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ATTRACTION AND INHIBITION OF ATTRACTION OF COFFEE BERRY BORER, *Hypothenomus hampei*. L. (COLEOPTERA: SCOLYTIDAE)

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Abstract: White multiple funnel traps from which methanol:ethanol mixtures are released are significantly more attractive to *Hypothenomus hampei* than similarly baited multiple funnel traps of other colors. Methanol:ethanol baited traps constructed of small funnels with small cone angles are as attractive as baited traps constructed of large funnels with large cone angles. Multiple funnel traps consisting of 2 funnels are as efficient as those containing 5. Methanol:ethanol mixtures varying in composition from 97:3 to 40:60 were found to be attractive to *H. hampei.* Methanol:ethanol (3:1) mixtures were attractive over a range of release rates varying from 22-1068 mg / 24hr. Optimal release of methanol:ethanol mixtures (3:1) is in the range of 200-300 mg / 24hr. Methanol:ethanol (3:1) extracts of green coffee berries were no more attractive to *H. hampei* than methanol:ethanol (3:1) released at sub-optimal (22 mg / 24 hr) rates. Traps baited with 20 green coffee berries were less attractive to *H. hampei* than traps from which methanol:ethanol (3:1) was released at 22 mg / 24 hr. Green leaf volatiles, especially Z-3-hexenol, are highly repellant to *H. hampei*, 3-methylcyclohex-2-en-1-one was not repellant while verbenone was mildly repellant and alpha-pinene exhibted no attractive or repellant activity.

The most effective trap for female *H. hampei* was constructed of small white cups baited with a lure emitting 186 mg / 24hr of 3:1 methanol:ethanol.

Key words – *Hypothenemus hampei*, coffee berry borer, kairomone-baited traps, green leaf volatiles.

INTRODUCTION

The coffee berry borer, *Hypothenemus hampei*, is the world's most serious insect pest of coffee affecting all major growing areas except Hawaii and Costa Rica (Borbon 1989). A typical coffee plantation yields 10-35 million berries per harvest of which 5-20% are normally infested with berry borer. This leads to an estimate of several million female berry borers per hectare per crop cycle (Borbon 1989). Females oviposit in berries at any stage after the pulp content has acceptable levels . At the stage of berry development in which there are an abundance of immature green berries females usually feed on several berries before ovipositing in one. A single female colonizes the majority of attacked

berries (Ref). After entering a berry females lay 10-20 eggs that yield 8-10 females (flying) for every male (non-flying) (Ref). Feeding by larvae and adults typically causes 5-20% reductions in bean weight after processing. Only females disperse to seek new berries in which to feed and oviposit. Scrupulous harvesting of berries is recommended to maintain low populations but alternate hosts allow *H. hampei* females to feed (not oviposit) and maintain a population until a subsequent crop of berries is acceptable (Ref). The usual method of intervention to manage populations of *H. hampei* is application of endosulfan to which resistance has been reported (Ref).

Several investigators have reported interception of dispersing females in traps. *H. hampei* is attracted to mixtures of methanol and ethanol both of which are reported to be emitted from coffee berries (Gutierrez-Martinez and Ondarza, 1996; Mendoza Mora, 1991). The most attractive blend is reported to be a 3:1 mixture of methanol:ethanol (Mendoza Mora, 1991). Release rates from 60 mg / day (Mendoza Mora, 1991 to 20,000 mg/day (Mathieu et al., 1997) have been examined. Multiple funnel traps of the size and design of Lindgren used in the US and Canada to trap other scolytids (Borden et al., 1982) are reported to be more efficient for *H. hampei* than other designs (Mendoza Mora, 1991). French investigators reported that released *H. hampei* are captured 1.6 X more efficiently in red than white multiple funnel traps (Mathieu et al., 1997).

Most economically important temperate-zone scolytids are pests of conifers. These scolytids invariably use aggregation pheromones and host odors in host selection and colonization. The necessity for *H. hampei* to produce and respond to adult-produced pheromones is considered to be low due to the maturation and mating of males and females inside coffee berries.

The primary activity of female *H. hampei* after emergence from coffee berries is location of a mature coffee berry for suitable for oviposition. For most insects efficiency in host location is thought to be increased by response to repellants such as anti-aggregation pheromones and volatiles of non-host plants (Visser, 1986). Verbenone, an anti-aggregation pheromone for *Dendroctonus ponderosae* (Amman et al. 1989) and *Ips typographus* (Bakke, 1981; Schlyter et al 1987a, 1989) bark beetles has been shown to decrease attraction of these species to traps and hosts baited with aggregation pheromones. Hexanyl and hexenyl aldehydes, alcohols and acetates are prominent

volatiles produced by green leaves of non-coniferous trees that are non-hosts for coniferphagous beetles. Dickens, Billings and Payne first demonstrated that alcohol and aldehyde components of green leaf volatiles decreased capture rates of *Dendroctonus frontalis*, *Ips grandicollis* and *I. avulsus* to traps baited with their aggregation pheromones and host volatiles (1992, 1993, 1995). As reviewed by Zhang et al. (1998) green leaf alcohols and aldehydes have been shown to behave similarly to the confier infesting scolytids *D. ponderosae, D. rufipennis, D. brevicomis, I. typographus, I. duplicatus, Tomicus pinerda* and three ambrosia beetles *Trypodendron lineatum, Gnathotrichus sulcatus* and *G. retusus.*

The goal of this study was to develop an effective trap for *H. hampei* and to use the trap to examine the biological activity of non-host volatiles, injury related green leaf volatiles and species-specific anti-aggregation pheromones, verbenone and MCH.

Materials and Methods

Study sites:

The study site was a 3 Ha plot of 2.5 meter high commercial coffee planted in rows 1.9 meters apart with 1 meter between plants in Finca Sta. Rosa near Jinotape, Nicaragua. The plot (Lat N 11 54' 38" Long E 86 13' 8" GPS) was surrounded on all sides by a 10 meter roadway and very which was bounded by similar plantings of coffee on all sides.

Infestation Surveys

A survey of damage conducted May 15, 1999 by examination of 100 berries taken at random from 10 plants in the plot revealed over 20% of coffee berries were infested with *H. hampei*.

Trap Designs

Lures were hung from second funnel of all funnel traps and except where noted water was the killing agent.

Funnels of multiple funnel traps (A) were constructed of cut and shaped white and colored cardboard or plastic file folders suspended by stapling on 3 strips of white cotton cloth. All funnels of all traps were consistently of one color both inside and outside of funnels except black funnels which were black on outside and white on inside. Tops of traps of type A were white plastic tops of 19 liter buckets. Insects were retained in bottoms in white plastic drinking cups held on the lowest funnel by paperclips and rubber bands.

Funnels of multiple funnel traps B were disposable white polypropylene drinking cups from which bottoms had been removed. Funnels were suspended from string and held in place with paper staples. Insects were retained in a disposable cup of the same size also suspended from the string with staples. Tops were disposable polypropylene picnic plates.

Funnels of multiple funnel traps C were non-disposable white polyethylene drinking cups from which bottoms had been removed. Funnels were held in place by nylon fishing line woven through 2-3 holes (3 mm dia) near the top of each funnel. Insects were retained in drinking cup of same size also suspended from nylon string. Tops were white plastic dishes.

Screen traps E and F were white polyethylene with 0.34 cm X 0.34 cm mesh of the overall dimensions given in Figure 1. These traps were coated with Stickem immediately before use. Lures were hung in center of screen.

Methanol:Ethanol lures

Lure X was a 40 mL plastic eyedropper bottle with a 0.2 mm hole in the restricted flow insert. Under laboratory conditions (25-27°C day maximum 15-17°C night minimum) this lure emitted 22 mg / 24hr when charged with 3:1 methanol:ethanol.

Lure Y was a permeable plastic bag which under laboratory conditions (25-27°C day maximum 15-17°C night minimum) emitted 62 mg / 24hr when charged with 3:1 methanol:ethanol.

Lure Z was a permeable plastic bag with one compartment charged with methanol and a second charged with ethanol which under laboratory conditions (25-27°C day maximum 15-17°C night minimum) emitted a total of 200 mg / 24hr.

Candidate repellants and lures

Test repellants were evaporated from permeable plastic sachets that emitted the following quantities of chemicals under laboratory conditions (25-27°C day maximum 15-17°C night minimum): Z-hex-2-en-1-ol (Bedoukain Research) (1.4 mg / 24hr), E-hex-2-en-1-ol (1.6 mg / 24hr), Z-hex-3-en-1-ol (Bedoukain Research) (1.7 mg / 24hr), E-hex-3-en-1-ol (1.8 mg / 24hr), Z-hex-2-en-1-al (1.3 mg / 24hr), E-hex-2-en-1-al (1.4 m / 24hr), Z-hex-3-en-1-al (1.4 mg / 24hr), E-hex-3-en-1-al (1.5 mg / 24hr), verbenone (Bedoukain Research) (1.6 mg / 24hr), 3-methylcyclohex-2-en-1-one (Bedoukain Research) (4.9 mg / 24hr) α-Pinene (Aldrich Chemical) (100 mg / 24hr).

Experimental design

Traps were hung at chest height on coffee bushes at least 5 plants from any border. Replicates of each experiment contained treatments placed randomly (complete randomized block design) in a row with at least 9 plants between any trap. Replicates were separated by 9 rows of plants. Insects were counted and removed daily between 9:00 AM and 12:00 noon at which time traps were moved to new (random) positions within replicates. An examination of flight patterns of female H. hampei revealed that no flight occurred before noon. Flight began about 12:30 PM, peaked between 3:00 and 4:00 PM and was negligible by 5:00 PM.

Data analysis

Daily capture rates for each experiment were recorded. Daily capture rates were analyzed to identify significant day-to-day differences. Only those daily capture rates for which no significant differences were found were combined within an experiment. Data was tested for heteroscadiscity and if necessary, transformed to achieve homogeneity (Zar 1984). Data was analyzed using Systat 5.2.1, fully factorial ANOVA analysis routine. Means are presented untransformed. Means topped or followed by a different letter are significantly different by Bonferonni t-test, $P > 0.95$.

Analysis of headspace volatiles

Thirty five fresh picked red coffee berries (1 hr) were placed in a 125 mL Erlenmeyer flask capped by a rubber septum. Extraction was via a SPME fiber of

Carboxen-polydimethylsiloxane of 75 micrometers diameter for 2 minutes at 20 minutes and hourly to 8 hours.

Thirty five fresh picked halved red coffee berries (1 hr) were placed in a 125 mL Erlenmeyer flask capped by a rubber septum. Extraction was via a SPME fiber of Carboxen-polydimethylsiloxane of 75 micrometers diameter for 2 minutes at 20 minutes and hourly to 8 hours.

Analyses were conducted on a Hewlett Packard 6890 gas chromatograph equipped with a 30 m X 0.32 mm ID, DB-1MS column (J & W Scientific) coupled to a Hewlett Packard 5793 quadrapole mass spectrometer. The injector temperature was 250^{o}C, a temperature program of ?? was used for the column and the He carrier gas had a linear velocity of 40 cm/sec. Selective ion monitoring at m/Z 15, 29, 31 and 45 were used for analysis of methanol and ethanol. Ion with m/z of 41, 67 82 and 100 were used to monitor Z-hex-3-en-1-ol. Analysis for the remaining 7 green leaf volatiles listed above was by full scan MS in the portion of the gas chromatogram in which standards of each eluted. Detection limits by the full scan technique were ~ 1 ng / L. Standards of each chemical to be analyzed were prepared by injection of a known amount into a 5 L glass flask capped with a rubber septum. After an hour a 75 micrometer diameter SPME fiber was injected into the standard for 2 minutes and then analyzed by GC/MS. This allowed determination of detection limits and a standard response for each chemical

RESULTS AND DISCUSSION

Brazilian investigators previously demonstrated that vane traps are less efficient in capture of *H. hampei* than multiple funnel traps of the same design as those used in North America to capture scolytid bark beetles (Mendoza Mora, 1991). In the only reported test of trap color preference French workers examined recapture of released *H. hampei* within a caged environment (Mathieu et al., 1997). Under these conditions using methanol:ethanol lures charged with 1:1 mixtures of methanol:ethanol and releasing 500, 1,500 or 20,000 mg / 24 hr, red traps were found to be more effective than white traps. Tests were not conducted under normal field conditions. In the present study capture of *H. hampei* in multiple funnel traps (Type A, Figure 1) of six different colors using lures charged with 3:1 methanol:ethanol and releasing 44 mg / 24hr revealed that white traps

were superior to other colors tested (Figure 2). White traps were > 7.5 X more efficient than red traps (Figure 2). The observation that *H. hampei* is captured efficiently in white traps is expected since this species is highly photopositive. The relatively high ranking of black traps in the current test (Figure 2) could be due to the construction of black traps of funnels that were black on the outside but white on the inside. All other traps were constructed of funnels that were the same color on both sides.

Figures 1 & 2 near here.

The size and cone angle of funnels in Trap A (Figure 1) is very similar to funnels of the Lindgren multiple funnel trap that has been used for nearly two decades to trap scolytids in North America. It has recently been demonstrated that the efficiency of capture of ambrosia beetles in Lindgren multiple funnel traps increases with trap size (Slessor et al JCE 2000). Although large surface areas in multiple funnel traps can be achieved by using large diameter funnels with small cone angles the Lindgren design uses large cone angles that, although not explicitly stated, would be expected to increase the efficiency of retention of intercepted insects that do not fall vertically after striking the trap. In the current study we examined the efficiency of several variations of the multiple funnel trap as well as the efficiency of glue coated plastic screens in the capture of female *H. hampei*. We initially examined the relative efficiency of Trap A and a multiple funnel Trap B (Figure 1) with a dramatically different cone size, cone angle and capture surface area (Figure 3). Multiple funnel Trap B proved to be as efficient as Trap A. The equivalent efficiency of multiple funnel traps with large and small cone angles indicates that after striking a trap surface *H. hampei* drop almost vertically.

Figure 3 near here.

Capture of scolytids in traps consisting of mesh screens has been reported to be efficient (Borden et al., 1982). In the next trial we compared the capture rate of a large screen Trap D and small screen Trap E (Figure 4). The small screen trap was as efficient as the large screen trap even though the surface area of the latter is only 47% of the

former. This experiment also compared multiple funnel Trap B with a smaller multiple funnel Trap C and the latter with Vapona as the killing agent instead of water. Although multiple funnel Trap C has less capture area than Trap B or any of the screen traps it is the most efficient trap in this experiment (Figure 4). The observation that Vapona is as efficient as water in retaining captured *H. hampei* allows use of this longer acting killing agent in traps. The results of this experiment encouraged us to observe approach of *H. hampei* to Trap C in the field. Although no statistical analysis was conducted we determined that most *H. hampei* approached the lower portion of Trap C. These observations suggested that a trap containing fewer funnels might be as efficient as Trap C. An experiment comparing Trap C with 5, 3 and 2 funnels revealed they were equally efficient in capture of *H. hampei* (Figure 5). The observed trap efficiencies can be rationalized by assuming that if approaching *H. hampei* miss a trap on first approach they probably approach again.

Figures 4 & 5 near here.

Brazilian investigators (Mendoza Mora, 1991) determined that mixtures of methanol and ethanol rich in methanol were more attractive than mixtures rich in ethanol. In this study we determined that response of *H. hampei* is relatively constant to methanol:ethanol ratios of 97:3 to 40:60 (Figure 6). Attraction to either pure methanol or pure ethanol is significantly lower than to mixtures of the two alcohols. The observation that ethanol was attractive to *H. hampei* was originally made by Benassi (1990). He reasoned that the almost universal attraction of conifer infesting scolytids by ethanol might also be observed in *H. hampei*. This work was followed by a more extensive study by Mendoza Mora, 1991 in which it was observed that mixtures of methanol and ethanol were more attractive to *H. hampei* than ethanol alone. Mendoza Mora (1991) was encouraged to examine methanol:ethanol mixtures by reports that mixtures of ethanol with methanol and acetaldehyde as well as other host volatiles were more attractive hard wood borers such as *Agrilus bilineatus* than ethanol alone (Montgomery and Wargo, 1983; Dunn et al 1986). Analysis of the headspace above fresh red whole coffee berries revealed methanol and ethanol were present at low concentrations initially and increased

to~85 ng/L for methanol and ~400 ng/L for ethanol after 8 hours. If berries were cut in half headspace analysis gave initial methanol concentrations of 13 ng/L and ethanol concentrations of 100 ng/L which rose to 725 ng/L and 200 ng/L after 8 hr. These analyses attest to the incisive analysis of Mendoza Mora in his selection of methanol and ethanol as potential attractants of *H. hampei.*

Figure 6 near here.

Previous studies of attraction of *H. hampei* to traps from which different amounts of 3:1 methanol:ethanol are released suggest that in the range of 60 to 180 mg / 24 hr capture rates decline (Mendoza Mora, 1991). Similarly, increasing release rates of 1:1 methanol:ethanol from 500 to 20,000 mg / 24 hr led to lower capture rates in multiple funnel traps (Mathieu et al., 1997). The first study was plagued by low capture rates (less than 2 H. hampei / trap / day) while the second examination of the effect of release rate was in a caged environment with complicating factors of illumination. In the present work an initial experiment in June 1999 examined the attraction of *H. hampei* to multiple funnel Trap C from which was released methanol:ethanol (3:1) over the range of 22 to 186 mg / 24 hr. Over this release rate range capture rates increased numerically but not significantly. In a second experiment in September 1999 release rates of methanol:ethanol (3:1) were varied from 53 to 1068 mg / 24 hr. In this experiment capture rates increased significantly between 53 and 319 mg / 24 hr. and then declined slightly. Attraction of *H. hampei* to Trap C was statistically equivalent for methanol:ethanol (3:1) release rates in the range of 212 to 1068 mg / 24 hr with attraction to traps baited with lures releasing 212-319 mg / day being numerically superior (Figure 7).

Figure 7 near here.

Several investigations have been conducted to locate host produced attractants that could increase the attraction of methanol:ethanol mixtures to *H. hampei*. Ticheler (1961) showed that green coffee beans were more attractive than red coffee beans to *H.*

hampei in a choice bioassay. It has been reported that *H. hampei* prefer red coffee berries over green ones (Mendoza Mora, 1991; Giordanengo, et al. 1993). Extracts of green coffee berries with polar organic solvents such as acetone, ethyl acetate and ethanol provide attractive mixtures (Giordanengo, et al. 1993). Extracts of dry, red and green coffee beans and bean parts with polar organic solvents provided equally attractive extracts (Gutierrez-Martinez and Ondarza, 1996).

We compared the capture of *H. hampei* in Trap B baited with methanol:ethanol, methanol:ethanol extract of green coffee berries, methanol:ethanol and 20 green coffee berries, 20 green coffee berries or unbaited (Figure 8). Unbaited traps and traps containing green coffee beans were not attractive to *H. hampei*. Traps from which methanol:ethanol were released at suboptimal levels were as attractive as traps from which methanol:ethanol were released at the same rates but which contained green berry extract or green berries. Thus no evidence was found that coffee berries contain additional attractants that add significantly to methanol:ethanol (3:1) released at 22 mg / 24 hr.

Figure 8 near here.

Push-pull strategies for the management of insect pests are attractive if both attractants and repellants can be located. Rational and successful searches for both have led to the development of push-pull strategies for the management of scolytids such as *Dendroctonus frontalis*, the southern pine beetle. US researchers slow the spread of these aggressive pests of conifers by attraction to trees baited with aggregation pheromones while simultaneously baiting trees in advance of a progressing infestation with verbenone, anti-aggregation pheromone, for this species. As a prelude to the development of push-pull strategies in the management of *H. hampei* we undertook the search for repellants. Our search utilized non-host volatiles and species-specific anti-aggregation pheromones of other scolytids.

An initial experiment tested the non-host volatiles α-pinene and green leaf volatiles as repellants for *H. hampei* (Figure 9). α-Pinene was not repellant while a mixture of 8 green leaf volatiles [alcohols, (E)-hex-3-en-1-ol, (Z)-hex-3-en-1-ol, (E)-hex-2-en-1-ol,

(Z)-hex-2-en-1-ol; aldehydes, (E)-hex-3-en-1-al, (Z)-hex-3-en-1-al, (E)-hex-2-en-1-al and (Z)-hex-2-en-1-al] significantly decreased capture rates to methanol:ethanol baited multiple funnel traps. While green leaf volatiles are repellant to a large number of conifer infesting scolytids (Zheng et al. 1998) they are not repellant to all scolytids. They increase attraction of the smaller European elm bark beetle, *Scolytus multistraitus* to its aggregation pheromone (Dickens et al., 1990). We suspected that the repellant effect of green leaf volatiles to female *H. hampei* could lie in their recognition as non-host vilatiles. Indeed, GC/MS analysis of red coffee berries and revealed that less than 1 ng/L of any of the green leaf volatiles tested were present in the headspace of fresh red coffee berries or fresh red halved coffee berries. The amount of Z-hex-3-en-1-ol in headspace volatiles of these samples was less than 0.02 ng/L.

Figure 9 near here.

In a second experiment capture rates of *H. hampei* in multiple funnel traps containing lures charged with methanol:ethanol near to which were placed lures emitting all eight green leaf volatiles were compared with traps in which the repellent mixture consisted only of the alcohol or aldehyde components of the green leaf volatile mixture (Figure 10). Both alcohol and aldehyde mixtures possessed repellency equivalent to the combined mixture of alcohols and aldehydes. Because the alcohols in the total blend are less irritating and more stable under field conditions we pursued identification of active components in the alcohol blend (Figure 11). In both experiments described in Figures 9 and 10 candidate repellant lures were placed outside traps.

In a third experiment capture rates of *H. hampei* in multiple funnel traps containing lures charged with methanol:ethanol were compared with capture rates of equivalently baited traps in which were placed lures emitting the anti-aggregation pheromones, 3-methylcyclohex-2-en-1-one (MCH), or verbenone. Alternatively traps were baited with methanol:ethanol lures and contained lures emitting individual green leaf alcohols or all 8 green leaf volatiles previously tested. The design of this test differed from that used in previous tests in that lures emitting candidate repellants were placed inside traps. Of the two species-specific anti-aggregation pheromones tested only

verbenone was significantly repellant. Repellency observed in Figure 9 for all eight green leaf volatiles that were released from a position 10-20 cm from the edge of the second funnel of traps was lower than the 90% repellency observed for the same mixture (Figure 11) when it was placed inside the trap. Repellant activity of each green leaf alcohol tested was statistically equivalent to the mixture of 8 green leaf volatiles but Z-hex-3-en-1-ol and E-hex-2-en-1-ol presented separately appeared to be superior repellants (Figure 11). These two alcohols usually exhibit the highest repellant activity of green leaf volatiles for other scolytids (Borden et al. 1996; Wilson et al. 1997).

Populations of *H. hampei* can reach several million / ha. Capture rates observed in this study (during crop ripening) did not suggest mass-trapping could be a viable strategy for management. We observed that after harvest competition from fruit decreased to the point that methanol:ethanol baited (200 mg / 24 hr) Trap C routinely captured in excess of 1,000 *H. hampei* / day (Bourbon et al. unpublished). We are presently investigating the obvious extension of the above in a push-pull strategy for management of *H. hampei*.

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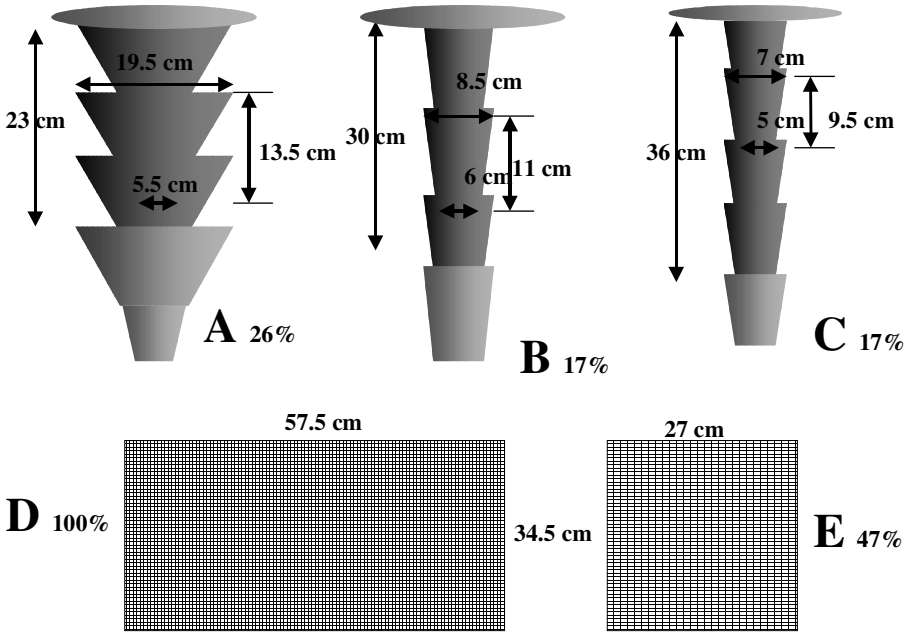


FIG. 1 Trap types tested for efficiency in capture of female *H. hampei.* Percentages refer to surface area available for capture releative to the large screen D.

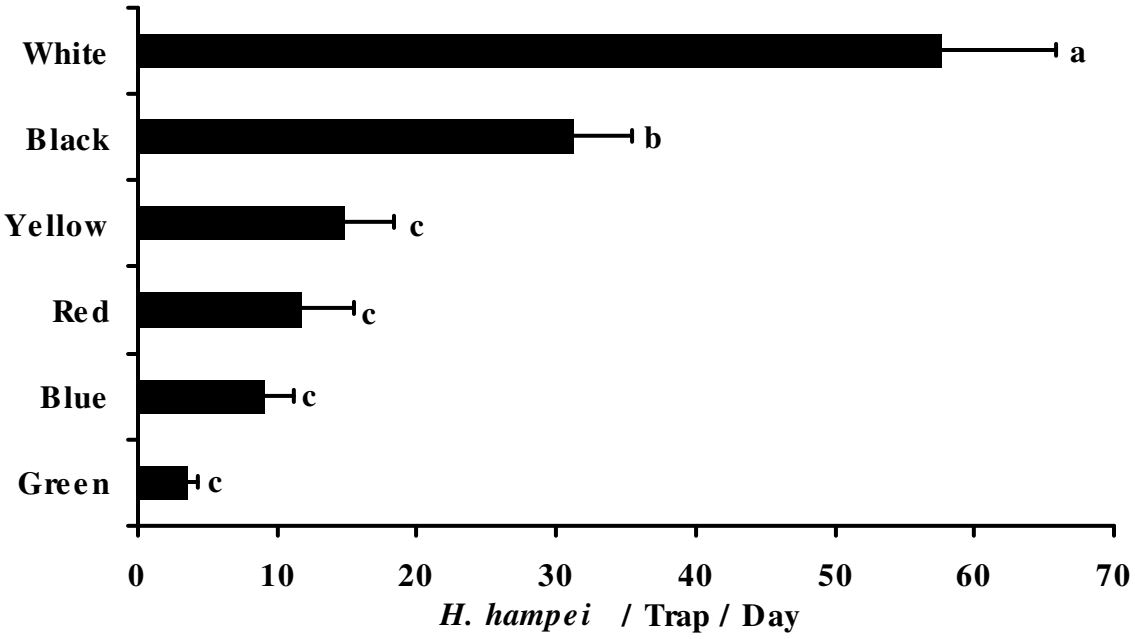


Figure 2. Mean (+SEM) female *H. hampei* captured in funnel Trap A of different colors each containing 2 dispensers (X) emitting a total of 44 mg / 24 hr from a 3:1 mixture of methanol:ethanol. Eleven replicates conducted each of May 11 and May 12, 1999. ANOVA on sqr (X +1) transformed data (n = 22) gave $F = 27.67$, $df = 5, 132$, $p < 0.05$. Means are presented untransformed.

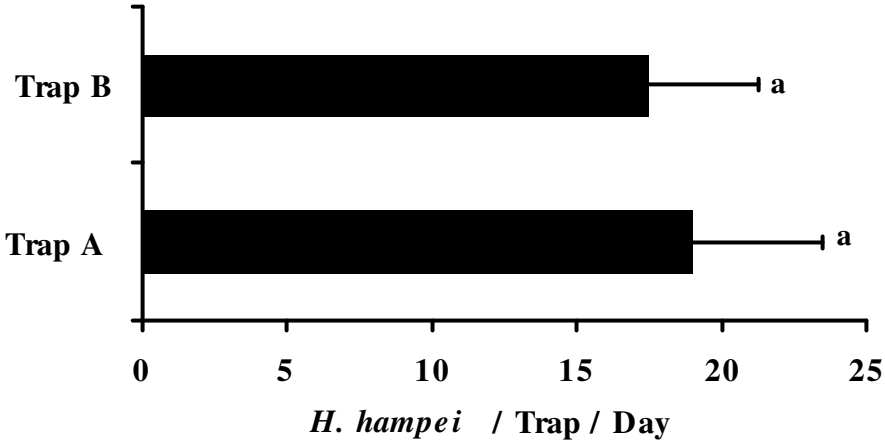
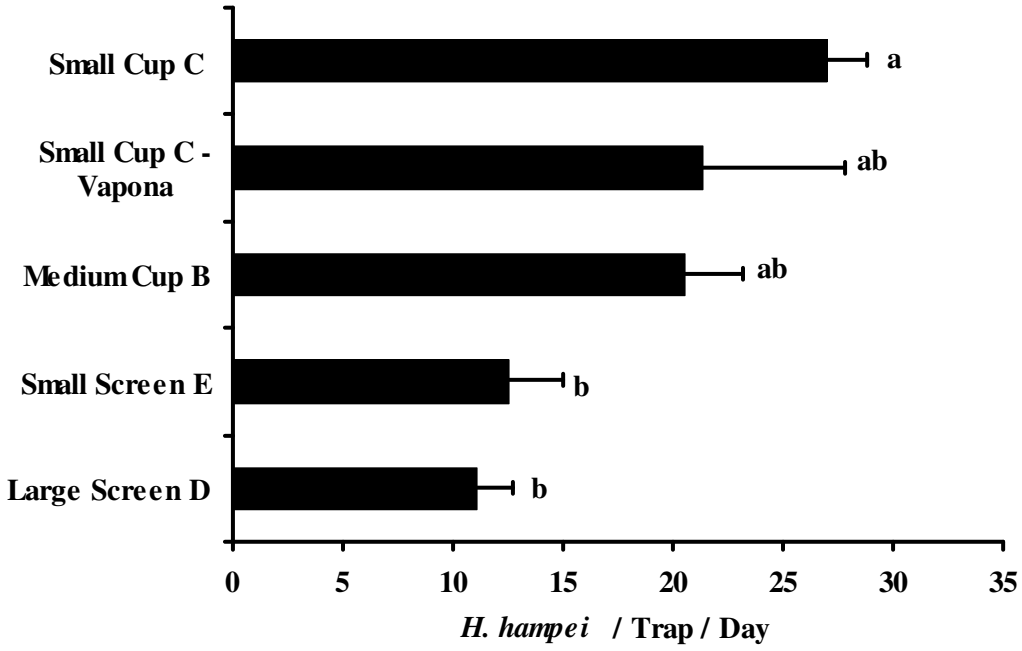


Figure 3. Mean (+SEM) female *H. hampei* captured in multiple funnel Trap A or B containing 1 dispenser charged with methanol:ethanol (3:1, X) emitting 22 mg / 24 hr. Test conducted May 13-14, 1999. ANOVA (n = 19-21) gave no significant difference between treatments.

Figure 4. Mean (+SEM) female *H. hampei* captured in white traps B and C or screens E and F each containing a dispenser (Y) emitting 62 mg / 24 hr when charged with 3:1 methanol:ethanol. ANOVA on log (X+1) transformed data (n = 18) gave df = 4, 40 F=



7.26, p<0.05. Means presented untransformed (+SEM), followed by different letter when different by Bonferonni, t-test (P<0.95). Nine replicates were run on June 17, 1999 then trap positions were re-randomized and nine replicates were run on June 18, 1999.

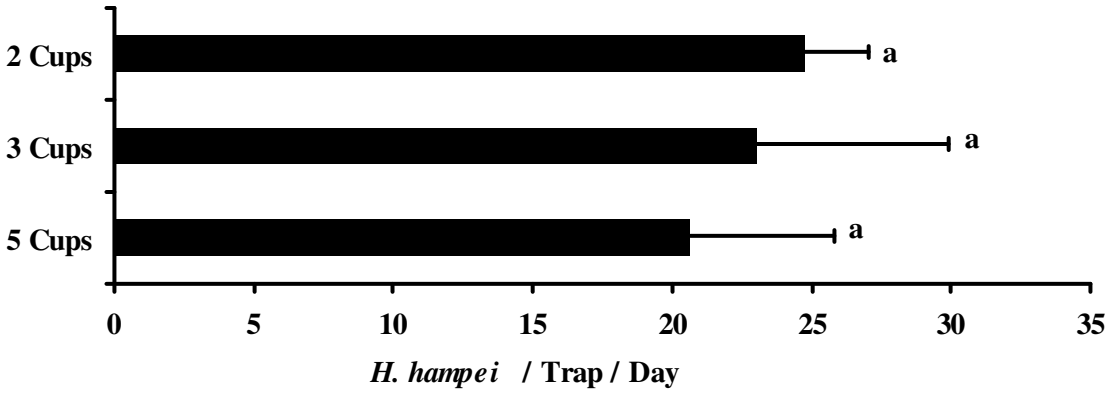


Figure 5. Mean (+SEM) female *H. hampei* captured in white Trap C containing 5, 3 or 2 funnels each containing a dispenser Z emitting 200 mg/day of methanol:ethanol (3:1). Test conducted March 22 to 27, 2000. ANOVA on data (n = 10) gave df = 2, 27 F = 0.15, p < 0.05.

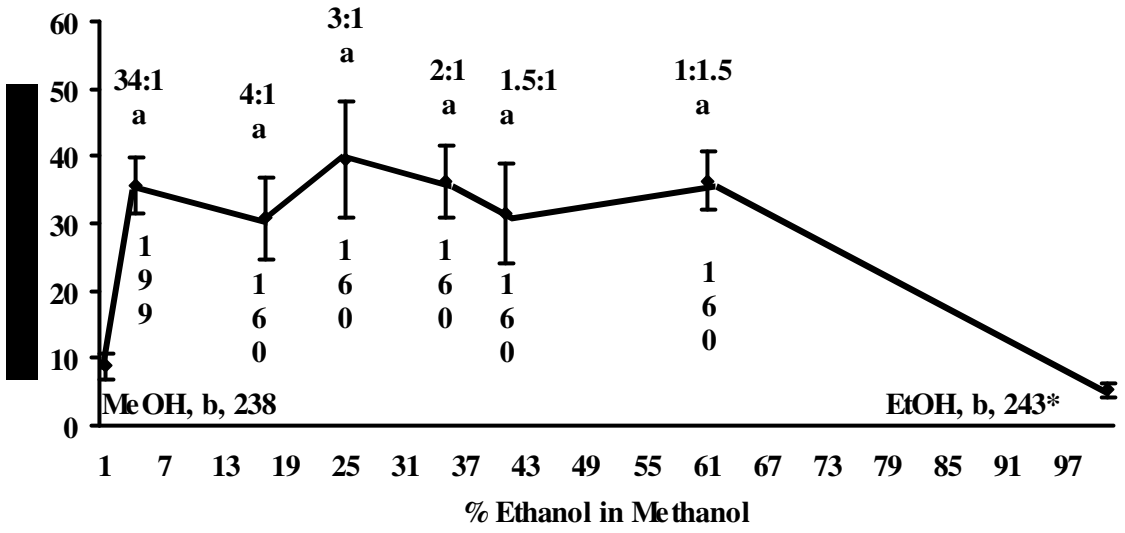


Figure 6. Mean (+SEM) female *H. hampei* captured September 20-23, 1999 in Trap B hung at chest height and baited with membrane release devices releasing methanol and ethanol at the % ethanol and methanol release rate shown. ANOVA (n = 8-16) gave $F = 7.09$, $df = 7, 111$, $p < 0.05$.*Release rate of ethanol.

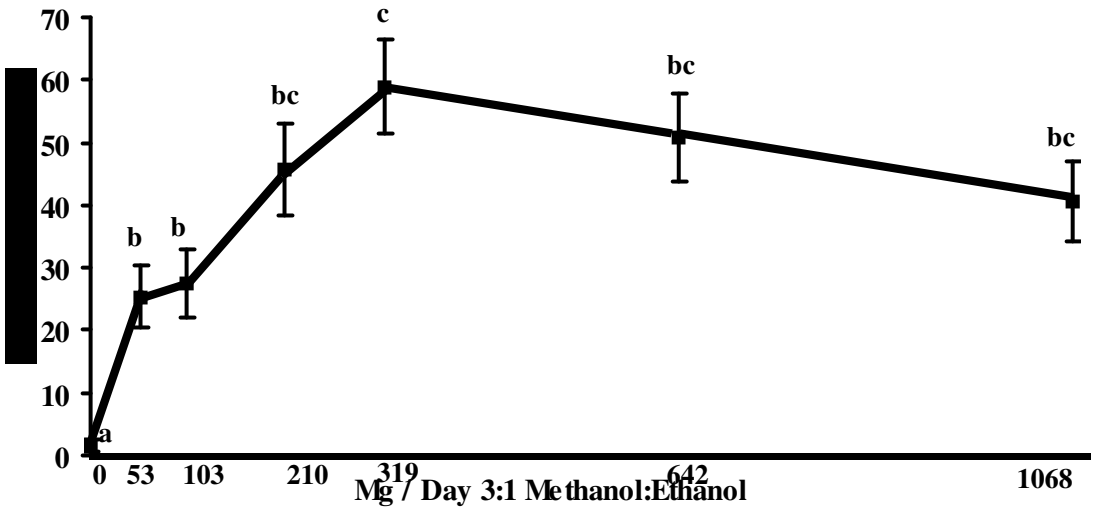


Figure 7. Mean (±SEM) female *H. hampei* captured in Trap B baited with membrane lures releasing 3:1 methanol:ethanol at total release rates given, September 22 and 24, 1999. ANOVA (n = 17-21) on log (X+0.5) transformed data gave $F = 50.50$, $df = 6, 133$, $p < 0.05$.

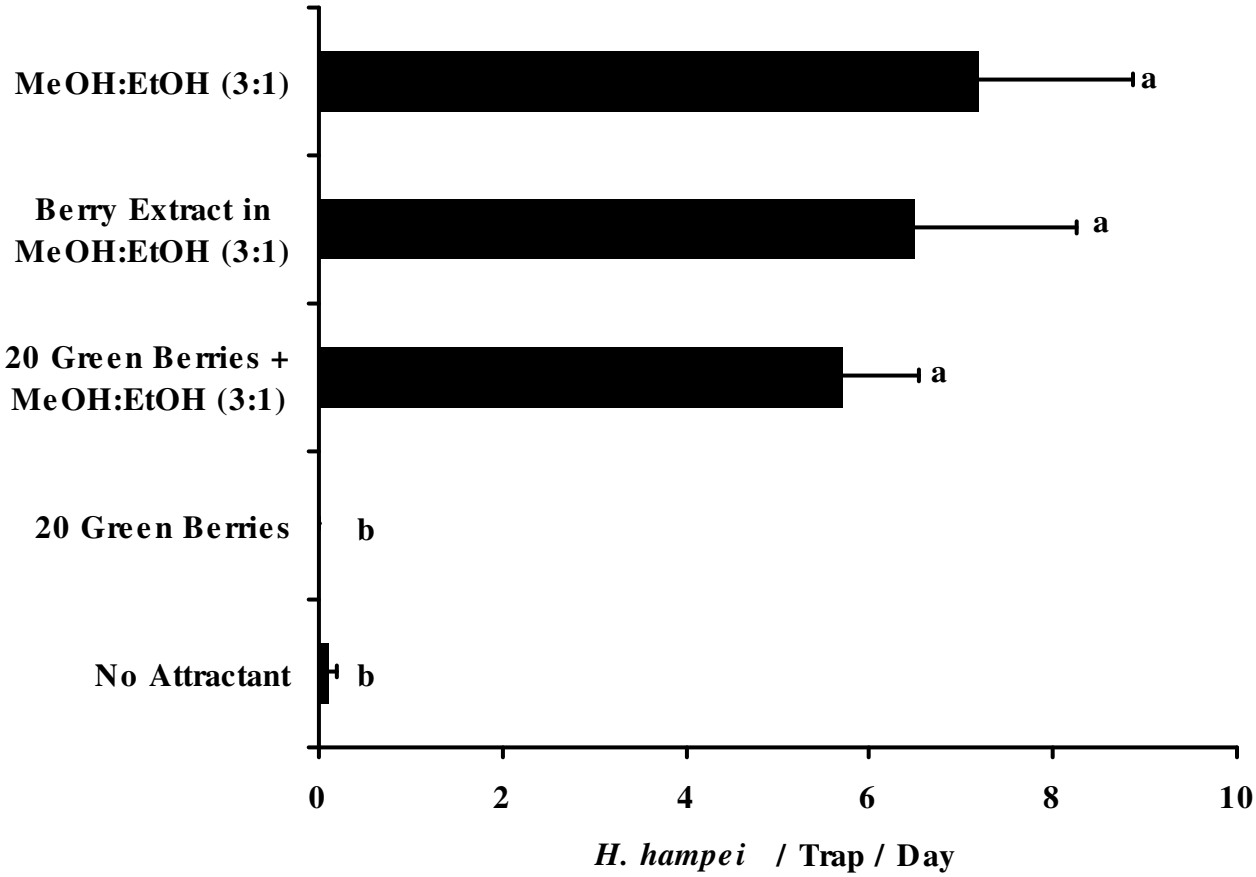


Figure 8. Mean (+SEM) female *H. hampei* captured in Trap B; baited with methanol:ethanol (3:1); methanol:ethanol (3:1) extract of green coffee berries; methanol:ethanol (3:1) and 20 green coffee berries; 20 green coffee berries or unbaited. All methanol:ethanol lures were of type X and emitted 22 mg/24 hr. Experiment conducted June 20, 1999. ANOVA (n = 10) gave $F = 6.99$, $df = 5,54$, $p < 0.05$.

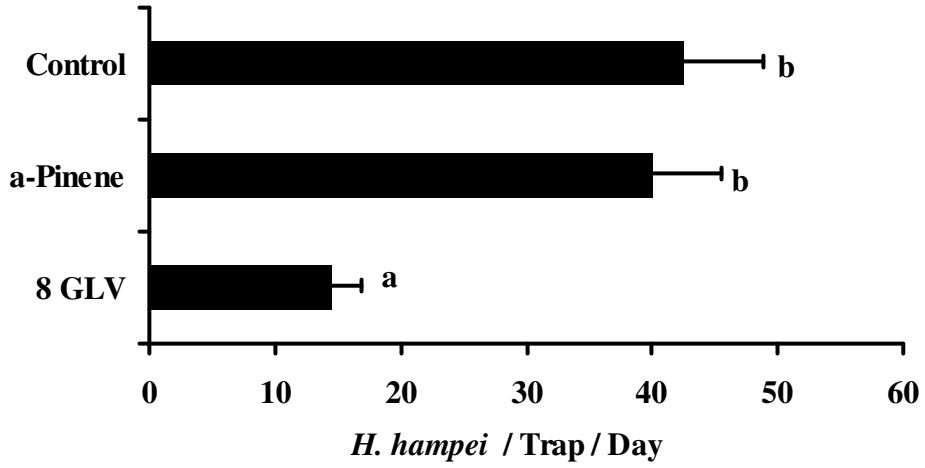


Figure 9. Mean (+SEM) female *H. hampei* captured in white Trap A each containing 2 dispensers (X) charged with 3:1 methanol:ethanol emitting a total of 44 mg / 24 hr. Test conducted May 15-16, 1999. □-Pinene (100 mg/day) or green leaf volatile (GLV) dispensers were hung within 20 cm of the second funnel of traps (outside the traps) in designated treatments. Green leaf volatiles consisted of (E)-hex-3-en-1-ol, (Z)-hex-3-en-1-ol, (E)-hex-2-en-1-ol, (Z)-hex-2-en-1-ol, (E)-hex-3-en-1-al, (Z)-hex-3-en-1-al, (E)-hex-2-en-1-al and (Z)-hex-2-en-1-al (E)-hex-3-en-1-ol released at rates indicated in the methods section. ANOVA (n = 16-23) gave df = 2, 58, F = 8.40, $p < 0.05$.

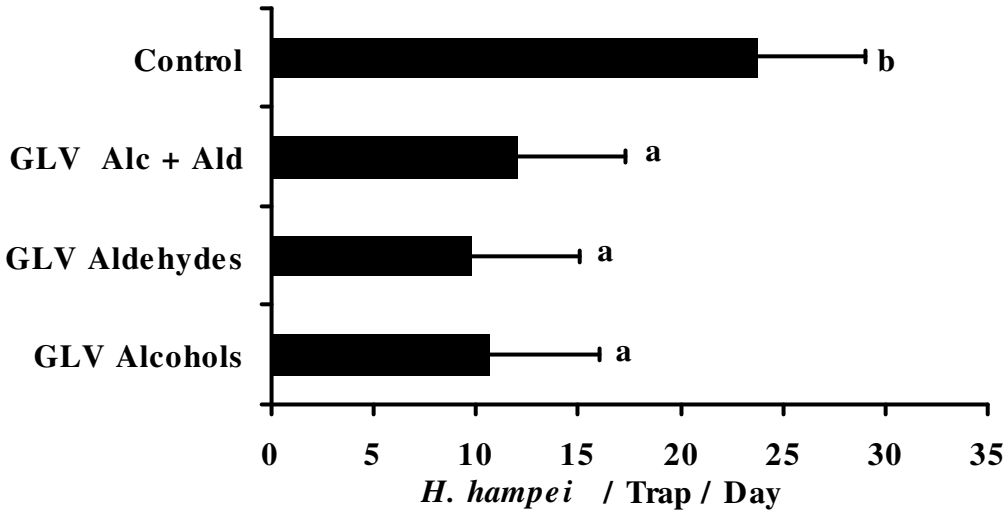


Figure 10. Mean (+SEM) female *H. hampei* captured in white funnel Trap A each containing 2 bottle dispensers (X) charged with methanol:ethanol (3:1) emitting a total of 44 mg / 24 hr. Green leaf volatile dispensers were hung outside traps but within 20 cm of the second funnel. Green leaf volatiles consisted of alcohols: (E)-hex-3-en-1-ol, (Z)-hex-3-en-1-ol, (E)-hex-2-en-1-ol, (Z)-hex-2-en-1-ol, or aldehydes, (E)-hex-3-en-1-al, (Z)-hex-3-en-1-al, (E)-hex-2-en-1-al and (Z)-hex-2-en-1-al released at rates designated in the methods section. Test conducted May 18, 1999. ANOVA on log (X+0.5) transformed data (n = 8-10) gave df = 3, 34, $F = 5.69$, $p < 0.05$.

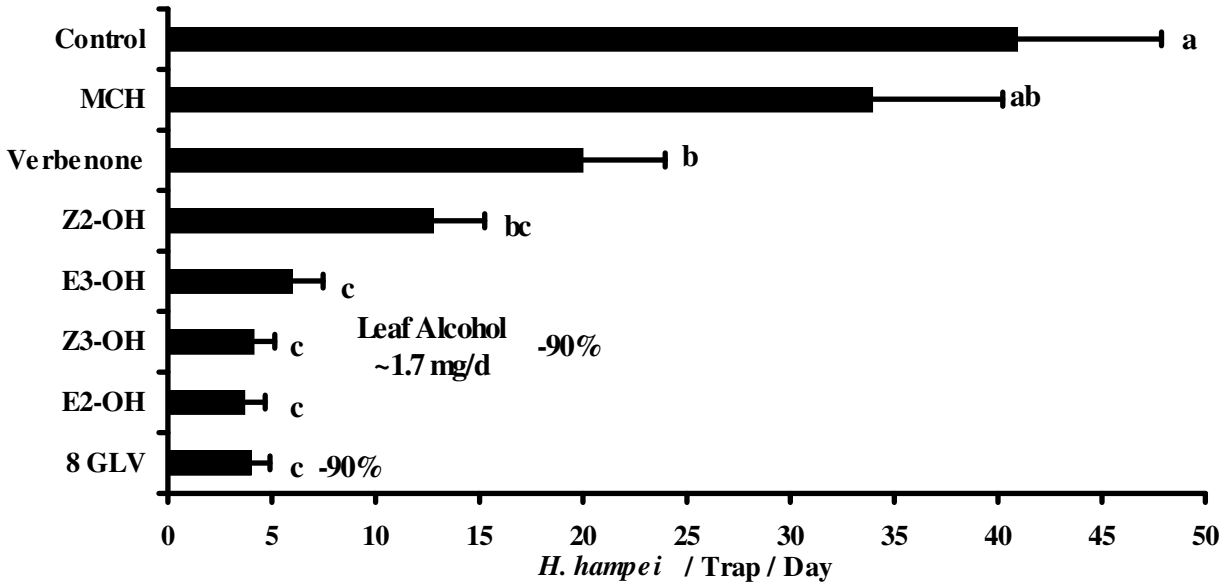


Figure 11. Mean (+SEM) female *H. hampei* captured in Trap C containing a dispenser (Y) emitting 62 mg / 24 hr when charged with methanol:ethanol (3:1). Test conducted June 17-18, 1999. Green leaf volatiles or α-pinene dispensers were hung inside traps in designated treatments. Green leaf volatiles consisted of (E)-hex-3-en-1-ol, (Z)-hex-3-en-1-ol, (E)-hex-2-en-1-ol, (Z)-hex-2-en-1-ol, (E)-hex-3-en-1-al, (Z)-hex-3-en-1-al, (E)-hex-2-en-1-al and (Z)-hex-2-en-1-al (E)-hex-3-en-1-ol, verbenone and 3-methylcyclohex-2-en-1-one released at rates given in the methods section. ANOVA on sqr (X+0.5) transformed data (n = 20) gave df = 7, 150, F= 20.02, $p<0.05$.