CONTROL OF BROWN ROT (*MONILINIA FRUCTICOLA*) ON ORGANIC APRICOTS

G.F. McLAREN and J.A. FRASER

HortResearch, Clyde Research Centre, R.D. 1 Alexandra

ABSTRACT

The effects of sulphur and copper on postharvest brown rot (*Monilinia fructicola* (Wint.) Honey) were studied for six years in a Bio-Gro registered apricot block at Clyde Research Centre, Central Otago. Four treatments of sulphur and/or copper were applied up to 9 times between flowering and harvest. Brown rot levels were high in seasons with a high rainfall from November to January (harvest). Sulphur (Kumulus DF) at either 120 or 160 g ai/100 litres or at 80 g with copper (Kocide DF) at 10 g ai/100 litres reduced brown rot levels in cvs Sundrop and CluthaGold. Seven organically acceptable alternatives to sulphur were also tested but none were more effective. However, alternatives to sulphur are needed for use close to harvest, to reduce both visible residues and the possible negative effect of sulphur on return bloom.

Keywords: brown rot, apricots, sulphur, copper, organic production.

INTRODUCTION

Brown rot, caused by *Monilinia fructicola* (Wint.) Honey, can lead to significant fruit losses, starting with blossom blight in spring, followed by fruit rots at harvest (Tate and Seelye 1977; Elmer 1990). Although the level of rots occurring in the field before harvest may be quite low, losses in storage can be high, eventually infecting a high proportion of fruit especially where there has been no fungicide programme in the field. Since modern synthetic fungicides cannot be used on organic summerfruit (stonefruit), the risk of brown rot infecting the crop is high and has a major influence on its market potential. The demand for organic produce is growing worldwide, driven by health and environmental concerns and limited product availability (Crawshaw1997). A research programme commenced in 1992 at the Clyde Research Centre to investigate brown rot control in organic orchards, with the aim of developing an effective programme for its control on apricots (*Prunus armeniaca* L.) and nectarines ((*Prunus persica* (L.) Batsch var. *nucipersica* (Suckow) C.K. Schneid) (McLaren *et al*. 1996; McLaren and Fraser 1996, 1998). The choice of products was initially restricted to sulphur and copper but alternative organically-acceptable products were later tested. This paper describes six years of trials to evaluate the efficacy of sulphur for the control of brown rot on apricots and to test some alternatives.

METHODS

Trial 1

Trials were carried out in a Bio-Gro registered block of apricots, planted in 1992 at Clyde Research Centre, consisting of 5 rows of cv. Sundrop and 6 rows of cv. CluthaGold, planted 4.5×2 m apart. Each row contained 19 trees and was divided into five 3-tree plots plus two 2-tree plots. Every alternate row was not treated and acted as a guard row and a source of brown rot inoculum. All treatments were replicated three times on each cultivar. The trial began in 1994/95 and continued for six years. Over that period, five treatments (including the untreated) were applied to the same trees each season. Two other treatments were changed each year to test alternative products. The trees were sprayed to run-off with a pressurised sprayer and handgun, applying 5 litres per tree at 400 psi. In the first year, applications were made over the flowering period only, but in all subsequent years they were made throughout the season (Table 1).

TABLE 1: Dates of spray application in brown rot control trials from 1994 to 2000.

Year	Flowering	Cover	Preharvest
1994/95	31 Aug., 6 &13 Sept.		
1995/96	11, 18 & 25 Sept.	13 Oct., 15 Nov., 15 Dec.	8 Jan. (SD only)[1]
1996/97	16 & 23 Sept.	30 Sept., 17 Dec.	10 & 20 Jan. (SD&CG)
1997/98	3, 10 &16 Sept.	24 Sept., 22 Oct., 20 Nov., 17 Dec.	13 & 20 Jan. (SD) 20 Jan., 2 Feb. (CG)
1998/99	7, 14 & 21 Sept.	21 Oct., 17 Nov., 14 Dec.	13 Jan. (SD) 13 & 22 Jan. (CG)
1999/00	8, 15 & 22 Sept.	15 Oct., 19 Nov., 20 Dec.	10 & 17 Jan. (SD) 17 & 27 Jan. (CG)

[1]Dates of application on Sundrop (SD) and CluthaGold (CG) were the same except at harvest time when the preharvest treatments were delayed on the later-ripening CluthaGold.

Five treatments were consistently applied throughout the five years. These were:

sulphur (Kumulus® DF 800 g/kg) 120 g ai/100 litres
sulphur (Kumulus® DF 800 g/kg) 160 g ai/100 litres
sulphur (Kumulus® DF 800 g/kg) 80 g ai/100 litres combined with copper hydroxide (Kocide® DF 400 g/kg) 10 g ai/100 litres
copper hydroxide (Kocide® DF 400 g/kg) 10 g ai /100 litres
untreated

The two new treatments each year were:

1995/96	MycoSan (1 kg/100 litres); sulphur (Kumulus® DF 800 g /kg) (80 g ai/100 litres)
1996/97	MycoSan (750 g/100 litres); MycoSan (1 kg/100 litres)
1997/98	Sodium bicarbonate (1 kg) plus Sunlight Liquid (100 ml/100 litres); sodium bicarbonate (1 kg) plus Ultrafine oil (12 ml/100 litres)
1998/99	MycoSin (1 kg/100 litres); calcium hydroxide (1 kg/100 litres)
1999/00	Protector (2 litres/100 litres); lime sulphur (500 ml/100 litres)

As required for Bio-Gro registration, no herbicides, insecticides or other fungicides were applied. When the risk of bacterial diseases was high after cold, wet weather, copper (Kocide® DF) was applied (10 g ai/100 litres) over the whole block on 23 November 1995, 7 and 18 October 1996 and 14 October 1997. Fruit were harvested once from each cultivar with three trays (36 fruit/tray) being picked and packed per plot whenever possible (total =324 fruit per cultivar per treatment). The fruit were packed in plastic ‘Plix’ trays inside single layer cardboard trays and stored in the laboratory at 20°C. Fruit were inspected twice per week; rots were identified and the infected fruit removed, until all had been discarded.

Annual soil samples were collected from 1996 to 2000 from under trees that had received sulphur at 120 and 160 g ai/100 litres, copper at 10 g ai/100 litres and the untreated plots (sampled from every replicate).

Trial 2

In 1999/2000 a block of 7-year old apricot trees cv. San Castrese (planted at 4.5 × 4 m spacing) was divided into four replicates of three treatments with two rows per replicate. Plots consisted of six trees separated by guard trees on all sides. The treatments were Protector 2 litres/100 litres, sulphur (Kumulus® DF) 140 g ai/100 litres and untreated. Treatments were applied with the same sprayer as in the first trial. Treatments were applied 6, 13 and 22 September, 15 October, 19 November, 20 December and 12 and 17 January. Fruit were harvested on 18 January 2000. Four trays of 36 fruit were harvested from each plot (total=576 fruit/treatment) and incubated at 20°C; fruit with rots were removed and recorded as described above.

Data analysis

The relationship between postharvest rots and rainfall from flowering (September) to harvest (January) over six years was determined by regression analysis, comparing each individual month and their combinations in that period.

Cumulative percentage losses from brown rot were analysed from data recorded after 5, 7 and 10 days incubation at 20°C. Because cumulative losses were so low on most treatments after five days, few statistical differences were found between the means. In contrast, after ten days, most losses were close to 100%. Therefore, the data set from Day 7 was selected for presentation, although this was probably a rather rigorous test. Cumulative percentage losses on Day 7 were arcsine transformed and subjected to analysis of variance. Means were back transformed for presentation in the tables.

RESULTS

Trial 1

Brown rot incidence on untreated fruit in storage varied between years on both Sundrop and CluthaGold (Table 2) with particularly high levels of rots on both cultivars in 1995/96 and 1999/2000 ($P<0.001$). These were associated on CluthaGold with high rainfall between November and January ($R^2 = 0.66$, $P=0.05$) and during January ($R^2 = 0.77$, $P<0.05$) but neither regression was significant on Sundrop. Regression analyses that started as early as September (flowering) were not significant ($P>0.05$).

There were inconsistent differences between cultivars in some years, e.g. 1997 and 1999 (Fig. 1, Table 2), indicating that one cultivar was no more susceptible than the other in that season.

TABLE 2: Percentage untreated apricot fruit with brown rot after 7 days storage over six years. Rainfall was recorded at Clyde Research Centre.

Year	% fruit with brown rot		Rainfall (mm)	
	Sundrop	CluthaGold	November to January	January
1994/95	5.6 a[1]	7.5 a	115	26
1995/96	42.5 ab	41.7 ab	264	88
1996/97	3.6 a	31.2 ab	97	32
1997/98	16.4 a	17.3 ab	118	22
1998/99	43.5 ab	2.9 a	58	21
1999/00	90.9 b	83.6 b	246	95

[1]Means followed by a common letter within a column are not significantly different ($P>0.05$) by Newman-Keuls test.

Sulphur at 120 or 160 g and sulphur at 80 g plus copper at 10 g reduced brown rot levels on Sundrop four years in six (Table 3). Results for CluthaGold compared with untreated were significant in just two years. Sulphur at the high rate (160 g) was the only treatment that reduced brown rot levels on CluthaGold in both years.

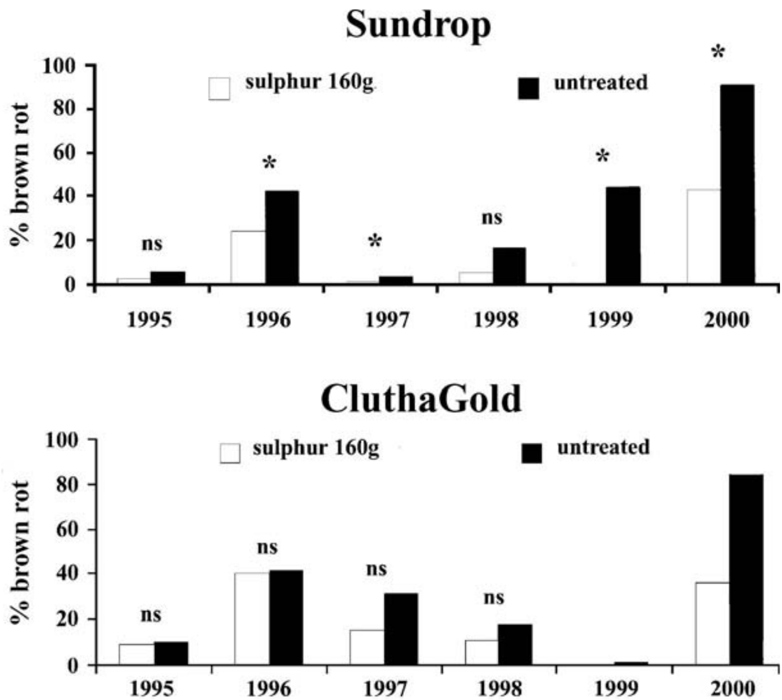

FIGURE 1: Percentage fruit with brown rot after 7 days incubation for sulphur 160 g ai/100 litres and the untreated control of Sundrop and CluthaGold over 6 years. * = means for that year were significantly different (P<0.05) by analysis of variance; ns = means were not significantly different (P>0.05).

TABLE 3: Mean percentage fruit lost due to brown rot after 7 days in storage at 20°C from 1995 to 2000 on Sundrop and CluthaGold.

Treatment	% fruit with brown rot after 7 days in storage					
(g ai/100 litres)	1995	1996	1997	1998	1999	2000
Sundrop						
S 160	2.2 a[1]	23.5 a	0.7 a	5.3 a	8.5 a	42.3 a
S 120	0.6 a	14.8 a	0 a	9.8 a	11.5 a	42.7 a
S 80 + Cu 10	4.4 a	14.1 a	0.2 a	1.2 a	19.6 a	57.2 a
Cu 10	3.3 a	21.0 a	0.4 a	8.2 a	13.9 a	65.3 ab
Untreated	5.6 a	42.5 b	3.6 b	16.4 a	43.5 b	90.9 b
CluthaGold						
S 160	9.0 a	40.3 a	14.8 a	10.8 a	0 a	35.8 a
S 120	9.0 a	40.4 a	9.7 a	7.4 a	0 a	74.5 b
S 80 + Cu 10	19.0 a	54.0 a	11.3 a	4.3 a	0 a	59.3 ab
Cu 10	10.0 a	58.1 a	14.4 a	27.0 b	0.9 ab	41.5 a
Untreated	7.5 a	41.7 a	31.2 a	17.3 ab	2.9 b	83.6 b

[1]Means followed by the same letter in any year for either cultivar are not significantly different by Newman-Keuls test (P>0.05). S = sulphur, Cu = copper.

When all the data from six years were analysed together, the three sulphur treatments (160 g 17.5%, 120 g 17.1% and 80 g + 10 g Cu 22.0%) reduced the level of brown rot on both cultivars ($P<0.001$). Copper alone (27.2%) was ineffective and no better than the untreated control (37.2%) ($P>0.05$).

The search for alternatives to sulphur did not identify a better treatment (Table 4).

TABLE 4: Mean percentage fruit lost due to brown rot after 7 days storage for sulphur and alternative treatments.

Year	Treatment (rate/100 litres)	% fruit with brown rot after 7 days storage Sundrop	CluthaGold
1995/96	Sulphur 160 g	23.5 a[1]	40.3 a
	Sulphur 80 g	21.3 a	41.5 a
	MycoSan 1000 g	7.4 a	45.1 a
1996/97	Sulphur 160 g	0.7 a	14.8 a
	MycoSan 750 g	0 a	9.9 a
	MycoSan 1000 g	3.6 b	11.9 a
1997/98	Sulphur 160 g	5.3 a	10.8 a
	Sodium bicarbonate + Sunlight Liquid	25.8 a	26.5 b
	Sodium bicarbonate + Ultra fine oil	3.3 a	35.3 b
1998/99	Sulphur 160 g	8.5 a	0 a
	MycoSin 1000 g	37.6 b	1.9 b
	Calcium hydroxide 1000 g	6.14 a	0 a
1999/00	Sulphur 160 g	42.3 a	35.8 a
	Protector 2 litres	83.4 b	75.0 b
	Lime sulphur 500 ml	56.1 a	54.4 a

[1]Means followed by a common letter in any year and within a column are not significantly different ($P>0.05$) by Newman-Keuls test.

Trial 2

On San Castrese apricots in 1999/2000, sulphur and Protector were equally effective in reducing the 64% losses which occurred on the untreated fruit ($P=0.05$) with Protector producing 45% losses and sulphur 37% on Day 7. There was no difference between the two treatments ($P>0.05$). This contrasted with the results on both Sundrop and ClutháGold where sulphur was significantly more effective than Protector (Table 4). Of the three cultivars tested in 1999/2000, untreated trees of San Castrese produced fewer rots on Day 7 (45.2%) than Sundrop (83%) ($P<0.01$), while ClutháGold (75%) was not statistically different from either of them ($P>0.05$).

Soil Tests

Soil tests from 1996 to 2000 showed that neither the sulphur (120 g ai/100 litres) nor the copper (10 g ai/100 litres) programmes changed the pH, sulphur or copper levels in the soil compared with the soil beneath the untreated trees.

DISCUSSION

Sulphur was effective in reducing levels of brown rot over six seasons. It was not very effective in seasons of high disease pressure (high rainfall such as 1999/00) or when preharvest sprays were omitted. For instance, the poor results on ClutháGold in 1995 and 1996 were probably due to the lack of preharvest sprays in those years, especially when it is noted that Sundrop received one preharvest spray in 1996 and good control was achieved. However, sulphur was effective when a full programme was applied and the period before harvest was relatively dry. Copper was generally not as effective as sulphur, but was effective in some years. None of the alternative products were more effective than sulphur and some presented new problems.

Calcium hydroxide left an unacceptable white deposit on the fruit. Sulphur, MycoSan and MycoSin also left white residues, but calcium hydroxide was the most extreme. MycoSan severely reduced the return bloom and crop in the following year, but when the sulphur in MycoSan, was omitted in MycoSin, this product was ineffective.

Prospects for Sulphur

Sulphur is a restricted product under Bio-Gro regulations but can still be used where justified and with permission. Earlier research showed that sulphur reduced return bloom in apricots (McLaren and Fraser 1998) and in the current trials left a visible residue on the fruit. There are also problems with the registration of sulphur as the label specifically excludes apricots. In the absence of a more effective alternative, one option would appear to be a mixed programme, using sulphur until the end of November, then switching to another product during the probable period of flower bud initiation (December/January). The selected product, e.g. Protector, needs to leave no visible residue.

Because a full sulphur programme can still put organic growers at greater risk in the market place in some years, a more effective fungicide is urgently needed if growers are to produce a reliable product.

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