Integration of Fly Baits, Traps, and Cords to Kill House Flies (Diptera: Muscidae) and Reduce Annoyance[1]

Joseph W. Diclaro II, Jeffrey C. Hertz, Ryan M. Welch, Philip G. Koehler, and Roberto M. Pereira[2]

Department of Entomology and Nematology, University of Florida, Gainesville, Florida, USA

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Abstract Combinations of commercial fly baits, traps, and cords were evaluated for integration into a fly management system. Imidacloprid granular and sprayable baits caused house fly, *Musca domestica* L., mortality at a faster rate than methomyl granular fly bait; however, the methomyl granular bait had the highest overall mortality at 24 h. Commercial fly traps had a variety of designs that resulted in differences in efficiency for retaining house flies. Among 6 commercial traps tested, the Trap n' Toss™ (Farnam Companies, Inc., Phoenix, AZ) captured the most flies, and the design was selected for our field cage studies. These cage studies with flies (~300) determined that without treated cord or attractant, fly traps captured and killed 5% of the fly population; whereas, fly traps with attractant captured and killed only 14% of the population in the first 24 h. A 46-cm cord (6 mm diam.) dipped in 2.5% imidacloprid was looped around a fly trap (identical to the Trap n' Toss), and the trap was baited with commercial fly attractant. The addition of the bait-treated cord killed 60 - 70% of flies at 24 h and 84 - 90% at 48 h. However, bait-treated fly cords used alone killed 70% of flies at 24 h and 94% at 48 h and demonstrated the relatively poor efficiency of commercial fly traps. Fly annoyance was eliminated by the high fly mortality resulting from the use of bait-treated cords. Bait-treated cords can be used to improve the efficiency of fly management programs, either in conjunction with commercial fly traps or alone.

Key Words *Musca domestica,* fly cords, fly traps, fly baits, imidacloprid

The house fly, *Musca domestica* L. (Diptera: Muscidae), continues to be a nuisance and potential disease transmitter in urban and agricultural areas. House flies are often managed using an integrated approach of both nonchemical and chemical methods (Kolbe 2004). Methods used to monitor, capture, or kill flies include the use of insecticidal baits, fly traps, and insecticide-treated fly cords (Geden 2005, Hertz et al. 2011). Fly baits are usually applied as either dry insecticidal granular baits or more recently as sprayable baits. Baits usually contain the active ingredient, fly attractant, (Z)-9-tricozene, a bittering agent, dyes, and other attractants (Chapman et al. 1998). In general, fly baits have many advantages over other types of insecticidal fly control products: they are easier to work with in field environments, they can be more attractive to flies residual sprays, and they usually have a long storage shelf life (Gahan et al. 1954, Darbro and Mullens 2004). However, granular fly baits need to be replaced

[1]Received 02 June 2011; accepted for publication 11 September 2011.
[2]Corresponding author (e-mail: rpereira@ufl.edu).

frequently in some areas when granules become covered by manure or other debris (Barson 1987). Therefore, sprayable baits are rapidly gaining favor.

A second method used in fly management programs is the fly trap, which usually consists of a foul-smelling attractant placed inside a trap that entices house flies to enter through a cone entrance (Pickens 1995). It is usually impossible to reduce fly numbers with traps because fly populations need to be reduced daily by 24 - 58% to achieve a 50 - 90% reduction of closed populations (Weidhaas and Haile 1978). In fact, fly traps alone have not been shown to reduce fly populations to acceptable levels (Smallegange 2004) because they are not sufficiently efficient (Pickens and Thimijan 1986). However, two ways to improve trap efficiency are (1) by placement close to areas of fly activity and (2) the use of attractants, like ammonium carbonate, yeast, and water mixture (Satrom and Stephens 1979) in the traps.

A third method of controlling house fly has been the use of insecticide-treated cords. Cords impregnated with organophosphate and chlorinated hydrocarbon insecticides were introduced in 1947 and found to provide good house fly control (Smith 1958). Fly cords have not been used recently because the active ingredients used in the 1940s and 1950s are no longer available. Newer insecticides impregnated in cords have been shown to effectively kill flies in field cages using low concentrations of active ingredients, such as 0.1% fipronil and 1.2% indoxacarb (Hertz et al. 2011). More recently, a sprayable imidacloprid bait has been registered and could be applied to cords.

Because fly baits, traps, and insecticide-treated cords can be useful tools in fly management programs, our goal was to integrate the use of these three tools. Our first objective was to determine the speed of action and efficacy of a sprayable fly bait in the laboratory compared with scatter baits. We compared the design characteristics of 6 commercially available fly traps and determined which trap best retained captured flies for subsequent use in field tests. We tested various combinations of baits, traps, and cords for their efficacy against house flies in field cages, and investigated the effects of fly suppression on fly annoyance.

Materials and Methods

Insects. For the laboratory experiments, the house flies were from the Horse Teaching Unit (HTU) strain established in 2004, from Gainesville, FL, and used in 2005 and 2006. For the field cage experiments, flies were collected from the University of Florida Horse Teaching Unit about 1 month prior to experiment, reared in the laboratory, and used at the F3 through F5 generation. Flies were reared following a method modified from Hogsette (1992) and Hogsette et al. (2002). However, our adult fly diet did not use powdered egg yoke, and our larval diet substituted Calf Manna (MannaPro Products, Chesterfield, MO) for alfalfa meal and corn meal. Larvae and adults were held in separate containers at 26.2 ± 0.5°C and 51.2 ± 3.5% RH.

Three to 7-d-old house flies were aspirated and placed in a freezer (-30°C) until inactive (~1 - 5 min). After removal from the freezer, they were counted and sexed on a chilled aluminum tray and allowed to recover for 1 h before placed in experiments.

Fly bait comparisons. Three fly baits, 2 dry scatter baits and 1 sprayable bait, were applied to polystyrene Petri dishes (100 × 15 mm; Fisher Scientific, Pittsburgh, PA). The methomyl granular bait (Golden Malrin®, Methomyl 1.1%, (Z)-9-Tricosene 0.049%, Wellmark International, Schaumburg, IL; dose: 0.23 g/0.9 m^2) and the imidacloprid granular bait (Maxforce® Granular fly bait, Bayer CropScience, KS City, MO;

dose: 30.17 g/0.9 m^2) were sprinkled on the Petri dish. The imidacloprid sprayable bait (Maxforce® Fly Spot bait, imidacloprid WG 10, Laboratory Code: 342/207 - 7, Bayer CropScience, Monheim am Rhein, Germany; dose: 0.45 g/0.9 m^2; rate: 0.12 g/ml/0.9 m^2) was suspended in tap water, sprayed on the Petri dish bottom using an airbrush (Paasche, Type H, Chicago, IL), and allowed to dry in a fume hood prior to being placed in the arena.

Arenas (31 × 25 × 21 cm) were constructed using PVC pipe (1.27 cm [0.5 in]) and were enclosed with a transparent plastic bag (3,721 cm^2 [61 × 61 cm], 1 mil polypropylene, Uline, Waukegan, IL). Bait dishes were placed in the center of the arena. A separate arena with an untreated Petri dish was used as the control. Untreated cords (15.2 cm length, 0.6 cm diam.) were hung from the top of the arena and served as resting positions for the flies. Groups of 50 female flies were placed within each arena and a 10% sugar water solution was provided *ad libitum*. Mortality was recorded at 1, 2, 3, 4, 5, and 24 h to determine short-term and long-term fly reduction. Flies were considered dead if they were unable to stand or fly. Each experiment was conducted in the laboratory at 30 ± 1°C under continuous light and replicated 3 times. Percent mortality data were arcsine square root transformed and submitted to one-way analysis of variance for bait product, and means were separated using Student Newman-Keuls test ($P = 0.05$; SAS 2001).

Commercial fly trap experiment. Fly traps were Trap n' Toss™ (Farnam Companies, Inc., Phoenix, AZ), Advantage Fly Trap™ (Advantage Traps, Inc., Columbia, SC), BC 1752 Dome™ (McPhail) Trap (AgriSence Agriculture, Pontypridd, UK), Rescue! Reusable Fly Trap™ (Sterling International, Inc., Liberty Lake, WA) with Victor Fly Magnet Trap™ (Woodstream, Lititz, PA), and Fly Terminator Pro™ (Farnam Companies, Inc., Phoenix, AZ). The traps were categorized as either top entry or bottom entry. Entrance color, diameter for each entrance and exit hole, slope of cone entrance, and fly trap volume were recorded for each trap design.

Our laboratory bioassay was designed to confine flies close to trap entrances to determine the efficiency of fly capture in traps. A fly attractant mixture consisting of 5 g dried active baker's yeast, 0.12 g ammonium carbonate, and 75 ml of water was placed into each fly trap immediately after mixing. The entrances of traps were connected to release cages (29 × 26 × 39 cm high) using a stocking net, with the bottom-entry traps mounted above the release cage and the top-entry traps mounted below. Fifty house flies (25 M: 25 F) were released into each cage. Experiments were conducted in a lighted room at 22.8 ± 0.02°C with 9 replicates for Trap n' Toss, 7 replicates for Advantage Fly TrapFly and BC 1752 Dome Trap, 5 replicates for Rescue Reusable Fly Trap and Victor Fly Magnet Trap, and 4 replicates for Terminator Pro.

Flies (50) were placed in the release cage and, after 24 h, house flies found in the traps and release cages were counted and sexed. Percentage of flies in each commercial trap was calculated by sex, arcsine square root transformed before analysis, and analyzed by analysis of variance. Means were separated using Student Newman-Keuls test ($P = 0.05$; SAS 2001).

Field cage tests. Integration of baits, traps, and cords was evaluated on populations of flies established in field cages. Field cages (1.8 × 3.7 × 1.8 m; Outdoor Cage, #1412A, 18 × 14 mesh, Bioquip, Rancho Dominguez, CA) with translucent plastic sheeting (6 mil) used to cover the floor were built on a grassy area shaded by pine trees. Food (1 L of 10% sucrose), water (1 L), or a 60-ml container of spent oviposition media (covered with paper towel to prevent fly access) were placed in each cage. The food, water, and oviposition media were placed to provide nutrition and to compete with the treatments for fly activity.

Trap n' Toss Fly Traps were used in the experiment, and 5 ml of the trap's attractant solution was mixed in the morning of the experiment, as directed, in tap water. The label sticker was removed from each trap to allow maximum visual fly response to the trap. Six treatments were evaluated: (1) fly trap with no attractant + untreated wool cord, (2) fly trap + attractant, no cord, (3) fly trap + attractant + untreated cord, (4) fly trap + attractant + treated cord, (5) fly trap with no attractant + treated cord, and (6) no fly trap, no attractant, only the treated cord hung in the shape of a halo.

Treated cords were prepared using imidacloprid bait (Maxforce Fly Spot bait) with 25 g of product in 100 ml of tap water. Wool cord pieces (Twisted, Natural Cord, Wooded Hamlet Designs, Greencastle, PA; 0.6 cm diam.) were cut to the length (46 cm) to match the circumference of the outside center of the fly trap and treated by dipping for 1 min in the insecticide solution. Untreated cords were dipped in tap water. All cords were dried overnight in a fume hood. Cords were then wrapped around the fly traps.

All treatments were placed in the field cages 1 h after a 35-ml volume of flies (containing ~300 flies, or ~45 flies per m^2 of field cage) was released in each cage. Fly traps were hung 1 m in front of the cage entrance and 14 cm from the cage ceiling; the cord halo was hung 28 cm from the cage ceiling. At 1, 24, and 48 h after trap placement, flies were collected from the floor of each cage and placed in a Mason jar (118 ml) to allow knocked down flies to recover in the cage. At each time after trap placement, flies on the floor of the cage, those remaining in the jar, and those collected in traps were counted. Numbers recovering from the treatment were counted to adjust mortality. After fly counts were recorded, a fly annoyance index was assigned to each cage by an observer who walked around the inside of the field cage for one complete revolution and tapped the cage mesh. During the following 1 min, annoyance was rated using following scale: 1 = no flies seen, 2 = few flies seen but none landing on the observer, 3 = <10 flies around face and arms of the observer, 4 = >10 & <20 flies around face and arms, 5 = >20 flies around the face and arms. Mortality data for each time after trap placement were analyzed by analysis of variance, and means were separated using Student Newman-Keuls test ($P = 0.05$; SAS 2001). Linear regression was used to correlate percent fly control with the annoyance index.

Results and Discussion

Fly bait comparisons. Imidacloprid granular and sprayable baits provided higher fly mortality than the methomyl granular fly bait at 3 h, but at 24 h the methomyl granular bait had the highest overall mortality (Fig. 1). When insecticides are used for house fly control, most users expect to see dead flies within hours and markedly reduced populations within 1 - 2 days. Thus, effective fly baits will attract flies quickly and cause high mortality within a relatively short period of time. In our bait comparison experiment, flies were affected by the imidacloprid baits sooner than by the methomyl bait. However, the higher fly mortality with the methomyl bait after 24 h suggests that methomyl may be a more effective, although slower-acting, active ingredient. Imidacloprid bait has been shown to have rapid onset of house fly toxicity (knockdown) although, due to recovery, more than 50% remained alive after 24 h; whereas, methomyl baits killed >95% (White et al. 2007). In our experiments, recovery was not seen in the house flies exposed to any of the bait comparison tests.

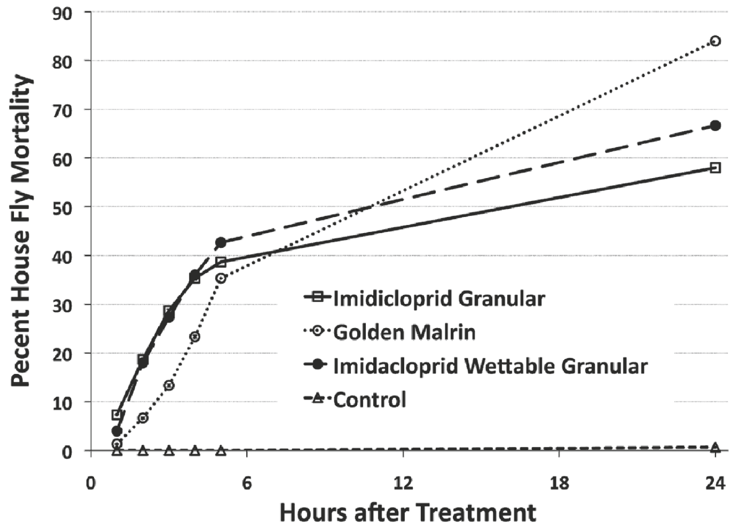

Fig. 1. Percent mortality of house flies exposed to scatter baits or a sprayable bait in laboratory cages for 24 h.

Commercial fly trap experiment. There were major physical design differences between the 6 commercial fly traps (Table 1) although all were designed to hold liquid fly attractant and captured flies. For all traps, only 38% of flies confined near the entrance were captured. Also, for all traps, only 32% of male flies and 43% of female flies were caught. There were few differences in 24-h fly trap efficiency among the commercial fly traps. The Advantage Fly Trap caught significantly more male flies than the Terminator Pro ($F = 2.87$; df = 5; $P = 0.0303$); whereas, the Trap n' Toss caught significantly more female flies than all the other traps, except the Rescue trap ($F = 4.58$; df = 5; $P = 0.0031$).

Even though flies were released and confined within centimeters of the fly trap entrances, the majority of flies were not captured within 24 h. One of the reasons for this poor efficiency was possibly trap design. Pickens (1995) suggested that the best fly traps should be white in color and have a cone with an entrance area of ~625 cm^2, exit area of ~1 cm^2, entrance/exit ratio of 625, and a 60° slope. The white color would be the most visually attractive to house flies; the cone design would allow easy fly entrance and make it difficult for them to leave the trap. None of the evaluated commercial fly traps used all his suggested best design features. There was only one trap (Advantage fly trap) that was white in color, but the cone had a smaller entrance area, a larger exit area, smaller entrance/exit ratio, and a steeper slope than Pickens' recommendations. The trap with the closest cone design (Trap n' Toss) had a yellow cone with the largest entrance area of all the commercial traps and a slope of about 62°. All the other traps had major differences from the best trap design (Pickens 1995).

Field cage tests. Flies released into field cages initially oriented to the top sides and corners of the cage. Eventually, flies were attracted to the traps or cords, food, water, and oviposition media. Flies attracted to traps or cords either were captured and died in the traps or died in the cage due to exposure to insecticide cords. Within 1 h, significant differences in fly mortality ($F = 5.12$; df = 5; $P = 0.0016$) were seen

Table 1. Characteristics of six commercially available fly traps used to evaluate house fly capture efficacy

Trap	Entrance	Entry Area (cm^2)	Exit (cm^2)	Ratio*	Slope (deg)	Volume (ml)	Color	% of Flies Captured ± SE Males	% of Flies Captured ± SE Females
Trap n' Toss™	Bottom	176	12	14.8	62	1936	yellow	38.2 ± 5.21 ab	66.2 ± 5.89 a
Advantage™	Bottom	47	9	5.1	75	1840	white	51.4 ± 7.33 a	35.4 ± 6.32 b
BC 1752 Dome	Bottom	49	11	4.6	76	748	yellow	22.9 ± 4.07 ab	34.9 ± 6.97 b
Rescue! ®	Top	3	2	1.6	85	1060	green	36.0 ± 9.38 ab	58.4 ± 12.24 ab
Fly Magnet ®	Top	6	3	2.0	90	983	black	24.8 ± 5.57 ab	32.8 ± 7.31 b
Terminator ® Pro	Top	21	21	1.0	90	3786	black	22.0 ± 13.71 b	28.0 ± 5.42 b

Data were arcsine square root transformed before analysis. Means within a column followed by the same letter are not significantly different ($\alpha = 0.05$, Student Newman-Keuls test; SAS 2001).

*Ratio = entrance (cm^2) ÷ exit (cm^2)

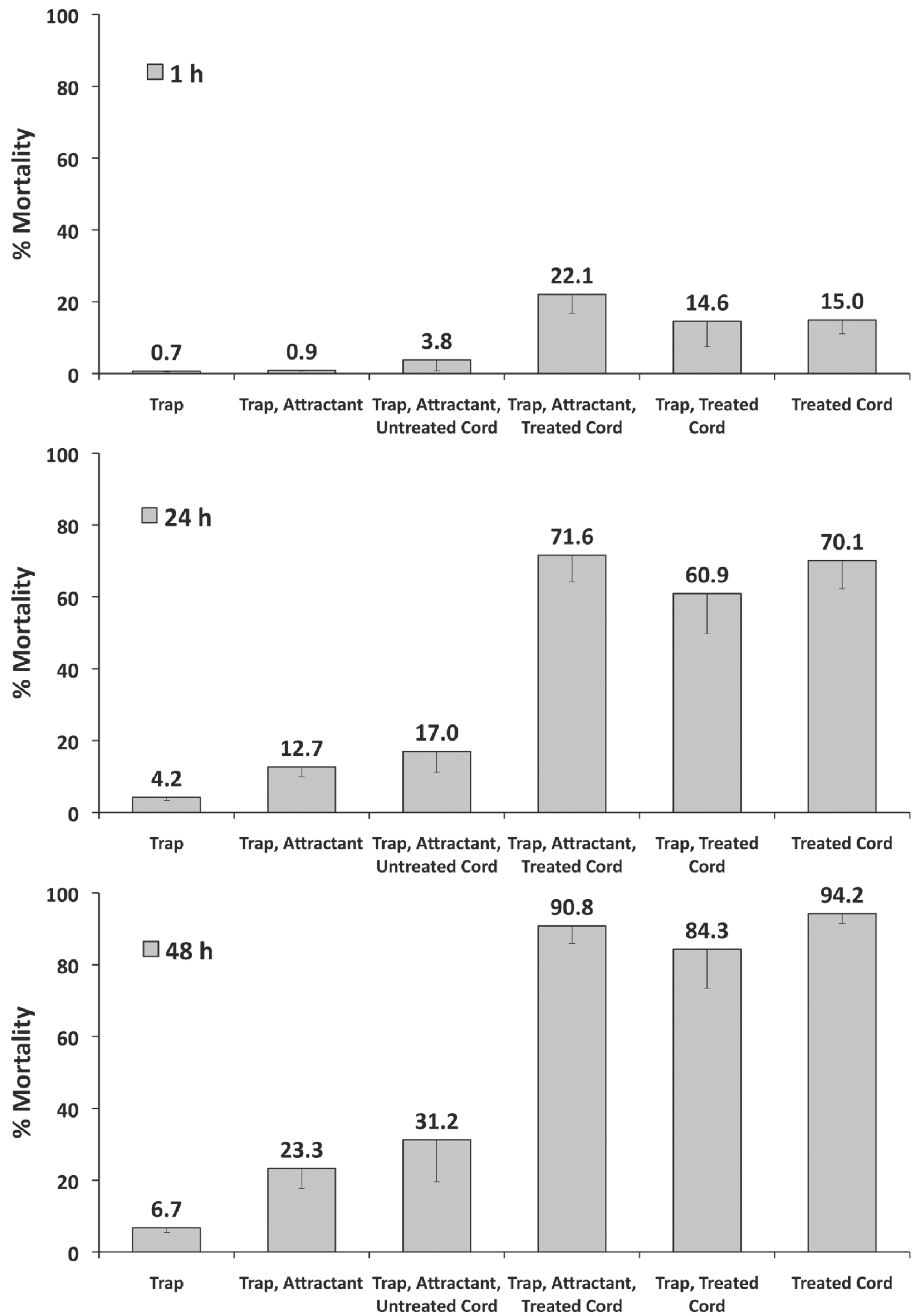

Fig. 2. Percent Mortality of house flies in field cages 1 (top), 24 (middle), and 48 (bottom) h after placement of different combinations of fly traps, attractant, and/or untreated or imidacloprid bait-treated cords.

among treatments (Fig. 2); treatments with treated-cords had higher mortality (21%) than those with traps alone (1%). After 24 h, all treatments containing treated cords had significantly higher mortality (68%) than treatments with traps alone (12%) (F = 16.82; df = 5; $P \leq 0.0001$). There were no significant increases in trap efficiency when attractant was added to either the trap alone (14% with attractant versus 6% without attractant) or traps with treated cords (64% with attractant versus 70% without attractant). After 48 h, these significant differences persisted (F = 87.41; df = 5; $P \leq 0.0001$), and traps with treated cords had killed 97% of flies; whereas, traps without treated cords had killed only 17%. The traps with no treated cords were not very efficient and trapped only 14% of the house fly population after 24 h.

The treatments with the treated wool cord reduced the fly population quickly, all of which killed >60% of the fly population in the first 24 h and close to 100% by 48 h. Imidacloprid has residual effects that will reduce fly populations quickly (Pospischil et al. 2005) and affect the house fly population in as quickly as 30 min (White et al. 2007).

Our results demonstrate that the combination of traps with treated cords can be effective in killing flies quickly; however, the treated cord alone was just as effective as the trap with the treated cord. One of the main reasons for treating fly populations is to reduce fly annoyance.

The fly annoyance index was negatively correlated with fly mortality in cages (Fig. 3). Only treatments that included imidacloprid-treated fly cords reduced fly annoyance below a scale of 4. Fly annoyance of humans was virtually eliminated at 48 h after placing the treatments with treated cords

Our laboratory experiments documented that sprayable bait performed as well as granular baits with a similar speed of action, and that sprayable bait applied to cords successfully controlled flies in field cages. Although we hypothesized that treated

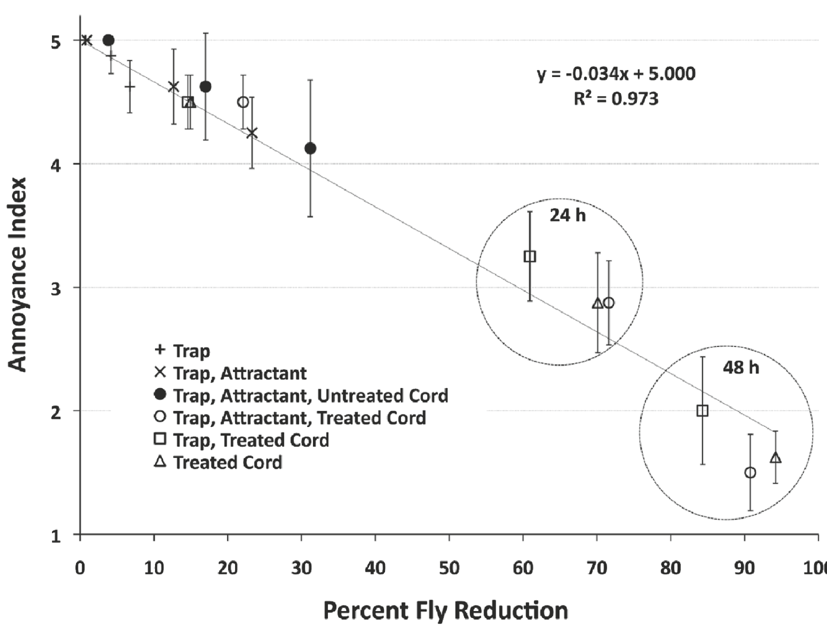

Fig. 3. Effect of fly population reduction on the annoyance to humans in field cages. Circles highlight readings after 24 and 48 h in treatments containing imidacloprid bait-treated cord.

cords combined with fly traps would improve efficacy, the treated cords alone, with lower cost and operational complexity, performed as well as the combination of traps and cords. In fact, the reductions in fly populations with the treated cords almost completely eliminated human annoyance.

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