Botrytis Bunch Rot of Grapes: The Influence of Selected Cultural Practices on Infection Under California Conditions

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ABSTRACT

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Grape vineyard cultural options including trellis type, midseason hedging, and a fungicide treatment were evaluated for their influence on the development of Botrytis bunch rot. The trials were conducted in an unirrigated coastal valley vineyard (cultivar Chenin blanc) in the 1980 and 1981 growing seasons during which there was no precipitation. Incidence of *Botrytis cinerea* infection at harvest under drought conditions in 1980 was significantly influenced by trellis type and by fungicide application made at bloom ($P < 0.05$). A commercial-scale harvest of all sprayed portions of the plot was conducted and Botrytis bunch rot damage as assessed by standard state inspection was significantly lower in the "two-wire vertical" trellis (TWV) than in the "crossarm" trellised blocks (XARM, $P < 0.001$). Viticultural parameters of sugar content, pH, total acid, and yield were also evaluated. The hedging treatment led to a significant delay in maturity (sugar content) at the time of commercial harvest ($P < 0.05$). There were no other significant influences of the trellis, hedging, or fungicide treatments on those viticultural parameters. In the 1981 season, the two trellis types were compared and the TWV trellis was associated with significantly lower rot incidence ($P < 0.05$) and also with lower severity expressed as estimated percent rot by weight ($P < 0.01$). Progress of individual infections through the cluster appeared to be slower in the TWV trellis than in the XARM type.

Botrytis cinerea Pers. is an important pathogen of wine grapes (*Vitis vinifera* L.) in the cooler coastal valleys of California. Severe fruit infection is associated with late-season rains or overhead sprinkling, but in certain vineyards, substantial infection may occur in the absence of rain or irrigation. The development of bunch rot caused by *B. cinerea* under these marginal moisture conditions is most pronounced in cultivars that develop dense canopies and compact fruit clusters. Infected clusters can be observed first in early August as the sugar content of the berries begins to increase (veraison), and more infections appear over time so that by harvest (September–October), 20–40% of the clusters are affected. Each infection also progresses from berry to berry through the cluster, leading to appreciable losses in terms of quality and commercial acceptability.

The etiology of these dry-season infections by *B. cinerea* has not been resolved, but at least some infection is attributable to events occurring during bloom in late May. McClellan and Hewitt (5) reported that colonization of the necrotic pistil of the grape flower occurs in May and remains latent until the fruit begins to ripen. They found that inoculations with conidia increased later fruit infection only if made during bloom and that fungicide applications during bloom reduced infections that appeared months later. Other workers have attributed bloom-related infection to the colonization of floral debris such as calyptras or unset flowers (3). Cluster injuries, which may result from insect feeding or from the expansion of berries in tight clusters, may also be important avenues of *B. cinerea* infections.

Severe *Botrytis* infection was observed primarily in vineyards with vigorous canopy growth (*unpublished*). It was therefore hypothesized that the microclimate within the vine and within the cluster allows growth of the pathogen to an extent that would not otherwise be possible. Under such circumstances, cultural procedures that influence canopy microclimate might also influence disease. Examples of disease control through presumed microclimate mechanisms are numerous (1,6), although relatively few have been accompanied by a quantification of the climate parameters involved (2,7,8). The purpose of this study was to investigate the influence of two sets of commercial cultural alternatives on Botrytis bunch rot of grapes in order to assess their potential for disease control.

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MATERIALS AND METHODS

Field studies were conducted in an 8.1-ha block within a commercial vineyard near Yountville in the Napa Valley of California. This 12-yr-old block of the cultivar Chenin blanc was of a very vigorous heat-treated clone. It was cordon trained, spur pruned, and planted at a 2.44-m spacing in rows with 3.66 m between rows. The rows were oriented east-west, which is roughly perpendicular to the prevailing wind direction. During the 1980 season, a three-way factorial plot design with four replicates was used to study combinations of the following paried regimes or practices.

Hedging vs. no hedging. The low canopy growth was removed in 12-row by 30-vine sections using a sickle-bar hedger on 23 July or approximately at veraison. About 100 cm of growth was removed, leaving about 75 cm between the foliage and the ground.

Crossarm vs. two-wire vertical trellis. The two-wire vertical trellis system (TWV) consists of one wire 110 cm from the ground that supports the permanent bilateral arms of the vines and a second wire attached to the top of the grape stakes at 160 cm. The crossarm trellis system (XARM) involves the substitution of a pair of wires at the upper 160-cm level separated by a 60-cm cross-member that holds one wire at each end. These are the two most common trellis types for premium wine grapes in California. Each trellis type was established in six-row by 30-vine blocks.

Spray vs. no spray. In three-row by 30-vine subblocks, vines were either treated or not treated with a standard application of 1.68 kg/ha benomyl 50W and 4.48 kg/ha captan 50W at early bloom (25 May 1980). Applications were made with a commercial over-vine boom sprayer.

Nine vines at least 25 m from the edge of the vineyard in each replicate of the eight-treatment combinations were evaluated several times through the season for the appearance of cluster infections. Twenty clusters on each vine were inspected and rated as follows: type 0 = having no visible infection, type 1 = having a single berry that is visibly infected, type 2 = having an infection that involved no more than the berries immediately surrounding the original site, and type 3 = a cluster that is more extensively infected than described for type 2 Fifty clusters of each rating category were dissected and the infected and uninfected berries separated and weighed to determine the mean percentage of rot by weight for each category. These percentages were used to calculate estimated percent rot by weight from visual assessments.

Blocks consisting of 90 vines each from all replicates of treatment combinations sprayed at bloom were harvested commercially into separate gondolas and weighed. Unsprayed treatments were not harvested in this manner because the logistics of using field crews was not conducive to avoiding partially sprayed buffer rows. A 25-kg commercial stab sample was taken from each gondola at the winery and sugar content, total acid, and pH were determined from a juice sample. In addition, standard state inspections for percent rot by weight were requested on each load.

In the 1981 season, the Yountville site was again studied but only the two trellis types were compared. The entire vineyard was sprayed at bloom and disease ratings were made on five vines in each subblock. All ratings were made on vines at least 100 m from the edge of the vineyard.

In both seasons, the sugar content of the crop was estimated by the random collection of large numbers (>200) of individual berries in each treatment. The berries were crushed and analyzed using a hand-held refractometer. At the final reading in the 1980 season, one vine from each replicate-treatment combination was harvested. The fruit was crushed and pressed and a sample of the juice was taken for sugar content determination.

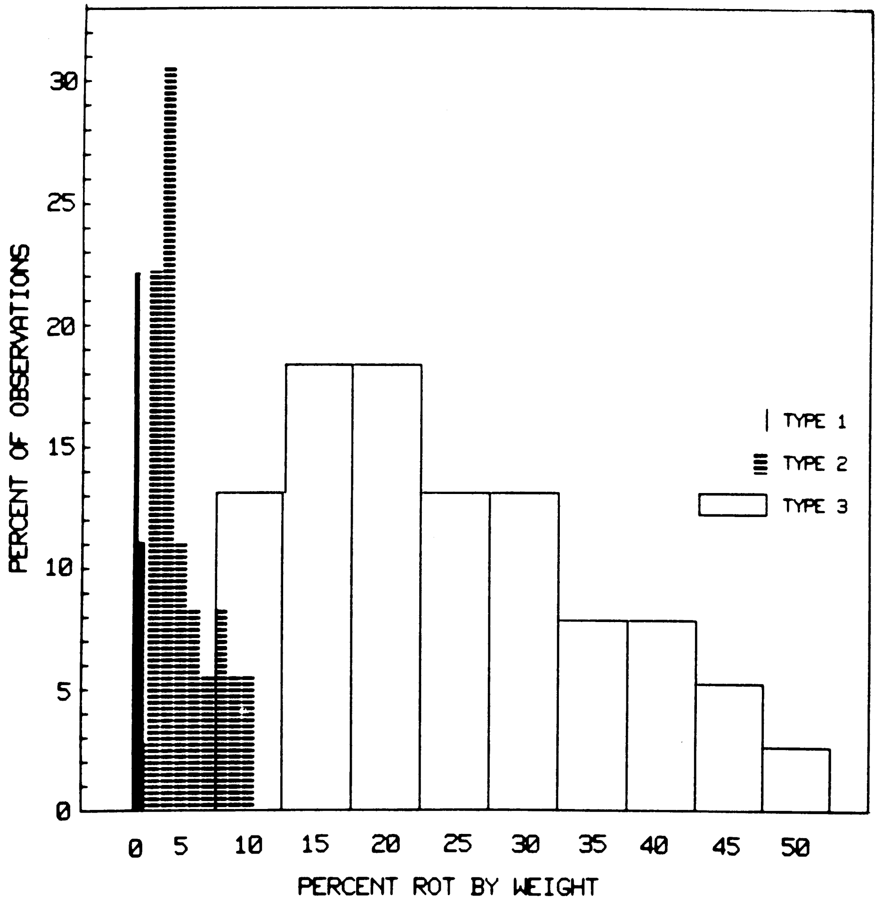

Fig. 1. Frequency distribution of the percentage of Botrytis rot by weight of dissected Chenin blanc grape clusters in three visual rating classes. Type 1 = having a single berry visibly infected, type 2 = having an infection that involved no more than the berries immediately surrounding the original site, and type 3 = a cluster that is more extensively infected than described for type 2.

RESULTS

Results of the full factorial combination trial in 1980 are presented in Table 1. The highest *B. cinerea* incidence at the September 26 rating (any infection, type 1 or higher) occurred in the blocks of the XARM trellis type that were neither sprayed nor hedged. All other treatment combinations had a significantly ($P<0.05$) lower infection incidence. Infection in the combination of TWV trellis without hedging but with the bloom-time spray was significantly lower than in the unsprayed TWV trellis without hedging. Infection levels in the treatment that combined spraying, hedging, and the TWV trellis were significantly lower than all other combinations. Overall, the influences of both spraying and trellis type on the incidence of Botrytis rot on 26 September were significant at $P<0.05$, with the largest F value for the trellis difference.

The general pattern of lower infection in the TWV trellis and sprayed or hedged treatments is also evident in the estimated

Table. 1. Effects of cultural practices on bunch rot of grapes and on viticultural parameters during 1980 in a block of the grape cultivar Chenin blanc near Yountville, CA

Treatment[x]			Final rating 26 September 1980[y]			Commercial harvest 9 October 1980				
S	H	T	Infected (%)	Rot by weight (%)	°Brix	Rot by weight (%)	t/ha	°Brix	Total acid	pH
−	−	X	28.2 a	4.84 a	21.6 a	...	...	...	...	...
−	−	2	23.1 b	3.50 b	20.1 abc	...	...	...	...	...
+	−	X	17.5 c	2.95 bc	21.2 ab	1.67 a	15.7 a	23.1 a	1.05 a	3.72 a
−	+	X	14.9 c	2.09 c	19.5 bc	...	...	...	...	...
−	+	2	14.4 c	1.80 cd	19.4 c	...	...	...	...	...
+	−	2	14.1 c	2.26 c	20.5 abc	0.20 b	18.6 a	22.2 ab	1.03 a	3.71 a
+	+	X	14.0 c	1.90 cd	20.1 abc	1.25 ab	15.5 a	21.8 b	1.00 a	3.70 a
+	+	2	8.9 d	0.92 d	20.6 abc	0.23 b	17.9 a	21.6 b	1.03 a	3.71 a
Factor					**F value and significance for each parameter[z]**					
Spray			10.8*	4.41+	0.79NS	...	...	...	...	...
Hedging			5.3NS	2.65NS	3.68NS	1.2NS	0.04NS	15.1**	0.014NS	0.003NS
Trellis			25.1*	5.60+	0.49NS	21.8***	1.89NS	4.3NS	0.435NS	0.018NS
df			70	70	70	12	12	12	12	12

[x] S = Bloom time spray applied (+) or not applied (−); H = vines hedged (+) or not hedged (−) at midseason; T = trellis type, crossarm (X), or two-wire vertical trellis (2).

[y] Means (of four replicates) followed by the same letter not significantly different ($P<0.05$) by Duncan's multiple range test.

[z] NS = $P\geq0.10$, + = $P<0.10$, * = $P<0.05$, ** = $P<0.01$, and *** = $P<0.001$.

percentage of rot by weight for the 26 September rating. This parameter was estimated based on the visual rating categories using a weighted mean percentage of rot by weight determined for each, the distributions of which are shown in Figure 1. This measure of infection indicated proportionally greater difference in the mean value between treatments; however, it was also more variable so that overall differences based on spray or trellis type were only significant at $P<0.10$. The sugar content (Brix) of both the XARM and TWV hedged and unsprayed treatments were significantly lower than that of the unsprayed unhedged XARM treatment. The overall effect of trellis type, spray, or hedging on sugar content was not significant in the sample taken on 26 September 1980.

The influence of trellis type on the percent rot by weight as determined by the state inspector at the commercial harvest (Table 1, 9 October) was highly significant, being lower in both TWV treatments than in the XARM unhedged treatment. The percentages in that commercial harvest rating are much smaller than in the 26 September visual rating, mostly because of the hot dry intervening period during which infected portions of the clusters became greatly dessicated. At the commercial harvest, no significant differences in yield, total acid, or pH were associated with either trellis type or hedging. The hedging procedure was, however, associated with a significant delay in crop maturity in the commercial harvest measurement (Table 1).

The results of the 1981 trial (Table 2) were comparable with those of 1980 except the difference between trellis types was greater. The rating on 26 August indicated that infection in the TWV trellis treatment was significantly lower than that in the XARM trellis treatment ($P<0.01$) whether expressed as percent infected clusters or as estimated percent rot by weight. An unexpected acceleration of crop maturity led to the extremely early harvest of the block (8 September) during which one replicate was picked before a final rot evaluation could be made. Even so, the TWV trellis was still associated with lower infection incidence ($P<0.05$) and percent rot by weight ($P<0.01$). There were no significant differences in sugar content between fruit samples in the two trellising treatments.

DISCUSSION

Throughout this study and in preliminary studies in 1978 and 1979 (M. A. Sall and M. Land, *unpublished*), the TWV trellis system has been associated with a moderate reduction in *B. cinerea* infection and bunch rot severity. The larger differences observed in the 1981 season may be attributable to the rating of vines that were at least 100 m from the edge of the vineyard and thus more subject to the microclimatic conditions created by the vineyard. Throughout these experiments, the TWV trellis blocks often showed commercially acceptable rot levels, whereas the XARM unsprayed treatment often sustained Botrytis bunch rot near the common commercial limit (commercial grape contracts often set 5% by weight as the maximum acceptable rot level). The XARM trellis was designed to increase radiation interception by the canopy in order to increase fruit-bearing capacity (4). The moderately higher disease levels in the XARM trellis are one disadvantage of that system.

The midseason hedging procedure was associated with slightly lower disease levels, but in some measures, there appeared to be a deleterious influence on sugar accumulation. This delay in maturity, in addition to having viticultural disadvantages, may also account for lower disease levels associated with that treatment because the incidence of infection increases very rapidly with increasing grape maturity. Midseason hedging also stimulates the development of lateral growth, which may have acted as a competitive sink with the fruit for photosynthate. Later hedging may avoid or lessen this effect.

The proportionally larger differences between treatments in terms of percentage rot by weight than in terms of infection incidence raised the question of the influence of the trellis regime on the rate

Table 2. Effects of trellis type on Botrytis bunch rot incidence (percent infected clusters) and severity (percent rot by weight) and on crop maturity (° Brix) during 1981 near Yountville, CA, in the grape cultivar Chenin blanc

	26 August 1981			8 September 1981		
Treatment	Infected (%)	Rot by weight (%)	° Brix	Infected (%)	Rot by weight (%)	° Brix
Crossarm (XARM)	20.7	2.42	21.5	32.3	5.47	23.4
	**[a]	**	NS	*	**	NS
Two-wire (TWV)	8.7	0.75	21.5	22.0	2.85	23.2

[a] * = Significantly different at $P<0.05$, ** = significantly different at $P<0.01$, and NS = not significantly different, two-way analysis of variance.

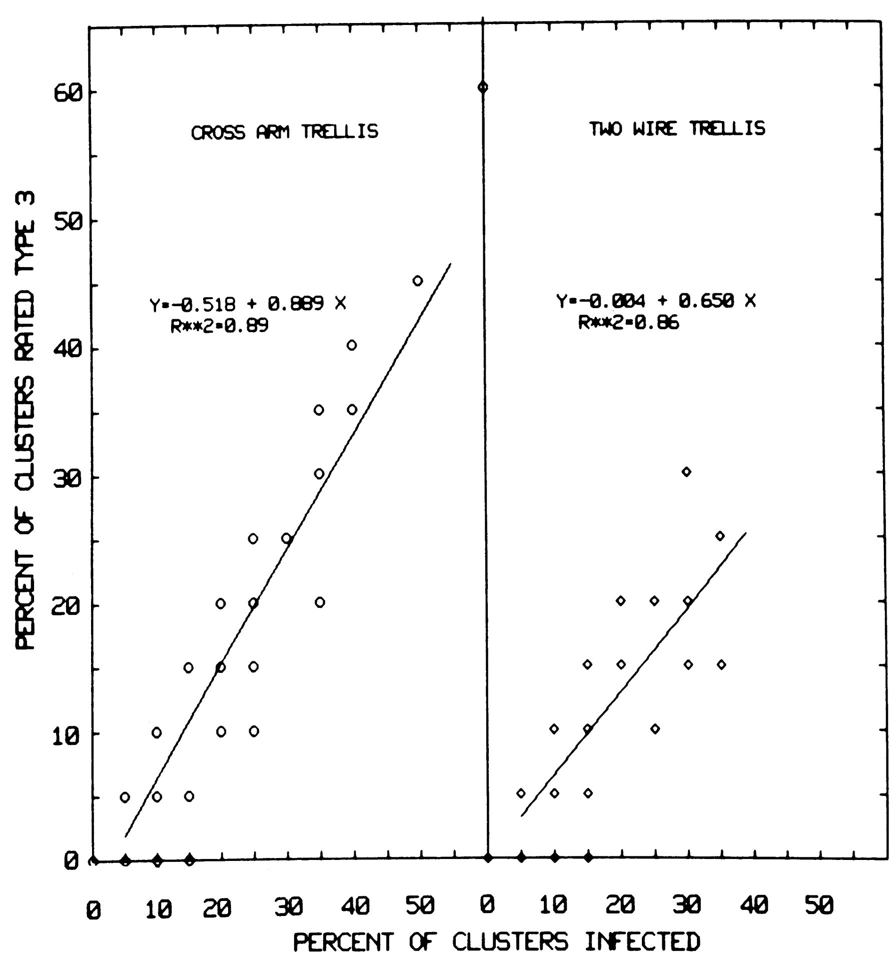

Fig. 2. Relationship of the percentage of clusters infected by *Botrytis cinerea* to the percentage of clusters in the most severe rating class based on visual inspections made on 26 August, 3 September, and 8 September 1981 in two trellis types.

of spread of infections through individual clusters. This is an aspect of disease progress that could also be influenced by microclimate through the conditions for mycelial extension between berries and the rate at which infected berries shrivel. An indication of the speed with which infections progress from early stages (type 1 or 2) to severe infections can be gained by observing the relationship between the total number of infected clusters and the number in the most severe category (Fig. 2). This relationship is approximately linear and the slopes of the regression lines for the relationship in the two trellis types differ significantly ($P<0.01$) so that proportionally fewer of the clusters are in the most severe category in the TWV regime than in the XARM regime at any given overall infection level. Therefore, it appears that infections occurring in the TWV trellis tend to take longer to progress to the type 3 rating category.

In conclusion, it appears that cultural practices, particularly trellis type, can influence the development of *B. cinerea* on grapes under the marginal moisture conditions for infection that occur in parts of California. In unirrigated coastal vineyards planted to highly susceptible cultivars and showing vigorous canopy development, the results of this study indicate that crossarm trellising should be avoided. In less vigorous cultivars or vineyards the influence of trellis type may be less important. The evaluation of additional cultural options is desirable and would be facilitated by an understanding of any microclimate mechanisms involved in the disease reductions observed in this study.

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