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An evaluation of (*Z*)-9-tricosene and food odours for attracting house flies, *Musca domestica,* to baited targets in deep-pit poultry units

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Abstract

Field trials investigating the effect of food baits on catches of *Musca domestica* at toxic targets impregnated with the female sex pheromone, (*Z*)-9-tricosene, were conducted in a caged-layer deep-pit poultry unit in southern England. Targets treated with an Alfacron-sugar mixture and baited with 2.5 g of 40% (*Z*)-9-tricosene beads caught significantly greater numbers of both male and female *M. domestica* than control targets. Egg and milk-baited targets were less attractive than controls, while brewers yeast slightly increased the numbers of *M. domestica* attracted. However, the inclusion of brewers yeast in (*Z*)-9-tricosene-impregnated targets produced a significant reduction in the number of male *M. domestica* attracted. Increased female attraction was elicited by baiting the targets with 2-phenylethanol, at the quantities of 1 mg and 10 mg. However, 2-phenylethanol had no effect on female attraction when presented in conjunction with (*Z*)-9-tricosene. The implications of these results in relation to the control of *M. domestica* populations in poultry units are discussed.

Introduction

Reliance on contact insecticides in intensive animal rearing units has led to the development of widespread resistance in many populations of *Musca domestica* L. (Diptera: Muscidae) (Chapman, 1985; Chapman & Morgan, 1992; Chapman et al., 1993). Control failure associated with persistent application of contact insecticides has resulted in an increase in the use of baited targets on many UK poultry farms (Barson, 1987; Freeman & Pinniger, 1992; J. W. Chapman, unpubl.) Localised toxic targets, in comparison with frequent applications of contact insecticides, not only decrease the risk of resistance developing in populations of *M. domestica* (Keiding, 1975), but also greatly reduce the amount of insecticide released into the environment. This minimises contamination of the manure pit, thus promoting conservation of the natural control agents of *M. domestica* immature stages (Axtell, 1970; Legner, 1971; Geden et al., 1988).

Due to the localised nature of toxic targets, the identification of powerful attractants is essential for the development of effective control strategies (Wall & Howard, 1994). One of the most promising chemical attractants for luring *M. domestica* would appear to be the female sex pheromone, (*Z*)-9-tricosene. Field trials in intensive animal rearing units have consistently demonstrated that baiting with (*Z*)-9-tricosene can significantly enhance catch rates of *M. domestica* in a wide range of trap types over a 24 h period (Carlson & Beroza, 1973; Morgan et al., 1974; Mitchell et al., 1975; Burg & Axtell, 1984). Trials investigating the efficiency of toxic targets in poultry units indicated that the attractant effect of (*Z*)-9-tricosene persisted for at least 24 weeks (Chapman et al., 1998). Furthermore, although laboratory investigations indicate that (*Z*)-9-tricosene does not modify female behaviour (Silhacek et al., 1972; Nicholas, 1988), catch rates of both sexes of *M. domestica* were significantly greater at (*Z*)-9-tricosene impregnated targets than control targets (Chapman et al., 1998).

However, there are problems associated with the use of (*Z*)-9-tricosene as an attractant for *M. domestica*. One difficulty is that targets baited with (*Z*)-9-tricosene attract significantly more males than females (Chapman et al., 1998). Lure and kill systems that preferentially attract males will probably be less effective at suppressing pest populations than strategies designed to attract both sexes or predominately females (Langley & Weidhaas, 1986; Wall & Howard, 1994). Therefore, identification of semiochemicals that attract females may be a prerequisite in the design of fly control strategies based on odour baited targets. Another problem associated with the use of (*Z*)-9-tricosene is its low volatility, a function of its relatively large molecular weight (322). The involatility of many dipteran sex pheromones, including that of *M. domestica*, has prompted some workers to suggest that volatile kairomones emitted from food or host sources may constitute more potent sources of attraction (Wall & Langley, 1991; Wall & Howard, 1994). These will be of particular value if they principally attract females.

One source of attractants may be the kairomones liberated from food sources. Adult *M. domestica* require carbohydrates in order to sustain flight (Busvine, 1980), and hence volatiles indicating the presence of carbohydrates may attract hungry flies of both sexes. However, protein is an essential requirement only for female *M. domestica* (Goodman et al., 1968). Therefore, kairomones liberated from protein sources may be expected to preferentially attract females. Previous field trials conducted in poultry units have demonstrated that baits containing protein, or products of protein putrefaction, attract *M. domestica* (Willson & Mulla, 1973; Mulla et al., 1977; Burg & Axtell, 1984). However, the duration of the attractant effect provided by such baits has not been examined. The interaction of protein baits with (*Z*)-9-tricosene, and the effect on the sex ratio of the attracted flies, has also yet to be quantified.

Another potential source of attractants are insectivorous plant volatiles, such as those produced by the pitcher plant *Sarracenia* (Sarraceniaceae). *Sarracenia* entices insect prey, primarily Diptera (Cresswell, 1991), and *M. domestica* is readily captured in its pitchers (J. W. Chapman, unpubl.) The lip of the pitcher of *Sarracenia* produces an essential oil containing aromatic hydrocarbons, alcohols and phenolics (Miles et al., 1975). Laboratory bioassays have indicated that one of the components of this essential oil, 2-phenylethanol, elicits attraction of *M. domestica* and stimulates proboscis extension (P. E. Howse, unpubl.) However, there are no published studies on the effect of 2-phenylethanol on *M. domestica* in the field. This study investigated the effect of food baits and 2-phenylethanol on the attraction of male and female *M. domestica* to toxic targets in a deep-pit poultry unit, and the interaction of these baits with (*Z*)-9-tricosene.

Materials and methods

Field site. The field trials were conducted in a deep-pit caged-layer poultry unit in southern England. The unit was composed of two identical houses situated adjacent to each other. Each house had a two-story structure, the birds being housed on the upper floor and the manure contained in the pit below, and was 100 m long by 30 m wide. The houses both contained 48,000 laying hens, housed in nine rows of tiered cages running the length of the house. At both ends of the row of cages there was a substantial opening to the manure pit below. These openings were the primary site of access to the upper story for adult *M. domestica* emerging in the manure pit below (J. W. Chapman, unpubl.) Apart from the toxic targets utilised in the experiments, no other house fly control strategies were employed during the duration of the trials. For three years prior to the experimental period Alfacron had been painted on to the walls of the poultry unit in an attempt to control *M. domestica* populations. The physiological and behavioural resistance status to Alfacron in the study population has not been established. Both houses in the poultry unit were used for experiments.

Toxic targets. The targets employed in all of the trials were plywood boards, 120 cm by 30 cm, painted with white, water soluble, gloss paint (Premier Water Based Gloss). Each board was then given an application of insecticide-sugar mixture. The insecticide used was Alfacron (Ciba-Geigy, UK), a residual organophosphate bait containing 10% azamethiphos. The toxic bait mixture was prepared by mixing 500 g of Alfacron powder with 1 kg of granulated sugar and 200 ml of water to form a thick paste. This mixture was sub-divided into 50 ml aliquots and painted onto the boards. Food baits and (*Z*)-9-tricosene were mixed into the 50 ml aliquots of Alfacron-sugar mixture before application. A large plastic bag affixed to a wire frame was attached to the bottom of each target to collect the flies killed by ingestion of the bait. Targets were hung at both ends of the cage rows, immediately

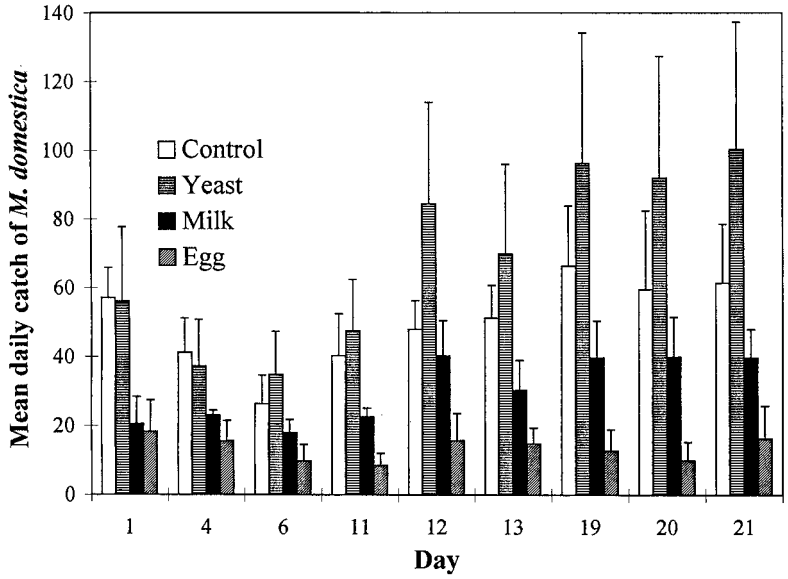

Figure 1. Mean daily catches of *M. domestica* during a 21-day period at targets baited with Alfacron-sugar alone (control), or Alfacron-sugar and one of the following treatments: (i) 25 g of brewers yeast, (ii) 25 g of powdered milk, or (iii) 25 g of egg. Means of 4 replicates ±1 S.E.

above the openings to the manure pit. Targets were therefore positioned at the site of principal *M. domestica* immigration into the upper floor of the poultry house (J. W. Chapman, unpubl.).

Pheromone formulation. The pheromone used in the trials was the synthetic female house fly sex pheromone, (*Z*)-9-tricosene, obtained from Agrisense BCS, UK. The formulation consisted of technical grade 9-tricosene (65% (*Z*)-9-tricosene, 15% (*E*)-9-tricosene, and 20% impurities) incorporated in a cross-linked polymer bead matrix at 40% w/w.

Experimental procedure. All trials were conducted during the summer of 1996. In each experiment four replicates of each treatment were prepared, and the 16 targets were positioned at the end of the cage rows, eight at each end of the house, by referring to a table of random numbers. Samples were collected every few days by inverting the collecting bag and emptying the contents into a sample bag. All *M. domestica* in the samples were identified and counted, and mean daily catches for each target were calculated. All house flies killed on a subset of the sample dates within each trial were sexed by examining the external genitalia under a binocular microscope.

Experiment 1 investigated the effects of three protein-containing food baits on the attractiveness of the toxic targets. The food baits utilised were dried brewers yeast (CPC UK, Ltd.), full fat powdered milk, and fresh broken eggs. The brewers yeast contained dead cell material, providing a source of protein and carbohydrate, and active cells that would have initiated fermentation of the sucrose substrate. Powdered milk and egg provided a source of carbohydrate and protein. Treatments were prepared by mixing 25 g of the food bait with 25 ml of water and 50 ml of the Alfacron-sugar mixture before application to the targets. Each target was prepared with one of the following treatments: (1) 50 ml of the Alfacron-sugar mixture and 25 ml of water (control targets), (2) 50 ml of the Alfacron-sugar mixture, 25 ml of water and 25 g of brewers yeast, (3) 50 ml of the Alfacron-sugar mixture, 25 ml of water and 25 g of powdered milk, or (4) 50 ml of the Alfacron-sugar mixture, 25 ml of water and 25 g of egg.

A 2×2 factorial design was used to investigate the interaction between (*Z*)-9-tricosene and brewers yeast in experiment 2. Targets were prepared with one of the following treatments: (1) 50 ml of the Alfacron-sugar mixture and 25 ml of water (control), (2) 50 ml of the Alfacron-sugar mixture, 25 ml of water and 25 g of brewers yeast, (3) 50 ml of the Alfacron-sugar mixture, 25 ml of water and 2.5 g of 40% (*Z*)-9-tricosene beads, or (4) 50 ml of the Alfacron-sugar mixture, 25 ml of water, 25 g of brewers yeast and 2.5 g of 40% (*Z*)-9-tricosene beads.

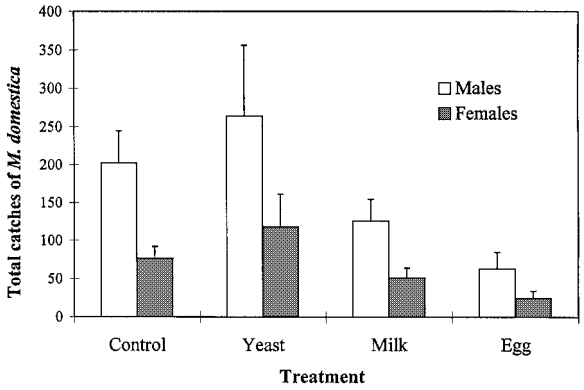

Figure 2. Total catches of male and female *M. domestica* at targets baited with Alfacron-sugar alone (control), or Alfacron-sugar and one of the following treatments: (i) 25 g of brewers yeast, (ii) 25 g of powdered milk, or (iii) 25 g of egg. Means of 4 replicates ±1 S.E.

Experiment 3 examined the effect of 2-phenylethanol on the attractive qualities of sugar baited toxic targets. Cored rubber septa (6 mm diameter aperture, Sigma, UK) were impregnated with a range of quantities of 2-phenylethanol in the laboratory, and then sealed in aluminum lined sachets until use to prevent evaporation. Targets were prepared with the Alfacron-sugar mixture and then a rubber septum was pinned to the center of the target. Three quantities of 2-phenylethanol were employed: 1 mg, 10 mg and 100 mg. Control targets were provided with a blank rubber septum.

The interaction between (*Z*)-9-tricosene and 2-phenylethanol was investigated with a 2 × 2 factorial design in experiment 4. Rubber septa were impregnated with 10 mg of 2-phenylethanol as previously described. Targets were prepared with one of the following treatments: (1) 50 ml of the insecticide-sugar mixture (control), (2) 50 ml of the insecticide-sugar mixture and 10 mg of 2-phenylethanol, (3) 50 ml of the insecticide-sugar mixture and 2.5 g of 40% (*Z*)-9-tricosene beads, or (4) 50 ml of the insecticide-sugar mixture, 10 mg of 2-phenylethanol and 2.5 g of 40% (*Z*)-9-tricosene beads.

Statistical analysis. Total catches of *M. domestica* over the entire sample period of each trial were analysed in GLIM (Generalized Linear Interactive Modeling) with Poisson errors (McCullagh & Nelder, 1989) according to treatment (plus pair-wise interactions where applicable). The error structure was substantiated during analysis. Model structure was simplified by removing redundant interaction terms and amalgamating factor levels that did not differ significantly from each other (Crawley, 1993). Total male and female catches were also analysed in the same way. Mean daily catches of *M. domestica* were analysed with repeated measures ANOVA to determine if the attractant effect of the food odours or (*Z*)-9-tricosene varied significantly over the duration of the trials. Repeated measures ANOVA designs are appropriate when data have been collected from the same replicate on successive dates without rerandomization (Paine, 1996). Mean daily catch rates of *M. domestica* at the toxic targets departed from normality. Log transformations were therefore conducted, and data re-tested for normality, before repeated measures analysis was performed.

Results

Experiment 1. Analysis in GLIM of total catches over the 3 weeks indicated that catches of *M. domestica* at the toxic targets varied significantly according to treatment ($\chi^2 = 11.97$, df = 3, $P < 0.01$). Yeast-baited targets attracted slightly more *M. domestica* than control targets, while milk and egg-baited targets were considerably less attractive (Figure 1). There was also a highly significant interaction between treatment and sample date (repeated measures ANOVA, $F = 2.56$, df = 24, 96, $P < 0.001$), indicating that there was significant variation in the relative attractiveness of treatments over time. It is apparent from Figure 1 that control and yeast targets attracted similar numbers of *M. domestica* initially, but that the attractiveness of the yeast bait increased in comparison with control targets from day 12 onwards. The relative attractiveness of milk baited targets also increased throughout the trial, although catch rates never attained the level experienced at control targets. However, there was no discernible variation in catch rates of egg baited targets, which were always considerably less attractive than control targets (Figure 1). The food baits also had a significant effect on the total catches of males ($\chi^2 = 11.00$, df = 3, $P < 0.05$) and females ($\chi^2 = 11.09$, df = 3, $P < 0.05$). All treatments attracted greater numbers of males than females (Figure 2). Yeast baited targets attracted slightly more males and females than control targets, but catch rates at milk and egg baited targets were clearly lower than control levels (Figure 2).

Experiment 2. Total catches of *M. domestica* were significantly enhanced by (*Z*)-9-tricosene ($\chi^2 = 33.3$,

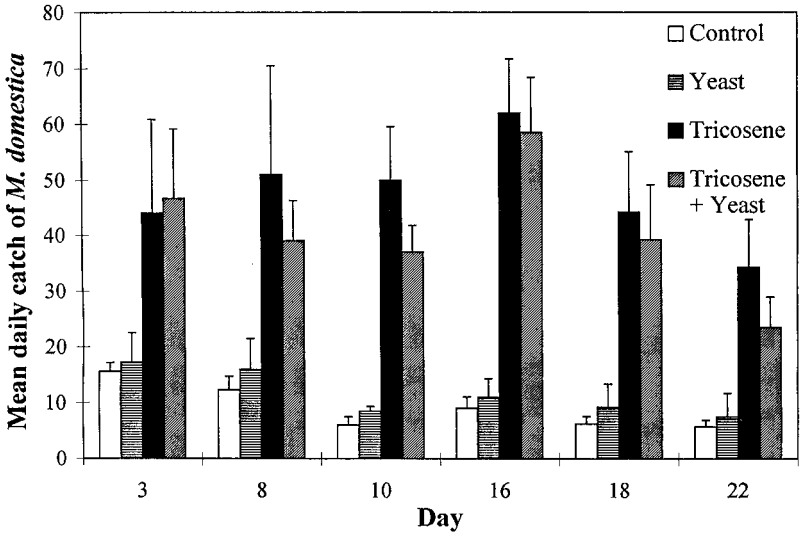

Figure 3. Mean daily catch of *M. domestica* at targets baited with Alfacron-sugar alone (control), or Alfacron-sugar and one of the following treatments: (i) 25 g of brewers yeast, (ii) 2.5 g of 40% (*Z*)-9-tricosene beads, or (iii) 25 g of brewers yeast and 2.5 g of 40% (*Z*)-9-tricosene beads. Means of 4 replicates ±1 S.E.

df = 1, $P < 0.001$) but not by yeast ($\chi^2 = 0.45$, df = 1, $P > 0.05$) (Figure 3). (*Z*)-9-Tricosene elicited a significantly increased attraction of both males ($\chi^2 = 81.5$, df = 1, $P < 0.001$) and females ($\chi^2 = 20.1$, df = 1, $P < 0.001$) (Figure 4). The addition of yeast to the (*Z*)-9-tricosene-impregnated targets produced a significant decrease in the numbers of males attracted ($\chi^2 = 4.30$, df = 1, $P < 0.05$), but had no effect on the numbers of females attracted ($\chi^2 = 0.38$, df = 1, $P > 0.05$) (Figure 4). In all cases the interaction between yeast and (*Z*)-9-tricosene was not significant ($P > 0.05$). Repeated measures analysis indicated that there was no significant interaction between sample date and either yeast or (*Z*)-9-tricosene ($P > 0.05$ in both cases), indicating that the relative effectiveness of treatments did not vary over the duration of the trial.

Experiment 3. Figures 5 and 6 indicate that the addition of 1 mg or 10 mg of 2-phenylethanol increased the catch rates of *M. domestica* compared to control targets. However, the effect of 100 mg of 2-phenylethanol on target efficiency was much less pronounced. Total catches at the 1 mg and 10 mg 2-phenylethanol treatments were consistently similar (Figure 5). Amalgamating the data from these two treatments did not produce a significant increase in the deviance ($P > 0.05$). The principle of parsimony requires the use of simplified analytical models by combining factor levels that do not differ significantly (Crawley, 1993). Therefore, analysis was conducted with only three levels of treatment: (i) control, (ii) 1 mg and 10 mg of 2-phenylethanol (combined), and (iii) 100 mg of 2-phenylethanol. The addition of 2-phenylethanol did not produce significant variation in the total catches of *M. domestica* at the targets ($\chi^2 = 4.38$, df = 2, $P > 0.05$), or in total numbers of males caught ($\chi^2 = 1.44$, df = 2, $P > 0.05$). However, total catches of females at the targets were significantly affected by treatment ($\chi^2 = 7.11$, df = 2, $P < 0.05$). Figure 6 indicates that the level of male attraction was relatively similar across all treatments, while female attraction was greater at 2-phenylethanol baited targets than controls. The increase in female attraction was particularly evident for the 1 mg and 10 mg treatments. This suggests that the increase in total catches of *M. domestica* at 2-phenylethanol baited targets observed throughout the trial (Figure 5) was primarily due to an increased attraction of females. The interaction between treatment and sample date was not significant (repeated measures ANOVA, $F = 0.66$, df = 15, 60, $P = 0.8$), suggesting that the attractiveness of 2-phenylethanol persisted for the duration of the trial.

Experiment 4. The effect of 10 mg of 2-phenylethanol and 2.5 g of 40% (*Z*)-9-tricosene beads on target effectiveness was ascertained in a two-way factorial analysis. Total catches of *M. domestica* were significantly higher at targets baited with (*Z*)-9-tricosene ($\chi^2 = 28.5$, df = 1, $P < 0.001$), but were unaffected

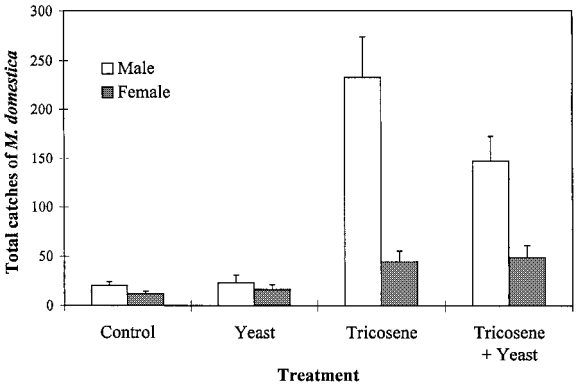

Figure 4. Total catches of male and female *M. domestica* at targets baited with Alfacron-sugar alone (control), or Alfacron-sugar and one of the following treatments: (i) 25 g of brewers yeast, (ii) 2.5 g of 40% (*Z*)-9-tricosene beads, or (iii) 25 g of brewers yeast and 2.5 g of 40% (*Z*)-9-tricosene beads. Means of 4 replicates ±1 S.E.

by 2-phenylethanol ($\chi^2 = 0.47$, df = 1, $P > 0.05$) (Figure 7). (*Z*)-9-Tricosene increased catches of both males ($\chi^2 = 57.5$, df = 1, $P < 0.001$) and females ($\chi^2 = 14.6$, df = 1, $P < 0.001$), although pheromone impregnated targets attracted about twice as many males as females (Figure 8). In contrast, 2-phenylethanol had no effect on the attractiveness of the targets to either sex (males: $\chi^2 = 0.04$, df = 1, $P > 0.05$; females: $\chi^2 = 1.10$, df = 1, $P > 0.05$) (Figure 8). In all cases the interaction between 2-phenylethanol and (*Z*)-9-tricosene was not significant ($P > 0.05$). The interaction between treatment and sample date was not significant for both 2-phenylethanol and (*Z*)-9-tricosene (repeated measures ANOVA, $P > 0.05$ in both cases), indicating that the relative effectiveness of both treatments did not vary with time.

Discussion

The results of the first experiment suggested that the protein-containing baits were relatively ineffective at eliciting attraction of either sex of *M. domestica*. Targets baited with yeast attracted greater numbers of *M. domestica* than control targets, but the increase was minimal and was not observed until 12 days post target installation (Figure 1). Milk and egg baited targets appeared to be repellent, as daily catches of *M. domestica* were consistently lower than at control targets. Milk's repellent effect diminished over the 3 weeks, whereas catch rates at egg baited targets remained constant (Figure 1). The initial poor response of *M. domestica* to milk accords well with the results of laboratory olfactometer studies demonstrating that fresh milk is repellent and fermented milk attractive to mixed sex house flies (Brown et al., 1961). However, the uniformly low catches of *M. domestica* at the egg-baited targets contradicts the findings of a previous study carried out in a poultry unit. Willson & Mulla (1973) demonstrated that a protein bait prepared from freeze-dried fermented egg solids induced a three-fold increase in the number of *M. domestica* caught in pan traps. Furthermore, this increase was primarily mediated by a response from nulliparous females. The discrepancy between the two studies may be accounted for by differences in bait formulation, trap design and positioning, or duration of exposure (24 h versus 3 weeks). Nevertheless, the findings of the present study infer that targets baited with fresh egg will probably be ineffectual at attracting *M. domestica* in caged-layer poultry units.

Catch rates of *M. domestica* at the yeast and milk-baited targets increased in relation to control levels as the trial progressed (Figure 1), indicating an increase in the attractive qualities of these baits over time. This effect was presumably evoked by the release of volatile products of protein putrefaction and carbohydrate fermentation of the food baits. Furthermore, active cells in the yeast bait would have initiated fermentation of the sucrose applied to the targets. The products of putrefaction and fermentation include many chemicals known to elicit attraction of *M. domestica* (Crumb & Lyon, 1917; Richardson, 1917; Wieting & Hoskins, 1939; Brown et al., 1961; Mulla et al., 1977; Hwang et al., 1978; Burg & Axtell, 1984).

Although the results indicated an increase in the attractiveness of the milk and yeast baits over time, the protein-containing baits attracted very few female *M. domestica* (Figure 2). Females require protein for complete maturation of their ovaries (Goodman et al., 1968), and hence it seems intuitive that the odours released from proteinaceous material may attract virgin females in considerable numbers. The failure of the food baits to substantially increase female attraction may have been caused by low release rates, or swamping of the volatiles, by odours liberated from other organic matter such as broken eggs and poultry manure. Alternatively, the inefficiency of the food baits at attracting females may be related to target positioning. The elevated catches of males, relative to females, at all the treatments suggest that the *M. domestica* local population in the vicinity of the targets may have been male biased. Stratification of *M. domestica* popula-

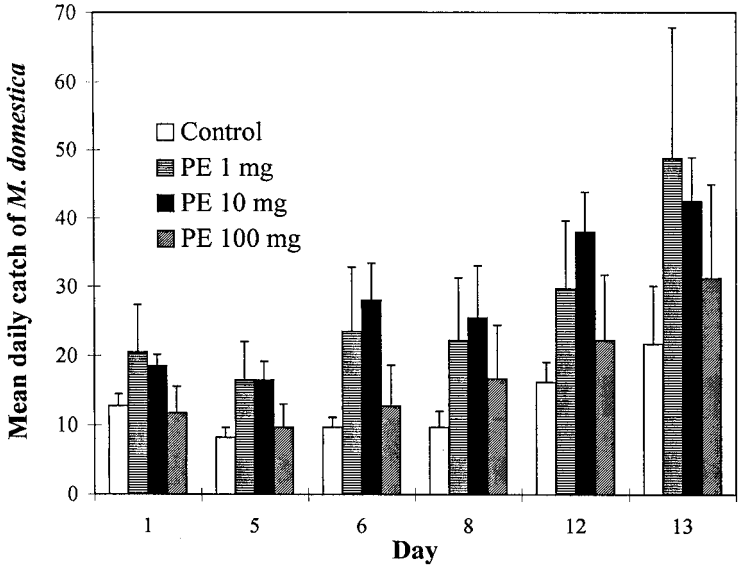

Figure 5. Mean daily catch of *M. domestic* during a 16-day period at targets baited with Alfacron-sugar alone (control), or Alfacron-sugar and one of the following treatments: (i) 1 mg of 2-phenylethanol, (ii) 10 mg of 2- phenylethanol, or (iii) 100 mg of 2-phenylethanol. Means of 4 replicates ±1 S.E.

tions, segregated in respect to sex, have been recorded in previous studies at animal rearing units (Willson & Mulla, 1973; Krafsur et al., 1985). The positioning of the targets may therefore explain the low catch rates of female *M. domestica* at the food baits. Detailed information on the size, age structure and sex ratio of the *M. domestica* population would be invaluable in the interpretation of these results. It is apparent that if food baits are to effectively attract female *M. domestica*, then the sexual distribution of *M. domestica* populations needs to be elucidated before planning and implementing control strategies. However, the data is inconclusive as to whether food baits can evoke female attraction to targets in poultry units.

Experiment 2 indicated that (*Z*)-9-tricosene elicited an increased attraction of *M. domestica* throughout the duration of the trial (Figure 3), as was observed in previous trials (Chapman et al., 1998). This increase was primarily mediated by the response of male *M. domestica*, though the numbers of females attracted to the (*Z*)-9-tricosene-impregnated targets were also significantly higher than control levels (Figure 4). Laboratory studies have demonstrated that (*Z*)-9-tricosene is highly attractive to male *M. domestica*, but does not elicit female attraction (Silhacek et al., 1972; Nicholas, 1988). The increase in female attraction observed in this experiment corresponds with the findings of previous field trials (Carlson & Beroza, 1973; Morgan et al., 1974; Mitchell et al., 1975; Chapman et al., 1998). Possible mechanisms for the elevated female catch at (*Z*)-9-tricosene-impregnated targets are discussed by Chapman et al. (1998).

The addition of brewers yeast to the (*Z*)-9-tricosene-impregnated targets produced a significant reduction in the number of male *M. domestica* attracted. This may be due to the release of volatile kairomones from the yeast that interfered with the perception of the pheromone by male *M. domestica*. Alternatively, the products of fermentation emitted by the action of the yeast cells may have reacted with the (*Z*)-9-tricosene and reduced its efficacy. Although brewers yeast may produce a slight increase in the catches of *M. domestica* when presented alone, it is clear that its incorporation into (*Z*)-9-tricosene-impregnated targets will be ineffectual.

Targets baited with 1 mg and 10 mg of 2-phenylethanol attracted significantly greater numbers of female *M. domestica* than controls, while there was no effect on the numbers of males attracted (Figure 6). This pattern was also evident for the 100 mg treatment, but the magnitude was diminished. This may have been due to swamping of the antennal chemosensory receptors, or perhaps a slight repellent effect induced by high concentrations. Attraction of both sexes to sources containing 2-phenylethanol have been documented in species of Lepidoptera, Diptera, Coleoptera and solitary Hymenoptera (Ishikawa et al., 1983; Haynes et al., 1991; Pierce et al., 1991; Roy

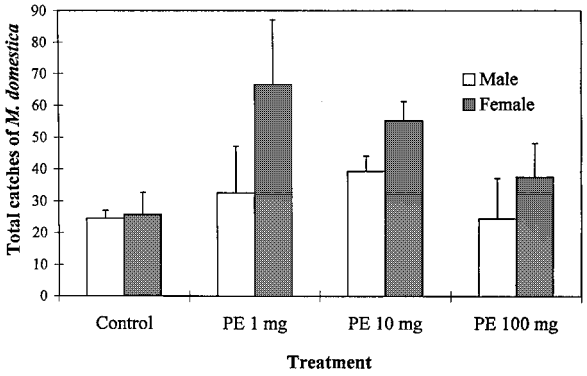

Figure 6. Total catches of male and female *M. domestica* at targets baited with Alfacron-sugar alone (control), or Alfacron-sugar and one of the following treatments: (i) 1 mg of 2-phenylethanol, (ii) 10 mg of 2-phenylethanol, or (iii) 100 mg of 2-phenylethanol. Means of 4 replicates ±1 S.E.

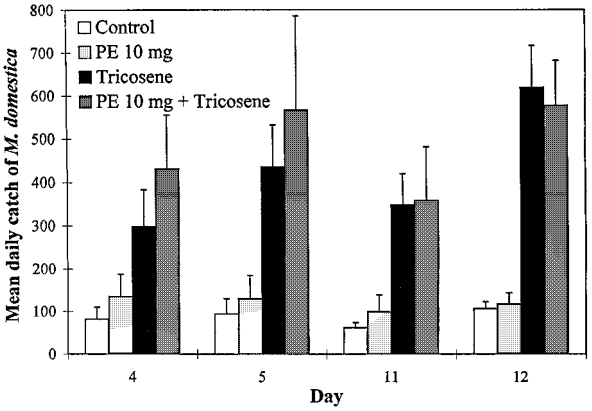

Figure 7. Mean daily catches of *M. domestica* during a 12-day period at targets baited with Alfacron-sugar alone (control), or Alfacron-sugar and one of the following treatments: (i) 10 mg of 2-phenylethanol, (ii) 2.5 g of 40% (*Z*)-9-tricosene beads, or (iii) 10 mg of 2-phenylethanol and 2.5 g of 40% (*Z*)-9-tricosene beads. Means of 4 replicates ±1 S.E.

& Raguso, 1997). This study is the first to demonstrate attraction of *M. domestica* to 2-phenylethanol in the field, and to our knowledge the first to indicate a female-specific response in an insect species where both sexes forage. 2-Phenylethanol is a component of the floral volatiles that advertise nectar sources in many flowers, insectivorous pitchers and fungal pseudoflowers (Miles et al., 1975; Buttery et al., 1982; Kumar & Motto, 1986; Haynes et al., 1991; Roy & Raguso, 1997). It is not readily apparent why nectar rewards would attract predominately female *M. domestica*, as both males and females require carbohydrates for locomotion (Busvine, 1980). However, 2-phenylethanol is also emitted from fungal-

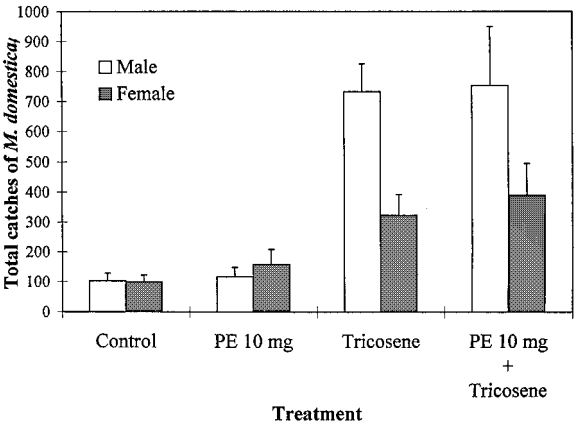

Figure 8. Total catches of male and female *M. domestica* at targets baited with Alfacron-sugar alone (control), or Alfacron-sugar and one of the following treatments: (i) 10 mg of 2-phenylethanol, (ii) 2.5 g of 40% (*Z*)-9-tricosene beads, or (iii) 10 mg of 2-phenylethanol and 2.5 g of 40% (*Z*)-9-tricosene beads. Means of 4 replicates ±1 S.E.

infected organic matter (Pierce et al., 1991; Cossé et al., 1994), and thus may indicate potential oviposition sites. Further work is required to elucidate the mechanism of attraction of female *M. domestica* to 2-phenylethanol-baited targets. The data so far suggests that 2-phenylethanol may have some use as a female attractant. However, the slight increase in female attraction elicited by 2-phenylethanol was swamped by the more substantial effect of (*Z*)-9-tricosene on the numbers of females caught (Figure 8).

In conclusion, it appears that the food baits tested during this trial elicited minimal attraction of females to the targets, particularly when presented in conjunction with (*Z*)-9-tricosene. Hence, it is still necessary to identify potent female attractants that will significantly increase the potential of toxic targets to exert population suppression. In the meantime (*Z*)-9-tricosene would seem to be the prime candidate for inclusion in lure and kill systems, as it increases the catch of both male and female *M. domestica* and persists for at least 24 weeks (Chapman et al., 1998).

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