Attraction of Pest Moths (Lepidoptera: Noctuidae, Crambidae) to Floral Lures on the Island of Hawaii

Peter Landolt[1], Eric Jang[2], Lori Carvalho[2], and **Michael Pogue[3]**
[1]USDA, ARS, Yakima Agricultural Research Laboratory, 5230 Konnowac Pass Road, Wapato, Washington 98951 USA (corresponding author, peter.landolt@ars.usda.gov)
[2]USDA, ARS, PBARC, 64 Nowelo St., Hilo, Hawaii 96720, USA, eric.jang@ars.usda.gov
[3]USDA, ARS, Systematic Entomology Laboratory, MRC-108, Smithsonian Institution, Washington DC 20013, USA, michael.pogue@ars.usda.gov

Abstract. Traps baited with floral chemicals on the island of Hawaii captured several pest moth species. *Chrysodeixis eriosoma* (Doubleday) (green garden looper), *Autographa biloba* (Doubleday) (bi-lobed looper), and *Mythimna unipuncta* (Haworth) (true armyworm), all Noctuidae, as well as *Hymenia recurvalis* (L.) (beet webworm), a Crambidae, were trapped with phenylacetaldehyde (PAA). There was no response by moths to β-myrcene (BM), methyl salicylate (MS), cis jasmone (CJ), methyl-2-methoxy benzoate (MMB), 2-phenylethanol (2PE), or linalool (LIN) when these chemicals were tested singly. When other floral chemicals were presented in traps with PAA, numbers of *C. eriosoma* captured were increased by BM, MS, 2PE or MMB. Numbers of *A. biloba* and *Peridroma saucia* (Hübner) (variegated cutworm) were increased by including BM with PAA in traps. Numbers of *M. unipuncta* were increased by BM or 2PE, and numbers of *H. recurvalis* were increased by MMB or LIN, presented with PAA. Both sexes of these five species of moths were trapped with floral lures, most females captured were mated, and many females possessed mature eggs.

Key Words: Crambidae, floral chemical, lure, Noctuidae, trap

Introduction

Flowers of several species of plants are sources of chemical attractants that can be used to trap some pest moths. These flowers include *Araujia sericiphera* (bladderflower) (Cantelo and Jacobson 1979), *Abelia grandiflora* (glossy Abelia) (Haynes et al. 1991), *Lonicera japonica* (Japanese honeysuckle) (Pair and Horvat 1997), *Cestrum nocturnum* (night-blooming Jessamine) (Heath et al. 1992), *Gaura* spp (Shaver et al. 1997), *Berberis aquifolium* (Oregongrape) (Landolt and Smithhisler 2003), *Buddleia davidii* (butterfly bush) (Guédot et al. 2008), and *Cirsium arvense* (Canada thistle) (El-Sayed et al. 2008). Pest species of loopers in the noctuid subfamily Plusiinae are noteworthy in their strong attraction to floral compounds from these plants. Floral chemicals have been experimentally demonstrated as attractants for trapping *Trichoplusia ni* (Hübner) (cabbage looper) (Landolt et al 2006), *Chrysodeixis includens* (Walker) (soybean looper) (Meagher 2002; Meagher and Landolt 2008), *Autographa californica* (Speyer) (alfalfa looper) (Landolt et al. 2001, 2006), *Autographa gamma* (L.) (silver Y moth) (Molleman et al. 1997; Toth et al. 2010), *Anagrapha falcifera* (Kirby) (celery looper) (Landolt et al. 2011), and *Thysanoplusia orichalcea* (F.) (old world soybean looper) (Stringer et al. 2008). Floral chemicals that attract pest Plusiinae include PAA, methyl salicylate (MS), methyl-2-methoxy benzoate (MMB), β-myrcene (BM), cis-jasmone (CJ), 2-phenylethanol (2PE), linalool (LIN), benzaldehyde, and benzyl alcohol (i.e., Cantelo and Jacobson 1979; Haynes et al. 1991; Heath et al. 1992; Landolt et al. 2001, 2006; Meagher and Landolt 2008, 2010; Molleman et al. 1997; Toth et al. 2010).

These chemicals, and combinations thereof, are also attractive to several non-pest Plusiinae species such as *Macdunnoughia confusa* (Stephens) (Toth et al. 2010), and *Argyrogramma verruca* (F.) and *Ctenoplusia oxygramma* (Geyer) (Meagher and Landolt 2008), and moths in other noctuid subfamilies and other families (Landolt et al. 2007, 2011; Lopez et al. 2000; Meagher and Landolt 2010; Toth et al. 2010).

Plusiinae moth responses to flower chemicals have been demonstrated for a number of North American species, although related moth taxa in other geographic areas are likely to respond similarly to these chemicals. For example, Stringer et al. (2008) demonstrated attraction of *T. orichalsea* to volatiles of flowers of Canada thistle in New Zealand. *Chrysodeixis eriosoma* (Doubleday), a plusiine noctuid referred to as the green garden looper, is widely distributed in the Orient (Konenko and Pinratana 2005) and has a broad host plant range, attacking numerous vegetable and forage crops (Holloway 1985). Its distribution includes the Hawaiian Islands, where it is an introduced pest of vegetables (Luther et al. 1996). We took advantage of *C. eriosoma* occurrence in an agricultural area on the island of Hawaii to determine if it is attracted to floral chemicals that are lures for other pestiferous Plusiinae. We were particularly interested to determine *C. eriosoma* responses to these chemicals because of the strong attraction to floral chemicals by the closely related *C. includens* of North and Central America (Meagher 2001; Meagher and Landolt 2008). Additional information was obtained and is here reported on the capture of several other noctuid moths and the beet webworm, *Hymenia recurvalis* (L.) (Crambidae) in traps baited with floral chemicals.

Materials and Methods

Four field trapping experiments (referred to as A, B, C, and D) evaluated moth attraction to floral chemicals and their combinations on the island of Hawaii. These experiments compared moths trapped with (A) PAA, BM, and MS, (B) PAA, CJ, and methyl-2-methoxy benzoate (MMB), (C) PAA, 2PE, and LIN, and (D) a range of release rates of the combination of PAA and BM. All experiments were conducted in a vegetable growing region near Waimea, Hawaii. Traps were placed within mixed fields of *Brassica oleracea* (cabbage), *Brassica alboglabra* (turnip mustard), *Brassica kali* (Chinese kale), *Raphanus sativa* (radish), *Lactuca sativa* (lettuce), *Cucurbita* spp. (squash), and *Cynara scolymus* (artichoke). Universal Moth Traps (UniTraps, AgriSense, PontyPridd, UK) that were used for these experiments consisted of a white bucket covered by a yellow cone and a green lid. A 2.2 cm^2 piece of Vaportape® (Hercon Environmental Inc., Emigsville, PA) was placed within the bucket to kill captured insects, and was replaced every 4 weeks. Traps were 10 m apart and were checked twice per week. Lures were 8 ml polypropylene vials (Nalge Nunc, Rochester, NY) with a 3 mm hole in the lid to provide release of volatilized chemicals. For each chemical tested, 4 ml of active ingredient were loaded onto cotton balls in the bottom of a vial as described by Landolt et al. (2001), and the vial was suspended within the inside of the trap bucket.

For all four field tests, a randomized complete block design was used, with six block replicates. The first three experiments tested for evidence of moth attraction to each of the tested chemicals, and for interaction between PAA and the other chemicals. Test dates and lure chemicals for each test are provided in Table 1.

Test D compared numbers of moths trapped over a range of release rates of PAA + BM. This chemical combination was used in this test because of its overall performance as a lure in test A. For all traps, PAA and BM were each loaded into separate 8 ml polypropylene vials, each at a dose of 4 ml per vial on cotton balls. The release rate was varied by the size of the hole in the lid of the vial. Trapping dates and treatments are provided in Table 1. A subset of female moths captured in test D was dissected to determine their mating status as indicated by the number of spermatophores in the bursa copulatrix, and numbers of eggs present. Moths were

Table 1. Trap baits for field experiment A, B, C, testing β-myrcene (BM), cis jasmone (CJ), linalool (LIN), methyl-2-methoxy benzoate (MMB), methyl salicylate (MS), 2-phenylethanol (2PE), and phenylacetaldehyde (PAA) alone compared to combinations of PAA and the other chemicals. Trap bait treatments for experiment D were different hole sizes in vials of a mixture of PAA+BM, providing varied release rates of the attractant. Waimea, Hawaii, 2011.

Experiment	Dates	Control	Treatment 1	Treatment 2	Treatment 3	Treatment 4	Treatment 5
A	18 March to 14 April	No lure	PAA	BM	PAA+BM	MS	PAA+MS
B	15 April to 31 May	No lure	PAA	CJ	PAA+CJ	MMB	PAA+MMB
C	15 April to 31 May	No lure	PAA	2PE	PAA+2PE	LIN	PAA+LIN
D	3 June to 7 July	No lure	1.5 mm	3.0 mm	6.0 mm	12.0 mm	-----

scored for their reproductive state as (I) unmated and no mature eggs, (II) mated and with mature eggs, and stage III, mated and no eggs.

For tests A, B, and C, trap captures for each species were analyzed and treatment means were separated by the Mann-Whitney Test (DataMost 1995). For test D, trap catch data were analyzed by a one-way ANOVA testing for effect of vial hole diameter on mean numbers of moths trapped. Within a species, and for female and male *H. recurvalis*, means were separated using Tukey's test at $p \leq 0.05$.

Voucher specimens of moth species trapped are deposited in the James Entomological Collection, Washington State University, Pullman, WA. We follow Lafontaine and Schmidt (2010) on the taxonomy of Noctuoidea.

Results

Test A. Numbers of *C. eriosoma* captured were significantly greater in traps baited with PAA+ BM and PAA + MS, compared to unbaited traps (Table 2). We interpret such responses to be evidence of attraction to trap lures. *Autographa biloba* (Doubleday) moths were most frequently captured in traps baited with PAA + BM, and numbers of these moths in PAA+BM traps were significantly greater than in unbaited traps. *Mythimna unipuncta* (Haworth) (true armyworm) moths were attracted to PAA, and the inclusion of BM significantly increased their numbers in traps. *Hymenia recurvalis* (L.) (beet webworm) moths were attracted to PAA, and inclusion of BM or MS with PAA did not significantly enhance their response over PAA alone (Table 2). The numbers of *H. recurvalis* moths trapped were much higher than the numbers of *C. eriosoma* or other noctuids captured. Totals of 22 *C. eriosoma*, 33 *M. unipuncta*, 20 *A. biloba*, and 466 female and 655 male *H. recurvalis* were captured in this test.

Test B. Numbers of *C. eriosoma* trapped were significantly greater in traps baited with PAA compared to unbaited traps (Table 3). *Mythimna unipuncta* moths were captured in traps baited with PAA, but other chemicals tested were not attractive and did not increase *M. unipuncta* response to PAA. *Hymenia recurvalis* moths were attracted to PAA, and numbers trapped with PAA + MMB were greater than with PAA alone. Totals of 14 *C.*

eriosoma, 18 *M. unipuncta*, and 278 female and 349 male *H. recurvalis* were captured in this test.

Test C. PAA was attractive to *C. eriosoma*, although numbers of moths captured were lower than in the other tests (Table 4). 2PE and LIN did not enhance *C. eriosoma* response to PAA. *Mythimna unipuncta* moths were attracted to the combination of PAA + 2PE. *Hymenia recurvalis* moths were attracted to PAA, and LIN increased their response to PAA. Totals of 10 *C. eriosoma,* 13 *M. unipuncta*, and 220 female and 163 male *H. recurvalis*, were captured in this test.

When results for unbaited and PAA-baited traps from the three tests are combined, the *C. eriosoma* response to PAA is highly significant by a paired t-test ($P = 0.002$, $t = 3.72$, $df = 17$). Similarly, for the three tests combined, numbers of *A. biloba* and *M. unipuncta* trapped with PAA were significantly greater than unbaited traps ($p=0.03$, $t=2.37$, $df=17$ for *A. biloba;* $p=0.004$, $t=3.34$, $df=17$ for *M. unipuncta*).

Test D. Numbers of four pest noctuid moths [*C. eriosoma*, *A. biloba*, *M. unipuncta*, and *Peridroma saucia* (Hübner)] were greater in traps baited with PAA + BM compared to unbaited traps (Figure 1a). Greatest numbers of *C. eriosoma* were captured with vials with a 6 mm diam hole in the lid. We did not demonstrate a clear optimum hole diameter (controlling chemical release) for *A. biloba*, *M. unipuncta* or *P. saucia*, but overall vials with a 6 mm diameter hole might be the best choice. For *A. biloba*, numbers of moths caught were greater for 6 mm diam vial holes, compared to 1.5 or 3 mm diam vial holes, and for *M. unipuncta*, numbers of moths caught were greater with 3, 6, or 12 mm vial hole diameters compared to 1.5 mm diam holes. For *P. saucia*, there were no significant differences in numbers trapped between any vial hole diameters (Figure 1a). Numbers of *H. recurvalis* moths captured were similar for PAA + BM lures across all vial hole diameters tested (Figure 1b). For male and female *H. recurvalis*, and for each vial hole diameter, nmbers of moths captured in baited traps were significantly greater than unbaited traps. Totals of 79 *C. eriosoma*, 35 *A. biloba,* 110 *M. unipuncta*, 47 *P. saucia*, and 441 female and 411 male *H. recurvalis* were captured in this test.

Small numbers of other species of pest moths were captured in traps baited with floral chemicals

Table 2. Mean numbers of pest moth species captured in traps baited with phenylacetaldehyde (PAA), β-myrcene (BM), methyl salicylate (MS) and combinations of those chemicals, Waimea, Hawaii. 2011.

Moth	Control	PAA	BM	PAA + BM	MS	PAA + MS
H. recurvalis ♂	0.0 ± 0.0 a	27.0 ± 10.1 b	0.2 ± 0.2 a	35.0 ± 6.9 b	0.0 ± 0.0 a	47.0 ± 7.2 b
H. recurvalis ♀	0.0 ± 0.0 a	19.5 ± 6.0 b	0.2 ± 0.2 a	23.2 ± 5.5 b	0.2 ± 0.2 a	34.7 ± 6.9 b
C. eriosoma	0.0 ± 0.0 a	0.5 ± 0.2 a	0.0 ± 0.0 a	1.8 ± 0.7 b	0.0 ± 0.0 a	1.3 ± 0.6 b
A. biloba	0.0 ± 0.0 a	0.7 ± 0.3 a	0.0 ± 0.0 a	2.0 ± 0.5 b	0.0 ± 0.0 a	0.7 ± 0.3 a
M. unipuncta	0.0 ± 0.0 a	0.8 ± 0.3 b	0.2 ± 0.2 a	3.3 ± 0.6 c	0.0 ± 0.0	1.2 ± 0.5 b

Means within a row followed by the same letter are not significantly different by the Mann Whitney Test, at $p \leq 0.05$.

Table 3. Mean numbers of pest moth species captured in traps baited with phenylacetaldehyde PAA), cis jasmone (CJ), and methyl-2-methoxy benzoate (MMB) and combinations of those chemicals.Waimea, Hawaii. 2011.

Moth	Control	PAA	CJ	PAA + CJ	MMB	PAA + MMB
H. recurvalis ♂	0.7 ± 0.3a	12.0 ± 1.5b	0.8 ± 0.5a	10.8 ± 1.4b	0.8 ± 0.4a	33.0 ± 4.3c
H. recurvalis ♀	0.2 ± 0.2a	8.2 ± 1.5b	0.2 ± 0.2a	12.0 ± 1.7b	0.3 ± 0.2a	25.5 ± 3.3c
C. eriosoma	0.0 ± 0.0a	0.8 ± 0.3b	0.0 ± 0.0a	0.7 ± 0.3a	0.0 ± 0.0a	0.8 ± 0.3b
M. unipuncta	0.0 ± 0.0a	0.8 ± 0.3b	0.2 ± 0.2a	1.0 ± 0.4b	0.0 ± 0.0a	1.0 ± 0.4b

Means within a row followed by the same letter are not significantly different by the Mann Whitney Test, at $p \leq 0.05$.

Table 4. Mean numbers of pest moth species captured in traps baited with phenylacetaldehyde (PAA), 2-phenylethanol (2PE), and linalool (LIN), and combinations of those chemicals, Waimea, Hawaii. 2011.

Moth	Control	PAA	2PE	PAA + 2PE	LIN	PAA + LIN
H. recurvalis ♂	0.5 ± 0.5a	4.2 ± 1.2b	0.5 ± 0.2a	6.3 ± 1.3b	0.0 ± 0.0a	15.7 ± 2.6c
H. recurvalis ♀	0.2 ± 0.2a	5.0 ± 0.9b	0.0 ± 0.0a	8.2 ± 1.2b	0.0 ± 0.0a	23.2 ± 4.1c
C. eriosoma	0.0 ± 0.0a	0.5 ± 0.2a	0 ± 0a	0.83 ± 0.2b	0.0 ± 0.0a	0.33 ± 0.2a
M. unipuncta	0.0 ± 0.0a	0.0 ± 0.0a	0.3 ± 0.2a	1.3 ± 0.2b	0.2 ± 0.2a	0.5 ± 0.3a

Means within a row followed by the same letter are not significantly different by the Mann Whitney Test, at $p \leq 0.05$.

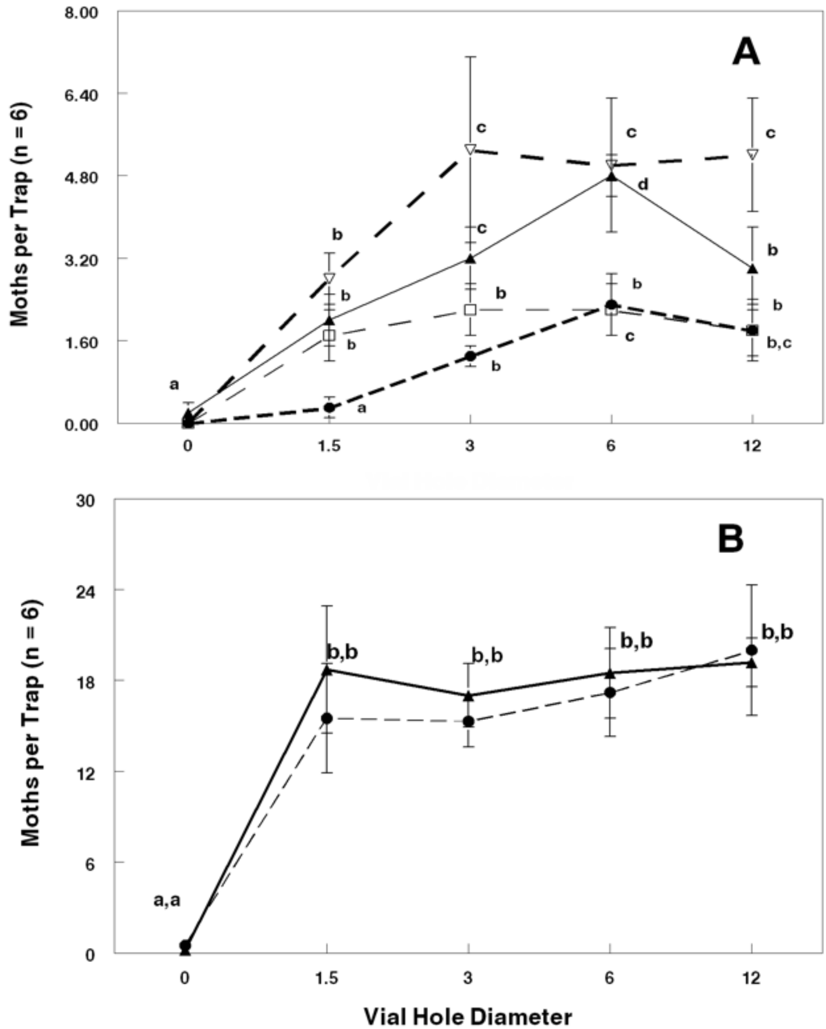

Figure 1. Numbers of noctuid pests (A) and a crambid moth pest (B) captured in traps baited with phenylacetaldehyde and β-myrcene dispensed from vials. Vials were provided holes in the lids for volatile release, and several vial hole diameters were used to vary volatile release rates from the vials. For A, filled triangles are for *C. eriosoma*, filled circles are for *A. biloba*, open triangles are for *M. unipuncta,* and open squares are for *P. saucia*. For B, filled circles are for male *H. recurvalis* and filled triangles are for female *H. recurvalis*.

in this study, but they were too few to be analyzed statistically. These included *T. ni*, *Helicoverpa zea* (Boddie) (the corn earworm), *Feltia subterranea* (F.) (subterranean cutworm), and *Spodoptera mauritia* (Boisduval). Numbers of *A. biloba* captured were insufficient for statistical analyses in tests B and C, and numbers of *P. saucia* were insufficient for statistical analyses in tests A, B, and C.

Both sexes of each of these moth species were captured in traps baited with these floral lures. For the 4 tests combined, we captured 82 female and 43 male *C. eriosoma,* 36 female and 30 male *A. biloba*, 56 female and 118 male *M. unipuncta,* 47 female and 23 male *P. saucia,* and 1404 female and 1578 male *H. recurvalis* moths. Most noctuids dissected were mated and had mature eggs, although smaller numbers were unmated or had no eggs (Table 5). Most *H. recurvalis* females were mated but were without eggs (Table 5). There were 1.6 ± 0.18 (n = 31) spermatophores per female *C. eriosoma*, 1.8 ± 0.22 (n = 13) spermatophores per female *A. biloba*, 2.2 ± 0.31 (n = 17) spermatophores per female *M. unipuncta*, 2.7 ± 0.22 (n = 31) spermatophores per female *P. saucia* and 1.3 ± 0.08 (n = 68) spermatophores per female *H. recurvalis*.

Discussion

Chrysodeixis eriosoma moths were attracted to PAA, but not to any other single-chemical lures that we tested. The lack of statistically significant differences between numbers of this species trapped with PAA versus unbaited traps in tests A and C may have been due to overall low numbers of moths present. The chemicals BM, 2PE, MS, and MMB, when presented with PAA, enhanced *C. eriosoma* moth response over PAA alone. Stringer et al. (2008) in New Zealand captured 91 *C. eriosoma* moths (64 female, 27 male) in traps baited with floral chemicals but did not provide information on which compounds they responded to or statistical support for *C. eriosoma* responses to lures. We are not aware of other reports of feeding attractants or lures for females of this species. This is the first experimental demonstration then of attraction of *C. eriosoma* to floral chemicals and confirms the observation of Stringer et al (2008) who trapped the moth with floral chemicals. We do not yet know if these lures are attractive enough to be of practical use in monitoring or managing pest populations of *C. eriosoma*. A female-produced sex pheromone that

Table 5. Female reproductive state and female mating frequency for moths captured in floral lure traps. Reproductive state I is unmated, II is mated and with mature eggs, and III is mated with no eggs. Mating frequency was determined as spermatophores per female. Waimea, Hawaii.

Moth species	% Reproductive state I	% Reproductive state II	% Reproductive state III	Spermatophores	N
C. eriosoma	13	52	36	1.65 ± 0.18	31
A. biloba	0	54	46	1.84 ± 0.22	13
M. unipuncta	5	53	42	2.18 ± 0.31	17
P. saucia	6	90	4	2.74 ± 0.22	31
H. recurvalis	5	40	55	1.32 ± 0.08	62

is attractive to *C. eriosoma* males was identified by Benn et al. (1982), and its field activity was confirmed by Hai et al. (2002).

The soybean looper moth, *C. includens*, is a close relative of *C. eriosoma,* and is also attracted to PAA. Like *C. eriosoma, C. includens* responded more strongly to traps baited with PAA + BM versus PAA alone, but unlike *C. eriosoma*, *C. includens* has not shown a statistically significant enhanced response to combinations of PAA with 2PE, MS, or MMB compared to PAA alone (Meagher and Landolt 2008). However, in that study (Meagher and Landolt 2008), numbers of *C. includens* trapped with PAA + MS and PAA + MMB were 76% and 60% higher respectively compared to PAA. *Chrysodeixis eriosoma*, unlike *C. includens* in Florida (Meagher and Landolt 2008), did not show an enhanced response to PAA + CJ versus PAA. Further experimentation is needed to further clarify the relative responses of *C. includens*, *C. eriosoma*, and other looper species to various floral chemicals and combinations thereof.

A second species of Plusiinae, *A. biloba*, was attracted to PAA in this study, and like *C. eriosoma*, more *A. biloba* moths were trapped when BM was added with PAA. This is the first report of *A. biloba* attraction to floral chemical lures. *Autographa biloba* is not generally considered a pest species, but is polyphagous and has been found on crop plants (Canerday and Arant 1966).

The captures of an armyworm (*M. unipuncta*) and a cutworm (*P. saucia*) species in the traps was unexpected, although moths in noctuid moth taxa other than Plusiinae are reported to be attracted to floral volatiles (Cantelo and Jacobson 1979, Toth et al. 2010, Landolt et al. 2011). *Mythimna unipuncta* is also attracted to the combination of acetic acid and 3-methyl-1-butanol, possibly as a feeding attractant (Landolt and Higbee 2002, Landolt et al. 2011). Interestingly, *M. unipuncta* was not trapped with a mixture of PAA, MS, MMB and BM during a field study comparing that floral lure with acetic acid plus 3-methyl-1-butanol (Landolt et al. 2011). This is a first report of *P. saucia* (Noctuinae) response to a floral lure. Small numbers of *P. saucia* were captured in traps baited with acetic acid plus 3-methyl-1-butanol by Landolt et al. (2011).

The beet webworm *H. recurvalis*, in the family Crambidae, was also trapped with PAA and not with other chemicals tested singly. MMB and LIN enhanced *H. recurvalis* attraction to PAA. This is the first experimental demonstration of *H. recurvalis* attraction to PAA or any other floral chemicals. Creighton et al. (1973) captured 21 *H. recurvalis* moths in traps baited with the combination of the sex pheromone of *T. ni* and PAA, and it is likely that *H. recurvalis* in that study responded to PAA and not to the *T. ni* sex pheromone. Several other species of Crambidae have been trapped with flower chemical lures. Meagher and Landolt (2008) captured *Diaphania nitidalis* Stoll (pickleworm), with the combinations of PAA plus CJ, LIN, MS, MMB or BM. Landolt et al. (2011) trapped the crambids *Achyra rantalis* (Guenée), *Petrophila avernalis* (Grote), and *Udea profundalis* (Packard) with a mixture of PAA, MS, MMB, and BM.

The numbers of *C. eriosoma, A. biloba*, and *M. unipuncta* captured were consistently low compared to responses to floral chemicals obtained for some noctuid moths in other studies, such as *C. includens* in Florida (Meagher and Landolt 2008), and *A. californica* in Washington (Landolt et al. 2001, 2006). Possible explanations are low population densities of the moths in these vegetable fields, a relatively low rate of response of moths to the lures, and competition between lures and other natural odor sources or abundant food sources. Studies relating the trapping of moths with feeding attractant lures and other measures of moth abundance are generally lacking.

All of these moths can be pests of agricultural crops. There may be potential to develop these attractants as a means of monitoring pest species in crops, or to develop attract-and-kill methods for population suppression. The trap response of female as well as male moths and the inclusion of females with eggs in trap catches suggest a potential to use these types of lures in an attract-and-kill approach to remove female moths and reduce oviposition on crop plants. Preliminary work to develop such an approach has been conducted with PAA to lure *T. ni* moths to a pesticide-treated food bait (Landolt et al. 1991) and to use PAA with BM to lure *A. californica* moths to a pesticide-treated visual target (Camelo et al. 2007).

Acknowledgments

Technical assistance was provided by D. Green and J. Brumley. T. S. Davis assisted with statistical analysis of data. We thank Ken Hufford and Paul Johnston for access to their vegetable farms.

Literature Cited

Benn, M. H., R. A. Galbreath, V. A. Holt, H. Young, G. Down, and **E. Priesner.** 1982. The sex pheromone of the silver Y moth *Chrysodeixis eriosoma* (Doubleday) in New Zealand. Z. Naturforsch. 37c: 1130–1135.

Camelo, L., D. A., P. J. Landolt, and **R. S. Zack.** 2007. A kairomone based attract-and-kill system effective against alfalfa looper (Lepidoptera: Noctuidae). J. Econ. Entomol. 100: 366–374.

Canerday, T. D., and **F. S. Arant.** 1966. The looper complex in Alabama (Lepidoptera: Plusiinae). J. Econ. Entomol. 59: 742–743.

Cantelo, W. W. and **M. Jacobson.** 1979. Phenylacetaldehyde attracts moths to bladderflower and to blacklight traps. Environ. Entomol. 8:444–447.

Creighton, C. S., T. L. McFadden, and **E. R. Cuthbert.** 1973. Supplementary data on phenylacetaldehyde: an attractant for Lepidoptera. J. Econ. Entomol. 66:114–116.

DataMost. 1995. StatMost Statistical Analysis and Graphics. Data Most Corp., Salt Lake City, UT.

El Sayed, A, M., A. M., J. A. Byers, L. M. Manning, A. Jurgens, V. J. Mitchell, and **D. M. Suckling.** 2008. Floral scent of *Cirsium arvense* (L.) Scop. and its potential as a generic insect attractant. J. Econ. Entomol. 101:720–727.

Guédot, C., P. J. Landolt, and **C. L. Smithhisler.** 2008. Odorants of the flowers of butterfly bush, *Buddleia davidii,* as possible attractants of pest species of moths. Florida Entomol. 91: 576–582.

Hai, T. V., L. V. Lang, P. K. Son, S. I. Inomata, and **T. Ando.** 2002. Sex attractants for moths of Vietnam: Field attraction by synthetic lures baited with known lepidopteran pheromones. J. Chem. Ecol. 1473–1481.

Haynes, K. F., J. Z. Zhao, and **A. Latif.** 1991. Identification of floral compounds from *Abelia grandiflora* that stimulate upwind flight in cabbage looper moths. J. Chem. Ecol. 17: 637–646.

Heath, R. R., P. J. Landolt, B. Dueben, and **B. Lenczewski.** 1992. Identification of floral compounds of night blooming jessamine attractive to cabbage looper moths. Environ. Entomol. 21: 854–859.

Holloway, J. D. 1985. Moths of Borneo. Noctuidae: Euteliinae, Stictopterinae, Plusiinae, Pantheinae. MalayNat. J. 38: 157–317.

Konenko, V. S., and **B. A. Pinratana.** 2005. Moths of Thailand. Volume Three. Noctuidae. Published by Brothers of St. Gabriel in Thailand. Bangkok. 261 p.

Lafontaine, J. D., and **B. C. Schmidt.** 2010. Annotated check list of the Noctuoidea (Insecta, Lepidoptera) of North America north of Mexico. ZooKeys 40: 1–239.

Landolt, P. J., and **B. S. Higbee.** 2002. Both sexes of the true armyworm (Lepidoptera: Noctuidae) trapped with the feeding attractant comprised of acetic acid and 3-methyl-1-butanol. Florida Entomol. 85: 182–185.

Landolt, P. J., and **C. L. Smithhisler.** 2003. Characterization of the floral odor of Oregon grape, *Berberis aquifolium* Prursch.: possible feeding attractants for moths (Insecta, Lepidoptera). Northwest Science 77: 81–86.

Landolt, P. J., B. Lenczewski, and **R. R. Heath.** 1991. Lure and toxicant system for the cabbage looper (Lepidoptera: Noctuidae). J. Econ. Entomol. 84: 1344–1347.

Landolt, P. J., T. Adams, H. C. Reed, and **R. S. Zack.** 2001. Trapping alfalfa looper moths (Lepidoptera: Noctuidae) with single and double component floral chemical lures. Environ. Entomol.

30: 667–672.

Landolt, P. J., T. Adams, and **R. S. Zack.** 2006. Field response of alfalfa looper and cabbage looper moths (Lepidoptera: Noctuidae, Plusiinae) to single and binary blends of floral odorants. Environ. Entomol. 35:276–281.

Landolt, P. J., A. Pantoja, A. Hagerty, L. Crabo, and **D. Green.** 2007. Moths trapped in Alaska with feeding attractant lures and the seasonal flight patterns of potential agricultural pests. Canadian Entomol. 139: 278–291.

Landolt, P. J., T. Adams, R. S. Zack, and **L. Crabo.** 2011. A diversity of moths (Lepidoptera) trapped with two feeding attractants. Ann. Entomol. Soc. Amer. 104: 498–506.

Lopez, J. D., T. N. Shaver, K. R. Beerwinkle, and **P. D. Lingren.** 2000. Feeding attractant and stimulant for adult control of noctuid and other Lepidoptera species. U.S. Patent 6,074,634. Issued June 2000.

Luther, G. C., H. R. Valenzuela, and **J. Defrank**. 1996. Impact of cruciferous trap crops on lepidopteran pests of cabbage in Hawaii. Environ. Entomol. 25: 39–47.

Meagher, R. L. Jr. 2001. Collection of soybean looper and other noctuids in phenylacetaldehyde-baited traps. Florida Entomol. 84: 154–155.

Meagher, R. L. Jr. 2002. Trapping noctuid moths with synthetic floral volatile lures. Entomol. Exp. Appl. 103: 219–226.

Meagher, R. L., Jr. and **P. J. Landolt.** 2008. Attractiveness of binary blends of floral odorant compounds to moths in Florida, USA (Lepidoptera: Noctuidae; Pyralidae). Entomol. Exp. Appl. 128: 323–329.

Meagher, R. L., and **P. J. Landolt.** 2010. Binary floral lure attractive to velvetbean caterpillar adults (Lepidoptera: Noctuidae). Florida Entomol. 93: 73–79.

Molleman, F., B. Drukker, and **L. Blommers.** 1997. A trap for monitoring pear psylla predators using dispensers with methyl salicylate. Proc. Exp. Appl. Entomol. 8: 177–182.

Pair, S. D. and **R. J. Horvat.** 1997. Volatiles of Japanese honeysuckle flowers as attractants for adult Lepidopteran insects. U.S. Patent 5,665,344. Issued 9 September 1997. United States Patent Office, Washington D.C.

Shaver, T. N., P. D. Lingren, and **H. F. N. Marshall.** 1997. Night time variation in volatile content of flowers of the night blooming plant *Gaura drummondii*. J. Chem. Ecol. 23: 2673–2682.

Stringer, L. D., A. El-Sayed, L. M. Cole, and **L. A. M. Manning.** 2008. Floral attractants for the female soybean looper, *Thysanoplusia orichalcea* (Lepidoptera: Noctuidae). Pest Management Science 64: 1218–1221.

Toth, M., I. Szarukan, B. Dorogi, A. Gulyas, P. Nagy, and **Z. Rozgonyi.** 2010. Male and female noctuid moths attracted to synthetic lures in Europe. J. Chem. Ecol. 36: 592–598.