C. B. HUFFAKER and C. E. KENNETT

Imported parasitic wasps show

Control of Olive Scale

with increasing effectiveness

Biological control of the olive scale—*Parlatoria oleae* (Colvée)—by a parasitic wasp imported to California, showed marked improvement in 1960 over 1956, when a previous survey was made.

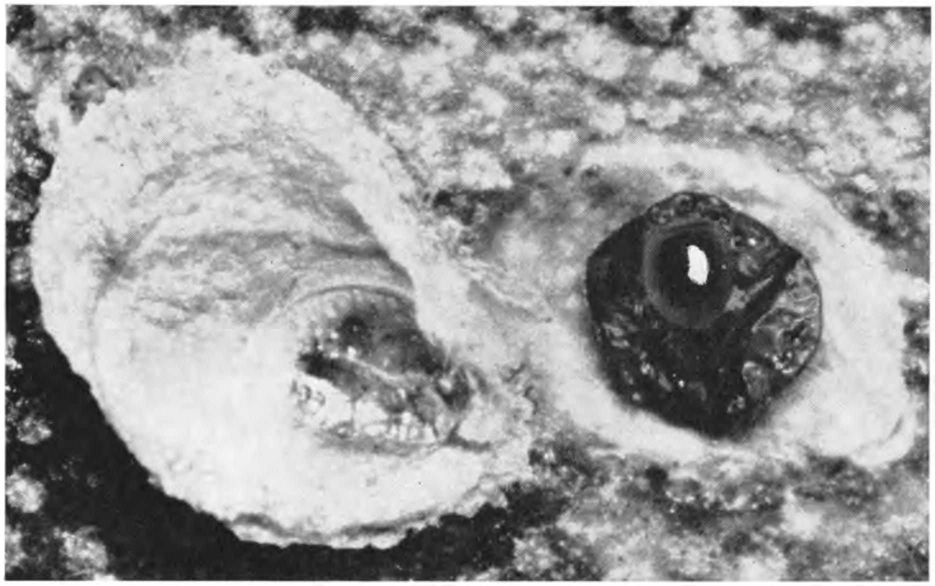
The parasite, a Persian wasp—*Aphytis maculicornis* (Masi)—was imported from Iran and Iraq, and first colonized in the San Joaquin Valley in 1952. During the following year—1953—nearly seven million parasites were colonized in approximately 300 locations in 21 counties. In 1960, total releases for initial colonization had surpassed 27 million in 24 counties. The parasites have not been released in Santa Cruz, Santa Barbara or Alameda counties because the problem of olive scale does not exist in those counties. It is rare that an old infestation of olive scale is found where the parasite is not present, except where insecticides are applied.

Colonization Period

A period of two to three years following initial colonization of the wasp may be required before the full effects can be expected and, in 1953, it was not known whether the parasite, even if given time, could give full commercial control. Consequently, many growers who had stocked their groves with parasites abandoned the biological control idea the first year, and turned to an insecticidal program, often using parathion which exterminates the parasite.

Investigations of the scale and of the parasite have continued for nine years. One early finding was that very low population densities of scales must be maintained to assure commercially clean olives. Trees that have infestations too low to affect vigor or yield may nevertheless have a considerable percentage

Left—Olive tree treated with DDT, infested with olive scale in absence of parasitic wasp. Right—Non-treated tree with olive scale controlled by imported parasite of the scale. *All photographs by F. E. Skinner.*



Parasitic grub feeding on olive scale. The grub is in the black center of the scale body from which the protective covering has been removed and is shown at the left of the scale.

of fruits which are culls because the olive scale in the crawler stage seems to prefer the olive fruits over the other parts of the tree.

The Parasite

The Persian wasp attacks principally the third stage female scales as a parasitic grub, feeding externally on the scale body beneath the covering. Yet the wasp does parasitize immature male scales and this source of generation is important during periods when the female scales are too young to be acceptable. The adult female wasp pierces the scale covering with a stiletto-like ovipositor and deposits a single egg on the host. The high degree of discrimination on the part of the wasp and her efficiency in searching for host scales at the proper stage of development are attested to by the fact that very rarely, and only under high population densities of parasites, are two eggs deposited on a host. This behavior is true even when scale densities are low, the parasite population is high, and 98% or more of the scales are parasitized.

The female wasp deposits eggs in comparable numbers to that of the scale—25 to 40 eggs during the life span—but the parasite has the potential of many more generations in a year. The scale has only two generations each year while the parasite may complete a generation in about 25 days in warm summer periods in the San Joaquin Valley.

Weather factors and absence of hosts in the proper stages—at certain critical times—prevent the wasp from approaching the high multiplication rate of which it is otherwise capable. The summer is adverse to the adult parasites and on hot dry days most of the females may die within 24 hours. However, the parasites in immature stages are protected by the host's covering, and by utilization of liquids available through feeding on the host. Adult female wasps may deposit a few eggs during such hot dry periods prior to dying but that barely permits survival of the parasite population at low densities. In the fall period of more favorable conditions a substantial rebound of the parasite populations from the low ebb at the end of summer is common. The winter usually is too cold for normal reproductive activity and the parasites overwinter in the immature stage. In the spring there is a phenomenal increase in parasite reproduction, the populations increasing in geometric fashion from fairly low levels in February to high levels—80% to 99%, or more, parasitization—in May.

Egg Production per Mature Female Olive Scale During the Spring Period When the Parasitic Wasp Is Active and During the Summer Period When the Parasite Is Nearly Absent

Year	Clovis Grove		Herndon Grove	
	Spring	Summer	Spring	Summer
1955	2.1	56.2	2.2	28.1
1957	0.9	37.3	5.2	28.7
1958	0.6	23.8	7.0	12.7
1959	0.8	29.4	0.2	20.1
1960	0.4	17.8	0	15.4

The stress of summer weather handicaps the parasite and often also the host scale in the crawler and young settled stages. The scale's two generations of young are produced in the spring and in the fall and are in their most susceptible stages when the weather stress is less severe than in July and August. Because of its shorter life cycle, the parasite is in its susceptible stage—the adult—during the period of severest summer stress. Consequently, severe weather favors the scale and one generation is free of effective control by the wasp. Possible selection of types of wasps better synchronized for early spring activity or more tolerant of summer conditions could give an increasing annual effectiveness.

The table in column 2 on this page shows the effects of parasitization of the scale by the wasp. The eggs produced per scale in the Clovis grove in the spring period were greater than 0.1 only in 1956 when parasites had just begun to exert their impact, while a large number of eggs were produced per female during the summer when the parasite is ineffective. Relatively, the same situation held in the grove at Herndon, but the contrasts were not so great. Interference with parasite activity by drift of insecticide appeared to be the explanation.

Commercial Control

Six commercial groves have been used for biological control experiments since 1955. Experimental check trees—where parasites were killed by repeated use of DDT, which does not kill olive scale—demonstrated the effectiveness of the wasp. The contrast in densities of scale populations under the two conditions—

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Densities of Scales on Parasite-Present and Parasite-Absent Trees

Grove	At initiation of test 1958		Densities in 1960		Ratio present densities to initial	
	Parasite present	Parasite absent	Parasite present	Parasite absent	Parasite present	Parasite absent
Lindsay	0.04+	0.01+	0.9	67.6	+2:1	+676:1
Seville	1.6	2.0	0.03	29.8	—5:1	+15:1
Hills Valley	1.3	0.8	0.10	90.7	—10:1	+113:1
Herndon	3.8	2.0	1.5	169.8	—3:1	+85:1
Clovis	3.0	1.2	2.5	287.8	1:1	+240:1
Madera	11.6	16.9	0.5	204.2	—23:1	+12:1

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parasite-present and parasite-absent—was outstanding. Densities of scales at the time of starting the test were nearly equal in all groves. They were moderately high in the test grove near Madera because of the short period of time under biological control, whereas in all other groves biological control was already in good operation.

After only two years, scale densities in the parasite-present trees had declined sharply at the Madera grove to $1/23$ the level in 1958 and had decreased somewhat, or remained nearly the same, at all the other groves. On the other hand, densities in the parasite-absent trees—DDT-treated—increased many times above the levels at the initiation of the tests. At the Lindsay grove there was a 676-fold increase, at the Seville grove a 15-fold increase, at the Hills Valley grove 113-fold. Since the original population levels varied markedly and, as well, the test in the Seville grove was started eight months later than the others, this variation in build-up of the scales in the absence of parasites is not unexpected.

The parasite-free trees developed heavily encrusted infestations, with dead and dying twigs, in relatively short time. The condition of the trees was reflected in the commercial level of the fruits. The table on page 5 shows the percentage of cull fruits under the parasite-present

Commercially Culled Fruits on Parasite-present and Parasite-absent Trees

Grove	Parasite-present trees		Parasite-absent trees	
	1959	1960	1959	1960
Lindsay	Fruit picked before sampling	1.0%	Fruit picked before sampling	93.0%
Seville	0.6%	0.0	Interference by oil	79.0
Hills Valley	1.4	0.3	42.0%	85.2
Herndon	7.4	0.4	93.5	98.0
Clovis	0.03	2.0	74.5	100.0
Madera	0.04	0.01	92.0	98.5

Fruit damaged by olive scale. Note scale encrusted leaves and twigs of the DDT-treated check tree.

and parasite-absent conditions. The accumulated effect is revealed in the records for 1960. The percentage of culls was very low, varying from none to 2.0%—commercially acceptable levels—in the parasite-present or biological control trees. On the other hand, fruits on the DDT-treated, parasite-free trees were distorted and discolored from high densities of scales, with 79.0% to 100% graded as culls.

Biological control gave excellent results in groves where scales otherwise would have caused complete loss of the crop, provided insecticidal control treatments were not used.

Surveys on the status of control of scale on olives throughout the major infested areas conducted in 1956 and again in 1960 showed a marked improvement in the degree of control by the parasite in trees well removed from sources of insecticidal drifts. Among some 35 places, the level of cull fruits in such locations was usually no more than from 0.5% to 4.0%.

However, examinations of some 10 or 12 locations adjacent to fields where drift of insecticides might interfere with control by the parasites revealed high densities of scales and in most of the locations the percentage of culls was excessive. A third category represented by a small minority of locations had moderately scaly fruits even though drift did not appear to be involved. One example involved a few scattered trees on a dry, windy hillside, and two others consisted of single rows of trees in dry back lots where backlot fires had been commonly built. These conditions may be too severe for the parasite. One example was a commercial orchard.

Insecticidal drift from adjacent crops to olive groves is a major problem. The disturbance varies with the kind, timing, frequency and manner of applications, and with wind direction, distance involved, and whether or not the source is massive or limited. In general, indica-

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Clean olives produced by tree where the olive scale is under biological control by the parasitic Persian wasp.

L. F. LIPPERT

Strain of aster yellows virus associated with

Spindling Sprout of Potato

in studies of disorder in California

An abnormal sprouting condition in potato tubers has been observed in California sporadically for the past 15 years. The disorder, termed spindling sprout or hair sprout, appears as weak, threadlike sprouts initiating from the eyes of apparently sound tubers. Spindling sprouts have been attributed to such varied causes as potato viruses, fungus infections, psyllid insects and adverse environmental conditions. Preliminary investigations have implicated the aster yellows virus as contributing to spindling sprout in California.

During the course of these studies, young White Rose and Russet Burbank potato plants in the greenhouse were leafhopper-inoculated with a strain of aster yellows virus collected in Tulelake, and transplanted to the field. Symptoms of Tulelake aster yellows virus in potato appeared first in the tops as narrow, chlorotic, curled leaflets, with or without purple pigmentation. Growth of the terminals was restricted, followed by stimulation of growth in the leaf axils as leafy shoots or tuberous swellings—aerial tubers. Infected plants rapidly wilted, and died before any tubers were formed.

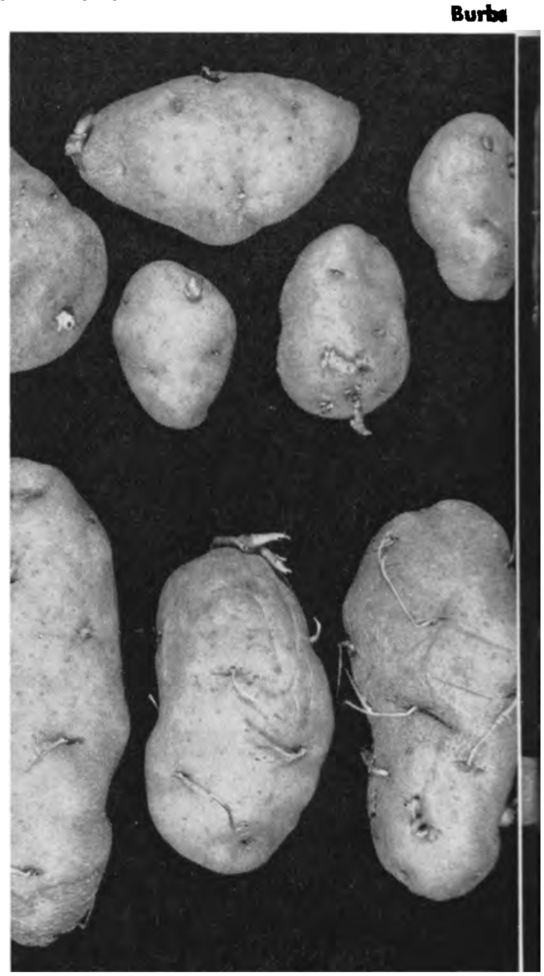
Leaf buds from symptomatic insect-inoculated plants were grafted to 54 healthy 45-day old field plants. Two Russet Burbank plants from this first graft series developed definite aster yellows symptoms 20 days after grafting. The two plants provided virus-infected scions for grafting an additional 20 healthy plants of each variety. The stock plants used for this late graft series were 65 days from planting.

Additional grafting experiments were conducted to determine the relationship of age of plant at time of infection and resultant spindling-sprout condition of the tubers. Groups of 10 each White Rose and Russet Burbank plants in the field were grafted with virus-infected scions at two-week intervals. Five groups of plants were grafted 30, 44, 58, 72 and 86 days after planting.

Records were made of plant symptoms during the season and tubers from individual plants were harvested at 120 days and stored for sprout germination.

Definite aster yellows symptoms were produced on 25 of 114 plants grafted with infected potato scions. The remain-

***Left*—Spindling- and normal-sprouted tuben inoculated with the Tulelake strain of aster spindling-sprouted tubers. *Right*—Spindling ι Burbı**



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tions are that spray applications by ground rigs do not influence biological control from more than three or four tree rows into the grove, but dust applications by airplane may have adverse effects at greater distances.

A regular program of adequate pruning to open up the tree, reduce clumping of branches and foliage, and to force long new leaders is conducive to full control by parasites. Successful control has been achieved in olive groves under gravity-flow and under sprinkler irrigation systems.

During the necessary time between the initiation of a biological control program and the achievement of general control by the parasites, a good oil spray may be used where needed. The oil interferes with the program much less than does parathion, for example, which kills the parasite, and oil treatments do not disrupt parasite control the following year.

Specific studies on the biological control of the olive scale on its many host plants in orchards, gardens, parks, and landscaped roadways, have not been conducted but the total value gained from control of the scale on such host plants by the parasitic Persian wasp may exceed the value gained in olive groves even if all the acreage of olives were under successful biological control.

C. B. Huffaker is Entomologist in Biological Control, University of California, Berkeley.

C. E. Kennett is Laboratory Technician in Biological Control, University of California, Berkeley.

Photographs by F. E. Skinner, Laboratory Technician, Department of Biological Control, University of California, Berkeley.

A. M. Boyce, Dean of the College of Agriculture, Riverside, imported the original stock of the Persian wasp from Iran and Iraq in 1951.

R. L. Doutt, Associate Professor of Biological Control, University of California, Berkeley, initiated the program of colonization in 1952.

G. L. Finney, Associate Specialist in Biological Control, University of California, Berkeley, and his associates propagated the colonization