

APPLE MAGGOT FLY (DIPTERA: TEPHRITIDAE) RESPONSE
TO PERFORATED RED SPHERESALAN H. REYNOLDS¹, RONALD J. PROKOPY¹, THOMAS A. GREEN²,
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ABSTRACT

Two traps, designed to kill with pesticide instead of a sticky coating, were evaluated for their potential to control apple maggot flies, *Rhagoletis pomonella* (Walsh). Both traps were designed to protect feeding stimulant and pesticide from rainfall, a problem with previous trap designs. The first trap was a perforated hollow red sphere, the interior of which contained odor attractants, feeding stimulant and pesticide. In field tests, internally baited spheres were slightly less attractive to *R. pomonella* than externally baited spheres, and alighting flies were highly reluctant to enter openings into the sphere interior. The second trap was a sphere in which odor attractants, feeding stimulant and pesticide were contained in a liquid inside the trap and released through a sponge at the surface. Few of the flies alighting on these traps were induced to feed. The post-alighting behavior of *R. pomonella* on both trap types tested suggests that neither type (as tested) holds much promise to replace existing designs.

Key Words: *Rhagoletis pomonella*, pesticide treated traps, odor attractants, Tangle-trap®.

RESUMEN

El potencial para controlar la mosca de la manzana, *Rhagoletis pomonella* (Walsh), fue evaluado en dos tipos de trampa diseñados para matar con pesticida en lugar de con una cubierta adhesiva. Ambos tipos de trampa fueron diseñados para proteger el fagoestimulante y el pesticida de la lluvia, lo cual había sido un problema en los diseños de trampas anteriores. La primera trampa fue una esfera hueca roja perforada, el interior de la trampa contenía olores atrayentes, fagoestimulante y pesticida. En pruebas de campo, las esferas cebadas interiormente fueron ligeramente menos atractivas a *R. pomonella* que las esferas cebadas externamente y las moscas que se posaban en ellas no entraban a través de los agujeros. La segunda trampa fue una esfera que contenía los olores atrayentes, el fagoestimulante y el pesticida en un líquido dentro de la trampa que pasaba a la superficie de esta mediante una esponja. Pocas de las moscas que se posaban en estas trampas se alimentaban. El comportamiento de *R. pomonella* después de posarse en ambas trampas sugiere que ninguno de los tipos probados es lo suficientemente prometedor para reemplazar las trampas ya existentes.

The apple maggot, *Rhagoletis pomonella* (Walsh), is a major pest of apples in eastern and central North America. Recently, odor-baited sticky traps have been used as a substitute for pesticide in controlling apple maggot in several commercial orchards (MacCollom 1987, Prokopy et al. 1990). To date, the most economically effective trap has proven to be an 8 cm red sphere coated with Tangletrap® adhesive and baited with synthetic food and/or fruit odor (Duan & Prokopy 1992). One of the impediments to greater use of such spheres by apple growers is the laborious process of coating the

spheres with a sticky adhesive and cleaning them of insects and debris every two weeks to maintain capturing effectiveness (Duan & Prokopy 1995b).

In concept, pesticide applied to spheres could be an effective substitute for adhesive in killing *R. pomonella*. Toward this end, Duan & Prokopy (1995a) showed that spheres coated with a mixture containing dimethoate, sucrose as a feeding stimulant eliciting fly ingestion of pesticide, and latex paint as a residue-extending agent killed a large majority of alighting *R. pomonella* before exposure to rainfall. After rainfall, however, the spheres were less effective, largely due to loss of feeding stimulant. An analogous trap for the olive fruit fly, *Dacus oleae* (Gmelin), consisting of a plywood rectangle soaked in deltamethrin and sucrose, provided effective control in Greece (Haniotakis et al. 1991). However, no rain fell during the trapping period due to the dry climate.

We have envisioned two principal approaches to eliminating the negative effects of rainfall on the residual activity of pesticide and feeding stimulant: (1) using a protective cover to prevent rainfall from contacting the spheres, and (2) finding a more effective residue-extending polymer to combine with, or substitute for, latex paint (Prokopy et al. 1995). Regarding the former, to date we have found that all tested variants of protective covers placed above spheres reduce alighting of *R. pomonella* by at least 50 percent, an unacceptable level (Duan & Prokopy 1992). A possible alternative to a protective cover is the placement of pesticide, feeding stimulant, and synthetic food and fruit odor within a hollow, perforated sphere. The wall of the sphere would serve to protect the interior from rainfall. A similar perforated, cylindrical trap baited with food odor is being developed for the Mediterranean fruit fly, *Ceratitis capitata* (Weidmann) (Health & Epsky 1995). However, to our knowledge, spheres of this type have not yet been evaluated against *R. pomonella* or any other tephritid flies. Previously, Reissig (1974, 1975) evaluated a yellow hollow rectangular box with a hole on each side and food odor and pesticide on the interior as a potential trap for *R. pomonella*. Initially, it appeared to be an effective trap in trees harboring hungry adults, but subsequently it proved ineffective when evaluated under a broader range of field conditions.

Here, we first evaluated *R. pomonella* response to internally and externally-baited red spheres perforated with holes and to internally-baited spheres with varying numbers of holes. We then observed post-alighting behavior on internally-baited spheres with varying numbers of holes. Finally, we evaluated commercially available red sphere traps designed so that both feeding attractant and pesticide are contained in a liquid inside the trap and are released through a sponge on the underside of the sphere, protected from rainfall.

METHODS AND MATERIALS

In the first experiment, internally and externally-baited red spheres were evaluated for propensity to capture *R. pomonella* in a commercial orchard. The spheres (obtained from Pest Management Supply Co., Hadley, MA) consisted of two separate, hollow halves (10 cm diam), which allowed odor baits to be placed inside the trap. Odor baits consisted of one unit each of synthetic fruit odor (butyl hexanoate, dispensed from a capped 15 ml polyethylene vial) and synthetic food odor (ammonium carbonate packet, purchased from R. Heath, Gainesville, FL). Spheres were perforated with three 2.4 cm holes. Four treatments were set up: (1) internally-baited spheres with two cardboard strips containing dimethoate (also placed inside) as the killing agent, (2) internally-baited spheres coated on the exterior with a layer of Tangletrap® (from the Tanglefoot Co., Grand Rapids, MI), (3) externally-baited

spheres (odors placed about 10 cm from the traps) with Tangletrap, and (4) externally-baited, non-perforated spheres with Tangletrap. The test was conducted in an orchard block of about 30 Gravenstein apple trees. Traps were positioned one per tree, according to methods described by Duan & Prokopy (1992). After one week, captured flies were counted and removed, and the trap types were rotated. Capture data were analyzed using a two way ANOVA, in which columns consisted of trap type and rows consisted of replicates.

In the second experiment, sticky 0-, 3-, 6-, 12-, and 24-hole spheres were evaluated for propensity to capture *R. pomonella*. Holes were 2.4 cm diam except for the 24-hole spheres, which were 1.4 cm. The odor baits used in this test were the same as in the first experiment. All traps were coated with Tangletrap and internally-baited (except for the 0-hole sphere, which was externally-baited). One trap of each type was hung in a large hawthorn tree known to contain a substantial *R. pomonella* population. Once daily, the traps were checked for *R. pomonella* captures, cleaned, and rotated. This was done for one complete rotation (5 days). For each day, the total number of fly captures over all trap types was summed and a percentage of that total was then calculated for each trap type. By using this approach, any day-to-day fluctuations in *R. pomonella* population size and activity were negated. Data were analyzed using a two way ANOVA, in which columns consisted of trap type and rows consisted of test days (trap position).

In the third experiment, post-alighting behavior of *R. pomonella* was observed on internally-baited red spheres with 3, 6, 12, or 24 holes. We wanted to determine fly inclination to enter holes to the interior of the trap (where feeding stimulant and pesticide could potentially be located). The same hawthorn tree and traps used in the second experiment were used in this test. Three traps of each type were hung and monitored for *R. pomonella* alightment, flies entering trap holes and time spent on the sphere. Residence times of *R. pomonella* on the spheres were analyzed by a one way ANOVA.

In the fourth experiment, an alternative trap type (Fruitect trap, mfd. by RonPal Ltd., Rishpon, Israel) and red wooden spheres were evaluated for *R. pomonella* post-alighting behavior. The Fruitect trap consisted of a red plastic sphere (12.5 cm diam) in which a feeding attractant (protein hydrolysate) and feeding stimulant (sucrose) were dispensed from the interior to the exterior via a sponge that formed a 1.0 cm band on the underside of the sphere. Red wooden spheres (8.0 cm diam) were dipped in an aqueous solution of 20% sugar prior to testing. The test was conducted in an indoor field cage by hanging four spheres (Fruitect and wooden spheres were tested separately) in a potted fig tree. For each trial, 40 female *R. pomonella* were released and allowed to forage freely for up to 1 h. Test flies were of wild origin, aged 3-4 weeks, and were either starved of all protein or continually fed protein since eclosion. Alighting flies were monitored for total time on the sphere and time spent feeding. Data on residence time, percent feeding, and feeding time were analyzed using two sample t-tests.

RESULTS

In Experiment 1 (Table 1), approximately 30-40% fewer *R. pomonella* were caught on 3-hole sticky traps internally-baited than on externally-baited sticky traps with or without 3 holes. Internally-baited 3-hole traps with pesticide instead of Tangletrap® as the killing agent failed to trap a single fly over the entire experiment.

In Experiment 2 (Table 2), externally-baited traps with no holes captured the highest number of flies and had the highest daily percentage of fly captures. Daily percent fly captures were about 15-40% less on the internally-baited spheres, although

TABLE 1. MEAN NUMBER OF *R. POMONELLA* CAPTURED PER REPLICATE (N=12) ON FOUR RED SPHERE TRAP TREATMENTS. EACH TREATMENT WAS BAITED WITH ONE UNIT EACH OF BUTYL HEXANOATE AND AMMONIUM CARBONATE.

Trap Type	Killing Agent	Odor Position	Mean No. Flies Captured Per Replicate \pm SE ¹
3-hole	Dimethoate	Internal	0.0 \pm 0.0c
3-hole	Tangletrap	Internal	24.3 \pm 5.8b
3-hole	Tangletrap	External	41.3 \pm 7.6a
0-hole	Tangletrap	External	36.1 \pm 5.8ab

¹Column values with different letters are significantly different according to two way ANOVA and LSD criterion at the 0.05 level.

two way ANOVA showed that differences among all five trap types were not significant.

In Experiment 3 (Table 3), 0, 0, 0 and 16% of alighting flies, respectively, entered holes in 3-, 6-, 12-, and 24-hole spheres. Flies spent significantly more time on 3- and 24-hole spheres than on 6- and 12-hole spheres.

In Experiment 4 (Table 4), a significantly greater proportion of alighting flies fed on red wooden spheres than on Fruitect traps. This was true for protein-fed flies (90 vs. 2%) and protein-starved flies (75 vs. 23%). Protein-fed flies on red wooden spheres fed much longer than flies on Fruitect traps (although the sample size feeding on Fruitect traps consisted of only one fly). Protein-starved flies on Fruitect traps and red wooden spheres showed no significant difference in mean time feeding.

DISCUSSION

Our findings indicate that the trap designs tested here are not an effective alternative to prototype pesticide-coated spheres described by Duan & Prokopy (1995a). To

TABLE 2. *R. POMONELLA* CAPTURES ON BAITED RED STICKY SPHERES WITH DIFFERENT NUMBERS OF HOLES. ALL TRAPS WERE INTERNALLY-BAITED EXCEPT THE 0-HOLE TRAP WHICH WAS EXTERNALLY-BAITED. RESULTS FOR EACH TRAP TYPE ARE EXPRESSED AS THE MEAN PERCENTAGE OF TOTAL DAILY CAPTURES FOR ALL TRAP TYPES COMBINED. THERE WAS A TOTAL OF 5 ONE-DAY CAPTURE PERIODS (N=5).

Trap Type	Total No. Trap Captures	Mean Percent of Total Daily Captures \pm SE ¹
0-hole	347	25.9 \pm 4.9
3-hole	285	21.4 \pm 3.3
6-hole	203	15.1 \pm 3.2
12-hole	193	15.3 \pm 1.9
24-hole	286	22.3 \pm 2.8

¹Differences in percentage captures between trap types were not significant according to two way ANOVA at the 0.05 level.

TABLE 3. MEAN *R. POMONELLA* RESIDENCE TIME AND FLY PROPENSITY TO ENTER HOLES IN RED SPHERE TRAPS WITH VARYING NUMBERS OF HOLES. EACH TRAP WAS INTERNALLY-BAITED WITH ONE UNIT EACH OF BUTYL HEXANOATE AND AMMONIUM CARBONATE.

Trap Type	No. Flies Alighting	Mean Time Per Fly Spent on Trap (s)±SE ¹	% Alighting Flies Entering Trap Holes±SE
3-hole	23	163.2±71.4a	0.0±0.0
6-hole	25	18.4±3.0b	0.0±0.0
12-hole	25	38.9±11.2b	0.0±0.0
24-hole	25	110.2±27.5a	16.3±7.5

¹Column values with different letters are significantly different according to two way ANOVA and LSD criterion at the 0.05 level.

kill *R. pomonella* alighting on a sphere using pesticide instead of Tangletrap[®], flies must remain on the sphere long enough to acquire a lethal dose of toxicant. This is best accomplished when toxicant is combined with a feeding stimulant (such as sucrose) and a high percentage of alighting flies contact the pesticide/sucrose mixture (Duan & Prokopy 1995a). The trap designs tested here failed in this regard.

The perforated hollow red spheres were constructed to protect both feeding stimulant and pesticide from rainfall by encasing them within the sphere. Success, however, is contingent upon the notion that alighting *R. pomonella* will readily enter trap holes to gain access to feeding stimulant and pesticide. This did not prove to be the case. In Experiment 3, only a very small percentage (no more than 16%) of flies alighting on perforated spheres actually entered a hole, regardless of the number of holes per sphere. Clearly, this is inadequate, as the vast majority of flies alighting on spheres would never come into contact with the killing agent. Reluctance to enter openings into traps has been shown in other tephritid flies as well. Reissig (1976) showed that

TABLE 4. MEAN RESIDENCE AND FEEDING TIMES OF *R. POMONELLA* ON FRUITECT AND RED WOODEN SPHERE TRAPS IN AN INDOOR FIELD CAGE STUDY.

<i>Fly type</i> —Trap Type	No. Flies Alighting	Mean Time Per Fly Spent on Trap (s)±SE ¹	% Feeding ±SE ¹	Mean Feeding Time Per Fly±SE ¹
<i>Protein Fed</i>				
—Fruitect	51	204.3±41.5a	2.0±2.0b	5.0±— ²
—Wooden sphere	30	204.8±46.2a	90.0±5.6a	212.0±51.2
<i>Protein Starved</i>				
—Fruitect	52	240.2±27.5a	23.1±5.9b	162.7±35.4a
—Wooden sphere	40	161.5±30.2a	75.0±6.9a	172.0±32.3a

¹Protein fed and protein hungry flies were analyzed separately. For each fly type, column values with different letters are significantly different according to a two sample t-test at the 0.05 level.

²Sample size (n) = 1.

with the cherry fruit flies, *Rhagoletis fausta* (Osten Sacken) and *R. cingulata* (Loew), traps requiring the flies to enter constricted openings were not effective. Prokopy & Economopoulos (1975) showed that non-sticky McPhail traps (which require flies to enter a port for capture) captured less than half of arriving olive flies. Similarly, Aluja et al. (1989) found that only 31% of *Anastrepha* spp. flies alighting on McPhail traps were ultimately captured. However, tests have shown that perforated cylindrical traps baited internally with food odor have promise for capturing both female and male Mediterranean fruit flies, although the percent of alighting flies that ultimately is captured is unknown (Heath & Epsky 1995). The reason why most *R. pomonella* in this study and most tephritid flies in other studies were not inclined to enter holes in traps containing bait on the interior is uncertain. Possibly most alighting flies do not come into contact with plumes of attractive odor emanating from trap holes.

The Fruitect red spheres tested here also failed to elicit a sufficient level of fly feeding to be effective. As was the case with hollow perforated spheres, most *R. pomonella* alighting on Fruitect traps departed without ever contacting the site of feeding stimulant and potential killing agent. The problem with Fruitect spheres may be that the sponge containing the feeding stimulant represents only a small part of the total surface area of the sphere. Conversely, flies that alighted on sucrose-coated red wooden spheres were exposed to feeding stimulant almost immediately upon tarsal contact with the sphere surface.

An additional factor to consider is trap attractiveness to foraging flies. We found in Experiments 1 and 2 that internally-baited red spheres were consistently slightly less attractive to *R. pomonella* than externally-baited spheres. A possible explanation for this is that the amount of odor released may have been reduced by positioning odors inside the sphere as opposed to outside.

To date, three approaches towards the development of a pesticide-treated sphere for controlling *R. pomonella* have been evaluated. The first of these is coating the exterior of the sphere with both feeding stimulant and pesticide. This approach is represented by the 8 cm wooden spheres described by Duan & Prokopy (1995a). Under dry conditions, these traps have been shown to be as effective as traditional red sticky spheres in managing *R. pomonella* in commercial orchard blocks, with the major drawback being negative effects of rainfall (Duan & Prokopy 1995b). The second and third approaches (tested here) attempted to modify sphere design so that feeding stimulant and pesticide could be protected from rainfall. The second approach places feeding stimulant and pesticide within the trap interior, thus protecting it from rain. The third approach places feeding stimulant on the interior which is dispensed to the surface of the trap through a sponge. Neither of these two designs showed promise as an alternative to the first approach. Future research efforts will be directed at increasing the residual effectiveness of exterior-coated pesticide spheres using residue extending agents.

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