PROJECT No. - 82-A9 - Navel Orangeworm, Mite and Insect Research
Pheromone Field Testing

COOPERATOR: USDA-ARS-WR
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I. OBJECTIVE: (1) To develop a control measure for NOW using synthetic sex perhomone for mating disruption; (2) to develop a lure for NOW using synthetic sex pheromone to attract male moths to traps; (3) to continue studies using peach twig borer (PTB) sex pheromone for PTB control by mating disruption.

II. INTERPRETIVE SUMMARY: A TRIENE compound was tested as a candidate mimic of the synthetic NOW sex pheromone component, (Z,Z)-11,13-hexadecadienal (Aldehyde). The TRIENE was prepared by Dr. Dave Carlson, USDA, Gainesville, Florida. It was first placed in small plastic containers (BEEM^{R} caps) which proved to be unsatisfactory as the material lost most of its mating disruption effect by the fifth night of a field test. Hercon formulated the material in the slow-release plastic laminate with which we have had considerable experience. We made direct comparisons of the TRIENE with the ALDEHYDE in mating disruption tests which showed the TRIENE to be active as a mating disruptant albeit the concentrations we tested were less effective than equivalent amounts of the ALDEHYDE. Pheromone mimics have potential because of greater stability, simpler formulation and much reduced costs of synthesis. In single tree plots treated with TRIENE, reductions in male catches in sticky traps were 92-99% during the first four weeks and 50-71% during the last two weeks of a test. Plots treated with ALDEHYDE showed reductions of 98-100% for male catches throughout the six-week test.

In 9-tree plots, reductions in male catches in sticky traps were 86% for the TRIENE and 99% for the ALDEHYDE for the first two weeks and 46% and 99%, respectively for the last week of a test. Mating reduction was 26% and 100%, respectively, for the first week and it was 3% and 100%, for the last two weeks of a test.

Two ALDEHYDE preparations (one made by Albany and the other by Zoecon) were tested in 9-tree plots to compare their effectiveness as mating disruptants. Both compounds were formulated by Hercon, using the slow-release plastic laminate. The Albany formulation was from the same batch used in the large scale tests near Ballico, California in the summer of 1981. Our test results indicated that the failure of the material as a mating disruptant in the 1981 tests was not caused by any defect in the formulation but was related to high populations of male NOW coupled with high temperatures that accelerated the release and/or breakdown of the ALDEHYDE.

Reductions in male catches in sticky traps were 91% for the Zoecon material and 89% for the 1981 material during the first four weeks of a test, and they were 74% and 55%, respectively, during the last four weeks of the same test. Mating reduction for virgin females placed in the field was 68% and 76%, respectively, in early season and 51% and 13%, respectively, in late season.

We received some candidate NOW pheromone from Dr. Tom Baker, University of California, Riverside, which was reportedly attractive to males in laboratory tests. Field tests of the material were negative when tested as an attractant. Tests were made very late in the season when male catches in female-baited traps were at a low level.

Two problems must first be resolved prior to any future large scale tests of mating disruption in almond orchards: (1) The isolation, identification, and synthesis of the complete pheromone. This would allow us to standardize our male NOW catches in sticky traps and provide us with a material that, theoretically, should be much more effective as a mating disruptant. (2) A formulation that would couple slow release and protection from environmental factors with small physical size and could be applied so that the entire canopy of the tree would be covered with a myriad of pheromone sources. This could be one approach that would work on higher NOW populations.

The testing of possible pheromone analogs in the field should be continued, but only after the material has been shown to have sufficient stability upon a given substrate.

III. EXPERIMENTAL PROCEDURES: Except as otherwise noted, all 1982 tests had the following in common: (1) Cooperating growers were William F. McFarlane, Herb Shapazian and Jeff Neely. (2) Varietal arrangements and interplot distances were standardized within blocks. (3) Pherocon® 1C sticky traps, each baited with 3 unmated NOW females contained in a 7 x 5 x 4-cm pyramidal fiberglass-screen cage were used as the basic measurement of male NOW activity. (4) Mating success in 9-tree blocks was evaluated by placing 3 wing-clipped, virgin-female NOW in each plot overnight. Two-day-old females were contained in 600 ml plastic freezer containers with a thin film of petroleum jelly on the inside lip of the container. A roost composed of a wooden block and wooden dowells provided resting sites for the females. (5) Two random block designs were used, one with 9-trees (3 by 3) as the basic unit and the other with single trees as the basic unit.

The 9-tree unit:

X X X
X O X
X X X

The materials being tested were applied only to the 8 perimeter trees (designated as "X") and were formulated in Hercon laminates (one 2.5 by 2.5-cm piece at 2 m, one 2.5 by 2.5 cm-piece at 5 m, and one 2.5 by 5.0-cm piece near top of tree). The center tree (designated as "O") was untreated and used for monitoring.

The 1-tree unit:

X X

0

X

The material being tested (designated as "X") were applied at a distance of 1 m from the trap or located within the trap (designated as "0").

A. Field attractiveness of the synthetic ALDEHYDE and other materials

III. EXPERIMENTAL PROCEDURE: A test was conducted using materials supplied by Dr. Tom Baker, University of California, Riverside. We received the samples in vials numbered one through four. Vial #4 was empty upon receipt. Each treatment was replicated 5 times using rows spaced at least 33 m apart as replicates. Treatments within a row were spaced 10 trees apart (ca. 46 m). Sticky traps were used to catch the male NOW. Each of the five rows contained one trap baited with 3 unmated females, one unbaited trap and 3 traps baited with 20 microliters of material from vials one, two or three. As per instructions from Dr. Baker the material was placed on filter papers at night during the time of male flight. Applications were made on October 13 and on October 15. All traps were placed ca. 2 m above the ground.

IV. RESULTS: No male NOW were caught in any of the traps baited with test materials or in unbaited traps. Traps baited with unmated females caught 0-7 (avg. = 2.2) males per trap per night.

V. DISCUSSION: The materials were received late in the season when even catches of males in female baited traps were at very low levels.

B. Disruption tests comparing ALDEHYDE with mimic (=TRIENE analog)

III. EXPERIMENTAL PROCEDURE: The first test was conducted using BEEM^{R} caps, each containing 5 mg TRIENE formulated by Dave Carlson, USDA, Gainesville, Florida, and received by us on August 9. The TRIENE was tested using the 1-tree plot in a block consisting of 9 sites. Three sites were used as checks, three were treatments with one cap attached to the inside of the trap top directly above the caged females, and three were treatments with 4 caps spaced around the trap at 1-m distances with one cap above the trap and 3 caps out from sides of trap. Traps were placed ca. 2 m above the ground and were checked daily except for weekends.

Two more tests were set up using the TRIENE formulated in 2.5 x 2.5-cm square Hercon laminate (2.94 mg TRIENE/cm^2) and (Z,Z)-11,13-hexadecadienal (ALDEHYDE) also formulated in 2.5 x 2.5-cm square Hercon laminate (2.71 mg ALDEHYDE/cm^2). The ALDEHYDE had been purchased from Albany in 1981. In one test, 1-tree plots were used. Treatments were checked, TRIENE in-trap, ALDEHYDE in-trap, TRIENE at 1 m from trap and ALDEHYDE at 1 m from trap. All treatments were replicated three times. Testing began September 13, 1982. Traps were placed ca. 2 m above the ground and were checked daily except for weekends. Catches of males were counted and females were replaced 3 times per week. In another test, 9-tree plots were used. Treatments were checks, ALDEHYDE and TRIENE. Testing began September 22. Traps were placed ca. 6 m above ground in the center tree of all treatment and check plots. Catches of males were counted and females were replaced 3 times per week. Mating success was monitored by wing-clipped females in a mating bucket open at top to afford easy access of feral males to the females. Mating success was evaluated two nights each week by placing one of the mating bucket setups in place of the sticky trap. These mating buckets were put in plots just before dark, ca. 1800 h, and collected just after first light, ca. 0700 h, the following morning. The number of mating pairs was counted and all females were held individually to determine number laying viable eggs.

Hercon laminates containing TRIENE and ones containing ALDEHYDE were aged for 0, 1, 3, 7, 10, 14, 23 and 28 days in the field. They were then held in a freezer until shipment to Dr. James Coffelt for release rate determinations.

IV. RESULTS: The results of the three tests with the TRIENE are shown in Figure 1 as cumulative male catch in sticky trays through time. When formulated in BEEM® capsules (Table 1), the TRIENE reduced male catches by 95% for the first three nights and by 60% for the last 6 nights of a test when placed in the sticky trap, and by 85% and 0%, respectively, when four capsules were spaced around the trap at 1-m distance.

In plots with three Hercon dispensers spaced around a sticky trap at 1-m distance from trap (Table 2), the reduction in male catch in traps was 97% in the first week and 50% in the sixth week after treatment with TRIENE. The reduction in the male catch was ca. 99% throughout the six-week test period for plots treated with ALDEHYDE.

Reductions in male catches in sticky traps in 9-tree plots (Table 3) were 90% for the TRIENE and 99% for the ALDEHYDE in early season and 46% and 99%, respectively, in late season.

The results for the mating buckets are shown in Table 4. The ALDEHYDE treatments completely disrupted mating for the duration of the test. The TRIENE treatments disrupted mating only on the second night of the test and were indistinguishable from the checks after that. Mating reductions were only 26% the first week and 3% for the last two weeks of the TRIENE test.

V. DISCUSSION: A pheromone mimic, a TRIENE compound, produced by Dr. Dave Carlson, U.S.D.A., Gainesville, Florida, was tested in the field. Direct comparisons with the ALDEHYDE showed that the mimic was not as good as the ALDEHYDE at the concentrations tested, but the mimic did show promise in its biological activity and might be very effective in higher application rates and/or better formulations.

Pheromone mimics have potential because of greater stability, simpler formulation and much reduced costs of synthesis.

The TRIENE material was received late in the season, and the 9-tree plot testing especially was subjected to large fluctuations in male catches and mating success due to erratic weather and harvest operations.

C. Disruption tests comparing two batches of ALDEHYDE in Hercon formulation

III. EXPERIMENTAL PROCEDURE: A test was conducted using ALDEHYDE preparations provided by Zoecon and Albany formulated by Hercon in the plastic laminate (2.65 mg Zoecon material/cm^2, and 2.71 mg Albany material/cm^2). The Albany material was the same as that used in 1981 tests conducted near Ballico, California. The first application of pheromone was on July 12, a second one on August 10 and a third one on August 24. This test set up was the same as that already described for 9-tree plots. The check was replicated six times and the Albany treatment and Zoecon treatment were both replicated three times.

Hercon laminates containing the two materials were aged for 0, 1, 3, 7, 10, 14, 21, 28, 35 and 42 days in the field. They were then held in a freezer until shipment to Hercon for release rate determinations. This was done for all three applications.

IV. RESULTS: Table 5 contains the data for the male catches in sticky traps and Table 6 contains the data for mating success for females placed in the field in mating buckets. Reductions in male catches in sticky traps were 91% for the Zoecon material and 89% for the 1981 material early in the season, and they were 74% and 55%, respectively, late in the season. Mating reduction for virgin females placed in the field was 68% and 76%, respectively, in early season and 51% and 13%, respectively, in late season. Duncan's multiple range test showed no significant difference between the Zoecon and Albany materials for either the sticky trap data or the mating bucket data.

V. DISCUSSION: It appears that the single component pheromone (ALDEHYDE) that we have been using and/or the rate being applied is not useful in controlling the navel orangeworm in orchards with high populations. This was confirmed in further testing in 1982 using 9-tree plots for a direct comparison of the 1981-pheromone material with high quality pheromone produced by Zoecon Corp. The material used in 1981 was somewhat less effective (not significantly different) than the Zoecon material for mating disruption, but both materials gave poor results as populations increased.

We need a more complete pheromone, better formulations to protect the pheromone from the elements (heat, UV, and oxidation) and perhaps higher rates of application.

Our experience with one plot in these tests and with bud failure trees with few leaves in other tests have demonstrated the importance of having plenty of pheromone material high in the tree canopy. Although we place a double dose at that position, we still have no information concerning release rate. We suspect that the material placed at the top of the tree has a much shorter useful life because of exposure to more solar radiation. Premature failure of treatments placed high in trees coupled with a larger than expected NOW population probably account for the results of the 1981 tests.

Table 1.--Male NOW catches in female-baited sticky traps after treatment of single-tree plots with TRIENE Compound Formulated in BEEM[R] capsules. Fresno, California, August 10, 1982.

No. Nights after application	No. males/trap/night* and (% reduction in catch over check)		
	Check	TRIENE in trap	TRIENE at 1 m**
1	9.7	1.0 (90)	1.0 (90)
2	10.3	0.3 (97)	1.3 (87)
3	8.3	0 (100)	2.0 (76)
6	9.0	1.0 (89)	8.7 (3)
7	20.0	9.7 (52)	32.7 (0)
8	5.0	7.0 (0)	7.3 (0)
9	10.0	5.3 (47)	10.3 (0)
1-3	9.4	0.4 (95)	1.4 (85)
4-9	10.3	4.1 (60)	12.7 (0)

* All treatments replicated three times.

** Four BEEM[R] caps spaced around trap at distance of one meter.

Table 2.--Male NOW catches in female-baited sticky traps after treatment of single-tree plots with ALDEHYDE or TRIENE Compounds Formulated in Hercon[R] laminates. Fresno, California, September 13, 1982.

Week No. after application	No. males/trap/week* and (% reduction in catch over check)				
	Check	TRIENE		ALDEHYDE	
		In trap	At 1 m**	In trap	At 1 m**
1	99.3	0.3 (99)	2.7 (97)	0.7 (99)	0.7 (99)
2	105.3	0 (100)	5.3 (95)	0 (100)	0.3 (99)
3	61.7	0 (100)	0.7 (99)	0 (100)	0.7 (99)
4	43.7	0.3 (99)	3.3 (92)	0 (100)	0 (100)
5	54.3	1.0 (98)	16.0 (71)	0 (100)	0.7 (99)
6	44.3	14.0 (68)	22.0 (50)	0 (100)	0.7 (98)
Total	408.7	15.7 (96.2)	50.0 (87.8)	0.7 (99.8)	3.0 (99.3)

* All treatments replicated three times.

** Three Hercon[R] laminates (2.5 by 2.5 cm) spaced around trap at distance of one meter.

Table 3.--Male NOW catches in female-baited sticky traps after treatment of 9-tree plots with ALDEHYDE or TRIENE Compounds Formulated in Hercon[R] laminates. Fresno, California September 21, 1982.

No. nights after application	No. males/trap/night* and (% reduction in catch over check				
	Check	TRIENE		ALDEHYDE	
2	28.9	1.2	(96)	0.2	(99)
6	3.7	1.6	(57)	0	(100)
9	12.0	1.4	(88)	0	(100)
13	21.2	4.3	(80)	0.2	(99)
16	33.0	16.6	(50)	0	(100)
21	12.5	7.3	(41)	0.2	(98)
Week No. 1	13.8	1.4	(90)	0.1	(99)
Week No. 2	17.5	3.1	(82)	0.1	(99)
Week No. 3	19.3	10.4	(46)	0.2	(99)

* Check replicated four times and treatments each replicated three times.

Table 4.--Mating success of female NOW placed overnight in plots after treatment of 9-tree plots with ALDEHYDE or TRIENE Compounds Formulated in Hercon[R] laminates. Fresno, California, September 21, 1982.

Date ♀'s placed in plot	No. nights after application	No. mated/total No. ♀'s recovered (= fraction mated)* and (% reduction in mating over check)		
		Check	TRIENE	ALDEHYDE
9/23	3	1/10	0/9 (100)	0/9 (100)
9/27	7	6/12	4/8 (0)	0/9 (100)
9/30	10	0/12	3/9 (0)	0/9 (100)
10/4	14	9/12	5/9 (26)	0/9 (100)
10/7	17	2/12	0/9 (100)	0/9 (100)
Totals	-	18/58	12/44 (12)	0/45 (100)

* Check replicated four times and treatments each replicated three times.

Table 5.--Male NOW catches in female-baited sticky traps after treatment of 9-tree plots with ALDEHYDE Formulated in Hercon[R] laminates. Fresno, California. 1982.

Application dates	Week No. after application	No. males/trap/night* (% reduction in catch over check)		
		Check	Albany	Zoecon
7/12	1	4.2	0 (100)	0.2 (95)
	2	2.5	0 (100)	0 (100)
	3	3.0	0.1 (97)	0.4 (87)
	4	8.7	1.9 (78)	1.1 (87)
8/10	1	16.1	0.9 (95)	0.4 (98)
	2	16.7	4.5 (73)	1.4 (92)
8/24	1	21.8	4.1 (81)	0.3 (99)
	2	26.9	15.1 (44)	11.2 (58)
	3	21.1	4.3 (80)	2.4 (89)
	4	28.0	18.6 (33)	9.8 (65)
7/12	4 weeks	4.6	0.5 (89)	0.4 (91)
8/10	2 weeks	16.7	2.7 (84)	0.9 (95)
8/24	4 weeks	24.6	11.1 (55)	6.3 (74)

* Check replicated six times and treatments each replicated three times.

Table 6.--Mating success of female NOW placed overnight in plots after treatment of 9-tree plots with ALDEHYDE Formulated in Hercon[R] laminates. Fresno, California, 1982.

Application dates	Date ♀'s placed in plot	No. nights after application	No. mated/total No. females recovered (=fraction mated) and (% reduction in mating over check)		
			Check	Albany	Zoecon
7/12	7/15	4	3/17	0/7 (100)	0/8 (100)
	7/19	8	8/16	0/8 (100)	0/7 (100)
	7/22	11	7/18	0/9 (100)	0/8 (100)
	7/26	15	11/19	0/9 (100)	0/9 (100)
	7/29	18	5/17	0/9 (100)	0/9 (100)
	8/2	22	16/18	3/9 (62)	4/9 (50)
	8/5	25	14/18	3/9 (57)	3/9 (57)
	8/9	29	14/18	3/8 (52)	5/8 (20)
8/10	8/12	3	14/18	5/10 (36)	2/9 (71)
	8/16	7	12/17	6/9 (6)	6/9 (6)
	8/19	10	15/18	5/9 (33)	6/10 (28)
	8/23	14	11/18	6/9 (0)	5/9 (9)
8/24	8/26	3	12/17	5/10 (29)	0/9 (100)
	8/30	7	15/19	5/8 (21)	3/8 (52)
	9/2	10	16/19	9/10 (0)	7/9 (8)
7/12	3 dates	-	78/141	9/68 (76)	12/67 (68)
8/10	4 dates	-	52/71	22/37 (19)	19/37 (30)
8/24	3 dates	-	43/55	19/28 (13)	10/26 (51)

VI. PUBLICATIONS:

(1) Landolt, P. J., and C. E. Curtis. 1982. Effects of temperature on the circadian rhythm of navel orangeworm sexual activity. Environ. Entomol. 11: 107-110.

(2) Landolt, P. J. and C. E. Curtis. 1982. Interspecific sexual attraction between Pyralis farinalis L. and Amyelois transitella (Walker) (Lepidoptera: Pyralidae). J. Kansas Entomol. Soc. 55: 248-252.

(3) Landolt, P. J., C. E. Curtis, J. A. Coffelt, K. W. Vick, and R. E. Doolittle. 1982. Field trials of potential navel orangeworm mating disruptants. J. Econ. Entomol. 75: 547-550.

(4) Curtis, C. E., G. S. Sibbett, M. Gerdts, and J. D. Clark. Yield of subsequent crop when tree shaking is used to remove mummy almonds for navel orangeworm control. J. Econ. Entomol. (In press)

Figure 1. Cumulative NOW male catch in female-baited sticky traps in plots treated with TRIENE or ALDEHYDE formulated in BEEM^{R} capsules or Hercon^{R} laminates. Fresno, California. 1982.

Fig. 1-A

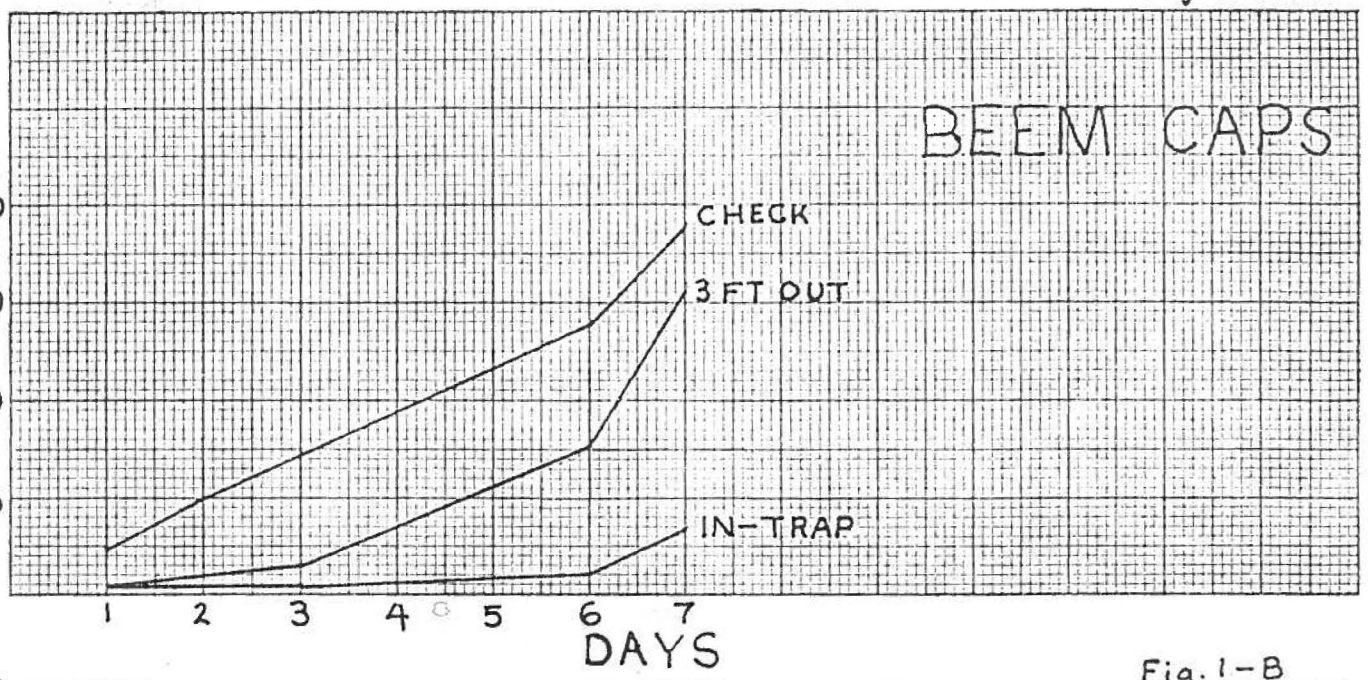
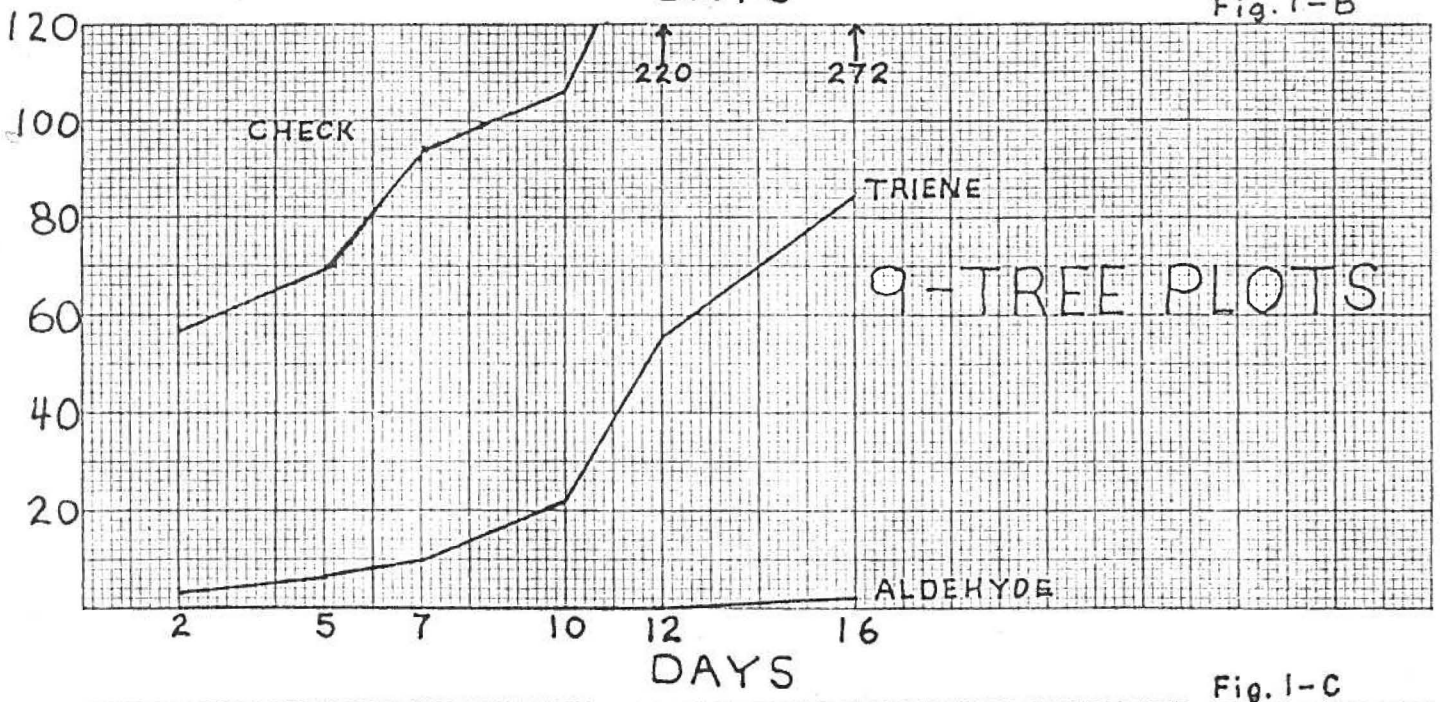


Fig. 1-B



MEAN CUMULATIVE ♂ CATCH PER TRAP

Fig. 1-C