Attract and kill of the olive fruit fly *Bactrocera oleae* in Greece as a part of an integrated control system

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**Abstract**: The "Attract and Kill" method was evaluated for several years in two olive groves to control the olive fruit fly *Bactrocera (Dacus) oleae*. Results indicated that in isolated olive groves and in areas where the olive fruit fly develops low or medium population densities, one killing device per tree, baited with ammonium bicarbonate and pheromone, has the potential to keep the olive fruit fly population and the fruit infestation low. The level of fruit infestation was similar to that obtained in the control field, treated at least three times by ground bait spray of protein hydrolyzate-dimethoate. In non-isolated olive groves and in areas where the olive fruit fly develops high population densities, one killing device per tree provides inadequate protection and at least one treatment by ground bait spray, with protein-insecticide is needed to keep the fly population and the fruit infestation at low level. The results showed that the "Attract and Kill" method could progressively replace the use of insecticides for the control of the olive fruit fly.

**Key words**: *Bactrocera (Dacus) oleae*, "Attract and Kill", Integrated Pest Management, Pheromones, Food Attractants.

**Introduction**

The olive fruit fly, *Bactrocera (Dacus) oleae* (Gmel.) is the most serious pest of olives in the Mediterranean countries. Economic losses due to this pest have been estimated to reach up to 15% of the olive crop, in spite of the fact that, pesticide treatments are applied every year to control the fly population.

The olive fly develops two to five generations per year. The females lay eggs in the mesocarp of the olive fruits; the larva feeds in the fruit and pupates in the fruit or in the soil. Larval stages develop from midsummer to late autumn. In regions where olive fruits remain on the trees in spring, the olive fly develops one or two generations in spring. There may be a wide overlap in generations due to adult longevity and a long oviposition period.

Protein hydrolyzate mixed with organophosphorous insecticides bait sprays applied either by air or the ground, have been used for many years against the olive
fly (Nadel, 1966; Manousis and Moore, 1987). Usually three to five treatments may be required, especially in years favourable to the pest.

The damage caused by the olive fly and its control measures' results in: a) reduction in yield and quality of fruit and hence of olive oil. b) use of expensive chemicals and application machinery that increases production cost. c) the use of toxic chemicals creating many environmental problems. These concerns have emphasised the need for more selective methods for the olive fly control. Accordingly, development of alternative improved management technology for the control of the olive fly has been the goal of a broad research effort since the early 1970s.

Attempts to control the olive fruit fly by luring them into killing devices were initiated in 1960's. McPhail traps baited with a solution of protein hydrolyzate were used to lure the flies into the traps (Orphanidis et al., 1958), Visual (yellow color) sticky traps have also been used to control the fly, (Economopoulos et al., 1977), but as many authors have emphasised, these traps can be detrimental to beneficial insects that also respond to the lures. (Broumas et al., 1983; Kapatos and Fletcher, 1983; Jones, 1987).

Since the pheromones of the olive fruit fly were identified (Baker et al., 1980; Mazomenos and Haniotakis, 1981; 1985), pheromone traps have been developed and tested as monitoring and control tools (Mazomenos et al., 1983; Ramos et al., 1983; Broumas and Haniotakis, 1987; Montiel-Bueno, 1987; Haniotakis et al., 1987; 1991).

In this paper we report the results obtain from the evaluation of the "Attract and Kill" method integrating pheromone and ammonium bicarbonate as lures in two regions in Greece, Markopoulo and Stylis, Attikis and Phiotidos, province respectively. The tests lasted for five years with a goal to develop environmentally safe method to control the olive fruit fly

Materials and Methods

Plot Selection and Description. The test areas were selected in Markopoulo, 30 Km from Athens and Stylis in Central Greece. The 8 ha experimental olive grove in Markopoulo was the main grove in this region surrounded by vineyards and pasture fields. The olive varieties cultivated, are Megaritiki, Manaki, Amphissis (table olives) and Koroneiki olive oil producing variety. The grove is intensively cultivated and regularly irrigated. During the previous years, the olive fruit fly population was suppressed by ground protein-organophorosporous (Dimethoate) bait sprays, and also cover spray insecticides treatments (Deltamethrin or Dimethoate) were applied to suppress the olive moth Prays oleae population. The olive trees were 8-12 years old, 5 m tall and 6-7 m apart; the tree density was ca 150 trees/ha. A small olive grove approximately 3 ha, 500 meter apart was treated with protein-dimethoate and was used as control. This olive grove was not irrigated; the cultivars present was more or less similar to that in the "Attract and Kill" grove the same control measures were applied
Attract & kill of olive fruit fly during the previous years to control the olive fly and the olive moth population.

A second experimental olive grove located in Stylis central Greece was added in 1994. The reason of selecting the Stylis region to evaluate the performance of the integrated approach developed was: The cultivar that predominates in this region is the Amphissis that suffers high fruit infestation from both *P. oleae* and *B. oleae*. The results obtained in the semi-isolated grove at Markopoulo were promising and our goal was to test the efficiency of the method in a non-isolated olive orchard. The experimental 33 ha olive grove in Stylis is located within a landscape that is entirely covered with olive trees. Olive fruit fly control in the Stylis region is achieved by air spray with protein hydrolizate-dimethoate baits. Usually 3 to 5 treatments are applied every year. Also 2-3 cover spray treatments are applied to control the olive moth population. The trees were more than 50 years old approximately 10-12 meters high and 9-12 meters apart. The tree density was 100-120/ha.

**Pheromone formulations used.** The major female olive fruit fly pheromone component 1,7-dioxaspiro (5,5) undecane was formulated in polyethylene vials or in _-cycloextrin (_-CD) (Mazomenos *et al.*, 1989, Kondilis *et al.*, 1990). The _-CD-spiroacetal complex was placed in small plastic bags; eight ml of water were added to the bag to improve the release rate of spiroacetal.

**Treatments.** During 1992 and 1993 in Markopoulo the killing devices used, were paper plastic bags impregnated with 10 mg of deltamethrin, 10% sugar solution and 1% glycerol (Vioryl A.E Kato Kifissia Greece). Each device was baited with seventy grams of ammonium bicarbonate placed inside the bags and a pheromone dispenser loaded with 50 mg of spiroacetal. Half of the killing devices, one every other tree were installed the third week of June. The first week of September, killing devices were added to the remaining trees. Under the condition tested the killing efficiency of these devices was limited to approximately 45 days from installation and the traps has to be replaced more than once.

During 1994, 1995 and 1996, the killing devices used were consisted of a wire cylindrical frame subtended by a cotton cloth. The cloth was dipped in a concentrated water solution of flowable Desis. It was designed to deliver on each device 40 mg of active ingredient. The attractant components of the killing devices included Ethylene Vinyl Acetate (EVA) board co-melted with ammonium bicarbonate salt (10 g) (AgriSence-BCS, Pontyprid, U.K.) and plastic bag containing a solution of water and 500 mg of _-CD-spiroacetal complex (the net pheromone was 50 mg per trap). Bioassays indicated that these killing devices under natural conditions are effective and kill insects for more than 5 months. The same killing devices were also used in 1994 and 1995, to control the olive fly in the Stylis olive grove. Each year in both groves the devices were suspended to the olive trees the last week of June. Killing devices baited with ammonium bicarbonate were hung on every tree, while on every third tree a plastic bag containing the suspension of _-CD-spiroacetal was added.

The insecticide treated groves used as control, were treated by ground bait sprays, using protein hydrolyzate and insecticides (dimethoate) and were followed
the control programme applied every year by the ministry of agriculture.

Assessment. The efficiency of "Attract and Kill" and insecticide treatments was assessed by comparing fly catches in McPhail and pheromone traps. Five 20 x 20 cm plywood boards coated with sticky material were used as pheromone traps. Five pheromone traps, baited with a 1 ml polyethylene vial loaded with 25 mg of spiroacetate and five McPhail traps, baited with 3% ammonium bicarbonate solution, were placed in each grove. The same number of traps was placed also in the insecticide treated groves. The traps were in operation from April to November to monitor the fly population. Traps were inspected weekly. Pheromone dispensers were replaced every three-months, while the ammonium bicarbonate solution in the McPhail traps was renewed every week.

Trap catches were transformed to log (x+1) prior to statistical analysis (ANOVA). Means' comparisons were made using the Duncan's multiple-range test.

Fruit infestation by *B. oleae* was also assessed; 10 trees in each plot were randomly selected, four twigs bearing olive fruits from each tree were collected and the number of fruits infested was recorded. Infestation data were statistically analysed using a chi-square 2 x 2 test of independence. The infestation level recorded in the Attract and Kill olive grove was compared to the infestation level recorded in the insecticide treated grove. The P=0.05 level was set for the rejection of the null hypothesis.

Results

Monitoring. The efficiency of pheromone and McPhail traps to monitor the olive fly population throughout the entire flight season as an overall view of the combined data obtained with McPhail and pheromone traps, from the five years studies in Markopoulo is presented in Figure 1. Trap catches indicated that the olive fly population varied through the year seasons. In spring (March - May) more flies were caught compared to the flies caught during the hot and dry summer months. In autumn the number of catches in both traps was increased. Pheromone traps were found to be more effective in trapping males during spring and autumn, (F=5.5, df=14 and F=31.8, df=26, P=0.05), while during summer McPail traps were more effective (F=24.7, df=26, P=0.05). Comparing the number of males and females caught in McPhail traps there is not significant difference in spring and autumn (F=3.2, df =14, and F=1.5, df=20, P=0.05), whilst in summer significant more females were caught (F=5.3, df=26 P=0.05). The pheromone traps caught very few females.

Attract and Kill (Markopoulo). Trap catches in 1992 and 1993 indicated that the fly population remained low in the "Attract and Kill" olive grove, until late August, where it was slightly increased. In this region this is the date of emergence of the most damaging generation of the fly (Fig 2A, 2B). The installation of the same number of new traps to the trees that were left without traps in June resulted to the
decreased of the fly population. The same development of the fly population was observed also for the insecticide treated field. This field received three bait sprays protein hydrolyzate-dimethoate treatments by ground in 1992 and two in 1993. The number of flies caught in both olive groves was not significant different in 1992 (F=0.21, df=74, P=0.05), while in 1993 significant more flies were caught in the insecticide treated grove (F=6.71, df=74, P=0.05).

In the insecticide treated grove, three ground bait spray treatments were applied in 1994 and two in 1995 and 1996. The mean number of flies caught were not significant different in 1994 (F=1.61, df=74, P=0.05) while in 1995 and 1996 more flies were caught in the insecticide treated olive grove (F=4.3, df=74 and F=5.2, df=74, P=0.05).

Figure 1. Number of olive fruit fly males and females caught in pheromone and Mcphail traps. Mcphail traps were baited with 3% solution of ammonium carbonate.

Figure 2. Mean number of *B. oleae* flies caught in McPhail traps in groves treated with the "Attract and Kill" and with bait spray insecticide. Arrows indicate the dates of treatments [Markopoulo, 1992 (A), 1993 (B)].

In 1994, 1995 and 1996, (Fig. 3A, 3B and 3C), where the new killing devices were used, after the installation of the killing devices the fly population in the "Attract and Kill" grove remained low until fruit harvesting. 80% of the olives in this grove are
table olives and are harvested beginning of October (green olives).

![Figure 3. Mean number of B. oleae flies caught in Mcphail traps in olive groves treated with the "Attract and Kill" and with bait spray insecticide. Arrows indicate the dates of treatments [Markopoulo 1994 (A), 1995 (B), 1996 (C)].](image)

**Fruit infestation.** The fruit infestation in 1992 remained low, 3 to 4% of the olives harvested in October was found to be infested, whilst the level of infestation for the olive oil producing varieties, that were harvested in November was 8% not statistical different than the final infestation measured in the insecticide treated grove (Z=3.7, P=0.05) (Fig. 4). In 1993 a year of low olive fruit production the level of infestation was relatively high in both fields and significant higher in the insecticide treated grove (Z=16.8, P=0.05) (Fig. 4). In 1994 and 1996, high fruiting years the level of fruit infestation remained low and not significant different (Z=0.2 and Z=0.9, P=0.05), in both "Attract and Kill" and insecticide treated groves, while in 1995 a low fruiting year the level of infestation was higher, in the insecticide treated plot (Z=16.3, P=0.05).

**Attract and Kill (Stylis).** In 1994 trap catches in spring and early summer was quite high in the experimental as well as the insecticide treated groves (Fig 5A). At this time of year females lay infertile eggs, and its contribution to the fruit infestation is practically nil although female punching to the olive fruits of the Amphissis variety resulted in secondary fungus infestation. The damage caused by secondary infestation was ranged to 5-8%. The application of the killing devices on June 26th, followed by air bait protein hydrolyzate-dimethoate spraying on June the 28th of all the olive groves in this region reduced the fly population. McPhail trap catch were almost nil in the "Attract and Kill" olive grove from July to October, when a slight in-
crease of flies caught occurred shortly before fruit harvesting. In the insecticide treated olive groves, the traps catches were increased late August and mid of September and two insecticide treatments were applied to keep the fly population low. The mean number of flies caught in both olive groves was not significant different (F=0.5, df=70, P=0.05)

Figure 4. Percentage of olive fruits infested in olive groves treated with the “Attract and Kill” method and groves treated with bait spray insecticides. Bars with the same letter are not statistically different (Duncans multiple range test P=0.05) (Markopoulo, Attikis Greece).

In 1995, killing devises were hung on the trees on June 24th, the fly population remained low and about at the same level as that in the insecticide treated grove until the middle of September (Fig. 5B). From middle of September the olive fly developed high population in this region, due to favourable weather conditions. In the "Attract and Kill" treated grove the fly population was increased, rather due to flies migration.

Figure 5. Mean number of *B. oleae* flies caught in McPhail traps in olive groves treated with the "Attract and Kill" and with bait spray insecticide. Arrows indicate the dates of treatments [Stylis 1994 (A), 1995 (B)].

To protect the olive fruits from damage we decided to spray by ground in the "Attract and Kill" grove with protein hydrolyzate-dimethoate on September 28. The
control olive grove was sprayed four times to secure acceptable level of fruit damage. The mean number of flies caught was not significant different in both groves (F=0.3, df=70, P=0.05).

*Fruit infestation.* The final fruit infestation in 1994, in the "Attract and Kill" and insecticide treated groves was 7% for the "Attract and Kill" and 4% for the control groves (Fig. 5). In 1995, the fruit infestation in both groves remained low until September and then started increasing. The final fruit infestation recorded was 12.3% and 11.8% for the "Attract and Kill" and insecticide treated groves respectively. (Fig. 5).

**Discussion**

McPhail and pheromone trap catches indicated that the olive fly adults are active through March to December. In both type of traps the higher number of flies was caught between September-December, another peak of fly activity was also recorded every year early in spring. The fly population density decreased during May to mid August. The number of males caught into the pheromone traps was nil, whilst few males and females were caught in Mcphail traps. Pheromone traps attracted more males in spring and autumn compared to McPhail traps. In summer more males were attracted to the McPhail traps. Our results are in agreement with those reported by (Ramos and Jones 1983, Montiel-Buenos 1987). It has been reported that the olive fly adults are sexually immature early in summer and the males are not responding to the pheromone traps. Maturation of the olive fruit fly depends on weather conditions and fruit ripeness (Fletcher and Kapatos, 1983). The olive fly sexual maturation and fruit susceptibility to egg attack and larval development is synchronous (Delrio and Cavalloro, 1977; Kapatos and Fletcher, 1983). The onset of male trap catches to the pheromone traps during summer is an advantage because it provides an accurate timing to applied control measures. During this period almost all the fly population present is sexually mature and applying control measures, the possibility for the fly to build up high population density is minimised. For accurate measurements of the fly population and timing the control measures it is suggested that both types of traps are necessary to be in operation, since during the summer months, where the temperature is high, the relative humidity low and limited food recourse available, both sexes respond better to the food attractant baited McPhail traps, than to the pheromone traps, also with McPhail traps a good estimation of the female population present in the olive grove is obtained.

The "Attract and Kill" method applied for five consecutive years in Markopulo and two years in Stylis olive groves clearly indicated that this method has the potential to replace or reduce substantially the insecticide treatments for the control the olive fruit fly. In Markopoulo olive grove that is a semi-isolated grove and the olive fruit fly develops moderate population during the year, one killing device per tree
placed at the end of June maintained low level of fly population throughout the entire season and keep the fruit infestation in low level, similar to those obtained in olive groves treated at least three times with insecticide. In years where the control olive grove was treated twice with insecticide the level of fruit infestation was higher than that in the "Attract and Kill" olive grove. On the other hand in the experimental olive grove where no insecticides were use for five years to control the olive moth and the olive fruit fly the number of beneficial insects was increased, improving the olive ecosystem self defence capacity against these pests and against other pests such as the black scale *Sassetia oleae*. *S. oleae* became recently major pest, due to the use of insecticides to control the olive fruit fly and the olive moth.

The results also indicated that the fly population was higher in the insecticides treated grove in years following high fruiting years. This is rather attributed to the availability of ovipotential substrate for the spring generation to lay eggs because many fruits remained on the olive trees after harvesting.

Results obtained from Stylis olive grove that is located in the middle of a landscape that is entirely covered with olives and usually high olive fruit fly population is developed, and extensive migration of the fly occurs, indicated that the "Attract and Kill" method is not sufficient to keep the fly population and the fruit infestation in acceptable level and additional control measures are needed. However even though additional control measures are needed the number of insecticide treatments is reduced substantially. Our findings are in agreement with those reported by other
workers that in isolated olive groves or in regions where the fly develops low populations per year the "Attract and Kill" method is self effective, while in regions where the fly develops high population density at least one insecticide treatment is necessary to keep the fruit infestation low (Broumas et al., 1983; Haniotakis et al., 1991). The problem of the fly migration can be overcome in cases where the method will be applied in the entire landscape where the presence of the killing devices through June to December will not allow the fly to build up high population density.

The "Attract and Kill" in general, presents certain advantage in controlling the olive fruit fly, since the killing devices are compatible with insecticide application. It is a simple method not requiring extensive technological background and a great amount of knowledge to be transferred to the farmers. Whether an integrated management approach will be adopted by the state authorities and the farmers, and will be used to control the olive pests and replace the insecticides, depends on the commercial availability of the killing devices, the attractants used, and the authorities concern on the protection of the environment and the improvement of the olive products quality. The amount of information available indicates that the replacement of toxic insecticides with environmentally safe methods to control the olive pest is now possible.

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References


