the timing of insect flights, or in the age of the plants when exposed to infection, or in a combination of both. The greenhouse experiment with stem cuttings (as mentioned) and caging experiments with cantaloupes will not support a contention that the altered physical environment within the cages suppresses mosaic leaf symptoms and sunken mottle of the fruit. In the fields in which cages were placed, unprotected melons which set earliest did not have sunken mottle; those fruits which were set later were badly affected; intermediate melons developed the blemish known as measles (photo 4). No measles appeared on melons in the screen cages.

To determine other possible causes of sunken mottle, many types of observations were again made on a larger number of fields in 1966—including consideration of soil moisture, disorders of roots, stems, and leaves, and damage by such insects as leaf miners and leafhoppers. None of these conditions except leaf mosaic symptoms was correlated with sunken mottle.

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CHEMICAL ATTRACTANTS *for Navel Orangeworm Moths*

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THE NAVEL ORANGEWORM, *Paramyelois transitella* (Walker), is a sporadic pest of almonds in California. Crop damage caused by this pest tends to increase and persist at an economically significant level for a few years in a particular locality, and then to drop to a low, chronic level for an indefinite period. The factors causing these changes in infestation are not known. Since this moth does not attack an almond crop until the nuts begin to ripen, the grower usually does not appreciate the extent of its damage until harvesting begins. A system to detect and assess changes in the pest population would enable growers to adjust harvest operations, if necessary, to minimize damage; for example, to harvest and fumigate susceptible soft-shell varieties as early as possible. These studies were to determine the value of chemical attractants in a detection program.

An effective insecticidal control program for this pest has not yet been developed. The larvae remain protected throughout their development within a single nut, and individuals in various stages of development may be found concurrently in an infested orchard. There are no periodic worm broods or moth flights. The overwintering and spring populations occur at low densities, and are maintained by the few unharvested almonds remaining in the trees from the previous season. The new crop becomes susceptible to attack when the hulls of maturing almonds split, in mid-July. The crop is attacked, therefore, immediately before and during

TABLE 1. NAVEL ORANGEWORM MOTHS AND TOTAL LEPIDOPTERA CAPTURED IN TRAPS BAITED WITH THREE SELECTED CHEMICAL ATTRACTANTS—SEPTEMBER 1–3, 1966

Chemical	Total navel orangeworm moths captured							Total Lepidoptera
Repl.	1	2	3	4	5	Total	Females	
							%	
Unbaited check	3	5	1	0	1	10	90.0	14
3–Bromopropyl phenyl ether	15	12	6	18	14	65	84.6	89
Phenyl ether	46	25	40	22	29	162	85.2	213
Phenyl propionate	123	79	44	62	57	365	87.1	482

TABLE 2. NAVEL ORANGEWORM MOTHS AND TOTAL LEPIDOPTERA CAPTURED IN TRAPS BAITED WITH FOUR SELECTED ATTRACTANTS—SEPTEMBER 2–6, 1966

Chemical	Total navel orangeworm moths captured						Total Lepidoptera
Repl.	1	2	3	4	Total	Females	
						%	
Unbaited check	3	2	2	0	7	100.0	13
Phenyl-n-propyl ether.......	3	2	5	5	15	80.0	31
DL-a-methyl-benzyl alcohol	29	34	18	26	107	80.4	155
Ethyl phenylacetate	49	23	28	32	132	76.5	154
Phenyl-2-propanone	56	72	49	44	221	62.0	275

TABLE 3. NAVEL ORANGEWORM MOTHS AND TOTAL LEPIDOPTERA CAPTURED IN TRAPS BAITED WITH PHENYL ISO-BUTYRATE AND THREE OF ITS ISOMERS—SEPTEMBER 15–19, 1966.

Chemical	Total navel orangeworm moths captured							Total Lepidoptera
Repl.	1	2	3	4	5	Total	Females	
							%	
Unbaited Check	0	0	3	1	1	5	100.0	10
2-Phenylethyl acetate	1	0	3	0	1	5	100.0	18
Benzyl propianate	3	5	5	1	2	16	87.5	52
Ethyl phenylacetate	4	7	6	15	23	55	81.8	76
Phenyl isobutyrate	22	11	21	27	12	93	89.2	129

TABLE 4. NAVEL ORANGEWORM MOTHS AND TOTAL LEPIDOPTERA CAPTURED IN TRAPS WITH THREE RELATED PHENYL ESTERS—SEPTEMBER 23–26, 1966.

Chemical	Total navel orangeworm moths captured					Total Lepidoptera
Repl.	1	2	3	Total	Females	
					%	
Unbaited check	0	2	0	2	100.0	2
Phenyl acetate	9	5	2	16	100.0	29
Phenyl isobutyrate	8	7	14	29	96.6	50
Phenyl propionate	37	21	16	74	95.9	125

the harvest period, at a time when insecticide applications are not feasible.

Although testing of promising insecticides will continue, emphasis is currently being directed toward other control techniques. An effective chemical lure is essential to the ultimate success of some of these proposed techniques. For example, the feasibility of using an attractant in combination with chemosterilants for field control is under study. The use of lures in conjunction with insecticide applications directed toward the moth stage of this pest is another possibility. Attractants would also be useful for studying flight habits of the moths and their distribution patterns in infested localities—subjects about which little is known.

Organic compounds

Approximately 225 organic compounds representing a variety of chemical categories were screened for attractiveness to navel orangeworm (NOW) moths. These trials were conducted in infested almond orchards near Arbuckle, California, over a period of three years (1964–66). Since prior studies with light traps showed that dense populations of these moths appear only during the period of crop ripening and harvest, August 15 to October 15 approximately, the testing program was confined to this part of each season.

Candidate chemicals were tested as water emulsions in polyethylene-lined paper buckets. These were hung in mature almond trees of susceptible, softshell varieties. Liquid chemicals were emulsified at concentrations of 1 ml per liter of water, while solids were mixed at rates of 1 gram per liter. Three drops of a wetting agent were added to help stabilize the emulsions. Unbaited water-filled traps with the wetting agent were used as checks.

Chemicals exhibiting consistent attractiveness in initial screening trials were then tested in conjunction with other promising compounds to obtain comparative data. As attractive chemicals were found, the screening program was adjusted to allow for more intensive study of these and chemically related materials. Of the 225 chemicals tested, 6 consistently exhibited a high degree of attractiveness to this moth. These were phenyl propionate, phenyl-2-propanone, phenyl ether, α-methylbenzyl alcohol, ethyl phenylacetate, and phenyl iso-butyrate. Of these, phenyl propionate appears to be the most promising material. Eleven other chemicals were attractive to these moths, but data available suggest that they are somewhat less promising than the above six compounds. These include methyl benzoate, ethyl benzoate, phenyl acetate, phenyl chloro-acetate, n- and iso-butyrophenone, 3-bromopropyl phenyl ether, benzylethyl ether, α-propylbenzyl alcohol, 3-chloropropyl benzene, and 3-bromopropyl benzene.

Results of some of the tests designed to compare promising attractants with related compounds and with unbaited water traps are presented in the tables. Sex ratios of captured navel orangeworm moths are given as percentages of females. Attractant-baited traps also captured other species of Lepidoptera, but caught relatively few insects of other kinds. Total Lepidoptera captured, including navel orangeworm moths, for each replicated series is included in the data. These figures suggest that some of these chemicals may be useful as lures for other moth species. The concentration of attractants in all the tests referred to in the tables was 1 ml per liter of water.

Phenyl propionate

A test to compare phenyl propionate with two other candidate chemicals is presented in table 1. The superiority of phenyl propionate is apparent. This test ran for two nights, and traps baited with phenyl propionate captured an average of 36.5 navel orangeworm moths per trap per night. Results of a test presented in table 2 show a relatively large number of male navel orangeworm moths attracted by phenyl-2-propanone as compared with three other candidate materials. Results of a test comparing the promising chemical, phenyl iso-butyrate with three of its isomers show (table 3) that changes in molecular configuration have a marked effect on attraction. Results of a test shown in table 4 compare phenyl propionate with two of its homologues, phenyl acetate and phenyl iso-butyrate.

This study provided data on the comparative attractiveness of individual chemicals. Additional work is needed on the effects of using different kinds of traps, of altering concentration levels, and of combining two or more chemical attractants in one trap. Trapping data also need to be interpreted in practical terms relative to actual population levels and to resultant crop losses.

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Mature navel orangeworm larva on partially eaten almond kernel.

Navel orangeworm moth on almond hull.