Status of Ceratitis capitata in Hawaii following the Introduction of Dacus dorsalis and its Parasites

By HENRY A. BESS[1, 2]

ENTOMOLOGIST, UNIVERSITY OF HAWAII, COLLEGE OF AGRICULTURE, AGRICULTURAL EXPERIMENT STATION

(Presidential address, presented at the meeting of December 8, 1952)

Immediately following the discovery in 1946 of the oriental fruit fly, *Dacus dorsalis* Hendel, in Hawaii and its subsequent rapid increase to epidemic levels, the Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann), became extremely scarce at lower elevations where it had been a pest for more than three decades. Even though *C. capitata* is seldom found in the more tropical lowland areas, it is still a formidable pest of peaches and persimmons which are grown in more temperate areas at higher elevations. However, since the egg-larval parasite, *Opius oophilus* Fullaway, became firmly established, there has also been an appreciable reduction in the infestation in these areas.

The present study was made to determine the occurrence of, and infestation by *C. capitata* and *D. dorsalis* in the various ecological zones in Hawaii. There was hope that eventually there would be an opportunity to make a more intensive study designed to attempt to explain why *C. capitata* was replaced by *D. dorsalis* in the more tropical lowland areas.

Methods

The procedure followed in this study was to collect periodically host fruits from localities at elevations between sea level and about 5,000 feet, and subsequently recover the flies and parasites from the fruits as they emerged in the insectary. Most of the detailed data presented were obtained from fruits collected in four general areas: on Maui, in the Kula area at elevations between 2,000 and 4,000 feet; on Hawaii, in the Kona area between 700 and 2,500 feet, the Volcano area between 4,000 and 5,300 feet, and the Waikii area at approximately 4,800 feet. However, collections were obtained occasionally from widely scattered areas throughout the islands where fruits and *C. capitata* could be found.

Peaches (*Prunus persica* [L.] Batsch.), coffee (*Coffea arabica* L.), Jerusalem cherries (*Solanum pseudocapsicum* L.), guavas (*Psidium Guajava* L.), and loquats (*Eriobotrya japonica* [Thunb.] Lindl.), were the principal fruits collected. Special collections of guavas were made near the upper occurence of guavas where *C. capitata* was found still to occur in guavas, even though usually in small numbers.

[1]Published with the approval of the Director of the Hawaii Agricultural Experiment Station as Technical Paper No. 281.

[2]The writer is indebted to F. H. Haramoto, T. Nishida, B. L. Pelot, C. S. Inada and E. T. Fukunaga for assistance in carrying out these studies.

Soon after collection, the samples of mature fruits were shipped to Honolulu via air, and held in an insectary on the University campus. The fruits were first counted and weighed and then (except guavas) placed on ¼-inch wire screen in 5-quart jars with a layer of sand into which the maggots entered on leaving the fruits. Guavas, on the other hand, were usually dissected and the maggots transferred to a papaya-yeast medium for development, as in the procedure followed in the more extensive studies on the establishment, spread, and build-up of the parasites imported to combat *D. dorsalis*. After emergence was complete, the number and sex of the flies and parasites were determined and the number of unemerged puparia recorded.

From the data obtained from the fruit samples an index of the total infestation or abundance of *C. capitata* and *D. dorsalis* was computed by two methods: one on the basis of the number of puparia per fruit, and the other on the basis of the number of emerged flies per fruit. Since the maggots and puparia of *C. capitata* and *D. dorsalis* are extremely difficult to distinguish apart, no attempt was made to determine the number of puparia of each. The index of abundance or infestation based on the number of emerged adults is considerably lower than that based of puparia, since parasitization alone often exceeded 50 per cent. However, it was useful for comparing the abundance of *C. capitata* with *D. dorsalis* in these fruit samples, and also the abundance of *C. capitata* in recent years with its abundance many years ago.

Status of Ceratitis capitata

The infestation by *C. capitata* in Hawaii has changed tremendously in the past 40 years. Within a year after *C. capitata* was first found in Honolulu in 1910 it became such a serious pest that widespread concern was aroused. A vigorous clean-up campaign was waged for three years, but in spite of it, the fly rapidly spread to the outer islands and became well established throughout the Territory. Since the fly thrived and spread even though an attempt was made to dispose promptly of all surplus fruits before, or as soon as, they ripened, its increase might be classed as being of an epidemic nature. However, there are no infestation or population data for this period available for comparison with those for subsequent years after the fly had reached a more stable and probably lower population level.

From 1916 to 1933 *C. capitata* was a serious pest (Willard and Mason, 1937). It has continued to cause damage at the higher elevations, but since 1947 it has rarely been seen at lower elevations.

Infestation in fruits that contained Dacus dorsalis.

The reduction in abundance of *C. capitata* at lower elevations following the introduction of *D. dorsalis* caused speculation as to the possible detrimental effects of *D. dorsalis* on *C. capitata*. Subsequently, studies were made to determine whether the larvae of *D. dorsalis* had an adverse effect on *C. capitata* larvae when they occurred together in individual fruits.

During the period between June 9 and August 4, 1949, data on emergence were obtained from ten or more individual peaches from 13 different collections. Of these individual fruits, 244 produced flies. Ninety-four of the fruits produced *C. capitata* alone, 79 *D. dorsalis* alone, and 71 produced both species. A total of 539 adults emerged from the 94 fruits that produced only *C. capitata,* 1,006 adults emerged from the 79 fruits that produced only *D. dorsalis,* and 467 *C. capitata* adults and 415 *D. dorsalis* adults emerged from the 71 fruits that produced both species. It is evident from these data, and those obtained from mechanically infested fruits in the insectary, that both species developed together successfully and in good numbers.

There were nine of the above 13 collections in which there were one or more fruits that produced *C. capitata* alone and also one or more fruits that produced both *C. capitata* and *D. dorsalis.* The number of *C. capitata* that emerged from fruits that produced only this species was not appreciably different from the emergence from fruits that also produced *D. dorsalis* (table 1).

Table 1. Comparison of the emergence of *C. capitata* from individual peaches that produced both *C. capitata* and *D. Dorsalis* with that from those that produced only *C. capitata.* Maui, 1949.

	C. capitata when *D. dorsalis* was present			*C. capitata* only		
Date collected	No. of fruits	No. of Cer. cap.	No. of Cer. cap. per fruit	No. fruits	No. of *C. c.*	No. of *C. c.* per fruit
June 9	20	140	7.0	5	24	4.8
June 9	20	95	4.8	8	44	5.5
June 30	4	8	2.0	4	12	3.0
July 12	1	1	1.0	3	8	2.7
July 12	3	11	3.7	1	2	2.0
July 15	4	32	8.0	19	113	5.9
August 3	7	44	6.3	4	58	14.5
August 4	3	26	8.7	3	19	6.3
August 4	7	108	15.4	2	15	7.5
Total	69	465	6.3	49	295	5.8

These data indicate that the number of *C. capitata* produced in the individual fruits was not reduced by *D. dorsalis.* A similar comparison between the emergence of *D. dorsalis* from fruits that produced only *D. dorsalis* and those that produced both species indicate that *C. capitata* did not affect adversely the production of *D. dorsalis.*

Infestation at different elevations.

As mentioned before, subsequent to the arrival of *D. dorsalis, C. capitata* became scarce at the lower elevations and has never recovered to any appreciable extent. To obtain information on the relative abundance of the two species at different elevations, special collections of fruits were made from time to time during the past four years to supplement the information being obtained from the numerous guava collections made throughout the islands in conjunction with the studies of the establishment, spread, and build-up of the various parasites introduced

to combat *D. dorsalis*. The more intensive of these collections were of peaches on Maui and of coffee berries in Kona, Hawaii, and these were supplemented with collections of loquats, Jerusalem cherries, and special collections of guavas.

Peaches. From June 9 to October 5, 1949, 70 collections of peaches were made at different elevations on Maui, shipped to Honolulu via air, and held in the insectary for fruit fly emergence. These collections produced a good deal of data on the infestation by and relative abundance of the two flies at these different elevations (table 2).

Table 2. Summary of data obtained from 70 collections of peaches from Maui, June 9-October 5, 1949.

Date	Elev. range	No. coll.	No. fruits	No. puparia	Emergence			%
					Cer.	Dacus	*Opius* spp.	Cer. cap.
6/14	800	1	24	842	2	804	0	0.2
6/ 9- 7/12	2,200-2,500	7	291	2,949	374	1,843	247	23.5
6/30- 8/22	2,500-2,800	11	365	6,522	2,117	2,942	510	39.8
6/30- 8/17	2,800-3,100	18	647	5,116	1,889	1,494	223	53.5
7/12-10/ 5	3,100-3,400	23	798	8,879	5,800	930	366	87.6
6/30- 8/17	3,400-3,700	7	222	1,256	565	75	18	85.1
7/25-10/ 5	3,700-4,000	3	54	247	159	8	21	98.0
Total		70	2,401	25,811	10,906	8,096	1,385	55.4

Total flies—19,002
Total emergence—20,387

The infestation based on the number of puparia of both flies per fruit decreased as the elevation increased (figure 1).

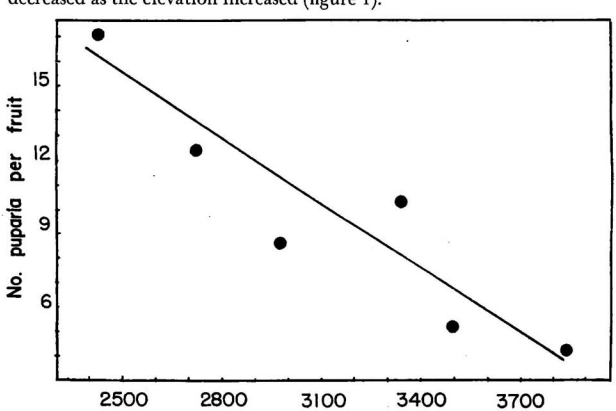

Figure 1. Infestation by *C. capitata* and *D. dorsalis* in peaches at different elevations on Maui, 1949.

As stated earlier, since the puparia of the two species could not be readily differentiated, it was necessary to use the number of adults that emerged, rather than the number of puparia produced, to estimate the infestation by each of the flies in the various collections. These emergence data indicated the average infestation by *C. capitata* was around 3 to 8 adults per fruit above 2,500 feet elevation, while only 2 adults emerged from the 24 fruits collected at the 800 foot elevation.

Coffee. Coffee is grown commercially in Kona, Hawaii, from an elevation of approximately 700 feet to slightly above 2,500 feet. Above 1,000 feet ripe coffee berries can be found throughout the year, even though they are more abundant in the fall. Collections of 300 ripe berries each have been made each month since August of 1949 on two plantations, one at 2,300 feet and the other at 1,200 feet and in a third plantation at 700 feet in the months when ripe berries were available. During this period, infestation data were obtained from a total of 105 collections composed of over 30,000 coffee berries. The combined infestation by both flies is shown graphically in figure 2.

Miscellaneous fruits. Many collections of Jerusalem cherries, loquats, and guavas were made in certain areas throughout the islands to obtain additional information on the occurrence of *C. capitata* and its interrelations with *D. dorsalis.* In addition a few collections of other fruits, such as apricots (*Prunus armeniaca* L.), plums (*Prunus* sp.), persimmons (*Diospyros kaki* L.f.), and English walnuts (*Juglans regia* L.) were obtained from which fruit flies were reared.

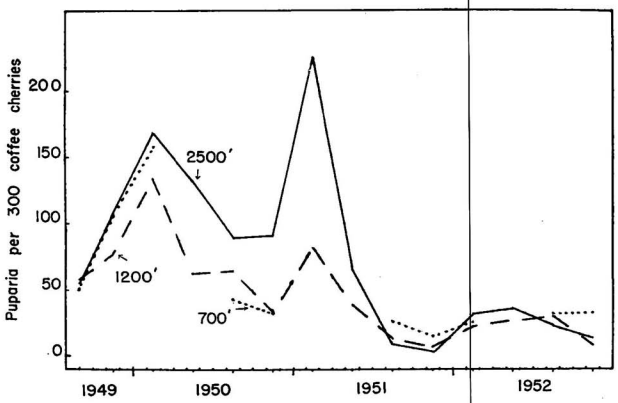

Figure 2. Infestation by *C. capitata* and *D. dorsalis* in coffee from three plantations at different elevations in Kona, Hawaii, August 1949 to December 1952.

Several collections of Jerusalem cherries were made from time to time along the Mauna Loa truck trail at elevations from 4,000 to 5,300 feet and at Waikii on the "Saddle Road" at an elevation of about 4,800 feet. There were a good number of *C. capitata* reared from both areas and along the Mauna Loa truck trail, the infestation in Jerusalem cherries decreased with elevation, as occurred in peaches on Maui.

Guavas collected from the higher elevations at which they are found on Maui, Hawaii, Molokai, Kauai, and Oahu produced a number of adults of *C. capitata,* while those collected at lower elevations seldom produced a single individual of this species. Guavas collected at elevations between 1,000 and 2,000 feet on Molokai and Lanai usually produced several *C. capitata* (table 3). Likewise, this fly commonly occurred in the guavas collected in the Kula-Ulupalakua area on Maui between 2,000 and 3,000 feet elevation and the Kona area of Hawaii between 1,500 and 2,500 feet.

Table 3. Summary of data obtained from collections of guavas from Lanai and Molokai in 1950, 1951, and 1952.

Date	No. coll.	No. puparia	No. puparia per fruit	Emergence		
				C. cap.	*D. dor.*	*Opius* spp.
			LANAI			
2-22-50	3	412	8.3	6	336	49
11-26-50	12	1,178	8.5	95	677	284
10-23-51	4	49	1.1	4	4	29
10- 3-52	6	221	1.8	69	61	64
			MOLOKAI			
2-21-50	4	575	9.6	183	351	18
11-26-50	3	346	3.4	33	142	73
3-28-51	3	349	4.0	29	147	112
10-22-51	4	299	3.9	0	75	212
9-23-52	4	103	1.3	10	11	47

Infestation at different seasons.

There is considerable evidence from both infestation data and the occurrence of adults in the field that *C. capitata* tends to increase during the late winter and spring months at the lower elevations where it occurs.

The data from coffee berries indicate that the infestation by *C. capitata* was lower from September to December than at other seasons. This period of lower infestation coincides with the period in which probably 75 per cent of the coffee berries are harvested at elevations below 1,600 feet but it does not coincide with the peak harvest at the 2,300 foot elevation which occurs during February, March, and April.

Infestation by Dacus dorsalis.

The data obtained from the studies on *C. capitata* have revealed much about the status of *D. dorsalis* at higher elevations. Since *D. dorsalis* has been suspected of affecting *C. capitata* adversely, it is considered pertinent to present some of the information obtained about *D. dorsalis* at these higher elevations.

From the peach collections made on Maui in 1949 it was found that several adults of *D. dorsalis* emerged per fruit from the collections at the lower elevations and that many of the collections above 3,100 feet failed to produce a single *D. dorsalis* adult. At elevations below 2,800 feet it caused considerable infestation but was scarce above 3,500 feet.

The data obtained from the coffee collected at the three different elevations (700, 1,200, and 2,300 feet) revealed that *D. dorsalis* was far more abundant in the collections from the 700 foot station than in those from the 2,300 foot station.

Similar trends in infestation associated with elevation have been indicated from the data obtained from the various fruits collected. There is no question that *D. dorsalis* is scarce at the higher elevations.

Ratio of Ceratitis capitata to Dacus dorsalis.

Many data are available which indicate that the ratio of *C. capitata* to *D. dorsalis* increased with elevation.

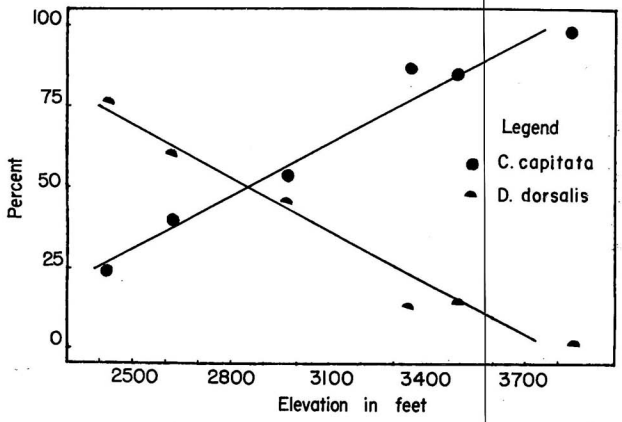

Figure 3. Relationship between *C. capitata* and *D. dorsalis* in peaches at different elevations on Maui, 1949.

In the peach samples collected on Maui in 1949 there was a pronounced increase in the ratio of *C. capitata* to *D. dorsalis* with elevation as is shown in figure 3.

On a few of the farms where peaches were ripening over a period of several weeks during 1949 it was possible to obtain a number of successive collections throughout the period. The ratio of *C. capitata* to *D. dorsalis* on four of these farms located at different elevations is shown in figure 4. These curves not only show that the ratio of *C. capitata* to *D. dorsalis* increased with elevation, but also suggest that the ratio was probably higher in the spring and decreased as the season progressed.

A similar increase in the ratio of *C. capitata* to *D. dorsalis* with elevation occurred in the coffee collections (figure 5). In guavas collected near their upper limit or range, which is seldom above 2,000 feet, *C. capitata* was usually less abundant than *D. dorsalis,* but in a few instances *C. capitata* predominated.

Seven collections of loquats made in the Kula area on Maui in 1950 produced an average of 81 per cent *D. dorsalis* and 19 per cent *C. capitata.* A similar number of collections from the same area in 1951 produced an average of 76 per cent *D. dorsalis* and 24 per cent *C. capitata.*

Over 90 per cent of the flies obtained from Jerusalem cherries collected in the Volcano and Waikii areas on Hawaii were *C. capitata.*

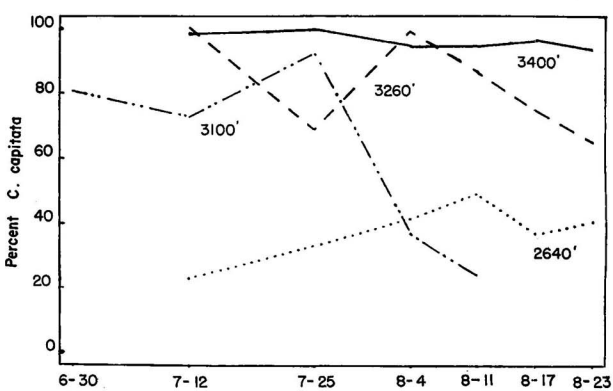

Figure 4. Relative abundance of *C. capitata* among the flies (*C. capitata* plus *D. dorsalis*) bred from peaches collected at different elevations on Maui, June-August, 1949. Each curve represents the percentage of *C. capitata* on a particular farm throughout the peach season.

Recent reduction in infestation.

During the past two to three years there has been a general reduction in the infestation by *C. capitata.*

The downward trend in infestation in peaches during the past three years is clearly indicated by the data in table 4, in guavas from higher elevations in table 3, and in coffee in figure 2. However, a large part of the decrease was due to the decrease in infestation by *D. dorsalis.*

Table 4. Summary of data obtained from collections of peaches on Maui in 1949, 1950, 1951, and 1952.

Date	No. coll.	No. of fruits	No. puparia	No. puparia per fruit	Emergence		
					C. cap.	*D. dor.*	*Opius* spp.
6/ 9-10/ 5/49	70	2,401	25,811	13.1	10,906	8,096	1,385
6/26- 7/28/50	12	578	5,594	9.7	3,525	457	552
7/23/51	12	338	1,324	3.9	699	0	102
9/25/52	3	146	468	3.2	257	0	135

Parasitization

The status of the several parasites that attack and successfully develop in *C. capitata,* like that of *C. capitata* and *D. dorsalis,* has changed during the past four years (Bess et al., 1950; van den Bosch, et al., 1951. These parasites can develop successfully in *C. capitata* (Clancy, 1952) and they have without doubt affected the status of both of these flies in Hawaii.

Since the maggots and puparia of *C. capitata* and *D. dorsalis* are extremely difficult to distinguish apart, the adult emergence data for *C. capitata, D. dorsalis* and their opiine parasites were used as a basis for calculating parasitization of both flies together and the relative abundance of the species involved.

The parasitization data obtained from the collections of various fruits at different elevations where *C. capitata* occurred (tables 2, 3, and 4, and figure 6) indicate that parasitization rose rapidly from 1949 to 1951 but in 1952 was not appreciably different from that in 1951.

There has been considerable parasitization in both peaches and coffee from collections which produced *D. dorsalis* adults, which indicates that *C. capitata* is being parasitized by the parasites of *D. dorsalis.*

Discussion

There was a great decrease in the abundance of *C. capitata* in the more tropical areas in Hawaii subsequent to the arival and establishment of *D. dorsalis* in 1946. However, it is doubtful that there was any great re-reduction in *C. capitata* at that time in the more temperate areas, even though *D. dorsalis* became abundant in these areas during the summer and fall months.

During the past five years *C. capitata* has been extremely scarce at lower elevations where it was once common in guavas, but the fly is still a pest of deciduous fruits, such as peaches and persimmons, at elevations between 2,000 and 5,000 feet. Since the decrease in the abundance of *C.*

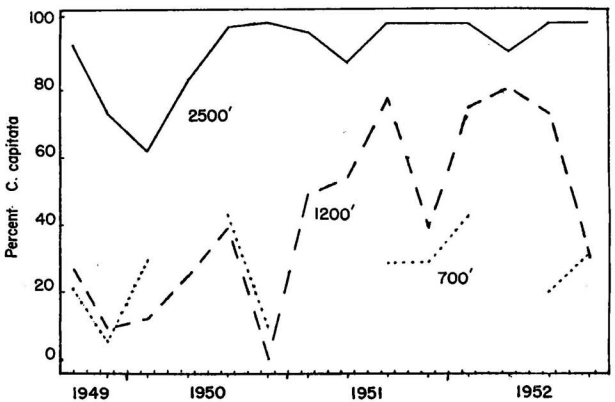

Figure 5. Relative abundance of *C. capitata* among the flies (*C. capitata* plus *D. dorsalis*) bred from coffee collected from three plantations at different elevations in Kona, Hawaii, August 1949 to December 1952.

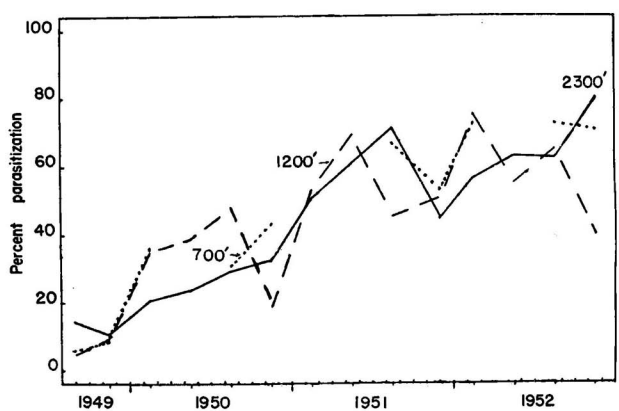

Figure 6. Parasitization of fruit flies (*C. capitata* plus *D. dorsalis*) in coffee collected from three plantations at different elevations in Kona, Hawaii, August 1949 to December 1952.

capitata in the more tropical lowland areas occurred following the introduction of *D. dorsalis*, it has been conjectured that the decrease was due in some way to the latter fly. There are also reports that in Australia there are localities where *C. capitata* was once abundant but became scarce or absent subsequent to the establishment of *Dacus* (*Strumeta*) *tryoni* (Froggatt) in those localities.

The minimum average infestation by *C. capitata* in peaches for any year between 1916 and 1924 was 13.6 flies per fruit, and the average infestation for the period was 18.4 flies per fruit (Willard and Bissel, 1930). In comparison, the recent peach collections produced an average of only 4.5 *C. capitata* adults per fruit in 1949, 6.1 in 1950, 2.1 in 1951, and 1.8 in 1952. These data indicate that the *C. capitata* infestation in peaches is probably less now than it was 3 to 4 decades ago.

The infestation by *C. capitata* in guavas averaged 8.2 flies per fruit for the period 1916-24, and 4.9 for 1925-33 (Willard and Mason, 1937). However, during the past 4 years practically no *C. capitata* adults have emerged from the hundreds of guavas collected at lower elevations, and the average infestation for the collections made at all elevations was less than one *C. capitata* adult per 100 guavas.

There was apparently less change or reduction in infestation by *C. capitata* in coffee berries than in peaches or guavas. The average infestation for collections from Kona, Hawaii was 0.4 flies per berry for the period 1916-24, and 0.1 for 1925-33 (Willard and Mason, 1937).

Soon after its arrival, *D. dorsalis* increased to tremendous numbers and caused widespread serious damage to fruits, but fortunately its numbers and infestation during 1951 and 1952 were only a fraction of what they were in 1948 and 1949. It is still a pest in lowland areas but during the past two years it was extremely scarce in the more temperate areas where it was once a pest and *capitata* still causes damage. Possibly competition by *D. dorsalis* in some way caused the reduction of *C. capitata* to insignificant numbers in the more tropical areas soon after the establishment of *D. dorsalis* in 1946, but it is doubtful that the similar, more recent reduction of *D. dorsalis* in the more temperate areas was due to competition by *C. capitata*.

The peach collections from Maui produced an average of 3.4 *D. dorsalis* adults per fruit in 1949, 0.8 in 1950, and none in either 1951 or 1952. Since most of these peaches were collected above 2,000 feet elevation, and not a single *D. dorsalis* was reared from them during the past two years, apparently this fly has become of little or no economic importance at these higher elevations in peaches, even though it still infests guavas, mangoes, and other fruits at lower elevations. Furthermore, very few adults were seen during the past two years at these higher elevations where it was once abundant.

During the peak years of infestation by *D. dorsalis* in 1948 and 1949 many collections of guavas produced more than 100 adults of this fly per fruit but since 1950 the infestation has averaged less than 5 flies per fruit.

The combined infestation by both *C. capitata* and *D. dorsalis* in peaches was far less serious in 1951 and 1952 than in previous years. It also seems likely that the infestation by both flies in guavas during these last two years was less than was caused by *C. capitata* alone from 1916 to 1933.

It is evident that *C. capitata* has comprised a larger part of the population or infestation in coffee berries during the past several months, than it did during the earlier months of the period of study. This increase in the ratio of *C. capitata* to *D. dorsalis* was due to the reduced infestation by the latter, for actually the infestation by *C. capitata* also declined, especially at the 1,200 and 2,300 foot elevations in Kona.

Infestation data obtained from various fruits collected throughout the islands indicate that *D. dorsalis* is better adapted to the warmer climate at lower elevations than to the cooler climate at higher elevations, and that *C. capitata* is better adapted than *D. dorsalis* to conditions at higher elevations. However, as would be anticipated, the climate at 1,000 feet elevation in one area may be cooler than at 2,000 feet in another, and there are corresponding differences in the relative abundance of the two flies. These differences in the relative abundanc of *D. dorsalis* and *C. capitata* may be related in some way to differences in the behavior patterns of the flies, or possibly adult food supply, rather than to direct detrimental effects of the climatic factors themselves.

There has been considerable change in the status of the various introduced parasites and this should be considered if a clear picture of their activity is to be obtained. Their history may be briefly summarized as follows.

Soon after its release in 1913, *Opius humilis* Silvestri, increased rapidly in abundance and within a few months parasitized as high as 90 per cent of the larvae in coffee berries in certain localities. However, with the subsequent establishment and build-up of *Opius tryoni* (Cameron) and *Opius fullawayi* (Silvestri), *O. humilis* became scarce (Back and Pemberton 1918). Later Willard and Mason (1937) summarized the data obtained from 1914-1933 which indicate that *O. humilis* was the dominant parasite of *C. capitata* in coffee berries collected in Kona, Hawaii, during 1914-1917. In 1918 *O. tryoni* was the dominant species, and by 1922 this second species had been surpassed by the third species, *O. fullawayi*, which continued to be the dominant species from 1922 to 1929. However, from 1931 to 1933 *O. tryoni* was again the dominant parasite. During the period from 1922 to 1933 neither *O. tryoni* nor *O. fullawayi* actually became scarce, and both species have been recovered many times during the past 4 years. In contrast, no specimens of *O. humilis* have been reared from the numerous collections of fruits made between 1949 and 1952 in conjunction with the intensive studies of *D. dorsalis* parasites.

The change in status of the more recently introduced opiine parasites of *D. dorsalis* and *C. capitata* parallels to some extent the change in status of the parasites introduced in 1913 and 1914 to combat *C. capitata*. *Opius longicaudatus* (Ashmead) became well established and abundant in 1948 and 1949; by the latter part of 1949 *Opius vandenboschi* Full-

away had surpassed *O. longicaudatus* in abundance and in 1950 *Opius oophilus* Fullaway became by far the most abundant parasite of D. *dorsalis* on Oahu (Bess, et al., 1950; van den Bosch, et al., 1951). The following year the latter parasite also became the dominant species on the outer islands.

These data show that there was not only a rapid increase of *C. capitata* and *D. dorsalis* following their introduction but there was a similar rapid increase of the six opiine parasites following their introduction. Furthermore, the two flies and 6 parasites are now less abundant in Hawaii than they were during the first 3 years after their introduction.

Many similar examples of rapid increase have occurred following the introduction of both injurious and beneficial species into new areas where they became successful. Clausen (1951) concluded that, "A *fully effective* parasite or predator is always easily and quickly established." Perhaps it is equally true that species destined to become pests have also been easily and quickly established.

Parasites have apparently been no more effective on *D. dorsalis* in the more temperate areas of the high elevations than in the more tropical lowland areas. The scarcity of *D. dorsalis* in these temperate areas is probably closely associated with its reduced abundance in the more tropical areas from which it spread in great numbers during the period in which it was tremendously abundant.

The reduced abundance of both *D. dorsalis* and *C. capitata* during the past three years has been directly related to increased parasitization. Since the egg-larval parasite, *O. oophilus*, became numerous the infestation has been much lower throughout the islands than it was previously. Furthermore the amplitude of the oscillations in infestation has been greatly reduced and the level of infestation has become at least for the present stabilized at a much lower level.

Summary

Both *C. capitata* and *D. dorsalis* developed successfully together in individual fruits and the larvae of one species apparently caused no reduction in the number of adults of the other species produced in those fruits.

In the more tropical lowland areas *D. dorsalis* was more abundant than *C. capitata*, and in the more temperate upland areas the latter species was more abundant. At elevations around 500 to 1000 feet *C. capitata* tended to become more abundant in late winter and spring and *D. dorsalis* more abundant during the fall.

The infestation by both flies during 1951 and 1952 was apparently lower than the infestation by *C. capitata* alone prior to the arrival of *D. dorsalis*.

Parasitization has averaged well above 50 per cent for many months. Furthermore, the *D. dorsalis* parasites appear to be attacking *C. capitata* in coffee berries about as readily as they attack *D. dorsalis*. Undoubtedly

these parasites, especially the egg-larval parasite, *O. oophilus,* which has continued to parasitize a high percentage of the population at these lower population levels, have been one of the main factors in the reduction of the fly infestation.

LITERATURE CITED

Back, E. A. and **C. E. Pemberton.** 1918. The Mediterranean fruit fly in Hawaii. U. S. Dept. Agr. Bul. 536, 119 pp., 21 pls., 24 figs.

Bess, H. A., Robert van den Bosch, and **Frank Haramoto.** 1950. Progress and status of two recently introduced parasites of the oriental fruit fly, *Dacus dorsalis* Hendel, in Hawaii. Proceedings Hawaiian Entomological Society 14 (1) :29-33.

Clausen, C. P. 1951. The time factor in biological control. Jour. Econ. Ent. 44(1):1-9.

van den Bosch, Robert, H. A. Bess, and **F. H. Haramoto.** 1951. Status of oriental fruit fly parasites in Hawaii. Jour. Econ. Ent. 44(5):753-759.

Willard, H. F. and **T. L. Bissel.** 1930. Parasitism of the Mediterranean fruit fly in Hawaii 1922-1924. U.S.D.A. Cir. 109:1-12.

Willard, H. F. and **A. C. Mason.** 1937. Parasitization of the Mediterranean fruit fly in Hawaii, 1914-33. U.S.D.A. Cir. 439, 18 pp.