

Recovery of Sweetpotato Vine Borer, *Omphisa anastomosalis* (Lepidoptera: Crambidae), in Sweetpotato Fields in Hawaii Through Field Collections and Detection Trapping

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Abstract. Sweetpotato, *Ipomoea batatas* (L.) Lamarck, has been cultivated in Hawaii since at least 1778, with production increasing in recent years to the point where it was the top volume-producing vegetable crop in Hawaii in 2017. Sweetpotato production in Hawaii, though, is subject to several major insect pests that can adversely affect the quality and quantity of the crop. One such pest is the sweetpotato vine borer, *Omphisa anastomosalis* Guenée (Lepidoptera: Crambidae). A binary sex pheromone, recently identified through research with sweetpotato vine borer populations in Vietnam, has been shown to be comparably attractive in sweetpotato vine borer populations in Hawaii. Herein, research results are reported from tests where this improved sweetpotato vine borer sex attractant is used to assess the effect of trap type, trap height and trap spatial location on catch of male sweetpotato vine borer adults. The results presented here indicate that delta traps baited with the binary sex pheromone are good tools for population detection, with five times or more moth recovery and higher percentage detection relative to wing or *Heliothis* traps. Traps should be placed between 0.5 to 0.75 m above the sweetpotato foliage for best adult male moth recovery. Although moths are present throughout the sweetpotato field, as well as in near-border areas, trap catch may be more reliable towards the edges of the sweetpotato field. Also presented herein is some background on the biology of the sweetpotato vine borer that may be helpful for other researchers who seek to develop improved control of this insect pest.

Key words: *Ipomoea batatas*, binary sex pheromone

Introduction

The cultivation of sweetpotato, *Ipomoea batatas* (L.) Lamarck, in Hawaii predates contact with America and Europe (Huaccho and Hijmans 2000). Hawaiians were already cultivating it when Captain Cook first reached the Islands in 1778 (Staples and Herbst 2005). In recent years, sweetpotato production in Hawaii has been increasing and was the top volume-producing vegetable crop in Hawaii in 2017, with an estimated production of 2.80

million kg (USDA-NASS 2018). Sweetpotato production in Hawaii, though, is subject to several major insect pests that can adversely affect the quality and quantity of the crop. One such pest is the sweetpotato vine borer, *Omphisa anastomosalis* Guenée (Lepidoptera: Crambidae) (Figure 1). The sweetpotato vine borer has been in Hawaii since at least 1900 (Zimmerman 1958). One sweetpotato grower in Hawaii told one of the authors (GTM) that it is the worst pest of sweetpotato because



Figure 1. Adult female sweetpotato vine borer, *Omphisa anastomosalis* (Lepidoptera: Crambidae).

it has the potential to kill vine tips and sweetpotato vines need foliage to develop roots. Weevil pests will damage roots, but not keep roots from forming. We've been conducting research on the sweetpotato vine borer in sweetpotato fields in Hawaii. A primary focus of our research has been to assess the attractiveness of a female-produced male attractant. A male attractant for the sweetpotato vine borer was identified by Wakamura et al. (2010). Working with field sweetpotato vine borer populations in Vietnam, a "Type 2" compound was subsequently identified which synergized the attractiveness of the initially identified ("Type 1") compound (Yan et al. 2014). We tested whether this binary sex pheromone was similarly effective with sweetpotato vine borer populations in Hawaii and found that it was (McQuate et al. 2019). After determining that it is an effective attractant for sweetpotato vine borer males in Hawaii, we were able to use this lure to learn more about sweetpotato vine borer field biology. Herein, we use a synthetic binary sweetpotato vine borer

sex pheromone to assess the effect of trap type, trap height and trap spatial location on catch of male sweetpotato vine borer adults. We also, initially, provide some background on biology of this species that may be helpful for other researchers who seek to develop improved control of this insect pest.

Materials and Methods

Attractant (lure). The binary sex pheromone 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 [E10, E14]-10,14-hexadecadienal (E10, E14-16Ald) 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. All field tests reported here were conducted using a 1:2 ratio of Type 1: Type 2 components with compounds loaded into separate grey rubber septa (West Pharmaceuticals Services, Exton, PA). Septa dosed with 2.0 mg Type 1 compound and 4.0 mg Type 2 compound were used in Tests 1 and 3, while 2.5:5.0 mg doses were used in Test 2. For all tests, the two different components were held in separate plastic lure baskets (Great Lakes IPM Inc., Vestaburg, MI).

Background biology. For our research efforts on the sweetpotato vine borer, we needed to have virgin female moths in order to compare male response to test lures versus male response to virgin females. We, also, wanted to have male moths to test for the distance of response of males to lure formulations in order to develop guidance as to trap spacing to use for male annihilation or pheromone disruption approaches to population suppression. In order to have adult moths, we needed to learn/develop techniques for field collection, pupal and adult sexing, and labora-

tory rearing. We begin our Results section (below) by describing some key aspects of sweetpotato vine borer biology which are helpful for researchers to know if conducting research on this pest species.

Field tests. The trap type, height and location tests were all conducted in separate fields on the Hamakua Coast of the island of Hawaii. For each test, 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. Listed below are further details on the location of each test, the weather data at each location over the course of the tests, and the test protocol.

Test 1. Test of the relative effectiveness of different trap types for detection of sweetpotato vine borer field populations. *Site and weather data.* The test of trap type was conducted in post-harvest sweetpotato fields, in which there was significant vine regrowth after harvest, located near Papaikou, Hawaii island, Hawaii, at: Universal Transverse Mercator [UTM] grid

[USGS 2001]: Zone 05 Q, Easting 0276655, Northing 2191935, 360 m elevation (replicates 1 and 3) and Easting 0277012, Northing 2191988, 351 m elevation (replicate 2). Over the course of the trial, temperature averaged $22.8^{\circ}\text{C} \pm 0.05^{\circ}\text{C}$ (SEM), relative humidity averaged $84.5\% \pm 0.11\%$ (SEM), wind speed averaged $3.6 \text{ mph} \pm 0.04$ (SEM) and there was an average weekly rain of $436.0 \pm 0.02 \text{ mm}$.

Field bioassay. Recent field tests of *O. anastomosalis* adult male response to compounds present in female pheromone glands excised from abdomens of virgin females have used “tent-shaped sticky traps” (SE-trap, Sankei Chemical Co., Kagoshima or Tokyo, Japan) (Wakamura et al. 2010, Yan et al. 2014). In our tests, delta traps (Great Lakes IPM Inc., Vestaburg, MI) were used which are of similar design, but have a smaller sticky card and the peak of the tent is proportionately higher. We compared catch in delta traps with catch in wing traps and Heliiothis traps (Great Lakes IPM, Inc.) (see Figure 2). Wing traps have two separate pieces:

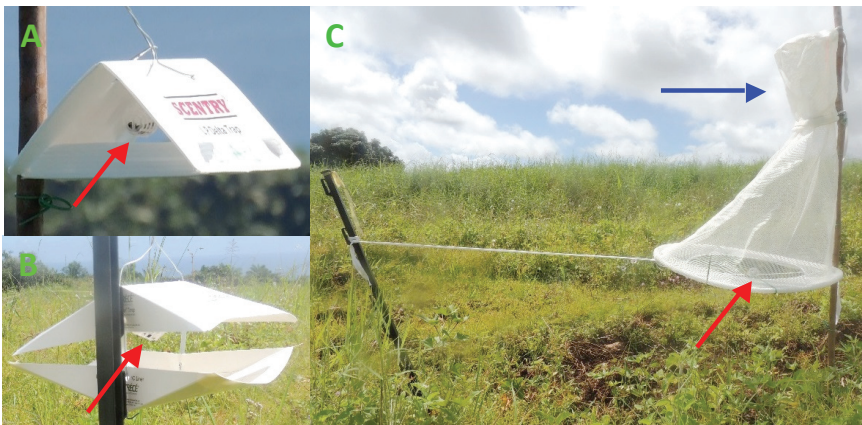


Figure 2. The three trap types tested for relative effectiveness of detection/monitoring of sweetpotato vine borer field populations: A. Delta trap; B. Wing trap; and C. Heliiothis trap. Red arrows point to the locations of the binary sex pheromone in each of the trap types. Blue arrow points to the netted cylinder in the Heliiothis trap from which attracted moths were recovered.

a covered top and a sticky base, and are open all around the sides. Delta traps are triangle shaped and are open only on the ends. We hypothesized that wing traps might improve catch of male sweetpotato vine borers because of their more open design, which would permit volatile diffusion over the full 360 degree exterior of the trap. Heliiothis traps are much larger traps but Texas pheromone traps (similar to the Heliiothis trap used in this study) have been reported to outcatch Jackson traps (a smaller version of a delta trap) for a number of different moth species, including eight different crambid species (Cantelo et al. 1982, Hartstack et al. 1979). Three randomly complete blocks of the three trap types were set out in the test field for replicate 1 on 25 September, 2018. Traps were at least 10 m apart both within and between rows and were all baited with the binary sex pheromone for the sweetpotato vine borer. The lure was suspended down from the middle of the trap on a wire in both the delta and wing traps and held at the middle of a wire stretched across the bottom of the Heliiothis traps. A sticky insert card (Great Lakes IPM, Inc., Vestaburg, MI) was inserted on the bottom of the delta traps, while the bottom piece of the wing trap had a pre-treated sticky surface. Moths attracted to lure associated with the Heliiothis trap were caught in a netted cylinder situated at the top of the trap. Delta and wing traps were hung on plastic fence post (DARE Products, Inc. Battle Creek, MI) (Figure 2) with the bottom of the trap positioned approximately 25 cm above the sweetpotato foliage. The bottom of the Heliiothis trap was also suspended about 25 cm above sweetpotato foliage on a yellow strawberry guava (*waiawi*; *Psidium cattleyanum* Sabine var. *littorale* [Raddi] Fosberg) pole, with a bottom tie attached to a plastic fence post to keep the trap from moving (Figure 2). All traps

were serviced one week later and moved to another site for replicate 2, where they were again serviced after one week and then moved to another site for replicate 3. New within block randomizations were used each week. The test was terminated one week later on 16 October, 2018.

Test 2. Effect of trap height on detection of sweetpotato vine borer field populations. *Site and weather data.* This field trial was conducted in a pre-harvest sweetpotato field located near Papaikou, Hawaii island, Hawaii, at: UTM grid: Easting 0276280, Northing 2191870, Zone 05 Q, 410 m elevation. Over the course of the trial, temperature averaged $19.0^{\circ}\text{C} \pm 0.12^{\circ}\text{C}$ (SEM), relative humidity averaged $88.6\% \pm 0.21\%$ (SEM), wind speed averaged $3.7 \text{ mph} \pm 0.08$ (SEM) and there was an average weekly rain of $112.0 \pm 41.3 \text{ mm}$.

Field bioassay. Delta traps (Great Lakes IPM Inc.) were deployed so that the bottoms of the traps were positioned at one of five different heights above sweetpotato foliage: 0.25, 0.5, 0.75, 1.0 and 1.5 m. Traps were hung on strawberry guava stakes. Traps were set out in three blocks with traps at least 10 m apart within blocks and blocks at least 10 m apart. A sticky insert card was placed at the bottom of the traps to capture attracted males. Traps were initially deployed on 31 January, 2018. Traps were serviced weekly with the relative location of traps held at different heights within each block re-randomized each week after trap servicing. Weekly trap servicing was terminated, after 8 weeks, on 28 March, 2018.

Test 3. Effect of trap location on detection of sweetpotato vine borer field populations. *Site and weather data.* This field trial was conducted in a pre-harvest sweetpotato field near Honomu, Hawaii island, Hawaii at: UTM grid: Easting 0275340, Northing 2196851, Zone 05 Q, 352 m elevation. Over the course of the trial, temperature averaged $20.6^{\circ}\text{C} \pm$

0.15°C (SEM), relative humidity averaged $93.1\% \pm 0.19\%$ (SEM), wind speed averaged $2.1 \text{ mph} \pm 0.07$ (SEM) and there was an average weekly rain of $144.9 \pm 19.6 \text{ mm}$.

Field bioassay. Delta traps (Great Lakes IPM Inc.) 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. A sticky insert card was placed at the bottom of the traps to capture attracted males. Traps were hung on plastic fence post (DARE Products, Inc.) with the bottom of the trap positioned approximately 0.25 m above the foliage. Traps were initially deployed on 3 April, 2018. Traps were serviced weekly with trap location within each block re-randomized each week after trap servicing. Weekly 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.

Statistical analyses. Trap catch was averaged by treatment each week. Analysis of Variance (ANOVA) on square root transformed total catch over a three-week trial (test of trap type) or over eight-week trials (tests of trap height and trap location) was used to test for significance of differences in trap catch by treatment, with Tukey HSD used for mean separation in all tests (SAS Institute Inc. 2013).

Results

Background biology. In order to gather sweetpotato vine borer individuals, we found it easiest to collect infested roots from previously harvested fields. It is common, in sweetpotato production on Hawaii

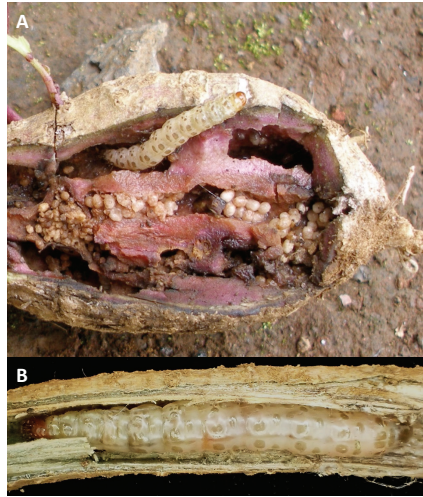


Figure 3. Sweetpotato vine borer caterpillars: A. Caterpillar leaving sweetpotato root. The root shows internal damage from the sweetpotato vine borer caterpillar and internal frass accumulation. B. Caterpillar within sweetpotato vine.

Island, for growers to collect marketable roots from the field and leave the cull roots in the field. With no sweetpotato foliage, or only limited regrowth foliage, in post-harvest sweetpotato fields, female sweetpotato vine borer moths will lay eggs on exposed roots (or on remaining vines) in the field. Following egg hatch, developing caterpillars (Figure 3) push their frass outside the root or vine (Figure 4), making a good detection tool for researchers to identify infested roots. One needed, though, to wait for at least one month after harvest before infested roots could readily be found. Infested roots and vines were brought back to an insect holding room at the Daniel K. Inoué U.S. Pacific Basin Agricultural Research Center and cut open to recover infesting caterpillars which were placed in 7.0 cm diameter x 7.5 cm screened-top HI-PLAS cups (Highland Plastic, Inc., Mira Loma, CA) with a small piece of sweetpotato



Figure 4. Frass pushed out of a sweetpotato root by a sweetpotato vine borer caterpillar feeding inside the root.

root to allow the caterpillars to develop further. All pupae (Figure 5) recovered at the time of root processing, as well as pupae recovered following further devel-



Figure 5. Sweetpotato vine borer shown pupating within a section of sweetpotato root.

opment of the recovered caterpillars, were sexed based on the presence (female) or absence (male) of a prominent notch on the 9th segment (Figure 6) (we found this sex differentiating feature described in Talekar et al. 1992). After sexing, pupae were held separately until adult emergence. Emerged adults were placed in a 30 x 30 x 30 cm screened-side wooden cubical cage that held a sweetpotato root

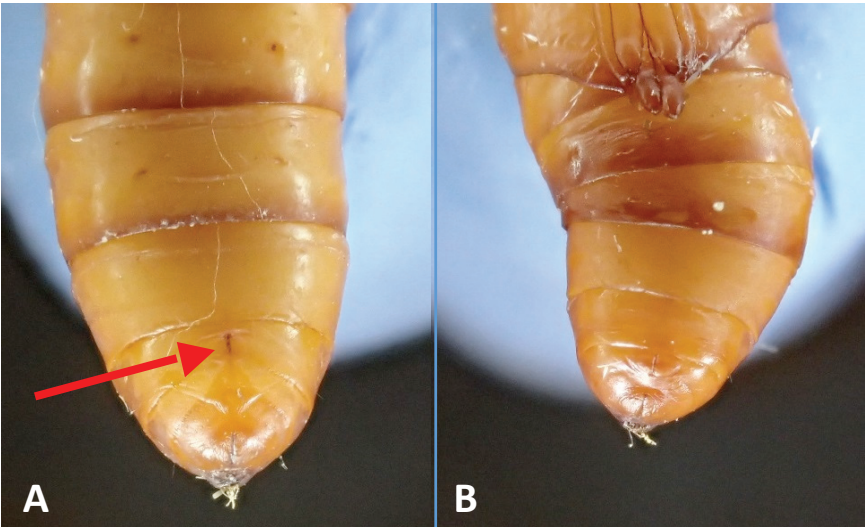


Figure 6. Posterior ventral surface of sweetpotato vine borer pupae showing the presence (A. female) or absence (B. male) of a prominent notch (indicated by red arrow) on the 9th segment.



Figure 7. Eggs laid by female sweetpotato vine borer on a sweetpotato root within a screen-walled cubical.

on the surface of which female moths would lay their eggs (Figure 7). Roots with eggs were then transferred to screened-top four liter HI-PLAS buckets (Highland Plastics, Inc.) and held to allow infesting caterpillars to develop further. The sex of adult moths was readily determined by the presence (male) or absence (female) of a pair of clasper like structures on the last abdominal segment (Talekar et al. 1992; Figure 8).

Test 1. Test of the relative effectiveness of different trap types for detection of sweetpotato vine borer field populations. There was a significant difference in average catch of adult male *O. anastomosalis* among trap types ($F = 18.25$; $df = 2,6$; $p = 0.0028$). Catch in delta traps was significantly (and at least five times) greater than catch in either wing or Heliiothis traps (Figure 9). There was no significant difference in catch between wing and Heliiothis traps. Population detection was also best with delta traps as there was moth capture in delta traps every week (and in every trap in two out of the three weeks) while there was moth capture in only one out of the three weeks for both the wing and Heliiothis traps.

Test 2. Effect of trap height on detection of sweetpotato vine borer field populations. There was a significant difference in average catch of adult male *O. anastomosalis* with variation in trap height ($F = 6.814$; $df = 4,10$; $p = 0.0065$). Highest catch was in traps positioned 0.5 or 0.75 m above the sweetpotato foliage,

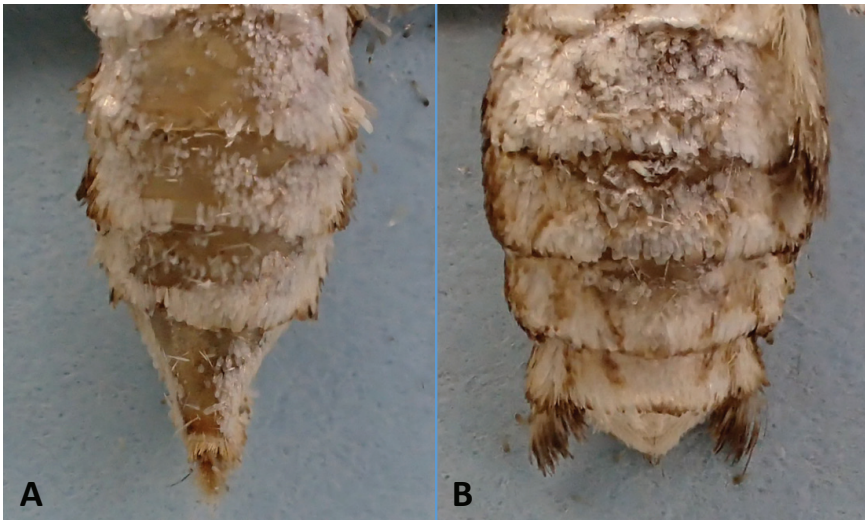


Figure 8. Posterior ventral abdominal surfaces of sweetpotato vine borer adults showing the absence (female) or presence (male) of a pair of clasper like structures on the last abdominal segment. A. adult female; B. adult male.

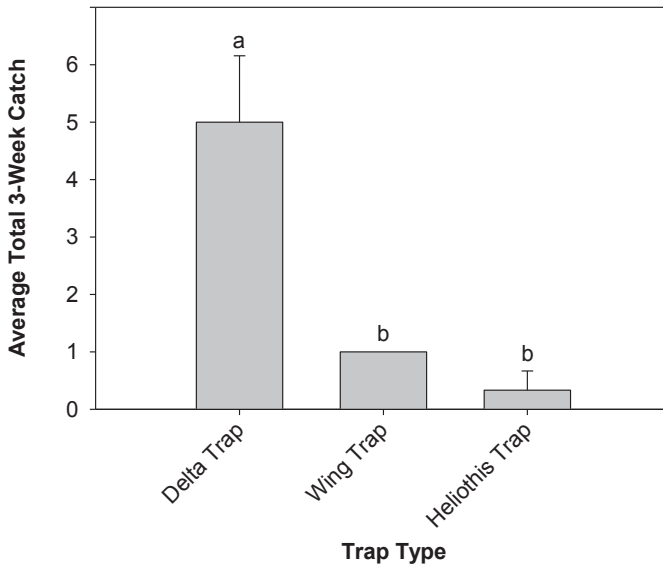


Figure 9. Average total 3-week catch of male sweetpotato vine borer adult moths in three different types of traps baited with binary sex pheromone lure consisting of a 2.0 mg: 4.0 mg ratio of Type 1: Type 2 lure components. See text for further description of the Type 1 and Type 2 components. Columns with the same letters above are not significantly different at the $\alpha = 0.05$ level.

but catch at these two heights was not significantly greater than catch in traps positioned at either 0.25 or 1.0 m above the sweetpotato foliage. Catch in traps positioned 0.5 or 0.75 m above the sweetpotato foliage was, though, significantly greater than catch in traps positioned 1.5 m above the foliage (Figure 10).

Test 3. Effect of trap location on detection of sweetpotato vine borer field populations. There was no significant difference in trap catch with respect to trap location ($F = 0.673$; $df = 2,9$; $p = 0.534$), though, numerically, average catch over the eight week trial was twice as high at edge and border locations than at interior trap locations (Figure 11).

Discussion

Although collection of sweetpotato vine borer-infested roots in the field

by locating roots with associated frass was an effective technique for gathering sweetpotato vine borer caterpillars, having emerged adults lay eggs on roots in the cubical screened-side cubical cage in the DKI-PBARC insect holding room led to much better caterpillar recovery per root because multiple eggs were typically laid on a provided root, whereas, in the field-collected roots, one typically recovered only one or two caterpillars per infested root. Recovery of infested roots from harvested sweetpotato fields was, also, quite variable from field to field. In some fields, many infested roots could be found, whereas, in other fields, only few infested roots could be found. Although greater caterpillar recovery could be achieved through laboratory-infested roots, one needed a good supply of adults so that both adult males and females were simultane-

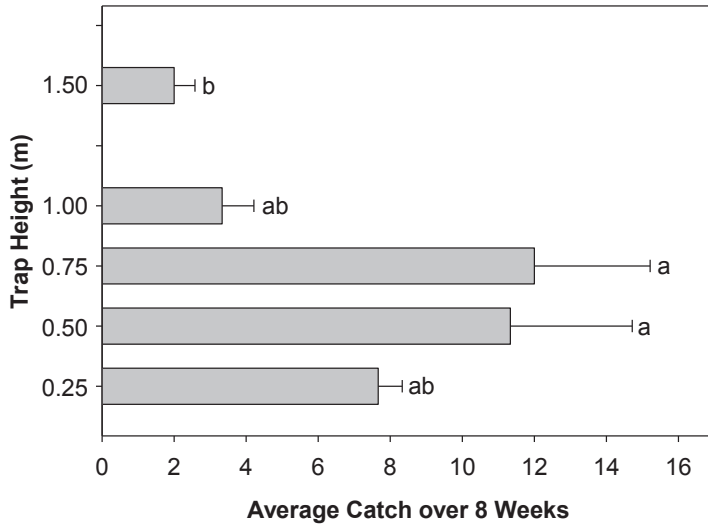


Figure 10. Average weekly catch of adult male sweetpotato vine borer moths in delta traps baited with binary sex pheromone lure consisting of a 2.5 mg: 5.0 mg ratio of Type 1: Type 2 lure components and positioned at different heights above sweetpotato foliage. See text for further description of the Type 1 and Type 2 components. Bars followed by the same letters are not significantly different at the $\alpha = 0.05$ level.

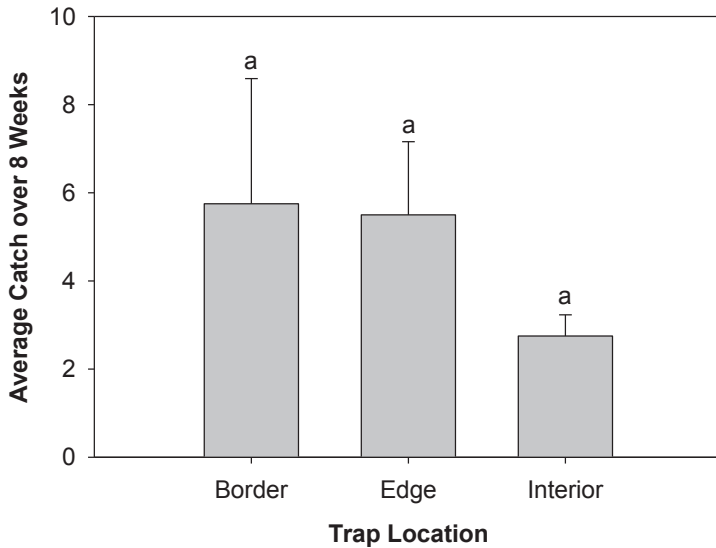


Figure 11. Average weekly catch of adult male sweetpotato vine borer moths in delta traps baited with binary sex pheromone lure consisting of a 2.0 mg: 4.0 mg ratio of Type 1: Type 2 lure components and positioned at different locations in or around a sweetpotato field. Columns with the same letters above are not significantly different at the $\alpha = 0.05$ level.

ously present, and mortality at the pupal stage limited numbers of adults available for in-lab infestation of sweetpotato roots.

The results presented here indicate that delta traps baited with the binary sex pheromone are good tools for population detection, with five times or more moth recovery and higher percentage detection relative to the other trap types tested. Traps should be placed between 0.5 to 0.75 m above the sweetpotato foliage for best adult male moth recovery. Moths were present throughout the sweetpotato field as well as in near-border areas, with catch possibly more reliable towards the edges of the field.

Although this study focused on detection through trapping, no studies have yet been conducted to assess whether the binary sex pheromone has potential for sweetpotato vine borer population suppression through male annihilation or mating disruption approaches. Five other crambid species have also been reported to have Z3,Z6,Z9-23:H as a sex pheromone component (see McQuate et al. 2019, and references therein). Of these, the binary pheromone system of the tomato fruit borer moth, *Neoleucinodes elegantalis* (Cabrera et al. 2001), has shown promise for population field suppression through mass trapping. Mass trapping with a selected blend of the binary pheromone system has significantly reduced in-field damage of tomatoes and is used to control *N. elegantalis* infestations in tomato plantations in Colombia, Brazil, Ecuador and Venezuela (Jaffe et al. 2007).

Acknowledgments

This study was funded by base funding of USDA-ARS, Daniel K. Inouye U.S. Pacific Basin Agricultural Research Center, Hilo, HI, USA. We thank the sweetpotato farmer for permission to conduct the trapping trials in his fields. We thank DKI-PBARC technicians MaryAnn

Villalun and Lori Carvalho for assistance with trap servicing. This article reports the results of research only. Mention of a proprietary product does not constitute an endorsement or a recommendation by the USDA for its use. USDA is an equal opportunity provider and employer.

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