Use of Ethyl (*E*,*Z*)-2,4-decadienoate in Codling Moth Management: Kairomone Species Specificity

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ABSTRACT

Ethyl (*E*,*Z*)-2,4-decadienoate (pear ester) is a kairomonal attractant for both male and female codling moth, *Cydia pomonella* (L.), in apple, pear and walnut. Studies were conducted in the western Untied States to evaluate the potential attractiveness of this kairomone for eight lepidopteran pests of these three crops, as well as, in cherry, peach/ nectarine, apricot, plum, almond, pistachio, grape, kiwi, and citrus. The pear ester was loaded (10.0 mg) into gray halobutyl septa and insects were monitored with diamond- or delta-shaped sticky traps. Lures were not attractive to peach twig borer, *Anarsia lineatella* (Zeller); oriental fruit moth, *Cydia molesta* (Busck); omnivorous leafroller, *Platynota stultana* Walshingham; navel orangeworm, *Amyelois transitella* (Walker); apple fruitworm, *Lacanobia subjuncta* (Grote & Robinson); pandemis leafroller, *Pandemis pyrusana* (Kearfott); obliquebanded leafroller, *Choristoneura rosaceana* (Harris); and western tentiform leafminer, *Phyllonorycter mespiella* (Hüebner). Additional studies with *C. molesta* populations attacking apple and pear would be useful.

Key Words: *Cydia pomonella*, *Cydia molesta*, pear ester, host plant volatiles, monitoring

INTRODUCTION

Codling moth, *Cydia pomonella* (L.), is the key pest of pears, apples, and walnuts worldwide (Barnes 1991). Identification of the pear ester, ethyl (*E*,*Z*)-2,4-decadienoate, as a kairomone attractant for adult and larval stages of codling moth has allowed the development of several new approaches to successfully monitor and manage this pest (Light *et al.* 2001, Knight and Light 2001; Knight *et al*. 2002; Knight *et al.* 2005). Pear ester is a characteristic volatile of ripe pear (Jennings *et al.* 1964) and has not been detected in headspace volatiles of unripe pear fruit and is not known to be present in pear leaves (Shiota 1990, Miller *et al.* 1989) or in walnut fruit or leaves (Buttery *et al.* 2000). However, it has been detected as a minor constituent in ripe 'Red Delicious' apple (Berger *et al.* 1984) and in quince (Schimizu and Yoshihara 1977).

The attractiveness of pear ester for insects other than codling moth has been reported. The yellowjacket wasp *Vespula vidua* (Saussure) was caught in low numbers in traps baited with pear ester (Day and Jeanne 2001); and higher lure loadings (> 40.0 mg) in gray halobutyl elastomer septa are attractive to the western yellow jacket, *Vespula pennsylvanic* (Saussure) in apple (ALK, unpublished data). Low numbers of adult stink bugs, *Euschistus conspersus* Uhler, have occasionally been observed in or near traps baited with > 20.0 mg pear ester septa (ALK and DML, unpublished data).

The attractiveness of pear ester to other lepidopteran species has also been reported. Two polyphagous tortricid species, *Hedya nubiferana* Haworth and *Cydia fa-*

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giglandana (Zeller), were caught in traps baited with pear ester in Swedish apple orchards (Coracini *et al*. 2004) and in a mixed apple and cherry orchard in Italy (Schmidt *et al*. 2004). In addition, the pest species, *Cydia splendana* (Hübner) was caught in traps baited with pear ester in chestnut orchards (Schmidt *et al*. 2004).

The attractiveness of pear ester to lepidopteran pests sympatric with codling moth in pome fruits and walnuts in western North America has not been studied. This complex of pest species includes tortricid leafrollers, noctuid fruitworms and cutworms, and gracillarid leafminers (Beers *et al.* 1993; VanBuskirk *et al.* 1999). Six tortricid leafroller species feed on the developing buds, leaves, and external surface of apple and pear fruit: *Choristoneura rosaceana* (Harris), *Pandemis pyrusana* (Kearfott), *Platynota stultana* Walsingham, *Archips rosanus* (L.), *Argyrotaenia citrana* (Fernald), and *Archips argyrospilus* (Walker). The western tentiform leafminer, *Phyllonorycter mespiella* (Hüebner), is a common indirect gracillarid feeding beneath the epidermis of apple and pear leaves but causing little economic damage to the crop. Several cutworm and fruitworm noctuid species including *Xestia c-nigrum* (L.) and *Lacanobia subjuncta* (Grote & Robinson), are occasional pests of apple and pear orchards and feed on buds, leaves, and fruit (Barnett *et al.* 1991; Landolt 1998). The oriental fruit moth, *Cydia molesta* (Busck), is a key pest of stone fruits attacking both developing shoots and fruits (Rothschild and Vickers 1991). However, this species has expanded its host range recently and has become a significant pest of apple and pear in some geographical regions (Civolani *et al.* 1998; Usmani and Shearer 2001; Il'ichev *et al.* 2003).

Many of these lepidopteran pest species of pome fruit have a broad host range that can include cherry, peach/nectarine, grape, citrus, kiwi, and pistachio, as well as uncultivated hosts (Barnett *et al.* 1991; Beers *et al.* 1993). Host races of codling moth are reported to sporadically attack other crops such as plum, apricot, and almonds (Barnes 1991) and have been reported to attack cherry (Mote 1926). Within these crops other important lepidopteran pests can occur. The navel orangeworm, *Amyelois transitella* (Walker), attacks walnuts, pistachios, and almonds (Barnett *et al.* 1991). The peach twig borer, *Anarsia lineatella* (Zeller), is another key pest damaging shoots and fruits of almonds and stone fruits (Barnes *et al.* 1993).

The objective of this study was to evaluate the attractiveness of pear ester for eight important lepidopteran pests that are sympatric with codling moth among several host crops in Washington and California. In addition, the attractiveness of pear ester for *P. stultana*, *C. molesta*, and *A. lineatella* was evaluated across a range of crops that are not hosts for codling moth.

MATERIALS AND METHODS

Specificity Studies in Washington. Studies were conducted in apple (n = 15), pear (n = 10), cherry (n = 5), and peach (n = 10) orchards during 1999 to evaluate the species specificity of pear ester. Groups of three diamond-shaped sticky traps (Pherocon IIB, Trécé Inc., Adair, OK) baited with gray halobutyl elastomer septa (No. 1888, size No. 1, West Co., Phoenixville, PA) loaded with either 10.0 mg pear ester (93.7% A.I. purity, Aldrich Chemical, Minneapolis, MN), sex pheromone (proprietary loading, Trécé Inc., Adair, OK), or a hexane solvent were spaced more than 50 m apart and hung in the upper third of the canopy within each orchard. Studies were conducted in apple, pear, cherry and peach orchards located near Moxee, Wapato, and Brewster WA. *Lacanobia subjuncta* and *P. mespiella* were each monitored simultaneously in 10 pear orchards from 9 – 23 August and in 10 apple orchards from 16 – 30 August. Traps baited with the sex pheromone of *P.*

mespiella were not included in the pear study. *Pandemis pyrusana* was monitored in five apple and cherry blocks from 24 – 31 August. *Choristoneura rosaceana* was monitored in five apple blocks from 9 – 16 September. *Cydia molesta* and *A. lineatella* were monitored simultaneously in 10 peach orchards for 2 – 7 nights from 11 August to 7 September. Nontarget insects caught in traps were counted and broadly categorized by order (e.g. small dipterans, dermapterans) or family or super family (e.g. chrysopids, coccinellids, muscoid flies). Numbers of adult white apple leafhopper, *Typhlocyba pomaria* McAtee, and codling moth were recorded for all traps in apple and pear and for all crops, respectively.

Specificity studies in California. Studies were conducted from 18 August – 16 September 1999 in orchard blocks of mixed cultivars of peach, apricot, plum, almond, pistachio, grape, kiwi, and citrus at the University of California campus in Davis, CA; and at its germplasm repository research station at Wolfskill in Winters, CA. All crops except citrus were monitored for *P. stultana.* *Cydia molesta* and *A. lineatella* were monitored in all crops except grape, kiwi and citrus. *Amyelois transitella* was present in the almond blocks but was not specifically monitored due to the ineffectiveness of the sex pheromone-baited trap. Orchard blocks were monitored with 10.0 mg pear ester, species' sex pheromone, and a trap baited with a solvent blank lure placed in either wing-shaped or diamond-shaped sticky traps (Pherocon 1CP and IIB, Trécé Inc., Adair, OK). Sex pheromone lures are commercially available and were provided by Trécé Inc. Traps were typically placed in the mid canopy of orchards of each crop in a randomized block design along 2 – 4 replicate orchard rows separated by 50 – 80 m.

Data analysis. Analysis of variance (ANOVA) was used to detect significant differences in mean moth catch per trap per night among the sex pheromone, pear ester, and solvent lures for each species, $P < 0.05$ (Analytical Software 2000). Means in significant ANOVA's were separated with a least significant difference test. A paired t-test was used to compare the catch of selected nontarget insects in traps baited with pear ester or blank septa.

RESULTS

Specificity studies in Washington. Species-specific sex pheromone-baited traps caught male *P. pyrusana*, *C. rosaceana*, *L. subjuncta*, *P. mespiella*, *A. lineatella*, and *C. molesta* across apple, pear, cherry, and peach orchards (Table 1). Mean daily moth catches in these sex pheromone-baited traps were significantly higher than moth catches in traps baited with pear ester or with blank lures. No differences occurred in the catch of each of these species in any crop between traps baited with pear ester and blank lure-baited traps. Low numbers of codling moth were caught per day in traps baited with pear ester in apple (0.24 $\pm$ 0.04) (mean $\pm$ SEM), pear (0.10 $\pm$ 0.06), cherry (0.03 $\pm$ 0.03), and peach (0.17 $\pm$ 0.13), indicating the pear ester lures were active.

Various other insect species were caught in sticky traps baited with sex pheromones, pear ester, or a blank lure: including low sporadic numbers of earwigs, lacewings, ladybird beetles, microhymenopterans, and various species of bees. Small dipteran species were commonly caught in traps though generally in low numbers. The two most common nontargets in apple and pear blocks in Washington during these trials were muscoid flies (means of 4 – 5 flies per trap) and white apple leafhopper, *T. pomaria* (means of 12 – 13 adults per trap). However, no significant difference in their densities were found in traps baited with either pear ester or blank lures for either group, *P*'s = 0.48 and 0.61, respectively (paired t-tests).

Table 1.

Captures of moths in traps baited with either a conspecific sex pheromone, ethyl (2*E*,4*Z*)-2,4-decadienoate (pear ester), or a blank lure in fruit orchards in Washington State.[1]

Pest species	Crop (no. orchards)	Mean ± SEM moths/trap/night: Conspecific sex pheromone	Mean ± SEM moths/trap/night: Pear ester	Mean ± SEM moths/trap/night: Blank	ANOVA: *F*-value; df; *P*-value
Pandemis pyrusana	Apple (5)	7.6 ± 0.7a	0.00 ± 0.00b	0.08 ± 0.06b	132.0; 2, 12; < 0.001
Pandemis pyrusana	Cherry (5)	5.4 ± 1.8a	0.00 ± 0.00b	0.02 ± 0.02b	8.43; 2, 12; < 0.01
Choristoneura rosaceana	Apple (5)	4.0 ± 0.8a	0.00 ± 0.00b	0.00 ± 0.00b	25.8; 2, 12; < 0.001
Lacanobia subjuncta	Apple (10)	0.8 ± 0.1a	0.00 ± 0.00b	0.03 ± 0.02b	122.0; 2, 27; < 0.001
Lacanobia subjuncta	Pear (10)	1.0 ± 0.1a	0.00 ± 0.00b	0.02 ± 0.02b	53.7; 2, 27; < 0.001
Phyllonorycter mespiella	Apple (10)	553.6 ± 19.2a	3.7 ± 1.3b	3.9 ± 1.4b	814.0; 2, 27; < 0.001
Phyllonorycter mespiella	Pear (10)	-	0.5 ± 0.3	0.4 ± 0.1	0.14; 1, 18; = 0.71
Anarsia lineatella	Peach (10)	13.8 ± 4.0a	0.0 ± 0.0b	0.1 ± 0.1b	11.90; 2, 27; < 0.001
Cydia molesta	Peach (10)	1.4 ± 0.7a	0.0 ± 0.0b	0.0 ± 0.0b	4.69; 2, 27; < 0.05

[1] Row means followed by a different letter were significantly different, $P < 0.05$ LSD test.

Specificity studies in California. *A. lineatella, C. molesta*, and *P. stultana* males were caught in sex pheromone-baited traps in peach, apricot, plum, almond and pistachio orchards in California (Table 2). In addition, male *P. stultana* were trapped in grape and kiwi sites. No moth species were caught in pear ester- or solvent-baited traps in any crop other than low catches of codling moth in blocks of peaches, almonds, and citrus more than 100 m from pome fruit orchards. These moth counts in the sex pheromone-baited traps were all significantly different than the zero catch in the pear ester-baited traps (*P*'s < 0.01).

DISCUSSION

The pear ester is a strong attractant for codling moth adults and has improved monitoring of this pest in walnut (Light *et al.* 2001), apple (Thwaite *et al.* 2004), and pear (Knight *et al.* 2005). It also has demonstrated potential to improve control via lure and kill approaches (Knight *et al.* 2002) and disruption of oviposition

Table 2.
Captures of moths in traps baited with either a conspecific sex pheromone, ethyl (2*E*,4*Z*)-2,4-decadienoate (pear ester), or a blank lure in fruit orchards and vineyards in California.

	Mean ± SEM moths/trap/night					
	Conspecific sex pheromone[1]			Pear ester		Blank
Crop	*Anarsia lineatella*	*Cydia molesta*	*Platynota stultana*	All other moth species	*Cydia pomonella*	Solvent Control
Peach	14.01 ± 2.55	14.89 ± 1.70	1.25 ± 0.33	0	0.07 ± 0.04	0
Apricot	10.68 ± 1.83	0.32 ± 0.12	2.46 ± 0.77	0	0	0
Plum	5.93 ± 2.44	0.32 ± 0.12	5.50 ± 1.02	0	0	0
Almond	7.86 ± 2.38	3.75 ± 0.53	0.79 ± 0.33	0	0.18 ± 0.14	0
Pistachio	3.04 ± 1.65	0.39 ± 0.15	0.57 ± 0.29	0	0	0
Grape	-	-	3.64 ± 0.95	0	0	0
Kiwi	-	-	11.38 ± 1.83	0	0	0
Citrus	-	-	-	0	0.04 ± 0.04	0

[1] Mean moth catch in sex pheromone-baited traps were all significantly different than moth catch in pear ester-baited traps, $P < 0.01$ (ANOVA).

(Pasqualini *et al.* 2004). Conversely, our studies reported here have demonstrated that pear ester is not attractive for eight lepidopteran pest species of a number of important horticultural crops in California and Washington. The majority of these lepidopteran pests either attack crops that do not produce pear ester or feed and oviposit primarily on foliage of pear or apple that also lack pear ester. Species that are known to be attractive to pear ester either feed on ripe pear such as yellowjackets (Akre and Davis 1979) and stink bugs (Beers *et al.* 1993); share the major sex pheromone component, (*E,E*)-8,10-dodecadien-1-ol with codling moth, such as *C. fagiglandana* and *H. nubiferana*, or can detect this compound, such as *C. splendana* (Schmidt *et al.* 2004), or have a closely related sex pheromone, such as methyl (*E,Z*)-2,4-decadieonoate for *Euschistus* spp. stink bugs (Aldrich *et al.* 1991).

Among the various lepidopteran pests in our study only *C. molesta* is a true internal fruit feeder that also attacks pear. Both codling moth and *C. molesta* can also attack quince (Cravedi and Ughini 1992), another fruit that can release pear ester (Schimizu and Yoshihara 1977). Pear host races of *C. molesta* have been reported in Australia (Il'ichev *et al.* 2003) and Italy (Civolani *et al.* 1998); however, the attractiveness of pear ester for *C. molesta* in these regions has not been examined. Efforts to improve monitoring of *C. molesta* populations, particularly in orchards treated with sex pheromone mating disruption, have focused on the identification of host plant volatiles attractive for females (Natale *et al*. 2003). While adult populations of *C. molesta* trapped in peach, apricot, plum, almond, and pistachios in our study were not attractive to pear ester, subsequent studies will evaluate the seasonal attractiveness of pear ester for *C. molesta* populations feeding on apple or pear.

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