Phenology and Ripening of *Vitis vinifera* L. and *Vitis labrusca* L. Varieties in the Maritime Climate of Samsun in Turkey's Black Sea Region

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Heavy rainfall in Turkey's northern Black Sea Region in spring and autumn, combined with insufficient sunshine during the vegetation period, results in poor ripening of European grape (*Vitis vinifera* L.) cultivars. Compared to other coastal provinces in the Central and Eastern Black Sea Region, Samsun receives relatively little rainfall. This study evaluated the adaptation of *Vitis vinifera* L. and *Vitis labrusca* L. grapes to Samsun by examining the phenology and ripening characteristics of these cultivars in 2010 and 2011 and calculating climatic indices using long-term data for Samsun in order to assess the potential for viticulture in the area. The following climatic characteristics were identified: annual sunshine duration, 1 836 hours; Branas Heliothermic Index (BHI), 3.0; Hydrothermic Index (HyI), 4 053.7°C mm; Winkler Index (WI growing degree days) 1 832/Region III "Warm"; and Huglin Index (HI) 1 978°C/HI-1 "Temperate". Phenological cycles (budburst to harvest) varied between 120 and 176 days, with Trakya İlkeren and Yalova İncisi the most precocious varieties and Favli the latest variety in both years. Heat summation requirements ranged from 1 210 to 1 844 GDD, with Trakya İlkeren requiring the least and Narince the most heat summation. Total soluble solid (TSS) values ranged from 15.1 °Brix (Trakya İlkeren) to 21.4 °Brix (Labrusca). Although Favli was the last to ripen, the TSS value for this variety was only 17.1%. These findings indicate that, with the exception of Favli, all the varieties examined are capable of maturing under the climatic conditions in the study area, suggesting that the coastal areas of Samsun province are suitable for early and mid-season *Vitis vinifera* L. grape viticulture.

INTRODUCTION

Very favourable climatic and soil conditions have allowed a wide variety of grapes to be grown in Turkey for thousands of years. According to recent data**,** Turkey ranks sixth in the world in terms of grape production and fifth in terms of growing area, with an annual output of 4 275 659 tons of grapes produced on 462 296 ha of vineyard area (FAOSTAT, 2012). Strong variations in climatic conditions allow for the production of table grapes, raisins and wine grapes. In total, 1 200 grape varieties are grown in Turkey, with most of them belonging to the species *Vitis vinifera* L. (Ergül & Ağaoğlu, 2001; Ergül *et al*., 2002; Uzun & Bayır, 2008). Moreover, 1 172 *Vitis vinifera* L. varieties are maintained in gene banks at the Tekirdag National Germplasm Repository Vineyard (Dilli, 2008). Although vineyards are spread throughout the country, production is concentrated mainly in the Aegean, Mediterranean, South-Central Anatolian and South Anatolian regions.

Grape cultivation is highly dependent on climate. Production requires a very specific set of conditions, namely an average growing-season temperature of 12ºC to 24ºC (Jones, 2007; Ramos *et al*., 2013) and appropriate mesoclimatic characteristics, viz. solar radiation, precipitation and evaporation (Hopphman, 1988; Van Leeuwen *et al*., 2004). Nemani *et al*. (2001) have stated that grape quality is affected by solar radiation and rainfall, frost intensity and duration, temperature variability and humidity levels during the growing season. According to Hunter and Bonnardot (2011), temperatures of 25°C to 30°C, wind speed of less than 4 m/s and relative humidity of between 60% and 70% are required for optimum vine photosynthetic activity. Variations in microclimatic and mesoclimatic conditions may affect the outlook for viticulture at higher altitudes and in coastal areas (Fraga *et al*., 2012a).

Ecological conditions favourable for viticulture exist in nearly all regions of Turkey (Çelik *et al*., 1998), with the exception of the higher altitudes in Northeastern Anatolia and along the Black Sea Coast, where viticulture is restricted by rainfall in excess of 2 000 mm annually (Durmus & Yigit, 2003; Çelik *et al*., 2008). The Aegean Region ranks first in terms of both area of vineyards and grape production, whereas the Black Sea Region ranks last. Due to heavy rainfall in the spring and autumn and insufficient sunshine over the veg-

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etation period, European grape cultivars (*Vitis vinifera* L.) tend not to ripen well in the Black Sea Region, which is the wettest climatic zone in Turkey. According to Cangi *et al*. (2006), climatic conditions in the region are responsible for widespread fungal disease, low fertility, poor quality and late ripening of *Vinifera* cultivars. By contrast, a diverse variety of native or open-pollinated *Vitis labrusca* L. are grown on backyard pergola systems or on redwood trees. These grapes have a foxy flavour, thick slip skins and a distinct aroma, and are consumed as table grapes, in marmalades and pickles, or as juice – according to local needs (Cangi, 1999; Çelik, 2004). Several previous studies have shown Labrusca grapes to be resistant to fungal diseases such as mildew and powdery mildew (Brown *et al*., 1999; Çelik, 2004; Wan *et al*., 2007; Çelik *et al*., 2008).

Vine phenology is a key component in vineyard planning. *Vitis vinifera* is a phenologically distinct crop, and its most important developmental stages consist of budburst, bloom, set, véraison and harvest (Mullins *et al*., 1992; Jones & Davis, 2000; Jones, 2007). Numerous systems have been used to assess and classify climatic structure and suitability of viticulture in a region, including the Multicriteria Climatic Classification System (Tonietto & Carbonneau, 2004), the Branas Heliothermal Index (Branas, 1974; Huglin, 1978), the Hidalgo Bioclimatic Index (Hidalgo, 2002), the Winkler Index (Winkler *et al*., 1974), the Hydrothermic Index (Branas *et al*., 1946), the Latitude-Temperature Index (Jackson & Cherry, 1988; Kenny & Shao, 1992), the Drought Index (Riou *et al*., 1994, Tonietto & Carbonneau, 2004), the Constantinescu Index (Constantinescu *et al*., 1964), the Huglin Index (Huglin, 1978) and the Cool Night Index (Tonietto & Carbonneau, 2004).

The Winkler Index (WI) is widely used as a guide to selecting grape varieties and determining the suitability of a given area to produce quality grapes (Amerine & Winkler, 1944; Winkler *et al* 1974; Huglin, 1978; Tonietto & Carbonneau, 2004, Jones, 2005). WI calculates climate as the sum of the daily average temperature above a base value of 10°C, the minimum temperature at which vine growth occurs, for each day in the period from budburst through harvest. The Huglin Index (HI) is another viticultural climate index based on heat summation that takes into account daily average temperature and daily maximum temperature, adjusting for day length during the vine-growing season (Huglin, 1978; Tonietto & Carbonneau, 2004; Van Der Schrier *et al*., 2012; Fraga *et al*., 2012b). The minimum HI for vine development is 1 500 (Huglin, 1978; Tonietto & Carbonneau, 2004) or 1 600 (Laget *et al*., 2008).

The aim of this study was to evaluate the adaptation of different grape varieties to the Black Sea Region in Turkey by assessing climatic structure, phenology and ripening performance of grapes grown in Samsun Province according to the Branas Heliothermic Index (BHI), the Hydrothermic Index (HyI), and WI and HI values.

MATERIALS AND METHODS

Geographical characteristics of the study area

Turkey is situated geographically within the wider Mediterranean region. Climatic conditions in the country are temperate, and the landscape is diverse, with mountains running parallel to the coastlines. Whereas the inland Anatolian plateau experiences extremes of hot summers and cold winters, with limited rainfall, the coastal regions enjoy milder climates (Şensoy *et al*., 2008). In the north of the country, the Black Sea Region has a humid, temperate climate characterised by rain throughout the year, with warmer temperatures in summer and cooler temperatures in winter, although local factors create distinct local climatic characteristics (Nişancı, 1988, 2002). Located in the Central Black Sea region, Samsun receives some of the smallest amounts of rainfall of any of the Central and Eastern Black Sea provinces, which have an average total annual rainfall of about 1 039 mm (Anonymous, 2013).

Samsun contains two mountain ranges extending in an east-west direction, while the Kızılırmak and Yeşilırmak Rivers, two of the longest rivers in Turkey, run from south to north through the province and empty into the Black Sea (Fig. 1). Samsun exhibits three distinct geomorphic characteristics: mountainous areas, which lie in the southern part of the province, including the highest point, Akdag (2 062 m.); plateaus, which lie to the north of the mountains; and coastal plains, which lie between the plateaus and the Black Sea (Fig. 1). Altitude varies widely, from 0 to 2 062 m (Candemir & Özdemir, 2010).

Climatic characteristics in Samsun vary greatly between the coast and the interior. Climate in the coastal areas is influenced by the Black Sea and the Akdağ and Canik Mountains, which prevent air masses from penetrating the southern part of the province. As a result, precipitation in the north of Samsun is higher than in the south (Güler *et al*., 2007). According to the Thornthwaite Climate Classification System, climate in the coastal areas, including the Carsamba Plain, is classified as semi-humid 'C2', whereas the interior, including the Bafra Plain, is classified as semi-dry, slightly humid 'C1', and the area in the southwest bordering the provinces of Amasya and Tokat, including the districts of Vezirköprü and Havza, are classified as semi-dry 'D' (Şensoy *et al*., 2008) (Fig. 2). Due to differences in temperature and topographic characteristics, and the influence of the Black Sea, relative humidity values for the province vary widely, from a high of 80% on the coast to a low of 50% inland. Overall annual average wind speed in the province is 2.4 m/s, with the dominant wind direction being south-southwest in autumn and winter, and north-northwest in spring and summer (Bahadır, 2013), while coastal areas experience average night-time wind speeds of 1.4m/s.

Samsun is an important agricultural centre, with 455 324 ha in the province devoted to agriculture, including 69 110 ha in Bafra in the north, and 53 300 ha in Çarşamba in the east – the two alluvial plains that constitute the major agricultural areas in the province. Higher rainfall in the coastal areas increases the risk of diseases such as downy mildew, especially in the east, which receives more rainfall than the west. In line with decreases in precipitation and humidity, the risk of disease decreases greatly with increasing distance from the coast; however, the need for irrigation increases as well, especially in the Vezirkoprü and Havza districts.

This study was conducted in a vineyard belonging to the Ondokuz Mayıs University Faculty of Agricultural (Fig. 3) over a two-year period from 2010 to 2011. The vineyard is

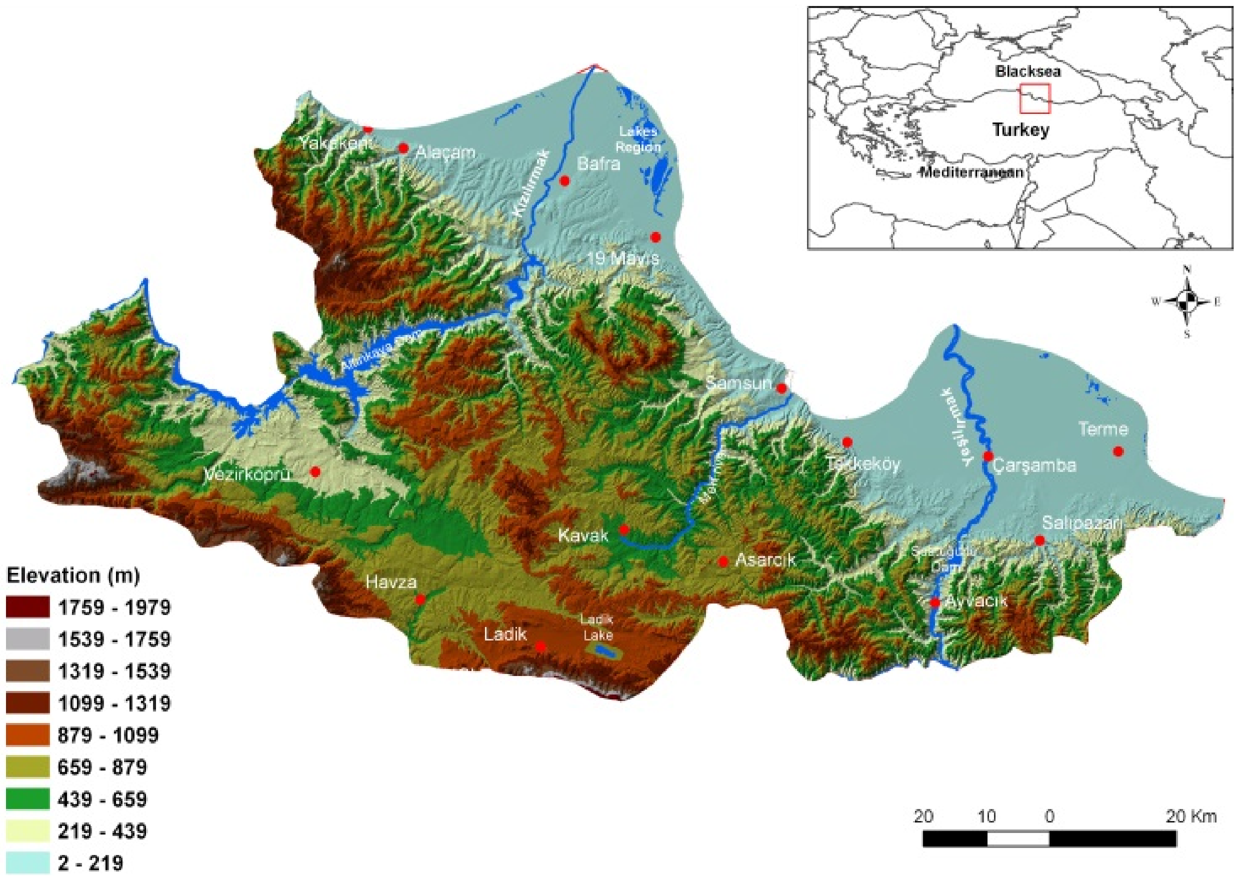

FIGURE 1
Topographic characteristics of Samsun Province, located in Turkey's Central Black Sea Region (Dengiz & Sarıoglu, 2011; Güler, 2013).

located at 41°21'52 N latitude and 36°11'29 E longitude, at an altitude of 195 m and a distance of about 2.8 km from the Black Sea coast. Towards the south of the vineyard, at a distance of approximately 3 km, is a 600 m high hill and, further away at a distance of 8.5 km, is Mt. Kocadağ, at a height of 1 270 metres above sea level. The prevailing wind direction in the study area is north, the average wind speed is 2.2 m/s (Koyuncu & Lüle, 2009), and the average night-time wind speed is 1.4 m/s

Plant material

This study was conducted using seven *Vitis vinifera* grape varieties (Narince, Çavuş, Yalova İncisi (Hönüsü × Siyah Gemre 4), Cardinal (Flame Tokay × Ribier), Trakya İlkeren (Alphonse Lavalleè × Perlette), Tekirdag Cekirdeksizi (Alphonse Lavalleè × Sultaniye), Favli (*Labrusca* × *Vinifera*)] and one *Vitis labrusca* L. genotype. Narince, one of the most important white wine and table grape varieties in Turkey, is produced in an area of 57 165 ha in the provinces of Tokat and Amasya (Cangi *et al*., 2011). Favli is produced mainly for juice, whereas all the other grapes evaluated are table grapes, including two very early varieties – Trakya İlkeren and Yalova İncisi. Trakya İlkeren grapes were grafted onto 5C rootstock, Çavuş, Narince, Yalova İncisi, Tekirdağ Çekirdeksizi and Cardinal grapes were grafted onto 5BB rootstock, and Favli and Labrusca grapes were grown on their own roots. Labrusca grapes were trained on a pergola system, whereas all other grapes were trained on double cordon systems. Pruning was performed in the third week of March in both years.

Climatic data and parameters

This study used long-term climate data (1960 to 2012) and data for the 2010 to 2011 research season collected by the Samsun Meteorological Observation Station (41°20'36 N latitude and 36°15'16 E longitude). Monthly maximum (Tmax), minimum (Tmin) and mean (Tmean) temperatures, insolation, precipitation and humidity were calculated from daily climatic data. The general climatic parameters and equations used to construct climatic indices for Samsun are given in Table 1 (Tonietto & Carbonneau, 2004; Blanco-Ward *et al*., 2007).

Grape phenology

Phenological data (budburst, blooming, véraison and harvest dates) were collected for 2010 and 2011. Budburst, blooming and véraison were considered to have occurred when 50% of the plants showed these physiological responses. Ripening dates were determined according to total soluble solids (TSS) and recorded in °Brix, using an Atago digital refractometer. Although a level of 16 °Brix is generally considered necessary to satisfy maturity (CODEX Standard 255, 2007; OIV, 2008; United Nations Economic Commission for Europe, 2010), harvesting varied by variety, in line with Turkish consumption habits (which include products such as molasses and traditional grape-based sweets, in addition to

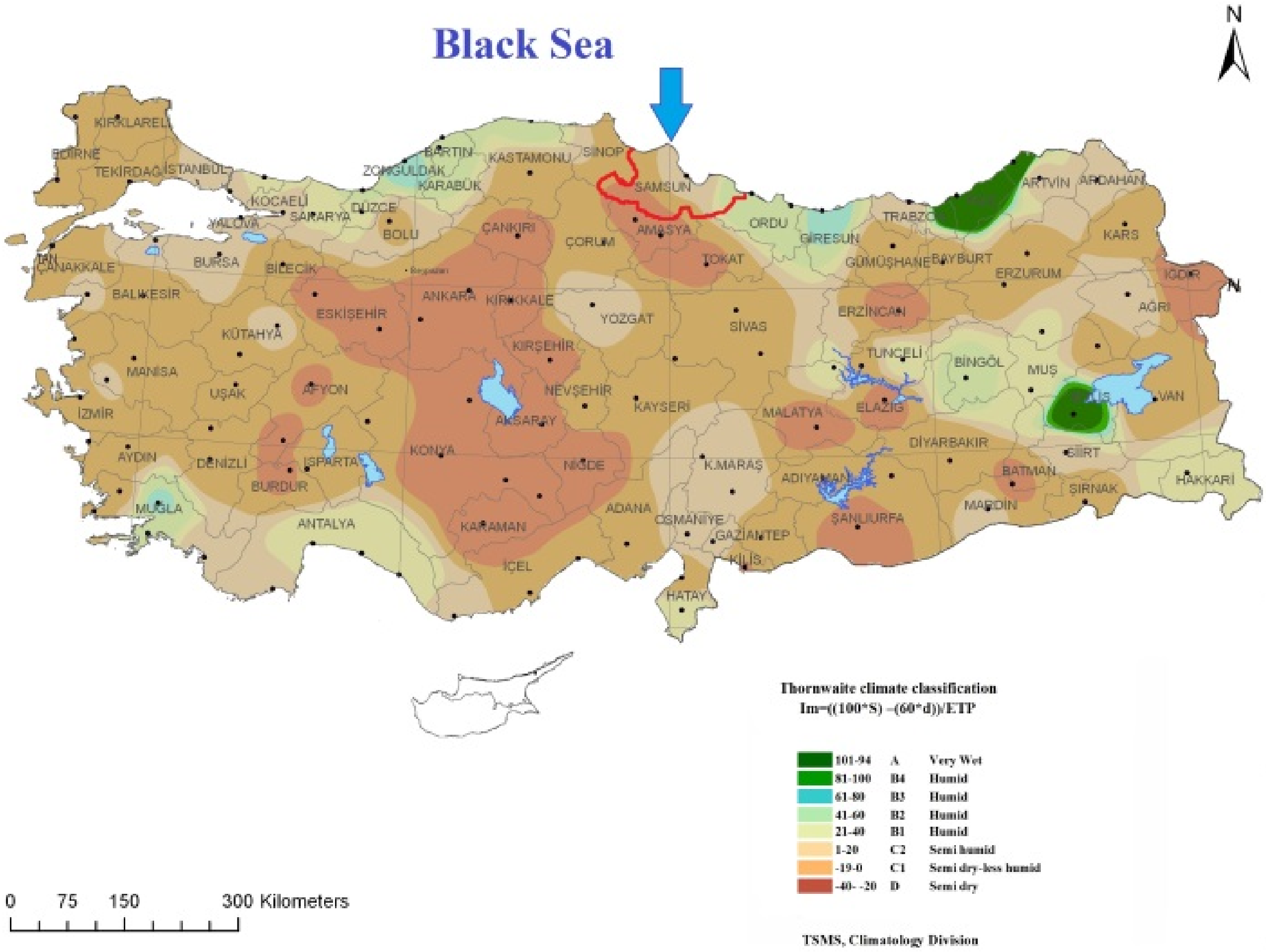

FIGURE 2
Thornthwaite Climate Classification of Turkey (Şensoy *et al*., 2008).

FIGURE 3
View of the study area (Google Earth Image).

raisins, juice and wine), as follows: early-ripening red, 15 °Brix; early-ripening white, 16 °Brix; mid-season ripening red, 17 °Brix; mid-season ripening white, 18 °Brix; Labrusca and late-season ripening *Vinifera* varieties, up to 20 °Brix.

RESULTS AND DISCUSSION

General climatic characteristics of Samsun

Long-term climate data (1960 to 2012) are presented in Fig. 4 (temperature and rainfall) and Fig. 5 (relative humidity and insolation), whereas data for the study period (2010

TABLE 1
General climatic parameters, definition and sources.

Climatic parameters	Definition	Source
Branas Heliothermic Index (BHI) Not suitable under 2.6	$\sum((Tavg-10°C)*\sum I_e*10^{-6})$ Tavg : Average temperature calculated for 01 April to 30 Sept; I_e : annual effective insolation	(Branas, 1974)
Hydrothermic Index (HyI) No risk: < 2 500 Moderate risk: 2 500 to 5 100 High risk: > 5 100	$\sum$ (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 warm) 1 941 to 2 220 Region V (hot) > 2 220	$\sum((Tmax+Tmin)/2)$ -10°C) Tmax: maximum temperature calculated for 01 April to 31 Oct; Tmin: minimum temperature calculated for 01 April to 31 Oct	(Amerine & Winkler, 1944)
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	$\sum((Tavg - 10°C) + (Tmax - 10°C)/2)*d$ Tavg : Average temperature calculated for 01 April to 30 Sept; Tmax : maximum temperature calculated for 01 April to 30 Sept; *d* : Length of day coefficient (40° to 50°) calculated as *d* = 1.03	(Huglin, 1978)

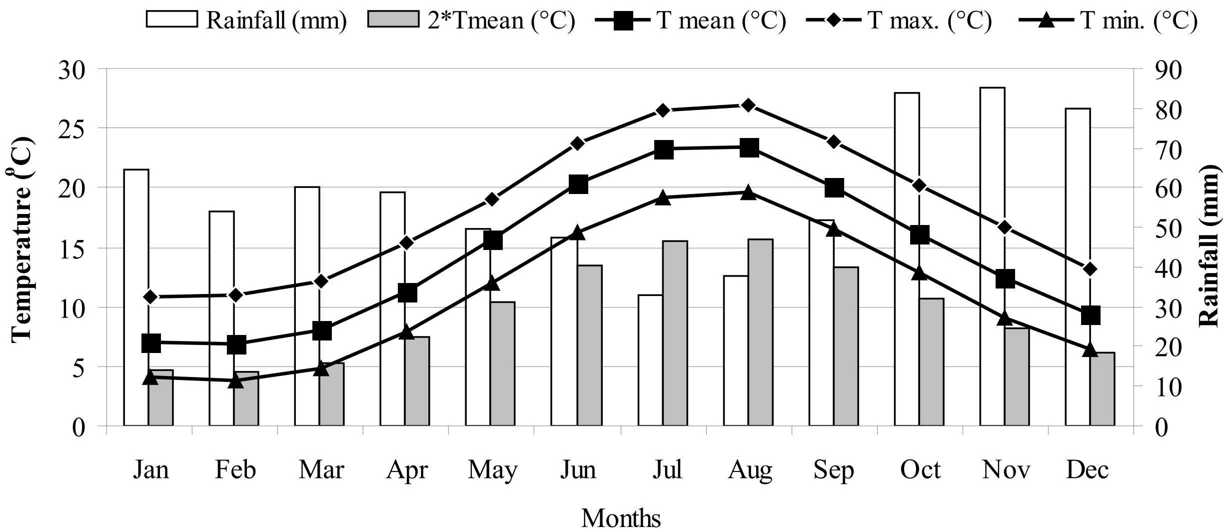

FIGURE 4
Long-term climate data: temperature and rainfall (1960 to 2012) for Samsun.

to 2011) are presented in Fig. 6 (temperature and rainfall) and Fig. 7 (relative humidity and insolation). The climate in the province of Samsun is dominated by the Black Sea. Summers are relatively cool, and winters are mild along the coastline, but snowy and cold inland and at higher altitudes. The long-term average annual temperature recorded for 1960 to 2012 was 14.5°C; the temperature in the average growing season (April to October) was 18.6°C; the average maximum temperature for the summer months (June, July and August) was 25.7°C; the average minimum temperature for the coldest months (January, February and March) was 4.2°C; the long-term annual precipitation, precipitation for the growing season (April to October), and precipitation over the hottest months (July to August) was 706.1 mm, 362.6 mm and 118.0 mm respectively; the average annual relative humidity was 73.7%; and the average daily insolation was 5.0 hours. For 2010 and 2011, the annual average temperature was 16.7°C and 14.5°C; the average temperature in the growing season (April to October) was 20.2°C and 18.9°C; the average maximum temperature for the hottest months (July to August) was 24.8°C and 23.1°C; the annual precipitation, precipitation for the growing season (April to October), and precipitation over the hottest months (July to August) was 731.0 and 670.8 mm, 426.4 and 303.7, and 136.4 and 99 mm; the

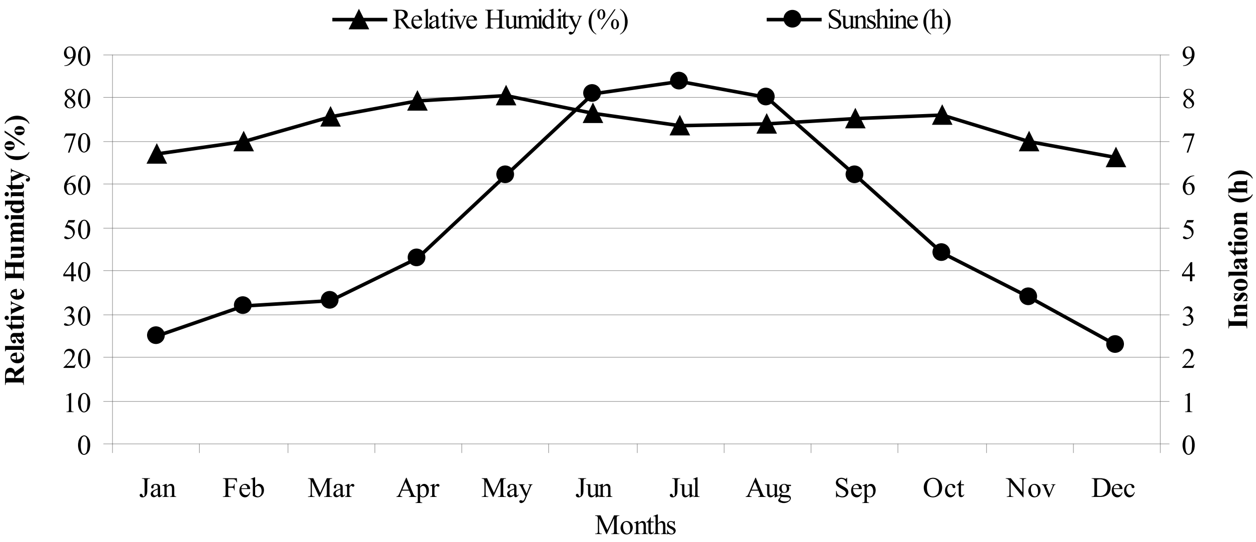

FIGURE 5
Long-term climate data: relative humidity (%) and Sunshine (h) (1960 to 2012) for Samsun.

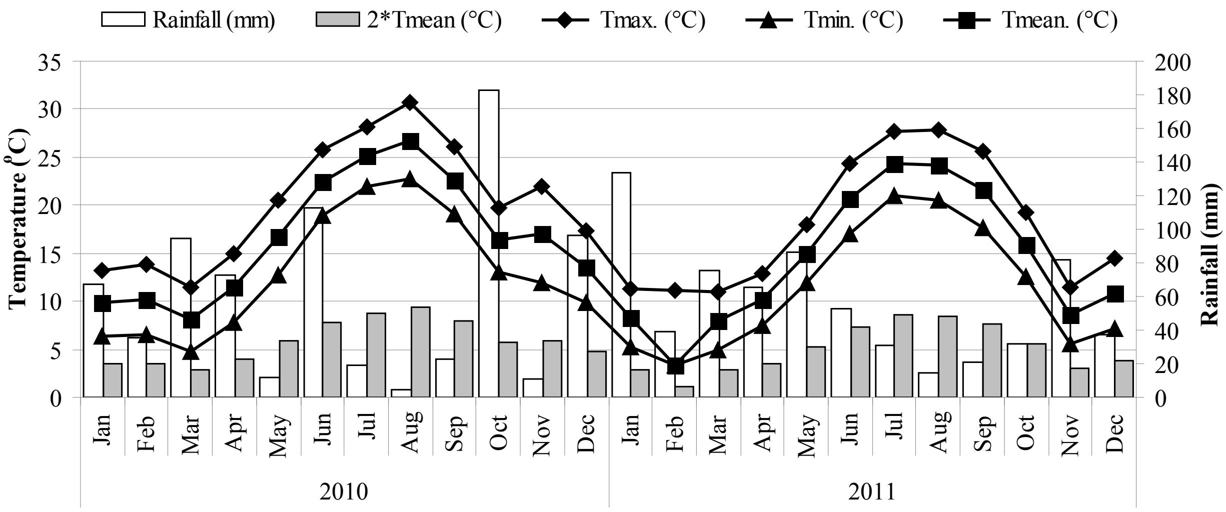

FIGURE 6
Temperature and rainfall values for the vineyard in Samsun for 2010 and 2011.

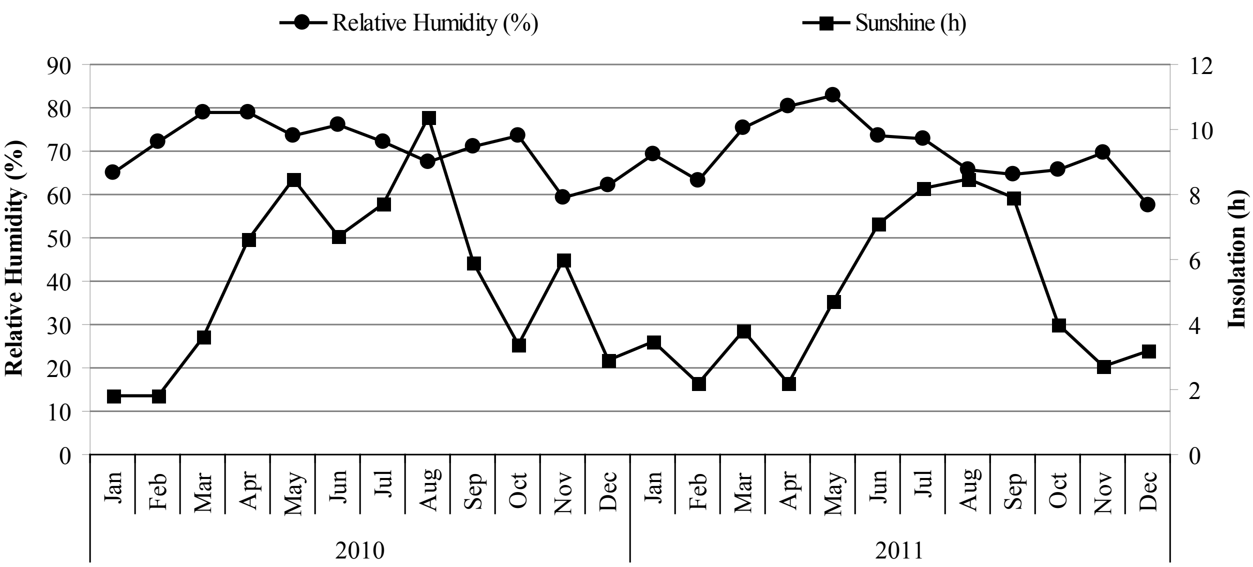

FIGURE 7
Relative humidity (%) and Sunshine (h) values for the vineyard in Samsun for 2010 and 2011.

TABLE 2
Climatic indices for Samsun: long-term (1960 to 2012), 2010, 2011 and mean (2010 to 2011).

	Long term (1960 to 2012)	2010	2011	Mean
Branas Heliothermic Index (BHI)	3.0	3.9	3.0	3.5
Hydrothermic Index (HyI)	4 054	4 142	4 167	4 154
Winkler Index (GDD)	1 832	2 138	1 854	1 996
Huglin Index (HI)	1 978	2 358	2 045	2 201

annual humidity was 70.9% and 70.1% respectively; and the average daily insolation was 5.4 and 4.8 hours respectively. Both long-term data and data for 2010 to 2011 showed that the maximum and minimum monthly precipitation tended to occur in January and July to August respectively, whereas the maximum and minimum monthly temperatures tended to occur in August and January respectively. A month is considered a 'dry month' when the value of the average monthly rainfall is equal to or less than twice the monthly mean temperature (Bagnouls & Gaussen, 1957). Long-term data showed July and August to be dry months, whereas data for 2010 and 2011 found July to September to be dry months. For Figs 4 and 6, the lines show monthly maximum, minimum and mean air temperatures, whereas the grey column refers to 2*T mean and the white column to monthly rainfall.

Insolation values were in line with acceptable values for grapevine phenology and grape ripening (Manica & Pommer, 2006). Many researchers have reported that optimal growth requires a minimum annual insolation of 1 500 to 1 600 hours and a minimum insolation of 1 200 to 1 400 hours during the phenological cycle (Oraman, 1970; Çelik *et al*., 1988; Smart & Robinson, 1991). Long-term annual insolation and growing season insolation (April to October) for Samsun were calculated as 1 825 and 1 391 hours respectively. These values were 1 986 and 1 502 hours respectively for 2010, and 1 764 and 1 301 hours respectively for 2011 (data not shown).

The frost-free period is defined as the average number of days between the last frost of winter and/or spring and the first frost of autumn. According to Tukey and Clore (1972), viticulture requires a frost-free period of a minimum of 180 days. January and February are the coldest months in Samsun. The average minimum temperature during the winter months was calculated from long-term data as 4.2°C, and the frost-free period for central Samsun was determined to be at least 229 days (latest frost: 04 April 2004; earliest frost: 11 November 1993); however, no frost occurred in this area during the growing season in either year of this study. In the coastal areas of Samsun, there is no risk of frost for grape growing.

Evaluation of climatic indices

The climatic indices are presented in Table 2. Four climatic indices were calculated to evaluate the climate of Samsun in terms of insolation, precipitation and heat summation requirements for viticulture.

Branas heliothermic index (BHI)

Solar radiation is a key factor affecting viticulture. Adequate insolation is required especially during maturation (Manica & Pommer, 2006). BHI is used to evaluate grape regions, cultivar adaptation, terroirs, phenological development and ripening characteristics in terms of solar radiation (Winkler *et al*., 1974; Lorenz *et al*., 1995; Barbeau *et al*., 1998; Huglin & Schneider, 1998; Tonietto & Carbonneau, 2004; Blanco-Ward *et al*., 2007; Irimia *et al*., 2013). In northern Europe, a minimum BHI value of 2.6ºC is considered necessary for viticulture (Carbonneau, 2003).

The BHI calculated from long-term data for Samsun was found to be 3.0ºC hours, whereas BHI values calculated from the data for 2010 and 2011 were 3.9ºC hours and 3.0ºC hours respectively. Mean daily insolation and annual temperature were higher in 2010 (5.4 hours, 16.7ºC) than in 2011 (4.8 hours, 14.3ºC). Despite the low BHI value, Samsun is considered to be suitable for viticulture, which requires between 1 280 and 1 610 hours of insolation during the growing season (01 April to 31 September). According to long-term data, total annual insolation and growing season insolation in Samsun are 1 825 hours and 1 391 hours respectively. BHI was found to parallel growing season insolation time.

BHI values for Samsun are similar to the BHI value reported by Blanco-Ward *et al*. (2007) for the Miño River Valley in Spain (3.5ºC hours). The authors of that study found a strong correlation between WI, HI and BHI values for heat and solar accumulation during the growing season. They concluded that the region showed great potential for viticulture, both in the lower coastal elevations with cooler climates and the warmer areas inland.

Hydrothermic index (HyI)

As reported by Carbonneau (2003), excessive humidity in the spring can trigger pests and diseases such as downy mildew. The HyI developed by Branas *et al*. (1946) combines the rate of precipitation and temperature during the growing season to determine the risk of downy mildew for grapevines. An HyI value below 2 500ºC mm is considered to represent a low risk of infection, whereas an HyI value above 5 100ºC mm is considered to represent a high risk of infection (Branas *et al*., 1946; Malheiro *et al*., 2010). HyI values for Samsun calculated from long-term data and for the study years 2010 and 2011 were 4 054 mm, 4 142 mm and 4 167 mm respectively. Although well above the low-risk limit, these values are still outside the high-risk boundary; thus, the coastal areas of Samsun might be considered to have a "middle-high" risk for downy mildew disease. In addition, high air humidity could represent as great a risk as high rainfall in terms of downy mildew in vineyards. Given the increasing rainfall and decreasing temperature and insolation time after August (Fig. 2), however, viticulture could be carried out in the coastal areas of Samsun between 01 April and 31 September. Alternatively, the interior districts of Kavak, Ladik, Vezirköprü and Havza, as well as the interior areas of the Bafra District, would appear to be suitable for viticulture, as the lower levels of precipitation and humidity make them low-risk areas for downy mildew.

Rainfall is a significant problem in many countries where grapes are cultivated. Fraga *et al*. (2013) stated that HyI data indicated a low to moderate risk of downy mildew disease in most of the Portuguese mainland, although a small area in northwestern Portugal (Alto Minho) was found to be at high risk for the disease. Malheiro *et al*. (2010) have suggested that projected increases in precipitation in the central and

TABLE 3
Phenological calendar of events in the study area for 2010 and 2011.

Varieties	Years	Budburst	Blooming	Véraison	Harvest
Cavus	2010	08/04	05/06	20/07	21/08
	2011	15/04	13/06	28/07	04/09
Trakya İlkeren	2010	05/04	07/06	12/07	08/08
	2011	11/04	15/06	21/07	20/08
Yalova İncisi	2010	07/04	07/06	15/07	08/08
	2011	17/04	15/06	21/07	15/08
Tekirdag Cekirdeksizi	2010	08/04	09/06	01/08	28/08
	2011	17/04	17/06	08/08	08/09
Cardinal	2010	11/04	07/06	29/07	25/08
	2011	20/04	15/06	07/08	09/09
Narince	2010	13/04	10/06	10/08	13/09
	2011	18/04	16/06	17/08	23/09
Favli	2010	08/04	07/06	20/08	25/09
	2011	18/04	15/06	28/08	10/10
Vitis labrusca L.	2010	08/04	25/05	01/08	03/09
	2011	15/04	07/06	07/08	10/09

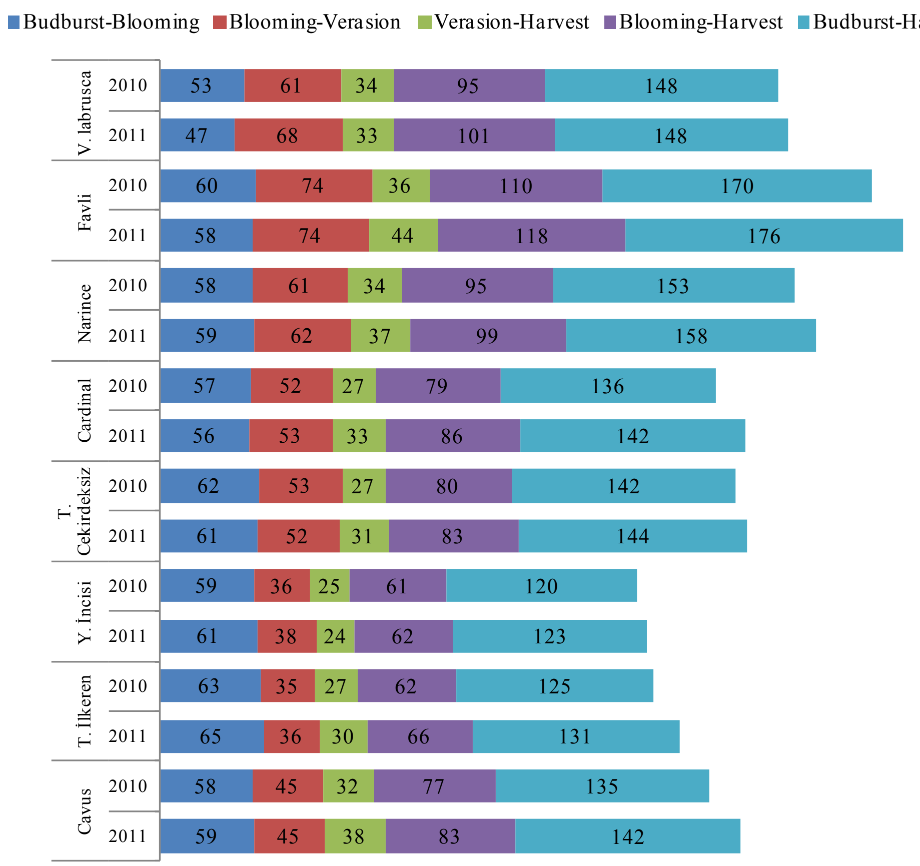

FIGURE 8
Number of days in each phenological stage for different grape varieties, 2010 and 2011.

western European grape-growing regions such as Alsace, Champagne, Bordeaux, Bourgogne, Loire, Mosel and Rheingau may result in an increase in pests and diseases such as downy mildew. In addition to pest- and disease-related risks, precipitation early in the growing season has been reported to have a negative effect by delaying growth, whereas late-season precipitation during the ripening period is reported to have a negative impact on berry sugar levels (Jones & Storchmann, 2001). A study by Chevet *et al*. (2010) reporting on long-term climatic conditions in Bordeaux for the years 1896 to 2009 found mean growing season temperature, annual rainfall and growing season rainfall to be 17.4ºC, 865.8 mm and 472 mm respectively. Irimia *et al*. (2013) reported that Dobrogea, a viticulture region along the Black Sea coast of Romania, had a temperate climate (HI-1).

Winkler Index-WI (growing degree days)

The Winkler Index (WI), which calculates growing degree days (GDD), attributes vintage quality to thermal environmental conditions during the growth period. WI is calculated for the period of budburst through harvest as the sum of each day's average temperature above a base value of 10°C, the minimum temperature at which vine growth occurs (Amerine & Winkler, 1944). WI values for the study area based on long-term data and data for 2010 and 2011 were calculated as 1 832.0 GDD, 2 137.5 GDD and 1 854.0 GDD respectively (Table 1). The GDD calculated for the phenological cycle of budburst to harvest using long-term

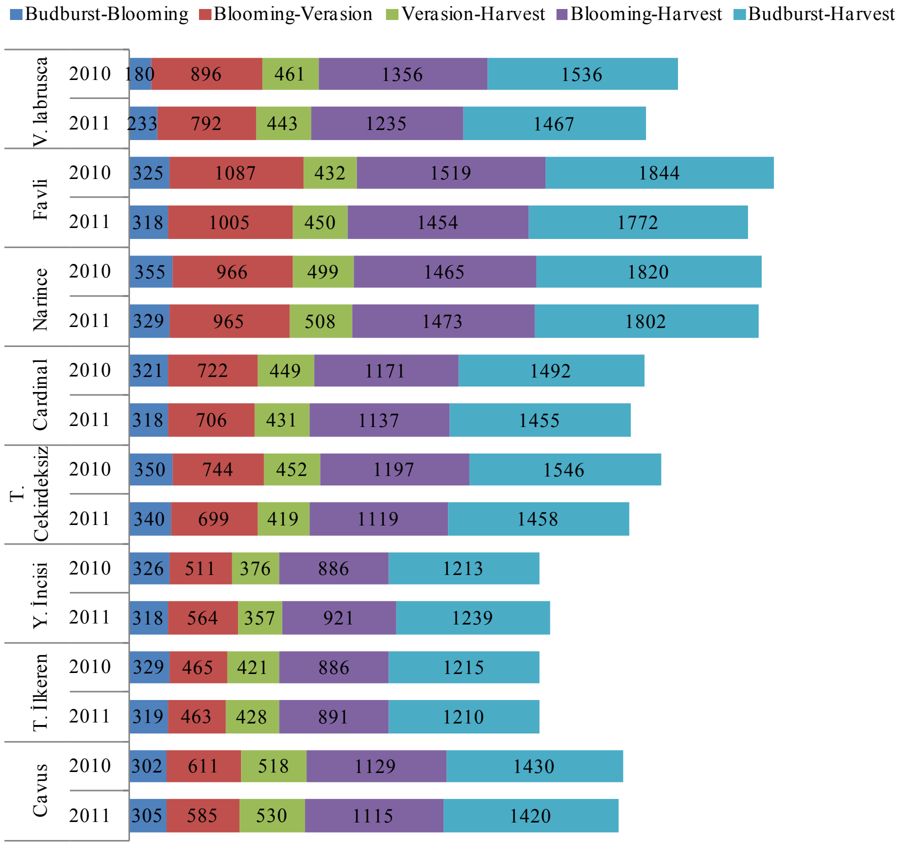

FIGURE 9

Heat summation requirements (GDD: growing degree days) from budburst to the phenological periods for the grape varieties evaluated in 2010 and 2011.

TABLE 4

Total soluble solids (TSS, °Brix) of grape varieties for 2010 and 2011.

Varieties	TSS (°Brix)		
	2010	**2011**	**Mean TSS**
Cavus	15.9	16.2	16.1
Trakya İlkeren	14.8	15.3	15.1
Yalova İncisi	15.2	15.9	15.6
Tekirdag Cekirdeksizi	16.4	16.0	16.2
Cardinal	16.8	16.3	16.6
Narince	18.2	18.5	18.4
Favli	16.8	17.3	17.1
Vitis labrusca	21.6	21.2	21.4

data places the region in WI Region III, i.e. "warm".

The study findings for Samsun are similar to those reported by Bois *et al*. (2008) for Bordeaux, which has a moderately warm climate, with a mean annual temperature of 13.8°C and an annual rainfall of 930 mm. The Rhône Valley in France and São Joaquim in Brazil were also reported to have a Region III WI classification (Falcao *et al*., 2010). Similarly, the warmest areas in Italy were classified as Region III and include the vicinity of Garda Lake, the Adige River Valley and low-elevation regions of Vicenza, Treviso and Pordenone. Region III permits the cultivation of red varieties such as Merlot and Cabernet Sauvignon, as well as local Italian Teroldego and Marzemino grapes (Zorer *et al*., 2013). By contrast, WI values for regions in northern New Zealand such as Kaitaia, the Bay of Islands, Whangarei and Matakana ranged from 1 268 to 1 694 GDD (Anderson *et al*., 2012).

Huglin Index (HI)

The Huglin Index (HI) is a viticulture climate index calculated from mean daytime temperatures, with a base value of +10°C (Huglin, 1978). According to long-term climate data, the HI for Samsun was calculated to be 1 978, and the climate was classified as "HI-1" (temperate). A similar classification was obtained from 2011 data (HI 2 044), whereas 2010 data (HI 2358) resulted in a classification of "HI+1" (temperate warm). The HI values calculated for Samsun's coastal area are similar to those reported by Irimia *et al*. (2013) for Romania's wine regions ("HI-1"), where climatic conditions are suitable for the maturation of Cabernet Sauvignon grapes. Queijeiro *et al*. (2006) also reported "HI-1" temperate climate classifications for Bordeaux in France and Modena and Treviso in Italy. Laget *et al*. (2008) have stated that HI 1 700 indicates suitability for Chardonnay grape cultivation, whereas HI 2 100 indicates suitability for Syrah. Furthermore, Stellenbosch, in the Western Cape (Coastal Region) of South Africa, has been reported to have a winter rainfall of 740 mm annually and an HI classification of "warm temperate", making it suitable for viticulture in terms of climatic requirements (Hunter & Bonnardot, 2011).

Phenological events for the study area: 2010 to 2011

Phenological data for 2010 and 2011 are presented in Table 3. The onset of budburst ranged from 05-04 to 20-04, with budburst starting earlier in 2010 than in 2011. The delayed budburst in 2011 compared to 2010 can be attributed to the lower average temperatures in 2011. In 2010, budburst occurred at a mean temperature of 11.4°C and following precipitation of 65.4 mm, compared to a mean temperature of 10.2°C and 72.8 mm of precipitation in 2011.

Blooming for the study period (2010 to 2011) occurred between 25-05 and 17-06 (Table 3), and the number of days from budburst to blooming ranged from 47 to 65 days (Fig. 8). Although budburst occurred earlier in 2010 than in 2011, the number of days between budburst and blooming did not differ between the two years (Fig. 8). The period from budburst to blooming was shorter for the Labrusca grapes than for the other grape varieties. A heat summation value of between 180 and 355 GDD was required between budburst to blooming, with the Labrusca grapes having the lowest heat requirements and the Tekirdag Cekirdeksizi and Narince varieties having the greatest requirements during this period (Fig. 8).

Véraison for the study period (2010 to 2011) occurred between 12-07 (Trakya İlkeren) and 28-08 (Favli), with the number of days between blooming and véraison ranging from 35 to 74. For both years, the Trakya İlkeren and Yalova İncisi varieties were the first to reach véraison, whereas the Labrusca and Favli grapes were the last.

The véraison to harvest period lasted between 24 and 44 days and required 357 to 530 GDD. The Yalova İncisi variety had the shortest véraison to harvest period, whereas the Favli variety had the longest. The duration between blooming and harvest ranged from 61 to 118 days (Fig. 3).

Harvest for the study period (2010 to 2011) occurred between 08-08 and 10-10. In both years, ripening (harvest) was earliest in the Trakya İlkeren and Yalova İncisi grape varieties and latest in the Favli grape variety (Table 3).

Overall phenological cycles (budburst/harvest) for the study period ranged from 120 to 176 days and required heat summation of 1 210.2 to 1 844.1 GDD. In both years, the Trakya İlkeren and Yalova İncisi varieties were the most precocious, with the shortest phonological cycle (125 for Trakya İlkeren and 120 for Yalova İncisi), whereas the Favli variety was the latest, with the longest phenological cycle (176 days) (Fig. 8).

Heat summation requirements for 2010 and 2011 varied according to variety, from 1 210 to 1 844 GDD (Fig. 9). Although the phenological cycle started and ended later in 2011 than in 2010, heat summation requirements were similar for both years, and the number of phenological days from budburst to harvest was also similar (Fig. 8). Increases in average temperatures of more than one degree may result in an increase in heat summation at 183 GDD between 01 April and 31 September. Thus, the somewhat greater heat summation requirement in 2010 in comparison to 2011 could be due to the higher average growing season temperature in 2010 (20.3°C) than in 2011 (19.4°C) (Fig. 9).

The ripening dates of the grape varieties are determined according to total soluble solids (TSS), as measured in °Brix. Mean TSS in the study area was found to be 15.1 °Brix in 2010 and 21.4 °Brix in 2011. Early-ripening grapes were harvested at 15 to 16 °Brix, mid-season grapes at 16 to 18 °Brix, and Labrusca grapes at up to 20 °Brix. TSS levels were lower in the early ripening grapes than in the mid-season and late-ripening grape varieties, with the lowest TSS found in the Trakya İlkeren (15.1 °Brix) and Yalova İncisi (15.6 °Brix) varieties, and the highest TSS in the Labrusca grapes (21.4 °Brix) (Table 4).

Early-ripening grapes require less heat summation than mid- and late-season grape varieties (Winkler, 1948; Oraman, 1972; Alishev, 1977). Dardeniz (2001) reported that the Cardinal grape variety could be harvested in the first week of August in Çanakkale (in Turkey's Marmara Region), with a TSS of 16 °Brix at harvest. Şensoy and Balta (2010) reported that Yalova İncisi grown in Van required a heat summation of 1 112.6 GDD, with an average of 17.1 °Brix at harvest. In the present study, Trakya İlkeren and Yalova İncisi were classified as early-season varieties; Cardinal, Çavuş and Tekirdağ Çekirdeksizi were classified as mid-season; and Labrusca, Narince and Favli were classified as late-season varieties. Although Favli was the latest grape variety to ripen, its TSS value was low, suggesting that Favli may require more heat summation to ripen than other varieties. In fact, climatic conditions in the coastal area of Samsun may not offer sufficient maturation time for late-maturing varieties, given the decrease in insolation and temperature and the increase in rainfall after the month of August.

The findings of the present study with regard to the relationship between climate and maturation are in line with a number of other studies. For example, Lorenzo *et al*. (2012) stated that low temperatures in August and September prevent grapes from reaching the optimal level of maturation, and Mehmel and Van Heerden (2010) reported that late-ripening grape cultivars planted in cool climates will not reach optimal maturity. These findings could be explained by the influence of insolation on photosynthetic activity, fruit development (Calò *et al*., 1996) and berry anthocyanin accumulation (Smart, 1985; Keller & Hrazdina, 1998; Van Leeuwen *et al*., 2004). Lorenzo *et al*. (2012) also reported that the Rías Baixas coastal region, one of the most productive viticultural regions in Spain, lies below an altitude of 300 m and has an Atlantic climate, with a mean annual temperature of about 15°C and an annual rainfall of about 1 600 mm. Montes *et al*. (2012) reported that the Casablanca Valley in Chile, near the eastern edge of the Maipo, Cachapoal and Maule Valleys – the highest zones near the Andes, is classified as temperate according to the HI (HI 1988). Although the heliothermal potential of such locations limits the cultivation of red wine varieties such as Cabernet Sauvignon and Carménère, which have relatively high thermal requirements, they can be suitable for early-ripening varieties such as Pinot Noir and Riesling. Tomasi *et al*. (2011) classified Italy's Veneto region as 1 813 GDD (Region III) and HI 2 457 (Warm), with an annual precipitation of 1 216 mm.

CONCLUSIONS

This study examined phenological and climatic data to determine the suitability of Samsun, a province in Turkey's Black Sea Region, for viticulture. The overall results indicate that grape varieties that ripen in early and mid-season may be recommended for the areas in the region with a maritime climate. The findings showed seven *Vinifera* grape varieties and one *Labrusca* grape variety to be adaptable to the region. Specifically, Narince, Çavus, Yalova İncisi, Cardinal, Trakya İlkeren, Tekirdag Çekirdeksizi and *V. labrusca* grapes demonstrated good potential for grape production in Samsun, whereas the Favli variety did not. In addition to providing data on the phenological timing of a range of early-, middle- and late-maturing cultivars to determine their suitability to the regional climate, this study detailed phenological trends and the influence of a warming climate, which has the potential to significantly affect cultivar suitability and grape production in this region. Climatic data showed higher precipitation at the end of spring (May to June) and beginning of autumn (October) in the coastal areas. Although the level of insolation was found to be sufficient for viticulture, given the increase in precipitation in October, very late ripening varieties should be considered inappropriate for the coastal areas of Samsun. Despite the low average rainfall during the summer months, humidity could create problems in terms of the emergence of disease in the coastal areas of Samsun; however, inland areas of Samsun Province may be suitable for early-, middle- and late-maturing cultivars of *Vitis vinifera* L.

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