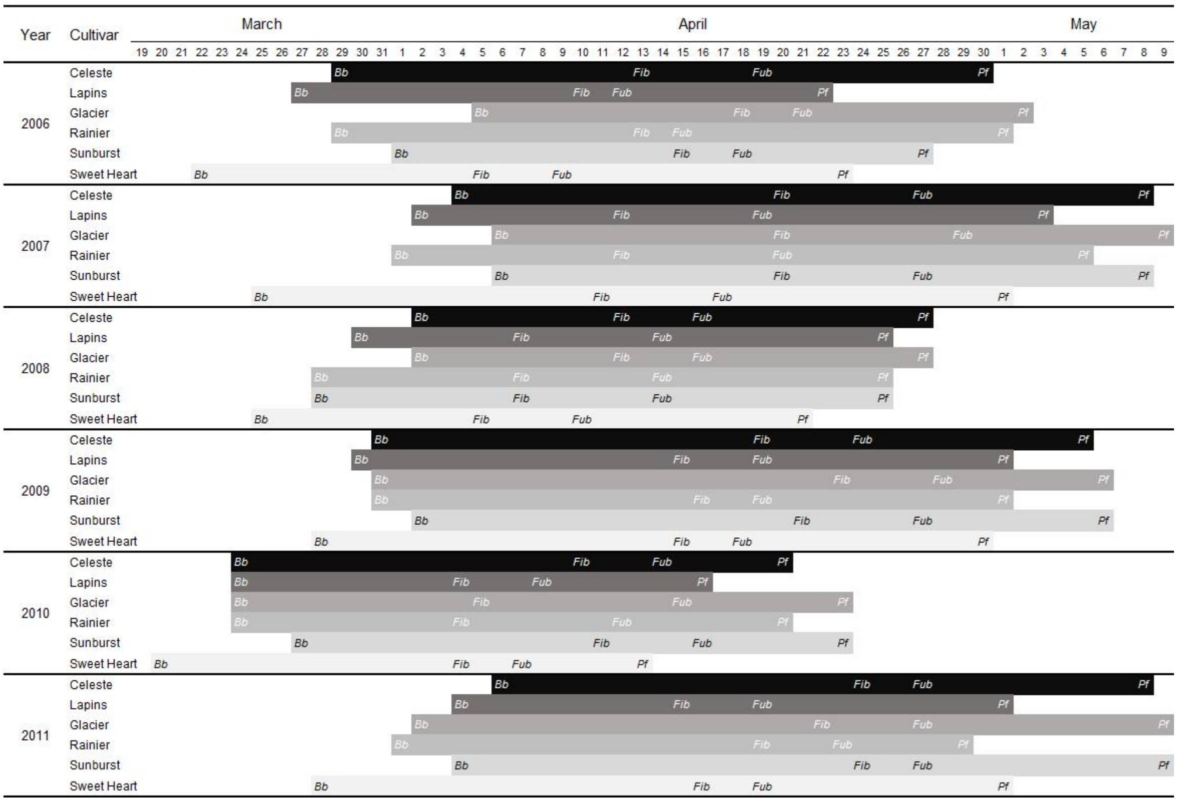

Figure 3. Flowering period of sweet cherry cultivars in consecutive six years. *Bb* Bud burst, *Fib* First bloom, *Fub* Full bloom, *Pf* Petal fall.

All the cultivars had different blooming periods during this study. In particular, the difference arising from bud breaking stood out. Sweetheart regularly started to bloom earlier than all other cultivars, which partially differed by years in this regard. For example, Glacier generally came up later than Celeste but entered into the stage of bud burst earlier in 2011 (Figure 3). Whiting vd. (2015) reported that there was variability in model parameters as a function of year and genotype. Therefore, a need to further advance the development of these models as more experimental data sets become available.

Conclusions

Glacier cultivar had the smallest fruits. Generally Sunburst and Celeste had heavier fruits than others. Rainier fruit diameter that it placed the first statistical group with Celeste and Sunburst in 2011. Celeste, Sunburst and Sweetheart cultivar had longer stalk than other cultivars in both years. Sunburst and Celeste offer the opportunity of more fruit flesh consumption. It was determined that Lapins and Sunburst had firmer fruit flesh than others 2010 and Lapins was the firmest in 2011. Sweetheart cultivar had the highest yield efficiency, followed by Rainier and Celeste. The lowest yield efficiency was obtained in Sunburst. Sweetheart regularly started to bloom earlier than all other cultivars, which partially differed by years in this regard. In terms of harvest time, Sunburst and Celeste reached harvest maturity +3 days, Lapins +6 days, Glacier +9 days, and Sweetheart +18 days after Rainier on the average.

As a conclusion, six different sweet cherry cultivars evaluated as grafted onto mazzard (*P. avium* L.) seedling rootstock under Turkish Lakeland conditions are thought to make significant contributions to productivity and distribution of harvest time. It will be possible to ensure income growth with high productivity, without compromising fruit quality much. Furthermore, these cultivars, which grow to maturity at different times, have a maturity period of up to 20 days. Especially Sweetheart and Celeste will boost the market thanks to their difference in terms of productivity and harvest time.

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