Project No. 80-A7
(Continuation of Project No. 79-A6)

Cooperator:
USDA/SEA/AR
Stored-Product Insects Research Laboratory
5578 Air Terminal Drive
Fresno, California 93727

Project Leader: Dr. Charles E. Curtis Phone (209) 487-5310

Personnel: Dr. Peter J. Landolt, Almond Board, Fresno, CA
Dr. James A. Coffelt, USDA/SEA, Gainesville, FL

Project: Navel Orangeworm Research
Pheromone Field Testing

Objectives: (1) To develop a control measure for n.o.w. using synthetic sex pheromone for mating disruption; (2) to continue work on development of pheromone materials as attractants for monitoring n.o.w. activity in the field; (3) to initiate studies using peach twig borer (PTB) sex pheromone for PTB control by mating disruption.

Progress: A sex pheromone of the n.o.w. has been isolated, identified and synthesized by a team of USDA scientists at the Insect Attractants Laboratory in Gainesville, Florida. Field testing has been conducted in 1978 and 1979. Testing of the n.o.w. pheromone has shown that the existing material is not useful in attracting male moths to a trap for monitoring moths' population for timing insecticide treatments. It appears that the material only attracts moths to a trap under extremely high moth population situations.

The existing n.o.w. pheromone has been shown to be very good for disrupting male catches in traps and mating when applied to 9-tree and one-acre plots. This means that the pheromone has a very good potential as a control measure in any integrated pest management (IPM) program. A long lasting (6 weeks), slow release formulation has been developed through the cooperation of Zoecon in Palo Alto, California, Hercon in New York and Conrel in Needham Heights, Massachusetts.

Plans: (1) To explore feasibility of using n.o.w. pheromone, PTB pheromone and combinations of the two pheromones for control of n.o.w. and PTB; (2) to continue work with cooperating commercial suppliers of pheromones and formulations to develop a supply of pheromone in long lasting, slow release formulations for extensive field tests; (3) to determine optimum release rates and application rates for disruption of mating in the field; (4) to continue studies on n.o.w. natural pheromone components and behavior for improvement of pheromone as an attractant for use in traps; (5) to obtain more biological and behavioral data by using night vision goggles in the field; (6) to determine influence of environmental factors such as temperature and wind velocity and direction on trap catch.

Almond Industry Participation $34,000

"80A7"

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PERSONNEL: Dr. Peter J. Landolt, Almond Board of CA
Fresno, CA

Dr. James A. Coffelt, USDA/SEA-AR
Gainesville, FL

I. OBJECTIVES: (1) To develop a control measure for navel orangeworm (NOW) using synthetic sex pheromone for mating disruption; (2) to continue work on development of pheromone materials as attractants for monitoring NOW activity in the field; (3) to initiate studies using peach twig borer (PTB) sex pheromone for PTB control by mating disruption.

II. INTERPRETIVE SUMMARY: A component of the sex pheromone of the NOW has been isolated, identified and synthesized by a team of USDA scientists at the Insect Attractants Laboratory in Gainesville, Florida. Field tests conducted in 1978, 1979 and 1980 showed this material was not useful for trapping male moths for monitoring populations and timing insecticide treatments. The material appeared to be useful only in trapping moths in extremely high populations and not useful during spring and early hullsplit when moth populations are normally at a low level.

The existing NOW pheromone was very useful in 1979-tests for disrupting male catches in traps and mating of females when applied to 9-tree and 1-acre plots. This meant that this material had good potential as a control measure in any integrated pest management (IPM) program. A long-lasting (6 weeks), slow-release formulation was developed through cooperation with Zoecon in Palo Alto, California, Hercon in New York City, Conrel in Needham Heights, Mass., and Chemsampco in Columbus, Ohio.

In 1980-tests, a major effort was made to accomplish a reduction in nut damage by using NOW pheromone for mating disruption in 20-acre plots. One possible way to control the NOW is by preventing mating and subsequent egg laying. Male moths find females for mating by following a trail of chemical scent (sex pheromone) released by the females. The pheromone trails made by the females can be camouflaged by permeating the air in an almond orchard with synthetic pheromone. This confuses the males or in some way prevents the males from finding the females. The pheromone, (Z,Z)-11,13-hexadecadienal can be released over a period of time from emitters hand placed or applied by ground or aerial equipment. About 5 grams (0.01 pound) of actual material per acre disrupts mating for about 3 weeks. This is influenced by population size, air temperature and other factors.

In 1979 and in 1980, we obtained such good results in small-plot tests that we set up 3 large plots in Merced County. For various reasons, a 20-acre plot that we treated by hand and a 20-acre plot that was treated by air did not give the desired results for the full growing season. Most of the Hercon 1/8-inch-laminates used in the aerial treatment did not stick to the tree foliage during application. We did reduce nut damage in the hand applied plot by 56% up to mid-August at which time the test had to be terminated due to lack of quality pheromone. Harvest samples on September 30 showed no difference in nut damage in treated and check plots. This left us with a 15-acre hand applied plot which yielded very promising results with 4 applications using a total of 15g of pheromone per acre for the entire season.

We monitored the effects of the sex pheromone treatments by checking for a reduction or elimination of male catches in sticky traps baited with virgin females, and by checking the mating success of females placed in orchard plots. Also, nut samples were collected for damage estimates. Male catches in 10 traps for the 7-week period of June 30 to August 18 were 3 in the test versus 2,045 in the check for a 99.9% reduction. The reduction in mating success was 94.5%. For the remainder of the season, 34 nights from August 19 until harvest on September 21, the trap catches were 108 versus 6,386 for a 98.3% reduction. Mating success showed a 79.8% reduction. Nut damage showed a 60% reduction in those samples collected between August 6, and September 2. However, we did not have enough pheromone to do a thorough job of mating disruption during a 10-day period in late August. At harvest we had 6.2% damage in the test versus 8.4% in the check which is only a 27% reduction in nut damage. However, the nut crop in the check was about twice as large as that in the test, and if we correct for the difference in crop size, this then shows a 61% reduction in nut damage.

We are still optimistic in being able to develop a pheromone control strategy as an alternative to in-season insecticide applications during spring and summer months. This would also reduce the chances of creating mite problems as predators and parasites would not be destroyed. There would also be no undesirable residues on almond kernels or hulls. It may take several years to develop the pheromone into a usable control program. We still have many problems in formulation and application, and we need a cheaper method of synthesis to make the use of pheromones economically feasible. We still hope to find other components so a more effective pheromone can be developed allowing the use of smaller amounts of material.

The pheromone system would still represent only one part of a pest management operation. Mating disruption works best against low insect populations. Therefore, the already proven good orchard management practices of orchard sanitation, early and rapid harvest and control of PTB would still be very important considerations. The fact that there are few insect pests of almonds is a plus for being able to develop sex pheromones for NOW and PTB control. We hope to do more work with mating disruption of the PTB in future tests. There may be some work with mass trapping using sex pheromones in the future, but this is not a very promising approach. Also, we still have to develop a much improved sex attractant for trapping male NOW.

A. Field attractiveness of the synthetic NOW aldehyde and other materials

III. Experimental Procedure: Five small tests were conducted with (Z,Z)-11,13-hexadecadienal [=(Z,Z)-11,13-HDDA1], hexadecanal (=HDA1), unmated female NOW and female-tip extracts for attractancy. Pherocon® 1C traps were used in all tests. The material to be tested was applied either to filter paper or rubber septa substrates. Traps were generally spaced 4 trees and 4 rows apart in a mature almond orchard. They were placed 2 m above the ground. All tests were conducted with a randomized complete block design. Dr. Coffelt from Gainesville, Florida, participated in tests made during the 3-week period beginning April 23, 1980.

The first test was conducted the night of April 30 to compare tip extracts (20 female equivalents), (Z,Z)-11,13-HDDA1 (100 ng), blanks and unmated female NOW (3/trap). Applications were made on filter papers when females began calling. Each treatment was replicated 3 times.

A second test was run the night of May 5, with (Z,Z)-11,13-HDDA1 and a mixture of (Z,Z)-11,13-HDDA1 and HDA1 at 1,10 and 100 ng doses. Blank but no female-baited traps were included for comparisons. Applications were made as in the first test.

A third test was set up May 10 with (Z,Z)-11,13-HDDA1 and a 93:7 mixture of (Z,Z)-11,13-HDDA1 and HDA1. These were applied to rubber septa at 1,10 and 100 μg. These treatments and untreated blanks were replicated 4 times and traps were monitored for 3 days.

A fourth test was set up May 14 with (Z,Z)-11,13-HDDA1, a 98:2 mixture and a 96:4 mixture of (Z,Z)-11,13-HDDA1 and HDA1. Each was applied at 1,10 and 100 μg to rubber septa. Each dose, untreated blanks, and unmated females (3/trap) constituted treatments that were replicated 3 times. Traps were checked for 4 days.

The fifth test was set up June 2 and was run for 3 days. Treatments were (Z,Z)-11,13-HDDA1 and a 98:2 mixture of (Z,Z)-11,13-HDDA1 and HDA1 at 100 μg per rubber septa replicated 10 times.

IV. RESULTS: Test 1 results (Table 1) show we were able to extract the active sex pheromone from female abdominal tips and use it to attract male moths to a trap. There was an indication in Tests 2-5 (Tables 2 and 3) that various ratios of (Z,Z)-11,13-HDDA1 and HDA1 were slightly more effective in trapping males than was (Z,Z)-11,13-HDDA1 alone. The 10 μg load of the 98:2 ratio in rubber septa (Test 4) gave trap catches that were about 8% of those using virgin females as trap bait.

V. DISCUSSION: The NOW aldehyde, (Z,Z)-11,13-HDDA1 has been field tested in 1978, 1979 and 1980 as a lure for trapping male moths. The material appears to be useful only in high populations and therefore, would not be useful for monitoring the spring and early summer moth activity for timing insecticide applications.

Table 1. Comparisons of NOW male catches in traps baited with 100 ng (*Z*,*Z*)-11,13-HDDA1 on filter paper, 3 unmated NOW females, extracts from abdominal tips of 20 unmated NOW females on filter paper, or unbaited blanks. Fresno, CA. 1980.

	No. males trapped in one night (Test 1)		
	Rep 1	Rep 2	Rep 3
(*Z*,*Z*)-11,13-HDDA1	1	0	0
Females	25	10	13
Tip extracts	21	17	7
Blanks	0	0	0

Table 2. Comparisons of NOW male catches in traps baited with 1,10 or 100 ng of (*Z*,*Z*)-11,13-HDDA1 or a 100:7 mixture of (*Z*,*Z*)-11,13-HDDA1 and HDA1 on filter papers, or unbaited blanks. Fresno, CA. 1980.

	No. males trapped in one night (Test 2)	
Dose (ng)	(*Z*,*Z*)-11,13 HDDA1	100:7 ratio
0	0	0
1	0	2
10	0	5
100	3	4

Table 3. Comparisons of NOW male catches in traps baited with (Z,Z)-11,13-HDDAl or mixtures of (Z,Z)-11,13-HDDAl and HDAl applied to rubber septa, untreated rubber septa, or 3 unmated NOW females. Fresno, CA. 1980.

Ratio of (Z,Z)-11,13-HDDAl to HDAl	No. males trapped in three nights (Test 3)			
	1 μg	10 μg	100 μg	Unmated females
0:0	0	0	0	--
100:0	3	1	1	--
93:7	-	4	1	--
	No. males trapped in four nights (Test 4)			
0:0	0	0	0	--
100:0	1	4	2	--
98:2	0	14	4	--
96:4	0	2	3	--
Females	--	--	--	168
	No. males trapped in three nights (Test 5)			
100:0	--	4	--	--
98:2	--	4	--	--

B. Comparisons of disruptant materials and formulations for NOW and PTB in 9-tree and 25-tree plots.

Hercon® Formulations of NOW Disruptants

III. EXPERIMENTAL PROCEDURE: Three different batches of navel orangeworm aldehyde, (Z,Z)-11,13-HDDAl, from two different sources were tested.

(1) Zoecon -- >99% purity
(2) Chemsampco -- 78% purity
(3) Chemsampco -- 86% purity

Purity statements represent the amount of material that was hexadecadienal. Isomeric compositions of the 3 batches according to analyses made at the Gainesville, Florida Laboratory were:

	Z,Z	Z,E	E,Z	E,E
(1) Zoecon®	99.7%	--	--	--
(2) Chemsampco (78%)	81.5%	3.5%	15.0%	0
(3) Chemsampco (86%)	82.0%	11.0%	7.0%	<0.5%

All 3 batches were formulated to provide 20 mg of material per 1x1-inch square Hercon® laminate and tested in 9-tree plots set up on April 17, 1980 in a completely randomized design. The check plot was always located in the northwest corner of a block which generally kept it upwind of any treatment. Varietal arrangements and inter-plot distances were standardized within blocks. All treatments were replicated 3 times along with 3 check plots receiving no treatment. Cooperating grower was McFarlane. The number of dispensers per tree was 1 at 2 m, 1 at 5 m and 2 at 7 m above ground.

	Hercon® Lot No.	Date Formulated	Active material applied per plot (mg)	per acre (g)
(1) Zoecon®	L244-12	4-10-80	638	5.32
(2) Chemsampco (78%)	L244-14	4-11-80	499	4.16
(3) Chemsampco (86%)	L244-13	4-11-80	550	4.59

The materials being tested were applied only to the 8 perimeter trees (designated as "X") leaving the center tree (designated as "O") for monitoring.

X X X

X O X

X X X

Pherocon 1C sticky traps, each baited with 3 virgin female NOW adults contained in a 7x5x4-cm fiberglass-screen cage were placed at 2 m and at 6 m above the ground in the center tree of all treatment and check plots. Traps were checked on most days and females were replaced every 3-4 days. Trap catches of males were used as the basis for comparing treatments. Also, mating success of wing-clipped females placed in the plots was used to evaluate mating disruption. Three wing-clipped females were placed in 7x7x4-cm wire basket with a few twigs for resting sites. Three of these set-ups were placed in the center tree in each plot; one at bottom, one at middle and one near top of tree canopy. These were put in plots in late afternoon and collected soon after sunrise the next morning. The number of mating pairs was then counted and all females were held individually to determine number laying viable eggs.

Six dispensers of each of the 3 batches were aged in the field for each of the following durations in days (0,1,3,7,10,14,21,28,35,42). Half of these was sent to Hercon® and half to Gainesville for release rate determinations.

A mixture of Hercon® dispensers from the 3 batches of material was also tested in 25-tree plots in which 21 trees received material and 4 were left untreated for monitoring with traps and mating baskets.

X	X	X	X	X
X	O	X	O	X
X	X	X	X	X
X	O	X	O	X
X	X	X	X	X

The test was set up on May 9, 1980, with only 2 replications - cooperating grower was Shapazian. The number of dispensers per tree was 1 at 2 m, 1 at 5 m and 2 at 7 m. Each 25-tree plot contained 20 dispensers with Zoecon® material, 32 with Chemsampco (78%) material and 32 with Chemsampco (86%) material. This provided 1.45 g of material per plot - equivalent to 4.35 g AI/acre. Monitoring for male trap catches and mating success was the same as for 9-tree plots.

Conrel® Formulations of NOW Disruptants

Three different formulations of the Chemsampco (86%) material were made by Conrel for testing in 9-tree plots.

(1) Black fibers (8 mil celcon), 2% Banox 20 BA (=Black)
(2) UV-stabilized fibers, 2% Banox 20BA (=UVS)
(3) Celcon fibers, 2% carstab, 2% Banox 20BA (=NC)

All of these formulations were made up to contain 10 fibers per dispenser; fibers were single open end of an active length of 1.75 cm and were filled neat with 0.4 mg Chemsampco (86%) material with 2% antioxidant (=Banox 20BA).

The 9-tree plots were set up on August 21, 1980. Test set-up and monitoring was as in previous tests. Three replications were made such that one complete replication was in each of 3 cooperators' orchards (Shapazian, Terzian, Boos). The number of dispensers per tree was 2 at 2 m, 3 at mid-canopy and 2 high in canopy. This provided 224 mg of material per plot - equivalent to 1.87 g AI/acre.

Three dispensers of each of the 3 formulations were aged in the field for each of the following durations in days (0,1,4,5,7,11,14,21,28,35). These were sent to Conrel® for release rate determinations.

One unreplicated 9-tree plot was set up on September 17 to further test the Conrel® black-fiber formulation. Terzian was cooperating grower. The number of dispensers per tree was 5 at 2 m, 5 at mid-canopy and 10 high in canopy. This provided 640 mg of material per plot - equivalent to 5.33 g AI/acre.

Hercon® Formulations of PTB Disruptants

Two different materials, E-5-decenyl alcohol and E-5-decenyl acetate, manufactured by Farchan Division of Chemsampco were tested separately and in combination for disruption of trap catch for PTB. The materials in various combinations are used commercially as lures for trapping PTB.

The PTB materials were formulated (6-12-80) in 1x1-inch square Hercon® laminated dispensers containing 17.5 mg of alcohol in one formulation and 18.5 mg of acetate in another formulation. These were tested in 9-tree plots set up and monitored for male NOW and PTB catches as previously described. Phercon® 1C sticky traps for catching PTB males were placed at 2 m and at 6 m and baited with Pherocon® PTB Caps. Test set-up was on August 7, 1980, with 3 treatments:

(1) 1x1-inch squares with alcohol
(2) 1x1-inch squares with acetate
(3) 0.5x1-inch pieces with alcohol plus 0.5x1-inch pieces with acetate.

Three replications were made such that one complete replication was in each of 3 cooperators' orchards (Terzian, Boos, Neely). The combination alcohol-acetate could only be replicated 2 times (Terzian and Boos). The number of dispensers per tree was 1 at 2 m, 1 at mid-canopy and 1 high in canopy. This provided 420 mg of alcohol per plot - equivalent to 3.5 g/acre; 444 mg of acetate per plot - equivalent to 3.7 g/acre; 210 mg of alcohol plus 2.22 mg of acetate per combination plot - equivalent to 3.6 g/acre.

IV. RESULTS:

Hercon® Formulations of NOW Disruptants

Male catches in female baited traps in 9-tree plots were at least 96.5% lower in treated plots than in check plots with the exception of a 89.4% reduction in trap catch in the Zoecon® plot during the 5th and 6th weeks (Table 4). Disruption of mating 2 weeks after treatment was 100% for the Chemsampco (86% purity), 93% for the Chemsampco (78% purity) and 79% for the Zoecon® materials (Table 5). There was no mating in the lower and middle areas of the tree canopy. Results for 25-tree plots were about the same as those for 9-tree plots during the first 4 weeks, but male catches were only 41.9 and 58.1% lower in treated plots than in check plots during the 5th and 6th weeks (Table 6). Disruption of mating was at least 83.3% for the 2 treated areas for all 6 weeks of the test (Table 7).

Conrel® Formulations of NOW Disruptants

Disruption of male trap catch was above 90% only for 3 nights and then for only 1 of the 3 treatments, the NC treatment (Table 8). For the 43 nights of the test, the NC formulation proved most effective, followed by the UVS and then the Black formulations (Table 8, Figures 1 and 2). There was some indication of more effective disruption of trap catch in low moth populations. Table 8 shows that the male catches in traps high in the tree canopy were disrupted by the NC, Black and UVS formulations by 76, 83 and 93%, respectively, where 395 moths were caught in the check; 80, 60 and 60%, respectively, where 735 moths were caught in the check; 68, 58 and 60%, respectively, where 1063 moths were caught in the check.

Male trap catches and percent reduction in trap catches are shown in Table 9 for one 9-tree plot treated with 5.33 g AI/acre (NOW aldehyde formulated in black fibers by Conrel®). Results show only a 73% reduction in male catch for the first night for a trap high in the tree canopy.

Hercon® Formulations of PTB Disruptants

PTB male catches in traps were low and variable throughout the PTB disruption test. Table 10 indicates some disruption of trap catch by the acetate and the combination of acetate and alcohol on the first night.

V. DISCUSSION: Tests with the Zoecon® and Chemsampco materials formulated in Hercon® laminates and applied to 9-tree plots showed that material with an overall purity as low as 78% and an isomeric purity as low as 81.5% *Z*,*Z* isomer (this meant that only 64% of the material was *Z*,*Z* isomer) was just as effective in reducing male catches in traps and mating of virgin females as was material that was 99.7% *Z*,*Z* isomer. Reduction in trap catches was at an acceptable level for the first 6 weeks of the test but fell to unacceptable levels during the last 9 days of the test.

All of the Conrel® formulations gave some degree of disruption of male catch in traps throughout the 43 days (August 22 - October 3) of this test. Overall, the regular Celcon (NC) formulation gave the highest degree of disruption of male catches in traps followed by the UV-stabilized (UVS) and then the black-fiber (Black) formulations. Conrel® has made much progress in stablizing the NOW aldehyde to protect it from UV and from oxidation. In 1979, their formulations gave a measurable degree of disruption for only 5 days. However, much remains to be done to increase the release rate to a level that will give nearly complete disruption of male catches.

Data for trapping and mating in all of the tests with NOW disruption have indicated less effective control of the NOW in the upper than in the lower tree canopy. This may be due to dilution to the pheromone by wind or possibly due to greater moth activity in the upper canopy.

PTB disruption trails need to be repeated with more material and different formulations to obtain some accurate data on the possibilities of using E-5-decenyl alcohol and E-5-decenyl acetate as disruptants. We were able to get some indication that the acetate might be active in disrupting PTB mating communication.

Table 4. Total number of male NOW caught in female-baited traps pretreatment and after treatment of 9-tree plots with sex pheromone of three different purities (Zoecon® 99.7%, Chemsampco 78% and 86%) formulated in Hercon® laminates. Fresno, CA. 1980.

		No. males caught in 3 traps at 2 m plus 3 traps at 6 m and (% reductions over check)			
Dates	No. of nights	Untreated Check	Zoecon	Chemsampco (78%)	Chemsampco (86%)
Pretreatment	1	202	211	164	271
4/17-4/30	14	780	6(99.2)	2(99.7)	3(99.6)
5/1-5/14	14	1148	25(97.8)	24(97.9)	29(97.5)
5/15-5/27	13	85	9(89.4)	3(96.5)	1(98.8)
5/28-6/5	9	39	19(51.3)	9(76.9)	25(35.9)

Table 5. Percent reduction in mating success of females placed overnight 2 weeks after treatment of 9-tree plots with sex pheromone of 3 different purities (Zoecon® 99.7%, Chemsampco 78% and 86%) formulated in Hercon® laminates. Fresno, CA. 1980.

	No. mated/total no. females (= fraction mated) and (% reductions over check)			
Position of females	Untreated	Zoecon	Chemsampco (78%)	Chemsampco (86%)
Low	7/9	0/7	0/7	0/8
Middle	4/8	0/7	0/6	0/3
High	6/7	3/6	1/8	0/8
Totals	17/24	3/20(79)	1/21(93)	0/19(100)

Table 6. Total number of male NOW caught in female-baited traps pre-treatment and after treatment of 25-tree plots with sex pheromone from a mixture of sources applied at 1.45 g of active material per plot. Fresno, CA. 1980.

Dates	No. of nights	No. males caught in 8 traps at 2 m plus 8 traps at 6 m and (% reduction over check)		
		Check	Treated #1	Treated #2
Pretreatment	1	133	119	97
5/9-5/20	12	152	0 (100)	0 (100)
5/21-6/5	16	139	9 (93.5)*	3 (97.8)
6/6-6/18	12	31	18 (41.9)	13 (58.1)

*All caught in the high trap in the trap tree in the northwest quadrant of plot.

Table 7. Percent reduction in mating success of females placed overnight in plots after treatment of 25-tree plots with sex pheromone from a mixture of sources applied at 1.45 g of active material per plot. Fresno, CA. 1980.

Dates	No. nights after treatment	No. mated/total no. females (= fraction mated) and (% reductions over check)		
		Check	Treated #1	Treated #2
5/14	6	9/31	1/33 (89.6)	0/35 (100)
5/21	13	7/21	1/24 (87.5)	1/27 (91.9)
5/29	21	6/32	0/33 (100)	1/32 (83.3)
Totals		22/84	2/90 (91.5)	2/94 (91.9)

Table 8. Conrel Hollow Fiber Test - NOW aldehyde - August 21, 1980

		August 22		23		24		25		28		September 3		4		6		10		11		12		17	
		High Gm	Low Gm	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L
Check	S	0	0	5	0	0	0	3	0	29	5	77	19	10	—	21	18	23	16	20	17	24	11	151	19
	T	89	59	77	64	60	71	106	82	82	94	93	80	63	—	57	58	55	92	76	67	44	38	66	4[illegible]
	B	25	16	38	8	13	3	79	20	72	89	116	70	34	—	20	63	—	50	70	29	16	12	80	2[illegible]
	Total	114	75	120	72	73	74	188	102	183	188	286	169	107	—	98	139	78	158	166	113	84	61	197	8[illegible]
	Avg.	38	25	40	24	24	25	63	34	61	63	95	56	36	—	33	46	39	53	55	38	28	20	66	2[illegible]
NC	S	0	0	0	0	0	0	0	0	0	1	2	0	2	—	1	0	16	0	2	1	3	0	2	1
	T	4	0	—	0	5	—	21	9	29	2	31	4	11	—	26	4	43	2	25	4	13	2	40	9
	B	0	0	0	0	0	0	11	0	13	0	22	1	0	—	55	—	1	0	0	0	0	0	1	0
	Total	4	0	0	0	5	0	32	9	42	3	55	5	13	—	82	4	60	2	27	5	16	2	43	1[illegible]
	Avg.	1.3	0	0	0	1.7	0	11	3	14	1	18	1.7	4.3	—	27	1.3	20	0.7	9	1.7	5.3	0.7	14	3.[illegible]
Black	S	0	0	0	0	0	0	0	0	1	0	4	0	0	—	3	1	0	1	10	0	9	0	15	3
	T	7	6	7	0	7	2	19	9	5	8	70	—	6	—	2	0	34	—	67	5	19	6	68	15
	B	0	0	1	0	6	0	10	0	12	2	28	3	6	—	32	0	19	2	8	1	6	0	32	3
	Total	7	6	8	0	13	2	29	9	18	10	102	3	12	—	37	1	53	3	85	6	34	6	115	21
	Avg.	2.3	2	2.7	0	4.3	0.7	9.7	3	6	3.3	34	1.5	4	—	12	0.3	18	1.5	28	2	11	2	38	7
UVS	S	0	0	0	0	0	0	0	0	0	0	2	0	0	—	4	0	1	0	1	0	3	0	2	0
	T	5	0	14	1	41	0	57	8	64	5	48	2	2	—	15	0	32	3	19	1	21	0	52	4
	B	0	1	4	0	1	0	9	2	15	0	27	2	0	—	33	3	21	5	14	0	11	1	33	1
	Total	5	1	18	1	42	0	66	10	79	5	77	4	2	—	52	3	54	8	34	1	35	1	87	5
	Avg.	1.7	0.3	6	0.3	14	0	22	3.3	26	1.7	26	1.3	0.7	—	17	1	18	2.7	11	0.3	12	0.3	29	1.7
Cumulative Totals																									
	Check	114	75	234	147	307	221	495	323	678	511	964	680	1071	—	1169	819	1247	977	1413	1090	1497	1151	1694	123[illegible]
	NC	4	0	4	0	9	0	41	9	83	12	138	17	151	—	233	21	293	23	320	28	336	30	379	40
	Black	7	6	15	6	28	8	57	17	75	27	177	30	189	—	226	31	279	34	364	40	398	46	513	67
	UVS	5	1	23	2	65	2	131	12	210	17	287	21	289	—	341	24	395	32	429	33	464	34	551	39
% Disruption																									
	NC	96	100	100	100	93	100	83	91	77	98	81	97	88	—	16	95	24	99	84	96	81	97	78	88
	Black	94	92	93	100	82	97	85	91	90	95	64	98	89	—	62	99	56	98	49	95	60	90	42	75
	UVS	96	99	85	99	42	100	65	90	57	97	73	98	98	—	47	98	58	95	80	99	58	98	56	94

Table 8. (Continued)

		September 18 H	September 18 L	19 H	19 L	24 H	24 L	25 H	25 L	October 3 (1 night) H	October 3 (1 night) L	Totals H	Totals L	Avg. % Disruption H	Avg. % Disruption L
Check	S	37	8	12	9	58	32	24	7	1	1	395	162	—	—
	T	48	35	33	38	54	62	56	52	4	6	1063	942	—	—
	B	67	19	13	2	48	44	40	1	4	0	735	448	—	—
	Total	152	62	58	49	160	138	120	60	9	7	2193	1552	—	—
	Avg.	51	21	19	16	53	46	40	20	3	2.3	—	—	—	—
NC	S	7	1	14	1	41	5	6	2	0	0	96	12	76	93
	T	29	2	8	7	18	22	42	1	0	0	345	68	68	93
	B	1	0	14	3	23	3	5	0	0	0	146	7	80	98
	Total	37	3	36	11	82	30	53	3	0	0	587	87	—	—
	Avg.	12	1	12	3.7	27	10	18	1	0	0	—	—		
Black	S	4	6	2	0	0	8	18	6	1	1	67	26	83	84
	T	52	3	33	3	46	53	5	0	1	3	448	113	58	88
	B	30	0	38	9	33	14	29	5	7	0	297	39	60	91
	Total	86	9	73	12	79	75	52	11	9	4	812	178	—	—
	Avg.	29	3	24	4	26	25	17	3.7	3	1.3	—	—		
UVS	S	2	0	5	1	3	2	4	0	0	0	27	3	93	98
	T	18	3	12	2	30	16	—	—	0	0	430	45	60	95
	B	32	0	5	0	30	11	57	4	1	0	293	30	60	93
	Total	52	3	22	3	63	29	61	4	1	0	750	78	—	—
	Avg.	17	1	7.3	1	21	10	30	2	0.3	0	—	—		
Cumulative Totals															
	Check	1846	1298	1904	1347	2064	1485	2184	1545	2193	1552	—	—	—	—
	NC	416	43	452	54	534	84	587	87	587	87	—	—	73	94
	Black	599	76	672	88	751	163	803	174	812	178	—	—	63	89
	UVS	603	42	625	45	688	74	749	78	750	78	—	—	66	95
% Disruption															
	NC	76	95	38	78	49	78	56	95	100	100				
	Black	43	85	0	76	51	46	57	82	0	43				
	UVS	66	95	62	91	61	79	49	93	89	100				

Test Setup 8-21-80

	S	B	T
NW	✓	✓	✓
NE	NC	Black	UVS
SE	Black	UVS	NC
SW	UVS	NC	Black

Table 9. Total number of male NOW caught in female-baited traps and percent disruption of trap catch in a 9-tree plot treated on September 17 with sex pheromone formulated in black fibers by Conrel®, Fresno, CA. 1980.

Dates	No. of nights	No. males caught in one trap in the high and one trap in the low position in tree: Check High	Check Low	Treated High	Treated Low	% reduction in in trap catch: High trap	Low trap
9/18	1	48	35	13	1	73	97
9/19	1	33	38	11	0	67	100
9/24	5	54	62	22	8	59	87
9/25	1	56	52	20	1	64	98
10/4	1	4	6	5	2	0	67
Totals	9	195	193	71	12	64	94

Table 10. Total number of male PTB caught in Pherocon® PTB Cap-baited traps pretreatment and after treatment of 9-tree plots with E-5-decenyl alcohol or E-5-decenyl acetate or a 1:1 mixture of the alcohol and acetate formulated in Hercon® laminates. Fresno, CA. 1980.

Dates	No. of nights	No. males caught in 3 traps* at 2 m plus 3 traps* at 6 m and (% reductions over check): Untreated Check	Alcohol	Acetate	Alcohol + Acetate
Pretreatment	3	20	10	17	29
8/7	1	6	3(50%)	1(83%)	1(83%)
8/8-8/10	3	13	5(62%)	17(0%)	8(38%)
8/11-8/13	3	4	4(0%)	0(100%)	0(100%)

*Only 2 traps for alcohol + acetate.

Figure 1

Conrel Hollow Fiber Test - NOW Aldehyde - 1980 - (High Traps)

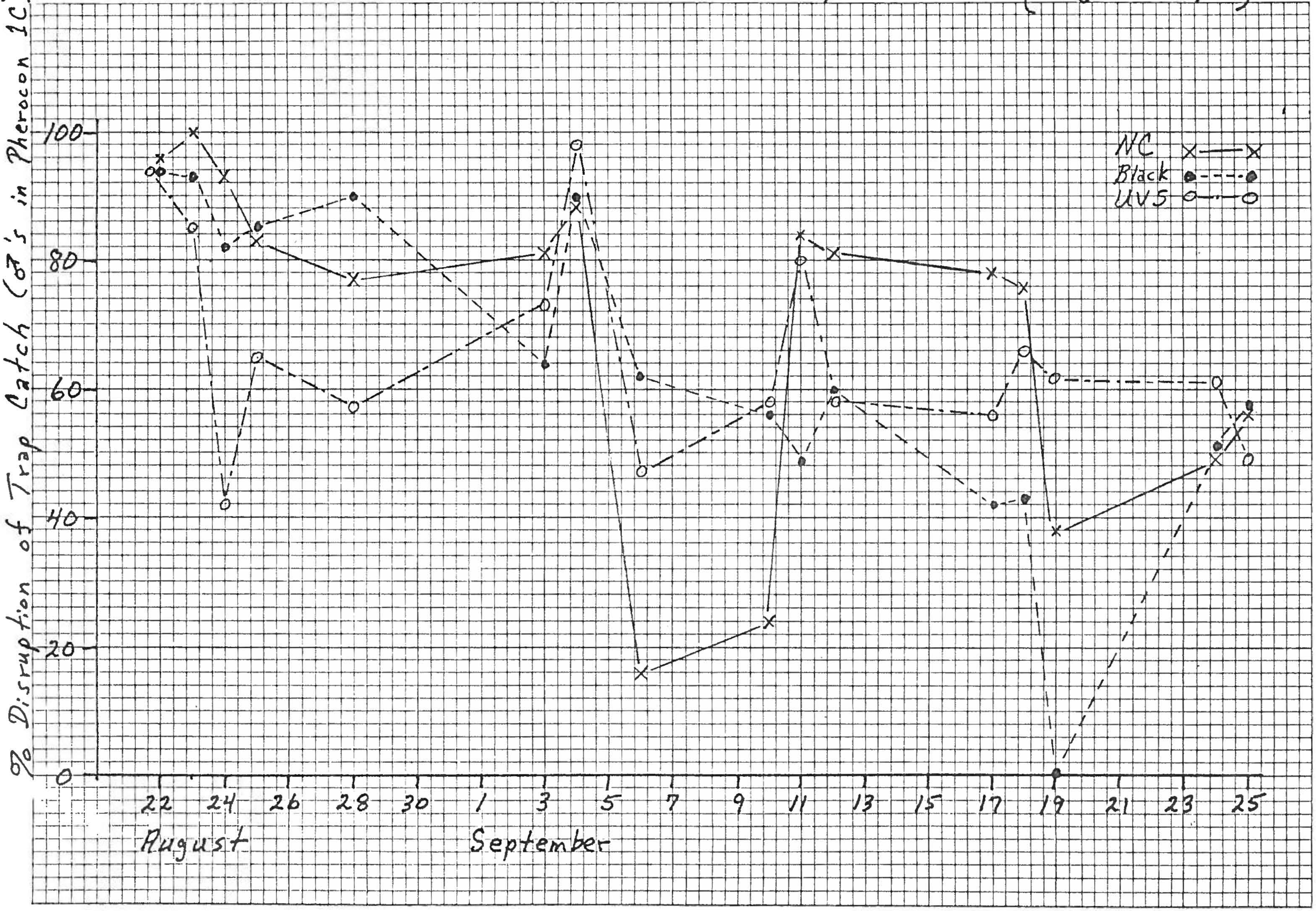


Figure 2

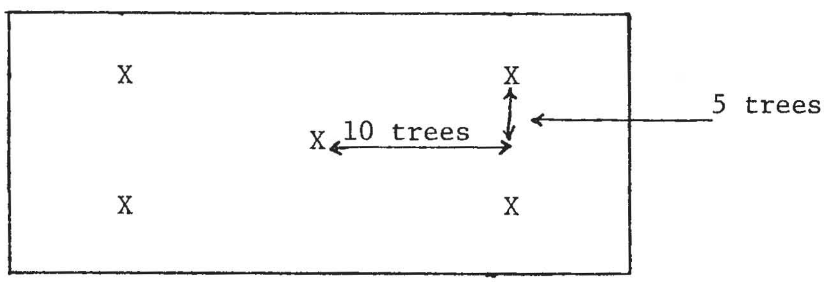
Conrel Hollow Fiber Test - NOW Aldehyde - 1980 - (Low Traps)

C. Disruption in 15-acre and 20-acre plots with (Z,Z)-11,13-hexadecadienal formulated in Hercon® laminates.

III. EXPERIMENTAL PROCEDURE: Three different large scale disruption plots were set up using the NOW sex pheromone component, (Z,Z)-11,13-HDDAl, formulated in Hercon® laminates.

(1) Zoecon®, hand applied to 15 acres.
(2) Chemsampco, hand applied to 20 acres.
(3) Chemsampco, aerially applied to 20 acres.

All 3 treatment plots were matched with an equal size check plot upwind (north or northwest) of the treated area within the same orchard. These plots were monitored for male NOW catches in Pherocon® 1C sticky traps, each baited with 3 virgin female NOW adults contained in a 7x5x4-cm fiberglass-screen cage. Trap trees received no pheromone treatment. One trap was placed at 2-2.5 m and another at 6-7 m above the ground depending on tree height in each of 5 trees per plot. Spacing of the monitor trees within a plot was like the "5" on a die, one in the center of plot and one at each of the four corners 10 trees along the



long axis by 5 trees along the short axis from center of plot. Trapping was begun on June 17, 1980, and was ended at harvest or when a test plot had to terminated.

Mating success of laboratory reared wing-clipped females placed in the plots one night per week was also used to evaluate mating disruption effectiveness. This was begun on July 8 and was done in the same trees used for trapping on the other 6 nights of the week. The sticky traps were not baited on this one night. Three wing-clipped females along with several twigs for resting sites were placed in a 1-pint polyethylene food container (10x10x7—cm) open at the top to afford easy access of feral males to the females. Petroleum jelly around the lip of the containers kept the females from escaping. Two of these set-ups were placed in each monitor tree, one at 3-4 m and a second at 6-7 m above the ground, late in the afternoon and collected soon after sunrise the next morning. The number of mating pairs was recorded at collection time and the females were held individually to determine number laying viable eggs.

Nut samples were collected at weekly intervals beginning shortly after first hull-split taking 100 nuts from Nonpareil trees near each of the 5 monitor trees in each plot. At harvest, 30 samples of 100 Nonpareil nuts each were taken from winrows, 5 sites in each of 6 winrows evenly distributed within each plot. These samples were evaluated for NOW, PTB and other insect damage and numbers of eggs, larvae and pupae.

Six dispensers of each of both the Zoecon® and the Chemsampco materials used in hand-applied plots were aged in the field for each of the following durations in days (0,1,3,7,10,14,21,28,35,42). Half was sent to Hercon® and half to Gainesville for release rate determinations.

Hand Applied - 15 Acres

The test plot was 14.8 acres in a planting of 90% Nonpareil: 10% Merced which measured 30 rows running EW by 37 trees on a 24-foot square spac ing. A check plot of the same dimensions was located 1600 feet north in the same orchard (Uhrhammer) but was a planting of 50% Nonpareil:25% Merced:25% Neplus.

The NOW aldehyde, 99.7% (Z,Z)-11,13-HDDA1, was synthesized by Zoecon® and formulated by Hercon® (Lot # NO590) in 0.8x1-inch square laminates (9126 units) at 20.8 mg AI/square inch.

The first application was at 5.0 g AI/acre on June 30, 1980. The number of dispensers per tree was 1 at 2 m, 1 at 5-6 m and 2 at 8 m above ground. The second application was 2.5 g AI/acre on July 24 with 1 dispenser at 2 m and 1 at 8 m. The third application was 2.6 g AI/acre on August 13 with 1 dispenser at 6 m and 1 at 8 m. The fourth application was 4.2 g AI/acre on August 29/ September 2 with 1 at 2 m, 1 at 5-6 m and 1 at 8 m above ground. This treatment had to be made using 86%-purity material made by Chemsampco and described under 9-tree plot test and 90.4%-purity material made by an undisclosed source. All of this material was supplied on short notice through the cooperation of Dr. Iain Weatherston at Conrel®. Hercon® (Lot #NO760) formulated the Chemsampco (86%) material in 1x1-inch square laminates (1563 units) at 26.1 mg AI/square inch and the 90.4% material in 1x1-inch square laminates (1893 units) (Lot #NO770) at 12.2 mg AI/square inch. The 26.1 mg-formulation was used at the 8 m positions on all trees and at the 5-6 m positions in every third row, and the 12.2 mg-formulation was used at the 2 m positions in all rows on August 29. The remaining 5-6 positions received the 12.2 mg-formulation on September 2.

Hand Applied - 20 Acres

The test plot was 20 acres in a planting of 66% Nonpareil:17% Neplus:17% Merced which measured 50 rows running NS by 30 trees on a 24-foot square spacing. The check plot of the same dimensions and planting pattern was located 2000 feet north in the same orchard (Pitts).

The NOW aldehyde, 80% HDDA1 of which 70% was Z,Z, 17% was Z,E, 12% was E,Z and 1% was E,E isomers, was synthesized by Chemsampco and formulated by Hercon® in 1x1.125-inch square laminates (9420 units) (Lot #NO670), at 15.3 mg AI/square inch. Also, part of the third treatment of this plot was with the 60%-purity material described under aerial-application plot formulated by Hercon® (Lot #NO 700) in 1x1.125-inch square laminates (2515 units) at 14.1 mg AI/square inch.

The first application was at 5.2 g AI/acre on June 30/July 1. This is so if Hercon® did take into account the 80% purity figure and if one can rely on our earlier finds that the Z,E and E,Z isomers as well as the Z,Z isomer are effective disruptants. The number of dispensers per tree was 1 at 2 m, 1 at 4-5 m and 2 at 7 m above ground. The second application was 2.6 g AI/acre on July 24/25 with 1 dispenser at 2 m and 1 at 7 m. The third treatment was mostly with the 60%-material at 1.7 g AI/acre on August 1 with 1 dispenser at 2 m and 1 at 5-6 m. The 1.7 g figure takes into account the 60% purity characteristic and the fact that 31% of that was the E,E isomer.

Aerial Application - 20 Acres

The test plot was 20 acres in a planting of 66% Nonpareil:17% Neplus:17% Thompson which measured 50 rows running NS by 30 trees on a 24-foot square spacing. The check plot of the same dimensions was located 500 feet northwest in the same orchard (Farm Management) but was a planting of 50% Nonpareil:25% Neplus:25% Mission.

The NOW aldehyde, 60% (Z,Z)-11,13-HDDA1 of which 36% was Z,Z, 20% was Z,E, 13% was E,Z and 31% was E,E isomers, was synthesized by Chemsampco and formulated by Hercon® (Lot #NO710) in 0.125x0.125-inch square laminates (1100 g calculated to be 2737 square inches of laminate containing 117.7 g AI) at 43 mg AI/square inch.

The application was at 4.0 g AI/acre on July 10. This is so if Hercon® did take into account the 60% purity figure and if we correct for the E,E isomer being found in earlier tests to be ineffective as a disruptant material. The application was made using an Ag Cat airplane fitted with specially made equipment to dispense the flakes coated with sticker. We calculated that 9730 flakes/acre (=130/24x24-foot tree space) were applied and that only about 18 acres were treated due to error in calibration of equipment or incorrect air speed.

Some of the 0.125x0.125-inch flakes plus some 0.25x0.25-inch experimental flakes were aged in the field for each of the following durations in days (0,3,7,14,21,28,35,42). These were sent to Hercon® for release rate determinations.

IV. RESULTS:

Hand Applied - 15 Acres

Trap catches of males were 99.9% lower in the treated area than in the check area during the first 7 weeks of the test. They were 98.3% lower during the last 5 weeks of the test (Table 11). Mating success of wing-clipped females placed in the plots was 94.5% lower in the treated area than in the check area for the first 7 weeks and 79.8% lower during the last 5 weeks of the test (Table 12). The reduction in male catch in traps at 2 m was much greater than that for traps at 6 m (Figure 3). The breakdown in mating disruption in late August between the third and fourth treatments can be seen in trap catch and mating success data in Figures 3 and 4. Figure 4 further shows this in the marked increase in egg counts in late August and in larval counts in early September.

Data for the 15-acre plot (Table 13) shows an average of 60% less Nonpareil nut damage in the treated than in the check for the first 5 sample dates. This drops to only a 27% reduction by USDA figures and a 12.5% reduction by Handler figures for harvest samples. However, a correction of the USDA figure to take into account the difference in crop size between the treated and check areas shows a 61% reduction in nut damage. There were 9.34 pounds production per tree in the treated area and 17.63 pounds in the check area.

Hand Applied - 20 Acres

Trap catches of males were 94.7% lower in the treated area than in the check area during the first 5.5 weeks and only 57.0% lower during the last 3 weeks of the test (Table 11). Trapping was terminated one month before harvest due to the poor disruption of trap catch. Mating success of females was 81.8% lower in the treated area than in the check area for the first 5 weeks and only 45.1% lower the last 2 weeks of the test (Table 12). One female was mated the first night (July 8) of the test. Figure 5 shows the greater reduction in male catches in traps at 2 m than in those at 6 m. Also the poor performance of the Chemsampco material is shown by the breakdown in disruption of trap catch 3 weeks after the first treatment and within a few days after the second and third treatments.

Nonpareil nut damage for the 20-acre plot (Table 13) was an average 56% less in the treated than in the check for the second and third sample dates. There was little or no reduction in nut damage by harvest as shown by USDA and Handler data. The crop size was larger for the treated than for the check area.

Aerial Application - 20 Acres

This plot was monitored for 23 days before treatment and for only one day after treatment. As 56% of the material went onto the ground at application time (Table 14), there was not enough material available to disrupt trap catches. There was no material or application equipment available to attempt a second treatment. Pretreatment trap catches were 566 in 5 high traps and 400 in 5 low traps in the check area. They were 1125 in 5 high traps and 715 in 5 low traps in the treated area. After treatment trap catches for one night were 40 in high traps and 20 in low traps in the check. They were 6 in high traps and 1 in low traps in the treated area.

V. DISCUSSION: Only the 15-acre hand applied plot was maintained for a long enough period to time to supply any meaningful data on mating disruption. Even in that plot, there was not enough material in the plot between the third and fourth treatments to prevent mating and subsequent egg laying. If the 61% reduction in nut damage can be repeated in another year of testing, then we can have some confidence in being able to develop the NOW aldehyde into a useful pest management tool. We can have a little more confidence in the 61% reduction in nut damage figure if we look at data collected during the Ballico Project years 1975-1977 when the area used for the pheromone treatment had significantly higher rejects than did the area used as the check.

We found that the NOW aldehyde material used needs to be at least 80% hexadecadienal composed of mostly Z,Z isomer and perhaps some E,Z and Z,E isomers. All of the material needs to be analyzed by a dependable laboratory before applying it to an orchard. At least 20 g of material will probably be required to protect for a full season, especially in areas of the state north of Madera county where the time from first hull split until harvest of the Nonpareil variety covers a 2-month period.

Table 11. Total number of male NOW caught in female-baited traps pretreatment and after treatment of a 15-acre plot with Zoecon® sex pheromone and a 20-acre plot with Chemsampco material, both materials formulated in Hercon® laminates. Ballico, CA. 1980.

Dates	No. of nights	No. males caught in 5 at 2 m plus 5 traps at 6 m		% Reduction in trap catch
		15-acre plot		
		Check	Treated	
Pretreatment	13	163	108	--
6/30-8/18	50	2045	3	99.9
8/19-9/21	34	6386	108	98.3
		20-acre plot		
Pretreatment	13	101	156	--
6/30-8/7	39	1159	61*	94.7
8/8-8/28	20	3336	1434	57.0

*21 males caught in one trap in a 3-night period.

Table 12. Percent reduction in mating success of females placed overnight in plots after treatment of a 15-acre plot with Zoecon® sex pheromone and a 20-acre plot with Chemsampco material, both materials formulated in Hercon® laminates. Ballico, CA. 1980.

Dates	No. of weeks	No. mated/total No. females (= fraction/mated)		% Reduction in mating success
		15-acre plot		
		Check	Treated	
7/8-8/19	7	102/165	6/178	94.5
8/25-9/22	5	106/146	21/143	79.8
		20-acre plot		
7/8-8/5	5	73/130	13/127	81.8
8/12-8/19	2	41/60	21/56	45.1

Table 13. Percent Nonpareil kernel damage due to NOW measured weekly by samples of 500 nuts per plot except that 3000 nuts per plot were taken at harvest, represented by last set of figures in columns. A 15-acre plot treated with Zoecon® sex pheromone and a 20-acre plot with Chemsampco material, both formulated in Hercon® laminates. Ballico, CA. 1980.

	15-acre plot		20-acre plot	
Dates	Check	Treated	Check	Treated
7/30	--	--	5.9	0.7
8/6	1.0	0.4	2.6	1.8
8/13	1.8	0.8	2.4	1.0
8/20	2.2	1.0	--	--
8/26	2.6	0.8	2.4	3.8
9/2	2.2	0.8	--	--
9/9	2.8	2.6	--	--
9/16	7.4	5.4	--	--
9/19 (Harvest)	8.43	6.17	--	--
9/30 (Harvest)	--	--	8.22	8.61
Handler	7.2	6.3	7.8	7.0

Table 14. Numbers of Hercon® flakes not adhering to trees at application time -- aerial application of Chemsampco material formulated in 0.125 x 0.125-inch Hercon® laminates (flakes). It was calculated that 130 flakes were applied to each tree space (24x24 feet).

	Number of flakes per 24x24 foot polyethylene sheet placed under each of 9 trees*		
Position in row	Thompson variety	Nonpareil variety	Nonpareil variety
South	58	66	53
Center	109	61	78
North	53	76	107
Totals	220	203	238

*This shows that 56% of flakes fell to ground at time of application.

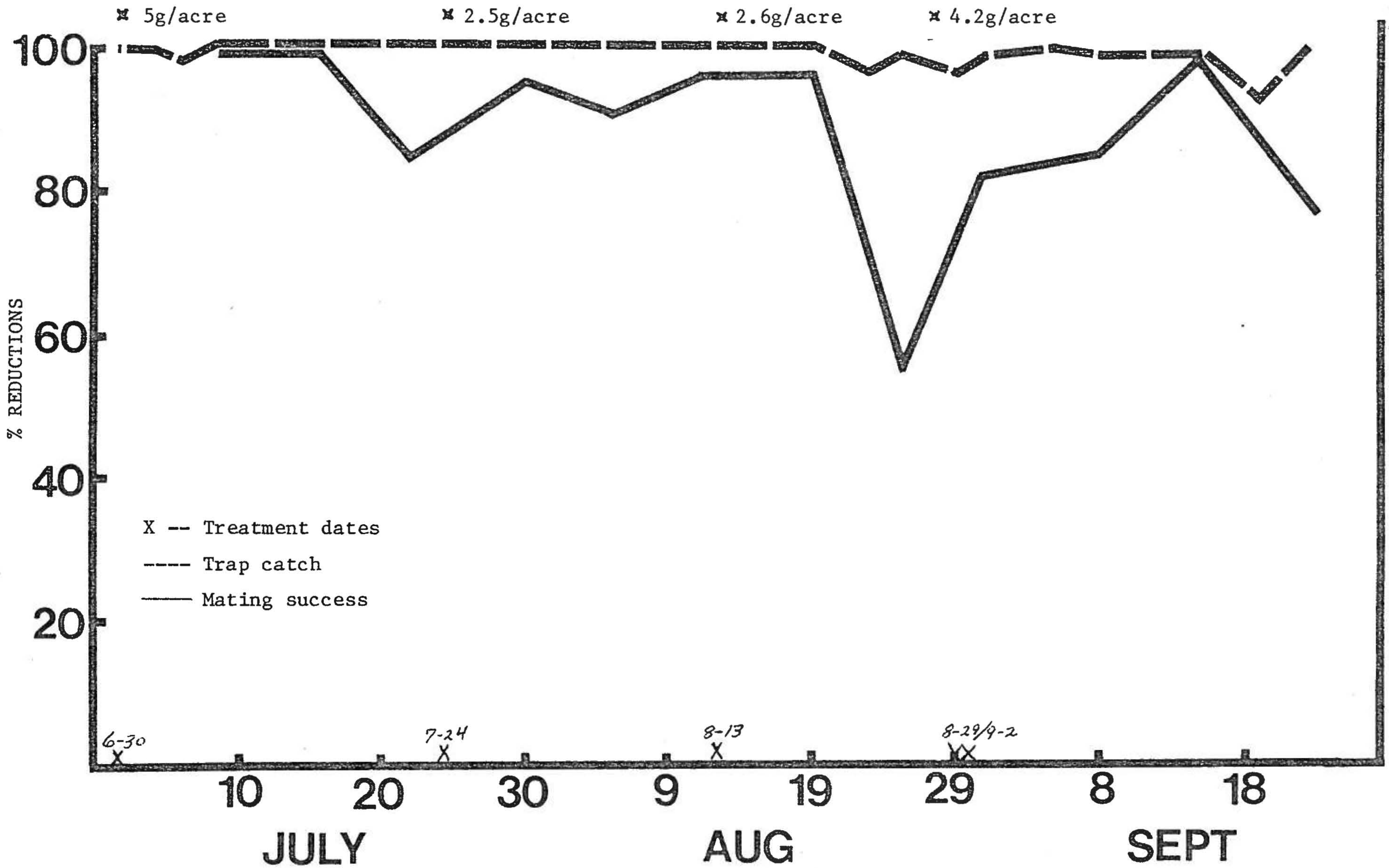


Figure 3 -- Percent reductions in male catches in female-baited traps and percent reductions in mating success of females placed in orchard treated with NOW sex pheromone made by Zoecon[R] and formulated in Hercon[R] laminates. Monitoring was done at 2 m and at 6 m in 5 trees within a 15-acre plot. Ballico, CA. 1980.

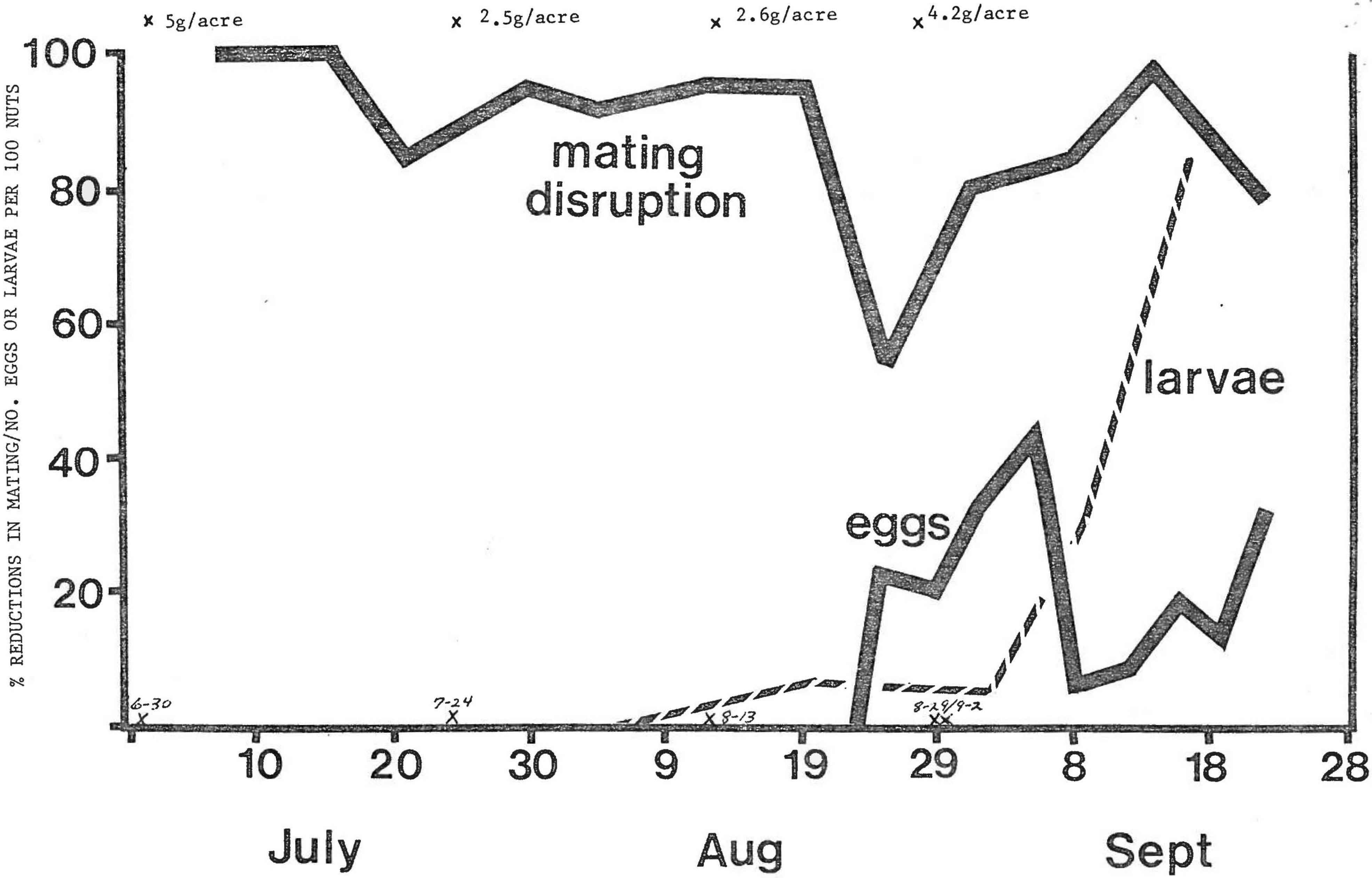


Figure 4 -- Percent reductions in mating success of females placed in orchard treated with NOW sex pheromone made by Zoecon[R] and formulated in Hercon[R] laminates. Shows failure in protection when there was not enough pheromone in orchard between treatments three and four resulting in a surge in egg laying beginning in late August and a surge in larval counts in early September. Ballico, CA. 1980.

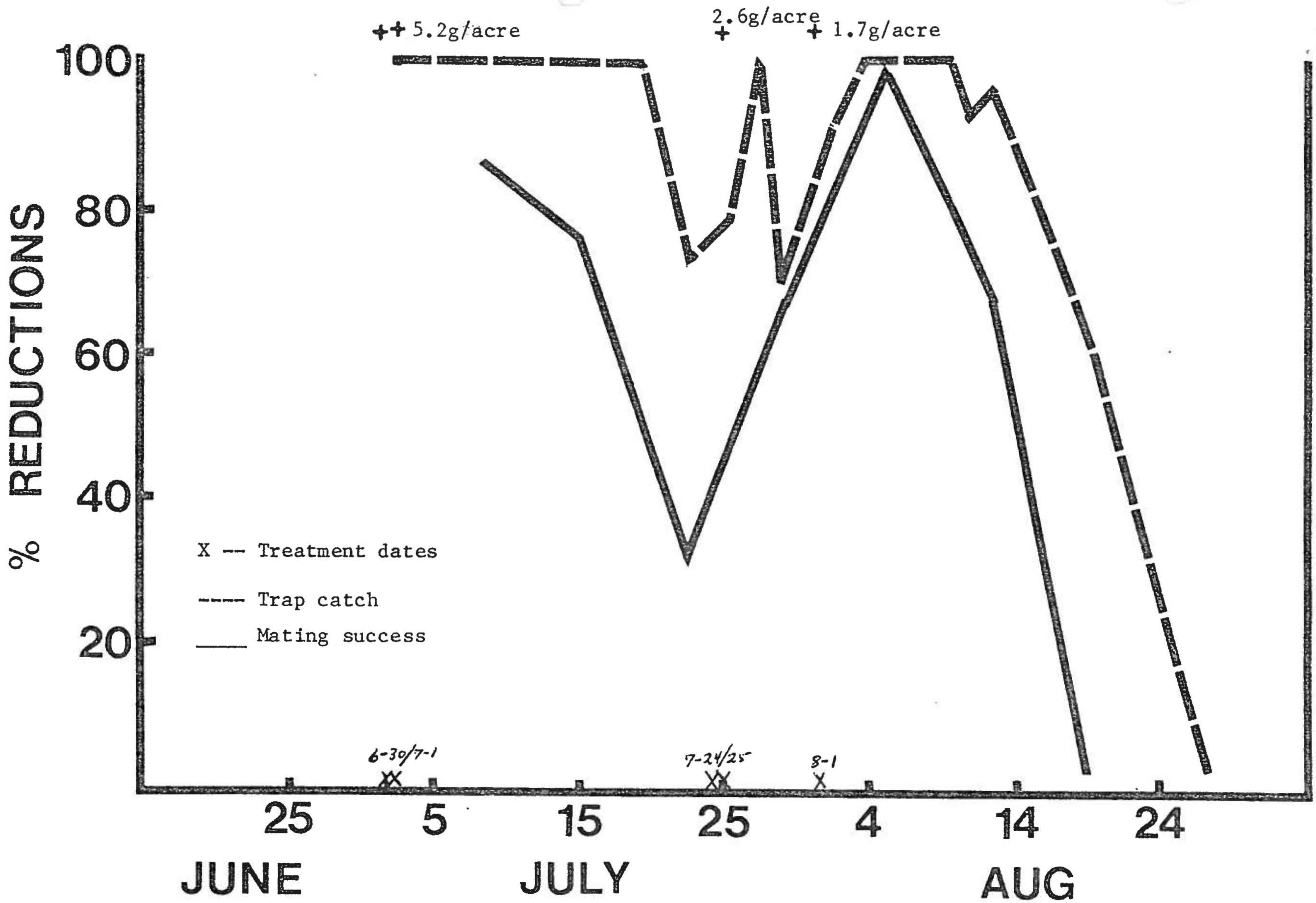


Figure 5 -- Percent reductions in male catches in female-baited traps and percent reductions in mating success of females placed in orchard treated with NOW sex pheromone made by Chemsampco and formulated in Hercon[R] laminates. Monitoring was done at 2 m and a 6 m in 5 trees within a 20-acre plot. Ballico, CA. 1980.

NAVEL ORANGEWORM PHEROMONE FIELD TESTING

Dr. Charles E. Curtis
Dr. Peter J. Landolt

USDA, SEA/AR, Fresno, California

It may be possible to control the navel orangeworm by preventing mating and subsequent egg laying. Male moths find female moths for mating by following a trail of chemical scent (sex pheromone) released by the females. Males can be confused or have their ability to find a female otherwise disrupted by the permeation of the air in an almond orchard with a synthetic component of the sex pheromone.

The synthetic sex pheromone, (Z,Z)-11,13-hexadecadienal, of the navel orangeworm can be released over a period of time from emitters hand placed or applied by ground or aerial equipment. About 5 grams, (0.01 pounds) of actual pheromone per acre of trees can disrupt mating for about 3 weeks.

In 1979 and in 1980, we obtained very good results in 9-tree and 25-tree plots. Therefore, in 1980 we set up a 15-acre plot and a 20-acre plot with hand application of the pheromone, and a 20-acre plot with aerial application of the pheromone. For various reasons the 20-acre hand applied plot and the 20-acre aerial applied plot did not give the desired results for the full growing season. We did reduce nut damage by 56% up to mid-August at which time the test had to be terminated due to lack of quality pheromone. Harvest samples on September 30 showed no difference in nut damage in the treated and check plots.

The results for the 15-acre hand applied plot are very promising. We monitored the effects of the sex pheromone treatment by checking for a reduction or elimination of males caught in sticky traps baited with virgin females, and by checking the mating success of females placed in treated plots. Also, nut samples were collected for damage estimates. Male catches in 10 traps for the 50 nights from June 30 to August 18 were 3 in the test versus 2,045 in the check for a 99.9% reduction. The reduction in mating success was 94.5%. For the 34 nights from August 19 until harvest on September 21, the trap catches were 108 versus 6,386 for a 98.3% reduction. Mating success showed a 79.8% reduction. Nut damage showed a 60% reduction in those samples collected between August 6, and September 2. However, we did not have enough pheromone to do a thorough job of mating disruption during a 10-day period in late August. At harvest we had 6.2% damage in the test versus 8.4% in the check which is only a 27% reduction in nut damage. However, the nut crop in the check was about twice as large as that in the test, and if we correct for the difference in crop size, this then shows a 61% reduction in nut damage. In addition to not having enough pheromone to put in the plot, high temperatures and high moth populations may have contributed to our problems resulting in high nut damage.

We are still optimistic in being able to develop a pheromone control strategy as an alternative to in-season insecticide applications during spring and summer months. This would also reduce the chances of creating mite problems as predators and parasites would not be destroyed. There would also be no undesirable residues on almond kernels or hulls. It may take several years to develop the pheromone into a usable control program. We still have many problems in formulation and application, and we need a cheaper method of synthesis to make the use of pheromones economically feasible. We still hope to find other components so a more effective pheromone can be developed allowing the use of smaller amounts of material.

The pheromone system would still represent only one part of a pest management operation. Mating disruption works best against low insect populations. Therefore, the already proven good orchard management practices of orchard sanitation, early and rapid harvest and control of peach twig borer would still be very important considerations. The fact that there are few insect pests of almonds is a plus for being able to develop sex pheromones for navel orangeworm and peach twig borer control. We hope to work with mating disruption of the peach twig borer in future tests. There may be some work with mass trapping using sex pheromones in the future, but this is not a very promising approach. Also, we still have to develop a much improved sex attractant for trapping male navel orangeworm.