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Evaluation of commercial traps of various designs for capturing the olive fruit fly *Bactrocera oleae* (Diptera: Tephritidae)

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Abstract
The attractiveness of six different traps, one hand-made and five commercially available, on olive fruit fly adults, was compared in the field. Experiments were undertaken at three different localities of Messinia Co., SW Greece, with varying conditions of fruit load and pest population density. The Glass-Plastic Elkofon Trap attracted more adult flies than any other type of trap. Satisfactory catches were also given by the Glass McPhail trap, the Plastic McPhail trap and the Plastic Elkofon trap, whereas low attractiveness was demonstrated by the Bottle trap and the Pouch trap. It is clear from the findings of this study that trap captures of the olive fruit fly are significantly influenced by trap design (e.g. shape, materials, special features), especially during the period of the high population peak (mid-September – early November) as well as in olive orchards with a high pest population density. In olive orchards with a low pest population density no significant differences were recorded among captures of different trap types. We discuss ways of improving the mass-trapping technique as a control method against olive fruit fly.

Keywords: *Mass trapping, olive crop, olive fly, Greece*

1. Introduction

The olive fruit fly *Bactrocera oleae* (Gmelin) (Diptera: Tephritidae) is the most serious insect pest of olive fruits in the world. It is known primarily from the Mediterranean area of southern Europe, and is also found in North Africa, the Middle East, and along the east coast of Africa to South Africa. It is generally agreed among olive fly researchers that this insect can survive and develop in any area of the world where olive trees are grown. Since olive is the most important crop in Greece, especially in the south-west, the olive fly is regarded as the most important agricultural pest in the country.

During the last decade, olive fly has been managed mainly by conventional insecticide bait or cover sprays from the ground. However, the ecological and toxicological side-effects of the extensive use of such chemicals (e.g. environmental pollution, human health hazards, killing natural enemies, pesticide residues in oil), as well as the growing interest in organic olive production, has turned attention to alternative control methods. The most widely used technique of this kind is mass trapping, which refers to the use of toxic, sticky or liquid containing traps of various designs to attract and kill olive fly adults of both sexes.

Several food attractants (Zervas 1982; Soultanopoulos 1986; Vita et al. 1990; Broumas and Haniotakis 1994; Broumas et al. 1998; and others), sex attractants (Broumas and Haniotakis 1994; Broumas et al. 1998; and others), killing agents (Broumas and Haniotakis 1994; Broumas et al. 2002; and others) and trap deployment systems (Neuenschwander and Michelakis 1979; Broumas et al. 1998, 2002) have been thoroughly studied in the field for the control of olive fly. However, all previous studies have focused on the sole or combined effects of these trap features without providing any information concerning the effect of trap design (e.g. shape, materials, special features).

The aim of this study was to compare commercial traps of various designs for capturing olive fly adults in olive orchards with different degrees of isolation, olive fruit load and olive fly population density, in order to evaluate them as mass trapping devices.

2. Materials and methods

Experiments were conducted from 10 July 2004 until 2 December 2004 in olive groves at three different locations of Messinia Co., one of the main oil-producing areas of Greece, near the villages of Analipsis, Arfara and Kardamili (see Figure 1). These experimental areas were chosen because of their varying conditions of fruit load and olive fly population density. From experimental data of the previous 10 years, kindly provided by the Department of Plant Protection of Messinia Prefecture, it

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was evident that the olive orchards at Analipsis are heavily infested by olive fly every year. It is the area with the most serious qualitative and quantitative losses in Messinia. By contrast, minor population levels are usually recorded at Arfara, whereas olive trees at Kardamili suffer average to significant losses. Thus, the choice of sites enabled us to evaluate trap types under different conditions of pest population density. Descriptions of each experimental site are presented in Table I.

No sprays were applied to olive trees in the experimental orchards during the study. Action was taken so as not to include experimental orchards in the annual bait spray programme against olive fly applied by the local Agricultural Services of Ministry of Agriculture almost in every olive orchard of Greece.

Six trap types were examined during the study (see Figure 2). Five types are commercially offered for sale by Greek companies and one is hand-made (see Table II). Despite the fact that a special attractant of unknown chemical constitution is provided by the manufacturer along with each of the commercial traps, all traps were baited with the same quantity (~450 ml) of the same attractant (2% water solution of ammonium sulphate), so as to isolate the effect of trap design. For the same reason all traps were of similar colour (transparent or translucent white).

Traps were hung in trees with a similar fruit load, inside the leaf canopy at a height of 2 m, so that it could be easily reached from the ground. Replacement of attractant and collection of captured flies was carried out every five days. After checking each trap

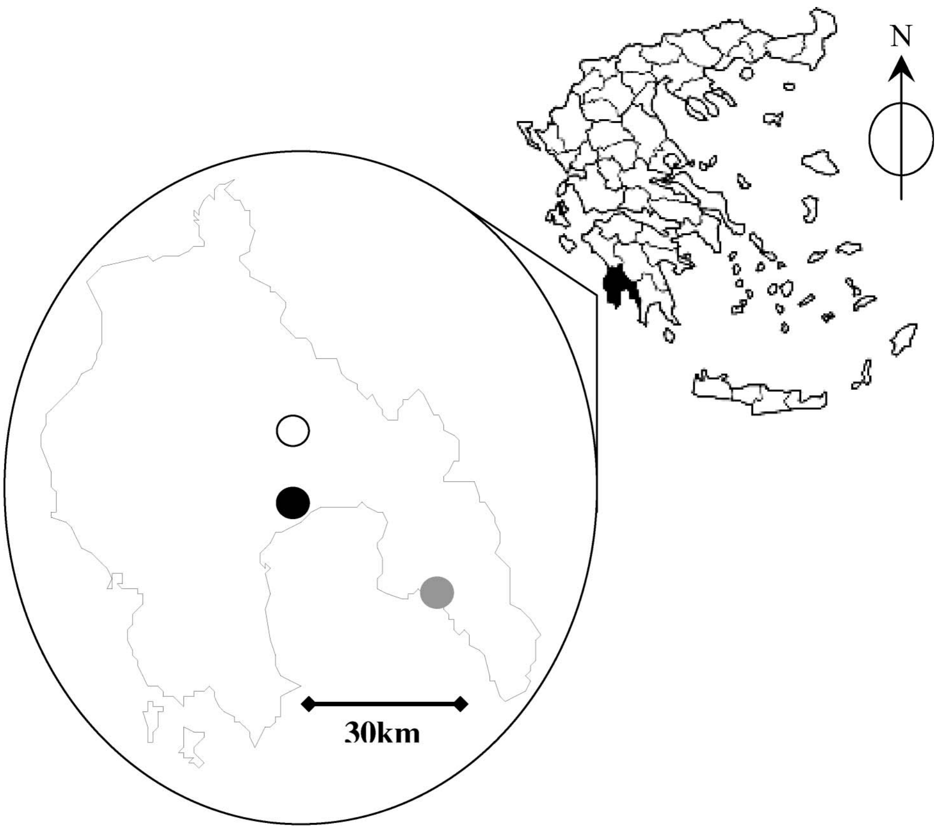

Figure 1. Locations of experimental orchards at Messinia Co. (○, Arfara; ●, Analipsi; ●, Kardamili).

Table I. Characteristics of experimental olive orchards.

Site name	Latitude	Longitude	Elevation	Description
Analipsis	37°01′ N	21°96′ E	12 m	A ~2000-olive tree orchard of 'Megaritiki' and 'Koroneiki' oil-producing varieties, which covered an area of about 18 ha. Olive trees were of average to large size with full fruit load. High olive fly populations are recorded every year in the area. Not irrigated.
Arfara	37°09′ N	22°02′ E	52 m	A ~5000-olive tree orchard of 'Megaritiki' and 'Tsounati' oil-producing variety, which covered an area of about 40 ha. Olive trees were of medium size with average fruit load. Low olive fly populations are usually recorded in the area. Not irrigated.
Kardamili	36°88′ N	22°23′ E	0 m	A ~1500-olive tree orchard of the 'Koroneiki' oil-producing variety, which covered an area of about 10 ha. Olive trees were of small size with average to full fruit load. High olive fly populations are often recorded in the area. Not irrigated.

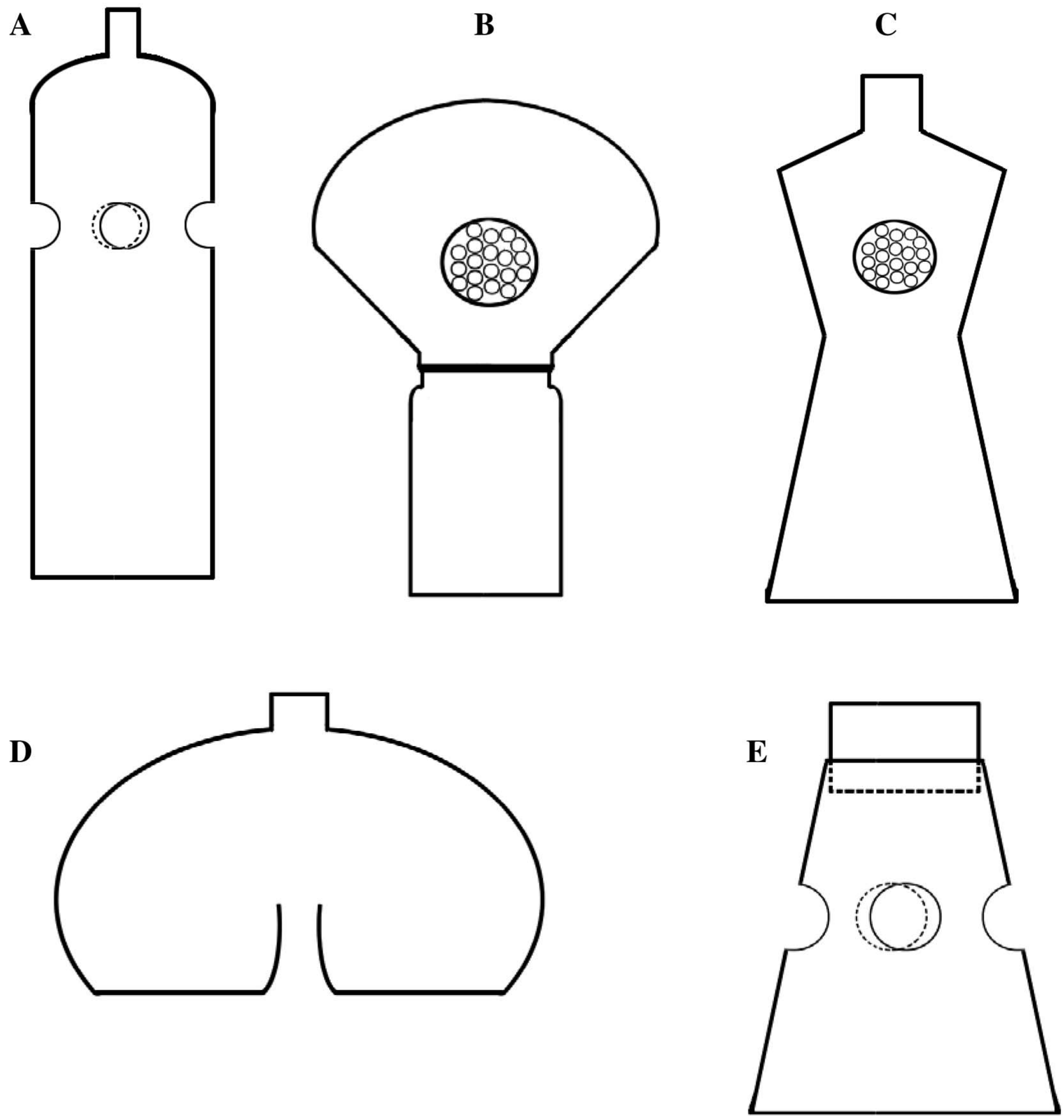

Figure 2. Trap designs employed in this study (A, Bottle Trap; B, Glass-Plastic Elkofon Trap; C, Plastic Elkofon Trap; D, McPhail Trap; E, Pouch Trap).

was rotated clockwise by one position (to the next tree with trap), in order to minimize the influence of trapping location. Given that each trap type was studied in five replications, five sets of six traps of different type were made by deploying a different trap type after two or three olive trees. Trap deployment in each experimental area is clearly depicted in Figure 3.

Data were subjected to ANOVA. Means were separated using the Tukey–Kramer HSD test (Sokal and Rohlf 1995) and all statistical analyses were performed using the statistical package JMP v.4.0.2 (SAS 1989).

3. Results

Total numbers of flies per trap caught in the experimental orchards in all trap types are shown in Figure 4. As expected, olive fly populations remained at low levels at Arfara ($\sim$2–9 flies/trap) and reached average and very high populations at Kardamili ($\sim$4–25 flies/trap) and Analipsis ($\sim$6–40 flies/trap), respectively. In total 5515, 4168 and 3105 flies of both sexes were captured at Analipsis, Kardamili and Arfara, respectively.

At Analipsis, GPET caught significantly more flies (23% of total) than BT (12.6%), PMT (15.8%) and PT (13.1%) ($F_{5,\ 894} = 6.1005$; $P < 0.0001$). Differences with GMT (18.2%) and PET (17.2%), although noticeable, did not prove to be statistically significant.

A similar phenomenon was recorded at Kardamili, where GPET captured most olive flies (21.4%) followed, in decreasing order, by GMT (18.8%), PET (17.9%) and PMT (16.3%). However, the differences were not statistically significant, given that: GPET caught significantly more flies only in comparison with BT (14.8%) and PT (14.1%) ($F_{5,\ 894} = 3.3682$; $P = 0.0051$) (see Figure 5).

Trap catches at Arfara were very low and did not differ significantly ($F_{5,894} = 2.3514$; $P > 0.05$). However, it should be noted that low trap catches

Table II. Description of the six trap types studied in the field.

Abbreviation	Name	Description	Manufacturer
BT	Bottle Trap	1.5-L cylindrical, translucent bottle made of PVC® (base diameter: 8 cm, height: 30 cm) with four entrance holes (~10 mm diameter) peripherally, 20 cm from bottom. The trap was filled with ~450 mL of attractant (see Figure 2A).	Hand-made
PMT	Plastic McPhail Trap	The classic McPhail trap made of opaque plastic with a capacity of 500 ml. The trap was filled with ~450 mL of attractant (see Figure 2D).	Giannadakis, Chania, Chania Co., Greece
GMT	Glass McPhail Trap	The most commonly used trap for capturing Tephritid flies. The conventional McPhail trap is a transparent glass pear-shaped invaginated container.The trap was filled with ~450 mL of attractant (see Figure 2D).	Not known
GPET	Glass-Plastic Elkofon Trap	It consists of a common glass jar (~500 mL capacity) and a plastic, mushroom-shaped, transparent cover. Insect entrance is achieved through a cylindrical hole of 35 mm, covered with an accessory with 19 smaller holes of 5 mm to prevent entrance of larger insects. The trap was filled with ~450 mL of attractant (see Figure 2B).	Phytophyl, Schimatari, Voiotia Co., Greece
PET	Plactic Elcofon Trap	It consists of a 1-L plastic, translucent bottle, constricted in the middle. Flies are entering through an accessory similar with GPET. The trap was filled with ~450 mL of attractant (see Figure 2C).	Phytophyl, Schimatari, Voiotia Co., Greece
PT	Pouch Trap	It consists of a 1-L plastic, translucent bag (30 cm height). Four entrance holes (15–20 mm) are located peripherally 15 cm from bottom. The trap was filled with ~450 mL of attractant (see Figure 2E).	Hellafarm, Athens, Attiki Co., Greece

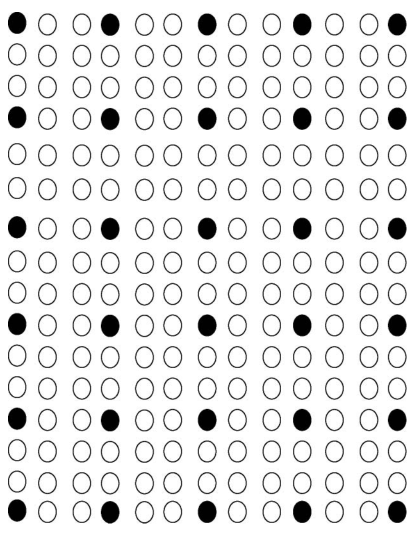

Figure 3. Trap deployment in each experimental area (○, olive tree; ●, olive tree with trap).

at this experimental area make meaningful comparisons impossible.

Differences among various trap type were more intense when the comparison was made for the period of high olive fly population density (more than 60% of flies were trapped during that short period from 3 October 2004 until 7 November 2004). In Analipsis, GPET caught significantly more flies (21.72 flies/trap) than GMT (16.25 flies/trap), PET (15.3 flies/trap), PMT (11.65 flies/trap), PT (9.15 flies/trap) and BT (8.57 flies/trap) ($F_{5,\ 234} = 18.3491$; $P < 0.0001$).

The same trap also attracted more olive fly adults in Kardamili (15.77 flies/trap) demonstrating statistically significant differences with PET (10.87 flies/trap), PMT (10.5 flies/trap), PT (6.77 flies/trap) and BT (6.35 flies/trap), but not with GMT (12.42 flies/trap), ($F_{5,\ 234} = 9.6473$; $P < 0.0001$). The pattern was slightly differentiated in Arfara despite the fact that trap captures were greatly reduced. GMT gave the highest catches (7.5 flies/trap) followed by GPET (6.22 flies/trap), PMT (6.15 flies/trap), PET (5.97 flies/trap), BT (5.4 flies/trap) and PT (4.15 flies/trap) ($F_{5,\ 234} = 5.0177$; $P = 0.0002$).

4. Discussion

During the last 30 years, a great variety of traps, utilizing several attractants have been designed and evaluated against *Bactrocera oleae* (Economopoulos 1977; Vita et al. 1980; Broumas et al. 1983, 2002; Haniotakis et al. 1986, 1991; Broumas and Haniotakis 1994; Nestel et al. 2002; Rizzi et al. 2005; and others) or other tephritid flies (Vita et al. 1982; Avery et al. 1994; Cohen and Yuval 2000; Katsoyannos et al. 2000; Ros et al. 2002; Garcia et al. 2003; and others). However, there are no published

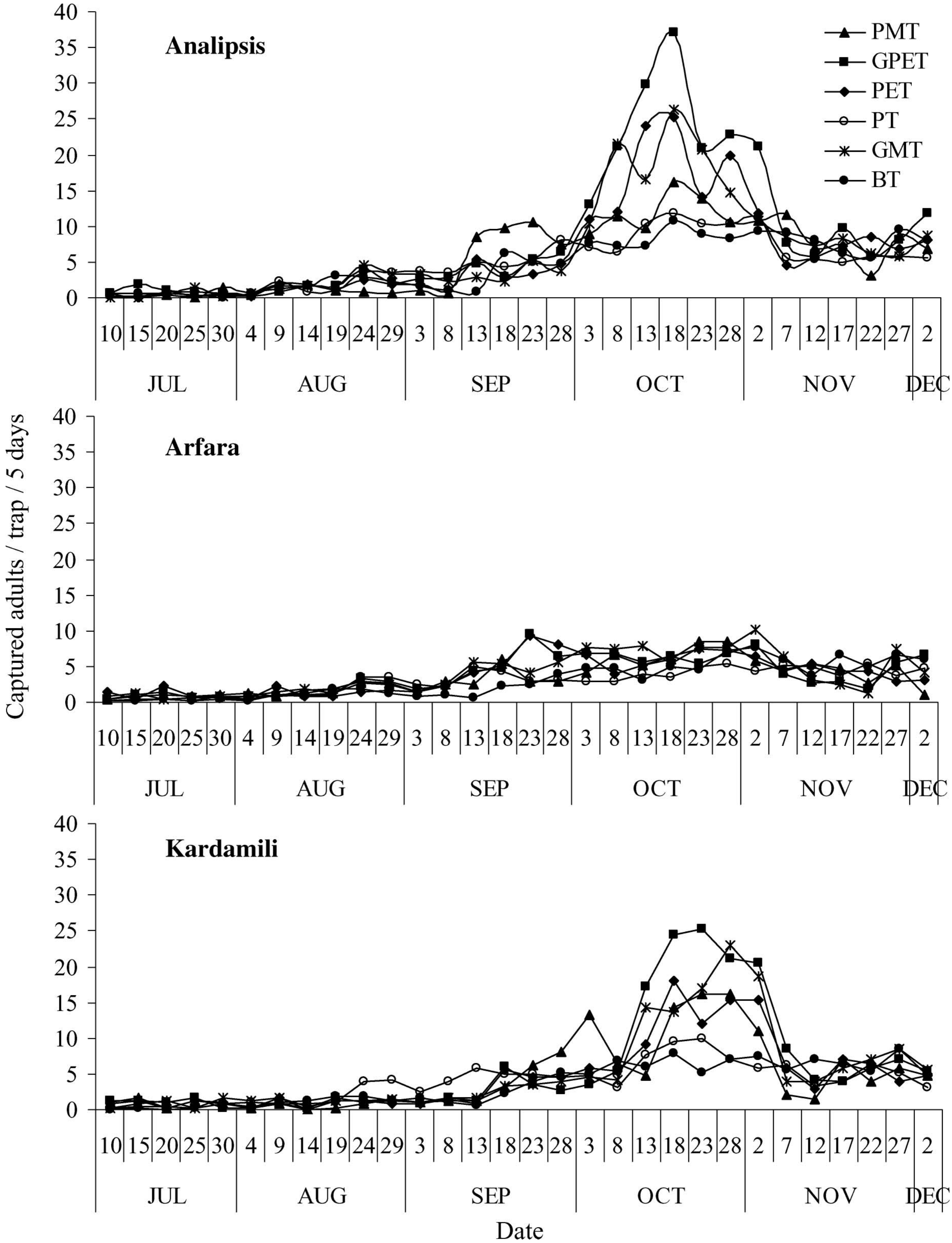

Figure 4. Total numbers of olive fruit flies per trap in the six different trap types at three experimental olive orchards.

experimental data concerning the efficacy of GPET, PET, PMT and PT against olive fly. This is the first comparative study that deals with mass trapping of *Bactrocera oleae* using these trap types manufactured by Greek companies.

The olive fly population pattern did not vary significantly at all experimental sites. Population increase began in mid-September and high population peaks were recorded during October and early-November. Low captures after that time may be attributed to olive fruit collection which commenced in 5, 12 and 26 November at Kardamili, Analipsis and Arfara, respectively.

As far as trap catches during every trapping interval are concerned, there was a definite trend toward higher captures on GPET, PET and GMT. However,

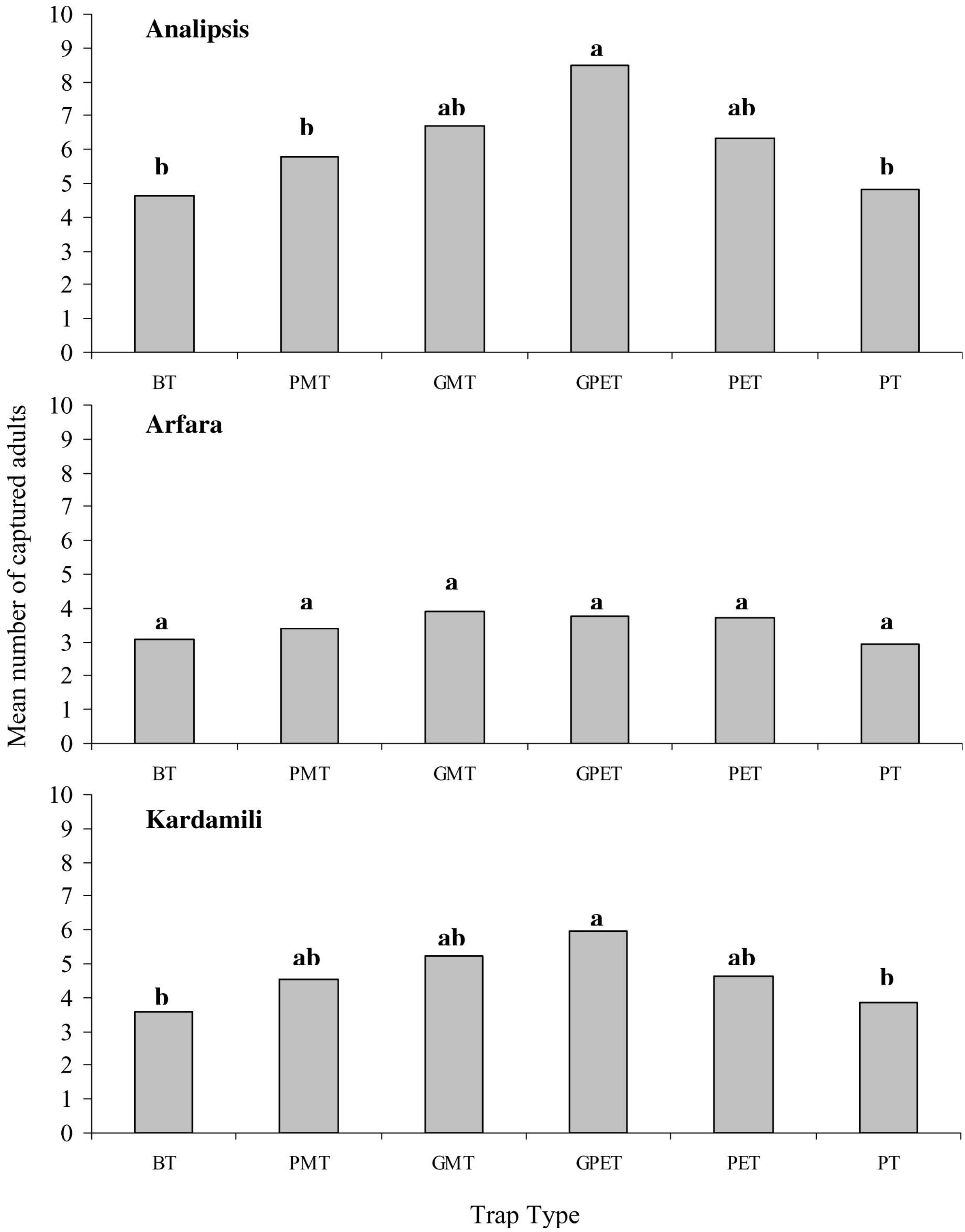

Figure 5. Mean trap catch of the six different trap types at three experimental olive orchards (means with the same letter are not significantly different, Tukey–Kramer HSD test, $p = 0.05$). See Table II for explanation of abbreviations used.

the differences in most cases were not statistically significant.

Apart from the catch of each trap type during a trapping interval, the total number of captures is also significant since it provides useful information concerning the effectiveness of a trap in mass trapping. The GPET seems to be the most effective trap among all tested during the present study. It attracted more flies at Analipsis and Kardamili, whereas the GMT gave slightly more catches at Arfara (see Figure 5).

This trend was more prominent at Analipsis where high trap catches were recorded. In total, GPET caught 45.3, 31.8, 21.8, 25.7, and 43.4% more flies than BT, PMT, GMT, PET and PT, respectively, in that experimental area. The respective differences at Kardamili were 40.3, 23.9, 12.6, 21.9, and 35%.

The increased attractiveness of GPET may be attributed to some special features of this trap. The evaporation rate, although not measured, seemed to be quite low given that almost half of the attractant quantity has remained in the jar on the day of evaluation. The same holds good for PET, the other trap of the same manufacturer, but not for the other trap types, where most or almost the whole attractant solution has been exhausted after 5 days, resulting in low attractiveness during the last 1 – 2 days of the trap check interval, especially during the hot and dry period of summer. The problem with McPhail and Bottle traps was also previously reported by other authors (Zervas 1982; Soultanopoulos 1986).

Apart from the low evaporation rate that GPET and PET recorded, it is quite likely that entering flies were unable to escape from GPET or PET, considering that the entrance holes were very small (5 mm), resulting in higher catches.

The Glass McPhail trap showed increased attractiveness, as was expected, since it has been the most commonly used trap for capturing olive fly during the last 60 years. The same holds true for the plastic McPhail which attracted a smaller number of olive flies. The two trap types with the fewest captures were the hand-made Bottle trap and the Pouch trap, manufactured by Hellafarm. This may be attributed to a high rate of escape by flies after entering the trap, given that the holes were quite large (10 – 20 mm).

Broumas and Haniotakis (1994) reported that no consistent differences in olive fly captures were obtained among different trap types. However, in this study different attractants (e.g. food, pheromone) were used with each trap type, making direct comparison of trap design impossible. Moreover, as the authors suggest, it was likely that the trap density (one trap per tree) did not allow the full expression of the differences. This is the reason why traps were more sparsely deployed in the our study (one trap per two or three trees).

The conclusions of this study cannot be placed in a commercial context, because the commercial traps by Phytophyl and Hellafarm employ different attractants to those used in this study. The traps used here are expected to demonstrate higher attractiveness if used with the manufacturer's attractant.

In conclusion, it is evident from our field study that trap design has a significant effect on captures of *Bactrocera oleae*, especially on high population levels. This should be taken into serious consideration, along with other factors (e.g. type of attractant, cost of manufacture, trap-labour checking costs, difficulty of application) when a mass trapping system is employed against the olive fruit fly.

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