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Phenological Development Stages and Effective Temperature Total Demand in Bursa Siyahı Fig Variety

Abstract

Temperature is one of the ecological factors limiting yield and quality in the care of the region where fig will be grown, as in many fruit species. The effective temperature total demand is one of the important parameters in determining the cultivation potential of a fruit species in any region. Temperature values are needed for the establishment of new orchards in the commercially important Bursa Siyahı fig variety. This study was carried out with the aim of determining the effective temperature total demand of Bursa Siyahı fig variety in Aydın conditions between the years 2019-2021. Although the sum of the effective temperature from bud burst to main crop ripening date on years, it was between 1314 °C-days, and the average of three years from bud bloom to leaf fall was 2506.18 °C-days. According to the BBCH scale, the main crop ripening date was 207 ± 2 days and 219 ± 2 days, although it varied between years. The total effective temperature during the harvest period was 1.040,07 °C-days, on average over three years. Optimum climate values should be taken into account in the garden facilities to be established in different regions with the table Bursa Siyahı fig variety, which has a high export value and economic importance.

INTRODUCTION

As a subtropical climate plant, fig grows in places with an annual average temperature of 18–20 °C (Aksoy et al., 2001). Turkey, one of the most important fig gene centers is the world leading producer of fresh and dried figs. The five countries that have come to the fore in terms of fresh fig production are Turkey, Egypt, Morocco, Algeria and Iran, respectively. According to 2020 data, 320.000 tons of world fresh fig production,

which is 1,264,943 tons, is produced by Turkey (FAOSTAT, 2021). It is reported that fig trees show a general distribution in Aegean, Marmara, Southeastern Anatolia, Black Sea, Mediterranean, Central Anatolia regions and some microclimate areas in Turkey (Aksoy, 1981). Fig production in Turkey is carried out with 11,536.630 trees on an area of 536.935 decares. Fresh fig yield per tree is 31 kilograms (TURKSTAT, 2021).



Figure 1. Ratios of some Provinces in total production of fresh figs in Türkiye (TURKSTAT, 2021)

Figs, are strongly affected by climatic conditions. For this reason, 70% of the world's fig production is concentrated in the countries on the Mediterranean coast (Arpacı, 2017). Although fig production can be made in every region in Turkey, high quality dried figs are grown in the Büyük and Küçük Mander in the Aegean Region due to their ecological demands such as climatic conditions, especially temperature, humidity and wind conditions during fruit ripening and drying season. The most preferred among the varieties produced in the Sarılop fig variety, which stands out with its many features, and it is grown in other varieties such as Bursa Siyahı, Göklop, Yeşilgüz, Morgüz and Bardacık (Anonymous, 2018). In recent years, plantations of Bursa Siyahı fig variety for fresh consumption have been increasing in Aydın. Temperature is one of the most

important ecological factor in order to realize economical fruit growth in a region (Boyacı, 2020). The sum of low and high temperatures in the period of compulsory winter rest in fruit growing, the beginning of development that starts with bud burst and the end of development until defoliation is of great importance in the selection of species and varieties in the region where fruit growing will be made (Özçağırın et al., 2003). It is important to know the phenological development stages in terms of determining the time in cultural processes, and it is predicted that it will provide yield and quality increases. Growth temperature totals are widely used to determine the phenological developmental stages of plants in different species in the world (Pérez-Pastor et al., 2004). As an important export product, Bursa Siyahı fig variety has started to be produced in different regions in order to

increase the production amount. The fig variety, which was first grown in Bursa and its surroundings, has spread to an important area including the Aegean and Mediterranean Regions now (Çatmadım, 2014; Çalışkan et al., 2020; Tangu et al., 2021). Aydın Province is important for the cultivation of this variety outside of its origin. In another respect, the determination of new production areas depending on the changing climatic conditions is important for figs, as it is for many fruit species. Determining the effective temperature total demand will contribute to the determination of new regions to be produced.

MATERIAL and METHODS

This study was carried out for 3 years (2019, 2020 and 2021) in the Bursa Siyahı land, which is located in the central operation of the Fig Research Institute Directorate, located in the Erbeyli District of Aydın Province Incirliova District. The trees used in the experiment were 9 trees for each variety and the trees were established in 2014.

Variety feature

Bursa Siyahı: The variety originating from the Marmara Region is most commonly grown in the Bursa region. It is produced for fresh consumption. The

development of the tree is strong and broad. Bursa Siyahı fig variety is Smyrna type, and the main crop, needs absolute pollination. It does not produce first crops. Fruit ripening continues from the beginning of August to mid-October in the Aegean Region, and from the beginning of September to mid-November in the Bursa region. The fruits are large and round in shape. The fruit shell color is dark purple or purplish black. Pulp color is dark red. Fruit has a short neck and the peel is easily and beautifully peeled off. The shell structure is durable, the fruit flesh is tight-textured, and it is a variety with good road resistance. Ostiol opening is small. There are no scratches and cracks peculiar to the variety on the shell. Bursa Siyahı is a good quality table variety with large, flamboyant, rind and interior color (Aksoy et al., 2001; Özen et al., 2007).

Features of the trial site

The climate data of the relevant years of the experiment are given in Tables 1. The climate data for the relevant years were obtained from the climate station of Fig Research Institute Directorate and were prepared as water years (USGS, 1911). The geographical location of the trial site is located at 37.86391021 north latitude and 27.66327703 east longitude, and its height above sea level is 48 m.

Table 1. Climatic data of the trial site

Climate data	Year	Water Year											
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Agt	Sep
Rainfall [mm]	2019	23.2	179.6	131.4	268.8	40.6	29.6	113.2	19	35	0	0	16.2
	2020	29.6	134.4	122.6	83.4	116.2	76.2	53.2	66.8	0.4	0.0	5.4	4.0
	2021	46.6	2.4	134.4	123.8	32.2	68.8	8.6	0.0	0.8	0.0	0.2	8.4
Temp. [°C]	2019	18.1	13.5	7.8	8.2	9.8	12.6	15.5	20.8	26.4	27.7	28.6	23.4
	2020	20.0	15.2	9.4	6.4	9.5	12.5	16.1	21.2	24.4	29.2	28.4	25.6
	2021	19.7	11.7	11.2	9.4	10.5	10.4	16.3	22.6	21.8	30.3	29.3	24.0
Relative humidity [%]	2019	73.1	75	82.7	82.3	76.9	67.5	63.7	60.1	56.5	48.5	48.3	61.7
	2020	72.0	81.4	85.3	76.8	78.5	75.3	68.2	59.2	56.8	47.5	47.5	57.5
	2021	68.4	69.7	84.2	82.7	71.3	67.9	58.8	48.6	43.1	42.9	41.4	48.0

Method

The trees were planted on an open vase system, and the pruning intensity was carried out according to the principles of Belge (2019) and Özkul (2019) applied in

classical cultivation, and the trial site was irrigated with a drip irrigation system according to the principles of Mutlu et al. (2022). Phenological observations on the basis of varieties were evaluated according

to the observation principles of Eroğlu (1982), Aksoy (1991) and Meier et al. (1991) BBCH scale.

Determination of effective temperature total demand

Necessary phenological observations were made on 9 trees with 3 replications and 3 trees in each replication. The effective temperature total requirements were determined according to different phenological stages, including bud burst, foliation beginning, date of fruit birth (main crop), full foliation, fruit ripening and defoliation date.

$ETS = \sum (T - T_t)$ calculated with (ETS= Effective temperature sum, T= Average daily temperature, T_t = threshold temperature)

The °C-day method is used in the effective temperature sum calculations; In many fruit species, the threshold temperature is taken between 5°C and 12°C (Amerine and Winkler, 1958; Brooks and Olmo, 1972; Richardson et al., 1974; Reynier, 1982; Hauagge and Cummins, 1991; Martinez et al., 1999; Bohro et al., 2015; Ruiz et al., 2018; Aktürk and Uzun; 2019; Boyacı, S., 2020). As a subtropical fruit species, the temperature threshold value of 12 °C used in figs and olives was used (Motisi et al., 2008; Tan et al., 2018).

RESULTS

Phenological observations

The phenological observations of the Bursa Siyahi fig cultivar of the relevant years are given in Table 3. As can be seen in Table 3, the bud burst date changes on a yearly basis, but takes place as of the second week of March. According to the data for 2021, bud burst occurred on

March 22, and the earliest bud burst occurred on March 10, 2019. Although full foliation varied between years, it took place between 24 March and 8 April. In 2019, when the earliest bud burst took place, the foliation beginning took place on March 24, earlier than in other years (Table 3). Although the full foliation and main crop birth dates varied from year to year, it occurred in the third week of May. The pollination process was generally carried out in the first week of June (Belge, 2018; Özkul, 2019). Full foliation in figs is accepted as the main crop's birth date (Aksoy, 1991). Even though the bud burst and beginning of leafing date in 2019 was earlier than in other years, full foliation took place on 21 May, close to other years. The date of full foliation/main crop birth was realized in the third week of May in the years of the study (Table 3). The fruit ripening date was realized in the last week of July and the first weeks of August in the years when the study was conducted. The earliest fruit ripening date was July 26, 2021, as shown in Table 3. Fig is a type of fruit that is harvested gradually, unlike many other fruit types. The duration of the harvesting period is important in terms of labor costs. In the years in which this study was carried out, the period between the first ripening fruit and the last ripening fruit was between 73 and 90 days (Table 3). In this study, although there was a day difference between the years as the leaf fall date, it took place in the first week of December. The defoliation date was accepted as the date that fifty percent of the leaves were shed, and generally took place in the first weeks of December (Table 3).

Table 3. Phenological observations of Bursa Siyahi fig variety

Year	Bud Burst	Foliation Beginnig	Full Foliation Date of Fruit Birth	Fruit Ripening Date	Harvesting Period (days)	Defoliation Date
2019	10 March ±2	24 March ±3	21 April ±1	4 August ±3	73	10 December ±2
2020	23 March±2	3 April ±3	19 April ±2	6 August ±2	79	4 December ±2
2021	22 March ±2	8 April ±2	19 April ±3	26 July ±2	90	6 December ±2

± number of days
Fruit: Main crop(summer crop)

As can be seen in Table 4, the development stages of the BBCH scale were determined. In the aforementioned evaluations, January 1 was accepted as the first day (Meier et al., 1991). As can be seen in Table 4, there are 147 ± 3 days between bud burst and fruit ripening date in 2019. In this study, when the average of

three years is considered, the earliest bud burst occurred in 2019, and the fruit ripening date was between 207 and 216 days. As can be seen in Table 4, there are 256 to 275 days between the bud burst and defoliation date, although it varies on a yearly basis.

Table 4. Bursa Siyahı fig variety BBCH scale development stages

BBCH Developmental Stage	2019		2020		2021	
	Days	Date	Days	Date	Days	Date
Bud Burst	69±2	10 March ±2	83 ±2	23 March ±2	81 ±2	22 March ±2
Foliation Beginnig	83 ±3	24 March±3	94 ±3	3 April ±3	98 ±2	8 April ±2
Full Foliation / Date of Fruit Birth	111 ±1	21 May ±1	140 ±2	19 May ±2	139 ±3	19 May ±3
Fruit Ripening Date	216 ±3	4 August ±3	219 ±2	6 August ±2	207 ±2	26 July ±2
Defoliation	344 ±2	10 December ±2	339 ±2	4 December ±2	340 ±2	6 December ±2

± number of days
Fruit: Main crop(summer crop)

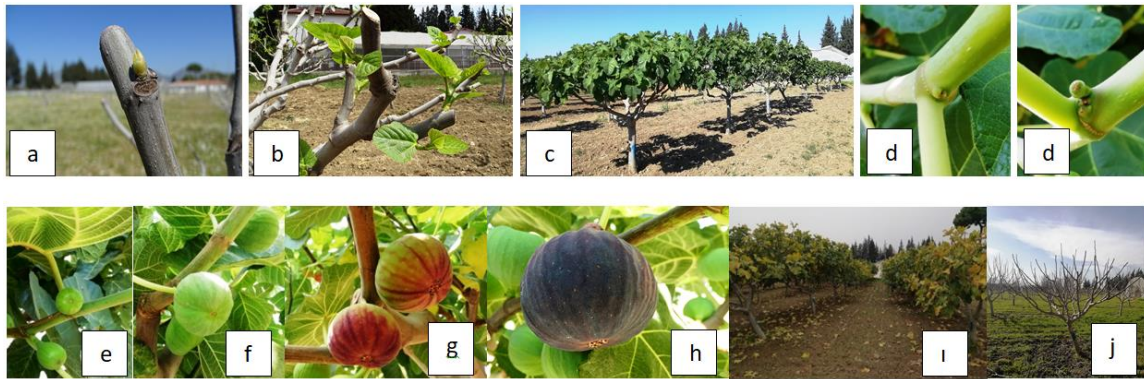
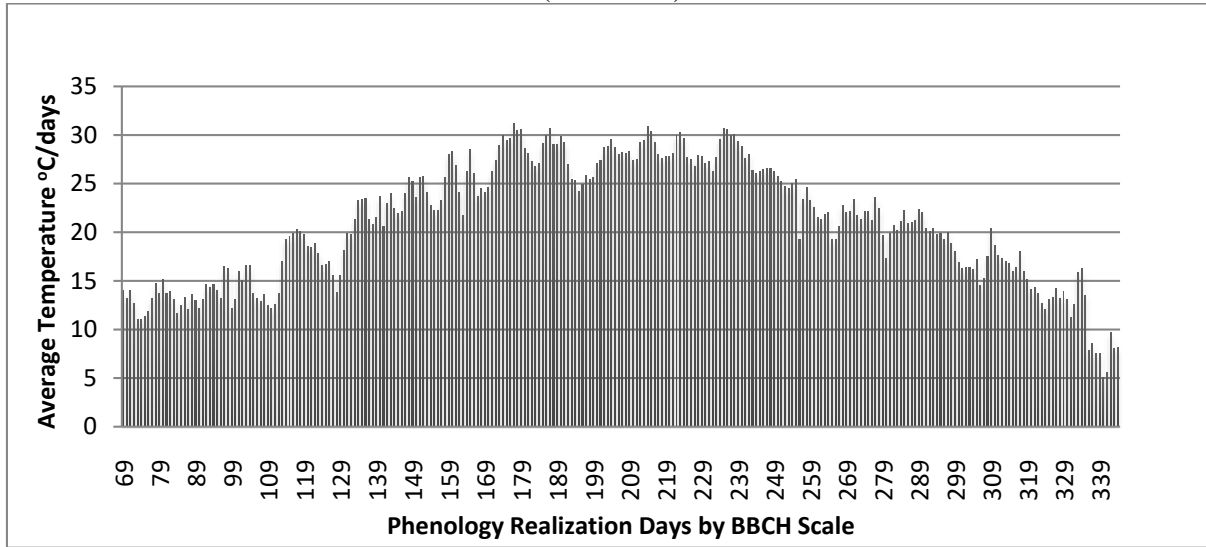
As can be seen in Tables 4 and 5, there are 11 to 17 days between bud burst and the foliation beginning, although it varies between years, and the total effective temperature was realized as 15.68 °C -days. The highest total demand for effective temperature between the foliation beginning and full foliation was realized in 2020, and it lasted for a total of 46 ± 2 days. The total effective temperature in the period between foliantion beginning and the full foliation / date of fruit birth was 278.99 °C -days for an average of three years (Table 5). As can be seen in Table 4 and 5, in 2020, which is the year in which the bud burst date takes place at the latest; The lowest effective temperature sum of 11.75 °C-days was determined between bud swelling and the foliantion beginning.

Failure to provide the temperature total may delay the date when the phenological periods will take place. The total effective temperature in the period between full foliation and fruit ripening date was realized as 1073.04 °C-days in three years, and the highest effective temperature total value in this period was realized in 2020 (Table 5). Gradual harvesting takes place in figs, and as can be seen in Table 3, the longest harvesting period was in 2021 with 90 days. As can be seen in Table 5, the total effective temperature during the harvest period was $1,040$ °C-day for three years. Considering the average of three years in Bursa Siyahı fig cultivar, the total effective temperature in the phenological period from bud burst to defoliation date was $2.506.18$ °C-days (Table 5).

Table 5. Total effective temperature of Bursa Siyahı fig variety (°C-days)

Phenological Periods	2019	2020	2021	Average
Bud Burst - Foliation Beginnig	18.15	11.75	17.16	15.68
Foliation Beginnig - Full Foliation (Date of Fruit Birth)	256.84	290.53	289.61	278.99
Full Foliation (Date of Fruit Birth) - Fruit Ripening Date	1100.33	1111.55	1007.25	1073.04
Harvesting Period	935.13	1019.10	1166.00	1,040.07
Fruit Ripening Date - Defoliation Date	1146.00	1092.41	1177.00	1138.47

Fruit: Main crop(summer crop)

Table 6. BBCH scale day values and average daily temperature values of Bursa Siyahı fig variety (Year 2019)**Figure 2.** Bursa Siyahı fig variety phenological periods; bud burst (a), foliage beginning (b), full foliage (c), fruiting process /main crop (d), polination time (e), fertilized crop (f), beginning of fruit ripening (g), ripe crop(h) , onset of defoliation (i), dormancy period (j).

As can be seen in Table 1 and Table 6, the daily average temperature increase, which starts with bud burst, reaches the highest average temperature during the fruit ripening date and harvesting period, and gradually decreases until defoliation. High temperature is important for the fruit ripening process in figs (Tan et al., 2018).

DISCUSSION

Bursa Siyahı fig variety is important in terms of production for export (Çakan, 2020). This variety originating from Bursa and its surroundings; In recent years, garden facilities have been carried out in the Aegean and Mediterranean

regions to meet the market demand and provide earliness (Tangu et al., 2021). Climate is one of the most important factors affecting the economic growth of a fruit variety other than its origin. Temperature is one of the most important parameters among climatic factors (Özçağiran et al., 2003; Pérez-Pastor et al., 2004). There are studies on the effective temperature summation requirement of cultivars of different fruit species (Amerine and Winkler, 1958; Brooks and Olmo, 1972; Richardson et al., 1974; Reynier, 1982; Hauagge and Cummins, 1991; Martinez et al., 1999; Bohro et al. 2015; Ruiz et al., 2018; Aktürk and Uzun; 2019;

Boyacı, 2020). Although there are some studies on dried fig varieties, studies on the demand for effective temperature summation in Bursa Siyahı fig variety have been limited (Kocataş, 2014; Tan et al., 2018). Aydın province is important in terms of cultivation of Bursa Siyahı fig variety outside its origin. In another respect, the determination of new production areas depending on the changing climatic conditions is important for figs, as it is for many fruit species. Determining the effective temperature total demand will contribute to the determination of the new regions where the production of the commercially important Bursa Siyahı fig variety will be made. Bud burst is an indication that the dormancy period has been completed and the shooting period has begun in the plant (Quinland and Preston, 1973). The bud burst date is important in terms of determining the date of winter pruning. Winter pruning in figs is carried out during the dormancy period after defoliation and generally in January and February (Özen et al., 2007). In different pruning and breeding studies, winter pruning was generally carried out in these months (Belge, 2019; ; Özkul, 2019; Gölcü, 2019; Çalışkan et al., 2020). In the years when this study was carried out, bud burst date in Bursa Siyahı fig cultivar was generally between 10th March and 23rd March. In different studies carried out on this variety in Aydın, the bud burst date generally takes place in March (Tomaş, 2016; Belge, 2019; Şirin, 2021). In the years when this study was carried out, the beginning of foliation was realized as the end of March and the beginning of April. In a study carried out in Hatay Province on Bursa Siyahı fig variety, it is stated that the start of foliation was carried out between March 10 and March 26 (Çalışkan et al., 2020). In a study carried out in Yalova Province conditions, the start beginning of foliation of Bursa Siyahı fig variety is stated as 25 March and 3 April (Tangu et al., 2021). The date of pollination is important in

terms of yield in Smyrna type fig varieties (Çalışkan and Bayazit, 2012; Çatmadım, 2014; Şirin, 2021; Ayar et al., 2021; Belge et al., 2022). There are some studies conducted on the frequency of harvesting and the selection of the appropriate pollinator (prophichi) in the Bursa Siyahı fig variety (Belge et al., 2018; Şirin, 2021). Accurate phenology follow-up is very important in terms of knowing when to do the polination (Figure 5-e). In this study, although the fruit ripening date varies between years, it was realized as the end of July and the beginning of August. Tangu et al., (2021), in a study conducted on Bursa Siyahı variety in Yalova Province, stated the fruit ripening date, between 15 and 25 August. Caliskan et al., (2020) reported the fruit ripening date between July 22 and August 2 in a study they carried out on Bursa Black variety in Hatay Province. Aksoy (1983) states that the fruit ripening date, which is the main crop of the Bursa Siyahı fig variety, takes place at the beginning of September in Bursa Province conditions, depending on the seasonal conditions. In a study carried out in Kuyucak District of Aydın Province, it is stated that the fruit ripening date of Bursa Siyahı fig variety is August 1 (Çatmadım, 2014). In a study conducted in Bursa Siyahı fig cultivar clones in Yalova, it is reported that the fruit ripening date is August 15 (Tangu et al., 2021). In different studies, it has been observed that the fruit ripening date of Bursa Siyahı variety in Aydın Province is earlier than Bursa Province (Çatmadım, 2014; Tomas, 2016; Şirin, 2021; Tangu et al., 2021). Effective temperature total demand is an important factor in terms of ripening and harvest time in figs as well as in different species. Many studies have been carried out in terms of breeding aimed at providing earliness (Çelikel et al., 1996; Hekimci, 2014; Çalışkan et al., 2020). Some of these include ethephon application and it has been demonstrated by different studies that they pose a residual risk (Azar et al., 2016; Hazarhun et al. 2021). Different studies are

continuing on earliness of fruit ripening, yield and quality in terms of breeders (Belge et al., 2021; Özkul et al., 2022; Kargıcak et al., 2022). Determination of new regions that will provide earliness in Bursa Siyahi fig variety is very important in order to supply products to the market in the early period. As in many fruit species, phenology follow-up is important in figs in terms of the time when aquaculture activities will be carried out. There are studies on the fruit quality of tillage in dried fig cultivation (Gülce et al., 2018). Fig is a type of fruit that is harvested gradually, unlike many other fruit types. The length of the harvest period causes an increase in labor costs. Aksoy (1983) states that the harvest period lasts for approximately 2.5 months in Bursa Province conditions, and this situation was observed approximately the same in this study. Research has been carried out on early harvest and chemical applications for shortening the harvest period, and it has been demonstrated by different studies that ethephon applications pose a residual risk (Azar et al., 2016; Hazarhun et al. 2021). In a study carried out in Aydın Province, it is stated that the Bursa Siyahı defoliation date was carried out between 15-18 December (Tomaş, 2016). Kocataş (2014), for the defoliation date of Bursa Siyahi fig variety in Erbeyli District; stated it as 18 December in 2012 and 29 November in 2013. Studies on the BBCH scale on fruit varieties belonging to different species have been carried out (Hess et al., 1997; Arcila-Pulgarín et al., 2002; Delgado et al., 2011; Razan et al., 2011; Flemmer et al., 2015; Sosa-Zuniga et al. 2017; Sütpak, 2019; Talghavi et al., 2022). In a study on the Sarılop fig cultivar in Aydın Province, it is stated that it occurs in Erbeyli location at the earliest in all phenological stages according to the BBCH scale in three different locations; In their study, Tan et al. (2018) stated that the time from bud burst to fruit ripening date is between 200 and 227 days, although it varies according to years and location in the Sarılop fig

variety. In this study, the date of bud burst and defoliation date in Bursa Siyahi fig variety varies between 256 and 275 days, although it varies on a yearly basis. Knowing the phenological stages is important for the harvesting date of the Bursa Siyahı fig, which is an important product for export (Çelikel et al., 1996; Çalışkan, 2012; Hekimci, 2014; Çalışkan et al., 2020; Çakan, 2020). As in many fruit species, the effective temperature total demand in figs is important in terms of the region where the variety will be cultivated. There are some studies on the dried Sarılop fig variety based on the temperature total demand, but the studies on the Bursa Siyahı fig variety have been limited (Kocataş, 2014; Tan et al., 2018). Tan et al. (2018) determined the highest total effective temperature demand from bud burst to fruit ripening date for the Aydın/Erbeyli District in Sarılop fig variety as 1410 °C-days in 2017. In our study for Bursa Siyahı fig variety; there were 126 to 147 days from bud burst to the beginning of foliation, but similar values were realized as 1314 °C-days and 1413 °C-days for the effective temperature sum from bud burst to fruit ripening date.

CONCLUSIONS

Temperature is important for the region where a fruit species will be grown. Depending on the climatic conditions, it is necessary to know the climatic data specific to the variety in order to evaluate whether a variety can be grown economically or not. In this study, the effective temperature total demand and phenological periods were determined in different years in order to contribute to the establishment of plantations to be established in different regions of the Bursa Siyahı fig variety, whose commercial importance is increasing day by day. Although the sum of the effective temperature from bud burst to fruit ripening date varies over years, it was between 1314 °C-days, and the average of three years from bud burst to defoliation

was 2506.18 °C-days. According to the BBCH scale, the ripening time of the ileum was 207 ± 2 days and 219 ± 2 days, although it varied between years. Optimum climate values should be taken into account in the garden facilities to be established in different regions with the Bursa Siyahı fresh fig variety, which has a high export value and economic importance.

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