(After these tests were conducted this model was removed from sale in most of California and most units already in use were replaced. The data are included in this report to demonstrate certain undesirable operating characteristics.)

Curve B, graph 5, is of an early-design controller using a reaction compensated valve with pedestal mounted weight. The controller tested was used, but reconditioned. The curve indicates that the valve did not shut off well at no flow (probably due to wear), but showed excellent performance throughout its entire normal working range—adequate for four to six units or a pump capacity above 50 cfm.

Curve C, graph 5, is of a more recent, yet obsolete, unadjustable controller of sleeve valve design with pedestal mounted weight. Proportionality is severe, safe usable capacity about 35 cfm, and absolute capacity is near 55 cfm.

Curve D, graph 5, is of a poppet-type valve with the weight suspended on a hollow sliding stem through which the admitted air is drawn. It is adjustable. Uniformity is good, the neutral zone is narrow, sensitivity is good at low flow rates. Proportionality is not excessive. Expected capacity is about 50 cfm.

Graph 6 is a composite of the three best and the three poorest test curves, plotted for comparison. (When several different weight adjustments were tested the setting nearest the common 14- to 15-inch vacuum level was plotted.) The three best controllers all gave high sensitivity from 5 to 60 cfm. The three poorest demonstrated excessive proportionality resulting in poor sensitivity, limited capacity, or excessively wide neutral zone.

Many of the milking machine vacuum controllers supplied through normal dairy equipment outlets were found to be rather crude proportional response air valves. Some showed evidence of deliberate design, but others were fabricated from common pipe fittings, apparently to remain price competitive. The several suppliers of the units tested made no particular reference to capacity. With high-capacity milking systems becoming standard, the need for adequate controllers is increasing. Udder health and operating efficiency must not be jeopardized by a poorly functioning controller. Capacity of each model of controller needs to be recognized, and the need of better engineering for this service is indicated.

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# *Control of* NAVEL ORANGEWORM

**F. M. SUMMERS · D. W. PRICE**

**Recent experiments indicate that chemical sprays applied to kill navel orangeworm moths in the spring may provide a practical way to control this pest.**

UNLIKE OTHER common fruitworms which attack stonefruits and nuts, the navel orangeworm has not previously responded to test sprays designed to protect maturing fruits against attack. Over the past eight years, a variety of pesticides have been sprayed in almond orchards once, twice and even three times during the period between early hull split and harvest date. None of these test sprays produced any material change in the amount of crop damage.

Failure to find a suitable remedy by this approach required that research be directed especially to analyzing the habits of the pest in all of its stages. The basis for a different approach to the problem resulted from some of these studies, as reported here.

Infestations in almonds appear to be self-sustaining. Almond orchards in isolated places—well away from fruit or nut orchards—may be severely affected by this pest. Black-light traps have shown that hulling sheds and machinery will not hold infestations over from one season to another—providing that they are reasonably clean and free of neglected piles of trash nuts. Trash nuts or mummies left on trees after harvest sustain the pest populations throughout most of the year. Unharvested nuts provide food and shelter for populations of overwintering larvae.

The reproductive periods of the navel orangeworm are not rhythmic; there are no clear cut "broods" or cycles during the growing season. However, during spring months, the populations of moths build up to a low-level maximum during the first half of May. These moths come from overwintered larvae maturing in the old nuts. During the growing season, the immature, green nuts of the new crop are not molested. Before the new crop ripens, the pest continues to breed on the few holdover trash nuts. After mid-May and before harvest date, light traps capture fairly small numbers of moths. There is a very sharp upswing in the population density during the harvest period, when new nuts come under attack.

A study of the relations between the moisture content of almond kernels and their susceptibility to attack by hatching larvae indicates that normal drying of nuts on the trees does not afford any appreciable protection. However, kernels artificially dried to less than 4% extractable free water show partial resistance to the entry of hatchling larvae. Perhaps the weakest link in attempts to protect ripening nuts with spray chemicals is the tendency of moths to deposit some of their eggs under the lips of splitting hulls. The hidden eggs and the tiny hatchling larvae are therefore not exposed to chemical residues deposited on the outer surfaces of the hull. Previous attempts to utilize dormant types of sprays to kill larvae established within old or new nuts have not been successful. An insecticidal bacterium, *Bacillus thuringiensis,* used to contaminate mummy nuts to make them unsuitable as food for orangeworm larvae was also ineffective.

Since navel orangeworm larvae established in either old or new nuts do not respond to conventional spray treatments, an attempt was made to control the pest

Navel orangeworm pupae in an overwintered, sticktight almond.

TABLE 1—PERSISTENCE OF MOTH-KILLING EFFECTS OF SPRAY RESIDUES ON SPRAYED ALMOND TREES AS ESTIMATED ON VARIOUS DAYS AFTER APPLICATION BY BIOASSAY TESTS

| Insecticides | Amounts per 100 gals. | Dates sprays applied and tests started | Days persistence to cut-off point (70 LMD)[1] |
|---|---|---|---|
| Dibrom 8E[2] | 1 pt | May 27 | 1 |
| Dibrom 8E | 1 pt | Aug. 19 | 3 |
| Diazinon 2E | 1 pt | July 5 | 3 |
| Diazinon 50W | 2 lbs | May 27 | 6 |
| Diazinon 50W | 2 lbs | Aug. 13 | 6 |
| Diazinon 4E | 1 pt | Aug. 11 | 8 |
| Parathion 25W | 2 lbs | May 28 | 6[3] |
| Parathion 25W | 2 lbs | June 17 | 5 |
| Parathion 25W | 2 lbs | Aug. 15 | 12 |
| Thiodan 50W[2] | 1 lb | June 17 | 7 |
| Thiodan 50W | 1 lb | Aug. 15 | 15 |
| Guthion M-E,2E[2] | 2 pts | June 26 | 7[3] |
| Guthion M-E,2E | 2 pts | Aug. 19 | 12 |
| Guthion 2E[2] | 2 pts | Aug. 12 | 15 |
| Guthion 25W[2] | 2 lbs | June 17 | 21[3] |
| Guthion 25W | 2 lbs | Aug. 12 | 26 |
| Sevin 50W[2] | 1 lb | Aug. 11 | 23 |
| Sevin 50W | 2 lbs | Aug. 10 | 31 |

[1] This is a rough measure of the period of time in days during which the bioassay tests yielded survival values below 70 LMD (Live Moth Days) after 5 days of exposure of 20 moths to treated foliage. A value of 70 LMD was chosen to be an arbitrary level of significance, or cut-off point, on a scale of 0–94 because test readings were noticeably erratic above this value. Check runs with unsprayed foliage yielded an average of 94 LMD; range 87–100 for 15 checks set up periodically during the test period.
[2] Trade-marked names.
[3] Tests concluded prematurely for reasons beyond control of experimenters.

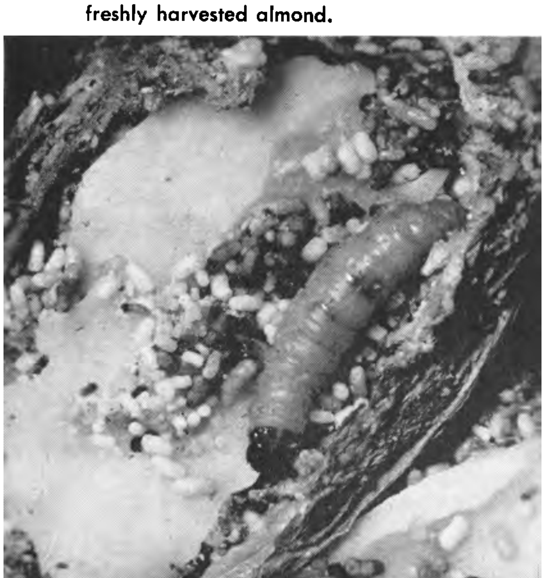
TABLE 2. PERCENTAGE OF INFESTATION IN SAMPLES OF 1,000 RIPE NONPAREIL NUTS HARVESTED IN PLOTS SPRAYED DURING OR AFTER THE SPRING PERIOD OF MOTH EMERGENCE FROM OVER-WINTERED TRASH NUTS

| Schedule | Test materials | Pounds per gallon | Gallons per acre | Dates sprayed | | | % kernels with navel orangeworm larvae | % reduction of infestation |
|---|---|---|---|---|---|---|---|---|
| A | Sevin 50W* | 2 | 400 | 5/2 | 5/17 | 6/1 | 3.7 | 5 |
| | Orchard check | – | – | – | – | – | 3.9 | |
| B | Sevin 50W | 4 | 250 | 5/21 | 6/21 | 7/23 | 8.5 | 47 |
| | Orchard check | – | – | – | – | – | 15.9 | |
| C | Guthion 25W* | 2 | 400 | 4/17 | 5/8 | 6/1 | 1.5 | 63 |
| | Orchard check | – | – | – | – | – | 4.0 | |
| D | Guthion 25W | 2 | 250 | 4/27 | 5/13 | 5/27 | 0.9 | 55 |
| | Orchard check | – | – | – | – | – | 2.0 | |
| E | Guthion 25W | 2 | 250 | 6/10 | 7/9 | 8/16 | 0.9 | 67 |
| | Orchard check | – | – | – | – | – | 2.7 | |

* Trade-marked names. Reduced gallonage used in Schedule D and E because young trees were not yet full size.

by killing the moths emerging from trash nuts during the spring. The spring period of moth emergence during 1964, as determined with black-light traps, is shown in figure 1 of the graph. Very few moths were present in orchards during March. A perceptible increase in numbers was detected during the first week of April, building up to a peak on or about May 10, after which the numbers declined. The sharp ups and downs in figure 1 of the graph indicate variations in the catch due to cold and windy weather conditions. Traps had also been operated during 1962 and the general pattern of spring flight activity in 1964 was found to coincide quite well with the earlier data. After mid-June and until early August in 1962, the numbers of moths present in almond orchards fluctuated around a low average.

Mature larvae of navel orangeworm in a freshly harvested almond.



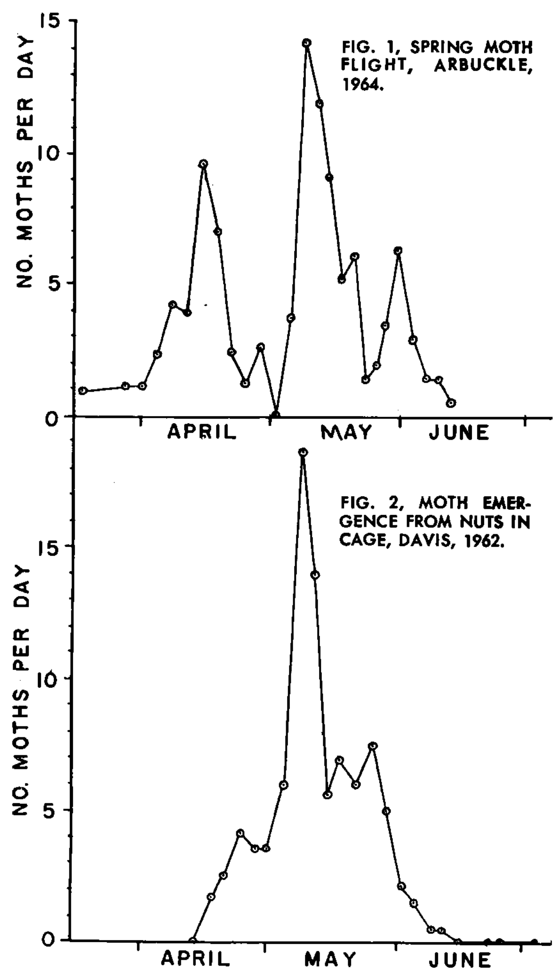
A walk-in screen cage was constructed out of doors in a semi-shaded location to further confirm information on the spring buildup. One hundred pounds of heavily infested in-shell nuts, taken directly from a processing plant, were distributed in the cage. The numbers of moths emerging in the cage during the spring of 1962 are plotted in fig. 2 of the graph.

The evidence, therefore, indicates that the spring emergence of moths is a slow, gradual process having a duration of about 90 days, but with the bulk of the population appearing in April and May. These are the moths which reinfest hold-over nuts—many of which already have supported one or more larvae through the winter.

Bioassay procedures were developed to identify the most persistent moth-killing pesticides among those used in recent tests. All of the chemicals listed in table 1 were known to be lethal to navel orangeworm in the active stages. The problem, however, was to determine how many days after spraying onto orchard trees each chemical would retain a significant killing effect upon navel orangeworms in the moth stage.

A sample of 20 one-day-old female moths was placed in a small cage containing one bouquet of almond foliage to which they were exposed for five days. Counts of survivors were made every day for five days for each cage. Bouquets were picked on the day of spraying, one day later, two days later, and then at longer intervals until the particular spray weathered away completely. The relative values obtained for the several pesticides tested are shown in table 1. The bioassay procedure showed that, among the materials tried, Sevin and Guthion have the longest residual life against navel orangeworm moths and should be most useful for field trials.

A program of sprays aimed at destroying the moth stage during the spring emergence period was implemented during the past season. The trials involved one- or two-acre test plots within orchards not otherwise sprayed except for mites. Each plot was sprayed three times with one or another of the two selected materials. Target dates for spraying were set at intervals of 15, 20, or 30 days and carried out as weather permitted. Three of the test plots, one per orchard, were



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sprayed by cooperating growers, and two plots were manually sprayed by the experimenters. Composite samples of 1,000 nuts, 100 from each of 10 trees near the center of each plot were harvested just before normal harvest operations began. The untreated samples were taken from the same number of unsprayed trees randomly selected around the test plot areas. Sample nuts were hulled and shelled by hand in order to identify the meats attacked by navel orangeworm.

Samples of nuts from the test plots (table 2) were consistent in showing differences in favor of the treatments. The reduction in worm-infested kernels ranged from approximately 5 to 67%. The three test plots sprayed with Guthion showed a greater per cent reduction in wormy nuts than the two plots sprayed with Sevin. One of the Sevin-sprayed plots showed better results than the other—for reasons not determined. The sequence of sprays applied at 30-day intervals beginning in June (Schedule E) was at least as good, or possibly better, than a sequence of three sprays timed to bracket the period of peak emergence (Schedules A, C, D). These preliminary results suggest that the timing of the sprays may not be as critical as first supposed.

None of the three-spray schedules produced results good enough to be accepted in commercial practice—but having a way to do at least this much, provides a basis for an area test. The hope that one or another of these schedules may be refined into a useful procedure hinges upon a factor not yet measured which may be called "plot interaction" or "edge effect." When a small plot of test trees located within an orchard of much greater size is disinfested, the effect of the treatment may fade out quickly since moths flying into the test plot from the large surrounding infested area are able to survive at least long enough to lay eggs on or in the nuts borne on the treated trees. A substantial improvement in results is anticipated when this one-sided geographical situation is reversed.

In other words, it now seems feasible to apply a treatment to an entire orchard space and to leave only an island of untreated trees as a check plot. If large-area spraying proves to be more effective than the experimentally applied spot treatments, the schedules now being tested may become practical remedies—at least for use in seriously infested orchards.

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