

Varietal Resistance of Grape to the Powdery Mildew Fungus, *Uncinula necator*¹

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Abstract

Powdery mildew of grapevines, caused by *Uncinula necator*, is considered to be a major disease worldwide. The fungus utilizes haustoria to withdraw nutrients from epidermal cells and spreads rapidly under favorable conditions. Commercial grapes originating from *Vitis* species are the most desirable varieties for commercial production but are usually most susceptible to powdery mildew. *Muscadinia* species possess disease resistant characteristics but poor fruit traits. The development of resistant germplasm has involved many countries and as a result, screening procedures are varied and utilize numerous evaluation criteria. Published studies on varietal resistance or relative susceptibility suffer from inconsistencies in terminology and approach. Further research to develop germplasm with standardized levels of susceptibility will benefit the grape industry. A list of cultivars and their relative susceptibilities to powdery mildew is compiled.

Introduction

Powdery mildew of grapevines is caused by the pathogen *Uncinula necator* (Schw.) Burr. The disease is prevalent in most of the grape growing regions of the world. It is a problem in California on *Vitis vinifera* L. vines as well as on many native American species. The effect of fungal infection on the fruit causes significant economic loss of table and wine grapes. (16). In 1987, the cost to California grape growers for powdery mildew control exceeded 30 million dollars (Andre's, personal communication).

Varietal resistance and pathogenesis have been investigated in Germany (14), France (10), Russia (38), Czechoslovakia (33), and the United States

(16). These investigations provide an excellent basis for further research into powdery mildew resistant cultivars. The purpose of this report is to review literature pertinent to powdery mildew resistant grape germplasm and group grape varieties according to their relative susceptibility to powdery mildew.

The development of commercially acceptable cultivars possessing resistance to powdery mildew would benefit grape growers. It would reduce the amount of fungicides used. The opportunity for the pathogen to develop resistance to fungicides would be reduced. The grape industry would have greater acceptance by society which currently is very critical of pesticides used in farming. The chance of air pollution or ground water contamination by fungicides would be reduced.

Pathogenesis

The causal organism *U. necator*, of powdery mildew is an obligate ascomycete in the order Erysiphales. The asexual mycelium of the fungus grow over the leaf surfaces of grapevines and produce appressoria for anchorage of the hyphae to the cell surfaces. The appressoria develop thread-like infection pegs which penetrate the epidermal cells. After ingress, the infection pegs develop into globular haustoria for drawing nutrients from the hosts epidermal cells (35).

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Colonization occurs by the formation of mycelia over the leaf surfaces. The mycelia produce conidiophores that generate conidia in a chain-like manner. Conidia are dispersed by wind and rain to other plant parts or to adjacent plants (35).

Under favorable growing conditions, the fungus spreads rapidly in a vineyard and its life cycle is repeated once a week. Germination and growth is most rapid at leaf surface temperatures of 21° to 30°C but it can grow at temperatures as low as 6°C. The fungus is killed by leaf temperatures above 35°C. The pathogen can develop over a wide range of relative humidity but free water may inhibit spore germination and wash conidia from the vine (35).

The role of cleistothecia in providing primary inoculum of grape powdery mildew has not been well documented in CA (35), but is known to occur elsewhere (31). The development of these fruiting bodies involves recombination of genetic material which may lead to new fungicide resistant strains (14).

Background

All commercial grapes originated from the genus *Vitis*. Two subgenera; *Euvtis* with 38 chromosomes and *Muscadinia* with 40, provide the important genetic resources for grapevine breeding (5). *Muscadinia* Small is considered by some scientists as a distinct genera (10, 29). *V. vinifera* possesses the best characteristics for commercial fruit and wine quality (4, 5). *M. rotundifolia* possesses the desirable characters to correct deficiencies of *V. vinifera*, namely, its susceptibility to the phylloxera root aphid *Daktulosphaira vitifoliae* Fitch and a variety of fungus diseases including powdery mildew (10).

Powdery mildew is thought to have originated on wild vines in the Eastern and Central United States (8). The disease was introduced into Europe in

the 1840's and caused extensive damage in every grape growing country within 10 years. Growers in France began using sulphur for control and regained normal production by 1859.

The disease was present in California as early as the 1860's and was mentioned by Bioletti in 1906 as existing in all parts of the state. Early researchers noted that species of native American vines were much less susceptible to powdery mildew than the European *V. vinifera*. This stands to reason since the disease probably existed endemically on native American grapevines.

Early European attempts to develop resistance to powdery mildew resulted in the introduction of the phylloxera root aphid from rooted American vines brought in for breeding purposes (12). The vineyards of Europe were then suffering from two pests introduced from North America.

The French government initiated breeding programs in the late 19th century to import germplasm from America for hybridization with French varieties (5). Undesirable flavor compounds introduced from American varieties caused these original hybrid direct producers (HDPs) to receive a great deal of condemnation. Germany developed restrictive legislation leading to a general prohibition of all fungus resistant grape varieties derived from hybridization with American *vitis* (4).

Grape breeders improved the early native American hybrids by making crosses with *vinifera* cultivars producing many of the French hybrids in use today (18). In European vineyards, most of these HDPs have been replaced by grafted vines utilizing phylloxera and disease resistant rootstock with traditional *vinifera* cultivars of limited disease resistance as scions (5).

Scientists have continued to believe in the possibility of combining fungus resistance and wine quality. It was in the 1930's that the German scientist, B.

Husfeld, initially proved the combining ability of high fungus resistance with a superior wine quality indistinguishable from *V. vinifera* (4). Many of the original HDPs such as Catawba, Concord, and Delaware are still used in eastern North America for wine production. (18).

In the United States, environmental concerns, food safety issues, and the economic reality of control costs make reductions in the use of fungicides to control powdery mildew necessary. The future of grape breeding looks very promising for production of disease resistant cultivars. New techniques such as identification and isolation of disease resistance genes (7) and advances in screening for resistant cultivars are at the forefront of this science.

Screening Procedures

Powdery mildew infection on grapevines has been studied in various experiments. The disease, however, does not occur in discrete ranges of severity so the evaluation of disease incidence reported may vary. The Horsfall-Barret rating system has been useful in evaluating the severity of plant disease and may be useful in powdery mildew screening. The rating system is based on 50 percent as a mid-point with grades decreasing by a factor of .5 in either direction (20).

The different criteria used for the evaluation of powdery mildew depend on the focus of a researcher and the needs of the grape industry in the region of production. Foliage can be examined and the amount of infected surface area determined; clusters observed for surface area with infected berries; or cluster rachis rated for general disease severity (30). The development of conidia, hyphae, or cleistothecia may also be evaluated under different physical conditions.

The process of rating natural field infections has been used by Doster and Schnathorst to quantify the susceptibility of various cultivars to in-

fection (16). All vines were subject to identical cultural practices and no fungicides were used. Fruit clusters and leaves were examined during the growing season for the presence of mildew. Results from this study support a proposal that fungicide applications for powdery mildew control on grapevines be varied according to the susceptibility of a cultivar.

In another experiment, Doster and Schnathorst inoculated vines in field and greenhouse experiments and used light microscopy to compare the development of *U. necator* on various aged leaves of resistant and susceptible cultivars (15). Pieces of tissue were excised from different aged leaves, stained, and observed for development of hyphae and conidia. Their results showed decreasing susceptibility of leaves as they matured which complicated cultivar comparisons.

Aldwinckle studied the relationship between field and greenhouse resistance by inoculating seedlings while still in greenhouse flats, scoring the plants for reaction based on percentage of leaf surface covered with powdery mildew, and then planting the seedlings in a vineyard (1, 3). After 3 years in the vineyard, the plants were again scored for natural infection. Greenhouse and field scores were compared. The levels of resistance were consistent enough to consider the test useful in eliminating susceptible seedlings from field trials.

Direct observation of germination, infection, and growth of the powdery mildew fungus in screening tests can be aided by the application of a thin membrane of commercial celloidin to the plant surface (13). The liquid quickly dries and can be stripped from the plant tissue thereby removing all fungus structures outside the cuticle. These structures become highly visible when stained and viewed by microscope on a slide.

Grape breeding programs are very time-consuming and laborious but sev-

eral exciting new techniques promise to overcome these obstacles. One such technique is the *in vitro* culture of grapevines (2). The growth of shoot segments on a special medium increases the speed of cultivar propagation, increases screening possibilities, and shortens the duration of test procedures (5). A dual culture of the grapevine host and *U. necator* provides additional opportunities for studying varietal resistance in isolation from external environmental contamination (22).

A unique approach to screening involves the use of a group of compounds known as phytoalexins which are inhibitory to fungal development. Resveratrol, a precursor to these compounds, is produced by *V. vinifera* in a response to infection of injury (24). Ultraviolet light induces the production of resveratrol and some observations show varying rates of synthesis in relation to incidence of disease in different *Vitis* species (32). Resveratrol can be identified by using quantitative thin-layer chromatography (6). This technique could be used in screening for powdery mildew resistance to eliminate the need for maintenance of fungus cultures for inoculation.

Varietal Resistance

A review of the published studies, reveals a pronounced lack of consistent terminology regarding relative susceptibility of grape cultivars to powdery mildew. The problem becomes even more apparent when a cultivar is reported in one study as resistant and in another study as susceptible (e.g. Petite Syrah, 9, 16). It should be noted that ampelographic problems can add to the confusion as with the cultivar Petite Syrah commonly used in California. The acceptable prime name for this cultivar is Durif (41).

The application of various criteria in separate studies (for example, conidia development in controlled incubation versus field density of cleistothecia)

on a particular cultivar can result in a confusing picture of the general level of susceptibility for that cultivar. Subsequent comparisons to other cultivars merely compound the problem. The situation complicates the process of putting together a list of cultivars for use in a variety trial. Different races of *U. necator* may also exist (10, 14). If so, the presence of different races of the pathogen in separate studies on the same cultivar could further complicate the evaluation of that cultivar.

Lacking a coherent system of evaluating grape germplasm resistance to powdery mildew, it is proposed that an international standard be established. It may be patterned after a program used in international wheat and maize breeding by CIMMYT (11). The program should be broad-based so it accumulates resistant germplasm, uses multilocational testing to expose resistant germplasm populations to various climatic effects and races of *U. necator*, and establishes standardized criteria for determining disease incidence.

The establishment of quantified levels of resistance to powdery mildew for specific varieties would provide researchers with a standard against which new cultivars could be compared. Evaluating the comparative susceptibility between an experimental cultivar and a known standard cultivar would aid in the development of effective control measures and proper fungicide use.

Compilation of a comprehensive list of cultivars with their relative resistance to powdery mildew (Table 1) from the presented literature necessitated a simplification of the wide range of descriptive terminology used for grouping. Cultivars which were described in the literature as highly resistant or to which a high degree of resistance could be inferred by interpretation of tabular results are labeled as Significantly Resistant. Cultivars

Table 1. Powdery mildew resistance found in grapes.

| Significantly resistant | Intermediate | Moderately resistant | Intermediate | Significantly susceptible |
|--------------------------------|---|-------------------------------------|---|---------------------------------------|
| Alicante Ganzini ²⁸ | Abouriou ^z 16,17 | Barbera ¹⁶ | Cabernet Sauvignon ^{9,16,17,35,39} | Aspiran ^{9,17} |
| Angur Kalan ³⁶ | Alicante Bouschet ^{8,16,21,34} | Catawba ^{23,39} | Chenin blanc ^{15,16,35} | Bacchus ¹⁴ |
| Aubun ¹⁷ | Aramon ^{8,9,17} | Durif ^{8,9,16,17,21,34,35} | Concord ^{23,29} | Black Corinth ²¹ |
| Babeasca Neagra ³⁶ | Belcan ^{8,21} | (Petite Syrah) | Gewurztraminer ^{16,39} | Boutellan ^{9,17} |
| Baroque ¹⁷ | Delaware ^{23,29} | Fredonia ²³ | Kerner ^{6,19,37} | Cardinal ^{16,35} |
| Castor ⁴ | Dutches ^{23,29} | Grenache ^{8,9,16,17} | Petite Bouschet ^{8,9,17,34} | Carignane ^{8,15,16,17} |
| Cayuga White ³⁹ | Elvira ^{23,39} | Grignolino ¹⁶ | Reising ^y 6,8,19,37,39 | Chardonnay ^{16,35,39} |
| Clinton ²³ | French Colombard ^{15,16} | Malbec ^{8,16} | Sylvaner ^x 16,17,40 | Clarette ^w 8 |
| Ives ^{23,39} | Mataro ^{8,21,34} | Marsanne ⁸ | Ugni Blanc ^{8,9,17} | Claverie ^w 9,17 |
| Janjal Khara ³⁶ | Orion ^{5,14} | Niagara ^{23,39} | | Emperor ^{13,16,17} |
| Maccabeu ¹⁷ | Royalty ^{16,28} | Pollux ^{4,14,19,37} | | Flame Tokay ^{8,34} |
| Mars ²⁵ | Sirius ^{5,14} | Riesling (White) ^{16,3} | | Merlot ³⁹ |
| Mauzac ¹⁷ | Ca-58-144,14,37 | Semillon ^{9,16,35} | | Muscadel ¹⁷ |
| Meunier ¹⁷ | Ca-58-304,6,19,37 | Vernaccia ⁸ | | Muscat Alexandra ^w 8,34,40 |
| Niabella ^{16,27} | | Zinfandel ^{15,3} | | Optima ¹⁴ |
| Phoenix ^{14,15} | | Ca-54-1419 | | Perlette ¹⁶ |
| Pinot blanc ¹⁶ | | | | Pinot noir ³⁹ |
| Rekasetai ³⁶ | | | | Rish Baba ²¹ |
| Riesling (grey) ¹⁵ | | | | Rosette ^{1,3} |
| Rubired ^{15,16,28} | | | | Thompson Seedless ^{15,16,35} |
| Silva ^{5,14} | | | | |
| Steuber ³⁶ | | | | |
| Tampa ²⁶ | | | | |
| Terret Noir ⁹ | | | | |
| Tinto Cao ²⁸ | | | | |
| Valdiguier ¹⁷ | | | | |
| Vidal ^{17,37} | | | | |
| C-97-45 ⁴ | | | | |
| Ga-47-42 ¹⁴ | | | | |
| Ga-52-42 ¹⁴ | | | | |
| Ga-50-34,19,37 | | | | |
| Ga-49-224,19,37 | | | | |
| Fr-993-606 ⁶ | | | | |

^zAbouriou is stated as prime name, may be listed in literature as Gamay Beaujolais (41).

^yMay be numerous ampelographic problems associated with the Riesling varieties (41).

^xMay be an acceptable synonym for Muller Thurgau (41).

^wClarette is stated as prime name for Muscat Alexandra (41).

which were described as highly susceptible, or to which a high degree of susceptibility could be inferred are labeled as Significantly Susceptible. All cultivars which are intermediate between the two groups, including those with a range of reported resistance, are grouped according to the prevailing degree of resistance. The addition of references after each cultivar will allow a researcher to determine criteria used by each author in reporting levels of resistance. It is hoped that the list will help facilitate the selection of appropriate grape cultivars for breeding programs.

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Performance of Cranberry Cultivars at Aylesford, Nova Scotia

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Abstract

Eight cranberry cultivars were evaluated for yield, fruit size, and berry quality in Nova Scotia. Cultivar 'Crowley' equalled or exceeded the currently important cultivar 'Stevens' in all categories.

Introduction

The first planting of cranberry vines in Nova Scotia was thought to be by William McNeill of Melvern Square in 1870 (E. L. Eaton, unpublished report). The success of this early planting led to additional planting during the next few decades. Local cranberry vines, obtained from the wild, were used to establish most of these bogs although some vines were imported from Massachusetts during the early 1900's. By

1941, 'Howes' and 'Early Black' were planted by several commercial growers in an attempt to improve productivity and fruit quality. In 1957, Eaton (1) described these two cultivars and another, 'Beaver', which originated in a bog at Beaver River, Nova Scotia. Eaton considered early ripening as the primary factor for cultivar selection in Eastern Canada.

After the introduction of several new cranberry cultivars in the U.S.A. (2, 3), the cranberry cultivar situation in Canada was reviewed by Hall (4). It was clear that an objective assessment of modern cranberry cultivars was required to make informed recommendations to growers in the Canadian Maritime Provinces.

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