Catch of the Adult Green Garden Looper, *Chrysodeixis eriosoma* (Lepidoptera: Noctuidae), in Sweetpotato Fields in Hawaii

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Abstract. Sweetpotato, *Ipomoea batatus* (L.) Lamarck, one of the top ten staple crops produced worldwide, was the top volume-producing vegetable crop in Hawaii in 2017. While conducting research on sweetpotato pests in Hawaii, we discovered that the green garden looper, *Chrysodeixis eriosoma* (Doubleday), was present in sweetpotato fields in Hawaii and we had recurrent non-target catch in traps baited with a binary pheromone lure for the sweetpotato vine borer, *Omphisa anastomosalis* Guenée. The green garden looper caterpillar is a generalist feeder that has the potential to damage a range of both vegetable and ornamental crops in Hawaii. Herein we report on the non-target catch of *C. eriosoma*, including documenting the effect of spatial trap location and trap height on trap catch. We also demonstrate that a commercially available lure formulated for *C. chalcites* is an effective detection/monitoring tool for *C. eriosoma* in Hawaii, as had previously been demonstrated in New Zealand.

Key Words: *Omphisa anastomosalis*, non-target catch, *Ipomoea batatas*

Sweetpotato, *Ipomoea batatas* (L.) Lamarck, is one of the top ten staple crops produced worldwide, trailing only corn, rice, wheat, potatoes, cassava, and barley (FAO 2018). Sweetpotato was the top volume-producing vegetable crop in Hawaii in 2017, with an estimated production of 2.80 million kg (USDA-NASS 2018). Sweetpotato, though, is subject to a wide range of insect pests. It has been reported that 270 insect and 17 mite species have been listed as pests of sweetpotato in the field and in storage around the world (Sorenson 2009). We have been conducting research on insect pests of sweetpotato in Hawaii, with recent emphasis on the chemical ecology of the sweetpotato vine borer, *Omphisa anastomosalis* Guenée (Lepidoptera: Crambidae). Crambids are in the superfamily Pyraloidea in which a number of species have been recently found to have both Type 1 and Type 2 sex pheromone components. Type 1 components are straight chain fatty alcohols and their derivatives, while Type 2 components consist of polyunsaturated hydrocarbons and their epoxy derivatives (Vang et al. 2018). Wakamura et al. (2010) identified (10*E*,14*E*)-10,14-hexadecadienal (*E*10,*E*14-16:Ald) as the major sex pheromone component for the sweetpotato vine borer which was later classified as a Type 1 pheromone component (Yan et al. 2014). Working with field sweetpotato vine borer populations in Vietnam, Yan et al. (2014) subsequently identified a Type 2 sex pheromone component ([3*Z*,6*Z*,9*Z*]-3,6,9-tricosatriene [Z3,Z6,Z9-23:H]) which synergized the attractiveness of the initially identified Type 1 compound. We tested whether this binary attractant (*E*10,*E*14-16:Ald + Z3,Z6,Z9-23:H) was

Figure 1. Adult *Chrysodeixis eriosoma* shown at rest, with wings folded over the back like a tent. Photo by GTM.

similarly effective with sweetpotato vine borer populations in Hawaii (McQuate et al. 2019). In the course of our field trials, we had recurrent non-target catch of the green garden looper, *Chrysodeixis eriosoma* (Doubleday) (Lepidoptera: Noctuidae) (Figure 1). There has been some uncertainty about this moth species in Hawaii. It was first reported from Hawaii by Butler (1877) as *Plusia verticillata*? Guénée ("It closely approaches *P. precationis*, from N. America, and *P. eriosoma*, from New Zealand"), which was listed as a synonym of *Plusia* (*Autographa*) *chalcites* (Esper) by Zimmerman (1958). In the revision by Kostrowicki (1961) of the Plusiinae subfamily of the family Noctuidae, the genus name *Chrysodeixis* was reinstated and the species was divided into two: *C. eriosoma* Doubleday, established in Australasia and the Pacific; and *C. chalcites* Esper, established in Africa and the western Palaearctic (Benn et al. 1982, Roberts 1979). Use of geographic range, DNA and pheromones are reported to be needed for the differentiation of the two species (Lafontaine and Schmidt 2013). Mitochondrial gene cytochrome c oxidase I (COI) data taken from a moth in Hawaii matched with *C. eriosoma* which has supported the proposal that the species present in Hawaii is *C. eriosoma* (N. B. Barr, personal communication). Interceptions of individuals, originating in Hawaii, identified as either *C. eriosoma* or *C. chalcites*, are considered to be *C. eriosoma* (Passoa 2007). Although sweetpotato has been listed as a host of larval *C. eriosoma* (Mau and Kessing 1991, Roberts 1979), there seems to be no concern at present for it adversely impacting sweetpotato root production in Hawaii. It is, though, good to document its presence in sweetpotato fields in Hawaii and report on a means of

trapping to detect and monitor this pest as it is a generalist feeder. It has the potential to damage a range of both vegetable (including basil [*Ocimum basilicum* L.], corn [*Zea mays* L.], eggplant [*Solanum melongena* L.], green beans [*Phaseolus vulgaris* L.], peas [*Pisum sativum* L.] and tomato [*Solanum lycopericum* L.]) and ornamental (*Aglaonema* spp., *Chrysanthemum* spp., *Ficus* spp., *Syngonium spp*., ti plant [*Cordyline fruticosa* (L.) A. Chev.], and orchids [Orchidaceae]) crops in Hawaii (Mau and Kessing 1991). Damage by *C. eriosoma* is caused by the caterpillar stage. Young caterpillars consume only one side of a leaf, leaving the opposite epidermis. With increasing age, caterpillars will eat holes through the leaves. Older caterpillars can also feed from the margin of the leaf. There have also been reports that caterpillars may feed on flowers and fruits (Mau and Kessing 1991, Zimmerman 1958). Sex pheromones, produced by female moths, have been identified for both *C. chalcites* and *C. eriosoma*. Wind tunnel studies by Dunkelblum et al. (1987) showed that compounds released from the female sex pheromone glands of *Chrysodeixis chalcites* elicit both directed flights and copulation attempts, at the end of the flights, by males. The sex pheromone components of the two species contain essentially the same compounds, but in different proportions (Benn et al. 1982). For population monitoring of *C. eriosoma* in Hawaii, we used the *C. chalcites* lure because it was available commercially (and there was no commercially available sex pheromone for *C. eriosoma*) and because it was known that *C. eriosoma* males were attracted to the *C. chalcites* sex pheromone (Benn et al. 1982). Herein, we report on male *C. eriosoma* response to the *O. anastomosalis* synthetic binary sex attractant, so that there is documentation of this non-target catch. Our sweetpotato vine borer field trials also assessed the effect of trap height and trap spatial location on trap catch. We, also, report here on the non-target *C. eriosoma* catch in these trials because it adds to the knowledge of the spatial distribution of this species. Finally, we, also, report on *C. eriosoma* male response to commercially available *C. chalcites* lure. Our results document the potential for use of this lure to detect and monitor *C. eriosoma* populations in sweetpotato, as well as in any of the other crops in Hawaii that may be subject to attack by *C. eriosoma*.

Materials and Methods

Attractants (lures). The male lure for *Chrysodeixis chalcites* was obtained from ISCA Technologies, Inc. (Riverside, CA) (Item # IT055 – Green garden looper). It should, though, be noted that the common name, "green garden looper," has been assigned to *C. eriosoma* in the Entomological Society of America Common Names of Insects database [ESA 2018]). ISCA Technologies lists the field life of this lure as 4 – 8 weeks, depending on environmental conditions. The binary male lure for the sweetpotato vine borer (SPVB) was obtained from Shin-Etsu Chemical Co., Ltd., (Tokyo, Japan) (Type 1 component) and from Pherobank BV, (Duurstede, The Netherlands) (Type 2 component). The type 1 component was [*E*10,*E*14)-10,14-hexadecadienal (*E*10,*E*14-16:Ald) and was of 94.19% purity. The type 2 component was (3Z,6Z,9Z)-3,6,9-tricosatriene (Z3,Z6,Z9-23:H) and was about 95% pure.

Field sites. Four bioassays were conducted, each in a separate fully vegetated (pre-harvest) sweetpotato field on the Hamakua Coast on the island of Hawaii. For each bioassay, a Davis Instruments wireless Vantage Pro2 Weather Station (Hayward, CA, USA) was deployed nearby for the collection of temperature, relative humidity, wind speed and rainfall data. Further details on the location of each test

and the weather data at each location over the course of the bioassay are presented in Table 1.

Bioassays.

Bioassay 1. Initial test of binary *Omphisa anastomosalis* male lure. Three Delta traps (Great Lakes IPM Inc., Vestaburg, MI) were set out, one in each of three 60 m sections of sweetpotato rows, spaced at least 10 m apart. Each section had seven assigned locations for traps, spaced 10 m apart along the row. Each trap held one septum loaded with 2.0 mg of the Type 1 pheromone component (*E*10*E*14-16:Ald) and two septa each loaded with 2.0 mg of the Type 2 pheromone component (Z3,Z6,Z9-23:H). All attractant lures were placed inside plastic baskets (Great Lakes IPM. Inc. Vestaburg, MI) and hung from a wire in the middle of the trap. Each lure type was held in a separate basket. A sticky insert card (Great Lakes IPM. Inc., Vestaburg, MI) was inserted on the bottom of the traps to capture attracted moths. Traps were hung on plastic fence post (DARE Products, Inc. Battle Creek, MI) with the bottom of the trap positioned approximately 0.25 m above the sweetpotato foliage. The selected trap height was a height that we commonly used for *O. anastomosalis*, as this test targeted *O. anastomosalis*, with *C. eriosoma* being a non-target catch. Traps were initially deployed on 9 January 2018. Traps were checked weekly to record moth captures. Sticky cards were replaced as needed. Traps within each row were randomly repositioned each week after trap servicing to a different trap location. Trap servicing was terminated, after 12 weeks, on 3 April 2018.

Bioassay 2. Effect of trap height on *Chrysodeixis eriosoma* response to the binary *Omphisa anastomosalis* male lure. Delta traps with sticky insert cards were deployed so that the bottoms of the traps were positioned at one of five different heights above sweetpotato foliage:

Table 1. Location details and weather conditions over the course of each bioassay. All bioassays were conducted in fully vegetated sweetpotato fields on the Hamakua Coast on Hawaii island, Hawaii. Bioassays 1 and 2 were conducted near Papaikou, while bioassays 3 and 4 were conducted near Honomu.

	Location (USGS 2001)				Average weather conditions			
Bioassay	Easting	Northing	Zone	Elev. (m)	Temp. (°C)	Rel. humidity (%)	Wind speed (m/s)	Weekly rain (mm)
1	0276361	2191816	05 Q	396	19.3 ± 0.12	88.2 ± 0.21	3.5 ± 0.08	97.2 ± 29.6
2	0276280	2191870	05 Q	410	19.0 ± 0.12	88.6 ± 0.21	3.7 ± 0.08	112.0 ± 41.3
3	0275340	2196851	05 Q	352	20.6 ± 0.15	93.1 ± 0.19	2.1 ± 0.07	144.9 ± 19.6
4	0275274	2196816	05 Q	361	19.6 ± 0.14	92.7 ± 0.22	2.0 ± 0.06	149.8 ± 61.7

0.25, 0.5, 0.75, 1.0 and 1.5 m. Traps were hung on strawberry guava (*Psidium cattleyanum* Sabine var. *littorale* (Raddi) Fosberg) stakes. Traps were set out in three blocks with traps at least 10 m apart within blocks and blocks at least 10 m apart. Each trap held one septum dosed with 2.5 mg Type 1 lure (*E*10*E*14-16:Ald) and two septa each dosed with 2.5 mg Type 2 lure (Z3,Z6,Z9-23:H), with different lure types held in separate plastic baskets. Traps were initially deployed on 31 January 2018. Traps were checked weekly and randomly re-positioned to a different location within each block after trap servicing. Trap servicing was terminated, after 8 weeks, on 28 March 2018.

Bioassay 3. Effect of trap location on *Chrysodeixis eriosoma* response to the binary *Omphisa anastomosalis* male lure. Delta traps with sticky insert cards were deployed so that the traps were positioned at three different spatial locations: border (2.0 m beyond sweetpotato plants), edge (2.0 m into a sweetpotato row from the edge) and interior (at least 20 m in on a sweetpotato plant row from the edge of the field). Four traps were deployed for each plant position: two on the west side of the field and two on the east side of the field. Each trap held one septum dosed with 2.0 mg Type 1 lure and one septum dosed with 4.0 mg Type 2 lure. Lure handling and trap positioning were as described above for Bioassay 1. Traps were initially deployed on 3 April 2018. Traps were checked weekly with trap location within each block randomly re-positioned to a different trap location after trap servicing. Trap servicing was terminated, after 8 weeks, on 29 May 2018. Over the course of the trial, each trap was positioned one time in each of eight positions for each of the three spatial locations.

Bioassay 4. Test of male *Chrysodeixis eriosoma* response to *C. chalcites* male lure in sweetpotato field. Three Delta traps with sticky insert cards were set out, one in each of three 70 m sections of sweetpotato rows, spaced at least 10 m apart. Each section had eight assigned locations for traps, spaced 10 m apart along the row. Each trap held one septum loaded with *C. chalcites* lure. Septa were placed inside plastic baskets (Great Lakes IPM. Inc.) and hung from a wire in the middle of the trap. Trap positioning was as described above for Bioassay 1. Traps were initially deployed on 13 February 2018. Traps were checked initially after 24 hours to remove early moth catches in order to avoid oversaturation of the sticky cards, as it was known that trap catch at first deployment was higher than the subsequent catch rate. Thereafter, traps were checked weekly. Position of each trap was randomly re-positioned to a different trap location within each row after each trap service. Trap servicing was terminated, after 8 weeks, on 10 April 2018.

Statistical analyses. Trap catch was averaged by treatment each week. Analysis of Variance (ANOVA) on square root transformed "total catch over eight weeks" (i.e., replicates were the sum of catches in each trap over the eight week trial) was used to test for significance of differences in trap catch by trap height (Bioassay 2) and trap location (Bioassay 3), with Tukey HSD used for mean separation (SAS Institute Inc. 2013). The change in *C. eriosoma* trap catch over eight weeks in traps baited with the *C. chalcites* lure (Bioassay 4) was fitted to a two parameter exponential decay curve (Systat Software, Inc. 2008), from which it was calculated at what point trap catch dropped to 50% of the original trap catch.

Results

Bioassay 1. Initial test of binary *Omphisa anastomosalis* male lure. *Chrysodeixis eriosoma* was recovered on 11 of the 12 weeks of the trial. Only during

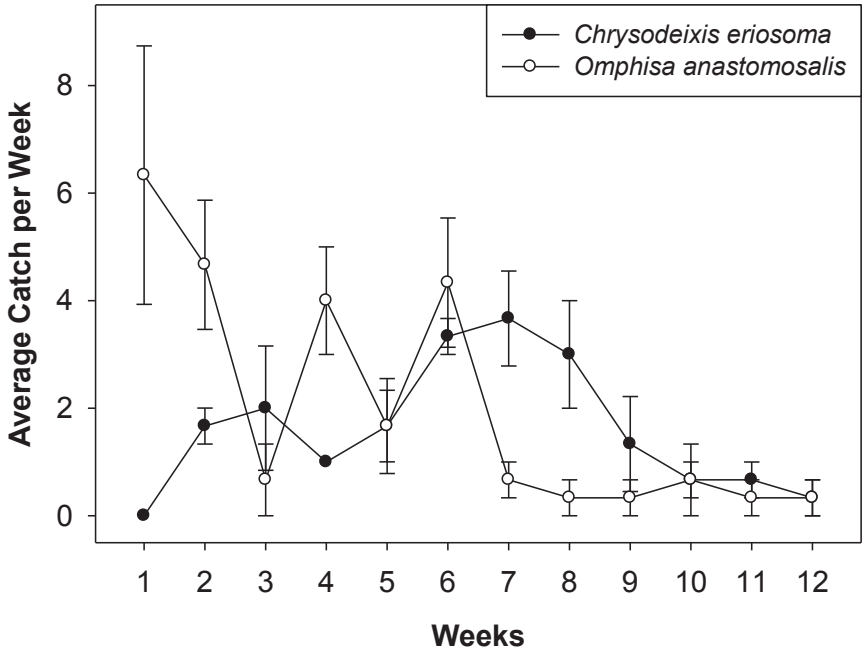

Figure 2. Average catch over 12 weeks of *Chrysodeixis eriosoma* and *Omphisa anastomosalis* in traps baited with a binary *O. anastomosalis* male lure (2.0 mg Type 1: 4.0 mg Type 2) in an in-crop sweetpotato field near Papaikou, Hawaii island, Hawaii (9 January–3 April 2018).

Week 1 was there no *C. eriosoma* catch. In 5 of the 12 weeks, average *C. eriosoma* catch exceeded *O. anastomosalis* catch, most occasions occurring in the latter half of the field trial. Over the full 12 week trial, *C. eriosoma* catch averaged 1.61 ± 0.35 moths per trap per week compared to an average of 2.03 ± 0.63 moths per trap per week for *O. anastomosalis* (Figure 2).

Bioassay 2. Effect of trap height on *Chrysodeixis eriosoma* response to the binary *Omphisa anastomosalis* male lure. There was no significant difference in average *C. eriosoma* trap catch among different trap heights ($F = 0.710$; df = 4,10; $p = 0.604$), with catch averaging between 1.13 per trap per week (at 1.0 m) and 1.96 per trap per week (at 0.5 m) for all heights (Figure 3).

Bioassay 3. Effect of trap location on *Chrysodeixis eriosoma* response to the binary *Omphisa anastomosalis* male lure. Although the overall test for significance of differences among trap locations fell just out of the range of significance ($F = 3.96$; df = 2,9; $p = 0.0583$), there were significant differences in mean separation, with average trap catch highest in interior traps (1.25 per trap per week) and lowest in border traps (0.41 per trap per week) (Figure 4).

Bioassay 4. Test of male *Chrysodeixis eriosoma* response to *C. chalcites* male lure in sweetpotato field. *Chrysodeixis eriosoma* catch was highest in the first week of trapping, averaging 33.3 ± 5.8 moths per trap per week (range 27–45). Trap catch dropped off in subsequent weeks, with no catch in weeks 7 and 8. The drop off in catch was fit well by a 2

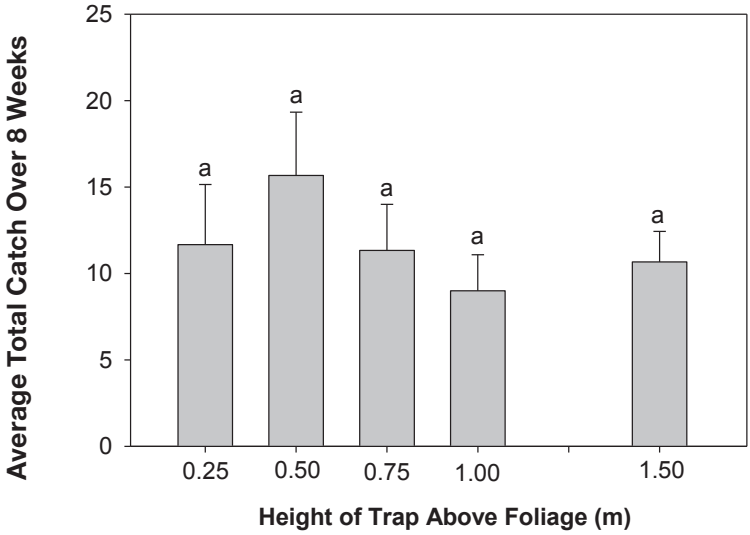

Figure 3. Average total *Chrysodeixis eriosoma* catch over eight weeks in traps positioned at five different heights above sweetpotato foliage near Papaikou, Hawaii island, Hawaii. Catch among the different heights was not significantly different at the $\alpha = 0.05$ level (31 January–28 March 2018).

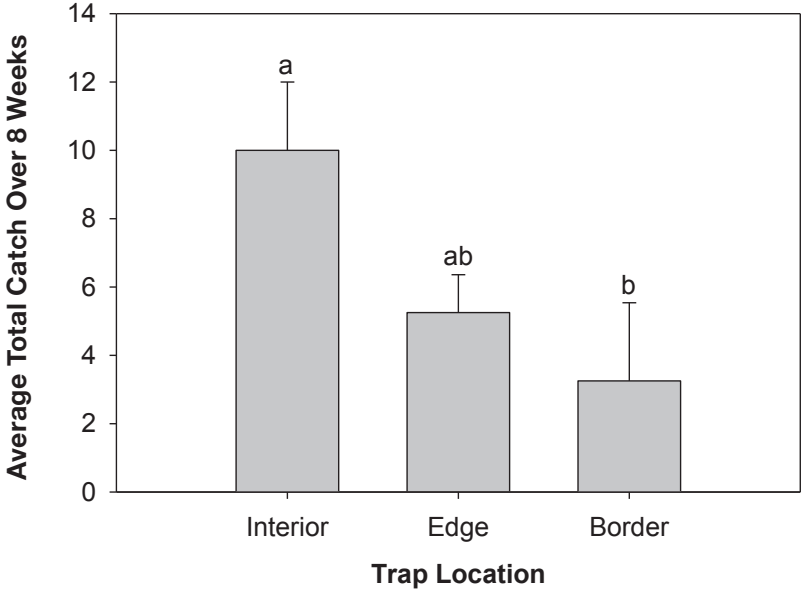

Figure 4. Average total *Chrysodeixis eriosoma* catch over eight weeks at interior, edge, and border locations in a sweetpotato field near Honomu, Hawaii island, Hawaii. Columns with the same letter at top are not significantly different at the $\alpha = 0.05$ level (3 April–29 May 2018).

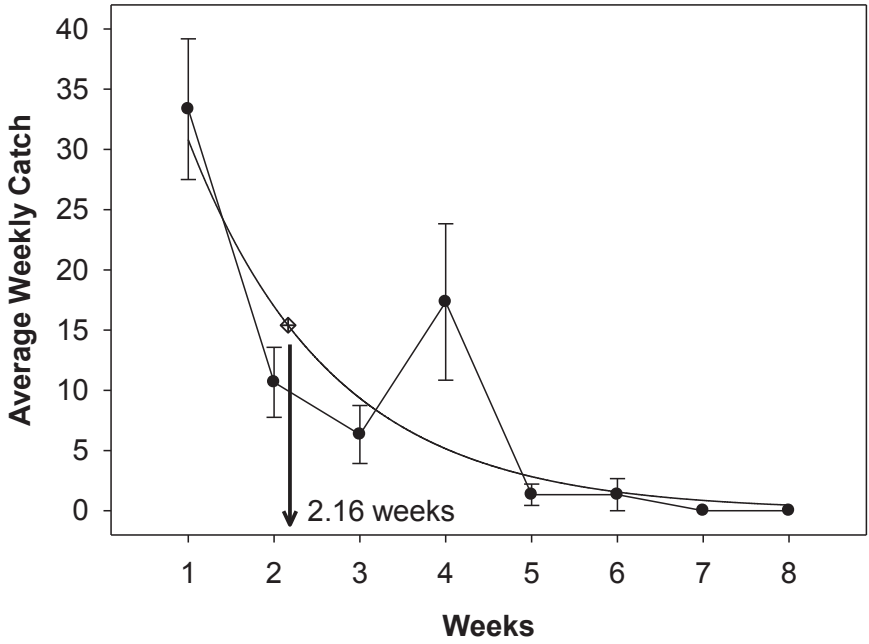

Figure 5. Average weekly catch of *Chrysodeixis eriosoma* over eight weeks in an in-crop sweetpotato field near Honomu, Hawaii island, Hawaii. Also shown is a fitted 2 parameter exponential decay curve: Average weekly catch = $55.906*e^{(-0.596*[\text{no. of weeks}])}$ ($F = 21.56$; df = 1,6; $p = 0.0035$ [$r^2 = 0.78$]) (13 February–10 April 2018).

parameter exponential decay curve: Average weekly catch = $55.906*e^{(-0.596*[\text{no. of weeks}])}$ ($F = 21.56$; df = 1,6; $p = 0.0035$ [$r^2 = 0.78$]). Based on the generated exponential decay curve, trap catch dropped down to 50% of the initial catch by 2.16 weeks (Figure 5).

Discussion

Although we present data from only four sweetpotato fields, we have also caught *C. eriosoma* in other fields on the Hamakua Coast on the island of Hawaii, while testing the response of *O. anastomosalis* to the binary sex pheromone, suggesting that *C. eriosoma* is commonly present in sweetpotato fields in Hawaii. Detection of *C. eriosoma* in sweetpotato fields is best done with traps deployed in interior locations, as trap catch tends to drop off for traps in edge or border placements. Trap height, though, is not too critical as there was little difference in *C. eriosoma* trap catch among traps positioned between 0.25 and 1.5 m above sweetpotato foliage. The male *C. chalcites* lure available through ISCA Technologies, Inc. seems to provide a good tool for detection/monitoring of *C. eriosoma*, though its duration of attractiveness is somewhat limited under field conditions in Hawaii. The composition of the lure is presumably a 5:1:1 mixture of (*Z*)-7-dodecenyl acetate (7Z12:Ac), (*Z*)-9-tetradecenyl acetate (9Z14:Ac), and (*Z*)-9-dodecenyl acetate (9Z12:Ac) (Dunkelblum et al. 1987, USDA-APHIS-CPHST 2014), though ISCA Technologies would not release the composition or dose details. Benn et al. (1982), working with *C. eriosoma* populations in New Zealand, had noted

that sex pheromones produced by female *C. chalcites* and *C. eriosoma* contained essentially the same compounds (based on abdominal tip extracts), but in different proportions (with comparisons made to *C. chalcites* results published in Dunkelblum et al. 1981). Benn et al. (1987) also noted that the males of both species had the same set of specialist receptor cells in antennal sensilla (for five compounds: cells responsive to 7Z-dodecenyl acetate [7Z12:Ac], 9Z-dodecenyl acetate [9Z12:Ac], 9Z-tetradecenyl acetate [9Z14:Ac], 5Z-dodecenyl acetate [5Z12:Ac], and 7Z-dodecenyl alcohol [7Z12:OH]) and that *C. eriosoma* males were attracted to the *C. chalcites* pheromone. Our field work has shown that males in *C. eriosoma* populations in Hawaii also respond to attractants synthesized for *C. chalcites*. Although changing the ratio of different *C. chalcites* pheromone components might improve *C. eriosoma* catch in Hawaii, we have demonstrated that commercially available *C. chalcites* lure can be used at least as a detection/monitoring tool for *C. eriosoma* populations in Hawaii.

In an overview of moth sex pheromone components, Byers (2006) reported that, out of 1572 moth species for which sex pheromones had been reported, 45% of the species had one pheromone component, while 36%, 12%, 5%, and 1% had two, three, four or five components, respectively. Where there are multiple components, the sex pheromone blends are mixtures of biosynthetically similar compounds. Sex pheromones among different species may differ in chain length, the functional group, stereochemistry, presence or absence of a double bond, or variation in ratio among different components. Any particular component may be used by several species, though sharing of a given component is more likely to occur among more closely related species (Byers 2006, Löfstedt et al. 2016). Among the Noctuidae, there are over 400 species for which pheromones or attractants have been reported. All consist of the typical Type 1 component, with only one possible exception (Löfstedt et al. 2016, Ando 2018). Of the greater than 400 species for which pheromones or attractants have been reported, 101 species have pheromone components identified, based on compounds identified in the female pheromone gland. One of the two identified pheromone components for *C. eriosoma* (7Z12:Ac) is an identified pheromone component in 16 of the other 21 species (76%) in the Noctuid subfamily Plusiinae, for which pheromone components have been identified. It is also present in some species in other noctuid subfamilies, but has not been reported in *O. anastomosalis* or in any of the other 61 crambid species for which pheromone components have been identified (Ando 2018). The second pheromone component identified for *C. eriosoma* (9Z12:Ac) is reported from only two of the other 21 Plusiinae species for which pheromone components have been identified (9.5%) and is reported from only one other noctuid species and from no crambid species. Overall, based on identified pheromone components, there is no clear reason, at present, why *C. eriosoma* is attracted to the *O. anastomosalis* binary sex pheromone.

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Literature Cited

Ando, T. 2018. The list of Lepidopteran sex pheromones and attractants. Internet database: https://lepipheromone.sakura.ne.jp/lepi_phero_list_eng.html.

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. Zeitschrift für Naturforschung C 37: 1130–1135.

Butler, A.G. 1877. List of *Heterocerous Lepidoptera* recently collected by the Rev. T. Blackburn in the Hawaiian Islands. Entomologist's Monthly Magazine 14:47–52.

Byers, J. A. 2006. Pheromone component patterns of moth evolution revealed by computer analysis of the *Pherolist*. Journal of Animal Ecology 75: 399–407.

Dunkelblum, E., R. Snir, S. Gothilf, and **I. Harpaz.** 1987. Identification of sex pheromone components from pheromone gland volatiles of the tomato looper, *Plusia chalcites* (Esp.). Journal of Chemical Ecology 13: 991–1003.

Dunkelblum, E., S. Gothilf, and **M. Kehat.** 1981. Sex pheromone of the tomato looper, *Plusia chalcites* (ESP). Journal of Chemical Ecology 7: 1081–1088.

Entomological Society of America (ESA). 2018. Common names of insects database (updated 24 August, 2018). Available online at https://www.entsoc.org/sites/default/files/files/scientific_name.pdf.

FAO. 2018. FAOSTAT (2016 production data). Available online at http://faostat.fao.org/site/339/default.aspx. (accessed 10 Sept. 2018).

Kostrowicki, A.S. 1961. Studies on the Palaearctic species of the subfamily Plusiinae (Lepidoptera, Phalaenidae). Acta Zoologica Cracoviensia 6(10): 367–472.

Lafontaine, J.D., and **B.C. Schmidt.** 2013. Additions and corrections to the check list of the Noctuoidea (Insecta, Lepidoptera) of North America north of Mexico. ZooKeys 264: 227–236.

Löfstedt, C., N. Wahlberg, and **J. G. Millar.** 2016. Evolutionary patterns of pheromone diversity in Lepidoptera, pp 43–78 *In*: Allison, J. D. and R. T. Cardé (eds.), Pheromone communication in moths. University of California Press, Oakland, CA.

McQuate, G.T., A. Cossé, C.D. Sylva, and **J.A. MacKay.** 2019. Field evaluation of a binary sex pheromone for sweetpotato vine borer, *Omphisa anastomosalis* (Lepidoptera: Crambidae), in Hawaii. Submitted (31 Oct., 2018) to the Journal of Insect Science.

Mau, R.F.L., and **J.L.M. Kessing.** 1991. *Chyssodeixis* (sic) *eriosoma* (Doubleday). Crop Knowledge Master. Available online at http://www.extento.hawaii.edu/kbase/crop/type/chrysode.htm (viewed 29 Aug. 2018).

Passoa, S. 2007. Quarantine significant Lepidoptera of concern to the Southern United States. USDA-APHIS-PPQ. Available online at http://www.ipmimages.org/spdn/invasive/presentations/13Passoa.pdf (p. 51).

Roberts, L.I.N. 1979. Biology of *Chrysodeixis eriosoma* (Lepidoptera: Noctuidae) in New Zealand. New Zealand Entomologist 7: 52–58.

SAS Institute Inc. 2013. JMP 11.0.0. SAS Institute Inc., Cary, NC, U.S.A.

Sorenson, K.A. 2009. Sweetpotato insects: Identification, biology and management, pp 161–188 *In*: Loebenstein, G. and G. Thottappilly (eds.), The sweetpotato. Springer, Dordrecht, Netherlands.

Systat Software, Inc. 2008. SigmaPlot for Windows, version 11.0. Systat Software, Inc., San Jose, CA, USA.

USDA-APHIS-CPHST. 2014. *Chrysodeixis chalcites*. CPHST Pest Datasheet. Available online at http://download.ceris.purdue.edu/file/3027.

USDA-NASS. 2018. Hawaii vegetable and melon crops report. Jan. 31, 2018. Available online at https://www.nass.usda.gov/Statistics_by_State/Hawaii/Publications/Vegetables/2018/201801vegrv.pdf (accessed 10 Sept. 2018).

USGS. 2001. The universal transverse merca-

tor (UTM) grid. Fact Sheet 077-01 (August 2001). 2001. Available online at https://pubs.usgs.gov/fs/2001/0077/report.pdf (accessed on 13 Sept. 2018).

Wakamura, S., S. Ohno, N. Arakaki, T. Kohama, D. Haraguchi, and **H. Yasui.** 2010. Identification and field activity of the sex pheromone component of the sweetpotato vine borer moth *Omphisa anastomosalis* (Lepidoptera: Crambidae). Appl. Entomol. Zool. 45: 635–640.

Yan Q., L.V. Vang, C.N.Q. Khanh, H. Naka, and **T. Ando.** 2014. Reexamination of the female sex pheromone of the sweet potato vine borer moth: Identification and field evaluation of a tricosatriene. J. Chem. Ecol. 40: 590–598.

Vang, L. V., Q. Van, N.T.N. Nghia, C.N.Q. Khanh, and **T. Ando.** 2018. Unsaturated cuticular hydrocarbon components of the sex pheromone of eggplant fruit borer, *Leucinodes orbonalis* Guenée (Lepidoptera: Crambidae). Journal of Chemical Ecology 44: 631–636.

Zimmerman, E.C. 1958. Insects of Hawaii. Volume 8. Lepidoptera: Pyraloidea. University of Hawaii Press, Honolulu, HI.