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PARASITISM OF THE MEDITERRANEAN FRUIT FLY IN HAWAII, 1922-1924

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INTRODUCTION

When the Mediterranean fruit fly (*Ceratitis capitata* Wiedemann) arrived in Hawaii, where it was discovered in 1910, it found itself in an almost ideal environment. Owing to a favorable climate, an abundance and variety of host fruits, and a lack of natural enemies it spread rapidly. The temperature range in littoral Hawaii is such that this fly can reproduce rapidly during the whole year. It has been shown by Back and Pemberton (*3, p. 75*)[2] that in the lower elevations of the islands 16 generations may be produced annually. There have been recorded in Hawaii 73 different varieties of fruits and other plants in which the Mediterranean fruit fly may reproduce, and at all times during the year some of these varieties are in bearing and in the proper condition for infestation. The species of insect enemies in Hawaii that attacked it when it arrived were so few and ineffective that they had very little influence in checking its spread; consequently, within a short time after it was discovered there it had become established upon all the larger islands of the Hawaiian group.

The use of introduced insect parasites has been found a more promising control measure under the peculiar horticultural conditions of Hawaii (where the majority of host fruits are either inedible or not worth the cost of spraying) than are the artificial control methods of spraying and the destruction of infested fruits employed in commercial fruit-growing areas in certain other parts of the world. In 1913 and 1914 the government of the Territory of Hawaii introduced and established four species of parasites which attack the larval stage of the fly. Three of the species were braconids and one a chalcid. Two braconids, *Opius humilis* Silvestri and *Diachasma fullawayi* Silvestri,

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[2] Italic numbers in parentheses refer to "Literature cited," p. 12.

and the chalcid *Tetrastichus giffardianus* Silvestri were imported from South Africa, and the braconid *Diachasma tryoni* Cameron was introduced from Australia. Other parasites were introduced, but the four mentioned were the only ones that became established. The uniform climate of Hawaii and the constant abundance of host maggots resulted in a rapid dispersal of these parasites, and within three years after liberation they were firmly established on the main islands of the Territory and were parasitizing between 30 and 50 per cent of the fruit-fly larvae.

Since these parasites became established the Bureau of Entomology of the United States Department of Agriculture has compiled a comprehensive series of records which show the amount of parasitism accomplished by each species and the degree of infestation of host fruits by the fly. These records have been obtained by making almost daily collections of host fruits about the city of Honolulu and securing from them the maggots as they emerged. These maggots were held in rearing jars and the numbers of emerging flies and parasites carefully recorded. In this manner the effectiveness of each species of parasite has been determined over monthly and yearly periods since 1914 for the various host fruits. The results of these observations up to and including 1921 have already been published (*1*, *2*, *4*, *6*, *8*, *9*, *10*).

During the first few years after the parasites were liberated in Hawaii yearly reports of their activities were of much interest. In that period there was considerable yearly variation in the effectiveness of each species and in the total parasitism by all species. Consequently, during the years from 1915 to 1921, inclusive, these records for each year were published separately, excepting those for 1919 and 1920 which were published together in one paper (*9*). The records for the last five years of this period, however, show that the work of the parasites has become more or less stabilized and that there is much less variation over yearly periods. Consequently, much of the necessity for yearly reports has disappeared, and a 3-year reporting period has been adopted and put into effect in this circular. It is believed that the reader can get a more thorough and comprehensive idea of the relationship and actual work of these parasites if the information for the period is included in one report instead of three.

RECORDS OF INFESTATION

In connection with the recording of parasitism, an attempt has been made to note any increase or decrease in abundance of *Ceratitis capitata* in the field. In making this attempt the following hypothesis was adopted: An increase or decrease in the number of maggots in infested fruits will indicate that there has been an increase or decrease in the number of adult flies. As all fruits collected for records of parasitism were held in the insectary long enough to allow all maggots to emerge, and as records of the numbers of all fruits and of the maggots emerging from them were kept, the average infestation per fruit for each species of host can be computed from these records. Tables 1 and 2 give the results of these observations and computations.

TABLE 1.—*Records of infestation of host fruits by larvae of the Mediterranean fruit fly in Hawaii during the years 1922, 1923, and 1924*

Host fruit	Number of fruits collected			Number of larvae emerging			Average number of larvae per fruit			Average number of larvae per fruit, 1916–1924, inclusive
	1922	1923	1924	1922	1923	1924	1922	1923	1924	
Indian almond (Terminalia catappa)	27,772	17,505	20,408	195,512	135,484	100,225	7.0	7.7	4.9	7.9
Mango (Mangifera indica)	3,198	2,313	3,189	18,362	23,923	21,923	5.7	10.3	6.9	5.9
Coffee (Coffea arabica)	------	21,515	20,647	------	1,270	6,302	----	.1	.3	.4
Strawberry guava (Psidium cattleianum)	13,318	3,813	2,494	21,795	4,613	3,059	1.6	1.2	1.2	1.5
Black myrobalan (Terminalia chebula)	2,036	------	------	6,598	------	------	3.2	----	----	6.0
French cherry (Eugenia uniflora)	6,453	5,510	12,980	6,056	5,202	16,897	.9	.9	1.3	1.2
Satin leaf (Chrysophyllum olivaeforme)	1,628	------	------	5,870	------	------	3.6	----	----	3.3
Rose apple (Eugenia jambos)	321	107	1,897	3,949	343	22,369	12.3	3.2	11.8	9.9
West Indian medlar (Mimusops elengi)	------	161	------	------	364	------	----	2.3	----	3.7
Carambola (Averrhoa carambola)	------	135	183	------	11	20	----	.1	.1	.6
Yellow oleander (Thevetia neriifolia)	1,265	5,150	422	4,548	26,493	814	3.6	5.1	1.9	4.0
Loquat (Eriobotrya japonica)	170	------	------	57	------	------	.3	----	----	2.4
Chinese orange (Citrus sp.)	42,195	31,731	26,750	119,816	66,049	58,812	2.8	2.1	2.2	2.4
Guava (Psidium guajava)	4,706	3,494	1,002	53,762	25,193	5,502	11.4	7.2	5.5	8.2
Orange (Citrus aurantium)	1,728	1,121	635	4,270	3,891	1,208	2.5	3.5	1.9	3.0
Tangerine (Citrus nobilis)	494	1,554	1,460	2,108	1,043	817	4.3	.7	.6	1.5
Lime (Citrus medica limetta)	354	244	393	386	67	75	1.1	.3	.2	.6
Noronhia emarginata	1,069	------	------	1,582	------	------	1.5	----	----	1.5
Ochrosia elliptica	167	------	------	0	------	------	.0	----	----	3.7
Kamani (Calophyllum inophyllum)	------	161	------	------	203	------	----	1.3	----	3.5
Peach (Amygdalus persica)	------	18	------	------	422	------	----	23.4	----	18.4
White sapote (Casimiroa edulis)	124	------	------	315	------	------	2.5	----	----	5.9
Star-apple (Chrysophyllum cainito)	------	------	1	------	------	0	----	----	.0	----------
Waiawi (Psidium guajava pyriferum)	------	------	149	------	------	1	----	----	.0	.5
Terminalia spp	------	------	28	------	------	193	----	----	6.9	6.9
Grapefruit (Citrus decumana)	------	------	66	------	------	21	----	----	.3	.3
Fig (Ficus carica)	------	------	89	------	------	453	----	----	5.1	5.1

TABLE 2.—*Average number of larvae of the Mediterranean fruit fly per fruit examined in Hawaii for each year of the period 1916 to 1924, inclusive, and for the period as a whole*

Host fruit	Average number of larvae per fruit in—									
	1916	1917	1918	1919	1920	1921	1922	1923	1924	Over 9-year period [1]
Indian almond	9.5	8.0	9.9	8.4	5.5	10.5	7.0	7.7	4.9	7.9
Mango	1.7	8.1	24.4	3.7	3.5	3.9	5.7	10.3	6.9	5.9
Coffee	.5	.8	.6	.4	.6	.4	------	.1	.3	.4
Strawberry guava	1.6	2.0	1.3	1.2	1.2	3.4	1.6	1.2	1.2	1.5
Black myrobalan	7.0	5.9	4.8	4.7	6.9	7.0	3.2	------	------	6.0
French cherry	.8	1.0	1.0	.9	1.4	1.9	.9	.9	1.3	1.2
Satin leaf	2.0	3.4	3.2	5.0	4.7	------	3.6	------	------	3.3
Rose apple	5.5	8.8	6.6	------	11.5	------	12.3	3.2	11.8	9.9
West Indian medlar	5.3	1.8	2.5	------	.4	6.6	------	2.3	------	3.7
Sapodilla	------	4.7	------	------	------	8.0	------	------	------	7.0
Carambola	1.3	1.6	.9	.1	.2	1.0	------	.1	.1	.6
Yellow oleander	3.6	5.7	6.0	1.7	1.9	------	3.6	5.1	1.9	4.0
Loquat	------	2.6	1.8	3.4	------	4.5	.3	------	------	2.4
Chinese orange	3.1	1.8	1.8	2.5	2.4	2.6	2.8	2.1	2.2	2.4
Guava	6.8	4.5	8.5	9.8	7.2	6.7	11.4	7.2	5.5	8.2
Orange	------	------	------	3.3	6.0	2.2	2.5	3.5	1.9	3.0
Tangerine	------	------	------	------	.9	3.1	4.3	.7	.6	1.5
Lime	------	------	------	------	1.2	------	1.1	.3	.2	.6
Noronhia emarginata	1.7	------	1.1	------	.1	1.8	1.5	------	------	1.6
Ochrosia elliptica	3.1	23.5	------	------	------	1.5	.0	------	------	3.7
Kamani	3.3	2.4	2.4	6.0	4.9	------	------	1.3	------	3.5
Peach	20.5	15.2	22.4	13.6	15.6	------	------	23.4	------	18.4
White sapote	------	7.6	------	------	------	------	2.5	------	------	5.9
Star-apple	------	------	------	------	------	------	------	------	.0	.0
Waiawi	------	------	------	------	.6	------	------	------	.0	.5
Terminalia spp	------	------	------	------	------	------	------	------	6.9	6.9
Grapefruit	------	------	------	------	------	------	------	------	.3	.3
Fig	------	------	------	------	------	------	------	------	5.1	5.1
Brazilian plum (Eugenia braziliensis)	.8	------	------	------	------	------	------	------	------	.8

[1] Weighted averages.

The records in Table 1 show for each species of host fruit the number of fruits under observation, the number of maggots emerging, and the average infestation per fruit for each year of the 3-year period under consideration. The average infestation per fruit for the 9-year period, 1916–1924, inclusive, is given to show how these yearly records compare with the average for the nine years. By referring to Table 2 it will be noted that some fruits were collected only occasionally during the 9-year period. On the basis of comparisons only with those fruits upon which records were secured during five or more of the nine years, Table 1 shows that during 1922 the average infestation per fruit in 42.9 per cent of the species collected was greater than the average for the 9-year period. In 1923 this average was greater in 26.7 per cent of the species of host fruits, and in 1924 it was greater in 25 per cent of the host fruits. The percentage of host fruits having a higher infestation than the average has been well under 50 per cent during each of the three years of this period and has shown a decrease each year, indicating an actual decrease in infestation and in the number of adult flies.

Table 2, showing the average infestation per fruit for each species of host during each year and for the 9-year period, 1916–1924, inclusive, is given to indicate the fluctuation of infestation from year to year. On the same basis as that outlined in the preceding paragraph, this table shows that the percentage of fruits having a higher average number of larvae per fruit in any yearly period than the average for the 9-year period is as follows: 1916, 56.2 per cent; 1917, 50 per cent; 1918, 41.2 per cent; 1919, 46.7 per cent; 1920, 38.9 per cent; 1921, 71.4 per cent; 1922, 42.9 per cent; 1923, 26.7 per cent; 1924, 25 per cent. These records show that during three years, 1916, 1917, and 1921, the infestation was above the average in 50 per cent or more of the fruits under observation. During the other six years less than 50 per cent of the host fruits showed infestation above the average, and in 1924 the percentage of 25 indicates that the infestation during that year was lower than for any other year covered by the table.

PARASITISM RECORDS

Owing to the oviposition habits of the parasites of the Mediterranean fruit fly now established in Hawaii, the effectiveness of these enemies in controlling the fly is governed to a large extent by the nature of the fruits in which the host maggots are developing. The three opiine parasites, *Opius humilis*, *Diachasma tryoni*, and *Diachasma fullawayi* deposit their eggs within the host larva by piercing the skin of the fruit and the integument of the larva with the ovipositor. The host maggot must therefore be near the surface of the fruit in order to be within reach of the parasite. Consequently, in fleshy fruits which afford an opportunity for maggots to burrow some distance beneath the skin parasitism is low, whereas in small fruits and those containing a large seed covered by thin pulp, where the maggots are necessarily always near the outer surface of the fruit, parasitism is high. *Tetrastichus giffardianus* oviposits directly into the host maggot and must come directly in contact with the maggot before oviposition is possible. In order to reach host maggots within a fruit, it must be able to enter through some break in the skin.

Fruits with tough skins which do not break readily when they fall from the trees usually have a very low parasitism by *T. giffardianus*. Fleshy fruits with comparatively thin skins which are broken easily offer a much better opportunity for the parasite to work.

The data in Table 3 show the effectiveness of each species of parasite for each host fruit under observation for each month in the year. The percentages of parasitism were figured from the numbers of larvae shown in the columns of the table under the caption "Number of larvae." The rate of development of host larvae varies in different species of fruits and with the season of the year, and exposure of host larvae to attack by parasites ceases when the fruits containing them are collected for records of parasitism. In view of these facts, and since the parasites attack only well-developed fruit-fly larvae, the numbers of larvae shown in these columns from which parasitism records were made are larvae emerging from fruits during the first two to six days after collection.

TABLE 3.—*Percentage of parasitism of the Mediterranean fruit fly in Hawaii in 1922, 1923, and 1924, for each host fruit over monthly periods*

Host fruit	Month	Number of larvae			Percentage of parasitism by—														
					Opius humilis			Diachasma tryoni			Diachasma fullawayi			Tetrastichus giffardianus			Total		
		1922	1923	1924	1922	1923	1924	1922	1923	1924	1922	1923	1924	1922	1923	1924	1922	1923	1924
Indian almond	January	104	482	554	.....	2.1	19.0	3.8	32.8	23.6	1.9	.....	.....	30.8	9.3	1.1	36.5	44.2	43.7
	February	104	25	1,832	23.1	.....	37.2	1.0	.....	11.0	.....	.....	0.1	1.0	.....	3.9	25.1	.....	52.2
	March	95	444	3,289	14.7	.9	33.4	3.2	12.6	25.3	.....	.....	.1	2.1	.5	3.9	20.0	14.0	62.7
	April	618	2,646	351	37.7	4.1	55.8	28.8	13.9	20.2	.....	.....	.....	8.7	1.3	1.1	75.2	19.3	77.1
	May	6,468	296	478	15.3	12.5	22.0	54.0	41.6	1.7	.....	.....	.....	.4	.5	.....	69.7	54.6	23.7
	June	2,442	.....	.....	.7	.....	.....	70.8	.....	.....	.....	.....	.....	.4	.....	.....	71.9	.....	.....
	July	124	753	1,340	4.0	.....	2.8	16.9	3.2	61.3	.....	.....	.4	2.4	.1	.6	23.3	3.3	65.1
	August	6,424	7,436	3,623	.6	3.0	6.4	20.5	14.0	27.6	.7	0.9	.1	4.7	21.6	2.1	26.5	39.5	36.2
	September	5,892	6,519	1,988	2.0	6.8	19.1	24.9	7.7	26.9	.7	.3	.....	6.6	53.0	10.9	34.2	67.8	56.9
	October	7,793	2,968	2,067	2.1	6.0	22.9	61.1	2.8	26.8	.1	.2	.....	3.9	64.3	6.6	67.2	73.3	56.3
	November	2,690	1,202	173	1.2	24.8	22.0	43.8	30.1	12.7	.5	.2	.....	6.8	16.7	19.7	52.3	71.8	54.4
	December	1,471	348	184	3.4	6.3	7.6	59.1	23.6	44.0	.1	.....	.....	9.9	28.4	5.4	72.5	58.3	57.0
Mango	March	.....	.....	31	.....	.....	9.7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	9.7
	April	442	.....	270	10.6	.....	14.1	6.1	.....	.7	.9	.....	.....	4.5	.....	.....	22.1	.....	14.8
	May	521	474	874	10.7	1.7	12.4	10.6	13.0	5.9	5.0	.4	1.1	3.3	6.8	.....	29.6	21.9	19.4
	June	206	1,629	473	2.9	.9	7.2	18.9	14.3	7.4	3.4	1.0	.....	5.3	9.2	1.1	30.5	25.4	15.7
	July	605	250	145	3.1	.8	6.2	16.0	9.2	6.2	5.3	1.2	.....	14.7	26.0	2.8	39.1	37.2	15.2
	August	102	.....	.....	2.9	.....	.....	6.9	.....	.....	4.9	.....	.....	20.6	.....	.....	35.3	.....	.....
Coffee	February	.....	104	.....	.....	.....	.....	.....	5.8	.....	.....	.....	.....	.....	.....	.....	.....	5.8	.....
	October	.....	144	180	.....	6.2	2.8	.....	43.1	7.8	.....	18.1	23.3	.....	.7	[1]11.1	.....	68.1	45.0
	November	.....	196	126	.....	.5	1.6	.....	32.1	24.6	.....	49.5	48.4	.....	.....	.....	.....	82.1	74.6
	December	.....	.....	2,856	.....	.....	.....	.....	.....	17.9	.....	.....	47.3	.....	.....	.....	.....	.....	65.2
Strawberry guava	February	.....	20	58	.....	.....	.....	.....	.....	13.8	.....	.....	.....	.....	15.0	.....	.....	15.0	13.8
	March	401	.....	150	18.7	.....	22.7	17.2	.....	7.3	1.7	.....	16.0	10.5	.....	1.3	48.1	.....	47.3
	April	333	800	.....	27.0	3.1	.....	30.6	38.9	.....	3.3	2.6	.....	3.9	11.1	.....	64.8	55.7	.....
	May	58	.....	.....	13.8	.....	.....	25.9	.....	.....	5.2	.....	.....	19.0	.....	.....	63.9	.....	.....
	June	2,856	.....	.....	1.8	.....	.....	49.3	.....	.....	8.2	.....	.....	6.0	.....	.....	65.3	.....	.....
	July	220	11	.....	1.8	.....	.....	21.4	54.5	.....	31.4	.....	.....	3.6	9.1	.....	58.2	63.6	.....
	August	1,182	7	.....	1.3	.....	.....	23.9	.....	.....	19.1	.....	.....	5.2	100.0	.....	49.5	100.0	.....
	September	.....	.....	106	.....	.....	20.8	.....	.....	21.7	.....	.....	1.9	.....	.....	7.5	.....	.....	51.9
	October	.....	.....	37	.....	.....	37.8	.....	.....	8.1	.....	.....	.....	.....	.....	5.4	.....	.....	51.3
Black myrobalan	August	29	.....	.....	3.4	.....	.....	.....	.....	.....	.....	.....	.....	6.9	.....	.....	10.3	.....	.....
	September	1,776	.....	.....	1.2	.....	.....	2.0	.....	.....	5.4	.....	.....	1.5	.....	.....	10.1	.....	.....

French cherry	January			146						54.8			2.1			.7			57.6
	February			489			1.8			29.9			5.9						37.6
	March	48		923	10.4		2.7			19.5	16.7		31.6			.1	27.1		53 9
	April		402	33		.2	6.1		2.0	9.1						6.1		2.2	21.3
	May	746	169		16.4	1.8		16.1	17.2		1.1	7.1					33.6	26.1	
	September	635			2.2			59.4			.9			3.3			65.8		
	October	132						34.1			12.1			9.1			55.3		
	November	1,453			4.9			35.8			29.3			.6			70.6		
	December	45		124	26.7			4.4			60.0		2.4				91.1		2.4
Satin leaf	May	1,237			14.2			4.6						.2			19.0		
Rose apple	April	227		113			10.6	16.3		.9							16.3		11.5
	May		66	692		9.1	17.5		47.0	6.8			.1		1.5	.6		57.6	25.0
	June			491			12.2			3.9						.4			16.5
	July	121	46					14.0	6.5		1.7			5.0	8.7		20.7	15.2	
	August	658			4.1			11.6						13.8			29.5		
West Indian medlar	May		74			2.7			1.3									4.0	
Carambola	October			4												25.0			25.0
	December		5												40.0			40.0	
Yellow oleander	January		18			5.6			22.2						5.6			33.4	
	June		201			1.5			3.5					3.0				13.0	
	July		1,228			.1			10.7					10.3				39.6	
	August	304	316		1.0	.6		9.2	1.9		10.5	2.8		33.2	9.8		53.9	15.1	
	September	144	271		4.2	1.5		5.6	7.0		2.8	34.7		34.0	17.7		46.6	60.9	
	October	68	104	5		3.8		19.1	1.9	40.0		1.0		23.5	32.7	20.0	42.6	39.4	60.0
	November			27			3.7			3.7						59.3			66.7
	December	55		10				5.5			1.8			29.1		20.0	36.4		20.0
Loquat	February	18			22.2						22.2			33.3			77.7		
Chinese orange	January	330	174	423	3.6		.2	4.8	5.7	13.9	3.0	.6	1.2	7.9	12.5	.9	19.3	18.8	16.2
	February	189	363	243	6.3	.6	1.2	16.4	11.8	6.6	1.6	.6	2.5	9.5	2.2	2.5	33.8	15.2	12.8
	March	222	88	137	3.6		8.0	2.3	9.1	3.6	.5	2.3	.7	5.0			11.4	11.4	12.3
	April	548	181	194	7.3	.6	14.4	4.6	29.8	2.1	1.6			4.0			17.5	30.4	16.5
	May	488	37	73	9.4		2.7	8.6	10.8	5.5	1.6			5.5	2.7		25.1	13.5	8.2
	June	536	72	155	.4		1.9	21.7	11.1	8.4				.7	2.8	.6	22.8	13.9	10.9
	July	170	461	145	3.5	1.7	1.4	17.6	1.7	2.1	1.8			5.3	2.7	2.1	28.2	6.1	5.6
	August		410	326		4.1	.3		1.5	9.8		.7			4.1	.6		10.4	10.7
	September		136	191		2.2	1.0		2.9	14.1					5.1	1.6		10.2	16.7
	October			20						5.0						5.0			10.0
	November	45	161					6.7	1.9		4.4			2.2	3.7		13.3	5.6	
	December	302	220	39	1.3			7.0	7.3		.3			3.3	.9		11.9	8.2	
Guava	January	477	296		.2	.3		13.0	12.2		1.0	1.0		40.3	29.1		54.5	42.6	
	February	26	69	23.1					4.3					26.9	30.4		50.0	34.7	
	March		880			.2			12.6			1.3			18.0			32.1	
	April	418	134		1.9	.7		5.7	4.5			.7		11.5	22.4		19.1	28.3	
	May	154	332			.9		45.5	17.2		.6	2.1		8.4	20.5		54.5	40.7	
	June	646	11		.6			9.4	9.1		2.5			13.5	36.4		26.0	45.5	
	July	968		95	.9		9.5	9.9		4.2	1.5			22.7		1.1	35.0		14.8
	August	701	1,067	25	.9	.3	12.0	33.0	11.0	8.0	1.9	1.4		5.3	10.9	8.0	41.1	23.6	28 0
	September	537	586	21	.7	1.7		6.7	3.3	14.3	2.0	.2		12.1	60.2	23.8	21.5	65.4	38.1
	October	287		449	.4		.4	8.0		6.9	1.0		.4	45.6		1.8	55.0		9.5
	November	480			.8			13.3			.8			12.7			27.6		
	December	964			.2			7.6			.4			36.6			44.8		

[1] This figure represents parasitism by the melon fly parasite *Opius fletcheri* Silvestri.

TABLE 3.—*Percentage of parasitism of the Mediterranean fruit fly in Hawaii in 1922, 1923, and 1924, for each host fruit over monthly periods*—Continued

Host fruit	Month	Number of larvae			Percentage of parasitism by—															
					Opius humilis			Diachasma tryoni			Diachasma fullawayi			Tetrastichus giffardianus			Total		
		1922	1923	1924	1922	1923	1924	1922	1923	1924	1922	1923	1924	1922	1923	1924	1922	1923	1924
Orange	January	21		21						14.3				9.5		38.1	9.5		52.4
	February	101	15	20						10.0		6.7		7.0	6.7		7.0	13.4	10.0
	March	32	57			3.5			5.3					25.0	1.8		25.0	10.6	
	April	31	101			5.0			9.9						7.9			22.8	
	May	86	145		2.3			9.3	4.1		1.2			20.9	13.8		33.7	17.9	
	June	74	12		1.4			8.1						6.8			16.3		
	July	42						2.4			2.4			33.3			38.1		
	August	66			1.5			4.5			7.6			48.5			62.1		
	September			25			4.0			16.0			12.0						32.0
	October	87	41	99			6.1	4.6		4.0	1.1	2.4	2.0	23.0	39.0	23.2	28.7	41.4	35.3
	November	29	243	61			6.6	13.8	8.6	3.3		3.3		6.9	31.9	47.5	20.7	43.8	57.4
	December	13	6											38.5	50.0		38.5	50.0	
Tangerine	January	20						15.0						5.0			20.0		
	February	12												33.3			33.3		
	May	37	63		2.7			21.6	22.2						1.6		24.3	23.8	
	June	398		4	.8			34.9									35.7		
	August			25															
	September			23			4.3												4.3
	October			73						1.4						1.4			2.8
	November		22						4.5						4.5			9.0	
	December			19						5.3									5.3
Lime	May	71			1.4			22.5									23.9		
	August			4												10.0			10.0
	October			10											5.0			5.0	
	November		20												22.2			22.2	
	December		9																
Noronhia emarginata	July	11									9.1						9.1		
	August	59						1.7						1.7			3.4		
Kamani	January		49						2.0									2.0	
Peach	May		76						52.6						1.3			53.9	
White sapote	February	8			25.0												25.0		
	May	11			18.2												18.2		
	June	18			16.7			5.6			5.6						27.9		
Grapefruit	October			15						6.7						6.7			13.4
Fig	June			52															
	July			33															

Indian almond is a good example of a fruit containing a large seed surrounded by thin pulp. The opiine parasites were much more effective than *T. giffardianus* during all periods for which records were kept for the 3-year period with the exception of January, 1922, and the last five months in 1923. During those five months large numbers of this fruit were collected within an area of about four city blocks, and owing to some undetermined cause *T. giffardianus* was able to parasitize an unusually large number of the developing maggots.

The coffee berry is another fruit having a very thin pulp and large seed. It is very seldom that *T. giffardianus* is reared from maggots in this fruit, but the parasitism by the opiine parasites is very high. The 11.1 per cent parasitism in October, 1924, shown in footnote 1 of Table 3, was the work of the melon fly parasite *Opius fletcheri* Silvestri. This parasite is occasionally reared from maggots of the Mediterranean fruit fly, but the high parasitism recorded during the month mentioned is very unusual. It was probably due to the fact that all of the coffee containing the maggots from which it was reared were collected in the Kona coffee fields on the island of Hawaii. Around these fields the Chinese cucumber *Momordica* sp. grows wild and is very abundant. The fruits of this plant are attacked freely by the melon fly, *Bactrocera cucurbitae* Coq., the maggots of which in turn are highly parasitized, resulting in an abundance of *O. fletcheri* about the coffee fields.

The mango is an example of a fleshy fruit with a comparatively tough skin which does not break easily when the fruit falls. The percentage of parasitism in this fruit by either the opiine parasites or the chalcid *T. giffardianus* is not high.

The guava, which is very abundant about Honolulu, has a very thin skin and a deep pulp. The majority of maggots are beyond the reach of opiine parasites, and this results in a very low degree of parasitism by them. The thin tender skin of this fruit breaks easily when the fruit falls to the ground or is often punctured by birds or by coming in contact with some part of the tree. Consequently, *T. giffardianus* is afforded an unusual opportunity to enter this fruit, and the parasitism by this species is in almost every instance higher than that by any of the opiine parasites. In a number of instances it was higher than the combined parasitism of all three species of opiines. These are mentioned as examples of the influence exerted by the structure of the infested fruits upon the effectiveness of the fruit-fly parasites, and this influence can be observed by reviewing the records in the table of the parasitism in other fruits.

Table 3 shows that all four species of parasites will attack their host in most of the fruits under observation. Though the structure of the infested fruit controls to a large extent the parasitism by *D. fullawayi*, the degree of its effectiveness in some fruits can not be attributed to this cause. This parasite in the majority of host fruits is comparatively ineffective, whereas in coffee and yellow oleander its effectiveness is greater than that of either of the other two opiine parasites. This may be an indication of some preference on the part of this parasite for maggots in certain fruits.

Table 4 records the effectiveness of each species of parasite in all fruits collected during each month of the three years. *O. humilis* was first in effectiveness during three months in 1922, during no month in

1923, and during five months in 1924. *Diachasma tryoni* was the most effective during seven months in each of the years 1922 and 1923, and during five months in 1924. *D. fullawayi* was the most effective during only one month of the 3-year period under consideration, namely, in December, 1924. *T. giffardianus* was the most effective parasite during two months in 1922, five months in 1923, and one month in 1924.

TABLE 4.—*Total parasitism of larvae of the Mediterranean fruit fly from all fruits collected in Hawaii in 1922, 1923, and 1924 (averaged by months)*

Month	Number of larvae			Percentage of parasitism by—												Total parasitism (per cent)		
				Opius humilis			Diachasma tryoni			Diachasma fullawayi			Tetrastichus giffardianus					
	1922	1923	1924	1922	1923	1924	1922	1923	1924	1922	1923	1924	1922	1923	1924	1922	1923	1924
January	952	1,019	1,144	1.4	1.2	9.3	8.9	20.5	23.9	1.8	0.4	0.7	26.6	15.1	1.7	38.7	37.2	35.6
February	458	596	2,642	10.5	.3	26.2	7.0	8.7	14.1	1.5	.5	1.4	9.4	5.6	2.9	28.4	15.1	44.6
March	798	1,469	4,530	12.8	.5	25.9	9.6	12.1	22.7	2.0	.9	7.1	7.9	11.0	2.9	32.3	24.5	58.6
April	2,617	4,264	961	16.0	3.3	28.7	15.0	17.5	8.4	.9	.5	----	6.0	3.8	.6	37.9	25.1	37.7
May	9,877	1,732	2,117	14.2	3.4	15.9	39.3	21.2	5.2	.5	1.2	.5	1.2	8.2	.2	55.2	34.0	21.8
June	7,176	1,925	1,175	1.2	.9	8.3	48.7	12.9	5.7	3.6	1.1	----	4.0	8.6	.7	57.5	23.5	14.7
July	2,261	2,749	1,758	1.9	.4	3.3	13.7	7.1	47.6	5.4	4.7	.3	15.4	11.3	.9	36.4	23.5	52.1
August	9,525	9,236	4,003	1.0	2.7	5.9	20.4	12.7	25.8	3.1	1.0	.1	6.8	19.3	2.0	31.3	35.7	33.8
September	8,984	7,512	2,354	1.8	6.1	17.2	21.4	7.2	25.1	1.7	1.5	.2	6.1	51.4	9.9	31.0	66.2	52.4
October	8,367	3,257	2,959	1.9	5.8	16.9	58.0	4.5	20.6	.3	1.0	1.6	5.8	60.2	5.9	66.0	71.5	45.7
November	4,697	1,844	387	2.3	16.2	11.6	37.6	24.4	14.5	9.5	5.9	15.8	5.4	16.5	20.4	54.8	63.0	62.3
December	2,850	588	3,232	2.4	3.7	.4	34.0	16.7	18.3	1.2	----	41.9	18.6	18.4	.4	56.2	38.8	61.0

[1] 0.7 per cent of the parasitism shown in this total was accomplished by *Opius fletcheri*.

O. humilis did its most effective work during the early months of the year. This can be attributed to the control of *O. humilis* by either species of Diachasma when it occurs in the same host maggot with them. It has been shown in a previous publication (*5*) that *O. humilis* is always eliminated under these conditions. Both species of Diachasma have been shown (*7, p. 430*) to hibernate to a considerable extent during the cooler months of the year, whereas *O. humilis* does not show this tendency. Consequently, with the advent of the cooler months, which begin about December, *D. tryoni* and *D. fullawayi* become less effective and do not retard the development of *O. humilis* to so great an extent as during the warmer months. The increase in the effectiveness for *O. humilis* begins at about that time.

The unusually high percentage of parasitism accomplished by *T. giffardianus* during the latter part of 1923 is due to the fact already mentioned that the records included larvae contained in fruits of Indian almond collected in one locality where the parasitism was abnormal. Should these records be discarded the parasitism by *T. giffardianus* would be less than half the figures shown.

The records in Table 5 are given to show the effectiveness of each species of parasite and the combined effectiveness of all four species since their establishment in 1915. In 1915 *Opius humilis* was responsible for the greater part of the total of 37.9 per cent of the parasitism. From that time its effectiveness gradually decreased until a minimum of 4.1 per cent was reached, in 1923. During 1924, however, it parasitized 14.5 per cent of all the larvae under observation and was more effective during that year than for any yearly period since 1916. *Diachasma tryoni* was less effective in 1923 than in any year since

1915. This parasite is usually the most effective of any of the four species. It has shown a fairly uniform degree of parasitism since it became well established in 1916. In 1923, as has been noted, *Tetrastichus giffardianus* was the most effective over a yearly period for the first time since its introduction.

TABLE 5.—*Total parasitism of all larvae of the Mediterranean fruit fly collected in Hawaii from 1915 to 1924, inclusive*

Year	Number of larvae	Percentage of parasitism by—				
		Opius humilis	Diachasma tryoni	Diachasma fullawayi	Tetrastichus giffardianus	Total
1915	28,010	31.5	0.3	5.9	0.2	37.9
1916	83,304	17.2	13.3	2.1	.6	33.2
1917	72,139	12.7	20.3	7.3	7.2	47.5
1918	63,480	12.4	34.6	2.6	6.2	55.8
1919	75,406	9.4	19.6	1.6	7.6	38.2
1920	57,406	9.4	22.7	12.1	7.7	51.9
1921	88,616	7.6	26.9	5.5	16.4	56.4
1922	58,562	4.6	33.7	2.5	6.4	47.2
1923	36,191	4.1	12.2	1.6	25.3	43.2
1924	27,262	14.5	20.7	6.8	3.1	45.1

The total parasitism by all species during the 3-year period covered by this report was comparatively uniform, ranging from 43.2 per cent to 47.2 per cent. During the three previous years, the total parasitism ranged from 38.2 per cent to 56.4 per cent. A comparison of the average parasitism during the two 3-year periods shows that it was nearly the same, although it was a little higher during the period 1919–1921.

SUMMARY

The Mediterranean fruit fly, since it was discovered in Hawaii in 1910, has been a major fruit pest in all parts of the Territory. Of the various methods employed in different parts of the world to control this pest, the use of introduced parasites is the only one which has been found adapted to the peculiar horticultural conditions of Hawaii. In 1913 and 1914 three braconids, *Opius humilis*, *Diachasma tryoni*, and *Diachasma fullawayi*, and one chalcid, *Tetrastichus giffardianus*, were introduced and established by the Territorial government. This circular records the effectiveness of these parasites during the 3-year period 1922 to 1924, inclusive, and is a continuation of similar records made since 1914.

The infestation of fruits by the fly during the three years under consideration was less in the majority of hosts than the average infestation per fruit over the 9-year period 1916 to 1924, inclusive. The decrease in infestation of host fruits indicates a decrease in the abundance of adult flies.

Parasitism by *Opius humilis* reached its minimum, 4.1 per cent, in 1923, owing probably to the effect upon it of the two species of Diachasma. In 1924 the parasitism (14.5 per cent) by this species was greater than for any year since 1916. Owing to the hibernation habits of *D. tryoni* during the cooler months of the year, the effectiveness of this parasite decreases during those months and at the same time there is a corresponding increase in effectiveness by *O. humilis*.

The work of these four parasites during the three years under consideration has not varied to any great extent from that of the preceding six years. They continued to parasitize nearly 50 per cent of the larvae about Honolulu, causing a corresponding decrease in infestation of the commercial hosts.

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