Variation in Sensitivity of Different Grapevine Genotypes to *Erysiphe necator* Growing under Unfavourable Climatic Conditions

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This paper reports the susceptibility to powdery mildew of 41 grapevine genotypes growing in the north and northwest of Spain over a three-year period. Although the humid climate of these vine-growing areas is not particularly favourable to the development of this disease, serious damages appears in some years when dry weather alternates with times of some rain. All the examined genotypes belonged to the collection of the *Misión Biológica de Galicia* (CSIC) (Pontevedra, Galicia, Spain). The incidence and severity of powdery mildew were determined on leaves three weeks after the onset of flowering and on clusters at harvest. The values for both variables were smaller than those recorded for other fungal diseases, although great differences in susceptibility between the different genotypes were observed. The most susceptible was Castañal (recently included in the Spanish Registry of Commercial Varieties), a genotype native to the O Rosal subzone of the Rias Baixas denomination of origin area. The present results could help viticulturalists grow different grapevine genotypes more successfully in regions with climatic conditions similar to those where the study was undertaken.

INTRODUCTION

Powdery mildew, a disease of vines caused by *Erysiphe necator* (Schw.) Burr., is very common in vineyards where, according to the classification of Koppen, the climate is of the Csa type (AEMET, 2010). In some years, however, it can also cause damage in areas with Cfb and Csb climates, such as in Galicia and Asturias (in the northwest and north of Spain respectively). *E. necator* survives the winter as a mycelium in the buds. In areas with a Cfb and Csb climate, the fungus extends in springtime via cleistothecia, which release ascospores that develop on leaves and other aerial organs (Pearson & Gadoury, 1987; Jarvis *et al*., 2002). In Csa climate areas, however, the mycelia in the infected buds may simply grow into the leaves etc., without the production of such spores (Van der Spuy & Mathee, 1977; Sall & Wrysinski, 1982; Pearson & Gartel, 1985). The disease appears as a whitish-grey powdery coating on the leaves and berries, i.e. the visible mycelium and conidia. Severe infections can debilitate vines, reduce net photosynthesis, delay ripening and reduce wine quality (Gadoury *et al*., 2001; Dry *et al*., 2010).

The initial symptoms on leaves are chlorotic spots on the upper surface that soon become whitish lesions. Late in the season, small, round black structures (cleistothecia) begin to appear within the white, powdery lesions (Gadoury *et al*., 2012). It is on the clusters, however, where the infection causes the most commercial damage. Clusters appear to be most susceptible to attack between flower setting and *véraison* (Ypema & Gubler, 2000; Gadoury *et al*., 2001); over this interval the berries can suffer considerable damage. The first cluster symptom is the appearance of a grey dust over the berries; those affected fail to develop properly and end up splitting, leaving the seeds exposed. This favours the entry of other pathogens such as *Botrytis cinerea*. If infection occurs after *véraison*, the berries may still grow, but the must quality can be seriously affected (Amati *et al*., 1996; Gadoury *et al*., 2001).

The environmental factors that limit the germination and growth of powdery mildew (temperature, rainfall and relative humidity) have been reported by several authors (Jarvis *et al*., 2002; Carroll & Wilcox, 2003). The ideal conditions for the growth of powdery mildew include temperatures of 20 to 28°C (optimum range 24 to 27°C), 80% to 90% relative humidity (RH), and relatively low light levels (such as those found inside dense vine canopies or during overcast weather). Temperatures of over 35°C inhibit spore germination and slow the growth of the fungus, while temperatures of over 40°C kill the spores (Keller *et al*., 2003). Powdery mildew can tolerate low RH levels (*e.g.* of

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around 40%), but the production of conidia, and therefore the rate at which the disease spreads, appears greatest at over 80% RH. An RH of above 90% may not be as favourable given the formation of free water droplets; powdery mildew conidia burst or germinate abnormally in water.

Certain species of *Vitis*, such as *V. riparia*, *V. rupestris*, *V. labrusca* and *V. rotundifolia*, are resistant to powdery mildew (Mullins *et al*., 1992; Gadoury *et al*., 2012; Pap *et al*., 2016), but nearly all varieties of *Vitis vinifera* are susceptible, and some more so than others (Li, 1993; Staudt, 1997; Merdinoglu *et al*., 2014; Atak, 2017). Gaforio *et al*. (2011) compared the susceptibility of different *V. vinifera* genotypes in central Spain, where the climate is semi-arid (Csa, with hot, dry summers). The aim of the present work was to assess the susceptibility to powdery mildew of 41 genotypes of *V. vinifera* (some the same as in the latter study) growing in the north and northwest of the Iberian Peninsula (some for more than 400 years), where the fungus sometimes causes damage even though the summers are much cooler.

MATERIALS AND METHODS

Plant material

The vine material used in this work belonged to 41 *V. vinifera* L. genotypes (19 white and 22 red, 10 plants per genotype, randomised block distribution), all part of the collection of the *Misión Biológica de Galicia* (CSIC). The plot where these genotypes are maintained lies 4 km from the town of Pontevedra, in Galicia (north-western Spain) (42° 25´ N, 8° 38´ W), at an altitude of 35 m. The soil of this plot is a sandy loam (70.1% sand, 6.1% silt, 13.8% clay) with an organic matter content of 7.3%. The plant rows are 2.5 m apart, with 2 m between plants, translating into a planting density of 2 000 plants/ha. All plants are grown employing a trellis system, and are pruned using the Sylvoz method. During the study period, the plants were gown according to standard viticultural practices; no fungicides or pesticides were used in the experimental area.

Most of the studied genotypes were found in different places in the Iberian northwest, where they have existed for more than 400 years. However, some arrived in the area from different parts of Europe after the occurrence of phylloxera (*e.g.*, Doña Blanca is from Castilla-León, Albarín blanco and Verdejo negro are from Asturias, Caíño blanco and Caíño tinto are from Galicia, Tempranillo is from La Rioja, Palomino is from Andalusia, Cabernet Sauvignon, Chenin blanc and Sauvignon blanc are from France, and Chasselas Dorée is from France or Switzerland, etc.).

The mean annual temperature for the last 50 years at the plot site is 14.11ºC; the mean annual rainfall for the same period is 1 686.68 mm (data recorded by a weather station on the plot). Over the study period (2009 to 2011), temperature, rainfall and relative humidity data were recorded at the same weather station (Fig. 1).

Evaluation of disease symptoms

In the experimental plot, primary infection is caused by ascospores released in spring via cleistothecia. The vines were monitored weekly for spores from spring onwards by collecting 10 to 15 basal leaves from approximately 50 plants at random and examining the underside of the leaves. Once the presence of spores was confirmed, leaf disease incidence and severity were recorded in 10 vines per genotype at about three weeks after the onset of flowering. The same variables were determined in clusters at harvest in 2009, 2010 and 2011. Disease incidence was determined as (*number of leaves or clusters with symptoms/total number of leaves or clusters*) × *100*, and disease severity as (*area of the leaves or cluster affected/leaves or clusters surface area*) × *100*. The resistance level of each genotype to powdery mildew was rated based on its severity index (SI) (Wang *et al*., 1995).

For the sake of comparison with the results of other authors (Gubler *et al*., 1999, Péros *et al*., 2006; Gaforio *et al*., 2011), the 'degree of susceptibility' shown by the different genotypes was also measured using the method of the Organisation of Vine and Wine (code 455 and 456) (OIV, 2009). This involves a scale from 1 to 9: a score of 1 to 3 reflects very low to low resistance (high susceptibility), 5 represents medium resistance (medium susceptibility), and a score of 7 to 9 indicates high to very strong resistance (low susceptibility).

Statistical analysis

The results were subjected to ANOVA. Means were compared using the least mean squares procedure. All calculations were performed using SAS System v. 8.1 software (SAS, 2000).

RESULTS

Springtime (May) temperatures over the study period were low (mean temperature < 15°C in all years of the study). This prevented strong powdery mildew attacks during this period; infections did occur, but the spread of disease was slow. Conditions were most favourable for the fungus between flowering (June) and *véraison* (August). Over this period the mean temperature was > 17°C and the maximum temperatures were < 33°C in all years of the study. Over most of the study period the relative humidity was between 69% and 80% (Fig. 1).

No powdery mildew symptoms were observed on the leaves at flowering for nearly all genotypes and over all three years of the study. Only the genotypes Castañal, Mouratón and Torrontés (disease incidence 25%, 15% and 18% respectively) showed higher susceptibility to this disease at this moment during the growth cycle in 2011.

For the clusters, however, significant differences were seen between genotypes in terms of disease incidence and severity over the three years of the study. The interaction *genotype x year* had a significant influence on these variables; the results were therefore analysed for each separate year. Incidence and severity were worse in 2011 than in the other years. The genotype Castañal showed the highest disease incidence (46% in 2009, 76% in 2010 and 98% in 2011) and severity (75% in 2009 and 2010 and 85% in 2011) in every year of the study; indeed, the values recorded were significantly higher than for all other genotypes.

Among the remaining genotypes, the most susceptible, *i.e.* showing significantly greater disease incidence and severity than the others (Table 1), was Blanca Desconocida 1 in 2009 (incidence 24%, severity 25%), Caíño Bravo in 2010 (14% and 28%), and Mouratón (48% and 45%) and Verdello

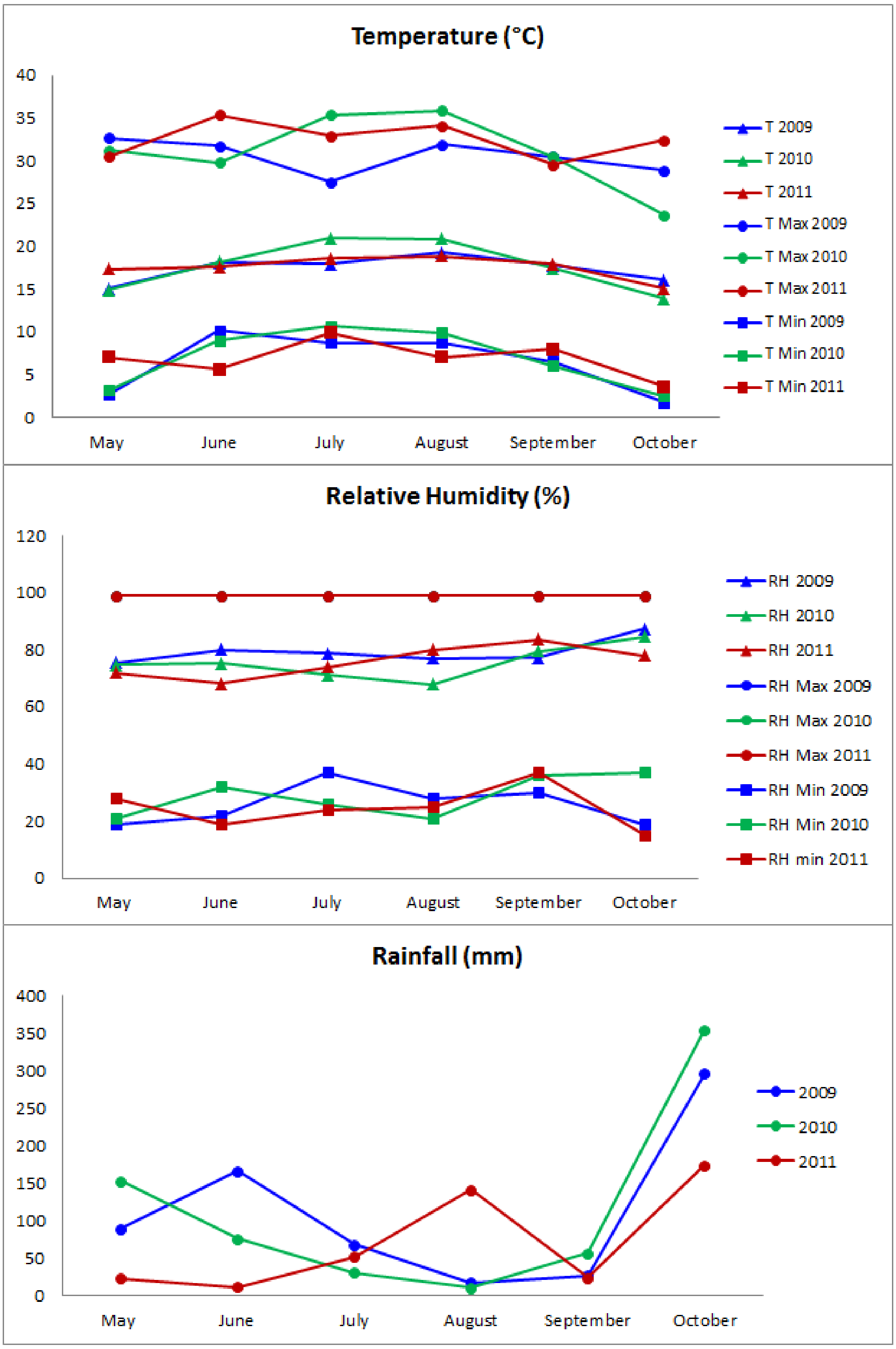

FIGURE 1
Weather data for the study period (2009 to 2011).

tinto (34% and 38%) in 2011. Many genotypes (Blanca Cabanelas, Godello, Chasselas Doré, Albarín blanco, Petit Bouschet, Albarín Francés and Silveiriña) never showed any symptoms of disease (*i.e.* zero disease incidence and severity) in any year. The genotypes Torrontés, Couxo, Caíño tinto, Caíño Longo, Alicante Henri Bouschet, Verdejo negro, Chenin blanc, Tempranillo, Albariño, Prieto Picudo, Pedral, Verdello tinto, Carrasco and Cabernet Sauvignon also showed very low susceptibility (incidence < 10% in all years, severity 0% to 25% depending on the year). According to the criteria of the OIV (OIV, 2009), nearly all the genotypes showed high resistance (H) to powdery mildew. Castañal, however, showed low (L) leaf resistance (code 455) in all study years and medium (M) cluster resistance (code 456) in 2009. Mouratón also showed medium cluster resistance (code 456) in 2011.

TABLE 1
Disease incidence (%) and severity (%) in the different genotypes.

Genotype	2009		2010		2011	
	Incidence	Severity	Incidence	Severity	Incidence	Severity
Castañal (R)	46.30a*	75a	76.4a	75a	97.53a	85a
Blanca Desconocida 1 (W)	23.55b	25c	0c	0c	1.07f	1.2g
Torrontés (W)	9.51c	25c	0.96c	0c	27.73cd	15.5cde
Caíño tinto (R)	5.59c	5d	0c	0c	3.40f	2.5fg
Caíño Longo (R)	5.00c	50b	0c	0c	19.36de	23c
Mouratón (R)	3.85c	5d	2.17c	2c	48.39b	45b
Alicante Henri Bouschet (R)	2.96c	5d	0c	0c	6.32f	6efg
Treixadura (W)	2.60c	5d	0c	0c	0f	0g
Verdejo negro (R)	2.01c	5d	0c	0c	1.26f	1.2g
Chenin blanc (W)	1.60c	5d	0c	0c	0.43f	0.06g
Tempranillo (R)	1.27c	5d	0c	0c	19.24de	6efg
Albariño (W)	1.10c	5d	0c	0c	1.92f	1.6fg
Sauvignon blanc (W)	1.02c	0d	0c	0c	0f	0g
Albarín negro (R)	0.71c	5d	0c	0c	0f	0g
Prieto Picudo (R)	0.68c	5d	0c	0c	10.87ef	12def
Pedral (R)	0.54c	5d	0c	0c	4.58f	2.2fg
Palomino (W)	0.46c	0d	0c	0c	0f	0g
Couxo (R)	0.43c	5d	0.64c	0.07c	1.69f	1.6fg
Caíño blanco (W)	0.20c	5d	0c	0c	0f	0g
Blanca Cabanelas (W)	0c	0d	0c	0c	0f	0g
Monstruosa (W)	0c	0d	0c	0c	0f	0g
Verdello tinto (R)	0c	0d	1c	20b	33.38c	38b
Loureiro blanco (W)	0c	0d	0c	0c	0f	0g
Brancellao blanco (W)	0c	0d	0c	0c	0f	0g
Godello (W)	0c	0d	0c	0c	0f	0g
Moscatel Grano Menudo Blanco (W)	0c	0d	0c	0c	0f	0g
Doña Blanca (W)	0c	0d	0c	0c	0f	0g
Silveiriña (W)	0c	0d	0c	0c	0f	0g
Chasselas Doré (W)	0c	0d	0c	0c	0f	0g
Albarín blanco (W)	0c	0d	0c	0c	0f	0g
Morrastrel Bouschet (R)	0c	0d	0c	0c	0f	0g
Ferrol (R)	0c	0d	0c	0c	0f	18cd
Caíño Bravo (R)	0c	0d	14.31b	28b	0f	0g
Follajeiro (R)	0c	0d	0c	0c	0f	0g
Petit Bouschet (R)	0c	0d	0c	0c	0f	0g
Moscatel Grano Menudo Rojo (R)	0c	0d	0c	0c	0f	0g
Albarín Francés (R)	0c	0d	0c	0c	0f	0g
Carrasco (R)	0c	0d	1.19c	0.08c	3.72f	2.5fg
Cabernet Sauvignon (R)	0c	0d	2.5c	1c	0.42f	1g
Mencia (R)	0c	0d	0c	0c	0f	0g
Blanca Desconocida 2 (W)	0c	0d	0c	0c	0f	0g
L.S.D. (0.05)	10.20	7	5.58	8	12.22	10

Values in the same column followed by the same letter are not significantly different (i.e. $P > 0.05$). W (white), R (red).

DISCUSSION

As expected, the climatic conditions greatly influenced disease incidence and severity. Until May, the minimum temperature recorded was always < 15°C in all years of the study. This led to disease symptoms being absent. In all three years, the mean temperature from June to October was > 15°C, which favoured fungal growth and the appearance of symptoms to a greater extent.

Several authors (Pearson & Gadoury, 1987; Jarvis *et al*., 2002) report that, while some moisture is needed for symptoms to appear, excessive rainfall slows the growth and spread of the fungus. In 2009 and 2010, the high rainfall in May and June (75 to 165 mm) slowed the spread of the disease, while in 2011 disease incidence and severity were high due to the lack of rainfall. From the end of July in 2009 and 2011, intermittent rainfall again prevented strong disease development. In 2010, the lack of rain and maximum temperatures of > 35°C for one week at the end of July reduced both the incidence and severity of disease.

In central Spain (Alcalá de Henares), which has a drier climate with hotter summers and colder winters, Gaforio *et al*. (2011) reported the genotype Torrontés to show low resistance to powdery mildew, while in the present work this genotype was associated with a mean incidence of 13% and a mean severity of 13.5% (low susceptibility according to the OIV scale). In contrast, while Gaforio *et al*. (2011) described the genotypes Chasselas Doré and Doña blanca to be of medium resistance (according to the OIV scale), and Mencía and Godello to show low resistance, in the present work these genotypes showed no symptoms at all in any year. The genotypes Caíño tinto, Prieto Picudo, Loureiro blanco and Petit Bouschet showed high resistance in both central and north-western Spain, despite the differences in climate.

In the present work, the genotypes Cabernet Sauvignon, Chenin blanc and Moscatel de Grano Menudo Blanco showed low susceptibility ("H" according to the OIV scale), but have been classed as very susceptible by other authors working in different countries with different climates (Li, 1993, Gubler *et al*., 1999, Péros *et al*., 2006). Atak (2017), who compared *V. labrusca* genotypes and interspecific cultivars grown in humid and dry regions, reported them to be resistant independent of the climate. Other authors indicate that, in several genotypes, resistance or susceptibility may differ between isolates (Montarry *et al*., 2008, 2009; Frenkel *et al*., 2012). Samples of the pathogen from areas of different climates are currently being characterised at our facility, and plants are being artificially inoculated to determine the effects *E. necator* races may have.

CONCLUSIONS

In conclusion, of the 41 genotypes studied, Castañal showed the greatest susceptibility to powdery mildew. This red grape genotype, a native of the O Rosal subzone of the Rías Baixas Denomination of Origin area (Northwest of Spain), was only recently included in the Spanish Registry of Commercial Varieties (Santiago *et al*., 2008). Huetz de Lemps (1967) describes it as highly susceptible to powdery mildew. The remaining genotypes showed low or no susceptibility. Comparison of the present results with those for some of the same genotypes grown in central Spain by other authors suggest that these genotypes are less susceptible to powdery mildew in humid regions, probably as a consequence of climate. The present results may help viticulturalists grow some genotypes more successfully in regions with climatic conditions similar to those of the study region.

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