CONTROL TRIALS AGAINST RED SCALE ON FIGS

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SUMMARY.

Control trials accompanied by seasonal life history studies were conducted with red scale (Aonidiella aurantii (Maskell)) on figs in the Sunnybank district during the period August 1949 to May 1952.

Reproduction by this insect occurred in every month of the year and generally more than 30 per cent. of living females were reproducing. Upsurges in reproduction alternated with peaks in the percentages of living females. Major reproduction peaks were in the periods May to June and December to January, with a minor peak in September. The December-January peak is of major economic importance.

Single applications of lime sulphur (1-35), white oil (1-40), and parathion (0.05%) made three times in a year, including one during the summer reproduction peak, caused only slight reductions in leaf and fruit infestations and were of no practical advantage.

Double applications of these insecticides greatly reduced the percentages of living insects and populations. White oil and parathion were comparable in preventing the spread of infestations to new twigs, leaves and fruit, but parathion had drastic effects on natural enemies and was of no value in preventing early leaf fall.

From these studies white oil is regarded as the only effective insecticide for red scale on figs and two applications 2-3 weeks apart in January are adopted as the standard control.

I. INTRODUCTION.

The commercial growing of figs (*Ficus carica* L.) in Queensland involves only one variety, Brown Turkey, and is confined to the Sunnybank district, adjacent to the Brisbane metropolitan area. From 1946 red scale (*Aonidiella aurantii* (Maskell)) increased in importance as a pest in the orchards and during the 1949 harvest scarcely a fruit was marketed without a scale infestation. In that year control trials against this insect were commenced and seasonal life history studies were made to determine the best time to apply control measures.

II. NATURE AND IMPORTANCE OF INFESTATIONS.

The incidence of red scale on commercial fig trees varies with orchard management. With proper control this pest is of little concern, but it is of major importance if control is neglected. Prior to the present studies some growers made regular summer applications of white oil.

Even in well-managed orchards red scale is known to be present throughout the year. Autumn and winter populations are reduced by the leaf fall and pruning. In the winter and early spring the insects are therefore located on trunks and branches and populations normally appear to be low.

The young in this period settle only in the vicinity of the parents. Young from the summer breeding, however, move upwards onto the new twigs and can cause heavy infestations on both leaves and fruit (Figs. 1 and 2). These infestations affect tree health and reduce both yield and market value of fruit.

III. SEASONAL OCCURRENCE.

From April 1950 to March 1952 regular records were made of the percentages of living adult females and the percentages of reproducing females in the scale populations.

(1) Living Adult Females.

Living adult females of red scale are bright and clear in appearance and turgid with body fluid. Pressure with a scalpel point breaks the scale and body wall and releases fluid. Dead scales are dull and darker in appearance and without body fluid. These differences were used to determine the percentages of living insects in the field samples. The scales were turned for examination, since the same individuals were used in counts of reproducing females.

At least once a month 20 twigs (two from each of 10 trees) known to be carrying scales, were cut approximately the same size and bulked together. This sampling was at about shoulder height and from different aspects of the trees. Twenty-five more or less consecutive adult female insects per twig were examined to a total of 250, obtained in most instances from 10 twigs.

The percentages of living adult females obtained are given in Fig. 3.

The figures show that at all times during the 2-year period the percentages of living adult females were comparatively low. On no occasion was half of the population alive; the maximum reached was 42·8 per cent. The highest peak occurred each year in the late winter-early spring period; a secondary peak occurred in late spring and another peak in the autumn. The lowest seasonal percentages were in December 1950 and January 1952.

In the above seasonal studies mostly non-bearing twigs were used. In other parts of these investigations it was noted that the nymphs from early summer breeding moved onto the new season's twigs. These insects were well grown in February and March and counts of such populations showed that the percentages of living females were higher than on non-bearing twigs. The average, however, was still only about 50 per cent.; rarely was 75 per cent. exceeded. A decline occurred in late autumn and a further decline in late winter; in the spring the percentage of living insects on these twigs dropped to the normal 30 per cent. level of the older twigs.

Fig. 1.

Heavy Infestation of Red Scale on a Fig Leaf.

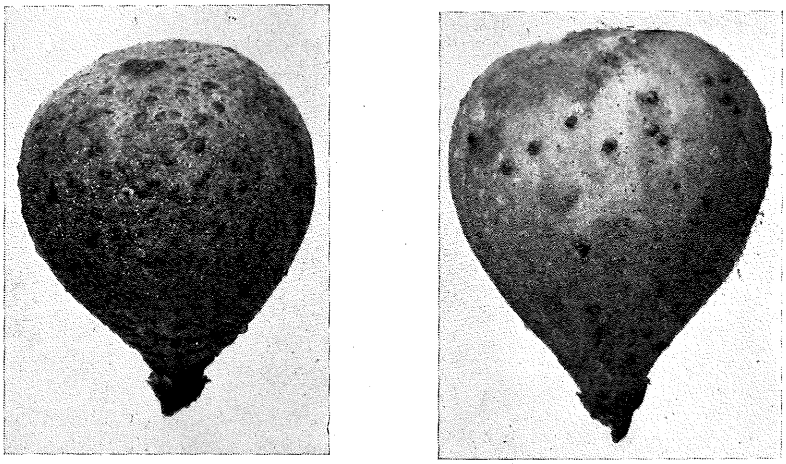

Fig. 2.

Red Scale on Fig Fruits.

(2) Reproducing Females.

Red scale is viviparous and one or two young may be still present beneath the parent when the next is born. These orange-coloured nymphs can be seen when the parent is turned over for examination. Females while producing young almost invariably give evidence of moisture when pressed with a scalpel point. The individuals with young beneath them and which gave at least evidence of moisture when pressed were therefore regarded as reproducing females.

The living individuals among the females used for determining the percentage of living females were also used for assessing the percentages of reproducing females. The counts, however, were continued until a total of 250 living individuals was examined from each set of samples, and for this purpose all of the 20 twigs were sometimes used.

The percentages of reproducing females are given in Fig. 3.

The figures show that reproduction of red scale on figs occurred in every month of the 2-year period and for the greater part of each year more than 30 per cent. of living females were reproducing. In each year there were three peaks in the percentages of reproducing females alternating with peaks in percentages of living insects; major peaks occurred in the May-June and December-January periods, with a minor peak in September. The times of low percentages of reproduction were in March, August and November, the lowest in each year being in March.

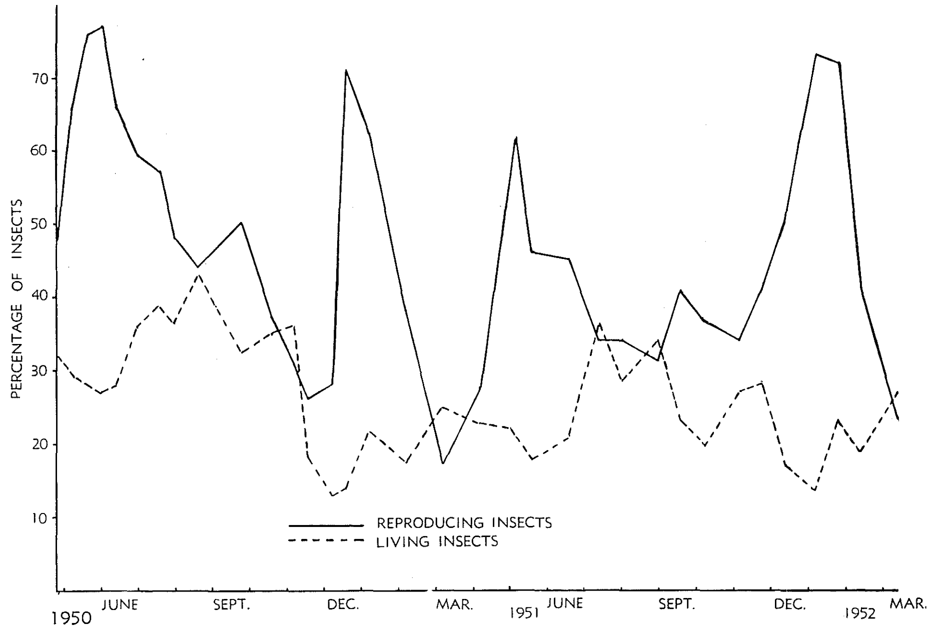

Fig. 3.

Percentages of Living Adult Females and Reproducing Females.

IV. MATERIALS AND METHODS.

Three control trials were conducted in the period from August 1949 to May 1952 to obtain data on the value of white oil and to compare it with parathion. Lime sulphur was also included as a treatment in the trials.

(1) Materials.

The materials used in each of the trials were as follows:—

(*a*) White oil: an emulsion containing 80·0% w/w mineral oil; diluted 1–40.

(*b*) Parathion: an emulsifiable preparation containing 22·4% w/v parathion; diluted 1–450.

(*c*) Lime sulphur: a solution containing 20·0% w/v sulphur as polysulphides; diluted 1–35.

(2) Methods.

Each trial comprised a 4 × 4 randomised layout, using single-tree plots. Trial 1 was of single applications, Trials 2 and 3 of double applications at an interval of 2–3 weeks. Applications were made at first by knapsack spray and later by stirrup pump, at the rate of $1\frac{1}{2}$ gal. of spray per tree without foliage and $3\text{–}3\frac{1}{2}$ gal. per tree in full foliage.

Regular twig samples were taken from each tree for determinations of the percentages of living insects before and after spray applications. In all trials only adult females were examined and all discussions relate to those insects.

The value of control treatments against a scale insect such as red scale on figs depends primarily on the ability of the insecticides to kill the insects. To determine this ability to kill requires the counting of large numbers of insects on treated and untreated trees before and at intervals after control applications. The volume of such counting can be an important factor limiting the size of a control trial and the sampling possible during its progress.

In order to facilitate subsequent work the original sampling in Trials 1 and 2 was made for two purposes: (*a*) a statistical analysis to determine an adequate sample, and (*b*) as a pre-treatment count.

Five scale-infested twigs of approximately the same size were taken at random from each of the 32 experimental trees, and on each 50 more or less consecutive insects were examined in groups of 10, and recorded as living or dead. Totals and percentages of dead insects in these counts are given in Table 1.

Table 1.

NUMBERS AND PERCENTAGES OF DEAD INSECTS.

Site A.			Site B.		
Tree Number.	Dead Insects.	Percentage Dead.	Tree Number.	Dead Insects.	Percentage Dead.
1 ..	179	71·6	5	218	87·2
12 ..	203	81·2	16	222	88·8
18 ..	197	78·8	22	151	60·4
27 ..	184	73·6	31	192	76·8
Mean ..	190·7	76·3	Mean	195·7	78·3
3 ..	188	75·2	7	175	70·0
10 ..	170	68·0	14	183	73·2
20 ..	195	78·0	24	173	69·2
25 ..	194	77·6	29	210	84·0
Mean ..	186·7	74·7	Mean	185·2	74·1
2 ..	145	58·0	6	139	55·6
11 ..	179	71·6	15	172	68·8
17 ..	197	78·8	21	144	57·6
28 ..	151	60·4	32	164	65·6
Mean ..	168·0	67·2	Mean	154·7	61·9
4 ..	175	70·0	8	178	71·2
9 ..	166	66·4	13	197	78·8
19 ..	206	82·4	23	149	59·6
26 ..	162	64·8	30	214	85·6
Mean ..	177·2	70·9	Mean	184·5	73·8

The percentages of dead insects were sufficiently uniform to enable a direct analysis but a transformed variable ϕ was used (where % = 100 $\sin^2\phi$) so as to provide an equalising effect on the variance for different percentages following the application of control treatments.

The 32 experimental trees comprised two sites and therefore analyses were made for each site on the basis that each 16 trees constituted a 4 $\times$ 4 randomised layout. Analyses of variance are given in Table 2.

Table 2.

ANALYSES OF VARIANCE.

Source of Variation.	Site A.		Site B.		Sites A and B.	
	D.F.	Mean Square.	D.F.	Mean Square.	D.F.	Mean Square.
Rows	3	1,071·03	3	3,121·96		
Columns	3	643·47	3	868·08		
Treatments	3	972·83	3	3,109·56		
Error	6	292·72	6	922·84		
Treatment + Error	9	519·42	9	1,651·75	18	1,085·58
Between Twigs ..	63	423·36	63	402·49	126	412·93
Within Twigs ..	313	137·94	316	130·91	629	134·41

The components of variability considered were:—

(*a*) Between groups of 10 insects on the same twig: σ_1^2,

(*b*) Between twigs on the same tree: σ_2^2,

(*c*) Between trees in the same site: σ_3^2.

The mean squares for sites A and B as a whole are estimates of the following quantities:—

$$\sigma_1^2 = 134\cdot41$$

$$\sigma_1^2 + 5\sigma_2^2 = 412\cdot93$$

$$\sigma_1^2 + 5\sigma_2^2 + 25\sigma_3^2 = 1085\cdot58$$

For the estimate of variability between trees the 9 degrees of freedom plus error was used since no treatment had yet been applied. The estimates for the two sites separately do not agree closely. The estimates between twigs and between groups of insects on each twig, however, agree closely, and since these are the components determining the efficiency of sampling, the lack of agreement between the tree-to-tree estimates is not initially of importance.

From the above estimates it was calculated that $\sigma_1^2 = 134\cdot41$, $\sigma_2^2 = 55\cdot70$ and $\sigma_3^2 = 26\cdot91$. With *m* twigs per tree and *n* groups of 10 insects per twig, the variance of a single tree mean would be $\sigma_3^2 + \frac{\sigma_2^2}{m} + \frac{\sigma_1^2}{mn}$, the last two terms representing the increase in variance due to sampling error. The variance for different values of *m* and *n* is given in Table 3.

Table 3.

VARIANCE FOR DIFFERENT VALUE OF m AND n.

n (groups of 10 insects).	m (twigs per tree).						
	1.	2.	3.	4.	5.	6.	7.
1 ..	217·0	122·0	90·3	74·4	64·9	58·6	54·1
2 ..	149·8	88·4	67·9	57·6	51·5	47·4	44·5
3 ..	127·4	77·2	60·4	52·0	47·0	43·7	41·3
4 ..	116·2	71·6	56·7	49·2	44·8	41·8	39·7
5 ..	109·5	68·2	54·4	47·6	43·4	40·7	38·7
6 ..	105·0	66·0	52·9	46·4	42·5	39·9	38·1
7 ..	101·8	64·4	51·9	45·6	41·9	39·4	37·6
∞	82·6	54·8	45·5	40·8	38·1	36·2	34·9

On the basis of the above estimates the variance per tree if completely counted would be 26·9. The difference between this figure and those in Table 3 represents increases in variability due to partial counting.

For any given total of insects to be counted the lowest variance would be obtained by taking as many twigs as possible. The proposed counting of 50 insects on each of 5 twigs per tree, involving a total of 250 insects, with a variance of 43·4, would be comparable in efficiency to counting 30 insects on each of 6 twigs per tree, involving a total of only 180 insects.

The efficiency of any sampling method chosen is ultimately dependent on the magnitude of the sampling error. The proposed 5 twigs of 50 insects per twig involved a sampling variance of 16·5—i.e., a s.e. of $\pm$ 4·1. On the data presented from these counts the average value is 60 (= 75 per cent. dead). Thus the uncertainty in the estimate due to sampling variation is $\pm$ 8 (i.e., 62–86 per cent.). For other levels of percentage of dead insects the 95 per cent. fiducial limits would be as follows:

10% or 90%	20% or 80%	30% or 70%	40% or 60%	50%
$\pm$ 8%	$\pm$ 11%	$\pm$ 13%	$\pm$ 14%	$\pm$ 14%

Accepting these limits as satisfactory for the work, any combination of twigs per tree and insects per twig providing comparable variance with 5 twigs of 50 insects each could be used with equal reliance. Consequently, 6 twigs per tree and 30 insects per twig were used in all trials because of the practical advantage in reducing considerably the number of insects to be counted.

During the trials, samples were also taken of leaves and fruit. In each instance six twigs were taken from each tree and counts were made from five consecutive leaves and five consecutive fruit on each twig. In determining the percentages of living insects, 20 more or less consecutive scales were examined on each leaf and each fruit. In addition, records were made of the numbers of clean leaves and fruit, and fruit with fewer than five scales on each.

V. TRIAL 1.

The single applications in this trial were made on Aug. 17 and Dec. 7, 1949, and on Apr. 3, 1950. Twig samples were taken before and after each application; dates of sampling were Aug. 17, Sept. 2, Oct. 18, Nov. 24, 1949, Jan. 9, Feb. 6, Apr. 3 and May 24, 1950. Leaf and fruit samples were taken on Feb. 6, 1950, and further fruit samples on Apr. 3, 1950.

(1) Results and Discussion.

(a) Twigs.

Results of the twig counts are given in Fig. 4. The figures show that on old twigs from untreated trees the percentage of living insects was initially low and in November 1949 was down to 10 per cent. of the population present. On new twigs, as shown in February, April and May 1950, this percentage was much higher.

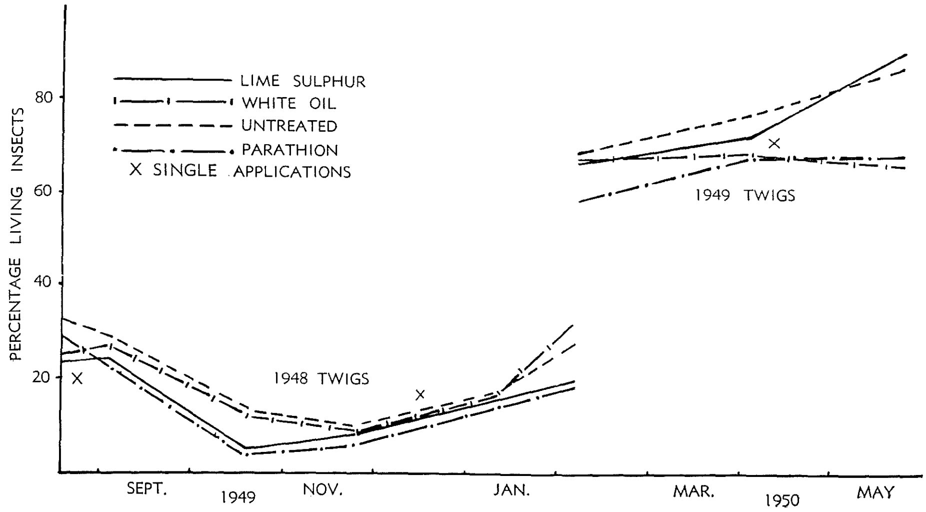

Fig. 4.

Percentages of Living Insects, Trial 1.

Generally the differences between the treatments were small and the figures did not warrant statistical analyses. Each insecticide was regarded as conveying no practical advantage in reducing the percentages of living insects.

(b) Leaves.

Figures showing the results of insect counts on leaves on Feb. 6, 1950, are given in Table 4.

Table 4.

INSECT POPULATIONS ON LEAVES.

Treatment.	Mean Insects per Leaf.	Equivalent Percentage Living Insects.	Equivalent Percentage Clean Leaves.
Lime sulphur ..	2·97	90·0	29·8
White oil ..	1·96	88·6	58·2
Untreated ..	8·20	85·7	11·2
Parathion ..	3·50	79·4	45·4
	Differences not significant.		

The figures show that amongst this first generation on the leaves the percentages of living insects were high, and that many of the leaves were infested in all treatments.

(c) Fruit.

Figures showing the results of insect counts on fruit on Feb. 6 and Apr. 3, 1950, are given in Table 5.

Table 5.

INSECT POPULATIONS ON FRUIT.

Date.	Treatment.	Mean Insects per Fruit.	Equivalent Percentage Living Insects.	Equivalent Percentage Clean Fruit.
Feb. 6, 1950	Lime sulphur ..	4·16	85·0	30·9
	White oil ..	5·26	91·7	27·6
	Untreated ..	7·58	86·8	9·9
	Parathion ..	3·63	73·8	39·4
		Differences not significant.		
Apr. 3, 1950	Lime sulphur ..	48·58	66·2	2·5
	White oil ..	119·78	72·8	0·9
	Untreated ..	108·17	66·8	0·0
	Parathion ..	47·10	61·2	3·3
		Differences not significant.		Not analysed.

A preliminary examination of fruit in November 1949 showed no evidence of scales. By Feb. 6, 1950, a considerable infestation was present and the percentages of living insects were high in all treatments. Although the mean number of scales present was 7·58 on untreated trees, more than 90 per cent. of the fruit was infested. Fruit on the parathion-treated trees showed half of the infestation of the untreated trees but even with this insecticide more than 60 per cent. of the fruit was infested.

One month later a very heavy infestation was present on the fruit of all treatments and with each insecticide treatment few fruit escaped infestation.

VI. TRIAL 2.

This trial commenced concurrently with Trial 1 but was continued for an extra two years and included yield data. Dates of application were Aug. 17 and Sept. 12, Dec. 7 and 21, 1949, Apr. 1 and 28 and Dec. 6 and 18, 1950. Twig samples were taken on Aug. 17, Sept. 2 and 20, Oct. 24, Nov. 29, Dec. 19, 1949, Jan. 11, Feb. 6, Mar. 27, Apr. 17, May 29, June 21, July 27, Aug. 28, Oct. 20, Nov. 23, 1950, Jan. 9, Mar. 12 and Apr. 9, 1951. Leaf samples were taken on Feb. 6, 1950, and fruit samples on Nov. 29, 1949, Feb. 6 and Mar. 27, 1950. Yield data were recorded for the summer–autumn harvests of 1951 and 1952.

(1) Results and Discussions.

(a) Twigs.

Figures showing percentages of living insects for the various samplings are shown in Fig. 5. Analyses of the data are given in Tables 6 and 7.

The figures show a downward trend from August to December 1949 in the equivalent percentages of living insects in all treatments. This was much greater with the insecticide treatments, particularly white oil and parathion, which in the September 1949 sampling were significantly superior to both the untreated and the lime sulphur treatment. This effect continued into October, although to a less extent with white oil. A delayed beneficial effect was shown in this month by lime sulphur, which together with parathion was significantly better than the untreated.

In December an upward trend was shown in living insects, but an application of the insecticides kept the percentages low in these treatments, and following the second application in this month all insecticide treatments were significantly better than the untreated. The beneficial effect of the insecticides was continued into February 1950.

The percentages of living insects on new twigs in Feburary were much greater in all treatments than on the old twigs (Fig. 5), and although the beneficial effect of the insecticides was evident differences were not significant. During the following two months the percentages tended to become uniform. Following further applications in April the beneficial effect was shown in May, especially with white oil. In June all insecticides were significantly better than the untreated and with parathion this was still so in July and August.

Table 6.

EQUIVALENT PERCENTAGES OF LIVING INSECTS ON TWIGS OF 1948 GROWTH.

Treatment.	1949.						1950.	
	Aug. 17.	Sept. 2.	Sept. 20.	Oct. 24.	Nov. 29.	Dec. 19.	Jan. 11.	Feb. 6.
A. Lime sulphur	20·8	17·6	14·5	5·9	1·8	3·9	1·0	5·3
B. White oil ..	25·6	19·1	3·7	9·1	6·3	3·7	3·9	5·9
C. Untreated ..	37·4	31·0	24·9	17·5	5·9	9·8	21·6	22·6
D. Parathion ..	25·6	14·9	3·8	1·9	1·1	1·5	0·1	1·9
	A<C		B, D «A, C A<C	D, A «C D<A B<C		D «C B, A<C	A, B, D «C D<B	D «C A, B<C

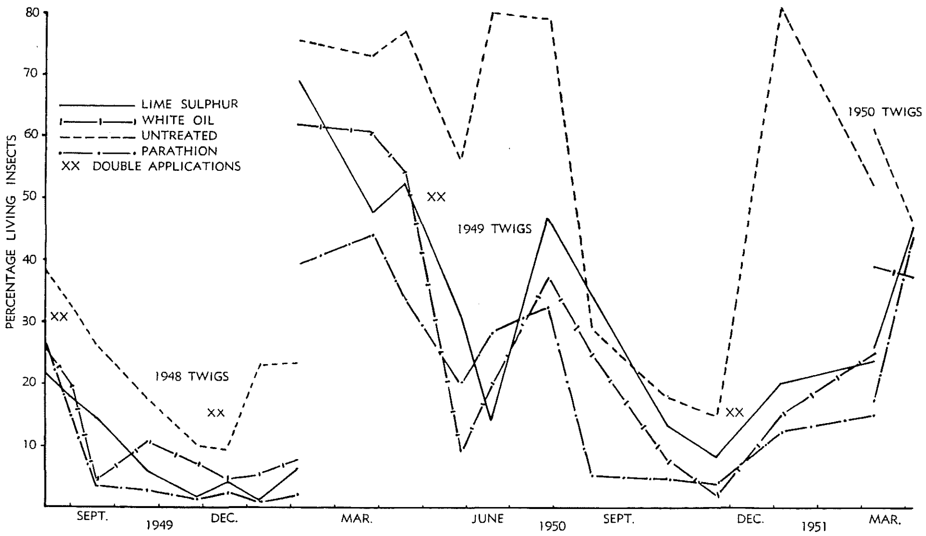

Fig. 5.
Percentages of Living Insects, Trial 2.

Table 7.

EQUIVALENT PERCENTAGES OF LIVING INSECTS ON TWIGS OF 1949 GROWTH.

Treatment.	1950.							1951.		
	Feb. 6.	Mar. 27.	Apr. 17.	May 29.	June 27.	July 27.	Aug. 28.	Nov. 25.	Jan. 9.	Mar. 12.
A. Lime sulphur ..	58·2	50·0	53·8	30·3	23·7	69·3	40·4	8·3	20·1	23·9
B. White oil ..	46·4	61·3	45·7	8·6	23·1	29·1	26·0	1·6	15·0	24·6
C. Untreated ..	75·6	73·1	77·1	56·0	72·1	69·7	25·3	15·4	70·7	52·4
D. Parathion ..	33·8	47·7	40·0	21·3	26·1	9·9	8·5	3·8	12·5	15·0
				B«C D<C	A,B,D <C	D<A, C	D<A	Not analysed.		

Towards the end of 1950 populations generally declined, due possibly to natural enemies favoured by mild winter conditions. Further insecticide applications in December 1950 were followed by slight increases, but an outstanding increase was shown in the untreated trees. In March and April 1951, after effects of the sprays had waned, the percentages of all treatments tended to become uniform especially on the new twigs.

The insecticides also had a marked effect in reducing scale populations on twigs. The mean numbers of insects on the six twigs per tree for each treatment are given in Fig 6.

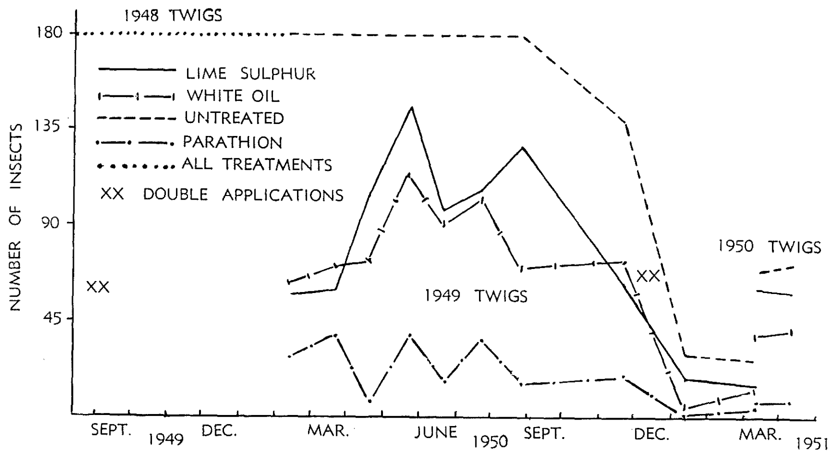

Fig. 6.

Mean Numbers of Insects on Six Twigs Per Tree, Trial 2.

From August 1949 to February 1950, the standard number of 180 insects per six twigs was obtained for all trees in all treatments. This number was also obtained on the new twigs of untreated trees from February to August 1950, but the numbers in the lime sulphur and white oil treatments were about half and still less with parathion. A natural general decline in numbers occurred on untreated trees from August 1950 to March 1951, but the numbers on the treated trees were still lower.

(b) Leaves.

Figures showing the results of insect counts on leaves on Feb. 6, 1950 are given in Table 8.

The figures show outstanding advantages of the spray treatments, especially white oil.

Table 8.

INSECT POPULATIONS ON LEAVES.

Treatment.	Mean Insects per Leaf.	Equivalent Percentage Living Insects.	Equivalent Percentage Clean Leaves.
A. Lime sulphur	0·4	85·7	86·1
B. White oil ..	0·1	50·0	99·2
C. Untreated ..	10·8	73·6	31·8.
D. Parathion ..	0·3	69·2	89·3
	A, B, D $\ll$ C		A, B, D $\gg$ C

(c) Fruit.

All fruit in samples taken in November 1949 were free from scales in all treatments.

The results from samples taken on Feb. 6 and Mar. 27, 1950 are given in Table 9.

Differences in the percentages of living insects between the treatments were slight, indicating that most of these insects must have moved onto the fruit subsequent to the insecticide applications in December. The advantages of the applications were in the marked reduction of this movement and the large percentages of almost clean fruit.

Table 9.

INSECT POPULATIONS ON FRUIT.

Date.	Treatment.	Mean Insects per Leaf.	Percentage Clean Fruit.	Percentage Fruit with $<$5 Scales per Fruit.
Feb. 6, 1950	A. Lime sulphur	1·0	71·6	96·2
	B. White oil ..	0·9	86·4	98·9
	C. Untreated ..	10·8	12·1	40·6
	D. Parathion ..	0·9	76·0	96·6
		A, B, D significantly better than C at 1·0% level.		
Mar. 27, 1950.. ..	A. Lime sulphur	3·6	40·9	78·5
	B. White oil ..	15·0	41·3	78·4
	C. Untreated ..	108·2	0·0	3·6
	D. Parathion ..	3·6	44·2	76·3
		A, B, D significantly better than C at 1·0% level.		

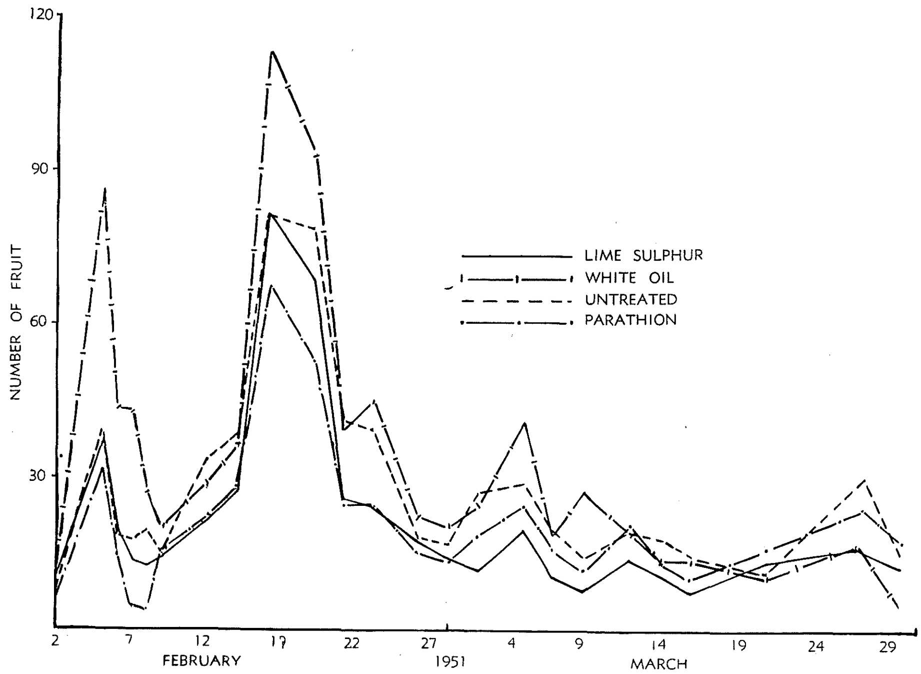

Fig. 7.

Yields in Mean Number of Fruit Per Tree, Trial 2.

Yields of fruit were recorded for the 1951 harvest. Dates of picking and yields in fruit numbers are shown in Fig. 7. Fruit weights were practically parallel with fruit numbers. Totals are given in Table 10.

Table 10.

MEAN YIELDS OF FRUIT NUMBERS AND WEIGHTS, 1951.

Treatment.	Number of Fruit.	Weight of Fruit.
		lb.
Lime sulphur ..	510	39·6
White oil ..	788	59·1
Untreated ..	660	53·2
Parathion ..	499	40·2
	Differences not significant.	

Yields from the same trees were recorded for the next harvest (1952) after 12 months of uniform conditions. Results for numbers and weights of fruit are summarised in Table 11.

Table 11.

MEAN YIELDS OF FRUIT NUMBERS AND WEIGHTS, 1952.

Treatment.	Number of Fruit.	Weight of Fruit.
		lb.
Lime sulphur ..	520	25·5
White oil ..	584	32·8
Untreated ..	637	31·8
Parathion ..	452	23·1
	Differences not significant.	

From these figures adjustments of the analyses in Table 10 were possible and the adjusted figures are given in Table 12.

Table 12.

ADJUSTED MEAN YIELDS OF FRUIT NUMBERS AND WEIGHTS, 1951.

Treatment.	Number of Fruit.	Weight of Fruit.
		lb.
Lime sulphur ..	538	47·7
White oil ..	753	52·8
Untreated ..	573	47·9
Parathion ..	593	43·6
	Differences not significant.	

The general effect of the adjustments was to bring the means closer together.

VII. TRIAL 3.

The third trial was commenced in another orchard in April, 1950. Double applications were made on Apr. 26 and May 17, and Dec. 6 and 18, 1950. Twig samples were taken on April 26, May 17, June 26, Aug. 2, Sep. 11, Nov. 21, 1950, Jan. 10 and May 1, 1951. Yields of numbers and weights of fruit were recorded in 1951 and 1952.

(1) Results and Discussion.

(a) Twigs.

Results showing the percentages of living insects are given in Fig. 8.

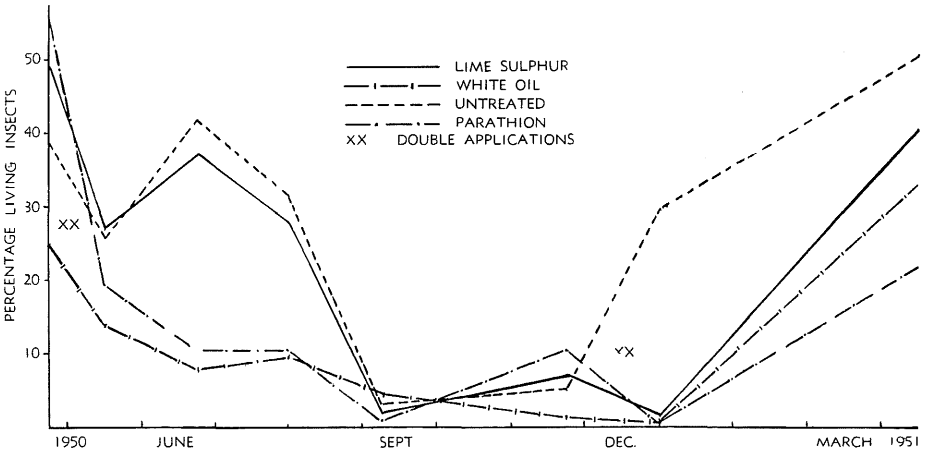

Fig. 8.

Percentages of Living Insects, Trial 3.

A regression in the percentages of living insects was shown in all treatments in May 1950. In June a peak occurred in the untreated plots and was closely approximated by the lime sulphur treatment, but the effect of both white oil and parathion was shown by a further reduction in living insects.

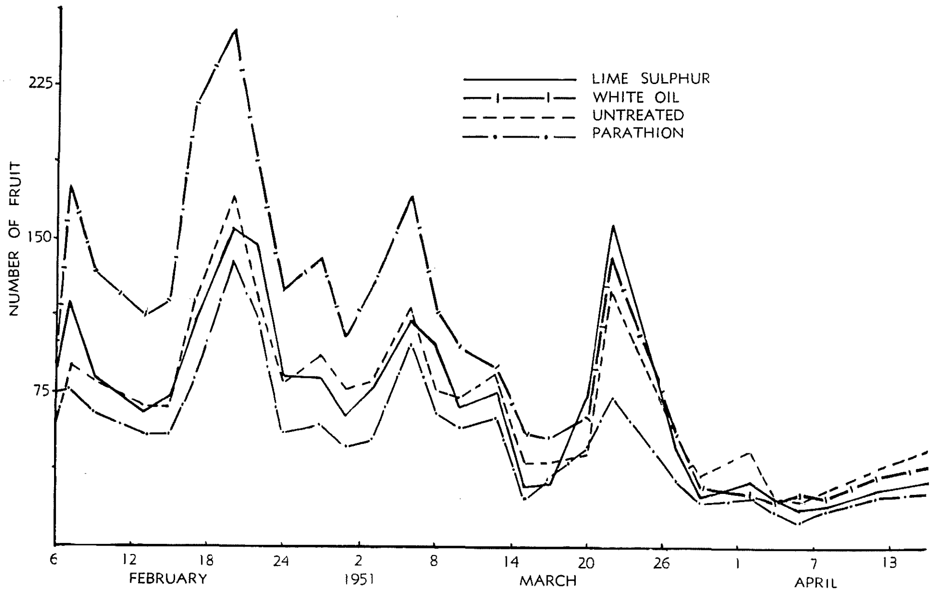

Fig. 9.

Yields in Mean Number of Fruit Per Tree, Trial 3.

The unusually mild wet winter favoured the development of an entomogenous fungus which possibly contributed to the low percentage of living insects in the spring. A slight rise in untreated plots in November was followed by a marked increase but all insecticides had a decided beneficial effect. A sampling in the autumn, however, showed that this effect had waned and the percentages of living insects in all treatments were tending to become uniform.

(b) Fruit.

Numbers of fruit harvested in 1951 as shown by progressive pickings are given in Fig. 9. Weights followed the same general pattern in each treatment. Totals are given in Table 13.

Table 13.

MEAN VALUES OF NUMBER AND WEIGHT OF FRUIT, 1951.

Treatment.	Number of Fruit.	Weight of Fruit.
		lb.
Lime sulphur ..	2,008	178·4
White oil ..	2,799	248·8
Untreated ..	1,999	203·1
Parathion ..	1,504	129·8
	Differences not significant.	

Yields from the same trees, after all plots were given uniform conditions for 12 months, were recorded for 1952. Results of these yields are given in Table 14.

Table 14.

MEAN VALUES OF NUMBER AND WEIGHT OF FRUIT, 1952.

Treatment.	Number of Fruit.	Weight of Fruit.
		lb.
Lime sulphur ..	1,966	133·3
White oil ..	2,270	173·6
Untreated ..	1,757	115·3
Parathion ..	1,386	93·6
	Differences not significant.	

From these figures adjustments were made for the 1951 yields and these are given in Table 15.

Table 15.

ADJUSTED MEAN YIELDS OF NUMBERS AND WEIGHTS OF FRUIT, 1951.

Treatment.	Number of Fruit.	Weight of Fruit.
		lb.
Lime sulphur ..	1,906	174·5
White oil ..	2,444	208·4
Untreated ..	2,072	215·5
Parathion ..	1,888	161·8
	Differences not significant.	

As in the previous trial, the adjustments tended to bring the means closer together.

VIII. EFFECT OF WHITE OIL ON LEAF FALL.

In 1951 fig trees generally in the district suffered from premature leaf fall. This was due at least in part to a general infection by fig leaf rust (*Cerotelium fici* (Butl.) Arth.). Differences in the amount of leaf fall were evident amongst experimental trees (Figs. 10–12) although these had uniformly received a copper spray; white oil treated trees carried most foliage (Fig. 12).

Fig. 10.

An Untreated Experimental Tree Almost Bare of Foliage. Photographed Mar. 24, 1951.

Fig. 11.

A Parathion Treated Tree With Sparse Foliage. Photographed Mar. 24, 1951.

A survey of all orchards in the district was made in the period Mar. 13–16, 1951, when insecticidal and fungicidal applications in each were recorded and ratings allotted from 0 to 4 for nil to heavy rust incidence and 0 to 4 for nil to virtually complete leaf fall. The results for the whole district are summarised in Table 16.

Table 16.

MEAN RATINGS OF FIG LEAF RUST INCIDENCE AND LEAF FALL.

Treatments.	Leaf Rust.		Leaf Fall.	
	One copper spray.	Two copper sprays.	One copper spray.	Two copper sprays.
No oil spray ..	2·9	1·2	2·2	1·0
Oil spray ..	2·5	0·8	1·0	0·4

The data showed that trees in orchards which had received neither copper nor oil sprays were either bare or almost bare of leaves (Fig. 13). The benefit of white oil in addition to copper sprays was marked and trees which received

Fig. 12.

A White Oil Treated Tree With Complete Foliage. Photographed Mar. 24, 1951.

both retained practically all leaves until the winter (Fig. 14). Amongst experimental trees, those sprayed with both parathion and copper also suffered moderately heavy premature leaf fall (Fig. 11).

The effect of the early leaf fall was also shown in yields. Picking in many orchards, especially those which had not received white oil, did not extend beyond the end of February, and had ceased by the middle of this month in some orchards. Those which had received both white oil and copper sprays continued to yield marketable fruit until April, and in one orchard receiving a late winter oil, a late spring copper and an early summer oil, commercial picking continued until the end of April (Fig. 14).

IX. NATURAL CONTROL.

The winter of 1950 was mild and unusually wet, favouring the development of the entomogenous fungus *Sphaerostilbe coccophila* Tul. During sampling in these months twigs obviously showing the fungus were avoided as much as possible. A normal random sampling was made in August 1950, and examined by the standard counting technique to determine fungal infection. The percentages of obviously infected scales for the various treatments were as follows: lime sulphur 0·0, white oil 25·5, untreated 10·8, parathion 0·5.

Fig. 13.

Trees in an Orchard That Did Not Receive Copper or White Oil Sprays, Bare of Foliage. Photographed Mar. 24, 1951.

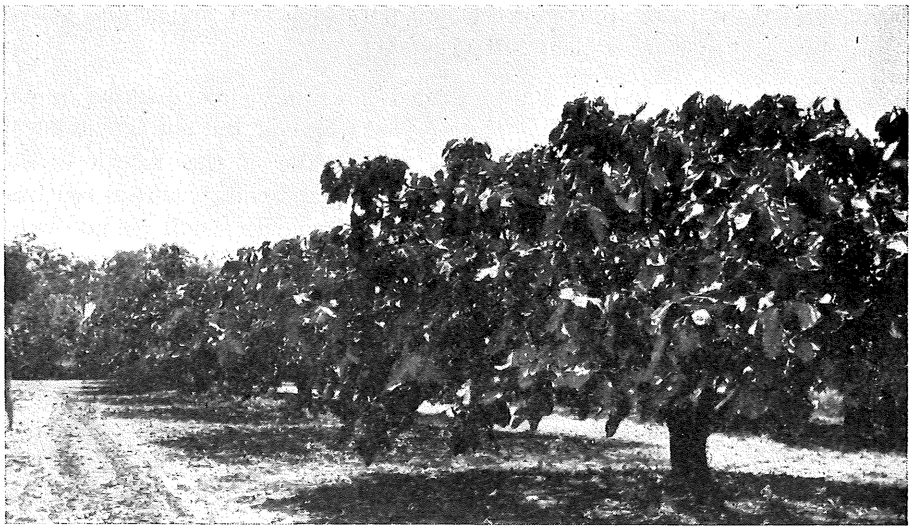

Fig. 14.

Trees in an Orchard That Received a Copper Spray in October and White Oil in August and December, 1950, With Complete Foliage. Photographed Mar. 24, 1951.

During the progress of the trials various ladybirds and their larvae were observed commonly on all trees other than those sprayed with parathion. During laboratory examinations the hymenopterous parasite *Aphelinus chrysomphali* Mercet. was noted operating on all trees but rarely on the parathion treated trees.

X. GENERAL DISCUSSION.

The absence of clearly defined generations of red scale on figs presents difficulties in planning a control schedule. Insecticide applications against the constantly emerging crawlers would be ineffective or economically unsound. Control applications therefore must be capable of killing settled insects whether as well-protected adults or as newly settled crawlers with at least some protective secretion. The newly settled crawlers are the more vulnerable and results may be best when treatments are applied following reproduction peaks. The seasonal life history studies showed three breeding peaks—May–June, September, and December–January. The peak occurring in the May–June period is of little economic concern because during the winter months survival is low, the sluggish young settle only on bare branches under or near the parents, and some of the population is removed by pruning. In the remaining population there is a general seasonal downward trend in living adults extending into the spring.

The minor peak in September also is of little concern because there is again a low survival and the general seasonal downward trend in living adults extends into the summer. Few if any crawlers move to or survive on the new actively growing twigs and leaves and no infestation occurs on fruit before the summer reproduction peak.

The summer peak can develop into major importance even from a low percentage of living females in the parent generation. At this time reproduction is at a high level. Survival is high and the young move upwards towards the light to settle on the now hardened twigs and leaves and well-grown fruit. The build-up in infestations on leaves and fruit was shown by these studies to be evident by early February, when both leaves and fruit of untreated trees had a mean of 10·8 adult scales. By the end of March, however, the number on fruit had increased to 108·2. Control, therefore, should be applied immediately after the summer reproduction peak to prevent the development of the destructive action by this generation.

Some of the control applications in the trials detailed above were made in December. These had outstanding effects on scale populations, especially on leaves and fruit, but even by early February some of the fruit on treated trees were infested with adult scales, and by the end of March more than half of the fruit were involved. The benefit of the treatments, however, was evident in that most of these fruit had only a few scales.

As shown by these studies, the summer peak in reproduction extends over December and January. The December applications therefore must have been only partially effective in checking leaf and fruit infestations and a better control should have been possible from January applications. April applications also had an outstanding beneficial effect, but as harvesting commences normally early in February, sometimes in the second half of January, the control applications should be made in January. The value of January applications and of these applications alone during the year have since been confirmed by orchard practice.

In the first control trial in 1949-50, comprised of single applications, some of the insecticides showed early promise of a reasonable control after the initial applications. The December applications, however, did not sufficiently check the population pressure of summer emergence to prevent large numbers of young from moving onto new twigs, leaves and fruit, and this resulted finally in a heavy infestation of fruit in all treatments. Consequently, single applications cannot be regarded as providing a satisfactory control of the scale.

The initial double applications in Trial 2 immediately showed to advantage in reducing the percentages of living insects, and after a few months there were no significant differences between the effects of each insecticide. This pattern followed each subsequent double application. The outstanding feature, however, was that the December 1949 applications suppressed the development of any population pressure from the summer emergence and precluded the movement of many young onto the new twigs, leaves and fruit. By early February untreated trees carried a moderately heavy infestation on more than half of the fruit, and by the end of March scarcely a fruit escaped a heavy infestation, whereas finally on the insecticide-treated trees more than three-quarters of the fruit were clean. The data in Trial 3 were not in such detail but generally confirmed these results.

At the time of commencement of these trials white oil was established as a control for red scale, but a new insecticide, parathion, was claimed by its manufacturers to be an effective control. In Trial 1 there were indications that both white oil and parathion might be of value, but the results were not significantly different from those on untreated trees. In Trial 2 lime sulphur was fairly consistently better than no treatment with respect to percentages of living insects and white oil and parathion rarely showed greater benefit, with little apparent difference between these two. In Trial 3 the ability of each insecticide to kill scale insects was in general similar to that in Trial 2. In the harvest of 1951 there was a suggestion that white oil was significantly superior to parathion, but the difference was reduced on adjusted yields after further yield studies in the following year.

Based on a district-wide survey, white oil proved to be of outstanding advantage over parathion in that trees which had received copper and white oil sprays retained the leaves and yielded for a much longer period than those receiving copper and parathion. Furthermore, figures from the August 1950 samples showed 25·5 per cent. of the scale population on white oil treated trees infected with entomogenous fungi and only 0·5 per cent. on the parathion treated trees. Parasites and predators were common on white oil treated trees but rare or absent on parathion treated trees.

The parathion concentration now permissible by law is less than one-third of that used in the trials and therefore white oil is regarded as the only effective insecticide for red scale on figs.

The standard control adopted for this pest (Brimblecombe 1951) is two applications of white oil (1–40) spaced 2–3 weeks apart in January each year.

XI. ACKNOWLEDGEMENTS.

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