RED SCALE CONTROL INVESTIGATIONS ON CITRUS IN QUEENSLAND, 1951–1958

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SUMMARY

Between 1951 and 1958 seasonal history observations and 12 field control trials were carried through on citrus in Queensland, mainly in the Gayndah district, on red scale (*Aonidiella aurantii* (Mask.)). Observations confirmed earlier work indicating that five generations and a partial sixth occurred each year. While these may overlap, distinct brood emergences were observed in October, December and May.

The earlier field trials investigated timing, concentration and combination of white oil and parathion sprays, and two formulations of parathion. The most effective treatment for scale control was found to be white oil at a concentration of 1 in 60 used twice in early December with a 2-week interval, followed by a 1 in 40 white oil spray in late January. The follow-up spray was best used in early April for Late Valencia orange. Glen Retreat mandarins required a lower oil dosage to avoid fruit injury, but control was easier in mandarins due to natural throwing of scale from the rind. For this variety it was found that single sprays in early December and late January of 1 in 80 white oil plus 0·015 per cent. parathion emulsion were quite effective.

Later field trials indicated that a paraffinic oil was equal to white oil as a scalicide and produced less damage on susceptible trees. Preliminary work on malathion showed that it had relatively low scalicidal value alone but a mixture of 1 in 80 white oil and 0·05 per cent. malathion gave indications of good protection.

White oil did not affect time of fruit maturity. The only effect on colouring of oranges caused by oil sprays was on early varieties picked green-mature and artificially coloured. The effect was of little consequence in fruit coloured on trees and late fruit.

I. INTRODUCTION

Red scale (*Aonidiella aurantii* (Mask.)) occurs as a pest of citrus throughout Queensland, and as the major pest in several subcoastal and inland areas. The most important of these areas is centred at Gayndah on the Burnett River, where standard measures for red scale control in the past consisted of

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white oil spraying and cyanide fumigation. These have been reported by Summerville (1934), Veitch (1938), Caldwell and Blackford (1941), May (1947), and officers of the Department of Agriculture and Stock (1951).

During the war years, materials and equipment for fumigation increased in cost and were difficult to obtain, so white oil alone was afterwards used almost entirely. Although control measures are assiduously applied in that district, reports varied on control efficiency and tree damage by oil. When, therefore, overseas reports such as that by Cressman, Munger, and Broadbent (1950) indicated success with parathion in controlling red scale, a trial of this material was warranted. At the same time, it seemed desirable to test oil as a double spray with reduced concentration and an interval of about two weeks between applications. This work was carried out between 1951 and 1955. During the first season the problem was surveyed; in each of the three subsequent seasons three trials were carried through. Following this work paraffinic oil became available and was compared with white oil in 1956-57. Malathion had been found of some value overseas for red scale control by Carman (1956) and was therefore compared with the oil sprays in the last trial.

II. SEASONAL HISTORY OBSERVATIONS

Samples giving a total of 200 scales on a minimum of 20 leaves or fruits were examined by lifting and probing and the numbers of scale alive and dead recorded. The occurrence of the first instar was also noted. This was done periodically through the year at Gayndah. At Palmwoods, where populations were lower, regular observations were made on marked leaves and fruits.

These studies confirmed early life-history studies made in Queensland by Summerville (1934), who stated that "young are produced practically continuously throughout the year" and "it is thought that normally there are five broods each year . . ." and "at times a partial sixth brood may appear."

Winter hatchings are very small and mortality is high. The major portion of the adult October population is produced in the May hatching and develops slowly through the winter. The first spring brood can commence in October to develop on the wood and leaves, while in November mobile forms may move onto the fruit. A second main hatching commences in December. Later the different generations overlap and become indistinguishable in a sample population. In May, however, an appreciable hatching is generally distinct. The occurrence of the December peak in breeding is considered of major importance in the timing of control measures.

Marked populations confirmed that five generations occur during the year, and there was occasionally a partial sixth generation. This life-history picture

makes the red scale problem in Queensland very different from that in Victoria and South Australia, where there are three generations with a partial fourth. This was reported by Ward and Johnston (1937) and Strickland (1938).

III. SCALICIDE TRIALS

(a) Materials

White oil.—An emulsion concentrate containing 72·5 per cent. w/v of white petroleum oil (in 1956-57 and 1957-58 trials).

Unspecified formulations (in 1952-53, 1953-54 and 1954-55 trials) but undoubtedly comparable to the above.

Paraffinic oil.—An emulsifiable concentrate containing 82 per cent. w/v paraffinic petroleum oil.

Parathion.—A dispersible powder containing 15 per cent. w/w parathion (in 1952-53 trials).

A dispersible powder containing 50 per cent. w/w parathion (in trials after 1953).

An emulsifiable concentrate containing 25 per cent. w/v parathion (in 1952-53 trials).

An emulsifiable concentrate containing 50 per cent. w/v parathion (in 1956-57 trials).

Unspecified formulations (in 1953-54 trials).

Malathion.—A miscible oil containing 50 per cent. w/v malathion.

Cyanide fumigation.—Unspecified materials. Dosage according to tables published by Veitch (1938).

(b) Methods

General.—All trials were conducted in irrigated orchards of the Gayndah district on standard varieties of orange and mandarin. Uniform tree size and uniform areas without missing trees were a primary consideration in the selection of sites. Sprays were applied by hand lances, or by "brooms", fed by various power sprays delivering pressures in the range 450–600 lb per sq. in. Maximum tree cover was the primary aim in all spraying operations. Spray usage to achieve it was variable, depending on size and foliage density; up to 20 gal per tree was used.

Co-operating orchardists applied routine control sprays for pests and diseases other than red scale. These included lime sulphur in midwinter, copper/zinc at petal fall, wettable sulphur as necessary for maori mite (*Phyllocoptruta oleivora* (Ashm.)), and DDT as necessary for fruit fly (*Strumeta tryoni* (Frogg.)) and bugs, mainly *Biprorulus bibax* Bred.

Layout, details of the various treatments and other relevant information are given later with the results for each trial. Single-tree plots were used in all trials. Where "double sprays" were made these comprised two applications two weeks apart.

Assessment of Scale Infestation.—The criterion selected for comparing pest kill efficacy was the degree of fruit blemish, since effects of the pest on tree vigour and crop size are of consequence only in the absence of control sprays. The degree of blemish was assessed on random samples at harvesting by (1) sorting 200 fruit per plot into categories of scale infestation, (2) counting the total number of scales on each of 20 fruit per plot, and (3) determining, by lifting and probing, the percentage of living scales, using a 200-scale sample spread over at least 10 fruit. The three types of count are now discussed separately.

The top market grade of fruit known as "specials", fit for export, would include fruit with 25 scales or fewer before brushing. Those with up to 100 scales could be placed, after brushing, into the "standard" grade, provided the percentage of living scales was not much higher than average and brushing was efficient. Recorded figures for the 200 fruit per plot were consequently adjusted for presentation to approximate these limits.

In the 1952-53 trials the number of scales per fruit were counted in 6 categories, namely 0, 1–5, 6–20, 21–100, 101–500, over 500. These have been grouped to show the percentages of fruit with 0–20 and 0–100 scales. Seven categories were used in subsequent trials—0, 1–25, 26–50, 51–75, 76–100, 101–500, over 500—and these are consolidated to present the percentages of fruit in the 0–25 and 0–100 groups. This method of sorting a large fraction of the crop into scale grades gave the best measure of spray efficacy.

The counts of total scales per fruit may be used to compare roughly the relative degrees of infestation of the trials. The occurrence of occasional fruits heavily infested by scales on the better plots led to difficulties in using the count to compare treatments within a trial.

Figures for percentages of living scales at harvesting are from counts made some time after spray applications. They were rarely significant and do not reflect the relative benefits derived from the sprays. This type of count therefore was not included in the last trial.

Tree and Fruit Damage.—Spray burn and effects of sprays on fruit colouring were noted from observations at harvesting. Fruit maturity was assessed in two trials by refractometer readings for total soluble solids in juice, expressed as a w/w percentage. Juice acidity was measured by titration with decinormal sodium hydroxide solution. A titration minimum of 24 ml of soda to 10 ml of juice is required for navel oranges under regulations of the Queensland Government (Anon. 1960).

(c) Results of 1952-53 Trials

Trial on Young Washington Navel Orange.—A 6 x 4 randomized layout was used on a block of vigorous 6-year-old Washington navels with a small initial scale population which increased considerably during the season. Results of scale counts and grades are presented in Table 1. The block was harvested green-mature on April 14 and coloured artificially. The colouring of fruit which had been sprayed with oil was delayed and extra time was required in the colouring chamber.

TABLE 1

1952–53 TRIAL ON YOUNG NAVEL ORANGES

Treatment	Time Applied	Fruit in Scale Grades				Living Scales (%)	Mean Scales per Fruit
		0–20 Scales per Fruit		0–100 Scales per Fruit			
		Mean (%)	Transformed Mean*	Mean (%)	Transformed Mean*		
Untreated		0·1	2·02	1·3	6·65	34·2	1806
White oil 1 in 40	December						
Fumigation	Late January	34·8	36·18	60·2	50·90	32·3	271
White oil 1 in 60 double spray ..	December						
White oil 1 in 40	Late January	78·2	62·15	93·0	74·65	19·6	30
Parathion dispersible powder 0·06%	February	11·3	19·60	28·4	32·18	32·2	424
Parathion dispersible powder 0·06% double spray	December						
Parathion dispersible powder 0·06%	Late January	68·8	56·02	77·8	61·88	33·8	182
Parathion emulsion 0·015% double spray	December						
Parathion emulsion 0·015% ..	Late January	16·1	23·62	33·4	35·30	35·9	473
Necessary differences for significance	5%		11·83		12·49		273
	1%		16·36		17·28		383

* Inverse sine.

Trial on Old Washington Navel Orange.—A 6 x 4 randomized layout was used on a block of large Washington navels which had been in full production for many years. The initial scale population did not build up much during the season. Results are presented in Table 2. The fruit was harvested on May 19 when fully mature, but some artificial colouring was needed by oil-treated fruit.

TABLE 2

1952–53 TRIAL ON OLD NAVEL ORANGE

Treatment	Time Applied	Fruit in Scale Grades				Living Scales (%)	Mean Scales per Fruit
		0–20 Scales per Fruit		0–100 Scales per Fruit			
		Mean (%)	Transformed Mean*	Mean (%)	Transformed Mean*		
Untreated		53·0	46·72	78·4	62·28	16·0	81·3
White oil 1 in 40	December						
Fumigation	Late January	73·0	58·68	86·3	69·25	12·6	96·7
White oil 1 in 60 double spray ..	December						
White oil 1 in 40	Late January	96·2	78·28	99·8	87·58	3·4	1·1
Parathion dispersible powder 0·06%	February	74·2	59·48	92·6	74·20	8·8	48·2
Parathion dispersible powder 0·06% double spray	December						
Parathion dispersible powder 0·06%	Late January	91·6	73·20	95·0	77·02	9·3	29·3
Parathion emulsion 0·015% double spray	December						
Parathion emulsion 0·015% ..	Late January	80·3	63·65	91·1	72·60	7·8	59·2
Necessary differences for significance { 5%			10·97		9·22	7·4	
1%			15·18		12·75	10·2	

* Inverse sine.

Trial on Late Valencia Orange.—A 6 x 4 randomized layout was used on a block of 12-year-old Late Valencias approaching full bearing. Scale population build-up during the season was large. Results are presented in Table 3. The fruit was harvested fully coloured on September 8. On this variety, oil did not give an obvious colour difference, but as in other varieties, it made fruit more smooth and shiny.

Discussion.—An improvement in fruit quality was shown by double-spraying with white oil with follow-up oil spray above the standard single oil with

follow-up fumigation. This was also true of the double parathion dispersible powder spray with follow-up parathion. In two of the three trials the oil showed improvement over the parathion. Two factors which influenced results were the differences in build-up of scale populations in the several trials, and the difference in time of harvesting. Late harvesting allowed greater winter mortality and throwing of dead scales before assessment.

TABLE 3

1952–53 TRIAL ON VALENCIA ORANGE

Treatment	Time Applied	Fruit in Scale Grades				Living Scales (%)
		0–20 Scales per Fruit		0–100 Scales per Fruit		
		Mean (%)	Transformed Mean*	Mean (%)	Transformed Mean*	
Untreated		5·5	13·52	25·1	30·05	5·8
White oil 1 in 40 Fumigation	December Late January	55·4	48·12	80·7	63·95	5·8
White oil 1 in 60 double spray White oil 1 in 40	December March	70·1	56·82	83·8	66·28	1·5
Parathion dispersible powder 0·06%	February	4·4	12·10	31·0	33·82	3·8
Parathion dispersible powder 0·06% double spray Parathion dispersible powder 0·06%	December March	63·9	53·05	83·6	66·12	4·7
Parathion emulsion 0·015% double spray Parathion emulsion 0·015%	December March	18·1	25·18	49·2	44·55	2·8
Necessary differences for significance	5%		10·65		15·13	
	1%		14·73		20·92	

* Inverse sine.

Summarizing observations on fruit colouring: the delay caused by oil was important only in the early-maturing variety and was accentuated by harvesting green-mature fruit. The greater total dosage of oil necessitated the longer period in the colouring chamber.

(d) Results of 1953-54 Trials

Trial on Young Washington Navel Orange.—A 10 x 4 randomized layout was used on 5-year-old Washington navels carrying a heavy crop. Scale populations became very large. Results of scale counts and grades are presented in Table 4. The fruit was harvested on May 3 showing early colour. Those on control trees ripened prematurely and were dry due to the large scale population. Those on oil-sprayed trees had colouring retarded, more so with heavier dosages. Maturity analyses of juice gave a range 7·61–9·13 (refractometer readings) for percentage total soluble solids for all fruit. Acidity readings were 9·4–13·1 ml. In these ranges untreated trees averaged 8·55 and 12·55 respectively. Flavour throughout indicated immature harvesting.

Trial on Old Washington Navel Orange.—A 10 x 4 randomized layout was used on 25-year-old Washington navels in vigorous condition. Scale populations were small. Results of scale counts and grades are presented in Table 5. The fruit was harvested mature on May 23 but some colouring was carried out. The difference between oil and other treatments on fruit colouring was of minor significance in this trial. Maturity analyses for each plot comparable to the previous trial gave a range of 7·91–11·87 for soluble solids and 8·0–16·0 for acidity. There were no significant differences between treatments.

Trial on Late Valencia Orange—A 10 x 4 randomized layout was used on 30-year-old Late Valencias in full bearing. Scale populations built up considerably over the summer but again the late variety threw off much of it before the time of sampling. Results are presented in Table 6. The fruit was harvested fully coloured on September 6 and no differences in colouring due to oil treatment were observed.

Discussion.—The three schedules giving consistently good results were (1) double white oil 1 in 60, with white oil 1 in 40 following, (2) double parathion dispersible powder 0·06 per cent., with the same spray following, and (3) double parathion dispersible powder 0·03 per cent. plus white oil 1 in 80, with the same spray following. Reduced strength oil sprays gave good control of light infestations. Parathion lost some effect when used as an emulsion when reduced below 0·06 per cent. or when reduced below 3 sprays.

The maturity tests demonstrated that the recognized measures of internal quality were not significantly affected by parathion or oil. Colouring was again delayed in navels by oil when green-mature fruit were picked. In this respect the young trees bearing fruit with thicker rinds were much worse than the old trees.

TABLE 4

1953–54 TRIAL ON YOUNG NAVEL ORANGE

Treatment	Time Applied	Fruit in Scale Grades				Living Scales (%)	Scales per Fruit	
		0–25 Scales per Fruit		0–100 Scales per Fruit				
		Mean (%)	Transformed Mean*	Mean (%)	Transformed Mean*		Mean No.	Transformed Mean†
Untreated		0		0·5		35·6	4040	3·61
White oil 1 in 60 double spray ..	December							
White oil 1 in 40	January	89·1	70·7	96·7	79·6	23·1	3·4	0·64
White oil 1 in 60 double spray ..	December							
White oil 1 in 60	January	78·6	62·5	89·3	70·9	24·7	5·0	0·78
White oil 1 in 80 double spray ..	December							
White oil 1 in 80	January	73·6	59·0	90·2	71·7	25·8	8·1	0·96
White oil 1 in 60 double spray ..	December	32·6	34·8	56·5	48·8	22·0	124·9	2·10
Parathion dispersible powder 0·06% double spray	December							
Parathion dispersible powder 0·06%	February	95·1	77·2	98·8	83·8	34·7	0·5	0·17
Parathion dispersible powder 0·06%	December							
Parathion dispersible powder 0·06%	February	73·9	59·3	88·0	69·7	25·5	7·3	0·92
Parathion dispersible powder 0·03% double spray	December							
Parathion dispersible powder 0·06%	February	77·8	61·9	88·6	70·2	26·8	3·6	0·66
Parathion emulsion 0·06% double spray	December							
Parathion emulsion 0·06% ..	February	71·9	58·0	84·1	66·5	26·2	4·8	0·76
White oil 1 in 80 plus parathion dispersible powder 0·03% double spray	December							
White oil 1 in 80 plus parathion dispersible powder 0·03%	January	92·1	73·7	97·5	81·0	9·1	0·8	0·26
Necessary differences for significance { 5%			9·2		7·2			0·37
Necessary differences for significance { 1%			12·5		9·8			0·51

* Inverse sine. † log (x + 1).

TABLE 5

1953–54 TRIAL ON OLD NAVEL ORANGE

Treatment	Time Applied	Fruit in Scale Grades				Living Scales (%)	Scales per Fruit	
		0–25 Scales per Fruit		0–100 Scales per Fruit				
		Mean (%)	Transformed Mean*	Mean (%)	Transformed Mean*		Mean No.	Transformed Mean†
Untreated		20·9	27·2	35·6	36·6	2·9	172·8	2·24
White oil 1 in 60 double spray ..	December							
White oil 1 in 40	January	93·1	74·8	97·4	80·8	7·7	1·2	0·34
White oil 1 in 60 double spray ..	December							
White oil 1 in 60	January	91·7	73·3	96·3	79·0	3·3	2·8	0·58
White oil 1 in 80 double spray ..	December							
White oil 1 in 80	January	89·4	71·0	94·3	76·2	4·8	2·1	0·49
White oil 1 in 60 double spray ..	December	63·7	52·9	78·5	62·4	7·4	12·8	1·14
Parathion dispersible powder 0·06% double spray	December							
Parathion dispersible powder 0·06%	February	89·4	71·0	92·2	73·8	8·0	1·9	0·46
Parathion dispersible powder 0·06%	December							
Parathion dispersible powder 0·06%	February	79·8	63·3	86·0	68·0	4·8	10·2	1·05
Parathion dispersible powder 0·03% double spray	December							
Parathion dispersible powder 0·06%	February	73·1	58·8	81·8	64·7	7·3	5·3	0·80
Parathion emulsion 0·06% double spray	December							
Parathion emulsion 0·06% ..	February	80·6	63·8	89·2	70·8	9·6	7·9	0·95
White oil 1 in 80 plus parathion dispersible powder 0·03% double spray	December							
White oil 1 in 80 plus parathion dispersible powder 0·03%	January	87·7	69·5	95·2	77·3	5·0	2·6	0·56
Necessary differences for significance { 5%			10·6		9·2			0·39
{ 1%			14·3		12·5			0·52

* Inverse sine. † log (x + 1).

TABLE 6

1953–54 TRIAL ON VALENCIA ORANGE

Treatment	Time Applied	Fruit in Scale Grades				Living Scales (%)	Scales per Fruit	
		0–25 Scales per Fruit		0–100 Scales per Fruit				
		Mean (%)	Transformed Mean*	Mean (%)	Transformed Mean*		Mean No.	Transformed Mean†
Untreated		1·5		11·3		3·6	420·7	2·62
White oil 1 in 60 double spray ..	December							
White oil 1 in 40	January	57·1	49·1	87·9	69·6	1·3	16·6	1·24
White oil 1 in 60 double spray ..	December							
White oil 1 in 60	January	54·8	47·8	88·7	70·4	1·3	39·7	1·61
White oil 1 in 80 double spray ..	December							
White oil 1 in 80	January	49·9	44·9	90·1	71·7	1·7	41·7	1·63
White oil 1 in 60 double spray ..	December	24·5	29·6	73·7	59·1	1·5	81·7	1·92
Parathion dispersible powder 0·06% double spray	December							
Parathion dispersible powder 0·06%	February	74·3	59·6	91·9	73·4	2·0	10·8	1·07
Parathion dispersible powder 0·06%	December							
Parathion dispersible powder 0·06%	February	51·0	45·6	77·1	61·4	2·1	48·6	1·70
Parathion dispersible powder 0·03% double spray	December							
Parathion dispersible powder 0·06%	February	51·2	45·7	79·7	63·2	2·5	22·6	1·37
Parathion emulsion 0·06% double spray	December							
Parathion emulsion 0·06% ..	February	43·8	41·4	79·7	63·2	3·2	12·2	1·12
White oil 1 in 80 plus parathion dispersible powder 0·03% double spray	December							
White oil 1 in 80 plus parathion dispersible powder 0·03%	January	84·2	66·6	97·7	81·3	3·9	3·8	0·68
Necessary differences for significance	5%		9·7		9·7			0·40
	1%		13·2		13·3			0·54

* Inverse sine. † log (x + 1).

(e) Results of 1954-55 Trials

Trial on Beauty of Glen Retreat Mandarin.—A 6 x 4 randomized layout was used on 5-year-old Beauty of Glen Retreat mandarins in their second year of bearing. The scale population build-up was large, but much was thrown from fruit as this sized and puffed. Results of scale counts and grades are presented in Table 7. The fruit was harvested when coloured on May 30. The double oil treatment with follow-up oil retarded colour and development and the rind was hardened. The single 1 in 60 oil with the same spray following also appreciably delayed colouring. No colouring delay from the other treatments including oil was observed.

TABLE 7

1954–55 TRIAL ON GLEN RETREAT MANDARIN

Treatment	Time Applied	Fruit in Scale Grades				Living Scales (%)	Scales per Fruit	
		0–25 Scales per Fruit		0–100 Scales per Fruit				
		Mean (%)	Transformed Mean*	Mean (%)	Transformed Mean*		Mean No.	Transformed Mean†
Untreated		1·4	6·7	24·6	29·7	3·1	160	2·21
White oil 1 in 80 double spray ..	December							
White oil 1 in 60	Early February	41·7	40·2	85·7	67·8	0·9	41	1·62
White oil 1 in 60	December							
White oil 1 in 60	Early February	30·9	33·8	72·9	58·6	0·9	67	1·83
White oil 1 in 60	Early February	2·7	9·4	47·4	43·5	1·2	113	2·06
White oil 1 in 80 plus parathion dispersible powder 0·015%	December							
White oil 1 in 80 plus parathion dispersible powder 0·015%	Early February	80·7	63·9	97·7	81·4	2·0	2·5	0·54
Parathion dispersible powder 0·06%	December							
Parathion dispersible powder 0·06%	Early February	39·2	38·8	77·5	61·7	1·4	41	1·62
Necessary differences for significance	5%		14·0		14·0			0·55
	1%		19·3		19·3			0·77

* Inverse sine. † log (x + 1).

Trial on Pride of Ellendale Mandarin.—A 6 x 4 randomized layout was used on 15-year-old Pride of Ellendale mandarins. A moderate population of red scale developed. Results are presented in Table 8. The fruit was harvested on July 17 and no effects of oil on colouring or maturity were apparent.

TABLE 8

1954–55 TRIAL ON ELLENDALE MANDARIN

Treatment	Time Applied	Fruit in Scale Grades		Living Scales (%)	Scales per Fruit
		0–25 scales per fruit	0–100 scales per fruit		
		Mean (%)	Mean (%)		
Untreated		26·5	66·6	1·5	128
White oil 1 in 60 double spray ..	December				
White oil 1 in 40	April	85·7	97·5	2·2	3·5
White oil 1 in 60 double spray ..	December				
White oil 1 in 40	January	90·4	96·1	4·5	2·7
White oil 1 in 80 double spray ..	December				
White oil 1 in 40	April	87·8	97·9	0·4	4·0
White oil 1 in 80 plus parathion dispersible powder 0·015% double spray	December				
White oil 1 in 80 plus parathion dispersible powder 0·015%	April	90·7	96·7	1·9	2·1
White oil 1 in 80 double spray ..	December				
White oil 1 in 60	April	80·4	96·1	1·5	7·5

Trial on Late Valencia Orange.—A 6 x 4 randomized layout was used on 5-year-old Late Valencia oranges. Scale populations were light. Results are presented in Table 9. The fruit was harvested on September 27 and no effects of oil on colouring or maturity were apparent.

Discussion.—The natural throwing of red scale from the rind of mandarins makes control on these varieties easier than on oranges. Figures for untreated plots in the two mandarin trials indicate that some control may be needed if scale populations are more than light.

The Beauty of Glen Retreat mandarin was known to be much more susceptible to damage by oil sprays than other citrus varieties. Results were therefore sought from schedules including oil at reduced concentration. The oil/parathion combination was most effective and gave no apparent damage. Two oil sprays in December with a follow-up spray in February, even at concentrations reduced from those used on oranges, seriously damaged the fruit.

TABLE 9

1954–55 TRIAL ON VALENCIA ORANGE

Treatment	Time Applied	Fruit in Scale Grades		Living Scales (%)	Scales per Fruit	
		0–25 scales per fruit	0–100 scales per fruit			
		Mean (%)	Mean (%)		Mean No.	Transformed mean†
Untreated		12·6	50·9	5·9	112	2·05
White oil 1 in 60 double spray ..	December					
White oil 1 in 40	April	79·6	92·2	16·8	2·7	0·57
White oil 1 in 60 double spray ..	December					
White oil 1 in 40	January	68·0	90·0	10·0	4·9	0·77
White oil 1 in 80 double spray ..	December					
White oil 1 in 40	April	63·6	90·7	9·5	10·3	1·05
White oil 1 in 80 plus parathion dispersible powder 0·015% double spray	December					
White oil 1 in 80 plus parathion dispersible powder 0·015%	April	86·7	95·2	28·8	1·5	0·40
White oil 1 in 80 double spray ..	December					
White oil 1 in 60	April	71·5	93·7	15·1	7·5	0·93
Necessary differences for significance	5%	11·9				
	1%	16·6				

† log (x + 1).

Conforming to accepted practice, the Pride of Ellendale mandarins were given experimental treatments similar to late varieties of oranges. Comparing the results with those for Late Valencia oranges, similar variations between treatments occur, but the readier control of red scale on mandarins is demonstrated.

The schedules were designed to investigate also the timing of the follow-up spray on the late varieties. There is a suggestion that April is a better time than January for this spray on Late Valencias but not on Pride of Ellendales.

(f) Results of 1956-57 Trials

Trial on Late Valencia Orange.—A 10 x 3 randomized layout was used on Late Valencia orange trees in full bearing. Red scale infestation was lighter than in previous trials but was sufficient to warrant treatment. Results are presented in

Table 10. The fruit was coloured on the tree and harvested on August 26. Lateness of colouring of some fruits was noticed throughout the block; it could not be associated with any treatment. White oil spray produced an internal leaf marking on shaded leaves. The leaf blade along the midrib, some veins and part of the edges were darkened. Paraffinic oil did not produce these marks.

TABLE 10

1956–57 TRIAL ON VALENCIA ORANGE

Treatment	Time Applied	Fruit in Scale Grades		Scales per Fruit
		0–25 scales per fruit	0–100 scales per fruit	
		Mean (%)	Mean (%)	
Untreated (two plots)		70·8	90·3	16·1
White oil 1 in 50	December			
White oil 1 in 50	April ..	95·7	98·7	1·3
White oil 1 in 60 double spray ..	December			
White oil 1 in 50	April ..	95·5	98·3	1·1
White oil 1 in 60	December			
White oil 1 in 50	April ..	95·8	98·5	0·8
White oil 1 in 50 double spray ..	December			
White oil 1 in 50	April ..	98·2	99·7	1·3
Paraffinic oil 1 in 50	December			
Paraffinic oil 1 in 50	April ..	93·7	98·8	2·0
Paraffinic oil 1 in 60 double spray ..	December			
Paraffinic oil 1 in 50	April ..	96·8	98·5	0·7
Paraffinic oil 1 in 60	December			
Paraffinic oil 1 in 50	April ..	93·2	98·5	2·1
Paraffinic oil 1 in 50 double spray ..	December			
Paraffinic oil 1 in 50	April ..	98·2	100	0·3

Trial on Glen Retreat Mandarins.—A 5 x 4 randomized layout was used on young Beauty of Glen Retreat mandarin trees. Red scale populations were much smaller than in previous trials. Results are presented in Table 11. Trees sprayed with three white oil sprays had no marketable fruit. Some of it fell off in a blackened condition soon after the third spray, and the remainder averaged 1 in. in diameter when harvested on June 14. Paraffinic oil produced little noticeable damage. There was a slight accentuation of fruit splitting, common through the district and attributed to dry conditions.

TABLE 11

1956–57 TRIAL ON GLEN RETREAT MANDARIN

Treatment	Time Applied	Fruit in 0–25 Scale Grade Mean (%)	Living Scales (%)	Scales per Fruit
Untreated		78	41·1	7·44
White oil 1 in 80 plus parathion emulsion 0·015%	December			
White oil 1 in 80 plus parathion emulsion 0·015%	January ..	100	45·5	0·15
White oil 1 in 80 plus parathion dispersible powder 0·015%	December			
White oil 1 in 80 plus parathion dispersible powder 0·015%	January ..	100	19·9	0·11
White oil 1 in 60 double spray	December			
White oil 1 in 50	January ..	100	—	—
Paraffinic oil 1 in 60 double spray ..	December			
Paraffinic oil 1 in 50	January ..	100	48·6	0·03

Discussion.—The paraffinic-type oil compared well with white oil as a scalicide on small populations of red scale. The test was not severe enough to show differences due to total dosage levels as shown for white oil in earlier trials.

There was a marked difference demonstrated in damage by the two oils at a high dosage level on Glen Retreat mandarins, but the paraffinic oil did give a suggestion of rind hardening.

In previous trials where parathion was compared as a dispersible powder and an emulsion at the same level, the dispersible powder proved significantly superior. By 1956, however, its commercial use in Queensland had been banned by health authorities. It then became necessary to compare the oil plus 0·015 per cent. parathion spray recommended for Beauty of Glen Retreat mandarins with one in which emulsion was substituted for dispersible powder. This comparison in the 1956-57 mandarin trial did not show significant differences under conditions of mild infestation.

(g) Results of 1957-58 Trial

Trial on Washington Navel Orange.—A 5 x 4 randomized layout was used on mature Washington Navel orange trees. A large increase in red scale populations occurred during the trial. Results are presented in Table 12. The fruit was harvested on April 22 and data from treated plots taken from the harvested

fruit. The large scale population gave a pronounced twig dieback and reduction in foliage canopy on the control trees, and data from these plots were taken on the tree on March 27 to allow tree health to be restored by a special spraying.

TABLE 12

1957–58 TRIAL ON NAVEL ORANGE

Treatment	Time Applied	Fruit in Scale Grades				Scales per Fruit	
		0–25 scales per fruit		0–100 scales per fruit			
		Mean (%)	Trans-formed Mean*	Mean (%)	Trans-formed Mean*	Mean No.	Trans-formed Mean†
Untreated		0		0		548	2·74
White oil 1 in 60 double spray ..	December						
White oil 1 in 50	January	74·3	59·6	91·7	73·3	6	0·86
Paraffinic oil 1 in 60 double spray	December						
Paraffinic oil 1 in 50	January	72·3	58·2	90·6	72·2	11	1·09
Malathion 0·1% double spray ..	December						
Malathion 0·1%	January	22·1	28·0	43·2	41·1	228	2·36
White oil 1 in 80 plus malathion 0·05% double spray	December						
White oil 1 in 80 plus malathion 0·05%	January	77·6	61·8	92·4	74·0	5	0·76
Necessary differences for significance { 5%			5·8		6·3		0·38
{ 1%			8·3		9·0		0·53

* Inverse sine. † log (x + 1).

Discussion.—The trial was intended to investigate the scalicidal value of malathion for possible use on Beauty of Glen Retreat mandarins but was switched to navels when no suitable mandarins could be located. For that reason double spraying was used in December to allow for the greater difficulty in control. Malathion miscible oil at 0·1 per cent. was obviously insufficient as a control spray when used alone. When added to oil of low concentration the combination gave results equal to the standard oil schedule. Paraffinic oil again gave results comparable to white oil, and neither produced undesirable symptoms on tree or fruit.

IV. GENERAL DISCUSSION

The earlier section of this work was used as the basis for the publication of improved spray schedules for red scale control by Manefield (1957). The changes incorporated the double spraying with 1 in 60 white oil, which proved superior to the single 1 in 40 spray, and the late follow-up spray for late varieties.

Parathion could not be recommended as a substitute for oil because it would be required at strengths prohibited at that time by law. Where oil as an effective scalicide was shown to produce gross damage to Beauty of Glen Retreat mandarins, parathion was recommended in combination with a low (1 in 80) oil concentration for single applications in December and late January.

The limitations on the use of oil reported by growers have been (1) its retarding effect on fruit maturity and colouring, (2) the necessity for moderate temperatures and moist conditions at the time of spraying, and (3) its incompatability with some other citrus sprays, notably sulphur. During this work the only retarding effect found was on early varieties picked green-mature and artificially coloured. Extra time was needed for colouring. Under the irrigated conditions of the trials, where moisture was not a limiting factor, temperatures did delay spraying in December to some extent. Where midday shade temperatures exceeded 90°F, and spraying was restricted to periods before mid morning and late afternoon, no fruit or foliage burn resulted. The separation of oil and sulphur sprays by at least three weeks allows a critically timed sulphur spray between the two December oil sprays and that in late January.

A paraffinic oil was tested on three varieties over two years. Although it was equal to white oil in scalicidal efficacy, scale populations allowed a severe test only on navel orange. On two occasions when white oil damaged leaves and fruits the paraffinic oil had much less effect.

In the final trial malathion showed preliminary indications of being a suitable substitute for parathion in the low oil concentration recommended for Beauty of Glen Retreat mandarin.

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