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COLORED SPHERICAL TRAPS FOR CAPTURE OF CARIBBEAN FRUIT FLY, *ANASTREPHA SUSPENSA*

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ABSTRACT

Colored spheres of five different sizes (6.3, 8.9, 14.0, 16.5, 20.0 cm diam) and five colors (orange, black, yellow, green, white) were coated with a trapping compound and presented to field-caged flies (males, virgin females, mated females). The most females were captured on the 20 cm orange, green, and white balls and the 8.9 cm yellow ball. There was no statistically significant preference on the part of males for any particular size or color. When the four most attractive spheres were presented simultaneously to mated and virgin females they were most likely to be captured on 20.0 cm orange and green spheres. More males were caught on the 20.0 cm orange ball. When data were summed, 20.0 cm orange balls were statistically superior overall. In a field release test, 20.0 cm orange balls, 20.0 cm orange balls with a protein hydrolysate bait, 20.0 cm diam orange balls with caged live males, and 10 cm yellow balls with food bait were compared to McPhail traps baited with protein hydrolysate. The orange sphere with males was superior to all the other traps.

RESUMEN

Esferas de cinco tamaños diferentes (6.3, 8.9, 14.0, 16.5, y 20.0 cm de diam.), y de cinco colores (naranja, negro, amarillo, verde, y blanco), se cubrieron con una substancia atrayente y ofrecida a moscas en jaulas en el campo (machos, hembras vírgenes, y hembras fertilizadas). Se capturaron más hembras en las esferas color naranja, verdes y blancas de 20 cm, y la amarilla de 8.9 cm. Estadísticamente no hubo ninguna diferencia significante en preferencia por parte de los machos hacia ningún tamaño o color en particular. Cuando las cuatro esferas más atractivas se les ofreció simultaneamente a hembras fertilizadas y vírgenes, fue mas probable que se capturaron en esferas de color naranja y verdes de 20.0 cm. Se capturaron más machos en la esfera color naranja de 20.0 cm. Cuando se sumaron las cifras, las esferas color naranja de 20.0 cm fueron generalmente estadísticamente superior. En una prueba de liberación en el campo, las esferas color naranja de 20.0 cm, esferas color naranja de 20.0 cm con un cebo de proteina hidrolisada, esferas color naranja de 20.0 con machos vivos enjaulados, y esferas amarillas de 10.0 cm con cebos de comida, se compararon a trampas de McPhail cebadas con proteina hidrolisada. La esfera color naranja con machos fue superior a todas las otras trampas.

Colored spheres attract tephritid fruit flies of several genera (*Rhagoletis*, Prokopy [1975]; *Ceratitis*, Nakagawa et al., [1978]; *Anastrepha*, Cytrynowicz et al. [1982]; *Toxotrypana.*, Landolt et al. [1988]). So strong is the reaction of some species to particular sizes and hues that, once coated with a trapping compound, colored spheres alone can serve as a sufficient means of control (Prokopy 1975). When combined with chemical attractants, either host cues, parapheromones, or pheromones, the ability of spheres to attract fruit flies is often enhanced (Swift 1982, Nakagawa et al. 1978, Landolt et al. 1988).

The standard means of monitoring the distribution of the Caribbean fruit fly, *Anastrepha suspensa* (Loew), is the McPhail trap, an invaginated glass bottle containing a solution of protein hydrolysate in water. Entomologists experienced in tephritid studies consider the McPhail trap baited with a food lure to be relatively less efficient than parapheromone baited traps developed for the capture of other species of fruit flies (C. O. Calkins, personal communication, see Sivinski & Calkins 1986). The following study describes sphere sizes and colors that were effective in trapping field-caged Caribbean fruit flies. In a field-release test, several alternative sphere traps were compared to the McPhail trap.

Methods and Results

The search for a Caribbean fruit fly sphere trap was undertaken in three stages: 1) to discover if different size spheres of a certain color are more attractive than others to flies in field cages; 2) to simultaneously compare in field cages the most attractive colored spheres discovered in experiment 1; and 3) to compare the attractive spheres by themselves and in conjunction with food lures and pheromone-producing males to the food-baited McPhail trap using released flies in the field.

Experiment 1. Relationship Between Size and Color.

Experiments were conducted at the USDA/ARS Insect Attractants, Behavior, and Basic Biology Research Laboratory at Gainesville, Florida, during the months of March-August. Flies were obtained from a colony maintained at the Laboratory for more than 10 years. Mated females (i.e. >12 days old and held since eclosion with males) and >12-day-old males were placed in 2.9 m X 2 m screen-mesh field cages erected in a shady woods on the laboratory grounds. The insects had been sterilized by exposure to 5 kR of radiation 24-28 h before eclosion. This is more than sufficient dosage for sterilization (Calkins et al. 1988; for details of irradiation see Webb et al. 1987), and was done to prevent infestations of local fruit by escapees. Due to equipment and space constraints, virgin females (>12 days old and separated from males at eclosion) were released into a 2.3 X 2.4 m field cage inside a greenhouse. In all instances, 100 insects were put into the cages at 0900 H and the traps and uncaught flies were removed at 1600 h.

At any one time, males and mated females were presented with five styrofoam balls (6.3 cm diam, 8.9 cm diam, 14 cm diam, 16.5 cm diam, 20.0 cm diam) of one of the following colors, orange (glowing sunset by Krylon, Columbus, OH), saturn yellow (Day Glo, Cleveland, OH), gloss black (Ace, Oak Brook, IL), gloss white (Ace), and signal green (Day Glo). Colors were chosen on the basis of previous tephritid work. *Anastrepha fraterculus* (Wied.) and the Mediterranean fruit fly, *Ceratitis capitata* (Wied.), are known to be attracted to black and yellow spheres (Nakagawa et al. 1978). The papaya fruit fly, *Toxotrypana curvicauda* Gerstäcker, comes to green spheres (Landolt et al. 1988), and *A. suspensa* is attracted to flat surfaces colored orange (Greany et al. 1977). Painted spheres were coated with the sticky trapping component, Tack Trap (Animal Repellents, Inc., Griffin, GA). Balls were spaced equidistantly, 25 cm from the margin of the cage. Five replicates of each color were presented and the position of the balls rotated each replicate so that each ball occupied each location once.

Because a different sized field cage was used to hold virgin females, they were exposed to a different regime of ball presentation. The colors were identical to the above, but only three size categories at a time were hung in the cage. The two sets of balls consisted of 8.9, 14.0, 16.5 cm diam spheres, followed by 14, 16.5, 20 cm diam balls. Thus, the 8.9 and 20 cm diam balls were presented three times, and the 14 and 16.5 cm diam balls six times; 6.3 cm balls were not presented. Statistical analysis was performed by two factor analysis of variance (SAS Institute 1982). Because a strong interaction was discovered between size and color, each combination of color and size was considered a separate factor of the variable color/size. Means were separated by Duncan's multiple range test (SAS Institute 1982).

Results:

There was no significant relationship between male capture and ball color (p = .08) or size (p = 10; Table 1). However, there were highly significant differences in female captures (color, virgin p = .0003, mated p = .001; size, virgin p = .001, mated p = .0003 (Table 1)). There were highly significant interactions between color and size (virgin p = .0001; mated p = .006). For instance, orange on large balls had the highest numerical values for both female types but other colors (e.g. yellow) had higher mean captures on smaller spheres. The highest captures of virgin females were on 20.0 cm orange, green, and white balls. More mated females were taken on 20.0 cm orange and green balls and 9.0 cm yellow balls.

TABLE 1. THE MEAN NUMBER (STANDARD ERROR) OF FLIES TRAPPED ON VARIOUS SIZES AND COLORS OF SPHERES.

	Sphere diam (cm)				
Color	6.3	8.9	14	16.5	20
			Males		
Orange	12.6(3.4)	17.6(5.5)	17.2(4.4)	18.0(5.0)	23.6(10.2)
Green	17.4(2.3)	19.6(5.7)	11.8(0.4)	14.2(4.3)	21.0(10.8)
Yellow	6.4(1.2)	5.6(2.0)	9.6(1.5)	16.6(3.1)	22.8(4.0)
Black	9.6(4.5)	11.8(4.0)	14.2(7.0)	14.8(5.1)	9.2(3.2)
White	5.6(2.7)	3.4(1.6)	13.2(5.1)	17.2(6.4)	12.6(10.1)
			Virgin Females		
Orange	—	10.7(0.9)	17.7(2.3)	37.3(6.6)	59.3(2.7)a[1]
Green	—	8.8(2.5)	7.3(1.0)	24.0(5)	50.0(1.2)a
Yellow	—	10.3(1.3)	21.3(5.9)	21.0(4.2)	22.3(4.9)
Black	—	15.3(2.4)	13.5(6.5)	31.0(4.2)	33.3(7.8)
White	—	10.0(3.1)	4.3(1.5)	15.8(3.9)	51.7(5.3)a
			Mated females		
Orange	11.5(2.5)	5.8(1.4)	10.4(2.2)	12.4(1.2)	23.4(7.7)a
Green	7.2(1.7)	6.0(3.4)	5.4(2.2)	8.8(1.8)	19.4(4.0)a
Yellow	12.3(3.7)	20.0(2.6)	18.6(2.4)a	8.8(2.6)	13.6(4.0)
Black	6.2(1.0)	10.4(1.3)	8.2(1.8)	8.2(1.5)	5.4(1.3)
White	2.4(0.9)	0.0(0.0)	0.6(4.0)	1.8(1.1)	7.2(1.3)

[1]Means marked with an 'a' are statistically identical yet significantly greater than other means in the same sexual category.

Experiment 2: Comparison of Most Effective Colors/Sizes.

Since the various colors were presented separately in experiment 1, it was considered prudent to simultaneously compare the most effective size and color combinations. The most effective colors and combination size for the capture of females were the 9.0 cm yellow and the 20 cm orange, green and white spheres, (male preference was not significant in regards to size and color in experiment 1). These were placed in an outdoor field cage in a manner similar to that previously described for males and mated females. Initial trap placement was random and spheres were rotated for each replicate. There were eight replicates each of males, virgin females, and mated females. Males were included to see if a statistically clear preference emerged in this different format. Statistical analysis was by analysis of variance and means were separated by Duncan's multiple range test (SAS Institute 1982).

Results:

The efficiency of the various traps was similar for virgin and mated female flies (Table 2). The 20.0 cm orange and green balls captured statistically more females than white and yellow balls. Orange balls were statistically more attractive than any other color for the capture of males and were also more attractive when results from males and females were combined.

Experiment 3: Comparison of Spheres and McPhail Traps.

Field comparisons of various traps were performed in mixed citrus groves on the USDA-ARS, A. H. Whitmore Foundation Farm in Lake County, Florida. Flies were sterilized by exposure to 5 kR of radiation 24 h before eclosion and were 10-18 days old at the time of release (see Webb et al. 1987, Calkins et al. 1988). Of a random sample of 292 flies taken from those to be released, 47% were males and 77% (10 of 13) of the females contained sperm in spermathecae. In addition to McPhail traps baited with protein hydrolysate and water solution (ca. 6.0 g/liter), the following spheres were presented: 20 cm orange with ca. 0.5 liter of the above mentioned protein hydrolysate solution suspended in an open jar 5.0 cm beneath, a 20.0 cm orange with a screen wire cage (7.5 X 6.9 cm) containing 12 mature (10 day old) males suspended beneath it, and a 10.0 cm yellow ball baited with 20 ml of protein hydrolysate solution. The yellow-sphere trap consisted of a plastic ball perforated by numerous large holes. The bait-containing vial was placed inside the sphere. Large orange spheres were chosen because of their overall higher capture rate in Experiment 2 and the neurological evidence that *A. suspensa's* eyes are most sensitive to orange light (Greany et al. 1977). The smaller yellow sphere was included because of its success in Experiment 1 and because if it competed well in this field format it might be

TABLE 2. THE MEAN NUMBER (STANDARD ERROR) OF FLIES TRAPPED ON SPHERES WITH THE MOST SUCCESSFUL SIZE AND COLOR COMBINATION.

	Virgin females	Mated females	Summed females	Males	Summed flies
20 cm Orange	18.3 (.71)a[1]	20.6 (.74)a	19.4 (.35)a	17.4 (1.9)a	18.8 (1.2)a
20 cm Green	17.0 (.82)a	15.6 (.57)a	16.3 (.35)a	11.5 (1.5)b	14.7 (1.1)b
20 cm White	8.3 (.32)b	9 (.57)b	8.5 (.23)b	5.4 (0.8)c	7.5 (0.7)c
8.5 cm Yellow	8.1 (.71)b	8.6 (.64)b	8.4 (.33)b	6.9 (1.2)c	7.9 (0.9)c

[1]Numbers in columns sharing the same letters are not significantly different; Duncan's multiple range test.

cheaper and easier to use on a large scale than 20 cm orange balls. One of each of the above was hung in trees in a pentagon pattern with ca. 11.5 m between different traps. Initial trap placement was random. Four pentagons, each 60 m or more apart, were set up.

Approximately 300 flies were released at ca. 1200 h in the center of each pentagon. On the following day (1130 h), flies were counted and removed from traps, the traps were then rotated and another 300 flies released. There were five replicates, sufficient for each trap to be placed in each location within a pentagon. Data were analyzed with Freidman's random block analysis of variance and the Newman-Keuls procedure (Zar 1974). The sex ratios of captured flies in various traps were compared through analysis of variance (SAS Institute, 1982).

Results:

About 4% of the released flies were captured by traps. There was no statistical difference between any of the traps with the exception of the orange sphere and adult male combinations that caught more flies of both sexes than any of the other traps (Table 3). There was no difference in the sex ratios of flies caught on the traps ($P>0.05$).

Discussion

There are similarities between the responses of *A. suspensa* to colored spheres and those of other tropical tephritids. In *C. capitata* and *A. fraterculus*, as well as *A. suspensa*, the size of a sphere influences the effectiveness of a particular color as an attractant (Cytrynowicz et al. 1982, Nakagawa et al. 1978). For instance, orange was more effective in capturing virgin females on 20.0 cm balls, but among 9.0 cm balls yellow was a more attractive color. A novel quality of *A. suspensa* is its sensitivity to and response to orange in addition to the black and yellow preferred by the other species (see Greany et al. 1977).

The superiority of the 20 cm orange sphere and adult male combination over the McPhail trap suggests that a sphere-pheromone combination might be an improvement over traditional food-bait trap designs. Male-emitted pheromones in the Tephritidae often have broad attractiveness to virgin females and (to some extent) mated females seeking insemination, and to males apparently searching for signaling positions within male mating aggregations (Perdomo 1974, Sivinski & Heath 1988). However, it is not clear to what extent the sphere itself contributes to the success of the sphere-male trap. Males in conjunction with simple sticky cardboard traps also are more attractive than McPhail traps (Perdomo et al. 1976). The question of sphere efficacy might be more profitably posed when and if synthetic *A. suspensa* pheromones are available. It should be kept in mind that the test releases did not include sexually immature flies that might be common in the field and perhaps more likely to respond to a food cue than a pheromone.

TABLE 3. THE MEAN NUMBER (STANDARD ERROR) OF FLIES TRAPPED IN THE FIELD ON VARIOUS TRAP DESIGNS.[1]

	O	O_b	O_m	Y	M
Total	2.1 (2.9) b	0.8 (1.1) b	5.8 (6.3) a	1.2 (1.9) b	2.5 (5.8) b
Males	0.8 (0.9) b	0.4 (0.7) b	2.7 (2.6) a	0.9 (1.7) b	0.7 (1.4) b
Females	1.4 (2.3) b	0.4 (0.9) b	3.7 (4.2) a	0.5 (0.7) b	1.9 (4.5) b

[1]O = 20.3 cm diam orange sphere, O_b = 20.3 cm diam orange sphere with food bait, O_m = 20.3 cm diam orange sphere with mature males, Y = 10 cm yellow sphere with food bait, M = McPhail trap with food bait. Numbers in a row sharing letters are not significantly different.

ENDNOTE

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