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Effect of floral debris removal from fruit clusters on botrytis bunch rot of Chardonnay grapes

by

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Summary: The relationship between senescent floral debris retained in fruit clusters and the incidence and severity of botrytis bunch rot was examined in Chardonnay grapevines over three seasons. Floral debris was removed from clusters at either early or late fruit set using compressed air or a back-pack leaf blower. Additional treatments were included to determine if a commercial sticker spray adjuvant (Nu-Film 17) increased debris retention in clusters. Physical removal of floral debris generally reduced botrytis bunch rot; however, reductions in botrytis bunch rot were only significant in some vineyards. The sticker spray adjuvant had no effect on retention of debris or on botrytis bunch rot. The incidence and severity of botrytis bunch rot were not affected by timing of debris removal, but late removal by compressed air, when berries were as much as 8 mm in diameter, did cause berry bruising. The data demonstrate that senescent floral debris and aborted berries can contribute to increased botrytis bunch rot, and that practical measures to reduce debris retention may aid disease control.

Key words: Botrytis cinerea, botrytis bunch rot, cluster floral debris, Vitis vinifera.

Introduction

Botrytis bunch rot, caused by the fungus *Botrytis cinerea*, Pers.: Fr., causes significant losses in grape yield and wine quality throughout the world. The disease can be particularly destructive in humid climates when botrytis-infected fruit is invaded by opportunistic, secondary pathogens (PEARSON and GOHEEN 1988), including those that cause sour rot (BISIACH *et al.* 1986).

Susceptibility to botrytis bunch rot is determined by cultivar, environment, and cultural practices. Grape cultivars rated as moderately to highly susceptible include Chardonnay, Riesling, Seyval, and Sauvignon blanc (FLAHERTY *et al.* 1982; NORTHOVER 1987; WOLF and POLING 1995). Cultivar susceptibility is influenced by cluster compactness (VAIL and MAROIS 1991), cuticle and epicuticular wax thickness (MAROIS *et al.* 1986; ROSENQUIST and MORRISON 1989; PERCIVAL *et al.* 1993; ELAD and EVENSEN 1995), and presence of phytoalexins (LANGCAKE and MCCARTHY 1979; STEIN and BLAICH 1985) or other fungal inhibitors (HILL *et al.* 1981). Cultural practices that increase canopy fruit zone ventilation or light penetration generally reduce botrytis bunch rot incidence (SAVAGE and SALL 1984; GUBLER *et al.* 1987; ENGLISH *et al.* 1989; ZOECKLEIN *et al.* 1992).

Botrytis bunch rot symptoms often become evident after fruit begins to ripen (veraison), especially following cool, wet weather (FLAHERTY *et al.* 1982; PEARSON and GOHEEN 1988). Symptoms include an initial discoloration of berries, followed by signs of sporulating hyphae (PEARSON and GOHEEN 1988). Botrytis may also cause early-season disease of fruit and foliage if environmental conditions are favorable. Infections of flowers and berries may destroy immature fruit (MCCLELLAN and HEWITT 1973; NAIR and PARKER 1985; JERMINI *et al.* 1986; PEZET and PONT 1986). Histologic studies, using radiolabelled conidia, have also suggested that flower infections by *B. cinerea* may cause late-season botrytis bunch rot following a period of fungal latency (PEZET and PONT 1986). Antifungal phytoalexins, tannins, organic acids, and phenolic compounds, some of which decrease with fruit maturation, may explain why *B. cinerea* can remain latent and then resume growth later in the season (HILL *et al.* 1981; PEARSON and GOHEEN 1988).

In addition to, or contrasting with, fungal latency, colonized senescent floral tissues and aborted berries can serve as inoculum for late-season infections of sound berries (KAMOEN *et al.* 1985; JERMINI *et al.* 1986; PEZET and PONT 1986). Furthermore, chemical spray adjuvants that are used to improve pesticide performance might increase the retention of floral debris in clusters. Certain adjuvants may also increase the susceptibility of berries to infection through modification or dissolution of the berry epicuticular wax (MAROIS *et al.* 1987).

Objectives of these studies were to determine if retention of senescent floral debris in Chardonnay fruit clusters would increase botrytis bunch rot incidence, whether a commercial sticker spray adjuvant would increase debris retention, and to explore practical means of reducing debris retention.

Materials and methods

Experiments were conducted in 1991, 1993, and 1994 in 5 different Chardonnay vineyards in central and north-

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ern Virginia (38–39° N latitude). All of the vineyards had a history of botrytis bunch rot, with incidence varying from year to year. A repeat of the 1991 study, started in 1992, was aborted after fruit set due to a damaging hail storm. All tests were conducted in commercial vineyards (≥ 6 years old), although training and other cultural practices differed somewhat among vineyards, as noted.

The 1991 experiment was conducted at Ivy Creek Vineyards, near Charlottesville, Virginia, and used vines in north-south oriented rows that were spaced 4.7 m apart. Vine spacing in the row varied from 2.3 to 4.7 m due to a combination of winter injury and intentional vine removal to increase cordon length and shoot number on retained vines. Vines were trained to a "U" shaped, divided canopy training system (CARBONNEAU and HUGLIN 1982) which consisted of cordons 1 m above ground, horizontally separated by 80 cm. The cordons were spur-pruned and shoots were vertically trained upright with the aid of multiple catch wires and manual shoot positioning. Shoots were thinned to 15 shoots per m of canopy before bloom, and shoot hedging or topping was performed as needed to maintain ca. 17 main leaves per shoot.

Treatments used in the 1991 experiment consisted of 3 main-effect variables: (i) use of a sticker spray adjuvant (Nu-Film 17, Miller Chemical and Fertilizer, Inc., Hanover, PA; a.i.= 96% di-1-p-dimethene), applied at either 0, 0.63, or 1.26 ml · l^{-1}; (ii) removal (*vs.* no removal) of floral debris after bloom with compressed air; (iii) bagging (*vs.* no bagging) of flower cluster pre-bloom with white paper bags (only for those clusters from which debris was not removed). Combinations of these variables resulted in 9 treatments, which were randomly assigned to individual clusters on the east canopy of vines. All clusters used in the experiment were basal clusters, selected before bloom, on shoots of uniform appearance and moderate internode length and diameter. The treatments were replicated 20 times in a randomized complete-block experimental design where each vine contained the 9 differently treated clusters.

The Nu-Film 17 was applied at mid-bloom (50% cap fall) with a hand-held sprayer to the point of drip, using distilled water as the control. Treatments with a paper bag were included to isolate clusters from routine pest management sprays applied to the vineyard. The bags were placed on clusters prior to bloom, and were removed one month later, well after fruit set. Floral debris removal was achieved by using a narrow stream of compressed air (ca. 830 kPa) to dislodge retained calyptras and other floral debris from fruit clusters at fruit set. The compressed air was directed at the cluster through a restricting nozzle (ca. 3 mm diameter) and care was taken not to damage developing berries or to affect non-target clusters. Berry development varied from cluster to cluster with diameters ranging from 5 to 7 mm at the time of debris removal.

Starting one month after treatment application, clusters were rated on 3 occasions for relative amount of retained floral debris, aborted berries and number of berries showing signs of *B. cinerea*. Debris retention was visually estimated using a scale of 0 to 5, where 0 indicated no debris and 5 represented the greatest retention observed. Debris consisted of aborted berries and senescent flower parts which included calyptras, anthers, and stamens. Debris was either adherent to individual berries or was trapped *en masse* within the cluster. Clusters were harvested on 8 August for the fourth and final rating, at which time the number of berries per cluster and number of berries affected by *B. cinerea* were counted.

Daily rainfall data were recorded at the vineyard. The pesticide spray program used at Ivy Creek in 1991 was typical of that recommended for the region (PFEIFFER *et al.* 1990). Fungicides and number of applications were: mancozeb (9x), wettable sulfur (7x), myclobutanil (7x), basic copper sulfate (2x), captan (1x), benomyl (once, at full bloom), and iprodione (2x, when berries were pea-sized, and 3 weeks before harvest). In addition, carbaryl insecticide was applied once during midseason for grape berry moth (*Endopiza viteana* Clemens) control.

The 1993 experiment was conducted in two vineyards: Oakencroft, near Charlottesville and Blue Ridge Chase, near Leesburg, in northern Virginia. The primary 1993 experiment included 4 treatments: the first consisted of application of sticker spray adjuvant (Nu-Film 17) at 1.26 mg · l^{-1}, at 40–50 % bloom, with a repeat application made at the same rate at 50–75 % bloom; a second treatment involved removal of cluster floral debris with compressed air at early fruit set (berries 1-2 mm in diameter); a third treatment consisted of cluster floral debris removal at late fruit set (berries up to 8 mm in diameter). The fourth treatment consisted of no cluster manipulation.

As in 1991, the 1993 experimental design consisted of a randomized complete-block arrangement, where individual clusters were the experimental units. Replicates, which contained all 4 treatments, were individual vines. A total of 40 vines or replicates were used. Vines at Oakencroft were trained to a quadrilateral cordon, divided canopy training system, similar to that used at Ivy Creek in 1991. Row x vine spacing was 3.7 m x 1.8 m. Treatments were only applied to clusters on the east canopy of the north/south oriented rows. Vines at Blue Ridge Chase were in north/south oriented rows, trained to a bilateral cordon training system, spur-pruned and were subjected to vertical, upright shoot positioning. Row and vine spacing were 2.8 m and 1.5 m, respectively.

Fungicides used and the number of applications at Oakencroft Vineyard were: mancozeb (6x), wettable sulfur (6x), captan (3x), myclobutanil (4x), ferbam (1x), and tribasic copper sulfate (2x). Three applications of carbaryl insecticide were also made at Oakencroft Vineyard. Fungicides used at Blue Ridge Chase Vineyard were: mancozeb (5x), wettable sulfur (6x), captan (3x), myclobutanil (4x) and triadimefon (3x).

All treatment clusters were rated for floral debris retention after the later debris removal treatment was applied (17 June at Oakencroft and 24 June at Blue Ridge Chase). The rating was performed by two independent observers as in 1991. In addition to that rating, the weight of debris retained by each cluster was determined at harvest by removing berries and collecting the debris dislodged from berries and rachises.

Clusters were evaluated for severity and incidence of botrytis bunch rot 2–4 weeks after the application of the late debris removal treatment, and immediately prior to commercial harvest in both vineyards. All berries on each harvested cluster were removed, counted, and classified as apparently healthy (sound) or rot-affected. Rot severity at harvest was expressed as the percentage of berries that showed symptoms of rot, regardless of rot etiology. Due to uncertainties about the cause of some of the rot in berries that lacked signs of *B. cinerea*, the severity rating at harvest was based on non-specific rot symptoms. Botrytis bunch rot incidence, specifically, was expressed as the percentage of clusters (out of 40) which had any berries with sporulating *B. cinerea*.

In addition to the individual cluster treatments, a second experiment was conducted at both vineyards in 1993 to evaluate the use of a motorized, back-pack leaf blower to dislodge cluster debris. The back-pack leaf blower forced air through an 8 cm diameter nozzle, resulting in a wind velocity in excess of 50 m · s^{-1} measured 30 cm from the nozzle. The leaf blower was used on 5 randomly selected 3-vine replicates, with an equal number of non-manipulated control plots. The leaf blower was used at the late fruit set stage identified in the cluster manipulation experiment. The operator walked slowly along the treatment plots and directed the discharge of air directly at the fruit zone, ca. 10 cm from fruit clusters. The treatment took 3 min to do 15 vines. Ten clusters per plot were immediately and independently rated for extent of debris retention by two individuals. Rating was performed as previons by described. An analysis of variance for debris retention rating indicated that the two raters assigned somewhat different average ratings; however, there was no interaction between ratings and treatments. Therefore the two ratings were averaged to quantify the effect of leaf blower treatment on debris retention.

The leaf blower treatment plots were rated for botrytis bunch rot incidence and severity about one month after treatment and at commercial harvest. Botrytis bunch rot incidence (percentage of clusters with botrytis signs) was assessed by examining each cluster. Bunch rot severity (number of rotten berries per cluster) was judged in mid-July, about one month after treatment, and again when clusters were harvested, just before commercial harvest in each vineyard. The earlier rating was done by examining all clusters on the vine and assigning each a rating of 0 to 3, where 0 indicated no apparent signs of botrytis, 3 represented about 10 affected berries per cluster, and 1 and 2 corresponded to intermediate numbers of botrytis-affected berries. The harvest rating was based on the averaged scores of two independent observations of harvested clusters, and used a 0 to 100 percent rating scale.

The 1994 experiment repeated the leaf blower treatments evaluated in 1993, and involved two vineyards, Blue Run and Afton Mountain, both located within

Table 1

Effect of spray adjuvant application, cluster floral debris removal, and cluster bagging on the retention of cluster floral debris and on botrytis bunch rot severity of Chardonnay in 1991

	Floral debris[a]		Botrytis severity[b]		
	24 June	3 July	24 June	3 July	8 August
Adjuvant (mg·l^{-1})					
0.00	2.1	1.9	0.3	1.1	2.6
0.63	2.3	1.9	0.5	0.9	2.6
1.26	2.5	2.3	0.5	1.2	2.9
Floral debris					
Removed	0.2	0.1	0.0	0.1	1.1
Not removed	3.1	2.4	0.4	0.7	2.6
Cluster bagging					
Bagged	3.7	3.6	0.9	2.3	4.4
Not bagged	3.1	2.4	0.4	0.7	2.6
Analysis of variance for model effects[c]					
Adjuvant (ADJ)	ns	*	ns	ns	ns
Debris removal (DEB)	***	***	***	***	*
Bagging (BAG)	**	***	*	***	*
Interaction					
ADJ x DEB	ns	ns	ns	ns	ns
ADJ x BAG	ns	ns	ns	ns	ns

[a] Average amount of floral debris visually estimated on a 0–5 scale (0: no debris, 5: greatest amount).

[b] Average percent of berries per cluster with signs of botrytis.

[c] NS, *, **, *** Nonsignificant or significant at $P \le 0.05$, 0.01 and 0.001, respectively. Interactions between debris removal (DEB) and cluster bagging (BAG), and the three-way interaction of those effects with adjuvant application (ADJ), could not be tested due to treatment design.

Table 3

Effect of spreader-sticker spray adjuvant application and two timings of cluster floral debris removal on the severity and incidence of botrytis and other bunch rots of Chardonnay at Oakencroft (OAK) and Blue Ridge Chase (BRC) vineyards during the 1993 growing season

	Early botrytis severity[b]		Harvest[a] Healthy berries/cluster		Rot severity (%)[c]		Botrytis incidence (%)[d]	
Treatment	OAK	BRC	OAK	BRC	OAK	BRC	OAK	BRC
Control	0.75 A[e]	2.23 A	100.2	106.2	5.51	8.28	48	76 A
Adjuvant	0.58 A	2.18 A	90.3	109.5	7.82	6.34	33	69 AB
Early debris removal	0.33 AB	0.53 B	102.0	113.6	5.06	4.49	36	53 B
Late debris removal	0.13 B	0.33 b	99.2	103.9	5.42	5.98	38	48 B

a Harvest dates were 6 September at Oakencroft and 10 September at Blue Ridge Chase.
b Severity rated as berries per cluster showing any sign of botrytis on 8 (Blue Ridge Chase) or 13 July (Oakencroft).
c Severity rated on harvested clusters as the percent of berries per cluster showing symptoms or signs of sour rot or botrytis bunch rot.
d Incidence rated as percent of harvested clusters bearing any sign of botrytis bunch rot.
e Mean separation within columns by Duncan's multiple range test. Means followed by the same letter or not followed by letters are not different at P = 0.05.

Table 4

Effect of back-pack leaf blower removal of floral debris from Chardonnay fruit clusters on cluster floral debris retention, incidence and severity of botrytis bunch rot at Oakencroft (OAK) and Blue Ridge Chase (BRC) vineyards in 1993

	Debris retention[b]		Botrytis incidence (%)[a] 13-14 July		7-10 Sept.		Botrytis severity 13-14 July[c]		7-10 Sept.[d]	
Treatment	OAK	BRC	OAK	BRC	OAK	BRC	OAK	BRC	OAK	BRC
Debris removed	1.1	0.6	19	13	45	27	0.2	0.1	4.2	1.6
No debris removed	3.3	3.3	22	36	52	67	0.3	0.5	5.2	4.0
Significance[e]	***	***	ns	***	ns	***	ns	***	ns	***

a Incidence of botrytis bunch rot (%): all clusters showing any sign of botrytis.
b Visual rating of cluster debris retention using 0-5 scale (0 = no debris, 5 = greatest observed retention). Rating done on 17 and 24 June at Oakencroft and Blue Ridge Chase, respectively.
c Botrytis bunch rot severity rated on a 0 - 3 scale: 0 = no evidence of botrytis bunch rot, 1 = one or two individually affected berries, 2 = ca. 5 affected berries, and 3 = ca. 10 affected berries per cluster.
d Severity of botrytis bunch rot (%): estimation of affected clusters by two observers after fruit harvest.
e Significance of Student's *t* test: *** represents significant difference at P = 0.001; ns = not significant.

removal was associated with significant reductions in botrytis bunch rot incidence and severity at Blue Ridge Chase, but not Oakencroft Vineyard.

1994 Experiment: The back-pack leaf blower treatments reduced botrytis bunch rot severity and incidence at Blue Run Vineyard in 1994 (Tab. 5). Leaf blower effects on botrytis bunch rot at Afton Mountain were not significant. Floral debris retention was not evaluated at either vineyard, and both vineyards experienced very low botrytis bunch rot incidence in 1994.

Discussion

The physical removal of senescent floral debris from clusters generally reduced botrytis bunch rot incidence and severity, but statistically significant reductions were in-

Table 5

Effect of leaf blower removal of floral debris from Chardonnay clusters on botrytis bunch rot incidence and severity at two vineyards on 18 August 1994

Vineyard	Floral debris removal	Botrytis bunch rot severity[a]	Botrytis bunch rot incidence (%)[b]
Afton Mt.	Removed	0.50	13
	Not removed	0.71	20
	Significance[c]	ns	ns
Blue Run	Removed	0.11	5
	Not removed	0.29	13
	Significance[c]	**	**

a Mean number of botrytis-affected berries per cluster.
b Percentage of clusters showing any signs of botrytis.
c Significance of *t* test of treatment means: ns = non-significant ** = significant at P = 0.01.

consistent. That variable response is not entirely surprising given that other factors are known to affect botrytis development. NORTHOVER (1987), for example, reported that floral debris accounted for only a portion of the *B. cinerea* infection sites of Aurore, Seyval and Chardonnay clusters in a study in Ontario, Canada. Split berries and grape berry moth (*E. viteana* Clemens) damage contributed additional means of ingress. One of the European grape berry moth species (*Lobesia botrana*, Den. & Schiff.) serves as a vector for *B. cinerea* as well as causing physical berry damage (FERMAUD and GIBOULOT 1992). Additionally, we occasionally observed symptoms of other fruit rots after veraison, including ripe rot (*Colletotrichum gloeosporioides* Penz.) and non-specific sour bunch rot, none of which would be expected to be influenced by presence or absence of senescent floral debris.

Our results were similar to those of JERMINI *et al.* (1986), who found that debris removal from Merlot grape clusters reduced botrytis bunch rot by about 30 %. It also justifies the proposal made by SAVAGE and SALL (1981) that debris provides an initial nutrient source for botrytis and increases available inoculum for subsequent infections. The relative importance of infection by direct mycelial growth from colonized debris may have implications in management of fungicide resistance. HOKSBERGEN and BEEVER (1984) showed that, on bean leaves, *B. cinerea* strains with low-level dicarboximide resistance could still be controlled by dicarboximide applications when the inoculum was in the form of conidia, but not when the inoculum was in the form of a mycelial plug.

High air speeds were necessary to dislodge all visible debris from grape clusters. Air speeds in the cluster zone normally achieved by air blast sprayers would not be expected to thoroughly remove debris. We estimated that debris removal with a back-pack blower as used in our treatments would require 10 h · ha^{-1}. That labor, and the inconsistent effects on bunch rot, would not justify making a general recommendation for using the practice. Commercial grapevine canopy leaf removers, operating with high pressure air, may achieve some debris removal in addition to their primary function.

The spray adjuvant Nu-Film 17 had no significant effect on floral cluster debris retention or on botrytis bunch rot incidence of Chardonnay. While limited in scope, the lack of direct effects of this adjuvant on botrytis bunch rot incidence is consistent with the findings of MAROIS *et al.* (1987) who evaluated Nu-Film 17 along with a number of other spray adjuvants under laboratory conditions.

Paper bagging of clusters in the 1991 experiment was intended to exclude effects of other vineyard pesticides during the bloom and fruit set period. The increased botrytis bunch rot observed with bagged clusters might have been due to differences in pesticide application but was more likely due to the effects of bagging on the cluster microclimate (MCCLELLAN and HEWITT 1973). Bagging would be expected to reduce sunlight (especially UV radiation) and windspeed and increase humidity, conditions known to favor botrytis sporulation, infection, and disease development (COLEY-SMITH *et al.* 1980).

Conclusions

Senescent floral debris retained in fruit clusters was colonized by *B. cinerea* and appeared, in some cases, to be associated with early and late-season botrytis bunch rot. Removal of debris reduced botrytis bunch rot, but the reductions were not always significant. A mechanized means of dislodging cluster floral debris might make the practice more attractive. Debris removal might be of benefit in a comprehensive program of bunch rot management if combined with other measures, such as selective leaf removal and the use of *B. cinerea* specific fungicides. A commonly used spray adjuvant had no effect on the amount of debris retained in fruit clusters or on botrytis bunch rot.

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Literature cited

BARNETT, H.; HUNTER, B.; 1972: Illustrated Genera of Imperfect Fungi. 3rd ed. Burgess Publ. Co., Minneapolis, MN.

BISIACH, M.; MINERVINI, G.; ZERBETTO, F.; 1986: Possible integrated control of grapevine sour rot. Vitis **25**, 118-128.

CARBONNEAU, A.; HUGLIN, P.; 1982: Adaptation of training systems to French regions. In: A. D. Webb (Ed.): Univ. Calif., Davis Grape and Wine Centennial Symposium Proceedings, 376-385.

COLEY-SMITH, J. R.; VERHOEFF, K.; JARVIS, W. R.; 1980: The Biology of Botrytis. Academic Press Inc., New York, NY.

ELAD, Y.; EVENSEN, K.; 1995: Physiological aspects of resistance to *Botrytis cinerea*. Phytopathology **85**, 637-643.

ENGLISH, J. T.; THOMAS, C. S.; MAROIS, J. J.; GUBLER, W. D.; 1989: Microclimates of grapevine canopies associated with leaf removal and control of botrytis bunch rot. Phytopathology **79**, 395-401.

FERMAUD, M.; GIBOULOT, A.; 1992: Influence of *Lobesia botrana* larvae on field severity of botrytis rot of grape berries. Plant Dis. **76**, 404-409.

FLAHERTY, D. L.; JENSEN, F. L.; KASIMATIS, A. M.; KIDO, H.; MOLLER, W. J.; 1982: Grape Pest Management. Division of Agricultural Sciences, University of California, Berkeley, California. Publication No.4105.

GUBLER, W. D.; MAROIS, J. J.; BLEDSOE, A. M.; BETTIGA, L. J.; 1987: Control of botrytis bunch rot of grape with canopy management. Plant Dis. **71**, 599-601.

HILL, G.; STELLWAAG-KITTLER, F.; HUTH, G.; SCHLÖSSER, E.; 1981: Resistance of grapes in different development stages to *Botrytis cinerea*. Phytopathol. Z. **102**, 328-338.

Hoksbergen, K. A.; Beever, R. E.; 1984: Control of low-level dicarboximide-resistant strains of *Botrytis cinerea* by dicarboximide fungicides. New Zealand J. Agricult. Res. **27**, 107-111.

JERMINI, M.; JELMINI, G.; GESSLER, C.; 1986: La lutte contre le *Botrytis cinerea* du Merlot au Tessin. Le rôle des infections latentes. Rev. Suisse Viticult. Arboricult. Horticult. **18**, 161-166.

KAMOEN, O.; JAMART, G.; VAN VAERENBERG, J.; GOUWY, P.; 1985: *Botrytis cinerea* infections in petals and green leaves. Med. Fac. Landbouw Rijksuniv. Gent. **50**, 1053-1059.

LANGCAKE, P.; MCCARTHY, W.V.; 1979: The relationship of resveratrol production to infection of grapevine leaves by *Botrytis cinerea*. Vitis **18**, 244-253.

MAROIS, J. J.; BLEDSOE, A. M.; BOSTOCK, R. M.; GUBLER, W. D.; 1987: Effects of spray adjuvants on development of *Botrytis cinerea* on *Vitis vinifera* berries. Phytopathology **77**, 1148-1152.

- -; NELSON, J. K.; MORRISON, J. C.; LILE, L. S.; BLEDSOE, A. M.; 1986: The influence of berry contact within grape clusters on the development of *Botrytis cinerea* and epicuticular wax. Amer. J. Enol. Viticult. **37**, 293-296.

MARTINEZ, N.; WOLF, T. K.; BAUDOIN, A.; WEAVER, M. J.; 1992: Relation between spreader-sticker application, blossom cap retention, berry scarring, and botrytis bunch rot in 'Chardonnay' grapes. Phytopathology **82**, 1083 (Abstract).

MCCLELLAN, W. D.; HEWITT, W. B.; 1973: Early botrytis rot of grapes: Time of infection and latency of *Botrytis cinerea* Pers. in *Vitis vinifera* L. Phytopathology **63**, 1151-1157.

NAIR, N. G.; PARKER, F. E.; 1985: Midseason bunch rot of grapes: an unusual disease phenomenon in the Hunter Valley, Australia. Plant Pathol. **34**, 302-305.

NORTHOVER, J.; 1987: Infection sites and fungicidal prevention of *Botrytis cinerea* bunch rot of grapes in Ontario. Can. J. Plant Pathol. **9**, 129-136.

PEARSON, R. C.; GOHEEN, A. C.; 1988: Compendium of Grape Diseases. The American Phytopathological Society Press, St. Paul, MN.

PERCIVAL, D. C., SULLIVAN, J. A.; FISHER, K. H.; 1993: Effect of cluster exposure, berry contact and cultivar on cuticular membrane formation and occurrence of bunch rot (*Botrytis cinerea* Pers.: Fr.) with 3 *Vitis vinifera* L. cultivars. Vitis **32**, 87-97.

PEZET, R.; PONT, V.; 1986: Infection florale et latence de Botrytis cinerea dans les grappes de *Vitis vinifera* (var. Gamay). Rev. Suisse Viticult. Arboricult. Horticult. **18**, 317-322.

PFEIFFER, D. G.; WEAVER, M. J.; DERR, J. F.; BAUDOIN, A.; 1990: 1990-1991 Pest Management Guide for Commercial Grape Production. Virginia Cooperative Extension Publication 456-006.

ROSENQUIST, J. K.; MORRISON, J. C.; 1989: Some factors affecting cuticle and wax accumulation on grape berries. Amer. J. Enol. Viticult. **40**, 241-244.

SAVAGE, S. D.; SALL, M. A.; 1984: Botrytis bunch rot of grapes: Influence of trellis type and canopy microclimate. Phytopathology **74**, 65-70.

STEIN, U.; BLAICH, R.; 1985: Untersuchungen über Stilbenproduktion und Botrytisanfälligkeit bei *Vitis*-Arten. Vitis **24**, 75-87.

VAIL, M. E.; MAROIS, J. J.; 1991: Grape cluster architecture and the susceptibility of berries to *Botrytis cinerea*. Phytopathology **81**, 188-191.

WOLF, T. K.; POLING, E. B.; 1995: The Mid-Atlantic Winegrape Growers Guide. North Carolina Cooperative Extension Service Publ. No. AG-535.

ZOECKLEIN, B. W.; WOLF T. K.; DUNCAN, N. W.; JUDGE, J. M.; COOK, M. K.; 1992: Effects of fruit zone leaf removal on yield, fruit composition, and fruit rot incidence of Chardonnay and White Riesling (*Vitis vinifera* L.) grapes. Amer. J. Enol. Viticult. **43**, 139-148.

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30 km of Charlottesville, Virginia. Vines at both vineyards were in north/south oriented rows, unilaterally (Blue Run) or bilaterally (Afton Mountain) cordon-trained, short cane- (Blue Run) or spur-pruned (Afton Mountain), with little or no shoot positioning being done at either vineyard. Row x vine spacing was 3.0 m x 1.8 m at Afton Mountain Vineyard, and 3.7 m x 1.8 m at Blue Run Vineyard. At Afton Mountain Vineyard, 10 three-vine plots were treated with the leaf blower when berries were 4-7 mm in diameter. The leaf blower was used on both sides of the vine canopy in a fashion similar to that described for the 1993 experiment. Ten additional plots were used as non-treated controls, in a randomized complete-block design with adjacent pairs of treated and non-treated plots serving as blocks. At Blue Run Vineyard, 16 two-vine plots were similarly treated when berry size averaged 5–7 mm, with 16 additional plots used as controls, again in a randomized complete block arrangement. Debris retained in clusters was not rated in 1994. Pesticide spray programs at Afton Mountain and Blue Run Vineyards were very similar to those previously described, but did include one iprodione spray at Afton Mountain Vineyard. Both the incidence and severity of botrytis bunch rot were evaluated in both vineyards on 18 August 1994, several weeks before commercial harvest. Those ratings were based on an average of 37 clusters per treatment plot at Afton Mountain and 28 clusters per panel at Blue Run Vineyard.

Results

1991 Experiment: Application of Nu-Film 17 had no effect on floral debris retention or botrytis bunch rot incidence in 1991 (Tab. 1). The debris removal treatments, as expected, significantly reduced floral debris retention, as well as botrytis bunch rot severity at the 3 July and 8 August ratings. Bagging of clusters increased debris retention as well as botrytis bunch rot severity. Interactions among the three main factors, where they could be evaluated, were not significant.

Total number of berries per cluster averaged 135. Bagged clusters had significantly fewer berries (115 per cluster) than did nonbagged clusters (145 per cluster); other berry number differences between treatments were not significant (data not shown).

Signs of *B. cinerea* were observed soon after anthesis on senescent flower parts, especially adherent calyptra, as well as on aborted berries (MARTINEZ *et al.* 1992). Identification of the fungus as *B. cinerea* was confirmed by culturing on potato dextrose agar and by microscopic examination of conidiophores (BARNETT and HUNTER 1972). The overall amount of botrytis bunch rot observed in 1991 was relatively low. Monthly rainfall totals (mm) at Ivy Creek Vineyard were 45 (May), 107 (June), 296 (July), and 55 (August). The average monthly rainfall between April and September is between 83 to 115 mm for that site.

1993 Experiment: Application of Nu-Film 17 spray adjuvant did not affect floral debris retention in either vineyard in the 1993 experiment as determined by cluster ratings soon after adjuvant application and by weighing the debris removed from harvested clusters (Tab. 2). Physical debris removal did, by comparison, result in a significant reduction in debris rating, and in the amount of debris removed from clusters at harvest. The later debris removal treatment resulted in less retained debris in June, and slightly (not significant) lower debris weight removed from harvested clusters. The compressed air debris removal caused some berry bruising when done at the later stage (up to 8 mm in diameter). The bruising, observed as a subepidermal discoloration, appeared soon after treatment and did not appear to affect berry development.

Nu-Film 17 application had no effect on the incidence or severity of botrytis bunch rot or other bunch rots at either vineyard in 1993 (Tab. 3). Both early and late debris removal resulted in a reduction of early botrytis bunch rot severity, as well as botrytis bunch rot incidence at harvest at Blue Ridge Chase Vineyard. The later debris removal treatment also reduced early botrytis bunch rot at Oakencroft, but that reduction was not significant full season. Total number of berries per cluster, determined at harvest, was comparable among the four treatments.

Monthly precipitation totals (mm) at Blue Ridge Chase Vineyard in 1993 were 107 (June), 41 (July), and 48 (August). Monthly precipitation totals (mm) at Oakencroft Vineyard that year were 56 (June), 66 (July), and 70 (August).

The back-pack leaf blower treatments reduced floral debris retention at both vineyards in 1993 (Tab. 4). Debris

Table 2

Effect of spray adjuvant application, cluster floral debris removal, and cluster bagging on the retention of cluster floral debris of Chardonnay fruit clusters at Oakencroft and Blue Ridge Chase (BRC) vineyards in 1993

Treatment	Debris rating (0 - 5 scale) Oakencroft 17 June[a]	Debris rating (0 - 5 scale) BRC 24 June[a]	Debris weight (g/cluster) at harvest Oakencroft 6 September[a]	Debris weight (g/cluster) at harvest BRC 10 September[a]
Control	3.55 A	3.66 A	0.16 A	0.25 A
Adjuvant	3.73 A	3.71 A	0.16 A	0.22 A
Early debris removal	1.11 B	1.31 B	0.06 B	0.09 B
Late debris removal	0.05 C	0.26 C	0.03 B	0.04 B

[a] Mean separation within columns by Duncan's multiple range test. Means followed by the same letter are not different at P = 0.05.