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Investigation of the Phenological and Climate Indices of Some Table and Wine Grapes and Their Growing Status in the Samsun-Bafra Plain (Türkiye)

Bazı Sofralık Ve Şaraplık Üzümlerin Fenolojik ve İklim Endeksleri ile Samsun-Bafra Ovasında Yetiştirilme Durumunun İncelenmesi

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INVESTIGATION OF THE PHENOLOGICAL AND CLIMATE INDICES OF SOME TABLE AND WINE GRAPES AND THEIR GROWING STATUS IN THE SAMSUN-BAFRA PLAIN (TÜRKİYE)

ABSTRACT

The aim of this study was to determine the viticultural potential of Bafra plain based on viticulture climate indices. Bafra district was classified as warm-temperate according to Winkler and Huglin indices. The Winkler index (WI) 1969.0, Huglin index (HI) 2184.4 °C units, Branas Heliothermic Index (BHI) 4.5, and Branas Hydrothermal Index (HYI) 3423.6 were obtained for the Bafra region. Annual sunshine duration was calculated as 2295.5 hours, while sunshine duration during the growing period was 1715.0 hours. Considering the HYI value being somewhat high, this combined with the high air humidity in the summer months shows an increased risk of fungal diseases. The bud burst occurred in the second week of April and flowering occurred in the first week of June in all cultivars. The earliest veraison initiated with early ripening 'Early Sweet' and 'Trakya İlkeren' cultivars and the latest veraison was in 'Ugni Blanc' and 'Red Globe'. The earliest ripening was determined in 'Early Sweet' with 937.7 GDD, and the latest ripening was determined in the 'Ugni Blanc' cultivar as 1729.2 GDD. The period from bud burst to maturity was 110 days in 'Early Sweet' and 170 days in the 'Ugni Blanc'. Sites selected with high altitude, areas that slope slightly to the south sides, low humidity, and far from sea areas are suitable for early and mid-season ripening grape cultivars. The high humidity in the summer and heavy rain in the fall season increase fungal disease risks in the Bafra region.

Keywords: Grapevine, Phenology, Climatic Indices, Ripening, Adaptation.

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BAZI SOFRALIK VE ŞARAPLIK ÜZÜMLERİN FENOLOJİK VE İKLİM ENDEKSLERİ İLE SAMSUN-BAFRA OVASINDA YETİŞTİRİLME DURUMUNUN İNCELENMESİ

ÖZ

Bu çalışmanın amacı, bazı iklim indekslerine dayanarak Bafra ovasının bağcılık potansiyelini belirlemektir. Bafra ilçesi Winkler ve Huglin İndekslerine göre sıcak-ılıman bölge olarak sınıflandırılmıştır. Bafra bölgesi için Winkler İndeksi (WI) 1969.0 gün.derece; Huglin İndeksi (HI) 2184.4 derece.birim; Branas Heliotermik İndeksi (BHI) 4.5 ve Branas Hidrotermik İndeksi (HYI) 3423.6 olarak elde edilmiştir. Yıllık güneşlenme süresi 2295.5 saat, yetiştirme dönemindeki güneşlenme

süresi ise 1715.0 saat olarak hesaplanmıştır. HYI değerinin biraz yüksek olduğu göz önüne alındığında, bu durum yaz aylarında havadaki yüksek nem oranıyla birleştiğinde mantar hastalıkları riskinin arttığını göstermektedir. Tüm çeşitlerde gözlerin uyanması Nisan ayının ikinci haftasında, çiçeklenme ise Haziran ayının ilk haftasında gerçekleşmiştir. En erken ben düşme erken olgunlaşan 'Early Sweet' ve 'Trakya İlkeren' çeşitlerinde başlamış, en geç ise 'Ugni Blanc' ve 'Red Globe' çeşitlerinde gerçekleşmiştir. En erken olgunlaşma 937.7 gün.derece ile 'Early Sweet' çeşidinde, en geç olgunlaşma ise 1729.2 gün.derece ile 'Ugni Blanc' çeşidinde belirlendi. Gözlerin uyanmasından olgunluğa kadar geçen süre 'Early Sweet' çeşidinde 110 gün, 'Ugni Blanc' çeşidinde 170 gün olarak hesaplanmıştır. Bafra ilçesinde; yüksek rakımlı, güneye hafif eğimli, nem oranı düşük, denizden uzak seçilen alanlar erken ve orta sezonda olgunlaşan üzüm çeşitlerine uygun olarak değerlendirilmiştir. Yazın nem oranının yüksek olması, sonbaharda ise yoğun yağışlar Bafra bölgesinde mantari hastalık riskini artırmaktadır.

Anahtar Kelimeler: Asma, Fenoloji, İklim İndisleri, Olgunlaşma, Adaptasyon.

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1. INTRODUCTION

The economic viability of viticulture is closely related to climatic conditions (Bahar et al., 2018). For viticulture in new regions or for the adaptation of new grape cultivars, it is necessary to determine whether the cultivars will reach the optimum maturity based on climatic indices. Especially in regions where ecological conditions limit viticulture, the determination of variety choice is extremely important (Kılıç et al., 2018). Ecological factors have a direct impact on the growth and development of the vine. Light and temperature are the leading climatic factors that affect the growth and development of the vine. Temperature is one of the main parameters that determine whether or not viticulture is viable in a specific region (Cangi and Demir, 2019). The intensity of sunlight and the duration of sunshine affect many properties of the vines such as photosynthesis, sugar, acidity, color, aroma, and ripening (Köse, 2014).

The phenological development of vines is under the influence of many environmental factors, especially climate. Climate indices are indicative of potential for viticulture for different cultivars in different growing regions (Çelik, 2007). The Black Sea Region is an area with limited viticulture industry in Türkiye. Across the coastal areas of the region; grape cultivation is not common except for the slip-skinned, foxy grapes that are derived from *Vitis labrusca* L. parentage. The rain and high humidity of the region makes it difficult to control fungal diseases. The desirability of traditional *V. labrusca* grapes as table grapes is generally very low, and grapes of this type are typically most suitable for grape juice production (Cangi, 1999; Çelik, 2004).

Samsun province is an important agricultural city with Bafra and Çarşamba plains. Samsun city is a highly populated location on the Black Sea coastline, and it is the largest city in the Black Sea region. The climate of Samsun province shows great differences in terms of climate characteristics between the coastal regions and inner parts. Towards the inner and western parts, precipitation and humidity decrease, temperature increases and continental climate features begin to emerge. By evaluating suitable locations in these areas for grape cultivation, the production range can be effectively increased, prodviding local producers the knowledge and opportunity to produce alternative viticultural products (Köse et al., 2011). Moreover, taking into account all these conditions and the effects of climate change, new grape cultivars continue to be developed through ongoing breeding studies in Türkiye (Atak, 2022; Atak et al., 2022).

This study aims to make a significant contribution to increasing the viticulture capacity in Samsun province, specifically within the Bafra district, by detailing the climatic indices and assessing the potential of important grape cultivars. Determining the viticulture potential of the region is important in this area where tobacco production has been abandoned, and yet the land may still bring new income-generating products through adapted viticultural production.

2. MATERIAL AND METHOD

In the study, 4-year-old grapevines of eight different table grape cultivars, 'Cardinal', 'Early Sweet', 'Red Globe', 'Trakya İlkeren', 'Alphonse Lavellee', 'Royal', 'Michele Palieri', 'Victoria', 'Ugni Blanc' and 'Merzifon Karası' were evaluated during 2018-2019 vegetation period. Grapevines were grafted onto 1103 Paulsen (*Berlandieri* × *Rupestris*) rootstock and they were trained with double-cordon trellis systems. Grapevines were planted at a spacing of 3m between rows and 1.5 m in-row. Vineyard irrigated with drip irrigation as needed. In the vineyard, fungicide application was carried out six times a year with a spraying machine mounted behind the tractor. Weed control was achieved by applying soil cultivator at regular intervals in the vineyard. The research region is usually characterized by a temperate climate and the long term weather data of the research region were obtained from Samsun Meteorology Weather Station. During this research period, vineyard temperature values were recorded by Hobo Data Logger (Onset Computer Corp., Bourne, MA). In the study; bud burst (EL 4), full bloom (EL 23), veraison (EL35), and maturity (EL 38) dates were determined according to Coombe and Dry (2004) separately for each cultivar.

2.1. Geographical Features of Bafra District

The climate of Samsun province differs between the coastline and inland areas. The coastal line is under the influence of the temperate Black Sea climate, and the

inner parts of the Akdağ and Canik Mountains are under the influence of the continental climate. Since the temperature average in Samsun city center is generally higher than in the inner parts, the crop phenology is typically earlier than in the inner parts (Köse, 2014). In the Bafra district, the weather is warm, humid, and partly cloudy during the summer season. In the Bafra plain, the temperate climate characteristics observed in the Central Black Sea Region are dominant (Arpacı and Yüksel, 1996). Bafra Plain, which is one of the most important delta plains of Türkiye, has importance not only to Samsun but also to the whole of Türkiye, especially the Black Sea Region, in terms of plant production (Figure 1). The total area of the plain is 145.700 hectares. 41% of this land is used as agricultural land (604.287 da); it covers the Kızılırmak delta, which is surrounded by mountains in the south. The city has a surface area of 9.579 km^2 between the deltas formed by the Yeşilırmak and Kızılırmak rivers. In the deltas of Yeşilırmak and Kızılırmak rivers, there are Bafra and Çarşamba Plains with high agricultural potential (Dengiz and Sarıoğlu, 2011). The Nebiyan, the highest mountain among these mountains, is 1.224 meters. The longest river in Türkiye, Kızılırmak, crosses these mountains with a deep valley and reaches the plain. The Bafra plain is completely formed by the Kızılırmak River. Many lakes were formed in the parts of the river close to the sea (MBSDA, 2019).

Figure 1. Map of the sampling locations in Bafra Plain.

2.2. Soil Properties of the Research Area

The study area is located in the center of Bafra, between latitude 41° 33 ‘42 “N and longitude 35° 52’ 06” E, within the Kızılırmak delta. The soil structure of the land is clayey, silty, and slightly calcareous, and the soil pH is 8.03 slightly alkaline. Soil properties of the trial area are given in Table 1.

Table 1. Soil characteristics of the experimental vineyard.

Criterion	Value	Criterion	Value
Silt	57.00	Organic matter	1.23
Clay	33.73	N	0.15
Sand	10.92	P (ppm)	6.50
pH	7.58	K (mek/100 g)	0.34
EC (ds/m)	0.021	Ca (mek/100 g)	21.00
Lime	11.70	Mg (mek/100 g)	6.80
		Na (mek/100 g)	1.12

2.3. Grape Cluster Characteristics

In the study, berry weight (g), berry width (mm), berry length (mm), total soluble solid content (TSS as ° Brix), Titratable Acidity (%), and pH were determined. Grape berries were randomly removed from cluster samples to determine quality parameters. Berry firmness (N) measured with digital penetrometer (FHT-802) except for two wine grape that was the namely 'Ugni Blanc' and 'Merzifon Karası' in the research. Because of not need berry firmness in wine grapes, we tested only table grapes in terms of berry firmness. TSS was determined using a digital refractometer (Atago Pocket PAL-1, Japan). Titratable acidity as tartaric acid (TA) was determined by titration with 0.1N NaOH to an endpoint of pH 8.2 (Model PHSJ-4A pH meter). Grape cluster characteristics were determined by taking the average of three clusters of over 10 vines in each cultivar during the maturity period. The following characteristics were examined in the grape bunches examined. Berry characterizations were calculated by taking an average of a total of 100 berries consisting of 10 berries taken from the middle, top, and sides of 10 clusters of each genotype.

2.4. Climatic Parameters

Multiple climatic indices were used to evaluate the viticultural potential of the Bafra District. In the study, Branas Heliothermic Index (BHI), Average growing season temperature (GST, °C), Branas Hydrothermic Index (HYI), Winkler Index (WI-GDD), Huglin Index (HI °C units) indices were used with descriptions in Table 2.

Table 2. Climate parameters used in determining the viticulture potential.

Climatic Indices	Equations	Sources
Branas Heliothermic Index (BHI) *Not suitable under 2.5*	$\Sigma(Tavg\text{-}10^{o}C) * \Sigma I_e * 10^{-6}$ *Tavg: Average temperature values between 01 April and 30 September,* I_e *: Annual effective sunshine duration (average sunshine duration * vegetation period)*	*(Branas, 1974)*
Average growing season temperature (GST, °C) Too cool < 13 °C Cool 13-15 °C Intermediate 15-17 °C Warm 17-19 °C Hot 19-21 °C Very hot 21-24 °C Too hot > 24 °C	$\Sigma \frac{(Tmax + Tmin)/2}{n}$ *01 April to 31 Oct* *("n" is the number of days in the period)*	*(Jones, 2006)*
Branas Hydrothermal Index (HYI) Hydrothermal Index (HYI) No risk: < 2 500 Moderate risk: 2 500 High risk > 5 100	$\Sigma (Tavg * Pgs)$ *Tavg : Average temperature calculated for 01 April to 30 Aug;* *Pgs: precipitation (mm) for 01 April to 30 Aug*	*(Branas et al., 1946)*
Winkler Index (WI-GDD) Region I (cold) < 1 390 Region II (moderately cold) 1 391 to 1 670 Region III (warm) 1 671 to 1 940 Region IV (moderately w	$\Sigma((Tmax+Tmin)/2)\text{-}10^{o}C)$ *Tmax: maximum temperature calculated for 01 April to 31 Oct;* *Tmin: minimum temperature calculated for 01 April to 31 Oct*	*(Amerine and Winkler, 1944)*
Huglin Index (HI °C units) Huglin Index (HI) Very cool (HI-3) < 1 500 Cool (HI-2) 1 500 to 1 800 Temperate (HI-1) 1 800 to 2 100 Temperate warm (HI+1) 2 100 to 2 400 Warm (HI+2) 2 400 to 2 700 Very warm (HI+3) > 2 700	$\Sigma ([(Tavg - 10^{o}C) + (Tmax - 10^{o}C)]/2) * d$ *Tavg: Average temperature between 01 April-30 September,* *Tmax Maximum temperature between 01 April-30 September,* *d : Length of day coefficient (40^{o}-50^{o}) calculated as d=1.03;*	*(Huglin, 1978)*

2.5. Statistical Analysis

The study was conducted according to the randomized block trial design. Eight grape cultivars phenological observations and cluster characteristics were examined in 3 replications and 5 vines in each cultivar. The statistical analysis of the results was performed using Duncan's Multiple Tests, using the SPSS, version 16 (SPPS Inc. Chicago, IL, USA). Cluster characteristics were evaluated according to

P<0.05. Correlations among grape cluster and quality characteristics were analyzed using the corrplot package in R version 4.2.2 (Wei and Simko, 2021). Genotypic variance, phenotypic variance, and heritability of traits were analyzed with metan package (Olivoto and Lúcio, 2020).

3. RESULTS AND DISCUSSION

3.1. Climate Features of the Experimental Area

In the research, climatic records of the Bafra district obtained from the Samsun Meteorological Institute for both the long term perspective (1929–2018) and the growing season 2019 (Table 3 and 4). According to long-term climate data, the annual average temperature is 13.8°C. The minimum average temperature occurs in January, while the highest occurs in July and August. Minimum monthly rainfall calculated in July was 27.6 mm, while the highest rainfall occurred in December as 93.7 mm (Table 3).

Table 3. The long term climatic features of Bafra district (1929 - 2018)

Climatic Parameters	Months												
	1	2	3	4	5	6	7	8	9	10	11	12	Year
Avg Temp.(°C)	7.0	7.0	7.9	11.2	15.6	20.3	23.3	23.6	20.1	16.2	12.5	9.3	14.5
Avg Min Temp (°C)	4.0	3.9	4.6	7.8	12.1	16.1	19.1	19.6	16.5	12.9	9.3	6.3	11.0
Avg Max Temp (°C)	10.7	11	12.1	15.3	19.1	23.6	26.5	27.1	23.9	20.3	16.7	13.0	18.3
Relative Humidity (%)	71.6	58.7	66.4	57	48.3	45.2	34.4	37.3	54.0	78.7	83.5	82.0	59.8
Sunshine Duration (h)	2.7	3.2	3.6	4.7	6.2	8.3	8.8	8.2	6.3	4.6	3.7	2.7	5.3
Rainfall (mm)	78.2	56.2	56.5	52.3	42.8	41.6	27.6	41.1	54.2	87.8	85.5	93.7	717.5

On the other hand, in the 2019 year the study was conducted, the annual average temperature was 15.1°C. The lowest average monthly temperature was 7.2°C in February. The average maximum temperature was in August (27.1 °C). The lowest monthly rainfall ccurred in June (11.6 mm), while the highest monthly rainfall was in December (77.2 mm) (Table 4). Typically, to be able to grow grapes economically, the annual average temperature should not be below 9°C, the monthly average temperature in the growing period should not be below 18°C, the average temperature in the summer months should not be below 20°C, and the average temperature in the coldest month should not be below 0°C (Çelik et al., 1998).

Table 4. The climatic characteristics of Bafra district for 2019.

Climatic Parameters	Months												Year
	1	2	3	4	5	6	7	8	9	10	11	12	
Avg Temp.(°C)	7.3	7.2	7.7	11.1	16.9	22.8	22.2	23.2	20.4	17.7	14.6	10.3	15.1
Avg Min Temp.(°C)	4.9	4.6	4.2	8.0	13.0	19.3	18.3	19.8	17.0	14.6	11.1	7.7	11.9
Avg Max Temp.(°C)	10.7	10.7	12.1	15.5	21.6	26.9	26.6	27.1	24.5	21.7	19.4	13.6	19.2
Relative Humidity (%)	70.7	83.8	75.6	82.6	85.0	81.5	74.0	74.4	73.4	80.7	65.2	65.4	76.0
Rainfall (mm)	63.8	35.2	32.8	48.4	41.0	11.6	43.0	42.0	33.2	57.0	35.8	77.2	521.0
Sunshine Duration (h)	2.9	3.7	5.5	5.5	6.2	9.5	10.8	8.8	7.3	5.4	6.5	3.3	6.3

The average summer temperatures (June to August) in the Bafra district is 22.4°C (Table 3) and over 22.7°C in 2019 (Table 4). Average relative humidity varied between 65% and 90% in the research year (Figure 2). Average annual total precipitation was calculated as 717.5 mm. On the other hand, in 2019, annual total precipitation was 521.0 mm, below the average (Table 3 and 4). Annual relative humidity was 76% in 2019 year. During the vegetative period, relative humidity was calculated between 63.6% and 92.6% in June and July, while average temperature was measured between 19.0°C and 25.2°C in the same term (Figure 2).

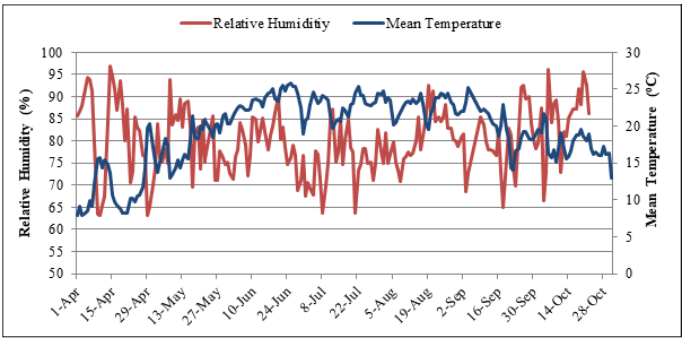

Figure 2. Average temperature (°C) and Relative humidity (%) of Bafra Plain between April 15 to October 21, 2019.

In 2019 the monthly rainfall was decreased in summer days compared to historical averages. In June, monthly rainfall was at its lowest level (11.6 mm) despite the historical average of 41.6 mm (Figure 3).

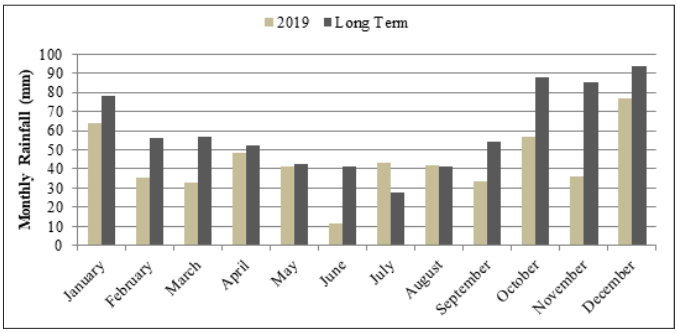

Figure 3. Average monthly rainfall of Bafra District belong to 2019 and long term (1963-2016).

3.2. Phenological Observations

The key stages of bud burst (EL 4), full bloom (EL 23), veraison (EL 35), and maturity (EL 38) dates were given separately for each genotype in Table 5. Bud-burst dates of grape cultivars were between 10 to 15 April. Early bud-burst dates were observed for 'Early Sweet' and 'Trakya İlkeren' grapes, which are early ripening cultivars; the latest bud-burst dates were obtained on 'Ugni Blanc', 'Alphonse Lavallee' and 'Victoria' cultivars. Blooming dates occurred within the first week of June in all cultivars. Although the blooming dates were close for all cultivars, it was started first at 'Early Sweet' and 'Trakya İlkeren' cultivars. The earliest veraison started in 'Early Sweet' and 'Trakya İlkeren' grapes whereas the latest veraison intiated for in 'Merzifon Karası' and 'Ugni Blanc' grapes. The maturity period started with 'Early Sweet' and 'Trakya İlkeren'. The final maturity was 'Ugni Blanc' grapevines.

Table 5. The phenological calendar of grown grape cultivars in the Bafra District.

Cultivars	Bud-Burst	Blooming	Veraison	Maturity
'Early Sweet'	10.04.2019	01.06.2019	02.07.2019	29.07.2019
'Trakya İlkeren'	10.04.2019	03.06.2019	09.07.2019	31.07.2019
'Victoria'	15.04.2019	04.06.2019	20.07.2019	15.08.2019
'Cardinal'	13.04.2019	05.06.2019	25.07.2019	25.08.2019
'Alphonse Lavellee'	15.04.2019	07.06.2019	07.08.2019	13.09.2019
'Royal'	13.04.2019	07.06.2019	08.08.2019	17.09.2019
'Red Globe'	12.04.2019	06.06.2019	09.08.2019	17.09.2019
'Michele Palieri'	12.04.2019	06.06.2019	27.07.2019	23.09.2019
'Merzifon Karası'	14.04.2019	07.06.2019	29.07.2019	26.09.2019
'Ugni Blanc'	15.04.2019	06.06.2019	09.08.2019	12.10.2019

The number of days from the bud burst to the blooming ranged from 48 days to 55 days, and varied by cultivar (Figure 4). While the number of days between flowering and veraison was lowest in 'Early Sweet' (31 days) and 'Trakya İlkeren' (36 days) cultivars, and longest (64 days) for 'Ugni Blanc'. The number of days between veraison and maturity was 22 days in 'Trakya İlkeren' and 27 days in 'Early Sweet' grapes. This phenological stage was determined as 58, 58, and 64 days in 'Michele Palieri', 'Merzifon Karası', and 'Ugni Blanc' cultivars, respectively.

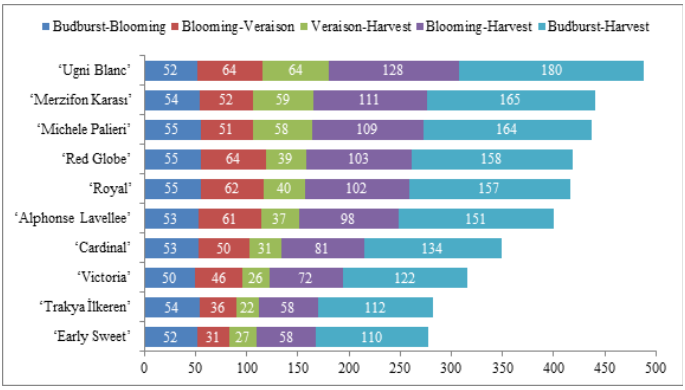

Figure 4. Number of days in each phenological stage for grape genotypes in the Bafra Plain.

When the number of days between blooming and maturity is examined, this period is 58 days in 'Trakya İlkeren' and 'Early Sweet' cultivars, while it is 109, 111, and 128 days in 'Michele Palieri', 'Merzifon Karası' and 'Ugni Blanc' cultivars. The number of days from the bud burst to the maturity date was determined as 110 and 112 days in the earliest maturing cultivars, 'Trakya İlkeren' and 'Early Sweet'. In the study, it was determined that the early cultivars such as 'Trakya İlkeren' and 'Early Sweet', and the mid-early season cultivars namely 'Victoria' and 'Cardinal' cultivars have potential to ripen early without being exposed to September rainfall. On the other hand, 'Alphonse Lavellee', 'Royal', 'Red Globe', 'Michele Palieri', 'Merzifon Karası' and 'Ugni Blanc' were identified as a higher risk cultivars that could be affected by heavy fall rains.

3.3. Evaluating of the Climatic Indices

In the study, some climatic parameters were calculated to establish a perspective of long term averages and to examine the 2019 research year (Table 6). The long term and 2019 values were calculated as follows: Hydrothermic Index (HYI) 4043.8 and 3423.6; Winkler Index (WI- GDD) 1847.7 and 1969.1; Huglin Index (HI °C units) 1982.9 and 2141.6. The Branas Heliothermic Index (BHI) was calcu-

lated as 3.5 (long term) and 4.5 (2019 value) compared to an acceptable lower limit reported as 2.5. The Bafra district aligns with many specifications calculated for Bordeaux. Ribereau-Gayon et al. (2006) stated that the Branas Heliothermic Index for Bordeaux is 4.0 and the Huglin Index is 2100 °C units.

Table 6. Climatic parameters calculated for the Bafra district, Samsun for long term (1929-2018) and the 2019 study year.

Climatic Parameters	Calculations	
	2019	(1929-2018)
Hydrothermic Index (HYI)	3423.6	4043.8
Winkler Index (WI GDD)	1969.1	1847.7
Huglin Index (HI °C units)	2141.6	1982.9
Branas Heliothermic Index (BHI)	4.5	3.5
Annual Insolation (AI-hr)	2295.5	1916.3
Growing Season Insolation (GSI-hr)	1636.9	1439.9
Annual Average Temperature (AVT °C)	15.1	14.5
Average Growing Season Temperature (GST °C)	19.6	18.6
Min. Growing Season Temperature (GST_{Min} °C)	15.7	14.9
Max. Growing Season Temperature (GST_{Max} °C)	22.9	22.3
Annual Precipitation (mm)	521.0	699.8
Growing Season Precipitation (mm)	276.2	364.5
Average Relative Humidity (%)	76.0	59.8
Growing Season Relative Humidity (%)	77.7	50.7

To place the values of Bafra plain in context, the coldest wine-growing region of Brazil, São Joaquim, is the highest-altitude vineyards and has an annual mean temperature of 13°C, annual mean precipitation of 1680 mm, and an annual mean solar radiation of 1832 hours. This is lower than the Annual Insolation for Bafra. During the growing season (September to April), the mean amount of solar radiation is 1264 hours (compared to the long term average of 1439.9 hours for Bafra), and this value allows the grapes to fully ripen (Santos et al., 2018). According to Sentelhas (1998), although it varies according to the variety, a sunshine period between 1200 and 1400 hours/year in a vegetation period is suitable for viticulture. Brandt et al. (2019) stated that the monthly sunshine hours varied between 1232 and 1309 hours during the vegetation period for 2016 and 2017 for adequate maturation in the Riesling grapes cultivar grown in the trial area in Rüdesheim (Rheingau), Germany.

Branas Hydrothermic Index (HYI) measures moisture excess or deficiency (Blanco-Ward et al., 2007). The HYI index covers the period between April and August. This index aims to identify the risk of mildew diseases in these months. Malheiro et al. (2010) noted that the risk of mildew development is low for HYI values below 2500 and high for values over 5100 (Lorenzo et al., 2016). According to the average values obtained for the Galician region in the north of Spain, the Winkler Index was 1382 GDD, the Huglin Index was 2049 °C units, the Branas Heliothermic Index was 3.5, and the Hydrothermic Index was 4439 (Blanco-Ward et al., 2007). The long-term HYI Index for Bafra was calculated as 3653.37. However, the HYI value for 2019, when the study was conducted, was found to be 3464.42. Since these calculated values are above 2500, there is a risk of fungal disease. Although the HYI calculation covers the months of April-August, it is seen that the precipitation in the region increases considerably in September and October. The risk of grape gray mold (*Botrytis cinerea*) may increase for grape cultivars that mature in October. For this reason, choosing cultivars that mature in the first week of September will minimize the risk of *Botrytis* and grape rot. Humidity and precipitation both effect fungal disease risks. Kandilli et al. (2022) implicated that fungal infection from powdery mildew (*Uncinula necator*) and downy mildew (*Plasmopara viticola*) was increased risk in Yalova growing conditions because the average precipitation during the growing season was 221.8 mm, relative humidity 75-80%, and temperature 22-25°C. Identifying fungal disease risks and pressure points can lead to a significant reduction in the number of sprays required annually, thus reducing production costs and the risk of environmental pollution (Cortiñas Rodríguez et al., 2020; González-Fernández et al., 2019).

According to Malheiro et al. (2010) the risk of gray mold contamination was low for BHI values below 2500 and high for values exceeding 5100 (Lorenzo et al., 2016). Similarly; Dina et al. (2020) pointed out that Murfatlar vineyard settled in the Romania has high risk with 4583.7°C mm in 2018-2019 years. Malheiro et al. (2010) noted the HYI shows areas with a Mediterranean-type climate maintain low risks of contamination; on the other hand, high and mid-latitude Europe growing conditions present moderate to high risks, with a typically increased risk of fungal disease pressure in Central and Eastern Europe. The climatic data of Yalova (Turkiye) has very similar climatic conditions when compared with the Bafra and production may adopt and utilize similar cultivars and management practices. Kandilli et al. (2022) calculated some climatic indices belonging to Yalova finding an average HYI of 4476, BHI of 836, Huglin Index of 2246 °C units, and Winkler Index of 2133 GDD. They noted that powdery mildew has a more devastating effect than downy mildew in the Yalova conditions.

3.4. Winkler Index (GDD-Growing degree-day)

The heat summation values calculated for different phenological periods according to the Winkler Index are given in Figure 5. The lowest heat summation required to proceed from bud burst to blooming was found in 'Early Sweet' and 'Trakya İlkeren' cultivars. On the other hand, the greatest heat summation requirement was for 'Alphonse Lavallee' and 'Royal' cultivars. In the study, the heat summation requirement from blooming to maturity and from bud burst to maturity were lowest in early cultivars as 'Trakya İlkeren' and 'Early Sweet', and highest in late ripen cultivars as 'Michele Palieri', 'Merzifon Karası' and 'Ugni Blanc'. From bud burst to maturity the heat summation demands of 'Early Sweet' and 'Trakya İlkeren' cultivars were calculated as 986.5 and 998.1 GDD, respectively. Contrastingly, 'Ugni Blanc' required 1806.2 GDD to achieve maturity.

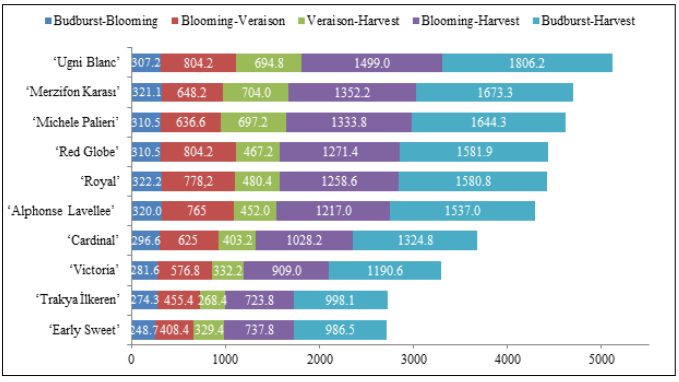

Figure 5. Heat summation values of grape cultivars calculated as Winkler Index (GDD).

In the year the study was conducted, the cummulative heat summation calculated according to the Winkler Index for the Bafra district was determined as 1969.0 GDD; as such, Bafra was identified as Region III (warm). This heat summation value shows that all cultivars, including the latest ripening 'Ugni Blanc' cultivar, can obtain their heat summation requirements in the Bafra region.

To be suitable for viticulture, the heat summation value typically must be above 900 GDD. Cultivars and regions are classified as cold (900-1400 GDD), cool (1401-1700 GDD), temperate (1701-1950 GDD), warm-temperate (1951-2250 GDD), and hot (2251 GDD and above) according to the values obtained (Çelik et al., 1998; Çelik, 2004). According to Uzun (1996) heat summation values of 1088 GDD were required for 'Trakya İlkeren' and 1397 GDD for 'Cardinal' grapes. In Kalecik (Türkiye) experimental conditions, heat summation values were determined as

1073 GDD in the 'Trakya İlkeren' cultivar and 1313 GDD in the 'Cardinal' cultivar (Çelik et al., 2005). Kamiloglu et al. (2014) reported that the heat summation values required for maturation of the 'Trakya İlkeren' grape cultivar in Hatay/Amik plain conditions in Türkiye were 1134 GDD and 1272 GDD from 2011 to 2012. The effective GDD needs for multiple cultivars were determined in Tekirdağ, Türkiye conditions, including for 'Trakya İlkeren' 1050 GDD, 'Cardinal' 1293 GDD, 'Royal' 1695 GDD, and 'Michele Palieri' 1715 GDD (Sağlam et al., 2009). Kılıç et al. (2018) noted the heat summation requirements of some grape cultivars in 2014 and 2015, calculated as 1189 GDD and 1052 GDD for 'Trakya İlkeren', 1685 GDD and 1572 GDD for 'Alphonse Lavallee', 1247 GDD and 1221 GDD for 'Cardinal', 1250 GDD and 1273 GDD for 'Victoria', 1682 GDD and 1572 GDD for 'Royal', and 1709 GDD and 1582 GDD for 'Michele Palieri'. Özdemir and Tangolar (2005) determined the heat summation requirements for 'Alphonse Lavallée' as 1468 GDD in Adana, Türkiye conditions. Altun (2015) determined the heat summation values of 'Michele Palieri', 'Red Globe', and 'Alphonse Lavallée' grape cultivars as 1491, 1522, and 1519 GDD, respectively in Sakarya, Turkiye conditions.

Another classification has been made based on the average growing season temperature (GST). These groupings start at an average GST of 13°C and end at 24°C. The four major maturity groups within this range are: (1) the cool climate maturity group ranging from 13°C to 15°C; (2) the intermediate climate maturity group ranging from 15°C to 17°C; (3) the warm climate maturity group ranging from 17°C to 19°C; and (4) the hot climate maturity group ranging from 19°C to 24°C (Jones, 2007; Jones et al., 2010; Yau, 2011). The average growing season temperature (GST °C) was calculated as 19.6°C in the study. These obtained temperature values are at a level that can obtain the heat summation requirements of many table and wine cultivars. The control of mildew, downy mildew, and grey rot diseases becomes difficult due to the high relative humidity in the region. Although the Bafra district heat summation values and average growing and annual temperature values meet the growing demand for grapes, due to high humidity and rising precipitation in September there is an increase in fungal disease risks, as such identifying varieities with early ripening may increase industry sustainability and fruit quality.

3.5. Bunch Characteristics of the Cultivars

The cluster characteristics of the examined cultivars are depicted in Table 7. Among the examined cultivars, the highest average cluster weight was obtained in the 'Red Globe' cultivar (441.6 g). This was followed by 'Michele Palieri' (346.7 g), 'Alphonse Lavallee' (330.3 g), and 'Trakya İlkeren' (329.0 g). The cultivar with the lowest bunch weight was 'Merzifon Karası' (165.6 g). The greatest bunch width was with 'Trakya İlkeren' (22.3 cm), the greatest bunch length was for 'Red Globe' (23.0 cm), the largest berry weight and width was 'Michele Palieri' (7.9 g and 22.5 mm), and the longest berry length was for 'Victoria' (26.3 mm).

Table 7. The bunch and berry characteristics of the grape cultivars

Cultivars	Bunch Weight (g)	Bunch Width (cm)	Bunch Length (cm)	Berry Weight (g)	Berry Width (mm)	Berry Length (mm)
'Early Sweet'	280.3bcd	10.1b	17.6cd	4.0d	17.4e	20.1e
'Trakya İlkeren'	329.0b	22.3a	20.9ab	3.9d	18.2d	17.5f
'Victoria'	292.5c	11.0b	17.8bcd	5.3bc	18.4d	26.3a
'Cardinal'	213.2de	8.6b	18.5bc	5.1c	20.4c	23.1bcd
'Alphonse Lavallee'	330.3b	14.3ab	19.6bc	5.8bc	21.2b	24.6ab
'Royal'	234.7cde	11.6b	17.8bcd	6.0b	20.4c	22.5cde
'Red Globe'	441.6a	16.3ab	23.0a	5.3bc	21.0b	21.9de
'Michele Palieri'	346.7b	13.3b	20.3abc	7.9a	22.5a	25.5ab
'Merzifon Karası'	165.6e	8.8b	15.0d	2.1e	15.1f	15.5fg
'Ugni Blanc'	301.2c	10.2b	19.2bc	1.9e	14.2g	14.0g
*SEM	7.754	0.907	0.32	0.080	0.054	0.263
P<0.05	**	*	**	**	**	**

*SEM: Standard error of the mean.

The TSS value of grape cultivars varied between 16.7% and 20.9% (Table 8). While 'Trakya İlkeren' (16.7%) and 'Victoria' (17.2%) cultivars had the lowest TSS values, 'Ugni Blanc' and 'Merzifon Karası' had the highest TSS as 20.9% and 20.7%, respectively. The TA ranges from 3.5 to 6.8 g/L. TA was highest in 'Ugni Blanc' and 'Merzifon Karası' (both 6.8 g/L); the lowest was 'Michele Palieri (3.5 g/L)'. The juice pH of the cultivars varied from 3.0 to 4.2. The highest pH was in 'Red Globe' and the lowest was in 'Trakya İlkeren' grapes. Vintage and maturity decision making influences final fruit chemistry as indicated by Cangi et al. (2011) stating that shifts in pH values were observed to varied between 3.27 and 4.20 in wine grapes based on maturity, cultivar, and year effects.

Berry flesh firmness values showed significant differences among grape cultivars (Table 8). The cultivars with the hardest fruits in terms of berry firmness were found on 'Early Sweet' and 'Trakya 'İlkeren' grapes. On the other hand, 'Victoria' and 'Cardinal' are medium hard; 'Alphonse Lavellee', 'Royal', 'Red Globe' and 'Michele Palieri' grapes were evaluated with soft berries. Cantürk and Kunter (2021) determined as 3.96 N; Kök (2021) 5.26 N; the berry firmness in the 'Trakya İlkeren' grape cultivar. Giuseppe-Ferrara et al. (2017) found fruit firmness in the 'Victoria' grape cultivar to be between 4.8-5.9 N; Alenazi et al. (2019) fruit firmness in 'Red Globe' was between 11.6–12.9 N. In our research, it is thought that the differences in fruit flesh firmness values are due to the ecology of the vineyard.

Table 8. TSS, TA, pH and berry firmess of the cultivars

Cultivars	TSS (%)	TA (g/L)	pH	Berry Firmness (N)
'Early Sweet'	17.8cd	4.7d	3.3efg	6.61a
'Trakya İlkeren'	16.7e	5.6c	3.0h	6.03b
'Victoria'	17.2de	5.2cd	3.3f	4.03c
'Cardinal'	17.5cd	4.8d	3.2g	4.06c
'Alphonse Lavallee'	19.1b	5.8bc	3.2fg	3.27e
'Royal'	18.1c	6.2b	3.3ef	2.98e
'Red Globe'	18.9b	5.0d	4.2a	3.33de
'Michele Palieri'	17.8cd	3.5e	3.5d	3.41d
'Merzifon Karası'	20.7a	6.8a	4.0b	----
'Ugni Blanc'	20.9a	6.8a	3.9c	----
*SEM	0.070	0.043	0.010	0.085
P<0.05	**	**	**	**

*SEM: Standard error of the mean.

For table grapes, broad-sense heritability (the proportion of phenotypic variance explained by genotypic variance) of berry and bunch characteristics ranged from 0.35 (bunch length) to 0.91 (berry width) (Figure 6). Berry traits (length, width, mass, and firmness) all exceeded a heritability of 0.60. Heritability of bunch characteristics were also high, with only bunch length below a heritability of 0.50. Among bunch characteristics, the greatest heritability was observed for bunch width (0.70) followed by bunch mass (0.60). The heritability of acid traits TA and pH were greater than TSS. Broad-sense heritability of pH was 0.88 and TA was 0.80, while TSS was 0.54.

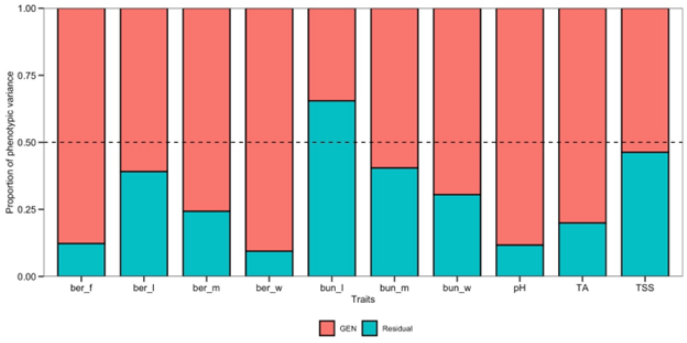

Figure 6. Proportion of phenotypic variance attributed to genotype (GEN) and residual for four berry traits (ber_f= berry firmness, ber_l= berry length; ber_m= berry mass; ber_w= berry width), three bunch traits (bun_l= bunch length; bun_

m= bunch mass; bun_w= bunch width), and three fruit chemistry traits (pH, TA= titratable acidity; TSS= total soluble solids) across eight table grape cultivars ('Alphonse Lavellee', 'Cardinal', 'Early Sweet', 'Michele Palieri', 'Red Globe', 'Royal', 'Trakya İlkeren', and 'Victoria') grown in the Bafra district.

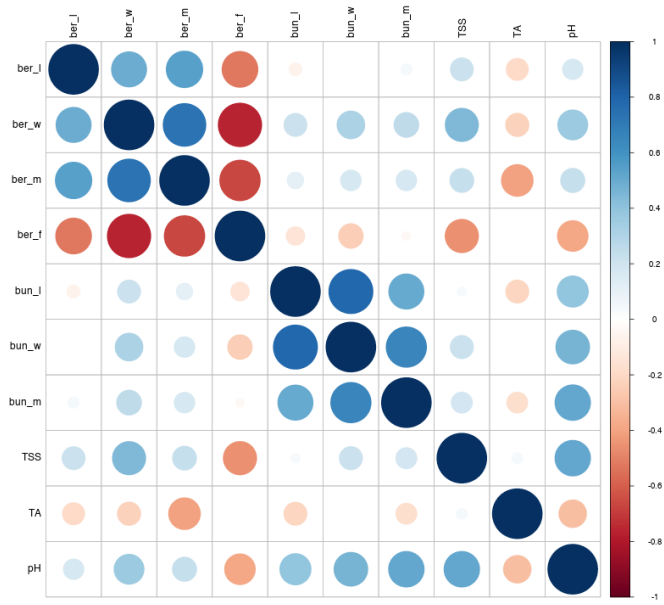

Figure 7. Phenotypic correlations among four berry traits (ber_f= berry firmness, ber_l= berry length; ber_m= berry mass; ber_w= berry width), three bunch traits (bun_l= bunch length; bun_m= bunch mass; bun_w= bunch width), and three fruit chemistry traits (pH, TA= titratable acidity; TSS= total soluble solids) across eight table grape cultivars ('Alphonse Lavellee', 'Cardinal', 'Early Sweet', 'Michele Palieri', 'Red Globe', 'Royal', 'Trakya İlkeren', and 'Victoria') grown in the Bafra district.

Correlations among berry traits were positive for berry size metrics (berry length, width, and mass); contrastingly, larger berries were correlated with a reduction in berry firmness (berry length: r= -0.521; p= 0.001; berry width: r= -0.763; p <.001; berry mass: r= -0.655; p <.001). Bunch metrics were all significant positively correlated (Figure 7). The fruit composition metric TSS was positvely correlated with berry width (r= 0.447; p = 0.010) and negatively correlated with berry firmness (r= -0.450, p =0.010). TSS was not significantly correlated with TA; however, TSS was positively correlated with pH (r= 0.513, p= 0.003).

4. CONCLUSION

It was determined that the early cultivars 'Early Sweet' and 'Trakya İlkeren' and mid-season cultivars 'Red Globe', 'Michele Palieri' and 'Victoria' have potential in the Bafra district. 'Early Sweet' and 'Trakya İlkeren' cultivars were the earliest ripening which contrasts with 'Ugni Blanc', the last cultivar to ripen. In light of the climatic parameters examined, the risk of fungal disease was determined to be high due to the high relative humidity and the precipitation that initiates after August in Bafra. As a result, 'Early Sweet', 'Trakya İlkeren', 'Cardinal', and 'Victoria' and other cultivars that mature before the precipitation in September may be advantageous for the Bafra plain. Simultaneously, site selection remains important, as such work must continue to identify arable land where humidity is relatively lower and altitude is relatively high within the Bafra plain to improve sustainability of grape cultivation.

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Conflict of Interest

The author declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on live animals or humans

Author Contribution Rates

Design of the Study: ŞK(30%), BK(70%)

Data Acquisition: ŞK(100%)

Data Analysis: ŞK(30%), BK(50%), AS(20%)

Writing of the Article: ŞK(20%), BK(60%), AS(20%)

Submission and Revision: ŞK(10), BK(70%), AS(20%)

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