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McPhail trap captures of Dacus oleae (Gmel.) (Diptera, Tephritidae) in comparison to the fly density and population composition as assessed by sondage technique in Crete, Greece

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Captures of adult *D. oleae* in protein hydrolysate baited McPhail traps were compared for 1.5 years with the actual population as determined from treatments of individual trees with a pyrethroid fog. The data were confirmed in other areas by sondage with an organophosphate.

Between May and August the attractivity of McPhail traps increased 30–40 times, and then diminished in September. During the hottest periods the fly population was up to seven times greater in irrigated trees. In summer the variety Tsounati, with its larger olives, was prefered up to 4.5 times over Koroneiki, which has very small fruit that become susceptible to an attack much later. This preference was obscured under dry conditions by the higher efficiency of the McPhail traps in the denser Koroneiki trees.

Throughout the year McPhail traps underestimated the proportion of juvenile females. In May, however, the proportion of females was highly overestimated. In Koroneiki trees, irrespective of fruit availability, the sex-ratio and the proportion of ripe females were overestimated.

Considering the differences between the actual population density, distribution, and composition, as assessed by sondage, and the McPhail trap captures, it is understandable that the relationship between trap catch and infestation on a tree to tree basis was barely significant. With a high fly population and favourable climatic conditions, the infestation was more closely related to the size of the olives than to the trap catch. The implications for the use of McPhail traps for monitoring fly populations in a pest management system are discussed.

For studies on population dynamics, estimates of the absolute population size are necessary. These are expressed as number of females per tree in relation to fruit number for instance, and take into account the proportion of gravid females. Quite often, however, as in the case of monitoring a pest insect population for predicting damage, it is already sufficient to measure changes in the density of a population and to correlate them to some other parameter, like infestation. Population densities of adult insects are often estimated from trap captures. Since traps which rely on attraction by a lure do not catch a random sample of the population, it is necessary for an interpretation of the trap catches to understand the interactions between the attractant in the trap and the insect. This calls for some sort of calibration of the trap under different climatic conditions (SOUTHWOOD, 1966).

Dacus oleae (GMEL.), the main pest insect on olives in the Mediterranean Basin, can reach damaging population densities from May–June up to harvest in winter, in dry as well as in wet regions. Great differences in severity and time of attack can be found within the same area. Humid or irrigated orchards (BERLESE, 1907; MELIS, 1930; MARTIN, 1952; DAMIANO, 1963; ARAMBOURG, 1964; STAVRAKIS, 1973) or early varieties (AVIDOV, 1953, 1958) thereby constitute focuses of an early attack which may be called «hot spots». In order to arrive at the definition of intervention thresholds for each set of conditions it is therefore essential to measure quantitative and qualitative differences in the attractiveness of the traps which are used for monitoring.

For *D. oleae* many different traps are available (review in NEUENSCHWANDER, 1979). Up to now, however, no trap in practical use has been shown to be specific. Ammonium salt solutions served as bait in McPhail traps in many countries. In Greece such solutions are used for large scale monitoring of *D. oleae* in order to time the bait sprays against the adult flies. They have the advantage of being chemically defined and clean to handle. Protein hydrolysates, however, proved to be more attractive (ORPHANIDIS *et al.*, 1958; PROKOPY & ECONOMOPOULOS, 1975). They can be used as bait also during winter, when ammonium traps yield especially low captures. McPhail traps baited with protein hydrolysates have therefore been widely used for monitoring in recent experiments covering the whole year (STAVRAKIS, 1973; ECONOMOPOULOS *et al.*, 1977; MCFADDEN *et al.*, 1977; MICHELAKIS, unpubl. results).

It has long been observed that the attractiveness of the McPhail traps increases at low relative humidities (KALOPISSIS, 1955) and high temperatures (AVIDOV, 1953). For *Anastrepha ludens* LOEW calibration curves which take into account humidity and temperature have been presented (MCPHAIL, 1937). It is however extemely difficult from such short term data, gained from 1.5 hour trap exposures, to estimate the attractiveness of the trap during a weekly exposure. Recently the attractiveness of protein baited McPhail traps in humid and dry areas has been estimated by comparison with traps baited with male sexlures (CUNNINGHAM *et al.*, 1978). This approach, however, is not yet feasible for *D. oleae.*

This study provides a direct comparison of the trap captures between irrigated and dry conditions within the same area. Furthermore the distribution of the fly according to two olive varieties is described. The number of flies caught and their physiological condition were then compared with captures from the same trees obtained by an unbiased method, namely knock-down with a pyrethroid insecticide. The aim of this study thus was twofold: First it should provide a tool for interpreting population curves obtained with McPhail traps. Second it describes the distribution of the fly in a heterogeneous orchard. This information then helps to improve forecasting the risk for local infestation and to time insecticide treatments where needed.

MATERIALS AND METHODS

Area and orchards

The experiments were carried out in the Souda bay area near Chania, Crete, Greece at sea level, from 1976 to 1978. In this relatively isolated area comprising some 3000 olive trees under private ownership, no aerial insecticide treatments against *D. oleae* are applied. Bait sprays from the ground are made from August–September onward. The area is highly heterogeneous; it consiste of many small orchards of the two main oil varieties in the Chania district, namely Tsounati and Koroneiki. Tsounati olives are rather big, while Koroneiki trees have many small fruit. The canopy of Tsounati trees tends to be rather open; Koroneiki trees often have a very dense and closed canopy. In some orchards understory

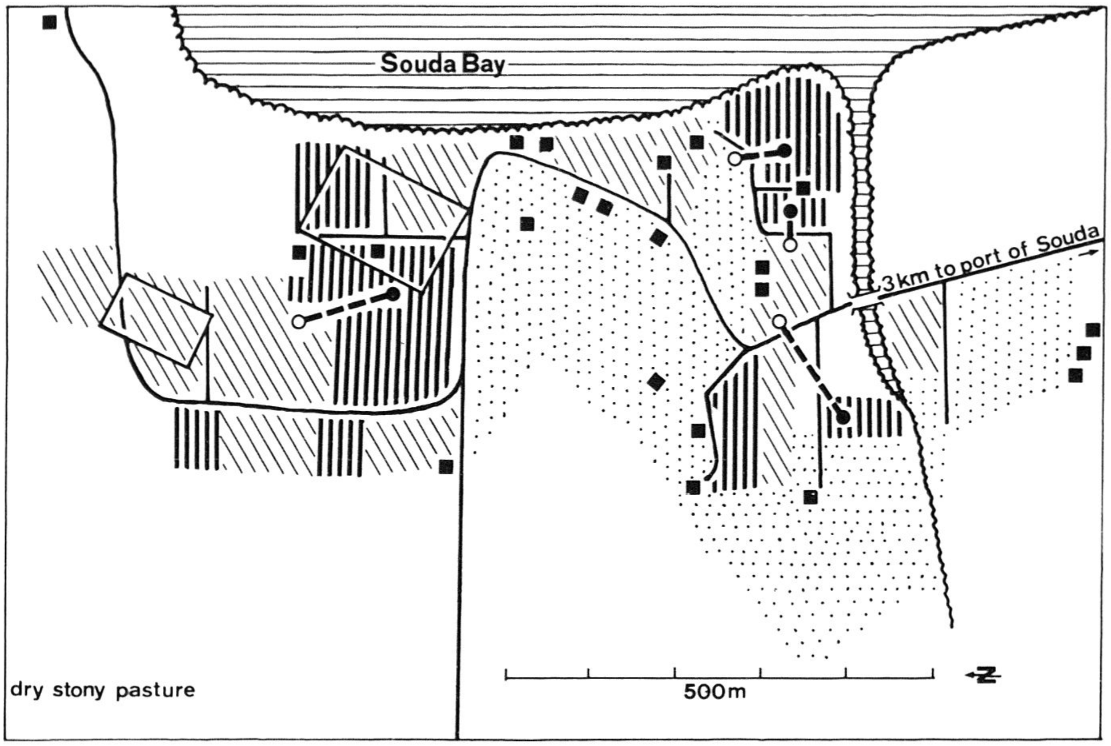

Fig. 1: Plan of the experimental area at Souda Bay. coast line, roads, ■ inhabited houses, IIIIIII irrigated olive orchards, half of them freshly planted, \\\\\\ densely planted unirrigated olive orchards, .·.·.·.· scattered unirrigated (= «dry») olive trees, ●—○ pairs of Tsounati trees of equal size and crop, one being irrigated, the other one dry, ▭ sondage area.

crops like tomatoes, squashes, and vegetables are grown. Trees in these orchards therefore receive abundant water during the short time the vegetables are grown. Other olive trees are interplanted with citrus or apricot trees and are irrigated rather haphazardly. Most olive trees however grow under dry conditions (fig. 1).

For the main sondage experiment 20 trees of about the same size (3-4 m high) and with a good crop were selected. Half belonged to the Tsounati, half to the Koroneiki variety. Half of each variety were irregularly irrigated in summer, the other ones growing nearby were not irrigated. Neighbouring experimental trees were 10-50 m (max. 120 m) apart. In 1976 only four repetitions, i.e. a total of 16 trees, were available for sondage.

Temperature and rainfall were registered at the official weather station of the Institute of Subtropical Plants and Olive Tree, Chania, Crete, about 2 km away from the experimental area. Monthly mean temperatures and relative humidities were calculated from three daily readings at 8 a.m., 2 and 8 p.m.

McPhail traps

McPhail traps were baited with Dacus Bait® (E.V.Y.P., Thessaloniki, Greece) plus 1.5% borax for preservation of the insects. Three different series of traps were installed (fig. 1):

1) General monitoring of the fly population was accomplished with 50 widely spaced traps, which covered all the different habitats in the interior of

the Souda bay area. This network of traps has been maintained without interruption since winter 1973/74. Data from these traps are presented in fig. 2.

2) Traps were installed in eight pairs of selected olive trees, one being irrigated, the other one dry (tab. 1). The distance between the trees of each pair averaged about 120 m (from 50 to 200 m). These traps, which were installed in summer 1978, extended into an adjacent area which was maintained under the same spray schedule.

3) A third series of traps was installed in 16 trees used for sondage in 1976 and 20 trees in 1977/78 which were all clustered in the same small area (tab. 2 to tab. 6). These traps were monitored from July to August 1976, and from May 1977 to September 1978. In 1976 the traps were charged three days only, just before sondage. In 1977/78 they were operated on a three week cycle: one week McPhail traps, sondage in the second week, and McPhail traps during the third week again. As a check, 20 traps from Megala Chorafia (near Chania) were also included in the experiment in July 1978.

Sondage technique

In 1976 in Souda (on 16 trees) and in 1978 in Megala Chorafia (on 12 trees) flies were knocked-down with dimethoate (Rogor L 40®, Montecatini, Milano, Italy) applied as a cover spray at 0.03% a.i., at the rate of 10 l per tree.

In 1977/78 in Souda (on 20 trees) the pyrethroid decamethrin (Decis®, Hoechst, Athens) was sprayed as a fog by means of a London Turbo Hand Fogger (Wingfield Industries, London): 100 ml Decis (2.5% a.i.) were added to 900 ml petrol, and roughly 250 ml of this mixture was applied per tree. Among several concentrations this one gave the best results. Sprays were performed between 6 and 11 a.m. on sunny days with little wind. The insecticide fog was maintained for about half a minute in the canopy by enclosing the tree partly with a 4x10 m plastic sheet supported by four poles. Insects which were knocked-down were collected after 15 and 30 minutes on a fine plastic net which was placed underneath the trees.

Two attempts were made to calibrate this system:

- In May 1977 on four occasions a total of 200 marked flies were released into the trees before sondage. Only 17.7% were recovered. It was however observed that many flies in their excited state left the trees before the insecticide could be applied.
- In winter 1978 on eight occasions a total of 400 flies were released into a 4x4x4m screen cage which contained a small tree. 15 minutes after the treatment with Decis a mean of 58.3% of all flies were recovered. Within 30 minutes recapture reached 77.6%, within 1 hour 82.7%, within 2 hours 86.2%, and within 4 hours 86.7%. The rest of the flies were killed, but stuck to the foliage when dead. For a correction of the sondage catches for the lost flies, the number of flies caught within 30 minutes therefore must be divided by 0.776.

In order to measure the residual effect of the Decis fog, flies were added to sprayed branches in small wooden cages (30x30x30 cm) with wire screen on three sides. Even two weeks after the treatment of the branches the residual insecticide was able to kill all flies within four days. In the field experiment, where

McPhail traps were installed before and after each of the 17 sondage dates, this residual effect seemed to play a smaller role: On seven occasions prespray captures were higher, on nine occasions afterspray captures were higher, and on August 1977 no flies were caught in either trapping week. It is concluded that even if the insecticide fog did lower the number of flies in the orchard, it did not affect adversely the comparison between McPhail trap and sondage captures.

Evaluation

All flies caught in McPhail traps as well as by sondage were counted and separated according to sex. Females were dissected under the microscope, and the number of ripe eggs in the ovaries was determined. From all trees a sample of 100 fruit was taken. Olives were dissected in the laboratory, and the eggs, larvae, pupae, and exit holes were recorded.

The evaluation of the numbers of flies caught in the sondage experiment in 1977/78 was done according to a split-split-plot design (COCHRAN & COX, 1957) with 399 degrees of freedom (d.f.) distributed as follows: 19 were in the main plot for the 20 trees, with 1 d.f. for irrigation, 1 for varieties, and 1 for interaction. In the sub-plots the 10 sampling periods and the corresponding interactions were listed. Finally the sub-sub-plots accounted for the paired values of sondage and McPhail trap captures (mean of the two weeks), leaving a sub-sub-plot error of 160 d.f. In order to stabilize the variance, all counts were log $(x + 1)$ transformed. Comparisons of the monthly means were made by a Dunn test (KIRK, 1968) for 28 chosen comparisons (i.e. 20 in tab. 2 plus 8 in tab. 3), and the critical interval $t_{Dunn} \cdot SE$ is indicated. If neighbouring means in a table are significantly different from each other at the level of $p = 0.05$ they are marked with an asterisk.

In order to compare the qualitative features in the catches from McPhail traps and sondage, data often were pooled over several sampling dates. For each period a separate Chi-square test in a 2x2 table was carried out where the lowest expected value was larger than 5. The correction for continuity was always applied. Chi-square values which are larger than $\chi^2 = 3.84$ are significant; they are marked with an asterisk.

Data from 1976 were evaluated accordingly. Moreover the separate influences of fruit weight (g per 100 fruit) and McPhail trap catch (log $[x + 1]$) on the infestation (N eggs and larvae, dead and living, per 100 fruit) was established in a regression analysis. The t-values and the explained variances r^2 of these regressions are indicated (SNEDECOR & COCHRAN, 1967).

RESULTS

Size and distribution of the fly population as estimated from sondage and McPhail trap captures

An overall view of the fluctuations in the size of McPhail trap captures is given in fig. 2, where data from five years are combined. Generally the fluctuations in trap captures were considerable. But from spring to early fall, when the first bait sprays had to be applied in order to avoid economic damage, a main trend emerged: a peak in capture in late March/early April was followed by low

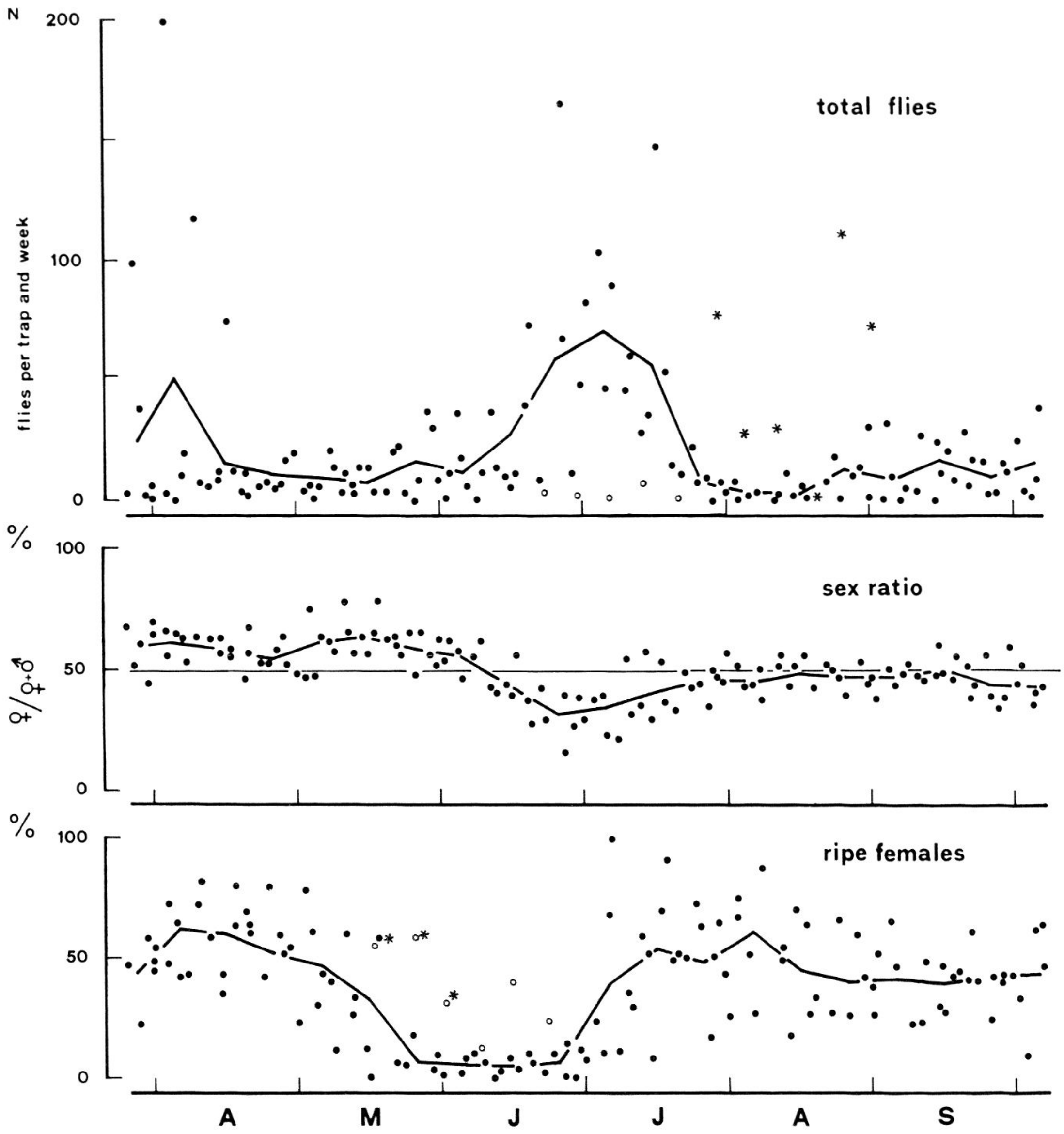

Fig. 2: General trends in McPhail trap captures of *Dacus oleae* during five years in Souda. (○ = catches following the heat wave in 1977; * = catches during the relatively cool summer of 1976).

catches in early May. Trap captures then increased to a marked peak in July, collapsed at the end of July, and started building up again in August-September. This phenology was derived from 50 traps which were distributed in a relatively isolated area consisting of irrigated and unirrigated trees of two varieties. Consistent differences are revealed if catches from traps which are placed into carefully chosen pairs of trees of the same variety, one being irrigated the other not, are compared (tab. 1): in May McPhail traps in unirrigated trees yielded more flies. But in June traps in irrigated trees caught up to five times more flies. This concentration of the flies in the relatively few irrigated trees occurred despite the fact that irrigation was very irregular.

In order to estimate how representative these McPhail trap captures are in comparison to the absolute population size, trap captures were compared monthly with sondage results from the same trees (tab. 2). This experiment was done in a

Tab. 1: Size and composition of McPhail trap captures of *Dacus oleae* from irrigated (I) and dry (D) Tsounati trees. Mean of 8 pairs of traps, Souda 1978.

Period	Total number of flies per trap sum of two weeks I	D	ratio I/D	Ripe females in % of total females[1] I	D
3 May - 17 May	4.25	7.71	0.55		59.2[2]
18 " - 31 "	11.02	15.60	0.71		8.7[2]
1 June - 14 June	20.88	17.20	1.21	4.1	7.4
15 " - 28 "	27.18 *[3]	5.03	5.41	0.0	2.5
29 " - 12 July	51.48	29.20	1.76	59.0	60.5
13 July - 26 "	20.38	6.76	3.01	53.6	31.4
27 " - 11 Aug.	6.94	6.59	1.05	63.1	69.7
12 Aug. - 23 "	22.99	12.49	1.84	63.3	67.3
24 " - 5 Sept.	37.90	27.18	1.39	26.9	33.7

[1]most values based on 200 dissected females
[2]not separated in I and D
[3]critical interval expressed as log(x+1) = 0.49

small part of the Souda bay region. The difference between irrigated and unirrigated trees therefore was smaller than in the previous experiments. Most often McPhail trap captures were higher in dry trees, though irrigated trees yielded up to seven times more flies in sondage in August 1978. The season of 1977 was marked by a heat wave in July, which suppressed the *D. oleae* population practically for the rest of the year. In order to arrive at a reasonable comparison several months had therefore to be pooled. In 1976, on the other hand, fly development was favoured by an unusually cool summer.

Tab. 2 shows that McPhail trap captures again reached a peak in July. Sondage however revealed that the fly population was higher in May, collapsed in June, and reached a second peak in July. This pattern was hidden in the trap

Tab. 2: Comparison of the total number of *Dacus oleae* adults caught in sondage (S) and McPhail traps (M) in Souda.

Month	Mean catch per tree irrigated S		M[1]	unirrigated S		M[1]	Ratio[2] 0.776·M/S	Weather data monthly means % RH	°C
May 1977	5.46	*[3]	1.57	34.48	*	4.01	0.14	59	21.6
June	0.95		0.62	0.38		0.95	0.96	55	25.2
July - Oct.	0.10	*	1.45	0.15		0.66	6.26	64	23.5
Nov. - Jan. 1978	0.35		0.10	0.29		0.20	0.40	73	12.9
Feb. - April	0.02		0.48	0.23		1.24	5.20	69	14.2
May	1.95		0.55	3.68	*	0.58	0.16	59	21.4
June	0.48	*	2.24	1.51		3.27	2.28	51	25.5
July	2.72	*	20.88	3.47	*	23.55	5.63	52	27.3
August	1.40	*	6.08	0.20	*	6.08	6.73	59	25.2
September	2.55		1.09	1.57		3.90	0.84	67	22.2
July 1976	10.48	*[4]	84.11	4.01	*	22.99	-	60	26.1
August	6.24		23.55	6.76		17.62	-	59	24.9

[1]mean per week
[2]calculated from transformed means S (irrigated + dry) and M (irrigated + dry)
[3]critical interval for comparisons during the same month (1977/78) between S and M either irrigated or dry (expressed as log(x+1)) = 0.36
[4]same for 1976 = 0.52

Tab. 3: Comparison of the total number of *Dacus oleae* caught in sondage and McPhail traps in dry Tsounati (T) and Koroneiki (K) trees in summer.

Period	critical interval in log(x+1)	Sondage			McPhail traps		
		T[1]	K[1]	ratio T/K	T[1]	K[1]	ratio T/K
1976 July - Aug.	0.34	9.47	2.72	3.48	16.38	24.12	0.68
1977 June	0.81	0.66	0.15	4.45	0.55	1.45	0.38
1978 June - Aug.	0.47	1.51	1.24	1.22	5.17	12.18	0.42

[1]mean catches per tree

captures because the attractivity of the trap increased from a corrected ratio (McPhail to sondage captures) of about 0.15 in May to over 6 in August, i.e. 30–40 times. The ratio then dropped to the low winter values, when the trap in one week caught only a small proportion of the fly population which could be knocked-down at any one moment. The high ratio for February–April 1978 probably was an artifact, since most of the McPhail trap captures resulted from one sampling date only (27 March 1978).

The interaction for trap and sondage captures between the two olive varieties in summer was significant ($F_{1;\ 24}$ for 1976 = 6.99*, $F_{1;\ 160}$ for 1977/78 = 7.41*). Thus the comparison of the corresponding means in tab. 3 reveals that, under dry conditions, traps in Koroneiki trees caught more flies than traps in Tsounati trees. In sondage, however, Tsounati trees showed higher values. This last result is to be expected, since this variety has much larger fruit which are susceptible to a fly attack about one month earlier than the Koroneiki olives. The high McPhail trap captures in unirrigated Koroneiki trees therefore do not represent a high fly population, but more likely a higher attractivity of the trap under dry conditions in the denser Koroneiki trees of the study area. Under irrigated conditions this higher attractivity is lost.

Composition of the fly population in sondage and McPhail trap captures

The sex-ratio and the proportion of ripe females in McPhail trap catches show distinctive changes in the course of the season (fig. 2). From April to the end of June the ratio of females decreased, then rebounced rapidly up to the end of July. Furthermore each year for several weeks in May–June almost all the females caught did not have any ripe egg in their ovaries. Each year this drop from 50% to about 5% of all females having ripe eggs in their ovaries was accomplished within a few weeks. Similarly fecundity raised rapidly to levels above 50% in July.

But how far do these trap captures reflect the composition of the wild population, and how far are they influenced by mere shifts in attractivity? In order to answer these questions the sex-ratio and the proportion of ripe females were compared monthly between sondage and McPhail trap captures (tab. 4). The composition of the fly population as assessed from McPhail trap captures deviated as follows from the composition of the population as determined from the flies knocked-down in sondage:

1) From June onward McPhail traps slightly but significantly underestimated the proportion of females. This was also confirmed by the captures from Megala Chorafia, where sondage was done with an organophosphate. In May, however,

Tab. 4: Comparison of sex-ratio and condition of females between catches of *Dacus oleae* obtained from sondage and McPhail traps.

Location and month	Sex-ratio sondage N	%♀	McPh. traps N	%♀	χ^2 S-M[1]	Proportion of ripe females sondage N	%♀	McPh. traps N	%♀	χ^2 S-M
Souda										
May 1977	575	46.1	150	64.0	-14.6*	211	0.0	96	4.2	
June	21	42.9	58	34.5	0.2	9	12.2	20	20.0	
July - Sept.	6	66.7	184	47.3		4	25.0	85	48.2	
Oct. - Dec.	25	60.0	40	40.0	1.8	15	26.7	16	12.5	
Jan. - April 1978	12	66.7	82	64.6		8	75.0	53	54.7	
May	95	45.3	28	64.3	-2.4	43	4.7	18	16.7	
June	26	53.8	146	37.7	1.8	14	14.3	54	20.4	
July	104	42.3	1189	35.0	1.9	44	84.1	404	63.4	6.6*
Aug.	23	47.8	182	49.5	0.0	11	18.2	90	64.4	-6.8*
Sept.	67	53.7	162	57.4	-0.1	36	22.2	93	32.3	-0.8
May 77 + May 78	670	46.0	178	64.0	-17.6*					
other months 77/8	284	49.6	2043	40.6	8.1*	395[2]	16.2	929[2]	47.1	-111.5*
Souda										
July - Aug. 1976	381	44.9	1897	46.9	-0.4	171	62.0	889	66.8	-1.3
Megala Chorafia										
July 1978	252	46.4	3585	35.3	12.2*	100	12.0	398	16.6	-1.0

[1]if the %♀ from sondage is smaller than the one from McPhail traps a negative sign is added
[2]including May

females were grossly overestimated. This different attractivity of the protein lure on the sexes was found in dry trees as well as in irrigated trees.

2) McPhail traps also consistently underestimated the juvenile females. A comparison of the trap catches between irrigated and dry trees during the hottest period (tab. 5), in both years when sufficient flies were caught (1976 and 1978), revealed that this overestimate of ripe females came from captures under dry conditions only. This result was confirmed by the McPhail trap captures from paired trees, one irrigated the other one dry (tab. 1): From 7 June to 5 September the overall proportion of ripe females in irrigated trees was 44.5% (N = 896) as compared to 37.9% (N = 1001) in dry trees (χ^2 = 8.4*). It is therefore concluded that the low fecundity of the females caught in traps in May-June (fig. 2) corresponds to an even lower fecundity in the population.

3) The composition of the McPhail trap catch was also influenced by the variety of olive tree (tab. 6). Irrespective of the season and the availability of olives the proportion of females, and among them the ripe females, was higher in traps installed in Koroneiki trees as compared to those from Tsounati trees. No such bias could be found in sondage results, where the only significant difference between olive varieties showed a trend in the other direction: in July-August 1976 in Tsounati trees 52.1% (N = 257) were females, whereas in Koroneiki only

Tab. 5: Comparison of the proportion of ripe females of *Dacus oleae* in sondage and McPhail trap catches during summer in irrigated and dry trees. Pooled data July-August 1976 and 1978, Souda.

Sondage irrigated N	% ripe ♀	dry N	% ripe ♀	χ^2	McPhail traps irrigated N	% ripe ♀	dry N	% ripe ♀	χ^2
134	62.7	92	66.3	0.2	937	61.5	446	74.0	20.4*

Tab. 6: Sex-ratio and proportion of ripe females of *Dacus oleae* attracted to McPhail traps in two olive varieties, Tsounati (T) and Koroneiki (K) in Souda.

Period	Conditions	Infestation mean % on 100 olives per tree		Sex-ratio			Ripe females		
				% females		χ^2	% females		χ^2
		T	K	T	K		T	K	
July - Aug. 1976	cool, high infestation in T and K	25.9	36.0 N=	43.5 1210	52.8 687	15.0*	53.4 526	86.2 363	102.9*
July - Aug. 1978	hot, only T susceptible	0.2	0.0 N=	32.3 775	43.0 596	16.1*	60.6 246	66.1 248	1.2
Oct. 77 - Feb. 78	wet, T and K susceptible	1.6[1]	0.1[1] N=	36.6 41	64.7 17	2.8	20.0 15	36.4 11	-

29.8% (N = 124) were females (χ^2 = 16.8*). Again this sondage result is easily explained by the better susceptibility of Tsounati olives for oviposition. But in the denser Koroneiki trees of the study area the attractiveness of the traps is higher. This results in a higher total catch of females as well as in a higher proportion of ripe females.

Tab. 7: Fruit weight and infestation in two olive oil varieties under dry and irrigated conditions. Souda 1978, 5 trees each, mean of two samples, weight and number of stings per 100 olives (g = grams, N = number).

Month	irrigated				unirrigated			
	Tsounati		Koroneiki		Tsounati		Koroneiki	
	weight g	stings N	weight g	stings N	weight g	stings N	weight g	stings N
June	47.5	0	29.7	0	37.5	0	28.3	0
July	87.4	0.8	60.8	0	65.4	0.2	45.5	0
Aug.	109.1	4.4	73.6	1.0	69.0	0	45.7	0
Sept.	181.3	3.2	94.8	0.7	98.9	0.2	67.1	0

The relationship between trap captures and infestation on a tree to tree basis

The previous results suggest that in the study area with its highly heterogeneous olive orchards the flies are very irregularly distributed during the hot season. Furthermore the attractivity of the McPhail traps differs under various conditions of the trees (irrigation, variety) and for the different parts of the insect population (sex, ripeness). Under those conditions, can the infestation of a tree be predicted from the McPhail trap catch? A comparison of McPhail trap captures and infestation on a tree to tree basis gives the following picture.

In summer 1977 the heat wave reduced the population to such an extent that total infestation only reached 4.8% on 15 September and a maximum of 5.6% on 12 October. In September conditions became favourable in the whole area irrespective of prior irrigation of the trees thereby requiring bait sprays. For 1978 the course of the infestation in irrigated and dry trees of the two main varieties is shown together with the fruit weight in tab. 7. The biggest difference in fruit weight between irrigated and dry trees was reached in August. Up to July no infestation was found on irrigated oil olives during this rather normal and representative season. The first infestation on dry Tsounati trees was found on 12 July, and on dry Koroneiki trees as late as 1 November. When the infestation on Tsounati olives started building up, the whole area was bait sprayed from the ground (on 19 September for the first time in this year). Thus the infestation in both summers (1977 and 1978) always remained too low for a reasonable comparison with McPhail trap catches.

In 1976, on the other hand, the summer was cool. The highest ten day mean temperature in July only reached 26 °C, and the absolute maximum temperature was 37 °C, as compared to the 29 °C and 43 °C respectively for 1977. A sudden high infestation in July ranging from no attack on some dry Koroneiki and Tsounati trees to a maximum of 128 stings per 100 olives in irrigated Tsounati and 138 stings on irrigated Koroneiki olives therefore allowed one a good comparison with McPhail trap captures. Since conditions remained highly favourable for oviposition for several weeks, it was possible to simply compare the transformed data of the McPhail trap catches (X_1) in three days with the total fresh infestation (Y) on the same tree, arriving at the following regression: $Y = -54.62 + 64.58\ X_1$. Points for both varieties thereby fitted the same line ($N = 16$, $t = 2.21^*$, $r^2 = 0.259$). According to this regression equation the predicted infestation is 0% in trees where the trap caught 6 flies or less, and 20% in trees with 13.3 flies caught. Under these exceptional conditions, when a high infestation was reached very fast already in July, the infestation indeed was significantly related to the trap catch on a tree to tree basis.

If however infestations were compared with fruit size (X_2) for both varieties separately, the regressions were much better:

Tsounati $Y = -106.46 + 2.14\ X_2$ ($N = 8, t = 3.47^*, r^2 = 0.668$) and

Koroneiki $Y = -119.15 + 3.76\ X_2$ ($N = 8, t = 3.19^*, r^2 = 0.629$).

The two lines cut the abscissa at 49.7 g/100 fruit for Tsounati and 31.7 g/100 fruit for Koroneiki. This means that no infestation is to be expected even under the most favourable conditions below these mean weights.

DISCUSSION

In order to obtain absolute population estimates of flies, mark-release-recapture methods have been widely used. Recently a model, which allows one recapture of *D. oleae* with McPhail traps, has been developed by T.R.E. Southwood (Fletcher, 1979). Under several assumptions absolute fly densities can thereby be estimated in homogeneous conditions. In heterogeneous conditions and where trees are to be compared individually, sondage techniques are applicable. This method has been used to check the efficiency of newly developed insecticides (Kolbe, 1960). Sondage with organophosphates is routinely applied in Greece to obtain additional estimates of the population density of *D. oleae,* especially in October–November, when the ammonium baited traps are inefficient. In order to estimate the efficiency of this technique, sondage itself should be calibrated. In calibration experiments with enclosed flies as accomplished in the present study, flies cannot escape from the insecticide fog. The percentage of flies recovered therefore is inflated, and the application of the correction factor to field data therefore leads to an underestimate of the wild population and an overestimate of the trap efficiency. At the beginning of this study Decis was the only commercially available pyrethrum/pyrethroid in Greece. For future studies, however, Decis should be replaced by natural pyrethrum with its stronger knock-down effect and much shorter half-life (Elliott *et al.,* 1978), which makes it ecologically less disruptive. Insecticide fogs are preferable over wet cover-sprays, where many dead insects which become glued to the foliage are lost. The same effect was observed when sondage with fog was applied to trees which were wetted by rains. By utilizing fogs on dry trees, repeated measurements on the same trees become possible, and thereby inter-tree variance in fly abundance can be kept under control.

Despite the shortcomings in this study the efficiency measured (expressed as corrected McPhail trap-sondage ratio in tab. 2) is corroborated by mark-release-recapture studies in Corfu. There, the efficiency of the trap increased from about 0.55 in May to 2–3 in summer (E.T. KAPATOS, B.S. FLETCHER, and S. PAPPAS, pers. comm.). For Crete, which is considerably drier than Corfu, the mean efficiency of the trap in summer was even higher. Efficiencies of the trap above 1.0 require that new flies move into the tree from outside. In the view of the high ratios found in this study it may therefore be feasible, especially in hot and dry regions, to out-trap a *D. oleae* population in summer.

Such efficiency measurements can now be utilized tentatively to link the size of the McPhail trap capture to the infestation level in the following way: Tsounati trees in Souda in a good year yield on the average 70 kg olives at harvest, or 40000 olives of a mean weight of 1.75 g. A one percent infestation by *D. oleae* achieved during one week therefore requires 400 eggs. Under field conditions of November for instance, caged females of all ages laid an average of 10.2 eggs per week (unpubl. results). In order to infest 1% of the olives of a tree 39.2 ripe females are therefore necessary. With a trap efficiency of 0.40 (tab. 2) this translates into a trap catch of 15.7 ripe females per week. For such estimates the trap efficiency has to be known; but evidently the result depends mainly on the measurements of the oviposition capacity of the females.

For monitoring purposes it is often sufficient to measure only changes in population density. From May to August the attractivity of the protein baited McPhail traps increased by a factor 30 to 40. This rapid change in the efficiency of the trap thereby hid a peak in population density in May. In winter, on the other hand, the efficiency of the trap was very low. During this study the weekly mean maximum temperature never dropped below 12 °C. Since lower thermal thresholds for flight activity were observed to be 12–14 °C (LUCCHESE, 1954; SACANTANIS, 1953; GIROLAMI & CAVALLORO, 1973) it is concluded that flies in Souda were capable of reaching the trapspractically throughout winter. This does not seem to be the case in northern Greece (ECONOMOPOULOS *et al.*, 1977) and in the mountains in Crete (unpubl. results) where McPhail traps do not catch any flies during the coldest period.

A comparison between trap efficiency and mean values of relative humidity and temperature (tab. 2) generally confirms that low humidities and high temperatures lead to an increased attractiveness of the trap (MCPHAIL, 1937; KALOPISSIS, 1955). In May, however, the trap is inefficient despite the warm and dry weather, and in late summer the reverse is true. This may be linked to the abundance in May of other possible protein sources for *D. oleae* like olive pollen (TSIROPOULOS, 1977) and soft scale honeydew (BERLESE, 1907) with which the trap has to compete in order to attract the flies to the food lure. Furthermore, at the end of May few females have ripe eggs in their ovaries. In August, on the other hand, olive pollen is absent, and soft scale honey-dew is scarce. Also half of all females are reproductively active and therefore more attracted to the protein bait.

Within a mixed orchard, flies exhibit clear preferences (AVIDOV, 1953, 1958). In this study they aggregated in Tsounati trees which become susceptible to a fly attack much earlier in the season than Koroneiki olives. On irrigated trees sondage in May caught less flies than on dry trees. In the course of the summer this ratio changed. Up to seven times more flies were captured on irrigated trees than on dry ones nearby. This aggregation in «hot spots» can be obscured in the McPhail trap captures because of the higher efficiency of the traps under dry conditions. For several years this irregular distribution of the flies in summer has now been taken into account successfully in a pest management programme in Souda, where up to the end of August only these «hot spots» received treatments against *D. oleae* (unpubl. results).

The great changes in the composition of the trap catch in the course of the season suggest that qualitative criteria should also be taken into consideration for decision making in pest management of *D. oleae*. McPhail trap catches over several years consistently exhibited a higher female ratio in April–May. Less females were caught in June, and to a minor degree during the whole summer. Regular seasonal changes in the sex-ratio have also been observed in other areas in McPhail trap captures (MARTIN, 1948; AVIDOV, 1953; ECONOMOPOULOS *et al.*, 1977; STAVRAKIS, unpubl. results) as well as with yellow traps (DELRIO & PROTA, 1975/76). Furthermore a high proportion of males has been associated with the beginning of each flight (MARTIN, 1952; AYOUTANTIS *et al.*, 1954). Sondage results in this study however demonstrate that the sex-ratio in the wild population stays nearer to 1:1 than the trap catches suggest. The regular fluctuations in the sex-ratio of McPhail trap captures are therefore to a large extent the result of different attraction of the sexes in the course of the year.

A period of several weeks in summer when most females contain no ripe eggs has been observed in McPhail trap studies in several areas (BARANOV, 1937; STAVRAKIS, 1973; ECONOMOPOULOS *et al.*, 1977; MCFADDEN *et al.*, 1977; FLETCHER *et al.*, 1978). The sondage results from this study demonstrate that this low percent fecundity is even lower in the total population than expected from the McPhail trap captures. Specially in dry conditions traps overestimate the proportion of ripe females. It is therefore concluded that it is worthwile to take into account the ripeness of females in pest management decisions.

The actual trap catch is the result of the reaction of the fly to the odour plume emanating from the trap (KENNEDY, 1977). The performance of a given trap depends on the climatic conditions. For a given fly population it is probably accurately described by studies as the one by MCPHAIL (1937). If the physiological condition of the flies and the composition of the population vary in time and space, a prediction of the trap efficiency becomes much more complicated. From the data reported here it can be concluded that reproductively active females are more attracted to the protein bait than juvenile females. This is specially true when the attractiveness of the trap is high as under dry conditions and/or in Koroneiki trees. To some extent this reaction also influences the sex-ratio. Furthermore, the higher attractivity of the traps in dense trees may be linked to a less disturbed odour plume under sheltered conditions.

It is concluded that McPhail trap captures as presented for instance in fig. 2 can be interpreted as follows: by taking into account changes in attractivity of the trap, the measurements of the population densities can be corrected. While absolute population estimates will remain doubtful, changes in the size of the fly population are rendered with greater accuracy. The sex-ratio of the trap catch mainly reflects differences in the behaviour of the sexes. The fecundity of the females caught in summer, on the other hand, is even lower in the wild population than in the trap catch. Since trap efficiency is influenced by the density of the foliage, trap position has to be kept as constant as possible.

It can be assumed that in general the conclusions reached in this study apply also when other unspecific food attractants like different protein hydrolysates or even ammonium salts are used as bait. The correlation between trap catch, respectively number of flies present in each tree, and the infestation in the same tree was quite poor, even when suddenly high infestation levels were reached under favourable climatic conditions. At the same time a good correlation between fruit size and infestation on a tree to tree basis was found. This suggests that the susceptibility of the olives to a fly attack merits more attention as an additional criterion for decision making in pest management than hitherto given. Nevertheless, the further use of McPhail traps for monitoring can be justified, as a trap with known biases is still better than a trap for which the efficiency under field conditions has not been tested.

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