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Mode of Action of Mineral Oils upon Armoured Scales (Diaspididae) in conjunction with Low-Volume Application*

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ABSTRACT

Evidence is presented that no satisfactory kill of California Red Scale could be achieved with oil when it was prevented from reaching the ventral surface of the scales by sealing their margins, which implies that oil covering the dorsal integument of the scales is a negligible control factor.

However, the addition of an organophosphorous insecticide (E.C.) to oil increased the mortality of margin-sealed scales by approximately 20% (due probably to a more effective penetration of the dorsal covering); this would appear to be a favourable development, as far as low-volume application is considered.

Introduction.

Low-volume application against insect pests of citrus is very advantageous, both from the economic point of view and as regards proper timing. While there is marked progress in this direction in connection with mite and the Mediterranean fruit fly control, nothing has yet been achieved against scale insects. A condition for satisfactory kill of oil- treated scale insects and inhibition of settling of crawlers is the building up of a continuous oil deposit, covering all morphological parts of the tree; this, however, is difficult to achieve with low-volume equipment.

During **1965** and **1966,** experiments were carried out with the view of promoting low-volume spray practice against the California Red Scale (Aonidiella aurantii Mask.).

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The present accepted conception on the mode of action of oil upon Diaspididae is as follows: oil, penetrating mainly through the ventral surface of the scale, reaches the spiracles and is subsequently drawn by capillarity through the tracheae; the thus occluded respiratory system causes suffocation (4, 5, 8). The insecticidal value of mineral oils therefore depends chiefly on their physical properties, such as molecular weight (6, 11), distillation range (2) and volatility, and much less on their toxic qualities. The suffocation process accounts for the great majority of killed scales in properly applied spray operations (5); hence the necessity of a continuous oil deposit upon the entire plant, as scales may settle on any part.

Some entomologists (1, 7, 8), however, attribute importance to physiological disturbances caused to scale insects through the direct action of oil on body tissues. Oil may also penetrate through openings of dermal glands and ducts on the cuticle (1, 7), macropores (7) on the ventral and dorsal side of the pygidium, and even through the anal opening (F. Bachmann, 1964, personal communication), thus increasing physiological disturbances. Some differences of opinion are also known to exist regarding the extent of oil penetration through the dorsal covering and its role as a mortality factor (7, 10); it was claimed that the amount of oil penetration is increased in young stages by the rotative movements of the pygidium.

Considering the possible importance of the above-mentioned additional ways of oil action (besides occlusion of the respiratory system) as mortality factors in low-volume technique, their close examination was therefore of interest.

Methods and Results.

The technique used was as described by Phillips and Smith (9), with some minor adjustments. Groups of adult red scales (pre- and ovoviviparous females) had their lateral margins or dorsal coverings sealed with latex (natural rubber) and subsequently treated with a medium grade naphthenic oil. The assessment of mode of action was based on mortality counts.

Mortality counts of oil-treated red scales are usually made several weeks after spraying; it was therefore important to ascertain that sealing the insects with latex - per se - had no harmful effect on them, even over a period of several weeks. Another point of importance was to confirm that latex actually protects the scale insects from effects of the type of proprietary oil used in Israel. Therefore, the following preliminary trials were carried out:

mortality counts.

a. Preliminary trial on the action of latex on scales.

Red scale-infested grapefruits were collected from a small plot of a citrus plantation; a sample of the scale material was examined and displayed a low mortality, namely 80% live females; parasitization was very low. The material was then divided into four groups and treated as follows:

I. - Sealing the entire external surface of the scale with latex, 24 days;

II. - Sealing the lateral margins (dorsal covering free), 24 days;

III. - Sealing the dorsal covering (margins free), 24 days;

IV. - Check, 24 days;

V. - As in I, 62 days; and

VI. - As in IV, 62 days.

Some of the material was examined 24 days after treatment, and some after 62 days; the results are recorded in Table 1.

Table 1. Preliminary trials concerning the possible action of latex on the mortality of scales.

Group	Category	Duration (days)	Scale counts (4 replicates)	
			Total number	% live
I	Fully sealed	24 days (6.II - 2.III.66)	79	84.1
II	Margins sealed	"	65	84.2
III	Dorsal covers sealed	"	66	73.8
IV	Check	" "	86	83.8
V	Fully sealed	62 days (14.II-17.IV.66)	68	69.1
VI	Check	"	76	82.6

b. Oil-protective properties of latex.

The results of laboratory trials summarised in Table 2 prove that sealing scales with latex (dorsal covering and lateral margin) protected them from the effects of 1.75% and 2% medium-grade summer oil emulsions.

Table 2. Oil-protective properties of latex.

Group	Category	Scale counts; average of 4 replicates			
		1.75% oil		2% oil	
		Total number	% live	Total number	% live
1	Scales sealed	44	75.4	66	62.7
2	Scales not sealed	44	6.8	171	13.3
3	Check	46	71.8	152	89.2

c. Laboratory trials on mode of action of oil.

Considering the problem from the point of view of spraying methods, one question remains dominant, viz: is the building up of a continuous oil deposit a necessary condition for successful kill of Diaspididae, or could significant scale mortality be achieved by a multitude of oil droplets, penetrating the tree canopy and deposited on the scale's dorsal armour? It is assumed that individually deposited basic oil droplets, when spreading over the scale or plant surface, will not assure the minimum effective dosage to the interior of the tree (a continuous deposit) - unless the external oil deposit on the periphery of the tree greatly surpasses the phytotoxic safety margin. The building up of a continuous oil deposit does not seem to be practical with low-volume equipment, whereas it is attainable when a drenching spray is applied with full-volume equipment.

To examine the extent of mortality caused by dorsal and ventral penetration of oil separately, the following trials were carried out:

Mature red scales (pre- and ovoviviparous females), settled on grapefruits, were divided into four groups and treated as follows: group (a) - scales not sealed with latex: group (b) - margins sealed with latex: group (c) - dorsal covering sealed with latex; and group (d) - check. Groups (a), (b) and (c) - four replicates each - were subsequently treated with

a 2% and 2.5% emulsion of medium-grade summer oil: group (d) served as check; mortality counts were carried out 20 (2.5% oil) and 27 (2% oil) days after treatment; the results are summarised in Table 3.

Table 3. Effect of oil on scales having their margins or dorsal coverings sealed with latex.

Category	2% Oil		2.5% Oil	
	Total No. examined scales	% survivors (average of 4 replicates	Total No. examined scales	% survivors (average of 4 replicates
Scales not sealed	99	26.7	86	0
Margins sealed, dorsal covering free	68	81.3	46	80.4
Dorsal covering sealed, margins free	56	34.2	69	21.0
Check	95	78.9		

d. The action of oil + insecticide.

Considering the poor prospects for using naphthenic oil in low-volume applications against the red scale, the behaviour and action of oil combined with E.C. and W.P. formulations of an organophosphorus insecticide upon the red scale were studied.

The same testing methods as above were applied, namely, sealing the scale's margins and dorsal coverings with latex and subsequent treatment with oil + insecticide (ethion).

In a preliminary trial, it was confirmed that latex protects the scales from the combined effects of oil and ethion. The following points were examined: insecticidal effect on the red scale of 1.75% oil, and oil 1.75% fortified with Ethion W.P. 0.3%, or with Ethion E.C. 0.15%; and the mode of action of an emulsion and suspension of Ethion combined with oil; the results are summarised in Table 4.

Table 4. Effect of oil and oil combined with Ethion on red scale.

Group	Category	Treatment	Number of examined scales	% survivors, average of 4 replicates
1 a	margins sealed, dorsal covering free	1.75% oil + 0.3 Ethion W.P. (25% a.i.)	64	76.2
b	margins free, dorsal covering sealed		81	15.8
c	scales unprotected		91	3.8
2 a	margins sealed, dorsal covering free	1.75% oil + 0.15 Ethion E;C; (50% a.i.)	71	55.9
b	scales unprotected		120	0.8
3 a	scales unprotected	1.75% oil	219	20.6
4 a		Check	114	79.9
b		% live scales on the date of treatment	391	81.6

Discussion.

Referring to Table 1, it is assumed that the action of latex upon the longevity of adult females either partially or fully sealed is a negligible factor, at least during the first month, and does not affect the outcome of the trials. It may also be mentioned that live crawlers and white cap stage larvae were found in great numbers after 24 days under maternal scales of fully covered females; live larvae and pupae of Aphytis were also found. After 62 days, only a few live crawlers were noted.

It is apparent (see Table 2) that scales are fairly safe from the locally used proprietary oil when they are sealed with latex. When penetration of oil through the scale's ventral surface has been prevented by sealing of margins, no scale mortality occurred (see Table 3); the percentages of live scales in this category were 81.3% and 80.4%, as compared with 78.9% in check. The percentage survival of unprotected scales

treated with 2% and 2.5% oil emulsion was 26.7 and nil, respectively. Sealing of dorsal coverings with latex (margins free) increased the percentage of survivors from 26.7 to 34.2%, and from 0 to 21% when scales were treated with 2% and 2.5% oil emulsion, respecticely, thus suggesting a limited lethal effect produced by oil penetration through the dorsal covering. It would therefore appear that the building of a continuous oil deposit on all morphological parts of the tree is a prerequisite for satisfactory kill of Diaspididae by means of a medium-grade naphthenic oil, without regard to the type of equipment; the unsuitability of low-volume equipment for achieving this condition has been pointed out previously.

The ratio of survival in groups 1c, 2b and 3a of Table 4 clearly indicates the increasing insecticidal effect of oil when combined with Ethion in both formulations. There is also an indication of a higher insecticidal effect of Ethion E.C. than W.P. There is a marked difference in the percentage of survivors in groups 1a and 2a in favour of emulsifiable concentrate as compared with wettable powder at identical quantities of active ingredients. The explanation for an approximate difference of 20% higher kill with E.C. than with W.P. seems to be the better penetration of the emulsion through the dorsal scale's covering. Actually, this was the first case in our experiments that a considerable number of scales were killed by an insecticide penetrating the dorsal integument.

Ethion W.P., when added to oil, acts in much the same way as oil alone, namely by penetration through the ventral membrane either of the saturated powder itself or else the active ingredient is rinsed and carried by the oil (see groups 1a and 1b, Table 4).

It is evident that no factor other than insecticidal effect was responsible for the high mortality rate of the treated scales during the experimental period (group 4a and 4b, Table 4). Of the three tested materials, oil with Ethion E.C. is the most promising, as far as low-volume application is concerned, since it is less dependent for its lethal effects on the existence of a continuous insecticidal deposit than are oil alone or in combination with Ethion W.P.

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