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Disease resistance and fruit quality characteristics of 12 *Vitis* spp. grown in a humid-like climate region

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Abstract
Viticulture is carried out for different purposes in almost every region of the world. Although *V. vinifera* L. cultivars are the most commonly grown species in Turkey, their cultivation is very limited in Yalova and similar humid regions. In these regions, fungal diseases are common due to heavy rain, limited sunlight and stagnant air movement, especially in spring and summer months. For this reason, viticulture can only be performed in these humid regions using intense fungicide. In this study, the aim was to determine the most suitable cultivars by comparing 80 years of climate data in Yalova province with eight bioclimatic indices obtained in two growing seasons using a reduced-synthetic-pesticide spray program. Some quality characteristics and susceptibility to fungal diseases (downy and powdery mildew) for a total of eight *V. vinifera* L., three *V. labrusca*, and one interspecies grape cultivar were evaluated in 2019 and 2020 in the humid Yalova region. *V. labrusca* × *V. vinifera* L. hybrids had higher total sugar (18.2% - 23.1%) and lower acidity (0.23% - 0.42%) than *V. vinifera* L. cultivars. In addition, these genotypes (Alden, Ülkemiz, Rizpem) had a lower incidence of powdery mildew in both years. 'Alden', 'Autumn Royal' and 'Erenköy Beyazı Cl.27' exhibited resistance to downy mildew.

Keywords
Yalova region, Downy mildew, Powdery mildew, Climate indices, Fruit quality

Introduction
The grapevine, believed to be cultivated around the world for thousands of years, is one of the world's most important fruit species. Viticulture has a long history in Turkey, which has a vineyard area of 460,000 hectares, and it plays a key role among eco-nomic fruit species. Its production is approximately 4,000,000 tonnes (FAOSTAT, 2021) and 52% of this amount is table grape production. Additionally, Turkey, which is among the countries that produce the most grapes, has an important role (second in the world) in the world table for grape production (TÜİK, 2021). Turkey has different climatic characteristics due to its geographical location and viticulture is carried out successfully in many areas which are humid, hot, cold, and rainy. In addition to its special location (surrounded by the sea on three sides, high mountain ranges in the north and south, increases in altitude from west to east, tectonic effects, etc.), this effect becomes stronger and the dif-ferences become more pronounced (Yılmaz and Çiçek, 2018).

Viticulture highly depends on weather conditions, which is the most important factor in modulating grapevine growth and development in almost all agricultural regions (Van Leeuwen et al., 2004; Fraga et al., 2013; Blanco-Ward et al., 2007; Jones et al., 2010). Considering the bio-ecological potential of the vine, the relationships between climate demands and biological reactions were transformed into numerical indicators and expressions called indices. Using these indicators, quantitative limits were derived to determine if a geographical region is suitable for viticulture (Bahar et al., 2010). These indices for temperature are the most commonly used measurements when regions are compared (Fregoni et al., 2003; Tonietto and Carbonneau, 2004; Blanco-Ward et al., 2007; Jones et al., 2010). The climate not only affects the choice of cultivar, yield, and quality of grapes (Badr et al., 2018; Blanco-Ward et al., 2007) but also intensifies the destructive effects of fungal diseases in vineyards. According to the classic plant disease triangle which represents the relationship between the physical environment and plant diseases, pathogens cannot cause diseases in a susceptible host if the weather conditions are unfavorable (Chakraborty et al., 2000). Grapes can be difficult to grow in humid regions and two fungal diseases that attack foliage and fruit clusters are particularly challenging. These diseases cause significant damage by affecting yield and quality in vineyards. Therefore, very intensive pesticide use may be required during the growing season.

For this reason, spraying is sometimes done 15-20 times, especially in humid areas (Kalliopi et al., 2020; Hazelrigg et al., 2021). Powdery mildew is a disease that is infectious in green leaves and fruit, particularly in the early fruit period (Caffi et al., 2011; Gaduory et al., 2003) and has negative effects such as delay in fruit ripening, reduction in yield, and change in wine composition depending on the severity of the disease (Pool et al., 1984; Calonnec et al., 2004; Stummer et al., 2005). High relative humidity and rainfall promote the severity of powdery mildew (Carroll and Wilcox, 2003; Caffarra et al., 2021) and downy mildew (Kennelly et al., 2005; Salinari, 2007; Chen et al., 2020).

Grape cultivars belonging to *Vitis vinifera* L. cannot mature at the desired level in humid regions due to heavy rainfall during the vegetation period and insufficient sunlight in spring and autumn. Due to climatic conditions in these areas, the susceptibility of *Vitis vinifera* to fungal diseases, low fertilization, late maturing and poor-quality grape production limits the cultivation of cultivars of this species. On the Marmara and Black Sea coastlines, table grape cultivation especially is carried out in a very limited area and has no significant commercial value. In the Eastern Marmara region including Yalova, Kocaeli, Sakarya, Düzce, and Bolu provinces (Köppen-Geiger classifi-cation Csa) total fruit production area is 17,596 ha and the share of vineyard area in the total fruit area is 3.2% in this region (TÜİK, 2021). Summer is hot in the Marmara region, but evaporation and drought are less than in the Mediterranean climate area (Erinç, 1962).

Several recent studies in the literature investigated the relationship between climate and both fungal diseases (Chakraborty et al., 2000; Caffarra et al., 2012; Salinari et al., Willocquet et al., 1996) and fruit quality (Coombe, 1987; Zsófi et al., 2011; Cogato et al., 2019). Interestingly, however, very little research was conducted in regions that are unsuitable in terms of climatic indicators for viticultural operations involving diseases and decreases in fruit quality. Therefore, the aim of this work was an exploratory investigation of the differences in severity of fungal diseases and a comparison of the quality values for 12 grape cultivars belonging to different *Vitis* spp. during two growing seasons under reduced-spraying conditions in a humid region.

Materials and Methods

Plant Material

This study was carried out over two years (2019 and 2020) in Yalova Ataturk Horticultural Research Institute (YAHCRI) vineyard in Yalova, Turkey. The experimental vineyard was planted in 2016 according to the randomized block design which included 12 different grape cultivars belonging to different *Vitis* species (Table 1 and Figure 1). The soil type is well-drained, clay-loam with pH 7.86. Four cultivars used in this study were obtained from breeding studies carried out by YAHCRI and two cultivars were obtained from Samsun Ondokuz Mayıs Agriculture Faculty (SOMAF). In addition to these, four standard cultivars completed the plant materials for this study (Table 1). The vines were grafted onto 1103 Paulsen rootstock and trained with two trunks per vine to a 2 m high-wire dual unilateral cordon spur-pruned system. Vine rows ran south-southeast to the north-northwest and the vine spacing was 2.5 m between vines and 3 m between rows. The vineyard was drip irrigated. The irrigation amount was decided by observing soil, plant, and precipitation conditions every other day. This experiment was carried out with three replicates arranged in a completely randomized block design, with six vines in each replication.

Table 1. List of grape cultivars and some characteristics.

Cultivar/Hybrid	Species	Berry colour	Special flavour	Seed status	Parents
Superior Seedless	*V. vinifera* L.	Yellow	No	Seedless	Cardinal X Unknown Seedless Variety
Autumn Royal	*V. vinifera* L.	Black	No	Seedless	Autumn Black X Fresno C74-1
Alden	Interspecies	Black	Foxy	Seeded	Ontario X Grosse Guillaume
Kyoho (4n)	Interspecies	Black	Foxy	Seeded	Centennial X Ishihara Wase
Atak 77	*V. vinifera* L.	Yellow	No	Seeded	Beyaz Cavus X Hamburg Misketi
Arifbey	*V. vinifera* L.	Yellow	No	Seeded	Beyaz Sam X Mueskuele
Pembe 77	*V. vinifera* L.	Dark Pink	No	Seeded	Alphonse Lavallee X Muscat Reine De
Gülgönül	*V. vinifera* L.	Dark Pink	No	Seeded	Local Variety
Erenköy Beyazı Cl.27	*V. vinifera* L.	Yellow	No	Seeded	Local Variety
Ata Sarısı	*V. vinifera* L.	Yellow	No	Seeded	Beyaz Cavus X Cardinal
Ülkemiz	*V. labrusca*	Black	Foxy	Seeded	Local Variety
Rizpem	*V. labrusca*	Rose	Foxy	Seeded	Local Variety

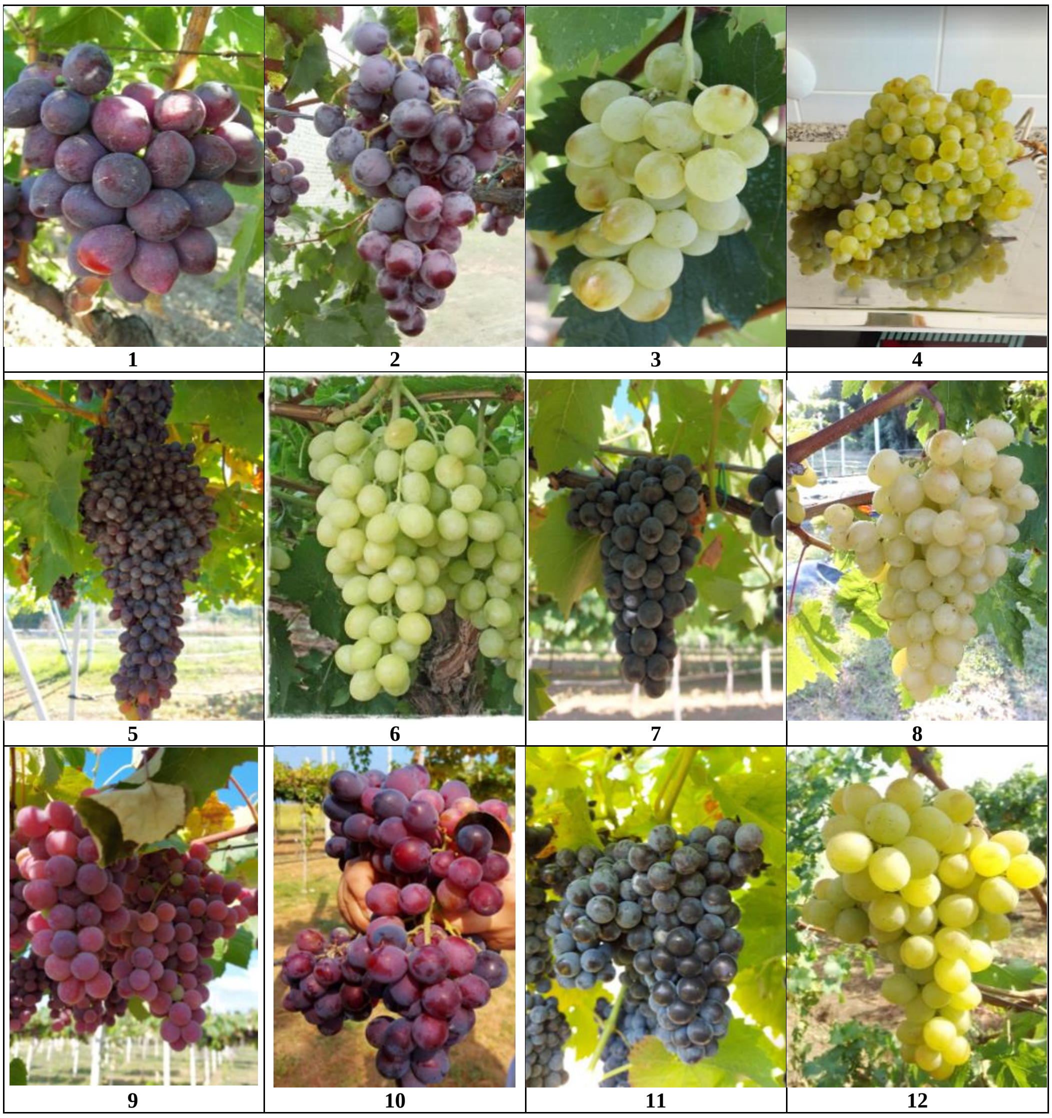

Figure 1. Photos of grape cultivars used in the study.
(1: Gülgönül, 2: Pembe 77, 3: Atak 77, 4: Erenköy Beyazı Clone 27, 5: Autumn Royal, 6: Superior Seedless, 7: Alden, 8: Arifbey, 9: Rizpem, 10: Kyoho (4n), 11: Ülkemiz, and 12: Ata Sarısı)

Research Area

Yalova is located on the northern shore of the Armutlu Peninsula and the northern slopes of the Samanlı Mountains. Yalova is situated in the south-eastern part of the northwest area of Turkey, known as the Marmara Region. The research vineyard is located at a latitude of 40° 39' 40.97" N and longitude 29° 17' 35.98" E (Figure 2a), between the Gulfs of İzmit and Gemlik, north of the Karlık Mountains, on the coast of the Marmara Region (0-10 m elevations) (Figure 2b). To the south of the site, there is a mountainous area in an east-west direction which is covered by forest. There are planted agricultural areas and urban areas between these forests and the study area (Figure 2c).

According to the Köppen-Geiger climate classification, Yalova and its surrounding coast are located in the Csa area; that is, the hot and dry summer (Mediterranean) climate zone. The Mediterranean, Aegean and Marmara coasts of Turkey have Csa characteristics (Figure 3a). Although the study area is located within the Csa climate area, it is separated from the Mediterranean and Aegean coasts by the summer precipitation it receives, it also has features close to the Cfa climate on the Black Sea coast, and essentially presents a character between Csa and Cfa areas. According to the Thornthwaite climate classification (Figure 3b), the site is B1B'1s2b3, humid first-degree mesothermal, semi-marine with severe water deficiency in summer (Yılmaz and Çiçek, 2016) while it has transitional features between the Mediterranean and Marmara regions (Atalay ve Mortan, 2006).

Climatic Data

The meteorological data was obtained from the Meteorological Data Information Presentation and Sales System (MEVBİS) for the period from 1970 to 2020 and from the Yalova Meteorological Observation Station from 2019 through 2020. Eight climatic indices - Winkler Index (WI-GDD), Huglin Index (HI), Branas Heliothermic Index (BHI), Hydrothermic Index (HyI), Cool Night Index (CI), Dryness Index (DI), Latitude Temperature Index (LTI) and Growing Season Temperatures (GST) - were used in this study to determine Yalova's climatic suitability for viticulture. The indices and their calculations are presented in Table 2.

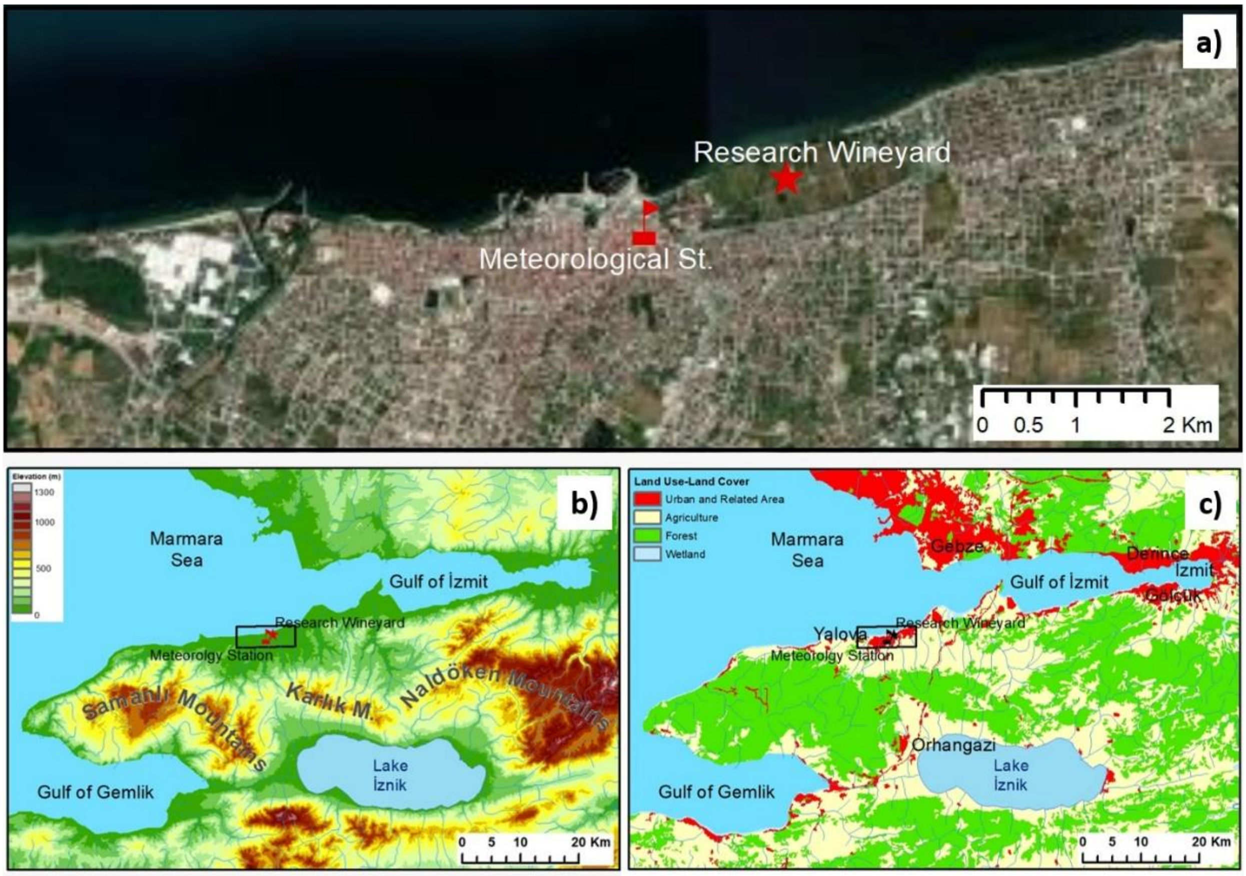

Figure 2. a) Location map of the research area, b) Relief map of study area and sur-roundings, c) Land use map of the study area and surroundings.

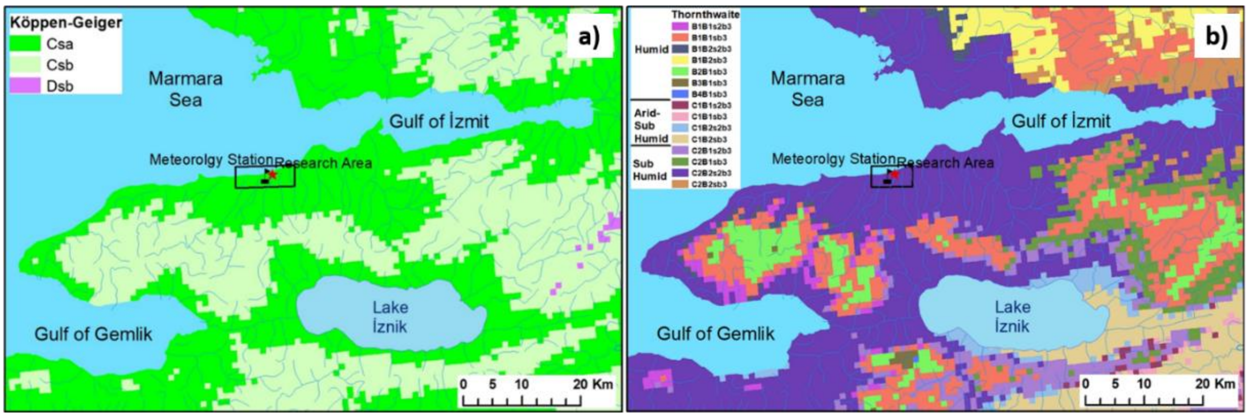

Figure 3. Köppen-Geiger climate map of the study area and surroundings (Yılmaz & Çiçek, 2018), b) Thornthwaite climate map of the study area and surroundings (Yılmaz & Çiçek, 2016).

Table 2. Climatic indices used in this study

Indices/Reference	Equation	Class of Viticultural Climate	Class Interval
Winkler index (WI-GDD) (Winkler et al, 1974)	$\sum_{01\ Apr}^{31\ Oct} = (T_0 - 10)$ T_0 = Mean daily temperature (°C)	Cold	≤ 1390
		Moderately cold	> 1390 ≤ 1670
		Warm	> 1670 ≤ 1940
		Moderately warm	> 1940 ≤ 2220
		Hot	> 2220
Huglin index (HI) (Huglin, 1978)	$= \sum_{01\ Apr}^{30\ Sep} \frac{[(T-10)+(\mathrm{Tx}-10)]}{2} d$ T=Mean daily temperature (°C) TX=Mean daily maximum temperature (°C) d=Day length coefficient (1.02 from 40°1" to 42°0")	Very cool	≤ 1500
		Cool	> 1500 ≤ 1800
		Temperate	> 1800 ≤ 2100
		Temperate warm	> 2100 ≤ 2400
		Warm	> 2400 ≤ 2700
		Very warm	> 2700
Branas Heliotermic index (BHI) (Branas, 1974)	$BHI = X.H.10^{-6}$ X=Annual effective temperature total (°C) H=Annual insolation time total (hour)	>2.6	
Hydrothermic Index (HyI) (Branas, 1946)	$HyI = \sum_{01\ Apr}^{31\ Aug} T \cdot P$ T=Mean monthly temperature (°C) P=Mean monthly precipitation (mm)	No risk	≤ 2500
		Moderate risk	> 2500 ≤ 5100
		High risk	> 5100
Night cold index (CI) (Tonietto, 1999)	The mean minimum night temperature during the month before maturity	Very cool nights	≤ 12
		Cool nights	> 12 ≤ 14
		Temperate nights	> 14 ≤ 18
		Warm nights	> 18
Dryness index (DI)* (Tonietto and Carbonneau, 2004)	$\sum_{01\ Apr}^{30\ Sep} (W_0 + P - T\mathrm{v} - Es)$	Very dry	≤ −100
		Moderately dry	≤ 50 > −100
		Sub-humid	≤ 150 > 50
		Humid	> 150
Latitude temperature index (LTI) (Jackson and Cherry, 1988)	LTI=MTWM (60 – latitude) MTWM: The mean temperature of the warmest month	Unsuitable	> 0 ≤ 380
		Group A	> 380 ≤ 460
		Group B	> 460 ≤ 575
		Group C	> 575 ≤ 700
		Group D	> 700
Average growing season temperatures (GST) (Jones, 2007))	$\sum_{01\ Apr}^{31\ Oct} \frac{(T_{max} + T_{\min}) / 2}{n}$	Cool	> 13 ≤ 15
		Cool temperate	> 15 ≤ 17
		Temperate	> 17 ≤ 19
		Hot	> 19 ≤ 21

*Dryness Index calculation is as follows: Dryness index (DI): $W = W_0 + P - Tv - Es$

Where W = soil water reserve in a certain period, P = precipitation, and Tv = potential transpiration in the vineyard (Tv = ETP. Ꝁ). ETP is the monthly total potential evapo-transpiration calculated according to (Penman, 1948) and the radiation coefficient received by the vine. It is variable according to the transpiration and canopy structure. Es is direct evaporation from the soil. ETP / N. (1-ꝁ) JPm N = number of days in the calculated month, and JPm is the number of days with evaporation in the calculated month. Monthly total potential evapotranspiration (PET) is calculated using the formula below.

PET = (mRn+ρa cp (δe)ga)/(λv (m+ γ))

m = slope of the saturation vapor pressure curve (Pa K^{-1})

R, n = net irradiance (W m^{-2})

ρ a = air density (kg m^{-3})

c p = heat capacity of air (J kg^{-1} K^{-1})

g a = momentum surface aerodynamic conductivity (ms^{-1})

δ e = vapor pressure deficit (Pa)

λ v = latent heat of vaporization (J kg^{-1})

γ = psychrometric constant (Pa K^{-1})

Cultural Practices and Phenological Data

Annual cultural practices (winter pruning, trimming, tillage, irrigation, shoot tying, and weed control) were carried out regularly in the experimental vineyard. Fungicide treatments were carried out only four times in accordance with the dosage recommended in the fungicide leaflet. The first application (4% Bordeaux mixture) was done after pruning, the second application when shoots were 15-20 cm, the third application (Azoxystrobin 200g/l+ Difenoconazole 125g/l) just before flowering and the last application (Fluopyram 200g/l+ Tebuconazole 200g/l) 4 weeks after full blooming. Budburst, blooming, veraison, and harvest dates were observed from April to the end of September for two growing seasons.

Fruit Quality Analyses

Berry firmness (N), acidity (%), Brix (%), and maturity index analyses were carried out in 2019 and 2020 for fruit quality analyses of the cultivars. For the analysis, the harvest time of the cultivars was checked with samples taken regularly every week, starting from the 3rd week after veraison. Berries taken from 12 clusters randomly selected from replications at harvest were used for analysis. A digital refractometer (Atago PAL-BX/ACID2) was used for Brix (%) and acidity (%) analysis. The maturity index was calculated according to Blouin and Guimberteau (2000) °Brix/Titratable Acid. A table type penetrometer was used for berry firmness (N) analysis. Berry firmness was measured as the penetration depth in grape berries with a 2 mm needle digital penetrometer (FM200, PCE Italia s.r.l., Capannori, Italy). The results obtained are given in Table 6 and Table 7.

Sensory quantitative descriptive analysis of cultivars was performed by a panel consisting of 10 members one time after harvest using the Atak and Kahraman (2012) methods with some modifications. The list of sensory terms included descriptors for general acceptance of the bunch (seeded/seedless, skin, flesh), visual appearance (colour, berry shape/size, free disease/pest, seeded/seedless), odour (fruity/foxy, muscat, special), colour (berry colour and homogeneity of colour) and taste (sweet, bitter and sour/acidic). They were rated on an anchored line scale that provided a 0-9 score range (0 = minimum; 9 = maximum intensity).

Evaluation of Fungal Diseases

The resistance levels of cultivars to powdery and downy mildew were observed under natural infection conditions without any artificial inoculation.

Ten leaves and four bunches were randomly selected for evaluation from each vine. Foliar powdery mildew disease severity was determined visually and evaluated following the OIV descriptor 455, but for bunches, the OIV 456 descriptor scale was used.

Ten randomly selected leaves were used for visual evaluation of downy mildew development in each vine at the end of June. The infection severity on leaves was determined based on a percentage of disease spots observed on the entire leaf area according to the procedure described in Table 3.

Table 3. Powdery and downy mildew disease scoring scale for foliage assessment of grape cultivars (GENRES, 2009)

Scale	Symptoms/Reaction (Powdery Mildew)*	Symptoms/Reaction (Downy Mildew)**	Host Response
1	Very low (tiny spots or no symptoms; neither visible sporulation nor mycelium)	Very low (tiny necrotic spots or no symptoms; neither sporulation nor mycelium)	Extremely Resistant
3	Low (limited patches < 2 cm diameter; limited sporulation and mycelium; the presence of *Uncinula* is only indicated by a slight curling of the blade)	Low (small patches < 1 cm in diameter; little sporulation or mycelium)	Resistant
5	Medium (patches usually limited with a diameter of 2–5 cm)	Medium (little patches 1–2 cm diameter; more or less strong sporulation; irregular formation of mycelium)	Tolerant
7	High (vast patches; some limited; strong sporulation and abundant mycelium	High (vast patches; strong sporulation and abundant mycelium; leaf drop later than below)	Susceptible
9	Very high (very vast unlimited patches or totally attached leaf blades; strong sporulation and abundant mycelium)	Very high (vast patches or totally attached leaf blades; strong sporulation and dense mycelium; very early leaf drop)	Extremely Susceptible

* OIV Descriptor: 455
** OIV Descriptor: 452

Statistical Analysis

Fruit quality parameters were analysed in triplicate (n = 3), and the experimental results obtained are expressed as means ± standard deviation. One-way analysis of variance (ANOVA) was used to test values that presented homogeneous variance. The differences were tested by LSMeans Student's test and the mean values were considered significantly different when $p<0.05$. We used JMP statistical software (version. 7.0, SAS Institute Inc., Cary, NC) (SAS, 2003).

Results and Discussion

Climatic data and Indices

According to the data from the Yalova Meteorology Station (YMS) (Figure 2a), the annual average temperature in the field was determined as 14.8°C (1970-2020), the lowest temperatures were recorded in January, and the highest temperatures in July and August. In 2019, the minimum temperatures in May, June and August (Figure 4) were higher than the long-term annual averages, while the minimum temperatures between June and October in 2020 were higher than the long-term annual averages. Similar features were also observed for average temperatures. The maximum temperatures in 2019 and 2020 coincided with the long-term average values for the first six months of the year, and had higher values in the last six months.

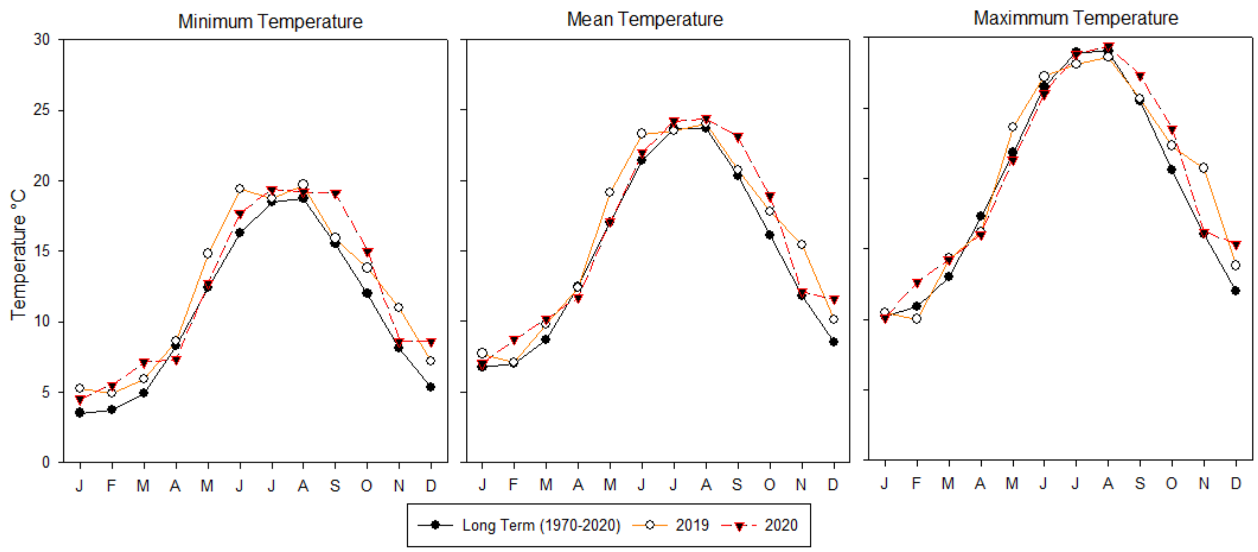

Figure 4. Monthly average minimum, mean, and maximum temperature at YMS.

The long annual total precipitation at YMS was 743 mm. This value was determined as 568 mm in 2019 and 616 mm in 2020. According to the long annual average values, high precipitation is encountered in Yalova in the winter. Moving towards the summer months, although there is a slight increase in precipitation in May, the precipitation decreases. The monthly total precipitation exceeds 100 mm in December and is measured slightly above 20 mm in July (Figure 5). In 2019, lower than normal precipitation fell from March to the end of July, the vineyard received more than 60 mm of precipitation in August, and precipitation that fell again in September increased towards December. In 2020, in May and especially in June, precipitation was higher than normal (115 mm), and almost no precipitation fell in July and August. This resulted in more humid conditions than normal in May and June.

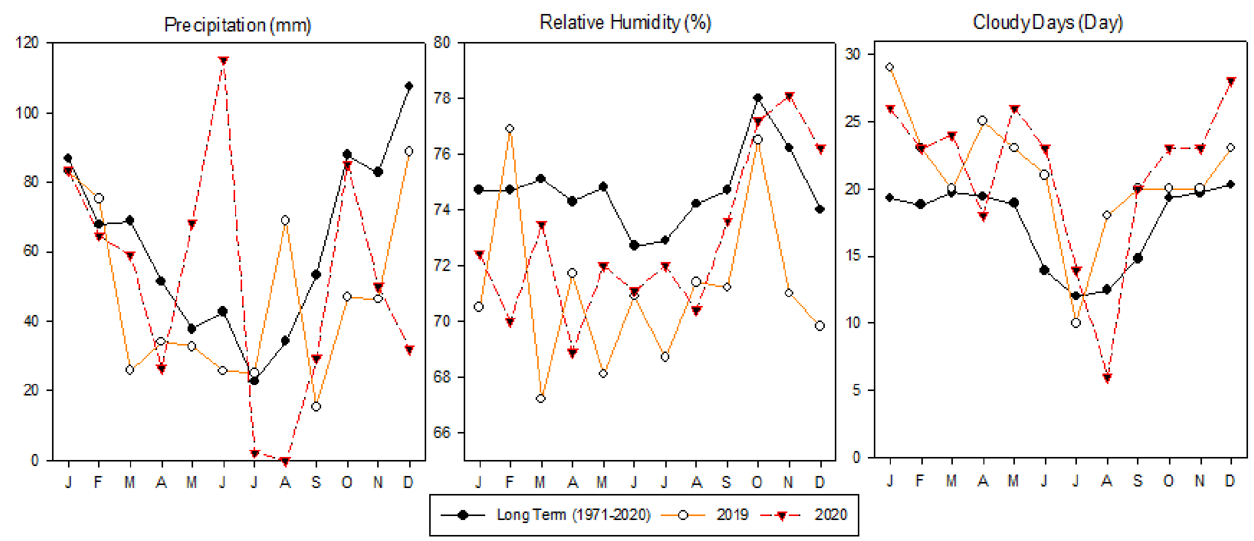

Figure 5. Monthly average total precipitation, average relative humidity, and cloudy days at YMS.

Yalova is an area where the relative humidity is higher than in other parts of Turkey (Koçman, 1993). Average humidity values are measured above 70% even in summer, and the highest relative humidity coincides with autumn (Figure 5). In 2019, humidity values were measured close to normal in February and October, and lower than normal relative humidity values were recorded in the other months. A similar situation continued in 2020 with humidity values in the summer months close to normal and exceeding normal at the end of the year. While the annual average number of cloudy days at YMS is around 20 days between October and May, it is between 10-15 days in the June-September period (Figure 5). In both 2019 and 2020, above-average cloudiness values were observed, exceeding 25 days between November and January. In both years, the number of cloudy days in May and June was much higher than normal. In July and August, cloudiness values below normal were determined.

At Yalova station, the duration of sunshine increases depending on the length of the day in summer approaching 10 hours, and decreases to a few hours in winter (Figure 6). Although a similar situation was experienced in 2019 and 2020, the duration of sunshine was high in all months, and this increase was observed very clearly in March 2019. According to long-term values, the number of dew days at Yalova station is 2.9. This number rises in April-

May and September-October, and approaches 6 days especially in autumn (Figure 5). In 2019, only one day of dew was experienced in September, February, March, October, and November in 2020, and the values were below normal.

According to the long-term annual values for Yalova station, the wind speed is 1.9 m/s. Wind speeds, which are high in winter, decrease during spring to 1.6 m/s around May and June, and after a small increase in July they decrease again in August and September, and then increase (Figure 6). In 2019 and 2020, the annual average wind speed reached 2.1 and 2.2 m/s, respectively, and windier-than-normal conditions were experienced. While the wind speed of 1.9 m/s measured in May 2019 was higher than normal, the wind speed exceeded 2 m/s between June and September, and increased again after falling in October-November.

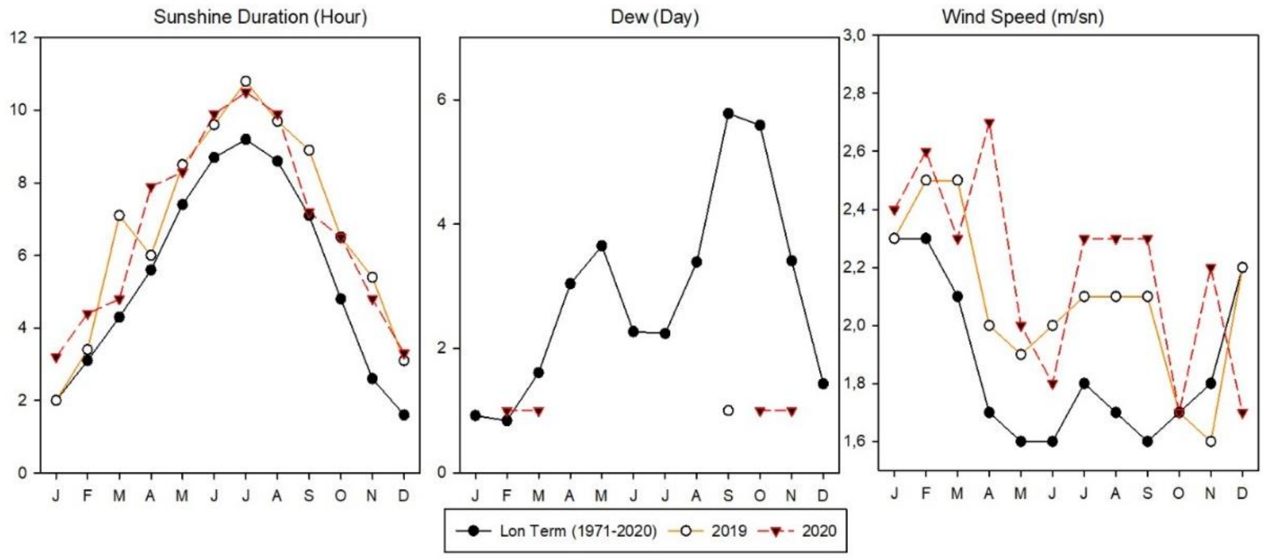

Figure 6. Monthly average sunshine duration, dew and wind speed at YMS.

A similar situation was experienced in 2020, and the wind speed, which was measured as 1.8 m/s in June, was above normal. The calculated climate indices, especially the Winkler Index, are increasing compared to the average for many years. This situation is associated with increasing average temperatures during the vegetation period. Hydrothermic Index (HyI) values, on the other hand, were calculated at 4400°C mm levels and this situation increases the risk in terms of fungal diseases.

Although there is no risk for mildew, a fungal disease, in cases below 2500°C mm, the risk increases between 2500°C mm and 5100°C mm. As the trend in temperature increases, which can be observed according to the GST indicator, it is expected that this indicator will rise above 5100°C mm and be classified as high risk (Malheiro et al., 2010). According to the Multi Criteria Climatic Classification (MCC) of the viticultural climate for 97 regions of the world, two regions are found in Turkey (Izmir and Tekirdag) (Tonietto and Carbonneau, 2004). The values for Yalova climate indices (HI, CI and DI) differ from the climate data for the Izmir and Tekirdag regions (Table 2 and Table 4).

Phenology

The phenology dates for both growing seasons show the differences between the years (Table 5). It was reported in similar studies that these differences may be related to climate, cultivars, or even species, especially on a yearly basis (Jones, 2010; Gashu et al., 2020). The temperatures for the 2019 growing season were warmer than those for the 2020 growing season (Table 4). While the date of budburst generally took place in the last week of March in 2019, it was observed in the first 10 days of April in 2020, except for two cultivars (Atak 77 and Erenköy Beyazı Clone 27). Budburst for the Atak 77 and Erenköy Beyazı Clone 27 cultivars is very late, so these cultivars can be recommended for places with high risk of frost in April. There were fewer differences between the blooming and veraison dates by year, except for *V. labrusca* cultivars. When the harvest dates are examined, the earliest cultivars are Superior Seedless and Gülgönül, while the latest cultivars are Atak 77, Erenköy Beyazı Clone 27, and Pembe 77. Consistent with similar studies (Köse, 2014; Londo and Johnson, 2014; Gupta et al., 2020) using different *Vitis* species, *Vitis vinifera* L. cultivars had a later bud-burst date than *V. labrusca*, but earlier veraison and maturity dates, although the study differs in terms of cultivar and ecology.

Fruit Quality Analyses

In these analyses, berry firmness (g), total acidity (%), Brix (%) and maturity index values were determined for two years (Tables 6 and 7). The highest value in terms of berry firmness (730.31 g) was obtained from Atak 77 (*V. vinifera* L.) cultivar, while the lowest value was obtained from Alden (Interspecies) cultivar (Table 7). In addition, *V. labrusca* cultivars (Ülkemiz and Rizpem) had very low berry firmness. These cultivars are therefore widely used in the production of grape juice and molasses (Köse, 2014; Toaldo et al., 2015). In terms of acidity, similar results were obtained for berry firmness. The highest acidity was obtained from Atak 77 (*V. vinifera*) cultivar, while the lowest value was obtained from Ülkemiz (*V. labrusca*) cultivar. *V. labrusca* cultivars (Ülkemiz and Rizpem) had very low acidity values, following them, the earliest cultivars (Gülgönül and Superior Seedless) had low acidity values (Table 7).

Table 4. Classes of climate for the climatic indices of Yalova

	Units	1931-2019	2019	2020	Mean (2019-2020)
Precipitation (Mean Annual)	mm	757.1	568	621.3	594.7
Precipitation (Vegetation)	mm	241.2	201.8	241.7	221.8
Insolation (Mean Annual)	hour	1.239	1.632	1.642	1.637
Insolation (Vegetation)	hour	567	731.3	793.7	762.5
	Climatic Indices				
Winkler index (WI-GDD)	Degree-day	1.884	2.124	2.142	2.133
Huglin index (HI)		2.183	2.330	2.161	2.246
Branas Heliotermic Index (BHI)	°C hour	5.38	8.14	8.63	8.39
Hydrothermic Index (HyI)	°C mm	4.527	4.206	4.746	4.476
Night Cold Index (CI)	°C	15.1	15.9	19.1	17.5
Dryness Index (DI)	mm	-107	-127	-115	-121
Latitude Temp. Index (LTI)		468	480	488	484
Growing Season Temperatures (GST)	°C	19	20.1	20.2	20.2

Table 5. Phenological dates of cultivars in two experimental years (2019/2020)

Cultivars	Budburst		Blooming		Veraison		Maturity	
Kyoho (4n)	20.03	07.04	29.05	01.06	03.08	04.08	02.09	01.09
Atak 77	25.03	22.04	04.06	07.06	02.08	08.08	09.09	16.09
Alden	24.03	07.04	24.05	28.05	01.08	17.08	26.08	14.09
Arifbey	24.03	08.04	02.06	04.06	01.08	05.08	27.08	31.08
Gülgönül	26.03	08.04	04.06	06.06	17.07	19.07	19.08	12.08
Ata Sarısı	25.03	09.04	02.06	07.06	05.08	04.08	02.09	31.08
Ülkemiz	24.03	10.04	24.05	28.05	01.08	18.08	27.08	14.09
Erenköy Beyazı Clon 27	25.03	22.04	04.06	07.06	09.08	11.08	09.09	16.09
Pembe 77	24.03	10.04	03.06	07.06	05.08	07.08	09.09	16.09
Rizpem	24.03	10.04	24.05	28.05	06.08	18.08	06.09	14.09
Superior Seedless	22.03	03.04	02.06	05.06	15.07	24.07	19.08/	17.08
Autumn Royal	25.03	09.04	05.06	07.06	02.08	04.08	29.08/	28.08

Table 6. Two-year Brix and maturity index of cultivars*

Cultivars	Brix (%)				Maturity Indice			
	2019		2020		2019		2020	
Kyoho (4n)	17.93±0.56	de	17.77±0.56	de	30.94±0.69	d-f	34.85±0.64	d
Atak 77	13.67±0.61	hi	17.50±0.37	de	19.92±1.98	gh	22.65±1.95	gh
Alden	19.10±1.14	cd	23.10±1.10	a	53.67±3.09	c	55.64±4.88	c
Arifbey	12.27±1.44	ij	12.30±1.44	ıj	21.27±1.53	h	21.79±3.55	gh
Gülgönül	11.40±1.15	j	14.43±0.62	gh	24.69±3.12	f-h	28.05±4.73	e-g
Ata Sarısı	16.37±1.51	e-g	17.90±0.70	de	23.13±3.75	gh	25.59±2.25	f-h
Ülkemiz	18.20±0.94	de	20.37±0.82	bc	80.46±4.84	a	67.67±4.85	b
Erenköy Beyazı Cl.27	11.03±0.48	j	11.03±0.26	j	22.00±1.78	gh	19.37±0.77	h
Pembe 77	13.93±1.21	hi	14.70±0.57	gh	21.87±2.54	gh	22.05±0.78	gh
Rizpem	18.40±0.96	d	22.30±0.22	ab	66.8±0.70	b	63.01±6.12	b
Superior Seedless	14.43±0.90	gh	17.17±1.23	d-f	34.89±1.51	d	32.65±1.38	de
Autumn Royal	14.10±0.85	hi	15.30±1.14	f-h	22.14±0.30	gh	24.95±3.66	f-h
CV	7.5				11.21			

*Variance analysis was applied for each parameter and different letters indicate significant differences between the cultivars at p≤0.05.

Table 7. Two-year berry firmness and acidity values of cultivars*

Cultivars	Berry Firmness (g**)				Acidity (%)	
	2019		2020		2019	2020
Kyoho (4n)	518.33±19.90	d-f	703.54±59.26	ab	0.58±0.02	0.51±0.02
Atak 77	677.08±87.94	a-c	783.54±73.88	a	0.69±0.04	0.78±0.05
Alden	210.42±11.92	g	185.42±4.12	g	0.36±0.02	0.42±0.02
Arifbey	406.25±21.38	f	519.38±38.77	d-f	0.58±0.05	0.57±0.04
Gülgönül	487.92±61.92	ef	615.21±91.60	b-d	0.46±0.01	0.53±0.09
Ata Sarısı	552.04±23.46	c-e	624.50±119.95	b-d	0.72±0.09	0.70±0.05
Ülkemiz	227.92±8.19	g	240.63±42.18	g	0.23±0.01	0.30±0.03
Erenköy Beyazı Clon 27	571.67±15.46	e	581.25±29.10	ce	0.50±0.03	0.57±0.01
Pembe 77	624.38±88.83	b-d	672.08±55.98	a-c	0.64±0.04	0.67±0.004
Rizpem	267.08±5.24	g	248.33±30.96	g	0.35±0.07	0.34±0.03
Superior Seedless	646.32±72.59	bc	637.29±91.73	bc	0.41±0.01	0.53±0.04
Autumn Royal	499.14±51.73	ef	725.21±23.58	ab	0.64±0.04	0.62±0.05
CV	13.6				9,6	

*Variance analysis was applied for each parameter and different letters indicate significant differences between the cultivars at p≤0.05.
** Grams needed to cause a 1 mm deflection of the grape berry skin.

While the maturity index values of *V. labrusca* cultivars vary between 50 and 80, this index value varied between 20 and 35 for *V. vinifera* L. cultivars. In terms of berry firmness, total acidity (%) and Brix (%), *V. labrusca* cultivars differ considerably from *V. vinifera* cultivars. Similar to our study, Liu et al. (2006) reported that *V. labrusca* × *V. vinifera* hybrids had higher total sugar and lower acidity than *V. vinifera* L. cultivars.

Sensory analysis is considered one of the main techniques to evaluate the organoleptic qualities of grapes. It is a frequently chosen evaluation method, especially to compare the results of different cultivars and treatments (Santillo et al., 2011). In this study, these analyses were carried out on grapes affected by fungal diseases to different degrees as a result of reduced spraying. When the sensory evaluation test was performed after the cultivars were harvested during two growing seasons, different results were obtained according to the cultivars and years (Table 8 and Table 9). Kyoho (4n) which had larger fruit and Superior Seedless cultivars with crispy flesh that can be associated with higher firmness (Table 7) and were favoured a little more than the others in terms of general acceptance and visual appearance. In addition, Erenköy Beyazı Clone 27 with small berries and 3-4 seeds was less appreciated than the other cultivars (Table 8). The phenological developmental stages, growing degree days (GDD) and some fruit quality parameters from budburst to maturity of the vine cultivars vary according to the cultivars and climatic conditions. The ripening date of a cultivar in different ecologies or the demand for effective temperature summation may be close to each other or quite distant. It was reported that this may be due to differences in growing conditions, ecology and measurement methods, as well as different responses of cultivars to different ecological conditions (Akturk ve Uzun, 2019).

Table 8. Two-year sensory analysis (general acceptance and visual appearance) score of cultivars*

Cultivars	General Acceptance				Visual Appearance			
	2019		2020		2019		2020	
Kyoho (4n)	7.32±0.45	a-c	7.57±0.92	ab	7.25±0.66	b-f	8.36±0.48	a
Atak 77	6.5±0.71	d-f	6.82±0.83	c-e	6.75±1.09	e-ı	7.54±0.67	a-e
Alden	6.88±0.93	a-e	7.09±0.90	a-d	6.50±0.71	f-ı	6.57±1.36	f-ı
Arif Bey	6.88±0.60	a-e	6.80±0.72	b-e	8.00±0.71	ab	7.09±0.79	d-g
Gülgönül	6.13±0.60	e-g	7.00±0.85	a-d	8.31±0.70	a	6.91±0.51	d-h
Ata Sarısı	6.04±0.63	e-g	7.55±0.78	a	6.63±0.47	d-j	8.00±0.60	ab
Ülkemiz	7.25±0.83	a-d	6.98±1.09	a-d	7.25±0.66	b-f	7.55±0.68	a-e
Erenköy Beyazı Cl.27	5.00±0.71	h	6.18±1.17	fg	6.13±0.93	ıj	6.91±1.16	d-h
Pembe 77	5.50±0.5	gh	6.13±0.94	ef	5.63±0.70	j	6.35±1.05	h-j
Rizpem	7.03±0.01	a-d	6.27±1.21	ef	6.38±1.11	g-j	6.88±1.22	e-ı
Superior Seedless	7.63±0.86	a	6.91±0.67	a-d	7.75±1.09	a-d	7.18±0.94	c-f
Autumn Royal	7.02±0.93	a-d	6.73±0.86	c-f	6.38±1.41	h-j	6.82±1.40	f-ı
CV	0.8				0.9			

*Variance analysis was applied for each parameter and different letters indicate significant differences between the cultivars at p≤0.05

Table 9. Two-year sensory analysis (odour, colour, and taste) scores of cultivars*

Cultivars	Odour				Colour				Taste			
	2019		2020		2019		2020		2019		2020	
Kyoho (4n)	4.94±1.15	d-h	7.66±0.94	ab	7.26±0.45	b-f	8.73±0.45	a	6.75±0.83	b-g	7.45±1.16	a-d
Atak 77	5.28±1.03	d-f	5.64±0.88	d	6.00±0.87	hı	6.82±0.57	d-g	6.50±0.71	c-h	6.91±0.99	b-f
Alden	6.88±1.17	ab	7.54±0.81	ab	7.75±0.43	a-c	6.45±1.08	gh	7.14±0.35	a-e	7.45±1.23	a-c
Arif Bey	4.42±1.05	gh	5.45±0.66	d	7.00±0.71	c-g	6.91±0.90	d-g	5.73±0.70	h-j	6.82±0.83	b-g
Gülgönül	5.78±0.99	cd	5.27±0.45	d	7.50±1.12	b-d	7.27±0.45	e	5.31±0.88	jk	6.93±0.83	b-f
Ata Sarısı	4.47±0.8	e-h	5.64±0.77	d	5.58±0.80	ı	7.18±0.83	b-f	5.99±1.15	g-j	7.64±0.64	ab
Ülkemiz	7.75±0.97	a	6.95±1.37	ab	7.63±0.48	b-d	7.91±0.51	ab	6.88±1.05	b-g	7.00±0.74	a-f
Erenköy Beyazı Cl.27	4.09±0.64	h	5.27±0.42	d	5.50±0.71	ı	6.58±1.11	f-h	4.63±0.48	k	4.00±1.05	l
Pembe 77	4.99±0.82	d-g	5.27±0.86	de	5.50±1.00	ı	5.93±0.94	hı	5.50±0.5	ıj	6.45±0.99	e-h
Rizpem	7.25±0.66	ab	6.65±1.02	bc	7.13±1.17	b-g	6.82±0.94	d-g	6.81±0.64	b-g	6.27±1.05	f-ı
Superior Seedless	5.50±1.11	d	5.36±0.48	d	7.63±1.41	b-d	7.55±0.66	b-d	8.00±0.87	a	6.67±0.78	c-g
Autumn Royal	4.57±1.49	f-h	5.45±0.66	d	7.25±0.66	b-f	6.64±1.19	e-h	6.50±1.00	d-h	6.82±0.83	b-g
CV	1.2				0.9				1.1			

*Variance analysis was applied for each parameter and different letters indicate significant differences between the cultivars at p ≤ 0.05

Evaluation of Fungal Diseases

The cultivars varied in terms of their resistance to powdery mildew (*Erysiphe necator*) and downy mildew (*Plasmopara viticola*) under natural inoculation conditions during the two experimental years (Table 10). Average precipitation during the growing season (PGS) was mean 221.8 mm of both years, with relative humidity 75-80% and temperature 22-25°C recorded just before veraison (EL XX). These conditions favour powdery mildew and downy mildew infections.

Powdery mildew had a more devastating effect in both growing years than Downy mildew. The climatic conditions seem to be favourable for *E. necator* development during the growing seasons. Heavy rainfall in May and June in 2020 increased the severity of powdery mildew. Favourable temperatures and heavy rainfall in the early growing season cause the release of ascospores from overwintered cleistothecia for Powdery mildew. Even if a routine fungicide is applied, the chemical spray is washed off by intense rainfall (Lu et al., 2020). Consistent with similar studies (Cadle-Davidson et al., 2011; Wan et al., 2007; Atak et al., 2017), *V. labrusca* cultivars (Alden, Ülkemiz, and Rizpem) were more resistant to powdery mildew than *V. vinifera* L cultivars. The long-term dew days in April and May keep the leaf surface moist and provides a favourable environment for the development of downy mildew. Several studies reported temperatures of 20 to 25°C and moist leaf surface are the most suitable development conditions for Downy mildew which has an impact on fruit quality (Salinari et al., 2007; Chen et al., 2020). Lakso et al. (1982) reported Powdery mildew causes necrotic cells within and between infected grape leaves that directly affect photosynthesis. Therefore, PM disease severity can affect fruit quality.

Alden cv. was detected to be the best resistant to the two fungal diseases. Ata Sarısı and Superior Seedless (*Vitis vinifera* L. cultivars) were susceptible to PM in both experimental years. Some berries cracked as a result of the intense effects of the PM disease on these cultivars.

Table 10. Powdery mildew and downy mildew evaluation scale for 2019 and 2020

Cultivars	PM (*Erysiphe necator*)			DM (*Plasmopara viticola*)		
	2019	2020	Mean	2019	2020	Mean
Ata Sarısı	6.3	7.0	6.7	2.3	4.3	3.3
Superior Seedless	5	5.7	5.4	2	3.7	2.9
Pembe 77	4.3	4.3	4.3	2	3.7	2.9
Atak 77	3.7	4.3	4	2	3.7	2.9
Arifbey	3.7	3.7	3.7	2.3	2.3	2.3
Kyoho (4n)	3.7	3.7	3.7	1	1.0	1
Gülgönül	3	3.0	3	1.7	3.0	2.4
E. Beyazı Cl 27	2.7	2.3	2.5	1	1.0	1
Autumn Royal	2	3.0	2.5	1	1.0	1
Alden	1	1.0	1	1	1.0	1
Ülkemiz	1	1.0	1	1.7	3.0	2.4
Rizpem	1	1.0	1	1.7	3.0	2.4

Conclusion

In this study, phenological analysis and berry quality traits of 12 *Vitis* species grown in the Yalova region were completed during two consecutive growing seasons (2019 and 2020), combined with the climatic indices calculated for these years and in the long-term period (1931-2019). Despite the favourable climate for fungal disease, grape quality parameters of *V. labrusca* and interspecies cultivars (Alden, Ülkemiz and Rizpem) were not affected by fungal diseases. While fruit quality analyses revealed that these grape cultivars differ from *V. vinifera* L cultivars in terms of fruit quality characteristics, these *V. labrusca* cultivars had low acidity and very high Brix ratio.

Although *V. labrusca* and interspecies cultivars are not widely accepted for fresh consumption due to thick skins and many hard seeds, they are widely used in the fruit juice industry especially in USA, Brazil, and Turkey. In this study, it was demonstrated that these cultivars can be grown in humid ecosystems for the production of much healthier grape products with very little spraying.

As a result of the study, both the viticulture potential of the north-western Turkish province was revealed with climatic data, and some cultivars were determined that could be grown with reduced pesticide applications for ecologies similar to Yalova.

Compliance with Ethical Standards

Conflict of interest

The authors declared that for this research article, they have no actual, potential or perceived conflict of interest.

Author contribution

The contribution of the authors to the present study is equal. All the authors read and approved the final manuscript. All the authors verify that the Text, Figures, and Tables are original and that they have not been published before.

Ethical approval

Ethics committee approval is not required.

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Data availability

Not applicable.

Consent for publication

Not applicable.

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