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Review Paper

An overview of the studies on resistance to downy mildew (*Plasmopara viticola*) on grapevines in Türkiye

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Abstract

Downy mildew caused by oomycete *Plasmopara viticola*, is one of the most damaging grapevine diseases. This disease can be found in all parts of the grapevines (*Vitis vinifera* L.) and causes quality and yield losses. Intensive spraying has been done in the vineyards against this disease for many years and the effectiveness of the fungucides used against this disease is gradually decreasing. For this reason, studies on the determination of disease-resistant Vitis species have increased in Türkiye as in the whole world. In this context, 1006 genotypes (59 *Vitis vinifera*, 47 *V. labrusca*, 1 *V. rotundifolia*, 899 interspecific crosses) were evaluated for their resistance to downy mildew disease. 20 genotypes (*V. vinifera*) among them were tested only under natural infection conditions, while 67 (21 *V. vinifera*, 34 *V. labrusca*, and 12 interspecific crosses) were tested both under natural infection and by artificial inoculation. The resistance of 919 genotypes (18 *V. vinifera*, 13 *V. labrusca*, 1 *V. rotundifolia*, 887 interspecific crosses) was determined by artificial inoculation only. In this review, the resistance tests of genotypes performed by different researchers in Türkiye are summarized by considering the inoculation conditions of Vitis spp and the pathogen. The changes in phenolic compounds of different genotypes before and after the disease were also included in the study. At the same time, this study will make important contributions to researchers who will conduct research on resistance to downy mildew in grapevines.

Introduction

Grapevine (*Vitis vinifera* L.) is an important plant that is cultivated economically in the northern and southern parts of the world. It is one of the most produced fruits with an annual production of more than 75 million tons (Güler and Karadeniz, 2022). However, the genotypes of *V. vinifera*, which are commercially produced in the world due to the high quality of its grapes, are susceptible to several pathogens such as *Erysiphe necator* Schw. and *Plasmopara viticola* (Berk. & M.A. Curtis) Berl. & De Toni, which cause powdery mildew and downy mildew diseases, respectively. Among them, downy mildew is an important problem especially in countries with humid climatic conditions worldwide. However, the development of pathogen is limited in Argentina, Chile and Egypt with dry climates (Emmet et al., 1992; Gessler et al., 2011).

Obligate oomycet *P. viticola* infects all green parts of the grapevine. The first symptoms occur 5-7 days after the inoculation and causes yellowish oilspot-like on the upper surface of the leaves. Mass of sporangia and sporangiophores in white colour appears on the under surface of the leaves (Ash, 2000) and other infected parts. If infections occur on the young bunch stalk, the pathogen can cause the death of inflorescence and berries (Figure 1).

The pathogen was first detected in the North East of the USA and then spreads to

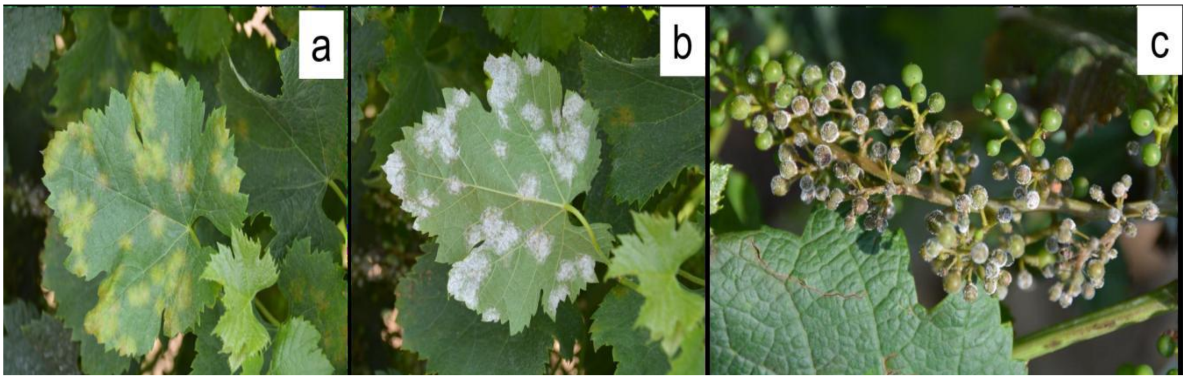

Figure 1. The symptom of downy mildew (Plasmopara viticola) (a: oil-spot on leaf; b: sporulation on the abaxial surface of leaves; c: culuster infection)

Europe. Today, cultural practices, early warning systems, chemical control and the use of resistant genotypes are the control methods of this disease, which cause substantial yield and economic losses in favorable climatic conditions (Emmett et al.,1992; Ash, 2000). Among the cultural practices prunning and avoiding overirrigation (for minimize leaf wetness), collecting diseased plant debris (to reduce sources of overwintering inoculum) are included.

Fungicide treatment is the most effective way to control the disease. However, extensive fungicide programs may be needed to keep disease levels at minimum under favorable climatical conditions for the disease. Copper is the oldest and most widely used ingredient among preventative fungicides, particularly in organic viticulture today (Weitbrecht et al., 2021). However, excessive copper use can have harmful impacts on the ecosystem, including buildup in the soil and harm to beneficial organisms (Toffolatti et al., 2018). The chemical industry created organic fungicides to control downy mildew following World War II. The market was then introduced to target-site fungicides. *P. viticola* has a significant capacity for evolution because of complicated life cycle, which includes sexual and asexual reproduction and polycyclic behaviour (Massi et al., 2021). In this context, it is known that the fungicides with active ingredients, dimethomorph, iprovalicarb, bentiavalicarb from the group Carboxylic Acid Amide (CAA) caused inheritable reduction in sensitivtiy of *P. viticola* (Gisi at al., 2007). Additionally, many studies reported that the presence of resistance population to some active ingredients such as cymoxanil from Cyanoacetamide-oxime group (Gullino et al., 1997), metalaxyl from Phenylamides (Staub and Sozzi, 1981; Bosshard and Schuepp 1983), pyraclostrobin, azoxystrobin (Giraud et al., 2013), famoxadone (Gullino et al., 2004) and fenamidone (Heaney et al., 2000) from Quinone outside Inhibitor (QoI). Some authors detected genetic mutation conferring resistance to mandipropamid from CAA (Blum et al., 2010), cyazofamid, amisulbrom from Quinone inside Inhibitors (QiI) (Cherrad et al., 2018; Fontaine et al., 2019) and ametoctradin from Quinone inside-outside Inhibitor (QioI) (Mounkoro et al., 2019, Fontaine et al., 2019). This situation and the negative effects of fungicides on human and environmental health have led grapevine breeders to breed studies to obtain resistant grapevine genotypes to downy mildew disease.

In recent years, grapevine breed studies in Türkiye have focused on yield, quality, seedlessness, early/late maturity, drought/cold resistant, resistance to pests and diseases, and suitability for mechanization (Çakır and Söylemezoğlu, 2018). Türkiye has a rich genotypic grapevine variety with different morphological and biochemical characteristics with different reactions to grapevine diseases. This review covers the studies on resistance to downy mildew disease with different grapevine cultivars or species and natural inoculation and artificial inoculation treatments in Türkiye.

Reactions of grapevine genotypes grown in Türkiye to downy mildew disease

The first documented paper dates back to 2013, when Gargın and Öztürk tested ten different grapevine genotypes (cv. Alphonse Lavallée, cv. Ata Sarısı, cv. Burdur Dimriti, cv.

Table 1. Different scales for disease symptom and resistance level used in Türkiye for the leaf resistance tests to P. viticola

	Scale value	Symptom	Reference		Resistance level	Severity index or sporulation area	Reference
A	0	No spot	Anonymous (2022)	**D**	ER	0-5.0	Boso et al., (2006)
	1	1 spot on the leaf			HR	5.1-25	
	2	1/4 of the leaf is spotted			R	25.1-50	
	3	Up to 1/2 of the leaf is spotted			S	50.1-75	
	4	More than 1/2 of the leaf is spotted			HS	>75.1	
B	1	Very low (tiny necrotic spots or no symptoms; neithersporulation nor mycelium)	IGPRI (1997)	**E**	ER	0	Wan et al., (2007)
	3	Low (small patches < 1 cm in diameter; little sporulation or mycelium			HR	0-5	
	5	Medium (little patches 1-2 cm diameter; more or less strong sporulation; irregular formation of mycelium			R	5.1-25	
	7	High (vast patches; strong sporulation and abundant mycelium; leaf drop later than below)			S	25.1-50	
	9	Very high (vast patches or totally attached leaf blades; strong sporulation and dense mycelium; very early leaf drop)			HS	50.1-100	
C	0	No symptoms	Wan et al. (2007)	**F**	ER	1	IGPRI (1997)
	1	0.1-5.0% (percentage of lesion of the whole leaf)			R	3	
	2	5.1-15.0% (percentage of lesion of the whole leaf)			T	5	
	3	15.1-30.0% (percentage of lesion of the whole leaf)			S	7	
	4	30.1- 45.0% (percentage of lesion of the whole leaf)			ES	9	
	5	45.1-65.0% (percentage of lesion of the whole leaf)		**G**	ER	0-0.05 mm^2	Özer et al., (2021)
	6	65.1-85.0% (percentage of lesion of the whole leaf)			HR	0.1-1,0 mm^2	
	7	85.1-100.0% (percentage of lesion of the whole leaf)			R	1.1-2 mm^2	
					S	2.1-10.0 mm^2	
					HS	10.1-15 mm^2	
					ES	>15.1 mm^2	

Italia, cv. Pembe Gemre, cv. Red Globe, cv. Senirkent Dimriti, cv. Siyah Gemre, cv. Sultani Çekirdeksiz, cv. Trakya İlkeren) for downy mildew resistance under natural infection conditions for 2 years in Isparta. Downy mildew disease evaluation was done using 0-4 scale in the related study (Table 1A). The high severity index values for two years differing from 0.41 to 1.87 were determined on the leaves of cv. Alphonse Lavallée, cv. Ata Sarısı, cv. Italia, cv. Pembe Gemre, cv. Sinirkent Dimriti, cv. Siyah Gemre and cv. Trakya İlkeren, while those of cv. Burdur Dimriti and Red Globe had low severity index values between 0.07 and 0.33 (Table 2). However, there is no information about resistance level of the genotypes tested.

In the following year (Atak, 2017), 13 *Vitis vinifera* genotypes, 8 *Vitis labrusca* genotypes and 6 interspecific crosses were evaluted using artificial inoculation of the pathogen to whole plants in pots in greenhouse and under natural infection condition in Yalova province using 1-9 scale (Table 1 B). Resistance level was recorded based on severitiy index (Table 1D) as reported by Boso et al. (2006). The genotypes belonging to *V. labrusca* and interspecific crosses were more resistant to the disease as compared with those from *V. vinifera* (Table 2-6). Among the tested genotypes, Giresun T1 (HR), Giresun T5 (HR), 53 Güneysu 02 (ER), Köfteci üzümü (ER) and Sinop T-3 (HR) from *V. labrusca* (Table 3 and 5), Alden (ER), Canadice (ER) and Kay Gray (ER) from interspecific crosses (Table 3 and 6) exhibited the same high resistance levels under both infection conditions. In the same year, Atak et al. (2017a) tested different *V. vinifera*, *V. labrusca*, and interspecific crosses using the same scale and resistance level assessment as Atak (2017) under artificial and natural infection conditions. The genotypes of this study, which were found to be extremely or highly resistant under both conditions, were 57 Erfelek 03 (ER), 28 Görele 01 (ER), Isabella-Tekirdağ (HR), 55 Merkez 06 (HR), 55 Merkez 09 (ER), 57 Merkez 07 (ER), 53 Pazar 02 (HR) and 61 Sürmene 01 (HR) from V. labrusca (Table 3 and 5), and Edelweis (HR), Glenora (Seedless)(HR), Himrod seedless (HR), Kyoho (HR) from interspecific crosses (Table 3 and 6).

Atak et al. (2017b) studied with 16 genotypes previously identified as resistant (Atak, 2017; Atak et al. 2017a) and 5 new genotypes in pots in the greenhouse and determined the disease index values according to the 1-9 scale (Table 1B) after *P. viticola* inoculation, but did not report the resistance level. The study also includes changes in total phenol and antioxidant activities after infection. The genotypes belong to V. *labrusca* (57 Ayancık 01, 55 Çarşamba 01, 53

Table 2. Disease severity or resistance level of genotypes from *V. vinifera* evaluated by various authors in vineyards of Türkiye with naturally downy mildew infested leaves

	Gargın and Öztürk, (2013)*	Atak (2017)	Atak et al. (2017)	Mermer Doğu et al. (2022)**
Akdimrit		S		
Alphonse Lavallée	0.53-0.65			
Antep büzgülü		S		
Arifbey		HR		
Atak 77		HR		
Ata Sarısı	0.43-0.46			
Autumn Royal (Seedless)			*HR*	
Barış				3.00-7.00%
Bilecik İri Karası clone107		ER		
Bozbey				2.75-0.50%
Burdur Dimridi	0.33-0.20			
Cabernet Sauvignon				14.00-10.25%
Cardinal				0.00-3.50%
Chardonnay				5.50-1.00%
Cinsaut				1.50-1.50%
Çavuş				0.25-2.50%
Erenköy Beyazı clone 27		HR		
Gamay				1.00-4.75%
Güzgülü				10.50-3.00%
Italia	0.42-0.43	HR	*HR*	
Kalecik Karası				1.00-2.00%
Kömüşmemesi		S		
Lival		HR		
Müşküle				1.75-1.75%
Özer karası				5.75-1.00
Papazkarası				3.50-3.00%
Pembe Gemre	1.87-0.63			
Pembe 77		HR		
Pembe üzüm		S		
Red Globe	0.07-0.19		*HR*	
Reçel Üzümü				0.75-1.50%
Ribol		HR		
Semillon				0.75-0.25%
Senirkent Dimriti	1.25-0.41			
Siyah Gemre	1.59-0.46			
Sultani Çekirdeksiz	0.62-0.19			2.00-1.50%
Tekirdağ Çekirdeksizi				5.75-2.75%
Trakya İlkeren	1.33-0.72			7.25-7.00%
Yalova İncisi				5.25-6.00%
Yapıncak				1.25-1.00%
86/1		HR		

*Disease index, **Disease severity (%), ER, Extremely Resistant; HR, Highly Resistant; S, Susceptible

Güneysu 01, 53 Merkez 02, 55 Merkez 11, 55 Merkez 12, 61 Of 04, 53 Pazar 02, Rizpem, 61 Sürmene 02), interspecies crosses (Kyoho, Phoenix, Regent, Sirius, Staufer) and *V. rotundifolia* (Sugargate) had index values of 1 or 3 (Table 5-6), while *V. vinifera* genotypes (Italia, Lival, Red Globe, Ribol) had value 5 (except Autom Royal) (Table 4). The authors reported that the highest amount of gallic acid accumulation was found in cv. Sugargate, which is known to be extremely resistant to downy mildew, and the highest amount of rutin hydrate accumulation was found in resistant Red Globe after *P. viticola* infection. Atak and Göksel (2019) determined the susceptibility of 15 genotypes, four of which (Alden, Italia, Kay Grey, 86/1) were tested in previous studies (Atak, 2017; Atak et al., 2017a, b), against downy mildew disease using a 1-9 scale (Table 1B) after artificially inoculation of potted plants. The authors also investigated the accumulation of phenolic substances in these genotypes after two years of downy mildew infection. As a result of the resistance tests, Erenköy Beyazı clone 29, FX1-1 and Özer Karası from V. vinifera had disease index value of 3 and the other genotypes showed the index value 5

Table 3. Disease severity or resistance level of genotypes from *V. labrusca* and interspecific crosses evaluated by different authors in vineyards of Türkiye with naturally downy mildew infested leaves

	V. labrusca		
Genotypes	Atak (2017)	Atak et al. (2017a)	Mermer Doğu et al., (2022)*
57 Ayancık 01		ER	
55 Çarşamba 01		ER	
Çeliksu		HR	
57 Erfelek 03		ER	
57 Gerze 01		ER	
57 Gerze 04		ER	
Giresun T-1	HR		
Giresun T-3	ER		
Giresun T-5	HR		
28 Görele 01		ER	
53 Güneysu 01		ER	
53 Güneysu 02	ER		
Isabella (Yalova)		ER	
Isabella (Tekirdağ)		HR	0.00-0.50
Köfteci üzümü	ER		
28 Merkez 01		ER	
53 Merkez 02		HR	
55 Merkez 06		HR	
55 Merkez 09		ER	
55 Merkez 11	ER		
55 Merkez 12		ER	
57 Merkez 07		ER	
61 Of 04		ER	
53 Pazar 02		HR	
Rizellim		ER	

Continued genotypes from *V. labrusca*		
Genotypes	Atak (2017)	Atak et al. (2017a)
Rizessi		ER
Rizpem		ER
Sinop T-1	R	
Sinop T-3	HR	
61 Sürmene 01		HR
61 Sürmene 02		ER
28 Tirebolu 02		ER
Ülkemiz		ER
61 Yomra 04		HR
Interspecific crosses		
Genotypes	Atak (2017)	Atak et al. (2017a)
Alden	ER	
Canadice	ER	
Edelweiss		HR
Glenora (Seedless)		HR
Himrod (Seedless)		HR
Kay Grey	ER	
Kyoho		HR
Lakemont	HR	
Mortensen	ER	
Seneca	ER	
Sheridan		HR
Steuben		HR

ER, Extremely Resistant; HR, Highly Resistant; R, Resistant,

Table 4. Disease index or resistance level of *V. vinifera* genotypes evaluated by various authors on artificially inoculated plants in greenhouse or detached leaves

Genotypes/individuals	Atak (2017)*	Atak et al. (2017a)*	Atak et al. (2017b)*	Atak ve Göksel (2019)*	Yıldırım et al., (2019)*	Atak et al. (2021)*	Özer et al. (2021)**	Kumaşoğlu et al. (2022) **
Akdimrit	S							
Alphonse Lavallée							ES	
Alüzüm					R			
Antep büzgülü	R							
Arcadia					R			
Arifbey	R				R			
Atak 77	R				S			
Autumn Royal (Seedless)		R	3					
Bilecik İri Karası klon 107	R							
Boscop Glory					S			
BX1-166				5	S	T		
Burdur Dimriti				5				
Cabernet Sauvignon							ES	
Erenköy Beyazı klon 27	R							
Erenköy Beyazı klon 29				3				
Çınarlı karası					S			
Favli					S			
FX1-1				3	R	R		
FX1-10				5	S	T		
Gülgönül				5	S			
Gürcü					R			
Güzgülü				5	S	T		
Italia	R	R	5	5		T		

Karasakız							S
Kömüşmemesi	S						
KXP-10				5	S	T	
Lival	R		5				
Mercan					S		
Müşküle							HR
Özer Karası				3	S	R	
Pembe 77	R				S		
Pembe üzüm	R						
Razakı					S		
Red Globe		R	5				
Ribol	R		5				
Siyah Geççi					R		
Tekirdağ Sultani							HS
Tilki Kuyruk					S		
Yusufeli iri beyaz					S		
85/1					S		
86/1	R			5	S	T	

*Inoculation of pathogen on the leaves of potted plants in greenhouse, **Inoculation of pathogen on detached leaves,
HR, Highly Resistant; R, Resistant, T, Tolerant; S, Susceptible, HS, Highly Susceptible,

Table 5. Disease index or resistance level of *V. labrusca* genotypes (and a *V. rotuntifolia* genotype) evaluated by various authors on artificially inoculated plants in greenhouse

Genotypes	Atak (2017)	Atak et al. (2017a)	Atak et al. (2017b)*	Atak ve Göksel (2019)*	Yıldırım et al. (2019)	Atak et al. (2021)
57 Ayancık 01		HR	1		R	
Batum 4					R	
Concord					S	
Çayeli 4					R	
55 Çarşamba 01		HR	1		HR	
Çeliksu		ER			R	
57 Erfelek 03		ER			R	
57 Gerze 01		HR			R	
57 Gerze 04		HR			R	

Giresun 1				1	R	
Giresun 2					R	
Giresun 3					HR	
Giresun 4				1		
Giresun T-1	HR					
Giresun T-3	HR					
Giresun T-5	HR					
28 Görele 01		ER			ER	
53 Güneysu 01		HR	1		HR	
53 Güneysu 02	ER					
Isabella (Yalova)		HR			R	
Isabella (Tekirdağ)		HR			R	HR
Katıkara 1					S	
Katıkara 2					R	
Köfteci üzümü	ER				HR	
28 Merkez 01		HR			R	
53 Merkez 02		R	3		R	
55 Merkez 06		HR			R	
55 Merkez 09		ER				
55 Merkez 11	R		3		R	
55 Merkez 12		HR	1		R	
57 Merkez 02					R	
57 Merkez 07		ER				
61 Of 04		HR	1		R	
53 Pazar 02		HR	1		R	
Rizellim		HR			R	
Rizessi		HR			R	
Rizpem		HR	1		HR	
Sinop 1					R	
Sinop 2					R	
Sinop 3					R	

Sinop T-1	HR			
Sinop T-3	HR			
61 Sürmene 01		HR		R
61 Sürmene 02		HR	1	R
28 Tirebolu 02		HR		R
Ülkemiz		ER		
61 Yomra 04		ER		
Sugargate (*V. rotuntifolia*)			1	ER

* Disease index, ER, Extremely Resistant; HR, Highly Resistant; R, Resistant

Table 6. Disease index or resistance level of interspecific crosses evaluated by various authors on artificially inoculated plants in greenhouse or detacted leaves

Genotypes	Atak (2017)*	Atak et al. (2017a)*	Atak et al. (2017b)*	Atak ve Göksel (2019)*	Yıldırım et al., (2019)*	Özer et al., (2021)**	Kumaşoğlu et al. 2022
Alden	ER			1	R		
Canadice	ER				ER		
Concord Seedless					R		
Edelweiss		HR			R		
Glenora (Seedless)		HR					
Himrod (Seedless)		HR					
Kay Grey	ER			1	R		
Kyoho		HR	3		R		
Lakemont	ER						
Mars					R		
Mortensen	HR				R		
Muscat Bailey A					R		
Niagara					R		
Orion					ER		
Phoenix			1		HR		
Price					R		
Regent			1		HR	HR	

Rize Geççi				S		
Seneca	HR					
Sheridan		ER				
Sirius			1	HR		
Staufer			1	R		
Steuben		ER		HR		
Sunbelt				ER		
Valiant				R		
61 F1 individuals					ER	
43 F1 individuals					HR	
101 F1 individuals					R	
186 F1 individuals					S	
96 F1 individuals					HS	
382 F1 individuals					ES	
119 (F1 individual) 154 (F1 Individual) 200 (F1 Individual)						R HR ER

*Inoculation of pathogen on the leaves of potted plants in greenhouse, **Inoculation of pathogen on detached leaves. ER, Extremely Resistant; HR, Highly Resistant; R, Resistant; S, Sensitive; HS, Highly Sensitive, ES, Extremely Sensitive

(Table 4. *V. labrusca* genotypes and interspecific crosses were evaluated with the lowest value (1) (Table 5-6). The study informed that the amount of phenolic substances increased after infection regardless of whether the cultivar or genotype was sensitive or resistant to downy mildew. However, the resistant FX1-1 (Amasya White X 28/259) was found to be remarkable after infection because it contained high amounts of total phenolic substances and especially chlorogenic acid.

In another study, Yıldırım et al. (2019) tested 80 grapevine genotypes using 0-7 scale for disease index (Table 1C) and the categories for resistance level (Table 1E) suggested by Wan et al (2007) after inoculation of potted plants in greenhouse. The disease resistance was also confirmed using Marker Assisted Selection coupled with inoculation observations. The study contained most of the genotypes (11 *V. vinifera*, 25 V. *labrusca*, 11 interspecific crosses, 1 V. *rotundifolia*), which were also evaluated in the studies of Atak (2017), Atak et al. (2017a, b) and Atak and Göksel (2019). A genotype from V. *vinifera* [Arifbey (R)], an interspecific cross [Canadice (ER)] and 6 genotypes from *V. labrusca* [55 Çarşamba 01 (HR), 28 Görele 01(ER), 53 Güneysu 01 (HR), 55 Merkez 02 (R), 55 Merkez 11 (R), Rizpem (HR)] exhibited the same resistance levels (Table 4-6) with those determined by Atak (2017), Atak et al. (2017a, b) and Atak ve Göksel (2019) However, resistance levels of most similar genotypes differed. This was most likely due to the use of different disease index scales and resistance level categories. In the study 32 new genotypes (12 *V. vinifera*, 11 *V. labrusca* and 9 interspecific crosses were also evaluated and Giresun 3 (HR), Orion (ER), and Sunbelt (ER) were found to be resistant at high levels. In this study, six Simple Sequence Repeats (SSR) markers and one Sequence Characterized Amplified Region (SCAR) marker were developed from various Vitis genetic resources for different resistance loci (Run1, Rpv1, Ren1, Rpv3, Ren3).

Atak et al. (2021) evaluated resistance of 9 genotypes (Table 4-5), which were tested in previous studies (Atak 2017, Atak et al. 2017 a, b, Atak and Göksel 2019, Yıldırım et al. 2019), using 1-9 scale (Table 1B) and resistance level category (Table 1F) suggested by IGPRI (1997). Additionally, they determined the contents of gallic acid, (+)-catechin, and (-)-epicatechin in the leaves of the genotypes after artificially downy mildew infection in potted plants for two years. The same disease index values with previous studies as mentioned above were determined for the genotypes tested. Isabella (Tekirdağ) was found as highly resistant, FX1-1 and Özer Karası as resistant (Table 5). The authors suggested that insignificant correlation was found between the values of gallic acid or (+)-catechin or (-)-epicatechin obtained before disease and after disease.

Özer et al. (2021), defending the view that evaluation of the downy mildew spots or sporulation intensity or sporulation severity by visual scale can vary depending on the observer and thus yield variable results as reported by many authors (Kim Khiook et al. 2013; Gomez Zeledón et al. 2013, 2017; Bove et al. 2019), developed a new scale based on the sporulation area as mm^2) (Table 1G) after artificially inoculation of pathogen on detached leaves of 869 individuals (Regent X Alphonse Lavallée). This study reported that the criterium of sporulation incidence could not describe all resistance levels, and the sporulation area allowed for detailed measurements of how the pathogen spread at the inoculation site. The authors detected 61 individuals as extremely resistant to downy mildew using the scale of sporulation area (Table 6). The following year (Akkurt et al. 2022), DNA samples from these hybrid plants were amplified in Polymerase Chain Reaction (PCR) for MAS using the GF18-06 and GF18-08 markers. The resistance scoring results and the alleles associated with the Rpv3.1 resistance locus were compared, and the markers'applicability in MAS was confirmed in the related study. It was discovered that the GF18-08/410 bp marker can be successfully used for MAS. The authors reported that using GF 18-08, the resistant parent Regent gave allele sizes ranging from 399 to 410 bp and the susceptible parent Alphonse Lavallee gave allele sizes ranging from 406 to 417 bp and that the GF 18-08/410 bp Regent allele was the strongly associated marker for downy mildew resistance with a 77.93% percentage.

Three *V. vinifera* (Karasakız, Müşküle and Tekirdağ Sultani) and three hybrid for brined leaves (119, 154 and 200, RegentXNarince) were tested for their resistance to *P. viticola* using sporulation area (Table 1G) on the detached leaves after inoculation of the pathogen (Kumaşoğlu et al., 2022). 119 is classified as resistant (R), 154 and Müşküle as highly resistant (HR), and 200 as extremely resistant (ER) according to the sporulation area (Table 4 and

6). Significant positive correlation was determined between sporulation area and the number of sporangium in this study. These authors also examined progress of the pathogen and stilbene production, which can serve as biomarkers for resistance to downy mildew in grapevine (Langcake, 1981; Gindro et al. 2012; Olivier et al. 2018), at different times after inoculation to the leaves. The pathogen infected the fewest stomata at 48 hours after inoculation (hpi) in extremely resistant 200, followed by highly resistant Müşküle and 154. At 15 hpi, pathogen vesicles were observed in the leaves of all tested plants; however, after 72 hpi, the vesicle primary hypha did not elongate into the intercellular spaces of the mesophyll. Elongation was limited to 72 hpi in 119, Müşküle, and 154. At 72 hours post infection, pathogen mycelia covered the intercostal fields in sensitive (Karasakız) and highly sensitive (Tekirdağ Sultani) genotypes. The role of ε-viniferin in 200 and pterostilbene in Müşküle and 154 in high resistance to *P. viticola*, as well as the importance of these grapevine types in downy mildew management, was emphasized by these authors. In the last study, downy mildew resistance was determined on 21 grapevine genotypes with different ampelographic characteristics such as fruit ripening time, berry color, and leaf hairiness using an 0-4 scale (Table 1A) under natural infection conditions during two years (Mermer Doğu et al., 2022). Due to insufficient rainfall during the flowering period in the evaluation years, the disease severities of the genotypes were not severe. Isabella (*V. labrusca*) had the lowest disease severity (Table 3); the disease severities in this cultivar were 0% and 0.50%, respectively, for two consecutive years. As a result of the study, it was suggested that the genotypes Isabella, Reçel Üzümü, Semillion and Yapıncak (Table 2), which exhibited very low disease severity in both years, could be used in production based on the desired consumption area. There was also no correlation found between disease severity and some ampelographic characteristics such as fruit ripening time, berry color, and leaf hairness.

Conclusion

Grapevine (*V. vinifera* L.) is an economically important fruit species in the world and in Türkiye. Downy mildew disease caused by P. *viticola* is an important factor limiting viticulture. The use of resistant genotypes is an important control method especially for sustainable/organic viticulture of grapevine growers. Studies demonstrated that *V. labrusca* cultivars were more resistant to mildew. There are also potential *V. vinifera* varieties in regards to resistance to downy mildew disease. However, these resistance tests take time and requires too much effort. Furthermore, yield and quality criteria of the genotypes, which were found to be extremely or highly resistant to this disease, are also important factors for grapevine breeding and is crucial for grapevine growers. Previous studies about resistance of grapevine to downy mildew in Türkiye showed that only a small part of rich gene diversity in Türkiye was evaluated under natural or artificial inoculation conditions. The resistance data from natural and artificial inoculation were found to be compatible in these studies. The concentration of phenolics also increased significantly after the infection, and there was a positive relationship between resistance and the amount of phenolic substances. These resistance studies need to continue and should be integrated into breeding programmes.

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Ethical Approval

An ethics committee document is not required.

Conflict of Interests

The authors declare that there is no conflict of interests.

Author Contribution

Authors DMD and NÖ planned the general disposition of manuscript. AA reviewed the genotypes mentioned in resistance to grapevine downy mildew. All authors have read and approved the final manuscript.

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