SULPHUR AS AN ALTERNATIVE TO COPPER FOR THE CONTROL OF BACTERIAL BLAST ON NECTARINE FRUIT

G.F. McLAREN¹, J.L. VANNESTE² and R.R. MARSHALL¹

¹HortResearch, Clyde Research Centre, Alexandra RD1,
Central Otago, New Zealand

²HortResearch, Ruakura Research Centre, Private Bag 3123,
Hamilton, New Zealand

Corresponding author: JMcLaren@hortresearch.co.nz

ABSTRACT

Bacterial blast, caused by *Pseudomonas syringae*, is a serious disease of stone fruit crops, affecting both tree health and fruit appearance. Fruitgrowers protect trees by applying copper from leaf fall to early summer using copper in various formulations, rates and times. There is pressure to reduce copper usage because of the potential for its accumulation in soil. Trials conducted over three years showed that copper, applied as copper hydroxide, was not effective in reducing bacterial blast symptoms on fruit, even when applied up to eight times in a season. In contrast, trees that were treated with sulphur produced fruit with significantly less bacterial damage. The benefit of sulphur on nectarine cv. Fantasia was demonstrated over three years on one site. Sulphur shows potential as a replacement for copper in the nectarine spray programme, but its effect on other stone fruit crops should be confirmed. The mode of action of sulphur is unclear.

Keywords: bacterial blast, *Pseudomonas syringae*, copper, sulphur, nectarines.

INTRODUCTION

Bacterial blast (bacterial canker), caused either by *Pseudomonas syringae* pv. *syringae* or pv. *persicae*, is a serious disease of stone fruit (summerfruit) crops in New Zealand. It is a common problem in most Central Otago orchards (Young 1987). Bacterial blast causes cankers (often associated with gumming) to develop on the trunk, branches or shoots. Branches and even whole trees may die, especially if they are young. Leaf spots develop in spring and this is followed a few weeks later by black spots appearing on the fruit. On nectarines, the first fruit spots appear in late November and can continue to develop until harvest. Recently, bacterial marking of fruit has been responsible for significant commercial losses in some cultivars (up to 40% of the crop). Bacterial marking on fruit may also be caused by bacterial spot, *Xanthomonas arboricola* pv. *pruni*, but this organism has been uncommon in Central Otago orchards in the past few years and absent from samples collected from the trial site between 2000 and 2005 (Vanneste et al. 2005).

The spray programme to control bacterial blast was developed more than fifty years ago and was designed to prevent infection in the trees (Dye 1956). Young & Paulin (1982) and Tate (1999) modified the programme slightly but all based their recommendations on copper applications. The programme generally consisted of two to three applications of Bordeaux mixture (containing copper sulphate) or copper hydroxide, applied over the leaf fall period in autumn, followed by at least two copper applications over the dormant period, particularly at the late dormant or bud movement stage before flowering. The antibiotic streptomycin is occasionally used in early spring. Surveys of orchardists'

spray programmes showed that copper is being applied in the form of copper sulphate, copper hydroxide, copper oxychloride or cuprous oxide to most commercial orchards in Central Otago (G.F. McLaren, unpubl. data). There is widespread pressure to eliminate the use of streptomycin and reduce the quantity of copper applied in orchards because of the negative effect of copper on soil biota, particularly earthworms.

Sulphur is considered to have little activity against *P. syringae* in the laboratory (C.N. Hale, pers. comm.). However, replicated trials conducted at Clyde Research Centre from 1995 to 2000 indicated that bacterial marking on nectarine fruits (cv. Fantasia) could be significantly reduced by applying 3-4 applications of sulphur over the 5-6 week period between flowering and shuck fall (G.F. McLaren, unpubl. data). These observations, as well as the need to find a more effective programme to control bacterial blast on fruit, led to the establishment of three consecutive field trials between 2002/03 and 2004/05. These evaluated the efficacy of copper and/or sulphur on nectarines. This paper describes the results of these trials.

MATERIALS AND METHODS

Field trials

All research was carried out on a block of nectarines cv. Fantasia at Clyde Research Centre. The trees had been planted in 1983 at 5 x 6 metre spacing. All treatments were re-randomised each year except in the second year when the sulphur treatments from the previous year were left untreated. At the end of the following season, the level of bacterial symptoms on the fruit of trees that had been treated with sulphur the previous year were the same as on the untreated trees in the current year ($P > 0.05$). Thus, it was assumed that there was no carryover of treatments from year to year.

Treatments were applied to the trees with a hand-gun to two-tree plots replicated six times in the first two years and three-tree plots replicated three times in the third year, in a randomised plot design. In the first two years, copper formulations were the main focus of the experiments with sulphur applied just once, either alone or with copper. By the third year, it was clear that sulphur justified more study, especially in relation to its time of application.

Possible phytotoxicity was avoided by applying sulphur or copper during the growing season at rates lower than those used on dormant trees. All applications of sulphur and copper were applied at the recommended time and within recommended label rates in autumn and the late dormant stage, but there is no label claim for the use of copper over the growing season, despite its frequent use on commercial orchards (G.F. McLaren, unpubl. data). Timing of applications and treatment details are summarised in Table 1. Copper hydroxide was applied as Kocide® 2000 DF (35% active copper), cuprous oxide was applied as Nordox Oleo 40 (65% active copper), copper oxychloride was applied as Copper Oxychloride 50 WDG (50% active copper) and sulphur was applied as Kumulus® DF (80% elemental sulphur).

At harvest (14 February 2003, 17 February 2004 and 21 February 2005), 80 fruit were collected from each plot and assessed for bacterial damage in the laboratory on the basis of presence or absence of symptoms. Analysis of variance was undertaken on the percentage fruit without bacterial blast using S-plus.

Effect of Kumulus® DF on *P. syringae*

The strain of *P. syringae* pv. *syringae* 02.43, isolated by Robert Taylor in 2002 from infected material from Clyde Research Centre, was grown overnight in Luria broth at 28°C. This overnight culture was diluted one hundred times in water or in Luria broth with or without Kumulus® DF. Two rates of Kumulus® DF were used for each growing medium: 150 g/100 litres and 1500 g/100 litres when using water; or 75 g/100 litres and 750 g/100 litres when using Luria broth. Populations were determined by dilution plating after 0, 7 and 24 h incubation at 28°C.

RESULTS

Applications of sulphur significantly increased the proportion of fruit that showed no bacterial damage symptoms at harvest ($P < 0.001$) in all three years (Table 1). None of the copper formulations or treatments increased the proportion of fruit without bacterial blast symptoms compared with the untreated in any year, irrespective of timing or copper formulation ($P > 0.05$). Sulphur was effective when applied to the tree four times between flowering and shuck fall (September/October) in both 2002/03 ($P < 0.001$) and 2003/04 ($P < 0.001$). However, in 2004/05 the four applications of sulphur between flowering and shuck fall only reduced bacterial damage symptoms compared to the untreated when the trees had also been treated with two applications of sulphur in August ($P < 0.001$). Sulphur was not effective at reducing bacterial damage symptoms when applied to the ground in 2004/05, despite receiving eight applications.

After 24 h incubation, the population of *P. syringae* 02.43 grew from 5×10^6 cfu/ml to 3×10^7 cfu/ml in water, and from 4×10^6 cfu/ml to 9×10^7 cfu/ml in Luria broth. Populations of *P. syringae* 02.43 in water or Luria supplemented with Kumulus®DF (both rates) were similar to those obtained when the strain was grown in water or Luria without Kumulus®DF (data not shown).

DISCUSSION

This series of trials has clearly demonstrated that foliar sulphur is effective at reducing symptoms of bacterial damage on nectarine fruit. In the first two years, four sulphur applications between flowering and shuck fall were sufficient to give a significant reduction in symptoms. However, in 2004/05, sulphur was only effective when applied in a programme that began while the trees were dormant in August and continued until shuck fall in early November, a total of six applications. Sulphur was not effective when applied in autumn only in 2004/05, but since this was the first time that autumn applications had been tested, this conclusion needs to be confirmed.

Sulphur is one of the essential nutrients for plant growth and is known to be naturally deficient in Central Otago soils (Ludecke 1962). However, there seem to have been few if any studies on sulphur deficiencies in fruit trees, either in New Zealand or overseas. The observed response to foliar sulphur could have been attributed to the correction of a soil deficiency, but there was no significant response to sulphur when it was applied to the ground, at least in the final year of this series of trials. However, there was sufficient indication of a possible response to encourage retention of the plots with sulphur-on-the-ground in the same sites in trials planned for next year.

Sulphur is reputed to have little effect on *P. syringae* in the laboratory and this was confirmed in the current study when *P. syringae* grew in water or Luria broth that had been supplemented with sulphur at rates ten times higher than those recommended for use in the field.

The benefits of sulphur seem to be short term as they failed to carry over from the first trial into the following season in 2003/04. The mode of action of sulphur is unclear since it has little effect on *P. syringae* in the laboratory and it does not appear to act as a soil nutrient. Possibilities include a direct effect on the tree or an indirect one, potentially through the tree's microflora. There is no doubt that the lack of understanding of the mode of action of sulphur limits its use to best advantage.

The lack of response to copper, regardless of the formulation or the timing, can probably be attributed to the existence of high levels of resistance to copper that were found in the *P. syringae* samples collected from the trial site. Resistance to copper is discussed by Vanneste et al. (2005).

Sulphur shows promise as a replacement for copper for the control of *P. syringae*. It is currently being tested on other cultivars and crops in Central Otago.

TABLE 1: Mean percentage fruit with no bacterial symptoms at harvest in relation to timing and rate of application (g active ingredient/100 litres) of sulphur and copper to nectarine cv. Fantasia at Clyde Research Centre in 2002/03, 2003/04 and 2004/05.

	Timing and rate of application			% fruit without symptoms ¹
	13 & 25 Sept; 8 & 17 Oct	4 & 18 Nov; 2 & 16 Dec	6 & 20 Jan; 3 Feb	
2002/03	Oct			
Cuprous oxide	19.5	-	-	65.6
Copper oxychloride	15	-	-	61.6
Copper hydroxide	10.5	-	-	61.7
Copper hydroxide	-	10.5	-	56.5
Copper hydroxide	-	-	10.5	54.6
Copper hydroxide and sulphur	10.5 + 80	-	-	98.5*
Sulphur	140	-	-	92.9*
Untreated	-	-	-	59.5
LSD (P=0.05)				10.8
	17 & 29 Sept; 10 & 21 Oct	11 & 26 Nov; 6 & 12 Dec		
2003/04	21 Oct	Dec		
Cuprous oxide	17.5			10.2
Copper oxychloride	17.5			14.7
Copper hydroxide	17.5			9.7
Copper hydroxide		17.5		9.6
Sulphur	140			51.4*
Sulphur	80			40.7*
Untreated ²				10.3
Untreated ³				14.0
Untreated				14.8
LSD (P=0.05)				12.4
	10 & 25 May	13 & 31 Aug	21 Sept; 4 & 18 Oct; 2 Nov	
2004/05				
Sulphur	140, 160	-	-	85.9
Sulphur	140, 160	160, 140	-	91.2
Sulphur	140, 160	160, 140	140,140,140,140	91.6
Sulphur		160, 140	140,140,140,140	98.9*
Sulphur			140,140,140,140	90.7
Sulphur on ground ⁴	140, 160	160, 140	140,140,140,140	86.5
Copper hydroxide	40, 66.5		-	79.3
Copper hydroxide	40, 66.5	66.5, 40	-	89.4
Copper hydroxide	40, 66.5	66.5, 40	10.5,10.5,10.5,10.5	84.5
Copper hydroxide	-	66.5, 40	10.5,10.5,10.5,10.5	75.5
Copper hydroxide	-	-	10.5,10.5,10.5,10.5	73.6
Untreated	-	-	-	76.0
LSD (P=0.05)				16.3

¹Means indicated by * were significantly different from untreated (P<0.05).

²Untreated in 2003/04 but treated with sulphur + copper hydroxide (80 g ai + 10.5 g ai/100 litres) in 2002/03.

³Untreated in 2003/04 but treated with sulphur (140 g ai/100 litres) in 2002/03.

⁴Sulphur was applied to the ground over a 5 x 6 metre area around trees using a hand-gun (4 litres/tree ground-space or 1330 litres/ha).

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REFERENCES

- Dye DW 1954. Blast of stonefruit in New Zealand. *New Zealand Journal of Science and Technology* A35: 451-461.
- Ludecke TE 1962. Formulation of a rational fertilizer programme in tussock country. *Proceedings New Zealand Grassland Association* 24: 29-41.
- Tate G 1999. Diseases and their management. In: McLaren GF, Tate G, Wood G, Grandison G, Horner I ed. *Summerfruit in New Zealand. Management of pests and diseases.* HortResearch/AGMARDT/Summerfruit New Zealand Inc., University of Otago Press, Dunedin, New Zealand. Pp. 74-115.
- Vanneste JL, McLaren GF, Yu J, Cornish DA, Boyd R 2005. Copper and streptomycin resistance in bacterial strains isolated from stone fruit orchards in New Zealand. *New Zealand Plant Protection* 58: 101-105.
- Young JM 1987. Orchard management and bacterial diseases of stone fruit. *New Zealand Journal of Experimental Agriculture* 15:257-266.
- Young JM, Paulin RN 1982. A spray programme to control bacterial blast of apricot. *The Orchardist of New Zealand* 82: 413.