FUNGICIDES FOR CONTROL OF BLACK SPOT AND POWDERY MILDEW IN ORGANIC APPLE PRODUCTION SYSTEMS

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SUMMARY

Sulphur alone and four other fungicide formulations (cupric hydroxide, copper sulphate/sulphur mixture, bentonite clay, and vegetable oil) with and without sulphur were evaluated for black spot (*Venturia inaequalis*) and powdery mildew (*Podosphaera leucotricha*) control at an organic apple orchard in Canterbury. Sulphur improved black spot, but not powdery mildew, control and caused little fruit russet. Cupric hydroxide gave the best control of both diseases, but caused fruit russet. Copper sulphate/sulphur gave moderate control of both diseases and little russet. Bentonite clay gave some black spot control, poor powdery mildew control, and caused russet and fruit drop. Vegetable oil gave good powdery mildew control, poor black spot control and caused russet and severe fruit drop.

Keywords: organic apple production, black spot, *Venturia inaequalis,* powdery mildew, fungicides

INTRODUCTION

Two principal fungal diseases of apples, black spot, caused by *Venturia inaequalis* (Cooke) Winter, and powdery mildew caused by *Podosphaera leucotricha* (Ellis and Everhart) Salmon, are readily controlled in conventional apple orchards with modern synthetic fungicides. In organic orchards, use of synthetic fungicides violates the principles of organic production, and only natural materials are permitted. A wide range of non-synthetic materials were used before the appearance of synthetic fungicides in the 1940's, including copper, sulphur, phenyl mercury and naphthoquinone compounds (Mills and Laplante 1954). Of these, only copper and sulphur compounds meet modern public health requirements.

There are several problems associated with the use of copper and sulphur for apple disease control. Both have only protectant activity, rather than curative or eradicant activity, and their efficacy depends on application before infection occurs. Copper and sulphur are phytotoxic and can cause fruit russet or leaf burning. Prolonged use of copper sprays may lead to copper levels in the soil which are toxic to earthworms and possibly to apple trees, and prolonged sulphur use may lead to soil acidification with associated tree health problems.

In an experimental organic apple orchard in Canterbury, control of black spot and powdery mildew in the 1989-90 growing season was based on a fortnightly spray programme alternating cupric hydroxide with sulphur. Although some disease control was achieved, incidences of black spot, powdery mildew and fruit russet were too high to allow economic returns. This paper describes a fungicide trial at the same site in the 1990-91 season which compared the effect of various compounds and spray regimes on disease control, and occurrence of fruit russet.

MATERIALS AND METHODS

The trial was conducted at Winchmore Research Station in Canterbury (Anon. 1990) during the 1990-91 growing season on 3 year old trees of cv. Royal Gala. The trees

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were in their second year of organic management with under-tree sprinkler irrigation and a red clover understory.

Five formulations of potentially fungicidal compounds were compared in spray programmes based on approximately fortnightly applications. The compounds were: cupric hydroxide (Shell Kocide 101, 125 g copper/100 litres), an experimental fungicidal mixture of tribasic copper sulphate and sulphur (96 g copper and 100 g sulphur/100 litres), bentonite clay (Yates Ulmasud, 57 g acidic clay minerals/100 litres), vegetable oil surfactant (Yates Naturoil, 190 ml vegetable oil/100 litres), sulphur (BASF Kumulus DF, 80 g/100 litres).

Sulphur applications were alternated with applications of one of the other four fungicides or was used alone. In addition, the four other fungicides were used without sulphur applications (Table 1). Treatments 2, 4, 6, 8 and 9 received five applications of fungicide, whereas treatments 1, 3, 5 and 7 received 10 applications. The treatment applications were made during the black spot primary infection period, between 10 October (early pink) and 12 December 1990. After that, all plots received a standard programme of fortnightly cupric hydroxide and sulphur until harvest.

Trees were sprayed to run-off using a hand lance sprayer operating at 2,758 kPa (400 psi) pressure. A randomized block design was used with nine five-tree plots in one row per replicate, and five replicates. An unsprayed control was not included because high disease levels were anticipated, and unsprayed plots may have masked any treatment effects through interplot interference (James *et al* 1976).

Black spot and powdery mildew were assessed on leaves and black spot and russet were assessed on fruit on 6 December, following four applications of sulphur and four applications of other compounds. The number of leaves per terminal shoot and the number with black spot and/or powdery mildew were determined on 30 shoots from the middle three trees in each plot. Black spot on fruit was scored as present or absent, and russet was scored relative to the New Zealand Apple and Pear Marketing Board export standard. Sixty fruit (20 per tree) were assessed per plot. At harvest on 27 February, the number of fruit on the middle three trees in each plot were determined.

TABLE 1: Fungicide programmes tested in the black spot and powdery mildew control trial.

Treatment number	Compounds applied		Reference in text
1.	cupric hydroxide	+ sulphur	(CH + S)
2.	cupric hydroxide	– sulphur	(CH – S)
3.	copper sulphate and sulphur	+ sulphur	(CS + S)
4.	copper sulphate and sulphur	– sulphur	(CS – S)
5.	bentonite clay	+ sulphur	(BC + S)
6.	bentonite clay	– sulphur	(BC – S)
7.	vegetable oil surfactant	+ sulphur	(VO + S)
8.	vegetable oil surfactant	– sulphur	(VO – S)
9.		+ sulphur	(S)

RESULTS

Black spot incidence on leaves on 6 December ranged from 6-45% (Table 2C). The best black spot control was achieved with the standard programme of cupric hydroxide alternated with sulphur (CH + S). In the analysis of variance, the main effect for the non-sulphur compounds (Table 2B), i.e. cupric hydroxide (CH), copper sulphate/sulphur (CS), bentonite clay (BC), and vegetable oil (VO), showed that they all differed significantly. The ranking was CH (most effective), followed by BC, CS and VO. The interaction between sulphur and non-sulphur compounds in the analysis was significant. Sulphur significantly improved control for CH, CS and VO, but not for BC. The sulphur alone programme was not included in the analysis, but the mean black spot incidence on leaves was high, being between VO-S and CS-S.

TABLE 2: Effects of fungicides on black spot on leaves and fruit, powdery mildew on leaves and russet on fruit on 6 December 1990, and fruit yields on 27 February 1991.

	Black spot				Powdery mildew		Fruit[2] russet		Fruit yield	
	Leaves[1]		Fruit[2]		Leaves[1]				(No./Plot)	
A. Main effect for sulphur										
+S[3]	18		21		15		37		36	
−S	28		44		11		36		21	
LSD 0.05	1.7		4.8		2.0		NS		7.3	
LSD 0.01	2.2		6.4		2.6		NS		9.6	
B. Main effect for non-sulphur compounds										
CH[3]	12		16		9		66		54	
CS	24		34		13		17		50	
BC	20		34		20		30		8	
VO	36		45		9		33		1	
LSD 0.05	2.4		6.8		2.8		7.2		10.3	
LSD 0.01	3.1		9.1		3.6		9.7		13.6	
C. Sulphur x Non-sulphur interaction										
	+S	−S	+S	−S	+S	−S	+S	−S	+S	−S
CH[3]	6	18	10	23	9	9	68	65	58	50
CS	20	28	23	45	14	12	21	14	73	26
BC	19	20	26	41	24	15	27	33	10	5
VO	26	45	24	66	12	5	34	31	1	1
S[4]	33	-	63	-	19	-	8	-	27	-
LSD 0.05	3.4		9.5		3.9		NS		14.5	
LSD 0.01	4.4		12.9		5.1		NS		19.2	

[1] Mean percentage of leaves per terminal shoot diseased (arcsine transformed data).
[2] Mean percentage of fruit per plot affected (arcsine transformed data).
[3] S = sulphur; CH = cupric hydroxide; CS = copper sulphate/sulphur; BC = bentonite clay; VO = vegetable oil.
[4] Sulphur alone was not included in the analysis.

Blackspot incidence on fruit ranged from 10-66% on 6 December (Table 2C). For the non-sulphur compounds, CH had significantly less disease than the others. The interaction between sulphur and non-sulphur compounds showed that the additional sulphur significantly improved black spot control on fruit for all the non-sulphur compounds.

Powdery mildew incidence on leaves on 6 December ranged from 5-24% (Table 2C). The main effect for sulphur (Table 2A) suggests that powdery mildew control was significantly worse with sulphur applications. However, the sulphur x non-sulphur interaction (Table 2C) shows that it was worse for BC and VO, but not for CH and CS. In the main effect for non-sulphur compounds, VO and CH gave the best control. Powdery mildew control by BC was poor.

Fruit russet on 6 December varied from 8-68% (Table 2C). The programme with sulphur alone caused very little russet, and there was no significant main effect for sulphur, nor for the interaction between sulphur and non-sulphur compounds. CH caused significantly more russet than the other non-sulphur compounds (Table 2B), followed by VO and BC, which did not differ significantly. CS caused significantly less russet than the other non-sulphur compounds.

Harvest data on 27 February showed that programmes with VO and BC yielded significantly less fruit than those with CH and CS (Table 2B). The lack of fruit in VO and BC programmes appeared to result from fruit drop throughout the season, rather than from poor fruit set. Fruit yield in the CS-S programme was inexplicably low. The main effect for sulphur was significant (Table 2A), and indicated that spray programmes with additional sulphur had significantly more fruit than those without additional sulphur.

DISCUSSION

The most effective fungicide tested for both black spot and powdery mildew control was cupric hydroxide, but it caused severe fruit russet. As a result this product could not be recommended at the application rate of 250 g/100 litres used in this trial. While lower application rates may reduce phytotoxicity, they may be accompanied by reduced disease control. The copper sulphate/sulphur formulation gave moderate levels of both black spot and powdery mildew control, caused relatively little russet, and gave the highest yield.

Fruit yields were severely depressed by both vegetable oil and bentonite clay. Vegetable oil may have a use as a chemical thinning agent during early fruit development, and its efficacy against powdery mildew would be useful in that part of the growing season. However, caution would be required as vegetable oil caused considerable fruit russet in the trial. Bentonite clay gave some black spot control, but its use appears limited because of fruit russet and poor powdery mildew control. Powdery mildew control with bentonite clay and vegetable oil was worse when additional sulphur applications were used, and this effect cannot at present be explained. Black spot control on leaves and fruit was generally improved when sulphur was alternated with one of the other fungicides. While this was not surprising, since the additional sulphur involved additional doses of fungicide, sulphur by itself appeared to be relatively ineffective for black spot control.

Had the number of marketable fruit been quantified, it would have been very low even with the best spray programme, due to severe black spot and russet. It is unlikely that economic returns would have resulted had it been a commercial production situation, even if there was a price advantage for organically-grown fruit. Black spot control was difficult in the 1990-91 growing season because of wet weather in January and February (17% and 23% above normal rainfall respectively). In addition, the cultivar Royal Gala was susceptible to both black spot and powdery mildew. With a less susceptible cultivar, and a season with more favourable weather, more saleable fruit may be achieved. However, it is likely that the combination of high cultivar susceptibility and low efficacy of the fungicides currently available for disease control will be continuing problems for the economic viability of organic production systems.

Copper and sulphur compounds, rather than the alternatives tested, appear most promising for disease control in organic orchards. Better control of russet may be achieved by varying the form of copper, the proportions of copper and sulphur, and the application rate. It is likely that prolonged intensive use of copper will be unacceptable in organic production because of its relatively high toxicity. To reduce the use of copper fungicides in the future, research is required into incorporation of disease forecasting methods to time sprays better (Beresford *et al* 1989; Manktelow *et al* 1989) and into the possible use of biological agents. Disease resistant cultivars must also be developed to reduce the reliance on chemicals for disease control.

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