Monitoring Codling Moth in Four Pear Cultivars with the Pear Ester

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Keywords: *Pyrus communis*, thresholds, seasonality, traps, pest management

Abstract

The pear ester, ethyl (2*E*,4*Z*)-2,4-decadienoate can be an effective attractant for codling moth, *Cydia pomonella*, **in pear orchards treated with sex pheromones. Differences in the attractiveness of the pear ester relative to a sex pheromone lure were found within pear cultivars. The pear ester outperformed high-load sex pheromone lures in 'Bartlett', 'D'Anjou', and 'Comice' but not in 'Bosc' orchards. The pear ester lure performed poorly in 'Bartlett' orchards with high levels of codling moth, > 20 moths per trap per season and occurrence of fruit injury. In general, the pear ester lure caught significantly more males than female moths. More than 70% of females captured in traps baited with the pear ester were mated.**

INTRODUCTION

Codling moth, *Cydia pomonella*, is the key pest of pear, *Pyrus communis*, throughout the tree fruit growing areas in western North America. The use of its major sex pheromone component, codlemone, for mating disruption has been widely adopted in this region (Thomson et al., 2001). Adult populations in sex pheromone-disrupted orchards are generally monitored with high-load sex pheromone-baited traps to aid decision making (Charmillot, 1990; VanBuskirk et al., 1999). Yet, the application of sex pheromones for mating disruption makes reliable monitoring with sex pheromone lures difficult. Recently, a major pear odorant, ethyl (2*E*,4*Z*)-2,4-decadienoate, was found to be a potent attractant for codling moth adults and larvae (Light et al., 2001; Knight and Light, 2001). The pear ester lure allows pest managers to directly monitor the emergence and density of female codling moths and its attractiveness is not strongly affected by the use of sex pheromones for mating disruption. The pear ester lure is also being evaluated to manage codling moth through "attract and kill" of adults (Knight et al., 2002a) and in combination with insecticides as a larvicide (Knight and Light, 2001).

The attractiveness of lures baited with the pear ester relative to codlemone has varied both seasonally and among crops. The pear ester appears to be most attractive within walnuts, *Juglans regia*, and is comparable to a sex pheromone lure in either conventional or sex pheromone-disrupted orchards (Light et al., 2001). Within apple, *Malus domestica*, the pear ester appears to be most effective early in the season in sex pheromone-disrupted orchards. The pear ester became less effective later in the season in apple and was never a strong lure for codling moth in conventional 'Bartlett' pear orchards (Light et al., 2001). Studies in apple found that the pear ester varied in its attraction relative to a standard pheromone lure among several apple cultivars. In particular, the lure was most effective in late-season cultivars such as 'Granny Smith' and 'Fuji' and least attractive in 'Gala' and 'Golden Delicious' (Knight, 2002a). Similar studies of the attractiveness of the pear ester among pear cultivars have not been reported. The effectiveness of the pear ester lure in sex pheromone-disrupted pear orchards has also not been reported. The objective of this study was to evaluate the effectiveness of the pear ester lure in monitoring codling moth in sex pheromone-disrupted orchards of four pear cultivars: 'D'Anjou', 'Bartlett', 'Comice' and 'Bosc' in three western States in the United States.

MATERIALS AND METHODS

Studies were conducted from 2001 – 2003 near Brewster and Yakima, Washington, Medford, Oregon, and in Lake and Mendocino Counties in California to evaluate the attractiveness of traps baited with either the pear ester or a high-load sex pheromone lure. All studies were conducted in pear orchards treated with sex pheromone for mating disruption of codling moth. All female moths except in California were dissected to determine their mating status. Seventeen blocks of 'D'Anjou' pears situated near Brewster, Washington were monitored in 2001-2002. All orchards were treated with Isomate C+ (Pacific Biocontrol, Vancouver, Washington) at 500 dispensers per hectare. Pairs of delta-shaped traps were baited with either the pear ester loaded in gray halobutyl septa (3.0 mg) or a proprietary high load sex pheromone lure (Megalure, Trécé Inc., Salinas, California) and spaced 100 meters apart. Traps were placed in the upper third of the canopy and checked weekly from 3 May to 1 September in 2001 and from 6 May to 6 September in 2002. A similar design was used to monitor nine 'Bartlett' orchards situated near Yakima, Washington in 2001-2002. These orchards were treated with Isomate C+ at 700 – 1,000 dispensers per hectare. Traps were checked weekly from 26 April to 1 September in 2001 and from 29 April to 26 August in 2002.

'Bartlett' orchards comprising 836 hectares in Lake and Mendocino Counties, California were monitored in 2002 with pairs of traps (n = 129) baited with either the pear ester or red rubber septa loaded with 10.0 mg codlemone (IPM Technologies, Portland, Oregon). Orchards were treated with either Isomate C+ at 1,000 dispensers per ha or with aerosol puffers (Suterra, Bend, OR) at a density of 4.4 units per hectare. Pear ester lures were placed in diamond-shaped traps (Pherocon IIC, Trécé Inc., Salinas, California) and the pheromone lures were used in IOBC carton traps. Traps were placed in the orchards from 30 March to 5 April and monitored weekly until 18 July. Each pair of traps was spaced > 30 meters apart. Red septa were replaced after 5 weeks and pear ester lures were replaced after 7 weeks. The red septa sex pheromone lures were replaced with the Megalure after 10 weeks of monitoring.

During 2003, nine pairs of traps were monitored in 'Bosc' and 'Comice' orchards situated near Medford, Oregon. All orchards were treated with Isomate C+ at densities from 700 – 1,000 dispensers per hectare. Orchards were monitored with delta-shaped traps baited with either the pear ester lure or the proprietary Biolure 10X sex pheromone lure (Suterra LLC, Bend, Oregon). Traps were placed in orchards on 17 April and checked weekly until 21 August. Pairs of traps were spaced > 50 meters apart and hung in the upper third of the canopy. Lures were replaced every 8 weeks.

Moth catch by the pear ester and codlemone lures within each cultivar were analyzed with paired t-tests for each generation and for the entire season (Analytical Software 2000). Cumulative moth counts through June were considered to be the first generation and all subsequent moths were included as the second generation. Count data were transformed (sqrt [x + 0.01]) prior to analyses. Due to the small sample sizes in three of the four studies, differences in moth catches between lures were considered to be significant at $P \leq 0.10$. A piecewise regression model was used to evaluate the apparent nonlinear response of moth catches in paired traps baited with sex pheromone or the pear ester lure in the 'Bartlett' orchards in Washington (Neter et al., 1985). An indicator variable was used to select a break point in the regression of moth catches by the pear ester lure as a function of moth catches by the sex pheromone lure where the slope of the regression line changed. Specifically a new variable was added to the model as DV(moth catch in traps baited with the sex pheromone lure – break) where DV = 1 if moth catch by the sex pheromone lure was greater than the break and DV = 0 if moth catch was less than or equal to the break. Break points of 18, 20, and 22 cumulative moths in the sex pheromone-baited traps were tested. The best model was chosen based on maximizing the r^2 of the regression equation.

RESULTS

The relative attractiveness of the pear ester lure compared with various high load sex pheromone lures varied among cultivars for the entire season (Table 1). No difference was found in the attractiveness of the pear ester and the Biolure 10X in 'Bosc' orchards. The Megalure was more attractive than the pear ester lure in 'Bartlett' orchards in Washington. However, the pear ester was more attractive than the 10X red septa lure in 'Bartlett' orchards in California, the gray septa Megalure in 'D'Anjou' orchards, and the membrane Biolure 10X lure in 'Comice' orchards. The relative attractiveness of the pear ester and sex pheromone lures was similar during both generations in all studies except with 'Bartlett' pear in Washington (Table 1). Significantly higher number of male than female moths were caught by the pear ester lure in 'Bartlett' and 'D'Anjou' in Washington and 'Comice' in Oregon. Moths from California were not sexed, and no significant difference was found in the proportion of each sex caught within 'Bosc' orchards. A high proportion of females were mated within orchards despite the use of sex pheromone dispensers for mating disruption (Table 1).

The 'Bartlett' orchards monitored in Washington had the highest codling moth densities among the five studies conducted (Table 1). Mean moth catches in the sex pheromone and pear ester-baited traps were approximately 31-times and 2-times higher than in the other studies, respectively. Cumulative moth catches were also highly variable among these nine orchards. In three orchards, the sex pheromone-baited traps caught > 150 codling moths during the season (Fig. 1). Levels of fruit injury from codling moth also exceeded 20.0% in each of these three orchards. The regression of moth catch by the pear ester versus the sex pheromone lure was strongly nonlinear (Fig. 1). A significant piecewise regression model found that cumulative moth catch by the pear ester lure (Y) was most highly correlated (r^2 = 0.65) with catch by the sex pheromone lure (X) where a breakpoint of 20 cumulative moths per season was used:

$Y = -2.13 + 1.49X - 1.49(X\text{-}20)DV$; where $DV = 1$ if $X > 20$ and $DV = 0$ if $X \leq 20$

For orchards with moth catch below the breakpoint the attractiveness of the two lures were similar (the 95% confidence interval of the slope [0.37 – 2.51] includes 1.0). In contrast, the slope of this regression was essentially flat (< 0.001) at moth counts above the breakpoint with the sex pheromone lure catching up to 10-times more moths than the pear ester lure (Fig. 1).

DISCUSSION

Initial studies exploring the activity of the pear ester as a tool to monitor codling moth suggested that this kairomone would be most useful in walnut and apple orchards and would likely be a weak attractant within a pear context (Light et al., 2001). Unfortunately, this conclusion was based on a limited data set collected from only three conventional 'Bartlett' orchards that all had high moth population densities (> 3 moths trapped per day with a sex pheromone lure and detectable levels of fruit injury). The relatively low attraction of the synthetic pear ester lure in these pear orchards was hypothesized to be due to olfactory "masking" of the lure by natural sources of the pear ester in the orchards, as well as the presence of a suite of competing host volatiles (Light et al., 2001). However, due to the presence of codling moth injured fruits in these orchards it was not known how important the release of host volatiles from uninjured 'Bartlett' fruit would be in masking the pear ester lure during the season. Our extensive data from California suggests that the pear ester lure is effective in monitoring codling moth in 'Bartlett' orchards. Secondly, since the pear ester is primarily an odorant of ripe pear fruit (Jennings et al., 1964) and has not been detected as a volatile from immature fruit or pear leaves (Miller et al., 1989; Scutareanu et al., 1997) one might expect the attractiveness of a synthetic lure to decline during the season. Yet, the pear ester lure performed as well or better than the sex pheromone lures during the second half of the season in all pear cultivars in our study. The occurrence and relative importance of the pear ester in the composition of ripe pear odors for the three cultivars other than 'Bartlett' has not been reported. Shiota (1990) compared the ratio of volatile constituents of 'Bartlett' and 'La France' pears and found large differences in the importance of the pear ester. The seasonal volatile profile of pear cultivars may be associated with the observed differences in the attractiveness of the pear ester lure observed in this study and should be further investigated.

Data presented here strongly suggest that the pear ester is an effective lure for monitoring codling moth in pear orchards treated with sex pheromone, except in orchards with detectable fruit injury by codling moth. Additional sources of fruit injury from bird pecks or hail could similarly affect the attractiveness of the pear ester lure, but these have not been examined. Clearly, studies are needed to evaluate the effectiveness of the lure in various pear cultivars with low to moderate levels of fruit injury. Factors such as crop load and the presence of ripening fruit may influence the effectiveness of the pear ester and should also be evaluated (Knight et al., 2002a). The optimal loading rate of pear ester in the gray halobutyl septa has not been fully investigated. The initial study of the pear ester evaluated lures loaded with 1.0 mg (Light et al., 2001). The relative attractiveness and longevity of lures loaded with 1.0 or 3.0 mg has not been reported in pear. Higher lure loadings (10.0 mg) have been observed to be more attractive within walnut orchards (Light et al., 2001) and should be evaluated in pear.

Sex pheromone-baited traps have been widely used to establish action thresholds for the use of insecticide sprays in pear orchards. Current thresholds established in the Pacific Northwest trigger an insecticide spray if traps catch 5 or more moths in the first generation or 3 or more moths in the second generation in orchards under a sex pheromone mating disruption program (VanBuskirk et al., 1999). However, the variability in the attractiveness of the various sex pheromone lures can create problems in establishing effective thresholds (Knight, 2002b). Differences in the sex pheromone lures evaluated in this study and trap and dispenser maintenance may have contributed to some of these observed differences. Standardization of traps and lures is essential in implementing an effective monitoring program (Knight, 2002b; Knight et al., 2002b).

The future role of the pear ester lure in pear pest management is unclear because it has not yet been widely tested in this crop. Within Pacific Northwest apple orchards, the pear ester is often used to help monitor problem areas of sex pheromone-treated orchards where sex pheromone lures have been ineffective in detecting codling moth populations. Sexing of moths in pear ester-baited traps may be useful in some situations. However, the mating status of females may not indicate the effectiveness of the sex pheromone program and the lure is biased for mated females (Knight 2002a). However, action thresholds based on the capture of female moths have been shown to improve the correlation with fruit injury in apple orchards (Knight 2002a). Similar and new approaches will likely be developed in pear orchards. For example, Zoller and Zoller (2003) recently reported that moth catch by the pear ester lure was more effective than with a sex pheromone lure in detecting low levels of codling moth eggs in pear orchards.

ACKNOWLEDGEMENTS

This project was partially funded by the California Walnut Board, Washington Tree Fruit Research Commission, and the Oregon Winter Pear Board. We would like to especially thank Loys Hawkins (Bear Creek Orchards Inc., Medford, OR) for her cooperation and collection of data.

Literature Cited

Analytical Software. 2000. Statistix 7. Tallahassee, FL.

Charmillot, P.J. 1990. Mating disruption technique to control codling moth in Western Switzerland, p.165-182. In: R.L. Ridgway, R.M. Silverstein and M.N. Inscoe (eds.), Behavior-modifying chemicals for insect pest management. Marcel Dekker, New York.

Jennings, W.G., Creveling, R.K. and Heinz D.E. 1964. Volatile esters of Bartlett pear, IV, esters of trans:2-cis-4-decadienoic acid. J. Food Sci. 29: 730-734.

Knight, A.L. 2002a. Using the kairomone lure, DA2313 to monitor codling moth in apple and pear. Proc. Western Orchard Pest and Disease Management Conference. Portland, OR 9-11 January. p.27.

Knight, A.L. 2002b. A comparison of gray halo-butyl elastomer and red rubber septa to monitor codling moth (Lepidoptera: Tortricidae) in sex pheromone-treated orchards. J. Entomol. Soc. Brit. Columbia 99:123-132.

Knight, A.L. and Light, D.M. 2001. Attractants from 'Bartlett' pear for codling moth, *Cydia pomonella* (L.), larvae. Naturwissenschaften 88:339-342.

Knight, A.L., Potting R.P.J. and Light, D.M. 2002a. Modeling the impact of a sex pheromone/kairomone attracticide for management of codling moth (*Cydia pomonella*). Acta Hort. 584:215-220.

Knight, A.L., Larson, D. and Christianson, B. 2002b. Flight tunnel and field evaluations of sticky traps for monitoring codling moth (Lepidoptera: Tortricidae) in sex pheromone-treated orchards. J. Entomol. Soc. Brit. Columbia 99:107-116.

Light, D.M., Knight, A.L., Henrick, C.A., Rajapaska, D., Lingren, B., Dickens, J.C., Reynolds, K.M., Buttery, R.G., Merrill, G., Roitman J. and Campbell, B.C. 2001. A pear-derived kairomone with pheromonal potency that attracts male and female codling moth, *Cydia pom*onella (L.). Naturwissenschaften 88:333-338.

Miller, R.L., Bills, D.D. and Buttery R.G. 1989. Volatile components from Bartlett and Bradford pear leaves. J. Agric. Food Chem. 37: 1476-1479.

Neter, J., Wasserman, W. and Kutner, M.H. 1985. Applied linear statistical models. Richard Irwin, Inc. Homewood, IL.

Scutareanu, P., Drukker, B., Bruin, J. Posthumus, M.A. and Sabelis M.W. 1997. Volatiles from *Psylla*-infested pear trees and their possible involvement in attraction of Anthocorid predator. J. Chem. Ecol. 23: 2241-2260.

Shiota, H. 1990. Changes in the volatile composition of La France pear during maturation. J. Sci. Food Agri. 52: 421-429.

Thomson, D., Brunner, J., Gut, L., Judd G. and Knight, A. 2001. Ten years implementing codling moth mating disruption in the orchards of Washington and British Columbia: starting right and managing for success! IOBC WPRS Bulletin 24(2):23-30.

VanBuskirk, P.D., Hilton, R.J., Simone, N. and Alway, T. 1999. Orchard pest monitoring guide for pears: a resource book for the Pacific Northwest. Good Fruit Grower Book Division, Yakima, WA.

Zoller, B.G. and Zoller, A.M. 2003. Comparison of kairomone DA2313 and pheromone lure trapping for codling moth with oviposition monitoring. Proc. Western Orchard Pest and Disease Management Conference. Portland, United States 15-17 January. p.22.

Tables

Table 1. A comparison of the mean catch of codling moth in traps baited with either the pear ester or codlemone for each moth flight in four pear cultivars (paired t-tests).

		Mean (SEM) moth catch per trap				
Lure type	Sex	'Bartlett' WA (n = 9)	'Bartlett' CA (n = 129)[a]	'D'Anjou' WA (n = 17)	'Bosc' OR (n = 9)	'Comice' OR (n = 9)
		First Generation				
Codlemone	Male	56.7(25.5)	2.1 (0.4)	1.5 (0.6)	0.6 (0.3)	1.3 (0.4)
Pear ester	Male + female	14.4 (3.6)	6.8 (1.0)	2.2 (0.8)	0.4 (0.4)	2.3 (0.7)
	P-value[b]	0.10	< 0.001	0.29	0.86	0.15
Pear ester	Male	8.7 (2.2)	-	1.4 (0.6)	0.1 (0.1)	1.7 (0.6)
Pear ester	Female	5.8 (1.8)	-	0.8 (0.3)	0.3 (0.3)	0.7 (0.4)
	P-value[b]	0.13	-	0.15	0.35	0.23
Proportion females mated		0.85	-	0.73	0.67	1.00
		Second generation				
Codlemone	Male	27.0 (10.8)	0.6 (0.1)	0.8 (0.3)	1.3 (0.5)	0.6 (0.2)
Pear ester	Male + female	8.2 (4.1)	2.5 (0.3)	7.6 (3.1)	0.4 (0.2)	1.6 (0.7)
	P-value[b]	0.16	< 0.001	0.03	0.18	0.11
Pear ester	Male	4.9 (2.3)	-	4.4 (2.0)	0.3 (0.2)	1.0 (0.4)
Pear ester	Female	3.3 (1.9)	-	3.2 (1.2)	0.1 (0.1)	0.6 (0.4)
	P-value[b]	0.18	-	0.24	0.17	0.38
Proportion females mated		0.81	-	0.73	1.00	1.00
		Both generations				
Codlemone	Male	83.7 (34.0)	2.7 (0.5)	2.3 (0.8)	1.9 (0.6)	1.9 (0.6)
Pear ester	Male + female	22.7 (3.6)	9.2 (1.3)	9.8 (3.7)	0.9 (0.7)	3.8 (1.1)
	P-value[b]	0.10	< 0.001	0.02	0.36	0.07
Pear ester	Male	13.6 (2.4)	-	5.8 (2.3)	0.4 (0.2)	2.7 (0.7)
Pear ester	Female	9.1 (2.0)	-	3.9 (1.5)	0.4 (0.4)	1.1 (0.7)
	P-value[b]	0.10	-	0.08	1.00	0.06
Proportion females mated		0.83	-	0.73	0.75	1.00

[a] Moths caught in traps baited with the pear ester were not sexed in the California study.
[b] Transformed data (sqrt[x + 0.01]) were analyzed with paired t-tests.

Figures

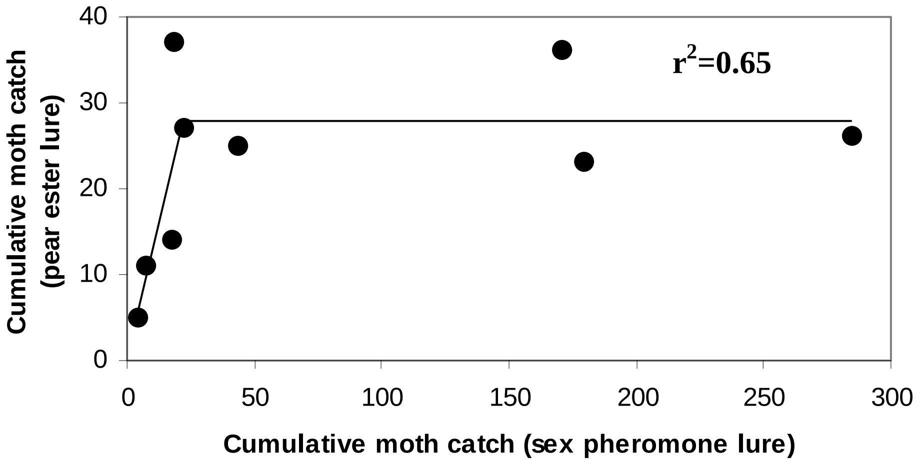

Fig. 1. Piece-wise regression of cumulative moth catch in traps baited with either a sex pheromone or a pear ester lure in nine 'Bartlett' pear orchards.