

SUSCEPTIBILITY TO DOWNY MILDEW (*PLASMOPARA VITICOLA*) AND POWDERY MILDEW (*ERYSIPHE NECATOR*) OF DIFFERENT *VITIS* CULTIVARS AND GENOTYPES

SUSCETIBILIDADE AO MÍLDIO (*PLASMOPARA VITÍCOLA*) E OÍDIO (*ERYSIPHE NECATOR*) DE DIFERENTES *VITIS* CULTIVARES E GENÓTIPOS

Arif Atak^{1*}, M. Akkurt², Z. Polat³, H.Çelik⁴, K. A. Kahraman¹, D. S. Akgül⁵, N. Özer⁶, G. Söylemezoğlu², G. G. Şire¹, R. Eibach⁷

¹ Department of Viticulture, Atatürk Horticultural Central Research Institute, 77102 Yalova, Turkey.

² Department of Horticulture, Agriculture Faculty, Ankara University, Ankara, Turkey.

³ Department of Plant Protection, Atatürk Horticultural Central Research Institute, 77102 Yalova, Turkey.

⁴ Department of Horticulture, Agriculture Faculty, Ondokuzmayıs University, Samsun, Turkey.

⁵ Department of Plant Protection, Agriculture Faculty, Çukurova University, Adana, Turkey.

⁶ Department of Plant Protection, Agriculture Faculty, Namık Kemal University, Tekirdağ, Turkey.

⁷ Julius Kühn-Institut, Institute for Grapevine Breeding Geilweilerhof, Siebeldingen, Germany.

*corresponding author: Tel: +90 226 814252 (ex 1220), +90 226 505 4804130; email: atakarif@gmail.com

(Received 06.09.2016. Accepted 18.03.2017)

SUMMARY

Turkey has a very old history of viticulture and also homeland of the grapevine (*Vitis* spp.). *Vitis* cultivars belonging to different species are grown in almost every region in the country. However, particularly downy mildew and powdery mildew diseases affect the cultivars belonging to *Vitis vinifera*. In northern of Turkey *Vitis labrusca* and hybrids between *V. vinifera* and *V. labrusca* are rather common. *V. labrusca* cultivars or genotypes exhibit generally higher degree of resistance than *V. vinifera* cultivars. However, resistance level can vary from cultivar to cultivar and even from clone to clone within one cultivar. In this study, different *Vitis* hybrids and genotypes which exhibit different downy and powdery mildew susceptibility are compared for two years. Especially some *V. labrusca* hybrids and genotypes appeared resistance for both diseases. On the other hand, interspecific crosses and *V. vinifera* cultivars were found to be more susceptible. Using resistant lines as parent in later breeding activities, it could be possible to grow high quality table cultivars with much fewer pesticide applications or possibly without them.

RESUMO

A Turquia tem uma longa história vitícola, sendo inclusive um dos pontos de origem da videira (*Vitis* spp.). As diferentes espécies de *Vitis* são cultivadas em quase todas as regiões do país. Doenças como o míldio e oídio afetam em particular as videiras pertencentes à espécie *V. vinifera*. No Norte da Turquia, as espécies *Vitis labrusca* e híbridos entre *V. vinifera* e *V. labrusca* são bastante comuns. As cultivares/genótipos de *V. labrusca* exibem um grau de resistência geralmente mais elevado do que as cultivares de *V. vinifera*. No entanto o nível de resistência pode variar de cultivar para cultivar e até mesmo de clone para clone dentro de uma mesma cultivar. Neste estudo foram comparados diferentes híbridos de *Vitis* e genótipos com diferentes suscetibilidades ao míldio e ao oídio por um período de dois anos. Alguns híbridos e genótipos de *V. labrusca* apresentaram resistência a ambas as doenças. Por outro lado, os cruzamentos interespecíficos e as cultivares de *V. vinifera* foram identificados como sendo mais susceptíveis. Usando linhas resistentes como linha parental em atividades de melhoramento posteriores, poderia ser possível desenvolver cultivares para produção de vinhos de mesa de alta qualidade com menores exigências de aplicações de pesticidas ou possivelmente sem eles.

Key words: *Vitis* spp., fungal diseases, inoculation, resistant, natural infection.

Palavras-chave: *Vitis* spp, doenças fúngicas, inoculação, resistência, infecção natural.

INTRODUCTION

Grape is cultivated over an area of 7.100.000 hectares with an annual production of 77.000.000 tonnes in the

world. Turkey has 460.000 hectares of vineyard area and produces approximately 4.000.000 tonnes (FAO, 2015). In Turkey 52% of the production is used as table grape. Turkey is one of the top producer of

grape and takes second place in table grape production in the world (TUIK, 2015).

Downy mildew (*Plasmopara viticola*) and powdery mildew (*Erysiphe necator*) are the most devastating diseases of grapes around the world. Especially they cause yield and quality loss in humid regions. Not only table grapes but also most of the wine grapes are damaged by both diseases. A large number of fungicide applications are needed in order to produce high quality grape. This situation leads to serious problems for human health. The reduction of pesticides is highly desirable for environmental protection, human health, and food safety (Hoffmann *et al.*, 2007; Deliere *et al.*, 2010; Riaz *et al.*, 2011).

There are great differences in susceptibility within *Vitis* species to fungal diseases. Several *Vitis* species and interspecific crosses have high resistance to many fungal diseases. For example, *V. vinifera* is considered highly susceptible, whereas the American species, such as *V. labrusca*, *V. riparia* and *V. rupestris* are much less susceptible. However, species and cultivars differ in their susceptibility to diseases (Wan *et al.*, 2007). Grapes might be successfully grown without spraying chemicals if naturally resistant and high quality cultivars are bred and selected. In recent years different breeding studies have been carried out to obtain downy and powdery mildew resistant or tolerant cultivars (Hajdu, 2007; Cindric *et al.*, 2009; Lisek, 2014).

However, between selected cultivars the degree of resistance can vary considerably. Different resistance levels can be also due to different pathogen races, severity of disease or ecology in different locations. Also, the severity of diseases varies from year to year, depending primarily on weather conditions, the presence of inoculum (history of the disease) and the susceptibility of the vines (Carisse *et al.*, 2006; Cadle-Davidson, 2008). Therefore, it will be the right approach to analyse resistant levels of cultivars in different ecologies. Some cultivars or accessions obtained by selection and hybridization were used in this study. The objective of this study is to compare downy mildew and powdery mildew resistance levels of different grape cultivars or genotypes which obtained by selection and hybridization. Especially accessions belonging to *V. labrusca* collected from northern Turkey are primarily screened for disease resistance. Moreover, a final goal was to determine cultivars/genotypes that could be successfully grown with reduced fungicide application, or possibly without them.

MATERIAL AND METHODS

Plant material

35 different grape cultivars/genotypes were used in this study. 26 *Vitis labrusca* genotypes considering to be resistant against fungal diseases constitute the main source of this study. These accessions were collected from north of the Turkey especially Black Sea coastline. In addition to these *V. labrusca* genotypes six inter-species hybrid grape cultivars which may be considered resistant in terms of downy and powdery mildew. Finally, three different *Vitis vinifera* cultivars are used for comparison. The *Vitis vinifera* cv. Italia is particularly used as a susceptible control since it is known to be highly susceptible to fungal diseases especially powdery mildew.

Natural infections

The experiments were carried out according to common procedures and no pesticides were carried out in the experimental areas. Natural vineyard conditions were supplied in the experimental area so infected leaves and shoots were distributed randomly within the plants in order to provide sufficient inoculation. All vines were potted (minimum three plants per cultivar) and suspended to natural infection. The natural infection evaluation was carried out on leaves and clusters during June, July and August.

Inoculation for powdery mildew

All vines were planted in pots and cultivated in the greenhouse for Inoculations (minimum three plants per variety). For inoculation the modified method of Wang *et al.* (1995) was applied. Fungal conidia were collected from infected leaves, washed with 0.78% glucose solution, imitating the osmotic pressure of powdery mildew conidia and then suspended in sterile water. Vine leaves were inoculated with the conidial suspension at the rate of 2×10^5 conidia/mL by spraying the upper surface of the leaves. Inoculated leaves were immediately covered by thin plastic for 6 hours.

Inoculation for downy mildew

The method of Rumbolz *et al.* (2002) and Boso *et al.* (2006) were used to propagate sporangia inoculum. *Plasmopara viticola* was obtained from naturally infected plants in the vineyards of the Atatürk Horticulture Central Research Institute Yalova, Turkey and Çukurova University Agriculture Faculty Adana, Turkey. For the propagation of the inoculum, plants were sprayed with a suspension of sporangia (40,000 sporangia mL⁻¹ distilled water) on the abaxial leaf side and whole plants were covered with a polyethylene cover during night. On following day,

the polyethylene covers were removed and incubation lasted 5-6 days at 25-26 °C. The same inoculation procedure was repeated after 5-6 days.

Evaluation of powdery mildew natural infection and inoculation of leaves

For disease evaluation, 4 young leaves from the top were selected from each vine (several plants) and were examined at different times during June–August. The infection severity on leaves was determined based on per cent of disease spots observed on the entire leaf area according to the procedure described by Table I (GENRES-081, 1997). Disease severity was evaluated 3 weeks after inoculation.

Table I

Rating levels for oidium infection of leaves of genotypes for their degree of resistance to powdery mildew under the same conditions.

Níveis de avaliação para a infecção por oídio das folhas de genótipos e seu grau de resistência ao oídio nas mesmas condições.

Level	Symptoms
1	Very low (tiny spots or no symptoms; neither visible sporulation nor mycelium)
3	Low (limited patches < 2 cm diameter; limited sporulation and mycelium; the presence of <i>Uncinula</i> is only indicated by a slight curling of the blade)
5	Medium (patches usually limited with a diameter of 2-5 cm)
7	High (vast patches; some limited; strong sporulation and abundant mycelium)
9	Very high (very vast unlimited patches or totally attached leaf blades; strong sporulation and abundant mycelium)

Evaluation of downy mildew natural infection and inoculation of leaves

For disease evaluation, all leaves of each plant was evaluated for downy mildew at different times during May–August. The infection severity on leaves was determined based on per cent of disease spots observed on the entire leaf area according to the procedure described by Table II (GENRES-081, 1997).

Disease assessments and statistical analysis

Scoring was done primarily to determine the response of plants to disease during the two growing season. Different methods and number of leaves are selected for each disease. When all leaves of each pot evaluated for downy mildew but only first 4 young leaves of each vines evaluated. Disease severity estimated as the percentage of affected leaves. Disease severity (infection degree, ID) was computed

using a scale of total number of classes with the Townsend–Heuberger formula (Townsend–Heuberger, 1943): $ID (\%) = \sum i(n_i \times v_i) / N \times V$ where v_i is the damage class, n_i is the number in one class, N is the total number, V is the highest class, i is the number of classes.

Table II

Rating levels for infection of leaves of genotypes for their degree of resistance to downy mildew under the same conditions.

Níveis de avaliação para a infecção de folhas de genótipos e seu grau de resistência ao míldio, nas mesmas condições.

Level	Symptoms
1	Very low (tiny necrotic spots or no symptoms; neither sporulation nor mycelium)
3	Low (small patches < 1 cm in diameter; little sporulation or mycelium)
5	Medium (little patches 1-2 cm diameter; more or less strong sporulation; irregular formation of mycelium)
7	High (vast patches; strong sporulation and abundant mycelium; leaf drop later than below)
9	Very high (vast patches or totally attached leaf blades; strong sporulation and dense mycelium; very early leaf drop)

Downy mildew resistance level of each cultivar was rated based on its Severity index (SI: ER) (Staudt and Kassemeyer, 1995):

- ER, Extremely Resistant, SI: 0-5.0
- HR, Highly Resistant, SI: 5.1-25
- R, Resistant, SI: 25.1-50
- S, Susceptible, SI: 50.1-75
- HS, Highly Susceptible, SI: > 75.1

Powdery mildew resistance level of each cultivar was rated based on its Severity Index (SI: ER):

- ER, Extremely Resistant, SI = 0
- HR, Highly Resistant, SI= 0.1 - 5.0
- R, Resistant, SI = 5.1 - 25 .0
- S, Susceptible, SI = 25.1 - 50
- HS, Highly susceptible, SI = 50.1 – 100

Each variant was examined by analysis of variance to determine significant differences among accessions. Also they were analysed randomized experimental design analysis of variance with three replicates also repeated two years. For each variant, LSMeans differences Student's test (minimum significant difference method) was used to determine the level of resistance for all accessions. Duncan's multiple range test was used to compare infections. Differences at $p < 0.05$ were considered to be significant. Pearson's correlation coefficient (R) was used to evaluate covariance relationships between variables. All

calculations were performed using JMP 7.0 software (SAS, 2007).

RESULTS AND DISCUSSION

Average of the experiments in the reactions of different cultivars/genotypes to downy and powdery mildew diseases during 2014 and 2015 are shown in Tables III and IV. During June and July climate

parameters in 2014 and 2015 are quite similar. In 2014, during June and July the average temperature was 22-26 °C and relative humidity was 75%. In 2015, during June and July the average temperature was 21.5-25 °C and relative humidity 75% (Figure 1 and Figure 2). Climatic conditions have also been very suitable for both diseases.

Table III

Disease severity of accessions for downy mildew
Gravidade da doença em função da exposição ao míldio

Accessions	Species	Natural Infection		Inoculation	
		Average (%)	Severity Index	Average (%)	Severity Index
57 Ayancık 01	<i>V.labrusca</i>	1 ⁱ	ER	14 ^{c-i}	HR
57 Erfelek 03	<i>V.labrusca</i>	2 ⁱ	ER	5 ^{ij}	ER
57 Gerze 04	<i>V.labrusca</i>	0 ⁱ	ER	11 ^{d-j}	HR
61 Of 04	<i>V.labrusca</i>	3 ^{g-i}	ER	20 ^{cd}	HR
61 Sürmene 01	<i>V.labrusca</i>	15 ^{b-e}	HR	10 ^{d-j}	HR
61 Sürmene 02	<i>V.labrusca</i>	4 ^{g-i}	ER	11 ^{d-j}	HR
61 Yomra 04	<i>V.labrusca</i>	11 ^{b-h}	HR	4 ^j	ER
53 Merkez 02	<i>V.labrusca</i>	25 ^a	HR	39 ^{ab}	R
Rizessi	<i>V.labrusca</i>	0 ^a	ER	16 ^{c-g}	HR
Rizpem	<i>V.labrusca</i>	4 ^{g-i}	ER	9 ^{e-j}	HR
Çeliksü	<i>V.labrusca</i>	9 ^{d-i}	HR	5 ^{h-j}	ER
Rizellim	<i>V.labrusca</i>	4 ^{g-i}	ER	18 ^{c-f}	HR
55 Merkez 06	<i>V.labrusca</i>	7 ^{e-i}	HR	19 ^{c-e}	HR
55 Merkez 12	<i>V.labrusca</i>	5 ^{f-i}	ER	16 ^{c-g}	HR
53 Güneysu 01	<i>V.labrusca</i>	4 ^{g-i}	ER	7 ^{g-j}	HR
Ülkemiz	<i>V.labrusca</i>	0 ⁱ	ER	4 ^j	ER
53 Pazar 02	<i>V.labrusca</i>	15 ^{b-e}	HR	19 ^{c-e}	HR
55 Çarşamba 01	<i>V.labrusca</i>	4 ^{g-i}	ER	6 ^{g-j}	HR
28 Tirebolu 02	<i>V.labrusca</i>	4 ^{g-i}	ER	8 ^{f-j}	HR
28 Görele 01	<i>V.labrusca</i>	3 ^{g-i}	ER	4 ^j	ER
28 Merkez 01	<i>V.labrusca</i>	1 ⁱ	ER	15 ^{c-j}	HR
55 Merkez 09	<i>V.labrusca</i>	0 ⁱ	ER	5 ^{h-j}	ER
57 Gerze 01	<i>V.labrusca</i>	0 ⁱ	ER	8 ^{f-j}	HR
57 Merkez 07	<i>V.labrusca</i>	2 ^{hi}	ER	2 ^j	ER
Isabella (Yalova)	<i>V.labrusca</i>	2 ^{hi}	ER	10 ^{d-j}	HR
Isabella (Tekirdağ)	<i>V.labrusca</i>	14 ^{b-f}	HR	8 ^{f-j}	HR
Steuben	Interspecific cross	9 ^{d-i}	HR	2 ^j	ER
Kyoho	Interspecific cross	6 ^{e-i}	HR	24 ^c	HR
Edelweiss	Interspecific cross	7 ^{e-i}	HR	9 ^{e-j}	HR
Sheridan	Interspecific cross	14 ^{b-f}	HR	4 ^{ij}	ER
Glenora (Seedless)	Interspecific cross	12 ^{b-g}	HR	10 ^{d-j}	HR
Himrod (Seedless)	Interspecific cross	14 ^{b-f}	HR	9 ^{e-j}	HR
Autumn Royal (Seedless)	<i>Vitis vinifera</i>	17 ^{a-d}	HR	38 ^b	R
Red Globe	<i>Vitis vinifera</i>	9 ^{d-i}	HR	49 ^a	R
Italia	<i>Vitis vinifera</i>	20 ^{ab}	HR	40 ^{ab}	R

* The severity values of the disease were obtained from the means of 2014 and 2015. Means in columns with the same letter do not differ according to Duncan's Multiple Range test at $p < 0.05$.

Table IV
Disease severity of accessions for powdery mildew
Gravidade da doença em função da exposição ao oídio

Accessions	Species	Natural Infection		Inoculation	
		Average (%)	Severity Index	Average (%)	Severity Index
57 Ayancık 01	<i>V.labrusca</i>	0 ^j	ER	11 ^{b-1}	R
57 Erfelek 03	<i>V.labrusca</i>	14 ^{g-j}	R	31 ^{b-f}	S
57 Gerze 04	<i>V.labrusca</i>	0 ^j	ER	39 ^{b-d}	S
61 Of 04	<i>V.labrusca</i>	5 ^{h-j}	HR	20 ^{e-k}	R
61 Sürmene 01	<i>V.labrusca</i>	0 ^j	ER	29 ^{c-h}	S
61 Sürmene 02	<i>V.labrusca</i>	1 ^{ij}	HR	1 ^l	HR
61 Yomra 04	<i>V.labrusca</i>	14 ^{g-j}	R	4 ^{kl}	HR
53 Merkez 02	<i>V.labrusca</i>	7 ^{h-j}	R	24 ^{d-i}	R
Rizessi	<i>V.labrusca</i>	5 ^{h-j}	HR	23 ^{d-j}	R
Rizpem	<i>V.labrusca</i>	2 ^{ij}	HR	12 ^{g-l}	R
Çeliksi	<i>V.labrusca</i>	4 ^{ij}	HR	27 ^{c-h}	S
Rizellim	<i>V.labrusca</i>	33 ^{de}	S	37 ^{b-e}	S
55 Merkez 06	<i>V.labrusca</i>	0 ^j	ER	4 ^{kl}	HR
55 Merkez 12	<i>V.labrusca</i>	6 ^{h-j}	R	0 ^l	ER
53 Güneysu 01	<i>V.labrusca</i>	0 ^j	ER	15 ^{fl}	R
Ülkemiz	<i>V.labrusca</i>	33 ^{df}	S	18 ^{fl}	R
53 Pazar 02	<i>V.labrusca</i>	7 ^{h-j}	R	26 ^{c-i}	S
55 Çarşamba 01	<i>V.labrusca</i>	21 ^{eg}	R	23 ^{d-j}	R
28 Tirebolu 02	<i>V.labrusca</i>	12 ^{g-j}	R	21 ^{d-k}	R
28 Görele 01	<i>V.labrusca</i>	5 ^{h-j}	HR	8 ^{i-l}	R
28 Merkez 01	<i>V.labrusca</i>	2 ^{ij}	HR	18 ^{fl}	R
55 Merkez 09	<i>V.labrusca</i>	11 ^{g-j}	R	0 ^l	ER
57 Gerze 01	<i>V.labrusca</i>	16 ^{g-i}	R	0 ^l	ER
57 Merkez 07	<i>V.labrusca</i>	19 ^{f-h}	R	0 ^l	ER
Isabella(Yalova)	<i>V.labrusca</i>	1 ^{ij}	HR	21 ^{d-k}	R
Isabella(Tekirdağ)	<i>V.labrusca</i>	11 ^{g-j}	R	13 ^{fl}	R
Steuben	Interspecific cross	39 ^{cd}	S	40 ^{b-d}	S
Kyoho	Interspecific cross	9 ^{g-j}	R	14 ^{fl}	R
Edelweiss	Interspecific cross	60 ^{ab}	HS	30 ^{b-g}	S
Sheridan	Interspecific cross	51 ^{a-c}	HS	48 ^{ab}	S
Glenora (Seedless)	Interspecific cross	41 ^{cd}	S	43 ^{bc}	S
Himrod (Seedless)	Interspecific cross	16 ^{g-i}	R	39 ^{b-d}	S
Autumn Royal (Seedless)	<i>Vitis vinifera</i>	7 ^{h-j}	R	15 ^{fl}	R
Red Globe	<i>Vitis vinifera</i>	46 ^{b-d}	S	24 ^{d-i}	R
Italia	<i>Vitis vinifera</i>	64 ^a	HS	64 ^a	HS

*The severity values of the disease were obtained from the means of 2014 and 2015. Means in columns with the same letter do not differ according to Duncan's Multiple Range test at $p < 0.05$.

The results were based on leaf-based assessments of natural infection and inoculation practices of both diseases. *V. labrusca* accessions found higher resistance than other species. When these cultivars analysed for natural downy mildew infection they showed between 0-25 disease severities. Nineteen cultivars/genotypes were found extremely resistance

group and sixteen were found highly resistance. In general, results of the experiment indicated that 54.3% of cultivars/genotypes were extremely resistance (ER) and 45.7% showed high degree of resistance.

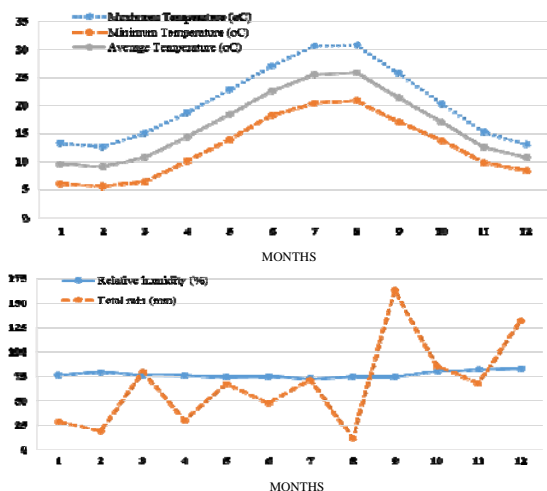


Figure 1. The main meteorologica data of experimental area in 2014.

Condições meteorológicas na área experimental em 2014.

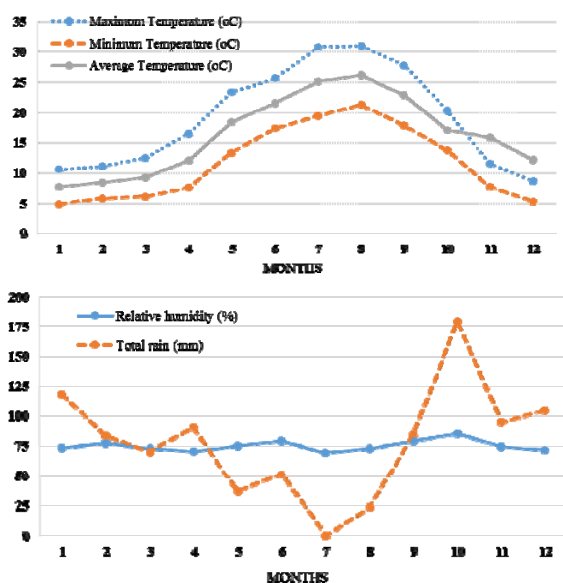


Figure 2. The main meteorological data of experimental area in 2015.

Condições meteorológicos na área experimental em 2015.

Evaluation of different cultivars/genotypes in reactions to downy mildew were obtained higher disease severity with 2-49 range. Generally, it was observed that inoculation was increased disease severity. This increase has been very evident in members of *V. vinifera* cultivars (Figure 3 and Figure 4). In a few cultivars of interspecific hybrids disease

severity was significantly higher than natural infection. Highest severity of disease after natural infection was obtained in 53 Merkez 02 coded *V. labrusca* genotype. On other hand, after inoculation the highest disease severity was obtained from *Vitis vinifera* cv. Red Globe (Table III). In general, downy mildew resistant level of cultivars/genotypes found that much better than powdery mildew (Figure 4). In terms of the downy mildew evaluation of 35 cultivars/genotypes found that nine showed extremely resistant (ER), and twenty-two showed high resistance (HR) and four ranked resistant (R). Results also indicated that 25.7% of hybrids and genotypes were extremely resistance to powdery mildew, 62.9% showed high degree of resistance and 11.4% were resistant to downy mildew disease (Figure 3).

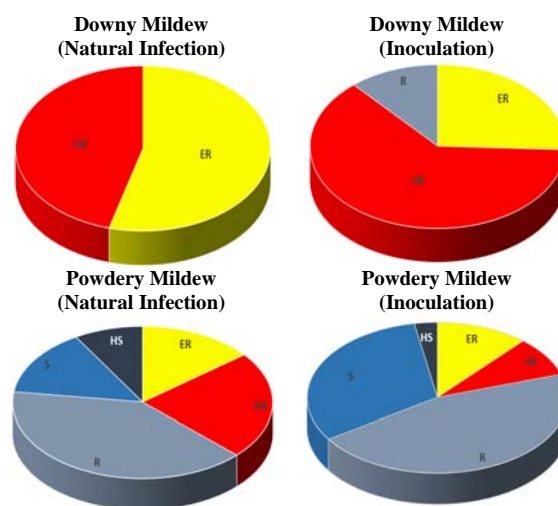


Figure 3. Distribution graph based on the number of accessions of disease severity (Extremely Resistant-ER; Highly Resistant-HR; Resistant-R; Susceptible-S; Highly susceptible-HS).

Gráfico de distribuição com base no número de acessos de severidade da doença (Extremamente Resistente-ER; Altamente Resistente-HR; Resistente-R; Suscetível-S; Altamente Suscetíveis-HS).

Results obtained powdery mildew evaluation also showed differences with downy mildew (Table IV). Disease severity of *V. labrusca* genotypes were realised respectively, after natural infection 0-33 and after inoculation 0-39 range. Overall disease severity of powdery mildew was held in the range of 0 to 64. Unlike the downy mildew, interspecific crosses were found higher disease severity of powdery mildew (Figure 4). Highest severity of disease after natural infection and inoculation was obtained *Vitis vinifera* cv. Italia which known very sensitive for powdery mildew. Cultivars/genotypes have been identified

more sensitivity in terms of the powdery mildew evaluation. Evaluation of different cultivars/genotypes in reactions to powdery mildew diseases under natural infection indicated that in natural field infection from among 35 cultivars/genotypes five cultivars were extremely resistance (ER) or immune, eight showed high resistance (HR), fourteen ranked resistant (R), five were susceptible (S), and finally three cultivars were high susceptible (HS) to powdery mildew causal pathogen. In this experiment cultivars/genotypes showed very different reactions to powdery mildew disease. In other words, like natural infection experiments, cultivars/genotypes ranked in five categories as extremely resistance, highly resistant, resistant, susceptible and highly susceptible. In general, results of the experiment indicated that 14.3% of hybrids and genotypes were extremely resistance to powdery mildew, 22.8% showed high degree of resistance, 40% were resistant, 14.3% were susceptible and 8.6% highly susceptible to powdery mildew disease (Figure 3).

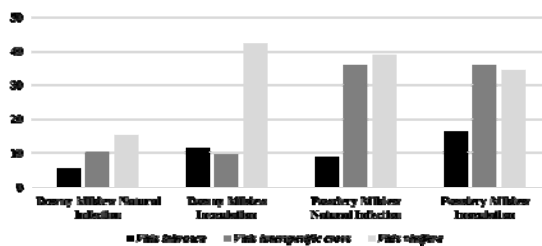


Figure 4. Average disease severity graphic of accessions.

Gráfico da severidade média da doença em *V. labrusca*, *V. vinifera* e híbridos interespecíficos.

After the inoculation of the cultivars/genotypes have been seen that increase their susceptibility to powdery mildew disease. Evaluation of different cultivars/genotypes in reactions to powdery mildew diseases under inoculation indicated that in greenhouse infection from among 35 cultivars/genotypes were classified as four extremely resistant (ER), three highly resistant (HR), sixteen resistant (R), eleven susceptible (S) and finally one highly susceptible (HS) (Table IV). Results also indicated that 11.4% of cultivars/genotypes were extremely resistance to powdery mildew, 8.6% showed high degree of resistance, 45.7% were resistant, 31.4% were susceptible and 2.9% highly susceptible to powdery mildew disease (Figure 3).

The result of the present study shows that differences in susceptibility to downy mildew and powdery

mildew exist among *Vitis* cultivars/genotypes, as previously reported (Staudt and Kassemeyer, 1995; Cadle-Davidson, 2008; Gee *et al.*, 2008). Differences in susceptibility were also seen between different species of *Vitis*, as earlier mentioned by several authors (Yu *et al.*, 2012; Boso *et al.*, 2014). Figueiredo *et al.* (2017) explained that following inoculation increase of hydrogen peroxide levels, cellular redox regulation, establishment of ROS signalling and plant cell death seem to be key points differentiating the resistant genotype. Lipid associated signalling events, particularly related to jasmonates appear also to play a major role in the establishment of resistance. The findings from this study also can explain this pathways contribute to a better understanding of genotype-specific differences that account for a successful establishment of a defence response to disease pathogens. Furthermore, Oliveira and Cunha (2015) reported that diversity of these pathogens also can affect disease resistance of *Vitis* spp.

Susceptibility of *V. labrusca* cultivars studied very limited numbers and these studies have highlighted that there may be differences between the cultivars (Cadle-Davidson, 2008; Gee *et al.*, 2008; Wu *et al.*, 2011). It is reported that even different ecology also affect resistance to powdery mildew disease (Cadle-Davidson *et al.*, 2011). Similar results were obtained in this study and some cultivars/genotypes came forward as more resistant. *Vitis labrusca* genotypes which are 55 Merkez 09, 57 Gerze 01 and 57 Merkez 07 were selected the most resistance genotypes when evaluated both diseases in this study. Addition to these genotypes, 55 Merkez 12, 55 Merkez 06 and 61 Sürmene 02 genotypes showed high resistant against powdery mildew. Also Ülkemiz, 28 Görele 01 and 57 Erfelek 03 genotypes showed high resistant against downy mildew.

In a similar way sensitivity of powdery mildew in interspecific crosses were higher. Similar results also were obtained in the Glenora and Himrod seedless cultivars. They were much more affected by powdery mildew disease. However, *Vitis vinifera* cv. Autumn Royal which are also seedless much more affected by downy mildew disease but not powdery mildew. Sha *et al.* (2007), similarly reported that Autumn Royal cultivar resistant to powdery mildew disease but other seedless cultivars are susceptible. The same authors also similarly reported that tetraploid Kyoho cultivar are resistant to powdery mildew.

The highest sensitivity was observed in *V. vinifera* cultivars with few exceptions. *Vitis vinifera* cv. Italia showed low resistance than other cultivars as expected but especially much more affected by

powdery mildew. Red Globe cultivar showed lower resistance to downy and powdery mildew. Wu *et al.* (2011), also found that Red Globe have high susceptibility both diseases furthermore they reported that the hybrids derived from *V.labrusca* have a higher resistance.

In addition to these analyzes, correlation analysis was used to explore the relationships between the variables (Table V). There was a significant

correlation between the natural infection and inoculation of both diseases. The significant positive correlation was found between powdery mildew natural infection and inoculation (0.602). Similarly, there was a found significant positive correlation between downy mildew natural infection and inoculation (0.486). This analysis suggests that powdery mildew disease is more effective on cultivars or genotypes.

Table V
Pearson correlation coefficients (R) between variables
Coefficientes de correlação de Pearson (R) entre variáveis

Variables	Downy Mildew (Natural Infection)	Downy Mildew (Inoculation)	Powdery Mildew (Natural Infection)	Powdery Mildew (Inoculation)
Downy Mildew (Natural Infection)	1	0.486	0.285	0.442
Downy Mildew (Inoculation)	0.486	1	0.163	0.193
Powdery Mildew (Natural Infection)	0.285	0.163	1	0.602*
Powdery Mildew (Inoculation)	0.442	0.193	0.602*	1

*p < 0.05. Correlations between 0.5 and 1.0 were considered significant

Powdery mildew and downy mildew in terms of the sensitivity of selected cultivars/genotypes were different. Especially it was realised that downy mildew resistance of cultivars/genotypes was higher than resistance of powdery mildew. Different types of resistance in *Vitis* spp. have been identified. Similar results are obtained with different species and cultivars by several studies. In general, *V. vinifera* cultivars have lower disease resistant but *V. labrusca* and other *Vitis* spp. have better disease resistant when compared species, especially some *V. labrusca* genotypes unexpectedly found low disease resistant. It is thought to be caused by parents and also reported that some species and cultivars can have different resistant levels in several studies. Variation, also been recorded between different cultivars of *V. vinifera*, and even between clones of the same variety (Boso *et al.*, 2006; Khiavi *et al.*, 2009; Alonso-Villaverde *et al.*, 2011; Yu *et al.*, 2012; Gaforio *et al.*, 2015). This variability in susceptibility may have several causes and mechanisms (anatomical, biochemical, molecular, etc.). Alonso-Villaverde *et al.* (2011) and Gindro *et al.* (2006) indicated that such differences among *V. vinifera* cultivars may be due to certain anatomical or histological features of the leaf structure. In recent years, researchers have also determined different genes which are responsible for downy and powdery mildew in different *Vitis* species.

Pap *et al.* (2016) reported that two distinct powdery mildew R loci designated Ren6 and Ren7 were found in multiple accessions from the Chinese species *V. piasezkii*. Also some QTLs with major DM-resistance effects have been identified, named Rpv (Resistance to *P. viticola*). New Rpv regions have been found on different chromosome numbers (Blasi *et al.*, 2011; Schwander *et al.*, 2012; Venuti *et al.*, 2013; Armijo *et al.*, 2016). As can be clearly seen in this study, cultivars or genotypes can have different resistant level even if they belong to the same species. Even some of them have gene regions that are responsible for the resistance, they may not be sufficient for enough disease resistance. Plant defense mechanisms are tightly regulated by hormone-mediated signaling pathways, mainly jasmonic acid (JA) and salicylic acid (SA). It is generally considered that JA and ethylene (JA/Et) mediate necrotrophic pathogens defense, while SA is involved against the biotrophic and hemibiotrophic ones (Pieterse *et al.*, 2009; Robert-Seilaniantz *et al.*, 2011).

CONCLUSIONS

Researches on the causes and mechanisms of resistance or susceptibility to diseases in plants have been going on for many years. Almost every year new gene regions and different biochemicals that are

effective on resistance are found by scientists. Different breeding studies transferring these genes to sensitive cultivars are still continue. However, the cultivars or genotypes carrying these resistant gene regions should primarily be determined as in this study. As a result of this study carried out for this main purpose some *V. labrusca* genotypes were selected the more resistance than other *Vitis* spp. when evaluated downy and powdery mildew diseases. They can be used as parents for transferring downy and powdery mildew resistance genes. In other words, they have potential as a breeding line for the future improvement of disease resistance. These genotypes will be very useful for future breeding programmes to obtain new cultivars with high resistance levels. Resistant lines are particularly valuable for breeding programmes when used to transfer multiple resistance genes into high yield. Also as results of this study may have practical applications in formulation of disease management

REFERENCES

- Alonso-Villaverde V., Boso S., Santiago J.L., Gago P., Rodriguez-García M.I., Martínez M.C., 2011. Leaf thickness and structure of *Vitis vinifera* cv. Albariño clones and its possible relation with downy mildew (*Plasmopara viticola*) infection. *J. Int. Sci. Vigne Vin*, **45**, 161-169.
- Armijo G., Schlechter R., Agurto M., Muñoz D., Nuñez C., Arce-Johnson P., 2016. Grapevine pathogenic microorganisms: understanding infection strategies and host response scenarios. *Front. Plant Sci.*, **7**:382.
- Blasi P., Blanc S., Wiedemann-Merdinoglu S., Prado E., Ruhl E.H., Mestre P., Merdinoglu D., 2011. Construction of a reference linkage map of *Vitis amurensis* and genetic mapping of Rpv8, a locus conferring resistance to grapevine downy mildew. *Theor. Appl. Genet.*, **123**, 43–53.
- Boso S., Alonso-Villaverde V., Gago P., Santiago J.L., Martínez M.C., 2014. Susceptibility to downy mildew (*Plasmopara viticola*) of different *Vitis* cultivars. *Crop Protec.*, **63**, 26-35.
- Boso S., Martínez M.C., Unger S., Kassemeyer H.H., 2006. Evaluation of foliar resistance to downy mildew in different cv. Albariño clones. *Vitis*, **4**, 23-27.
- Cadle-Davidson L., 2008. Variation within and between *Vitis* spp. for foliar resistance to the downy mildew pathogen *Plasmopara viticola*. *Plant Dis.*, **92**, 1577-1584.
- Cadle-Davidson L., Chicoine D.R., Consolie N.H., 2011. Variation within and among *Vitis* spp. for foliar resistance to the powdery mildew pathogen *Erysiphe necator*. *Plant Disease*, **95**, 202-211.
- Carisse O., Bacon R.L., McFadden-Smith W., 2006. Identification guide to the major diseases of grapes. Agriculture and Agri-Food, 31 p. Canada Publication 10092.
- Cindric P., Korac N., Kovac V., 2009. Grape breeding for fungal resistance using North American and Asian donor genotypes. *Acta Hort.*, **827**, 631-634.
- Deliere L., Miclot A.S., Sauris P., Rey P., Calonnec A., 2010. Efficacy of fungicides with various modes of action in controlling

strategies for controlling both diseases in a safe environment. The use of resistant hybrids or genotypes to manage different plant diseases including grape downy and powdery mildew can potentially replace or minimize the application of harmful chemical fungicides. Also they could be used as an important component of Integrated Pest Management Programmes which is a very useful approach to a sustainable and also maybe organic agriculture.

ACKNOWLEDGMENTS

This research was funded by the National Scientific and Technological Research Council of Turkey (Grant No.1130641).

the early stages of an *Erysiphe necator*-induced epidemic. *Pest Manag. Sci.*, **66**, 1367-1373.

FAO, 2015. Production of grape. Available at: <http://faostat.fao.org/site/339/default.aspx>. Accessed 2015 November 20.

Figueiredo A., Martins J., Sebastiana M., Guerreiro A., Silva A., Matos A.R., Monteiro F., Pais M.S., Roepstorff P., Coelho A.V., 2017. Specific adjustments in grapevine leaf proteome discriminating resistant and susceptible grapevine genotypes to *Plasmopara viticola*. *J. Proteomics*, **152**, 48-57.

Gaforio L., Cabello F., Organero G.M., 2015. Evaluation of resistance to downy mildew in grape cultivars grown in a Spanish collection. *Vitis*, **54**, 197-191.

Gee C.T., Cadle-Davidson L., Gadoury D.M., 2008. Ontogenetic resistance to *Uncinula necator* varies by genotype and tissue type in a diverse collection of *Vitis* spp. *Plant Dis.*, **92**, 1067-1073.

GENRES-081 1997. Descriptors for grapevines (*Vitis* spp.). International Union for the Protection of New Cultivars of Plants, Geneva, Switzerland/Office International de la Vigne et du Vin, Paris, France/International Plant Genetic Resources Institute, Rome, Italy.

Gindro K., Spring J.L., Pezet R., Richter J., Viret O., 2006. Histological and biochemical criteria for objective and early selection of grapevine cultivars resistant to *Plasmopara viticola*. *Vitis*, **45**, 191-196.

Hajdu E., 2007. Breeding of table grape cultivars in Hungary and beyond our national borders. *Hung. Agric. Res.*, **4**, 4-9.

Hoffmann S., Cindric P., Kozma P.Jr., 2007. Breeding resistant cultivars to downy and powdery mildew. XXX. World Congress of Vine and Wine. http://www.oiv2007.hu/documents/viticulture/314_breeding_resistance_cultivars_to_1_.pdf.

Khiavi H.K., Shikhlini H., Ahari A.B., Heydari A., 2009. Evaluation of different grape cultivars for resistance to powdery mildew caused by *Uncinula necator*. *J. Plant Prot. Res.*, **49**, 434-440.

- Lisek J., 2014. Evaluation of yield and healthiness of twenty table grapevine cultivars grown in Central Poland. *J. Horti. Res.*, **22**, 101-107.
- Oliveira M., Cunha M., 2015. Study of the Portuguese populations of powdery mildew fungus from diverse grapevine cultivars (*Vitis vinifera*). *OENO One*, **49**, 173-182.
- Pap D., Riaz S., Dry I.B., Jermakow A., Tenschler A. C., Cantu D., Oláh R., Walker M. A., 2016. Identification of two novel powdery mildew resistance loci, Ren6 and Ren7, from the wild Chinese grape species *Vitis piasezkii*. *BMC Plant Biol.*, **16**, 170.
- Pieterse C.M., Leon-Reyes A., VanderEnt S., Van Wees S. C., 2009. Networking by small-molecule hormones in plant immunity. *Nat. Chem. Biol.*, **5**, 308-316.
- Riaz S., Tenschler A.C., Ramming D.W., Walker M.A., 2011. Using a limited mapping strategy to identify major QTLs for resistance to grapevine powdery mildew (*Erysiphe necator*) and their use in marker-assisted breeding. *Theor. Appl. Genet.*, **122**, 1059-1073.
- Robert-Seilaniantz A., Grant M., Jones J.D., 2011. Hormone cross talk in plant disease and defense: more than just jasmonate-salicylate antagonism. *Annu. Rev. Phytopathol.*, **49**, 317-343.
- Rumbolz J., Wirtz S., Kassemeyer H.H., Guggenheim R., Schäfer E., Büche C., 2002. Sporulation of *Plasmopara viticola*: differentiation and light regulation. *Plant Biol.*, **4**, 413-422.
- SAS, 2007. JMP statistical discovery software. JMP 7.0 Edition of programme. SAS Institute Inc Cary, North Carolina, USA.
- Schwander F., Eibach R., Fechter I., Hausmann L., Zyprian E., Topfer R., 2012. Rpv10: a new locus from the Asian *Vitis* gene pool for pyramiding downy mildew resistance loci in grapevine. *Theor. Appl. Genet.*, **124**, 163-176.
- Sha Y., Wang G., Fan Z., Zhang Y., Zhang X., 2007. Study on the resistance of different grape cultivars to downy mildew. *J. Fruit Sci.*, **24**, 803-809.
- Staudt G., Kassemeyer H.H., 1995. Evaluation of downy mildew (*Plasmopara viticola*) resistance in various accessions of wild *Vitis* species. *Vitis*, **34**, 225-228.
- Townsend G.R., Heuberger J.W., 1943. Methods for estimating losses caused by diseases in fungicide experiments. *Plant Dis. Rep.*, **27**, 340-343.
- TUIK, 2015. Production of Fruits; Beverage and Spice Crops (For Selected Products). <http://www.turkstat.gov.tr/UstMenu.do?metod=temelist>. Accessed 2015 November 20.
- Venuti S., Copetti D., Foria S., Falginella L., Hoffmann S., Bellin D., Cindric P., Kozma P., Scalabrin S., Morgante M., Testolin R., Gaspero G., 2013. Historical introgression of the downy mildew resistance gene Rpv 12 from the Asian species *Vitis amurensis* into grape vine varieties. *Plos One*, **8**, e61228.
- Wan Y., Schwaninger H., He P., Wang Y., 2007. Comparison of resistance to powdery mildew and downy mildew in Chinese wild grapes. *Vitis*, **46**, 132-136.
- Wang Y., Li Y., He P., Chen J., Lamikanra O., Lu J., 1995. Evaluation of foliar resistance to *Uncinula necator* in Chinese wild *Vitis* species. *Vitis*, **34**, 159-164.
- Wu X., Liu N., Zhang J., Wang Y., 2011. Field natural identification of resistance of grape resources from USA and Xinjiang of China to primary fungi diseases. *J. Fruit Sci.*, **28**, 998-1009.
- Yu Y., Zhang F., Yin L., Lu J., 2012. The mode of host resistance to *Plasmopara viticola* infection on grapevines (*Vitis* L). *Phytopathology*, **102**, 1094-1101.