Leaf Removal for Control of Botrytis Bunch Rot of Wine Grapes in the Midwestern United States

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ABSTRACT

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The influences of leaf removal on canopy structure and Botrytis bunch rot were examined in two wine grape vineyards in Missouri. Leaf removal significantly reduced canopy density and increased evaporative potential in vines of hybrid grape cultivars Vignoles and Seyval blanc. However, the effectiveness of the practice in reducing disease varied with seasonal weather patterns and with vine support and trellis system. In the warm and dry growing season of 1991, grapes matured very early and no disease occurred in Vignoles with or without leaf removal. Disease levels also were low in Seyval blanc; however, leaf removal significantly reduced the incidence and severity by up to 47 and 79%, respectively, compared to vines without leaf removal. Application of iprodione provided no additional disease control. In the much wetter season of 1992, bunch rot occurred at both vineyards; and leaf removal significantly reduced the incidence and severity of bunch rot in both cultivars. However, iprodione applied to Seyval blanc also reduced disease incidence significantly in vines with or without leaf removal. Evaporative potential provided a simple means of measuring the degree of canopy opening and the drying conditions created by leaf removal.

Leaf removal has been adopted by many growers as a cultural practice for control of bunch rot, caused by *Botrytis cinerea* Pers.:Fr., in wine grape (*Vitis vinifera* L.) vineyards in California. This canopy management practice has proven particularly effective in controlling disease in cool coastal valleys which are under marine influences (8). Leaf removal also has utility for controlling Botrytis bunch rot in the warmer, interior valleys of the state (15). Both of these regions are characterized by growing seasons with limited, if any, rain until the time of harvest. Leaf removal is beginning to receive consideration as an important disease management practice in the eastern United States (10) and elsewhere in the world (9).

Leaf removal in grape production areas of the western United States typically involves the removal of leaves from the basal portions of shoots in the fruit zone of grapevine canopies (1,6,8,15). Leaves are removed either manually or by machine (7,11). The means by which leaf removal reduces bunch rot development are not well understood. It is known, however, that the practice reduces canopy density, increases wind movement through the canopy, and enhances the drying conditions or evaporative potential in the fruit zone (4–6). Increases in these environmental factors have been associated with reduced growth and reproduction of *B. cinerea* on infected berries (16).

Reports of cultural control of Botrytis bunch rot have been confined generally to the traditional European grape cultivars within *V. vinifera*. Many of these cultivars cannot be grown in Missouri and other midwestern states because of climatic limitations. Alternatively, in these regions, commercial wine grape production is based on hybrids of European and North American species of *Vitis*. Some of the cultivars within these hybrids are very susceptible to *B. cinerea*, and disease cannot be managed effectively with fungicides.

It is not known whether leaf removal, as practiced in the western United States, would be effective in controlling bunch rot of hybrid wine grapes in Missouri. In particular, it is not known how the humid and potentially wet growing seasons in the Midwest would affect the efficacy of this cultural practice. Therefore, experiments were conducted in 1991 and 1992 to evaluate the utility of leaf removal for control of Botrytis bunch rot on two major cultivars of hybrid wine grapes grown in the region.

MATERIALS AND METHODS

Leaf removal trials were established in two vineyards in Missouri in 1991 and 1992. One of the vineyards, planted in 1980 with a tight-clustered cultivar, Vignoles (*V. vinifera* × *V. rupestris* Scheele), was located in Phelps county within the Ozark Plateau region. Vines were trained as quadrilateral cordons and were supported on a Geneva double curtain trellis (13) with shoots positioned downward just prior to implementing leaf removal treatments. Vines managed in this way have divided canopies. The second vineyard, planted in 1987 with a loose-clustered cultivar, Seyval blanc (*V. vinifera* × *V. rupestris*), was located in Gasconade county in the Missouri River Valley. These vines were trained as a quadrilateral system with upper and lower bilateral cordons, and were supported on a two-wire trellis (2). Vine structure of Vignoles was the same in both years except that shoots were not positioned in the second year. In the Seyval blanc vineyard, vines used in the second year of the experiment were trained as low, bilateral cordons and were supported on a single-wire trellis with shoots positioned upwards.

In 1991 and 1992 at the Vignoles vineyard, a leaf removal treatment was imposed in early June, approximately 2 wk after full bloom. In treated plots, leaves and lateral shoots were removed from the nodes opposite clusters and from the first node above and below the clusters. Care was taken to retain leaves which shaded clusters from direct sunlight. Leaf removal was imposed in both curtains of these divided canopies. In control plots, leaves were not removed. Four replicate plots were established for each treatment, and each replicate plot comprised four adjacent vines. Treatments were established in a completely randomized design.

In both years at the Seyval blanc vineyard, the same leaf removal treatments, with consideration for cluster shading, were established on both sides of vines in early June about 2 wk after full bloom. However, treatments were evaluated in combination with or without fungicide treatment. In fungicide-treated plots, iprodione (Rovral 50WP) was applied with a commercial air-blast sprayer at an equivalent rate of 1.1 kg a.i./ha at bloom and just before closure of clusters. This was the rate and schedule recommended for Missouri (3). Four replicate plots, each comprising four adjacent vines, were established for each treatment in a completely randomized design. All vines were also treated with mancozeb and captan for control of downy mildew and black rot, myclobutanil and

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wettable sulfur for control of powdery mildew, carbaryl for control of cutworms, and diazinon for control of grape berry moth. All materials were applied according to schedules recommended for Missouri (3).

Prior to harvest at each vineyard, densities of canopies in the fruit zone were measured using the point-quadrat method described by Smart (14). In this procedure, a count was made of the number of leaf contacts when a thin rod was passed through a canopy at the level of the fruit zone. The rod was inserted through the canopy at 10-cm intervals along the length of each vine. Canopy density was defined as the average number of leaf-rod contacts, or leaf layers, over all vines in a replicate plot. A relative measure of canopy density also was made just prior to harvest by recording the percentage of the photosynthetic photon flux fluence rate which reached the fruit zone of vines relative to that which impinged on the tops of canopies. The photon flux fluence rate was measured between 1100 and 1300 hours with a quantum line sensor. To measure the drying conditions in the fruit zone, evaporative potentials (4,5) were measured with standardized white, spherical atmometers twice during crop maturation in late July or early August. At each date, one atmometer was placed arbitrarily in the fruit zone of a single vine in each replicate treatment plot not sprayed with iprodione. Atmometers were left in the vines for 24–48 hr before evaporative loss was read.

Bunch rot was evaluated in each vineyard at the time of commercial harvest. In 1991, Vignoles was harvested on 6 August, when the soluble solids of mature fruit were about 19 Brix. Seyval blanc was harvested on 8 August, and soluble solids of mature fruit were about 18 Brix. In 1992, Vignoles was harvested on 20 August, when soluble solids of mature fruit were about 20 Brix. Seyval blanc was harvested on 28 August, and soluble solids of mature fruit were about 21 Brix. All clusters in treatment plots were evaluated for disease. Disease incidence was estimated as the percentage of clusters with infected berries, and disease severity was estimated as the percentage of rotted berries per infected cluster. The significance of treatment influences on canopy characteristics and disease development were determined by standard analysis of variance procedures (12) with significance levels of $P = 0.05$, unless otherwise stated. In instances where significant fungicide treatments were not detected, data from sprayed and nonsprayed plots were combined before comparing the significance of leaf removal.

RESULTS

In 1991, leaf removal significantly altered canopy structure and microenvironment in vineyards planted with Vignoles and Seyval blanc. In both vineyards, leaf removal reduced the canopy density significantly. Although not quantified, very little sunburning of grape berries was observed in leaf removal or control treatments. The numbers of leaf layers in treated canopies were reduced by at least 40% in both cultivars compared to control vines (Table 1). Reductions in canopy density caused by leaf removal also were measurable by significant increases in light penetration to the fruit zone. Increases in photon flux fluence rate ranged from 81% in the upper cordon of Seyval blanc to 133% in vines of Vignoles. Reductions in canopy density affected drying conditions variably. For example, in Vignoles, evaporative potential was increased significantly only on 14 July (Table 1). In contrast, evaporative potential was increased significantly at both sampling dates in the upper cordon of Seyval blanc; leaf removal increased evaporative potentials in these canopies by more than 20%. Evaporative potential in the lower cordon of Seyval blanc was increased at both sampling dates, but the increase was significant only on 17 July. Although canopy structure and microenvironment were altered significantly by leaf removal, the practice did not significantly affect the number of clusters per vine in either vineyard.

The 1991 growing season was characterized by high temperatures early in crop development and limited rainfall, in the form of localized storms, between bloom and harvest. The combination of these conditions resulted in grapes being harvested about 30 days earlier than usual. Consequently, development of Botrytis bunch rot was limited. In the Vignoles vineyard, no bunch rot was observed regardless of canopy treatment. In the Seyval blanc vineyard, bunch rot occurred predominantly in the upper cordon; and leaf removal significantly reduced both incidence and severity in this canopy region (Table 2). Application of iprodione provided no significant reduction in disease in the upper cordons of Seyval blanc with leaf removal; however, application of this fungicide did reduce severity significantly in the control treatment. In the lower cordon, both incidence and severity of disease were less than in the upper cordons. Neither leaf

Table 1. Influence of leaf removal on vine characteristics and microenvironment in 1991

Cultural treatment	Clusters per vine (no.)	Leaf layers (no.)[a]	Ambient light (%)[b]	Evaporative potential (ml water evaporated/hr): First sampling[c]	Evaporative potential (ml water evaporated/hr): Second sampling[d]
Vignoles					
Leaf removal	60.3	1.3*[e]	20.8*	0.57*	0.89
Control	53.3	2.2	8.9	0.48	0.84
				1.0[f]	1.1[f]
Seyval blanc					
Upper cordon					
Leaf removal	37.3	2.3*	5.8*	0.99*	0.66*
Control	41.3	4.5	3.2	0.74	0.54
Lower cordon					
Leaf removal	23.3	1.2*	2.8*	0.90	0.57*
Control	24.3	3.2	1.2	0.84	0.48
				1.49[f]	1.39[f]

[a]Number of leaf layers through the canopy wall as estimated by the point-quadrat method (14).
[b]Percentage of ambient photosynthetic photon flux fluence rate reaching the fruit zone of the vine.
[c]For Vignoles, 14 July; for Seyval blanc, 18 June.
[d]For Vignoles, 1 August; for Seyval blanc, 17 July.
[e]Within grape cultivar and cordon, an asterisk indicates a significant difference between leaf removal and control treatments at $P = 0.05$.
[f]Ambient evaporative potential, measured 1 m above vine canopy.

Table 2. Influence of leaf removal on development of Botrytis bunch rot in Seyval blanc in 1991[a]

Cultural treatment	Incidence[b]	Severity[c]
Upper cordon		
Nonsprayed vines		
Leaf removal	10.0*[d]	4.6*
Control	15.2	21.8
Sprayed vines		
Leaf removal	7.0*	4.7*
Control	13.2	8.1
Lower cordon		
Nonsprayed vines[e]		
Leaf removal	8.4	3.9
Control	9.1	4.3
Sprayed vines		
Leaf removal	2.2	3.0
Control	6.3	4.5

[a]No bunch rot was observed in vines of Vignoles.
[b]Percentage of clusters with rotted berries.
[c]Percentage of rotted berries per infected cluster.
[d]Within spray treatment, an asterisk indicates a significant difference between leaf removal and control treatments at $P = 0.05$.
[e]Application of iprodione did not reduce incidence or severity of bunch rot in lower cordons.

Table 3. Influence of leaf removal on vine characteristics and microenvironment in 1992

Cultural treatment	Clusters per vine (no.)	Leaf layers (no.)[a]	Ambient light (%)[b]	Evaporative potential (ml water evaporated/hr) First sampling[c]	Second sampling[d]
Vignoles					
Leaf removal	72.6	3.2*[e]	27.8*	0.64*	0.66
Control	80.9	4.3	22.1	0.56	0.64
				0.93[f]	0.91[f]
Seyval blanc					
Leaf removal	24.4	1.4*	14.0*	0.78*	0.62*
Control	30.4	4.2	5.0	0.67	0.52
				1.09[f]	0.87[f]

[a]Number of leaf layers through the canopy wall as estimated by the point-quadrat method (14).
[b]Percentage of ambient photosynthetic photon flux fluence rate reaching the fruit zone of the vine.
[c]3 August.
[d]For Vignoles, 17 August; for Seyval blanc, 21 August.
[e]Within grape cultivar, an asterisk indicates a significant difference between leaf removal and control treatments at $P < 0.05$.
[f]Ambient evaporative potential, measured 1 m above vine canopy.

Table 4. Influence of leaf removal on development of Botrytis bunch rot in 1992

Cultural treatment	Incidence[a]	Severity[b]
Vignoles		
Leaf removal	13.8*[c]	15.0*
Control	28.7	25.1
Seyval blanc		
Nonsprayed		
Leaf removal	28.3*	27.3*
Control	42.8	31.2
Sprayed		
Leaf removal	17.4*	20.5*
Control	34.1	32.1

[a]Percentage of clusters with rotted berries.
[b]Percentage of rotted berries per infected cluster.
[c]Within grape cultivar and spray treatment, an asterisk indicates a significant difference between leaf removal and control treatments at $P = 0.05$.

removal nor fungicide treatment significantly reduced disease.

In 1992, leaf removal also significantly affected canopy structure and microenvironment. In the Vignoles vineyard, shoots were not positioned; thus, canopy density was generally greater than in 1991 (Table 3). Leaf removal significantly reduced the number of leaf layers compared to control vines; however, the reductions in density were only about 25%. Reductions in canopy density were reflected in significant increases in light penetration and in evaporative potential on 3 August.

In contrast to Vignoles, leaf removal modified canopy structure in the Seyval blanc vineyard to an equivalent or greater extent than in 1991. For example, the number of leaf layers in the fruit zone of vines with leaf removal was decreased by about 67% compared to control vines (Table 3). The influence of altered structure on microenvironment was also significant; however, changes were not always as great as in the previous year. For example, although light penetration to the fruit zone was increased by 180%, evaporative potential was increased by less than 20% on both 3 and 21 August.

In contrast to the previous year, the 1992 growing season was cooler with several periods of prolonged rainfall, the combination of which prolonged the time to harvest by at least 30 days. Consequently, higher levels of disease were observed in both vineyards. Regardless of the limited modifications in canopy structure and microenvironment in Vignoles, significant reductions in incidence and severity of disease were observed (Table 4). Incidence and severity of disease also were greater in Seyval blanc in 1992 than in the previous year (Table 4). Both leaf removal and fungicide application significantly reduced bunch rot development. Similar significant reductions in incidence and severity were caused by leaf removal in vines sprayed with iprodione.

DISCUSSION

The efficiency of leaf removal for control of Botrytis bunch rot of hybrid wine grapes in Missouri varied in relation to seasonal weather patterns and the training system used in a vineyard. In 1991, a season in which rains were infrequent and of short duration, little bunch rot developed regardless of the vine training system used. Nonetheless, leaf removal reduced the amount of disease that did occur under these conditions to significantly lower levels than in nontreated vines. As was observed in California (8), fungicide applications during periods of low rainfall provided no additional significant control of bunch rot beyond that brought about by leaf removal.

In contrast, in a wetter and more humid growing season, such as 1992, significant gains in disease control were obtained by leaf removal and fungicide treatment. Leaf removal alone enhanced the drying conditions in the fruit zone sufficiently to reduce bunch rot development significantly. Under these climatic conditions, however, leaf removal alone was not sufficient, and further gains were obtained by fungicide treatment.

Significant impact of leaf removal on canopy structure was reflected in the alterations of several parameters, including canopy density, light penetration, and evaporative potential. Measuring canopy density by the point-quadrat method is a time-consuming and labor-intensive procedure. However, evaporative potential is measured easily and inexpensively. Thomas et al (16) demonstrated in laboratory studies that evaporative potential above a defined threshold inhibits growth and sporulation of *B. cinerea* on infected fruit. This type of effect may have a strong impact on epidemic development. Evaporative potential is an environmental factor which has relevance to the biology of the pathogen, and it may be a useful parameter to guide growers in modifying canopy structure. Evaporative potential has been shown to be inversely related to canopy density (5). To date, no relationship has been established between specific levels of evaporative potential and disease development under field conditions. However, results from the present and past (5) studies suggest that canopies in which evaporative potential approaches 1 ml of water evaporated per hour diminish bunch rot development. Further investigations of the relationship of evaporative potential to epidemic processes under field conditions will help growers optimize canopy structure for disease control.

The seasonal and daily weather patterns in Missouri and other areas of the midwestern United States are less predictable than those in the drier regions of the West. However, the results of the present experiments demonstrate that canopies of hybrid grape cultivars in these regions can be modified sufficiently to obtain significant control of Botrytis bunch rot by leaf removal alone. Although these canopy modifications may optimize microclimate in the fruit zone for disease control, growers may still have to resort to the use of fungicides after periods of prolonged rainfall.

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