Application of Fungicides Against Postharvest *Botrytis cinerea* Bunch Rot of Table Grapes in the Western Cape*

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Fungicide programmes for the control of postharvest *Botrytis* bunch rot on table grapes were evaluated in six trials from 1984/85 to 1991/92 in the Western Cape. The study demonstrated the ineffectiveness of dicarboximide applications during bloom to early pea size in well managed vineyards. Dicarboximides were most effective when applied from bunch closure to ripening. Iprodione/sulphur treatments at véraison and before harvest reduced *Botrytis* bunch rot, but they were ineffective in inhibiting infection during storage. Control was only achieved when grapes were exposed to SO_2 during storage. Although bunch dip treatments reduced infection in the vineyard, this control was not commercially acceptable. Therefore no real advantage was found when bunches were dipped in fungicide at véraison to ensure better coverage. The fact that berries became infected primarily during harvest, package operations and storage, emphasised the necessity for reducing *B. cinerea* inoculum on harvested grapes. It is suggested that the results of this investigation may lay the foundation for incorporating biological control in *Botrytis* bunch rot control.

Postharvest bunch rot, caused by *Botrytis cinerea* Pers.: Fr., is an annual threat to the quality of table grapes worldwide. The disease is chiefly combated by fungicide sprays during the growing season (Bulit & Dubos, 1988) and by postharvest fumigation of bunches with SO_2 (Nelson, 1983). These techniques, however, have become increasingly unacceptable because of the development of fungicide resistant *Botrytis* isolates (Leroux & Clerjeau, 1985; Löcher, Lorenz & Beetz, 1987; Northover, 1988; Beever, Laracy & Pak, 1989), and for human health and environmental considerations (National Academy of Sciences, 1987). Methods for the control of postharvest *Botrytis* bunch rot should, therefore, aim at reduced fungicide usage in future management systems.

In a recent study on colonisation of table grape bunches in the Western Cape (De Kock & Holz, 1991), no clear relation between infection during the early stages of bunch development and postharvest *Botrytis* rot could be found. Postharvest *Botrytis* bunch rot was largely ascribed to infection during storage by inoculum present in bunches at véraison or at later stages. This suggests that in the Western Cape fungicide applications during the early stages of bunch development might be unnecessary. It has been hypothesised, however, that as the berries increase in size, penetration of fungicide into bunches might become increasingly difficult. Floral parts colonised by *B. cinerea* (Gessler & Jermini, 1985; Nair & Parker, 1985; Northover, 1987) could, therefore, remain unexposed after bunch closure and inner bunch surfaces are thus inadequately protected by fungicide. This would necessitate early fungicide applications.

The objective of the present investigation was to evaluate bunch dip treatments as an alternative method of fungicide application in the vineyard and to achieve maximum control of the disease with minimum use of fungicide.

MATERIALS AND METHODS

Vineyards: The studies were conducted in experimental plots selected in commercial *Vitis vinefera* vineyards of cultivars Barlinka and Waltham Cross in the Paarl and Hex River Valley areas. All vines were trained to a slanting trellis and micro-irrigated. Canopy management and bunch preparation were done according to the guidelines of Van der Merwe, Geldenhuys & Botes (1991). A recommended programme for the control of downy and powdery mildew (De Klerk, 1985) was followed by all farmers. Sprays against downy mildew started at 10-15 cm shoot length and were applied every 14 days until pea size. Fungicides used were folpet (Folpan 50% wp, Agrihold), fosetyl-Al/mancozeb (Mikal M 44/26% wp, MayBaker), mancozeb (Dithane M45 80% wp, FBC Holdings) and mancozeb/oxadixyl (Recoil 56/8% wp, Bayer). Applications against powdery mildew started at 2-5 cm shoot length and were applied every 14 days until 3 weeks before harvest. Fungicides used were penconazole (Topaz 10% ec, Ciba-Geigy), pyrifenox (Dorado 48% ec, Maybaker) and triadimenol (Bayfidan 25% ec, Bayer).

Fungicide spray programmes: Unless otherwise stated, fungicide treatments were applied to single-row plots, each consisting of six mature vines. Data rows were separated by untreated buffer rows from the commercial vines. Each treatment was conducted as a completely randomised design with six replicates. Fungicides formulated as emulsifiable or suspension concentrates or wettable powders were applied at 500 g a.i./ha in 1000 ℓ of water/ha to run off with a mistblower (Stihl SR 400) fitted with a nozzle and deflector baffle screen. Dusting powders were applied at 600 ga.i./ha with a powder duster (Hatsuta Am-8 model "Blowmic").

Fungicide timing: To determine the critical phenological stage for protection against infection by *B. cinerea,* procymidone (Sumisclex 25% sc, Agricura) was used during the

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1984/85 and 1986/87 seasons in several programmes on Barlinka vines. These comprised 1-6 applications, each being made at a defined stage of bunch development between full bloom and harvest. In 1984/85, SO_2 generators were enclosed at packing to minimise the effect of late-arriving inoculum. In 1986/87, bunches from each treatment were divided into two groups; one group was packed with SO_2 generators, the other without.

Five-schedule spray with different fungicides: The following fungicides were evaluated against *B. cinerea* in a five-schedule spray programme in the 1988/89 to 1991/92 seasons: benomyl (Benlate 50% wp, Du Pont), CGZA 190 (25% ec, Ciba Geigy), chlorothalonil (Bravo 50% sc, Shell Chemical Division), folpet (Folpet 50% wp, ICI Agrochemicals), iprodione (Rovral 25% sc, Maybaker), iprodione/sulphur (Rovral/sulphur 3/90% dp, Maybaker), mancozeb (Dithane M45 80% wp, FBC Holdings), prochloraz (Sportak 45% ec, FBC Holdings), procymidone (Sumisclex 25% sc, Agricura), procymidone/sulphur (Sumisclex/sulphur 3/90% dp, Agricura), thiram (Pomarsol 75% wp, Bayer), thiram/iprodione (Dirac Express 53,2/7,8% wp, Rhodiagri-Littorale) and vinclozolin (Ronilan 50% sc, BASF). Three sprays were applied during early season and two during late season in 1988/89, whereas from 1989/90 to 1991/92 two sprays were applied during early season and three during late season. Sprays against downy mildew were not applied in these programmes. Bunches from each treatment were divided into two groups and were either exposed or not exposed to SO_2 during storage.

Fungicide dip treatments of inoculated bunches

Experiment 1: The effect of fungicide dip treatments on inoculum administered to bunches at different stages of bunch development was evaluated during the 1987/88 season in the Paarl area. Bunches of the cultivar Barlinka were inoculated on the vines at either full bloom, pea size or véraison. Inoculum was prepared from a lyophilised stock culture, isolated from naturally-infected grapes, as described previously (De Kock & Holz, 1991). Germination of conidia on water agar was examined to verify their viability (≥90%). At each of the developmental stages 54 bunches were sprayed with a suspension containing approximately 2,5 x 10^6 spores/ml, avoiding run off. Inoculated bunches were covered with polyethylene bags containing a little water to maintain a high humidity. The bags, sealed with wire ties, were removed after 24 h. Fungicides evaluated were procymidone, iprodione, prochlorax and folpet. They were applied either as a spray or the bunches were dipped for 5 sec in the fungicide suspension (1000 mg a.i./l). Each treatment was applied to six inoculated bunches. To ensure flower infection and formation of sufficient necrotic flowers, bunches inoculated at full bloom were first treated with fungicide at early pea size. Bunches inoculated at pea size or at véreaison were treated 2 days after inoculation. Follow-up fungicide treatments were applied at véraison and 1 wk before harvest.

At the following periods 20 necrotic flowers were collected from each bunch: from bunches inoculated at full bloom 27 days after inoculation and 18 days after the first fungicide treatment; from bunches inoculated at pea size 1 day after inoculation and 18 days after the first fungicide application. The flowers were incubated on water agar in Petri dishes at 25°C in the dark. The percentage of flowers with sporulating conidiophores of *B. cinerea* was recorded after 14 days' incubation. Harvested bunches were packed without SO_2 generators.

Experiment 2: The ability of dip treatments to protect inner surfaces of bunches against infection by *B. cinerea* was evaluated on grapes treated at véraison and inoculated after that. Barlinka vines in the Paarl area were sprayed during the 1987/1988 season with procymidone (full bloom) and vinclozolin (pea size) to keep bunches free from early-arriving inoculum. At véraison either procymidone, iprodione or prochloraz was applied to 24 bunches either by spraying or as a dip as described before. No fungicide was applied to bunches of the control treatment. All the bunches were inoculated as described previously at intervals of either 1, 7, 14 or 21 days after fungicide application. The bunches were harvested 28 days after fungicide application and packed without SO_2 generators.

Infection periods: Temperature and rainfall for the 1984-1992 growing seasons were recorded at weather stations at Bellevue (Paarl) and De Doorns experimental farms (Hex River Valley). Infection periods during each growing season were determined on the basis of the infection criteria of Sall, Teviotdale & Savage (1981). A rainy period was considered conducive to the natural development of *B. cinerea* if more than 5 mm rain was recorded during 24 h (relative humidity ≥92%; average temperature 15-22°C), or if 1-5 mm rain fell on each of two consecutive days (relative humidity ≥92%; average temperature 15-22°C).

Assessment of *Botrytis* bunch rot: Starting at véraison, bunches in experimental plots were routinely observed for symptoms of *B. cinerea* infection. Unblemished bunches were selected at harvest from the centre vines in each plot and bunches were packed as for export with or without an SO_2 generator (0,3-0,55 g $Na_2S_2O_2$ affixed to a paper sheet [Laszlo *et al.*, 1981; Nelson, 1983]) inside a polyethylene bag in corrugated cartons (Patent no. RSA 75/6116). Postharvest bunch rot was determined after storage at -0,5°C for 21-28 days followed by 14 days at 10°C. In 1985, the percentage bunch rot was assessed according to the evaluation rating described by Unterstenhöfer (1963) for the infection of berries by *Plasmopara viticola* and the percentage rot of each replicate was calculated with the formula of Kremer & Unterstenhöfer (1967). In the following seasons, percentage postharvest rot of each bunch was determined on a mass basis (De Kock & Holz, 1991) and the average rot per treatment calculated.

Statistical analysis: All data were subjected to a standard analysis of variance and significance of differences between treatments was determined by means of a D-value based on the Studentized Q-test (Snedecor & Cochran, 1967).

RESULTS

Fungicide spray programmes

Infection periods and rot development: Infection periods occurred yearly in each vineyard during the principal phenological stages. An exception was the 1986/87 season, when periods conducive to *Botrytis* development were recorded only at late bloom and early véraison in the Barlinka vineyard (Table 1). Despite the more or less evenly distributed occurrence of these periods, bunches from unsprayed and treated plots were symptomless at

harvest and *Botrytis* bunch rot was noticed only after storage. Lesions that developed occurred scattered over the berry surface and were rarely seen on peduncles. There was no evidence of berry infections having arisen from latent infections of the stigma. On Barlinka infection was lightest in 1986/87 and severe during 1988/89, 1989/90 and 1990/91. Postharvest bunch rot on Waltham Cross was less severe than on Barlinka.

Fungicide timing: All the treatments reduced *Botrytis* bunch rot significantly (Table 2). However, differences in rot between the differently scheduled procymidone applications (1984/85) were not significant.

TABLE 1
Infection periods and incidence of postharvest *Botrytis* rot on naturally infected, unsprayed table grapes from 1984 to 1992.

Cultivar/ Season	Infection periods during growth stage[a]									Post-harvest rot (%)
	1	2	3	4	5	6	7	8	9	
Barlinka										
1984/85	–[b]	–	+	+	–	+	–	+	+	–[c]
1986/87	–	–	+	–	–	–	+	–	–	67,4
1988/89	+	–	–	–	+	+	+	+	+	81,9
1989/90	–	+	+	–	–	+	+	–	+	83,7
1990/91	–	+	–	–	+	+	–	–	+	86,0
1991/92	–	+	–	–	+	–	–	+	+	73,8
Waltham Cross										
1988/89	+	–	–	–	+	+	–	+	–	56,7
1989/90	–	–	+	–	–	+	+	+	+	65,7[d]
1990/91	+	+	–	+	–	+	–	–	+	32,2
1991/92	+	–	+	–	+	–	–	+	+	39,9

[a] Growth stage 1 = early bloom, 2 = full bloom, 3 = late bloom, 4 = early pea size, 5 = pea size, 6 = late pea size, 7 = early véraison, 8 = véraison, 9 = late véraison.
[b] + = Favourable infection period, – = unfavourable (see text).
[c] Grapes were treated with SO_2 during storage.
[d] High incidence was due to a 24 h delay in cooling after packing. Barlinka grapes are usually harvested 2 wk later than Waltham Cross.

Results in 1986/87 confirmed that early season sprays are not essential for the control of postharvest bunch rot (Table 2). A spray programme with four procymidone applications (full bloom, pea size, véraison, 1 wk before harvest) reduced infection to the same extent as a programme with only two late-season sprays (véraison, 1 wk before harvest).

Five-schedule spray with different fungicides: In 1988/89, almost complete control of Botrytis bunch rot was achieved with the different fungicide applications in Waltham Cross grapes exposed to SO_2 (Table 3). On most Barlinka grapes exposed to SO_2 less than 1% postharvest rot occurred on bunches from the various fungicide programmes. An exception was the pre-véraison iprodione application. Least postharvest bunch rot of SO_2-unexposed grapes occurred on Barlinka bunches from vines treated with iprodione/sulphur during late season and on Waltham Cross bunches where thiram was applied during the early season.

On Barlinka stored without SO_2 during 1989/90 (Table 4), only the programme which included two iprodione/sulphur dust applications prior to harvest reduced bunch rot. Postharvest bunch rot was minimal on fungicide-treated grapes exposed to SO_2. On Waltham Cross severe postharvest rot occurred on all treatments. This was due to a 24 h delay in cooling after packing.

Programmes with an iprodione/sulphur dust treatment during late season were repeated during the 1990/91 season. On grapes unexposed to SO_2 these programmes gave good control of bunch rot (Table 4). On grapes unexposed to SO_2, all the iprodione/sulphur dust programmes caused a significant reduction in bunch rot; nevertheless, these reductions could not be regarded as commercially acceptable. As in previous programmes only the combination of fungicide sprays with SO_2 treatment decreased *B. cinerea* infection appreciably in 1991/92 (Table 4).

Fungicide dip treatments of inoculated bunches

Experiment 1: Weather conducive to the development of *B. cinerea* prevailed for the 5-day period before and during the day of the first sampling of flowers. On the afternoon after the first fungicide treatment, 19,2 mm of rain fell whereas more infection periods occurred 7 days and 2 days before the next sampling. High incidences (65-97%) of dead flowers that supported conidiophore formation of *B. cinerea* were recorded at each occasion. None of the fungicides caused a significant reduction in the percentage of infected flowers (data not shown). Neither necrotic floral parts nor *Botrytis* bunch rot was detected at véraison.

Postharvest bunch rot after storage without SO_2 fumigation is given in Table 5. The dicarboximides significantly reduced postharvest rot on bunches inoculated at full bloom and treated from pea size onwards. A similar trend was found on bunches inoculated at pea size and treated after that. When bunches were inoculated at véraison and treated afterwards, the fungicide procymidone gave best control when applied as a dip treatment.

Prochloraz dip and folpet sprays consistently reduced postharvest rot irrespective of application frequency or the developmental stage at which bunches were inoculated. Prochloraz was ineffective when applied as a spray.

Experiment 2: The ability of fungicide spray and dip treatments to protect inner surfaces of bunches after closure against infection by *B. cinerea* is given in Table 6. Procymidone consistently controlled *B. cinerea* more than the other fungicides, whereas a dip treatment was more effective than a spray. Iprodione, applied either as a spray or a dip, was not as effective as procymidone and gave no control on bunches inoculated 21 days after the fungicide had been applied. Prochloraz was ineffective in controlling bunch rot.

TABLE 2
Effect of timing and frequency of procymidone application on the incidence of postharvest *Botrytis* rot of table grapes (cv. Barlinka) during two growing seasons.

Timing of application								Number of applications	Postharvest rot (%)[a]	
					Wk after véraison					
Full bloom	3 wk after full bloom	Pea size	3 wk after pea size	Véraison	1	2	3		+SO_2	–SO_2
1984/85 season[b]										
+	+	+	o	o	–	–	o	6	0,8	–
+	+	+	+	+	–	–	o	6	2,4	–
+	+	+	+	+	–	–	+	6	2,9	–
–	–	–	–	+	+	+	+	4	1,3	–
–	–	–	–	–	+	–	+	2	0,4	–
–	–	–	–	+	–	–	+	2	5,9	–
–	–	–	–	–	–	–	–	0	38,1	–
D-value ($p \leq 0,05$)									12,55	–
1986/87 season[c]										
+	–	+	–	+	–	+	–	4	0,0	16,9
+	–	–	–	–	–	–	–	1	1,7	51,7
–	–	+	–	–	–	–	–	1	1,7	40,4
–	–	–	–	+	–	+	–	2	0,8	23,8
–	–	–	–	–	–	–	–	0	10,0	67,4
D-value ($p \leq 0,05$)									10,69	15,17

[a] Forty-eight bunches per treatment were stored for 35 days. Percentage rot calculated as described by Kremer & Unterstenhöfer (1967).
[b] Trial was conducted in a vineyard in the Hex River Valley; + = spray application, o = dust application, – = no treatment; fungicide applied on: 21/11 (full bloom), 11/12 (3 wk after full bloom), 01/01 (pea size), 22/01 (3 wk after pea size), 12/02 (véraison), 19/02 (1 wk after véraison), 26/02 (2 wk after véraison), 05/03 (3 wk after véraison) and grapes harvested on 12/03.
[c] Trial was conducted in a vineyard in the Paarl area; fungicide applied on: 25/11 (full bloom), 18/12 (pea size), 09/02 (véraison), 25/02 (2 wk after véraison) and grapes harvested on 04/03.

TABLE 3
The effect of timing and frequency of different fungicide applications on Waltham Cross during the 1988/89 season on the incidence of postharvest *Botrytis* rot of table grapes.

Programme No.	Fungicide application[a]					Postharvest rot (%)[b]			
						Waltham Cross		Barlinka	
	Full bloom	Pea size	3 wk after pea size	Vér-aison	1 wk before harvest	+SO_2	–SO_2	+SO_2	–SO_2
1	Ct	Ct	Ct	I	I	0,05	32,5	0,25	25,6
2	F	F	F	I	I	0,06	36,0	0,51	48,0
3	B	B	B	I	I	0,00	32,3	0,37	22,6
4	T	T	T	I	I	0,00	16,2	0,17	36,2
5	I	F	F	I	I	0,00	32,8	0,12	44,2
6	–	–	–	I	I	0,00	32,2	0,34	45,4
7	I	I	I	–	–	0,06	45,2	1,42	66,6
8	I	I	I	I	I	0,00	43,2	0,66	33,5
9	I	I	I	I/S	I/S	0,00	26,2	0,38	12,6
10	–	–	–	–	–	0,08	56,7	1,49	81,9
D-value ($p \leq 0,05$)						0,12	12,41	0,88	11,42

[a] Fungicide application: 16/11 (ful bloom), 08/12 (pea size), 05/01 (3 wk after pea size), 31/01 (véraison) and 14/02 (1 wk before harvest); fungicide application on Barlinka: 17/11 (full bloom), 09/12 (pea size), 06/01 (3 wk after pea size), 09/02 (véraison) and 28/02 (1 wk before harvest); fungicides used were: Ct = chlorothalonil, I = iprodione, F = folpet, B = benomyl, T = thiram, I/S = iprodione/sulphur.
[b] Mean percentage of 48 bunches per treatment that were stored for 42 days; percentage rot of each bunch was determined on a mass basis.

TABLE 4
The effect of different fungicide applications during three seasons on the incidence of postharvest *Botrytis* rot of table grapes.

Fungicide application[a]					Postharvest rot (%)[b]			
					Waltham Cross		Barlinka	
Full bloom	Pea size	Véraison	2 wk after véraison	1 wk before harvest	$+SO_2$	$-SO_2$	$+SO_2$	$-SO_2$
1989/90 season[c]								
M	M	I	I	I	15,6	40,0	0,4	28,0
I	I	I	M	M	16,0	40,6	1,3	16,8
I	I	I	I	I	34,2	57,5	0,7	18,5
I	I	I	I/S	I/S	13,9	46,4	0,2	4,4
–	–	–	–	–	37,6	65,7	5,5	83,7
D-value ($p \leq 0,05$)					9,01	9,47	4,94	12,23
1989/90 season[d]								
M	M	M	I	I	7,13	25,0	7,03	48,6
M	M	M	I/S	I/S	3,25	11,6	5,50	25,8
I	I	I	I	I	4,97	25,2	1,72	51,4
I	I	I	I/S	I/S	3,05	22,3	1,75	20,9
–	–	–	–	–	10,03	32,2	17,40	86,0
D-value ($p \leq 0,05$)					5,35	11,62	9,28	19,99
1991/92 season[e]								
F	F	F	F	F	5,8	24,4	7,7	37,2
M	M	M	M	M	5,2	22,3	9,5	60,7
F	F	F	I/S	I/S	4,5	15,5	4,2	33,8
M	M	M	I/S	I/S	2,0	20,4	4,5	40,7
De	De	De	I/S	I/S	0,3	7,4	4,5	40,9
I	I	I	Sp	Sp	2,9	12,9	2,3	32,3
I	I	I	Cg	Cg	2,4	10,3	3,3	26,4
I	I	I	I/S	I/S	3,9	27,3	4,6	73,3
–	–	–	–	–	13,6	39,9	15,3	73,8
D-value ($p \leq 0,05$)					5,36	12,53	6,81	28,48

[a] Fungicides used were: De = thiram/iprodione, F = folpet, Cg = CGZA 190, I = iprodione, I/S = iprodione/sulphur, M = mancozeb, Sp = prochloraz.
[b] Mean percentage of 48 bunches per treatment that were stored for 42 days; percentage rot of each bunch was determined on a mass basis.
[c] Fungicide application on Waltham Cross: 14/11 (full bloom), 13/12 (pea size), 30/01 (véraison), 15/02 (2 wk after véraison) and 21/02 (1 wk before harvest); fungicide application on Barlinka: 15/11 (full bloom), 13/12 (pea size), 08/02 (véraison), 23/02 (2 wk after véraison) and 08/03 (1 wk before harvest).
[d] Fungicide application on Waltham Cross: 29/11 (full bloom), 19/12 (pea size), 30/01 (véraison), 13/02 (2 wk after véraison) and 22/02 (1 wk before harvest); fungicide application on Barlinka: 05/12 (full bloom), 19/12 (pea size), 07/02 (véraison), 19/02 (2 wk after véraison) and 06/03 (1 wk before harvest).
[e] Fungicide application on Waltham Cross: 13/11 (full bloom), 12/12 (pea size), 06/02 (véraison), 18/02 (2 wk after véraison) and 27/02 (1 wk before harvest); fungicide application on Barlinka: 21/11 (full bloom), 18/12 (pea size), 13/02 (véraison), 28/02 (2 wk after véraison) and 10/03 (1 wk before harvest).

TABLE 5
Control of *Botrytis* postharvest rot of table grapes (cv. Barlinka) artificially inoculated and treated with fungicide at three stages of bunch development during 1987/88.

Fungicide treatment	Postharvest rot (%)[a]					
	Full bloom[b]		Pea size[c]		Véraison[d]	
	Spray	Dip	Spray	Dip	Spray	Dip
Procymidone	46,5	49,4	57,8	73,8	45,9	27,8
Iprodione	48,9	57,3	77,2	79,9	54,0	49,0
Prochloraz	78,3	45,2	86,9	45,0	73,3	41,3
Folpet	44,4	47,2	49,1	57,1	40,9	52,9
Untreated[e]	81,3		94,1		97,6	
D-value ($p \leq 0,05$)	11,39		9,63		12,16	

[a] Mean percentage of 48 bunches that were stored without an SO_2 generator for 35 days; percentage rot was determined on a mass basis.
[b] Inoculated at full bloom, fungicides applied at pea size, véraison and 1 wk before harvest.
[c] Inoculated at pea size, fungicides applied at pea size, véraison and 1 wk before harvest.
[d] Inoculated at véraison, fungicides applied at véraison and 1 wk before harvest.
[e] Inoculated bunches received no fungicide treatments.

TABLE 6
Control of *Botrytis* bunch rot on grapes (cv. Barlinka) artificially inoculated with *Botrytis cinerea* and treated with fungicides applied as a spray or a dip at véraison.

Fungicide treatment	Postharvest rot (%)[a]							
	Interval inoculated after fungicide treatment (days)							
	1		7		14		21	
	Spray	Dip	Spray	Dip	Spray	Dip	Spray	Dip
Procymidone	31,8	42,8	38,8	47,7	56,7	44,4	78,9	66,9
Iprodione	39,0	66,2	53,7	54,4	69,8	51,0	90,6	95,2
Prochloraz	82,8	95,2	84,4	89,5	89,9	92,6	84,4	84,8
Untreated[b]	62,0		88,7		96,5		95,2	
D-value ($p \leq 0,05$)	9,44		17,18		13,44		10,65	

[a] Mean percentage of 48 bunches that were stored without an SO_2 generator for 35 days; percentage rot was determined on a mass basis.
[b] Inoculated bunches received no fungicide treatments.

DISCUSSION

Our study demonstrated that dicarboximide applications between full bloom until late pea size were of no benefit in the control of postharvest *Botrytis* bunch rot in the Western Cape. The downy mildew fungicides mancozeb and folpet, which are normally applied during bloom and the green berry stages, proved to be as effective against early infections as the dicarboximides. Routine dicarboximide sprays are therefore unnecessary and even undesirable if the possible buildup of resistance (Leroux & Clerjeau, 1985; Löcher, Lorenz & Beetz, 1987; Northover, 1988; Beever, Laracy & Pak, 1989) is considered. Iprodione/sulphur treatment at véraison and before harvest, integrated with cultural practices (Gubler *et al.*, 1987; English *et al.*, 1989) should provide adequate reduction in *B. cinerea* infection in the vineyard. Others have also (Pearson & Riegel, 1983 and other references cited therein) questioned the need for fungicide application at bloom and have indicated good control of the disease on wine grapes with only two sprays beginning at vérasion.

Although fungicides were applied at different times in various programmes, none inhibited infection during storage. Control was only achieved when grapes were exposed to SO_2 during the storage period. Sulphur dioxide does not kill the fungus established inside the berry, but only eradicates spores on the surface (Harvey, 1955; Peiser & Yang, 1985; Marois *et al.*, 1986a). On unsprayed bunches exposure to SO_2 drastically reduces the amount of *Botrytis* rot developing in storage. This killing effect was more pronounced on bunches sprayed with fungicides. Thus, apart from reducing inoculum that has landed after bunch closure on bunches, late-season dicarboximide applications enhance the effectivity of SO_2. This synergistic effect might be due to the lower spore levels against which SO_2 must operate.

McClellan & Hewitt (1973) found that inoculations with conidia increased later fruit infection only if made during bloom and that fungicide applications during bloom reduced stigma infections that appeared months later. Other researchers also found evidence of berry infections having arisen from latent infections of the stigma (Sparapano *et al.*, 1981; Nair, 1985; Nair & Parker, 1985). As in a previous study (De Kock & Holz, 1991), we have been unable to show that a relation exists between early infections and subsequent postharvest *Botrytis* bunch rot. This does not necessarily imply that infections during bloom or during the green berry stages do not occur in the western Cape Province. Instead, infections occurring after véraison may mask those that occur earlier.

Infected flowers did not contribute to the development of postharvest bunch rot of table grapes. On wine grapes, bunch architecture influences the microclimate at the berry surface and has a dramatic effect on *Botrytis* bunch rot epidemics (Vail & Marois, 1991). Colonisation of loose floral debris within bunches by the fungus has been observed as foci for infection at véraison (Gessler & Jermini, 1985; Nair & Parker, 1985; Northover, 1987). In bunches of the table grape cultivar Barlinka, dead flowers infected with *B. cinerea* were found until late pea size. At véraison most of the dead flowers had abscised. The absence of early bunch rot in the table grape vineyards might be due to the grape bunches being looser, thereby allowing abscised floral parts to drop from the bunch. As the berries are less compressed and the bunches better aerated, they may dry more rapidly after wet or humid weather. Spores of *B. cinerea* require prolonged periods of free moisture on surfaces of grape berries to germinate and infect (Nelson, 1951). Also, berry contact areas that are more susceptible to infection due to altered epicuticular wax (Marois *et al.*, 1986b) would be less abundant on table grape berries. Therefore no real advantage was gained when closing bunches were dipped in fungicides to ensure better coverage.

Improvements to the control of *Botrytis* bunch rot have occurred as a result of increased knowledge of the epidemiology of the disease (Gubler *et al.*, 1987, Thomas, Marois & English, 1988; English *et al.*, 1989, 1990). The fact that berries become infected primarily during harvest, packing operations and storage, emphasises the necessity for reducing *B. cinerea* inoculum on harvested grapes in the Western Cape. Biological control offers an alternative to fungicide use for the control of postharvest *Botrytis* bunch rot. Recent research (Ben-Arie *et al.*, 1990) has demonstrated the feasibility of this approach, which may become a cornerstone in the strategic management of postharvest *Botrytis* bunch rot. In such a system the principal times of colonisation of table grape bunches by the pathogen in a given region should be known when planning strategic disease management incorporating biological control agents. The behaviour of the pathogen under local conditions indicates that biocontrol applications from véraison until postharvest may be a productive area to explore.

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