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Some experiments in citrus red scale control

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THE red scale (Aonidiella aurantii Masc.) is widely distributed throughout the world but tends to be a serious pest in those countries with semi-arid climates such as California, South Africa, Palestine and Australia. The home of the pest is probably China, but it has been known in Australia for over 70 years and it was from the continent that it was introduced into North America.

It has been described as the most serious insect pest of citrus, and in many countries this is undoubtedly true. In Western Australia it is widely established but is not the major pest in this State that it is in the Eastern States.

DESCRIPTION
The adult female is an almost circular soft-bodied insect which has no power of movement. It is protected by a hardened reddish-brown waxy scale about 1/10th of an inch across. The insect has sucking mouth parts, the sucking tube being produced into a hair-like organ much longer than the whole body of the scale.

The male insect is rarely seen. It differs greatly from the female, having a pair of well-developed wings and a tuft of filamentous threads, forming a kind of tail. It passes its early development covered by a waxy scale, but when it reaches maturity it pushes out from under its covering and goes in search of a mate. The male scales or coverings are rather smaller than those of the female and are oblong instead of circular in shape.

LIFE HISTORY AND HABITS
The red scale (unlike many other coccids) does not lay eggs but gives birth to living young. The young or larvae may remain under the protecting mother scale for a brief period after birth, especially if the weather is cold.
The young scales, on emergence, are only just visible to the naked eye, and look like tiny yellow specks of sulphur. Under a lens they will be seen to have three pairs of functional legs and a pair of feelers or antennae.

As a rule the young or "crawlers" do not migrate far, but settle down within a few inches of the parent. The active crawling stage may last a few hours or a couple of days, then the mouths parts are inserted into the plant tissue, the antennae and legs are drawn in under the body and the first cottony threads of the covering scale appear.

When finally settled down, the female red scale remains fixed in position throughout its life.

After imbibing sap for some time the young scale moults its skin and at the same time loses its legs and antennae. It grows considerably and adds to the scale covering, then after a second moult it reaches maturity.

The time required to develop from crawler to adult varies with the season of the year and the locality. The main breeding season in Western Australia extends from November to May, when several generations may be developed.

Exact details are not known for local breeding rates, but in South Australia it has been shown that it takes about nine weeks in the summer and about 20 weeks in the winter for a newly-hatched female to be ready to give birth to the next generation.

After starting to produce young in the early summer, females may continue to give rise to crawlers for about two months, during which time 150 may be born. This reproduction may continue on fruits even after they have been picked and held in store.

Normally, red scale does not reproduce during the winter. Individuals which have settled down just before the onset of the cold weather may go on developing slowly and be ready to breed the following summer, but many perish.

**METHOD OF DISPERSAL**

It is clear from what has already been said about the larval scales that their actual movements and activity have little to do with the spread and distribution of the pest.

Transport of infested trees and fruits, picking boxes and so on is the main cause of spread of the pest. Wind is probably the chief agent within an orchard, as "crawlers" are known to have been carried 400 ft. by this means. They have also been known to attach themselves to the bodies of birds and insects and thus be carried far afield.

**HOST PLANTS**

There is no complete list of host plants in Western Australia, but the fact that, in South Africa, no less than 200 plants have been listed as carrying the scale shows that citrus are by no means the only species attacked.

Locally, in addition to all types of citrus it has been recorded on figs, mulberries, roses, apples, plums, vines, nectarines, pears, white cedar, castor oil and zamia palms. Although it is of little economic importance on trees other than citrus, these alternative hosts must be considered when sources of infestation or carry-over in an orchard are being investigated.
**TYPE OF INJURY**

Red scale attacks all parts of the tree—leaves, fruit, twigs and branches. It may become so thick as to form an incrustation of over-lapping scales.

It is the only common citrus scale in the State which actually infests the fruit and consequently it may be easily recognised on this account. Another characteristic is the yellow discoloration which may be seen around the feeding puncture, either on leaves or green fruits. Even when the scale has been rubbed off this evidence of its presence persists for some time.

The first indication of the adverse effects of the scale is a yellowing and then a dropping of leaves. In bad infestations, the twigs and young branches may die back, to be followed finally by death of the whole tree.

Unlike the black and soft brown scale, the red scale does not secrete honey dew and so the unsightly accumulation of black sooty mould associated with these varieties is absent.
Recent Investigations into Red Scale Control

The standard recommendation for control of citrus red scale has been a white oil spraying programme. However, as a result of the occasional failure of this treatment experiments were started in 1959 to investigate citrus red scale control in Western Australia.

ARMADALE EXPERIMENT 1959

A randomised block experiment was laid out at Mr. W. Eddy's orchard, Armadale in December, 1959, to test some of the newer spray combinations for scale control.

Six treatments were compared, each being replicated five times. Each treatment plot consisted of four trees. Small Valencia trees were chosen so that adequate coverage from the ground could be obtained with the spray unit available.

The following materials were compared:

1. MALATHION WETTABLE POWDER
   25 PER CENT.: 2 lb. per 100 gals. plus 2 oz. Agral wetting agent plus superior summer oil 1 in 80.

2. TRITHION WETTABLE POWDER: 2 lb. per 100 gals. plus 2 oz. Agral wetting agent plus superior summer oil 1 in 80.

3. GUSATHION WETTABLE POWDER: 2 lb. per 100 gals. plus 2 oz. Agral wetting agent plus superior summer oil 1 in 80.

4. MALATHION EMULSION 50 PER CENT.: 1 pint per 100 gals. plus 2 oz. Agral wetting agent plus superior summer oil 1 in 80.

5. WHITE OIL: 1½ gals. per 100 gals.


The experiment was sampled during the first week of December, 1960, by a leaf count technique. Twenty leaves were picked at random from the inside of each tree—so that 80 leaves were examined for scales from each plot.

Each treatment total was obtained from the scale counts on 400 leaves.

UPPER SWAN EXPERIMENT 1960-62

Following the results of the above experiment a replicated experiment was laid out at Mr. J. Anderson's property at the Upper Swan to further evaluate these materials.

A randomised block design was used, with six treatments replicated four times. This was applied to a block of 96 Washington Navel trees. These were large trees, about 18 to 20 feet high with a uniformly high scale population.

The following treatments were applied:

A. GUSATHION WETTABLE POWDER: 2 lb. per 100 gals. (0.05 per cent.) plus 2 oz. wetting agent plus superior summer spraying oil 1 in 80.

TABLE 1

<table>
<thead>
<tr>
<th>TREATMENT</th>
<th>TOTAL SCALES ALL BLOCKS (400 LEAVES)</th>
<th>CONTROL</th>
<th>MALATHION W.P.</th>
<th>GUSATHION</th>
<th>TRITHION</th>
<th>WHITE OIL</th>
<th>MALATHION W.P.</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1,664</td>
<td>771</td>
<td>156</td>
<td>453</td>
<td>1,460</td>
<td>453</td>
<td></td>
</tr>
<tr>
<td>Total log x transformation</td>
<td></td>
<td>1,198</td>
<td>1,053</td>
<td>726</td>
<td>945</td>
<td>1,214</td>
<td>982</td>
<td>6,118</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>239.6</td>
<td>210.6</td>
<td>145.2</td>
<td>189.0</td>
<td>242.8</td>
<td>196.4</td>
<td>203.933</td>
</tr>
</tbody>
</table>

L.S.D. Treatment Means:—P < .05 = 34.5508; P < .01 = 47.1223; P < .001 = 63.7683.

Ranked Means in order of efficiency:—

Gusathion Trithion Malathion [Malathion W.P. | Malathion Emuls. | Control | White Oil]

| Ranked Means | 145.2 | 189.0 | 196.4 | 210.6 | 239.6 | 242.8 |

Means not underscored by the same line are significantly different at the 5 per cent, level.
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(Department of Agriculture)

Parents are reminded that applications for 1964 admission to Muresk Agricultural College close on December 31 of this year. A preliminary selection of 1964 entrants is made after the Junior results are available early in 1963.

The successful applicants then continue with Sub-Leaving, or higher studies, in 1963.

Before the course can be commenced applicants must have studied:

Junior.—
(a) English; Maths A; Maths B.
(b) Physics and Chemistry (or Science A and Science B), or General Science.
(c) Book-keeping.
(d) Others such as Geography.

Sub-Leaving.—English; Maths A; Physics; Chemistry and others.

Those who take General Science need extra Chemistry and Physics in the following year. Some prefer to take Junior Book-keeping in the same year.

Should places still exist for 1964 commencement after the preliminary selection early in 1963, they are filled in order of application during 1963, by qualified applicants.

Duration of Course.—Two years.

Fees.—Approximately £190 per annum covering full residential charges.

Scholarships.—Department of Agriculture (3), the "Countryman" and J. J. Poynton Memorial (2).

Boarding Allowance.—Most Muresk students are eligible for the Education Department Boarding Allowance (£50 per annum).

Full details of the College are obtainable from the Principal, Muresk Agricultural College, Muresk, W.A., or the Department of Agriculture, Perth.
B. As in (A).

C. TRITHION WETTABLE POWDER: 1\(\frac{3}{4}\) lb. per 100 gals. (0.05 per cent.) plus 2 oz. wetting agent plus superior summer spraying oil 1 in 80.

D. As in (C).

E. SUPERIOR SUMMER OIL: 1\(\frac{1}{2}\) gals. per 100 gals. plus 2 oz. wetting agent.

F. MALATHION WETTABLE POWDER 25 PER CENT: 2 lb. per 100 gals. (0.05 per cent.) plus 2 oz. wetting agent plus superior summer spraying oil 1 in 80.

Each plot was composed of four adjoining trees forming a square. Each block comprised 6 x 4 trees.

The experiment was sprayed to coincide with the liberation of the young crawlers. In the first season these dates were 12th-15th December, 1960, and 12th-15th March, 1961. In second season the dates were 4th-5th December, 1961, and 19th-20th March, 1962.

The trees were sprayed from both outside and inside. (Trees had been pruned to give easy access.)

The tops of the trees were sprayed from a tower mounted on the spray vat, to give a platform 15 feet above ground level. An adequate coverage of both leaves and wood was obtained in this manner. From eight to 10 gallons of spray material were applied per tree.

At the end of the second season the experiment was sampled by harvesting 50 fruit from the inner part of each plot. The totals in table 2 show the scales from 800 fruit for each treatment.

The sampled fruit was taken at random from the layer between 4 to 8 feet from the ground.

**SCALE DISTRIBUTION**

A series of Valencia trees in Mr. Anderson's orchard, Upper Swan, were harvested in full to determine the distribution of scale within the trees.

These trees were divided into four arbitrary equal horizontal layers and the scales on the fruit from each layer counted. The trees were uniform in shape and about 18 feet high.

There was a marked predominance of scale population in the crown.

Spraying from a platform about 15 feet above the ground and mounted on the spray vat enables a good coverage of the leaves and wood to be made.

This trend (shown in table 3) was definite in all trees, although they had received varying insecticidal sprays for scale control.

**DISCUSSION**

At the properties used for the above experiments there had been a history of repeated failure to control scale with the standard white oil sprays.

The white oil treatment at the Armadale orchard was comparable to the nil treatment, while the superior summer spraying oil treatment at the Upper Swan orchard was not commercially acceptable. The totals in table 2, which give the results of the Upper Swan experiment, allow a direct comparison between the oil treatment and oil plus organic phosphates.

In both experiments the success of the oil plus either gusathion or trithion treatments was demonstrated.
### TABLE 2

**Citrus Red Scale Control—Upper Swan Experiment, 1960-62**

<table>
<thead>
<tr>
<th>TREATMENTS</th>
<th>OIL + GUSATHION</th>
<th>OIL + TRITHION</th>
<th>OIL + TRITHION</th>
<th>OIL + MALATHION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block I—Scales/200 fruit</td>
<td>158</td>
<td>250</td>
<td>676</td>
<td>318</td>
</tr>
<tr>
<td>Block II—Scales/200 fruit</td>
<td>172</td>
<td>91</td>
<td>371</td>
<td>920</td>
</tr>
<tr>
<td>Block III—Scales/200 fruit</td>
<td>624</td>
<td>186</td>
<td>225</td>
<td>1,294</td>
</tr>
<tr>
<td>Block IV—Scales/200 fruit</td>
<td>212</td>
<td>537</td>
<td>938</td>
<td>730</td>
</tr>
<tr>
<td>TOTALS—Scales/800 fruit</td>
<td>1,166</td>
<td>1,064</td>
<td>2,210</td>
<td>3,262</td>
</tr>
<tr>
<td>Total of Transformation</td>
<td>9-57</td>
<td>9-38</td>
<td>10-72</td>
<td>11-43</td>
</tr>
<tr>
<td>Mean</td>
<td>2-393</td>
<td>2-340</td>
<td>2-660</td>
<td>2-858</td>
</tr>
</tbody>
</table>

Standard Error = 5.7430% of G.M.

L.S.D. Treatment Means: — P < .05 = 0.371; P < .01 = 0.514; P < .001 = 0.709.

**Ranked Means in Order of Efficiency**

<table>
<thead>
<tr>
<th>Oil + GUSATHION</th>
<th>Oil + TRITHION</th>
<th>Oil + MALATHION</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.390</td>
<td>2.330</td>
<td>3.698</td>
</tr>
</tbody>
</table>

Means not underscored by the same line are significantly different at the 5 per cent. level.

### TABLE 3

**Citrus Red Scale Control—Distribution Within Trees**

<table>
<thead>
<tr>
<th>TREE</th>
<th>CROWN</th>
<th>3rd LEVEL</th>
<th>2nd LEVEL</th>
<th>LOW LEVEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6,699</td>
<td>1,053</td>
<td>278</td>
<td>106</td>
</tr>
<tr>
<td>Nos. Fruit</td>
<td>535</td>
<td>608</td>
<td>522</td>
<td>279</td>
</tr>
<tr>
<td>SCALES PER FRUIT</td>
<td>13</td>
<td>2</td>
<td>0.5</td>
<td>0.3</td>
</tr>
<tr>
<td>2</td>
<td>1,596</td>
<td>1,333</td>
<td>653</td>
<td>332</td>
</tr>
<tr>
<td>Total Scales</td>
<td>16</td>
<td>5</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Nos. Fruit</td>
<td>99</td>
<td>287</td>
<td>544</td>
<td>266</td>
</tr>
<tr>
<td>SCALES PER FRUIT</td>
<td>16</td>
<td>5</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>7,575</td>
<td>3,972</td>
<td>1,463</td>
<td>1,151</td>
</tr>
<tr>
<td>Total Scales</td>
<td>333</td>
<td>452</td>
<td>254</td>
<td>241</td>
</tr>
<tr>
<td>Nos. Fruit</td>
<td>22</td>
<td>9</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>SCALES PER FRUIT</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>5,155</td>
<td>3,965</td>
<td>2,645</td>
<td>1,297</td>
</tr>
<tr>
<td>Total Scales</td>
<td>328</td>
<td>205</td>
<td>137</td>
<td>137</td>
</tr>
<tr>
<td>Nos. Fruit</td>
<td>15</td>
<td>12</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>SCALES PER FRUIT</td>
<td>15</td>
<td>12</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>5</td>
<td>5,586</td>
<td>8,577</td>
<td>1,080</td>
<td>832</td>
</tr>
<tr>
<td>Total Scales</td>
<td>202</td>
<td>485</td>
<td>186</td>
<td>119</td>
</tr>
<tr>
<td>Nos. Fruit</td>
<td>28</td>
<td>18</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>SCALES PER FRUIT</td>
<td>28</td>
<td>18</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>6</td>
<td>14,342</td>
<td>11,971</td>
<td>2,766</td>
<td>1,169</td>
</tr>
<tr>
<td>Total Scales</td>
<td>422</td>
<td>529</td>
<td>157</td>
<td>136</td>
</tr>
<tr>
<td>Nos. Fruit</td>
<td>34</td>
<td>23</td>
<td>18</td>
<td>6</td>
</tr>
<tr>
<td>SCALES PER FRUIT</td>
<td>34</td>
<td>23</td>
<td>18</td>
<td>6</td>
</tr>
</tbody>
</table>
Commercial Trial

During the two seasons 1960-1962 the whole orchard at the Upper Swan experimental site was sprayed in a commercial trial by officers of the Department of Agriculture. The gusathion superior oil mixture was used, following the results of the Armadale experiment, and a commercially acceptable result was obtained.

Two sprays were applied during each season to coincide with crawler emergence. This was in late November to early December and again in late February to early March. A spasmodic third generation appeared in 1961 but no further spraying was carried out.

Two unsprayed check trees were left during the first season. These became highly infested with scale and severe defoliation occurred. All fruit was covered completely with scale and very few fruit matured. The adjacent trees showed a marked increase in scale incidence above the rest of the orchard. These two trees were given routine sprays during the next season but did not regain their normal yield, although the foliage thickened. Scale population remained comparatively high.

Importance of the Crown

Table 3 shows the high scale population found in the crown of a citrus tree.

Trees 1 and 2 received thorough sprays of oil and gusathion and oil and trithion respectively.

The tops were sprayed from a tower and from eight to 10 gallons of material were applied to each tree. However there remained a big enough population to give average scale counts of 13 and 16 per fruit in the crowns of these two trees. Although this is commercially acceptable, there remains a reservoir of scale on the wood and leaves which readily reinfests the tree during the following season. The fruit harvested from the two lower levels of these trees had average scale counts considerably below the crown level, and higher quality fruit was obtained.

This was the first season that a spraying tower had been used on these trees, and it is likely that with the adequate coverage now obtainable these crown counts will be lowered in coming seasons.

Prevention of Spread to Apple Trees

The results on trees 1 and 2 in table 3 also show the high number of surviving scales in what is considered a commercially acceptable control.

This is in marked contrast to the results achieved in San José scale spraying on apple trees, where the dormant schedule enables complete coverage of the tree, and the residual leaf population does not survive.

Where citrus and apple trees are grown close together, a vigorous spraying programme is necessary to prevent the spread of citrus red scale to apple trees.

BIOLOGICAL CONTROL

Exhaustive efforts have been made in many parts of the world to obtain effective parasites and predators of the red scale.

The small yellow wasp Aphytis chrysomphali (Mercet.), is widely established in some areas and plays a part in controlling scale. This insect was introduced into Western Australia in 1905 and became successfully established in the Chittering area.

In 1943 a second wasp parasite, Comperiella bifasciata (How.), was introduced. This has been periodically recaptured from the field but its actual effectiveness in controlling scale has not been assessed.

In 1960 a further parasite introduction programme was commenced by the Department of Agriculture and a range of insects was obtained from various parts of the world through the Commonwealth Institute of Biological Control.

The following insects have been liberated in the Darling Range, Gosnells, and Chittering districts in the last two seasons: Prospaltella perniciosi Tower. Aphytis lueganensis Comp. Aphytis melinus DeBach. Aphytis diaspidis How. Chilocorus circumdatus (Schon.) Chilocorus hauseri Weise. Chilocorus bifugus Mulsant. Chilocorus kuwanae Silv. Comperiella bifasciata (How.)

Although some recoveries have been made it will take many years to determine whether these will survive and exert any influence on the scale population.

Where biological control is exerting an influence on scale population the indiscriminate use of the organic phosphate
and oil mixtures can lead to an increase in scale populations. The citrus red scale parasites can survive the white oil sprays but not the toxic organo-phosphate mixtures.

A common practice in some parts of the world where biological control exerts a partial reduction of the citrus red scale population, is to spray alternate strips of the orchard. The unsprayed trees enable parasite populations to build up and spread at a later date to the sprayed trees, which are left unsprayed in the following season.

In this way scale population is kept down chemically and the parasites are able to survive.

A further development of this technique for Western Australia, where parasite populations are an unknown factor, would be to spray the alternate strips with the white oil sprays instead of leaving them unsprayed. The orchard would then have alternate strips of white oil sprayed trees an organophosphate-oil mixture sprayed trees. This would be reversed in the next season.

Where a satisfactory control of scale is achieved with white oil sprays it is most likely that there is some influence being exerted by a parasite. On NO ACCOUNT should an organophosphate mixture be substituted over the whole of the orchard where this is the case.

SPRAYING TECHNIQUES

In citrus red scale control it is necessary to obtain adequate coverage of both foliage and wood. With a large tree this can be both a difficult and costly operation if adequate spray machinery is not available.

To spray citrus trees, which may be about 20 ft. high, it is necessary to employ high pressure equipment. Machines capable of operating at 500 lb. per square inch and delivering 10 to 15 gallons per minute are desirable.

Examples of this type of machine are the three cylinder Kent Orchard Sprayer, and the four cylinder Ronaldson Tippet Sprayer.

A certain economy of spray material is achieved with these machines because the operator can be confident that complete penetration has taken place in the few seconds that the machine is operated in one position. Although the output is high, there is none of the waste brought about by the overspraying of lower portions when attempting to reach the high areas, that is common when using low pressure equipment.

However it is possible to adequately cover large trees with low pressure (150-200 lb. per sq. inch) equipment, provided a spray tower is used and sufficient attention is paid to the inside of the tree. The apron should be pruned up from the ground to facilitate access to the inner parts of the tree.

A large citrus tree yielding 15 bushels of fruit may require from eight to 10 gallons of spray material to achieve satisfactory scale control.

Concentrate type spray machines are not recommended.

Recommendations for Control of Citrus Red Scale

As a result of the above investigations new recommendations for citrus red scale control have been formulated. The recommended sprays are:—

WHITE OIL:—

This mixture is widely used throughout the State and consists of 1 part of oil to 40 parts of water applied in late summer.

It is more effective to apply two sprays to coincide with the emergence of the young crawlers. If this double spray technique is used the concentration of oil may be reduced to 1 in 80.

ORGANOPHOSPHATE MIXTURES:—

Where white oil does not give adequate scale control the following mixtures may be used to advantage if timed to coincide with crawler emergence.
(1) GUSATHION WETTABLE POWDER 25 PER CENT.: 2 lb. per 100 gals. plus superior summer oil, 1½ gals. plus 2 oz. wetting agent. This mixture will also control both the soft brown and the black olive scale.

(2) TRITHION WETTABLE POWDER 30 PER CENT.: 1½ lb. per 100 gals. plus superior summer oil, 1½ gals. plus 2 oz. wetting agent.

(3) MALATHION WETTABLE POWDER 25 PER CENT.: 2 lb. per 100 gals. plus superior summer spraying oil plus 2 oz. wetting agent. This mixture is inferior to both (1) and (2) but gives some control.

Note.—White oil may be used instead of superior type summer oil but the wetting characteristics are inferior. The organophosphate powder should be premixed with a little water and the wetting agent and then brought up to the full volume. The oil should be added last.

TIME OF APPLICATION:—
Sprays should be applied to coincide with the emergence of the young mobile crawling stage from beneath the parent scale. This will vary from district to district but should be in late November to early December and again in late February early March.

Both sprays are necessary to achieve control of citrus red scale.

METHOD OF APPLICATION:—
High volume, high pressure equipment and thorough wetting of both sides of the leaves and the wood are necessary. A large tree may require up to 10 gallons of spray. A spray tower may be needed.

Concentrate equipment is NOT recommended.

WARNING:—
Organophosphate materials should be handled with care and the manufacturers' safety precautions closely followed.

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REFERENCES

Thompson, W. L., 1942.—The effect of magnesium deficiency on infestations of purple scale on citrus. J.E.E. 35: 351.


Rogor 40 is the insecticide of choice controlling a wide range of insect pests including aphids, mites and fruit fly. The effectiveness of Rogor 40 has been proved in widespread commercial use throughout the world. Fewer applications are needed to maintain insect control. The double action of Rogor 40 ensures both initial control and prolonged systemic protection. Safety nearer harvest and safety in use have been established over four years successful field experience.

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