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INFLUENCE OF ANNUALLY SCHEDULED TREATMENTS ON MAGNITUDE AND INTRA-TREE DISTRIBUTION OF CALIFORNIA RED SCALE POPULATIONS ON CITRUS

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ABSTRACT

The results of a long-term comparison of three dosage levels of parathion and a standard petroleum oil treatment for the control of California red scale on navel oranges in Southern California are presented. Matched and adjacent trees treated with the highest dosage of parathion and with petroleum oil respectively were terminally examined to determine the number of scale present and their distribution in directional quadrants of the tree and at various levels above the ground. Approximately fifty times as. many scale were found on the oil-treated tree as on the parathion-treated tree with larger numbers being found in the upper areas of the former tree in contrast to a reasonably uniform distribution in the latter tree. Fewer scale were found in the northeast quadrant of the oil-treated tree whereas lower numbers of scale were found in the entire north half of the parathion-treated tree.

The practical values of spray treatments for the control of California red scale, Aonidiella aurantii (Mask.), on citrus are normally evaluated within the year following their application, but it is often of more than academic interest to observe the long-term effectiveness and other posttreatment responses to treatments when they are used repetitively on an annual basis for a number of years. The overall advantages and disadvantages of a specific control treatment applied to a permanent crop such as citrus can be better appreciated by this experimental technique than by any other procedure, providing the schedule of treatments parallels the expectancies for good agricultural practice.

Such a regimen of consecutive, but practicably scheduled, applications is primarily useful in delineating the cumulative value of the treatment for scale control but additionally may be instrumental in eliciting acute phyto- toxicities often interdependent on other environmental factors, chronic tree responses associated with maintained exposure, or unfavorable population trends in other economic species present.

The duration of such tests is usually less than five years but the present report emanates from a study which involved eight consecutive annual applications of parathion (0, 0-diethyl O-p-nitrophenyl phosphorothioate) at each of three dosage levels and of a standard petroleum oil spray. The termination of the study was dictated by the desirabilities of relinquishing the grove assignment at the Citrus Research Center in Riverside for a more favorable test grove and as an accommodation of a plan to establish a new planting of citrus on the test site for use in conjunction with a special tree development study. The thus pending tree removal program afforded an opportunity to undertake a limited but quantitative evaluation of scale populations on paired trees with sustained treatment histories, and it is the primary purpose of this paper to present the results of this particular scale population analysis.

Experimental Procedures. - The parent study was established in a mature navel orange grove located on the property of the Citrus Research Center in Riverside, California. Because of the limited number of trees available in relation to the number of treatments, each treatment plot consisted of eight single tree replicates randomly assigned within blocks. Tree spacings in the grove were 22 feet by 22 feet (90 trees per acre).

The scale control treatments were applied once a year, normally in August or early September. However, the initial treatment in 1951 was applied on July 26 because of the immediacy of scale control need and a second application was applied October 26 to the low dosage parathion plot (i. e., 0. 5 pound 25 per cent wettable powder per 100 gallons) because of the failure of this treatment to reverse the population trend following the initial application. Subsequently, this low dosage plot received only annual spray applications.

As required, maintenance treatments for the control of citrus red mite, Panonychus citri (McG.), citrus thrips, Scirtothrips citri (Moult.), and several species of aphids were applied uniformly over the entire test block, utilizing only materials known to have no appreciable effect on California red scale.

All treatment applications were made with a conventional citrus sprayer unit equipped with a 55 gallon per minute capacity reciprocating pump operating at a pump-side pressure of 550 pounds per square inch. Spraying was undertaken from the catwalk of an hydraulically-positioned spray tower and from ground stations within and peripheral to the tree canopy, using manually operated orchard spray guns. Thorough wetting of all aerial surfaces of the tree was required in all of the scale control applications. The amount of dilute spray required per tree per application ranged from 24 to 29 gallons, depending upon tree size and existing degree of foliation and fruit cropping.

A 25 per cent wettable powder formulation of parathion was used at dosages of 0. 5, 1. 0, and 2. 0 pounds respectively per 100 gallons of

dilute spray. The petroleum oil used in the standard treatment was obtained from grower supply sources and in all cases conformed to the specifications of the California State Department of Agriculture classifications (Erb 1932).

Population levels of California red scale were evaluated periodically by examining 40 fruit and 40 leaf units, randomly selected in proportionate numbers from each quadrant, of each tree and determining the number of units infested with live adult female scale. Such examinations were made at approximately three month intervals throughout the course of the experiment and in all cases immediately preceding or shortly after the annual applications. Results were expressed in terms of the number of units infested with live adult female scale.

With the impending termination of the study occasioned by the scheduled removal of the grove, permission was obtained to destroy two trees prior to the harvest of the crop. The selected trees were adjacent to one another and ideally similar in size and basic conformation. One had received the highest dosage level of parathion used in the test and the other had been oil sprayed.

Guy wires between peripherally positioned poles were used to establish zones of tree structure based on directional quadrants of each 3 foot vertical stratum starting at ground level. Detailed counts were obtained by physically removing the tree components from each of these predetermined zones and recording the number of live adult female scales found on specific tree substrates (e.g., leaf, green wood, gray-green wood, gray wood less than one inch in diameter and gray wood more than one inch in diameter). The examinations were completed between June 29 and July 8 at a time when the small green fruits present were not infested. The lower portions of each tree were removed first and the trunk and principal scaffold branches were left intact and examined in situ. Because of the desirability of completing the counts within a limited time period, no effort was made to record immature stages of the California red scale and the presence of other pest species or to effect surface and/or volume measurements of the tree structures in each zonal section.

Results and Discussion. -- The overall control of California red scale achieved by the treatments used in this test in the extended sequence of applications is indicated by a comparison of the pretreatment and annual terminal counts on fruit and leaf units presented in Table 1. Since the annual terminal count made approximately one year following application represents the greatest degree of population resurgence, the several interim counts made each year for monitoring purposes assume less significance and are not herein reported.

Differences in initial population levels such as are encountered from tree to tree and plot to plot, compounded by a sequence of annual

Table 1. -- Effect of annual applications of parathion and petroleum oil for control of *California red scale* on naval orange trees at Riverside, California, as indicated by percentage of fruits and leaves infested with live adult female scale before and after spray applications of July 26, 1951, September 17, 1952, September 17, 1953, August 17, 1954, August 19, 1955, August 23, 1956, August 12, 1957, and August 12, 1958.

Material	Amounts per 100 gallons	Pretreatment count 7/24/51	Annual terminal counts								
			8/29/52	9/8/53	7/27/54	7/26/5	8/22/56	8/9/57	8/16/58	8/21/59	CRI[a]
			Per Cent Fruit Infested								
Parathion 25WP	0.5 lb[b]	50.0	3.8	2.5	0.6	0.6	0.6	2.2	4.6	25.0	58
" "	1.0 lb	48.8	8.1	1.2	0.7	0.0	0.3	0.0	8.0	11.6	44
" "	2.0 lbs	50.9	3.1	1.2	0.0	1.0	0.3	0.0	6.6	11.4	34
Petroleum oil, light medium grade, emulsive type	1.75 gals.	54.1	19.4	1.6	0.6	1.3	0.7	0.8	25.9	24.3	100
			Per Cent Leaves Infested								
Parathion 25WP	0.5 lb[b]	36.9	2.5	0.9	0.0	1.6	-	2.2	2.8	9.7	100
" "	1.0 lb	46.6	4.4	0.0	0.3	1.6	-	0.3	2.8	5.6	61
" "	2.0 lbs	44.4	2.2	0.3	0.3	0.6	-	1.9	1.2	5.0	49
Petroleum oil, light medium grade, emulsive type	1.75 gals.	53.8	14.7	0.3	0.0	3.1	-	0.3	1.6	8.6	100

a/ Corrected relative infestation (Ebeling, 1947); inclusive of all posttreatment counts.

b/ Extra supportive spray of this treatment applied October 26, 1951.

terminal counts, pose some difficulty in effecting a comparative interpretation of the data. Since it may be expected that the number of scales initially surviving a treatment reflects both the magnitude of the pretreatment population and the efficacy of the treatment, differences between plots in the pretreatment population density may have a notable influence on the ultimate posttreatment population levels. The resultant difficulty in interpreting results based on posttreatment data alone may be partially resolved by utilizing the equation $x = 100 (ab'/a'b)$, which Ebeling (1947) suggested and termed the "corrected relative infestation" (C. R. I.). In the equation a and a' represent, respectively, pretreatment and posttreatment counts for a standard treatment, and b and b' represent the similar values for any given treatment in the experimental series. The C. R. I. values express the change in population level caused by each of the several treatments in an experiment in terms of the change effected by a standard or reference treatment which is arbitrarily assigned a C.R.I. value of 100. C. R. I. values of less than 100 indicate relative superiority of the treatment over the standard treatment and values greater than 100 indicate the converse. Within the limits of mathematical restrictiveness, the equation applies a correction factor for the differences in the pretreatment infestation levels of the various plots in a test, and the C. R. I. values often facilitate a useful comparison of treatments.

The overall effectiveness of the low dosage of parathion (0. 5 pound 25 per cent wettable powder per 100 gallons dilute spray) is more apparent than real since an extra application was made in October of 1951 to effect a reduction in scale population which would permit continuance of the plot. The essential inadequacy of this dosage level of parathion was again evident during the terminal period of the test when conditions for scale development were increasingly favorable. However, a degree of residual effectiveness characteristic of parathion appeared to induce some lag in the population response compared to that in the petroleum oil treated plot. The development of California red scale populations in Southern California was abnormally depressed during the period from 1953 through 1957 as judged by a number of indices and in this test was particularly evident on the oil-sprayed trees where population resurgence is normally experienced during the terminal portion of the treatment protection period.

It should be noted that the scale distribution studies were completed prior to the initial summer buildup of scale populations. On the specific trees involved in this evaluation no scale were found on a 40-leaf sample taken from the parathion-treated tree on June 18 preceding the operation and only three leaves infested with live adult female scale were found on a similar sample taken from the oil-treated tree. In the light of this assessment based on the usual procedures for characterizing population levels of California red scale on citrus trees, the total numbers of live adult female scale found on these trees shortly thereafter as shown in Tables 2 and 3 are of significant interest. With the anticipation that more scale was present on the oil-

Table 2. Population distribution of California red scale on a navel orange tree at Riverside, California, following annual treatments from 1951 through 1958 with parathion sprays as measured by number of live adult female scale found on various tree surfaces in tree quadrants at various levels above the ground. a/ b/

Tree Quadrant	Tree Surfaces					
	Leaf	Green Wood	Gray-Green Wood	Gray Wood (diameter)		Totals
				<inch	>inch	
	Ground Level to 3 Feet					
Southeast	41	40	13	0	0	94
Northeast	9	8	5	0	0	22
Northwest	32	22	11	1	0	66
Southwest	41	23	7	0	0	71
Subtotals	123	93	36	1	0	253
	3 to 6 Feet					
Southeast	60	90	32	9	1	192
Northeast	20	13	4	1	0	38
Northwest	17	24	11	2	0	54
Southwest	33	50	18	0	0	101
Subtotals	130	177	65	12	1	385
	6 to 9 Feet					
Southeast	26	52	46	4	0	128
Northeast	11	21	11	2	0	45
Northwest	4	15	7	0	0	26
Southwest	22	53	21	4	0	100
Subtotals	63	141	85	10	0	299

Table 2 (cont'd)

Tree Quandrant	Tree Surface: Leaf	Green Wood	Gray Green Wood	Gray Wood (diameter) < inch	Gray Wood (diameter) > inch	Totals
	9 to 12 Feet					
Southeast	9	23	27	8	0	67
Northeast	13	22	20	10	0	65
Northwest	7	26	11	0	0	44
Southwest	8	31	29	11	0	79
Subtotals	37	102	87	29	0	255
	12 Feet to Top of Tree					
Southeast	3	16	22	6	0	47
Northeast	1	4	10	6	0	21
Northwest	0	4	1	1	0	6
Southwest	0	22	40	9	0	71
Subtotals	4	46	73	22	0	145
Grand Totals	357	559	346	74	1	1337

a/ All treatments parathion 25% wettable powder at a concentration of 2.0 pounds per 100 gallons.

b/ Counts made during the period from July 6 to July 8, 1959.

Table 3. Population distribution of California red scale on a navel orange tree at Riverside, California, following annual treatments from 1951 through 1958 with petroleum oil sprays as measured by number of live adult female scale found on various tree surfaces in tree quadrants at various levels above the ground. [a/] [b/]

Tree Quadrant	Tree Surfaces					
	Leaf	Green Wood	Gray Green Wood	Gray Wood (diameter) ≤inch	Gray Wood (diameter) >inch	Totals
Ground Level to 3 Feet						
Southeast	221	117	46	32	0	416
Northeast	93	88	32	16	0	229
Northwest	62	55	20	2	0	139
Southwest	89	76	30	6	0	201
Subtotals	465	336	128	56	0	985
3 to 6 Feet						
Southeast	739	324	190	162	4	1419
Northeast	405	211	81	91	23	811
Northwest	1135	255	128	71	11	1600
Southwest	1157	401	212	125	14	1909
Subtotals	3436	1191	611	449	52	5739
6 to 9 Feet						
Southeast	3915	807	659	357	87	5825
Northeast	1211	413	367	196	15	2202
Northwest	3631	656	400	336	115	5138
Southwest	3480	973	726	594	130	5903
Subtotals	12237	2849	2152	1483	347	19068

Table 3 (cont'd)

Tree Quadrant	Tree Surface: Leaf	Green Wood	Gray Green Wood	Gray Wood (diameter) <inch	Gray Wood (diameter) >inch	Totals
			9 to 12 Feet			
Southeast	3292	1059	795	412	100	5658
Northeast	1531	401	412	192	67	2603
Northwest	4966	1352	1092	777	294	8481
Southwest	6990	1567	961	931	51	10500
Subtotals	16779	4379	3260	2312	512	27242
			12 Feet to Top of Tree			
Southeast	1818	681	940	735	66	4240
Northeast	1374	633	533	417	15	2972
Northwest	950	475	524	353	37	2339
Southwest	1622	710	446	278	0	3056
Subtotals	5764	2499	2443	1783	118	12607
Grand Totals	38681	11254	8594	6083	1029	65641

a/ All treatments light-medium grade oil at a concentration of 1.75 gallons per 100 gallons.

b/ Counts made during the period from June 29 to July 6, 1959.

sprayed tree, it was examined first but since the entire operation was accomplished within a ten-day period, changes in the composition of the respective scale populations were probably of minor importance.

The fact that almost fifty times as many scales were found on the oil-treated tree as on the parathion-treated tree is in full support of the control data exhibited in Table 1 and of the accumulated evidence that parathion is the more effective scalicidal treatment. The extent to which other differences shown in the data are meaningful is questionable because of the limitation of single tree units available for the study. It does appear that survivorship was proportionally greater on the leaf and gray wood surfaces of the oil-sprayed tree in contrast to the tendency for surviving scale on the parathion-sprayed tree to be found in relatively larger numbers on the green and gray-green wood surfaces. Cressman and Broadbent (1944) did not present confirming evidence but stated in their report on studies with oil sprays on lemons that leaves bore a relatively small proportion of the total scale population. This apparent difference may be related to the preferential wetting of the lemon leaf by oil (Ebeling, 1939) and to the appreciably lower deposition of oil on orange leaves in contrast to lemon leaves (Allison, 1931).

As regards oil deposition on gray wood surfaces, it is commonly stated that the scalicidal effectiveness of the oil in relation to its quantitative presence is lessened because of penetration into and adsorption on the spongy-like outer portion of the bark. The data presented herein lend some credence to this supposition.

A more remarkable contrast is shown by the vertical distribution of scale in the two trees. The difference is most readily shown in the percentage distribution figures of Table 4. Although well developed trees with peripheral canopies reaching to the ground were selected for this study, some less tree structure existed in the ground level to 3 foot vertical stratum. Tree structure in the 12 foot to top of tree stratum was particularly limited because of the characteristic rounding of the tree conformation at the tops which were approximately 15 to 16 feet above ground level. Taking these considerations into account the slightly downward trend of scale distribution with increasing height in the parathion-treated tree is in interesting contrast to the sharply upward scale distribution trend with increasing height in the oil-sprayed tree. While a measurement of the available tree surface in each vertical stratum was not secured, it would be more probable that the scale distribution trend on the parathion-treated tree would correlate more nearly with the actually available host surface area in each vertical stratum than would be the case with the oil-sprayed tree. The lesser amount of scale in the northeast quadrant of the latter tree fortifies the supposition that the greater incidence of scale in the upper tree areas may relate in great part to the more rapid posttreatment loss of oil deposits from these areas of the tree which are more exposed to sunlight, air movements, and other potentially

Table 4. Population distribution of California red scale in two navel orange trees at Riverside, California, following annual treatments from 1951 through 1958 with parathion and petroleum oil sprays respectively as shown by percentage of live adult female scale found in tree quadrants at various levels above the ground. [a/]

Vertical Strata	Tree Quadrant SE	SW	NW	NE	Totals
		Parathion Treated Tree[b/]			
Ground level to 3 feet	7.0	5.3	4.9	1.7	18.9
3 to 6 Feet	14.4	7.6	4.0	2.8	28.8
6 to 9 Feet	9.6	7.5	1.9	3.4	22.4
9 to 12 Feet	5.0	5.9	3.3	4.9	19.1
12 Feet to Top of Tree	3.5	5.3	0.5	1.5	10.8
Totals	39.5	31.6	14.6	14.3	100.0
		Petroleum Oil Treated Tree[c/]			
Ground level to 3 Feet	0.6	0.3	0.2	0.4	1.5
3 to 6 Feet	2.2	2.9	2.4	1.2	8.7
6 to 9 Feet	8.9	9.0	7.8	3.4	29.1
9 to 12 Feet	8.6	16.0	12.9	4.0	41.5
12 Feet to Top of Tree	6.5	4.7	3.6	4.4	19.2
Totals	26.8	32.9	26.9	13.4	100.0

a/ Counts made during the period from June 28 to July 8, 1959.

b/ All treatments parathion 25% wettable powder at a concentration of 2.0 pounds per 100 gallons.

c/ All treatments light-medium grade oil at a concentration of 1.75 gallons per 100 gallons.

dissipative factors. Other factors could be even more determinative, but more important than their identification may be the practical implications of this distribution pattern.

Experience in the use of petroleum oil sprays in Southern California for the control of California red scale on citrus has clearly demonstrated the importance of achieving spray coverage in the tops of trees. Dependence upon tower spraying for satisfactory control has been repeatedly demonstrated. The results of this study would suggest the feasibility of additional effort to secure absolute spray coverage in this part of the tree, the use of adjuvants to retard the loss of oil from tree surfaces, the differential treatment of the upper tree areas with more persistent oil fractions or other materials, or the use of other stratagems designed to provide more uniform scale control throughout the tree areas. Similar considerations would be suggested by the greater survival of scale in the south half of the parathion-treated tree but the practical value of increasing the overall effectiveness of the parathion treatment is less cogent.

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