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Comparative Field Studies of Various Traps and Attractants for the Olive Fruit Fly, *Bactrocera oleae*[1]

G.E. HANIOTAKIS[2], TH. BROUMAS[3] and C. LIAROPOULOS[4]

[2] *N.R.C. "Demokritos", Institute of Biology, P.O. Box 60228, 15310 Athens, Greece*
[3] Benaki Phytopathological Institute, 145 61 Kifissia, Athens, Greece
[4] National Agricultural Research Foundation, Athens, Greece

ABSTRACT

In the framework of an ongoing effort for development of an effective trap for the control of the olive fruit fly, *Bactrocera oleae* (Gmelin) (Diptera, Tephritidae), by mass trapping, four trap types (wood, cloth, laminate, McPhail), seven different colors of laminate traps, different food attractants, attractant combinations or formulations (total of ten cases), and two insecticides (deltamethrin, b-cyfluthrin) used as killing agents on the traps, were compared under field conditions. The following conclusions may be drawn: Laminate traps (paper envelopes with a polyethylene lining inside, 15X20 cm in size, containing 70 g of ammonium bicarbonate salt and impregnated with 15 mg (a.i.) of an insecticide), were more effective than wood traps. Effectiveness of laminate traps can be enhanced by using an attracting color or in the case of the food attractant ammonium bicarbonate, by incorporating copper oxychloride. Combinations of two protein hydrolysates were more effective than one hydrolysate alone. Effectiveness of protein hydrolysates is not constantly higher than that of ammonium bicarbonate, the use of which is more economic and convenient. The insecticide b-cyfluthrin may be used on traps instead of deltamethrin, which is known to have a repellent effect on the olive fly, especially under high concentrations, and is unstable under natural UV light.

Introduction

The olive fruit fly, *Bactrocera oleae* (Gmelin) (Diptera, Tephritidae), like most tephritid species, responds strongly to behaviour-modifying agents, such as food and visual attractants, and pheromones. A variety of traps utilizing one or more of these agents has been designed and evaluated and several attempts have been made for the control of this major olive pest by mass trapping (Cirio et al. 1979; Quaglia et al. 1983; Delrio 1984; Economopoulos et al. 1986; Zervas 1986; Broumas et al. 1990; Haniotakis et al. 1991 and references included in these papers). Use of a trap combining an attractant sex pheromone, an aggregation pheromone, a food attractant, a phagostimulant, a hygroscopic substance, and a toxic substance has given the most promising results (Haniotakis et al. 1991). At low to medium insect population densities, this method gives acceptable olive protection and constitutes the most commonly used olive fruit fly control method for biological olive growing. At high population densities, however, complementary spray applications are required to achieve acceptable crop protection. An ongoing refining and testing program aims at enhancing

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trap effectiveness to the point that mass trapping can suppress enough the populations so that no complementary measures will be required under any conditions Convenience and cost reduction are also examined in this process. Refinement refers to individual trap effectiveness as well as to the efficacy of the method itself. Parameters being tested for enhancing the efficacy of the method include trap density, trap deployment and trap type combinations (Broumas et al., 1998). Parameters being tested for enhancing the effectiveness of individual traps include material used for trap construction, insect killing agent (adhesives, insecticides), trap design, trap color, type of food attractant (ammonia releasing salts, protein hydrolysates, combinations of the two), and attractant formulations (solid, liquid, use of catalyst). The role of pheromones in the effectiveness of the traps as well as the performance of pheromone dispensers are well understood (Broumas and Haniotakis, 1994), therefore no pheromones were included in the tests we report here, concerning experiments we conducted during 1992 and 1993.

Materials and Methods

The tests were conducted in olive orchards of the Tanagra area (Viotia, central Greece) with medium to large olive trees of the variety Megaritiki, cultivated for oil production. Selection of test orchards was based on uniformity of tree size and general tree condition, crop load, and cultural practices applied. Traps were placed as in mass trapping applications, i.e. one per tree inside the canopy at a height of ca 2 m. Traps were checked every 5-6 days. A completely randomized block design was used, with numbers of replicates ranging from 10 to 20. Means were separated by Duncan's multiple range test. Four trap types, seven trap colors, ten food attractants, attractant combinations or formulations and two insecticides were tested.

Trap types:

a) Wood traps. Plywood rectangles 15X20 cm of natural brown color, coated either with a transparent or a yellow-colored adhesive in order to contain the attracted insects for counting. b) Laminate traps of white color coated with a transparent adhesive substance (Vioryl S.A., Kato Kifissia, Athens Greece). They were made of 60g/m2 paper, lined with 70g/m2 polyethylene layer folded into air-tight envelopes (polyethylene inside, paper outside), 15X20 cm in size. Envelopes were sealed by means of a heat press and coated with a transparent adhesive substance. Laminate traps as above of six different colors coated with a transparent adhesive were made by Phytophyl, G. Stavrakis, Schimatari Viotia, Greece and designated as No.1, 2, 3, 4, 5, and 6 for olive fly attracting yellow (Prokopy et al., 1975), yellow-green, yellow-lemon, yellow-orange, dark green, and white coated with yellow-colored adhesive, respectively. Food attractants (see below) in dry form were contained inside the traps. Attractants in liquid form were contained either inside the traps, or inside plastic bottles which were inserted inside the traps. Attracting volatile substanses were released through four (two on each side) 1 mm diameter holes punctured into the traps during installation. c) Cloth traps (Fitsakis, Iraklion, Crete, Greece). These traps were made of densely woven cotton cloth sown into envelopes 15X20 cm in size. Inside each envelope was inserted a polyethylene bag, open at the top, which was filled with water. Between the cloth envelope and the polyethylene bag was stapled a paper bag containing 70 g of ammonium bicarbonate. Attractants in wood, laminate or cloth traps were not replaced during the experimental period. d) McPhail type glass traps filled with 300 ml of ammonium sulfate water solution (2%). The solution was replaced at every trap check.

Food Attractants:

a) Ammonium bicarbonate salt was contained inside the laminate traps at 70 or 35 g per trap, or in polyethylene bags 8X14 cm, which were fastened on the wood traps at 70 g per trap. b) Ammonium bicarbonate combined with copper oxychloride (2g/trap), which enhances ammonia release (activator), or with glycerine (10ml/trap). c) Ammonium bicarbonate in a special pill formulation (AgreSense-BCS Ltd. Unit 1, Taffsmead Road, Treforest Industrial Estate, Pontypridd, Mid Glamorgan, CF375SU, U.K.). d) Ammonium carbonate salt, used the same way as the ammonium bicarbonate. e) Combination of ammonium carbonate and ammonium bicarbonate salts in equal parts. f) Tamella (Phytophyl, G. Stavrakis, Schimatari, Viotia, Greece). This is soy-protein hydrolysate, used as 1% or 10% water solution, 500 ml per trap, in laminate traps. g) Wheat-gluten hydrolysate (Phytophyl), used as 1% water solution, 500 ml per trap in laminate traps. h) Combination of (f) and (g), used as 0.5% water solutions, equal parts, 500 ml per trap in laminate traps. I) Enzymatic soy-protein hydrolysate (Phytophyl), used as 0.1, 0.5, and 1% water solution in laminate traps, 500 ml per trap. j) Ammonium sulphate salt,

used as 2% water solution in McPhail type glass traps, 300 ml per trap.

Insecticides on traps:

For mass trapping, wood, laminate and cloth traps were impregnated with 15 mg (a.i.) of deltamethrin or b-cyfluthrin. To test possible repellency of these insecticides to target insects, impregnated traps were placed inside 0.6 mesh sticky screen cages 23X17X4 cm for insect counting. For impregnation, traps were dipped in a water emulsion of the appropriate concentration of insecticide to retain the 15 mg of active ingredient.

Two experiments in 1992 and three in 1993 were conducted. Combinations of variables tested in the five different tests are summarized in Table 1.

In Test A thirteen variables were included, aiming at comparison of a) three trap types (wood, laminate, McPhail), b) five different colors of laminate trap (white, dark green, yellow-green, yellow-lemon, yellow-orange), c) six different attractants (ammonium bicarbonate in full and half doses, ammonium bicarbonate with an activator, ammonium bicarbonate in combination with ammonium carbonate, ammonium carbonate alone, Tamella).

In Test B four variables were included, aiming at the comparison of two attractants (ammonium bicarbonate alone or in combination with glycerine, and Tamella contained inside the trap or a plastic bottle inside the trap) in laminate traps of a dark green color.

In Test C five variables were included, aiming at the comparison of: a) two formulations of ammonium bicarbonate (salt in plastic bags, polymer formulation) b) four trap types i.e. wood, laminate, and cloth (all baited with ammonium bicarbonate), and McPhail), and c) at the detection of possible repellent effect of the insecticides deltamethrin and b-cyfluthrin on the olive fly.

In Test D nine variables were included, aiming at the comparison of: a) wood and laminate traps of white color both baited with ammonium bicarbonate, b) wood traps of natural color and wood traps coated with yellow-pigmented adhesive, c) laminate traps of white color coated with transparent or yellow-pigmented adhesive, d) laminate traps of three different colors (white, yellow-green, orange), e) three different food attractants (ammonium bicarbonate, Tamella, wheat gluten hydrolysate, and combination of the last two) in laminate traps of yellow-green color.

In Test E seven variables were included, aiming at the comparison of: a) two trap types (wood, and white laminate), b) laminate traps of two non-attractive colors (white, dark green), and one attractive color (yellow-orange), and c) three concentrations of a food attractant (enzymatic soy-protein hydrolysate).

TABLE 1. Combination of variables tested in the various tests conducted during 1992 and 1993.

Test A. Conducted from July 13 to November 30, 1992. Each combination was replicated 15 times.

No	Trap type	Trap color	Attractant
1	Wood	Natural brown	Ammonium bicarbonate
2	Laminate	White	Ammonium bicarbonate
3	Laminate	Dark green	Ammonium bicarbonate
4	Laminate	Dark green	Ammonium bicarbonate + activator
5	Laminate	Dark green	Tamella in bottle
6	Laminate	Yellow orange	Ammonium bicarbonate
7	Laminate	Yellow green	Ammonium bicarbonate
8	Laminate	Yellow green	Ammonium carbonate
9	Laminate	Yellow green	Ammonium bicarbonate + activator
10	Laminate	Yellow green	Ammonium bicarbonate (35g)
11	Laminate	Yellow green	Ammonium bicarbonate + Ammonium carbonate
12	Laminate	Yellow lemon	Ammonium bicarbonate +activator
13	McPhail	Transparent	Ammonium sulfate

Test B. Conducted from September 7 to November 30, 1992. Each combination was replicated 10 times.

No	Trap type	Trap color	Attractant
1	Laminate	Dark green	Ammonium bicarbonate
2	Laminate	Dark green	10% Tamella (inside)
3	Laminate	Dark green	10% Tamella in bottle
4	Laminate	Dark green	Ammonium bicarbonate + glycerine 10g

TABLE 1. (cont.)

Test C. Conducted from July 15 to November 17, 1993. Each combination was replicated 15 times.

No	Trap type	Trap color	Attractant
1	Wood[1]	Natural	Ammonium bicarbonate
2	Wood[1]	Natural	Ammonium bicarbonate pill
3	Laminate[2]	White	Ammonium bicarbonate
4	Cloth[1]	White	Ammonium bicarbonate
5	McPhail	Transparent	Ammonium sulfate

[1] Treated with deltamethrin and contained inside screen cage with adhesive.
[2] Treated with b-cyfluthrin and contained inside screen cage with adhesive.

Test D. Conducted from July 8 to November 19, 1993. Each combination was replicated 20 times.

No	Trap type	Trap color	Attractant
1	Wood	Natural	Ammonium bicarbonate
2	Wood	Yellow adhesive	Ammonium bicarbonate
3	Laminate	White	Ammonium bicarbonate
4	Laminate	White, yellow adhesive.	Ammonium bicarbonate
5	Laminate	Yellow green	Ammonium bicarbonate
6	Laminate	Orange	Ammonium bicarbonate
7	Laminate	Yellow green	1% Tamella in bottle
8	Laminate	Yellow green	1% Gluten in bottle
9	Laminate	Yellow green	Tamella+gluten

Test E. Conducted from September 8 to November 19, 1993. Each combination was replicated 12 times.

No	Trap type	Trap color	Attractant
1	Wood	Natural	Ammonium bicarbonate
2	Laminate	White	Ammonium bicarbonate
3	Laminate	Yellow orange	Ammonium bicarbonate
4	Laminate	Dark green	Ammonium bicarbonate
5	Laminate	Yellow	Soy protein hydrolysate enzymatic, 0.1%
6	Laminate	Yellow	Soy protein hydrolysate enzymatic, 0.5%
7	Laminate	Yellow	Soy protein hydrolysate enzymatic, 1.0%

Results

The results of the first test (Test A) are shown in Fig. 1. The conclusions may be summarized as follows: a) Captures by McPhail, wood, and laminate traps of white or dark green color, i.e. colors not attractive to the olive fruit fly, baited with ammonium bicarbonate, captured a small number of flies with no significant differences between them (treatments 1, 2, 3, 13); b) Laminate traps of yellow-green or yellow-orange color with ammonium bicarbonate, (treatments 6, 7), caught significantly more flies, both male and female, than laminate traps of white or dark green color with ammonium bicarbonate (treatments 2, 3); c) Ammonium bicarbonate combined with copper oxychloride (activator) in laminate traps of a dark green color caught significantly more flies, both male and female, than ammonium bicarbonate alone contained in laminate traps of the same color (treatments 3, 4). However in laminate traps of a yellow-green color, the activator did not increase captures of ammonium bicarbonate inside a trap of the same or a yellow-lemon color (treatments 7, 9, 12). Thus the effect of the activator, was expressed in laminate traps of dark green color but not in the laminate traps of yellow-green or yellow-lemon color. This means that the incorporation of either a yellow color known to be attractive to the olive fruit fly (yellow-green, yellow-orange, yellow-lemon) or an activator into a laminate trap of a neutral color, containing ammonium bicarbonate, significantly increased fly captures of both sexes. The effect of the combination of both yellow color and activator in the same trap was not additive, however. d) Captures by ammonium bicarbonate and ammonium carbonate in laminate traps of yellow-green color

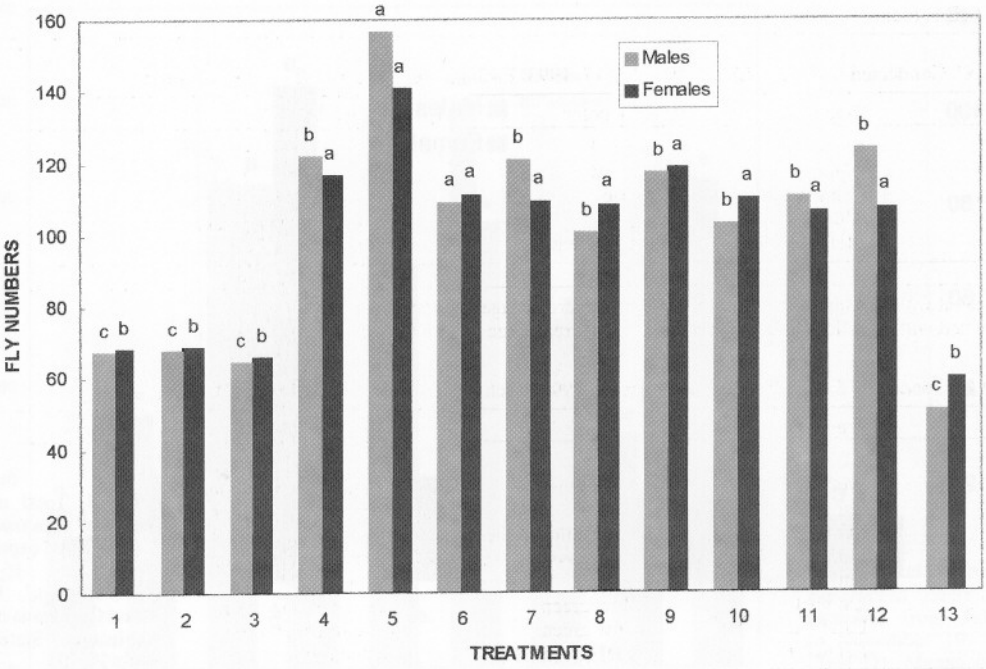

FIG. 1. Total numbers of *Bactrocera oleae* flies captured from July 13 to November 30, 1992 (Test A). Means of 15 replicates. For each sex, means followed by same letters are not significantly different, Duncan's multiple range test, $P>0.05$. For treatments see Table 1.

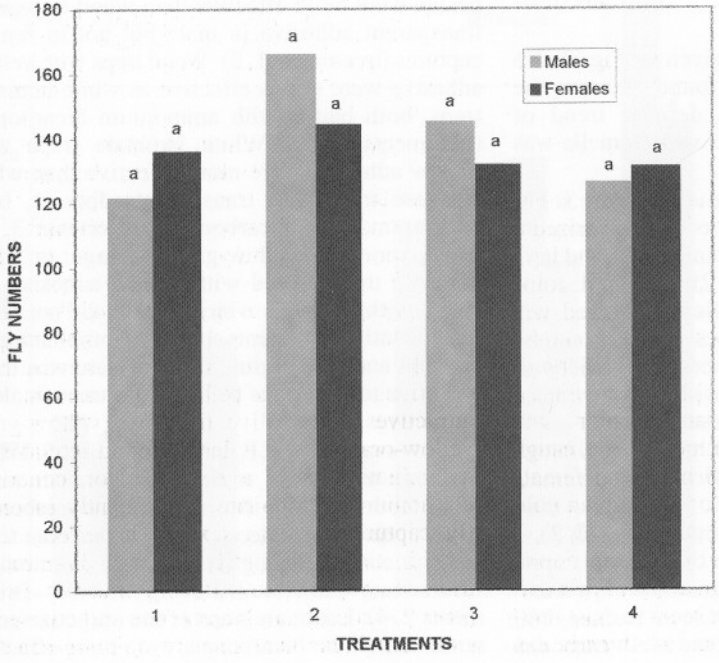

FIG. 2. Total numbers of *Bactrocera oleae* flies captured from September 7 to November 30, 1992 (Test B). Means of 10 replicates. Statistics as in Fig. 1.

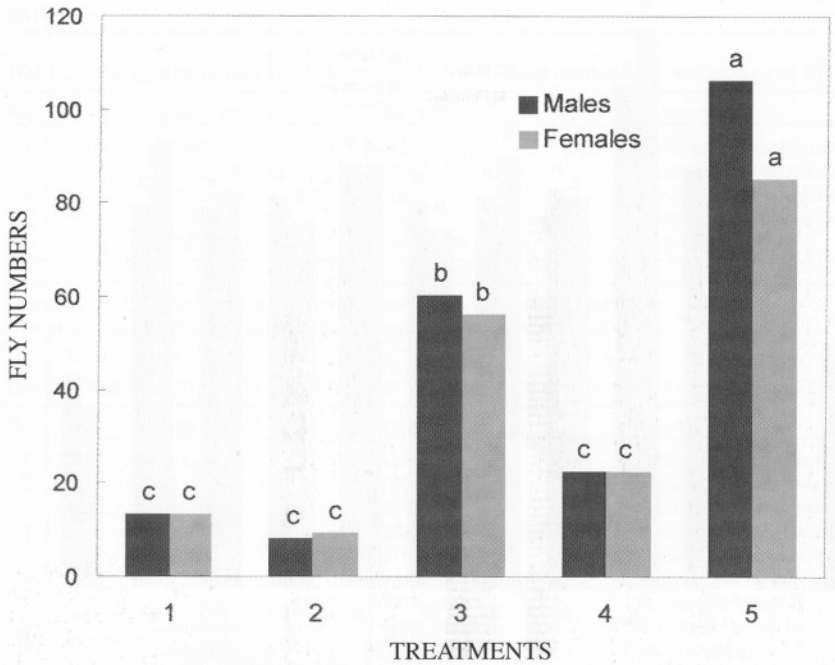

FIG. 3. Total numbers of *Bactrocera oleae* flies captured from July 15 to November 17, 1993 (Test C). Means of 10 replicates. Statistics as in Fig. 1.

did not differ significantly for either sex (treatments 7, 8). e) Laminate traps of a dark green color baited with Tamella captured significantly more male and female flies than the same traps baited with ammonium bicarbonate (treatments 3, 5): f) Response of the two sexes to various treatments was similar.

The results of test B are given in Fig. 2. No significant differences were found between the four treatments, although a definite trend of higher captures in traps baited with Tamella was observed.

The results of test C are given in Fig. 3. Fly captures by the two formulations of ammonium bicarbonate were very low and did not differ significantly (treatments 1, 2). McPhail traps (treatment 5) captured significantly more flies than any of the other trap types tested. It should be pointed out that all traps except McPhail were inside screen cages coated with adhesive (see insecticides on traps in materials and methods). White laminate traps treated with b-cyfluthrin (treatment 3) captured significantly more flies than either wood (treatments 1, 2) or cloth (treatment 4) traps treated with deltamethrine This may be due to the repellence of the commercial formulation of deltamethrin (P. Kalmoukos unpublished information) which does not seem to exist in b-cyfluthrin. Captures of wood and cloth traps did not differ significantly (treatments 1, 2, 4).

The results of test D are given in Fig. 4. Wood traps were less effective than white laminate traps, both baited with ammonium bicarbonate (treatments 1, 3). Wood traps coated with yellow adhesive were more effective than wood traps with transparent adhesive in male but not in female captures (treatments 1, 2). Wood traps with yellow adhesive were not as effective as white laminate traps, both baited with ammonium bicarbonate (treatments 2, 3). White laminate traps with yellow adhesive were more effective than white laminate traps with transparent adhesive, both with ammonium bicarbonate (treatments 3, 4). Effectiveness of yellow-green, orange, or white laminate traps coated with yellow adhesive, all baited with ammonium bicarbonate, did not differ significantly (treatments 4, 5, 6). Combination of Tamella and wheat-gluten hydrolysate was more attractive to olive flies than either attractant alone (treatments 7, 8, 9).

The results of test E are given in Fig. 5. White laminate traps were more effective than wood traps, both baited with ammonium bicarbonate (treatments 1, 2). Effectiveness of laminate traps of two non attracting colors with ammonium bicarbonate did not differ significantly (treatments 2, 4). Laminate traps of the attractive color with ammonium bicarbonate were more effective

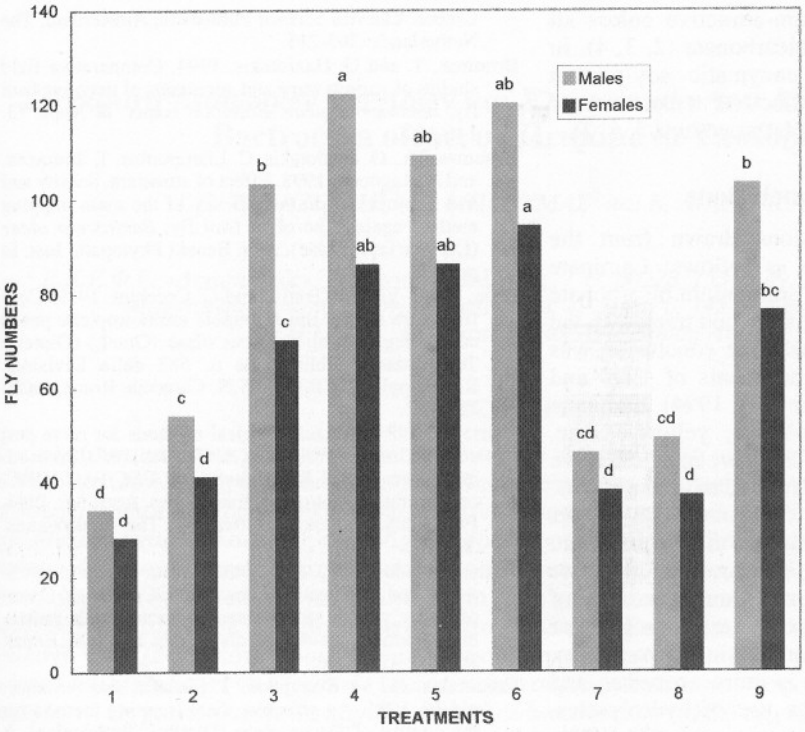

FIG. 4. Total numbers of *Bactrocera oleae* flies captured from July 8 to November 19, 1993 (Test D). Means of 15 replicates. Statistics as in Fig. 1.

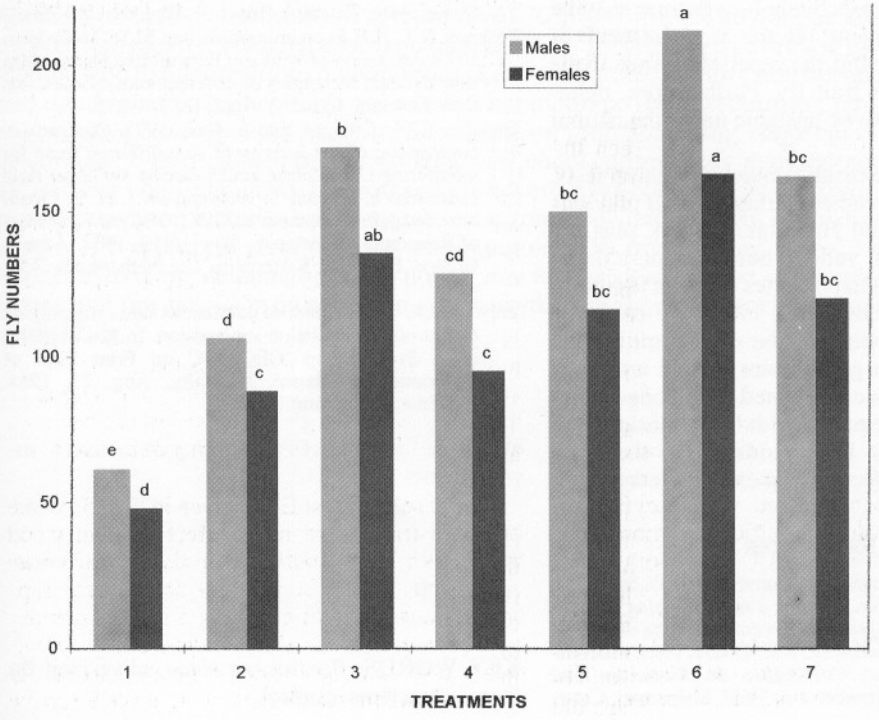

Fig. 5. Total numbers of *Bactrocera oleae* flies captured from September 8 to November 19, 1993 (Test E). Means of 15 replicates. Statistics as in Fig. 1.

than traps of the two non-attractive colors all baited with ammonium bicarbonate (2, 3, 4). In yellow laminate traps enzymatic soy-protein hydrolysate was more effective at the dose of 0.5% than at 0.1%, or 1.0% (treatments 5, 6, 7).

General conclusions

The general conclusions drawn from the present experiments are as follows: Laminate traps of white color with ammonium bicarbonate are as effective or better than wood traps with the same food attractant. The same conclusion was also drawn from the experiments of 1990 and 1991 (Broumas and Haniotakis, 1994). Laminate traps of yellow, yellow-green, yellow-orange, yellow-lemon, or orange color are more effective than laminate traps of white, or dark green colors. Ammonium bicarbonate combined with copper oxychloride is more attractive than ammonium bicarbonate alone in laminate traps of white or dark green colors but not in laminate traps of yellow hues. Protein hydrolysates are as good or better as attractants than ammonium bicarbonate, but the use of the latter is more economic and more convenient than the use of hydrolysates, which are effective only in water solutions. Soy-protein hydrolysate combined with wheat-gluten hydrolysate is more effective than either hydrolysate alone. The insecticide b-cyfluthrin may be used as killing agent on the traps instead of deltamethrin, to avoid the repellent effect of the latter on the olive fruit fly. Furthermore, deltamethrin is known to be unstable under the natural UV light.

Considering the results obtained in these tests, as well as those obtained during the two previous years (Broumas and Haniotakis 1994), plus the fact that traps of yellow hues attract a large number of beneficial species present in olive orchards (Neuenschwander, 1982), we conclude that for mass trapping of the olive fruit fly the laminate trap of a green color, baited with ammonium bicarbonate combined with copper oxychloride and impregnated with b-cyfluthrin as the killing agent may be considered as the most convenient and effective trap existing today.

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KEY WORDS: *Bactrocera oleae,* olive fruit fly, traps, attractants, control.

Σύγκριση Διαφόρων Παγίδων και Ελκυστικών του Δάκου της Ελιάς, Bactrocera oleae, σε Πειράματα Υπαίθρου

Γ.Ε. ΧΑΝΙΩΤΑΚΗΣ[1], Θ. ΜΠΡΟΥΜΑΣ[2] και Κ. ΛΙΑΡΟΠΟΥΛΟΣ[3]

[1] Ε.Κ.Ε.Φ.Ε. «Δημόκριτος», Ινστιτούτο Βιολογίας, Τ.Θ. 60228, 15310 Αγ. Παρασκευή Αττικής
[2] Μπενάκειο Φυτοπαθολογικό Ινστιτούτο, Σ. Δέλτα 8, 145 61 Κηφισιά, Αθήνα
[3] ΕΘ.Ι.ΑΓ.Ε., Εντομοτροφείο, Λυκόβρυση Αττικής

ΠΕΡΙΛΗΨΗ

Στα πλαίσια μιάς συνεχιζόμενης προσπάθειας για την ανάπτυξη μιάς αποτελεσματικής παγίδας για την καταπολέμηση του δάκου της ελιάς *Bactrocera oleae*, με τη μέθοδο της μαζικής παγίδευσης, τέσσερεις τύποι παγίδων (ξύλινη, υφασμάτινη, χαρτοπλαστική και McPhail), επτά διαφορετικά χρώματα της χαρτοπλαστικής παγίδας, διάφορα τροφικά ελκυστικά, διάφοροι συνδυασμοί ελκυστικών, διάφορα σκευάσματα ελκυστικών (συνολικά δέκα διαφορετικές περιπτώσεις) και δύο εντομοκτόνα (deltamethrin) και (b-cyfluthrin) που χρησιμοποιούνται για τη θανάτωση των εντόμων, δοκιμάστηκαν σε συγκριτικά πειράματα υπαίθρου. Σκοπός των πειραμάτων αυτών ήταν η επιλογή του πλέον αποτελεσματικού συνδυασμού για τη χρησιμοποίησή του στην πράξη. Από τα αποτελέσματα μπορεί να εξαχθούν τα παρακάτω συμπεράσματα που παρουσιάζουν πρακτικό ενδιαφέρον. Οι χαρτοπλαστικές παγίδες (φάκελοι διαστάσεων 15Χ20 εκ., από φύλλο χαρτιού εξωτερικά και πλαστικού εσωτερικά, που περιέχουν 70 γραμμάρια δισανθρακικού αμμωνίου και είναι εμποτισμένοι με 15 mg δραστικής ουσίας ενός εντομοκτόνου) είναι περισσότερο αποτελεσματικές από τις ξύλινες (τεμάχια κόντρα-πλακέ των ίδιων διαστάσεων με τις χαρτοπλαστικές, εφοδιασμένα με το ίδιο ελκυστικό και εντομοκτόνο). Χαρτοπλαστικές παγίδες με κίτρινες ή πρασινοκίτρινες αποχρώσεις είναι περισσότερο αποτελεσματικές από εκείνες λευκού χρώματος αλλά και περισσότερο βλαβερές για το οικοσύστημα. Χαρτοπλαστικές παγίδες που συνδυάζουν δισανθρακικό αμμώνιο και οξυχλωριούχο χαλκό είναι περισσότερο αποτελεσματικές από εκείνες που περιέχουν μόνο δισανθρακικό αμμώνιο. Σε περίπτωση χρησιμοποίησης υδρολυμένων πρωτεϊνών ως ελκυστικών, ο συνδυασμός δύο συγκεκριμένων υδρολυμάτων ήταν περισσότερο αποτελεσματικός από ένα υδρόλυμα μόνο. Η αποτελεσματικότητα των υδρολυμάτων δεν είναι σταθερά ανώτερη από εκείνη του δισανθρακικού αμμωνίου, η χρήση του οποίου είναι ευκολότερη και οικονομικότερη. Η b-cyfluthrin είναι δυνατόν να χρησιμοποιηθεί στις παγίδες ως τοξική ουσία μεγάλης διάρκειας αντί της deltamethrin, στη μορφή που κυκλοφορεί σήμερα στο εμπόριο, η οποία διασπάται από την υπεριώδη ακτινοβολία και σε μεγάλες συγκεντρώσεις είναι απωθητική για το δάκο της ελιάς.