1989 ANNUAL PROGRESS REPORT

ALMOND BOARD OF CALIFORNIA

Project No. 89-A10b. Navel Orangeworm Attractants and Carob Moth Pheromone

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Objectives: (1) Develop and field test controlled release formulations of almond oil plus insecticide to attract and kill egg-laying navel orangeworm female moths during spring flight. (2) In collaboration with Dr. P.L. Phelan, conduct field tests designed to improve the field longevity of the oviposition disruptant formulation that significantly reduced damage after hull split in test plots in 1988. (3) Optimize the attractiveness, both in the laboratory and in the field, of the blend of synthetic sex pheromone components recently identified from carob moth females.

Interpretive Summary

Navel orangeworm: 1). Ovipositional attractants: Mass trapping field tests utilizing almond press cake impregnated with varying percentages of a mixture of long chain fatty acids are as competitively attractive as split nuts to gravid female navel orangeworm. Data obtained indicate that the attract and kill strategy is feasible against this insect. 2). In replicated tests, three formulations containing almond oil fatty acids, applied at hull split by ground sprayer, virtually shut down egg traps for 8 - 10 days post application. At harvest, the sprayed plots had 32%, 30% and 30% less nut damage attributable to navel orangeworm, than did untreated control plots. 3). Carob Moth: Three compounds, namely, Z-9-tetradecenal, Z.E-9,11-tetradecadienal and Z,E-9,11,13-tetradecatrienal have been confirmed as the major components of the carob moth sex pheromone. Wind tunnel studies have shown that mixtures of these three synthetic aldehydes are equivalent to 5 female equivalents of the natural pheromone in eliciting

response to, upwind flight towards and landing at the attractive source. A blend of the above compounds [1:1:8] dispensed at 333µg or 500µg from polyethylene Beem capsules has been successfully employed, this summer and fall, to monitor the generations of carob moth in dates.

Materials and Methods

1] *MASS TRAPPING* Two trapping tests were conducted, one in almonds (Ranch 388 Field 9B) and one in pistachios (Ranch 425). At the former location three bait treatments, A - 15g almond pressed cake/10% crude almond oil; B- 15g almond pressed cake/10% synthetic fatty acid mixture and C- standard egg trap bait used by Paramount Farming Company and consisting of 15g of almond pressed cake (obtained from Liberty Vegetable Oil Co.), each replicated 5 times were tested for their attractancy to gravid female navel orangeworm using standard black cylindrical egg traps (Trécé) deployed from 8/24 until 9/12. The traps were set out on Merced variety of almonds on every third tree [W>E] within each replicate with two rows [S>N] between replicates. Egg counts were recorded 8/28, 9/1, 9/4, 9/8 and 9/12. The synthetic fatty acid mixture used in the bait consisted of oleic acid (70%), linoleic acid (20%) and palmitic acid (10%); these proportions having been derived from the acid mixture obtained by hydrolysis of almond soap stock donated by Liberty vegetable Oil Co.

The mass trapping test took place between 8/7 and 9/7 on approximately 21 acres of pistachios (surrounded by olives). The block, 32 trees wide [N>S] and 58 rows long [E>W] was divided into three plots, the check plot (30 rows long) and two treatment plots (A & B, these are the baits detailed above) each 14 rows long. In the check plot two egg traps baited with A were deployed, one in the center of the plot, the other in the most westerly row. Each treatment plot contained 112 traps, one trap every fourth tree in every row. Egg counts were taken for the egg traps in four rows [2,6,10 and 14] of each treatment plot on 8/10, 8/14, 8/21, 8/29 and 9/7. Infestation level in all three plots was determined at harvest [9/15] by sampling a total of 2400 nuts/treatment, 1200 from six rows in each of the treatment plots and the check and 100 from each of 12 subplots within each of the treatment plots and the control plot.

2]. *OVIPOSITION DISRUPTION* These tests were carried out on block 98 of ranch 388 [Paramount Farming Company]. Fifteen plots less than 5 acres each (20 x 17 rows) were used, six of these plots were control or no treatment plots and the remaining nine were single replicate tests of three sprayable formulations. The control plots, situated at the northern end of the block, were upwind of the treatment plots. All plots were flagged and two egg traps/plot deployed on 6/8 (one trap in the center of the plot and one on the edge). All traps were baited with 15g of pressed cake/10% crude almond oil. Between 6/8 and the application [6/26] the traps were monitored five times. On 6/23 an application of Diazanon [3lb/acre] was made for peach twig borer control. The three formulations of the fatty acid mixture [Snyder material; Diversitec 480 and Diversitec 480.9] were applied in water at a spray volume of 100 gal/acre. on the morning of 6/26.

Between the application and the removal of the traps from the plots [8/1], the baits were changed once [7/20] and trap counts were made10 times. A mini-harvest was carried out on 7/26 in which 20 open nuts [10 from the top of the tree and 10 from eye level] were taken from Nonpariel trees along the SE>NW diagonal of each plot.

3]. *CAROB MOTH PHEROMONE* Mixtures of the major pheromone components isolated from virgin female carob moth were characterized in the wind tunnel. The mixtures were made from 40ng of the major component, Z,E-9,11,13-tetradecatrienal, the other components being added at the stated ratios.

Field tests of a [1:1:8] mixture of Z-9-tetradecenal, Z,E-9,11-tetradecadienal and Z,E-9,11, 13-tetradecatrienal deployed at either 333µg or 500µg were carried out in Sun World date gardens near Indio, Coachella Valley. The synthetic pheromone blend was dispensed from an open polyethylene Beem capsule place inside a Pherocon 1C wing trap (Trécé) suspended from a rope and pulley at the level of the date bunches [up to 45ft]; initially, a second trap was also deployed about eye level. Subsequently only the high trap position was used. All tests contained one treatment in which virgin female carob moths were used as the attractant bait.

Results

1]. *MASS TRAPPING* In the bait comparison test the mean number of eggs/trap is given below

Date	8/28	9/1	9/4	9/8	9/12	Σ eggs	X egg/trap/night(±S.D.)
Bait A	11.8	10.4	9.4	6.6	3.8	210	2.21(±0.83)
Bait B	32.4	36.2	32.8	15.6	9.4	632	6.65(±3.22)
Bait C	4.8	5.4	0.0	1.2	0.2	48	0.51(±0.58)

These data indicate that Bait B is significantly more attractive to gravid female navel orangeworm than Bait A and at least six times more attractive than Bait C. It should be noted that Bait A, pressed cake with 10% crude almond oil would contain approximately 0.3% of the fatty acid mixture whereas Bait B contains 10% of the acid mixture (33 times more). The reason for the drop in egg count [Baits A & B] between 9/4 and 9/8 cannot be determined from the data however three plausible reasons are (a) a reduction in the number of gravid female moths available, (b) a greater availability of split nuts as competing oviposition sites, or (c) exhaustion of the bait, although this is unlikely.

In the mass trapping test only 32 egg traps in each treatment were monitored during the test; the total number of eggs per date are given below.

			Σ eggs/date				
Date	8/10	8/14	8/21	8/29	9/7	Σ eggs	$\bar{X}$ eggs/trap(±S.D.)
Bait A	258	160	96	33	81	628	3.92 (±2.43)
Bait B	858	680	645	228	396	2807	17.54(±6.95)

Apart from 8/10 when B garnered 77% of the total eggs in the traps, at all other monitoring times B accounted for more than 80% of all deposited eggs. Comparison of the mean number of eggs per trap shows that at the point source level used both treatments were impacting the oviposition of navel orangeworm and that the magnitude of the impact is reflected by the amount of fatty acid mixture present in the bait.

At harvest the percent infestation level in the check plot was 6.4% whereas in the two treatment plots A and B it was 5.8% and 3.6% repectively, *ie.* the mass trapping reduced the infestation level by 9.4% and 43.8%. These data indicate that a mass trapping strategy, if employed from May through hull split to harvest could possibly significantly reduce navel orangeworm damage. These data also indicate that, in principle, an attract and kill strategy targeting gravid females is feasible. More types of baits, possibly granular baits should be tested and that a cheaper, disposable egg trap/ insecticide device should be devised and tested.

2]. *OVIPOSITION DISRUPTION* The data collected from the aerial dissemination of the formulations fatty acid mixtures on to the almonds at approximately 10% hull split is given in summary below.

Control plots

	#1	#2	#3	#4	#5	#6	Mean /plot (±S.D.)
Egg trap counts							
Pre-appl.	0	4	16	10	30	23	13.83(±10.43)
Appl+10 days	8	70	52	0	9	0	23.16(± 27.47)
Appl+36 days	163	128	84	96	65	86	103.67(±32.57)

Damage (%)							
Mini-harvest	3.04	0.50	1.50	4.0	0.50	2.53	2.01(±1.30)
Harvest data							
NOW damage	13.2	16.7	10.2	13.6	14.8	11.8	13.40(±2.05)
Total damage	13.3	17.3	10.6	13.8	15.2	12.3	13.73(±2.09)

Treatment #1 (Snyder material)

	1A	1B	1C	Mean(± S.D.)
Egg trap counts				
Pre-appl.	7	10	6	7.67(±1.69)
Appl+10 days	11	0	7	6.00(±4.56)
Appl.+36 days	44	120	134	99.33(±39.54)
Damage(%)				
Mini-harvest	0.5	2.5	3.0	2.00(±1.08)
Harvest data				
NOW damage	13.2	6.7	7.4	9.17(±2.86)
Total damage	13.9	8.0	7.8	9.90(±2.83)

Treatment #2 (Diveristec 480)

	2A	2B	2C	Mean(±S.D.)
Egg trap counts				
Pre-appl.	23	20	6	16.33(7.41)
Appl+10 days	4	0	11	5.00(±4.55)
Appl+36 days	125	161	124	136.67(±17.2)
Damage(%)				
Mini-harvest	3.5	4.0	3.0	3.50(±0.41)
Harvest data				
NOW damage	6.6	11.7	9.9	9.40(±2.11)
Total damage	7.5	12.3	11.1	10.30(±2.04)

Treatment #3 (Diversitec 480.9)

	3A	3B	3C	Mean (± S.D.)
Egg trap counts				
Pre appl.	71	36	11	39.33(±24.60)
Appl.+10 days	5	0	0	1.67(±2.36)
Appl.+36 days	174	176	142	164.00(±15.58)
Damage(%)				
Mini-harvest	3.5	4.5	4.8	4.27(±0.56)
Harvest data				
NOW damage	9.7	9.7	8.8	9.40(±0.42)
Total damage	10.7	10.7	9.7	10.37(±0.47)

From the above data it can be deduced that all three formulations reduced the number of eggs laid on the monitoring traps for up to ten days. Despite the fact that the control plots 4,5 and 6 were affected by spray drift, only the control plots exhibited an increase in egg laying during the ten days following the application. If plots 4,5 and 6 are discounted,then the mean egg count in the controls at application plus 10 days equals 43.4, and 125.0 at application plus 36 days.

It is evident that between day 10 and day 36 following the application the disruption effect of the formulations was declining as evidenced by the increase in egg count in both the control and treatment plots. This phenomenon is most probably due to (a) reduction in the amount of available acids in the atmosphere through evaporation and/or (b) reduction in the amount of available acids due to degradation and/or absorption in to the plant.

Data from the mini-harvest (4 weeks after the application) is inconclusive with damage in the treatment plots being equivalent or higher than that in the control plots..

At harvest, about 6 weeks post application, the damage attributable to navel orangeworm in the control plots averaged at 13.4% whereas that in the treatment plots averaged at 9.1%, 9.4% and 9.4%. This approximately 31% reduction in damage might have been reduced still further with a second application of the acid mixture about 8 - 10 days after the original one. However no more formulated material was availbale for application. If plots are paired based on their preapplication egg count, *eg.,* Control 2 *vs* T-1C; Control 4 *vs* T-1B; Control 6 *vs* T-2A and Control 5 *vs* T-3B, then the damage in the treatment plots ranges from 35% to 56%

less than the paired control plot. These results indicate that the application of the fatty acid mixture does have the desired effect of reducing oviposition on vulnerable nuts. Lack of greater control may be the result of the mixture lacking one or more components or, more likely, that the emission profiles of the controlled release formulations are sub-optimal. The overall results of the tests indicate that the mixture of the three fatty acids in a controlled release formulation is sufficient to significantly disrupt navel orangeworm oviposition and reduce damage at harvest, and that the commercial feasibility of using such a system in a control program primarily depends on two factors, the development of a better formulation and the economics of the optimized formulation.

3]. *CAROB MOTH* The results of three series of wind tunnel tests are reported here. In all tests the male moths were scored on their behaviors which have been characterized as, response to pheromone, upwind flight, flight to between 50 - 11 cm from the source, upwind flight to within 11 cm from the source, and landing on the source. In these tests the source was a filter paper which had been impregnated with the test pheromone blends. Unless otherwise stated the trienal was always loaded into the blend at 40 nanograms. In designating the blend ratios, the first number is the Z,E-9,11,13-tetradecatrienal; the second is the dienal and the third is Z-9-tetradecenal. The significance of the 11cm distance from the source, is that it is the distance between the site of the pheromone releaser and the edge of the Pherocon 1C trap, in the system used in the field.

In the first test, using 60 flight capable male moths per treatment, four blends were compared to 5 female equivalents of extract from virgin female carob moths.

	8:0:0	8:0:1	8:1:0	8:1:1	5FE
	% response				
Response to pheromone	98	100	100	100	100
Upwind flight	80	87	90	93	88
To within 50 - 11 cm of source	68	82	83	85	82
To within 11 cm of the source	55	78	73	85	82
Landing on source	50	77	67	78	82

All three components isolated from the virgin female carob moths individually elicit EAG responses. Although the trienal initiates behavioral responses in the male moths, and these responses are improved by the addition of either of the other two components, a blend of all three EAG active compounds is comparable with 5 female equivalents.

In the second test, the 8:1:1 blend was tested at different loading levels; 28 moths per treatment were used.

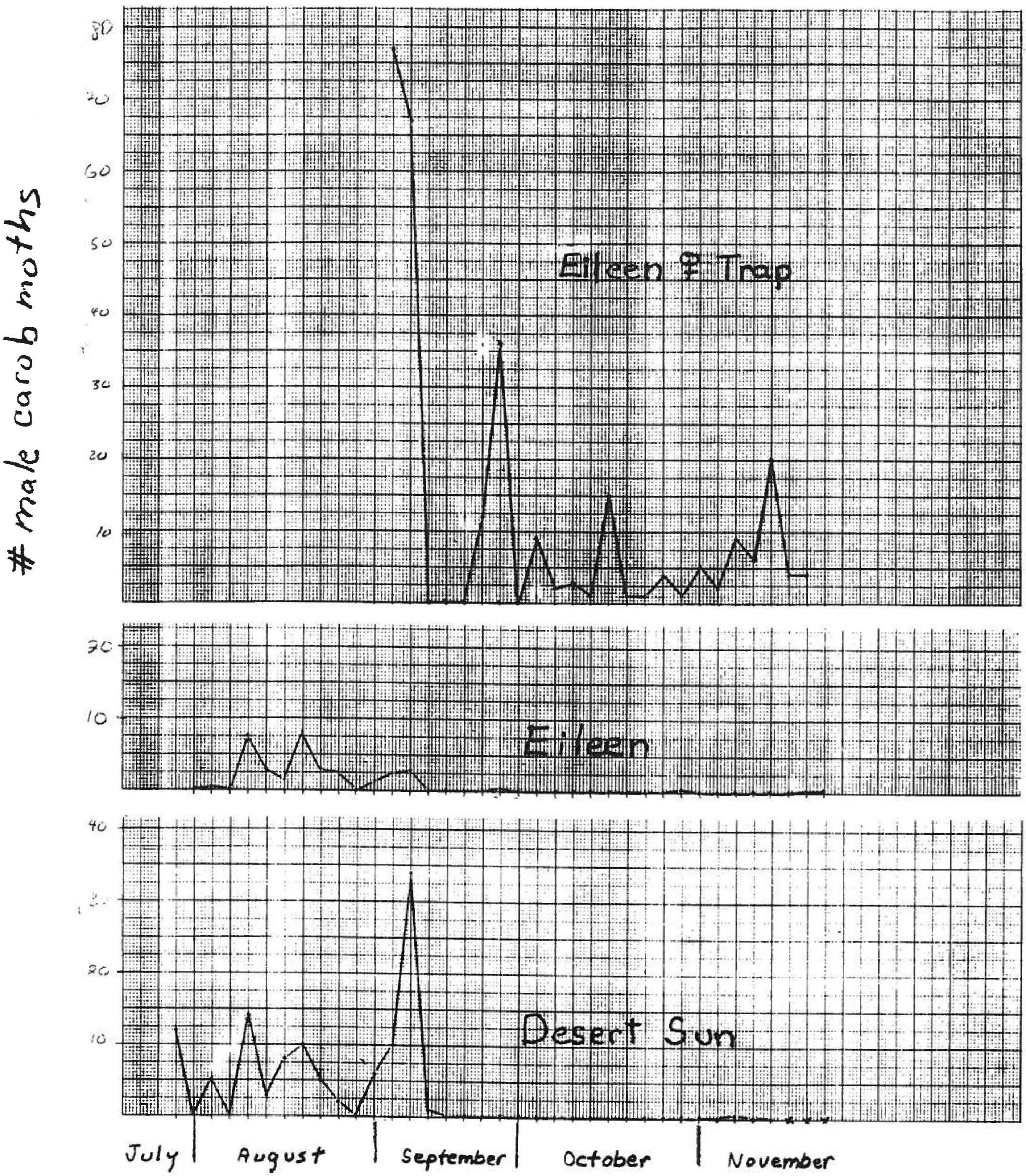
	0.04ng	0.4ng	4.0ng	40ng	400ng	4000ng	5FE
			% response				
Response to pheromone	39	68	100	93	100	100	96
Upwind flight	25	54	86	79	86	79	86
To within 50 - 11 cm of source	21	39	86	79	79	75	86
To within 11cm of the source	7	32	75	61	68	71	86
Landing on source	0	21	57	54	57	68	86

As can be seen from the above data, loadings less than 4.0ng failed to give a satisfactory response, and although the higher loadings were equivalent to the female extract in inducing upwind flight not even the highest loading tested approximated the female extract with regard to landing on the source.

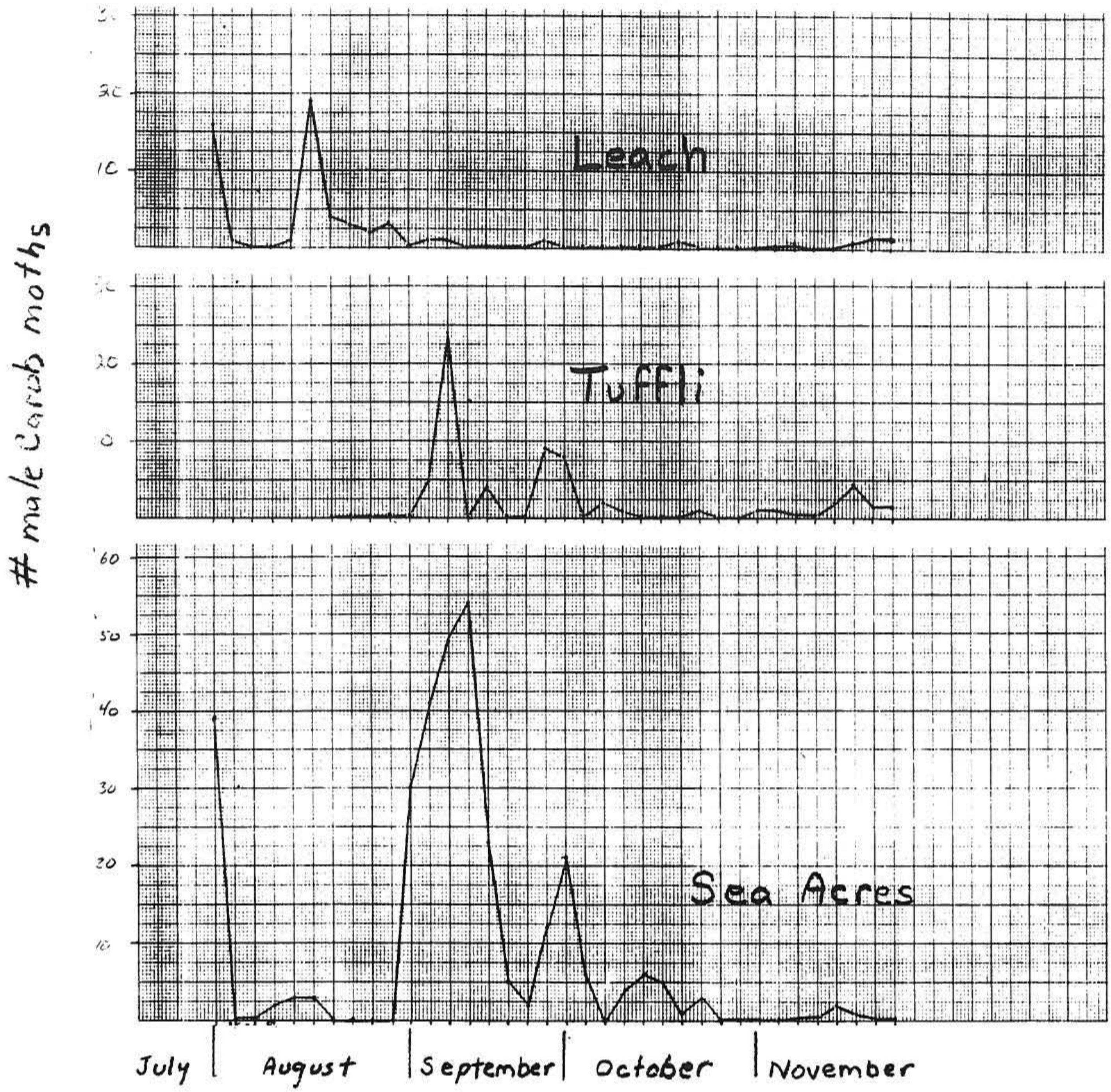
Testing various ternary mixtures of the aldehydes against female extract, utilizing 29 - 35 moths per treatment gave the following results

	[2:1:1]	[1:0:0]	[1:1:1]	[25:1:1]	[8:1:1]	5 FE
			% response			
Respose to blend	100	97	100	100	100	100
Upwind flight	85	86	74	89	82	84
To between 50-11cm	73	72	53	77	71	84
To within 11cm	62	48	50	66	68	84
Land on source	61	34	47	51	65	81

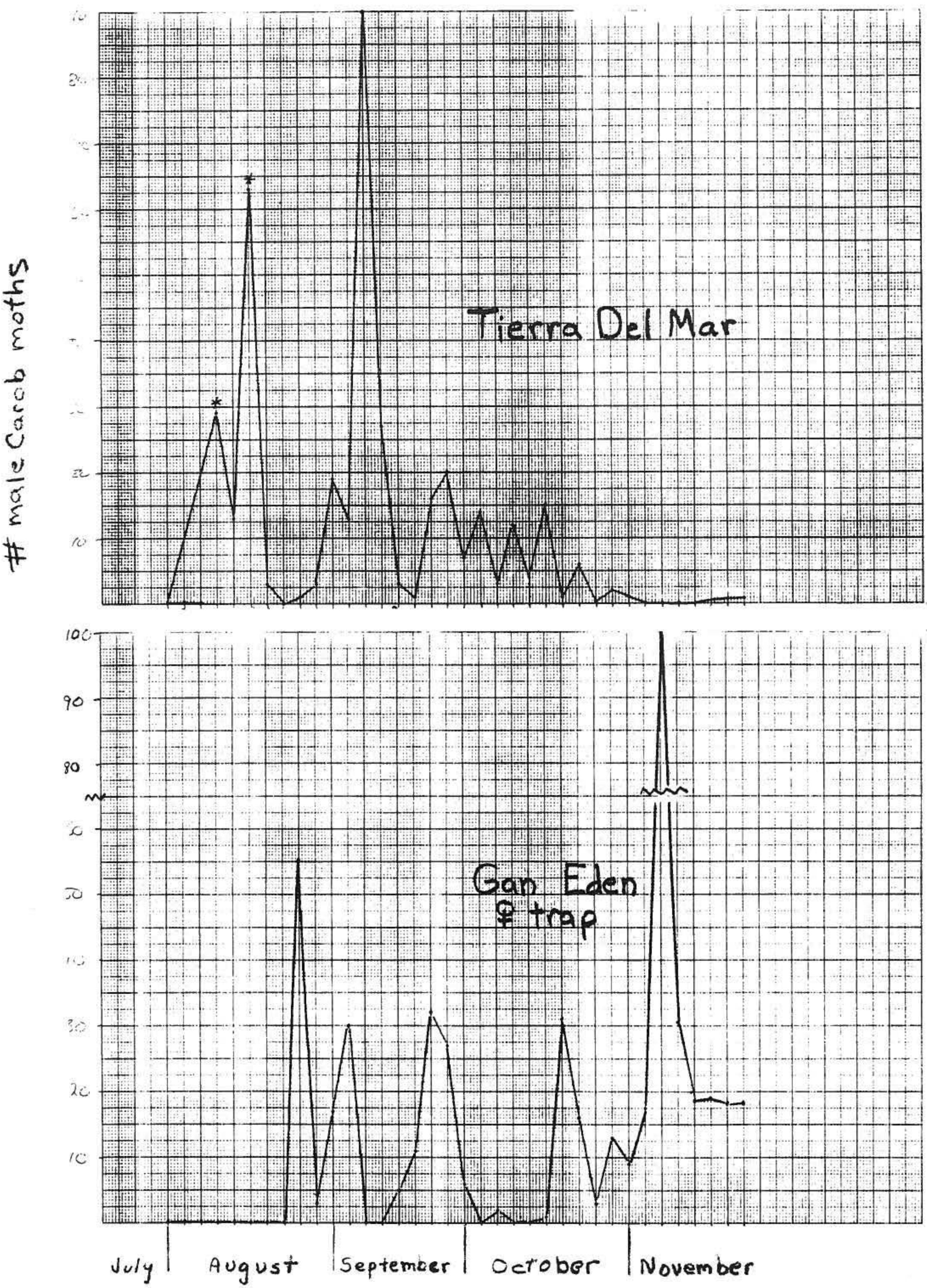
In this test the [8:1:1] blend is the best of the five tested, however as can be seen from the table it is not equivalent to the female extract. Nevertheless it was decided that this lure could probably yield useful information on the presence, and to a certain extent, the density level of adult carob moths in date gardens. Initially, trapping was carried out, with two traps per tree, one at the height of the date bunches (High) and the other about eye level (Low); this was discontinued once it was established that High traps outcaught the Low traps by a wide margin, after which only High traps were used. Trap data for the summer and fall of 1989 are attached.



male carob moths
Eileen ♀ Trap
Eileen
Desert Sun
July
August
September
October
November



male Carob moths
Leach
20
10
Tuffli
20
60
50
40
30
20
Sea Acres
July
August
September
October
November



male Carob moths
Tierra Del Mar
Gan Eden
♀ trap
100
90
80
10
July
August
September
October
November

As can be seen from the above data, even although all trapping sites were within a ten mile radius there was a great variation in the numbers of carob moth males caught. In general, the female baited traps [Gan Eden and Eileen] performed better than the traps baited with the synthetic blend. In all gardens with the exception of Leach, a flight is indicated during the first and second week of September with subsequent peaks at approximately four week intervals. In Eileen where there was a direct comparison, the traps baited with the synthetic blend did indicate peaks at the beginning of September and the last week in September, however peaks about the middle of October and again about the middle of November indicated by the female baited traps, are not seen in the data from the traps baited with the synthetic blend. There are two inexplicable anomalies in the data presented; these are (a) the lack of trap catch in Desert Sun and Eileen after the middle of September, and (b) the large trap catch recorded for the female baited trap in Gan Eden at the end of the first week in November although there are indications of increases in trap catch in Leach, Sea Acres and Tuffli (synthetic baits) and Eileen (female baits) later in November.

In summary, although it is necessary to improve and optimize the synthetic blend, this year's field studies have indicated that even an inefficient bait has proven useful in determining the presence of carob moth in the date gardens.

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July 31, 1989

Ms. Susan P. McCloud
Research Director
ALmond Board of California
P.O. Box 15920
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Dear Susan:

Thanks for the note concerning the California Farmer article. I was not aware of this publication and would appreciate receiving a copy of it. I have enclosed another article on the NOW disruption project from Almond Facts that you may have already seen, but I thought I would send a copy just in case. By the way, we received the research support check the other day, so thanks for speeding that up, I was starting to get desparate.

Sincerely,

P. Larry Phelan

Blue Diamond Almond Facts March/April 1989

Larry Phelan, seen here in a laboratory at Ohio State University, is experimenting with odor confusion technology to disrupt navel orangeworm egg laying.

Something in the Air

An Ohio entomologist is developing what could become a 'star wars' approach to navel orangeworm control

By Dan Campbell

If navel orangeworm moths smell their way to almonds to lay their eggs, why not flood orchards with a scent designed to confuse the destructive little pests so they won't know where to lay their eggs? Then, when the larvae hatch, the worms won't be able to burrow into almonds. Better still, accomplish all this by using a non-toxic substance which won't pose any pollution problems and won't destroy beneficial insects.

That's the theory an Ohio entomologist has been pursuing, and after just one full summer of field trials, he's produced some startling results. Dr. Larry Phelan is an insect chemical ecologist at Ohio State University's Department of Entomology in Wooster. His job is to identify the chemicals insects use to find each other for mating and for locating the host plants they use for feeding and egg laying. Last summer, Phelan and project co-leader Dr. Tom Baker of UC Riverside treated almond trees near Bakersfield with a non-toxic substance extracted from peanut oil. It so confused NOW moths in the test orchards that egg laying was slashed by up to 98 percent and nut damage was drastically reduced.

The experiment was conducted on three five-acre blocks of almonds trees, says Phelan, who was interviewed after a presentation he made at the Almond Research Conference in Sacramento in December. A five-acre control block was left untreated, while each of the other five-acre blocks were sprayed with equal doses of peanut oil extract, although different carrying agents were used.

The effective agent in the spray is made of long-chain fatty acids, which Phelan says are non-toxic and won't cause groundwater pollution or other harmful side effects. The material was applied to the test orchard just before hullsplit. Egg traps were checked for four weeks following application, revealing that egg laying had been reduced by 94 percent in one of the treated blocks and by 98 percent in the other compared to the untreated block. Nut damage five weeks after hullsplit was reduced four-fold in one treated block and 15-fold in the other block compared to the untreated trees.

"We got the type of results we were hoping for. Based on the first time in field, it looks very promising," Phelan says of his experiment.

In effect, what Phelan is trying to do is create "a cloud of protection" from NOW over an orchard. When egg-bearing NOWs enter this cloud of odor, they can't smell their way to the almonds to lay their eggs. "That's why I jokingly call it the 'star wars' approach to pest control," Phelan says. "It's a novel strategy. I don't know of another where host odors are used to disrupt host finding by a pest from long distance."

He's encouraged by the positive reactions from growers and the Almond Board, which is helping to finance his research. "I had a lot of growers at the conference tell me 'Keep it up — this is the way we like to see our research dollars being spent.'"

Only mated NOW females respond to the spray. Phelan says males and virgin females don't seem to be affected by the spray, which is being formulated so that it can be applied with conventional spray equipment.

Phelan became involved in his current line of research while doing post-doctoral work at UC Riverside in 1985, where he was trying to identify the chemicals female NOW moths use to "cue in" on almonds. Dr. Robert Van Steenwyk, at UC Extension in Berkeley, was having some success at that time disrupting egg-laying patterns by spraying crude, unprocessed almond oil across orchards.

Phelan had been working on an attracticide project at the time, trying to formulate an insecticide to lure females into traps. As a side issue, he got interested in Van Steenwyk's experiment. "I sort of came in through the back door on this project," he says.

Because of concern about the possibility of spreading aflatoxin molds with crude nut oil, Phelan began formulating free long-chain fatty acids from peanut oil. Almond oil would also suffice as a source, but he had a more reliable source of peanut oil. "The stuff is very cheap and gives us active constituents in a pure form," he says. While the active ingredient is inexpensive, formulating the material into a spray has proven difficult.

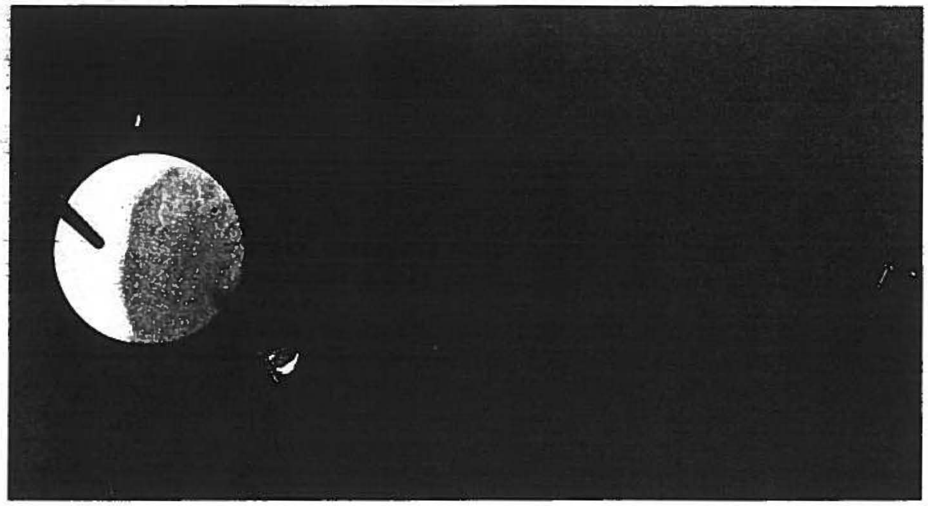
"If you were to spray long-chain fatty acids in an orchard, they probably wouldn't last very long — maybe a couple of days to a week. We needed to find a way to protect the material so it would volatilize more slowly over a longer period." New carrying agents were developed with a field life of four to five weeks. Phelan has been working over the winter and spring to stretch the field life of the sprays still further.

"The carrying agent tends to be rather expensive, so it is the limiting factor in terms of cost. But even as it is formulated now, the cost is comparable to a commercial insecticide spray, and I hope that it can be made cheaper still," Phelan says.

"Even if we only achieve a comparable cost, this pest control strategy has a lot of advantages. You reduce problems with groundwater contamination because you are spraying a material that is extremely nontoxic. And you aren't killing off beneficial insects, predatory mites and parasitic wasps that help keep NOW and pest mites in check to some extent. You get improved control without knocking the natural control system out of whack.

"That is why this project is so exciting to me. Developing non-toxic insect control materials was the main reason I got into this career. Based on my experience at the conference talking to growers and farm consultants, this approach seems to be widely supported by others in the almond industry as well. I had growers tell me this is what they need to help cope with tougher environmental laws, such as Proposition 65."

Paul LaVine, Almond Board research director at the time of the conference, says he is encouraged by Phelan's first year results. "The industry needs all the help it can get



Navel orangeworm moths fly down a wind tunnel toward scented bait.

because the Environmental Protection Agency is being pressured by the environmentalists to get rid of chemical pesticides," LaVine says. Growers have already been able to reduce the amount of chemical sprays they use by following UC's recommended pest control strategy, which relies heavily on orchard sanitation to eliminate winter hosting places for NOW. "The present 'four-way-control' program developed by the University of California and the Almond Board is one of the real success stories of integrated pest management," LaVine says.

Almonds are fairly impervious to NOW up until hullsplit. Once they split open, females lay eggs inside the hull. Then the larvae hatch and burrow into the almond kernel.

> "You get improved control without knocking the natural control system out of whack."
>
> — Dr. Larry Phelan

Part of the problem with insecticides is that once the larvae burrow inside the hull, they are somewhat protected from insecticides, Phelan says. "So it's easier to shoot for the adults."

He plans to continue his field trials this summer in California. If the results continue to be good, Phelan hopes the material will be on the market in the next five years. "But that may be overly optimistic. I'm far too inexperienced in that area to predict a possible release date with any accuracy," he says. It's too early to know how many more years of experiments will be needed to see if this treatment is as effective as first year results indicate and to get regulatory approval. However, some chemical manufacturers have already expressed interest in marketing the product.

The same type of insect control strategy could also prove feasible for controlling other insect pests, Phelan believes. That's one of the main reasons Ohio State University is allowing him to continue to research control methods for a pest which doesn't even exist in Ohio. "I think the same strategy will prove workable in other areas, we just haven't worked out which ones yet," he says.

Another problem with pesticides is that insects tend to develop a natural immunity to them over time. But Phelan doubts they could develop an immunity to an odor-confusion technology. "You never want to think you've outwitted an insect, because they have an incredible ability to evolve to cope with new circumstances. But I think it would be very hard for NOW to develop an immunity to this approach. If you use the very chemicals that the insects track to hone-in on nuts, I can't think how else they would find the almonds, unless they could start using tactile cues and feel their way to them — groping in the dark, so to speak. I can't think of a way they could develop such a resistance, but I would never say it couldn't happen. Stranger things have happened with insects."

Much of the laboratory research has been conducted using a wind tunnel. An odor is introduced on the upwind end of tunnel and mated female NOW moths are placed about three meters downwind. Researchers then observe what percentage of them fly to the odor source.

"It's a nice, discriminating tool for use in identifying the active constituents in various attractant compounds," Phelan says. Wind tunnels were first used by entomologists to identify the sex pheromones that attract mating insects. It's now a standard tool for pheromone research.

Phelan also credits the work of some other researchers, without whom "the work couldn't proceed." Dr. Rod Youngman, who was a post-doctoral researcher at UC Riverside and is now at Virginia Polytechnic Institute, played an important role, as did Caryn Roelofs, a research associate at Ohio State.