EAST MALLING RESEARCH

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Tests of the phytotoxicity of sulphur to blackcurrants 2005

Undertaken for Defra and the GlaxoSmithKline/HDC growers fund (Defra project HH3115TSF.)

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Authentication

I declare that this work was done under my supervision according to the procedures described herein and that this report is a true and accurate record of the results obtained.

Signed…………………………………………………………..
J. V. Cross

Dated…………………………………………………………

East Malling Research is an officially recognised efficacy testing organisation (Certification No. ORETO 043)

Tests of the phytotoxicity of sulphur to blackcurrants, 2005

Summary

A replicated field experiment was done at East Malling Research in 2005 to determine the phytotoxic effects to the blackcurrant varieties Ben Hope and Ben Tirran of two early season foliar sprays of sulphur and the effect of a range of additional sprays of sulphur and or Masai as shown in the table below. These treatments were the same as tested in the acaricides trial done in 2005, though a treatment with the novel acaricide acrinathrin was omitted.

Late dormant	First grape visible	Additional sprays†
Sulphur SC	Sulphur SC	-
Sulphur SC	Sulphur SC	Masai
Sulphur SC	Sulphur SC	Masai + Sulphur SC 1/3 rate
Sulphur DF	Sulphur DF	Masai
Sulphur SC	Sulphur SC	Sulphur SC 1/3 rate
Sulphur SC	Sulphur SC	3 x Sulphur SC 1/3 rate
Sulphur SC	Sulphur SC	3 sprays Sulphur SC 1/10 rate
Untreated	Untreated	Untreated
†single sprays were applied at the end of flower, the programmes of sprays were applied at approximately 2 week intervals following on from the first grape visible spray		

The full dose rates for application of the sprayable concentrate (SC) and dry flowable (DF) formulations of sulphur were 10 litres and 10 kg of 80% product respectively. Sprays were applied at 500 l/ha with a hand lance, which gave complete cover. The effects of the treatments were assessed by measuring yields of hand picked and dropped ripe fruit and the length of extension growth. The main findings and conclusions of the experiment were:

- None of the treatments tested caused any visual symptoms of phytotoxicity on either Ben Hope or Ben Tirran. None had any significant effects on the yield of Ben Tirran.
- Two early season sprays of sulphur SC, at the bud burst and first grape visible growth stages respectively, did not cause significant phytotoxicity to Ben Hope.
- Comparison of yields from treatment with two early season sprays of sulphur SC versus sulphur DF, both followed by a spray of Masai at the end of flower, suggests that the two early sprays of sulphur DF were phytotoxic to Ben Hope, reducing yield by 20% compared to the untreated control. Caution in drawing the conclusion that DF formulations are more phytotoxic than SC is urged.
- Sprays of Masai applied in hot conditions (air temp 26-30 ºC) at end of flowering were not phytotoxic to Ben Hope.
- A single additional spray of sulphur SC at the end of flowering, or the programmes of 3 sprays of sulphur SC at 1/3 or 1/10 rate at fortnightly intervals, were phytotoxic to Ben Hope, reducing yield by 20%. Application of the end of flowering sprays in hot conditions (air temp 26-30 ºC) is likely to have caused or exacerbated the phytotoxic effects.

Introduction

In project HH3115TSF, jointly funded by Defra and the GlaxoSmithKline blackcurrant grower's research fund, a 3 year series of experiments is being done at East Malling Research to determine the phytotoxic effects of foliar sprays of sulphur on blackcurrant. The conclusions of the first experiment done in 2003 (Cross and Harris, 2004) were as follows:

- A single foliar spray of sulphur (12.5 l of sulphur 800 g/l SC in 500 l water/ha) applied just before flowering was phytotoxic to 2 year old bushes of the blackcurrant varieties Ben Gairn, Ben Hope, Ben Lomond, Baldwin and Ben Tirran causing leaf discoloration, an 11.4% reduction in yield and possible slight reductions in growth.
- A single spray just of sulphur just after flower did not significantly reduce yield or growth.
- A programme of 3 sprays, one just pre-flowering, one post flowering and a third approximately 14 days later, caused greater phytotoxicity than the single pre-flowering spray, reducing yield on average by 14.6%.
- The data suggests that Baldwin may be more sensitive to sulphur than the other varieties, but this could not be proven by detailed statistical analyses.

A second field experiment was done at East Malling Research in 2004 to determine the phytotoxic effects of foliar sprays of sulphur (12.5 l of 800 g/l sulphur SC in 500 litres water /ha) applied with a hand lance just before grape emergence (Growth stage C3-D) or at the end of flowering (GS I2-I3), or of two sprays one at each of these timings, on the yield and growth of the blackcurrant varieties Baldwin, Ben Gairn, Ben Hope Ben Lomond or Ben Tirran, in comparison with untreated controls. The conclusions of this second experiment were as follows:

- The treatments caused clearly visible symptoms of phytotoxicity on all the varieties except Ben Tirran.
- The two spray (pre-grape emergence + end of flower) treatment caused the most severe phytotoxicity, followed by the end of flower treatment with the least phytotoxicity being caused by the pre-grape emergence treatment.
- The severity of the visual phytotoxicity symptoms differed markedly between varieties. Symptoms were most severe on Ben Gairn where the lower leaves were blackened, followed by Baldwin. Ben Hope and Ben Lomond showed only slight symptoms. The effects of the treatments were barely perceptible on the Ben Tirran
- The yields of Ben Lomond and Ben Tirran did not appear to be reduced significantly by any of the sulphur treatments.
- The pre-grape + end of flowering sulphur treatment reduced yield by 19% averaged across all varieties, but by 27% on Baldwin.
- The single end of flowering treatment reduced yield by 13.5% on average with the strongest treatment effects on Baldwin.
- The pre-grape emergence spray reduced the yield of Baldwin by 17%, but did not significantly reduce the yields of the other varieties.
- The sulphur treatments did not affect the mean length of extension shoots or the numbers of shoots per bush. There was slight evidence of greater overall growth per bush for the untreated controls than for the two single spray treatments, but

the logical pattern was somewhat upset by the combined treatment having the second highest total growth (although this was not significantly different from any other treatment).

- The severity of the phytotoxicity caused by the end of flower sprays may have been exacerbated by the high temperatures (20.5-25.0 ºC) when treatments were applied. In the 2003 experiment, where phytotoxicity from post flowering sprays was less pronounced, temperatures at the time of application were lower, 14 ºC and 21 °C for the sprays at the end of flower and 2 weeks later respectively.

Here we report the results of the third experiment done in 2005. The objective was to conduct a field experiment to evaluate the effects of seven different programmes of sprays of sulphur factorially on the yield and growth of two blackcurrant varieties Ben Hope and Ben Tirran, in comparison with untreated controls. The seven spray programmes consisted of three different timings and combinations of sulphur at the recommended rate, sulphur 1/3 recommended rate and in mixture with Masai applied during the growing season.

Methods and materials

Site

An experimental plantation (CE 179; MR O.S. Landranger 188 708554) CE 186 was planted at East Malling Research in March 2003 with 1 year old rooted bushes for the purposes of the experiment. It consisted of six 8 x 4 arrays of 32 plots, three arrays of each of the two varieties Ben Hope, Ben Tirran (total 192 plots). The row spacing was 3.0 m and the spacing between bushes in the row was 0.5m. Plots were separated by 1.5 m in the row. The plant density was thus 6667 bushes/ha.

Treatments

Treatments were foliar sprays of sulphur applied at bud burst and at grape emergence supplemented with various additional sprays starting at the end of flowering as shown in Table 1. Products and their rates of application are given in Table 2. Treatments were applied at the appropriate time for the particular variety.

Table 1. Treatments in blackcurrant acaricides phytotoxicity experiment 2005

Treatment and mnemonic	Time of application of sprays				
	Late dormant†	**First grape visible‡**	**Additional sprays**	**Ben Hope**	**Ben Tirran**
A SL,SL	Sulphur SC	Sulphur SC			
B SL,SL,M	Sulphur SC	Sulphur SC	Masai end of flower	27 May	20 June
C SL,SL,M+1/3SL	Sulphur SC	Sulphur SC	Masai + Sulphur SC 1/3 rate end of flower	27 May	20 June
D SP,SP,M	Sulphur DF	Sulphur DF	Masai at end of flower	27 May	20 June
E SL,SL,1/3SL	Sulphur SC	Sulphur SC	Sulphur SC 1/3 rate end of flower	27 May	20 June
F SL,SL,1/3SLx3	Sulphur SC	Sulphur SC	3 sprays Sulphur SC 1/3 rate	28 Apr, 12 & 27 May	12, 27 May, 20 Jun
G SL,SL,1/10SLx3	Sulphur SC	Sulphur SC	3 sprays Sulphur SC 1/10 rate	28 Apr, 12 & 27 May	12, 27 May, 20 Jun
H Untreated	Untreated†	-			

† 31 March Hope, 7 April Tirran ‡12 April Hope, 28 April Tirran

Table 2. Products and their rates of application.

Treatment name	Active substance	Product	Dose product (/ha)
Sulphur SC	Sulphur 800 g/l SC	Sulphur Flowable†	10.0 litre
Sulphur SC 1/3 rate	Sulphur 800 g/l SC	Sulphur Flowable†	3.3 litre
Sulphur SC 1/10 rate	Sulphur 800 g/l SC	Sulphur Flowable†	1.0 litre
Sulphur DF	Sulphur 80% DF	Kumulus DF	10.0 kg
Masai	Tebufenpyrad 20% w/w WB	Masai	0.5 kg

† United Phosphorus

Spray application

Sprays were applied with a Cooper Pegler CP 2000 knapsack sprayer fitted with a handlance in a spray volume of 500 l/ha. 225 ml of sprayate was applied / bush. The applications gave good, near complete, spray cover.

Experimental design and layout

The experiment consisted of 6 eight by four arrays of plots, three arrays of each variety. variety each array containing four replicates of each of the eight treatments (see Table 3). Each plot consists of six bushes in a row 0.5 m between bushes, 1.0 m between plots and 3 m between rows.

Meteorological records

Wet and dry bulb temperature were measured with a whirling psychrometer, wind speed and direction were taken before and after spraying. Full records were available from the EMR met station.

Table 4. Weather conditions at the time of spray application

Date (2005)	Temp ºC	Humidity %
31 March	11	90
7 April	14	60
12 April	15	65-80
28 April	16	
12 May	13	60-65
27 May	26-30	65-75
20 June	27	70-80%

Table 3. Experiment randomisation

	Plot	Treatment	Block	Plot	Treatment	Block	Plot	Treatment	Block	Plot	Treatment	Block	Plot	Treatment	Block	Plot	Treatment	Block	Plot	Treatment	Block	Plot	Treatment	Block
Array 1	1	G	1	2	E	1	3	B	1	4	F	1	5	D	3	6	F	3	7	H	3	8	A	3
Tirran	17	A	1	18	H	1	19	D	1	20	C	1	21	C	3	22	B	3	23	G	3	24	E	3
	33	B	2	34	G	2	35	F	2	36	D	2	37	F	4	38	D	4	39	C	4	40	G	4
	49	E	2	50	C	2	51	A	2	52	H	2	53	H	4	54	A	4	55	E	4	56	B	4
Array 2	65	A	5	66	F	5	67	D	5	68	H	5	69	D	7	70	A	7	71	H	7	72	G	7
Hope	81	E	5	82	G	5	83	C	5	84	B	5	85	F	7	86	B	7	87	E	7	88	C	7
	97	G	6	98	E	6	99	F	6	100	A	6	101	B	8	102	H	8	103	G	8	104	E	8
	113	H	6	114	C	6	115	B	6	116	D	6	117	C	8	118	D	8	119	A	8	120	F	8
Array 3	129	F	9	130	A	9	131	B	9	132	D	9	133	B	11	134	D	11	135	C	11	136	A	11
Tirran	145	H	9	146	E	9	147	G	9	148	C	9	149	E	11	150	H	11	151	F	11	152	G	11
	161	G	10	162	B	10	163	H	10	164	F	10	165	A	12	166	G	12	167	E	12	168	B	12
	177	D	10	178	C	10	179	A	10	180	E	10	181	C	12	182	F	12	183	D	12	184	H	12
Array 4	9	C	13	10	B	13	11	D	13	12	E	13	13	E	15	14	D	15	15	C	15	16	F	15
Hope	25	F	13	26	H	13	27	A	13	28	G	13	29	A	15	30	G	15	31	H	15	32	B	15
	41	G	14	42	F	14	43	E	14	44	D	14	45	B	16	46	C	16	47	G	16	48	A	16
	57	H	14	58	A	14	59	B	14	60	C	14	61	D	16	62	E	16	63	F	16	64	H	16
Array 5	73	B	17	74	G	17	75	F	17	76	A	17	77	A	19	78	H	19	79	D	19	80	G	19
Tirran	89	D	17	90	E	17	91	H	17	92	C	17	93	F	19	94	C	19	95	E	19	96	B	19
	105	G	18	106	D	18	107	C	18	108	F	18	109	C	20	110	F	20	111	A	20	112	D	20
	121	H	18	122	A	18	123	B	18	124	E	18	125	E	20	126	B	20	127	G	20	128	H	20
Array 6	137	H	21	138	B	21	139	D	21	140	A	21	141	E	23	142	F	23	143	B	23	144	H	23
Hope	153	C	21	154	E	21	155	F	21	156	G	21	157	G	23	158	C	23	159	A	23	160	D	23
	169	A	22	170	D	22	171	H	22	172	B	22	173	B	24	174	A	24	175	C	24	176	E	24
	185	F	22	186	G	22	187	E	22	188	C	22	189	D	24	190	H	24	191	G	24	192	F	24

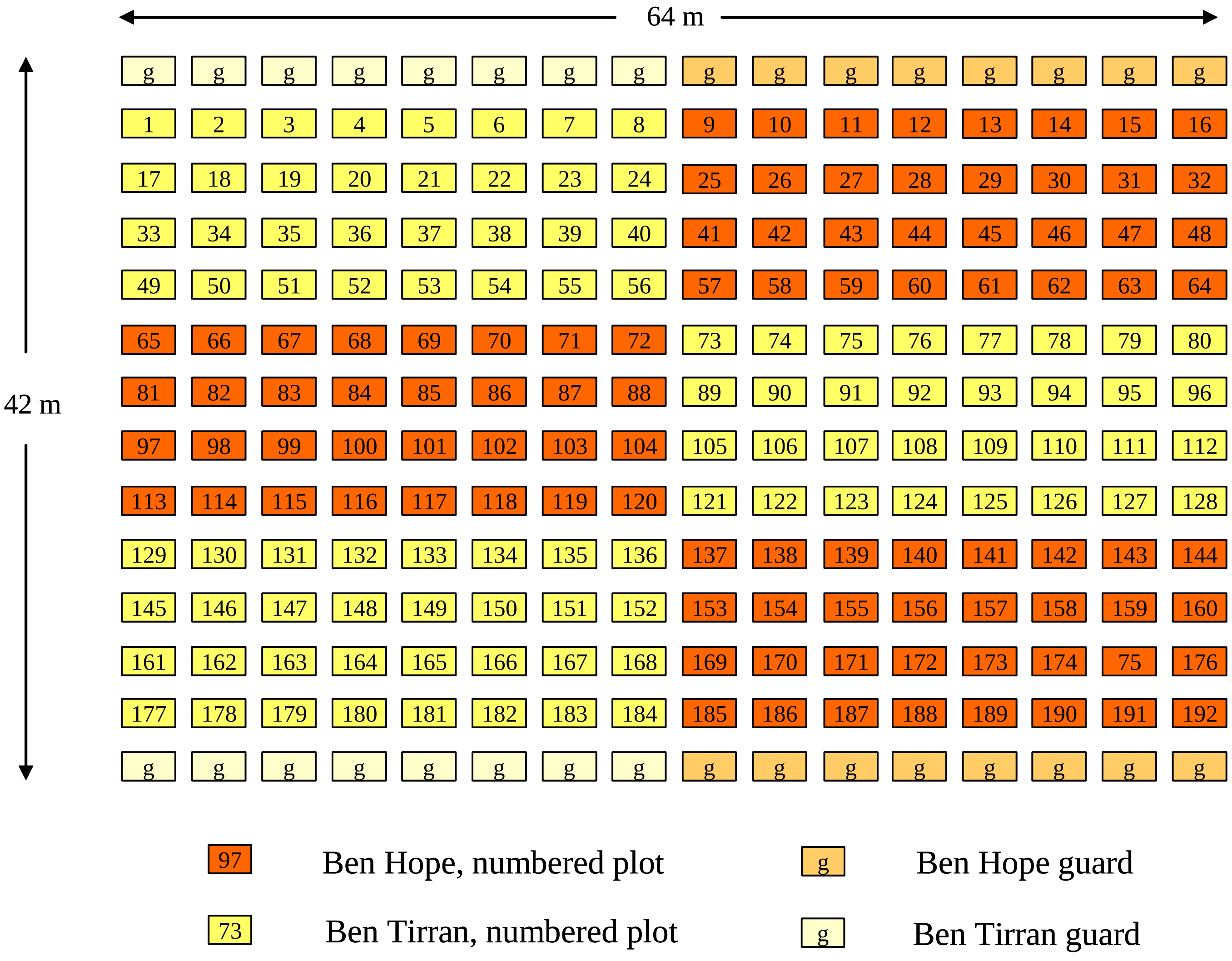

Figure 1. Layout of the experimental plots

Assessments

Visual phytotoxicity symptoms: The plots were inspected for visual signs of phytotoxicity on 14 June 2004.

Yields: Yields were recorded at harvest by hand picking and weighing each bush in each plot. The fallen fruit on the ground under each bush was gathered and weighed separately for each bush. The fruit was harvested at the appropriate time for each variety: Ben Hope was picked on 3 August 2005, Ben Tirran on 17 August 2005.

Growth: Growth was determined by estimating the average length of extension growth at the end of the season. The length of each of the current season's shoots was measured to the nearest cm on two bushes in the centre of each plot (bush numbers 3 and 4). The total length of shoots on the bush will be calculated.

Statistical analysis

Yields: Analysis of variance was done on the total yield (picked + dropped fruit) per plot for each variety separately.

Extension growth

Results

Visual symptoms of phytotoxicity

No visual phytotoxicity symptoms were apparent.

Yield

The analyses of variance showed strong, statistically significant (Fprob=0.032) for Ben Hope (Table 5). LSD testing (P=0.05) indicated that treatments C, D, E and G all significantly reduced yield ($P<0.05$) compared to the untreated control. On average, these treatments reduced yield by 20% compared to the untreated control. Reduction by treatment F was not quite significant at the 5% level, but very nearly so. The fact that treatment D reduced yield significantly whereas treatment B did not suggests that the two early season sprays of the DF formulation of sulphur caused phytotoxicity whereas the SC formulation did not. All the treatments with additional sulphur SC sprays reduced yield significantly, indicating application of sulphur SC at these later timings causes phytotoxicity to Ben Hope, even when only a single spray at 1/3 dose is applied. Treatment effects were not even nearly statistically significant for Ben Tirran (Fprob=0.885).

Table 5. Mean yield (t/ha)

Treatment		Ben Hope	Ben Tirran
A	SL,SL	6.54	2.88
B	SL,SL,M	7.10	3.57
C	SL,SL,M+1/3SL	5.54*	3.58
D	SP,SP,M	5.56*	3.25
E	SL,SL,1/3SL	5.53*	3.21
F	SL,SL,1/3SLx3	5.80†	3.10
G	SL,SL,1/10SLx3	5.69*	3.01
H	Untreated	7.00	3.26
Fprob		0.032	0.885
SED (77 df)		0.623	0.536
LSD (P=0.05)		1.241	1.067

*Significantly less than the control P < 0.05
†Significantly less than control P < 0.06

Growth

Length of extension shoots:

Number of extension shoots per bush:

Total length of extension growth per bush: Relationship between total extension growth and yield in 2004:

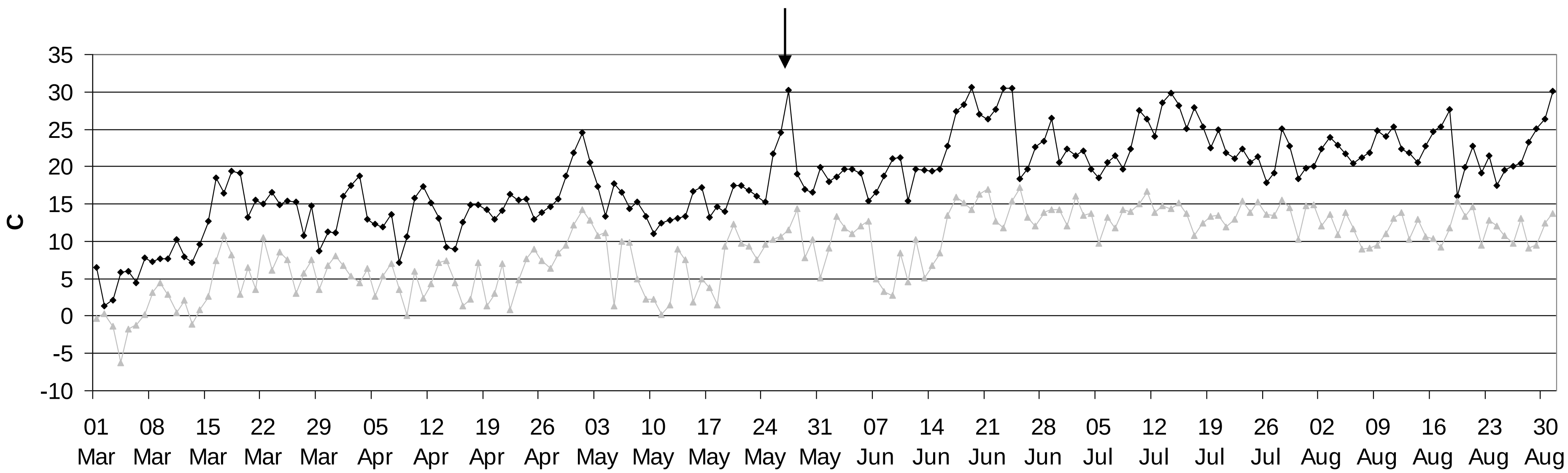

Figure 2. Daily maximum and minimum temperature (º C). The timing of the end of flower sprays on Ben Hope is marked with an arrow.

Discussion

The previous phytotoxicity experiments in 2003 and 2004 indicated that there were large differences in the sulphur shyness of different blackcurrant varieties. Ben Hope and especially Ben Tirran were of low risk of phytotoxicity from sulphur sprays. These earlier findings are corroborated by this experiment. Further work is needed to investigate the phytotoxic effects of sulphur on different blackcurrant varieties.

This experiment also confirms earlier work that two early season sprays of sulphur SC are not phytotoxic to these varieties. However, comparison of yields from treatment B with D, suggests that the two early sprays of sulphur DF were phytotoxic to Ben Hope, reducing yield by 20% compared to the untreated control. This single result has to be viewed with caution. Further work is needed to investigate the phytotoxic effects of sulphur SC versus sulphur DF formulations on different blackcurrant varieties.

The sprays at the end of flowering of Ben Hope on 27 May were applied in hot conditions (26-30 ºC). The previous experiments have also pointed to an increased risk of sulphur phytotoxicity in high temperatures. Application of end of flowering sprays in hot conditions is likely to have caused or exacerbated the phytotoxic effects. It is interesting that these effects were apparent even at 1/10 dose. It is also interesting to speculate that sulphur phytotoxicity may only occur when application is made when temperatures are high, whatever the growth stage. The finding that two early season sprays is not phytotoxic may simply because the temperatures were low at the time of and/or after application were low.

Conclusions

- None of the treatments tested caused any visual symptoms of phytotoxicity on either Ben Hope or Ben Tirran. None had any significant effects on the yield of Ben Tirran.
- Two early season sprays of sulphur SC, at the bud burst and first grape visible growth stages respectively, did not cause significant phytotoxicity to Ben Hope.
- Comparison of yields from treatment with two early season sprays of sulphur SC versus sulphur DF, both followed by a spray of Masai at the end of flower, suggests that the two early sprays of sulphur DF were phytotoxic to Ben Hope, reducing yield by 20% compared to the untreated control. Caution in drawing the conclusion that DF formulations are more phytotoxic than SC is urged.
- Sprays of Masai applied in hot conditions (air temp 26-30 ºC) at end of flowering were not phytotoxic to Ben Hope.
- A single additional spray of sulphur SC at the end of flowering, or the programmes of 3 sprays of sulphur SC at 1/3 or 1/10 rate at fortnightly intervals, were phytotoxic to Ben Hope, reducing yield by 20%. Application of the end of flowering sprays in hot conditions (air temp 26-30 ºC) is likely to have caused or exacerbated the phytotoxic effects.

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