PHENOLOGY OF THE OLIVE FRUIT FLY (*Dacus oleae* Gmel.) IN THE COASTAL PLAIN OF ISRAEL *

By

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INTRODUCTION

In a previous paper (1) the author surveyed the occurrence of the olive fruit fly in a small olive grove at Mikve Israel during the years 1947—52. Trapping of adult flies in that grove, which consisted of European varieties only, showed two annual population peaks — one during June, when about 30% of the total catch was trapped, and the other during October, with about 18% i.e. 240 flies per trap per annum (average of 6 years).

From this it was concluded that four generations develop annually; emergence dates are as follows: first half of July; second half of August; second half of September; and from early November until the beginning of February. Flies that emerged during November were kept alive in the laboratory for a period of up to six months.

Activity tests showed that the adult fly's activity is normal during daylight hours when temperatures range between 20°—30° C. Above this range flies become frantic and oviposition is thereby inhibited, and by 35° C activity completely ceases. It was also shown by Tominic (4) that larval mortality is high when temperatures rise above 30° C, particularly amongst first and second instar maggots.

In order to extend our knowledge of the phenology of this pest in the entire coastal plain of Israel, systematic observations were initiated at the Hulda olive grove in 1952. This grove, about 450 dunams** in area, was planted 50 years ago and consists mainly of local olive varieties, except for some 20 dunams which were top-worked into European varieties about 15 years ago. The trees, spaced at 10 m intervals, are regularly sprinkled and well-tended. Data concerning fruit yields during the course of study are presented in Table 2. During 1955, which was a lean year for olives throughout the coastal plain, only 45 trees, from a total of 4000 trees of local varieties at

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** 1 dunam — approx. 1/4 acre.

Hulda, bore a reasonable crop; and in 1956 hardly any fruits were produced by the European varieties following a very severe attack by the leopard moth (*Zeuzera pyrina* L.) during the previous season. With the exception of 1955, average yields of local varieties were 30—75 kgs per tree, as compared to 35—85 kgs for the European varieties.

All of the European olives, and most of the local ones, were picked for green pickling. Only in years of high yield, when there was a shortage of farm hands, was part of the local olives left to blacken for oil extraction. Green picking of European olives took place from mid-August to mid-September, and of local varieties from early September to the end of October. After this the olives begin to blacken.

In mid-May, 1952, twelve trap-jars, containing a 5% solution of ammonium sulphate as bait, were suspended on 12 observation trees, six in the local section and six in the European section. The distance between traps within the same section was 30—50 m, and between sections 600—700 m. The traps were emptied at weekly intervals, the bait replaced and the flies transferred to the laboratory for identification and sexing. The female flies, some or all from each trap, were dissected to determine the number of eggs in their abdomens.

TRENDS IN CATCH

The mean monthly catch per trap (from May 1952 to December 1956) for both olive varieties is presented in Table 1. Whereas the trends for both sections are similar, the total number of flies was about 40% higher on local

TABLE 1

AVERAGE MONTHLY CATCH PER TRAP (1952—1956).

Month	*European olives section*		*Local olives section*	
	monthly catch	*percentage of annual total*	*monthly catch*	*percentage of annual total*
January	9.2	1.5	13.3	1.6
February	8.3	1.4	7.4	0.9
March	15.5	2.6	9.7	1.1
April	14.9	2.5	14.4	1.7
May	17.0	2.8	16.0	1.9
June	42.6	7.1	73.8	8.6
July	40.8	6.8	33.0	3.9
August	76.0	12.7	99.8	11.8
September	60.8	10.1	139.9	16.5
October	139.7	23.3	225.9	26.6
November	140.7	23.5	171.3	20.2
December	34.5	5.7	43.5	5.2
Total	600.0	100.0	848.0	100.0

olives than on European olives. The peak in the numbers of trapped flies, amounting to half the catch, occurred during October and November, and the ebb, during the coldest months, January and February. The total catch at Hulda was considerably higher than at Mikve Israel (600 vs. 240, respectively); at the latter place there were only European olives, growing in small numbers among rows of plum trees, whereas at Hulda there was a uniform and extensive area of olives including late-picked local varieties on which the fly could breed at least until November.

The attack usually ceases at the end of November or mid-December, according to temperature. During most years the mean temperature for December is 13—15° C. Between January and April there is practically no fruit, and new fruit sets begin only during the second half of April. The first gravid females were trapped between the last week of May and the second week of June. The first ovipositions on European olives were observed during the first or second week of June, and only later on local olives. Hence, there is no practical significance to the trapping records of the period December-May during which no oviposition occurs. Thus figures pertaining to the period of June-November only are shown in Table 2.

TABLE 2

AVERAGE CATCH PER TRAP AND FRUIT YIELD ON EUROPEAN AND LOCAL OLIVE VARIETIES.

Month	*European varieties*					*Local varieties*				
	1952	1953	1954	1955	1956	1952	1953	1954	1955	1956
June	36.0	70.5	10.3	71.3	10.0	82.0	102.2	58.9	117.0	9.0
July	30.0	50.7	5.0	52.7	0.7	60.0	30.0	0.1	75.0	0.1
Aug.	318.0	1.7	1.3	38.7	0.5	478.0	2.4	0.6	17.9	0.0
Sept.	204.0	8.0	2.7	12.7	2.0	677.0	5.5	4.3	12.4	0.5
Oct.	430.0	114.2	12.0	26.0	13.2	943.0	95.9	28.1	36.6	25.8
Nov.	152.0	38.5	458.3	2.0	52.5	207.0	61.8	485.6	6.0	96.0
Total	1170.0	283.6	479.6	203.4	78.9	2447.0	297.8	577.6	264.9	131.4
Yield in Tons	—	7	17	0	scanty	191	130	290	scanty	280

Differences among annual catch totals were remarkable. The number of flies trapped on European olives in the peak year (1952) was 14 times greater than that of the depression year (1956); for the local olives the ratio was as high as 18:1. During the whole period of observation, however, the traps on the local varieties invariably yielded more flies than those on European varieties, i.e. 5—55% more in 1953 and 1956 respectively.

An interesting feature of Table 2 is the correlation between the number of flies in June and that of the preceding autumn. The November fly-population not only comprises adults of the third annual generation, which emerge

during September and survive till mid-November, but also adults of the fourth generation which begin to emerge in November, winter over and reproduce the following June. Since there is quite a high rate of mortality among the overwintering population, the number caught in June is smaller than that of the preceding November. The only exception was June 1956, during which month the catch appears to be larger. It should however be reiterated that, due to the unusual scarcity of olive fruits during 1955, the summer population and subsequently the number of overwintering flies were too small to warrant a conclusive comparison.

The relationship between monthly mean temperatures and trap-yields on local olives is demonstrated in Fig. 1. This figure shows that during June the mean temperature range was generally 23—25° C, rising to above 26° C in July, except for 1952. In our laboratory breedings, the adults of the first generation always emerged during the first two weeks of July and the second generation developed from early or mid-July till mid-August. The reproduction and development of the second generation is largely suppressed when temperatures exceed 30° C (see Introduction). During 1952, when the mean July temperature was below 26° C, the number of flies rose substantially and steadily whereas in all other years it remained rather low. The likelihood and the extent of olive-fly injury to European varieties, green-picked during August-September, is thus determined both by the number of flies available in June-July and the July temperature. This statement is well exemplified by Table 3 where trap records and infestation percentages of green-pickling olives are compared.

TABLE 3

AVERAGE CATCH PER TRAP DURING THE TWO MONTHS PRECEDING PICKINGS; FRUIT-INFESTATION PERCENTAGES AT PICKING TIME.

Mikve Israel			*Hulda*				
Ascolano variety			*Merkhaviah variety*			*local variety*	
year	*trap yield June-July*	*infestation %*	*year*	*trap yield June-July*	*infestation %*	*trap yield July-Aug.*	*infestation %*
1947	181.0	56.7	1952	66.0	22.4	538.0	27.4
1948	112.0	55.6	1953	121.2	38.1	32.4	2.7
1949	45.6	16.3	1954	15.3	13.5	0.1	0.4
1950	137.2	severe*	1955**	(54.7)	(22.7)	92.9	9.5
1951	99.0	noticeable*	1956	10.7	0.1	0.1	0.0
1952	16.3	8.0					

* Only estimates were available

** Since there were no fruits at Hulda the records for that year were "borrowed" from the Merkhaviah olives of the nearby Na'an grove (2).

The table clearly indicates the close relationship between percentage of infestation at picking time and the size of the fly population during the two preceding months on all three varieties in both localities. However, the rates between percentage of infestation and number of flies is much smaller in local olives as compared to European varieties. This may be attributed to the abundance of local trees, covering 430 dunams, on which oviposition can be sparsely distributed; the adjacent European olives, which are attacked at a much earlier date, occupy no more than 20 dunams.

From Fig. 1 it is concluded that the European olives were attacked in 1952 mainly by flies of the second generation, whilst in all other years by first generation flies. This fact can be helpful in properly timing the insecticidal applications required for the control of this pest. Thus, no more than one application, early in June, was needed for the control of the fly during 1953, 1954 and 1955 on European olives picked green. As for local olives, no treatment was required at all during 1953—56, provided that picking was completed by the end of October. Although a considerable rise in numbers of flies was noticed during October in all of these years, and although those flies even oviposited and their eggs hatched, the maggots progressed so little in their development prior to fruit picking that no economic damage was caused to fruits picked by the end of October.

The highest rate of increase in catch was recorded in October, when the number of trapped flies was 2 to 30 times larger than that for September, according to year and variety. The mean monthly temperature in October was 24° C or less, which is well within the favorable range .According to Fig. 1, the number of flies trapped in 1952 and 1953 decreased from October to November, whilst in 1954 and 1956 it increased during the same period. The reason for this may be found in the November temperature, which in the two former years was below 19° C, whilst in the latter two years it remained well above this point.

PERCENTAGE OF FEMALES IN THE CATCH

Average values of females per trap during the whole period of investigation are summarized in Table 4. This table shows that females comprised about a third of the total annual catch, slightly less than that in the local olives section and somewhat more in the European section. Since it is known from laboratory breedings that the actual sex ratio in the population is 1 : 1, it must be assumed that more males are lured by the bait than females. In both sections of the orchard, half of the total was trapped during October and November only. The patterns of monthly female-distribution for both sections of the grove roughly parallel and largely resemble those of the total fly-catch (Table 1).

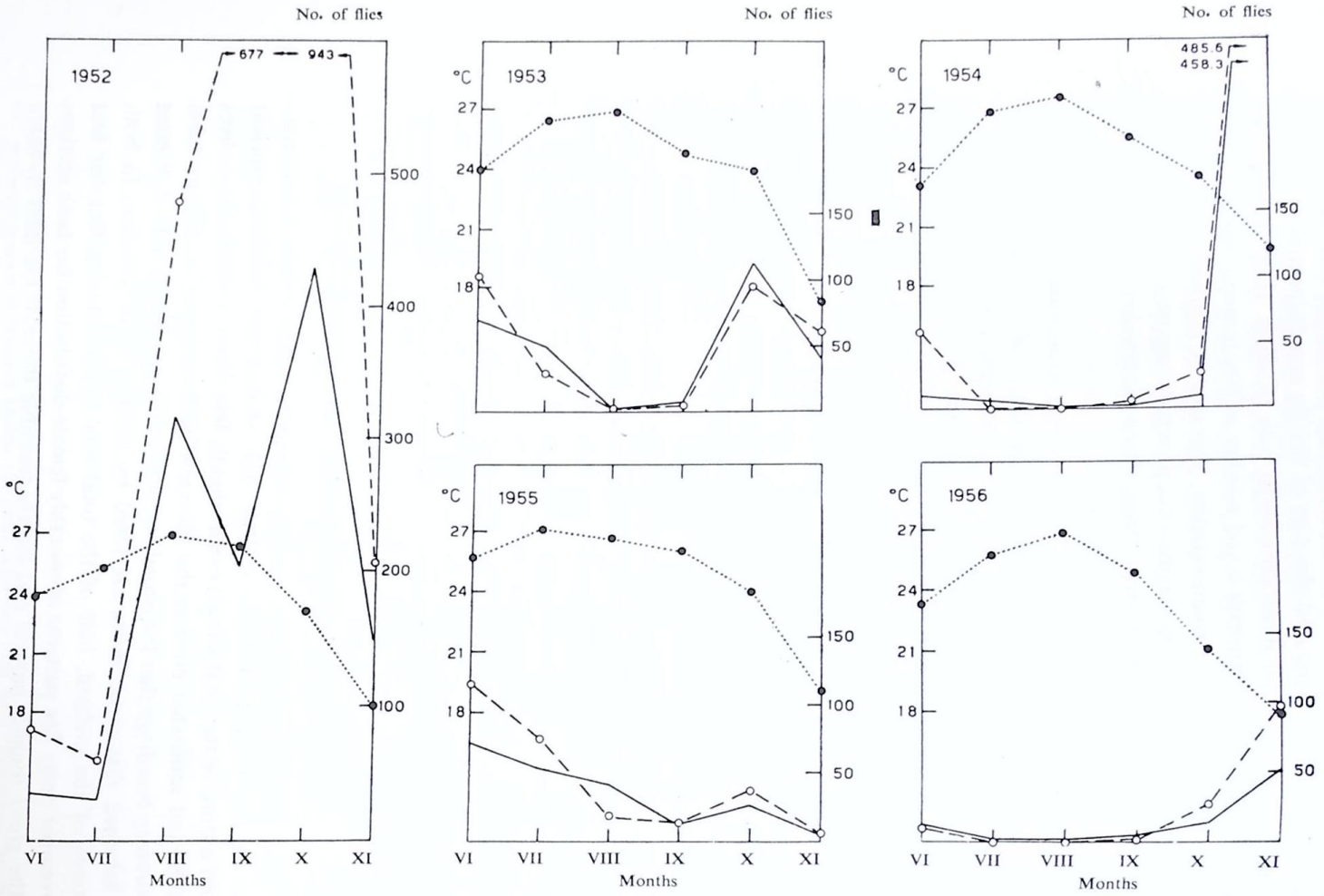

Fig. 3. Catch per trap and temperature
average for 1952—1956

European olives
local olives
temperature

TABLE 4

AVERAGE FEMALE CATCH PER TRAP

Month	European olives section			Local olives section		
	females trapped	*monthly distribution (%)*	*% females in total catch*	*females trapped*	*monthly distribution (%)*	*% females in total catch*
Jan.	7.9	3.6	85.9	7.3	2.7	54.9
Feb.	5.0	2.2	60.2	3.9	1.5	52.7
March	4.2	1.9	27.1	4.9	1.8	50.5
April	7.3	3.3	49.0	7.1	2.6	49.3
May	5.9	2.7	34.7	5.4	2.0	33.7
June	21.0	9.6	49.3	16.6	6.3	22.5
July	14.2	6.6	34.8	10.5	4.0	31.8
Aug.	16.0	7.4	21.1	23.7	9.0	23.7
Sept.	14.2	6.6	23.3	26.8	10.1	19.2
Oct.	51.1	23.4	36.6	65.7	24.7	29.1
Nov.	57.8	26.6	41.1	72.0	27.0	42.0
Dec.	13.4	6.1	38.9	22.1	8.3	50.8
Total	218.0	100.0	36.3	266.0	100.0	31.3

During June, the females comprised 50% of the total catch on the European olives, whereas on local olives their percentage was no more than 23. This highly preferential female attraction to the European varieties, which resulted in an early attack, is due to the faster development of these fruits, which by June have already attained a stage suitable for the fly's oviposition. However, following the removal of the European fruits later in the season, this selective luring was hardly noticeable in the local varieties (Table 4), which number 20 times more than that of the European varieties; flies are therefore more sparsely distributed.

TABLE 5

GRAVID FEMALES PER TRAP.

Month	European olives section				Local olives section			
	No. of gravid females	*monthly distribution %*	*% gravid among females*	*% gravid of total catch*	*No. of gravid females*	*monthly distribution %*	*% gravid among females*	*% gravid of total catch*
June	14.0	12.5	66.7	32.9	7.6	5.6	45.8	10.3
July	6.8	6.1	47.9	16.7	5.5	4.1	52.4	16.7
Aug.	8.8	7.9	55.0	11.6	12.7	9.4	53.6	12.7
Sept.	10.8	9.6	76.1	17.7	20.9	15.3	78.0	14.9
Oct.	34.2	30.5	66.9	24.5	44.3	32.8	67.4	19.6
Nov.	30.0	26.7	51.9	21.3	37.0	27.5	51.4	21.6
Annual total	112.0		51.4	18.7	135.0		50.8	15.9

Records on gravidity are presented in Table 5. Since during the months of December-May only 5—7% of the trapped females were gravid, these months were omitted from the table for the sake of brevity. The individual females found to be gravid during winter and spring must have started ovipositing, or at least had been mature for it, by the previous autumn, but the low temperatures of the on-coming winter had prevented them from voiding their ovaries.

Gravid females constituted slightly over 50% of the total female catch, whereas of the total fly catch they comprised 19% and 16% in the European and local sections, respectively. The monthly distribution or gravidity resem-

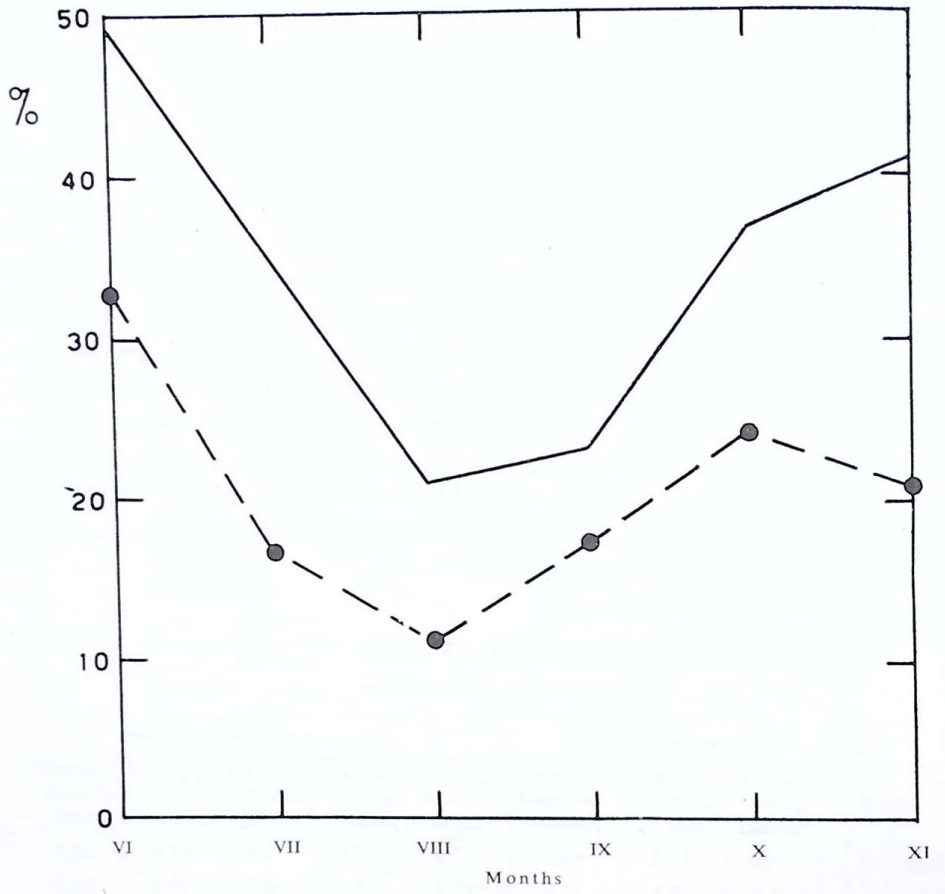

Fig. 2 A: Percentage of gravid females in total catch

European varieties

total females

gravid females

bled that of both total female catch, and total fly catch. Sixty percent of the total of gravid females were caught during the 2 peak months, October and November. Gravid females caught in the traps in the European section during June, comprised about a third of the total fly population. At the same time the percentage on local olives was no more than 10, (see Fig. 2). Here again the attraction of laying females to European olives, in early summer, is plainly manifested.

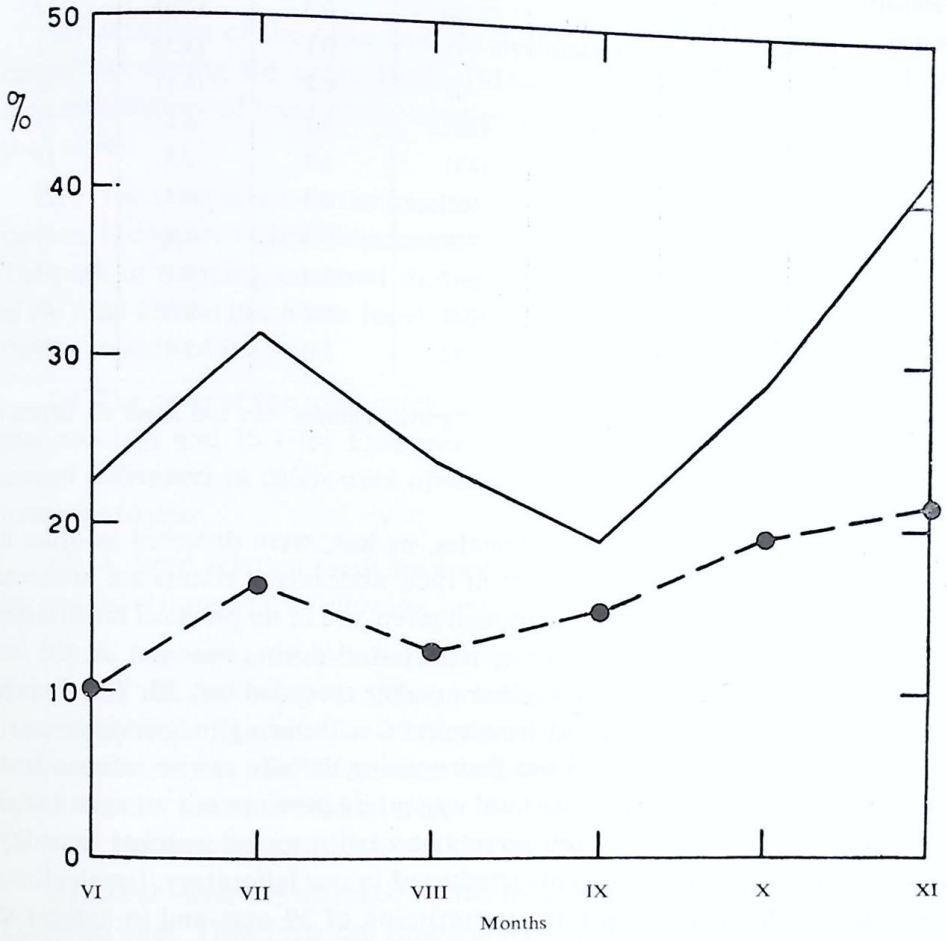

Fig. 2B: Percentage of gravid females in total catch

Local varieties

total females

gravid females

TABLE 6

RESULTS OF DISSECTIONS OF FEMALES

Month	Number of females		Number of eggs			
	dissected	gravid	total	average per female		maximum per female
				total	gravid	
January	75	9	90	1.2	(10.0)	27
February	142	12	94	0.7	(7.8)	16
March	115	6	30	0.3	(5.0)	13
April	208	3	13	0.1	(4.3)	7
May	222	6	41	0.2	(6.8)	12
June	513	237	1567	3.1	6.6	33
July	340	189	1471	4.3	7.8	23
August	205	103	680	3.3	6.6	26
September	174	104	929	5.3	8.9	41
October	468	263	2547	5.4	9.7	48
November	503	308	3041	6.2	9.9	46
December	175	70	582	3.3	8.3	29

Note: Parentheses indicate that the number of gravid females was too small to obtain a reliable mean.

Out of each weekly catch 25 females, or less, were dissected in order to determine the number of eggs found in their abdomens; results are presented in Table 6. Records for December, though given, are of no practical importance. Forty-eight eggs, the highest number, were found during autumn, i.e. the last generation. During summer the highest number recorded was 33. The average number of eggs found in a gravid female was 6—10 during the period of possible attack. It should be pointed out that nothing definite can be inferred from these dissection-records regarding total egg production, as not all eggs mature simultaneously, but they can still serve as an indicator of seasonal fecundity. In fact, in fly breeding experiments conducted in our laboratory, females living on a sucrose diet laid, in summer, a maximum of 39 eggs and in autumn 89 eggs each*, thus supporting the aforementioned view that the fly's fecundity in autumn is higher than in summer. Hence, fruits left on trees after October are subject to a severe attack. At Hulda, however, European olives were never left to blacken. Even local olives in our observation plots were picked, at the latest, on October 21, 1954, while still green. Thus no records regarding the extent of infestation are available for fruits left beyond October, particularly those left to blacken. Our observations over many years show, however, that

* I. Moore — personal communication.

whenever olive fruits remain on the trees after October they are severely infested to an extent estimated at 50% or more. Yet country-wide surveys over the past three decades clearly indicate that the autumn infestation is always smaller when October and November are cooler than usual, particularly in mountainous areas (3).

SUMMARY

(a) Sampling of the olive fruit fly population by means of trap jars was carried out during the years 1952—1956 at the large olive grove at Hulda, consisting mainly of local olive varieties, in addition to a small area of European olives.

(b) The total catch on the local olives section was about 40% higher than that on European olives. Population trends for both varieties were parallel. The peak in trapping occurred during October-November, when about 50% of the total annual catch was lured. The ebb in trap yields was recorded during the first months of the year.

(c) The ratio of the total catch of the peak year to that of the depression year was 14:1 and 18:1 for European and local olives, respectively. Although annual differences in catch were observed, the varietal differences ran parallel from year to year.

(d) A direct relation exists between the number of flies caught in November and those trapped the following June.

(e) A July mean temperature of over 26° C resulted in a low number of flies during the following summer months; after a cooler July, trapping was remarkably high. The number of flies available during June and July and the temperature during the latter month determine the reproductive capacity of the summer generations, and hence the extent of infestation of fruits picked for green pickling during August and September.

(f) Local olives are attacked by the fly at least a month later than are the European ones. Therefore, the temperature and the availability of flies during July-August is decisive in regard to an attack on the former, when picked green in September and October.

(g) Regular trapping of flies and temperature readings can provide an accurate indicator for the proper timing of control applications.

(h) When a monthly mean temperature in autumn ranges between 23—24° C, the fly population increases steadily, causing great damage to fruits left on the trees after October. However, from late November to early December oviposition ceases and the attack subsides.

(i) The seasonal trend in occurrence of gravid females parallels that of the total females, as well as that of the total fly catch. Females comprised about a third of the annual catch and the gravid ones some 16—19% of it. During June, females (two-thirds of them gravid) made up about half of the total monthly catch on European olives, whilst on local olives, during the same month, only 23% of the total catch were females, less than half of them gravid. Thus during June, females are preferentially attracted from the extensive local section of the grove to the small European section, where fruits suitable for oviposition are abundantly available as early as that month.

(j) The maximum number of eggs was found in the ovaries of the females during the autumn months, i.e. at a time when reproduction and fruit-infestation are highest.

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