

Development of aerosol devices for management of codling moth and leafrollers.

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Abstract: The effectiveness of battery-powered aerosol devices (Paramount Aerosol Pheromone Dispenser; aka - puffers) emitting sex pheromones were evaluated for the management of both *Cydia pomonella* and *Choristoneura rosaceana* in replicated field trials during 1999-2000 in 16-ha apple orchards near Brewster, WA, U.S.A. The array of puffers in all orchards was similar: units were placed 50 m from the orchard's edge and spaced 100 m apart. In addition, a 10-m band around the perimeter of each orchard was treated with hand-applied Isomate dispensers at a rate of 1,000 per ha. During 1999 four orchards were treated with puffers releasing 7.5 mg of (*E,E*)-8-10-dodecadienol (codlemone) and 7.5 mg (*Z*)-11-tetradecenyl acetate (*Z*11-14:AC). Moth catch of released sterile *C. pomonella* and native *C. rosaceana* were compared with similar orchards treated with either 500 or 1,000 Isomate CM/LR dispensers per ha. Four three-week tests were conducted to evaluate the performance of puffers releasing pheromone every 15 min for 24 h, 30 min for 24 h or 15 min for 12 h daily versus the hand-applied dispensers. No differences in moth catch for *C. pomonella* was found among pheromone treatments in any of the four tests. However, significant differences in moth catch of *C. rosaceana* occurred among treatments during three of the four tests. Mean moth catch was higher in the puffer-treated plots than in plots treated with either dispenser rate during June. Conversely, moth catch was lower in the puffer-treated plots than in those treated with the low rate of Isomate CM/LR during the August and September trials. During 2000 the effectiveness of puffers for *C. pomonella* alone or for both species was evaluated in sixteen orchards. Puffers released either 7.5 mg puffs of codlemone, 7.5 mg puffs of both codlemone and *Z*11-14:AC (dual high), or 5.0 mg codlemone and 7.5 mg *Z*11-14:AC (dual low) every 15 minutes for 12 hours per day (1500 – 0300 hours). Fruit injury was measured prior to harvest and results were compared with paired orchards treated with Iso-mate-C+ dispensers at a rate of 500 dispensers per ha. Fruit injury from *C. pomonella* and *C. rosaceana* ranged from 0.0 to 3.1% and 0.0 to 0.9%, respectively among the puffer-treated orchards. The mean *C. pomonella* injury in the puffer-treated orchards was not significantly different than in the Isomate-C+ comparison blocks. Fruit injury by *C. rosaceana*, however, was significantly lower in the dual puffer-treated versus the orchards not treated with leafroller pheromone.

Key words: Sex pheromone, apple, *Cydia pomonella*, *Choristoneura rosaceana*, mating disruption, sex pheromone, pest management.

Introduction

The technology of emitting the sex pheromone of codling moth (*Cydia pomonella* L.) from a high density array of plastic dispensers has been adopted in over one half of the apple and pear acreage (40,000 hectares) in Washington State in just ten years. During this rapid transition in orchard pest management Washington growers have reduced the density of dispensers applied and have supplemented dispensers with limited use of organophosphate insecticides over the majority of this acreage. Today the average codling moth management program entails the use of 500 dispensers per hectare and one cover spray (Alway 1997). The incentives that led to this design were both the high cost of using sex pheromones and their perceived moderate efficacy.

The effectiveness of disrupting codling moth mating in orchards treated with sex pheromone has been questioned by the consistent body of data generated with light traps, passive interception traps, and more recently with traps baited with a bisexual kairomone lure showing that 50 – 100% of the female moths trapped in pheromone-treated orchards are mated (Howell 1992, Knight 2000, Knight and Light 2000). The complementary hypothesis that a delay in mating by female codling moths may also contribute to the observed population reduction in pheromone-treated orchards has been supported with experimental studies (Knight 1997). In addition, the removal of organophosphate insecticide sprays can enhance the role of biological control of eggs and neonate codling moth (Knight et al. 1997). Nevertheless, sole reliance on the use of sex pheromones to manage codling moth is rarely undertaken unless the population density of this pest has been strongly suppressed by other factors, i.e. chemical control, orchard isolation, or area wide management (Calkins 1998).

The successful use and rapid adoption of sex pheromones for codling moth is now threatened by the current poor economics in tree fruit production in the United States. Growers have abandoned orchards and reduced their general use of pesticides. It appears that the regional density of codling moth in Washington's major fruit growing areas is increasing and this likely portends increasing difficulties in managing its population without insecticides. The loss of registrations for organophosphate insecticides coupled with the moderate effectiveness of the newer, more selective insecticides creates an important challenge for tree fruit pest management in the first decade of the new millennium. In addition, the emerging importance of other pest species such as tortricid leafrollers and pentatomid bugs requires the development of new integrated management programs. To address a portion of these dynamic issues we have conducted studies to develop a lower cost and more effective sex pheromone-based management program for codling moth. Concurrently, we have examined the potential for managing leafroller populations with sex pheromones (Knight et al. 1998, Knight and Turner 1999).

Farkas et al. (1974) first envisioned the idea of using widely spaced high emis-

sion sex pheromone emitters to achieve mating disruption. Shorey and co-workers formulated a working hypothesis that the effectiveness of any sex pheromone-based mating disruption system is controlled by the mean airborne concentration of pheromone and is thus regulated by the interaction of point source emission rate and the spacing of emitters (Shorey et al. 1996). The development of a mechanical device (puffer) allowed them to test this hypothesis for several lepidopteran pest species (Shorey et al. 1996, Shorey and Gerber 1996a, b, c). Puffers are battery-powered devices that release pheromone from pressurized aerosol cans. Three advantages of puffers were perceived to be their flexibility in allowing users to release pheromone only during pre-selected time periods, protection of the sex pheromones from environmental degradation, and maintaining a uniform release rate independent of ambient temperature. Shorey and Gerber (1996b) evaluated puffers for codling moth by ringing the perimeter of walnut orchards with puffers spaced 44 m apart to create a density of 2.5 puffers per hectare. This approach appeared promising and orchard trials in California were conducted in apple, pear, and walnut with puffer densities between 2.5 and 5.0 units per hectare. My preliminary studies with puffers in Washington State followed the work by Dr. Shorey and focused on two species of tortricid leafrollers, but following Dr. Shorey's death in 1998 the study was expanded to include codling moth.

Two major changes were made to Dr. Shorey's original approach with puffers to make their use competitive with the cost of the most common usage of hand-applied dispensers for codling moth in Washington State (500 Isomate-C+ dispensers/ha). Based on current retail prices of dispensers and the wholesale cost of sex pheromone, I estimated that deploying one puffer per hectare would be somewhat less expensive than the current program. Furthermore, I assumed that the spacing between units required to treat only the perimeter of the orchard with this low density of puffers would be too great to be effective and that puffers placed on the downwind side of the orchard would be the least effective. Subsequent studies with codling moth demonstrated the sphere of influence of puffers on lure-baited traps to be < 10 m into the orchard when placed on the downwind edge versus > 50 m when placed on the upwind edge or in the center of the orchard (unpubl. data). Instead, I designed a program in 1998 based on the use of an internal grid of puffers. Puffers were placed 50 m from the edges of the orchard and 100 m apart (1 puffer/ha). In addition, the perimeter of the orchard (a 10 – 20 m wide border) was treated with hand-applied dispensers at the full, labelled rate (1,000 Isomate dispensers per hectare). This idea was inspired by the earlier work of Charmillot et al. (1995) with *Lobesia botrana* in grape where they treated the borders of vineyards with a high density of dispensers and used a large spaced grid of dispensers inside.

Herein, I report the results of studies conducted in apple during 1999 and 2000 to evaluate the success of this program coined I. - H.E.L.P. (Integrated High Emission Low Point) for both codling moth and oblique banded leafroller, *Choristoneura rosaceana* (Harris).

Materials and Methods

All studies were conducted during 1999-2000 in 16-hectare apple orchards situated near Brewster, WA. Orchards were either plantings of 'Red Delicious', 'Fuji', or 'Granny Smith'. During 1999, twelve orchards were selected and pheromone treatments were randomly assigned to create four replicates of three pheromone treatments: I. - H.E.L.P. with a 10 m-wide border application of 1,600 Isomate CM/LR dispensers, 500 Isomate CM/LR dispensers per hectare, and 1,000 Isomate CM/LR dispensers per hectare. Pheromone treatments were applied during the first week of May. Four separate tests were conducted to evaluate several puffer emission rates. Each test lasted three weeks and puffers were removed from orchards for one week between tests. Puffers were programmed to release 7.5 mg of both (*E,E*)-8-10-dodecadienol (codlemone) and 7.5 mg (*Z*)-11-tetradecenyl acetate (*Z*11-14:AC). Test 1 was conducted from 8 June to 1 July and puffers emitted pheromone every 30 minutes for 24 hours each day. Test 2 was conducted from 7 - 27 July and puffers released pheromone every 15 minutes for 24 hours each day. Test 3 was run from 3 - 25 August and puffers released pheromone every 15 minutes for 12 hours each day (1500 - 0300 hours). Test 4 was run from 1 - 22 September and puffers released pheromone every 30 minutes for 24 hours each day. Orchards were monitored with 12 traps baited with lures for both species (Trece Inc., Salinas, CA). During tests 1 and 2 codling moth was monitored with 10 mg red septa and with both 1 and 10 mg lures during tests 3 and 4 placed in separate traps approximately 25 m apart. Traps in all tests were placed in the upper third of the canopy. Lures for *C. rosaceana* were always placed in the same trap with the 10 mg codling moth lure. Chilled codling moth adults sterilized with radiation in Canada and marked with an internal dye were transported to orchards each week and 8,000 moths were released from eight pre-assigned sites. Mean moth catch per test for each lure type was first transformed (square root [x]) and then compared among treatments for each test with analysis of variance. Significant means were separated with Fisher's LSD test.

During the 2000 season, sixteen apple orchards were treated with the I. - H.E.L.P. program. Orchards were treated daily from May 1 to September 25 with sex pheromone puffs released every 15 min from 1500 - 0300 hours. Three types of puffers were used: five orchards were treated with 7.5 mg puffs of codlemone and *Z*11-14:AC (High Dual), four orchards were treated with 5.0 mg and 7.5 mg puffs of codlemone and *Z*11-14:AC, respectively (Low Dual), and seven orchards were treated with only 7.5 mg puffs of codlemone (CM only). Orchards treated with dual puffers were ringed with 1,600 Isomate CM/LR dispensers, while orchards treated with CM only puffers were ringed with the same number of Isomate-C+ dispensers. Eight traps were deployed around the perimeter of each orchard and baited with the lures of both species. Fruit injury was assessed in each orchard prior to harvest by inspecting 600 fruit per orchard quadrant (30 fruit from 10 trees situated in the center and on the edge of the quadrant). Each puffer-treated orchard was paired with a

similar orchard treated with Isomate C+ based on an assessment of their initial pest pressure, similar management staff, insecticide usage, cultivar, and location (> 400 m but < 1,600 m distant from each other). Fruit injury in these paired orchards was compared using the non-parametric Wilcoxin Matched Pairs statistical test.

Results

Recapture of sterile codling moths in 1999 was remarkably uniform among traps within each orchard and no significant differences were found in moth catch by either 1 mg or 10 mg-baited trap among treatments during any of the four tests conducted (Table 1). Moth catches were six- and three-fold lower in the 1 mg versus the 10 mg-baited traps in the third and fourth test across all treatments, respectively. Few wild codling moths were caught in any of the 12 apple orchards (a range of 4.17 to 4.43 wild moths per trap per season among the three treatments).

Table 1. Mean (SE) recapture of sterile, male codling moths in pheromone-baited traps loaded with 1 mg and 10 mg codlemone lures in replicated 16 hectare apple orchards (N = 4) treated either with the I. – H.E.L.P. arrangement of Paramount puffers or 500 or 1,000 Isomate-CM/LR dispensers per hectare. Puffers released 7.5 mg codlemone per puff.

	Dates of Test			
	Daily Cycle / Puffing Frequency			
Pheromone treatment	6/11 - 7/1 24 h - 30 min 10 mg lure	7/7 - 7/27 24 h - 15 min 10 mg lure	8/3 - 8/25 12 h - 15 min 1 mg / 10 mg lure	9/01 - 9/22 24 h - 30 min 1 mg / 10 mg lure
Isomate CM/LR 500/ha	31.4 (2.3)	30.4 (1.2)	4.2 (0.5) / 30.3 (2.0)	3.7 (0.3) / 11.1 (1.0)
Isomate CM/LR 1,000/ha	26.6 (4.5)	33.6 (2.7)	4.4 (0.6) / 25.2 (1.7)	3.2 (0.1) / 10.4 (0.6)
Paramount PufferI. – H.E.L.P.	30.5 (3.3)	35.1 (1.6)	4.2 (0.3) / 25.7 (1.5)	3.3 (0.3) / 10.2 (0.2)

No significant differences were found among column means, ANOVA, $P > 0.05$.

Catches of male obliquebanded leafroller varied among treatments in three of the four tests (Table 2). Mean moth catch was significantly higher in puffer-treated

blocks (30 minute puffs for 24 hours per day) than Isomate CM/LR-treated orchards during the first test, $F = 6.32$; $df = 2, 9$; $P < 0.05$). However, in the second test when puffers released pheromone every 15 min for 24 hours per day no significant differences among treatments were found ($P = 0.47$). Mean moth catch was significantly lower in the puffer-treated orchards than in orchards treated with 500 Isomate CM/LR dispensers per hectare during the third test, $F = 4.50$; $df = 2, 9$; $P < 0.05$. The puffer setting of 30 minute puffs for 24 hours per day was repeated in the fourth test and the results differed from test 1 (Table 2). During September moth catch per trap in the puffer treatment was significantly lower than in orchards treated with 500 Isomate CM/LR dispensers per hectare, $F = 6.85$; $df = 2, 9$; $P < 0.05$ (Table 2).

Table 2. Mean (SE) capture of wild, male oblique banded leafrollers in pheromone-baited traps in replicated 16 hectare apple orchards ($N = 4$) treated either with the I. – H.E.L.P. arrangement of Paramount puffers or 500 or 1,000 Isomate-CM/LR dispensers per hectare. Puffers released 7.5 mg (Z)-11-tetradecenyl acetate per puff.

Pheromone treatment	Dates of Test			
	Daily Cycle / Puffing Frequency			
	6/11 - 7/1 24 h - 30 min	7/7 - 7/27 24 h - 15 min	8/3 - 8/25 12 h - 15 min	9/01 - 9/22 24 h - 30 min
Isomate CM/LR 500 per hectare	2.1 (0.6)b	5.4 (0.5)a	3.3 (0.4)a	5.1 (0.7)a
Isomate CM/LR 1,000 per hectare	1.4 (0.5)b	5.8 (0.3)a	2.5 (0.4)ab	4.0 (0.3)ab
Paramount Puffer I. – H.E.L.P.	4.6 (0.8)a	5.1 (0.5)a	1.8 (0.2)b	2.8 (0.1)b

Column means followed by a different letter were significantly different, ANOVA, $P < 0.05$, Fishers LSD.

During 2000, no significant differences were found in codling moth fruit injury between orchards treated with any of the three puffer types (Dual Low, Dual High, and CM-only) versus orchards treated with Isomate C+ dispensers (Table 3). Injury levels $> 1.0\%$ occurred in only two puffer-treated orchards. Moth catch per trap in both of these orchards exceeded the threshold established for codling moth in pheromone-treated orchards during the first flight (> 4.0 moths per trap [Gut and Brunner 1996]), but they were not supplemented with insecticides until later in the summer. Similarly, the Isomate C+-treated orchards paired with these two orchards were also not sprayed during the first moth generation and suffered high levels of fruit injury.

Fruit injury by the oblique banded leafroller across all nine orchards treated with the Dual puffer ranged from 0.0 to 0.9% and was significantly lower ($Z = 2.24$, $P < 0.05$) than the paired orchards not treated with any sex pheromone for leafrollers (Isomate C+ only) (Table 3). However, the full impact of sex pheromone in managing oblique banded leafroller was difficult to discern in this study as all but one orchard pair was treated with either spring or summer applications of *Bacillus thuringiensis* Berliner or spinosid-based insecticides.

Table 3. Mean (SE) fruit injury from codling moth and oblique banded leafroller at harvest in 16-hectare apple orchards treated with either the Paramount puffer releasing both codlemone and (Z)-11-tetradecenyl acetate at 5.0 mg and 7.5 mg per puff, respectively (Dual Low), both pheromones at 7.5 mg per puff (Dual High), or 7.5 mg puffs of codlemone (CM only) versus paired orchards treated with Isomate-C+ dispensers (500 dispensers per hectare), Brewster, WA, 2000.

Puffer treatment	Mean (SE) % CM Injury		Mean (SE) % OBLR Injury	
	Puffer - treated orchards	Isomate C+ - treated orchards	Puffer - treated orchards	Isomate C+ - treated orchards
Dual Low n = 4	0.70 (0.49)	1.71 (0.93)	0.13 (0.09)	0.58 (0.28)
Dual High n = 5	0.66 (0.61)	0.40 (0.38)	0.25 (0.11)	0.73 (0.13)
All Dual n = 9	-	-	0.19 (0.10)	0.66 (0.14)
CM only n = 7	0.13 (0.10)	0.31 (0.21)	-	-

Mean oblique banded leafroller fruit injury between all Dual puffer-treated and their paired Isomate C+-treated orchards (n = 9) was significantly different, $P < 0.05$ (Wilcoxin Matched Pairs test).

Discussion

The use of a widely-spaced array of mechanical devices releasing high rates of pheromone has been tested for a number of lepidopteran pest species over the last eight years (Shorey et al. 1996; Shorey and Gerber 1996a,b,c; Mafra-Neto and Baker 1996, Baker et al. 1997, Shorey et al. 1998, Issacs et al. 1999). These studies have used a variety of battery-powered devices including the Technical Concepts (Chicago, IL) puffer (Shorey et al. 1996), the MSTRS device (metered semiochemical timed release system) (Mafra-Neto and Baker 1996), the Paramount Aerosol Pheromone Dispenser (Shorey et al. 1998), and the Michigan State Microsprayer (Issacs et al. 1999). Unfortunately, due the rapid development of this technology few studies have been conducted to address the effectiveness or the factors contributing

to the effectiveness of this approach for any given pest species. Thus optimisation of these puffer-based pest management programs within a crop-based management system have not been completed.

The development of puffers by Shorey and co-workers for the management of codling moth in pears in California has probably been the most well studied system (Shorey et al. 1998). Their initial work used a unit designed as an indoor bathroom deodorizer. Units were wrapped in aluminium foil and sprayed with silicon to allow them to operate in orchards treated with overhead irrigation and to withstand rain-fall. Originally, these puffers were placed only on the perimeter of the orchards (2.25 puffers per hectare) and released codlemone (68.5 mg per spray) onto a cloth pad every 30 min for 24 hours per day (Shorey and Gerber 1996). However, by 1998 the Paramount Aerosol Pheromone Dispenser was developed (Shorey et al. 1998) and this unit gave the user greater flexibility in specifying and adjusting the amount of pheromone released, the frequency of release, the daily period of release, and included the use of a lower temperature release threshold. Shorey's design still placed puffers on the perimeter of the orchard but also included mid-orchard transects. Under this arrangement puffers were used at a density of up to five units per hectare. The biggest change made from Shorey's 1996 design was that the puffers were programmed to release 7.5 mg pheromone puffs every 15 minutes for 12 hours per day (Shorey et al. 1998). This represented a 75% reduction in the amount of pheromone used during the season. The Paramount Aerosol Pheromone Dispenser was registered in the U.S. in 1999 and was used effectively at a density of 3.5 to 4.0 units per hectare on over 800 hectares of pear in 2000.

The success of the I. – H.E.L.P. program in Washington apple orchards during 2000 represents a substantial reduction in the use of sex pheromone for disruption of codling moth compared with the Shorey design. Studies reported herein support use of the 15 minute / 12 hour cycle of pheromone release for both codling moth and the oblique banded leafroller. However, the success during the 2000 season of treating orchards with the Dual Low puffer releasing only 5.0 mg codlemone puffs suggests that further studies are needed to establish the minimum effective dose required for disruption of codling moth.

Integrating the internal grid of puffers with a high density border treatment of dispensers likely improves the distribution of pheromone (Milli et al. 1997) in the most sensitive portion of the orchard to codling moth attack. However, disrupting codling moth within border areas will remain problematic due to this area's greater wind speed and turbulence and higher moth density. The common practice of supplementing sex pheromones with border insecticide applications (Knight 1995) would likely be an effective management practice replacing the border dispenser application to supplement the internal grid of puffers. However, future studies will examine the integrated use of border applications of microencapsulated sprayable pheromones, attract and kill formulations, and insecticide-impregnated bait stations with the internal puffer grid.

Mechanical devices have allowed greater flexibility in the application of pheromone. However, the high cost of individual units (\$25 – 40 U.S.) limits the density of units that can be deployed. In addition, a number of operational problems have occurred during our studies that limit their practical use: loss of units due to theft or vandalism (< 5%), units not functioning due to problems with the unit or batteries (10%), and the common occurrence of severe phytotoxic effects on the surrounding fruit and foliage. Puffers were monitored weekly due to the potential impact on pest management following the loss of even one puffer for a short time. This high cost of monitoring the status of the Paramount Aerosol Pheromone Dispenser is increased further by the difficulty in assessing its operational status with a remote control device. Instead we were forced to develop a rating system to judge each unit based on the physical characteristics of the cabinet and the surrounding foliage. While studies are planned to further optimise the performance of puffers for management of codling moth and leafrollers, we will also begin to develop high emission passive dispenser systems.

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References

- Alway, T. 1997. Mating disruption use in Washington State: grower survey report. Areawide IPM Update 2: 1-3.
- Baker, T. C. T. Dittl, and A. Mafra-Neto. 1997. Disruption of sex pheromone communication in the blackheaded fireworm in Wisconsin cranberry marshes by using MSTRS devices. *J. Agric. Entomol.* 14: 449-457.
- Calkins, C. O. 1998. Review of the codling moth areawide suppression program in the western United States. *J. Agric. Entomol.* 15: 327-333.
- Charmillot, P. J., D. Pasquier, N. J. Alipaz, and U. Neuman. 1995. Effect of pheromone dispensers placed as a belt on the distribution of male catches, tethered female matings and damage of *Lobesia botrana* Den. & Schiff. in vineyards. *J. Appl. Entomol.* 119: 201-206.
- Farkas, S. R., H. H. Shorey, and L. K. Gaston. 1974. Sex pheromones of Lepidoptera. The use of widely separated evaporators of Looplure for the disruption of pheromone communication in *Trichoplusia ni*. *Environ. Entomol.* 3: 876-877.
- Gut, L. J. and J. F. Brunner. 1996. Implementing codling moth mating disruption in Washington pome fruit orchards. Washington State University, Tree Fruit Research and Extension Center Information Series, No. 1. Good Fruit Grower, Wenatchee, WA
- Howell, J. F. 1992. Two years of commercial use of Isomate-C to disrupt mating for control of

- codling moth. Proceedings Washington Horticultural Association 88: 176-181.
- Isaacs, R., M. Ulczynski, B. Wright, L. J. Gut, and J. R. Miller. 1999. Performance of the micro-sprayer with application for pheromone-mediated control of insect pests. *J. Econ. Entomol.* 92: 1157-1164.
- Knight, A. 1995. The impact of codling moth (Lepidoptera: Tortricidae) mating disruption on apple pest management in Yakima Valley, Washington. *J. Entomol. Soc. Brit. Columbia* 92: 29-38.
- Knight, A. L. 1997. Delay of mating of codling moth in pheromone disrupted orchards. *Technology Transfer in Mating Disruption IOBC Bulletin* 20: 203-206.
- Knight, A. L., J. E. Turner, and B. Brachula. 1997. Predation on eggs of codling moth (Lepidoptera: Tortricidae) in mating disrupted and conventional orchards in Washington. *J. Entomol. Soc. Brit. Columbia* 94: 67-74.
- Knight, A. L., D. R. Thompson, and S. D. Cockfield. 1998. Developing mating disruption of obliquebanded leafroller (Lepidoptera: Tortricidae) in Washington State. *Environ. Entomol.* 27: 1080-1088.
- Knight, A. L. and J. E. Turner. 1999. Mating disruption of *Pandemis* spp. (Lepidoptera: Tortricidae). *Environ. Entomol.* 28: 81-87.
- Knight, A. L. 2000. Monitoring codling moth (Lepidoptera: Tortricidae) with passive interception traps in sex pheromone-treated apple orchards. *J. Econ. Entomol.* 93: 1744-1751.
- Knight, A. L. & Light, D. 2000: Monitoring codling moth with a bisexual attractant. Abstract 25th Meeting IOBC-WPRS Working Group 'Use of pheromone and other semiochemicals in integrated control'.
- Mafra-Neto, A. and T. C. Baker. 1996. Timed, metered sprays of pheromone disrupt mating of *Cadra cautella* (Lepidoptera: Pyralidae). *J. Agric. Entomol.* 13: 149-168.
- Milli, R., U. T. Koch, and J. J. de Kramer. 1997. EAG measurements of pheromone distribution in apple orchards treated for mating disruption of *Cydia pomonella*. *Entomol. Exper. Et Appl.* 82: 289-297.
- Shorey, H. H., C. B. Sisk, and R. G. Gerber. 1996. Widely separated pheromone release sites for disruption of sex pheromone communication in two species of Lepidoptera. *Environ. Entomol.* 25: 446-451.
- Shorey, H. H. and R. G. Gerber. 1996a. Use of puffers for disruption of sex pheromone communication among navel orangeworm moths (Lepidoptera: Pyralidae) in almonds, pistachios, and walnuts. *Environ. Entomol.* 25: 1154-1157.
- Shorey, H. H. and R. G. Gerber. 1996b. Use of puffers for disruption of sex pheromone communication of codling moths (Lepidoptera: Tortricidae) in walnut orchards. *Environ. Entomol.* 25: 1398-1400.
- Shorey, H. H. and R. G. Gerber. 1996c. Disruption of pheromone communication through the use of puffers for control of Beet armyworm (Lepidoptera: Noctuidae) in tomatoes. *Environ. Entomol.* 25: 1401-1405.
- Shorey, H., R. Gerber, and R. Elkins. 1998. Disruption of pheromone communication for control of codling moth in pears. pp. 23 – 36 *In* 1998 California Pear Research Reports. California Pear Advisory Board, Sacramento, CA.