Bionomics of the Whitefly-Parasite Complex Associated with Cotton in Southern California (Homoptera: Aleurodidae; Hymenoptera: Aphelinidae)[1]

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ABSTRACT

Three species of whiteflies, *Aleyrodes spiraeoides* Quaintance, *Bemisia tabaci* (Gennadius), and *Trialeurodes abutilonea* (Haldeman), infest cotton in the Coachella and Imperial Valleys of southern California. From February to April no green cotton leaves are available. *A. spiraeoides* is found during that period on *Sonchus oleraceus* L., *B. tabaci* is found on *Malva parviflora* L., and *T. abutilonea* is found on a variety of plants, including *Pluchia sericea* Coville. Six species of parasites are known to attack the whiteflies. *Encarsia formosa* Gahan, *E. meritoria* Gahan, and *Eretmocerus haldemani* Howard parasitize all 3 whitefly species; *Encarsia coquilletti* Howard parasitizes *A. spiraeoides* and *T. abutilonea;* and *Encarsia* sp. and the females of *Prospaltella* species z. attack only *T. abutilonea.* Females of all parasite species and males of *E. haldemani* are solitary, internal parasites of whitefly nymphs; males of *Encarsia* spp. are parasites of *Encarsia* females; and males of *Prospaltella* z. are parasites of eggs of Lepidoptera. Of the whiteflies, *A. spiraeoides* is rare, *B. tabaci* predominates the whitefly fauna in the Coachella Valley from July on, and *T. abutilonea* predominates the whitefly fauna in the Coachella Valley until July and is predominant throughout the season in the Imperial Valley. *Encarsia* sp. and *E. coquilletti* are rare; *E. formosa* and *Prospaltella* z. occur in low numbers. *E. meritoria* occurs in low numbers in the Imperial Valley, but is abundant during the first two-thirds of the season in the Coachella Valley. *Eretmocerus haldemani* is the major constituent of the parasite fauna in the Coachella Valley during the late summer, and in the Imperial Valley throughout the season. Treatments with both trichlorfon and a combination of methyl parathion and endrin greatly reduced the adult populations of whiteflies and parasites. The reduction caused by trichlorfon was usually less drastic than that by methyl parathion + endrin. The whiteflies and parasites usually regained their pretreatment population levels 2 weeks after treatment.

Cotton is grown in southern California primarily in the Coachella and Imperial Valleys. Three species of whiteflies, *Bemisia tabaci* (Gennadius), *Trialeurodes abutilonea* (Haldeman), and *Aleyrodes spiraeoides* Quaintance, infest cotton in these areas. These insects do not usually cause economic damage. When such damage occurs it often follows an insecticide application on or near the field in question, and is most pronounced near the margins of the field or in unusually poor cotton stands. These facts suggest that natural control factors play an important role in keeping the whitefly populations at low levels.

This paper reports the results of biological and ecological studies of the aphelinid parasites that attack the aforementioned whiteflies.

MATERIALS AND METHODS

All plant rearing and laboratory studies with hosts and parasites were conducted in the greenhouse (approx temp range winter, 74°–80°F; summer, 60°–90°F; and relative humidity range, 62%–66%) unless specified otherwise. The cotton variety Delta Pine Smooth Leaf was used as a host plant; *A. spiraeoides,* the iris whitefly; *B. tabaci,* the sweet-potato whitefly; and *T. abutilonea,* the banded-wing whitefly, were used as host insects. The host and parasite material were collected in the Coachella and Imperial Valleys, either as free-living adults or as immatures on the cotton leaves. In addition, *T. vaporariorum* (Westwood), the greenhouse whitefly, obtained from local infestations, was used for some host-parasite specificity studies.

Host and parasite populations were sampled over a period of several years and under a variety of conditions:

1. The Coachella Valley.—All samples were taken in Indio from both untreated fields (1962 through 1965) and treated fields (1963 and 1964). All treatments were made with trichlorfon, which was purchased under the trade name Dylox®.

2. The Imperial Valley.—Sampling was done in Westmoreland in an untreated field, a field treated with methyl parathion + endrin, a field treated with trichlorfon, except for the last 2 treatments which were made with methyl parathion + endrin (1963), and a field treated with trichlorfon only (1964).

Numbers of both whiteflies and parasites were determined from weekly suction samples collected with a "D-Vac" suction machine. The weekly samples were taken during the morning hours and from the same general area within the field, and consisted of 100 suctions each, i.e., each was a pooled sample from 100 individual plants. This sampling was always followed by separation of the insects from the debris accumulated during the sampling process. A Berlese-type funnel was used for separation; the insects were then placed and kept in alcohol.

Percentage parasitism was calculated from the sum of all whiteflies and parasites found in the sample. Because each whitefly pupa gave rise either to 1 whitefly adult or 1 parasite, this sum represented the total number of whitefly pupae from which the sampled population emerged, provided the samples were taken from a field that was not treated with insecticides.

THE WHITEFLIES

T. abutilonea is distributed throughout much of North America. Russell (1963) listed 33 States in the United States, 5 States in Mexico, and the West

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Indies as places where this whitefly species occurs. In California, *T. abutilonea* was found in both the Coachella and Imperial Valleys, as well as in Blythe and near Yuma, Ariz.

T. abutilonea has been recorded from at least 140 plant species (Russell 1963), some of which are important agricultural crops (e.g., cotton, citrus, beans, corn). This pest damages the plants through direct feeding and through the production of honeydew. It also was implicated as a vector of the yellow dwarf virus of sweet potatoes. (Hildebrand 1961).

B. tabaci has been recorded from many countries. These include Italy (Silvestri 1939), Israel (Avidov 1956), India (Misra and Lamba 1929), and the United States (Dickson et al. 1954). In the United States, *B. tabaci* was recorded from California only. However, it was found also in Yuma County, Ariz. (R. C. Dickson, unpublished records).

This whitefly species is a pest of at least 56 plant species (Avidov 1956, Kirkaldy 1907), including crop plants such as clover, cotton, eggplants, and tomatoes. In addition to injuring the plants by sucking their juices and excreting honeydew, *B. tabaci* was found to transmit the leaf-crumple virus of cotton, vein-clearing virus of sweet potatoes (Loebenstein and Harpaz 1960), and tomato yellow leaf-curl virus (Cohen and Harpaz 1964).

A. spiraeoides is a pest of numerous ornamentals (Essig 1926) and potatoes (Landis et al. 1958), and has been recorded in the continental United States (from California, Oregon, and Washington) and in Canada (from British Columbia). Specimens belonging to this species were collected during the winter in the Coachella and Imperial Valleys by R. C. Dickson and by the author, on wild host plants including *Sonchus oleraceus* L. In addition, the author found small colonies of these insects infesting cotton in the Cochella Valley throughout the summer.

T. vaporariorum, an omnivorous pest with a cosmopolitan distribution, has not been recorded on cotton in the Coachella and Imperial Valleys. It was used in this study to test the host range and intraspecific variations of the parasites, in general, and of *Encarsia formosa* Gahan, in particular.

Overwintering Sites.—In the Coachella and Imperial Valleys, cotton is usually planted during early April; it germinates and reaches the true leaf stage late in April or May. Rapid growth commences thereafter until, at harvest time, the plants are bushy and are usually 4–6 ft tall. After the cotton has been picked, new shoots and a few leaves often appear, which remain green until December or January, when they are killed by frost or are plowed under. No stub cotton is grown in southern California.

As implied in the preceding paragraph, green cotton leaves, on which whiteflies could develop, are scarce or absent from February to time of plant emergence. The present studies revealed that the whiteflies and their parasites move onto alternate host plants during that period. All developmental stages of *B. tabaci* were found on *Malva parviflora* L.; *T. abutilonea* were found on *M. parviflora*, *Pluchea sericea* Coville (arrowweed), *Medicago sativa* L. (alfalfa), and on numerous other plants; and *A. spiraeoides* were collected on *Sonchus oleraceus* L.

M. parviflora occurs throughout southern California. It is a common weed in areas which are, or have been, under cultivation. Under the climatic conditions that prevail in the Coachella and Imperial Valleys, *M. parviflora* plants germinate during September and October and reach their largest dimension at bloom during February and March. A month later, as the ambient temperature rises, they set fruit and the foliage shrivels and dies (V. M. Stern, unpublished data). *M. parviflora* is hardier and more frost resistant than most other weed species growing in the Coachella and Imperial Valleys. This fact became apparent in January 1963, when temperatures dropped below 32°F during several successive nights and *M. parviflora* was the only broadleaf weed species inspected that survived the frost.

Its growing season and coldhardiness render *M. parviflora* suitable as a host to numerous plant pests. These include tetranychid mites, various Lepidoptera, and whiteflies. Both immature stages and adults of *B. tabaci* and *T. abutilonea* were found on *M. parviflora* plants growing under citrus trees in the Coachella Valley. Parasites of these pests also were found in the same locale.

The arrowweed, *P. sericea*, native to the area, is common in river bottoms, near springs, along irrigation canals, and by the shores of the Salton Sea. Two species of aleyrodids were found infesting it, *Tetralicia* sp. and *Trialeurodes abutilonea* (both determined by Dr. L. Russell, United States National Museum).

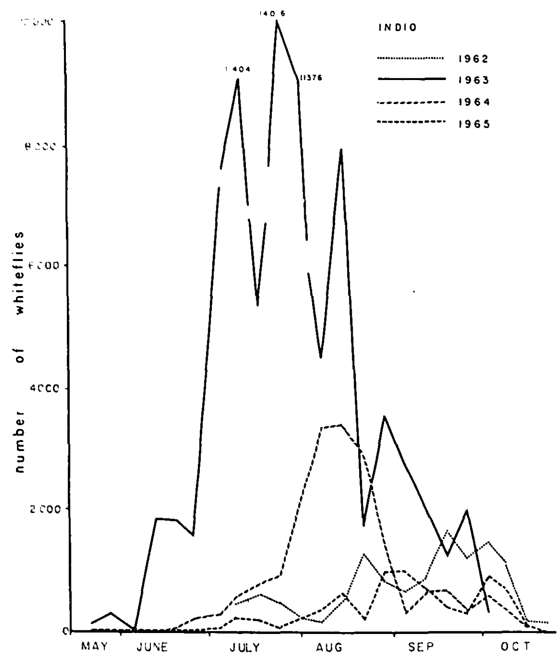
S. oleraceus, infested by *A. spiraeoides*, grew among the undergrowth in citrus groves of the Coachella Valley from December until May.

Abundance and Fluctuations of the Whitefly Populations Throughout the Cotton-Growing Season.—A study was made of the suction samples taken from untreated fields in Indio (Coachella Valley) from 1962 to 1965 and in Westmoreland (Imperial Valley) in 1963. The result (Fig. 1 and 2; Table 1) show that the whiteflies undergo a similar population cycle every year despite large numerical differences among the individual years.

The cycle can be summarized as follows: during May, adults of *B. tabaci* and *T. abutilonea* leave their overwintering hosts and move to cotton seedlings as soon as the latter have developed their true leaves. The whitefly populations increase with the onset of high summer temperatures (maxima above 100°F) and reach a peak during August or September. They then decline and reach a more or less stable low population until harvest time or until the plants are killed by frost.

Large differences in the abundance of whiteflies from year to year were observed. In 1963 the whitefly population per sample in Indio reached a maximum of 14,016 specimens; in 1962 it reached only 1622; and in 1965, only 997. The causes for these differences are not known.

As mentioned previously, the whitefly complex



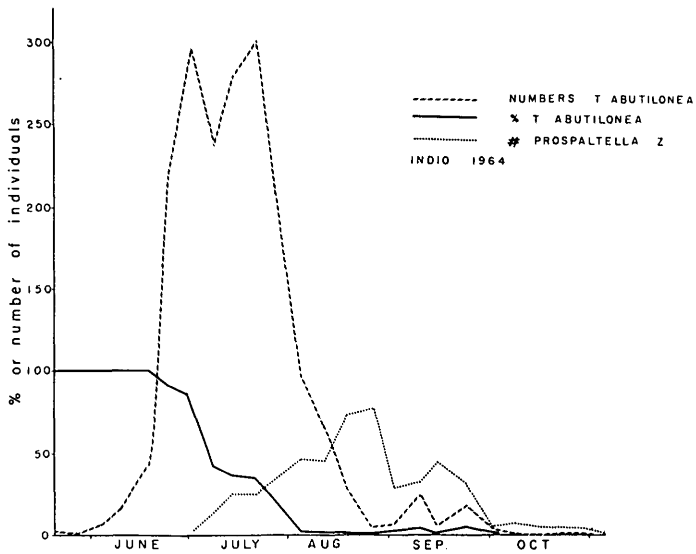


FIG. 1 (top left).—Numbers of adult whiteflies collected in untreated fields in Indio. 1962–65. FIG. 2 (top right). —Numbers of adult whiteflies collected in an untreated field in Westmoreland. 1963. FIG. 3 (bottom).—Percent *Trialeurodes abutilonea* of the total whitefly fauna, and numbers of *T. abutilonea* and *Prospaltella* sp. z. in Indio. 1964.

under consideration is composed of 3 species. Of these, *A. spiraeoides* occurs only rarely, while *B. tabaci* and *T. abutilonea* comprise most of all whitefly populations. Therefore, only the last 2 species will be considered in the following discussion.

Fig. 3 and 4 show differences in the specific seasonal and numerical distribution of *B. tabaci* and *T. abutilonea* in the Coachella and Imperial Valleys. In Indio (Coachella Valley) *T. abutilonea* constituted almost 100% of the whitefly fauna during May and early June. It dropped sharply in June and July until, at the end of July, it amounted to a few percent only. Hence, when the whitefly population reached its peak abundance, during late July, August, and September, it was composed primarily of *B. tabaci*. The populations of *T. abutilonea* continued to decline until only a few individuals, if any, were recovered in October and November.

Table 1.—Numbers of adult whiteflies in samples taken throughout the study in Indio and Westmoreland. *T.a.* = *Trialeurodes abutilonea*; *B.t.* = *Bemisia tabaci*.

Sampling date	Untreated fields									Treated fields[a]								
	Indio									Indio[b]				Westmoreland				
			1964			1965			W'm'd		1964					1964[b]		
	total 1962	total 1963	*T.a.*	*B.t.*	Total	*T.a.*	*B.t.*	Total	1963 total	1963 total	*T.a.*	*B.t.*	Total	1963[c] total	1963[d] total	*T.a.*	*B.t.*	Total
May 14																19	0	19
22		140	2	0	2											25	0	25
29		308	1	0	1				48							9	0	9
June 6		24	6	0	6						52	2	54			16	0	16
13		1832	17	0	17	13	0	13	1		29	11	40			25	0	25
20		1804	42	7	49	13	1	14	170		68	47	115			61	4	65
26		1563	220	20	240	36	7	43	100		193	140	333	*		158	1	159
July 5		7280	297	51	348	55	12	67	128		171	1116	1287	112		94	0	94
10	436	11404	238	348	586	222	20	242	176		204	876	1071	176		255	1	256
18	614	5348	281	513	794	137	43	180	384		102	1360	1462	32*		171	7	178
25	474	14016	302	593	902	24	37	61	640		291*	2725*	3016*	344		75	14	89
Aug. 1	234	11376							448	*	86	1612	1698	236	200	106*	14*	120*
8	160	4496	95	3263	3358	144	234	378	482	1448	95	1773	1868	304*	204	44	3	47
15	492	7904	65	3335	3400	611	36	647	976	520	284	2127	2411	232	248*	251	22	273
22	1258	1732	29	2918	2947	25	200	225	284	3760	23	1384	1407	244	96*	247	175	422
29	817	3536	4	1421	1425	5	951	956	220	1776*	45	831	876	128	72	113*	28*	141*
Sep. 5	648	2736	6	301	307	21	976	997	464	932	25	853	878	468*	524*	62	1	63
12	885	808	24	613	637				192	56	154	913	1067	488*	22	61*	31*	92*
19	1622	1244	5	662	667	25	660	685	528	416	175	1646	1821	48	340	6	0	6
26	1188	2016	18	345	363				100	504*	217	510	727	760	728*	25	3	28
Oct. 3	1456	388	3	591	594				208	64	317	360	677	808*	2200	5	0	5
9	1116		1	362	363	4	363	367	128		38	199	237	316	1078	6	1	7
16	158		0	96	96	1	277	278			11	195	206			1	0	1
23	124																	
30			1	58	59						1	137	138			0	1	1
Nov. 6			0	82	82						2	32	34					

[a] Asterisks indicate that the respective fields were treated with insecticide between the indicated date and the next following date.
[b] Treatments were with trichlorfon.
[c] Treatments prior to Sept. 12 were with trichlorfon, subsequent treatments with methyl parathion + endrin.
[d] All treatments were with methyl parathion + endrin.

Table 2.—The parasites attacking whiteflies on cotton in the Cochella and Imperial Valleys, their host associations, and method of reproduction.

Parasite	Host insects[a]	Reproduction
Eretmocerus haldemani	*A.s.*, *B.t.*, *T.a.*, and *T.v.*	Biparental
Encarsia formosa	*A.s.*, *B.t.*, *T.a.*, and *T.v.*	Uniparental
E. meritoria	*A.s.*, *B.t.*, *T.a.*, and *T.v.*	Biparental
E. coquilletti	*A.s.*, and *T.a.*	Biparental
Encarsia sp.	*T.a.*	Biparental
Prospaltella sp. z. ♀	*T.a.*[b]	Biparental
Prospaltella sp. z. ♂	Eggs of Lepidoptera	

[a] *A.s.* = *Aleyrodes spiracoides*; *B.t.* = *Bemisia tabaci*; *T.a.* = *Trialeurodes abutilonea*; *T.v.* = *T. vaporariorum*.
[b] Stoner and Butler (1965) inferred that *Encarsia (Prospaltella) lutea* (Masi) develops on *T. vaporariorum* as well as on *T. abutilonea*. Possibly this parasite is conspecific with *Prospaltella* sp. z., but the present work failed to confirm the inferred host association.

In the Imperial Valley (Fig. 4), in contrast to the Coachella Valley, *T. abutilonea* continued to constitute up to 90% of the populations as late as September. Moreover, wild plants like *Solanum elaeagnifolium* Esch. and *Xantium* sp., which occurred on the margins of cotton fields, supported heavy populations of *T. abutilonea* throughout the winter.

The whitefly populations in the Coachella and Imperial Valleys differ not only in the ratio of *B. tabaci* to *T. abutilonea* but in absolute numbers as well (Table 1). In 1963, the numbers of whiteflies per sample in Indio exceeded 10,000 on 3 separate occasions, while in Westmoreland it reached a maximum of only 976 specimens. In 1964, the maximum number of specimens per sample exceeded 3000 in Indio, while in Westmoreland it reached only 422.[3] It is noteworthy that the much lower incidence in whitefly occurrence in Westmoreland coincided with the predominance of *T. abutilonea* over *B. tabaci*. This study did not offer a satisfactory explanation of this phenomenon.

THE PARASITES

The species of whitefly parasites collected during the present study are listed in Table 2, which also shows their host associations and indicates whether they reproduce uni- or biparentally under field conditions.

The parasites, all within the family Aphelinidae, belong to 3 genera: *Eretmocerus* Haldeman, *Encarsia* Foerster, and *Prospaltella* Ashmead.[4]

Females of all 3 genera and males of *Eretmocerus* develop as primary parasites of whitefly nymphs and pupae. The males of *Encarsia* develop as parasites of *Encarsia* larvae, and those of *Prospaltella* as parasites in the eggs of Lepidoptera. All the parasites are solitary, 1 host giving rise to 1 adult parasite only.

Of the 6 species listed in Table 2, *Encarsia* sp. and *E. coquilletti* Howard occurred only sporadically and in low numbers, and will be mentioned only occasionally. The remaining 4 species, *Encarsia formosa, E. meritoria* Gahan, *Eretmocerus haldemani* Howard, and *Prospaltella* sp. z. comprise the bulk of the parasite fauna and will be dealt with at length.

The population fluctuations of the total parasite fauna usually assumed a pattern similar to that of the whitefly population, i.e., they were low in the beginning of the summer, rose to 1 or more peaks between July and September, and declined in October and November. This pattern was not evidenced in 1964, when parasite populations maintained a high level throughout the season and showed a rise in October and November (Table 3).

The suction samples established that the whitefly parasites in Indio were not abundant. Only once (August 12, 1963) were more than 2000 parasites recovered in a given sample. Except for 1964, percentage parasitization also was low, and usually did not exceed 20% (Fig. 5). This low percentage was independent of absolute whitefly density, since both low (1962) and high (1963) populations were parasitized to a similar low extent.

During 1964, when parasitization was the highest recorded, the months of September, October, and November were characterized by parasitization of 40% and above (Table 3) in both treated and untreated cottonfields.

In Westmoreland there were fewer parasites, as well as whiteflies, than in Indio. However, percentage parasitism was somewhat higher (Fig. 5; Table 3).

The percentages used in discussing the roles of individual parasite species were calculated from total parasite fauna present on a particular occasion. The relative abundance of the 4 major parasite species during 1963 in Westmoreland and Indio are depicted in Fig. 5 and 6, respectively. Data on the absolute abundance and percentage of each parasite species are shown in Table 4.

PARASITES BELONGING TO THE GENUS *Encarsia*

Only slight interspecific variations exist in the developmental history of the *Encarsia* species. Therefore, the following generalized description pertains to all *Encarsia* mentioned.

Development of Females.—The females of *Encarsia* discussed here are primary parasites of aleyrodids and, in biparental species, develop from fertilized eggs only.

The elongate, oval, white egg (Fig. 7a), is deposited within the body fluids of the host. It hatches therein after 3–5 days.

The first- and second-instar larvae each have 13 body segments, a head that is equipped with a pair of mandibles and enclosed in a sclerotized capsule, and a tail. The tail may bear numerous spines.

The third and last larval instar (Fig. 7b) occupies most of the host's pupal case. It is the only instar to possess spiracles, and these may vary in number from 6 to 9 pairs. This instar has no tail, and its posterior extremity is marked by an anal cleft to which the rectum opens.

The pupal period begins about 1 day after the third-instar larva has cast its meconia. The pupa lies with its venter facing the venter of the host. Be-

[3] Three insecticide treatments were applied to that field (Fig. 12). However, this was done when the whitefly populations were declining, and can not account for the observed 7-fold difference.
[4] The generic name *Prospaltella* is applied here to parasite females with a clearly 3-segmented antennal club, and *Encarsia* to females lacking such a club.

Table 3.—Percent parasitism of whiteflies at Indio and Westmoreland. Blank spaces indicate dates on which no whiteflies were collected.

Sampling date	Untreated fields					Treated fields[a]				
	Indio				W'm'd	Indio[b]		Westmoreland		
	1962	1963	1964	1964	1963	1963	1964	1963[c]	1963[d]	1964[b]
May 14										5
22		1	0							4
29		1	0		2					18
June 6		4	0							11
13		1	0	0	0		5			7
20		1	1	0	9		4			8
26		8	1	0	4		4	*		5
July 5		3	1	0	4		6	3		13
10	22	6	3	0	8		7	10		9
18	3	4	4	2	6		10	*		22
25	6	5	7	2	5		10*	4		46
Aug. 1	17	5			12	*	7	8	0	10*
8	25	13	4	1	12	7	26	15*	5	27
15	3	22	3	4	8	34	22	8	9*	12
22	6	16	11	18	24	6	82	6	2*	28
29	7	13	25	2	36	7*	43	9	0	29*
Sep. 5	14	5	45	5	6	2	29	10*	0*	6
12	7	19	31		9	62	28	2*	0	36*
19	7	14	28	6	13	31	39	6	3	0
26	6	21	48		80	6*	29	8	11*	26
Oct. 3	7	19	40		31	0	52	3*	1	81
9	6		46	4	27		57	0	12	50
16	24		58	11			63			87
23	9									
30			74				55			25
Nov. 6			65				79			

[a] Asterisks indicate that the respective fields were treated with insecticide between the indicated date and the next following date.
[b] Treatments were with trichlorfon.
[c] Treatments prior to Sept. 12 were with trichlorfon, subsequent treatments with methyl parathion + endrin.
[d] All treatments were with methyl parathion + endrin.

fore emergence, the adult turns over so that its mandibles face the anterodorsum of the host's pupal case. Emergence always commences from this position.

Development of Males.—Males of *Encarsia,* so far as known, are not primary parasites of Aleurodidae. Instead, they develop as secondary parasites, parasitizing *Encarsia* females. They develop from unfertilized eggs, usually deposited by the female prior to mating. However, it has been shown that the females of at least 1 species, *E. pergandiella* Howard, are able to deposit male-producing eggs before and after mating (Gerling 1966).

Like the females, the males of *Encarsia* develop from eggs deposited in the body fluids of their hosts. The 3 larval instars that follow resemble those of the female in many morphological details. However, the male larva differs from the female in that the latter spends its entire life within the host, while the male larvae leaves the host in the beginning of the second instar and commences to feed on it externally.

The third-instar male larva devours the remnants of the female larva (Fig. 7c), except the sclerotized organs. These then attain the shape of a scalelike brown object usually visible between the male parasite and the dorsum of the host's pupal case.

The pupae of *Encarsia* males resemble those of the females but are distinguishable by their darker color, by the dark brown scalelike remnants of the female, and by the presence of 2 groups of meconial pellets (Fig. 8).

Females of *E. formosa* are easily recognizable by their dark thorax and head and their yellow abdomen (Fig. 9). The males are completely black, are rare, and are not usually produced under field conditions (Gerling 1966).

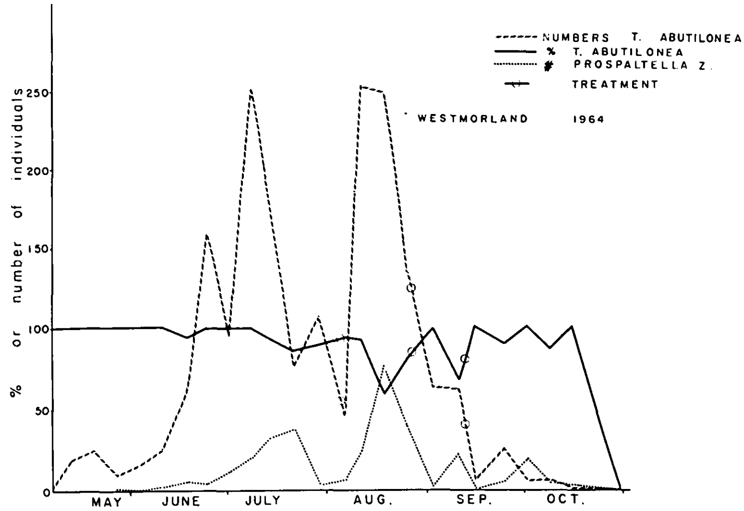
Two distinct forms of *E. formosa* were encountered during the present study. One, the "conventional" form, was found in Riverside and in many other non-desert locations. When these individuals are reared on *T. vaporariorum* they are characterized by the dark brown thorax and by the black (Fig. 10) attained by the pupal cases of their hosts. The second or desert form has a light brown thorax, and its larvae do not cause melanization of *T. vaporariorum* (or any other whitefly) pupae. As mentioned, these parasites are uniparental though bisexual. Therefore, no cross-fertilization experiments were carried out, and the possibility that there may be 2 distinct species was not pursued.

The developmental history of *E. formosa* conforms with the generalized pattern discussed previously. The females develop on a variety of whitefly species, whereas males of the conventional form develop as parasites of the females. The biology of the males of the desert form was not investigated.

Owing to intensive studies carried out by Burnett (1949, 1962, 1964), the physical ecology of *E. for-*

mosa is better known than that of any other whitefly parasite. He found that it lays a maximum number of eggs (32) at 75°F, that at this temperature parasite longevity is 15 days, and that the duration of its life cycle from egg to adult also is 15 days. As temperature rises to 86°F the number of eggs per female drops to 10, longevity decreases to 4 days, and the life cycle to 10. It should be noted that the parasites with which Burnett worked originated in a country with a cold climate (England). It is possible that the *E. formosa* females found in the hot regions of southern California have higher temperature optima than those found by Burnett.

The conventional form of *E. formosa* was found throughout the nondesert areas of southern California. The desert form was collected from the Coachella and Imperial Valleys, as well as from Yuma County, Ariz. In addition to *A. spiracoides*, *B. tabaci*, *T. abutilonea*, and *T. vaporariorum* the conventional form was also reared from *Aleyrodes pruinosa* Quaintance and the desert form from *Aleurocybotus occiduus* Russell.



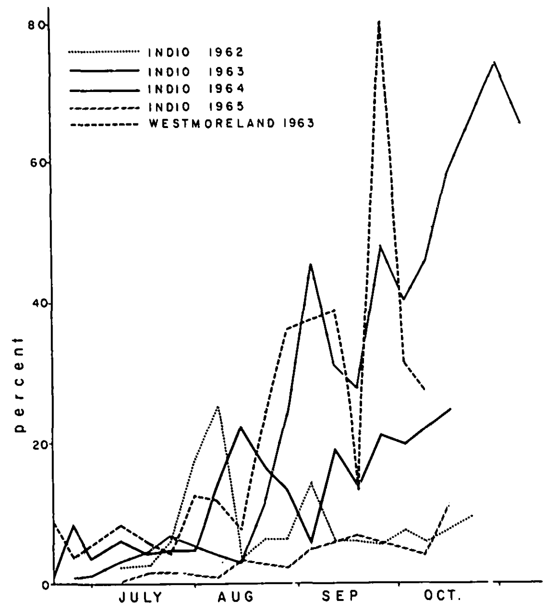


Fig. 4 (top).—Percent *Trialeurodes abutilonea* of the total whitefly fauna, and numbers of *T. abutilonea* and *Prospaltella* sp. z. in Westmoreland. 1964. Fig. 5 (bottom left).—Percent parasitization of whiteflies in untreated fields in Indio (1962–65) and in Westmoreland (1963). Fig. 6 (bottom right).—Composition of the parasite fauna in an untreated field in Indio. 1963.

Regular recovery of *E. formosa* populations in the suction samples started in July or August. Thereafter, they were picked up in low numbers but continuously throughout the season. Their role in the total parasite fauna varied from sample to sample, but the data indicate that in Indio the populations of *E. formosa* played a greater role in 1962 (average 16%, maximum 40%) than in 1963, 1964, and 1965 (average 8%, maximum 32%) (Table 4; Fig. 11).

In Westmoreland, populations of *E. formosa* were collected also in small numbers only (average 13%, maximum 40%). Their percentage was higher than that of the populations in Indio during 1963, 1964, or 1965, but somewhat lower than that in 1962 (average 14%, maximum 39%).

Males of *E. meritoria* are brown except for the head, antennae, posterior and lateral mesonotal margins, parapsides, scutellum, and legs, all of which are yellow. The females are golden yellow and bear a superficial resemblance to those of *Eretmocerus haldemani*, but can be readily recognized by their somewhat darker color, 8-segmented antennae (Fig. 7d), and 5-segmented tarsi I and III.

No studies on the physical ecology of *Encarsia meritoria* were conducted. It was noted that this parasite was most prevalent in Riverside and in the Coachella Valley during the summer. However, small numbers of *E. meritoria* were recovered throughout the year.

E. meritoria was recovered from *A. spiraeoides* in Riverside and *B. tabaci* in the Coachella and Imperial Valleys in greater numbers than from *T. vaporariorum* and *T. abutilonea*, respectively. Whiteflies of the genus *Trialeurodes* have box-shaped pupae (with erect side walls), whereas those of *B. tabaci* and *A. spiraeoides* are more or less hemispherical.

In Indio, the role of *E. meritoria* as a component of the parasite fauna, as indicated by suction samples, varied from year to year (Table 4). In 1962 it maintained an average of 59% of the parasite fauna throughout the season. In 1963, *E. meritoria* populations in June and July accounted for between 50% and 89% of the total parasite fauna; in August, between 24% and 63%; and in September, between 8% and 52%.

In 1964, parasitization by *E. meritoria* accounted for a relatively low percentage of the total parasite population, e.g., 11%–15% in July, 18%–48% in August, 14%–30% in September, and 5%–19% in October and November. It is noteworthy that 1964 was also the year during which total whitefly parasitization was the highest recorded.

In 1965, recovery of *E. meritoria* in appreciable numbers started as late as August 15. During August and September it attained 40%–59% of the total parasite population, but in the 2 samples taken during October, percentage parasitism declined to 33% on the 9th and 13% on October 16.

Despite the diversity observed in percentage parasitism, it is possible to present the data in 2 groups: (1) the *E. meritoria* populations maintained a consistently high percentage throughout the season, as in 1962; (2) a drop in percentage was noted at the end of the season, as in 1963, 1964, and 1965.

In Westmoreland (1963), populations of *E. meritoria* were low throughout the season both in numbers and in percentage (Fig. 11). The largest number of parasites collected in a single sample was only 16 (September 26) and the highest percentage recorded was 7% (October 9). The pattern, which indicates that populations of *E. meritoria* in Westmoreland maintain a low percentage of the parasite fauna throughout the season, was observed also in fields which were treated with insecticides during both 1963 and 1964.

Females of *E. coquilletti* were occasionally recovered from *T. abutilonea* and *A. spiraeoides.* Females of this parasite are completely dark except for the silvery-white dorsum of abdominal segments 5 and 6. The males resemble the females in color, but lack the silvery-white stripe; males were not recovered during the present study.

In addition to the present record, *E. coquilletti* was also found to parasitize *T. abutilonea* on potatoes in the State of Washington (Landis et al. 1958) and on cotton in Arizona (G. Butler, personal communication). In the Coachella Valley, *E. coquilletti* was recovered mainly during June and July. In the Imperial Valley it was recovered from May to October.

Unidentified parasites of the genus *Encarsia* were also found to parasitize *T. abutilonea.* The females resemble somewhat those of *E. formosa* in their yellow abdomen and dark head and thorax. However, unlike *E. formosa* these females have brown markings along the pleural margins and the dorsum of the abdomen; their head and thorax are black (not brown as in *E. formosa*), and all tarsi are 5-segmented.

This parasite species was reared in large numbers from *T. abutilonea* on *Pluchea sericea* during the winter and spring and on *S. elaeagnifolium* during late summer and fall. It was also occasionally recovered from *T. abutilonea* on cotton in the Imperial Valley.

E. coquilletti and *Encarsia* sp. were rare in all cotton fields examined.

In Westmoreland both *E. coquilletti* and *Encarsia* sp. were recovered. They occurred there throughout the season, from May to October. The maximum number of *E. coquilletti* found in 1 sample was 16 and that of *Encarsia* sp., 10.

In Indio, only *E. coquilletti* was recovered. With 1 exception (treated field of 1963) this parasite was found only during June and July. The maximum number of parasites recovered in 1 sample was 5.

PARASITES BELONGING TO GENERA OTHER THAN *Encarsia*

Prospaltella species z. resembles *E. meritoria.* Several characteristics, helpful in distinguishing between these 2 genera, are shown in Table 5 and Fig. 7f and 7g. *Prospaltella* sp. z. is biparental, its females develop as primary parasites of *T. abutilonea* and their developmental history is in accord with that previously outlined for the females of *Encarsia.*

However, the developmental history of *Prospaltella* sp. z. males differs from that of *Encarsia* in that the former develop in eggs of Lepidoptera whereas the latter develop at the expense of their own females.

Parasitization of eggs by the males of *Prospaltella* sp. z. differs markedly, and is easily distinguishable from parasitization by a more prevalent parasite, *Trichogramma* sp.

Only 1 *Prospaltella* sp. z. male develops in each egg. It does so at the expense of the lepidopterous embryo and thus develops only on fertilized eggs. Developmental duration from egg to adult at 75°F is approximately 17 days, and the emerging parasite leaves behind several black scalelike objects in addition to the meconia.

Trichogramma sp. often produces 2 or 3 individuals from each egg. These develop on the fluids contained within the egg regardless of the latter's vitality. At 75°F the developmental period of *Trichogramma* is 7–8 days and the chorion of the parasitized egg is completely melanized by parasitization.

Females of *Prospaltella* sp. z. have been found to

Table 4.—Numbers and respective percentages of the 4 major parasites of whiteflies taken on approximately weekly sampling dates between May 14 and November 6 at Indio and Westmoreland. Dates on which the given species was not taken in any field in any year are omitted.

Sampling date	Untreated fields										Treated fields[a]									
	Indio								W'm'd		Indio[b]				Westmoreland					
	1962		1963		1964		1965		1963		1963		1964		1963[c]		1963[d]		1964[h]	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
A. *Encarsia formosa*																				
June 13															4	100				
26			4	3											2	100*				
July 5																			1	7
10															28	64			1	4
18	1	5			2	6			8	100					4	100*				
25					2	3								*	8	40			10	14
Aug. 1			4	1					4	6		*			11	35			2	14*
8			4	1	5	4			12	19			18	3	5	28*	4	33	3	18
15	1	6	32	1	17	18	2	8	8	10	4	5	14	4	4	25		*	3	9
22	14	16	0		26	20			8	10	8	8	45	2			1	50*	6	5
29	6	10	24	4	25	5	3	14	4	8	4	3*	27	4	20	92			6	12*
Sep. 5	22	18	4	2	27	11	6	11	1	3	0		0		4	25*		*	1	25
12	3	4	0		23	8			40	32	12	9	17	4	1	33*			5	9*
19	16	13	12	5	20	8	6	13	0				34	3			3	6	0	
26	6	7	0		29	9			40	10			29	10			44	63*	0	
Oct. 3	40	34	12	13	29	7			24	20			27	14			16	29	1	4
9	28	40			36	12	1	7	4	2			24	8			88	90	1	12
16	12	23			4	3	1	3					18	5					2	29
23	2	15																		
30					15	9							15	9					1	33
Nov. 6					20	13							34	27						
B. *Encarsia meritoria*																				
May 22			1	100																
29			3	100																
June 13			9	52					1	100										
20			16	89					1	7										
26			104	77												*				
July 5			172	65									7	8						
10	4	66	464	72	3	15							7	9	8	18				
18	5	26	164	72	4	11							23	14		*				
25	12	40	444	64	8	12	1	100					79	22*					1	1
Aug. 1	33	67	360	63					4	6		*	1	1					2	14*
8	39	72	164	24	62	50	2	50			84	72	128	19		*			1	6
15	14	78	1160	51	20	21	14	56			60	75	156	44			8	33*	2	6
22	56	66	172	41	181	64	20	40	2	2	56	56	414	22			1	50*	4	4
29	38	63	256	47	120	26	13	59	4	8	120	86*	137	20	1	4			1	2*
Sep. 5	81	66	84	52	75	29	25	48			8	40	110	31	3	18*		*	0	
12	31	47	60	31	87	31			8	7	80	62	114	28	1	33*			2	4*
19	60	51	56	26	66	26	21	47	4	5	56	33	157	14					0	
26	48	58	8	8	46	14			16	4	16	50*	179	59	12	38	1	1*	1	16
Oct. 3	60	50	24	26	30	7			12	10			88	47			14	25	1	4
9	36	51			58	19	5	33	8	17			82	26			2	2	0	
16	36	71			14	10	5	13					137	38			8	100	1	14
23	10	77																	0	
30					9	5							23	13						
Nov. 6					15	10							14	11						

Table 4.—Numbers and respective percentages of the 4 major parasites of whiteflies taken on approximately weekly sampling dates between May 14 and November 6 at Indio and Westmoreland. Dates on which the given species was not taken in any field in any year are omitted. (Continued.)

Sampling date	Untreated fields										Treated fields[a]									
	Indio								W'm'd		Indio[b]				Westmoreland					
	1962		1963		1964		1965		1963		1963		1964		1963[c]		1963[d]		1964[b]	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
C. *Prospaltella* sp. z.																				
May 29																			2	100
June 13													1	100					2	100
20			2	11					5	38			5	100					5	100
26			24	18									13	100		*			4	66
July 5			20	7	2	50							67	81					11	79
10	2	33	0		14	70			8	50			54	75					20	88
18	13	68	20	9	25	71	1	33					114	69		*			32	64
25	16	53	28	4	25	38			4	14			188	53*					37	52
Aug. 1	16	32	8	1					16	25		*	16	13	12	38			4	29*
8	15	28	4	1	56	45	1	25			8	7	151	22	16	29*			6	35
15	3	17	16	1	55	59	1	4			4	5	102	29				*	23	71
22	14	16	28	7	73	26	4	8			8	3	322	17				*	76	68
29	16	27	8	1	77	16	5	23			4	3*	137	20	1	4			39	78*
Sep. 5	16	13	4	2	28	11	1	2	1	3	0		68	19	1	6*		*	2	67
12	31	47	4	2	32	11					2	2	49	12	1	33*			22	41*
19	38	32	20	9	44	17	2	4	4	5	8	5	102	9			45	90	0	
26	27	32	0		31	9			20	5	4	12*	0		4	12	14	20*	5	83
Oct. 3	12	10	6	6	4	1							12	6			25	46	19	86
9	3	4			7	2	0		4	2			6	2			3	30	4	50
16	1	2			5	4	1	3					17	5					1	14
30					0								1	0						
Nov. 6					1	1														
D. *Eretmocerus haldemani*																				
May 22																			1	100
29									1	100										
June 6									0										2	100
13			8	7	1	100			0											
20			0		0				7	53										
26			4	3	1	100			0							*			2	33
July 5			72	27	2	50			0				9	11	4	100			2	14
10			200	28	2	10			8	50			11	14	8	18			2	8
18			44	19			2	67	0				28	17	0	*			17	33
25	2	7	224	32	23	35			24	86			81	23*	12	60			22	31
Aug. 1			196	34					40	62		*	100	84	8	23			6	43*
8			504	74			1	25	48	75	24	21	376	56	8	14*	8	67	7	41
15			1064	47			8	32	65	85	12	15	79	22	12	75	16	67*	4	12
22	1	1	220	52			26	52	66	82	28	28	1062	57	8	100	0	*	27	22
29			256	47	245	52	1	4	64	88	12	8*	376	55	0		0		3	6*
Sep. 5	4	3	68	42	124	49	20	38	24	92	12	60	178	50	8	50*	2	100*	0	
12			124	64	140	50			74	60	34	26	223	55	0	*	0		24	45*
19	3	2	128	59	125	49	16	35	68	89	104	62	765	72	2	100	2	4	0	
26	2	2	92	92	229	68			320	80	12	37*	93	31	16	50	10	14*	0	
Oct. 3	7	6	50	54	336	84			80	69			60	32	20	100*	0		5	23
9	3	4			206	67	9	60	36	75			201	64	0		4	4	3	37
16	2	4			112	83	30	81					185	52					3	43
23	1	7			0															
30					143	86							135	78					2	66
Nov. 6					117	76							79	62						

[a] Asterisks indicate that the respective fields were treated with insecticide between the indicated date and the next following date.
[b] Treatments were with trichlorfon.
[c] Treatments prior to Sept. 12 were with trichlorfon, subsequent treatments with methyl parathion + endrin.
[d] All treatments were with methyl parathion + endrin.

develop on *Trialeurodes abutilonea* only. The males develop in eggs of *Vanessa* spp.; *Helicoverpa zea* (Boddie); the alfalfa caterpillar, *Colias eurytheme* Boisduval; and other, unidentified, Lepidoptera. *Prospaltella* sp. z. was recorded from the Coachella and Imperial Valleys of California and from Arizona.

Observations revealed that enough eggs are usually present in the field to allow for the development of males. Therefore, the distribution and abundance of *T. abutilonea* is a limiting factor in the distribution and abundance of *Prospaltella* sp. z.

In Indio, the populations of *T. abutilonea* reached their peak abundance during July (Fig. 3). Thereafter, they declined until only a few individuals were present in September. Populations of *Prospaltella* sp. z. were first recorded in July, during the peak of the host populations. They multiplied slowly, reached peak numbers late in August or September, and declined through October and November. Thus, a lag of approximately 1 month existed between the peak populations of the host and those of the parasite.

Suction-sample results showed that the percentages of *Prospaltella* sp. z. in June and July varied from year to year (Table 4). The highest value recorded for 1963 was 17% and for 1964, 71%. Regardless of their initial value, the percentages usually decreased

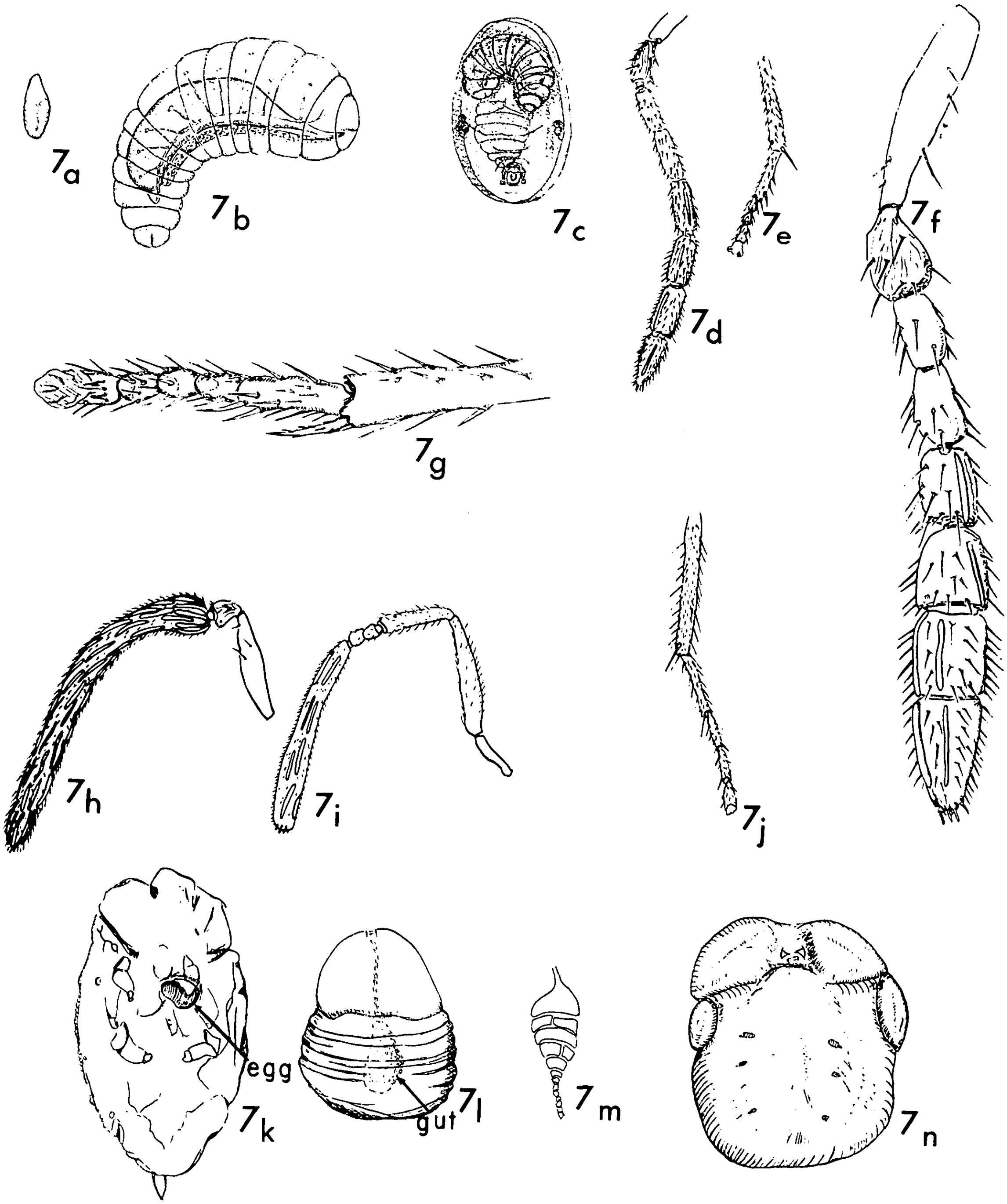
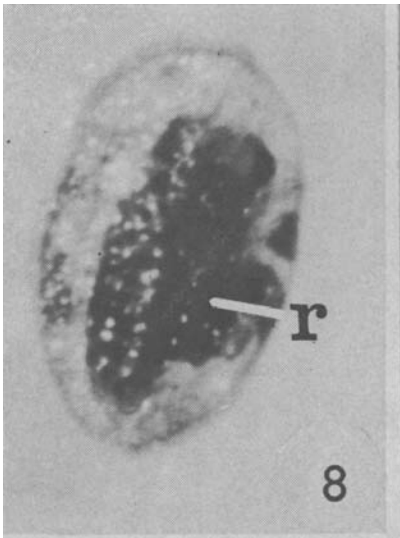


FIG. 7.—a–c, Development of *Encarsia:* a, egg; b, third-instar larva; c, a male larva devouring a female larva. d–e, *E. meritoria* ♀ : d, antenna; e, tarsus. f–g, *Prospaltella* sp. z. ♀ : f, antenna; g, tarsus. h–n, *Eretmocerus haldemani:* h, ♂ antenna; i, ♀ antenna; j, ♀ tarsus II; k, egg on ventral surface of whitefly nymph; l, first-instar larva; m spiracle of same; n, third-instar larva.



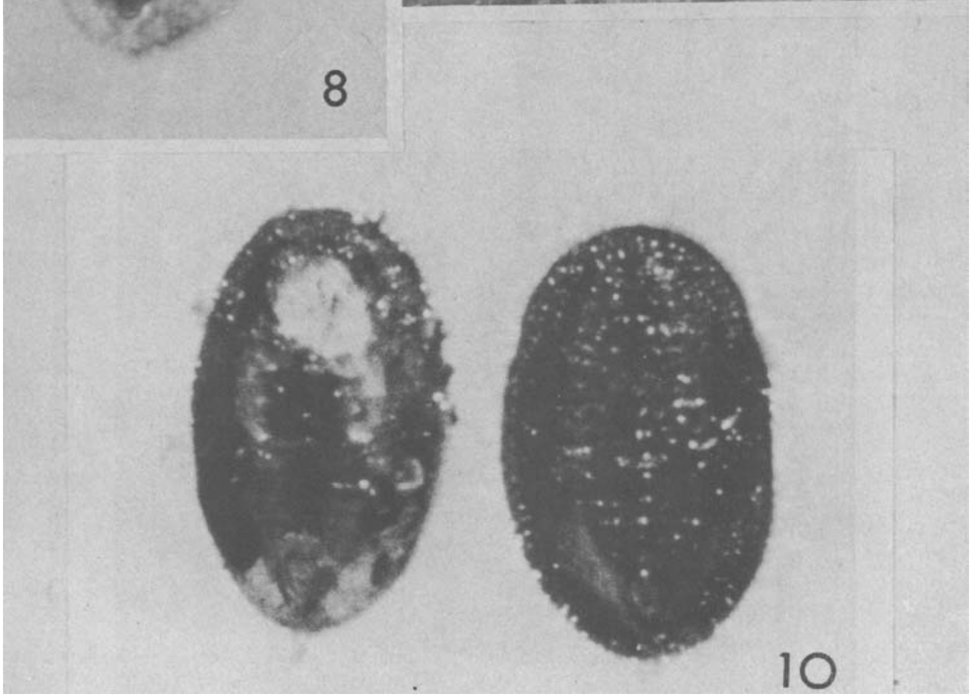


FIG. 8.—Pupae of a male *Encarsia*, showing the black remnants (r) of the female. FIG. 9.—*Encarsia formosa*, ♀. FIG. 10.—Two melanized pupae of the greenhouse whitefly, that at left showing the emergence hole of *E. formosa*.

with time. The decreases in percentage parasitization were observed to parallel decreases in absolute parasite numbers. Only in 1963, when a sharp decline in the total parasite population occurred in August and September, did the percentage of *Prospaltella* sp. z. rise with time.

In 1962, the number of *Prospaltella* sp. z. in Indio constituted a higher percent of the parasite population than in 1963, 1964, or 1965. However, the population trend observed in 1962, showing a decline toward the end of the season, was similar to that in the other years.

In Westmoreland, the breakdown of the whitefly fauna to *T. abutilonea* and *B. tabaci* was recorded only for an insecticide-treated field in 1964 (Fig. 4). The data obtained then, coupled with field observations, indicate that *T. abutilonea* comprises more than 50% of the whitefly fauna throughout the season. Therefore, host material was continuously available for *Prospaltella* sp. z. which was recovered, in low numbers, from June to October and comprised an average of 18% of the total parasite population. The percentage was higher (31%, 50%, etc.) at the beginning of the season than at the end (3%, 5%, etc.) (Table 4; Fig. 11).

Eretmocerus haldemani is easily recognizable by the 4-segmented tarsi and large antennal clubs (Fig. 7 h–j). The females are lemon yellow; the males have a dark yellow dorsum with a light brown mesoscutum.

E. haldemani females deposit white pear-shaped eggs (Fig. 7k), one at a time between the ventral surface of the immature whitefly and the leaf. Upon hatching (after 4 days at 75°F), the first-instar larva (Fig. 7 l) inserts its mandibles in the venter of the host and starts to feed. During the third and fourth days following eclosion, it penetrates the whitefly, where it molts to the second instar.

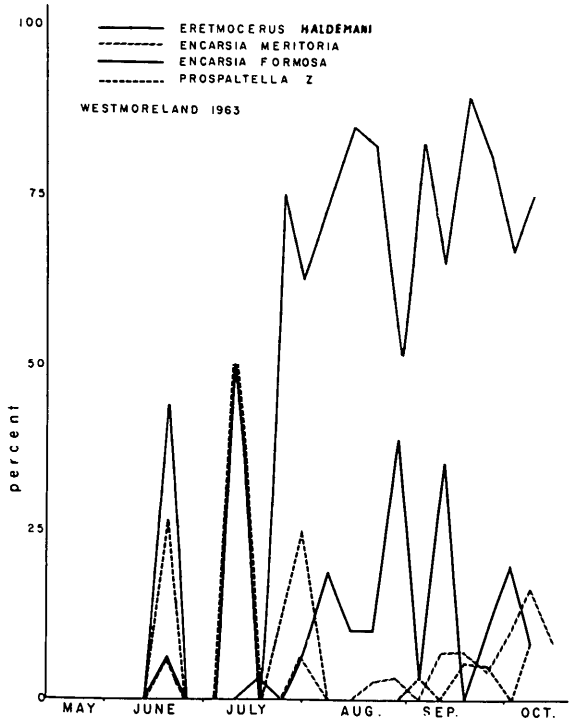


FIG. 11.—Composition of the parasite fauna in an untreated field in Westmoreland. 1963.

The second-instar larva of *E. haldemani* commences to develop only after pupation of the host. Thereafter, its development takes approximately 4 days, ending with transformation into the third, and last, instar. Both second and third instars are globular (Fig. 7n) and have recessed mouthparts. These consist of 2 triangular mandibles and several appendicular sclerites. The third larval instar alone possesses spiracles. These are arranged in 4 pairs and are characterized by their large multichambered atria (Fig. 7m).

At 75°F, the larva of *E. haldemani* reaches the adult stage 22 days after oviposition. The waste products accumulated in the gut of the parasite larva during development are not deposited as meconia prior to emergence, but are voided by the adult after emergence is completed. It is a biparental species. In the Coachella and Imperial Valleys, where the males were shown to be essential for continuous reproduction, the sex ratio is 1 ♂ to 3 or 4 ♀. But in Riverside males are not needed for continuous reproduction and the sex ratio is only 1:10.

E. haldemani is a parasite of numerous whitefly species. In addition to *A. spiraeoides, B. tabaci* and *T. abutilonea,* it was reared from *A. pruinosa, Tetraleurodes* sp., *Tetralicia* sp., and *Trialeurodes vaporariorum.* This parasite occurs throughout southern California, but it was found to be more abundant in the interior valleys than along the coast.

Table 4 reveals that in Indio, *E. haldemani* was first collected in June or July and usually constituted up to ⅓ of the parasite fauna. However, the role of this species in the parasite fauna rose gradually. In August it averaged 32% (maximum 74%) whereas in September and October it averaged 67% (maximum, 92%). Thus, in Indio, although it started at a relatively low level, it assumed an increasing role in the composition of the parasite fauna until, at the end of the season, it became the major constituent thereof.

In Westmoreland, *E. haldemani* was a major constituent of the parasite fauna throughout the season. It had already reached 75% on July 25 and maintained an average of 71% during August, 78% during September, and 71% during October (Fig. 11).

The difference between Indio, where *E. haldemani* populations rose gradually, and Westmoreland, where they were high throughout the season, may be attributable in part to larger numbers of overwintering *E. haldemani* in the Imperial Valley. These are able to move onto cottonfields and establish relatively high populations in June or July, whereas the populations in Indio move onto cottonfields in much lower numbers and need 2 or 3 months to reach their peak abundance.

KEY TO THE PARASITES OF WHITEFLIES ON COTTON IN THE COACHELLA AND IMPERIAL VALLEYS OF CALIFORNIA

Females:

1. Body all yellow 2
   Body not all yellow 4
2. Antenna 5-segmented, club 1-segmented, about ⅓ body length, oar-shaped; all tarsi 4-segmented (Fig. 7i, 7j). Present year-round, abundant .... ***Eretmocerus haldemani***
   Antenna 8-segmented 3
3. Last 3 antennal segments wider than others, forming a club; all tarsi 5-segmented (Fig. 7f, 7g). Host, *Trialeurodes abutilonea.* Present year-round, but rare except June–September .... ***Prospaltella*** sp. z.
   No antennal club as above; tarsus II 4-segmented (Fig. 7e). Present year-round, abundant .... ***Encarsia meritoria***
4. Head and thorax dark, abdomen yellow 5
   Completely dark, except for silvery-white dorsum of abdominal segments 5 and 6; tarsus II 5-segmented. Hosts, *Aleyrodes spiraeoides* and *T. abutilinea.* June–July in Coachella Valley, May–October in Imperial Valley, rare .... ***Encarsia coquilletti***
5. Abdomen completely yellow; tarsus II 4-segmented. Present year-round (Fig. 9) .... ***Encarsia formosa*** (desert form)
   Abdomen with brown markings dorsally and laterally; all tarsi 5-segmented; head and thorax usually darker than in *E. formosa.* Host, *T. abutilonea.* Year-round; not abundant in cottonfields. .... ***Encarsia*** sp.

Males:

1. Body yellow or yellow and brown 2
   Body dark brown or black 4
2. Mesothorax light brown; all yellow elsewhere; antenna 3-segmented, with long club (about ⅔ as long as body); all tarsi 4-segmented (Fig. 7h) .... ***Eretmocerus haldemani***
   Body partly brown; antenna 8-segmented 3
3. Antenna filiform; tarsus II 4-segmented .... ***Encarsia meritoria***
   Antenna with 3-segmented club; tarsus II 5-segmented .... ***Prospaltella*** sp. z.
4. Tarsus II 5-segmented. Rare in cottonfields .... ***Encarsia*** sp.; ***Encarsia coquilletti***
   Tarsus II 4-segmented; body all black. Rare to absent in field .... ***Encarsia formosa***

Table 5.—Differences between adults of *Prospaltella* sp. z and *Encarsia meritoria*.

	Prospaltella sp. z		*Encarsia meritoria*	
	Male	Female	Male	Female
Last 3 antennal segments	Slightly clubbed	Strongly clubbed	Filiform	Filiform
Tarsus II	5-segmented	5-segmented	4-segmented	4-segmented
Eye color	Dark red	Dark red	Dark red	Green or transparent in life
Body color	Yellow and brown; axillae entirely brown	Light yellow	Yellow and brown	All yellow, somewhat darker than *Prospaltella*

REACTIONS OF THE WHITEFLY AND THE PARASITE POPULATIONS TO INSECTICIDE TREATMENTS

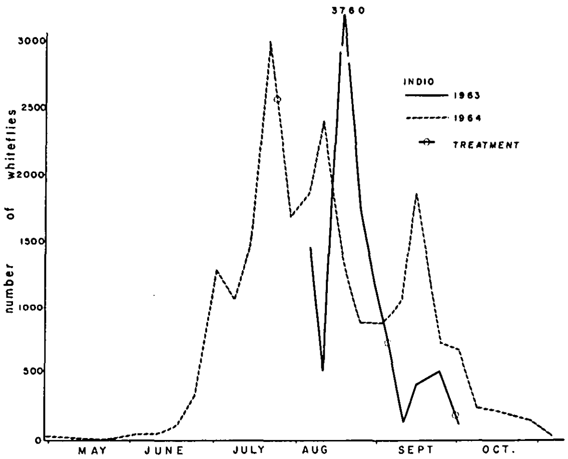
Toxicants were applied to the cottonfields studied only when danger of economic damage was at hand. No such danger was posed by the whiteflies, and consequently none of the treatments was applied specifically for these pests. The toxicants used were either trichlorfon (purchased as Dylox®), applied primarily to control *Lygus hesperus* Knight, or a mixture of methyl parathion + endrin for the control of the bollworm, *Helicoverpa zea*. All applications were made by airplane at the rate of ¼–1 lb of active ingredient/acre.

When studying samples taken from treated fields, one must consider that, barring systemic action, only adults are affected. Therefore, while the number of adult parasites is greatly reduced by the treatment, the abundance of the whitefly nymphs (i.e., the host stage susceptible to parasitism) remains unchanged. Moreover, because of insecticide-induced mortality, the total number of adult whiteflies and parasites collected no longer represents the number of whitefly pupae present. In such cases, the calculated percentage of parasitism indicates the ratio between the total adult whitefly and parasite populations in the sample, rather than the percentage of whitefly pupae parasitized at a given period.

The Whiteflies.—Table 1 and Fig. 12–15, which summarize the data obtained from the weekly samples, show extreme variations in the effect of insecticides on the whitefly populations. In 1963 in Indio, ¾ lb trichlorfon/acre reduced the whitefly populations 48% on September 4, and 87% on October 1. During the same year at Westmoreland, where all treatments were applied at 1 lb/acre, population increases of more than 10-fold were recorded following the treatment of July 19, but decreases of 24% and 48% were recorded after the treatments on August 10 and 24, respectively.

The reaction of whiteflies to toxicants, as discussed in the previous paragraphs, appears inconsistent. This inconsistency can be explained by taking into consideration the sampling method (suction) in conjunction with the fluctuation of the adult whitefly populations in untreated fields.

Populations of whiteflies in the field overlap only to a small extent. Sometimes adults are rare and immatures are abundant, other times immatures are rare and adults are abundant. These natural fluctuations in numbers of adult whiteflies are reflected in suction samples because only adults are picked up by the suction machine. For example, on July 10, 1963, 11,404 whitefly adults were collected in Indio (Table 1; Fig. 1). By July 18 many of these had died, but their progeny had not yet reached the adult stage and therefore were not counted. Consequently, only 5341 adults were collected on that date. By the time of the



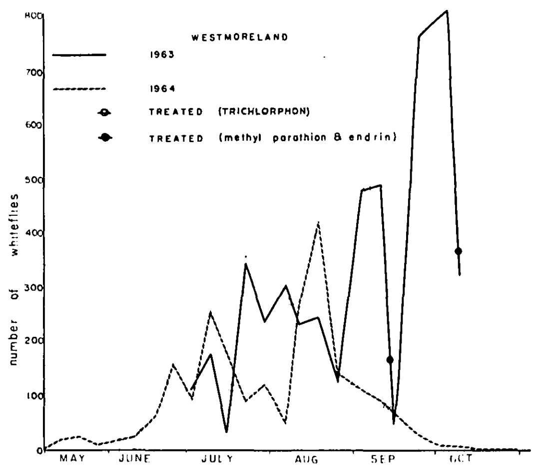
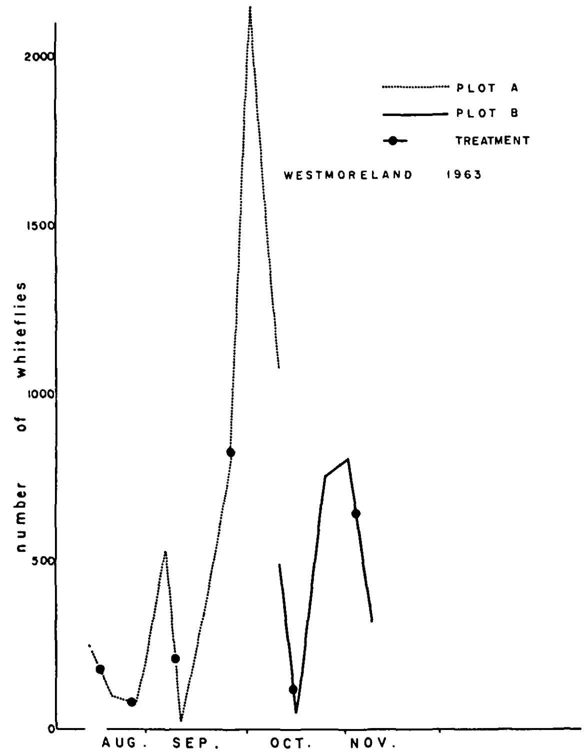


FIG. 12 (top).—Number of whiteflies in samples from treated fields in Indio. 1963 and 1964. FIG. 13 (bottom).—Numbers of whiteflies in samples from fields treated with trichlorfon in Westmoreland. 1963 and 1964.



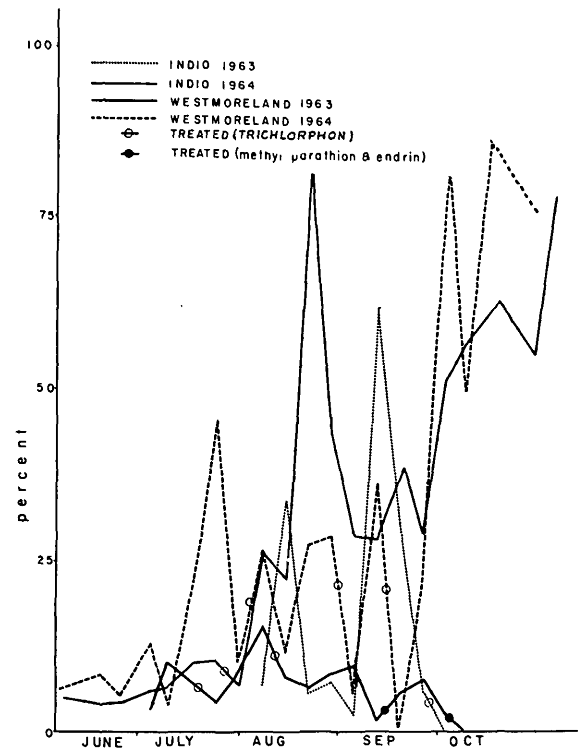


FIG. 14 (top).—Number of whiteflies in samples from 2 plots treated with methyl parathion + endrin in Westmoreland. 1963. FIG. 15 (bottom).—Percent parasitization in samples from treated fields in Indio (1963 and 1964) and in Westmoreland (1963 and 1964).

next sample (July 25), a new generation of adults had emerged, as reflected by a recovery of 14,016 specimens.

In 1964, only 1 insecticide application was made in Indio. It caused a 47% drop in the whitefly population. The 3 applications made during the same year in Westmoreland reduced the populations by 39%, 45%, and 6% of their former values. In addition to a count of the whiteflies present, a count was made also of the *T. abutilonea* and *B. tabaci* present within the whitefly populations. These counts indicate a possible differential effect of trichlorfon on the 2 whitefly species, i.e., *T. abutilonea* populations were reduced 31% in Indio, and between 21% and 100% in Westmoreland, whereas *B. tabaci* populations were reduced only 41% in Indio and between 46% and 90% in Westmoreland.

In 1963, methyl parathion + endrin, in addition to trichlorfon, was used on some of the sampled fields in Westmoreland (Table 1; Fig. 13, 14). A reduction of the whitefly populations followed the application of parathion + endrin in all but 1 case (September 27). This reduction was often more drastic than that obtained through the use of trichlorfon. However, the data obtained from the 6 cases in which methyl parathion + endrin was used were not sufficient to give an accurate comparison.

The toxicants used affected only adult whiteflies and parasites; moreover, they were used without regard to the adult/immature ratio of the whiteflies and parasites. Therefore, some materials were applied when the adult population was high (Indio 1963, 1964; Westmoreland, September 15 and October 5, 1963), some when it was declining (Westmoreland, August 10, 1963, and all of 1964) and some when the adult whitefly population was at a low ebb or rising (Westmoreland, June 26, July 19, and September 6, 1963). In the first case, severe reduction in the population followed; in the second, only moderate reduction occurred; in the third, an increase was observed.

It thus becomes evident that an insecticide with a long residual activity will be most effective in checking the whitefly populations that emerge after the cotton has been treated. This fact may be reflected by the apparently stronger effect of methyl parathion plus endrin over that of trichlorfon and is attributable to endrin's long residual activity.

The Parasites.—The parasite samples often included only a few individuals, thus rendering the results insignificant. Therefore, most of the weight was given to the few samples which involved 15 or more specimens.

It should be borne in mind that the treatments were applied against cotton pests other than whiteflies, and that some of the results obtained may be due to normal fluctuations in the parasite populations, not to the influence of insecticides.

Eretmocerus haldemani.—Table 4 contains data concerning the reaction of this species to trichlorfon on 10 occasions and to methyl parathion + endrin on 6 occasions. Six of the former showed a decline, 3 an increase, and 1 remained unchanged, following treatment. Only 2 samples, that of July 25, 1964, in Indio and that of September 14, 1964, in Westmoreland, contained more than 15 individuals. Of these, the former showed an increase and the latter a decrease in the number of parasites recovered in the week following treatment.

Two of the samples taken in plots treated with methyl parathion + endrin did not have any *E. haldemani* in them prior to the treatment. The remaining four, which had 2, 10, 16, and 20 parasites in them, were all reduced to 0 the week following treatment.

These data, when compared with the data for *E. haldemani* in untreated fields (Table 4), indicate that trichlorfon or a combination of methyl parathion + endrin have a detrimental effect on populations of *E. haldemani*. The effect was more pronounced with the latter toxicants than with the former.

Recovery of the parasite populations from the treatment, as indicated by an increase in the number of parasites collected in the second week after treatment, was observed for both types of treatments used.

Encarsia formosa reacted to both trichlorfon and methyl parathion + endrin similarly to *Eretmocerus haldemani* (Table 4). Use of either of the toxicants was followed by a reduction in the populations sampled during the week following treatment. They often regained their pretreatment level in the sample taken 2 weeks after treatment.

Encarsia meritoria appeared to be severely affected by trichlorfon (Table 4). The 3 populations that contained 16, 19, and 120 specimens before the treatment were reduced to 0, 1, and 8, respectively. Reduction also followed the treatments with methyl parathion + endrin. In most cases, populations approximated their pretreatment levels during the second week after treatment.

Prospaltella sp. z., like *E. meritoria,* showed drastic reduction following an application of trichlorfon (Table 4). The data were too few to permit conclusions concerning the detriment caused by methyl parathion + endrin. Population recovery by the second week after treatment was again noticed.

On the whole, a comparison of Fig. 5 and 15 reveals that a few insecticide applications increase the amplitude of the oscillations of percent parasitization but do not change its upward trend (Indio 1964), whereas many applications both increase the amplitudes of the oscillations and cause a downward trend in percent parasitization (Indio 1963), especially when a combination of methyl parathion + endrin is used (Westmoreland 1963).

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